EPSG Draft Standard 301

Ethernet POWERLINK

Communication Profile Specification

Version 1.5.1

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Pre. 2 History

Vers.	State	Date	Author / Company		Description
1.0.0	DS	2006-04-18	Knopke et al.	Lenze et al.	DS version created from working documents
1.0.1	WDP	2008-01-30	Kirchmayer	B&R et al.	WDP version created from DS 1.0.0 Changes from TWG meetings in 6/07 and 10/07.
1.0.2	WDP	2008-06-13	Kirchmayer	B&R et al.	Changes from TWG meetings in 2/07 and 2/08.
1.0.3	WDP	2008-07-23	Kirchmayer	B&R et al.	Changes from TWG meeting in 6/08.
1.0.4	WDP	2008-09-05	Kirchmayer	B&R et al.	Objects used in EPSG DS 302-A are marked as reserved. Feedback from certification meeting
1.0.4	DSP	2008-09-08	Kirchmayer	B&R et al.	Status changes to Draft Standard Proposal
1.0.5	DSP	2008-10-17	Kirchmayer	B&R et al.	Feedback from TWG conference call in 10/08
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1.1.1	WDP	2010-01-13	Kirchmayer	B&R et al.	WDP version created from DS 1.1.0 Changes from TWG meeting in 6/09 Feedback from ITEI (China)
1.1.2	WDP	2010-08-04	Kirchmayer	B&R et al.	Changes from TWG meeting in 3/10
1.1.3	WDP	2011-08-12	Kirchmayer	B&R et al.	Changes from TWG meeting in 9/10 Refer ot IEC instead of IAONA standards
1.1.4	WDP	2012-08-30	Kirchmayer	B&R et al.	Changes from TWG meeting in 10/11
1.1.5	WDP	2013-02-27	Kirchmayer	B&R et al.	Changes from TWG meeting in 9/12 Contribution list removed PDO mapping attribute of 1F8Ch is Opt
1.1.6	WDP	2013-04-30	Kirchmayer	B&R et al.	Changes from TWG meeting in 3/13 Reference to polling order corrected in 4.2.4.4 Maximum SDO payload size corrected No PReq to CN in NMT_CS_STOPPED corrected
1.1.7	WDP	2013-06-11	Kirchmayer	B&R et al.	Changes from TWG telco in 5/13, Clarify Tab. 53, Replace Sender/Receiver by Client/Server in Fig. 45 to Fig. 54
1.1.7	DSP	2013-06-11	Kirchmayer	B&R	Status change to DSP
1.2.0	DS	2013-12-18	Kirchmayer	B&R	Changes from TWG meeting in 12/13 Update of references to other standards Status change to DS
1.2.0	DS	2014-05-28	Kirchmayer	B&R	Typos corrected
1.2.1	WDP	2014-09-25	Kirchmayer	B&R	Changes from TWG meeting 06/14
1.2.2	WDP	2015-09-25	Kirchmayer	B&R	Changes from TWG meeting 06/15
1.2.3	DSP	2015-12-16	Kirchmayer	B&R	Changes from TWG meeting 12/15 Status change to DSP
1.3.0	DS	2016-03-23	Kirchmayer	B&R	Status change to DS
1.3.0a	DS	2016-11-23	Kirchmayer	B&R	Typos and other corrections
1.3.1	WDP	2016-12-19	Kirchmayer	B&R	Changes from TWG meeting 9/16
1.3.2	WDP	2017-05-22	Kirchmayer	B&R	Changes from TWG meeting 5/17, Typos and NMT_EPLNodeID_TYPE corrected
1.3.3	WDP	2017-08-18	Kirchmayer	B&R	Changes from TWG meeting 7/17
1.3.4	DSP	2018-08-18	Kirchmayer	B&R	Changes from TWG meeting 3/18 Status change to DSP
1.4.0	DS	2018-11-13	Kirchmayer	B&R	Changes from TWG meeting 10/18 Status change to DS
1.4.1	WDP	2021-08-21	Kirchmayer	B&R	Remove default values from 1F93h si1 (NodeID_U8) and si3 (SWNodeID_U8) Missing text in Fig. 62 completed Typos and update of referenced versions Remove dates/versions from references
1.5.0	DS	2021-09-22	Kirchmayer	B&R	Status change to DS
1.5.1	DS	2023-04-06	Kirchmayer	B&R	© B&R due to dissolution of the EPSG

Pre. 3 Change Record

The changes based on the last valid Communication Profile Specification (EPSG DS 301 V1.5.0a) are tracked in a separate change record. Hereby the change record provides a detailed history from the last draft standard to the current one.

Pre. 4 Content

Pre. 5 Tables

Pre. 6 Figures

Pre. 7 Definitions and Abbreviations

Pre 7.1 Definitions

Ageing	*Ageing* is a common mechanism to maintain (cache) tables. Entries which are not used or refreshed are removed after a specified time.
Application Process	The Application Process is the task on the Application Layer
Async-only CN	An *Async-only CN* is operated in a way, that it isn't accessed cyclically in the isochronous slot by the MN. It is polled during the asynchronous period by a StatusRequest message.
Asynchronous Data	Data in a POWERLINK network which is not time critical. Within the POWERLINK cycle there is a specific period reserved for *Asynchronous Data* which is shared by all nodes. Each node connected to the network can send asynchronous data by requesting it to the Managing Node. The Managing Node keeps a list of all asynchronous data requests and will subsequently grant the network access to one node after the other.
Asynchronous Period	The *Asynchronous Period* is the second part of the POWERLINK cycle, starting with a *Start of Asynchronous* (SoA) frame.
Asynchronous Scheduling	The MN's asynchronous scheduler decides when a requested asynchronous data transfer will happen.
Basic Ethernet Mode	Basic Ethernet Mode provides the Legacy Ethernet communication.
CANopen	CANopen is a network technology optimized for the usage in industrial control environments, in machine internal networks and in embedded systems (any control unit deeply "embedded" in a device with electronics). The lower-layer implementation of CANopen is based upon CAN (Controller Area Network).
Continuous	*Continuous* is a POWERLINK communication class where isochronous communication takes place every cycle (the opposite to *multiplexed*).
Controlled Node (CN)	Node in a POWERLINK network without the abilty to manage the SCNM mechanism.
Cycle State Machine	The *Cycle State Machine* controls the POWERLINK cycle on the Data Link Layer and is itself controlled by the NMT state machine defining the current operating mode.
Cycle Time	The time between two consecutive *Start of Cycle* (SoC) frames – i.e. repeating – process. The *Cycle Time* includes the time for data transmission and some idle time before the beginning of the next cycle.
Deterministic Communication	Describes a communication process whose timing behaviour can be predicted exactly. I.e. the time when a message reaches the recipient is predictable.
Device Configuration File	The configuration parameters of a specific device are stored in the *Device Configuration File* (XDC).
Device Description File	All device dependent information is stored in the *Device Description File* (XDD) of each device.
Destination NAT (D-NAT)	*D-NAT* (Destination- Network Address Translation) changes the destination address of the IP / ICMP packet.
Domain	In the context of CANopen: A *Domain* is a data object of arbitrary type and length which can be transferred over a POWERLINK network. In the context of internet protocols: A *Domain* is a part of the internet name space which is supported by the Domain Name System (DNS).
Ethernet POWERLINK (EPL)	An extension to *Legacy Ethernet* on layer 2, to exchange data under hard real-time constraints. It was developed for deterministic data exchange, short cycle time and isochronous operation in industrial automation.

IdentRequest	*IdentRequests* are POWERLINK frames sent by the MN in order to identify active CNs waiting to be included into the network.
IdentResponse	The *IdentResponse* is a special form of an ASnd frame in response to an *IdentRequest*.
Idle Period	The *Idle Period* is time interval remaining between the completed asynchronous period and the beginning of the next cycle.
IEEE 1588	This standard defines a protocol enabling synchronisation of clocks in distributed networked devices (e.g. connected via Ethernet).
Isochronous	Pertains to processes that require timing coordination to be successful. Isochronous data transfer ensures that data flows continously and at a steady rate in close timing with the ability of connected devices.
Isochronous Data	Data in a POWERLINK network which is to be transmitted every cycle (or every n^{th} cycle in case of multiplexed isochronous data).
Isochronous Period	The *Isochronous Period* of a POWERLINK cycle offers deterministic operation, i.e. it is reserved for the exchange of (*continuous* or *multiplexed*) isochronous data.
Legacy Ethernet	Ethernet as standardised in IEEE 802.3 (non-deterministic operation in non-time-critical environments).
Managing Node (MN)	A node capable to manage the SCNM mechanism in a POWERLINK network.
Media Access Control (MAC)	One of the sub-layers of the Data Link Layer in the POWERLINK reference model that controls who gets access to the medium to send a message.
Multiplexed	*Multiplexed* is a POWERLINK communication class where cyclic communication takes place in such a way that m nodes are served in s cycles (the opposite to *continuous*).
Multiplexed CN	A node which is allowed to send isochronous data every n^{th} cycle.
Multiplexed Timeslot	A slot destined to carry multiplexed isochronous data, i.e. the timeslot is shared among multiple nodes.
NetTime	The MN’s clock time is distributed to all CNs within the SoC frame.
Network Management (NMT)	*Network Management* functions and services in the POWERLINK model. It performs initialisation, configuration and error handling in a POWERLINK network.
NMT State Machine	The state machine controlling the overall operating mode and status of a POWERLINK node.
Object Directory	The repository of all data objects accessible over POWERLINK communications.
PollRequest	A PollRequest is a frame, which is used in the isochronous part of the cyclic communication. The MN request with this frame the CN to send its data.
PollResponse	A PollResponse is a frame, which is used in the isochronous part of the cyclic communication. The CN responses with this frame to a PollRequest frame from an MN.
POWERLINK Command Layer	The *POWERLINK Command Layer* defines commands to access parameters of the object dictionary. This layer is on top of the *Sequence Layer* and distinguishes between an expedited and a segmented transfer.
POWERLINK Cycle	Data exchange within a POWERLINK network is structured in fix intervals, called cycles. The cycle is subdivided into the isochronous and the asynchronous period and is organized by the MN.
POWERLINK Mode	The *POWERLINK Mode* includes all NMT states in which POWERLINK cycles are run.
POWERLINK Node ID	Each POWERLINK node (MN, CN and Router) is addressed by an 8 bit *POWERLINK Node ID* on the POWERLINK layer. This ID has only local significance (i.e. it is unique within a POWERLINK segment).

Precision Time Protocol (PTP)	IEEE 1588, Standard for a Precision Clock Synchronisation Protocol for Networked Measurement and Control Systems
Process Data Object (PDO)	Object for isochronous data exchange between POWERLINK nodes.
Reserved	Reserved bits shall be set 0 by the sender. The receiver shall not interpret such bits. It is not allowed to use reserved bits. Their use is reserved for further development or by extensions of this specification.
Router Type 1	A Type 1 POWERLINK Router is a coupling element in a network that allows IP communication between a POWERLINK segment and any other datalink layer protocol carrying IP e.g. legacy Ethernet, POWERLINK etc. It is usually a separate network element acting as Controlled Node within the POWERLINK segment.
Router Type 2	A Type 2 POWERLINK Router is a router between a POWERLINK segment and a CANopen network.
Service Data Object (SDO)	Peer to peer communication with access to the object dictionary of a device.
Sequence Layer	The POWERLINK *Sequence Layer* provides the service of a reliable bidirectional connection that guarantees that no messages are lost or duplicated and that all messages arrive in the correct order.
Slot Communication Network Management (SCNM)	In a POWERLINK network, the managing node allocates data transfer time for data from each node in a cyclic manner within a guaranteed cycle time. Within each cycle there are slots for *Isochronous Data*, as well as for *Asynchronous Data* for ad-hoc communication. The *SCNM* mechanism ensures that there are no collisions during physical network access of any of the networked nodes thus providing deterministic communication via *Legacy Ethernet*.
Source NAT (S-NAT)	*S-NAT* (Source - Network Address Translation) changes the source address of the IP / ICMP packet.
StatusRequest	A StatusRequest frame is a special SoA frame used to poll the status of a node.
StatusResponse	A *StatusResponse* frame is transmitted by a CN upon assignment of the asynchronous slot via the *StatusRequest* in the SoA frame.

Pre 7.2 Abbreviations

ACL	Access Control List
ARP	Address Resolution Protocol
ASnd	Asynchronous Send (POWERLINK frame type)
CAN	Controller Area Network
CiA	CAN in Automation
CN	POWERLINK Controlled Node
DCF	Device Configuration File
EIA	Electronic Industries Association
EMC	Electro Magnetic Compatibility
EPL	Ethernet POWERLINK
EPSG	Ethernet POWERLINK Standardisation Group
ICMP	Internet Control Message Protocol
ID	Identifier
IEC	International Electrotechnical Comission
IEEE	Institute of Electrical and Electronic Engineers
IP	Internet Protocol
MAC	Media Access Control
MIB	Management Information Base

MN	POWERLINK Managing Node
MS	Multiplexed Slot (flag in POWERLINK frame)
MSS	Maximum Segment Size
MTU	Maximum Transmission Unit
NAT	Network Address Translation
NIL	Not in List (Basic Data Type)
NMT	Network Management
PDO	Process Data Object
PR	Priority (bit field in POWERLINK frame)
PReq	PollRequest (POWERLINK frame type)
PRes	PollResponse (POWERLINK frame type)
PS	Prescaled Slot (flag in POWERLINK frame)
PTP	Precision Time Protocol
RD	Ready (flag in POWERLINK frame)
RFC	Requests for Comments
RPDO	Receive Process Data Object
RS	Request to Send (flag in POWERLINK frame)
EA	Exception Achnowledge (flag in POWERLINK frame)
SCNM	Slot Communication Network Management
SDO	Service Data Object
EN	Exception New (flag in POWERLINK frame)
SNMP	Simple Network Management Protocol
SoA	Start of Asynchronous (POWERLINK frame type)
SoC	Start of Cycle (POWERLINK frame type)
TCP	Transmission Control Protocol
TIA	Telecommunications Industry Association
TPDO	Transmit Process Data Object
TTL	Time to live
UDP	User Datagram Protocol
VPN	Virtual Private Network
XDC	XML device configuration file
XDD	XML device description file

Pre. 8 References

[1] EPSG Draft Standard 302-A (EPSG DS 302-A), Ethernet POWERLINK, Part A: High Availability

[2] EPSG Draft Standard 302-B (EPSG DS 302-B), Ethernet POWERLINK, Part B: Multiple-ASnd

[3] EPSG Draft Standard 302-C (EPSG DS 302-C), Ethernet POWERLINK, Part C: PollResponse Chaining

[4] EPSG Draft Standard 302-D (EPSG WDP 302-D), Ethernet POWERLINK, Part D: Multiple PReq/PRes

[5] EPSG Draft Standard 302-E (EPSG WDP 302-E), Ethernet POWERLINK, Part E: Dynamic Node Allocation

[6] EPSG Draft Standard 302-F (EPSG WDP 302-F), Ethernet POWERLINK, Part F: Modular Device

[7] IEC 61918 Industrial communication networks – Installation of communication networks in industrial premises

[8] IEC 61784-5-13 Industrial communication networks – Profiles – Part 5-13: Installation of fieldbuses – Installation profiles for CPF 13

1 Introduction

Ethernet POWERLINK is a communication profile for Real-Time Ethernet (RTE). It extends Ethernet according to the IEEE 802.3 standard with mechanisms to transfer data with predictable timing and precise synchronisation. The communication profile meets timing demands typical for high-performance automation and motion applications. It does not change basic principles of the Fast Ethernet Standard IEEE 802.3 but extends it towards RTE. Thus it is possible to leverage and continue to use any standard Ethernet silicon, infrastructure component or test and measurement equipment like a network analyzer.

1.1 Slot Communication Network Management

POWERLINK provides mechanisms to achieve the following:

1. Transmit time-critical data in precise isochronous cycles. Data exchange is based on a publish/subscribe relationship. Isochronous data communication can be used for exchanging position data of motion applications of the automation industry.
2. Synchronise networked nodes with high accuracy.
3. Transmit less time-critical data asynchronously on request. Asynchronous data communication can be used to transfer IP-based protocols like TCP or UDP and higher layer protocols such as HTTP, FTP,…

POWERLINK manages the network traffic in a way that there are dedicated time-slots for isochronous and asynchronous data. It takes care that always only one networked device gains access to the network media. Thus transmission of isochronous and asynchronous data will never interfere and precise communication timing is guaranteed. The mechanism is called Slot Communication Network Management (SCNM). SCNM is managed by one particular networked device – the Managing Node (MN) – which includes the MN functionality. All other nodes are called Controlled Nodes (CN).

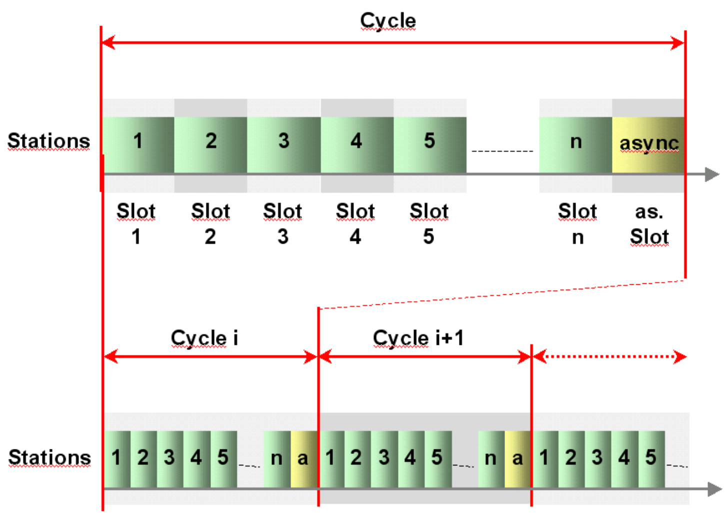

Fig. 1. Slot Communication Network Management (SCNM)

1.2 POWERLINK key features

POWERLINK provides the following key features:

- Ease-of-Use to be handled by typical automation engineers without indepth Ethernet network knowledge.
- Up to 240 networked real-time devices in one network segment
- Deterministic Communication Guaranteed
  - Down to 100 µs cycle times
  - Ultra-low jitter (down to <1µs) for precise synchronisation of networked devices
- Standard Compliant

  - IEEE 802.3u Fast Ethernet
  - IP based protocols supported (TCP, UDP,...)
  - Integration with CANopen Profiles EN 50325-4 for device interoperability
  - Implementation based on standard Ethernet Chips - No special ASICs necessary
- Direct peer-to-peer communication of all Nodes (Publish/subscribe)
- Hot Plugging
- Seamless IT-Integration – Routing of IP protocols

POWERLINK is based on the ISO/OSI layer model and supports Client/Server and Producer/ Consumer communications relationships.

The Ethernet POWERLINK Standardisation Group (EPSG) worked closely with the CiA (CAN in Automation) organisation to integrate CANopen with POWERLINK. CANopen standards define widely deployed communication profiles, device profiles and application profiles. These profiles are in use millions of times all over the world. Integration of POWERLINK with CANopen combines profiles, high performance data exchange and open transparent communication with TCP/UDP/IP protocols.

The POWERLINK communication profile is based on CANopen communication profiles DS301 and DS302. Based on this communication profile, the multitude of CANopen device profiles can be used in a POWERLINK environment without changes.

A main focus of POWERLINK is ease of use. Ethernet technology can be quite complex and confusing for machine and plant manufacturers which are not necessarily networking experts. The following features have been implemented:

- Easy wiring, flexible topologies (line structures, tree structures or star structures). The network is adapting to the needs of the machine.
- Utilization of well known industrial infrastructure components
- Simple address assignment by switch is possible
- Easy replacement of devices in case of failure
- Straightforward network diagnostics
- Basic security features
- Simple engineering separated from end user IT infrastructure
- Easy integration of RTE network with IT infrastructure

1.3 Integration

The advantages listed before result from protecting the POWERLINK RTE network segment from regular office and factory networks. This matches typical machine and plant concepts. Hard real time requirements are met within the machine with POWERLINK. Full transparency to the factory network and above is provided, yet it is taken care of protection against hacker attacks on machine level. Modification efforts through machine integration into existing IT infrastructures are minimized. To achieve this POWERLINK provides a private Class-C IP segment solution with fixed IP addresses. A router establishes the connection to factory floor networks or company networks. NAT mechanisms allow the assignment of any IP address to RTE networked nodes.

RTE based on POWERLINK is ideal to support modern modular machine concepts. Producer/Consumer and Client/Server communication relationships, enable centralized master/slave as well as decentral multimaster structures.

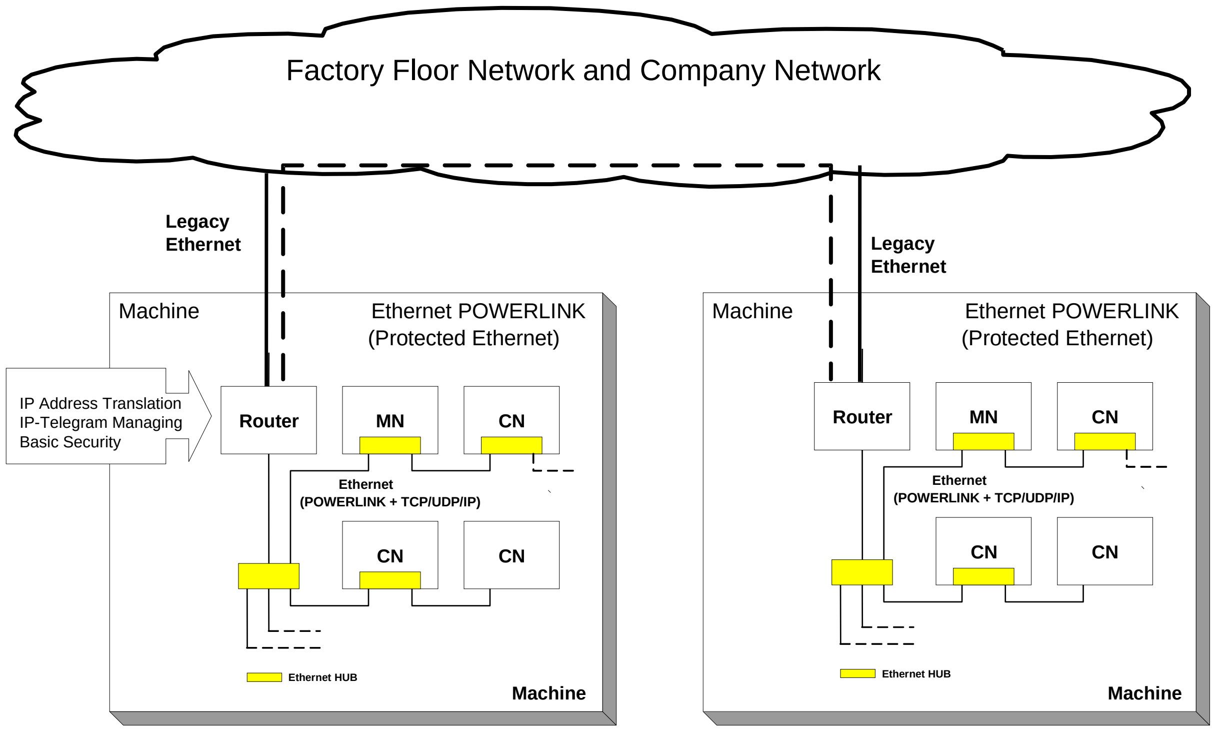

Fig. 2. Integration POWERLINK based machines into the IT infrastructure of end customer

1.4 Modular Machines

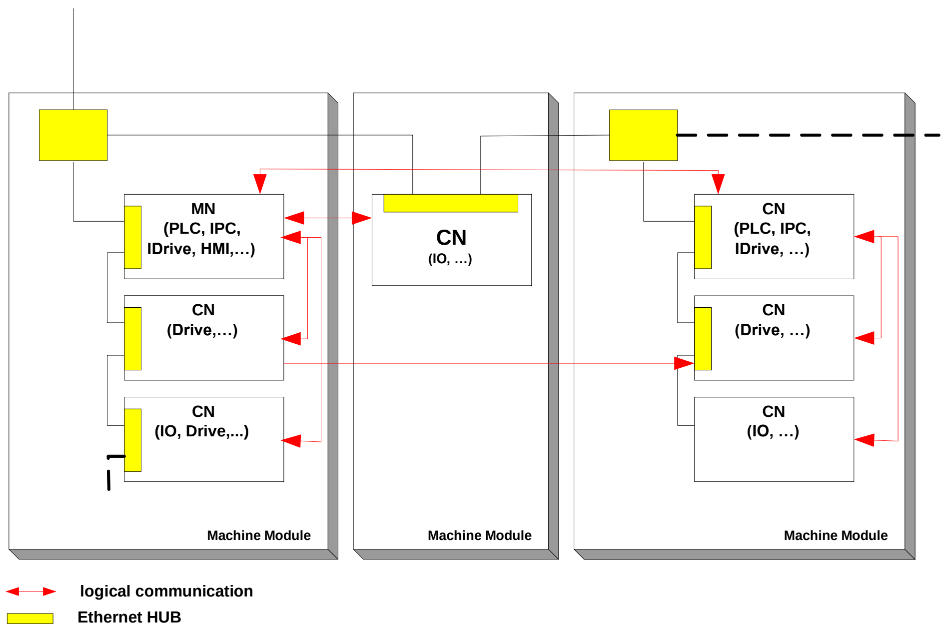

Fig. 3. Typical centralized and decentralized controller structures

A machine concept with autonomous machine modules is illustrated in Fig. 3. Every machine module can be designed separetly whith its own internal communication relationships. The assembling of the machine can be done in a flexible way by adding additional direct communication relationships between machine modules.

2 Modelling

POWERLINK-based networks use the following reference model, device model, and communication model.

2.1 Reference Model

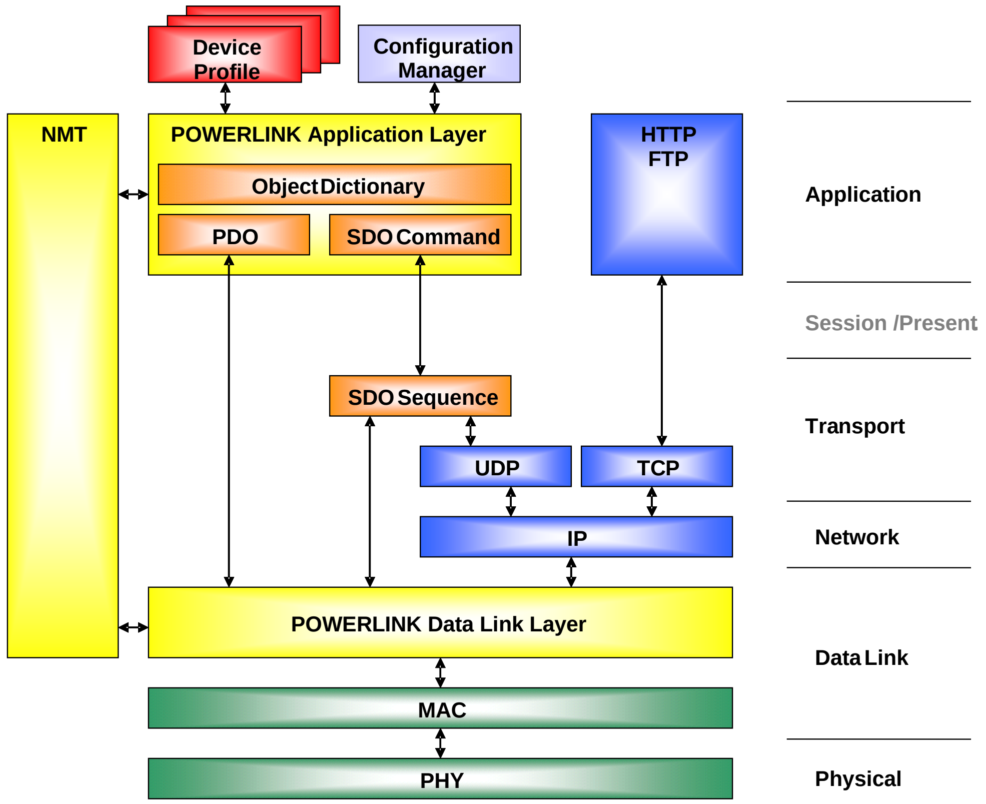

Fig. 4. Reference model

The communication concept can be described with reference to the ISO-OSI Reference Model (right-hand side of Fig. 4).

2.1.1 Application Layer

The Application Layer comprises a concept to configure and communicate real-time-data as well as the mechanisms for synchronisation between devices. The functionality the application layer offers to an application is logically divided over different *service objects* (see SDO) in the application layer. A service object offers a specific functionality and all related services.

Applications interact by invoking services of a service object in the application layer. To realize these services, the service object exchanges data via the Network with (a) peer service object(s) via a protocol. This protocol is described in the *Protocol Specification* of that service object.

2.1.1.1 Service Primitives

Service primitives are the means by which the application and the application layer interact. There are four different primitives:

- a *request* is issued by the application to the application layer to request a service
- an *indication* is issued by the application layer to the application to report an internal event detected by the application layer or indicate that a service is requested

- a *response* is issued by the application to the application layer to respond to a previous received indication
- a *confirmation* is issued by the application layer to the application to report the result of a previously issued request.

2.1.1.2 Application Layer Service Types

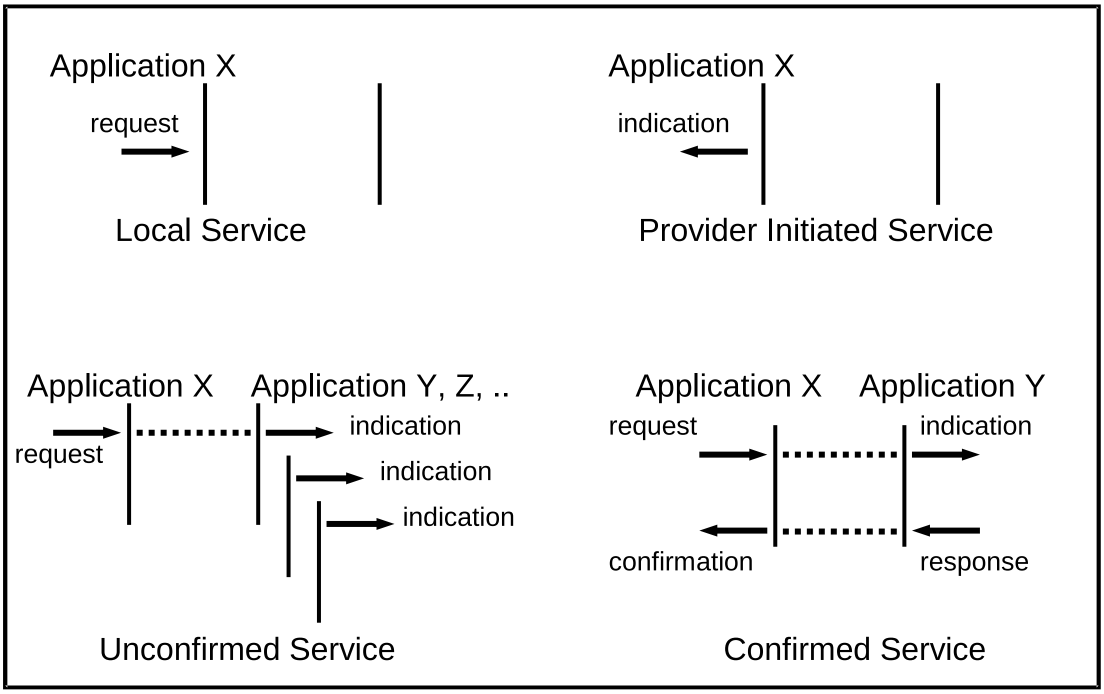

Fig. 5. Service types

A *service type* defines the primitives that are exchanged between the application layer and the co-operating applications for a particular service of a service object.

- A *Local Service* involves only the local service object. The application issues a request to its local service object that executes the requested service without communicating with (a) peer service object(s).
- An *Unconfirmed Service* involves one or more peer service objects. The application issues a request to its local service object. This request is transferred to the peer service object(s) that each pass it to their application as an indication. The result is not confirmed back.
- A *Confirmed Service* can involve only one peer service object. The application issues a request to its local service object. This request is transferred to the peer service object that passes it to the other application as an indication. The other application issues a response that is transferred to the originating service object that passes it as a confirmation to the requesting application.
- A *Provider Initiated service* involves only the local service object. The service object (being the service provider) detects an event not solicited by a requested service. This event is then indicated to the application.

Unconfirmed and confirmed services are collectively called *Remote Services*.

2.2 Device Model

2.2.1 General

A device is structured as follows (see Fig. 6):

- Communication – This function unit provides the communication objects and the appropriate functionality to transport data items via the underlying network structure.

- Object Dictionary – The Object Dictionary is a collection of all the data items that have an influence on the behaviour of the application objects, the communication objects and the state machine used on this device.
- Application – The application comprises the functionality of the device with respect to the interaction with the process environment.

Thus the Object Dictionary serves as an interface between the communication and the application. The complete description of a device's application with respect to the data items in the Object Dictionary is called the *device profile.*

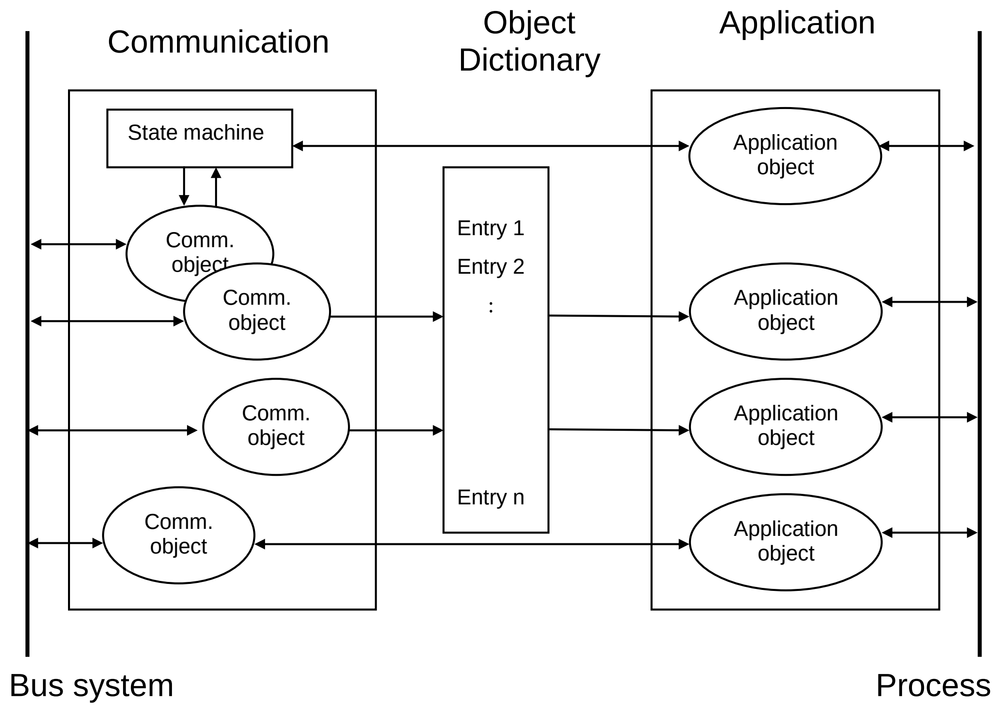

Fig. 6. Device model

2.2.2 The Object Dictionary

The most important part of a device profile is the Object Dictionary. The Object Dictionary is essentially a grouping of objects accessible via the network in an ordered, pre-defined fashion. Each object within the dictionary is addressed using a 16-bit index.

The overall layout of the standard Object Dictionary is shown by Tab. 1. This layout closely conforms to other industrial serial bus system concepts.

The Object Dictionary may contain a maximum of 65536 entries which are addressed through a 16-bit index.

The Static Data Types at indices 0001_h through $001F_h$ contain type definitions for standard data types like BOOLEAN, INTEGER, floating point, string, etc. These entries are included for reference only; they cannot be read or written.

Index	Object
0000_h	not used
0001_h .. $001F_h$	Static Data Types
0020_h .. $003F_h$	Complex Data Types
0040_h .. $005F_h$	Manufacturer Specific Complex Data Types
0060_h .. $007F_h$	Device Profile Specific Static Data Types
0080_h .. $009F_h$	Device Profile Specific Complex Data Types
$00A0_h$ .. $03FF_h$	Reserved for further use
0400_h – $041F_h$	POWERLINK Specific Static Data Types
0420_h – $04FF_h$	POWERLINK Specific Complex Data Types
0500_h .. $0FFF_h$	Reserved for further use
1000_h .. $1FFF_h$	Communication Profile Area
2000_h .. $5FFF_h$	Manufacturer Specific Profile Area
6000_h .. $9FFF_h$	Standardised Device Profile Area
$A000_h$ .. $BFFF_h$	Standardised Interface Profile Area
$C000_h$ .. $FFFF_h$	Reserved for further use

Tab. 1 Object dictionary structure

Complex Data Types at indices 0020_h through $003F_h$ are pre-defined structures that are composed of standard data types and are common to all devices.

Manufacturer Specific Complex Data Types at indices 0040_h through $005F_h$ are structures composed of standard data types but are specific to a particular device.

Device Profiles may define additional data types specific to their device type. The static data types defined by the device profile are listed at indices 0060_h - $007F_h$, the complex data types at indices 0080_h - $009F_h$.

A device may optionally provide the structure of the supported complex data types (indices 0020_h - $005F_h$ and 0080_h - $009F_h$) at read access to the corresponding index. Sub-index 0 provides the number of entries at this index, and the following sub-indices contain the data type encoded as UNSIGNED16 according to 6.1.4.5.

POWERLINK Specific Static Data Types shall be described at indices 0400_h – $041F_h$. These entries are included for reference only; they cannot be read or written. POWERLINK Specific Complex Data Types shall be described at indices 0420_h – $04FF_h$

The Communication Profile Area at indices 1000_h through $1FFF_h$ contains the communication specific parameters for the POWERLINK network. These entries are common to all devices.

The standardised device profile area at indices 6000_h through $9FFF_h$ contains all data objects common to a class of devices that can be read or written via the network. The device profiles may use entries from 6000_h to $9FFF_h$ to describe the device parameters and the device functionality. Within this range up to 8 different devices can be described. In such a case the devices are denominated Multiple Device Modules. Multiple Device Modules are composed of up to 8 device profile segments. In this way it is possible to build devices with multiple functionality. The different device profile entries are indexed at increments of 800_h.

For Multiple Device Modules the object range 6000_h to $9FFF_h$ is sub-divided as follows:

- 6000_h to $67FF_h$ device 0
- 6800_h to $6FFF_h$ device 1
- 7000_h to $77FF_h$ device 2
- 7800_h to $7FFF_h$ device 3
- 8000_h to $87FF_h$ device 4
- 8800_h to $8FFF_h$ device 5
- 9000_h to $97FF_h$ device 6
- 9800_h to $9FFF_h$ device 7

The Object Dictionary concept caters for optional device features: a manufacturer does not have to provide certain extended functionality on his devices but if he wishes to do so he must do it in a pre-defined fashion.

Space is left in the Object Dictionary at indices 2000_h through $5FFF_h$ for truly manufacturer-specific functionality.

2.2.2.1 Index and Sub-Index Usage

A 16-bit index is used to address all entries within the Object Dictionary. In the case of a simple variable the index references the value of this variable directly. In the case of records and arrays, however, the index addresses the whole data structure.

To allow individual elements of structures of data to be accessed via the network a sub-index is defined. For single Object Dictionary entries such as an UNSIGNED8, BOOLEAN, INTEGER32 etc. the value for the sub-index is always zero. For complex Object Dictionary entries such as arrays or records with multiple data fields the sub-index references fields within a data-structure pointed to by the main index. The fields accessed by the sub-index can be of differing data types.

2.3 Communication Model

The communication model specifies the different communication objects and services and the available modes of frame transmission triggering.

The communication model only specifies the POWERLINK-specific communication objects of the POWERLINK Mode and Basic Ethernet Mode (4.2 resp. 4.3). The mechanism for Legacy Ethernet communication in Basic Ethernet mode is not within the scope of this specification.

The communication model supports the transmission of isochronous and asynchronous frames. Isochronous frames are supported in POWERLINK Mode only, asynchronous frames in POWERLINK Mode and Basic Ethernet Mode.

By means of isochronous frame transmission a network wide coordinated data acquisition and actuation is possible. The isochronous transmission of frames is supported by the POWERLINK Mode cycle structure. The system is synchronised by SoC frames. Asynchronous frames may be transmitted in the asynchronous slot of POWERLINK Mode cycle upon transmission grant by the POWERLINK MN, or at any time in Basic Ethernet Mode.

With respect to their functionality, three types of communication relationships are distinguished

- Master/Slave relationship (Fig. 7 and Fig. 8)
- Client/Server relationship (Fig. 9)
- Producer/Consumer relationship (Fig. 10 and Fig. 11)

2.3.1 Master/Slave relationship

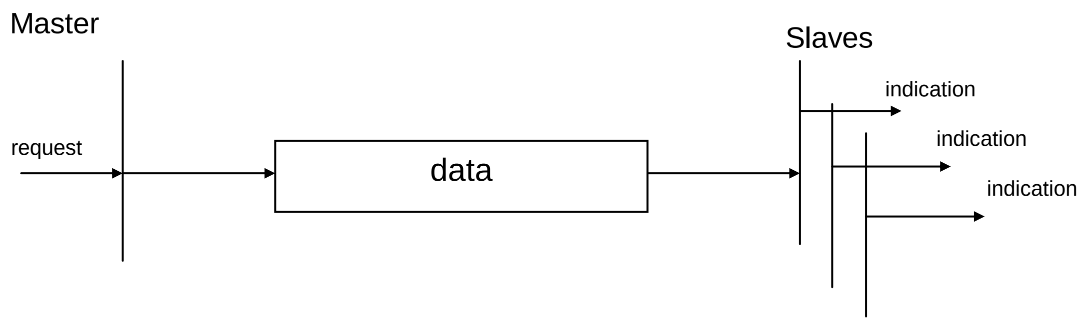

Fig. 7. Unconfirmed master slave communication

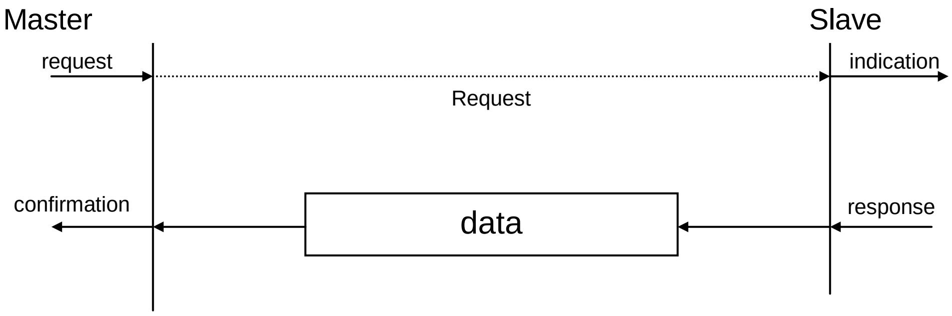

Fig. 8. Confirmed master slave communication

At any time there is exactly one device in the network serving as a master for a specific functionality. All other devices in the network are considered as slaves. The master issues a request and the addressed slave(s) respond(s) if the protocol requires this behaviour.

2.3.2 Client/Server relationship

This is a relationship between a single client and a single server. A client issues a request (upload/download) thus triggering the server to perform a certain task. After finishing the task the server answers the request.

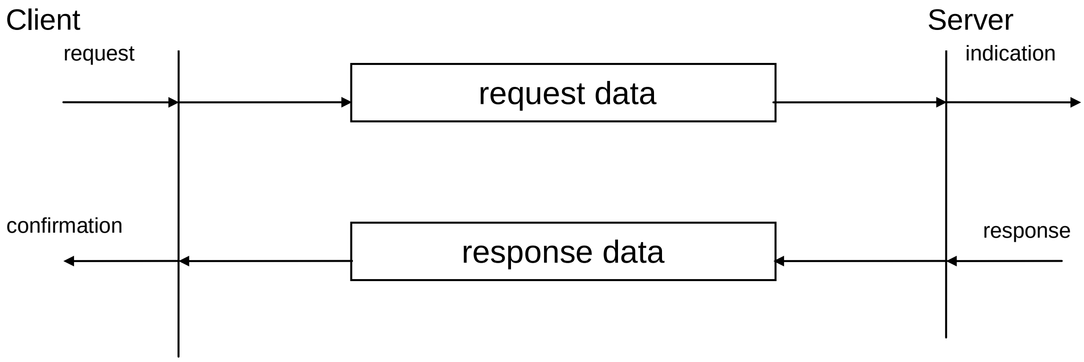

Fig. 9. Client/Server communication

2.3.3 Producer/Consumer relationship - Push/Pull model

The producer/consumer relationship model involves a producer and zero or more consumer(s). The push model is characterized by an unconfirmed service requested by the producer. The pull model is characterized by a confirmed service requested by the consumer.

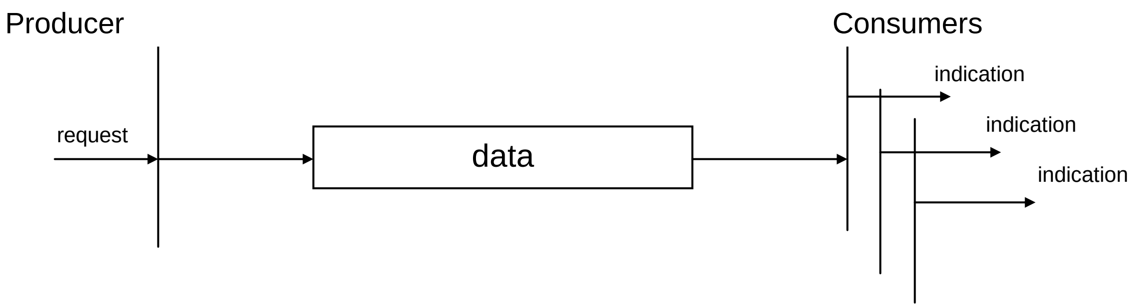

Fig. 10. Push model

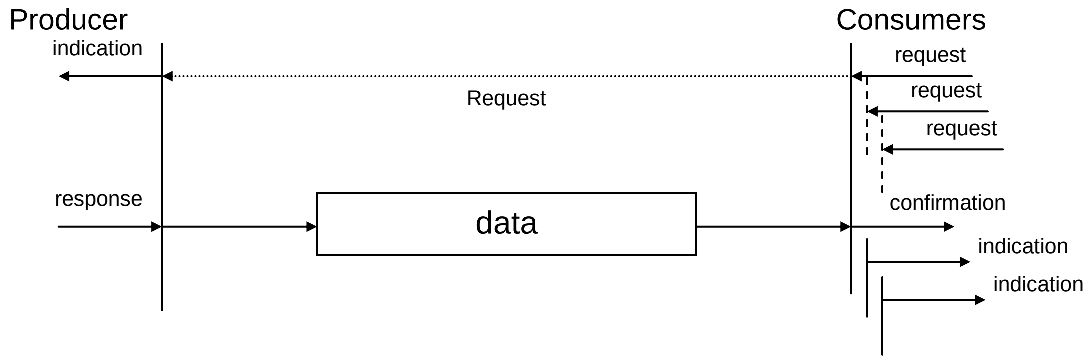

Fig. 11. Pull model

2.3.4 Superimposing of Communication Relationships

POWERLINK collects more than one function into one frame (refer 4.6). It is therefore not usually possible to apply a single communication relationship to the complete frame, but only to particulars services inside the frame.

The PollResponse frame for example (refer 4.6.1.1.4) transmitted by the CN includes several services:

- Transmission of the current NMT state of the CN is the response part of a confirmed master/slave relationship triggered by the MN.
- Request of the asynchronous slot is the request part of a client/server relationship.
- Transmission of PDO data occurs in conformance to a push model Producer/Consumer relationship.

3 Physical Layer

POWERLINK is a protocol residing on top of the standard IEEE 802.3 MAC layer. The physical layer is 100BASE-X (copper and fiber, see IEEE 802.3). Half-Duplex transmission mode shall be used.

Autonegotiation is not recommended.

POWERLINK uses Ethernet as it is, without any modifications. Hence any advancement in Ethernet Technology can be exploited (e.g. Gigabit Ethernet).

3.1 Topology

3.1.1 Hubs

To fit POWERLINK jitter requirements it is recommended to use hubs to build a POWERLINK network. Class 2 Repeaters shall be used in this case.

Hubs have the advantage of reduced path delay value (indicated by D_PHY_HubDelay_U32) and have small frame jitter (indicated by D_PHY_HubJitter_U32).

Hubs may be integrated in the POWERLINK interface cards.

Hub integration shall be indicated by D_PHY_HubIntegrated_BOOL. The number of externally accessible POWERLINK ports provided by a device shall be indicated by D_PHY_ExtEPLPorts_U8.

3.1.2 Switches

Switches may be used to build a POWERLINK network. The additional latency and jitter of switches has to be considered for system configuration.

It has to be considered that any POWERLINK network constructed with anything but Class 2 Repeater Devices does not conform to the POWERLINK standard as defined in this document.

3.2 Network Guidelines

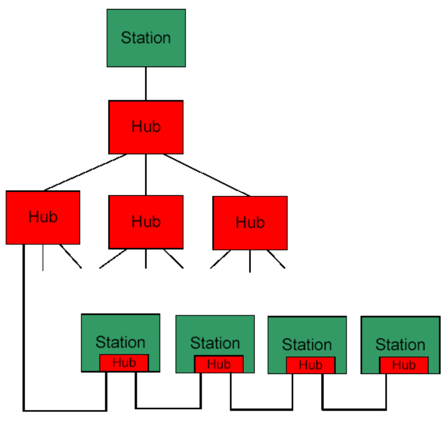

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Fig. 12. Star topology and line topology

POWERLINK does not cause collisions. This is why the most extreme topology guideline of the IEEE standard (5120 ns maximum round trip signal runtime) does not apply.

Due to this leniency in the topology, line structures that are required in applications in the field are made possible. Nodes may use integrated hubs, further simplifying construction in the field. A mixed tree and line structure is available when a large number of nodes are being used.

Fiber optic transducers may be used. However, they should be tested to establish whether they cause more jitter and latency than normal hubs. When designing the network infrastructure some timing constraints shall be considered. The MN uses a timeout after sending a PollRequest Frame to detect transmission errors and node failures. The round trip latency between the MN and a CN shall not exceed the timeout value. The timeout value can be set for every single node.

3.2.1 Jitter

Every hub level introduces additional Jitter (equal or below 70 ns). Only the number of hub levels between MN and most distanced CN is relevant. If the MN is located in the center of line or ar star topology, the number of hub level between the most distanced CNs is irrelevant for synchronisation jitter.

3.3 Ports and Connectors

To connect POWERLINK devices one of two types of connectors shall be used:

4. RJ-45: for light duty environments.
5. M12: for heavy duty environments.

Both types may be mixed on the same cable.

For further information please refer to IEC 61918 and IEC 61784-5-13.

3.3.1 RJ-45

Pin assignment as defined by EIA/TIA T568B.

The following is provided for convenience; please refer to the corresponding International Standards.

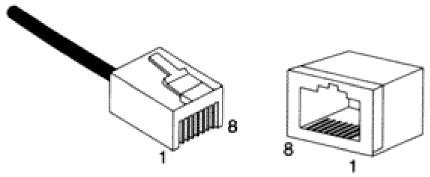


Fig. 13. RJ45 pin assignment (left: connector, right: port)

The pictures shows an RJ45 connector on the cable and a port (on the device or Hub).

The pin assignment on each node shall be that of a hub/switch port. Therefore the port pins are assigned as follows:

Pin	Wire color code	Assignment 100BASE-TX
1	WHT/ORG	Rx+
2	ORG	Rx-
3	WHT/GRN	Tx+
4	BLU	
5	WHT/BLU	
6	GRN	Tx-
7	WHT/BRN	
8	BRN	

Tab. 2 Pin assignment RJ45 port

3.3.2 M12

For IP67 requirements. 4 pin D-coded as recommended in IEC 61076-2-101.

Male side is fitted on the cable, female on the device or hub.

The following is provided for convinience; please refer to the corresponding International Standard.

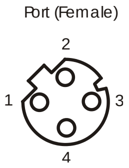


Fig. 14. IP67 port pin assignment.

Pin	Wire color code	Assignment 100BASE-TX
1	BLU/YEL	Tx+
2	YEL/WHT	Rx+
3	WHT/ORG	Tx-
4	ORG/BLU	Rx-

Tab. 3 Pin assignment IP67 port

3.3.3 Crossover Pin Assignment

The pin assignment shall be that of a crossover cable.

Therefore all devices can be interconnected by one type of cable. The pin assignment of a crossover cable is defined as:

- Tx+ to Rx+
- Tx- to Rx-
- Rx+ to Tx+
- Rx- to Tx-

3.3.3.1 RJ45 to RJ45

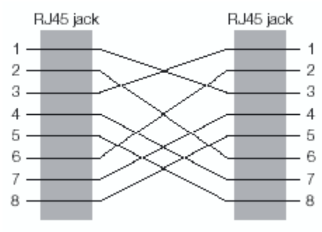


Fig. 15. recommended RJ45 to RJ45 pin assignment

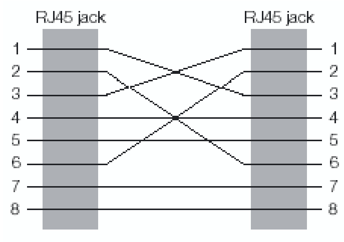


Fig. 16. not recommended RJ45 to RJ45 pin assignment

3.3.3.2 M12 to M12

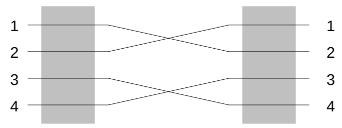


Fig. 17. M12 to M12 pin assignment

3.3.3.3 M12 to RJ45

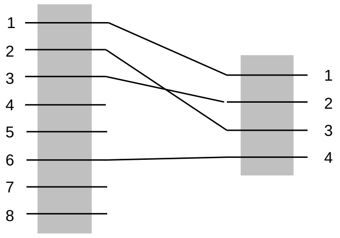


Fig. 18. M12 to RJ45 pin assignment

3.4 Cables (recommendation)

Please refer to IEC 61918 and IEC 61784-5-13.

The following is provided for convenience; please refer to the corresponding International Standards.

To increase noise immunity only S/FTP or SF/FTP cables should be used (Cat5). The maximum cable length (100 meters) predefined by Ethernet 100Base-TX shall apply.

The pin assignment shall be that of a crossover cable.

Regarding wiring and EMC measures, the IEC 61918 and IEC 61784-5-13 shall be considered.

4 Data Link Layer

4.1 Modes of Operation

Two operating modes are defined for POWERLINK networks:

- POWERLINK mode

  In POWERLINK Mode network traffic follows the set of rules given in this standard for Real-time Ethernet communication. Network access is managed by a master, the POWERLINK Managing Node (MN). A node can only be granted the right to send data on the network via the MN. The central access rules preclude collisions, the network is therefore deterministic in POWERLINK Mode.

  In POWERLINK Mode most communication transactions are via POWERLINK-specific messages. An asynchronous slot is available for non-POWERLINK frames. UDP/IP is the preferred data exchange mechanism in the asynchronous slot; however, it is possible to use any protocol.

- Basic Ethernet mode

  In Basic Ethernet Mode network communication follows the rules of Legacy Ethernet (IEEE802.3). Network access is via CSMA/CD. Collisions occur, and network traffic is non-deterministic.

  Any protocol on top of Ethernet may be used in Basic Ethernet mode, the preferred mechanisms for data exchange between nodes being UDP/IP and TCP/IP.

4.2 POWERLINK Mode

4.2.1 Introduction

POWERLINK Mode is based on the standard Ethernet CSMA/CD technique (IEEE 802.3) and thus works on all Legacy Ethernet hardware.

Determinism is achieved with a pre-planned and organized message exchange: messages are grouped in cycles, which are subdivided into the isochronous and the asynchronous phase.

Each node gets permission for sending its own frames by the POWERLINK MN. Therefore, no collisions should occur and the collision-resolving re-transmission of messages defined by IEEE802.3, which is responsible for the non-deterministic behavior of Legacy Ethernet, is not used.

4.2.2 POWERLINK Nodes

The node managing the permission to send messages to the Ethernet is called the POWERLINK Managing Node (MN).

All other nodes transmit only within communication slots assigned by the MN. They are thus called Controlled Nodes (CN).

4.2.2.1 POWERLINK Managing Node

Only the MN may send messages independently – i.e. not as a response to a received message. Controlled Nodes shall be only allowed to send when requested to by the MN.

The Controlled Nodes shall be accessed cyclically by the MN. Unicast data shall be sent from the MN to each configured CN (frame: PReq), which shall then publish its data via multicast to all other nodes (frame: PRes).

Optionally, the MN may send a multicast Pres frame in the isochrononous phase (see Fig. 19). With this frame the MN may publish its own data to all other nodes.

All available nodes in the network shall be configured on the MN.

Only one active MN is permitted in a POWERLINK network.

The ability of a node to perform MN functions shall be indicated by the device description entry D_DLL_FeatureMN_BOOL.

4.2.2.2 POWERLINK Controlled Node

CNs shall be passive bus nodes. They shall only send when requested by the MN.

The ability of a node to perform CN functions shall be indicated by the device description entry D_DLL_FeatureCN_BOOL.

4.2.2.2.1 Isochronous CN

Each isochronous CN shall receive a unicast PReq frame from the MN in the POWERLINK cycle and shall send back a PRes frame to the MN. PReq and PRes frames may transport isochronous data.

CNs may be accessed every cycle or every n^{th} cycle (multiplexed nodes, n > 1).

PReq can only be received by the specifically addressed CN. However, PRes frames shall be sent by the CN as multicast messages, allowing all other CNs to monitor the data being sent.

Additional data from the MN may be received by a multicast PRes message transmitted by the MN.

Isochronous CNs shall request the right to transmit asynchronous data from the MN, if required.

The ability of a CN to perform isochronous communication shall be indicated by a feature flag in the object dictionary entry NMT_FeatureFlags_U32 ($1F82_h$) and the device description entry D_NMT_Isochronous_BOOL.

No POWERLINK CN device shall rely on being polled as isochronous CN, when the network performs the isochronous POWERLINK cycle (4.2.4.1), Async-only CN type communication shall be guaranteed. Application level function limitations may occur when a device enabled to perform isochronous functions is operated in Async-only mode.

4.2.2.2.2 Async-only CN

CNs may be operated in a way, that they aren’t accessed cyclically in the isochronous phase by the MN.

The MN shall cyclically poll each async-only CN during the asynchronous phase with a StatusRequest – a special form of the SoA frame. The CN shall respond with a StatusResponse, special form of Asynchronous Send frame. The poll interval shall be at least C_NMT_STATREQ_CYCLE. It is affected by the asynchronous scheduling and is thus non-deterministic.

Async-only CNs shall request the right to transmit asynchronous data from the MN, if required.

Async-only CNs shall actively communicate during the asynchronous phase only. Nevertheless, they may listen to the multicast network traffic, transmitted by the MN and the isochronous CNs.

4.2.3 Services

POWERLINK provides three services:

- Isochronous Data Transfer

  One pair of messages per node shall be delivered every cycle, or every n^{th} cycle in the case of multiplexed CNs.

  Additionally, there may be one multicast PRes message from the MN per cycle.

  Isochronous data transfer is typically used for the exchange of time critical data (real-time data).

- Asynchronous Data Transfer

  There may be one asynchronous message per cycle. The right to send shall be assigned to a requesting node by the MN via the SoA message.

  Asynchronous data transfer is used for the exchange of non time-critical data.

- Synchronisation of all nodes

  At the beginning of each isochronous phase, the MN transmits the multicast SoC message very precisely to synchronise all nodes in the network.

4.2.4 POWERLINK Cycle

The POWERLINK cycle shall be controlled by the MN.

4.2.4.1 Isochronous POWERLINK Cycle

Isochronous data exchange between nodes shall occur cyclically. It shall be repeated in a fixed interval, called POWERLINK cycle.

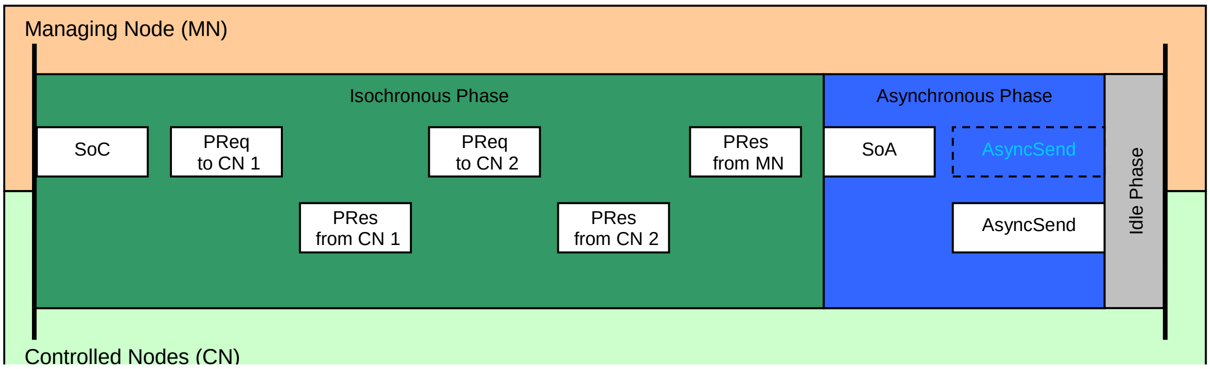


Fig. 19. POWERLINK Cycle

The following time phases exist within one cycle:

- Isochronous phase
- Asynchronous phase
- Idle phase

It is important to keep the start time of a POWERLINK cycle as exact (jitter-free) as possible. The length of individual phases can vary within the preset phase of a POWERLINK cycle.

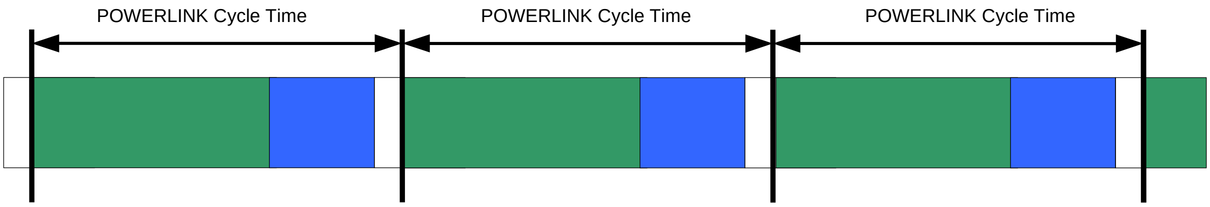


Fig. 20. POWERLINK - an isochronous process

The network shall be configured in a way that the preset cycle time is not exceeded. Adherence to the cycle time shall be monitored by the MN.

All data transfers shall be unconfirmed, i.e. there is no confirmation that sent data has been received. To maintain deterministic behavior, protecting the isochronous data (PReq and PRes) is neither necessary nor desired. Asynchronous data may be protected by higher protocol layers.

4.2.4.1.1 Isochronous phase

At the beginning of a POWERLINK cycle, the MN shall send a SoC frame to all nodes via Ethernet multicast. The send and receive time of this frame shall be the basis for the common timing of all the nodes.

Only the SoC frame shall be generated on a periodic basis. The generation of all other frames shall be event controlled (with additional time monitoring per node).

The MN shall start the isochronous data exchange after the SoC frame has been sent.

A PReq frame shall be sent to every configured and active node. The accessed node shall respond by a PRes frame.

PReq shall be an Ethernet unicast frame. It is received by the target node only. PRes shall be sent as an Ethernet multicast frame.

Both the PReq and the PRes frames may transfer application data. The MN only sends PReq data to one CN per frame. PReq transfer is dedicated to data relevant for the addressed CN only.

In contrast, the PRes frame may be received by all nodes. This makes communication relationships possible according to the producer/consumer model.

The PReq / PRes procedure shall be repeated for each configured and active isochronous CN.

The MN may send a multicast PRes frame to all nodes. This frame is dedicated to transfer data relevant for groups of CNs.

Support of PRes transmission by the MN is optional. The ability of an MN to transmit PRes shall be indicated by the device description entry D_DLL_MNFeaturePResTx_BOOL. If the feature is provided, transmission shall be enabled by NMT_NodeAssignment_AU32[C_ADR_MN_DEF_NODE_ID].Bit 12.

The isochronous phase shall be calculated from start of SoC to start of SoA.

The size of the POWERLINK cycle is predominantly affected by the size of the isochronous phase. When configuring the POWERLINK cycle, the sum of the times required by the PReq / PRes accesses to each configured CN shall be taken into account, i.e. the time needed to access all configured nodes in one cycle has to be accounted for. Use of the multiplexed access technology (4.2.4.1.1.1) may reduce the amount of time.

When operating the isochronous phase, the length of this phase may vary according to the number of active CNs.

The order in which CNs are polled may be implementation specific or controlled by object NMT_IsochrSlotAssign_AU8 if supported by the MN. An implementation should pack the performed PReq / PRes packages to the begin of the isochronous phase. It should provide means to rearrange the poll order, to avoid location of the nodes having the worst SoC latency time value (D_NMT_CNSoC2PReq_U32) at the slot following SoC.

Isochronous phases may be counted by the device. If implemented, counting shall be performed on base of transmitted or received SoC frames. The counter value may be accessed via DIA_NMTTelegrCount_REC.IsochrCyc_U32.

4.2.4.1.1.1 Multiplexed Timeslots

POWERLINK supports CN communication classes, that determine the cycles in which nodes are to be addressed.

- Continuous

  Continuous data shall be exchanged in every POWERLINK cycle.

- Multiplexed

  Multiplexed data to and from one CN shall not be exchanged in every POWERLINK cycle.

  The accesses to the multiplexed CNs shall be dispersed to the multiplexed cycle that consists of a number of POWERLINK cycles.

  The dispersion allows the isochronous access to a large number of CNs without elongating the POWERLINK cycle to an unacceptable amount. However, multiplexed CN access reduces the poll frequency to the particular CN.

  The configuration of the multiplexed cycle is shown in 4.2.4.4.

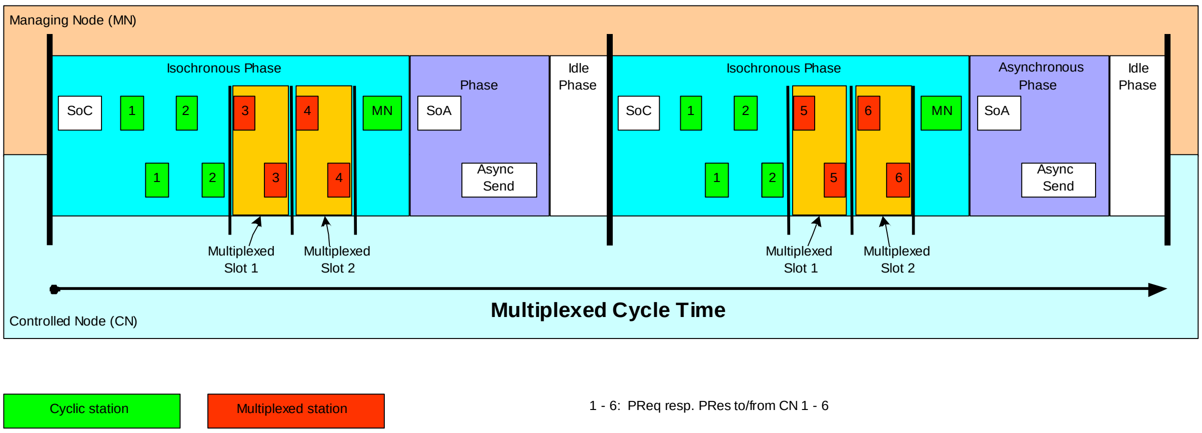


Fig. 21. Multiplexed POWERLINK cycle

Continuous and multiplexed access may be operated in parallel during one POWERLINK cycle. The apportionment of the isochronous phase to continuous and multiplexed slots shall be fixed by configuration (NMT_MultiplCycleAssign_AU8, NMT_IsochrSlotAssign_AU8).

Although the multiplexed nodes are not processed in each cycle, they can monitor the entire data transfer of the continuous nodes because all PRes frames are sent as multicast frames.

E.g. in Motion Control, multiplexed timeslots can be used for a large number of slave axes to receive position data from few master axes. The master axes are configured to communicate continuously, accesses to the slave axes multiplexed. In this way, the master axes transmit their data to the (monitoring) slave axes in each cycle, while the slave axes also take part in the communication in a slower cycle.

The size of each particular multiplexed slot shall be equal to the maximum time necessary for the PReq / PRes access of the CN assigned to the slot.

In case of MN cycle loss, the multiplexed access sequence shall be continued on a per time base, after the cycle loss error phase is over. E.g. CNs shall be skipped to maintain time equidistance of access to nodes not affected by the cycle loss.

The ability of an MN enabled node to perform control of multiplexed isochronous operation shall be indicated by the device description entry D_DLL_MNFeatureMultiplex_BOOL. The ability of a CN enabled node to be isochronously accessed in a multiplexed way shall be indicated by the device description entry D_DLL_CNFeatureMultiplex_BOOL.

4.2.4.1.2 Asynchronous phase

In the asynchronous phase of the cycle, access to the POWERLINK network may be granted to one CN or to the MN for the transfer of a single asynchronous message only.

There shall be two types of asynchronous frames available:

- The POWERLINK ASnd frame shall use the POWERLINK addressing scheme and shall be sent via unicast or broadcast to any other node.
- A Legacy Ethernet message may be sent.

If no asynchronous message transmission request is pending at the MN scheduling queues (4.2.4.1.2.1), the MN shall issue a SoA without assignment of the right to send to any node. No ASnd frame will follow to the SoA frame in this case.

The MN shall start the asynchronous phase with the SoA. The SoA shall be used to identify CNs, request status information of a CN, to poll async-only CNs and to grant the asynchronous transmit right to one CN.

The SoA frame is the first frame in the asynchronous phase and is a signal to all CNs that all isochronous data have been exchanged during the isochronous phase.

The asynchronous phase shall be calculated from the start of SoA to the end of the asynchronous response. If no asynchronous response is allowed for any node, the asynchronous phase shall be terminated by the end of SoA .

This definition is valid from the network's point view. It may be different from the node's application point of view. Due to the AsyncSend addressing scheme, the asynchronous phase may be terminated by the end of SoA on those nodes not being addressed, whereas it ends at the end of the asynchronous response on the addressed nodes.

Asynchronous frames may be counted by the device. If implemented, received frames shall be indicated by DIA_NMTTelegrCount_REC.AsyncRx_U32 and transmitted frames by DIA_NMTTelegrCount_REC.AsyncTx_U32.

4.2.4.1.2.1 Asynchronous Scheduling

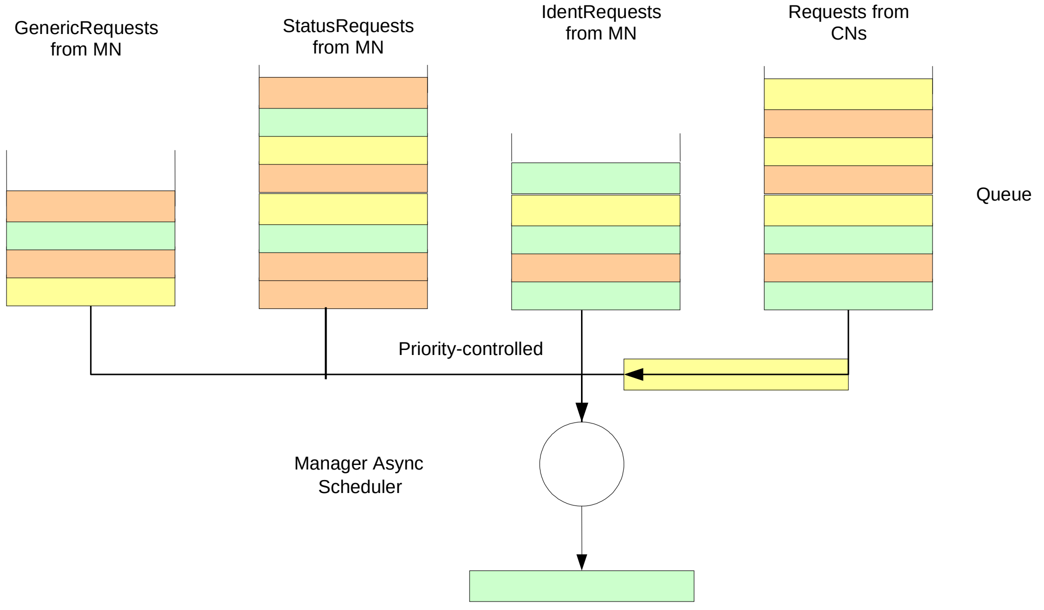


Fig. 22. Asynchronous scheduling

The MN handles scheduling of all asynchronous data transfers.

If a CN wants to send an asynchronous frame, it shall inform the MN via the PRes or the StatusResponse frame.

The asynchronous scheduler of the MN shall determine in which cycle the right to send the asynchronous frame will be granted. It shall guarantee that no send request will be delayed for an indefinite amount of time, even if network load is high.

The MN shall select a node from all queued send requests (including its own). It shall send a SoA frame with a Requested Service Target identifying which node is allowed to send an asynchronous frame.

The MN shall manage the dispatching of the asynchronous phase using different queues:

- Generic transmit requests from the MN.
- IdentRequest frames from the MN to identify CNs
- StatusRequest frames to poll CNs
- Transmit requests from the CNs

4.2.4.1.2.2 Distribution of the Asynchronous phase

With the PRes, IdentResponse or StatusResponse RS flag (3 bits, see 4.6.1.1.4, 7.3.3.2.1, 7.3.3.3.1) the CN shall indicate the number of send-ready packages in it’s queues.

An RS value of 0 (000_b) shall indicate that the queues are empty and an RS value of 7 (111_b) shall indicate that 7 or more packages are queued.

The assignment of the asynchronous phase shall decrement the MN-administered number of frames requested by the respective CN. If the MN queue length reached zero, no more further asynchronous phases are assigned.

The algorithm that is used to assign the asynchronous phase when there are multiple requests pending shall be manufacturer-specific.

4.2.4.1.2.3 Asynchronous Transmit Priorities

Asynchronous transmit requests may be prioritized by 3 PR bits in the PRes, the IdentResponse and StatusResponse frame (see 4.6.1.1.4, 7.3.3.2.1, 7.3.3.3.1).

POWERLINK supports eight priority levels. Two of these levels are dedicated to POWERLINK purpose:

- PRIO_NMT_REQUEST
  This is the highest priority that shall be exclusively applied if a CN requests an NMT command to be issued by the MN
- PRIO_GENERIC_REQUEST
  Medium priority which is the standard priority level for non-NMT command requests. SDO via asynchronous communication (see 6.3.2) requests shall apply this priority level. Application requests may apply PRIO_GENERIC_REQUEST

The remaining priority levels above and below PRIO_GENERIC_REQUEST are available for application purpose.

Requests with a high priority level shall be preferentially assigned by the MN compared to those with low priority numeric value.

Requests of different priorities shall be handled by independent priority specific queues on the CN..

The PRes PR flags shall indicate the highest priority level containing pending requests. The RS flags shall indicate the number of pending requests at the reported priority level. Lower priority request indication shall be suspended until all high priority requests have been assigned.

Fig. 23 shows an example of priority related asynchronous request handling.

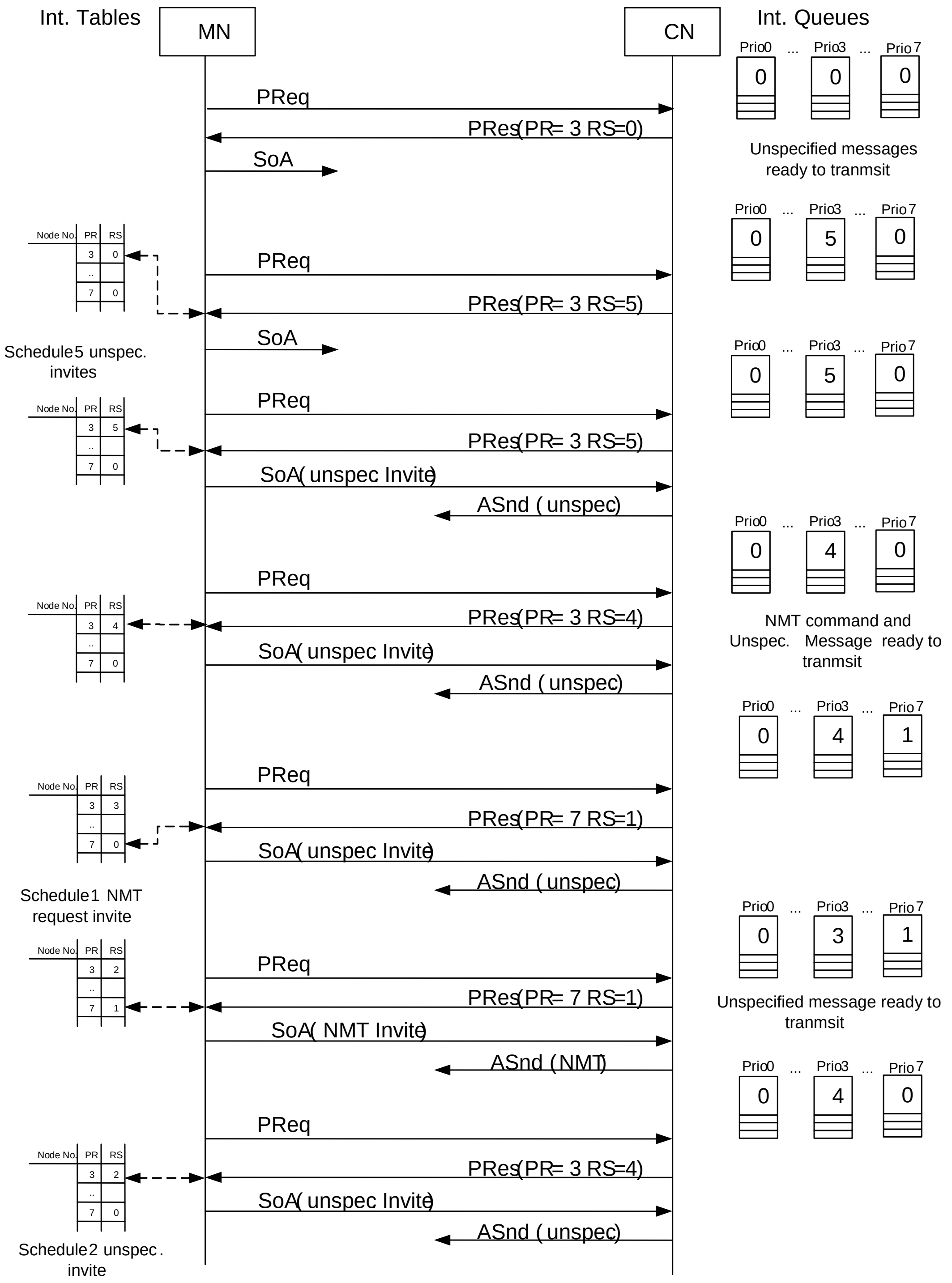


Fig. 23. Asynchronous transmit priority handling
(Priority level PR: 7 = PRIO_NMT_REQUEST, 3 = PRIO_GENERIC_REQUEST)

4.2.4.1.3 Idle Phase

The Idle Phase is the remaining time interval between the end of the asynchronous phase and the beginning of the next cycle.

During the Idle Phase, all network components shall "wait" for the beginning of the following cycle. The duration of the Idle Phase may be 0, i.e. an implementation shall not rely on an existing or fixed Idle Phase.

The idle phase shall be calculated from end of SoA or ASnd (see 4.2.4.1.2) to start of SoC.

4.2.4.2 Reduced POWERLINK Cycle

During system startup (NMT state NMT_MS_PRE_OPERATIONAL_1), a reduced POWERLINK Cycle shall be applied to diminish network load, while the system is being configured via SDO communication.

The Reduced POWERLINK Cycle shall consist of queued asynchronous phases only. The duration of the asynchronous phase and thus the duration of the Reduced POWERLINK Cycle may vary from one cycle to the next.

If a CN is assigned to send and there are no information about the length of the expected AsyncSend frame available at the MN, the next Reduced POWERLINK Cycle shall not start until at least the timeout given by the length of a maximum size ethernet frame NMT_CycleTiming_REC.AsyncMTU_U16) plus the maximum response time to the SoA invite message required by the CNs (NMT_CycleTiming_REC.ASndMaxLatency_U32) elapsed.

If the MN endues AsyncSend length information, i.e. if the MN assignes the Asynchronus Slot to itself or if the MN is the target node of the asynchronous message, it may reduce the Reduce POWERLINK cycle length (Fig. 24).

If there is no assignment to any node (MN included), the next Reduced POWERLINK Cycle may follow without any timeout.

The assignment mechanism used for the asynchronous phase of the isochronous POWERLINK cycle (4.2.4.1.2) shall also be applied to the Reduced POWERLINK Cycle.

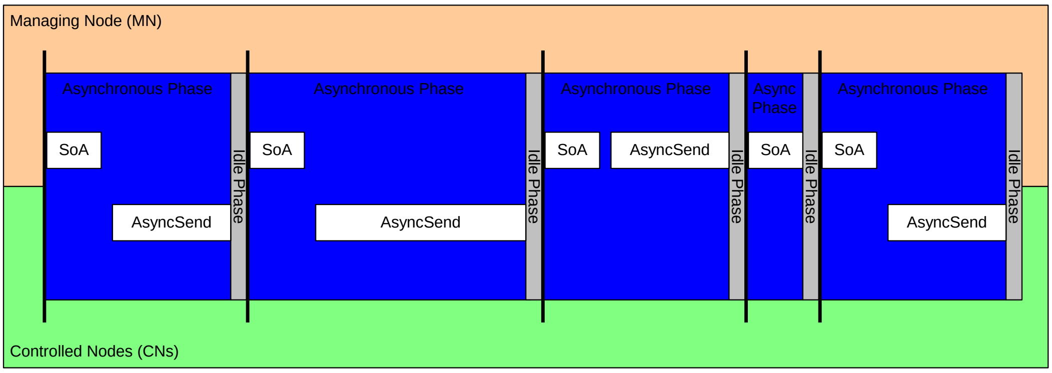


Fig. 24. Reduced POWERLINK cycle

The Reduded POWERLINK Cycle shall be robust to collisions. Collisions shall be resolved by CSMA/CD. In case of collision, the next Reduced POWERLINK Cycle shall start after a timeout given by the double length of a maximum size ethernet frame (1518 Bytes).

4.2.4.3 POWERLINK Cycle Timing

Fig. 25, Fig. 26 and Fig. 27 show the timing of the isochronous POWERLINK cycle. The figures show a system of three nodes. The MN is physically located between two isochronously accessed CNs.

The figures are a schematic approach. They are valid for the NMT states NMT_MS_READY_TO_OPERATE and NMT_MS_OPERATIONAL or NMT_CS_READY_TO_OPERATE and NMT_CS_OPERATIONAL. The amount of time shown does not reflect the realistic timing relationships of a real system.

Fig. 25 shows the typical sequence of messages in the isochronous phase. The PRes frames from one CN are received by the other CN (cross traffic). Fig. 26 depicts the timing of a transmission of an asynchronous frame by a CN, Fig. 27 the less critical case of asynchronous transmission by the MN.

Tab. 4 provides the description of the timing parameters introduced by the figures, the source of the data, special handling of the data and object dictionary entries containing the parameters.

The node located verifications proposed by Tab. 4 are optional on the node if not mentioned otherwise. A POWERLINK network configuration tool shall perform all the verifications during configuration process.

Application hint:
The timing parameters introduced by this chapter allows a sophisticated fine tuning of the cycle timing, required by notably cycle time sensitive high end applications.
The majority of applications will apply default values for most of the parameters. Only a few variables will remain to be setup to configure a typical POWERLINK network.

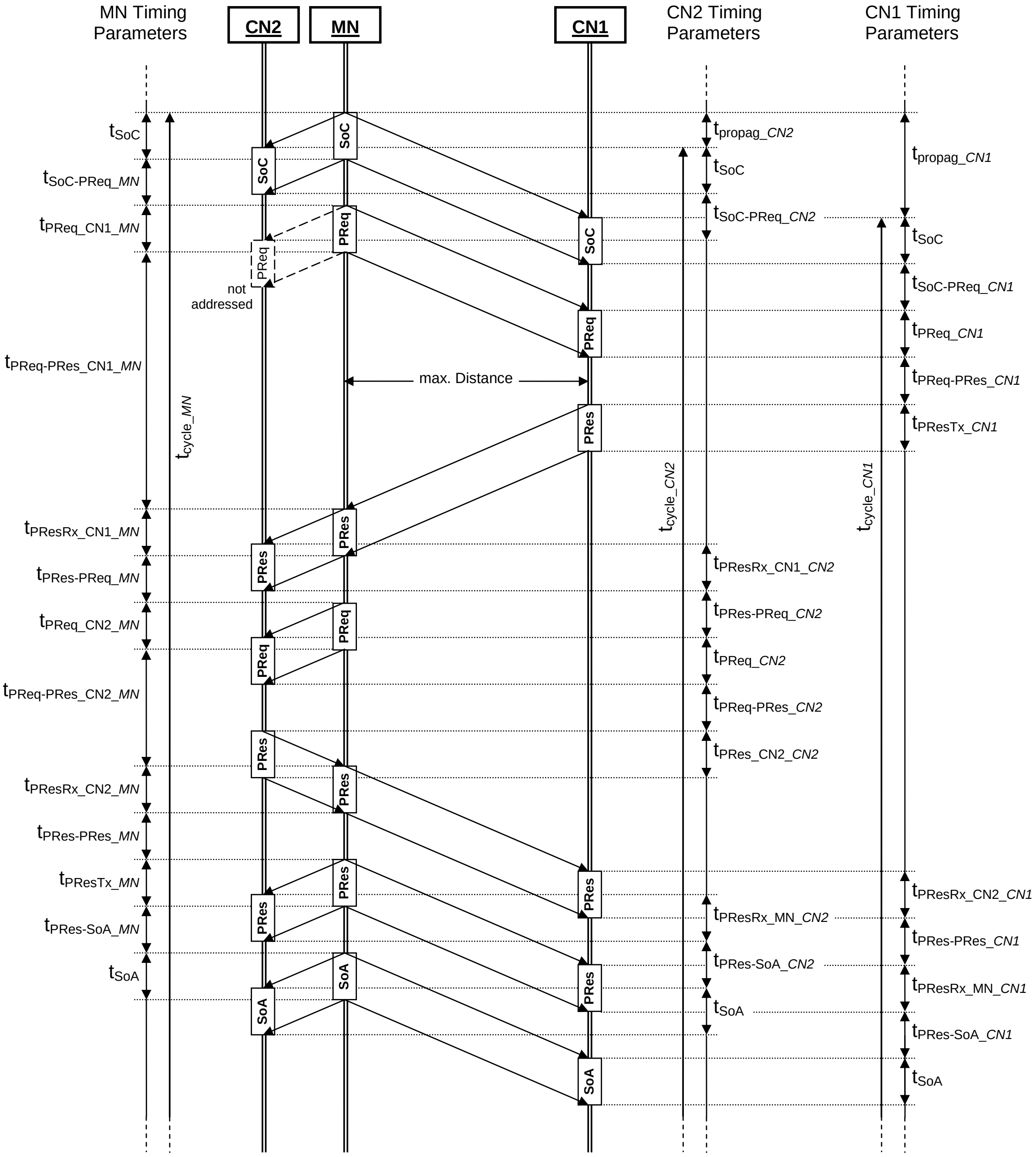
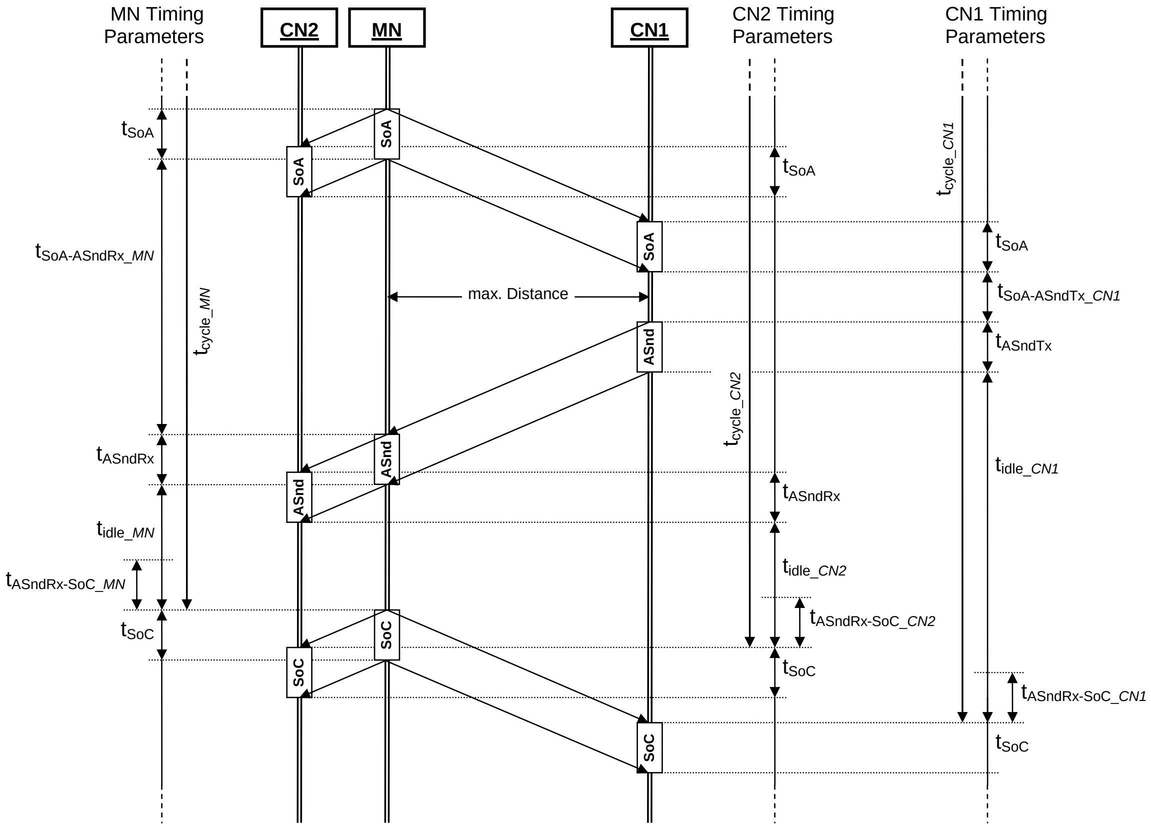
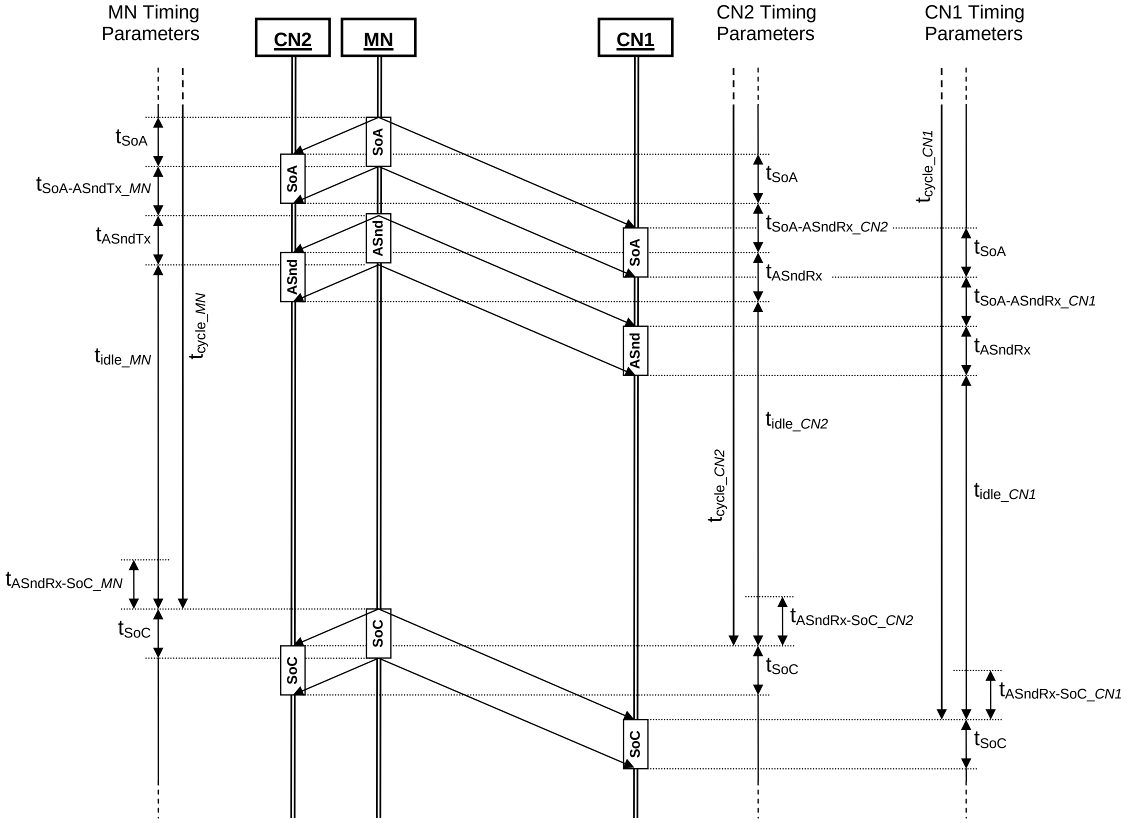


Fig. 25. POWERLINK cycle timing, start phase and isochronous phase



Hint: ASnd refers to POWERLINK ASnd frames and non-POWERLINK frames

Fig. 26. POWERLINK cycle timing, asynchronous phase, AsyncSend transmission by CN



Hint: ASnd refers to POWERLINK ASnd frames and non-POWERLINK frames

Fig. 27. POWERLINK cycle timing, asynchronous phase, AsyncSend transmission by MN

No	Parameter	Description	Data Source	Handling[1]	Index
1	t_{cycle_MN}, t_{cycle_CNn}	length of POWERLINK isochronous cycle	system configuration	MN may verify before isochronous access to CN_n: $t_{cycle\_MN} = t_{cycle\_CNn}$	NMT_CycleLen_U32
2	t_{SoC}	SoC frame time consumption	constant t_{SoC} = C_DLL_T_MIN_FRAME + C_DLL_T_PREAMBLE	--	--
3	t_{propag_CNn}	signal propagation time MN $\rightarrow$ CN_n and vice versa	system configuration	$t_{propag\_CNn} = (t_{PReq-PRes\_CNn\_MN} - t_{PReq-PRes\_CNn}) / 2$	--
4	$t_{SoC-PReq\_MN}$	delay between end of SoC transmission and start of PReq transmission	system configuration	depends on implementation of NMT_MNCycleTiming_REC. WaitSoCPReq: a. $t_{SoC-PReq\_MN}$ = max ($t_{SoC-PReq\_CNn}$, $t_{SoC-PReqMin\_MN}$) b. $t_{SoC-PReq\_MN} = t_{SoC-PReqMin\_MN}$	a. NMT_MNCycleTiming_REC. WaitSoCPReq b. --
5	$t_{SoC-PReqMin\_MN}$	MN minimum delay between end of SoC transmission and start of PReq transmission	MN device description D_NMT_MNSoC2PReq_U32	$t_{SoC-PReqMin\_MN} \geq$ C_DLL_T_IFG	--
6	$t_{SoC-PReq\_CNn}$	minimum delay required by CN_n between end of SoC reception and start of PReq reception	CN_n device description D_NMT_CNSoC2PReq_U32	$t_{SoC-PReq\_CNn} \geq$ C_DLL_T_IFG	--
7	$t_{PReq\_CNn\_MN}$ t_{PReq_CNn}	time consumption of PReq frame to be transmitted to CN_n	$t_{PReq\_CNn\_MN}$ = ($t_{PReqPL\_CNn\_MN}$ + C_DLL_T_EPL_PDO_HEADER + C_DLL_T_ETH2_WRAPPER) * 8 * C_DLL_T_BITTIME + C_DLL_T_PREAMBLE	--	--
8	$t_{PReqPL\_CNn\_MN}$	payload of PReq frame to be transmitted to CN_n	system configuration	MN may verify at start up: $t_{PReqPL\_CNn\_MN} \leq t_{PReqPLMax\_MN}$ MN may verify before isochronous access to CN_n: $t_{PReqPL\_CNn\_MN} = t_{PReqPL\_CNn}$	NMT_MNPReqPayloadLimitList_AU16 [$NodeID_{CNn}$]
9	$t_{PReqPLMax\_MN}$	size of MN isochronous frame transmit buffer (referring to payload)	system configuration	--	NMT_CycleTiming_REC. IsochrTxMaxPayload_U16
10	t_{PReqPL_CNn}	payload of PReq frame expected by CN_n	system configuration	CN_n may verify at start up: $t_{PReqPL\_CNn} \leq t_{PReqPLMax\_CNn}$	NMT_CycleTiming_REC. PReqActPayloadLimit_U16

[1] The node located verifications are optional if not mentioned otherwise. A configuration tool shall perform the verifications during network configuration process.

No	Parameter	Description	Data Source	Handling[1]	Index
11	$t_{PReqPLMax\_CNn}$	size of CN_n isochronous frame receive buffer (referring to payload)	system configuration	--	NMT_CycleTiming_REC. IsochrRxMaxPayload_U16
12	$t_{PReq-PRes\_CNn}$	delay between end of PReq reception and start of PRes transmission	system configuration	$t_{PReq-PRes\_CNn} \geq$ C_DLL_T_IFG	NMT_CycleTiming_REC. PResMaxLatency_U32
13	t_{PResTx_CNn} $t_{PResRx\_CNn\_MN}$ $t_{PResRx\_CNn\_CNm}$	time consumption of PRes to be transmitted by CN_n	t_{PResTx_CNn} = ($t_{PResPLTx\_CNn}$ + C_DLL_T_EPL_PDO_HEADER + C_DLL_T_ETH2_WRAPPER) * 8 * C_DLL_T_BITTIME + C_DLL_T_PREAMBLE	--	--
14	$t_{PResPLTx\_CNn}$	payload of PRes to be transmitted by CN_n	system configuration	CN_n may verify at start up: $t_{PResPLTx\_CNn} \leq t_{PResPLTxMax\_CNn}$	NMT_CycleTiming_REC. PResActPayloadLimit_U16
15	$t_{PResPLTxMax\_CNn}$	size of CN_n PRes frame transmit buffer (referring to payload)	system configuration	--	NMT_CycleTiming_REC. IsochrTxMaxPayload_U16

16	$t_{PReq-PRes\_CNn\_MN}$	delay timeout between end of transmission of PReq to CN_n and start of reception of PRes from CN_n	system configuration	if 1st device polled after SoC depends on implementation of NMT_MNCycleTiming_REC. WaitSoCPReq (cf. Tab. 4, Line 4):
				a. $t_{PReq-PRes\_CNn\_MN}$ = $t_{PReq-PRes\_CNn}$ + 2 * t_{propag_CNn}
				b. $t_{PReq-PRes\_CNn\_MN}$ = max ($t_{SoC-PReq\_CNn}$) + $t_{PReq-PRes\_CNn}$ + 2 * t_{propag_CNn}
				else
				$t_{PReq-PRes\_CNn\_MN}$ = $t_{PReq-PRes\_CNn}$ + 2 * t_{propag_CNn}
				used by CN response supervision of Error Handling DLL
					depends on implementation of NMT_MNCycleTiming_REC. WaitSoCPReq
					(cf. Tab. 4, Line 4)
					a. NMT_MNCNPResTimeout_AU32 [$NodeID_{CNn}$]
					b. NMT_MNCNPResTimeout_AU32 [$NodeID_{CNn}$], NMT_MNCycleTiming_REC. WaitSoCPReq

17	$t_{PResPLRx\_CNn\_MN}$	payload of PRes frame from CN_n expected by MN	system configuration	MN may verify at start up: $t_{PResPLRx\_CNn\_MN} \leq t_{PResPLRxMax\_MN}$ MN may verify before isochronous access to CN_n: $t_{PResPLRx\_CNn\_MN} = t_{PResPLTx\_CNn}$	NMT_PresPayloadLimitList_AU16 [$NodeID_{CNn}$]

No	Parameter	Description	Data Source	Handling[1]	Index
18	$t_{PResPLRxMax\_MN}$	size of MN PRes frame receive buffer (referring to payload)	system configuration	--	NMT_CycleTiming_REC. IsochrRxMaxPayload_U16
19	$t_{PResPLRx\_CNm\_CNn}$	payload of PRes frame from CN_m expected by CN_n	system configuration	CN_n may verify at start up: $t_{PResPLRx\_CNm\_CNn} \leq t_{PResPLRxMax\_CNn}$[2] and $t_{PResPLRx\_CNm\_CNn} \geq t_{PResPLTx\_CNm}$	NMT_PresPayloadLimitList_AU16 [$NodeID_{CNm}$]
20	$t_{PResPLRxMax\_CNn}$	size of CN_n PRes frame receive buffer (referring to payload)	system configuration	--	NMT_CycleTiming_REC. IsochrRxMaxPayload_U16
21	$t_{PRes\text{-}PReq\_MN}$	delay between end of PRes reception and start of PReq transmission	MN device description D_NMT_MNPRes2PReq_U32	$t_{PRes\text{-}PReq\_MN} \geq$ C_DLL_T_IFG	--
22	$t_{PRes\text{-}PReq\_CNn}$	minimum delay between end of PRes reception and start of PReq reception	CN_n implementation requirement	every CN shall support $t_{PRes\text{-}PReq\_MN}$ = C_DLL_T_IFG	--
23	$t_{PRes\text{-}PRes\_MN}$	delay between end of reception of PRes from CN_n and start of transmission of PRes by MN	MN device description D_NMT_MNPRes2PRes_U32	$t_{PRes\text{-}PRes\_MN} \geq$ C_DLL_T_IFG	--
24	$t_{PRes\text{-}PRes\_CNn}$	minimum delay between end of reception of PRes from CN_n and start of reception of PRes from MN [3]	CN_n implementation requirement	every CN shall support $t_{PRes\text{-}PRes\_MN}$ = C_DLL_T_IFG	--
25	t_{PResTx_MN} $t_{PResRx\_MN\_CNn}$	time consumption of PRes frame to be transmitted by MN	$t_{PResTx\_MN\_MN}$ = ($t_{PResPLTx\_MN\_MN}$ + C_DLL_T_EPL_PDO_HEADER + C_DLL_T_ETH2_WRAPPER) * 8 * C_DLL_T_BITTIME + C_DLL_T_PREAMBLE	--	--
26	$t_{PResPLTx\_MN\_MN}$	payload of PRes frame to be transmitted by MN	system configuration	MN may verify at start up: $t_{PResPLTx\_MN\_MN} \leq t_{PResPLTxMax\_MN}$	NMT_PresPayloadLimitList_AU16 [$NodeID_{MN}$]
27	$t_{PResPLTxMax\_MN}$	size of MN PRes frame transmit buffer (referring to payload)	system configuration	--	NMT_CycleTiming_REC. IsochrTxMaxPayload_U16
28	$t_{PResPLRx\_MN\_CNn}$	payload of PRes frame from MN expected by CN_n	system configuration	CN_n may verify at start up: $t_{PResPLRx\_MN\_CNn} \leq t_{PResPLRxMax\_CNn}$	NMT_PresPayloadLimitList_AU16 [$NodeID_{MN}$]

[2] see 7.2.1.5.5

[3] For future development, CNs shall also support the reception of several PRes from other CNs without intermitting time gaps.

No	Parameter	Description	Data Source	Handling[1]	Index
29	$t_{PRes\text{-}SoA\_MN}$	if PRes transmission by MN: delay between end of PRes transmission by MN and start of transmission of SoA by MN else delay between end of reception of PRes from CN_n and start of transmission of SoA by MN	MN device description D_NMT_MNPResTx2SoA_U32 resp. D_NMT_MNPResRx2SoA_U32	$t_{PRes\text{-}SoA\_MN} \geq$ C_DLL_T_IFG	--
30	$t_{PRes\text{-}SoA\_CNn}$	minimum delay between end of reception of PRes and start of reception of SoA	CN_n implementation requirement	every CN shall support $t_{PRes\text{-}SoA\_MN}$ = C_DLL_T_IFG	--
31	t_{SoA}	SoA frame time consumption	constant t_{SoA} = C_DLL_T_MIN_FRAME + C_DLL_T_PREAMBLE	--	--
32	$t_{SoA\text{-}AsndTx\_CNn}$	delay between end of SoA reception and start of AsyncSend transmission	system configuration	$t_{SoA\text{-}AsndTx\_CNn} \geq$ C_DLL_T_IFG	NMT_CycleTiming_REC. ASndMaxLatency_U32
33	t_{ASndTx} t_{ASndRx}	time consumption of asynchronous frame to be transmitted	t_{ASndTx} = ($t_{ASndPLTx}$ + C_DLL_T_ETH2_WRAPPER) * 8 * C_DLL_T_BITTIME + C_DLL_T_PREAMBLE	--	--
34	$t_{ASndPLTx}$	payload of asynchronous frame to be transmitted	application	Node shall verify: $t_{ASndPLTx} \leq t_{ASndMTU\_MN/CNn}$	--
35	$t_{ASndPLRx}$	payload of received asynchronous frame	application	--	--
36	$t_{ASndMTU\_MN/CNn}$	maximum size of asynchronous frame to be transmitted (referring to payload)	system configuration	Node may verify: $t_{ASndMTU\_MN/CNn} \leq t_{ASndPLTxMax\_MN/CNn}$ and $t_{ASndMTU\_MN/CNn} \leq t_{ASndPLRxMax\_MN/CNn}$ MN may verify: $t_{ASndMTU\_MN} = t_{ASndMTU\_CNn}$	NMT_CycleTiming_REC. AsyncMTU_U16
37	$t_{ASndPLTxMax\_MN/CNn}$	size of AsyncSend frame transmit buffer (referring to payload)	system configuration	--	NMT_CycleTiming_REC. AsyncMTU_U16
38	$t_{ASndPLRxMax\_MN/CNn}$	size of MN AsyncSend frame receive buffer (referring to payload)	system configuration	--	NMT_CycleTiming_REC. AsyncMTU_U16

No	Parameter	Description	Data Source	Handling[1]	Index
39	$t_{SoA-AsndRx\_MN}$	delay timeout between end of transmission of SoA and start of reception of AsyncSend from that CN, that requires the most time for signal travel and response to SoA	system configuration	$t_{SoA-AsndRx\_MN}$ = max ($t_{SoA\_AsndTx\_CNn}$ + 2 * t_{propag_CNn}) used by CN response supervision of Error Handling DLL in case of SoA.StatusRequest or SoA.IdentRequest	NMT_MNCycleTiming_REC
40	t_{idle_MN}, t_{idle_CNn}	idle time before next cycle	system configuration, time consumption by asynchronous traffic	MN may verify: $t_{idle\_MN} \geq t_{ASndRx-SoC\_MN}$ CN_n may verify: $t_{idle\_CNn} \geq t_{ASndRx-SoC\_CNn}$	--
41	$t_{ASndRx-SoC\_MN}$	minimum delay between end of reception of AsyncSend and start of transmission of SoC	MN device description D_NMT_MNASnd2SoC_U32	$t_{ASndRx-SoC\_MN} \geq$ C_DLL_T_IFG	--
42	$t_{ASndRx-SoC\_CNn}$	minimum delay between end of reception of AsyncSend and start of reception of SoC	CN_n implementation requirement	every CN shall support $t_{ASndRx-SoC\_MN}$ = C_DLL_T_IFG	--
43	$t_{SoA-AsndTx\_MN}$ $t_{SoA-AsndRx\_CN}$	delay between end of transmission of SoA and start of transmission of AsyncSend by MN	MN device description D_NMT_MNSoA2ASndTx_U32	$t_{SoA-AsndTx\_MN} \geq$ C_DLL_T_IFG	--

Tab. 4 POWERLINK cycle timing parameters

Hint: Tab. 4 does not differentiate between frame size and the time required to transmit the frame. Both quantities shall be regarded to be equivalent. The transmission time shall be calculated from the size by multiply with transmit time per byte.
When regarding the supporting indices, the frame type specific protocoll overhead in frame size shall be considered by time calculation (see 4.6).

4.2.4.3.1 POWERLINK Cycle Timing Error Handling

POWERLINK cycle timing may be safeguarded at runtime by the node located verifications claimed by Tab. 4. Tab. 5 provides error codes to be issued, when the respective verification fails and the handling of the errors.

All errors shall be stored at the local error history (see 6.5). Errors identified by the CN shall be entered to the Emergency Queue of the Error Signaling. Mode of all errors shall be 3_h (refer 6.5.1). The errors shall be assigned to the POWERLINK profile (002_h).

Tab. 4 No	Verification	Error Code	Error History Additional Information	Error Handling
1	MN may verify before isochronous access to CN_n: $t_{cycle\_MN} = t_{cycle\_CNn}$	E_NMT_CYCLE_LEN	CN_n Node ID	do not access CN_n isochronously
8	MN may verify at start up: $t_{PReqPL\_CNn\_MN} \leq t_{PReqPLMax\_MN}$	E_NMT_PREQ_LIM	--	do not change NMT state to NMT_MS_PRE_OPERATIONAL_2
8	MN may verify before isochronous access to CNn: $tPReqPL_{CNn\_MN} = tPReqPL_{CNn}$	E_NMT_PREQ_CN	CN_n Node ID	do not access CN_n isochronously
10	CN_n may verify at start up: $t_{PReqPL\_CNn} \leq t_{PReqPLMax\_CNn}$	E_NMT_PREQ_LIM	--	do not change NMT state to NMT_CS_PRE_OPERATIONAL_2
14	CN_n may verify at start up: $t_{PResPLTx\_CNn} \leq t_{PResPLTxMax\_CNn}$	E_NMT_PRES_TX_LIM	--	do not change NMT state to NMT_CS_PRE_OPERATIONAL_2
16	see Error Handling DLL (see 4.7.6.3)			
17	MN may verify at start up: $t_{PResPLRx\_CNn\_MN} \leq t_{PResPLRxMax\_MN}$	E_NMT_PRES_RX_LIM	CN_n Node ID	do not change NMT state to NMT_MS_PRE_OPERATIONAL_2
17	MN may verify before isochronous access to CN_n: $t_{PResPLRx\_CNn\_MN} = t_{PResPLTx\_CNn}$	E_NMT_PRES_CN	CN_n Node ID	do not access CN_n isochronously
19	CNn may verify at start up: $tPResPLRx_{CNm\_CNn} \leq tPResPLRxMax_{CNn}$ and $tPResPLRx_{CNm\_CNn} \geq tPResPLTx_{CNm}$	E_NMT_PRES_RX_LIM	CN_m Node ID	CN_n: do not read PRes from CN_m
26	MN may verify at start up: $t_{PResPLTx\_MN\_MN} \leq t_{PResPLTxMax\_MN}$	E_NMT_PRES_TX_LIM	--	do not change NMT state to NMT_MS_PRE_OPERATIONAL_2
28	CN_n may verify at start up: $t_{PResPLRx\_MN\_CNn} \leq t_{PResPLRxMax\_CNn}$	E_NMT_PRES_RX_LIM	MN Node ID	CN_n: do not read PRes from MN
34	Node shall verify: $t_{ASndPLTx} \leq t_{ASndMTU\_MN/CNn}$	E_NMT_ASND_TX_LIM	--	do not transmit frame
36	Node may verify: $t_{ASndMTU\_MN/CNn} \leq t_{ASndPLTxMax\_MN/CNn}$ and $t_{ASndMTU\_MN/CNn} \leq t_{ASndPLRxMax\_MN/CNn}$	E_NMT_ASND_MTU_LIM	--	do not change NMT state to NMT_MS_PRE_OPERATIONAL_2 or NMT_CS_PRE_OPERATIONAL_2
36	MN may verify: $t_{ASndMTU\_MN} = t_{ASndMTU\_CNn}$	E_NMT_ASND_MTU_DIF	CN_n Node ID	do not change NMT state to NMT_MS_PRE_OPERATIONAL_2 or NMT_CS_PRE_OPERATIONAL_2
39	see Error Handling DLL (see 4.7.6.4)			

Tab. 4 No	Verification	Error Code	Error History Additional Information	Error Handling
40	MN may verify: $t_{idle\_MN} \geq t_{ASndRx\text{-}SoC\_MN}$	E_NMT_IDLE_LIM	--	do not change NMT state to NMT_MS_PRE_OPERATIONAL_2
40	CN_n may verify: $t_{idle\_CNn} \geq t_{ASndRx\text{-}SoC\_CNn}$	E_NMT_IDLE_LIM	--	do not change NMT stateto NMT_CS_PRE_OPERATIONAL_2

Tab. 5 POWERLINK cycle timing verification: Error codes and handling

4.2.4.4 Multiplexed Slot Timing

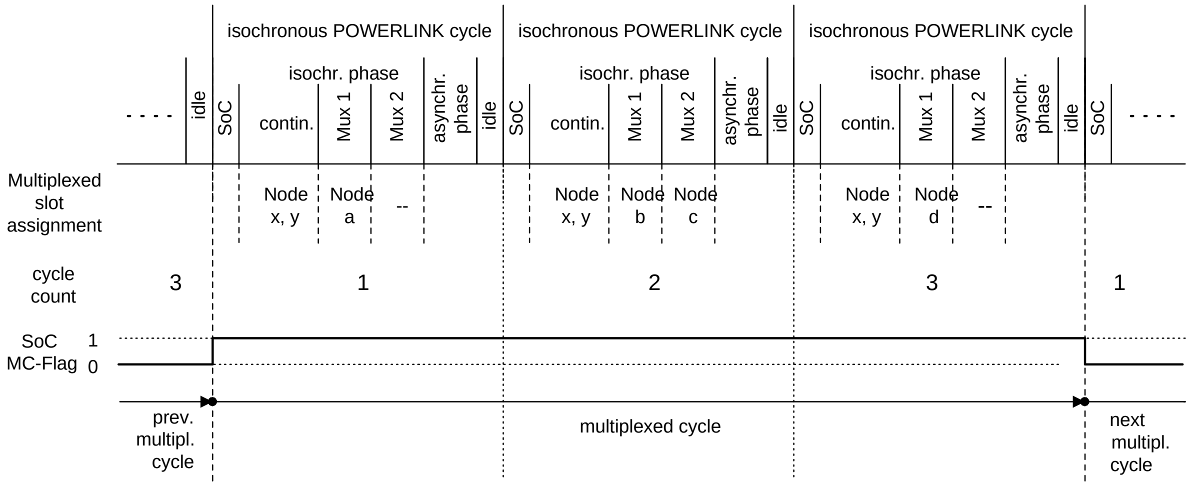


Fig. 28. Multiple slot assignment

Fig. 28 demonstrates the assignment of the multiplexed slots to CNs. The multiplexed slots are identified by “Mux 1” and “Mux 2”.

The assignment is controlled by the object dictionary entries NMT_CycleTiming_REC.MultiplCycleCnt_U8 and NMT_MultiplCycleAssign_AU8.

NMT_CycleTiming_REC.MultiplCycleCnt_U8 defines the length of the multiplexed cycle in POWERLINK cycle counts. If NMT_CycleTiming_REC.MultiplCycleCnt_U8 is zero, the multiplexed access method shall not be applied, e.g. all CNs shall be accessed continuously.

The respective sub-index of NMT_MultiplCycleAssign_AU8 defines the cycle count inside the multiplexed cycle, when the respective CN shall be polled by the MN. If the sub-index is zero, the CN shall be accessed continuously.

The order in which the CNs are polled by the MN may be set up by object NMT_IsochrSlotAssign_AU8.

The number of slots per isochronous cycle can not be programmed directly by the configuration. It is derived from the maximum number of CN assignments that are cumulated to a cycle.

The following table shows the parameter values that contol the system in Fig. 28:

NMT_CycleTiming_REC.MultiplCycleCnt_U8	3
NMT_MultiplCycleAssign_AU8 [$NodeID_a$]	1
NMT_MultiplCycleAssign_AU8 [$NodeID_b$]	2
NMT_MultiplCycleAssign_AU8 [$NodeID_c$]	2
NMT_MultiplCycleAssign_AU8 [$NodeID_d$]	3
NMT_MultiplCycleAssign_AU8 [$NodeID_x$]	0
NMT_MultiplCycleAssign_AU8 [$NodeID_y$]	0

4.2.4.5 CN Cycle State Machine

4.2.4.5.1 Overview

The cycle state machine of the CN (DLL_CS) handles communication within a POWERLINK Cycle. The DLL_CS tracks the order of the frames received within a cycle and reacts as described below. The expected order of frame reception is dependant on the NMT_CS state (see 4.2.4.5.4)

If an error in the communication is detected by the DLL_CS, an error event to DLL Error Handling will be generated. The DLL_CS will attempt to uphold communication regardless of any errors.

4.2.4.5.2 States

- **DLL_CS_NON_CYCLIC**

  This state means that the isochronous communication isn't started yet or the connection was lost. It depends on the current state of the NMT_CS, which events are processed and which will be ignored.

- **DLL_CS_WAIT_SOC**

  The state machine waits in this state after receiving the SoA frame until the beginning of the next cycle (triggered by a SoC frame from the MN). Ethernet frames of any type may be received between the SoA and the SoC frames (asynchronous phase).

- **DLL_CS_WAIT_PREQ**

  After the beginning of the cycle, the state machine waits in this state for a PReq frame. After PReq reception the CN shall respond with a PRes Frame. The CN may receive and process PRes Frames from other CN whilst in this state.

- **DLL_CS_WAIT_SOA**

  After reception of a PReq frame the state machine waits for the reception of a SoA frame.

  Reception of a SoA frame confirms the end of the isochronous phase. The CN may receive and process PRes Frames from other nodes whilst in this state.

4.2.4.5.3 Events

- **DLL_CE_SOC**

  This Event signifies that a POWERLINK SoC frame was received from the MN. It marks the beginning of a new cycle and simultaneously the beginning of the isochronous phase of the cycle.

- **DLL_CE_PREQ**

  This Event signifies that a POWERLINK PReq frame was received from the MN.

- **DLL_CE_PRES**

  The CN may be configured to process the PRes frames of other CN's (cross traffic). Every time a PRes frame is received, a DLL_CE_PRES event is generated

- **DLL_CE_SOA**

  This event signifies that a SoA frame was received from the MN. It marks the end of the isochronous phase of the cycle and the beginning of the asynchronous phase.

- **DLL_CE_ASND**

  This event signifies that an ASnd frame or a non POWERLINK frame has been received. Since the frame types during the asynchronous phase are not limited to POWERLINK types, this event is generated on reception of all legal Ethernet frames.

- **DLL_CE_SOC_TIMEOUT**

  This event signifies that a SoC frame of the MN was lost. It occurs, when the SoC timeout supervision detects a missed SoC frame.

4.2.4.5.4 Dependance of the NMT_CS on the DLL_CS

The state of the NMT_CS represents the network state and is used as a qualifier for certain transitions of the DLL_CS. Because the NMT state influences the behaviour of the DLL_CS we could filter out the relevant DLL_CS transitions for a single NMT state, so we see only DLL_CS transitions which are possible in a distinct NMT state.

Notation comment:

For clarity purposes the NMT_CS states as conditions for DLL_CS transitions have been omitted. Because of comprehension and clarity purposes, the relevant transitions of single NMT_CS states are filtered out and displayed within an own diagram as an "operation mode" of the DLL_CS. Some *operation modes are nearly similar, so they are shown within a single figure and the differencies are described in the transition table.*

4.2.4.5.4.1 State NMT_GS_INITIALISATION, NMT_CS_NOT_ACTIVE, NMT_CS_BASIC_ETHERNET, NMT_CS_PRE_OPERATIONAL_1

In this NMT states the DLL_CS is in state DLL_CS_NON_CYCLIC.

For description of these NMT states see 7.1.4.

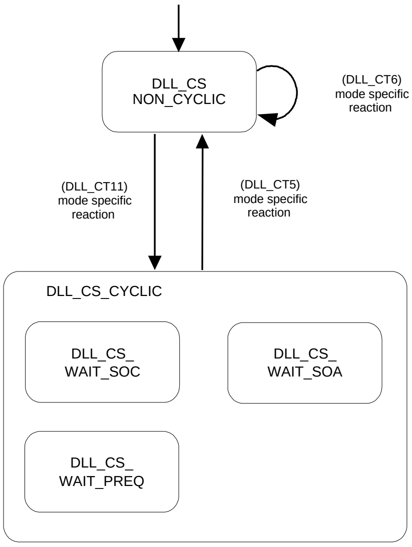


Fig. 29. CN cycle state machine, states NMT_GS_INITIALISATION, NMT_CS_NOT_ACTIVE, NMT_CS_PRE_OPERATIONAL_1, NMT_CS_BASIC_ETHERNET

4.2.4.5.4.1.1 Transitions in other NMT states

DLL_CT6, DLL_CT5	DLL_CE_* [ ] / NMT state specific reaction
	The cycle state machine is not active in the NMT states NMT_GS_INITIALISATION, NMT_CS_NOT_ACTIVE, NMT_CS_PRE_OPERATIONAL_1 and NMT_CS_BASIC_ETHERNET. This means, after the initial transition to DLL_CS_NON_CYCLIC its state does not influence the reaction of the CN. The reactions are defined by the state of the NMT_CS only. (see 7.1.4)
DLL_CT11	DLL_CE_* [ ] / NMT state specific reaction
	This transition is triggered by the NMT state machine when changing from NMT_CS_PRE_OPERATIONAL_1 to NMT_CS_PRE_OPERATIONAL_2 (NMT_CT4)

Tab. 6 Transitions for CN cycle state machine, states NMT_GS_INITIALISATION, NMT_CS_NOT_ACTIVE, NMT_CS_PRE_OPERATIONAL_1, NMT_CS_BASIC_ETHERNET

4.2.4.5.4.2 State NMT_CS_PRE_OPERATIONAL_2, NMT_CS_READY_TO_OPERATE, NMT_CS_OPERATIONAL, NMT_CS_STOPPED

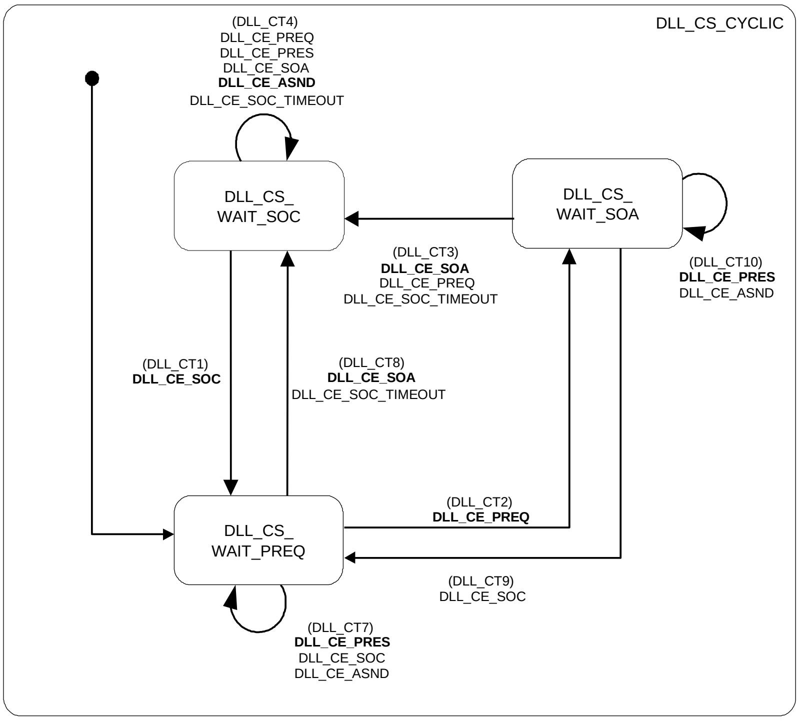


Fig. 30. CN cycle state machine (DLL_CS), valid for NMT_CS_PRE_OPERATIONAL_2, NMT_CS_READY_TO_OPERATE, NMT_CS states NMT_CS_OPERATIONAL

In the NMT_CS_OPERATIONAL and NMT_CS_READY_TO_OPERATE states, there are three mandatory frames for a non-multiplexed node, which shall occur each cycle in the specified order: SoC, PReq and SoA. If a node is accessed multiplexed, only the SoC and SoA frames are mandatory for every cycle. The PReq frame is only mandatory in the multiplexed cycle the node was configured for.

In the NMT_CS_PRE_OPERATIONAL_2 state, there are two mandatory frames, which shall occur each cycle in the order SoC and SoA. The PReq frame may occur between SoC and SoA.
In the NMT_CS_PRE_OPERATIONAL_2 state the timeout detection of the SoC is disabled because the node may not be configured yet.

The cycle state machine keeps track of all receive frames to detect frame losses. Receive frames shall be accepted by the CN independent of the current cycle state machine state.

4.2.4.5.4.2.1 Transitions

DLL_CT1	DLL_CE_SOC [ ] / synchronise the start of cycle and generate a SoC trigger to the application
	The occurrence of the SoC event indicates the beginning of a new POWERLINK cycle. The asynchronous phase of the previous cycle ends and the isochronous phase of the next cycle begins.
DLL_CT2	DLL_CE_PREQ [ ] / Process the PReq frame and send a PRes frame
	The PReq event occurs within the isochronous phase of communication.

DLL_CT3	DLL_CE_SOA [ ] / process SoA, if allowed send an ASnd frame or a non POWERLINK frame DLL_CE_SOC_TIMEOUT [CN NMT state != NMT_CS_PRE_OPERATIONAL_2] / Synchronise to the next SoC, report error DLL_CEV_LOSS_SOC and DLL_CEV_LOSS_SOA DLL_CE_PREQ [ ] / accept the PReq frame and send a PRes frame, report error DLL_CEV_LOSS_SOC and DLL_CEV_LOSS_SOA
	The DLL_CE_SOA event denotes the end of the isochronous phase and the beginning of the asynchronous phase of the current cycle. If the SoA frame includes an invitation to the CN, the CN may respond with one valid frame. The occurrence of a DLL_CE_PREQ signifies that the expected SoA and SoC frames were lost. The DLL Error Handling shall be notified. In case of a DLL_CE_SOC_TIMEOUT event happened in NMT_CS_READY_TO_OPERATE or NMT_CS_OPERATIONAL, SoA and SoC frames may have been lost. The DLL Error Handling shall be notified.
DLL_CT4	DLL_CE_ASND [ ] / process frame DLL_CE_PREQ [ ] / respond with PRes frame, report error DLL_CEV_LOSS_SOC DLL_CE_PRES [ ] / report error DLL_CEV_LOSS_SOC DLL_CE_SOA [ ] / report error DLL_CEV_LOSS_SOC DLL_CE_SOC_TIMEOUT [CN NMT state != NMT_CS_PRE_OPERATIONAL_2] / report error DLL_CEV_LOSS_SOC
	If an ASnd frame has been received it shall be processed. The state shall not be changed. Although only one asynchronous frame per cycle is allowed, the state machine of the CN does not limit the amount of received frames within the asynchronous phase of the cycle. If a SoA, PReq or PRes frame is received, there may be a loss of a SoC frame in between. The DLL Error Handling shall be notified with the error DLL_CEV_LOSS_SOC. This event shall be triggered once per cycle only. In case of a DLL_CE_SOC_TIMEOUT event happened in NMT_CS_READY_TO_OPERATE or NMT_CS_OPERATIONAL, SoA and SoC frames may have been lost. The DLL Error Handling shall be notified. If a PReq frame was received, the incoming data may be ignored and a PRes frame shall be sent.
DLL_CT7	DLL_CE_PRES [ ] / process PRes frames (cross traffic) DLL_CE_SOC [ ] / synchronise to the cycle begin, report error DLL_CEV_LOSS_SOA DLL_CE_ASND [ ] / report error DLL_CEV_LOSS_SOA
	If a PRes frame of another CN was received (cross traffic), the PRes frame shall be processed (if configured to do so). The CN waits for either a PRes from another CN (cross traffic) or a PReq frame. The reaction to a SoC frame is state independent. The state machine synchronises to the start of a new cycle. ASnd frames and non POWERLINK frames shall be processed during the isochronous phase.
DLL_CT8	DLL_CE_SOA [CN NMT state = NMT_CS_STOPPED] / process SoA, if invited, transmit a legal Ethernet frame DLL_CE_SOA [CN = multiplexed] / process SoA; if invited, transmit a legal Ethernet frame DLL_CE_SOA [CN != multiplexed] / process SoA; if invited, transmit a legal Ethernet frame, additionally report error DLL_CEV_LOSS_PREQ DLL_CE_SOC_TIMEOUT [CN NMT state != NMT_CS_PRE_OPERATIONAL_2] / Synchronise on the next SoC, report error DLL_CEV_LOSS_SOC and DLL_CEV_LOSS_SOA
	If the CN is in the NMT_CS_OPERATIONAL or NMT_CS_READY_TO_OPERATE the CN will assume a LOSS_OF_PREQ if the number of cycles since the last PReq is greater than that expected. (1 for non multiplexed CNs, n for multiplexed CNs where n is NMT_CycleTiming_REC.MultiplCycleCnt_U8) In case of a DLL_CE_SOC_TIMEOUT event happened in NMT_CS_READY_TO_OPERATE; NMT_CS_OPERATIONAL or NMT_CS_STOPPED, SoA and SoC frames may have been lost. On non-stopped and non-multiplexed nodes or if a multiplexed node should have been requested this cycle, the PRes frame was additionally lost. The DLL Error Handling shall be notified.
DLL_CT9	DLL_CE_SOC [ ] / synchronise on the SoC, report error DLL_CEV_LOSS_SOA
	The reaction on reception of a SoC is independent of the NMT state, the state machine assumes that an expected frame was lost and (re-)synchronises on the SoC.
DLL_CT10	DLL_CE_PRES [ ] / process PRes frames (cross traffic) DLL_CE_ASND [ ] / report error DLL_CEV_LOSS_SOA
	The CN may process PRes of other CNs. ASnd frames and non POWERLINK frames shall be accepted during the isochronous phase.

Tab. 7 Transitions for CN cycle state machine, states NMT_CS_OPERATIONAL, NMT_CS_PRE_OPERATIONAL_2, NMT_CS_READY_TO_OPERATE

Common issues:

- Loss of frames will be detected when an unexpected frame was received or the DLL_CE_SOC_TIMEOUT occurs.
- The Cycle State machine informs the NMT_CS of an error, which will then be processed by the NMT_CS (see 7.1.4).
- DLL_CEV_LOSS_SOA and DLL_CEV_LOSS_PREQ are optional and may be omitted if not supported by the DLL Error Handling
- The DLL error handling shall be notified only once for every real error event although the same error may be detected more often in a cycle.
  e.g. DLL_CEV_LOSS_SOC in DLL_CT4

4.2.4.6 MN Cycle State Machine

4.2.4.6.1 Overview

The cycle state machine of the MN (DLL_MS) shall manage the communication within a POWERLINK cycle.

The DLL_MS generates the flow of the frames during a POWERLINK cycle and monitors the reaction of the CNs. The flow order is NMT_MS state dependent (see 4.2.4.6.4).

Usually the CNs are synchronised by the reception of the SoC. This means the most significant parameter for the synchronisation of the POWERLINK network is the timing accuracy of the event DLL_ME_SOC_TRIG.

If an error in the communication is detected by the DLL_MS, an error event to DLL Error Handling will be generated.

4.2.4.6.2 States

- **DLL_MS_NON_CYCLIC**

  This state means that the cyclic communication is not started yet or was stopped by the NMT_MS state machine (NMT state NMT_MS_PRE_OPERATIONAL_1). The state machine waits here until the NMT state changes to NMT_MS_PRE_OPERATIONAL_2. It depends on the current NMT state, which events will be processed and which will be ignored.

- **DLL_MS_WAIT_SOC_TRIG**

  If the communication of the cycle is finished, the state machine remains in this state until the next cycle begins with a DLL_ME_SOC_TRIG.

- **DLL_MS_WAIT_PRES**

  After the sending of the PReq frame the state machine waits in this state for a response. The waiting time is limited by a timeout.

- **DLL_MS_WAIT_ASND**

  If a SoA with an Invite is sent, the state machine waits in this state until the asynchronous phase ends with the event DLL_ME_SOC_TRIG.

  In DLL_MS_NON_CYCLIC the event DLL_ME_SOA_TRIG shall be generated instead of DLL_ME_SOC_TRIG.

  If a ASnd is expected and the timeout NMT_MNCycleTiming_REC.AsyncSlotTimeout_U32 occurs, the error DLL_MEV_SOA_TIMEOUT shall be generated.

- **DLL_MS_WAIT_SOA**

  If a SoA with an Invite is sent that is not to be answered, the MN waits in this state until the timeout of the async phase elapsed or any Ethernet frame was received before the next reduced POWERLINK cycle starts.

4.2.4.6.3 Events

The DLL_MS is triggered by events which are generated by an event handler. The DLL_MS has an interface to:

- the hardware
- the NMT state machine

The event handler should serialize the events (it’s possible that a timeout occurs simultaneously with an Ethernet frame receiving). The implementation of the interface to the hardware is out of the scope of this specification.

- **DLL_ME_PRES**

  This event signifies that a PRes frame was received.

- **DLL_ME_PRES_TIMEOUT**

  This event is produced when the PRes frame was not (or not completely) received within a preconfigured time.

- **DLL_ME_ASND**

  This event means that an ASnd frame or an non POWERLINK frame was received.

- **DLL_ME_ASND_TIMEOUT**

  This event is produced when the ASnd frame was not (or not completely) received within a preconfigured time.

- **DLL_ME_SOC_TRIG**

  This event triggers emission of the SoC frame and starts a new POWERLINK cycle. The timing accuracy determines the synchronisation accuracy of the POWERLINK network.

- **DLL_ME_SOA_TRIG**

  This event means that a new reduced POWERLINK cycle shall start. The event can either be generated cyclically or directly after the reception of a requested ASnd message to continue the reduced POWERLINK cycle as fast as possible.

4.2.4.6.4 Usage of the NMT_MS state by the DLL_MS

The state of the NMT_MS represents the network state and is used as a condition in some transitions of the DLL_MS. Relevant DLL_MS transitions for a single NMT state could be filtered out.

A notation comment:

The transitions of DLL_MS could be displayed within a single diagram where the states of the NMT_MS are conditions for the transitions. Because of comprehension and clarity purposes, the relevant transitions of single NMT_MS states are filtered out and displayed within an own diagram as an “operation mode” of the DLL_MS.

4.2.4.6.4.1 State NMT_GS_INITIALISATION, NMT_MS_NOT_ACTIVE

In these states the MN cycle state machine is not active. This means, prior to the initial transition to DLL_MS_NON_CYCLIC its state does not influence the reaction of the MN. The reactions are defined by the state of the NMT_MS.

4.2.4.6.4.2 NMT_MS_BASIC_ETHERNET

In this state the cycle state machine is not active. This means, prior to the initial transition to DLL_MS_NON_CYCLIC its state does not influence the reaction of the MN. The reactions are defined by the state of the NMT_MS.

4.2.4.6.4.3 State NMT_MS_PRE_OPERATIONAL_1

In the NMT_MS_PRE_OPERATIONAL_1 state, the cycle state machine of the MN generates the Reduced POWERLINK Cycle and observes the behaviour of the CNs. Error handling is described in chapter 4.6. The DLL_MS is in the DLL_MS_NON_CYCLIC mode.

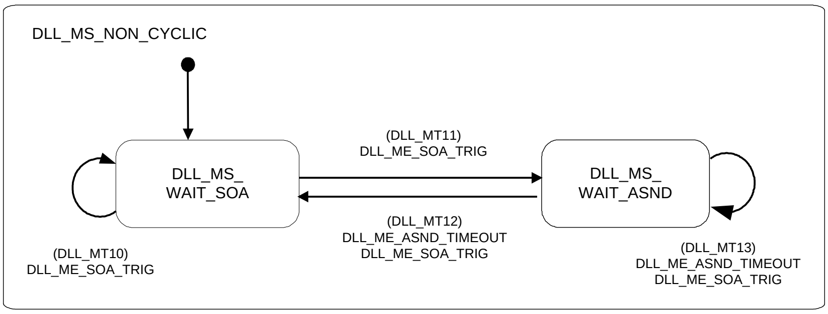


Fig. 31. MN cycle state machine, state NMT_MS_PRE_OPERATIONAL_1

4.2.4.6.4.3.1 Transitions

DLL_MT10	DLL_ME_SOA_TRIG [async_in != 0 & no resp. expected] / send SoA with Invite DLL_ME_SOA_TRIG [async_in = 0 & async_out != 0] / send SoA with Invite to MN and send ASnd or non POWERLINK frame DLL_ME_SOA_TRIG [async_in = 0 & async_out = 0] / send SoA
	If there is an asynchronous transmission request from a CN, the MN sends a SoA message with Invite. The next reduced POWERLINK cycle shall start after the asynchronous slot timeout elapsed or any frame is received. If there is outgoing asynchronous MN communication to be done in the current cycle, the MN sends this frame directly after the SoA frame with an Invite to the MN itself. The next reduced POWERLINK cycle shall start after transmission of the ASnd or non POWERLINK frame. If there is no Invite for a CN and no ASnd or non POWERLINK frame from MN the next DLL_ME_SOA_TRIG shall be generated after the asynchronous slot timeout.
DLL_MT11	DLL_ME_SOA_TRIG [async_in != 0 & resp. expected] / send SoA with Invite
	After sending the SoA invite message to the CN, the MN changes to the state DLL_MS_WAIT_ASND to detect transmission timeouts.
DLL_MT12	DLL_ME_SOA_TRIG | DLL_ME_ASND_TIMEOUT [async_in = 0] / send SoA, ASnd if available DLL_ME_SOA_TRIG | DLL_ME_ASND_TIMEOUT [async_in != 0 & no resp. expected] / send SoA with Invite
	The waiting time ends with either a DLL_ME_SOA_TRIG or a DLL_ME_ASND_TIMEOUT (configurable via NMT_MNCycleTiming_REC.AsyncSlotTimeout_U32). If a certain CN shall be invited, the MN sends a SoA containing an invite for the node. If there is no CN to be invited, the MN sends a SoA. If there is outgoing asynchronous communication to be done in the current cycle, the MN sends this frame after the SoA frame. Afterwards the state changes to DLL_MS_WAIT_SOA. The error event DLL_MEV_ASND_TIMEOUT shall be generated.
DLL_MT13	DLL_ME_SOA_TRIG | DLL_ME_ASND_TIMEOUT [async_in != 0 & resp. expected] / send SoA with Invite, report error DLL_MEV_ASND_TIMEOUT
	A SoA message containing an Invite for a CN is transmitted. The MN stays in the state MS_WAIT_ASND as an answer of the CN is expected. The timeout event DLL_ME_ASND_TIMEOUT (configurable via NMT_MNCycleTiming_REC.AsyncSlotTimeout_U32) shall generate DLL_MEV_ASND_TIMEOUT.

Tab. 8 Transitions for MN cycle state machine, state NMT_MS_PRE_OPERATIONAL_1

Abbreviations used in the transition table:

- „no resp. expected" means that there is no answer expected upon the async invite of the MN (e.g. unicast message exchange)
- „async_in != 0" means that an invite must be sent in this cycle and an ASnd or a non POWERLINK frame could be received.
- "async_out != 0" means that an ASnd must be send in this cycle after a SoA was sent.

Common issues:

- DLL_MEV_ASND_TIMEOUT is optional and may be omitted if not supported by the DLL Error Handling
- If a StatusRequest was sent and the asynchronous slot time expires without receiving a StatusResponse frame the DLL Error Handling will be notified with the error DLL_MEV_LOSS_STATUSRESPONSE.

4.2.4.6.4.4 State NMT_MS_OPERATIONAL, NMT_MS_READY_TO_OPERATE and NMT_MS_PRE_OPERATIONAL_2

In the NMT_MS_OPERATIONAL, NMT_MS_READY_TO_OPERATE and NMT_MS_PRE_OPERATIONAL_2 state, the cycle state machine of the MN generates the POWERLINK Cycle and observes the behaviour of the CNs. Error handling is described in chapter 4.6.

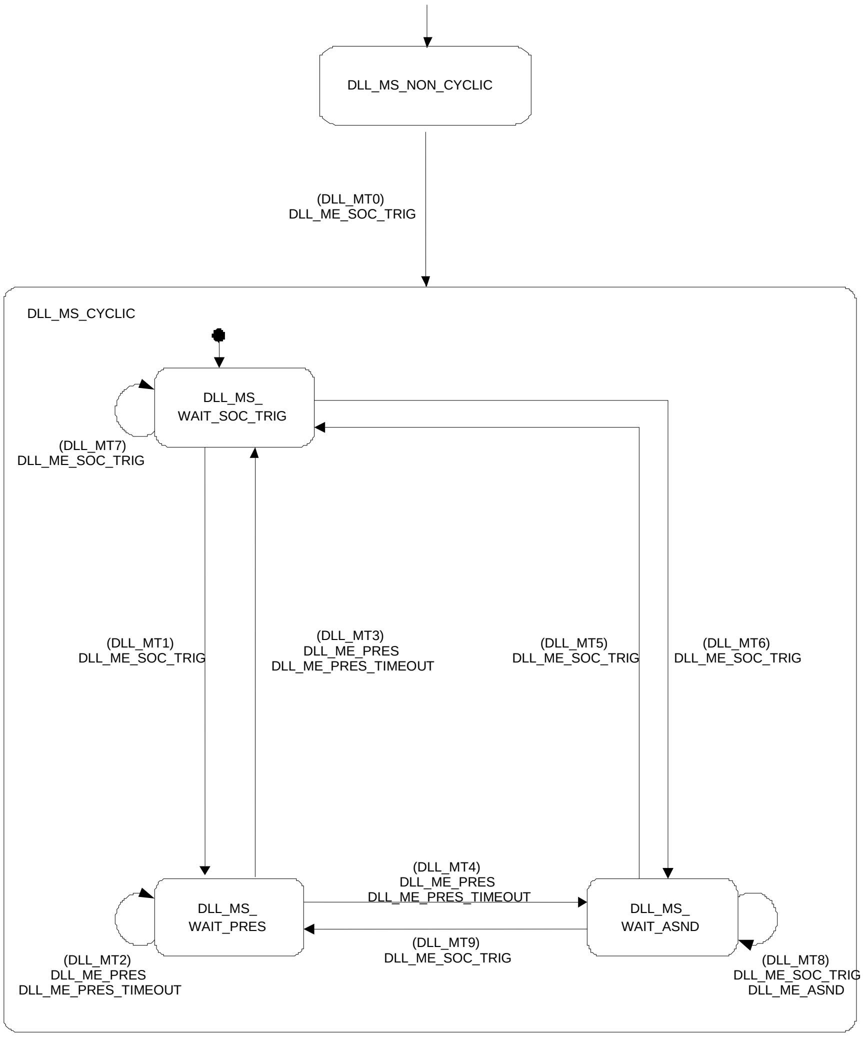


Fig. 32. MN cycle state machine, States NMT_MS_OPERATIONAL, NMT_MS_READY_TO_OPERATE and NMT_MS_PRE_OPERATIONAL_2

4.2.4.6.4.4.1 Transitions

DLL_MT0	DLL_ME_SOC_TRIG [ ] / go to state DLL_MS_WAIT_SOC_TRIG
	If the NMT state machine of the MN (NMT_MS) changes the mode to NMT_MS_PRE_OPERATIONAL_2 the DLL_MS shall start the cycle timer (value configurable by NMT_CycleLen_U32), which generates the DLL_ME_SOC_TRIG. The DLL_MS shall prepare the system for the start of the first cycle.
DLL_MT1	DLL_ME_SOC_TRIG [isochr != 0] / send SoC, PReq
	Immediately after DLL_ME_SOC_TRIG event occurred a SoC frame is sent, the communication with the NMT state machine will be done. If there are isochronous frames to send, the first PReq will be sent and a timer will be started to observe the response time (configurable via NMT_MNCNPResTimeout_AU32[Node ID]).
DLL_MT2	DLL_ME_PRES [isochr != 0] / send next PReq DLL_ME_PRES_TIMEOUT [isochr != 0] / send next PReq, report error DLL_MEV_LOSS_PRES
	The waiting time ends with either a DLL_ME_PRES or a DLL_ME_PRES_TIMEOUT. The MN sends the next PReq if more frames in the isochronous queue exist. The state does not change.

DLL_MT3	DLL_ME_PRES [isochr = 0 & async_in = 0] / send PRes [isochr_out != 0], SoA and ASnd [async_out != 0] DLL_ME_PRES_TIMEOUT [isochr = 0 & async_in = 0] / send PRes [isochr_out != 0], SoA and ASnd [async_out != 0], report error DLL_MEV_LOSS_PRES
	The isochronous phase ends with either a DLL_ME_PRES or a DLL_ME_PRES_TIMEOUT (configurable via NMT_MNCNPResTimeout_AU32[Node ID]). If there is no more communication to be done (neither isochronous nor asynchronous), the MN sends a SoA frame and changes the state to DLL_MS_WAIT_SOC_TRIG. If there is outgoing asynchronous communication to be done in the current cycle, the MN sends this frame after the SoA.
DLL_MT4	DLL_ME_PRES [isochr = 0 & async_in != 0] / send PRes [isochr_out != 0] and SoA with Invite DLL_ME_PRES_TIMEOUT [isochr = 0 & async_in != 0] / send PRes [isochr_out != 0] and SoA with Invite, report error DLL_MEV_LOSS_PRES
	The isochronous phase ends with either a DLL_ME_PRES or a DLL_ME_PRES_TIMEOUT (configurable via NMT_MNCNPResTimeout_AU32[Node ID]). If the MN is configured to send a PRes this frame shall be sent before the SoA. If the scheduled asynchronous communication for the current cycle is directed from the CN to the MN or another CN, an invite within the SoA frame will be send.
DLL_MT5	DLL_ME_SOC_TRIG [isochr = 0 & async_in = 0] / send SoC, PRes [isochr_out != 0], SoA and ASnd [async_out != 0]
	Immediately after the DLL_ME_SOC_TRIG event (value configurable via NMT_CycleLen_U32) a SoC frame will be sent, the communication with the NMT state machine will be done. If there is no communication to be done, then a SoA frame is additionally sent. The state does not change. If the MN is configured to send a PRes this frame shall be sent before the SoA. If there is outgoing asynchronous communication to be done in the current cycle, the MN sends this frame after the SoA frame and changes the state to DLL_MS_WAIT_SOC_TRIG.
DLL_MT6	DLL_ME_SOC_TRIG [isochr = 0 & async_in != 0] / send SoC, PRes [isochr_out != 0] and SoA with Invite
	Immediately after the DLL_ME_SOC_TRIG (value configurable via NMT_CycleLen_U32) a SoC frame will be sent. Then, the communication with the NMT state machine will be done. If the MN is configured to send a PRes this frame shall be sent before the SoA. If there are only asynchronous frames to send, the SoA frame will be send. If the asynchronous communication is directed to a CN, an ASnd frame will be sent additionaly.
DLL_MT7	DLL_ME_SOC_TRIG [isochr = 0 & async_in = 0] / send SoC, PRes [isochr_out != 0], SoA and ASnd [async_out != 0]
	Immediately after the DLL_ME_SOC_TRIG event a SoC frame will be sent, the communication with the NMT state machine will be done. If the MN is configured to send a PRes this frame shall be sent before the SoA. If there is no communication to be done, then a SoA frame is additionally sent. The state does not change. If there is outgoing asynchronous communication to be done in the current cycle, the MN sends this frame after the SoA.
DLL_MT8	DLL_ME_ASND [ ] / process the frame DLL_ME_SOC_TRIG [isochr = 0 & async_in != 0] / send SoC and SoA with Invite
	Immediately after the DLL_ME_SOC_TRIG a SoC frame will be sent. Then, the communication with the NMT state machine will be done. If there are only asynchronous frames to send, the SoA frame will be send. If the asynchronous communication is directed to a CN, an ASnd frame will be sent additionally.
DLL_MT9	DLL_ME_SOC_TRIG [isochr != 0] / send SoC and PReq
	Immediately after DLL_ME_SOC_TRIG event occurred (value configurable via NMT_CycleLen_U32) a SoC frame is sent, the communication with the NMT state machine will be done. If there are isochronous frames to send, the first PReq will be sent and a timer will be started to observe the response time (configurable via NMT_MNCNPResTimeout_AU32[Node ID]).

Tab. 9 Transitions for MN cycle state machine, states NMT_MS_OPERATIONAL, NMT_MS_READY_TO_OPERATE and NMT_MS_PRE_OPERATIONAL_2

Abbreviations used in the transition table:

- „isochr != 0" means that there are frames in the isochronous list, which must be send during the current cycle.
- „isochr_out != 0” means that the MN is configured to send a PRes
- „async_in != 0" means that an invite must be sent in this cycle and an ASnd or a non POWERLINK frame could be received.

- “async_out != 0” means that an ASnd must be send in this cycle after a SoA was sent.

The reaction on unexpected events is not described in the above figures and tables because of clarity purposes. A general statement for these events can be given:

- The unexpected frame types and unexpected sender shall be accepted. The state does not change. The PRes frames shall be passed to the NMT state machine, which may analyse this frames (and e.g. remove the corresponding CN from the communication). The state machine does not react in any other way to this event.
- If the DLL_MS receives frames, which can be sent by another MN only (SoC, SoA, PReq), it shall notify the NMT state machine and the DLL Error Handling.
- If an unexpected internal event (e.g. timeout) occurs, an internal error will be assumed and the NMT_MS will be notified.
- It could happen that the DLL_ME_SOC_TRIG occurs in states where it was not expected or during transmission or reception of Ethernet frames. (e.g. malconfiguration of PRes timeouts). In this case the DLL Error Handling will be notified with the error DLL_MEV_CYCLE_EXCEED

If a StatusRequest was sent and the asynchronous slot time expires without receiving a StatusResponse frame the DLL Error Handling will be notified with the error DLL_MEV_LOSS_STATUSRESPONSE.

4.2.5 Recognizing Active Nodes

The MN shall be configured with a list of all nodes on the network.

All configured nodes shall be marked as inactive when the MN boots. Configured but inactive CNs shall be periodically accessed by an IdentRequest, a special form of the SoA frame. When a CN receives an IdentRequest addressed to itself, it shall return an IdentResponse, a special form of an ASnd frame, in the same asynchronous phase.

The CN shall be marked as active if the MN receives an IdentResponse from the CN. An active CN may take part in the isochronous data transfer, e.g. it may be accessed via a PReq.

4.3 Basic Ethernet Mode

Network communication behaves according to the rules of the Legacy Ethernet (IEEE 802.3). The network medium is accessed according to CSMA/CD.

The network communication is collision-prone and non-deterministic.

In the Basic Ethernet Mode any protocol on top of Legacy Ethernet can be used. Data between the nodes are preferentially exchanged via UDP/IP and TCP/IP. The large extension of the maximum topology of an Ethernet POWERLINK Network conflicts with the topology rules of IEEE 802.3. Due to this fact, CSMA/CD might work poorly in large POWERLINK networks. Higher layer protocols shall be applied to handle communication errors caused by collisions unresolved by CSMA/CD.

POWERLINK nodes shouldn’t operate in Basic Ethernet Mode, when the node is part of a automation system. Basic Ethernet Mode is provided for point to point configurations, to be used for node setup and service purpose only.

4.4 MAC Addressing

A POWERLINK node must support unicast, multicast and broadcast Ethernet MAC addressing in accordance with IEEE802.3.

4.4.1 MAC Unicast

The high-order bit of the MAC address is 0 for ordinary addresses (unicast). The unicast addresses used for POWERLINK shall be globally unique, or at least unique within the POWERLINK segment.

4.4.2 MAC Multicast

For group addresses the high-order bit of the MAC address is 1. Group addresses allow multiple nodes to listen to a single address. When a frame is sent to a group address, all the nodes registered for this group address receive it. Sending to a group of nodes is called multicast.

The following MAC-multicast addresses shall be used:

	MAC-Multicast address
Start of Cycle (SoC)	C_DLL_MULTICAST_SOC
PollResponse (PRes)	C_DLL_MULTICAST_PRES
Start of Asynchronous (SoA)	C_DLL_MULTICAST_SOA
AsynchronousSend (ASnd)	C_DLL_MULTICAST_ASND
Active Managing Node Indication (AMNI) used by EPSG DS302-A [1]	C_DLL_MULTICAST_AMNI

Tab. 10 Assigned multicast addresses

4.4.3 MAC Broadcast

The address consisting of all 1 bits is reserved for broadcast.

4.5 POWERLINK Addressing

Each POWERLINK node (MN, CN and Router) has a unique Node ID within a POWERLINK segment. The number 240 is permanently assigned to the MN. A node set to 240 Node ID operates as the MN, if the node has MN functionality. Devices with pure CN function cannot be assigned the Node ID 240. POWERLINK Node IDs 1-239 may used for the CNs. Tab. 11 shows the POWERLINK Node ID assignment and allowed CN access options for the POWERLINK Node ID intervals.

The POWERLINK Node ID is either configured by the application process or is set on the device (e.g. using address switches).

The terms unicast, multicast and broadcast refer to POWERLINK addresses if not otherwise mentioned. If the POWERLINK broadcast address is used, the frame shall be sent with the dedicated MAC multicast address (see Tab. 10). If no MAC multicast address is assigned to this type of POWERLINK frame the MAC broadcast address shall be used instead.

POWERLINK dummy node shall be used to transmit messages addressing none of the existing node. POWERLINK dummy Node ID shall never by occupied by an existing node. No node shall expect valid data from the POWERLINK dummy node.

The self addressing Node ID shall never be assigned to any node. It may be used only by PDO mapping to indicate reception and evaluation of a PDO transporting PRes frame, transmitted by the receiving node itself.

Diagnostic device shall be a default node, available without any configuration. It’s default access options shall be optional and async only. By configuration isochronous operation may be declared.

A device may support less than the maximum number of regular CNs defined by this specification. The number of supported regular CNs may be provided by the device description entry D_NMT_MaxCNNumber_U8. The upper limit of the interval of POWERLINK Node IDs available for regular CNs may be reduced by the device description entry D_NMT_MaxCNNodeID_U8.

If only D_NMT_MaxCNNumber_U8 is provided the Node IDs may be selected from the complete interval 1 .. 239. If D_NMT_MaxCNNodeID_U8 is additionally provided, valid regular CN Node IDs shall be selected from the interval 1 .. D_NMT_MaxCNNodeID_U8.

POWERLINK Node ID		Description	access options
0	C_ADR_INVALID	Invalid	no
1 .. 239		regular POWERLINK CNs	no / mandatory / optional isochronous / async only
240	C_ADR_MN_DEF_NODE_ID	POWERLINK MN	mandatory isochronous
241 .. 250		Reserved. Used by EPSG DS302-A [1]	no
251	C_ADR_SELF_ADR_NODE_ID	POWERLINK pseudo Node ID to be used by a node to address itself	no
252	C_ADR_DUMMY_NODE_ID	POWERLINK dummy node	no
253	C_ADR_DIAG_DEF_NODE_ID	Diagnostic device	optional isochronous / async only
254	C_ADR_RT1_DEF_NODE_ID	POWERLINK to legacy Ethernet Router	no / mandatory / optional isochronous
255	C_ADR_BROADCAST	POWERLINK broadcast	no

Tab. 11 POWERLINK Node ID assignment

4.6 Frame Structures

4.6.1 Integration with Ethernet

POWERLINK is a protocol residing on top of the standard 802.3 MAC layer.

POWERLINK messages shall be encapsulated in Ethernet II frames. The Ethernet Type (Ethertype) field shall be set to $88AB_h$.

The length of the frame shall be restricted to the configured size. Otherwise the cycle time could not be guaranteed. Ethernet frames shall not be shorter than the specified minimum of 64 octets.

4.6.1.1 POWERLINK Frame

To be independent of the underlying protocol, POWERLINK defines its own addressing scheme (refer 4.5) and header format.

4.6.1.1.1 POWERLINK Basic Frame

The POWERLINK Basic Frame format shall contain 5 fields:

- Reserved (1 bit)
- MessageType (7 bits)
- Destination node address (1 octet), POWERLINK addressing scheme (See 4.5)
- Source node address (1 octet), POWERLINK addressing scheme (See 4.5)
- Payload (n octets)

The POWERLINK Basic Frame format shall be encapsulated by the Ethernet II wrapper consisting of 14 octets of leading Ethernet header (Destination and Source MAC addresses, EtherType) and 4 octets of terminating CRC32 checksum.

	Bit Offset								entry defined by
Octet Offset [4]	7	6	5	4	3	2	1	0	
0 .. 5	Destination MAC Address								Ethernet type II
6 .. 11	Source MAC Address								
12 .. 13	EtherType								
14	res	MessageType							Ethernet POWERLINK
15	Destination								
16	Source								
17 .. n	Data								
n+1 .. n+4	CRC32								Ethernet type II

C_DLL_MIN_PAYL_OFFSET+14 ≤ n ≤ C_DLL_MAX_PAYL_OFFSET+14

Tab. 12 Ethernet POWERLINK frame structure

The Ethernet POWERLINK defined part of the Ethernet frame shall be regarded to be the POWERLINK frame.

Field	Abbr.	Description	Value
Destination MAC Address	dmac	MAC address of the addressed node(s)	see 4.4
Source MAC Address	smac	MAC address of the transmitting node	see 4.4
EtherType	etyp	Ethernet message type	C_DLL_ETHERTYPE_EPL
MessageType	mtyp	POWERLINK message type identification	see Tab. 14
Destination	dest	POWERLINK Node ID of the addressed node(s)	see 4.5
Source	src	POWERLINK Node ID of the transmitting node	see 4.5
Data	data	Data depending on MessageType shall be made up to C_DLL_MIN_PAYL_OFFSET bytes by lower layer using padding bytes, if data length is below this limit	refer below
CRC32	crc	CRC32 checksum	

Tab. 13 Ethernet POWERLINK frame fields

The following message types shall be applied:

Message Type	ID / Abbr.	MAC Transfer type
Start of Cycle	SoC	Multicast
PollRequest	PReq	Unicast
PollResponse	PRes	Multicast
Start of Asynchronous	SoA	Multicast
Asynchronous Send	ASnd	Multicast

Tab. 14 POWERLINK message types

Refer 4.4.2 for multicast addresses to be used by the respective message type.

Reserved values shall be set to 0.

[4] Octet Offset refers to the start of the Ethernet frame.

4.6.1.1.2 Start of Cycle (SoC)

	Bit Offset							
Octet Offset [5]	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	res	MessageType						
1	Destination							
2	Source							
3	reserved							
4	MC	PS	res	res	res	res	res	res
5	res	res	res		res			
6 .. 13	NetTime / reserved							
14 .. 21	RelativeTime / reserved							
22 .. 45	reserved							

Tab. 15 SoC frame structure

SoC shall be transmitted using a multicast MAC address (See 4.4.2).

Field	**Abbr**	**Description**	**Value**
MessageType	mtyp	POWERLINK message type identification	SoC
Destination	dest	POWERLINK Node ID of the addressed node(s)	C_ADR_BROADCAST
Source	src	POWERLINK Node ID of the transmitting node	C_ADR_MN_DEF_NODE_ID
Multiplexed Cycle Completed	MC	Flag: Shall be toggled when the final multiplexed cycle has ended	
Prescaled Slot	PS	Flag: Shall be toggled by the MN every n-th cycle (n is configurable by NMT_CycleTiming_REC.Prescaler_U16). This prescaled signal is useful for “slow“ nodes, which can not react every cycle (The SoC reception shall be signalled to the application every n-th cycle).	
NetTime	time	MN may distribute the starting time of the POWERLINK cycle. NetTime shall be of data type NETTIME NetTime transmission is optional. Support is indicated by D_NMT_NetTime_BOOL. IEEE 1588 conform distribution via NetTime is is indicated by D_NMT_NetTimeIsRealTime_BOOL.	
RelativeTime	reltime	MN may distribute a relative time, which is incremented by the cycle time (NMT_CycleLen_U32) when a SoC is generated. RelativeTime shall be set to 0 when NMT state equals NMT_GS_INITIALISING. RelativeTime shall be of data type UNSIGNED64. RelativeTime shall be transmitted in µs. RelativeTime transmission is optional. Support is indicated by D_NMT_RelativeTime_BOOL.	

Tab. 16 SoC frame data fields

[5] Octet Offset refers to the start of the POWERLINK frame. Offset to the start of the Ethernet frame is 14 Octets.

4.6.1.1.3 PollRequest (PReq)

	Bit Offset							
Octet Offset [6]	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	res	MessageType						
1	Destination							
2	Source							
3	res							
4	res	res	MS	res	res	EA	res	RD
5	res[7]	res[8]	res			res		
6	PDOVersion							
7	res							
8 .. 9	Size							
10 .. n	Payload							

n ≤ C_DLL_MAX_PAYL_OFFSET

Tab. 17 PReq frame structure

PReq shall be transmitted using the unicast MAC address of the CN (See 4.4.1).

Field	Abbr	Description	Value
MessageType	mtyp	POWERLINK message type identification	PReq
Destination	dest	POWERLINK Node ID of the addressed node(s)	CN Node ID
Source	src	POWERLINK Node ID of the transmitting node	C_ADR_MN_DEF_NODE_ID
Multiplexed Slot	MS	Flag: Shall be set in PReq frames to CNs that are served by a multiplexed timeslot	
Exception Acknowledge	EA	Flag: Error signaling, refer 6.5.2	
Ready	RD	Flag: Shall be set if the transferred payload data are valid. It shall be set by the application process of the MN. A CN shall be allowed to accept data only when this bit is set.	
PDOVersion	pdov	Shall indicate the version of the PDO encoding used by the payload data, refer 6.4.2	
Size	size	Shall indicate the number of payload data octets.	0 .. C_DLL_ISOCHR_MAX_PAYL
Payload	pl	Isochronous payload data sent from the MN to the addressed CN. The lower layer shall be responsible for padding. Payload to be used by PDO, refer 6.3.4	

Tab. 18 PReq frame data fields

The PReq POWERLINK PDO message header consists of all components of the PReq Frame besides the payload.

[6] Octet Offset refers to the start of the POWERLINK frame. Offset to the start of the Ethernet frame is 14 Octets.

[7] *Used by EPSG DS302-A [1]*

[8] *Used by EPSG DS302-A [1]*

4.6.1.1.4 PollResponse (PRes)

	Bit Offset							
Octet Offset [9]	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	res	MessageType						
1	Destination							
2	Source							
3	NMTState							
4	res	res	MS	EN	res	res	res	RD
5	res[10]	res[11]	PR			RS		
6	PDOVersion							
7	reserved							
8 .. 9	Size							
10 .. n	Payload							

n ≤ C_DLL_MAX_PAYL_OFFSET

Tab. 19 PRes frame structure

PRes shall be transmitted using the multicast MAC address (See 4.4.2).

Field	**Abbr**	**Description**	**Value**
MessageType	mtyp	POWERLINK message type identification	PRes
Destination	dest	POWERLINK Node ID of the addressed nodes	C_ADR_BROADCAST
Source	src	POWERLINK Node ID of the transmitting node	CN Node ID
NMTState	stat	Shall report the current status of the CN's NMT state machine	
Multiplexed Slot	MS	Flag: Shall be set in PRes frames from CNs that are served by a multiplexed timeslot. Based on this information, other CNs can identify that the transmitting CN is served by a multiplexed slot	
Exception New	EN	Flag: Error signaling, refer 6.5.2	
Ready	RD	Flag: Shall be set if the transferred payload data are valid. It shall be handled by the application process in the CN. All other CNs and the MN shall be allowed to accept data only if RD is set	
Priority	PR	Flags: Shall indicate the priority of the frame in the asynchronous send queue with the highest priority. (See 4.2.4.1.2.2)	C_DLL_ASND_PRIO_NMTRQST, C_DLL_ASND_PRIO_STD
RequestToSend	RS	Flags: Shall indicate the number of pending frames in asynchronous send queue on the node. The value C_DLL_MAX_RS shall indicate C_DLL_MAX_RS or more requests, 0 shall indicate no pending requests	0 - C_DLL_MAX_RS
PDOVersion	pdov	Shall indicate the version of the PDO encoding used by the payload data, refer 6.4.2	
Size	size	Shall indicate the number of payload data octets	0 .. C_DLL_ISOCHR_MAX_PAYL
Payload	pl	Isochronous payload data sent from the node to the POWERLINK network. The lower layer shall be responsible for padding. Payload to be used by PDO, refer 6.3.4	

Tab. 20 PRes frame data fields

The PRes POWERLINK PDO message header consists of all components of the PRes Frame besides the payload.

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[9] Octet Offset refers to the start of the POWERLINK frame. Offset to the start of the Ethernet frame is 14 Octets.

[10] *Used by EPSG DS302-A [1]*

[11] *Used by EPSG DS302-A [1]*

4.6.1.1.5 Start of Asynchronous (SoA)

	Bit Offset							
Octet Offset [12]	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	res	MessageType						
1	Destination							
2	Source							
3	NMTState							
4	res	res	res	res	res	EA/res	ER/res	res
5	res	res	res			res		
6	RequestedServiceID							
7	RequestedServiceTarget							
8	EPLVersion							
9 .. 45	reserved							

Tab. 21 SoA frame structure

SoA shall be transmitted using the multicast MAC address 3 (See 4.4.2).

Field	Abbr	Description	Value
MessageType	mtyp	POWERLINK message type identification	SoA
Destination	dest	POWERLINK Node ID of the addressed nodes	C_ADR_BROADCAST
Source	src	POWERLINK Node ID of the transmitting node	C_ADR_MN_DEF_NODE_ID
NMTState	stat	Shall report the current status of the MN's NMT state machine	
Exception Acknowledge	EA	Flag: Error signaling, refer 6.5.2 EA bit shall be valid only, if RequestedServiceID equals StatusRequest.	
Exception Reset	ER	Flag: Error signaling, refer 6.5.2 ER bit shall be valid only, if RequestedServiceID equals StatusRequest.	
Requested ServiceID	svid	Shall indicate the asynchronous service ID dedicated to the SoA and to the following asynchronous slot (refer below). NO_SERVICE shall indicate that the asynchronous slot is not assigned.	see Tab. 23
Requested ServiceTarget	svtg	Shall indicate the POWERLINK address of the node, which is allowed to send. C_ADR_INVALID shall indicate the asynchronous slot is not assigned.	
EPLVersion	eplv	Shall indicate the current POWERLINK Version of the MN (See Tab. 112).	

Tab. 22 SoA frame data fields

RequestedServiceID and RequestedServiceTarget are combined to a AsyncInvite Command.

4.6.1.1.5.1 RequestedServiceID s

The following values shall be used for the RequestedServiceID entry, indicating the granted asynchronous service:

[12] Octet Offset refers to the start of the POWERLINK frame. Offset to the start of the Ethernet frame is 14 Octets.

Description / ID	Comment
NoService / NO_SERVICE	Shall be used if the asynchronous slot is not assigned to any node. RequestedServiceTarget shall be C_ADR_INVALID.
IdentRequest / IDENT_REQUEST	Shall be used to identify inactive CNs and/or to query the identification data of a CN. The addressed CN shall answer immediately after the reception of the SoA with the node specific IdentRequest frame.The IdentResponse frame is based on the ASnd frame.
StatusRequest / STATUS_REQUEST	Shall be used to request the current status and detailed error information of a node. Async-only CNs shall be cyclically queried by StatusRequest to supervise their status and to query their requests for the asynchronous slot. The addressed node shall answer immediately after the reception of the SoA, with the node specific StatusRequest frame. The StatusResponse frame is based on the ASnd frame.
NMTRequestInvite / NMT_REQUEST_INVITE	Shall be used to assign the asynchronous slot to a node that has indicated a pending NMTCommand / NMTRequest by a Request to Send (RS bit of PRes, StatusResponse or IdentResponse) with the priority level PRIO_NMT_REQUEST. The addressed node shall answer immediately after the reception of the SoA with the NMTCommand / NMTRequest frame. The NMTCommand and NMTRequest frames are based on the ASnd frame.
Manufacturer specific / MANUF_SVC_IDS	Shall be used for manufacturer specific purposes.
UnspecifiedInvite / UNSPECIFIED_INVITE	Shall be used to assign the asynchronous slot to a node that has indicated a pending transmit request by a Request to Send (RS bit of PRes, StatusResponse or IdentResponse). The addressed node shall answer immediately after the reception of the SoA, with any kind of a POWERLINK ASnd or a Legacy Ethernet frame.

Tab. 23 Definition of the RequestedServiceID in the SoA frame

Assignment of the asynchronous slot to the MN itself shall be indicated in the same way as assignments to CNs.

4.6.1.1.6 Asynchronous Send (ASnd)

	Bit Offset							
Octet Offset [13]	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	res	MessageType						
1	Destination							
2	Source							
3	ServiceID							
4 .. n	Payload							

n ≤ C_DLL_MAX_PAYL_OFFSET

Tab. 24 ASnd frame structure

The transmission of an ASnd frame by a node shall occur immediately after the transmission / reception of a SoA frame.

ASnd frames shall be transmitted using a unicast or multicast MAC address (See 4.4). Received ASnd frames having a unicast, multicast or broadcast MAC address shall be accepted.

Field	Abbr.	Description	Value
MessageType	mtyp	POWERLINK message type identification	ASnd
Destination	dest	POWERLINK Node ID of the addressed node(s)	
Source	src	POWERLINK Node ID of the transmitting node	
ServiceID	svid	Shall indicate the service ID dedicated to the asynchronous slot	see Tab. 26
Payload	pl	Shall contain data, that are specific for the current ServiceID	

Tab. 25 ASnd frame data fields

4.6.1.1.6.1 ServiceID values

The following values shall be used for the ServiceID entry:

[13] Octet Offset refers to the start of the POWERLINK frame. Offset to the start of the Ethernet frame is 14 Octets.

Description / ID	Comment
IdentResponse / IDENT_RESPONSE	Shall be issued by a node that received an IdentRequest via SoA.
StatusResponse / STATUS_RESPONSE	Shall be issued by a node that received a StatusRequest via SoA.
NMTRequest / NMT_REQUEST	Shall be issued by a CN that received a NMTRequestInvite via SoA.
NMTCommand / NMT_COMMAND	Shall be issued by the MN upon an internal request or upon an external request via NMTRequest.
SDO / SDO	May be issued by a CN that received an UnspecifiedInvite via SoA to indicate SDO transmission via ASnd.
Manufacturer specific / MANUF_SVC_IDS	Shall be used for manufacturer specifc purposes.

Tab. 26 ServiceID values in the ASnd frame

Service IDs not listed by Tab. 26 are reserved.

4.6.1.2 Non-POWERLINK Frames

Non-POWERLINK frames may be transmitted in accordance with the specifications of any Legacy Ethernet protocol. Non-POWERLINK frame transmission is allowed by the MN if the asynchronous slot is requested by a node..

Refer 5.1 for special requirements to IP (non-POWERLINK) frames.

4.6.1.3 Transfer Protection

Transfer disturbances shall be detected by the Ethernet CRC32.

4.7 Error Handling Data Link Layer (DLL)

The error handling on the data link layer forms the basis for diagnosis. Often the real error source can be detected only by analysing/interpreting of multiple error symptoms on multiple nodes. Depending on the error symptom / error source the nodes have to react on different layers. The error handling should be simple and easy to implement.

4.7.1 Possible Error Sources and Error Symptoms

The following error sources are handled by the MN and the CN. Details are explained in the following sections.

- Physical layer error sources
  - Loss of link (no link condition – port of Ethernet controller)
  - Incorrect physical Ethernet operating modes (10 Mbit/s or full duplex)
  - Transmission Errors detected by CRC errors
  - Rx buffer overflow
  - Tx buffer underrun
- POWERLINK Data Link Layer error symptoms
  - Loss of frame
    - SoC-Frame/ SoA-Frame
    - PReq / PRes Frame
  - Collisions
  - Cycle Time exceeded
  - POWERLINK Address Conflict
  - Multiple Managing Nodes
  - Timing Violation (late Response)

Error recognition strongly depends of the device’s hardware and software implementation. Device implementation should be close to this specification but some of the optional error classes listed by the following paragraphs may not be supported. Support shall be indicated by the respective device description entry.

4.7.2 Error Handling Table for CN

Error Symptoms detected by the CNs	Cumulative Cnt	Threshold Cnt	Direct Reaction	DLL Local Handling	Error Codes	NMT Local Handling
Loss of link	o		o	These are considered to be error sources	E_DLL_LOSS_OF_LINK	Logging in Error History
Incorrect physical operating mode			o		E_DLL_BAD_PHYS_MODE	Logging in Error History
Tx/Rx buffer underrun / overflow			o		E_DLL_MAC_BUFFER	NMT_GT6 Internal Communication Error (handling of internal SW errors) Logging in Error History
CRC error	m	o			E_DLL_CRC_TH	NMT_CT11, Error Condition Logging in Error History
Collision	o	o			E_DLL_COLLISION_TH	NMT_GT6 Internal Communication Error (handling of internal SW errors) Logging in Error History
Invalid format			m		E_DLL_INVALID_FORMAT	NMT_GT6 Internal Communication Error (handling of internal SW errors) Logging in Error History
SoC jitter out of range	o	o	o		E_DLL_JITTER_TH	NMT_CT11, Error Condition Logging in Error History
Loss of PReq	o	o			E_DLL_LOSS_PREQ_TH	NMT_CT11, Error Condition Logging in Error History
Loss of SoA	o	o			E_DLL_LOSS_SOA_TH	NMT_CT11, Error Condition Logging in Error History
Loss of SoC	m	m		CN sends (PRes) the last or actual values. Invalid data shall not be sent in any case.	E_DLL_LOSS_SOC_TH	NMT_CT11, Error Condition Logging in Error History

Tab. 27 CN error handling table

Remarks:

- Change of NMT state shall be signalled to all nodes (reason can be read at ERR_History_ADOM)
- In ERR_History_ADOM, all logging events shall be registered.
- None of the described Error symptoms on the CN shall be signalled via emergency queue to the MN.
- Cumulative Cnt, Threshold Cnt

  m mandatory (Counters: shall be implemented / Detection: shall be detected)

  o optionally (Counters: may be implemented / Detection: may be detected)
- Direct Reaction:

  m a direct Reaction on an error occurrence shall be proceeded either on the DLL state machine or on the NMT state machine

  o a direct Reaction on an error occurrence may be proceeded either on the DLL state machine or on the NMT state machine

4.7.3 Error Handling Table for MN

Error Symptoms	Cumulative Cnt	Threshold Cnt	Direct Reaction	DLL Local Handling	Error Codes	NMT Local Handling
Loss of link	o		o	These are considered to be an error source	E_DLL_LOSS_OF_LINK	Logging in Error History
Incorrect physical operating mode			o		E_DLL_BAD_PHYS_MODE	Logging in Error History
Tx/Rx buffer underrun / overflow			o		E_DLL_MAC_BUFFER	NMT_GT6 Internal Communication Error (handling of internal SW errors) Logging in Error History
CRC error	m	o			E_DLL_CRC_TH	NMT_MT6 Logging in Error History
Collision	o	o			E_DLL_COLLISION_TH	NMT_GT6 Internal Communication Error (handling of internal SW errors) Logging in Error History
Collision			m	Communication suspends for a configurable number of cycles . Changes its state to: DLL_MS_WAIT_SOC _TIME	E_DLL_COLLISION	Logging in Error History
Invalid format			m s		E_DLL_INVALID_FORMAT	Remove respective CN from configuration, send NMT State Command “NMTResetNode” to respective CN. Logging in Error History
Multiple MNs			o		E_DLL_MULTIPLE_MN	State != NMT_MS_NOT_ACTIVE-> NMT_GT6 Internal Communication Error State = NMT_MS_NOT_ACTIVE -> reside in NMT_MS_NOT_ACTIVE Logging in Error History
POWERLINK address conflict			m s		E_DLL_ADDRESS_CONFLICT	Remove all involved CNs from configuration
Loss of PRes	o s	m s			E_DLL_LOSS_PRES_TH	Remove respective CN from configuration, send NMT State Command NMTResetNode to respective CN. Logging in Error History
Late PRes	o s	o s			E_DLL_LATE_PRES_TH	Remove respective CN from configuration, send NMT State Command NMTResetNode to respective CN Logging in Error History
Loss of StatusResponse	o s	m s			E_DLL_LOSS_STATUSRES_TH	Remove respective CN from configuration, send NMT State Command NMTResetNode to respective CN. Logging in Error History
Cycle time exceeded	o	o			E_DLL_CYCLE_EXCEED_TH	NMT_MT6 Logging in Error History
Cycle time exceeded			m	Skip next cycle	E_DLL_CYCLE_EXCEED	Logging in Error History

Tab. 28 MN error handling table

Remarks:

- Change of NMT state shall signalled to all nodes (See Object ERR_History_ADOM)
- In Object ERR_History_ADOM, all logging events shall be registered.
- Cumulative Cnt, Threshold Cnt
  - m mandatory (Counters: shall be implemented / Detection: shall be detected)
  - o optionally (Counters: may be implemented / Detection: may be detected)
  - s per CN (Counters: per CN a Counter is used / Detection: Error shall be assigned to a CN)
- Direct Reaction:
  - m a direct reaction on an error occurrence shall be proceeded either on the DLL state machine or on the NMT state machine
  - o a direct reaction on an error occurrence may be proceeded either on the DLL state machine or on the NMT state machine
  - s per CN (Reaction: per CN / Detection: Error shall be assigned to a CN)

4.7.4 Error Handling Registration

This section gives an overview of the error registration on the MN and on CNs. The figure below shows all events that can occur and how the may get registered. On each node an Error History exists, where the occurred error symptoms are stored.

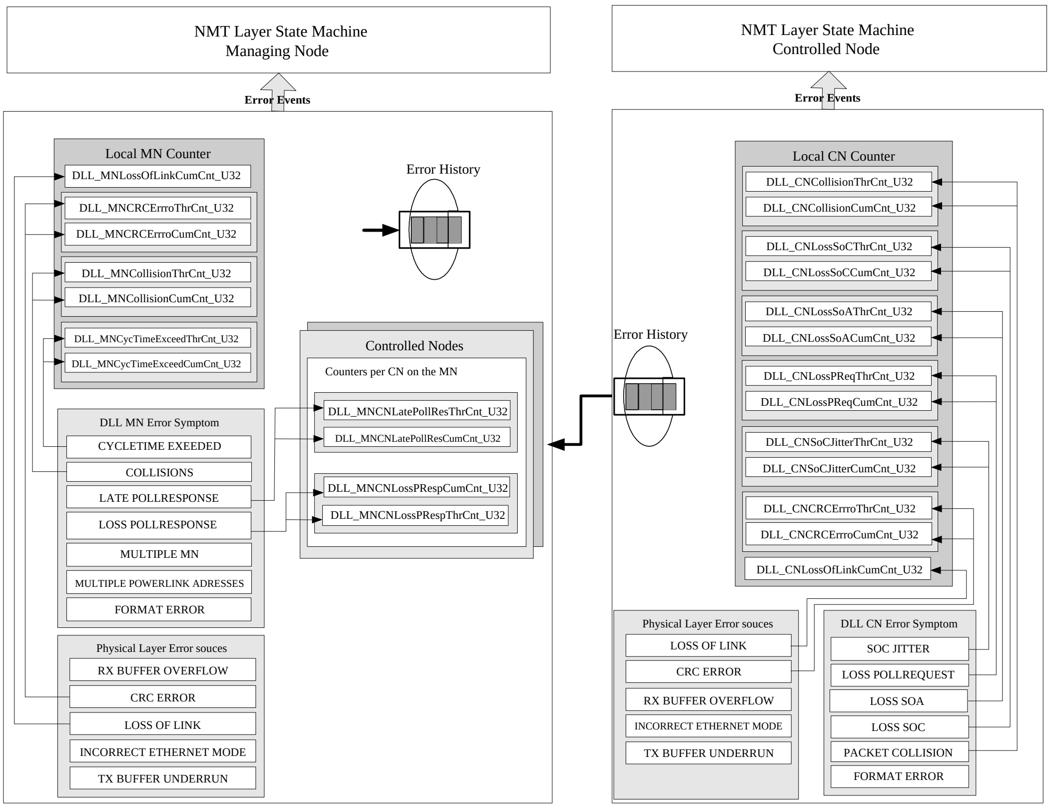


Fig. 33. Error registration

4.7.4.1 Threshold counters

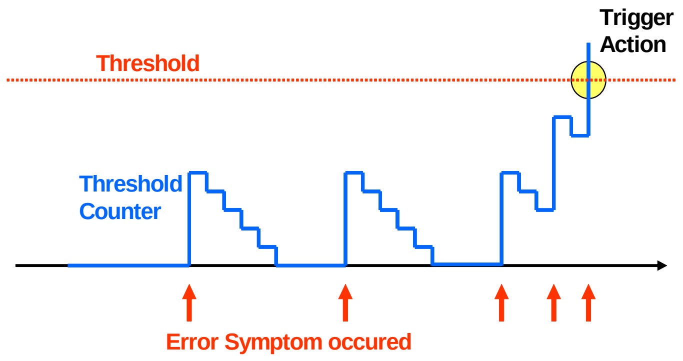


Fig. 34. Threshold counter

Every time an error symptom occurs the threshold counter shall be incremented by 8. After each cycle without reoccurance of the error the counter shall be decremented by one (Threshold counter 8:1).

When the threshold value is reached (threshold counter ≥ threshold), it shall trigger an action and the threshold counter shall be reset to 0.

All kinds of POWERLINK cycle, e.g. reduced and isochronous cycle, shall decrement threshold counters. Async-only and multiplexed nodes shall decrement at every cycle but not only to cycles addressing them.

The threshold value shall be configurable.

Immediate error reaction shall be commanded by a threshold value of 1.

Threshold counting and error reaction may be deactivated by setting the threshold value to 0.

Threshold counter handling shall be performed on a per error source basis.

4.7.4.2 Cumulative Counter

The Cumulative counter shall be incremented by 1 every time an error symptom occurs. An overflow may occur.

Cumulative counters shall not be reset by reset commands. An application may provide means to reset cumulative counters.

4.7.5 Physical Layer Error Sources

The data link layer uses the physical layer error sources for diagnosis of DLL communication error symptoms.

4.7.5.1 Loss of Link

- **Error source**

  The Loss of Link can occur if the connection is interrupted, e.g. wire breaks, somebody pulls out the network cable or a hub in the POWERLINK network is defect.

- **Error recognition**

  Loss of Link is a late detected error source explaining the primary error detections. Whenever a loss of a frame or a timing violation on the Data Link Layer is detected, the MN resp. CN checks the Physical Layer for a no link condition on the Ethernet MAC controller.

  Recognition is optional.

- **Handling**

  If the Loss of Link is detected, it is logged in the Error History.

  Loss of Link shall be reported regardless any error log triggered by the preceding primary error detection.

- **Registration**

  Optionally a cumulative counter (DLL_MNLossOfLinkCum_U32, resp. DLL_CNLossOfLinkCum_U32) is incremented.

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_DLL_LOSS_OF_LINK	XXXX	

4.7.5.2 Incorrect physical Ethernet operating mode

- **Error source**

  During the initialisation the new node may check whether it is 100 Mbit/s half duplex Ethernet operating mode. Otherwise timing requirements won't be fulfilled. This situation may occur if auto negotiation is used (not recommended, see Par. 3) and the communication partner is using 10 MBits (e.g. a Hub) or 100 MBit full duplex (e.g. a Switch).

- **Error recognition**

  Incorrect physical Ethernet operating mode is a late detected error source explaining the primary error detections. Whenever a loss of a frame or a timing violation on the Data Link Layer is detected, the MN resp. CN checks the Physical Layer for an incorrect physical Ethernet operating mode on the Ethernet MAC controller. Every time, when one of the following error symptoms occurs, it checks if the cause of the error symptom was an incorrect physical ETHERNET operating mode.

  Recognition is optional. Support shall be indicated by D_DLL_ErrBadPhysMode_BOOL.

- **Handling**

  If an incorrect physical Ethernet operating mode is detected, it is logged in the error history.

  Incorrect physical Ethernet operating mode is late detected error source explaining the primary error detections specified by 4.7.6.2, 4.7.7.3.1, 4.7.7.3.2 and 4.7.7.3.3. It shall be reported regardless any error log triggered by the preceding primary error detection.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_DLL_BAD_PHYS_MODE	XXXX	

4.7.5.3 Rx MAC buffer overflow / Tx MAC buffer underrun

- **Error source**

  If the receive MAC buffer of a CN or MN overflows, it cannot receive frames for a while.

  The transmit MAC buffer underrun error on the physical layer occurs; when the buffer becomes empty during transmission.

- **Error recognition**

  Buffer overflow resp underrun is a late detected error source explaining the primary error detections. Whenever a loss of a frame or a timing violation on the Data Link Layer is detected, the MN resp. CN checks the Physical Layer for an Rx MAC buffer overflow or a TX MAC buffer underrun on the Ethernet MAC controller.

  Recognition is optional. Support shall be indicated by D_DLL_ErrMacBuffer_BOOL.

- **Handling**

  If a Buffer error is detected, it is logged in the error history and the NMT layer is notified. The CN resp. MN NMT state machine handles this error source as an internal Communication Error (NMT_GT6) and changes its state to NMT_GS_RESET_COMMUNICATION.

  It shall be reported regardless any error log triggered by the preceding primary error detection.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_DLL_MAC_BUFFER	XXXX	

4.7.5.4 Transmission / CRC Errors

- **Error source**

  Transmission errors are detected by hardware (CRC-Check) in the Ethernet-Controller. Received frames containing CRC errors are simply discarded.

- **Error recognition**

  Every time a frame is lost, the node shall check if a CRC error has occurred.

  A device may also detect CRC errors on unexpected frames.

- **Handling**

  If a CRC error is detected, it shall be logged in the error history.

  Error reaction shall be triggered by the threshold counter mechnism (see 4.7.4.1).

  If the threshold counter DLL_MNCRCError_REC.ThresholdCnt_U32, resp. DLL_CNCRCError_REC.ThresholdCnt_U32 violates the threshold DLL_MNCRCError_REC.Threshold_U32 resp. DLL_CNCRCError_REC.Threshold_U32, the CN resp. MN NMT state machine shall handle this error source as an “error condition“ (NMT_CT11 resp. NMT_MT6) and shall change it’s state to NMT_CS_PRE_OPERATIONAL_1 resp. NMT_MS_PRE_OPERATIONAL_1.

  It’s not recommended to enable error reaction if unexpected frame CRC error recognition is active.

- **Registration**

  MN and CN shall operate a cumulative counter (DLL_MNCRCError_REC.CumulativeCnt_U32, resp. DLL_CNCRCError_REC.CumulativeCnt_U32, see. 4.7.4.2).) and a threshold counter (DLL_MNCRCError_REC.ThresholdCnt_U32, resp. DLL_CNCRCError_REC.ThresholdCnt_U32).

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_DLL_CRC_TH	XXXX	

4.7.6 Communication Error Symptoms detected by the MN

This section describes the error symptoms on the data link layer which are detected and handled by the MN.

4.7.6.1 Timing Violation

4.7.6.1.1 Slot Time Exceeded

Certain timing constellations must be distinguished when a frame is received. The timing behaviour of nodes shall be monitored, otherwise the entire cycle time can exceed.

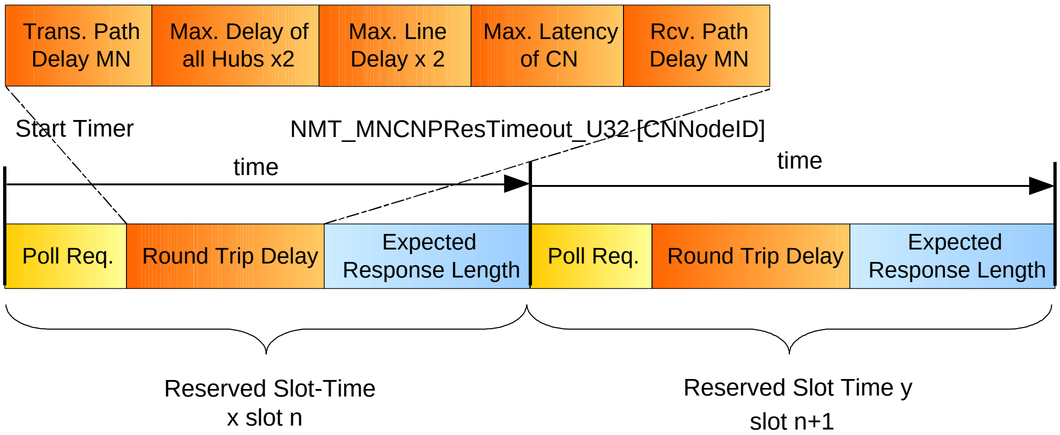


Fig. 35. Timeouts

The PRes frame of the CN must have been received completely before the slot timeout given by NMT_MNCNPResTimeout_AU32[CN Node ID] expires. The violation of the slot time produces the situations described below.

4.7.6.1.1.1 Case 1-2 Frame received in time

The behaviour is identical. The second case shows the latest acceptable time for the frame receipt. The current slot timeout is switched off immediately after the frame is received.

4.7.6.1.1.2 Case 3 Loss of PRes: Frame not received

The Loss of a PRes frame is detected by the slot timeout.

4.7.6.1.1.3 Case 4-6 Late PRes: Frame received in foreign slot (also collisions)

The cases 4 - 6 have one fact in common: A frame is received, which does not belong to the current slot. The worst case could lead to a violation of the cycle time. This kind of error can disturb the entire power link communication. Only in case 4 and 6 a Late PRes error can be detected. In case 5 a collision occurs as a result of a Late PRes error.

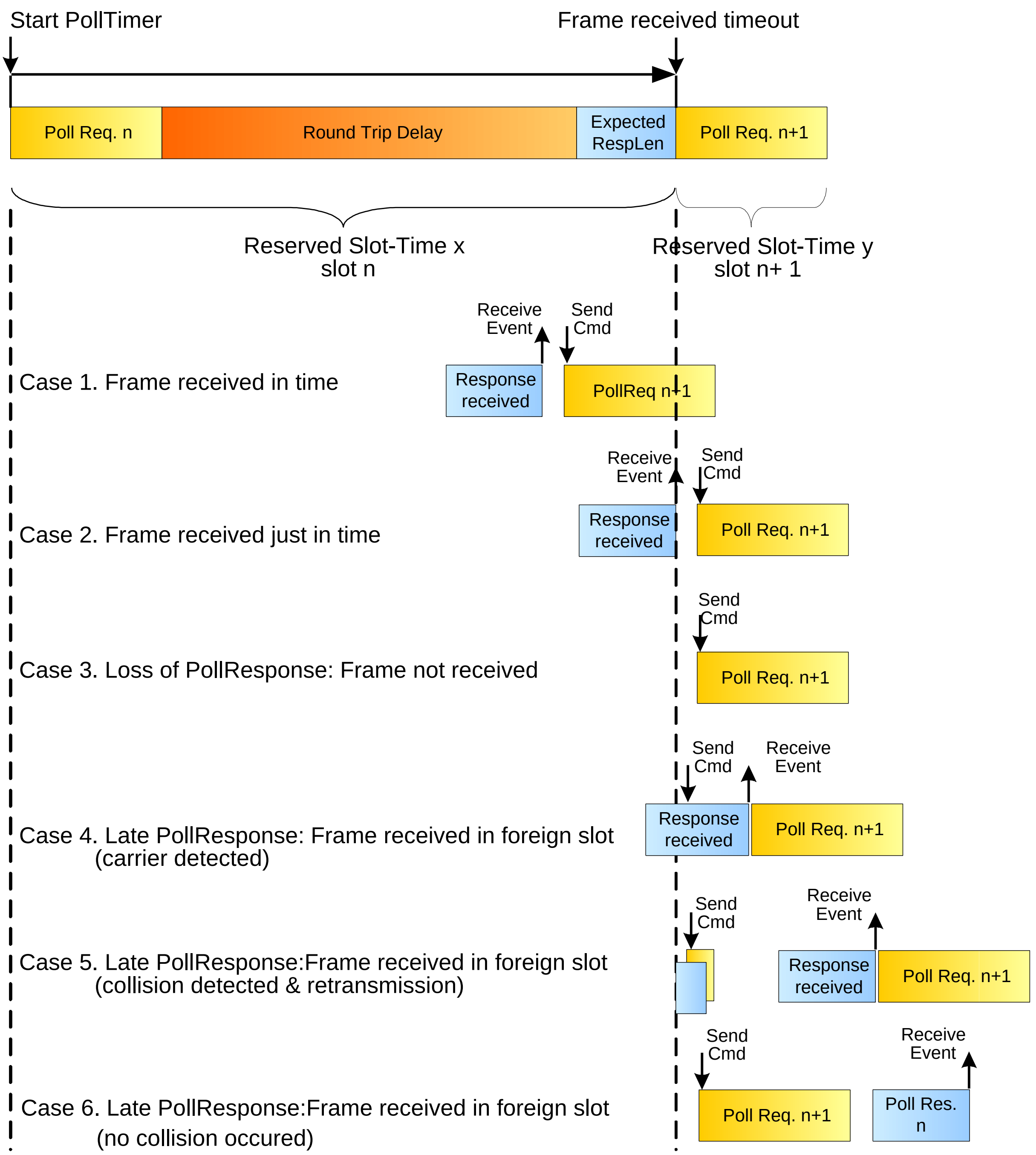


Fig. 36. Timing violation

4.7.6.2 Loss of PRes

- **Error source**

  Following possible error sources could cause this error symptom:

  - Physical error sources on the MN
    - Transmission Error (CRC Error)
    - Loss of link
    - Rx Buffer overflow
    - Tx Buffer underrun
  - Error symptoms on a CN in the POWERLINK network
    - Frame Collision error symptom

- A CN, which response latency is higher than allowed.
- A component of the network structure is defect.
- Power failure on a CN
- Etc.

- **Error recognition**

  If the slot timer expires, no frame was received during the reserved slot time. (See Slot Time exceeded: Case 3).

  Loss of PRes is detected by the MN cycle state machine and reported via error event DLL_MEV_LOSS_PRES.

- **Handling**

  After detecting a CN's Loss of PRes by the NMT_MNCNPResTimeout_AU32[CN Node ID], the MN shall proceed with the PReq for the next CN (or SoA if the end is reached).

  Error reaction shall be triggered by the threshold counter mechnism (see 4.7.4.1).

  If the threshold counter DLL_MNCNLossPResThrCnt_AU32[CN Node ID] violates the threshold DLL_MNCNLossPResThreshold_AU32[CN Node ID], the MN NMT State machine shall consider the CN inactive and shall remove it from the isochronous processing. Additionally it shall send the command NMTResetNode to the respective CN. On this command the CN will change its state (See 7.1.4). Whenever this error symptom is detected, the MN shall check for a physical layer error source.

  The error symptom shall be logged in the Error History every time the threshold value is reached.

- **Registration**

  The MN shall operate a threshold counter array DLL_MNCNLossPResThrCnt_AU32 and optionally a cumulative counter array DLL_MNCNLossPResCumCnt_AU32 (see. 4.7.4.2). CNs are represented by the subindices of the arrays.

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_DLL_LOSS_PRES_TH	XXXX	

4.7.6.3 Late PRes

- **Error source**

  Following possible error sources could cause this error symptom:

  - Physical error sources on the MN
    - Transmission Error (CRC Error)
    - Loss of link
    - Rx Buffer overflow
    - Tx Buffer underrun
  - Error symptoms on a CN in the POWERLINK network
    - Frame Collision error symptom
  - A CN, which response latency is higher than allowed.
  - A component of the network structure is defect.
  - Power failure on a CN
  - Etc.

- **Error recognition**

  A Late PRes error symptom may be detected on the MN, when the carrier is busy while trying to send the PReq frame (See Slot Time exceeded: Case 4) or when it receives a PRes frame from an unexpected CN (See Slot Time exceeded: Case 6).

Error recognition shall be performed at NMT states NMT_MS_PRE_OPERATIONAL_2, NMT_MS_READY_TO_OPERATE and NMT_MS_OPERATIONAL on isochronous CNs.

Recognition is optional.

- **Handling**

After detecting a Late PRes error, the MN proceeds with the PReq for the next CN (or SoA if the end is reached).

Error reaction shall be triggered by the threshold counter mechnism (see 4.7.4.1).

If the threshold counter DLL_MNCNLatePResThrCnt_AU32[CN Node ID] violates the threshold DLL_MNCNLatePResThreshold_AU32[CN Node ID], the MN NMT State machine shall consider the CN inactive and shall remove it from the isochronous processing. Additionally it shall send the command NMTResetNode to the respective CN. On this command the CN will change it's state (See 7.1.4).

If a PRes frame, that does not belong to the current slot, is received, the frame shall be rejected.

Whenever a Late PR error is detected, the MN shall check for a physical layer error source.

The error symptom shall be logged in the Error History every time the threshold value is reached

- **Registration**

The MN shall operate a threshold counter array DLL_MNCNLatePResThrCnt_AU32 and optionally a cumulative counter array DLL_MNCNLatePResCumCnt_AU32 (see. 4.7.4.2). CNs are represented by the subindices of the arrays.

History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_DLL_LATE_PRES_TH	XXXX	

4.7.6.4 Cycle Time Exceeded

- **Error source**

Following possible error sources could cause this error symptom:

- POWERLINK configuration failure
- A CN, which Response latency is higher than allowed.
- A component of the network structure, which is defect.
- Etc.

- **Error recognition**

A cycle time violation situation is defined as: The POWERLINK network was busy up to a time where a SoC should have been sent. If an ASnd frame or an Ethernet frame at the end of a cycle is delayed, then it may cause a collision with the SoC frame or a delay of the SoC frame.

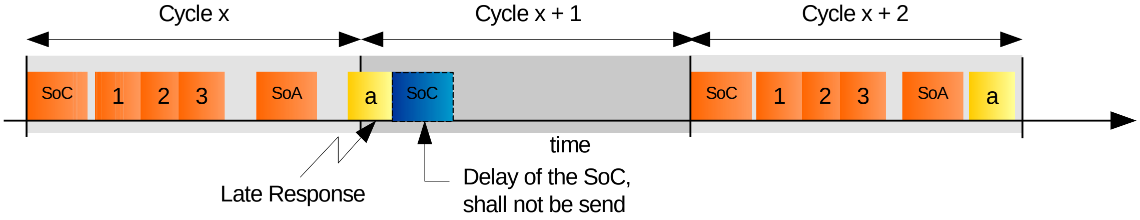


Fig. 37. Cycle time exceeded

Error detection is performed by the MN cycle state machine and reported via error event DLL_MEV_CYCLE_EXCEED.

To prevent cycle time exceed error the cycle shall be dimensioned for the worst case (with max response times / timeouts).

On line check may be done by verifying the remaining cycle time ≥ maximum async slot time (refer. DLL) before sending the SoA frame. No inviting SoA shall be transmitted if verification failed.

- **Handling**

A cycle time violation is considered a configuration error, hence the default behaviour shall be to suspend one cycle and to log the error symptom at the error history.

Optionally a threshold counter DLL_MNCycTimeExceed_REC.ThresholdCnt_U32 and a cumulative counter DLL_MNCycTimeExceed_REC.CumulativeCnt_U32 may be operated. Every time DLL_MNCycTimeExceed_REC.ThresholdCnt_U32 reaches the threshold DLL_MNCycTimeExceed_REC.Threshold_U32 or, if no Threshold counter is implemented, every time the error symptom occurs, the MN NMT state machine shall be notified. It shall handle this error source as an “error condition“ (NMT_MT6) and shall change it’s state to NMT_MS_PRE_OPERATIONAL_1.

Every error event shall be logged at the error history by E_DLL_CYCLE_EXCEED, threshold violations by E_DLL_CYCLE_EXCEED_TH.

- **Registration**

The MN may optionally operate a threshold counter DLL_MNCycTimeExceed_REC.ThresholdCnt_U32 and optionally a cumulative counter array DLL_MNCycTimeExceed_REC.CumulativeCnt_U32 (see. 4.7.4.2).

History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_DLL_CYCLE_EXCEED	XXXX	
3_h	002_h	E_DLL_CYCLE_EXCEED_TH	XXXX	

4.7.6.5 Collisions

- **Error Source**

The number of hubs in the POWERLINK network may violate the path delay variability specification of IEEE 802.3. Because standard Ethernet controllers according to IEEE 802.3 are used, collisions can be detected only in some cases.

ETHERNET powerlink does not depend on the discovery of collisions.

In NMT_MS_PRE_OPERATIONAL_1, NMT_MS_PRE_OPERATIONAL_2, NMT_MS_READY_TO_OPERATE, and NMT_MS_OPERATIONAL, no collisions should occur due to the POWERLINK cycle design. If a node does not follow these requirements, then the determinism and the high precision synchronisation cannot be guaranteed anymore. Nevertheless collisions can occur in case of configuration failures or defect nodes.

- **Error recognition**

If the Ethernet controller discovers a collision in the POWERLINK network, it shall start the standard Ethernet procedure for collisions.

- **Handling**

MN shall log the error symptom in the error history and and shall suspends cycle generation for a configurable number (DLL_MNCycleSuspendNumber_U32) of cycles, before continuing with the isochronous and asynchronous communication.

The MN data link layer state machine shall change its state to DLL_MS_WAIT_SOC_TIME.

Optionally a threshold counter DLL_MNCollision_REC.ThresholdCnt_U32 and a cumulative counter DLL_MNCollision_REC.CumulativeCnt_U32 may be operated. Every time DLL_MNCollision_REC.ThresholdCnt_U32 reaches the threshold DLL_MNCollision_REC.Threshold_U32 or, if no Threshold counter is implemented, every time the error symptom occurs, the MN NMT state machine shall be notified. It shall handle this error source as an “internal Communication Error (NMT_GT6)” and shall change its state to NMT_GS_RESET_COMMUNICATION.

Every error event shall be logged in the error history by E_DLL_COLLISION, threshold violations by E_DLL_COLLISION_TH.

- **Registration**

  The MN may optionally operate a threshold counter DLL_MNCollision_REC.ThresholdCnt_U32 and a cumulative counter DLL_MNCollision_REC.CumulativeCnt_U32 (see. 4.7.4.2).

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_DLL_COLLISION	XXXX	
3_h	002_h	E_DLL_COLLISION_TH	XXXX	

4.7.6.6 Invalid Formats

- **Error Source**

  Invalid Formats can result from software faults or hardware errors in the nodes. Format Errors shall only be detected on PRes and ASnd frames with correct CRC. Format Errors in the asynchronous communication not using the POWERLINK ASnd frame shall be ignored.

  Invalid Format Errors can also occur if there are various firmware versions within the POWERLINK network. In that case nodes may not support frame formats of other nodes.

- **Error recognition**

  An invalid Format error symptom shall be recognized if a POWERLINK frame header contains an unsupported value. This may be a false Node ID, etc. An invalid format error shall also be caused, if the received frame size is larger than the predicted buffer input size.

  A false resp. unknown message type or service ID does not result in an invalid format error.

  Note: Otherwise the mixing of old and new devices that support extensions of the specification with new message types or service IDs will result in invalid format errors in old CNs.

- **Handling**

  If a CN causes an invalid format error, the MN NMT State machine shall consider the CN inactive and shall remove it from the isochronous processing. Additionally it shall send to the CN the command NMTResetNode. On this command the CN will change its state (See 7.1.4).

  The error symptom shall be logged to error history, every time it occurs.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_DLL_INVALID_FORMAT	XXXX	

4.7.6.7 POWERLINK Address Conflicts

- **Error source**

  Because of the distinct MAC address of each node it is not possible that two or more nodes own the same MAC address but it is still possible that two or more nodes own the same powerlink node address. Only in the asynchronous communication multiple CNs can answer on a SoA frame (service channel: Ident). Since the MN sends a MAC multicast (SoA frame) to a unicast powerlink address, several CNs with the same powerlink address are able to respond.

- **Error recognition**

  The MN shall detect multiple used POWERLINK addresses in a network by counting the responses on an IdentRequest SoA frame.

- **Handling**

  If the MN detects that multiple CNs cause POWERLINK address conflicts, the MN NMT State machine shall consider the involved CNs inactive and shall remove them from the configuration.

The error symptom shall be logged to error history, every time it occurs.

- **Registration**

History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_DLL_ADDRESS_CONFLICT	XXXX	Status of the MN

4.7.6.8 Multiple MNs on a single POWERLINK Network

- **Error source**

In NMT_MS_NOT_ACTIVE the MN shall observe the POWERLINK network whether another MN is already running.

If multiple MNs simultaneously start the communication, a combination of error symptoms will be detected. One of these symptoms will be the receipt of SoC or SoA frames from the other MN.

- **Error recognition**

The MN will receive SoC or SoA frames from the other MN.

Recognition is optional. Support shall be indicated by D_DLL_ErrMNMultipleMN_BOOL.

- **Handling**

If the MN is in the state NMT_MS_NOT_ACTIVE and detects that another MN is running, it shall reside in its state.

If multiple MNs start the communication simultaneously and an MN detects this error symptom it notifies the NMT state machine. It handles this error source as an “internal Communication Error (NMT_GT6)” and changes its state to NMT_GS_RESET_COMMUNICATION.

The error symptom shall be logged every time it occurs.

- **Registration**

History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_DLL_MULTIPLE_MN	XXXX	

4.7.6.9 Loss of StatusResponse

- **Error source**

Following possible error sources could cause this error symptom:

- Physical error sources on the MN
  - Transmission Error (CRC Error)
  - Loss of link
  - Rx Buffer overflow
  - Tx Buffer underrun
- Error symptoms on a CN in the POWERLINK network
  - Frame Collision error symptom
- A CN, which response latency is higher than allowed.
- A component of the network structure is defect.
- Power failure on a CN
- Etc.

- **Error recognition**

If a StatusRequest was sent and the asynchronous slot time expires, no StatusResponse frame was received during the asynchronous slot.

The error is detected by the MN cycle state machine and reported via error event DLL_MEV_LOSS_STATUSRESPONSE.

- **Handling**

  After detecting a CN's Loss of StatusResponse by the NMT_MNCycleTiming_REC. AsyncSlotTimeout_U32, the MN shall proceed with the SoC of the next cycle.

  Error reaction shall be triggered by the threshold counter mechnism (see 4.7.4.1).

  If the threshold counter DLL_MNLossStatusResThrCnt_AU32[CN Node ID] violates the threshold DLL_MNLossStatusResThreshold_AU32[CN Node ID], the MN NMT State machine shall consider the CN inactive and shall remove it from the (isochronous) processing. Additionally it shall send the command NMTResetNode to the respective CN. On this command the CN will change its state (See 7.1.4). Whenever this error symptom is detected, the MN shall check for a physical layer error source.

  The error symptom shall be logged in the Error History every time the threshold value is reached.

- **Registration**

  The MN shall operate a threshold counter array DLL_MNLossStatusResThrCnt_AU32 and optionally a cumulative counter array DLL_MNLossStatusResCumCnt_AU32 (see. 4.7.4.2). CNs are represented by the subindices of the arrays.

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_DLL_LOSS_STATUSRES_TH	XXXX	

4.7.7 Communication Error Symptoms detected by the CN

This section describes error symptoms on the data link layer detected and handled by CNs.

4.7.7.1 Collisions

- **Error Source**

  The number of hubs in the POWERLINK network may violate the path delay variability specification of IEEE 802.3. Because standard Ethernet controllers according to IEEE 802.3 are used, collisions can be detected only in some cases.

  ETHERNET powerlink does not depend on the discovery of collisions.

  In NMT_CS_PRE_OPERATIONAL_1, NMT_CS_PRE_OPERATIONAL_2, NMT_CS_READY_TO_OPERATE, and NMT_CS_OPERATIONAL, no collisions should occur because of the POWERLINK cycle design. If a node does not fullfill these requirements, then the determinism and the high precision synchronisation can not be guaranteed anymore. Nevertheless collisions can occur in case of configuration failures or defect nodes.

- **Error recognition**

  If the Ethernet controller discovers a collision in the POWERLINK network, it shall start the standard Ethernet procedure for collisions.

- **Handling**

  A threshold counter DLL_CNCollision_REC.ThresholdCnt_U32 and a cumulative counter DLL_CNCollision_REC.CumulativeCnt_U32 may be operated optionally. Every time the threshold counter reaches the threshold DLL_CNCollision_REC.Threshold_U32, the CN NMT state machine shall be notified. It shall handle this error source as an "Internal Communication Error (NMT_GT6)" and shall change its state to NMT_GS_RESET_COMMUNICATION.

  Threshold violations shall be logged in the error history.

- **Registration**

  The CN may optionally operate a threshold counter DLL_CNCollision_REC.ThresholdCnt_U32 and a cumulative counter DLL_CNCollision_REC.CumulativeCnt_U32 (see. 4.7.4.2).

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_DLL_COLLISION_TH	XXXX	

4.7.7.2 Invalid Formats

- **Error Source**

  Invalid Formats can result from software faults or hardware errors in the nodes. Format Errors shall be detected on all POWERLINK frames with correct CRC received by the CN, e.g SoC, PReq, PRes, SoA and ASnd. Format Errors in the asynchronous communication not using the POWERLINK ASnd frame shall be ignored.

  Invalid Format Errors can also occur if there are various firmware versions within the POWERLINK network. In that case nodes may not support frame formats of other nodes.

- **Error recognition**

  An invalid Format error symptom shall be recognized if a POWERLINK frame header contains an unsupported value. This may be a false Node ID, etc. An invalid format error is also caused, if the received frame size is larger than the predicted buffer input size.

  A false resp. unknown message type or service ID does not result in an invalid format error.

  Note: Otherwise the mixing of old and new devices that support extensions of the specification with new message types or service IDs will result in invalid format errors in old CNs.

- **Handling**

  If a CN detects an invalid format error, it shall notify it's NMT State machine. The CN NMT State machine handles this error source as an "Internal Communication Error (NMT_GT6)" and changes its state to NMT_GS_RESET_COMMUNICATION.

  The error symptom is logged to error history every time it occurs.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_DLL_INVALID_FORMAT	XXXX	

4.7.7.3 Loss of Frames

Loss of Frame errors are detected by the CN cycle state machine and reported via error events. The state machine only detects the loss of frames, which were sent by the MN.

- **Error source**

  Following error sources could cause this error symptom:

  - Physical error sources on the MN (see 4.7.5)
    - Transmission Error (CRC Error)
    - Loss of link
    - Rx Buffer overflow
    - Tx Buffer underrun
  - Error symptoms on a CN in the POWERLINK network
    - Frame Collision (see 4.7.7.1)
  - A component of the network structure is defect.
  - Power failure on a CN or an MN

- Etc.

4.7.7.3.1 Loss of SoC

- **Error recognition**

  Loss of SoC error is detected by the CN Cycle State Machine and reported via error event DLL_CEV_LOSS_SOC.

- **Handling**

  On detecting a Loss of SoC the cumulative counter DLL_CNLossSoC_REC.CumulativeCnt_U32 shall be incremented. The CN shall reply on any invitation with the data of the previous cycle. The CN shall accept new isochronous or asynchronous data.

  Error reaction shall be triggered by the threshold counter mechnism (see 4.7.4.1).

  If the threshold counter DLL_CNLossSoC_REC.ThresholdCnt_U32 violates the threshold DLL_CNLossSoC_REC.Threshold_U32, the CN shall notify its NMT state machine and shall log the error symptom to the error history. The CN NMT state machine shall handle this error source as an “error condition (NMT_CT11)” and shall change it’s state to NMT_CS_PRE_OPERATIONAL_1.

  Whenever this error symptom is detected, the CN shall check for a physical layer error source (see 4.7.5).

- **Registration**

  The CN shall operate a threshold counter DLL_CNLossSoC_REC.ThresholdCnt_U32 and a cumulative counter DLL_CNLossSoC_REC.CumulativeCnt_U32 (see. 4.7.4.2).

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_DLL_LOSS_SOC_TH	XXXX	

4.7.7.3.2 Loss of SoA

- **Error recognition**

  Loss of SoA error is detected by the CN Cycle State Machine and reported via error event DLL_CEV_LOSS_SOA.

- **Handling**

  On detecting a Loss of SoA the cumulative counter DLL_CNLossSoA_REC.CumulativeCnt_U32 shall be incremented. The CN shall continue operation. It shall accept new isochronous or asynchronous data.

  Error reaction shall be triggered by the threshold counter mechnism (see 4.7.4.1).

  If the threshold counter DLL_CNLossSoA_REC.ThresholdCnt_U32 violates the threshold DLL_CNLossSoA_REC.Threshold_U32, the CN shall notify its NMT state machine and shall log the error symptom to the error history. The CN NMT state machine shall handle this error source as an “error condition (NMT_CT11)” and shall change it’s state to NMT_CS_PRE_OPERATIONAL_1.

  Whenever this error symptom is detected, the CN checks for a physical layer error source (see 4.7.5).

- **Registration**

  The CN shall operate a threshold counter DLL_CNLossSoA_REC.ThresholdCnt_U32 and a cumulative counter DLL_CNLossSoA_REC.CumulativeCnt_U32 (see. 4.7.4.2).

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_DLL_LOSS_SOA_TH	XXXX	

4.7.7.3.3 Loss of PReq

- **Error recognition**

  Loss of PReq error is detected by the CN Cycle State Machine and reported via error event DLL_CEV_LOSS_PREQ.

- **Handling**

  On detecting a Loss of PReq the cumulative counter DLL_CNLossPReq_REC.CumulativeCnt_U32 shall be incremented. The CN shall continue communication and listen to cross traffic. It shall accept new isochronous or asynchronous data.

  Further error reaction shall be triggered by the threshold counter mechnism (see 4.7.4.1).

  If the threshold counter DLL_CNLossPReq_REC.ThresholdCnt_U32 violates the threshold DLL_CNLossPReq_REC.Threshold_U32, the CN shall notify its NMT state machine and shall log the error symptom to the error history. The CN NMT state machine shall handle this error source as an “error condition (NMT_CT11)” and shall change it’s state to NMT_CS_PRE_OPERATIONAL_1.

  Whenever this error symptom is detected, the CN checks for a physical layer error source (see 4.7.5).

- **Registration**

  The CN shall operate a threshold counter DLL_CNLossPReq_REC.ThresholdCnt_U32 and a cumulative counter DLL_CNLossPReq_REC.CumulativeCnt_U32 (see. 4.7.4.2).

  History Entry Object ERR_History_ADOM

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_DLL_LOSS_PREQ_TH	XXXX	

4.7.7.3.4 SoC Jitter out of Range

- **Error source**

  This error could have various error sources:

  - Jitter on not POWERLINK compliant network components
  - Collisions in the POWERLINK network
  - Failure during the transmission
  - MN failures
  - Late response of CN causes a delay of the SoC
  - Etc.

- **Error recognition**

  A CN may control the SoC cycle time jitter.

  Every time it receives the SoC frame, it shall measure the cycle time. A SoC jitter error shall be recognized, when the difference between the nominal cycle time and the measured time is out of a configurable range DLL_CNSoCJitterRange_U32.

  Recognition shall be performed in NMT_CS_READY_TO_OPERATE and NMT_CS_OPERATIONAL.

- **Handling**

  If the CN detects a SoC Jitter range violation the cumulative counter DLL_CNSoCJitter_REC.CumulativeCnt_U32 shall be incremented,

  Further error reaction shall be triggered by the threshold counter mechnism (see 4.7.4.1).

If the threshold counter DLL_CNSoCJitter_REC.ThresholdCnt_U32 violates the threshold DLL_CNSoCJitter_REC.Threshold_U32, the CN shall notify its NMT state machine and shall log the error symptom to the error history. The CN NMT state machine shall handle this error source as an “error condition (NMT_CT11)” and shall change it’s state to NMT_CS_PRE_OPERATIONAL_1.

- **Registration**

  The CN shall operate a threshold counter DLL_CNSoCJitter_REC.ThresholdCnt_U32 and a cumulative counter DLL_CNSoCJitter_REC.CumulativeCnt_U32 (see. 4.7.4.2).

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_DLL_JITTER_TH	XXXX	

4.7.8 DLL Error Handling Objects

In this section the objects used by the DLL error handling are described.

Support of threshold counter objects requires support of the respective threshold value object and vice versa.

4.7.8.1 Object $1C00_h$: DLL_MNCRCError_REC

The following objects are used to monitor CRC errors. The record consists of a cumulative counter and a threshold counter data object and its threshold data object.

Index	$1C00_h$	Object Type	RECORD
Name	DLL_MNCRCError_REC		
Data Type	DLL_ErrorCntRec_TYPE	Category	MN: M CN: -

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	1 .. 3	Access	const
Default Value	-	PDO Mapping	No

- **Sub-Index 01_h: CumulativeCnt_U32**

Sub-Index	01_h		
Name	CumulativeCnt_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	rw
Default Value	0	PDO Mapping	No

The cumulative counter shall be incremented by 1 every time a CRC error occurs. Its value monitors all CRC errors that were detected by the MN.

- **Sub-Index 02_h: ThresholdCnt_U32**

Sub-Index	02_h		
Name	ThresholdCnt_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

The threshold counter shall be incremented by 8 every time a CRC error occurs on the MN and decremented by 1 at every cycle without reoccurance of the error. Its value monitors the quality of network in relation to the CRC error occurrence.

- **Sub-Index 03h: Threshold_U32**

Sub-Index	03h		
Name	Threshold_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rws
Default Value	15	PDO Mapping	No

Every time ThresholdCnt_U32 reaches the threshold, a defined action shall proceed and ThresholdCnt_U32 shall be reset to 0. (See 4.7.7.1)

Threshold Counting may be deactivated by setting Threshold_U32 to 0. If Threshold Counting is deactivated, no error reaction will occur.

4.7.8.2 Object 1C01h: DLL_MNCollision_REC

The following objects are used to monitor Collision error symptoms. The record consists of a cumulative counter and a threshold counter data object and its threshold data object.

Index	1C01h	Object Type	RECORD
Name	DLL_MNCollision_REC		
Data Type	DLL_ErrorCntRec_TYPE	Category	MN: O CN: -

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	0 .. 3	Access	rw
Default Value	-	PDO Mapping	No

- **Sub-Index 01h: CumulativeCnt_U32**

Sub-Index	01h		
Name	CumulativeCnt_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rw
Default Value	0	PDO Mapping	No

The cumulative counter shall be incremented by 1 every time a Collision error symptom occurs. Its value monitors all Collision error symptoms that were detected by the MN.

- **Sub-Index 02h: ThresholdCnt_U32**

Sub-Index	02h		
Name	ThresholdCnt_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

The threshold counter shall be incremented by 8 every time a Collision error symptom occurs on the MN and decremented by 1 at every cycle without reoccurance of the error. Its value monitors the quality of network in relation to the Collision error occurrence.

- **Sub-Index 03h: Threshold_U32**

Sub-Index	03h		
Name	Threshold_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rws
Default Value	15	PDO Mapping	No

Every time ThresholdCnt_U32 reaches the threshold, a defined action shall proceed and ThresholdCnt_U32 shall be reset to 0. (See 4.7.7.1)

Threshold counting may be deactivated by setting Threshold_U32 to 0. If Threshold Counting is deactivated, no error reaction will occur.

4.7.8.3 Object 1C02h: DLL_MNCycTimeExceed_REC

The following objects are used to monitor “Cycle time exceeded” error symptoms. The record consists of a cumulative counter and a threshold counter data object and its threshold data object.

Index	1C02h	Object Type	RECORD
Name	DLL_MNCycTimeExceed_REC		
Data Type	DLL_ErrorCntRec_TYPE	Category	MN: O CN: -

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	0 .. 3	Access	const
Default Value	-	PDO Mapping	No

- **Sub-Index 01h: CumulativeCnt_U32**

Sub-Index	01h		
Name	CumulativeCnt_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rw
Default Value	0	PDO Mapping	No

The cumulative counter shall be incremented by 1 every time a “Cycle time Exceeded“ error symptom occurs. Its value monitors all “Cycle Time exceeded” error symptom that were detected by the MN.

- **Sub-Index 02h: ThresholdCnt_U32**

Sub-Index	02h		
Name	ThresholdCnt_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

The threshold counter shall be incremented by 8 every time a “Cycle Time exceeded” error symptom occurs on the MN and decremented by 1 at every cycle without reoccurance of the error. Its value monitors the quality of network in relation to the “Cycle Time exceeded error occurrence.

- **Sub-Index 03_h: Threshold_U32**

Sub-Index	03_h		
Name	Threshold_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rws
Default Value	15	PDO Mapping	No

Every time ThresholdCnt_U32 reaches the threshold, a defined action shall proceed and ThresholdCnt_U32 shall be reset to 0. (See 4.7.7.1)

Threshold Counting may be deactivated by setting Threshold_U32 to 0. If Threshold Counting is deactivated, no error reaction will occur.

4.7.8.4 Object 1C03h: DLL_MNLossOfLinkCum_U32

The following objects are used to monitor the “Loss of Link” error source. The cumulative counter shall be incremented by 1 every time a “Loss of Link“ error symptom occurs. Its value monitors all “Loss of Link” error symptoms that were detected by the MN.

The object may be implemented only if the error recognition is provided.

Index	$1C03_h$	Object Type	VAR
Name	DLL_MNLossOfLinkCum_U32		
Data Type	UNSIGNED32	Category	MN: Cond CN: -
Value Range	UNSIGNED32	Access	rw
Default Value	0	PDO Mapping	No

4.7.8.5 Object 1C04h: DLL_MNCNLatePResCumCnt_AU32

This array on the MN contains for every CN in the POWERLINK network a cumulative counter of Late PRes events. The cumulative counter of the respective CN shall be incremented by 1 every time a “Late PollResponse“ error symptom occurs. Its value monitors all “Late PollResponse” error symptoms that were detected by the MN.

The object may be implemented only if the error recognition is provided.

Index	$1C04_h$	Object Type	ARRAY
Name	DLL_MNCNLatePResCumCnt_AU32		
Data Type	UNSIGNED32	Category	MN: Cond CN: -

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	ro
Default Value	254	PDO Mapping	No

- **Sub-Index 01_h – FE_h: CumCnt**

Sub-Index	01_h – FE_h		
Name	CumCnt		
--	--	Category	M
Value Range	UNSIGNED32	Access	rw
Default Value	0	PDO Mapping	No

The sub-index is valid only if there is an isochronous CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bits 0, 1 and 8.

4.7.8.6 Object 1C05$_h$: DLL_MNCNLatePResThrCnt_AU32

This array on the MN contains for every CN in the POWERLINK network a threshold counter of late PRes. The threshold counter of the respective CN shall be incremented by 8 every time a “Late PollResponse” error symptom occurs on the MN and decremented by 1 at every cycle without reoccurance of the error. Its value monitors the quality of network in relation to the “Late PollResponse” error occurrence.

The object may be implemented only if the error recognition is provided.

Index	1C05$_h$	Object Type	ARRAY
Name	DLL_MNCNLatePResThrCnt_AU32		
Data Type	UNSIGNED32	Category	MN: Cond CN: -

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	ro
Default Value	254	PDO Mapping	No

- **Sub-Index 01$_h$ – FE$_h$: ThrCnt**

Sub-Index	01h – FEh		
Name	ThrCnt		
--	--	Category	M
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

The sub-index is valid only if there is an isochronous CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bits 0, 1 and 8.

4.7.8.7 Object 1C06$_h$: DLL_MNCNLatePResThreshold_AU32

This array on the MN contains for every CN in the POWERLINK network a threshold of late PRes.

Every time the respective DLL_MNCNLatePResThrCnt_AU32 value reaches the threshold, a defined action shall proceed and the respective DLL_MNCNLatePResThrCnt_AU32 value shall be reset to 0. (See 4.7.7.1)

Threshold Counting may be deactivated by setting respective DLL_MNCNLatePResThreshold_AU32 value to 0. If Threshold Counting is deactivated, no error reaction will occur.

The object may be implemented only if the error recognition is provided.

Index	$1C06_h$	Object Type	ARRAY
Name	DLL_MNCNLatePResThreshold_AU32		
Data Type	UNSIGNED32	Category	MN: Cond CN: -

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	ro
Default Value	254	PDO Mapping	No

- **Sub-Index 01_h – FE_h: Threshold**

Sub-Index	01_h – FE_h		
Name	Threshold		
--	--	Category	M
Value Range	UNSIGNED32	Access	rws
Default Value	15	PDO Mapping	No

The sub-index is valid only if there is an isochronous CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bits 0, 1 and 8.

4.7.8.8 Object $1C07_h$: DLL_MNCNLossPResCumCnt_AU32

This array on the MN contains for every CN in the POWERLINK network a cumulative counter of Loss of PRes events. The cumulative counter of the respective CN shall be incremented by 1 every time a "Loss of PollResponse" error symptom occurs. Its value monitors all "Loss PollResponse" error symptoms that were detected by the MN.

Index	$1C07_h$	Object Type	ARRAY
Name	DLL_MNCNLossPResCumCnt_AU32		
Data Type	UNSIGNED32	Category	MN: O CN: -

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	ro
Default Value	254	PDO Mapping	No

- **Sub-Index 01h – FEh: CumCnt**

Sub-Index	01h – FEh		
Name	CumCnt		
--	--	Category	M
Value Range	UNSIGNED32	Access	rw
Default Value	0	PDO Mapping	No

The sub-index is valid only if there is an isochronous CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bits 0, 1 and 8.

4.7.8.9 Object $1C08_h$: DLL_MNCNLossPResThrCnt_AU32

This array on the MN contains for every CN in the POWERLINK network a threshold counter of Loss of PRes.The threshold counter of the respective CN shall be incremented by 8 every time a "Loss of PollResponse" error symptom occurs on the MN and decremented by 1 at every cycle without reoccurance of the error. Its value monitors the quality of network in relation to the "Loss of PollResponse" error occurrence.

Index	1C08h	Object Type	ARRAY
Name	DLL_MNCNLossPResThrCnt_AU32		
Data Type	UNSIGNED32	Category	MN: M CN: -

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	ro
Default Value	254	PDO Mapping	No

- **Sub-Index 01h – FEh: ThrCnt**

Sub-Index	01h – FEh		
Name	ThrCnt		
--	--	Category	M
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

The sub-index is valid only if there is an isochronous CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bits 0, 1 and 8.

4.7.8.10 Object 1C09h: DLL_MNCNLossPResThreshold_AU32

This array on the MN contains for every CN in the POWERLINK network a threshold of lost PRes.

Every time the respective DLL_MNCNLossPResThrCnt_AU32 value reaches the threshold, a defined action shall proceed and the respective DLL_MNCNLossPResThrCnt_AU32 value shall be reset to 0. (See 4.7.7.1)

Threshold counting may be deactivated by setting respective DLL_MNCNLossPResThreshold_AU32 value to 0. If Threshold Counting is deactivated, no error reaction will occur.

Index	1C09h	Object Type	ARRAY
Name	DLL_MNCNLossPResThreshold_AU32		
Data Type	UNSIGNED32	Category	MN: M CN: -

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	ro
Default Value	254	PDO Mapping	No

- **Sub-Index 01h – FEh: Threshold**

Sub-Index	01h – FEh		
Name	Threshold		
--	--	Category	M
Value Range	UNSIGNED32	Access	rws
Default Value	15	PDO Mapping	No

The sub-index is valid only if there is an isochronous CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bits 0, 1 and 8.

4.7.8.11 Object 1C0A$_h$: DLL_CNCollision_REC

The following objects are used to monitor “Collision” error symptoms detected by a CN. The record consists of a cumulative counter and a threshold counter data object and its threshold data object.

The object may be implemented if the error recognition is provided.

Index	1C0A$_h$	Object Type	RECORD
Name	DLL_CNCollision_REC		
Data Type	DLL_ErrorCntRec_TYPE	Category	MN: - CN: O

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	0 .. 3	Access	const
Default Value	-	PDO Mapping	No

- **Sub-Index 01$_h$: CumulativeCnt_U32**

Sub-Index	01$_h$		
Name	CumulativeCnt_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rw
Default Value	0	PDO Mapping	No

The cumulative counter shall be incremented by 1 every time a “Collision“ error symptom occurs. Its value monitors all “Collision” error symptoms that were detected by the CN.

- **Sub-Index 02$_h$: ThresholdCnt_U32**

Sub-Index	02$_h$		
Name	ThresholdCnt_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

The threshold counter shall be incremented by 8 every time a “Collision” error symptom occurs and decremented by 1 at every cycle without reoccurance of the error. Its value monitors the quality of network in relation to the “Collision” error occurrence.

- **Sub-Index 03$_h$: Threshold_U32**

Sub-Index	03$_h$		
Name	Threshold_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rws
Default Value	15	PDO Mapping	No

Every time ThresholdCnt_U32 reaches the threshold, a defined action shall proceed and ThresholdCnt_U32 shall be reset to 0. (See 4.7.7.1)

Threshold Counting may be deactivated by setting Threshold_U32 to 0. If Threshold Counting is deactivated, no error reaction will occur.

4.7.8.12 Object 1C0B$_h$: DLL_CNLossSoC_REC

The following objects are used to monitor “Loss of Soc” error symptoms detected by a CN. The record consists of a cumulative counter and a threshold counter data object and its threshold data object.

Index	1C0B$_h$	Object Type	RECORD
Name	DLL_CNLossSoC_REC		
Data Type	DLL_ErrorCntRec_TYPE	Category	MN: - CN: M

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	3	Access	const
Default Value	3	PDO Mapping	No

- **Sub-Index 01$_h$: CumulativeCnt_U32**

Sub-Index	01$_h$		
Name	CumulativeCnt_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	rw
Default Value	0	PDO Mapping	No

The cumulative counter shall be incremented by 1 every time a “Loss of SoC“ error symptom occurs. Its value monitors all “Loss of SoC” error symptoms that were detected by the CN.

- **Sub-Index 02$_h$: ThresholdCnt_U32**

Sub-Index	02$_h$		
Name	ThresholdCnt_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

The threshold counter shall be incremented by 8 every time a “Loss of SoC” error symptom occurs and decremented by 1 at every cycle without reoccurance of the error. Its value monitors the quality of network in relation to the “Loss of SoC” error occurrence.

- **Sub-Index 03$_h$: Threshold_U32**

Sub-Index	03$_h$		
Name	Threshold_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	rws
Default Value	15	PDO Mapping	No

Every time ThresholdCnt_U32 reaches the threshold, a defined action shall proceed and ThresholdCnt_U32 shall be reset to 0. (See 4.7.7.3.1)

Threshold Counting may be deactivated by setting Threshold_U32 to 0. If Threshold Counting is deactivated, no error reaction will occur.

4.7.8.13 Object 1C0Ch: DLL_CNLossSoA_REC

The following objects are used to monitor “Loss of SoA” error symptoms detected by a CN. The record consists of a cumulative counter and a threshold counter data object and its threshold data object.

The object may be implemented only if the error recognition is provided.

Index	1C0Ch	Object Type	RECORD
Name	DLL_CNLossSoA_REC		
Data Type	DLL_ErrorCntRec_TYPE	Category	MN: - CN: Cond

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	0 .. 3	Access	const
Default Value	-	PDO Mapping	No

- **Sub-Index 01h: CumulativeCnt_U32**

Sub-Index	01h		
Name	CumulativeCnt_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rw
Default Value	0	PDO Mapping	No

The cumulative counter shall be incremented by 1 every time a “Loss of SoA“ error symptom occurs. Its value monitors all “Loss of SoA” error symptoms that were detected by the CN.

- **Sub-Index 02h: ThresholdCnt_U32**

Sub-Index	02h		
Name	ThresholdCnt_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

The threshold counter shall be incremented by 8 every time a “Loss of SoA” error symptom occurs and decremented by 1 at every cycle without reoccurance of the error. Its value monitors the quality of network in relation to the “Loss of SoA” error occurrence.

- **Sub-Index 03h: Threshold_U32**

Sub-Index	03h		
Name	Threshold_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rws
Default Value	15	PDO Mapping	No

Every time ThresholdCnt_U32 reaches the threshold, a defined action shall proceed and ThresholdCnt_U32 shall be reset to 0. (See 4.7.7.3.2)

Threshold Counting may be deactivated by setting Threshold_U32 to 0. If Threshold Counting is deactivated, no error reaction will occur.

4.7.8.14 Object $1C0D_h$: DLL_CNLossPReq_REC

The following objects are used to monitor "Loss of PReq" error symptoms detected by an isochronous CN. The record consists of a cumulative counter and a threshold counter data object and its threshold data object.

The object may be implemented only if the error recognition is provided.

Index	$1C0D_h$	Object Type	RECORD
Name	DLL_CNLossPReq_REC		
Data Type	DLL_ErrorCntRec_TYPE	Category	MN: - CN: Cond

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	0 .. 3	Access	const
Default Value	-	PDO Mapping	No

- **Sub-Index 01_h: CumulativeCnt_U32**

Sub-Index	01_h		
Name	CumulativeCnt_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rw
Default Value	0	PDO Mapping	No

The cumulative counter shall be incremented by 1 every time a "Loss of PReq" error symptom occurs. Its value monitors all "Loss of PReq" error symptoms that were detected by the CN.

- **Sub-Index 02_h: ThresholdCnt_U32**

Sub-Index	02_h		
Name	ThresholdCnt_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

The threshold counter shall be incremented by 8 every time a "Loss of PReq" error symptom occurs and decremented by 1 at every cycle without reoccurance of the error. Its value monitors the quality of network in relation to the "Loss of PReq" error occurrence.

- **Sub-Index 03_h: Threshold_U32**

Sub-Index	03_h		
Name	Threshold_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rws
Default Value	15	PDO Mapping	No

Every time ThresholdCnt_U32 reaches the threshold, a defined action shall proceed and ThresholdCnt_U32 shall be reset to 0. (See 4.7.7.3.3)

Threshold Counting may be deactivated by setting Threshold_U32 to 0. If Threshold Counting is deactivated, no error reaction will occur.

4.7.8.15 Object $1C0E_h$: DLL_CNSoCJitter_REC

The following objects are used to monitor “SoC Jitter” error symptoms detected by a CN. The record consists of a cumulative counter and a threshold counter data object and its threshold data object.

The object may be implemented only if the error recognition is provided.

Index	$1C0E_h$	Object Type	RECORD
Name	DLL_CNSoCJitter_REC		
Data Type	DLL_ErrorCntRec_TYPE	Category	MN: - CN: Cond

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	0 .. 3	Access	const
Default Value	-	PDO Mapping	No

- **Sub-Index 01_h: CumulativeCnt_U32**

Sub-Index	01_h		
Name	CumulativeCnt_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rw
Default Value	0	PDO Mapping	No

The cumulative counter shall be incremented by 1 every time a “Soc Jitter“ error symptom occurs. Its value monitors all “SoC Jitter” error symptoms that were detected by the CN.

- **Sub-Index 02_h: ThresholdCnt_U32**

Sub-Index	02_h		
Name	ThresholdCnt_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

The threshold counter shall be incremented by 8 every time a “SoC Jitter” error symptom occurs and decremented by 1 at every cycle without reoccurance of the error. Its value monitors the quality of network in relation to the “SoC Jitter” error occurrence.

- **Sub-Index 03_h: Threshold_U32**

Sub-Index	03_h		
Name	Threshold_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rws
Default Value	15	PDO Mapping	No

Every time ThresholdCnt_U32 reaches the threshold, a defined action shall proceed and ThresholdCnt_U32 shall be reset to 0. (See 4.7.7.3.1)

Threshold Counting may be deactivated by setting Threshold_U32 to 0. If Threshold Counting is deactivated, no error reaction will occur.

4.7.8.16 Object 1C0F$_h$: DLL_CNCRCError_REC

The following objects are used to monitor CRC errors. The record consists of a cumulative counter and a threshold counter data object and its threshold data object.

Index	1C0F$_h$	Object Type	RECORD
Name	DLL_CNCRCError_REC		
Data Type	DLL_ErrorCntRec_TYPE	Category	MN: - CN: M

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	1 .. 3	Access	const
Default Value	-	PDO Mapping	No

- **Sub-Index 01$_h$: CumulativeCnt_U32**

Sub-Index	01$_h$		
Name	CumulativeCnt_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	rw
Default Value	0	PDO Mapping	No

The cumulative counter shall be incremented by 1 every time a CRC error occurs. Its value monitors all CRC errors that were detected by the CN.

- **Sub-Index 02$_h$: ThresholdCnt_U32**

Sub-Index	02$_h$		
Name	ThresholdCnt_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

The threshold counter shall be incremented by 8 every time a CRC error occurs on the CN and decremented by 1 at every cycle without reoccurance of the error. Its value monitors the quality of network in relation to the CRC error occurrence.

- **Sub-Index 03$_h$: Threshold_U32**

Sub-Index	03$_h$		
Name	Threshold_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rws
Default Value	15	PDO Mapping	No

Every time ThresholdCnt_U32 reaches the threshold, a defined action shall proceed and ThresholdCnt_U32 shall be reset to 0. (See 4.7.5.4)

Threshold Counting may be deactivated by setting Threshold_U32 to 0. If Threshold Counting is deactivated, no error reaction will occur.

4.7.8.17 Object 1C10$_h$: DLL_CNLossOfLinkCum_U32

The following objects are used to monitor the “Loss of Link” error source. The cumulative counter shall be incremented by 1 every time a “Loss of Link“ error symptom occurs. Its value monitors all “Loss of Link” error sources that were detected by the CN.

The object may be implemented only if the error recognition is provided.

Index	1C10$_h$	Object Type	VAR
Name	DLL_CNLossOfLinkCum_U32		
Data Type	UNSIGNED32	Category	MN: - CN: Cond
Value Range	UNSIGNED32	Access	rw
Default Value	0	PDO Mapping	No

4.7.8.18 Object 1C12$_h$: DLL_MNCycleSuspendNumber_U32

The DLL_MNCycleSuspendNumber_U32 parameter is used to define the number of cycles that will be suspended, when a collision has occurred. (See also Tab. 28 MN error handling table and 4.7.6.5 Collisions)

Index	1C12$_h$	Object Type	VAR
Name	DLL_MNCycleSuspendNumber_U32		
Data Type	UNSIGNED32	Category	MN: M CN: -
Value Range	UNSIGNED32	Access	rw
Default Value	1	PDO Mapping	No

Value 0 means that it will finish the current cycle and continue with the followed cycle; 1 means, that it suspends the followed cycle.

4.7.8.19 Object 1C13$_h$: DLL_CNSoCJitterRange_U32

The DLL_CNSoCJitterRange_U32 parameter is used to define the range in ns within the SoCJitter may vary.

The object may be implemented only if the error recognition is provided.

Index	1C13$_h$	Object Type	VAR
Name	DLL_CNSoCJitterRange_U32		
Data Type	UNSIGNED32	Category	MN: - CN: Cond
Value Range	UNSIGNED32	Access	rw
Default Value	2000	PDO Mapping	No

4.7.8.20 Object 1C14$_h$: DLL_CNLossOfSocTolerance_U32

The object provides a tolerance interval in [ns] to be applied by CN’s Loss of SoC error recognition (see 4.7.7.3.1).

Index	$1C14_h$	Object Type	VAR
Name	DLL_CNLossOfSocTolerance_U32		
Data Type	UNSIGNED32	Category	MN: - CN: M
Value Range	0 .. D_DLL_CNLossOfSoCToleranceMax_U32	Access	rws
Default Value	D_DLL_CNLossOfSoCToleranceMax_U32	PDO Mapping	No

4.7.8.21 Object $1C15_h$: DLL_MNLossStatusResCumCnt_AU32

This array on the MN contains for every CN in the POWERLINK network a cumulative counter of Loss of StatusResponse events. The cumulative counter of the respective CN shall be incremented by 1 every time a “Loss of StatusResponse“ error symptom occurs. Its value monitors all “Loss StatusResponse” error symptoms that were detected by the MN.

Index	$1C15_h$	Object Type	ARRAY
Name	DLL_MNLossStatusResCumCnt_AU32		
Data Type	UNSIGNED32	Category	MN: O CN: -

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	ro
Default Value	254	PDO Mapping	No

- **Sub-Index 01h – FEh: CumCnt**

Sub-Index	01h – FEh		
Name	CumCnt		
--	--	Category	M
Value Range	UNSIGNED32	Access	rw
Default Value	0	PDO Mapping	No

The sub-index is valid only if there is a CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bits 0 and 1.

4.7.8.22 Object $1C16_h$: DLL_MNLossStatusResThrCnt_AU32

This array on the MN contains for every CN in the POWERLINK network a threshold counter of Loss of StatusResponse. The threshold counter of the respective CN shall be incremented by 8 every time a “Loss of StatusResponse” error symptom occurs on the MN and decremented by 1 at every StatusRequest without reoccurance of the error. Its value monitors the quality of network in relation to the “Loss of StatusResponse” error occurrence.

Index	$1C16_h$	Object Type	ARRAY
Name	DLL_MNLossStatusResThrCnt_AU32		
Data Type	UNSIGNED32	Category	MN: M CN: -

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	ro
Default Value	254	PDO Mapping	No

- **Sub-Index 01_h – FE_h: ThrCnt**

Sub-Index	01_h – FE_h		
Name	ThrCnt		
--	--	Category	M
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

The sub-index is valid only if there is a CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bits 0 and 1.

4.7.8.23 Object $1C17_h$: DLL_MNLossStatusResThreshold_AU32

This array on the MN contains for every CN in the POWERLINK network a threshold of lost StatusResponse.

Every time the respective DLL_MNLossStatusResThrCnt_AU32 value reaches the threshold, a defined action shall proceed and the respective DLL_MNLossStatusResThrCnt_AU32 value shall be reset to 0. (See 4.7.7.1)

Threshold counting may be deactivated by setting respective DLL_MNLossStatusResThreshold_AU32 value to 0. If Threshold Counting is deactivated, no error reaction will occur.

Index	$1C17_h$	Object Type	ARRAY
Name	DLL_MNLossStatusResThreshold_AU32		
Data Type	UNSIGNED32	Category	MN: M CN: -

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	ro
Default Value	254	PDO Mapping	No

- **Sub-Index 01h – FEh: Threshold**

Sub-Index	01h – FEh		
Name	Threshold		
--	--	Category	M
Value Range	UNSIGNED32	Access	rws
Default Value	15	PDO Mapping	No

The sub-index is valid only if there is an isochronous CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bits 0 and 1.

4.7.8.24 Object 0424h: DLL_ErrorCntRec_TYPE

Index	0424h	Object Type	DEFSTRUCT
Name	DLL_ErrorCntRec_TYPE		
Sub-Index	Component Name	Value	Data Type
00h	NumberOfEntries	03h	
01h	CumulativeCnt_U32	0007h	UNSIGNED32
02h	ThresholdCnt_U32	0007h	UNSIGNED32
03h	Threshold_U32	0007h	UNSIGNED32

5 Network / Transport Layer

5.1 Internet Protocol (IP)

The Internet Protocol version 4 (IPv4) and its referred transport layer protocols UDP and TCP are the preferred protocols in the asynchronous phase.

- RFC 791 defines Internet Protocol (IP)
- RFC 768 defines the User Datagram Protocol (UDP)
- RFC 793 defines the Transmission Control Protocol (TCP).

5.1.1 IP Host Requirements

This section discusses the requirements for a POWERLINK node implementation of the Internet Protocol. To use IP transparently in the asynchronous phase, the POWERLINK nodes shall be conformed to RFC1122 “Requirements for Internet Hosts -- Communication Layers”. However, this would prohibit several low-end POWERLINK nodes, communicating with IP in the asynchronous phase. Therefore the following conformance classes are introduced.

5.1.1.1 Nodes without IP Communication

MNs shall support IP communication.

CNs that don’t support SDO via UDP/IP do not need an IP stack.

At the CN, support of IP communication may be indicated by the device description entry D_NWL_IPSupport_BOOL.

5.1.1.2 Minimum Requirements for SDO Communication

This conformance class shall be fulfilled, to ensure that a POWERLINK node is able to communicate in the asynchronous phase via SDO. It is not guaranteed that protocols from the Internet Protocol suite will work – e.g. Socket communication, TFTP, FTP HTTP, etc.

5.1.1.2.1 IP Stack Requirements

To communicate via IPv4 in the asynchronous phase, the POWERLINK node shall at least cope with 256 Bytes SDO payload. Therefore, the IP stack shall process at least C_DLL_MIN_ASYNC_MTU bytes (including IP header and IP payload) that can be received. IP fragmentation and reassembly is not required to fulfil this conformance class. Hence the size of the asynchronous phase shall be equal or bigger than 256 Bytes SDO payload.

5.1.1.2.2 UDP Requirements

A POWERLINK node shall implement the User Datagram Protocol specified in RFC 768 and shall support at least one UDP socket.

5.1.1.3 Minimum Requirements for Standard IP Communication

This conformance class shall be compatible to RFC 1122 and shall cover the entire conformance class for minimum requirements for SDO communication listed above. For convenience the following core requirements are listed.

5.1.1.3.1 IP Stack Requirements

- The IPv4 layer shall implement reassembly of IP datagrams – see RFC1122 chapter 3.3.2 Reassembly.
- The IPv4 layer shall implement a mechanism to fragment outgoing datagrams intentionally – see RFC1122 chapter 3.3.3 Fragmentation.
- In general an IPv4 capable POWERLINK node shall at least process IP datagrams up to 576 bytes (including header and data) – see RFC 1122 chapter 3.3.2/3.3.3.
- ICMP (RFC 792) support is optional. It shall be indicated by D_NWL_ICMPSupport_BOOL.

5.1.2 IP Addressing

Each IP-capable POWERLINK node possesses an IPv4 address, a subnet mask and default gateway. These attributes are referred to as the IP parameters.

- **IPv4 Address**

  The private class C Net ID 192.168.100.0 shall be used for a POWERLINK network – see RFC1918. A class C network provides 254 (1-254) IP addresses, which matches the number of valid POWERLINK Node ID's. The Host ID of the private class C Net ID 192.168.100.0 shall be identical to the POWERLINK Node ID. Hence the last byte of the IP address (Host ID) has the same value as the POWERLINK Node ID. The following figure illustrates the construction of the IP address.

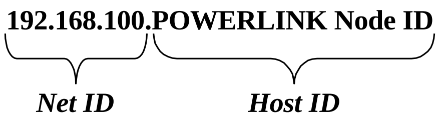


Fig. 38. Construction of the IPv4 address

  Remarks:

  Knowing the Node ID of a POWERLINK node, its IP address and vice versa can be determined easily without any communication overhead.

- **Subnet mask**

  The subnet mask of a POWERLINK node shall be 255.255.255.0. This is the subnet mask of a class C net.

- **Default Gateway**

  The Default Gateway preset shall use the IP address 192.168.100.254. The value may be modified to another valid IP address.

Generally the IPv4 Address and Subnet mask parameters of a POWERLINK node shall be fixed. The downside of the fixed IP parameters are compensated by the POWERLINK Router using Network Address Translation (see 9.1.4.2.2).

The following table summarises the default IP parameters.

IP Parameter	IP address
IP address	192.168.100.<POWERLINK Node ID>
Subnet mask	255.255.255.0
Default Gateway	192.168.100.254 (may be modified)

Tab. 29 IP parameters of a POWERLINK node

5.1.3 Address Resolution

The Address Resolution Protocol (ARP) specified in RFC 826 shall be used to obtain the IP to Ethernet MAC relation of a POWERLINK node. Depending on the POWERLINK node state:

- NMT_CS_EPL_MODE and NMT_MS_EPL_MODE state: ARP shall be performed in the asynchronous phase. To reduce the traffic in the asynchronus phase, the MN may determine the IP to MAC address relation from the ident process.

- NMT_CS_BASIC_ETHERNET state: ARP shall be performed like an IEEE802.3 compliant node does, using CSMA/CD.

Optional the MN or CN may send the NMT Managing command NMTFlushArpEntry (see 7.3.2.1.2) if one of them detects that an upcoming node has a new MAC address. This can be done to flush the ARP cache of all nodes in the POWERLINK network. The POWERLINK node may process NMTFlushArpEntry.

Alternativley an unsolicited ARP request frame (containing its IP address) may be broadcasted initiated by the respective POWERLINK node at startup. As a result, the neighbours ARP caches shall be updated.

5.1.4 Hostname

Each IP capable POWERLINK node shall have a hostname. The hostname is of type VISIBLE_STRING32. The hostname can be used to access POWERLINK nodes with its name instead of its IP address.

The admissible values of type VISIBLE_STRING for the hostname shall be restricted to:

- 30_h - 39_h (0 - 9)
- 41_h - $5A_h$ (A - Z)
- 61_h - $7A_h$ (a - z)
- $2D_h$ (-)

The data are interpreted as ISO 646-1973(E) 7-bit coded characters.

The default hostname shall be constructed from the POWERLINK Node ID and the Vendor ID parted by the character “-“ (<POWERLINK Node ID>-<Vendor ID>). POWERLINK Node ID and the Vendor ID shall be hexadecimally coded.

If no hostname is explicitly assigned, the POWERLINK node shall use the default hostname instead.

The hostname located on the POWERLINK node shall be set with the NMT Managing command NMTNetHostNameSet (refer 7.3.2.1.1). Modification of the hostname value shall not take effect until the POWERLINK node enters the NMT_GS_INITIALISATION state. The hostname is read by the ASnd with the Ident Response Service.

A hostname to IP address resolution service may be provided to gather the hostname to IP address association of all POWERLINK nodes within a POWERLINK network. This service configures for example the DNS table of the DNS server located on the POWERLINK to legacy Ethernet Router or a local hostname table on a diagnostics device.

5.1.5 Object description

5.1.5.1 Object 1E4A$_h$: NWL_IpGroup_REC

The NWL_IpGroup_REC object is a subset of the IP Group RFC1213. The object specifies information about the IP stack.

The Object shall be supported only if IP is supported by the device.

Index	1E4A$_h$	Object Type	RECORD
Name	NWL_IpGroup_REC		
Data Type	NWL_IpGroup_TYPE	Category	Cond

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	2 .. 3	Access	const
Default Value	-	PDO Mapping	No

- **Sub-Index 01$_h$: Forwarding_BOOL**

Sub-Index	01$_h$		
Name	Forwarding_BOOL		
Data Type	BOOLEAN	Category	M
Value Range	FALSE (Not-forwarding) TRUE (forwarding)	Access	ro/rws
Default Value	FALSE (Not-forwarding)	PDO Mapping	No

The indication whether this entity is acting as an IP router in respect to the forwarding of datagrams received by, but not addressed to this entity. IP routers forward datagrams. IP hosts do not (except those source-routed via the host).

The ability to forward datagrams is indicated by D_NWL_Forward_BOOL. On device not supporting forwarding sub-index 01$_h$ shall be FALSE, access shall be ro. On device supporting forwarding sub-index 01$_h$ may be FALSE or TRUE, access shall be rw.

- **Sub-Index 02$_h$: DefaultTTL_U16**

Sub-Index	02$_h$		
Name	DefaultTTL_U16		
Data Type	UNSIGNED16	Category	M
Value Range	UNSIGNED16	Access	rws
Default Value	64	PDO Mapping	No

The default value inserted into the Time-To-Live (TTL) field of the IP header of datagrams originated at this entity, whenever a TTL value is not supplied by the transport layer protocol.

Note: The TTL field in the IP header is of different length. In the IP protocol TTL is an 8-bit field.

- **Sub-Index 03$_h$: ForwardDatagrams_U32**

Sub-Index	03$_h$		
Name	ForwardDatagrams_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	-	PDO Mapping	No

The number of input datagrams for which this entity was not their final IP destination, as a result of which an attempt was made to find a route to forward them to the final destination.

5.1.5.2 Object 1E40h .. 1E49h: NWL_IpAddrTable_*Xh*_REC

The IP address table contains this entity's IP addressing information. The NWL_IpAddrTable_*Xh*_REC object is a subset of the IP Group RFC1213. It assigns IP parameters to an interface indicated by NMT_ItfGroup_*Xh*_REC.ItfIndex_U16. The IP address table shall have 1 to 10 entries that may be configured via SDO.

The Objects shall be supported only if IP is supported by the device.

POWERLINK interfaces shall be described by the low order objects (e.g. 1E40h, 1E41h, …).

Index	1E40h .. 1E49h	Object Type	RECORD
Name	NWL_IpAddrTable_Xh_REC		
Data Type	NWL_IpAddrTable_TYPE	Category	1E40h: Cond 1E41h .. 1E49h: O

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	5	Access	const
Default Value	5	PDO Mapping	No

- **Sub-Index 01h: IfIndex_U16**

Sub-Index	01h		
Name	IfIndex_U16		
Data Type	UNSIGNED16	Category	M
Value Range	1..10	Access	ro
Default Value	-	PDO Mapping	No

The index value which uniquely identifies the interface to which this entry is applicable. The interface identified by a particular value of this index is the same interface as identified by the same value of NMT_InterfaceGroup_*Xh*_REC.InterfaceIndex_U16.

- **Sub-Index 02h: Addr_IPAD**

Sub-Index	02h		
Name	Addr_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	ro/rws
Default Value	-	PDO Mapping	No

The IP address to which this entry's addressing information pertains.

If the object describes an Ethernet POWERLINK interface, access shall be ro. Addr_IPAD shall be 192.168.100.xxx with xxx = NMT_EPLNodeID_REC.NodeId_U8 (cf. 5.1.2).

- **Sub-Index 03h: NetMask_IPAD**

Sub-Index	03h		
Name	NetMask_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	ro/rws
Default Value	-	PDO Mapping	No

The subnet mask associated with the IP address of this entry. The value of the mask is an IP address with all the network bits set to 1 and all the hosts bits set to 0.

If the object describes an Ethernet POWERLINK interface, access shall be ro. NetMask_IPAD shall be 255.255.255.0 (cf. 5.1.2).

- **Sub-Index 04h: ReasmMaxSize_U16**

Sub-Index	04h		
Name	ReasmMaxSize_U16		
Data Type	UNSIGNED16	Category	M
Value Range	UNSIGNED16	Access	ro
Default Value	-	PDO Mapping	No

The size of the largest IP datagram which this entity can re-assemble from incoming IP fragmented datagrams received on this interface.

- **Sub-Index 05h: DefaultGateway_IPAD**

Sub-Index	05h		
Name	DefaultGateway_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	-	PDO Mapping	No

The default gateway associated with the IP address of this entry.
If the object describes an Ethernet POWERLINK interface, the entry shall indicate the router type 1 device. Default value shall be C_ADR_RT1_DEF_NODE_ID .

5.1.5.3 Object 0425h: NWL_IpGroup_TYPE

Index	0425h	Object Type	DEFSTRUCT
Name	NWL_IpGroup_TYPE		
Sub-Index	Component Name	Value	Data Type
00h	NumberOfEntries	03h	
01h	Forwarding_BOOL	0001h	BOOLEAN
02h	DefaultTTL_U16	0006h	UNSIGNED16
03h	ForwardDatagrams_U32	0007h	UNSIGNED32

5.1.5.4 Object 0426h: NWL_IpAddrTable_TYPE

Index	0426h	Object Type	DEFSTRUCT
Name	NWL_IpAddrTable_TYPE		
Sub-Index	Component Name	Value	Data Type
00h	NumberOfEntries	05h	
01h	IfIndex_U16	0006h	UNSIGNED16
02h	Addr_IPAD	0402h	IP_ADDRESS
03h	NetMask_IPAD	0402h	IP_ADDRESS
04h	ReasmMaxSize_U16	0006h	UNSIGNED16
05h	DefaultGateway_IPAD	0402h	IP_ADDRESS

5.2 POWERLINK compliant UDP/IP format

In order to enable the transmission of POWERLINK frames encapsulated in UDP/IP frames, the payload portion of the UDP/IP frame shall be leaded by a slightly modified POWERLINK frame header.

The parameter MessageType defined by Ethernet POWERLINK shall be in conformance to the requirements of 4.6.1.1.1. Destination and Source fields of the original POWERLINK header shall be reserved but shall not be supported, when transmission occurs via UDP/IP.

	Bit Offset								**entry defined by**
Octet Offset [14]	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	
0 - 5	Destination MAC Address								Ethernet type II
6 - 11	Source MAC Address								
12 - 13	EtherType								
14 - 33	IP Header								RFC 791
34 - 41	UDP Header								RFC 768
42	MessageType								Ethernet POWERLINK
43	reserved (Destination)								
44	reserved (Source)								
45	ServiceID / reserved								
46 - n	Payload Data								Application
n+1 - n+4	CRC32								Ethernet type II

n ≥ 59

Tab. 30 POWERLINK compliant UDP/IP frame structure

5.3 POWERLINK Sequence Layer

see 6.3.2.3, 6.3.3.1

[14] Octet Offset refers to the start of the Ethernet frame.

6 Application Layer

6.1 Data Types and Encoding Rules

This paragraph describes the data formats and encoding rules to be used by frames according to the Ethernet POWERLINK syntax (EtherType = $88AB_h$). The rules apply to the POWERLINK-Content, service specific header and data payload embedded into the Ethernet frame. The encoding of the Ethernet frame follows the rules of IEEE 802.3.

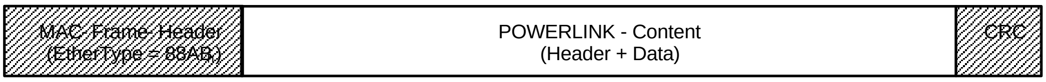


Fig. 39. POWERLINK frame structure

The rules also apply to POWERLINK specific payloads that are embedded into non-POWERLINK frame types (EtherType ≠ $88AB_h$), e.g. SDO-Transfer via UDP/IP etc. The Ethertype specific encoding of these frames, described by RFC 791 (IP) and RFC 768 (UDP), is not the concern of these rules.

Fig. 40. POWERLINK compliant UDP/IP frame structure

The encoding of non-POWERLINK frames (EtherType ≠ $88AB_h$) without POWERLINK specific payload is not the concern of these rules.

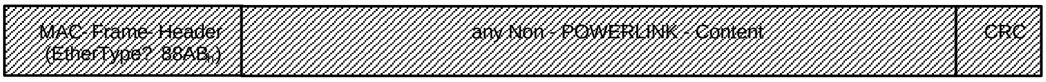


Fig. 41. Legacy Ethernet frame structure

6.1.1 General Description of Data Types and Encoding Rules

In order to exchange meaningful data across a POWERLINK network, the data format and its meaning must be known by the producer and consumer(s). This document specifies data formats and meanings using data types.

The encoding rules define the representation of values of data types and the POWERLINK network transfer syntax for the representations. Values are represented as bit sequences. Bit sequences are transferred in sequences of octets (bytes). For numerical data types the encoding is little endian style as shown in Tab. 31.

Applications often require data types beyond the basic data types. Using the compound data type mechanism the list of available data types can be extended. Some general extended data types are defined as “Visible String” or “Time of Day” (for example see 6.1.6.2 and 6.1.6.4). The compound data types are a means to implement user defined “DEFTYPES” in the terminology of this specification and not “DEFSTRUCTS” (see 6.2.2).

6.1.2 Data Type Definitions

A data type determines a relation between values and encoding for data of that type. Names are assigned to data types in their type definitions. The syntax of data and data type definitions is as follows (see EN 61131-3).

data_definition	::=	type_name data_name
type_definition	::=	constructor type_name
constructor	::=	compound_constructor | basic_constructor

```
compound_constructor   ::=  array_constructor |
                            structure_constructor
array_constructor      ::=  'ARRAY' '[' length ']' 'OF' type_name
structure_constructor  ::=  'STRUCT' 'OF' component_list
component_list         ::=  component { ',' component }
component              ::=  type_name component_name
basic_constructor      ::=  'BOOLEAN' |
                            'VOID' bit_size |
                            'BYTE' bit_size |
                            'INTEGER' bit_size |
                            'UNSIGNED' bit_size |
                            'REAL32' |
                            'REAL64' |
                            'NIL'
bit_size               ::=  '1' | '2' | <...> | '64'
length                 ::=  positive_integer
data_name              ::=  symbolic_name
type_name              ::=  symbolic_name
component_name         ::=  symbolic_name
symbolic_name          ::=  letter { [ '_' ] ( letter | digit ) }
positive_integer       ::=  ( '1' | '2' | <...> | '9' ) { digit }
letter                 ::=  'A' | 'B' | <...> | 'Z' | 'a' | 'b' | <...> | 'z'
digit                  ::=  '0' | '1' | <...> | '9'
```

Recursive definitions are not allowed.

The data type defined by type_definition is termed either basic, when the constructor is basic_constructor, or compound, when the constructor is compound_constructor.

6.1.3 Bit Sequences

6.1.3.1 Definition of Bit Sequences

A bit can take the values 0 or 1.

A bit sequence b is an ordered set of 0 or more bits.

If a bit sequence b contains more than 0 bits, they are denoted as b_j, $j \geq 0$.

Let $b_0, ..., b_{n-1}$ be bits, n a positive integer. Then

$$b = b_0\ b_1\ ...\ b_{n-1}$$

is called a bit sequence of length $|b| = n$.

The empty bit sequence of length 0 is denoted ε.

Examples: 10110100, 1, 101, etc. are bit sequences.

The inversion operator ($\neg$) on bit sequences assigns to a bit sequence

$$b = b_0\ b_1\ ...\ b_{n-1}$$

the bit sequence

$$\neg b = \neg b_0 \neg b_1\ ...\ \neg\ b_{n-1}$$

Here $\neg 0 = 1$ and $\neg 1 = 0$ on bits.

The basic operation on bit sequences is concatenation.

Let $a = a_0\ ...\ a_{m-1}$ and $b = b_0\ ...\ b_{n-1}$ be bit sequences. Then the concatenation of a and b, denoted ab, is

$$a_b = a_0\ ...\ a_{m-1}\ b_0\ ...\ b_{n-1}$$

Example: (10)(111) = 10111 is the concatenation of 10 and 111.

The following holds for arbitrary bit sequences a and b:

$$|ab| = |a| + |b|$$

and

$\varepsilon a = a\varepsilon = a$

6.1.3.2 Transfer Syntax for Bit Sequences

For transmission across a POWERLINK network a bit sequence is reordered into a sequence of octets. Here and in the following hexadecimal notation is used for octets. Let $b = b_0 ... b_{n-1}$ be a bit sequence with $n \le 11920_d$ (1490_d Byte * 8_d Bit/Byte).

Denote k a non-negative integer such that $8(k-1) < n \le 8k$. Then b is transferred in k octets assembled as shown in Tab. 31. The bits b_i, $i \ge n$ of the highest numbered octet shall be ignored.

octet number	1.	2.	k.
	b_7 .. b_0	b_{15} .. b_8	b_{8k-1} .. b_{8k-8}

Tab. 31 Transfer syntax for bit sequences

Octet 1 is transmitted first and octet k is transmitted last. The bit sequence is transferred as follows across the POWERLINK network:

$b_7, b_6, ..., b_0, b_{15}, ..., b_8, ...$

Example:

Bit 9	...	Bit 0
10_b	*0001_b*	*1100_b*
2_h	*1_h*	*C_h*
		$= 21C_h$

The bit sequence $b = b_0 .. b_9 = 0011\ 1000\ 01_b$ represents an UNSIGNED10 with the value $21C_h$ and is transferred in two octets:

First $1C_h$ and then 02_h.

6.1.4 Basic Data Types

For basic data types “type_name” equals the literal string of the associated constructor (cf. symbolic_name), e.g.,

BOOLEAN BOOLEAN

is the type definition for the BOOLEAN data type.

6.1.4.1 NIL

Data of basic data type NIL is represented by ε.

6.1.4.2 Boolean

Data of basic data type BOOLEAN attains the values TRUE or FALSE.

The values are represented as bit sequences of length 1. The value TRUE is represented by the bit sequence 1, and FALSE by 0.

A BOOLEAN shall be transferred over the network as UNSIGNED8 of value 1 (TRUE) resp. 0 (FALSE). Sequent BOOLEANs may be packed to one UNSIGNED8. Sequences of BOOLEAN and BIT type items may be also packed to one UNSIGNED8.

6.1.4.3 Void

Data of basic data type VOIDn is represented as bit sequences of length n bits.

The value of data of type VOIDn is undefined. The bits in the sequence of data of type VOIDn must either be specified explicitly or else marked "do not care".

Data of type VOIDn is useful for reserved fields and for aligning components of compound values on octet boundaries.

6.1.4.4 Bit

Data of basic data type BITn are represented as bit sequences of length n bits.

The interpretation of the value of type BITn data is defined by the context of the variable, that is implemented using BITn data type.

If a BIT value is not member of compound data type, it shall be transferred over the network as UNSIGNED8 of value 1 resp. 0. Sequent BITs may be packed to one UNSIGNED8. Sequences of BOOLEAN and BIT type items may be also packed to one UNSIGNED8.

6.1.4.5 Unsigned Integer

Data of basic data type UNSIGNEDn has values in the non-negative integers. The value range is 0, ..., 2^n-1. The data is represented as bit sequences of length n.

The bit sequence

$b = b_0 \ldots b_{n-1}$

is assigned the value

$UNSIGNEDn(b) = b_{n-1}\ 2^{n-1} + \ldots + b_1\ 2^1 + b_0\ 2^0$

Note that the bit sequence starts on the left with the least significant byte.

Example: The value 266_d = $10A_h$ with data type UNSIGNED16 is transferred in two octets across the bus, first $0A_h$ and then 01_h.

The following UNSIGNEDn data types are transferred as shown below:

octet number	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
UNSIGNED8	$b_7..b_0$							
UNSIGNED16	$b_7..b_0$	$b_{15}..b_8$						
UNSIGNED24	$b_7..b_0$	$b_{15}..b_8$	$b_{23}..b_{16}$					
UNSIGNED32	$b_7..b_0$	$b_{15}..b_8$	$b_{23}..b_{16}$	$b_{31}..b_{24}$				
UNSIGNED40	$b_7..b_0$	$b_{15}..b_8$	$b_{23}..b_{16}$	$b_{31}..b_{24}$	$b_{39}..b_{32}$			
UNSIGNED48	$b_7..b_0$	$b_{15}..b_8$	$b_{23}..b_{16}$	$b_{31}..b_{24}$	$b_{39}..b_{32}$	$b_{47}..b_{40}$		
UNSIGNED56	$b_7..b_0$	$b_{15}..b_8$	$b_{23}..b_{16}$	$b_{31}..b_{24}$	$b_{39}..b_{32}$	$b_{47}..b_{40}$	$b_{55}..b_{48}$	
UNSIGNED64	$b_7..b_0$	$b_{15}..b_8$	$b_{23}..b_{16}$	$b_{31}..b_{24}$	$b_{39}..b_{32}$	$b_{47}..b_{40}$	$b_{55}..b_{48}$	$b_{63}..b_{56}$

Tab. 32 Transfer syntax for data type UNSIGNEDn

The data types UNSIGNED24, UNSIGNED40, UNSIGNED48 and UNSIGNED56 should not be applied by new applications.

UNSIGNEDn data types of length deviating from the values listed by Tab. 32 may be applied by compound data types only.

6.1.4.6 Signed Integer

Data of basic data type INTEGERn has values in the integers. The value range is $-2^{n-1}, \ldots, 2^{n-1}-1$.

The data is represented as bit sequences of length n.

The bit sequence

$b = b_0 .. b_{n-1}$

is assigned the value

$INTEGERn(b) = b_{n-2}\ 2^{n-2} + \ldots + b_1\ 2^1 + b_0\ 2^0$ if $b_{n-1} = 0$

and, performing two's complement arithmetic,

$INTEGERn(b) = -\ INTEGERn(\hat{}b) - 1$ if $b_{n-1} = 1$

Note that the bit sequence starts on the left with the least significant bit.

Example: The value -266_d = $FEF6_h$ with data type INTEGER16 is transfered in two octets across the bus, first $F6_h$ and then FE_h.

The following INTEGERn data types are transfered as shown below:

octet number	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
INTEGER8	$b_7..b_0$							
INTEGER16	$b_7..b_0$	$b_{15}..b_8$						
INTEGER24	$b_7..b_0$	$b_{15}..b_8$	$b_{23}..b_{16}$					
INTEGER32	$b_7..b_0$	$b_{15}..b_8$	$b_{23}..b_{16}$	$b_{31}..b_{24}$				
INTEGER40	$b_7..b_0$	$b_{15}..b_8$	$b_{23}..b_{16}$	$b_{31}..b_{24}$	$b_{39}..b_{32}$			
INTEGER48	$b_7..b_0$	$b_{15}..b_8$	$b_{23}..b_{16}$	$b_{31}..b_{24}$	$b_{39}..b_{32}$	$b_{47}..b_{40}$		
INTEGER56	$b_7..b_0$	$b_{15}..b_8$	$b_{23}..b_{16}$	$b_{31}..b_{24}$	$b_{39}..b_{32}$	$b_{47}..b_{40}$	$b_{55}..b_{48}$	
INTEGER64	$b_7..b_0$	$b_{15}..b_8$	$b_{23}..b_{16}$	$b_{31}..b_{24}$	$b_{39}..b_{32}$	$b_{47}..b_{40}$	$b_{55}..b_{48}$	$b_{63}..b_{56}$

Tab. 33 Transfer syntax for data type INTEGERn

The data types INTEGER24, INTEGER40, INTEGER48 and INTEGER56 should not be applied by new applications.

INTEGERn data types of length deviating from the values listed by Tab. 33 may be applied by compound data types only.

6.1.4.7 Floating-Point Numbers

Data of basic data types REAL32 and REAL64 have values in the real numbers.

The data type REAL32 is represented as bit sequence of length 32. The encoding of values follows the IEEE 754-1985 Standard for single precision floating-point.

The data type REAL64 is represented as bit sequence of length 64. The encoding of values follows the IEEE 754-1985 Standard for double precision floating-point numbers.

A bit sequence of length 32 either has a value (finite non-zero real number, ± 0, ± _) or is NaN (not-a-number). The bit sequence

$b = b_0 \ldots b_{31}$

is assigned the value (finite non-zero number)

$REAL32(b) = (-1)^S \, 2^{E-127} \, (1+ F)$

Here

$S = b_{31}$ is the sign.

$E = b_{30}\, 2^7 + \ldots + b_{23}\, 2^0$, $0 < E < 255$, is the un-biased exponent.

$F = 2^{-23} \; (b_{22}\, 2^{22} + \ldots + b_1\, 2^1 + b_0\, 2^0)$ is the fractional part of the number.

E = 0 is used to represent ± 0. E = 255 is used to represent infinities and NaN's.

Note that the bit sequence starts on the left with the least significant bit.

Example:

6.25 = 2 E-127 (1 + F) with
E =129 =27 +20 and
F = 2-1 +2-4 = 2 -23(222+219) hence the number is represented as:

S	*E*	*F*
b_{31}	$b_{30} .. b_{23}$	$b_{22} .. b_0$
0	*100 0000 1*	*100 1000 0000 0000 0000 0000*

6.25 = $b_0 .. b_{31}$ *= 0000 0000 0000 0000 0001 0011 0000 0010*

It is transferred in the following order:

octet number	**0**	**1**	**2**	**3**
REAL32	00_h	00_h	$C8_h$	40_h
	$b_7..b_0$	$b_{15}..b_8$	$b_{23}..b_{16}$	$b_{31}..b_{24}$

Tab. 34 Transfer syntax of data type REAL32

6.1.4.8 MAC Address

The data type MAC_ADDRESS is used to describe the MAC address of an Ethernet adapter. It is represented by 6 octets. It may be interpreted as UNSIGNED48.

The MAC address is divided into two sub-items:

- Organisational Unique Identifier (OUI), describing the adapter's manufacturer
- adapter specific unique identifier

Octet	**5**	**4**	**3**	**2**	**1**	**0**
	OUI			adapter's individual identifier		
Example	00_h	$0A_h$	86_h	xx_h	xx_h	xx_h

Tab. 35 MAC address encoding, *example 00-0A-86-xx-xx-xx shows a Lenze device*

6.1.4.9 IP address

The data type IP_ADDRESS is used to describe the IP address of a network adapter, subnet masks etc. It is represented by 4 octets. It may be interpreted as UNSIGNED32.

The IP address is divided to a Net Id part and a Host ID part. Tab. 36 shows the the coding of Net and Host ID. The bit consumption of these parts depends on the type of the subnet and is therefore not fixed.

Octet	**3**	**2**	**1**	**0**
	NetID	⟶	⟵	HostID
Example	$C0_h$	$A8_h$	64_h	$F0_h$
	192	*168*	*100*	*240*

Tab. 36 IP address encoding, *example shows the IP address of a POWERLINK MN 192.168.100.240*

6.1.5 Compound Data Types

Type definitions of compound data types expand to a unique list of type definitions involving only basic data types. Correspondingly, data of compound type ´type_name´ are ordered lists of component data named ´component_name_i´ of basic type ´basic_type_i´.

Compound data types constructors are ARRAY and STRUCT OF.

STRUCT OF

basic_type_1 component_name_1,
basic_type_2 component_name_2,
… …
basic_type_N component_name_N

type_name

ARRAY [length] OF basic_type type_name

The bit sequence representing data of compound type is obtained by concatenating the bit sequences representing the component data.

Assume that the components ´component_name_i´ are represented by their bit sequences

b(i), for i = 1,…,N.

Then the compound data is represented by the concatenated sequence.

$b_0(1)$ .. $b_{n-1}(1)$ .. $b_{n-1}(N)$.

Example: Consider the data type

STRUCT OF

INTEGER10 x,
UNSIGNED5 u

NewData

Assume $x = -423_d = 259_h$ *and* $u = 30_d = 1E_h$*. Let b(x) and b(u) denote the bit sequences representing the values of x and u, respectively. Then:*

b(x)	$= b_0(x) .. b_9(x)$	*= 1001101001*
b(u)	$= b_0(u) .. b_4(u)$	*= 01111*
b(xu) = b(x) b(u)	$= b_0(xu) .. b_{14}(xu)$	*= 1001101001 01111*

The value of the structure is transferred with two octets, first 59h and then 7Ah.

6.1.6 Extended Data Types

The extended data types consist of the basic data types and the compound data types defined in the following subsections.

6.1.6.1 Octet String

The data type OCTET_STRING*length* is defined below; *length* is the maximum length of the octet string.

ARRAY [*length*] OF UNSIGNED8 OCTET_STRING*length*

If the actual length of the string is shorter than *length* the rest shall be filled up with 0_h.

6.1.6.2 Visible String

The data type VISIBLE_STRING*length* is defined below. The data type is VISIBLE_STRING whether a length is defined in the data type name or not. A VISIBLE_STRING with a length definition defines the maximum length allowed. Otherwise any length is allowed.

The admissible values of data of type VISIBLE_CHAR are 0_h and the range from 20_h to $7E_h$. The data are interpreted as ISO 646-1973(E) 7-bit coded characters.

UNSIGNED8 VISIBLE_CHAR

ARRAY [*length*] OF VISIBLE_CHAR VISIBLE_STRING*length*

There is no 0_h necessary to terminate the string. However, if the actual length of the string is shorter than *length* the rest shall be filled up with 0_h.

6.1.6.3 Unicode String

The data type UNICODE_STRING*length* is defined below; *length* is the maximum length of the unicode string.

ARRAY [*length*] OF UNSIGNED16 UNICODE_STRING*length*

If the actual length of the string is shorter than *length* the rest shall be filled up with 0_h.

6.1.6.4 Time of Day

The data type TIME_OF_DAY represents absolute time. It follows from the definition and the encoding rules that TIME_OF_DAY is represented as bit sequence of length 48.

Component ms is the time in milliseconds after midnight. Component days is the number of days since January 1, 1984.

```
STRUCT OF
    UNSIGNED28      ms,
    VOID4           reserved,
    UNSIGNED16      days
TIME_OF_DAY
```

6.1.6.5 Time Difference

The data type TIME_DIFFERENCE represents a time difference. It follows from the definition and the encoding rules that TIME_DIFFERENCE is represented as bit sequence of length 48.

Time differences are sums of numbers of days and milliseconds. Component ms is the number milliseconds. Component days is the number of days.

```
STRUCT OF
    UNSIGNED28      ms,
    VOID4           reserved,
    UNSIGNED16      days
TIME_DIFFERENCE
```

6.1.6.6 Domain

Domains can be used to transfer an arbitrarily large block of data from a client to a server.

6.1.6.7 Net Time

The data type NETTIME represents a high precision time value. The NETTIME data type is identical to an improved version of the TimeRepresentation type of IEEE 1588.

NETTIME is composed as follows:

STRUCT OF
UNSIGNED32 seconds
UNSIGNED32 nanoseconds
NETTIME

The nanoseconds member is defined such that the most significant bit represents the sign bit, 1 indicating a negative number, and the least significant 31 bits represent the nanoseconds portion of the time being represented. TimeRepresentation thus defines a sign magnitude representation for time stamps and time intervals.

The range of the absolute value of the least significant 31 bits of the nanoseconds portion of the representation shall be restricted to:

0 <= | least significant 31 bits of nanoseconds | < 10^9

The sign of the nanoseconds member shall be interpreted as the sign of the entire representation. For example:

- +2.0 seconds is represented by seconds = 00000002_h and nanoseconds = 00000000_h
- -2.0 seconds is represented by seconds = 00000002_h and nanoseconds = 80000000_h
- +2.000000001 seconds is represented by seconds = 00000002_h and nanoseconds = 00000001_h
- -2.000000001 seconds is represented by seconds = 00000002_h and nanoseconds = 80000001_h

Timestamps shall be relative to 01-01-1970 00:00 h. A negative timestamp shall indicate time prior to this point of time. Timestamps using NETTIME will overflow in January 2106.

NETTIME shall be used for timestamps and time increments.

6.2 Object Dictionary

This section details the Object Dictionary structure and entries which are common to all devices.

The overall layout of the Object Dictionary is shown in 2.2.2.

6.2.1 Object Dictionary Entry Definition

An Object Dictionary entry shall be defined by the following items:

- **Index**

  Index denotes the objects position within the Object Dictionary. This acts as a kind of address to reference the desired data field. Index shall be declared as hexadecimal value.

  Index shall be used to indicate the accessed object of “by index”-type SDO commands.

  Object may be subdivided to sub-indices. The sub-index is used to reference data fields within a complex object such as an array or record. The sub-index is not specified here.

- **Object Type**

  Object Type contains an entry according to Tab. 37. It is used to denote what kind of object is at that particular index within the Object Dictionary. The following definitions are used:

Object Type	Comments	Code
NULL	A dictionary entry with no data fields	0
DEFTYPE	Denotes a static data type definition such as a Boolean, UNSIGNED16, float and so on	5
DEFSTRUCT	Defines a record type	6
VAR	A single value such as an UNSIGNED8, Boolean, float, Integer16, visible string etc.	7
ARRAY	A multiple data field object where each data field is a simple variable of the same basic or extended data type e.g. array of UNSIGNED16 etc. Sub-index 0 is of UNSIGNED8 and therefore not part of the ARRAY data	8
RECORD	A multiple data field object where the data fields may be any combination of simple variables. Sub-index 0 is of UNSIGNED8 and therefore not part of the RECORD data	9

Tab. 37 Object type definitions

- **Name**

  Name provides a simple textual description of the function of that particular object.

  Name shall be in accordance to IEC 61131-3. It consists of:

  domain prefix, indicating the association of the object to a functional domain, 3 uppercase characters followed by underline

  name (verbally). composed of words, each word shall be leaded by an uppercase character followed by lowercase characters or digits, no underlines or spaces

  data type postfix, indicating the data type of the object (underline followed by up to 5 uppercase characters or digits)

  Total length of name shall be equal or below 32 characters.

  Name shall be used to indicate the accessed object of “by name”-type SDO commands.

- **Data Type**

  The entry provides information about the data type of the object. These include the following pre-defined static data types: Boolean, floating point number, unsigned integer, signed integer, visible/octet string, time-of-day, time-difference and DOMAIN (see 6.1). It also includes the pre-defined complex data types and may also include types which are either manufacturer or device specific.

  It is not allowed to define records of records, arrays of records or records with arrays as fields of that record. In the case where an object is an array or a record the sub-index is used to reference one static data type data field within the object.

- **Category**

  Category defines whether the object is Mandatory (M) or Optional (O). A mandatory object shall be implemented on a device. An optional object needs not to be implemented on a device. The support of certain objects or features however may require the implementation of related objects. In this case, the relations are described in the detailed object specification.

  Category may be Conditional (Cond) if the M/O category of an object depends on the implementation of another object.

  Category may be Not-Relevant (“-“) if the object is of no meaning for MN resp. CN.

The following entries shall be indicated for static data types only. In case of complex data types the respective entries shall be provided for each sub-index individually.

- **Access**

  The entry defines the access rights for a particular object. The view point is from the bus into the device. It can be one of the following:

rw	read and write access, value shall not be stored on writing dedicated sub-indices of NMT_StoreParam_REC
rws	read and write access, value shall be stored on writing dedicated sub-indices of NMT_StoreParam_REC
wo	write only access, value shall not be stored on writing dedicated sub-indices of NMT_StoreParam_REC
wos	write only access, value shall be stored on writing dedicated sub-indices of NMT_StoreParam_REC
ro	read only access
const	read only access, value is constant
cond	variable access controlled by the device further information about access is provided by the object description

Tab. 38 Access attributes for data objects

Optional objects listed in the Object Dictionary with the Attribute rw may be implemented as read only. Exceptions are defined in the detailed object specification.

Access type entries may be supplemented by additional information, e.g. reflecting data validity restrictions.

- **Value Range**

  The entry indicates the value range of the respective object. It may consist of one or more distinct values or ranges of values. If the item shows a data type identifier, the complete value range of the mentioned data type shall be allowed.

  "-" means that this specification does not predefine a value range. In this case the value range of the device profile resp. device description shall apply.

  Default value ranges in the device description file shall be equal to predefined default value ranges in this specification.

- **Default Value**

  The entry indicates the initialisation value that shall be assigned by the communication profile implementation.

  "-" means that this specification does not predefine a default value. In this case the default value of the device profile resp. device description shall apply.

  Default values in the device description file shall be equal to predefined default values in this specification.

- **PDO Mapping**

  The entry indicates whether an entry may be mapped to a PDO message. It can be one of the following:

Opt	Object shall be mappable into a PDO
Def	Object is part of the default mapping (see device profile)
No	Object shall not be mappable into a PDO

Tab. 39 PDO mapping attributes for data objects

A complete static data type object definition (Object Type = VAR) example is displayed below:

Index	1234_h	Object Type	VAR
Name	SDO_VarDummyParameter_S16		
Data Type	INTEGER16	Category	M
Value Range	-15 000 .. 10 000	Access	rw
Default Value	0	PDO Mapping	Opt

Tab. 40 Static data type object definition example

Complex data type object definitions (Object Type = ARRAY or RECORD) are of reduced form, because Access, Value Range, Default Value, and PDO mapping must be defined individually for the the sub-indices

Index	2345_h	Object Type	ARRAY
Name	SDO_ArrayDummyParameter_AU16		
Data Type	UNSIGNED16	Category	M

Tab. 41 Complex data type object definition example

- **Category**

  refers to the complex data type object as a whole, but not to the particular sub-index. A mandatory object may be composed of mandatory and optional sub-indices. This means that the object must be supported but some of its' sub-indices are optional. It's also allowed, to define optional object with mandatory sub-indices. This means that these sub-indices must be supported, if the object is implemented.

- **Data Type**

  shall contain a static data type in case of ARRAY type objects and a complex data type in case of RECORD type objects.

The definition of data type describing objects (Object Type = DEFTYPE or DEFSTRUCT) is shown by 6.2.2.

6.2.1.1 Sub-Index Definition

Complex object types (ARRAY, RECORD) objects are composed of up to 256 data items. Each data item may be addressed by an UNSIGNED8 type sub-index.

Sub-Indices are used in the following way:

- **Sub-Index 00_h NumberOfEntries**

  NumberOfEntries describes the highest available sub-index that follows, not considering FFh. This entry is encoded as UNSIGNED8, regardless the type of the object. If the object exists, NumberOfEntries is mandatory. Data Type and Category are not denoted at NumberOfEntries descriptions.

  NumberOfEntries is described by this specification as displayed below:

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	1..15	Access	rw
Default Value	15	PDO Mapping	No

Tab. 42 NumberOfEntries sub-index description example

In case of ARRAYs, NumberOfEntries may be modified (Access = rw) to show the umber of occupied items in a list. In case of RECORDs, NumberOfEntries shall be hold constant (Access = ro or Const).

NumberOfEntries may mapped to PDO to indicate the number of occupied items.

- **Sub-Index 01_h - FE_h Object Specific Data**

  Sub-Indices between 01_h and FE_h hold the object's payload data. The highest accessible index is given by NumberOfEntries.

  Sub-Indices of RECORD type objects are defined as follows:

Sub-Index	01_h		
Name	RecItem1_U8		
Data Type	UNSIGNED8	Category	M
Value Range	1..255	Access	rw
Default Value	1	PDO Mapping	Def

Tab. 43 Record type object sub-index description example

- Name is composed of a describing text followed by a data type postfix. Refer the object name rules for further information, the domain prefix is omitted.

  If a name entry is defined by a data type definition, the sub-index name shall be equal to it.

  The sub-index name shall be used in combination to the object name to access the sub-index via “by name” SDO commands. According to IEC 61131-3 object and sub-index name shall be separated by a dot:

  SDO_RecordExamle_REC.RecItem1_U8.

- Category refers to respective sub-index only. Mandatory (M) means that the sub-index must be implemented when the object ist implemented. A mandatory sub-index does not force the hosting object to be mandatory.

Sub-Indices of ARRAY type objects are defined as follows:

Sub-Index	01_h		
Name	ArraySubindex1		
--	--	Category	M
Value Range	UNSIGNED16	Access	rw
Default Value	0	PDO Mapping	Opt

Tab. 44 Array type object sub-index description example

Name consists of a describing text. Refer the object name rules for further information, the domain prefix and data type postfix are omitted. If a name entry is defined by a data type definition, the sub-index name shall be equal to it.

- The sub-index name is for informational purpose only. Sub-index access via “by name” SDO commands shall occur according to IEC 61131-3 via numerical index:

  SDO_ArrayExamle_AU16[1]

- Category refers to respective sub-index only. Mandatory (M) means that the sub-index must be implemented when the object ist implemented. A mandatory sub-index does not force the hosting object to be mandatory.
- Despite of the functional equivalence of all sub-indices of an array, there may be defined more than one sub-index entry to a particular object to show differences of the Category, Access and / or PDO Mappings options of the sub-indices.

- **Sub-Index FF_h StructureOfObject**

Sub-index FF_h describes the structure of the entry by providing the data type and the object type of the entry. Regardless the type of the object, it is encoded as UNSIGNED32 and organised as follows:

	MSB			**LSB**
Bit-No.	31 - 24	23 - 16	15 - 8	7 - 0
Value	00h	Data Type (refer 6.2.2) (High Byte□)	(Low Byte□)	Object Type (refer Tab. 37)□

Tab. 45 Structure of sub-index FF_h

It is optional to support sub-index FF_h. If it is supported throughout the Object Dictionary and the structure of the complex data types is provided as well, it enables to upload the entire structure of the Object Dictionary. If StructureOfEntry is not supported, sub-index FF_h shall be reserved.

StructureOfObject is not shown by object definitions of this specification.

6.2.2 Data Type Entry Specification

The static data types are placed in the Object Dictionary for definition purposes only. However, indices in the range 0001h - 0007h may be mapped in order to define the appropriate space of the RPDO (Dummy Mapping) as not being used by the device (do not care). The indices 0009h - 000Bh, 000Fh may not be mapped to a PDO.

See App. 1.1, index range 0001_h to $04FF_h$ for data type specifiing object dictionary entries.

6.2.2.1 Static Data Types

The static data type (Object Type = DEFTYPE) representations used are detailed in 6.1.

A device may optionally provide the length of the static data types encoded as UNSIGNED32 at read access to the index that refers to the data type. E.g. index $000C_h$ (Time of Day) contains the value 30_h=48_d as the data type „Time of Day“ is encoded using a bit sequence of 48 bit. If the length is variable (e.g. $000F_h$ = Domain), the entry contains 0_h.

6.2.2.2 Complex Data Types

The predefined complex data types’ (Object Type = DEFSTRUCT) representations are provided by the respective paragraph or by the device profile.

For the supported complex data types a device may optionally provide the structure of that data type at read access to the corresponding data type index. Sub-index 0 then provides the number of entries at this index not counting sub-indices 0 and 255 and the following sub-indices contain the data type according to App. 3.5 encoded as UNSIGNED16.

As an example the entry at Index 0023h describing the structure of the Identity object NMT_IdentityObject_REC looks as follows:

Index	0023_h	Object Type	DEFSTRUCT
Name	IDENTITY		
Sub-Index	Component Name	Value	Data Type
00_h	NumberOfEntries	04_h	
01_h	VendorId_U32	0007_h	UNSIGNED32
02_h	ProductCode_U32	0007_h	UNSIGNED32
03_h	RevisionNo_U32	0007_h	UNSIGNED32
04_h	SerialNo_U32	0007_h	UNSIGNED32

Tab. 46 Complex data type description example

Standard (simple) and complex manufacturer specific data types can be distinguished by attempting to read sub-index 1h: At a complex data type the device returns a value and sub-index 0h contains the number of sub-indices that follow, at a standard data type the device aborts the SDO transfer as no sub-index 1h available.

Note that some entries of data type UNSIGNED32 may have the character of a structure (e.g. NMT_DeviceType_U32, see 7.2.1.1.1).

6.2.2.3 Extension for Multiple Device Modules

For devices or device profiles that provide Multiple Device Modules like multiple axis controllers e.g. the DEFTYPE / DEFSTRUCT mechanism is enhanced for each virtual device with an offset of 40_h for up to 7 additional virtual devices.

6.3 Service Data (SDO)

To access the entries of the object dictionary of a device via Ethernet POWERLINK a set of command services is specified.

SDO communication attends to the client / server model (see 2.3.2). Support of SDO client functions shall be indicated by D_SDO_Client_BOOL, support of SDO server functions by D_SDO_Server_BOOL.

6.3.1 SDO Layer Model

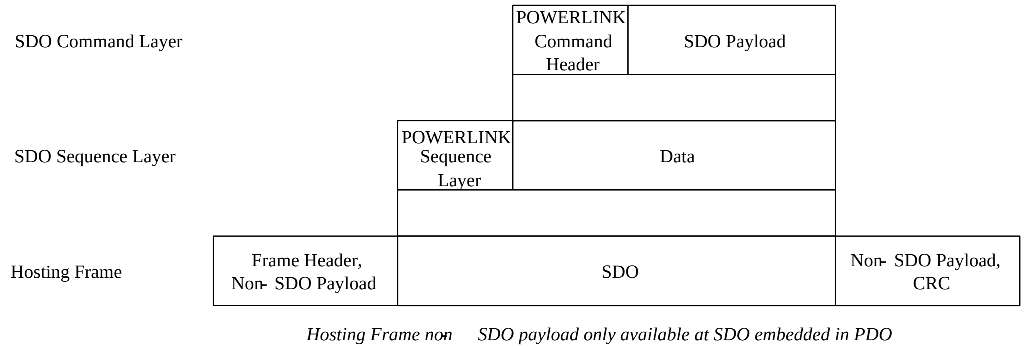


Fig. 42. SDO layer model

Two sublayers are distinguished in the POWERLINK Protocol:

- POWERLINK Sequence Layer (6.3.2.3, 6.3.3.1)
  The Sequence Layer is responsible for sorting the segments of a segmented transfer command so that a correct byte stream is offered to the POWERLINK Command Layer.
- POWERLINK Command Layer (6.3.2.4, 6.3.3.2)
  The Command Layer defines commands to access the parameters of the object dictionary. This layer distinguishes between an expedited and a segmented transfer.

6.3.1.1 SDO Hosting in Frames

Ethernet POWERLINK provides three SDO transfer methods:

1. SDO transfer via UDP/IP frames in asynchronous phase
2. SDO transfer via POWERLINK ASnd frames in asynchronous phase
3. SDO embedded in PDO in isochronous phase

The methods 1 (6.3.2.1) and 2 (6.3.2.2) share a common Sequence (6.3.2.3) and Command Layer (6.3.2.4).

At method 3 (6.3.3), SDO data are packed to a compact container to be inserted to the PDO data. Sequence and Command Layer are adapted to the compact layout of the container.

On an MN, support of methods 1 and 2 shall be mandatory.

Support of method 1 shall be indicated at the object dictionary by NMT_FeatureFlags_U32 Bit 1 and and in the device description by D_SDO_SupportUdpIp_BOOL. Support of method 2 shall be indicated by NMT_FeatureFlags_U32 Bit 2 and D_SDO_SupportASnd_BOOL.

Support of method 3 is optional at MN and CN. Support of method 3 shall be indicated at the object dictionary by NMT_FeatureFlags_U32 Bit 3 and in the device description by D_SDO_SupportPDO_BOOL.

Remark: The NMT_FeatureFlags_U32 are reported to the MN by IdentResponse.

6.3.2 SDO in Asynchronous Phase

6.3.2.1 SDO via UDP/IP

The parameter transfer is based on a UDP/IP frame, allowing data transfer via a standard IP-router. Because UDP does not support a reliable connection oriented data transfer, this task must be supported by the sequence and command services.

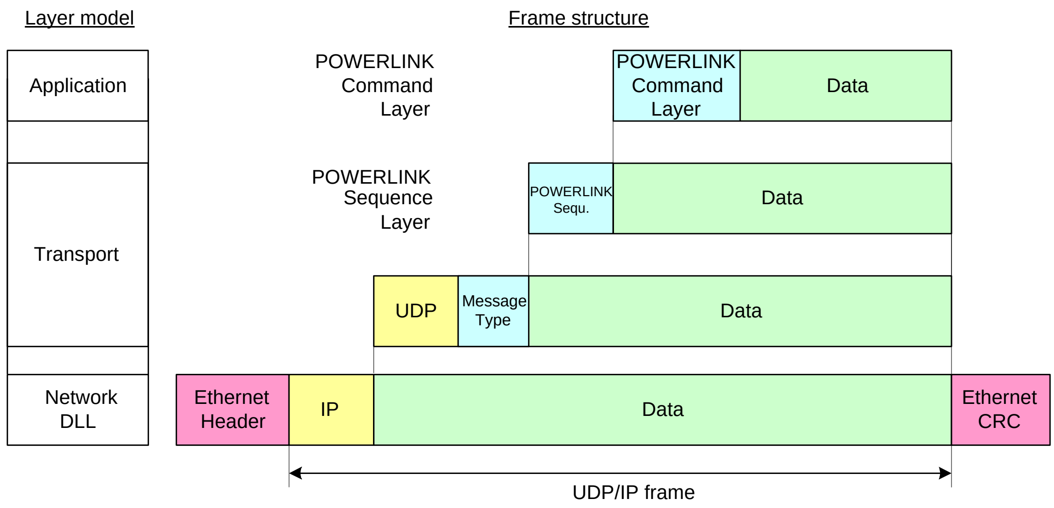


Fig. 43. POWERLINK SDO embedded in UDP/IP frame

SDO via UDP/IP uses the Asynchronous Sequence Layer (6.3.2.1) and the Asynchronous Command Layer (6.3.2.2).

For applications that do not require short cycle times and low jitter, POWERLINK telegrams may be inserted in a UDP/IP datagram, in effect running POWERLINK over UDP/IP. For this reason the message type (defined in the Data Link Layer) is inserted in front of the Sequence Layer.

	Bit Offset							
Octet Offset	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	MessageType = ASnd							
1 .. 2	reserved							
3	ServiceID = SDO							
4 .. 7	Sequence Layer Protocol							
8 .. k-1	Command Layer Protocol							
k .. 1471	SDO Payload Data							

Tab. 47 SDO via UDP/IP

Field	**Abbr.**	**Description**	**Value**
MessageType	mtyp	POWERLINK Message type (App. 3.1)	ASnd
reserved	res	These fields are reserved They are used for POWERLINK Destination and Source Address when sending SDO without UDP/IP	Zero, when embedded in UDP/IP Frame else mt specific
ServiceID	sid	ASnd ServiceID (App. 3.3)	SDO
Sequence Layer Protocol		POWERLINK Sequence Layer (6.3.2.1)	
Command Layer Protocol		POWERLINK Command Layer (6.3.2.2)	

Tab. 48 SDO via UDP/IP field interpretation

6.3.2.1.1 UDP Layer

The UDP Header contains:

Field	Size	Description	Used in POWERLINK
Source Port	2 Byte	Port Number of the sending process	Logical channel[15]
Destination Port	2 Byte	Port Number of the receiving process	
Length	2 Byte	Data length of the whole UDP frame incl. header	not used
Checksum	2 Byte	optional Checksum	not used

Tab. 49 UDP header

Parameters are transferred in a communication channel characterized by the IP addresses (source and destination) and UDP Ports (source and destination). This communication channel is known as a *datagram socket*. It establishes a peer-to-peer communication channel between two devices. A device may support more than one channel. One supported server channel is the default case (Default Channel). The default channel uses the UDP port C_SDO_EPL_PORT.

The maximum number of supported channels shall be indicated by D_SDO_MaxConnections_U32.

There may be multiple channels established between one client and one server. The maximum number of such parallel channels shall be indicated by D_SDO_MaxParallelConnections_U32.

The client starts the transfer using the standard destination port C_SDO_EPL_PORT and a client dependent source port (> 1024). The server responds to the request with the source port C_SDO_EPL_PORT and the destination port defined by the client. Therefore up to (2^{16}–1024) logical channels (sockets) can be opened between a client and a server. Each device is responsible for handling its logical channels.

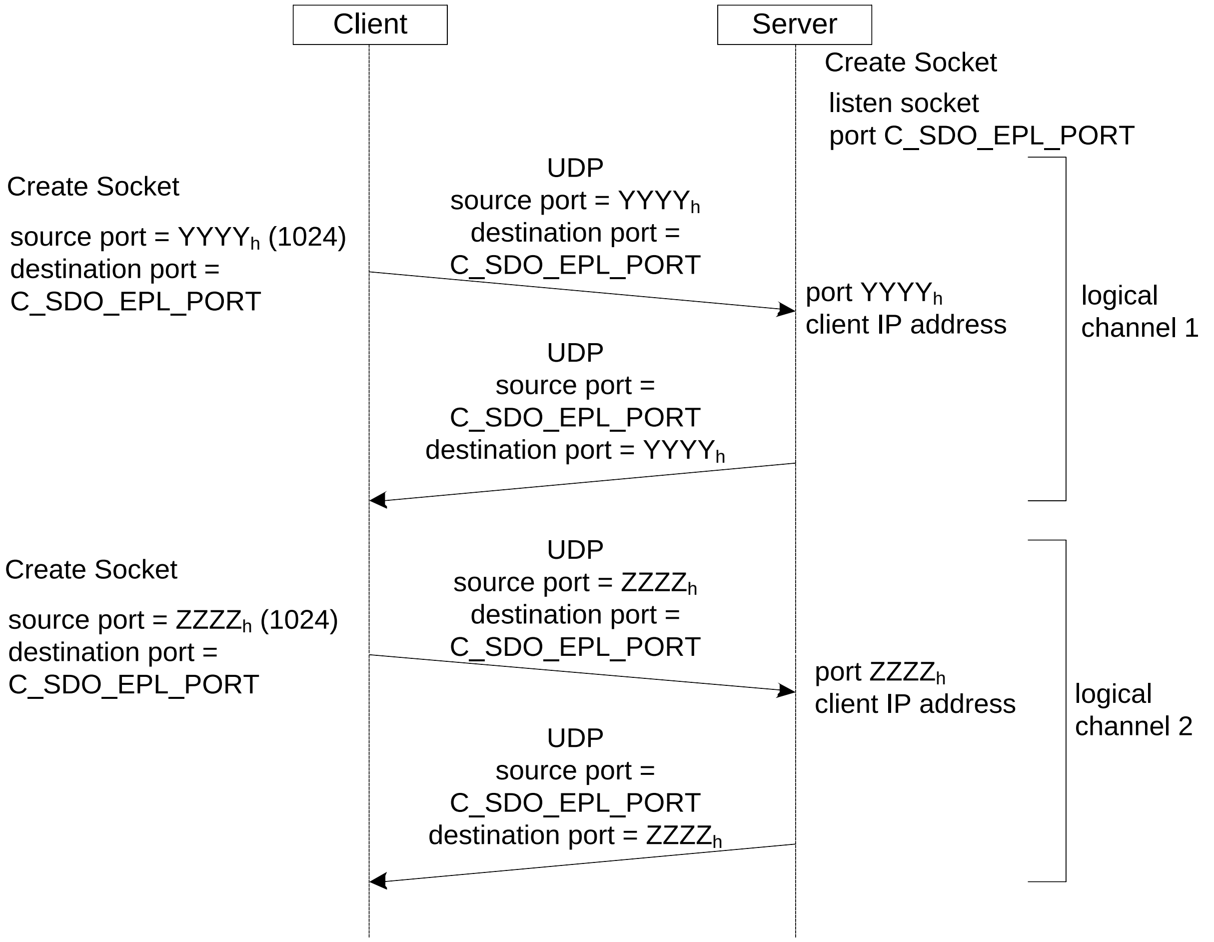


Fig. 44. UDP socket

[15] in combination with the client and server IP address.

6.3.2.2 SDO via POWERLINK ASnd

SDO via POWERLINK ASnd applies POWERLINK frames for SDO communication.

Since POWERLINK frames are not forwarded by a POWERLINK Router Type 1 (s. 9.1), it is not possible to access nodes exclusively providing SDO via POWERLINK ASnd from outside of the POWERLINK segment.

SDO transfer by POWERLINK ASnd frames is well suited for devices providing reduced ressources, because it does not require an IP stack.

	Bit Offset							
Octet Offset	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	MessageType = ASnd							
1	Destination							
2	Source							
3	ServiceID = SDO							
4 .. 7	Sequence Layer Protocol							
8 .. k-1	Command Layer Protocol							
k .. 1471	SDO Payload Data							

Tab. 50 SDO via POWERLINK ASnd

Field	Abbr.	Description	Value
MessageType	mtyp	POWERLINK Message type (App. 3.1)	ASnd
Destination	dest	POWERLINK Node ID of the addressed node(s)	
Source	src	POWERLINK Node ID of the transmitting node	
ServiceID	sid	ASnd ServiceID (App. 3.3)	SDO
Sequence Layer Protocol		POWERLINK Sequence Layer (6.3.2.3)	
Command Layer Protocol		POWERLINK Command Layer (6.3.2.4)	

Tab. 51 SDO via ASnd field interpretation

SDO via POWERLINK ASnd applies the Asynchronous Sequence Layer (6.3.2.3) and the Asynchronous Command Layer (6.3.2.4).

6.3.2.3 Asynchronous SDO Sequence Layer

The POWERLINK Sequence Layer provides the service of a reliable bidirectional connection that guarantees that no messages are lost or duplicated and that all messages arrive in the correct order.

Fragmentation is handled by the SDO Command Layer (6.3.2.4).

The POWERLINK Sequence Layer Header for asynchronous transfer shall consist of 2 bytes.

There shall be a sequence number for each sent frame, and an acknowledgement for the sequence number of the opposite node, as well a connection state and a connection acknowledge.

	Bit Offset							
Octet Offset	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	ReceiveSequenceNumber						ReceiveCon	
1	SendSequenceNumber						SendCon	
2 .. 3	reserved							

Tab. 52 POWERLINK sequence layer in asynchronous data frame

Remark:
Using bits 0 and 1 for connection instead of bits 6 and 7 eases the handling of sequence number. The sequence number easily can be increased by one by increasing the whole byte by four. This increment has no influence to ReceiveCon and SendCon.

Field	Abbr.	Description	Value
ReceiveSequenceNumber	rsnr	Sequence number of the last correctly received frame	0 ... 63
ReceiveCon	rcon	Acknowledge of connection code to the opposite node	0: No connection 1: Initialisation 2: Connection valid 3: Error Response (retransmission request)
SendSequenceNumber	ssnr	Own sequence number of the frame, shall be increased by 1 with every new frame	0 ... 63
SendCon	scon	Own connection code	0: No connection 1: Initialisation 2: Connection valid 3: Connection valid with acknowledge request

Tab. 53 Fields of POWERLINK sequence layer in asynchronous data frame

6.3.2.3.1 Connection

6.3.2.3.1.1 Initialisation of Connection

The client shall request initialisation by setting scon to 1. This shall be responded by the server with the same connection code and the same sequence number.

If the server had already a connection to the client the existing connection shall be shut down, i.e. closed internally without sending an explicit close request before opening the new one.

Additionally the sequence number shall be initialised at the server.

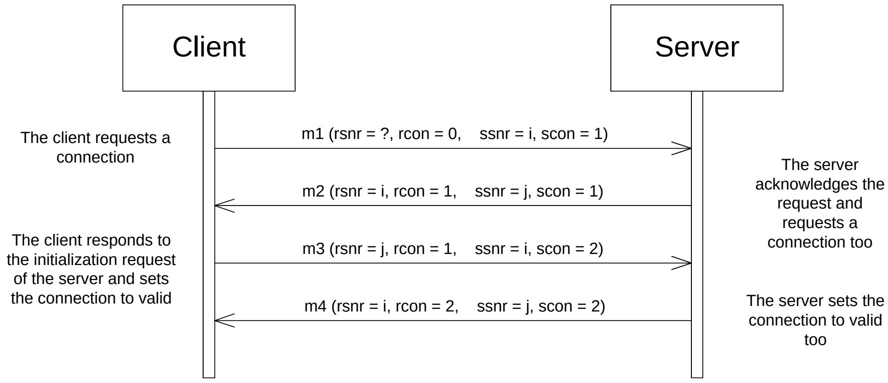


Fig. 45. Initialisation of a asynchronous connection

After this the bidirectional connection is established.

The sequence numbers shall not be incremented until the bidirectional connection initialisation has been completed. It shall be increased by 1 for the first SDO command after the initialisation. No command shall be sent while initialising the bidirectional connection.

6.3.2.3.1.2 Closing a connection

A connection should be shut down, when it is no longer needed.

A node, i.e. client or server, may shut down a connection, if it needs the resources for other reasons.

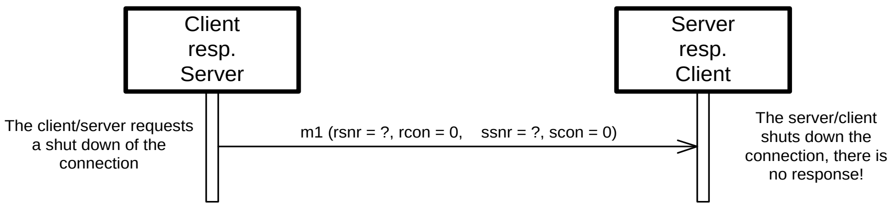


Fig. 46. Closing of asynchronous connection

Closing a connection shall be indicated by rcon = 0 and scon = 0.

There shall be no acknowledge for closing a connection.

6.3.2.3.1.3 Data Transfer

When the connection is established each node is allowed to send frames.

Each node shall keep the sent data in a history buffer until it is acknowledged. Size of the history buffer is indicated by D_SDO_SeqLayerTxHistorySize_U16. If all history buffer slots are occupied by unacknowledged frames, no additional frame may be sent (see 6.3.2.3.1.5).

Each sent frame shall contain the acknowledgement of the last correctly received frame from the opposite side.

When the sender sends an acknowledge request, the receiver shall send an acknowledge.

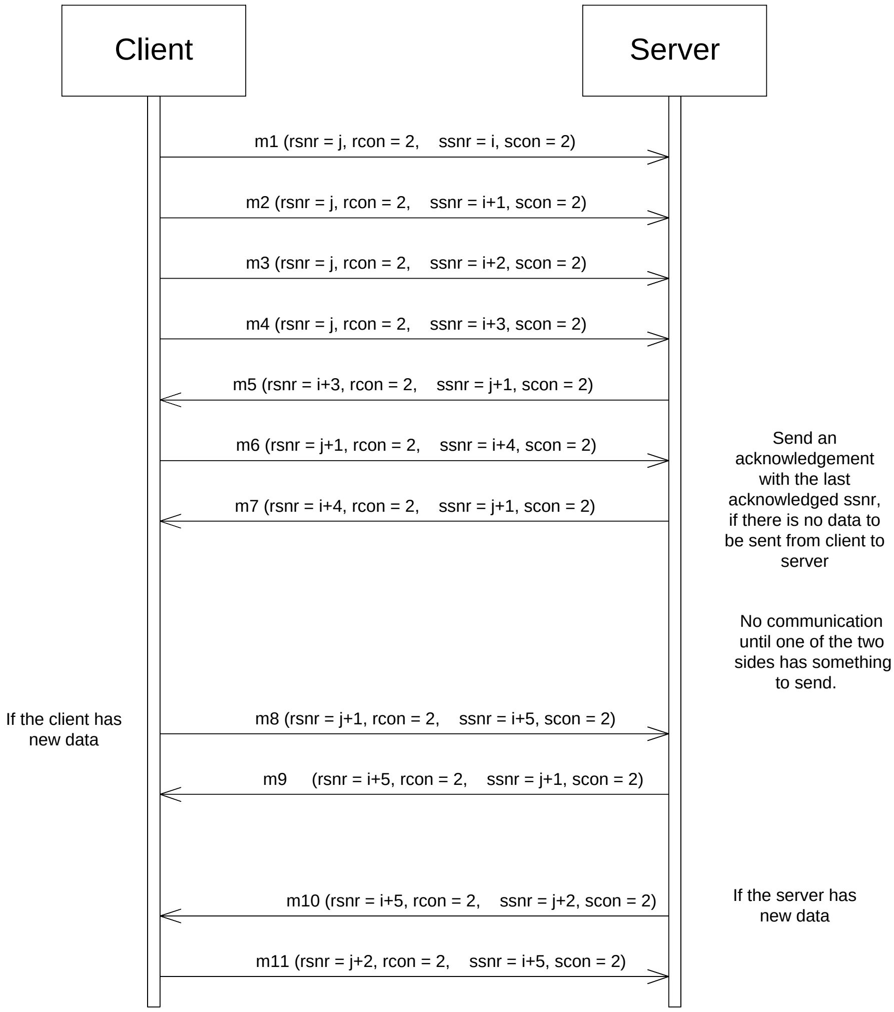


Fig. 47. Normal asynchronous communication

If the receiver has no new data to transmit it shall send an acknowledge frame to the sender, that contains the last sent ssnr. If that ssnr was already acknowledged, the data may be omitted, because the other side will drop the data (as repeated) anyway.

Because of the sliding window protocol only half of the sequence number range may be used. So the maximum possible History Buffer size is 31. Otherwise it is not possible to distinguish between old duplicated frames and new frames.

On the receiving node no buffering of the received frames is required. This may cause flooding of the receiving node with commands (cf. 6.3.2.3.2.6).

6.3.2.3.1.4 Data Transfer with Delay

Due to delays in network, hardware and software layers it may take some cycles until the frame is received by the receiver, and the acknowledge gets back to the sender.

The sender shall not forward more than D_SDO_SeqLayerTxHistorySize_U16 frames before receiving an acknowledgement.

This example shows a configuration where the frames are delayed. A typical situation where frames are delayed is when POWERLINK Networks are connected by means of routers over a legacy Ethernet.

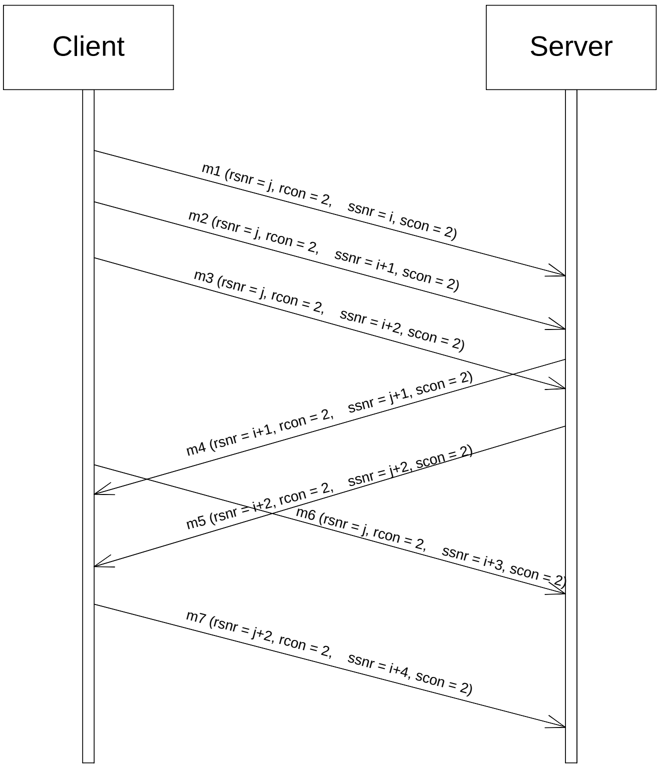


Fig. 48. Delayed asynchronous communication

6.3.2.3.1.5 Sender History Full

When the buffer for keeping frames is full (sliding window size exhausted), the sending node may explicitly request an acknowledgement by sending a frame with acknowledge request.

The receiver shall acknowledge this frame with an empty acknowledge frame, if it has no frames of its own to be sent.

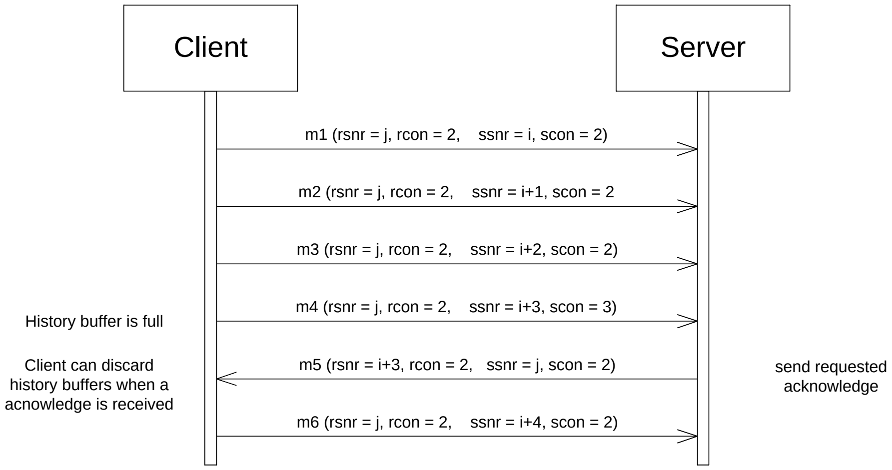


Fig. 49. Asynchronous communication when history buffer gets full

6.3.2.3.2 Errors

Errors that may occur in the physical and data link layer:

- Loss of frames

- Duplication of frames
- Overtaking of frames
- Broken connection

Errors that may occur in the sequence layer:

- Flooding with commands

6.3.2.3.2.1 Error: Loss of Frame with Data

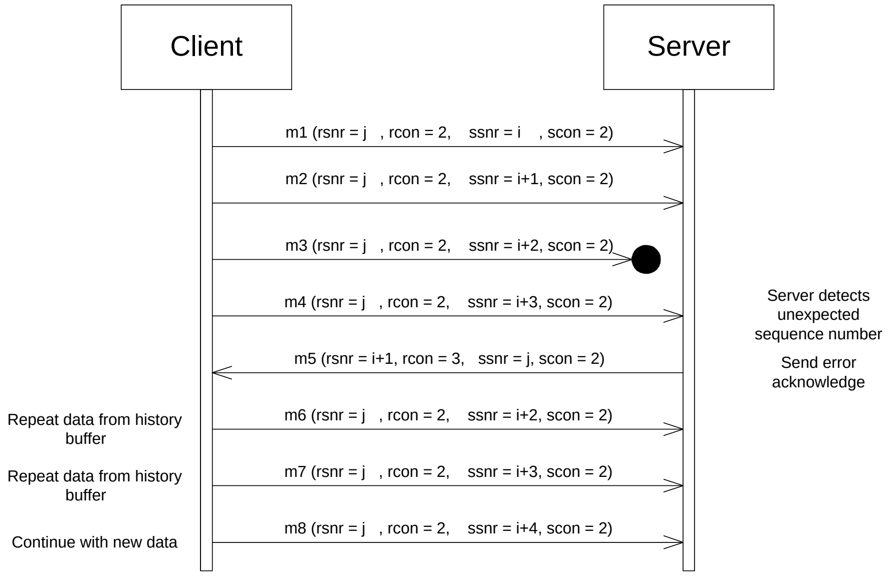


Fig. 50. Error loss of asynchronous frame

If the receiver detects a sequence number that is more than 1 higher than the last correctly received sequence number, it shall respond with rcon=3 and the last correctly received sequence number to indicate this error.

This error response may contain data (from the command layer).

The sender shall repeat all the frames that followed the responded sequence number.

The acknowledge fields in the repeated frames shall be updated.

6.3.2.3.2.2 Error: Loss of Acknowledge Frame

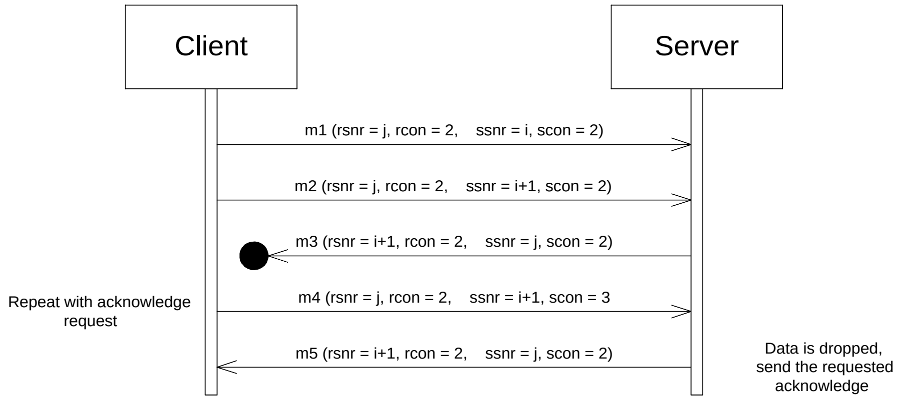


Fig. 51. Error loss of asynchronous acknowledge

If the sender is waiting for an acknowledgement and has no new frames to be sent, it shall repeat the latest message with acknowledge request after a timeout.

6.3.2.3.2.3 Error: Duplication of Frame

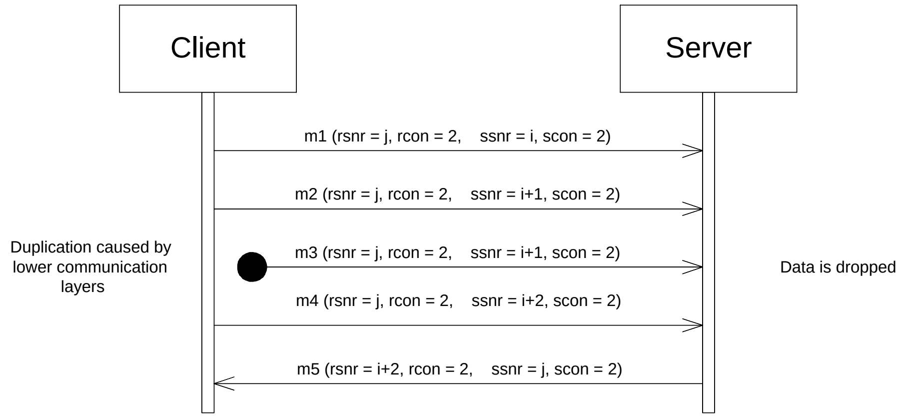


Fig. 52. Error duplication of asynchronous frame

If the receiver detects a sender sequence number that is lower than or equal to the last correctly received sequence, it shall drop that message.

If that message has scon=2 no further action is required.

If that message has scon=3 the receiver shall acknowledge the last correctly received sequence to the sender.

6.3.2.3.2.4 Error: Overtaking of Frames

When a frame overtakes, the receiver at first detects a lost frame. The receiver shall send an error response to the sender so that the sender repeats the frame.

Then the overtaken frame arrives at the receiver and is accepted.

After this the repeated frame arrives and is dropped at the receiver, because it is recognized as a duplicated frame.

Remark:

Overtaking of frames will never occur inside the POWERLINK network domain. Only on connections over Internet using Type I routers overtaking can occur on the Legacy Ethernet side.

6.3.2.3.2.5 Broken Connection

It shall be detected, that the connection is broken, if the opposite node is shut down or disconnected from the network.

The connection shall be considered broken when no acknowledgement is received within the timeout given by SDO_SequLayerTimeout_U32.

Within this timeout multiple acknowledge requests shall be sent (see 6.3.2.3.2.2). The number of acknowledge requests to be sent shall be described by SDO_SequLayerNoAck_U32. If SDO_SequLayerNoAck_U32 is not implemented a minimum value of C_SDO_SEQULAYERNOACK shall be used instead.

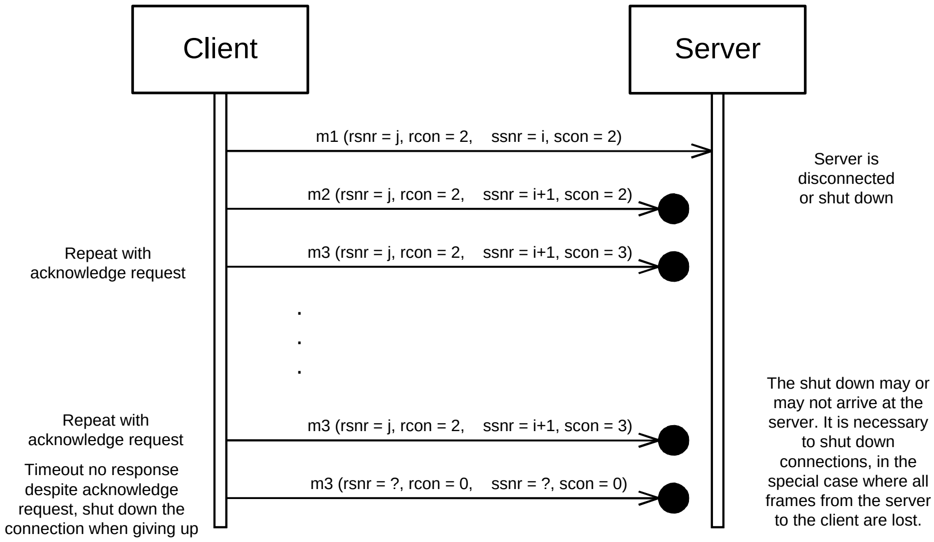


Fig. 53. Error asynchronous communication broken

6.3.2.3.2.6 Error: Flooding with commands

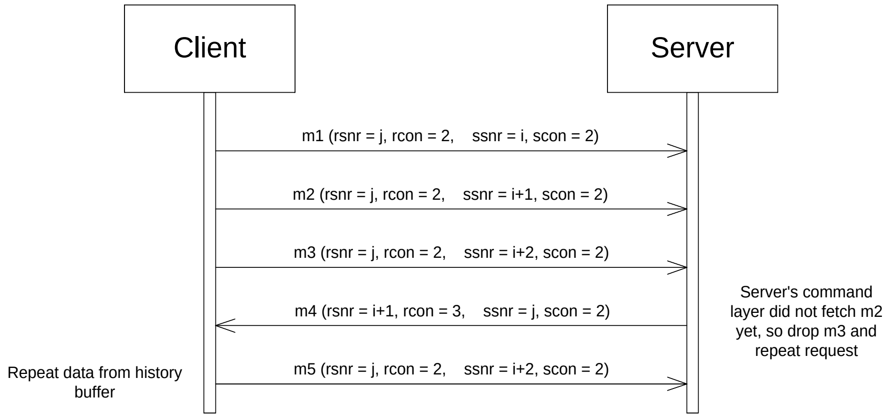


Fig. 54. Error flooding with asynchronous commands

If the sender sends commands at a rate too high, the command layer at the receiver may not be able to process the commands in time. In this case the sequence layer on the receiver side drops newly arriving frames and shall send an acknowledgement of the last correctly handled frame and a rcon=3 back to the sender.

This causes the sender to repeat the dropped frame, and the receiver gains some time to handle the request.

This shall not be misused as a flow control mechanism, flow control shall be done in higher layers.

6.3.2.4 Asynchronous SDO Command Layer

Tasks of the POWERLINK Command Layer

1. Addressing of the parameters, e.g. via index/sub-index or via name
2. Provide additional services
3. Distinguish between expedited and segmented transfer

The POWERLINK Command Layer is embedded in the POWERLINK Sequence Layer. If a large block is to be transferred the POWERLINK Command Layer has to decide whether the transfer can be completed in one frame (*expedited transfer*) or if it must be segmented in several frames (*segmented transfer*). Further it has to know whether an Upload or a Download should be initiated.

For all transfer types it is the client that takes the initiative for a transfer. The owner of the accessed object dictionary is the server of the Service Data Object (SDO). Either the client or the server can take the initiative to abort the transfer of a SDO. All commands are confirmed. The remote result parameter indicates the success of the request. In case of a failure, an Abort Transfer Request must be executed.

Fig. 55 shows the structure of the information in the POWERLINK Command Layer Header.

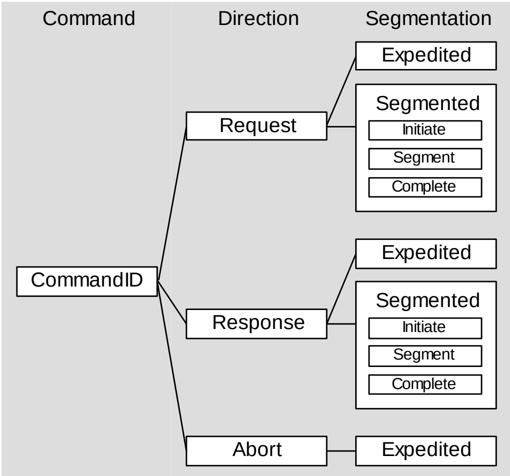


Fig. 55. Information structure of POWERLINK command layer

6.3.2.4.1 POWERLINK Command Layer Protocol

This chapter defines the fixed part of the POWERLINK Command Layer protocol.

The POWERLINK Command Layer is structured in the following way:

Octet Offset[16]	Bit Offset								
	7	6	5	4	3	2	1	0	
0	reserved								Fixed part
1	Transaction ID								
2	Res-ponse	Abort	Segmentation		reserved				
3	Command ID								
4 .. 5	Segment Size								
6 .. 7	reserved								
8 .. 11	Data Size (only if Segmentation = Initiate)								Variable part
(8 + 4*d) .. k-1	Command ID specific header								Command ID specific part
k .. 1463	Optional Payload Data								

k = Length of Command ID specific header; k < 1464
d: if seg = Initiate d = 1
else d = 0

Tab. 54 POWERLINK command layer

[16] Offset related to beginning of POWERLINK command layer.

Field	Abbr.	Description	Value
reserved	res	Reserved This byte is used when embedding the SDO in cyclic data (chapter 6.3.3).	0
Transaction ID	tid	Unambiguous transaction ID for a command. Changed by the client with every new command.	0 – 255
Response	rsp	Request / Response	0: Request 1: Response
Abort	a	The requested Transfer could not be completed by the client/server	0: transfer ok 1: abort transfer
Segmentation	seg	Differentiates between expedited and segmented transfer	0: Expedited Transfer 1: Initiate Segment Transfer 2: Segment 3: Segment Transfer Complete
Command ID	cid	Specifies the command	see Tab. 58
Segment Size	ss	Length of segment data. Counting from the end of the command header (beginning with octet offset 8)	256 –1456
Data Size	ds	Contains the number of bytes of the transferred block. Counting from the end of the command header (beginning with octet offset 8) Only used for the Initiate SegmentTransfer Frame (seg = Initiate) If ds = 0000h, the size is not indicated	0 – 2^{32}-1
Command ID specific		Specifies the command referenced by the cid.	See 6.3.2.4.2

Tab. 55 POWERLINK command layer field interpretation

The Transaction ID may be used to support several logic channels parallel via the same UDP socket resp. ASnd channel.

The Segment Size (ss) indicates the length of the segment in the command layer, i.e. the valid data length in the command layer. A minimum size of 256 bytes must be supported by every device. A maximum of 1456 bytes (i.e. 1500 byte payload data for the Ethernet frame) may be supported. The client can use the command “Maximum Segment Size” (see 6.3.2.4.2.4.1) to get the maximum usable size for a communication to a server.

Note: The maximum segment size is limited to 1456 bytes, because an Ethernet frame can carry a maximum of 1500 bytes. In case of SDO via UDP all the remaining bytes are needed for the protocol overhead (IP (20 bytes), UDP (8 bytes), message type / service ID / etc. (4 bytes), POWERLINK Sequence Layer (4 bytes) and the fixed part of the POWERLINK Command Layer (8 bytes)). In case of SDO via ASnd the maximum possible length of 1500 bytes is not fully used because the protocol overhead is shorter (message type / service ID / etc. (4 bytes), POWERLINK Sequence Layer (4 bytes) and the fixed part of the POWERLINK Command Layer (8 bytes)). However this guarantees an SDO command layer independent of the underlaying transfer method (UDP/IP or ASnd).

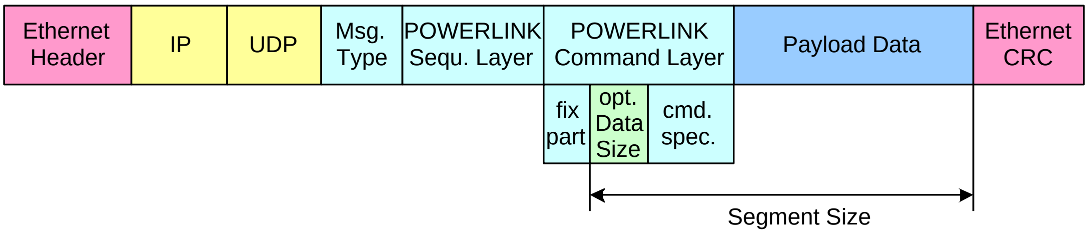


Fig. 56. Definition of segment size

For Initiate Segmented Transfer (seg=1) the number of bytes to be transferred in the command is indicated in the Data Size field. Therefore the offset for the Command ID specific header is 8 (Expedited Transfer) or 12 (Initiate Segmented Transfer) (cf. Tab. 54).

6.3.2.4.1.1 Download Protocol

The download service is used by the SDO client to download data to the server (owner of the object dictionary).

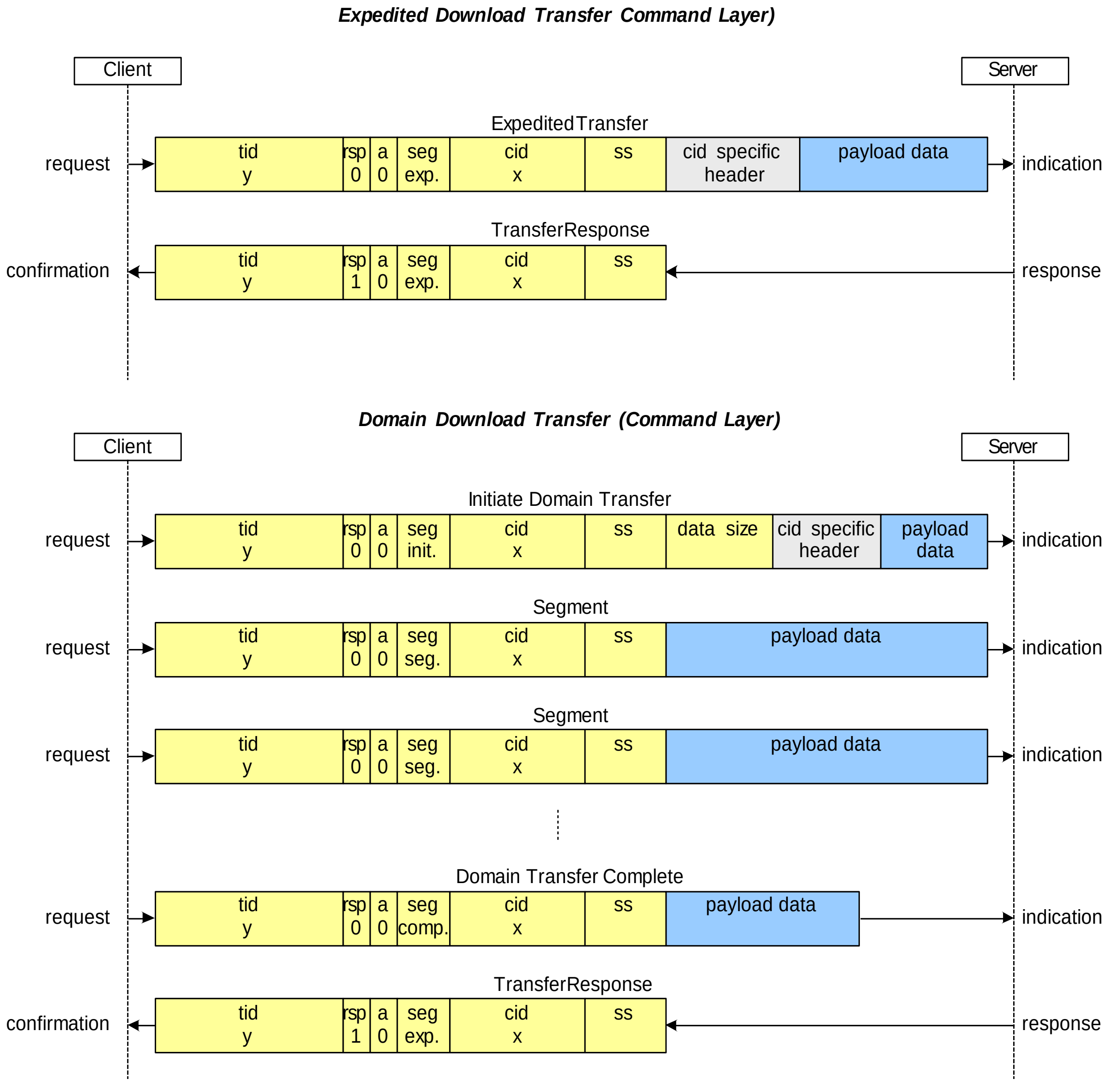


Fig. 57. POWERLINK command layer: Typical download transfer

In an expedited download, the data identified by the cid specific header is transferred to the server.

In a segmented transfer SDOs are downloaded as a sequence of zero or more Download SDO Segment services preceded by an Initiate SDO Download service and followed by a Segment Transfer Complete frame. The sequence is terminated by:

- A response/confirm, indicating the successful completion of a normal download sequence.
- An Abort SDO Transfer request/indication, indicating the unsuccessful completion of the download sequence.

The SDO Sequence Layer is not shown in Fig. 57. There may be more frames involved in the initialisation of the SDO Sequence Layer, see chapter 6.3.2.3 for details.

6.3.2.4.1.2 Upload Protocol

The Upload service is used by the SDO client to upload data from the server.

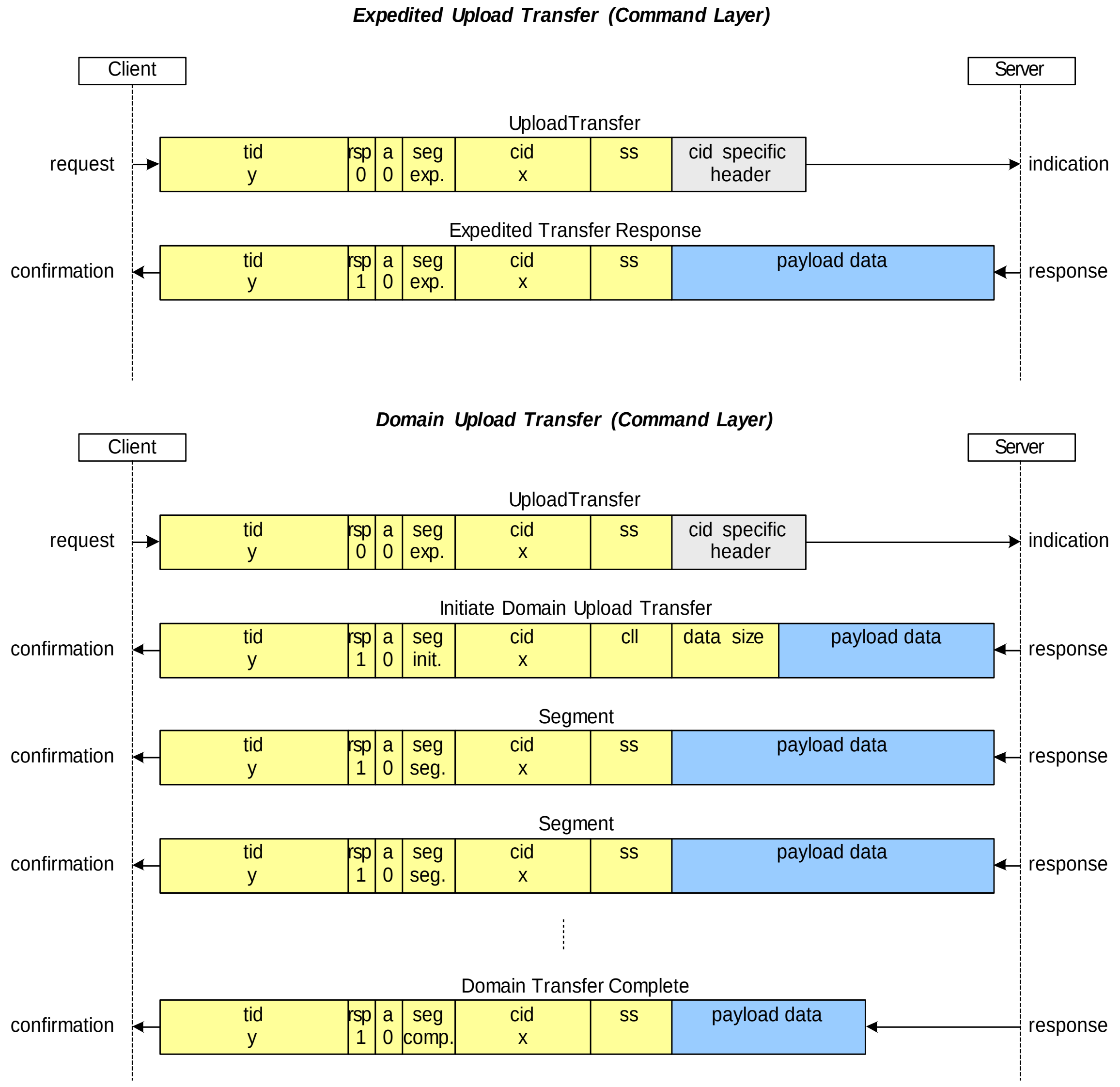


Fig. 58. POWERLINK command layer: Typical upload transfer

If an expedited upload is successful, the service concludes the upload of the data set identified by the cid specific header and the corresponding data is confirmed.

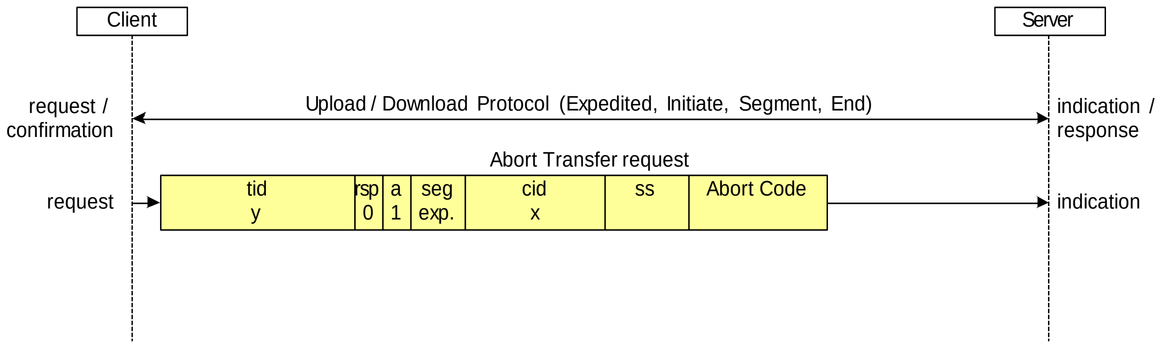
In a segmented transfer, SDOs are uploaded as a sequence of zero or more Upload SDO Segment services preceded by an Initiate SDO Upload service and followed by a Segment Transfer Complete frame. The sequence is terminated by:

- The Segment Transfer Complete frame, indicating the successful completion of a normal upload sequence.
- An Abort SDO Transfer request/indication, indicating the unsuccessful completion of the upload sequence.

6.3.2.4.1.3 Abort Transfer

The Abort Transfer service aborts the up- or download referenced by the Transaction ID. The reason is indicated.

Abort Transfer Client → Server



Abort Transfer Server → Client

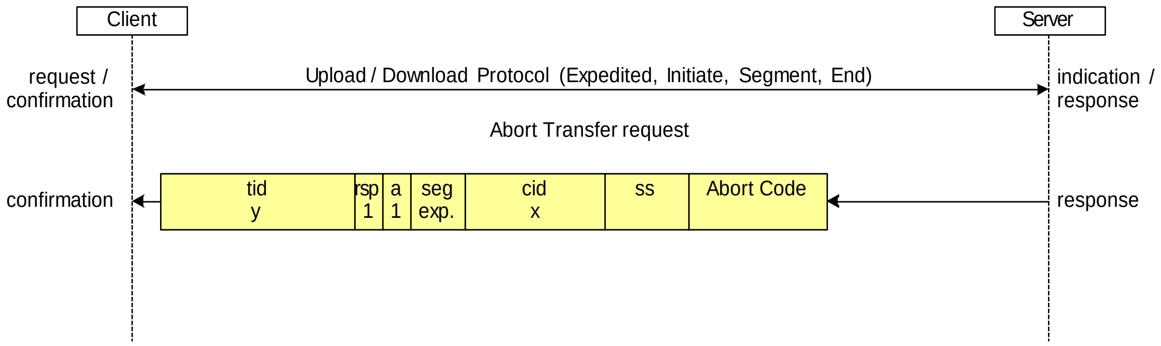


Fig. 59. Abort transfer

The Abort service is unconfirmed. The service may be executed at any time by either the client or the server of a SDO. If the client of a SDO has a confirmed service outstanding, the indication of the abort is taken to be the confirmation of that service.

	Bit Offset							
Octet Offset	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	reserved							
1	Transaction ID							
2	Res-ponse	Abort 1	Segmentation		reserved			
3	Command ID							
4 .. 5	Segment Size							
6 .. 7	reserved							
8 .. 11	Abort Code							

Tab. 56 Abort transfer frame

Field	**Abbr.**	**Description**	**Value**
Abort Code	ac	Reason of the abort	see App. 3.10

Tab. 57 Abort transfer frame field interpretation

The abort code is encoded as UNSIGNED32. A list of SDO abort codes is provided by App. 3.10.

6.3.2.4.2 Commands

This chapter describes the Command ID specific part of the POWERLINK Command Layer.

Command	Command Description // Device Description Entry	Cmd ID	M/O
NIL[17]	Not in List	0_h	M
SDO Protocol			
Write by Index	Write a parameter, addressing via index/sub-index	1_h	M
Read by Index	Read a parameter, addressing via index/sub-index	2_h	M
Write All by Index	Write a parameter, addressing via index, all sub-indices // D_SDO_CmdWriteAllByIndex_BOOL	3_h	O
Read All by Index	Read a parameter, addressing via index, all sub-indices // D_SDO_CmdReadAllByIndex_BOOL	4_h	O
Write by Name	Write a parameter, addressing via name // D_SDO_CmdWriteByName_BOOL	5_h	O
Read by Name	Read a parameter, addressing via name // D_SDO_CmdReadByName_BOOL	6_h	O
File Transfer			
File Write	Simple file transfer // D_SDO_CmdFileWrite_BOOL	20_h	O
File Read	Simple file transfer // D_SDO_CmdFileRead_BOOL	21_h	O
Variable groups			
Write Multiple Parameter by Index	Write multiple parameter within one command, addressing via index/sub-index // D_SDO_CmdWriteMultParam_BOOL	31_h	O
Read Multiple Parameter by Index	Read multiple parameter within one command, addressing via index/sub-index // D_SDO_CmdReadMultParam_BOOL	32_h	O
Parameter Services			
Maximum Segment Size	Exchange the maximum segment size	70_h	Cond[18]
Manufacturer specific		80_h – FF_h	O

Tab. 58 Command services and command ID

Support of particular commands is optional. Support shall be indicated by device description entries (c.f. Tab. 58).

6.3.2.4.2.1 SDO Protocol

Note: The Download Protocol (6.3.2.4.1.1, including Fig. 57) is used for write commands and the Upload Protocol (6.3.2.4.1.2, including Fig. 58)is used for read commands.

6.3.2.4.2.1.1 Command: Write by Index

Using the Write by Index service the client of a SDO downloads data to the server (owner of the object dictionary). The data, the multiplexor (index and sub-index) of the data set that has been downloaded and its size (only for segmented transfer) is indicated to the server.

---

[17] The NIL command shall be ignored on the command layer but processed at the sequence layer, that is the sequence layer shall send an acknowledge response but the NIL command will otherwise be ignored.

[18] Conditional: Only necessary if a segment size > 256 Byte should be transferred

	Bit Offset							
Octet Offset	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0 .. 7	Command Layer (fixed part)							
8 .. 11	Data Size (only if Segmentation = Initiate)							
(8 .. 9) + 4*d	Index							
10 + 4*d	Sub-Index							
11 + 4*d	reserved							
(12 + 4*d) .. 1463	Payload Data							

d: if seg = Initiate d = 1
else d = 0

Tab. 59 Command: Write by Index request

Field	**Abbr.**	**Description**	**Value**
Index	i	Specifies an entry of the device object dictionary	0 .. 65535
Sub-Index	si	Specifies a component of a device object dictionary entry	0 .. 254

Tab. 60 Write by Index request field interpretation

6.3.2.4.2.1.2 Command: Read by Index

Using the Read by Index service the client of a SDO requests that the server upload data to the client. The multiplexor (index and sub-index) of the data set whose upload is initiated is indicated to the server.

	Bit Offset							
Octet Offset	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0 .. 7	Command Layer (fixed part)							
8 .. 9	Index							
10	Sub-Index							
11	reserved							

Tab. 61 Command: Read by Index Request

Field	**Abbr.**	**Description**	**Value**
Index	i	Specifies an entry of the device object dictionary	0 .. 65535
Sub-Index	si	Specifies a component of a device object dictionary entry	0 .. 254

Tab. 62 Read by Index request field interpretation

6.3.2.4.2.1.3 Command: Write All by Index

Using the Write All by Index service the client of a SDO downloads data to the server (owner of the object dictionary). The service addresses all sub-indices (except sub-index 0) of the indicated index. The length of the payload data must confirm to the length of data for all sub-indices and all sub-indices must be writable.

	Bit Offset							
Octet Offset	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0 .. 7	Command Layer (fixed part)							
8 .. 11	Data Size (only if Segmentation = Initiate)							
(8 .. 9) + 4*d	Index							
10 + 4*d	reserved							
11 + 4*d	reserved							
(12 + 4*d) .. 1463	Payload Data							

d: if seg = Initiate d = 1
else d = 0

Tab. 63 Command: Write All by Index request

Field	Abbr.	Description	Value
Index	i	Specifies an entry of the device object dictionary	0 .. 65535

Tab. 64 Write All by Index request field interpretation

6.3.2.4.2.1.4 Command: Read All by Index

Using the Read All by Index service the client of a SDO requests that the server upload data to the client. The service addresses all sub-indices (except sub-index 0) of the indicated index. All sub-indices must be readable.

	Bit Offset							
Octet Offset	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0 .. 7	Command Layer (fixed part)							
8 .. 9	Index							
10 .. 11	reserved							

Tab. 65 Command: Read All by Index Request

Field	Abbr.	Description	Value
Index	i	Specifies an entry of the device object dictionary	0 .. 65535

Tab. 66 Read All by Index request field interpretation

6.3.2.4.2.1.5 Command: Write by Name

Using the Write by Name service the client of a SDO downloads data to the server. The data, the name of the data set that has been downloaded and its size (only for segmented transfer) are indicated to the server.

	Bit Offset							
Octet Offset	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0 .. 7	Command Layer (fixed part)							
8 .. 11	Data Size (only if Segmentation = Initiate)							
(8 .. 9) + 4*d	Offset Payload Data (k)							
(10 + 4*d) .. (k – 1)	Name							
k .. 1463	Payload Data							

k = Offset of the name length; k < 1464, 4-aligned
d: if seg = Initiate d = 1
else d = 0

Tab. 67 Command: Write by Name request

Field	Abbr.	Description	Value
Offset Payload Data	opd	Specifies the beginning of the payload data (in bytes) in this segment, counting from end of the fixed command header (beginning with octet offset 8)	0 .. 1463
Name	n	Specifies an entry of the device object dictionary	

Tab. 68 Write by Name request field interpretation

- The name may not be terminated by a \0.
- The definitions made in IEC 61131-3 for identifiers are adapted to the name conventions[19]. These are:
  - A name is a sequence of characters, dots, digits and underlines, beginning with a character or an underline.
  - Underlines shall be significant in identifiers, e.g. A_BC and AB_C are different identifiers.
  - Multiple leading or embedded underlines are not allowed.
  - Identifiers shall not contain embedded space (SP) characters.

[19] The IEC 61131-3 defines several keywords utilized as individual syntax elements. These keywords shall not be used as a parameter name. POWERLINK does not define further keywords.

- At least six unique characters shall be supported in all systems.
- The payload data shall be 4-byte-aligned. Therefore the name may have to be padded.

The Write by Name service is defined to access application objects (e.g. global variables) that do not have an index/sub-index.

6.3.2.4.2.1.6 Command: Read by Name

Using the Read by Name service the client of a SDO requests that the server upload data to the client. The name of the data set whose upload is initiated is indicated to the server.

	Bit Offset							
Octet Offset	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0 – 7	Command Layer (fixed part)							
8 – 11	Data Size (only if Segmentation = Initiate)							
(8 + 4*d) .. k	Name							

k < 1464

d: if seg = Initiate d = 1
else d = 0

Tab. 69 Command: Read by Name request

Field	**Abbr.**	**Description**	**Value**
Name	N	Specifies an entry of the device object dictionary	see 6.3.2.4.2.1.5

Tab. 70 Read by Name request field interpretation

The payload data shall be 4-byte-aligned. Therefore the name may have to be padded.

The Read by Name service is defined to access application objects (e.g. global variables) that do not have an index/sub-index.

6.3.2.4.2.2 File Transfer

A simple File transfer protocol is defined.

For file access, in addition to the naming conventions (see 6.3.2.4.2.1.5) the valid character set is extended with the characters:

- “/” and “\”
- “*”
- “:”

A file open/close service is not defined because this would cause related services with different Command IDs.

6.3.2.4.2.2.1 Command: File Write

The File Write protocol combines several typical operation system commands for file access:

- File open
- File seek
- File write

	Bit Offset							
Octet Offset	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0 .. 7	Command Layer (fixed part)							
8 .. 11	Data Size (only if Segmentation = Initiate)							
(8 .. 11) + 4*d	Address							
(12 .. 13) + 4*d	Offset Payload Data (k)							
(14 .. 15) + 4*d	reserved							
(16 + 4*d) .. (k – 1)	File Name							
k .. 1463	Payload Data							

k = Offset of the payload data; k < 1464, 4-aligned
d: if seg = Initiate d = 1
else d = 0

Tab. 71 Command: File Write request

Field	Abbr.	Description	Value
Address	addr	Address of the data from the beginning of the file.	0 .. 2^{32}-1
Offset Payload Data	opd	Specifies the beginning of the payload data (in bytes) in this segment, counting from the end of the fixed command header (beginning with octet offset 8)	0 .. 1463
File Name	fn	File name (complete path)	

Tab. 72 File Write request field interpretation

The Address field indicates the relative address of the data in the file.

6.3.2.4.2.2.2 Command: File Read

	Bit Offset							
Octet Offset	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0 .. 7	Command Layer (fixed part)							
8 .. 11	Data Size (only if Segmentation = Initiate)							
(8 .. 11) + 4*d	Address							
(12 + 4*d) .. k	File Name							

k < 1464
d: if seg = Initiate d = 1
else d = 0

Tab. 73 Command: File Read request

Field	Abbr.	Description	Value
Address	addr	Address of the data from the beginning of the file.	0 .. 2^{32}-1
File Name	fn	File name (complete path)	

Tab. 74 File Read request field interpretation

6.3.2.4.2.3 Variable groups

6.3.2.4.2.3.1 Command: Write Multiple Parameter by Index

Using the Write Multiple Parameter by Index service the client of a SDO downloads multiple data sets to the server. The data, the multiplexor (index and sub-index) of the data sets that are downloaded and the size of the transfer (only for segmented transfer) are indicated to the server.

A device shall be able to process this command up to a size which can be transferred in a maximum sized Ethernet frame.

6.3.2.4.2.3.2 Write Multiple Parameter by Index Request

	Bit Offset							
Octet Offset	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0 .. 7	Command Layer (fixed part)							
8 .. 11	Data Size (only if Segmentation = Initiate)							
(8 .. 11) + 4*d	Octet Offset of next Data Set (k)							
(12 .. 13) + 4*d	Index							
14 + 4*d	Sub-Index							
15 + 4*d	reserved						Padding Length	
(16 + 4*d) .. (k – 1)	Payload Data							
k .. (k + 3)	Octet Offset of next Data Set (m)							
(k + 4) .. (k + 5)	Index							
k + 6	Sub-Index							
k + 7	reserved						Padding Length	
(k + 8) .. (m – 1)	Payload Data							
m …	… (further write requests)							

d: if seg = Initiate d = 1
else d = 0
k, m 4-aligned

Tab. 75 Command: Write Multiple Parameter by Index Request

Field	Abbr.	Description	Value
Octet Offset of next Data Set	o2d	Octet offset of the next data set. The value is the absolute offset, counting from the beginning of the fixed command header (beginning with octet offset 0) If o2d=ZERO the last data set has been reached.	0 .. 2^{32}-1
Index	i	Specifies an entry of the device object dictionary	0 .. 65535
Sub-Index	si	Specifies a component of a device object dictionary entry	0 .. 254
Padding Length	pl	Number of padding bytes in the last quadlet (4-byte word) of the payload data	0 .. 3
reserved	res	Reserved for future use.	0

Tab. 76 Write Multiple Parameter by Index request field interpretation

6.3.2.4.2.3.3 Write Multiple Parameter by Index Response

	Bit Offset							
Octet Offset	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0 .. 7	Command Layer (fixed part)							
8 .. 11	Data Size (only if Segmentation = Initiate)							
(8 .. 9) +.4*d	Index							
10 + 4*d	Sub-Index							
11 + 4*d	SubAbort	reserved						
(12 .. 15) + 4*d	Sub-Abort Code							
(16 .. 17) + 4*d	Index							
18 + 4*d	Sub-Index							
19 + 4*d	SubAbort	reserved						
(20 .. 23) + 4*d	Sub-Abort Code							
24 …	… (further write responses)							

d: if seg = Initiate d = 1
else d = 0

Tab. 77 Command: Write Multiple Parameter by Index Response

Field	Abbr.	Description	Value
Index	i	Specifies an entry of the device object dictionary	0 .. 65.535
Sub-Index	si	Specifies a component of a device object dictionary entry	0 .. 254
Sub-Abort	sa	The requested transfer could not be processed by the server	0: transfer ok 1: abort transfer
reserved	res	Reserved for future use	0
Sub-Abort Code	sac	Reason of the sub-abort	see App. 3.10

Tab. 78 Write Multiple Parameter by Index response field interpretation

In the response a list of all invalid object accesses is transferred.

The list entries consist of the index and sub-index of the object, a sub-abort flag (sa) and the sub-abort code (sac).

The abort flag (a) in the command header is set only if the data contain one single abort code instead of a response list. E.g. “Command ID not valid or unknown”.

If all accesses are valid and processed by the server the command specific header is empty, i.e. the abort flag (a) is not set and the list of faulty accesses is empty.

6.3.2.4.2.3.4 Command: Read Multiple Parameter by Index

Using the Read multiple parameter service the client of a SDO requests that the server for upload multiple data sets to the client. The multiplexor (index and sub-index) of the data sets whose upload is initiated is indicated to the server.

A device shall be able to process this command up to a size which can be transferred in a maximum sized Ethernet frame.

6.3.2.4.2.3.5 Read Multiple Parameter by Index Request

	Bit Offset							
Octet Offset	7	6	5	4	3	2	1	0
0 .. 7	Command Layer (fixed part)							
8 .. 11	Data Size (only if Segmentation = Initiate)							
(8 .. 9) + 4*d	Index							
10 + 4*d	Sub-Index							
11 + 4*d	reserved							
(12 .. 13) + 4*d	Index							
14+4*d	Sub-Index							
15+4*d	reserved							
16 …	… (further read requests)							

d: if seg = Initiate d = 1
else d = 0

Tab. 79 Command: Read Multiple Parameter by Index request

Field	Abbr.	Description	Value
Index	i	Specifies an entry of the device object dictionary	0 .. 65535
Sub-Index	si	Specifies a component of a device object dictionary entry	0 .. 254
reserved	res	Reserved for alignment	0

Tab. 80 Read Multiple Parameter by Index request field interpretation

6.3.2.4.2.3.6 Read Multiple Parameter by Index Response

Octet Offset	Bit Offset							
	7	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0 .. 7	Command Layer (fixed part)							
8 .. 11	Data Size (only if Segmentation = Initiate)							
(8 .. 11) + 4*d	Octet Offset of next Data Set (k)							
(12 .. 13) + 4*d	Index							
14 + 4*d	Sub-Index							
15 + 4*d	SubAbort	reserved					Padding Length	
(16 + 4*d) .. (k – 1)	Payload Data / Sub-Abort Code							
k .. (k + 3)	Octet Offset of next Data Set (m)							
(k + 4) .. (k + 5)	Index							
k + 6	Sub-Index							
k + 7	SubAbort	reserved					Padding Length	
(k + 8) .. (m – 1)	Payload Data / Sub-Abort Code							
m …	… (further read responses)							

d: if seg = Initiate d = 1
else d = 0
k, m 4-aligned

Tab. 81 Command: Read Multiple Parameter by Index response

Field	**Abbr.**	**Description**	**Value**
Octet Offset of next Data Set	o2d	Octet offset of the next data set. The value is the absolute offset, counting from the beginning of the fixed command header (beginning with octet offset 0) If o2d=ZERO the last data set has been reached.	0 – 2^{32}-1
Index	i	Specifies an entry of the device object dictionary	0 – 65.535
Sub-Index	si	Specifies a component of a device object dictionary entry	0 – 254
Sub-Abort	sa	The requested transfer could not be served by the server	0: transfer ok 1: abort transfer
Padding Length	pl	Number of padding bytes in the last quadlet (4-byte word) of the payload data	0 – 3
reserved	res	Reserved for future use	0
Sub-Abort Code	sac	Reason of the sub-abort	see App. 3.10

Tab. 82 Read Multiple Parameter by Index response field interpretation

In the response a list of all object accesses is transferred.

The list entries consist of the index and sub-index of the object, a sub-abort flag (sa) and the payload data resp. the sub-abort code (sac).

The abort flag (a) in the command header is set only if the data contain one single abort code instead of a response list. E.g. “Command ID not valid or unknown”.

6.3.2.4.2.4 Parameter Services

6.3.2.4.2.4.1 Command: Maximum Segment Size

The maximum segment size (MSS) indicates the maximum length of a segment in the command layer.

The minimum segment size that must be supported by every device is 256 bytes. If the client and the server can handle more than 256 bytes the client can use this command to negotiate the maximum segment size.

	Bit Offset							
Octet Offset	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0 .. 7	Command Layer (fixed part)							
8 .. 9	MSS Client							
10 .. 11	MSS Server							

Tab. 83 Command: Maximum Segment Size

Field	Abbr.	Description	Value
MSS Client	mssc	MSS of the client	256 –1456
MSS Server	msss	MSS of the server If 0000h the length is not indicated (request from client to server)	256 –1456

Tab. 84 Maximum Segment Size field interpretation

The maximum segment size is limited to 1456 independent of the transfer method (UDP/IP or ASnd).

In the request frame from the client the *mssc* is indicated to the server. The *msss* is set to ZERO and therefore not indicated.

In the response the server repeats the *mssc* of the client and indicates its own *msss*.

Both, client and server, must compare the *mssc* to the indicated *msss* and must calculate the minimum of both. This is the used MSS.

Used MSS = min {mssc; msss}

6.3.3 SDO Embedded in PDO

It is possible to embed the SDO in the cyclic PDO. The embedded SDO is used as a container mapped into the PDO.

The Read/Write by Index command layer protocol is used to access the data. The Header of the container starts with a shortened Sequence Layer (1 Byte). The fixed part of the following POWERLINK Command Layer protocol is adopted in the following points:

- as the container has a fixed length, the valid data length has to be indicated. Therefore the field “valid payload length” is inserted. Up to 255 bytes of payload data may be transferred in a container.

	Bit Offset								
Octet Offset	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	
0	Sequence Layer embedded in PDO								Sequence Layer
1	Transaction ID								Command Layer
2	Res-ponse	Abort	Segmentation		reserved				Command Layer
3	Valid Payload Length								Command Layer
4	Command ID								Command Layer
5 .. 6	Index								Command Layer
7	Sub-Index								Command Layer
8 – 11	Data Size (only if Segmentation = Initiate)								Variable Part
(8 + 4*d) .. k – (8 + 4*d)	Optional Payload Data								Payload

k = Length of container in byte
d: if seg = initiate d = 1
else d = 0

Tab. 85 SDO embedded in PDO

Field	Abbr.	Description	Value
Sequence Layer (see chapter 6.3.3.1)			
Command Layer			
Transaction ID	tid	Unambiguous transaction ID for a command. Must be changed by the client with every new command.	0 .. 255
Response	rsp	Request / Response	0 : Request 1 : Response
Abort	a	The requested Transfer could not be served by the client/server	0: Transfer ok 1: Abort transfer
Segmentation	seg	Differentiates between expedited and segmented transfer	0: Expedited Transfer 1: Initiate Segment Transfer 2: Segment 3: Segment Transfer Complete
Valid Payload Length	vpl	Length of valid payload data in the container in bytes.	0 .. 255
Command ID	cid	Specifies the command	See Tab. 58
Index	i	Specifies an entry of the device object dictionary	0 .. 65535
Sub-Index	si	Specifies a component of a device object dictionary entry	0 .. 254
Data Size	ds	see definition in Tab. 57	

Tab. 86 SDO embedded in PDO field interpretation

The container needs a minimum of 8 bytes for header information.

If segmented transfer is supported, the data size field must be inserted for the initiate frame as defined in the POWERLINK Command Layer Protocol so the header will be 12 byte.

The embedded SDO transfer establishes a peer-to-peer communication channel between two devices. This is a unidirectional Client-Server connection. If a device needs to transfer data using this method to several other devices it must establish a SDO communication channels for each.

The client SDO container (CSDO) and the server SDO container (SSDO) parameter are described by the SDO communication parameter objects SDO_ServerContainerParam_*XXh*_REC resp. SDO_ClientContainerParam_*XXh*_REC. For each SDO channel a pair the communication parameters is mandatory.

6.3.3.1 Embedded Sequence Layer for SDO in PDO

For embedding of SDO in cyclic data (PollRequest and PollResponse) the first byte within POWERLINK Command Layer is reserved for Embedded Sequence Layer.

	Bit Offset							
Octet Offset	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	SequenceNumber						Connection	
1 …	Command Layer Protocol							

Tab. 87 POWERLINK sequence layer for embedding of SDO in cyclic data

Remark:
Only one sequence number for both directions is suitable, because the communication is embedded in the cyclic communication. And therefore it is guaranteed that there are messages in both directions.

Field	Abbr.	Description	Value
SequenceNumber	snr	Shall be increased by one with each new request frame.	0 ... 63
Connection	con	Shows the different connection states	0: No connection 1: Initialisation 2: Connection valid 3: Error Response (Retransmission Request)

Tab. 88 Fields of POWERLINK sequence layer for embedding of SDO in cyclic data

6.3.3.1.1 Connection

6.3.3.1.1.1 Initialisation of Connection

Connection is not initialised (e.g. after power up). The server has shut down the connection to this client. Now client and server know that the connection is down. “?” is used for counters that shall be ignored.

After this the connection is established.

The sequence number shall not be incremented until the connection initialisation has been completed No command shall be transferred during the initialisation.

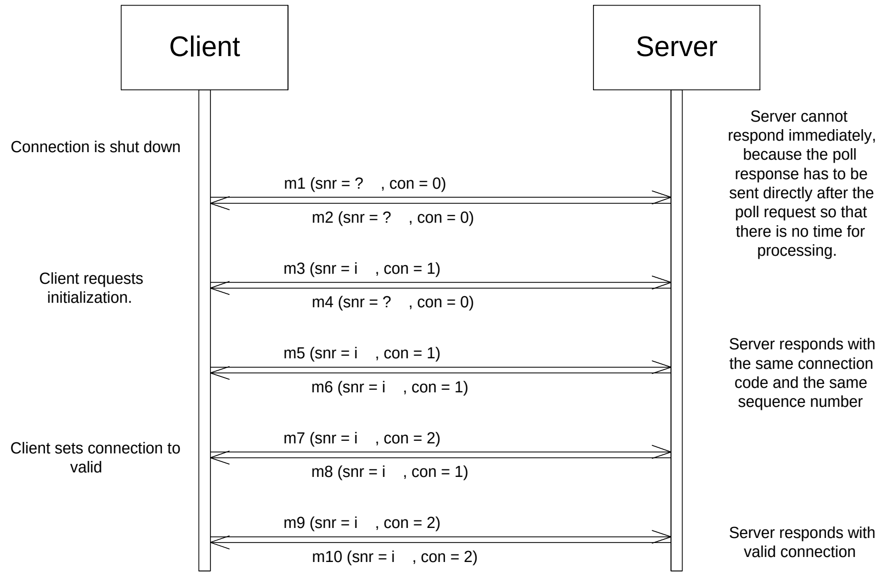


Fig. 60. Initialisation of embedded connection

6.3.3.1.1.2 Closing a connection

A connection should be shut down, when it is no longer needed.

A node may shut down a connection if it needs the resources for other reasons.

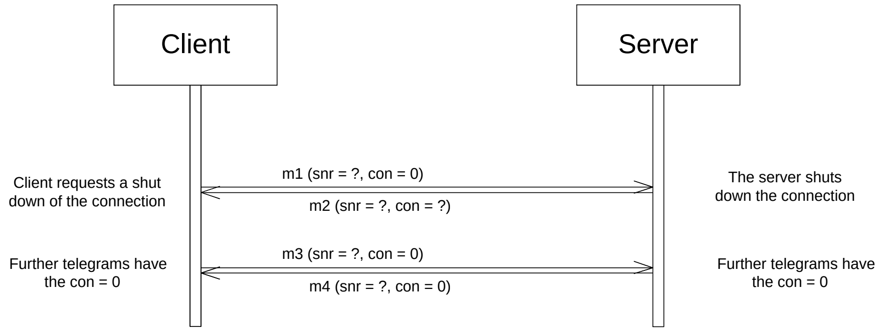


Fig. 61. Closing of connection

Closing a connection shall be indicated by con = 0.

6.3.3.1.1.3 Data Transfer

When the connection is established the client is allowed to send new request frames. Client and server have to keep the sent frames in some sort of a history buffer.

It is possible to send request frames in advance from client to server in consecutive cyclic frames, even if the responses to the preceding requests have not yet been received. The response frames then are received some cycles later than the corresponding request frames.

If there is nothing to send, the most recently sent packet shall be repeated.

To make the error recovery (see next chapter) for this protocol work, the client has to know how many responses the send history on the server holds. This history size parameter can be read from the object directory, the default value is 1.

The client holds a send history to be able to regain a lost response by repeating the request.

With a send history size of n in the server and a send history size of m in the client, the client shall not forward more than min(m, n) requests before receiving the response.

Sample with six new request frames:

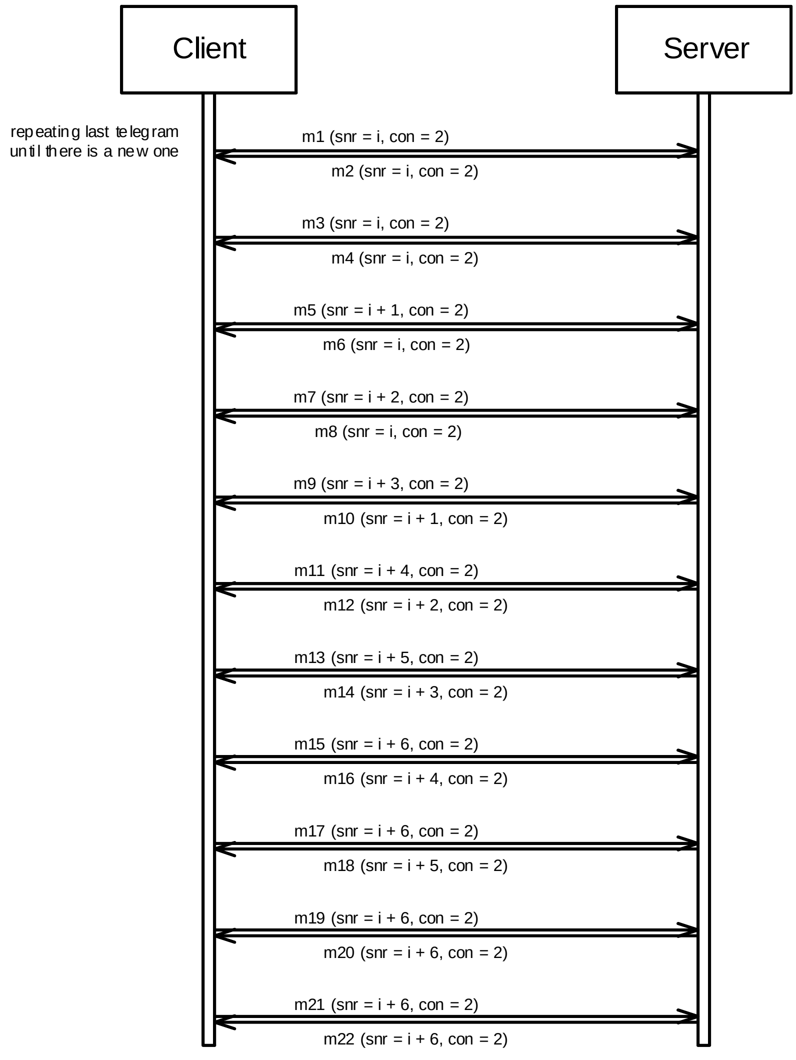


Fig. 62. Normal embedded communication

6.3.3.1.2 Errors

6.3.3.1.2.1 Error: Request Lost

If server detects an unexpected sequence number, that is not 1 higher than the last correctly received sequence number, it responds with connection code 3 and the sequence number of the last successful received frame. The client then has to repeat all frames starting after the sequence number of the last successful transferred frame.

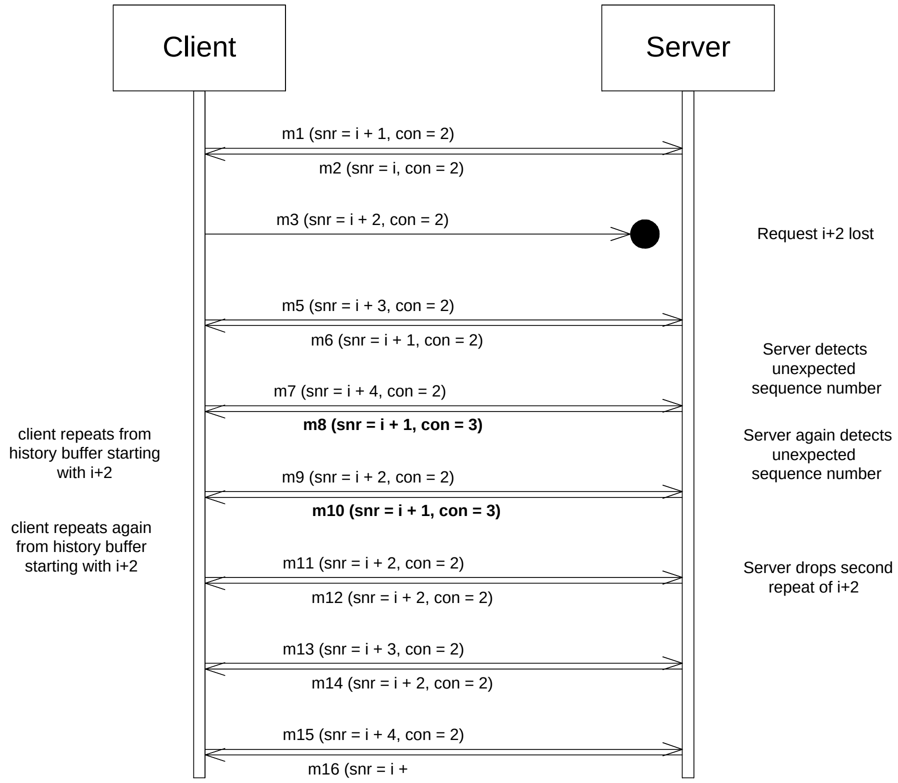


Fig. 63. Error embedded request lost

6.3.3.1.2.2 Error: Response Lost

If the client detects an unexpected sequence number that is not 1 higher than the last correctly received sequence number, it has to repeat that frames with connection code 3 for which no response was received.

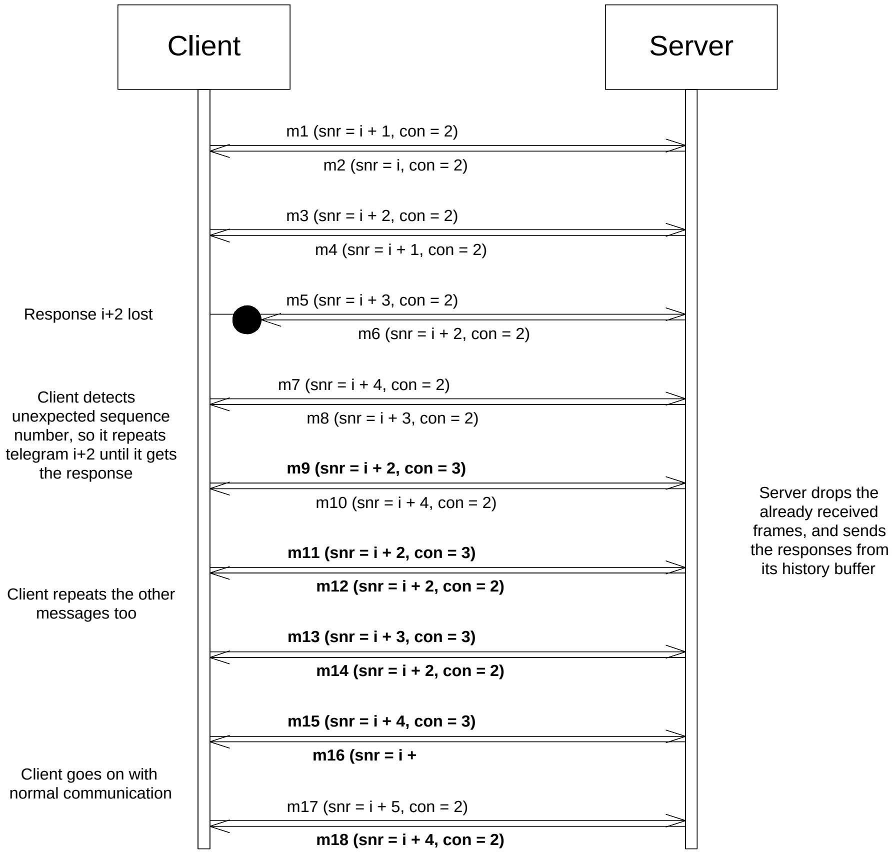


Fig. 64. Error embedded response lost

6.3.3.1.3 Handling of Segmented Transfers

6.3.3.1.3.1 Segmented Download from Client to Server

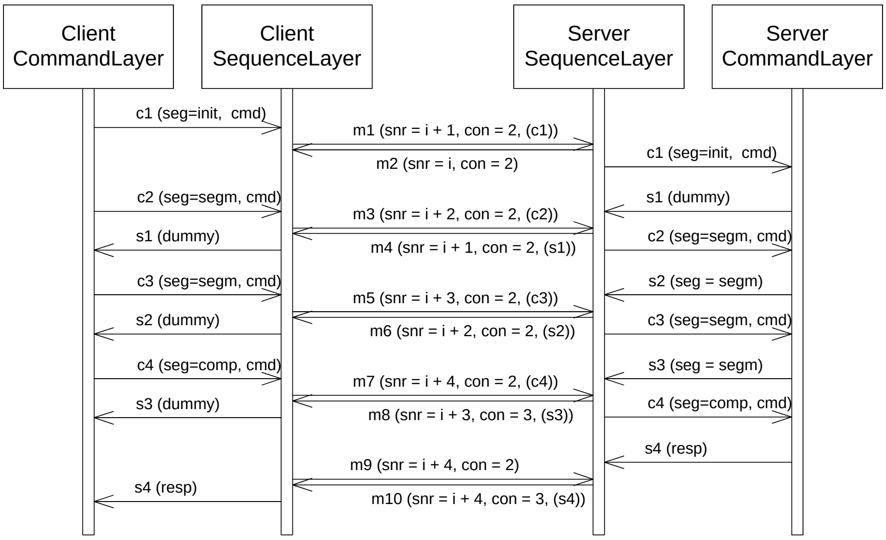


Fig. 65. Embedded segmented download

For SDO embedded in cyclic data each new frame requested by the client shall be responded by the server. In the case of a segmented download from the client to the server, the client will produce more command frames than the server.

So the server shall acknowledge the sequence numbers with dummy frames that contain Command ID “NIL”, while the segmented transfer is running.

6.3.3.1.3.2 Segmented Upload from Server to Client

In the case of a segmented upload from the server to the client the server will produce more commands than the client. To provide the server with enough sequence numbers the client shall send dummy commands that contain Command ID “NIL”, to the server until the upload is complete.

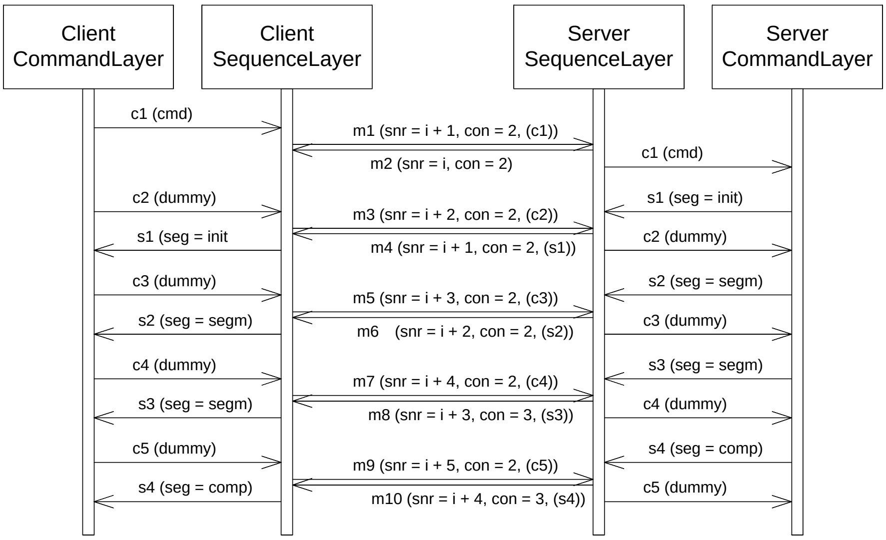


Fig. 66. Embedded segmented upload

6.3.3.2 Embedded Command Layer for SDO in Cyclic Data

Remark: Even though this specification only defines the services Write / Read by Index via SDO in PDO all other commands specified in the SDO Command Layer (chapter 6.3.2.4) can be supported in a similar way.

6.3.3.2.1 Command Write by Index via PDO

	Bit Offset							
Octet Offset	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	Sequence Layer embedded in PDO							
1	Transaction ID							
2	Res-ponse	Abort	Segmentation		reserved			
3	Valid Payload Length							
4	Command ID = Write by Index							
5 .. 6	Index							
7	Sub-Index							
8 .. 11	Data Size (only if Segmentation = Initiate)							
8 + 4*d k – (8 + 4*d)	Payload Data							

k = Length of container in byte

Tab. 89 Command: Write by Index Request via PDO

6.3.3.2.2 Command Read by Index via PDO

	Bit Offset							
Octet Offset	7	6	5	4	3	2	1	0
0	Sequence Layer embedded in PDO							
1	Transaction ID							
2	Res-ponse	Abort	Segmentation		reserved			
3	Valid Payload Length							
4	Command ID = Read by Index							
5 – 6	Index							
7	Sub-Index							

Tab. 90 Command: Read by Index Request via PDO

6.3.3.3 Object Description

6.3.3.3.1 Object 1200_h .. $127F_h$: SDO_ServerContainerParam_*XXh*_REC

The SDO_ServerContainerParam_*XXh*_REC objects contain the parameters for the SDOs for which the device is the server.

To map the container in the PDO the corresponding index shall be mapped.

To allow access by name "_*XXh*" shall be replaced by a name index. Name index shall be "_*00h*" if object index is 1200_h. It shall be incremented up to "_*7Fh*" corresponding to object index $127F_h$.

Index	1200_h .. $127F_h$	Object Type	RECORD
Name	SDO_ServerContainerParam_*XXh*_REC		
Data Type	SDO_ParameterRecord_TYPE	Category	O

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	4	Access	const
Default Value	4	PDO Mapping	No

- **Sub-Index 01_h: ClientNodeID_U8**

Sub-Index	01_h		
Name	ClientNodeID_U8		
Data Type	UNSIGNED8	Category	M
Value Range	UNSIGNED8	Access	rws
Default Value	-	PDO Mapping	No

POWERLINK Node ID of SDO client

- **Sub-Index 02_h: ServerNodeID_U8**

Sub-Index	02h		
Name	ServerNodeID_U8		
Data Type	UNSIGNED8	Category	M
Value Range	UNSIGNED8	Access	rws
Default Value	-	PDO Mapping	No

POWERLINK Node ID of SDO server

- **Sub-Index 03h: ContainerLen_U8**

Sub-Index	03h		
Name	ContainerLen_U8		
Data Type	UNSIGNED8	Category	M
Value Range	UNSIGNED8	Access	rws
Default Value	-	PDO Mapping	No

Max. data length of the container (incl. header) in byte

- **Sub-Index 04h: HistorySize_U8**

Sub-Index	04h		
Name	HistorySize_U8		
Data Type	UNSIGNED8	Category	M
Value Range	0 .. 63	Access	rws
Default Value	-	PDO Mapping	No

Client Request history size (for sequence layer, see 6.3.3.1)

6.3.3.3.2 Object 1280h .. 12FFh: SDO_ClientContainerParam_*XXh*_REC

The SDO_ClientContainerParam_*XXh*_REC objects contain the parameters for the SDOs for which the device is the client. If the entry is supported, all sub-indices must be available.

To map the container in the PDO the corresponding index shall be mapped.

To allow access by name "*_XXh*" shall be replaced by a name index. Name index shall be "*_00h*" if object index is 1280h. It shall be incremented up to "*_7Fh*" corresponding to object index 12FFh.

Index	1280h .. 12FFh	Object Type	RECORD
Name	SDO_ClientContainerParam_*XXh*_REC		
Data Type	SDO_ParameterRecord_TYPE	Category	O

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	5	Access	const
Default Value	5	PDO Mapping	No

- **Sub-Index 01h: ClientNodeID_U8**

Sub-Index	01h		
Name	ClientNodeID_U8		
Data Type	UNSIGNED8	Category	M
Value Range	UNSIGNED8	Access	rws
Default Value	-	PDO Mapping	No

POWERLINK Node ID of SDO client

- **Sub-Index 02h: ServerNodeID_U8**

Sub-Index	02h		
Name	ServerNodeID_U8		
Data Type	UNSIGNED8	Category	M
Value Range	UNSIGNED8	Access	rws
Default Value	-	PDO Mapping	No

POWERLINK Node ID of SDO server

- **Sub-Index 03$_h$: ContainerLen_U8**

Sub-Index	03$_h$		
Name	ContainerLen_U8		
Data Type	UNSIGNED8	Category	M
Value Range	UNSIGNED8	Access	rws
Default Value	-	PDO Mapping	No

Max. data length of the container (incl. header) in byte

- **Sub-Index 04$_h$: HistorySize_U8**

Sub-Index	04$_h$		
Name	HistorySize_U8		
Data Type	UNSIGNED8	Category	M
Value Range	0 .. 63	Access	rws
Default Value	-	PDO Mapping	No

Server Response history size (for sequence layer, see 6.3.3.1)

- **Sub-Index 05$_h$: reserved**

6.3.3.3.3 Object 0422$_h$: SDO_ParameterRecord_TYPE

Index	0422h	Object Type	DEFSTRUCT
Name	SDO_ParameterRecord_TYPE		
Sub-Index	Component Name	Value	Data Type
00$_h$	NumberOfEntries	04$_h$	
01$_h$	ClientNodeID_U8	0005$_h$	UNSIGNED8
02$_h$	ServerNodeID_U8	0005$_h$	UNSIGNED8
03$_h$	ContainerLen_U8	0005$_h$	UNSIGNED8
04$_h$	HistorySize_U8	0005$_h$	UNSIGNED8

6.3.4 SDO Timeouts

6.3.4.1 Object 1300$_h$: SDO_SequLayerTimeout_U32

The object provides a timeout value in [ms] for the connection abort recognition of the SDO sequence layer (see 6.3.2.3.2.5).

Index	1300h	Object Type	VAR
Name	SDO_SequLayerTimeout_U32		
Data Type	UNSIGNED32	Category	M
Value Range	100 ms – Max(UNSIGNED32)	Access	rws, valid on reset
Default Value	C_SDO_SEQULAYERTIMEOUT	PDO Mapping	No

Note: The default value of C_SDO_SEQULAYERTIMEOUT will be high enough even for diagnosing nodes over the internet.

Note: Take care when configuring the sequence layer timeout. If the configured value is too low, SDO access to the device is impossible after ResetConfiguration.

6.3.4.2 Object 1301$_h$: SDO_CmdLayerTimeout_U32

The object provides a timeout value in [ms] for the connection abort recognition of the SDO command layer.

If SDO_CmdLayerTimeout_U32 is not implemented a value of C_SDO_CMDLAYERTIMEOUT shall be used instead for detecting a command layer timeout.

Index	1301h	Object Type	VAR
Name	SDO_CmdLayerTimeout_U32		
Data Type	UNSIGNED32	Category	O
Value Range	100 ms – Max(UNSIGNED32)	Access	rws, valid on reset
Default Value	C_SDO_CMDLAYERTIMEOUT	PDO Mapping	No

Note: Take care when configuring the command layer timeout.
This timeout is valid for each and every SDO command. When configuring its value a long duration for SDO access has to be considered, e.g. for firmware download or storing the OD.
If the configured value is too low, SDO access to the device is impossible after ResetConfiguration.

6.3.4.3 Object 1302$_h$: SDO_SequLayerNoAck_U32

The object provides the number of acknowledge requests for the connection abort recognition of the SDO sequence layer (see 6.3.2.3.2.5).

Index	1302h	Object Type	VAR
Name	SDO_SequLayerNoAck_U32		
Data Type	UNSIGNED32	Category	O
Value Range	2 – Max(UNSIGNED32)	Access	rws, valid on reset
Default Value	C_SDO_SEQULAYERNOACK	PDO Mapping	No

6.4 Process Data Object (PDO)

The real-time data transfer is performed by means of Process Data Objects (PDO).

PDO communication in POWERLINK is always performed isochronously by PReq and/or PRes frames. The PRes frames are sent as broadcasts following the producer/consumer scheme. The PReq frames with unicast addresses comply with the master/slave relationship.

The transmission type of PDO is continuous. There is no “on event” or “on change” transmission type provided.

From the device’s view, there are two types of PDO usage: data transmission and data reception. Transmit PDOs (TPDOs) and Receive PDOs (RPDOs) shall be distinguished. Devices supporting TPDOs are PDO producers or PDO masters and devices which are able to receive PDOs are called PDO consumers or PDO slaves.

The numbers of supported channels shall be provided by the application.

An MN device may support up to 256 RPDO and 256 TPDO channels.

On a CN device, only one TPDO channel may be available while up to 256 RPDO may be supported . An Async-only CN device shall not support any TPDO channel but may provide up to 256 RPDO channels.

The size of PDO channels is application-specific.

A PDO channel shall be described by a pair of objects:

- PDO communication parameter describing communication attributes of the PDO. Mapping version and address information are provided.
  PDO communication parameter are held by the objects PDO_TxCommParam_XXh_REC and PDO_RxCommParam_*XXh*_REC (Index number 1800$_h$ .. 18FF$_h$ resp. 1400$_h$ .. 14FF$_h$).
- PDO mapping parameter describing the mapping of the objects contained in PDO payload to object dictionary entries.
  PDO mapping parameter are held by the objects PDO_TxMappParam_XXh_AU64 and PDO_RxMappParam_XXh_AU64 (Index number 1A00$_h$ .. 1AFF$_h$ resp. 1600$_h$ .. 16FF$_h$).

Corresponding PDO communication and mapping parameters shall be identified by equal low byte values of the index numbers. TPDO and RPDO object pairs shall be distinguished.

The mapping of application objects into a PDO may be transmitted to a device during the device configuration process by applying the SDO services to the corresponding entries of the Object Dictionary.

Regarding the complete network, TPDO and RPDO mappings applied to a dedicated isochronous frame may be different. Especially in producer/consumer relationships using PRes frames, individual objects mapped by the TPDO mapping of the producer may be targeted to different consumers. The RPDO mapping of a consumer may skip objects not targeted to it.

6.4.1 PDO Mapping Limitations

PDO mapping description may require a large amount of memory. Other restriction may derive from the internal structure of a device, e.g. buffer size, interfaces etc.

Devices may limit the amount of PDO data to be transmitted and received per POWERLINK cycle.

A device shall not impose restrictions on the sequence of mapped objects within a PDO.

6.4.1.1 TPDO Mapping Limitations

Transmit PDO description amount may be limited in following ways:

- The maximum number of supported TPDO channels may be indicated by D_PDO_TPDOChannels_U16. It limits the number of PDO_TxCommParam_XXh_REC and PDO_TxMappParam_XXh_AU64 objects.
- The maximum number of mapped objects per TPDO channel may be indicated by D_PDO_TPDOChannelObjects_U8. It limits the number of PDO_TxMappParam_XXh_AU64 sub-indices.
- An overall limit to the number of mapped objects regardless their distribution to channels may be indicated by D_PDO_TPDOOverallObjects_U16. It provides an upper limit to the sum of the TPDO objects of all channels.
- D_PDO_TPDOChannels_U16, D_PDO_TPDOChannelObjects_U8 and D_PDO_TPDOOverallObjects_U16 may be combined. If one of the values violates a calculatoric limit given by the other ones it shall be ignored.

  *Ex*ample: D_PDO_TPDOChannels_U16 *and* D_PDO_TPDOChannelObjects_U8 *together provide an upper limit to the overall number of available mapping object entries. If D_PDO_TPDOOverallObjects_U16 is greater than the product of* D_PDO_TPDOChannels_U16 *and* D_PDO_TPDOChannelObjects_U8*, it shall be ignored.*

TPDO limits caused by the internal structure of a device shall indicated as following:

- On a per telegram base, TPDO may be limited by
  - TX buffer size,
  - the bandwidth of an internal interface, that transport complete TPDO payload from application to POWERLINK stack
  - etc.

  Such kind of limits shall be indicated by NMT_CycleTiming_REC.IsochrTxMaxPayload_U16.
- On a per cycle base, TPDO data amount may be limited by the bandwidth of an internal interface that transports all TPDO data that shall be transmitted during a cycle. D_PDO_TPDOCycleDataLim_U32 shall indicate such kind of limit.

  It is assumed that TPDO telegram generation is performed on the POWERLINK stack side of the interface. TPDO objects mapped to multiple TPDO channels shall be transported once over the interface and distributed to the channels on the POWERLINK stack side. Thus they shall be once taken into account when calculating the bandwidth.

6.4.1.2 RPDO Mapping Limitations

Receive PDO description amount may be limited in following ways:

- The maximum number of supported RPDO channels may be indicated by D_PDO_RPDOChannels_U16. It limits the number of PDO_RxCommParam_XXh_REC and PDO_RxMappParam_XXh_AU64 objects.
- The maximum number of mapped objects per RPDO channel may be indicated by D_PDO_RPDOChannelObjects_U8. It limits the number of PDO_RxMappParam_XXh_AU64 sub-indices.

- An overall limit to the number of mapped objects regardless their distribution to channels may be indicated by D_PDO_RPDOOverallObjects_U16. It provides an upper limit to the sum of the RPDO objects of all channels.
- D_PDO_RPDOChannels_U16, D_PDO_RPDOChannelObjects_U8 and D_PDO_RPDOOverallObjects_U16 may be combined. If one of the values violates a calculatoric limit given by the other ones it shall be ignored.

  Example: refer 6.4.1.1

RPDO limits caused by the internal structure of a device shall indicated as following:

- On a per telegram base, RPDO may be limited by
  - RX buffer size,
  - the bandwidth of an internal interface, that transport complete RPDO payload from POWERLINK stack to application
  - etc.

  Such kind of limits shall be indicated by NMT_CycleTiming_REC.IsochrRxMaxPayload_U16.
- On a per cycle base, RPDO data amount may be limited by the bandwidth of an internal interface that transports all RPDO data that have been received during a cycle. D_PDO_RPDOCycleDataLim_U32 shall indicate such kind of limit.

6.4.1.3 Further Limitations

The overall memory consumption of the objects defining the mapping (PDO_TxMappParam_XXh_AU64, PDO_TxCommParam_XXh_REC, PDO_RxMappParam_XXh_AU64 and PDO_RxCommParam_*XXh*_REC) may be limited. The limit is given by D_PDO_MaxDescrMem_U32. The size is calculated as follows:

- Each object PDO_TxCommParam_XXh_REC whose mapping is activated (PDO_TxMappParam_XXh_AU64.NumberOfEntries is not equal to 0) uses 2 Bytes.
- Each object PDO_RxCommParam_XXh_REC whose mapping is activated (PDO_RxMappParam_XXh_AU64.NumberOfEntries is not equal to 0) uses 2 Bytes.
- Each object PDO_TxMappParam_XXh_AU64 uses PDO_TxMappParam_XXh_AU64.NumberOfEntries * 8 Bytes.
- Each object PDO_RxMappParam_XXh_AU64 uses PDO_RxMappParam_XXh_AU64.NumberOfEntries * 8 Bytes.

The sum of these sizes must not exceed D_PDO_MaxDescrMem_U32.

The minimum size of mapped objects may be indicated by D_PDO_Granularity_U8. The mapped offset shall be a multiple of the granularity.

6.4.2 PDO Mapping Version

Compatibility of TPDO channels and corresponding RPDO channels may be ensured by PDO mapping version handling.

PDO mapping version is held by PDO_TxCommParam_XXh_REC.MappingVersion_U8 and PDO_RxCommParam_*XXh*_REC.MappingVersion_U8. Tab. 91 shows the PDO mapping main and sub version encoding.

High nibble	**Low nibble**
Main version	Sub version

Tab. 91 Structure of PDO Mapping version

The assigned value of the PDO Mapping version is application specific.

If the PDO Mapping is changed in a compatible manner e.g. expanding the PDO contents, the sub version shall be incremented.

PDO Mapping may be variable or static. Variable mapping may be dynamically modified by the application, even under operation. Static mapping is pre-defined and may not be modified in any way.

Support of variable mapping shall be indicated by NMT_FeatureFlags_U32 Bit 6 and D_PDO_DynamicMapping_BOOL.

To control compatibility of PDO mapping, PDO_TxCommParam_XXh_REC.MappingVersion shall be set. The version info shall be transmitted by the master or producer with every PDO transporting PReq and PRes frame (s. 4.6.1.1.3 resp. 4.6.1.1.4).

The PDO slave or consumer shall check the mapping version of received PDOs using the corresponding PDO_RxCommParam_*XXh*_REC.MappingVersion entry. PDOs with differing main version shall be ignored. PDOs with equal main version but differing sub version shall be accepted.

A PDO mapping version value of 0 indicates that there is no mapping version available. This does not disable the version check. If the mapping version in the received PDO is 0 the corresponding PDO_RxCommParam_*XXh*_REC.MappingVersion entry shall be 0 too and vice versa. Otherwise the received mapping is ignored.

6.4.3 SDO via PDO Container

A container may be used by the PDO mapping to enable exchange of SDO data via PDO communication channels.

See 6.3.3 for detailed description of SDO embedded in PDO.

The type of container is defined by a referencing object at index SDO_ServerContainerParam_*XXh*_REC or SDO_ClientContainerParam_*XXh*_REC

6.4.4 Transmit PDOs

If sub-index 0 of the mapping object (PDO_TxMappParam_XXh_AU64) is 0 the TPDO is invalid. The RD flag of the TPDO transporting Frame shall be reset. (refer Tab. 105 or 7.1.4)

Sending PDO data is implicitly isochronous for a node in the state NMT_CS_OPERATIONAL and NMT_MS_OPERATIONAL. In NMT_CS_READY_TO_OPERATE and NMT_MS_READY_TO_OPERATE, PDO data are sent in the same way, but they are not valid. The RD flag of the TPDO transporting Frame shall be reset..

6.4.5 Receive PDOs

RPDO data shall be valid if the RD flag of the RPDO transporting frame is set in the state NMT_CS_OPERATIONAL and NMT_MS_OPERATIONAL. The data shall be occurred to the objects assigned by the RPDO mapping parameters. The application may access the received PDO data by reading these objects.

If the RD flag is not set in the received message, the mapping shall not be performed, e.g. the data shall not be copied to the mapped objects. The application shall further make use of the old data earlier received. RD flag signaling to the application shall be implementation specific.

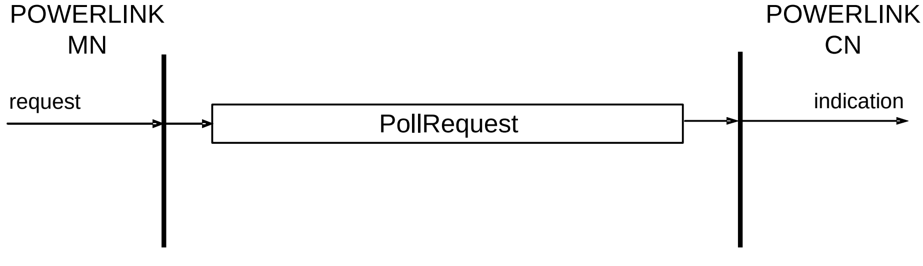
In NMT states not equal NMT_CS_OPERATIONAL resp. NMT_MS_OPERATIONAL, RPDO data shall be invalid and shall be ignored.

If the length of the data actually received is less than the length of the mapped objects or if the received and the expected PDO mapping versions differ in an incompatible manner the received data has to be ignored and a fault situation occurs.

6.4.6 PDO via PReq

PDO via PReq transmission follows the master/slave relationship as described in 2.3.1.

PDO via PReq is carried out according to the following protocol.



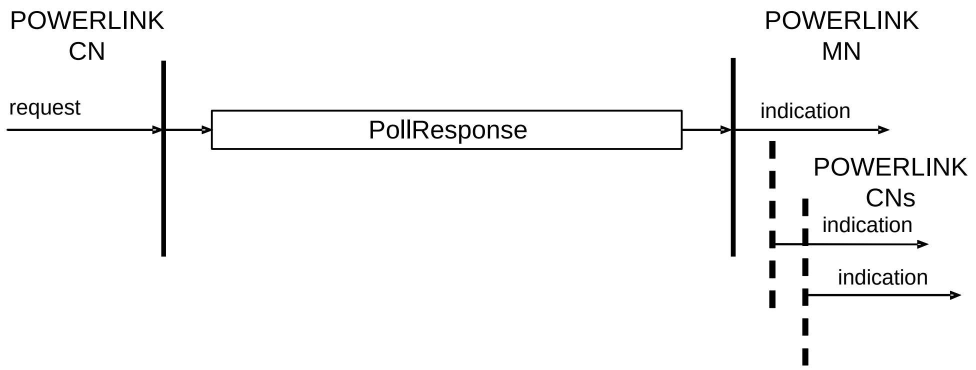
The following data elements in the PReq frame (for the frame structure see 4.6.1.1.3) are relevant for PDO transport:

- The RD flag indicates if the PDO data is valid. If the bit is 0_b, the PDO data is not valid and shall not be interpreted by the POWERLINK CN.
- Size indicates the user data length of the PDO payload data.
- Payload indicates the PDO data.

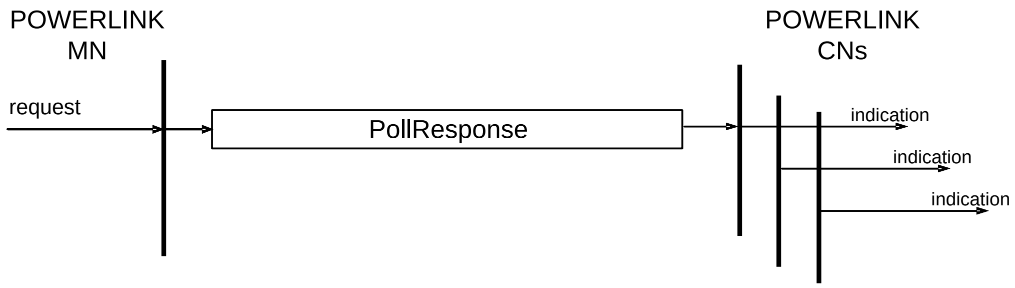
6.4.7 PDO via PRes

PDO via PRes transmission follows the producer/consumer relationship as described in 2.3.3.

PDO via PRes from a CN is carried out according to the following protocol.



PDO via PRes from the MN is carried out according to the following protocol.



The following data elements in the PRes frame (for the frame structure see 4.6.1.1.4) are relevant for PDO transport:

- The RD flag indicates if the PDO data is valid. If the bit is 0_b, the PDO data is not valid and shall not be interpreted by the POWERLINK CN.
- Size indicates the user data length of the PDO payload data.
- Payload indicates the PDO data.

6.4.8 PDO Error Handling

6.4.8.1 Dynamic Errors

6.4.8.1.1 Incompatible Mapping

If an incompatible PDO Mapping version is received, the PDO shall be ignored.

This error situation shall be logged and signaled to the application. Typically this error occurs many times, so the error shall be logged and signaled once for every received wrong PDO mapping version. The bit corresponding to the error causing node may be set to 1_b in PDO_ErrMapVers_OSTR.

Error code	Description
E_PDO_MAP_VERS	PDO with wrong Mapping version received, PDO ignored

6.4.8.1.2 Unexpected End of PDO

If a PDO is received which is shorter than the amount of mapped objects, the PDO shall be ignored.

This error situation shall be logged and signaled to the application. Normally this error occurs many times, so the error shall be logged and signaled once for each PDO. The bit corresponding to the error causing Node may be set to 1_b in PDO_ErrShort_RX_OSTR.

Error code	Description
E_PDO_SHORT_RX	RX PDO length too short, PDO ignored

6.4.8.2 Configuration Errors

If an attempt to change the PDO mapping results in a memory consumption of mapped objects that exceeds the configured payload size limits NMT_CycleTiming_REC.IsochrRxMaxPayload_U16 or NMT_CycleTiming_REC.IsochrTxMaxPayload_U16, this attempt shall be rejected anyway.

If only the limit NMT_CycleTiming_REC.PReqActPayloadLimit_U16 or NMT_CycleTiming_REC. PResActPayloadLimit_U16 is violated the mapping shall be activated. However the RD flag shall be reset resp. the received data shall be ignored.

If any of the limits introduced in 6.4.1 is violated, the attempt shall be rejected too.

The memory size check shall be done when a mapping is enabled by writing the number of mapped objects to PDO_RxMappParam_XXh_AU64.NumberOfEntries or PDO_TxMappParam_XXh_AU64. NumberOfEntries. .

Error code	Description
E_PDO_MAP_OVERRUN	Mapping exceeds payload size or mapped object number limit

6.4.9 Object Description

6.4.9.1 Object 1400_h .. $14FF_h$: PDO_RxCommParam_*XXh*_REC

This description handles a sequence of up to 256 objects. These indices describe the communication attributes of the RPDO channels. Mapping version and address information are provided.

The number of objects may be less than 256 (refer 6.4.1). Objects shall be implemented starting at Index 1400_h.

The validity of the respective object depends on the NumberOfEntries_U8 entry of the corresponding (s. 6.3.4) RPDO mapping index PDO_RxMappParam_XXh_AU64.

To change the PDO communication parameter, the PDO shall be deactivated by setting PDO_RxMappParam_XXh_AU64.NumberOfEntries to 0. To enable modifications, PDO_RxMappParam_XXh_AU64.NumberOfEntries shall be set to a value not equal 0.

Index	1400_h .. $14FF_h$	Object Type	RECORD
Name	PDO_RxCommParam_XXh_REC		
Data Type	PDO_CommParamRecord_TYPE	Category	Cond

To allow access by name, "_*XXh*" shall be replaced by a name index. Name index shall be "_00h" if object index is 1400_h. It shall be incremented up to "_FFh" corresponding to object index $14FF_h$.

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	2	Access	const
Default Value	2	PDO Mapping	No

- **Sub-Index 01_h: NodeID_U8**

Sub-Index	01_h		
Name	NodeID_U8		
Data Type	UNSIGNED8	Category	M
Value Range	0, 1 .. 254	Access	rws
Default Value	-	PDO Mapping	No

Node ID of the node transmitting the corresponding PRes. Valid Node IDs shall be determined by NMT_NodeAssignment_AU32 [Node ID] Bits 0 and 8.

Node ID entry 0 is reserved for PReq received by a CN.

Node ID entry C_ADR_SELF_ADR_NODE_ID shall indicate mapping of the RPDO to the TPDO describing the locally transmitted PRes frame. This Node ID always refers to the locally transmitted PRes, independent of the local Node ID setting.

The local Node ID may be also used to indicate the reception of self-transmitted PDO (e.g. Node ID 3). But in this case the mapping is fixed to this Node ID. If the local Node ID changes (e.g. from 3 to 4), the mapping still refers to the PRes of Node ID 3

Receipt of self-transmitted PDO is optional. It shall be indicated by the device description entry D_PDO_SelfReceipt_BOOL.

- **Sub-Index 02_h: MappingVersion_U8**

Sub-Index	02_h		
Name	MappingVersion_U8		
Data Type	UNSIGNED8	Category	M
Value Range	UNSIGNED8	Access	rws / ro
Default Value	-	PDO Mapping	No

Access shall be ro if only static mapping is provided by the device.

6.4.9.2 Object 1600_h .. $16FF_h$ PDO_RxMappParam_XXh_AU64

This description handles a sequence of up to 256 objects. These indices describe the mapping of the objects contained in RPDO payload to object dictionary entries.

The number of objects and subindices may be limited (refer 6.4.1). Objects shall be implemented starting at Index 1600_h.

To change the PDO mapping, the PDO shall be deactivated by setting NumberOfEntries to 0. The new mapping may then be given by writing object mapping entries to sub-index 1 and higher. To enable the PDO mapping again, NumberOfEntries shall be set to the number of the highest sub-index containing the object mapping to be activated. When the mapping is enabled, it shall be verified, that the cumulative length of all mapped objects does not violate the payload size limit NMT_CycleTiming_REC.IsochrRxMaxPayload_U16 and on the CN additionally the limit NMT_CycleTiming_REC.PReqActPayloadLimit_U16 for the PReq frame. For the appropriate error handling see 6.4.8.2.

On some device, add or remove entries to or from the current list of mapping entries may be performed by modifying NumberOfEntries without effecting the ObjectMapping sub-indices. To do so, NumberOfEntries shall be set to 0 before writing the new NumberOfEntries value.

Default mapping values may be provided by the device profile.

Index	1600$_h$ .. 16FF$_h$	Object Type	ARRAY
Name	PDO_RxMappParam_XXh_AU64		
Data Type	UNSIGNED64	Category	Cond

To allow access by name, "_*XXh*" shall be replaced by a name index. Name index shall be "_00h" if object index is 1600$_h$. It shall be incremented up to "_FFh" corresponding to object index 16FF$_h$.

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	0, 1 .. 254	Access	rws
Default Value	-	PDO Mapping	No

Number of mapped objects. 0 indicates that the mapping index and the corresponding RPDO communication index (6.4.9.1) is deactivated.

On devices providing only static mapping, the value shall be set to the number of entries corresponding to the static mapping or 0.

Note: By this it is also possible to activate / deactivate (0) a static mapping.

- **Sub-Index 01$_h$ .. FE$_h$: ObjectMapping**

Sub-Index	01$_h$ .. FE$_h$		
Name	ObjectMapping		
--	--	Category	O
Value Range	UNSIGNED64	Access	rws / ro
Default Value	-	PDO Mapping	No

Access shall be ro if only static mapping is provided by the device.

- **Sub-Index 01$_h$ .. FE$_h$ Value Interpretation**

For every PDO channel up to 254 objects may be mapped.

The offset related to the start address of the PDO payload and the length of data shall be provided for every mapped object.

Octet Offset	Name	Description
0 – 1	Index	Index of the object to be mapped
2	Sub-index	Sub-index of the object to be mapped
3	reserved	for alignment purpose
4 – 5	Offset	Offset related to start of PDO payload (Bit count)
6 – 7	Length	Length of the mapped object (Bit count)

Tab. 92 Structure of PDO Mapping Entry

Tab. 93 shows the internal bit mapping of an object mapping entry. See 6.1.4.5 for information about data type encoding for transmission purpose.

	UNSIGNED64				
	MSB				**LSB**
Bits	63 .. 48	47 .. 32	31 .. 24	23 .. 16	15 .. 0
Name	Length	Offset	reserved	Sub-index	Index
Encoding	UNSIGNED16	UNSIGNED16	-	UNSIGNED8	UNSIGNED16

Tab. 93 Internal bit mapping of PDO mapping entry

Mapped objects of length ≥ 8 Bits shall be aligned to a byte boundary offset.

Overlapping of mapped objects should be avoided.

The following example shows the mapping interpretation:

Index 6000$_h$, Sub-index 4 with a data length of 8 bit shall be mapped to offset 16 [bit].

Bits	63 .. 48	47 .. 32	31 .. 24	23 .. 16	15 .. 0
Name	Length	Offset	reserved	Sub-index	Index
Data	8	16	0	4	6000_h

The object above is mapped with the following value (big endian):

- *$0008.0010.00.04.6000_h$*

It is transmitted in the following order (little endian):

- *$0060.04.00.1000.0800_h$*

6.4.9.3 Object 1800_h .. $18FF_h$ PDO_TxCommParam_XXh_REC

This description handles a sequence of up to 256 objects. These indices describe the communication attributes of the TPDO channels. Mapping version and address information are provided.

As a CN has only one TPDO channel, only the first index PDO_TxCommParam_XXh_REC shall be implemented on a CN.

On the MN, the number of objects may be less than 256 (refer 6.4.1).

Objects shall be implemented starting at Index 1800_h.

The validity of the respective object depends on the NumberOfEntries_U8 entry of the corresponding (s. 6.3.4) TPDO mapping index PDO_TxMappParam_XXh_AU64.

To change the PDO communication parameter, first the PDO has to be deactivated by means of setting PDO_TxMappParam_XXh_AU64.NumberOfEntries to 0. To enable modifications, PDO_TxMappParam_XXh_AU64.NumberOfEntries shall be set to a value not equal to 0.

Index	1800_h .. $18FF_h$	Object Type	RECORD
Name	PDO_TxCommParam_XXh_REC		
Data Type	PDO_CommParamRecord_TYPE	Category	Cond

To allow access by name, "*_XXh*" shall be replaced by a name index. Name index shall be "_00h" if object index is 1800_h. It shall be incremented up to "_FFh" corresponding to object index $18FF_h$.

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	2	Access	const
Default Value	2	PDO Mapping	No

- **Sub-Index 01_h: NodeID_U8**

Sub-Index	01_h		
Name	NodeID_U8		
Data Type	UNSIGNED8	Category	M
Value Range	0, 1 .. 254	Access	rws
Default Value	-	PDO Mapping	No

Node ID of the PDO target:

- CN: not used (0)
- MN: Node ID of the PReq target (CN). Valid Node IDs shall be released by NMT_NodeAssignment_AU32 [Node ID] Bits 0 and 8.
  Node ID entry 0 shall indicate multicast PRes transmitted by the MN.

- **Sub-Index 02_h: MappingVersion_U8**

Sub-Index	02_h		
Name	MappingVersion_U8		
Data Type	UNSIGNED8	Category	M
Value Range	UNSIGNED8	Access	rws / ro
Default Value	-	PDO Mapping	No

Access shall be ro if only static mapping is provided by the device.

6.4.9.4 Object $1A00_h$ .. $1AFF_h$ PDO_TxMappParam_XXh_AU64

This description handles a sequence of up to 256 objects. These indices describe the mapping of the objects contained in TPDO payload to object dictionary entries.

As a CN has only one TPDO channel, only the first index PDO_TxMappParam_XXh_AU64 shall be implemented on a CN.

On the MN, the number of objects may be less than 256 (refer 6.4.1).

Objects shall be implemented starting at Index $1A00_h$.

The number of subindices may be limited (refer 6.4.1).

To change the PDO mapping, the PDO shall be deactivated by setting NumberOfEntries to 0. The new mapping may then be given by writing object mapping entries to sub-index 1 and higher. To enable the PDO mapping again, NumberOfEntries shall be set to the number of the highest sub-index containing the object mapping to be activated. When the mapping is enabled, it shall be verified, that the cumulative length of all mapped objects does not violate the payload size limit NMT_CycleTiming_REC.IsochrTxMaxPayload_U16 and additionally the limit NMT_CycleTiming_REC.PResActPayloadLimit_U16 for the Pres frame. For the appropriate error handling see 6.4.8.2.

On some device, add or remove entries to or from the current list of mapping entries may be performed by modifying NumberOfEntries without effecting the ObjectMapping sub-indices. To do so, NumberOfEntries shall be set to 0 before writing the new NumberOfEntries value.

Default values may be provided by the device profile.

Index	$1A00_h$ .. $1AFF_h$	Object Type	ARRAY
Name	PDO_TxMappParam_XXh_AU64		
Data Type	UNSIGNED64	Category	Cond

To allow access by name, “*_XXh*” shall be replaced by a name index. Name index shall be “_00h” if object index is $1A00_h$. It shall be incremented up to “_FFh” corresponding to object index $1AFF_h$.

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	0, 1 .. 254	Access	rws
Default Value	-	PDO Mapping	No

0 indicates that the mapping index and the corresponding TPDO communication index (6.4.9.1) is deactivated. The RD flag of the TPDO transporting frame shall be reset (TPDO is invalid).

On devices only providing static mapping, the value shall be set to the number of entries corresponding to the static mapping or 0.

Note: By this it is also possible to activate / deactivate (0) a static mapping.

- **Sub-Index 01_h .. FE_h: ObjectMapping**

Sub-Index	01_h .. FE_h		
Name	ObjectMapping		
--	--	Category	O
Value Range	UNSIGNED64	Access	rws / ro
Default Value	-	PDO Mapping	No

Access shall be ro if only static mapping is provided by the device.

- **Sub-Index 01_h .. FE_h Value Interpretation**

see PDO_RxMappParam_XXh_AU64.ObjectMapping Value Interpretation (6.4.9.2)

6.4.9.5 Object $1C80_h$: PDO_ErrMapVers_OSTR

This object contains a list of all the nodes, sending a wrong mapping version (see 6.4.8.1.1).

The bits are arranged in the node list format (refer 7.3.1.2.3). If a wrong mapping version is detected, the bit corresponding to the node transmitting the PDO, shall be set to 1_b. Reset shall be handled by the application.

Hint: A configuration tool shall refresh the object to avoid erroneously pending error indication.

Index	$1C80_h$	Object Type	VAR
Name	PDO_ErrMapVers_OSTR		
Data Type	OCTET_STRING32	Category	O
Value Range	-	Access	rw
Default Value	0	PDO Mapping	No

6.4.9.6 Object $1C81_h$: PDO_ErrShort_RX_OSTR

This object contains a list of all the nodes, sending a too short PDO (see 6.4.8.1.2).

The bits are arranged in the node list format (refer 7.3.1.2.3). If a short PDO is detected, the bit corresponding to the node transmitting the PDO, shall be set to 1_b. Reset shall be handled by the application.

Hint: A configuration tool shall refresh the object to avoid erroneously pending error indication.

Index	$1C81_h$	Object Type	VAR
Name	PDO_ErrShort_RX_OSTR		
Data Type	OCTET_STRING32	Category	O
Value Range	-	Access	rw
Default Value	0	PDO Mapping	No

6.4.9.7 Object 0420_h: PDO_CommParamRecord_TYPE

Index	0420_h	Object Type	DEFSTRUCT
Name	PDO_CommParamRecord_TYPE		
Sub-Index	Component Name	Value	Data Type
00_h	NumberOfEntries	02_h	
01_h	NodeID_U8	0005_h	UNSIGNED8
02_h	MappingVersion_U8	0005_h	UNSIGNED8

6.5 Error Signaling

This chapter describes how to record errors and events which are generated by a POWERLINK Node and the procedure how a CN shall indicate and transfer errors/events to the MN.

All communication layers as well as the application shall have access to the Error Signaling.

The Data Link Layer of a CN shall query the Error Signaling cyclically for new StatusResponse data.

If there was no change in the Static Error Bit Field and the Status Entries since the last query from the DLL and the Emergency Queue is empty, the Error Signaling shall not provide data to the DLL.

If there was a change or the Emergency Queue is not empty the Error Signaling shall generate new StatusResponse data and pass it to the DLL at the next query.

- Static Error Bit Field : 8 Bytes, see 6.5.8.1
- Error Entry: 20 Bytes / Entry, see Tab. 94

If the Emergency Queue is used, the space for at least 1 History Entry shall be available in the StatusResponse frame. This History Entry may not contain emergency data to make sure the CN can transmit the Emergency Queue entries to the MN.

Emergency Queue support is optional. D_NMT_EmergencyQueueSize_U32 indicates support (D_NMT_EmergencyQueueSize_U32 > 0) and queue size.

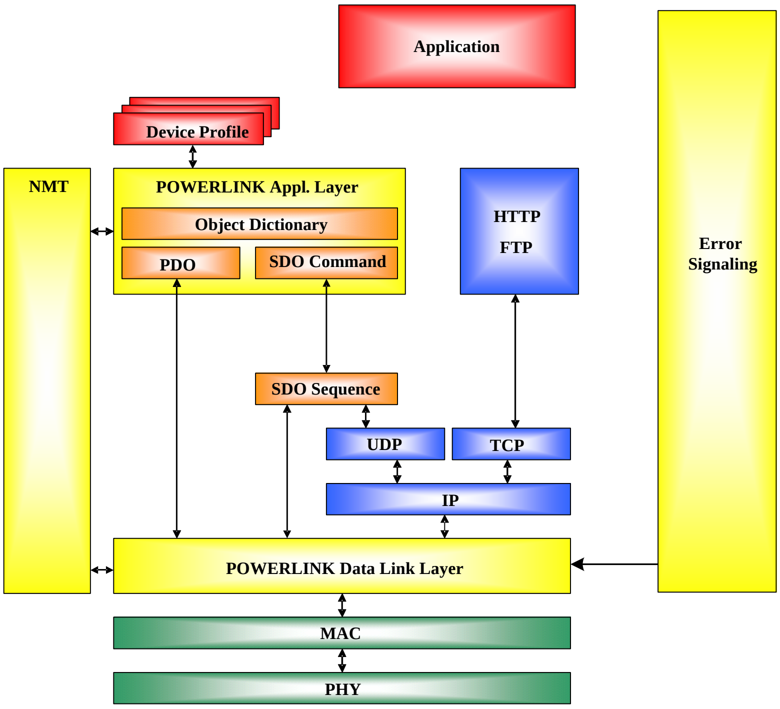


Fig. 67. Error signaling – Reference model

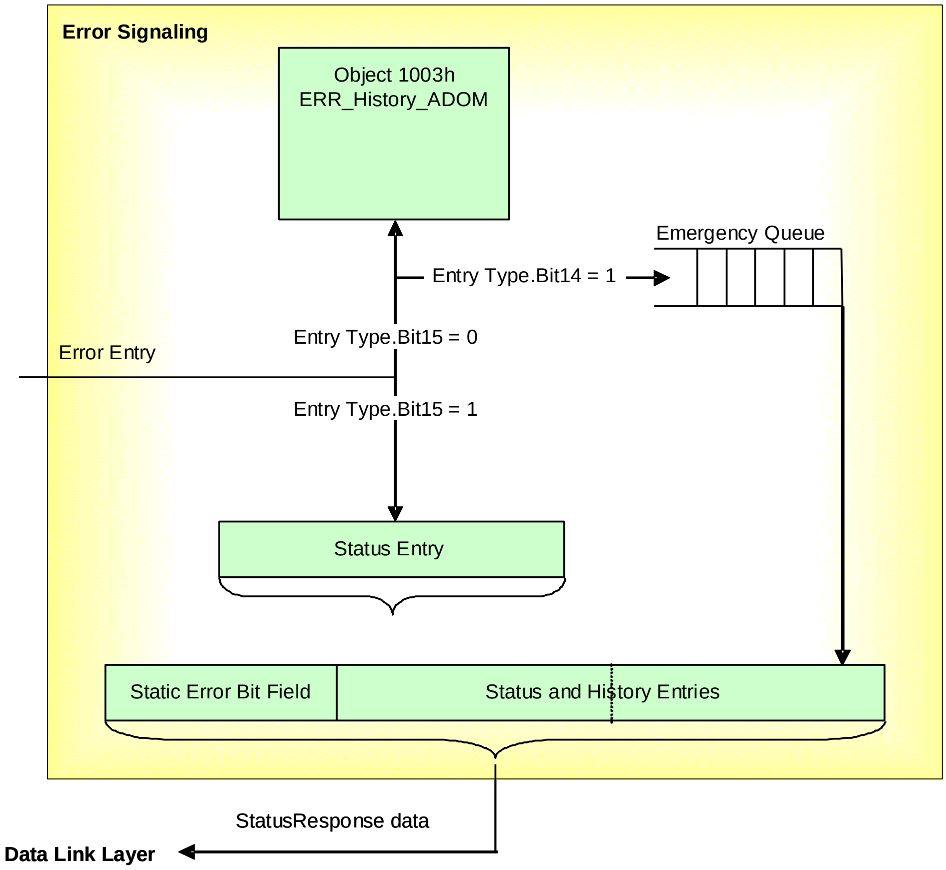


Fig. 68. Error signaling – Overview

6.5.1 Error Entry

This chapter describes the function and the data format of an Error Entry listed in the Error History object 1003h ERR_History_ADOM or the StatusResponse.

The Error History object holds the errors and events that have occurred on the device..

An ErrorEntry_DOM has the following format:

Octet Offset	Description
0 .. 1	Entry Type
2 .. 3	Error Code
4 .. 11	Time Stamp
12 .. 19	Additional Information

Tab. 94 Format of one entry

Field	Abbr.	Description	Value
Entry Type	type	see Tab. 96	UNSIGNED16
Error Code	code	Depending on the Entry Type the error codes are described in the device profiles , device descriptions or the communication profile. Communication profile specific error codes are described in App. 3.9.	UNSIGNED16
Time Stamp	time	SoC Nettime from the cycle when the error/event was detected.	NETTIME
Additional Information	add	This field contains device profile or vendor specific additional error information.	UNSIGNED64

Tab. 95 Description of one entry

All elements of the Error Entry shall be stored and transferred in little endian format.

Octet	Bit	Value	Description
0 .. 1	15 (status)	0_b	ERR_History_ADOM Entry
		1_b	Status Entry in StatusResponse frame (Bit 14 shall be set to 0_b)
	14 (send)	0_b	ERR_History_ADOM only
		1_b	Additional to the ERR_History_ADOMthe entry shall also be entered in to the Emergency Queue of the Error Signaling.
	13 .. 12 (mode)	0_h	Not allowed in ERR_History_ADOM. Entries with this mode may only be used by the Error Signaling itself to indicate the termination of the History Entries in the StatusResponse frame.
		1_h	An error has occurred and is active (e.g. short circuit of output detected)
		2_h	An active error was cleared (e.g. no short circuit anymore) (not allowed for Status Entries)
		3_h	An error / event occurred (not allowed for Status Entries)
	11 .. 0 (profile)	000_h	Reserved
		001_h	The field Error Code in Tab. 94 contains a vendor specific error code
		002_h	The field Error Code in Tab. 94 contains POWERLINK communication profile specific errors which are listed in App. 3.9 (Network errors, communication errors, data link errors …)
		003_h .. FFF_h	The field Error Code in Tab. 94 contains device profile specific errors. e.g. 191h … CiA 401, Device Profile for Generic IO Modules 192h … CiA 402, Drive Profile

Tab. 96 Format of the field entry type

6.5.2 Interface to Error Signaling

Any layer of the MN or CN which intends to generate an Error Entry shall provide the following information to the Error Signaling:

- Entry Type (all fields shall be provided, see Tab. 96)
- Error Code (see Tab. 94)
- Additional Information (see Tab. 94)

6.5.3 Processing of CN Error Information on the MN

History or Status Entries received from CNs shall be passed to the application layer.

6.5.4 Error Signaling Bits

To avoid that the MN has to poll ERR_History_ADOM for changes, the following mechanism shall inform the MN when the Static Error Bit Field, the Status Entries or the History Entries of the CN StatusResponse frame have changed.

The following bits shall be used for a confirmed transmission from the CN to the MN:

Field	**Abbr.**	**Description**
Exception Reset	ER	Initialisation of the Error Signaling When a CN receives the value 1_b it shall reset its EN bit to 0_b and clear the Emergency Queue. The MN shall send the ER bit with the following frame: SoA(StatusRequest)
Exception Clear	EC	In this bit the CN shall mirror the last received ER from the MN. This is required to indicate the MN that the initialisation of the Error Signaling was done. A CN shall send the EC bit with the following frame: Asnd(StatusResponse)
Exception New	EN	By toggling this bit the CN informs the MN that the Static Error Bit Field or the Status Entries have changed or that new History Entries are available in the StatusResponse frame. A CN shall send the EN bit with the following frames: Pres Asnd(StatusResponse) For isochronous CNs the MN shall evaluate the EN bit of the Asnd(StatusResponse) only in NMT_CS_PRE_OPERATIONAL_1.
Exception Acknowledge	EA	When the MN detects that the last sent EA bit is different to the last received EN bit it shall send a StatusRequest frame to the CN. After the StatusResonse frame was successfully received by the MN, it shall set EA=EN. When the bit is transferred to the CN the next time, the CN knows that it may generate a new StatusResponse frame and toggle the EN bit again. The MN shall send the EA bit with the following frames: Preq SoA(StatusRequest) Isochronous CNs shall evaluate the EA bit of the SoA(…) only in NMT_CS_PRE_OPERATIONAL_1.

Tab. 97 Error signaling bits

A CN shall only evaluate the ER and EA flags of the respective SoA(…) frames when the RequestedServiceTarget is the CNs POWERLINK Node ID.

6.5.5 Initialisation

With this initialisation the MN shall prepare the CN for the Error Signaling.

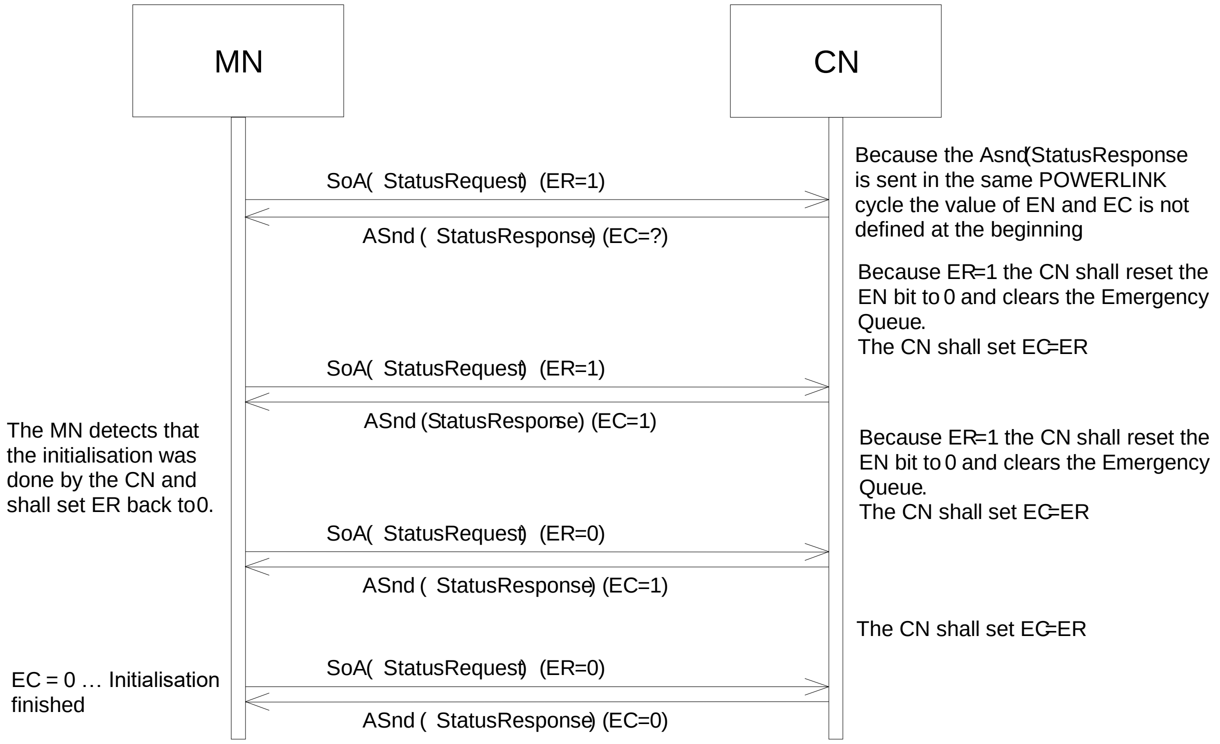


Fig. 69. Error signaling initialisation

6.5.5.1 Startup value and behaviour of the EC flag

At startup (NMT_GT1, NMT_GT2 or NMT_GT8) the CN shall reset the Error Signaling and set EC=1.

The CN shall not change the EC flag before at least 1 valid frame with ER=1 was received.

This regulation is necessary for the following case :

- The MN completes the initialisation until ER=0, the CN is still in NMT_CS_PRE_OPERATIONAL_1
- The CN has a power fail and starts up again. The next received frame from the MN contains ER=0 … Now the CN shall respond with EC=1 to show the MN that the Error Signaling is not initialised.
- The MN shall restart the intialization of the Error Signaling

Other NMT transitions shall not automatically initialise the Error Signaling in order to allow the MN to receive emergency messages even if the NMT state of the CN changes for e.g. to NMT_GS_INITIALISATION because of any reason.

The Error Signaling shall only be initialised by NMT_GT1, NMT_GT8, NMT_GT2 or explicit Error Signaling reset by the MN (ER=1).

6.5.6 Error Signaling with Preq and Pres frames

For isochronous CNs only the Preq and Pres frames shall be used for the Error Signaling.

If an isochronous CN is in the state NMT_CS_PRE_OPERATIONAL_1 the Error Signaling shall behave like an Async-only CN (6.5.7)

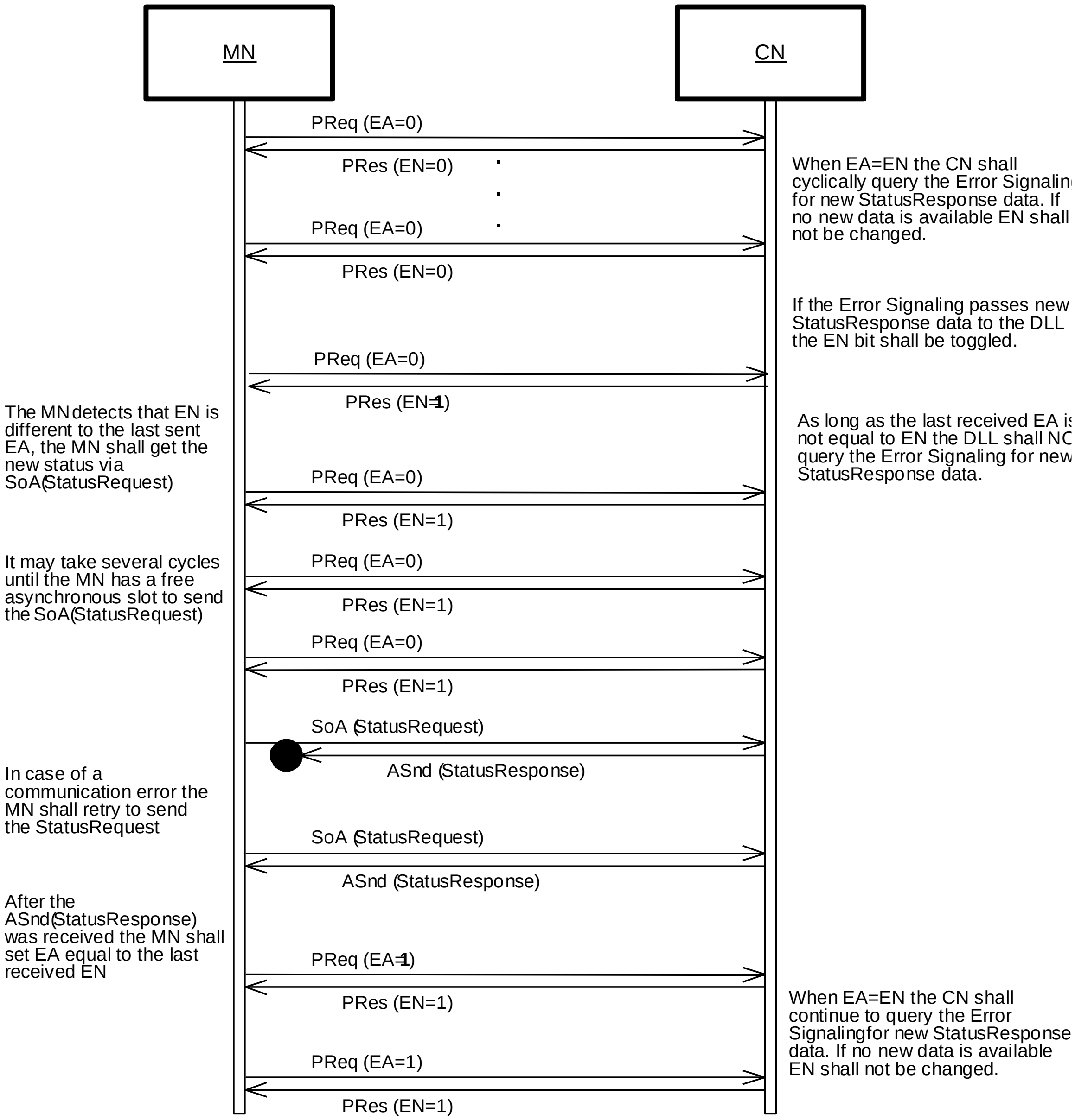


Fig. 70. Error signaling with Preq and Pres

6.5.7 Error Signaling with Async-only CNs

Async only CNs are periodically requested by the MN.

This shall be also done for isochronous CNs in NMT_CS_PRE_OPERATIONAL_1.

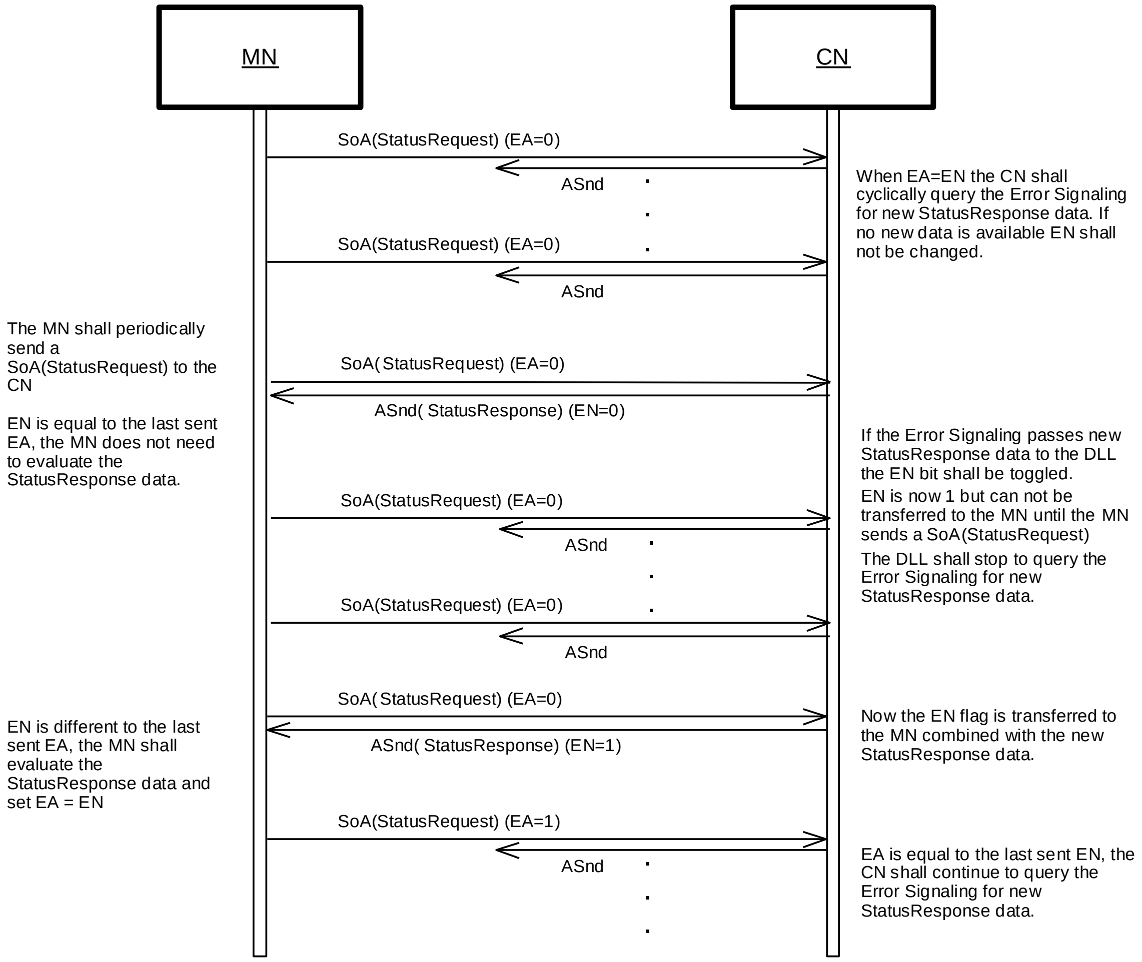


Fig. 71. Error signaling for Async-only CNs and CNs in state NMT_CS_PRE_OPERATIONAL_1

6.5.8 Format of StatusResponse Data

Refer to 7.3.3.3.1 for StatusResponse frame structure.

6.5.8.1 Static Error Bit Field

Octet Offset[20]	Description
6	Content of ERR_ErrorRegister_U8
7	Reserved
8 .. 13	Device profile or vendor specific errors

Tab. 98 Static error bit field

6.5.8.2 Status and History Entries

If not all available entries of the StatusResponse are used, an entry with Mode 0 (see Tab. 96) shall be used to terminate the History and Status Entry list and declare this and all following entries as unused.

The CN may also change the length of the StatusResponse frame to fit the required Status and History fields. In this case no entry for termination is required.

[20] Octet offset relates to the beginning of the ASnd service slot (See 7.3.3.3.1)

The number of used Status / History Entries is defined by D_NMT_ErrorEntries_U32 .

Status Entries shall be located in front of the History Entries inside the StatusResponse frame.

6.5.9 Examples

The examples in this chapter are an implementation proposal for the creation of the StatusResponse frames on the CN.

Another buffer handling may be implemented in consideration of the following points:

- The CN shall notify the MN about changes of the StatusResponse frame using the EN bit as shown in 6.5.6 or 6.5.7
- After the CN has indicated new StatusResponse data to the MN by toggling the EN flag, the StatusResponse frame on the CN may not be changed anymore as it can be requested by the MN at any time. Only if the reception of the response is acknowledged by the EA flag of the MN, the CN may change the StatusResponse frame data again.

The following examples make use of the following abbreviations:

Abbreviation	Description
BF	Static Error Bit Field
S	Bit 15 (status) of the Entry Type (see Tab. 94 Format of one entry)
M	Bit 13-12 (mode) of the Entry Type (see Tab. 94 Format of one entry)
C	Error Code (see Tab. 94 Format of one entry)

Tab. 99 Abbreviations for the following examples

The Octet Offsets relates to the beginning of the Ethernet frame.

6.5.9.1 Case 1 – Only Bit Field, No Status/History Entries

This is the most simple implementation of the Error Signaling. Only the Static Error Bit Field is used to signal errors from the CN to the MN.

The length of the StatusResponse frame is fixed and does not change during runtime:

Octet Offset	Description
0 .. 23	Headers
24 .. 31	Static Error Bit Field
32 .. 51	Entry 0 (M=0)
52 .. 71	Entry 1 (M=0)
72 .. 75	Ethernet CRC

Field	Description
Headers	Ethernet / POWERLINK / Asnd(StatusResponse) Header (see 7.3.3.3.1)
Static Error Bit Field	The bit field containing the status information (see 6.5.8.1)
Entry 0, Entry 1	For this example no Status Entry is required. Since the frame must have a minimum length the first two entries can not be removed by shortening the frame. To avoid that the MN processes this data, the field Mode of the Entry Type is 0.

At startup the Error Signaling shall generate 2 identical empty StatusResponse Frames and pass one of them to the Data Link Layer as initial StatusResponse data. A third frame shall be generated for further use.

This frame of the Data Link Layer may be requested by the MN at any time.

- Frame 1: Owner = Error Signaling (May be changed at any time)
- Frame 2: Owner = Data Link Layer
- Frame 3: Owner = Error Signaling (unused until Frame 1 is changed)

If the Static Error Bit Field has changed, the value is copied to frame 3 which will be passed to the Data Link Layer:

- Frame 1: Owner = Error Signaling (May be changed at any time)
- Frame 2: Owner = Data Link Layer (DLL)

- Frame 3: Owner = Error Signaling (Copy of the changed Frame 1, ready to be taken from the DLL)

Now the Error Signaling is not allowed to change this Frame 3 because it can be taken from the Data Link Layer at any time.

The next time the DLL queries for new data the Error Signaling passes Frame 3 to the DLL which shall set the EN flag to signal the MN that new data is available. Frame 2 shall be passed back to the Error Signaling for further use:

- Frame 1: Owner = Error Signaling (May be changed at any time)
- Frame 2: Owner = Error Signaling (unused until Frame 1 is changed)
- Frame 3: Owner = Data Link Layer (DLL)

If the Error Signaling has changed Frame 1 before Frame 2 was passed back it shall immediately create a copy of Frame 1, otherwise it shall wait for the next change of Frame 1 and then create the copy.

- Frame 1: Owner = Error Signaling (May be changed at any time)
- Frame 2: Owner = Error Signaling (Copy of the changed Frame 1, ready to be taken from the DLL)
- Frame 3: Owner = Data Link Layer (DLL)

The sequence continues in this manner and Frame 2/Frame 3 are passed alternatively to the DLL for transmission to the MN. The DLL shall only query the Error Signaling for the next frame if EN=EA, that means the MN has successfully picked up the last changed frame.

6.5.9.2 Case 2 – Status Entries

In this example the CNs are allowed to signal errors using the Static Error Bit Field and/or the Status Entries of the StatusResponse frame.

The frame sequence is the same as in Example 1. Every time the Error Signaling makes changes of the StatusResponse frame content (Static Error Bit Field or in one of the Status Entries) it shall provide a new frame for the DLL which will be I as soon as EN=EA.

Example with 4 Status Entries:

Octet Offset	Description
0 .. 23	Headers
24 .. 31	Static Error Bit Field
32 .. 51	Status Entry 0
52 .. 71	Status Entry 1
72 .. 91	Status Entry 2
92 .. 111	Status Entry 3
112 .. 115	Ethernet CRC

Field	Description
Status Entry 0 .. 3	S=X,M=0 This entry and all following entries are not valid S=1,M=1,C=0 The entry does not contain status information but the next entry is valid S=1.M=1,C>0 The entry contains valid status information

If all 4 status entries contain status information and the CN wants to remove Status Entry 1 and 2 it has two ways to do so.

- Set C of Entry 1 and Entry 2 to 0 to invalidate the entries
- Copy Entry 3 to Entry 1 and set M of Entry 2 to 0 to terminate the list
- Copy Entry 3 to Entry 1 and shorten the frame size

6.5.9.3 Case 3 – History Entries

The CN sends History Entries or static errors to the MN. The MN shall only process the received History Entries if EN is not equal EA so each entry will be processed only once.

The initial frame shall not contain valid Status or History Entries.

Octet Offset	Description
0 .. 23	Headers
24 .. 31	Static Error Bit Field
32 .. 51	Entry 0 (M=0)
52 .. 59	Padding
60 .. 63	Ethernet CRC

Initial frames at startup:

- Frame 1: Owner = Error Signaling (May be changed at any time)
- Frame 2: Owner = Data Link Layer
- Frame 3: Owner = Error Signaling (unused until Frame 1 is changed)

As in Example 1, the CN may change the Static Error Bit Field and perform the same sequence as in Example 1 to signal the change to the MN.

Additionally the Error Signaling shall check periodically if the Emergency Queue (see Fig. 68 Error signaling – Overview) contains any entries. In this case the Error Signaling also shall create a copy of Frame 1 and append as many History Entries from the Emergency Queue to the frame as possible and remove these entries from the queue.

Frame 1 never contains History Entries.They shall be only added to the frame passed to the DLL !

Assume the Emergency Queue contains 10 History Entries and the length of the Status Response is limited to a maximum of 150 byte, the next frame prepared for the DLL will be the following:

Octet Offset	Description
0 .. 23	Headers
24 .. 31	Static Error Bit Field
32 .. 51	History Entry 0
52 .. 71	History Entry 1
72 .. 91	History Entry 2
92 .. 111	History Entry 3
112 .. 131	History Entry 4
132 .. 135	Ethernet CRC

The frame will transport 5 of the 10 queue entries to the MN. The next time the Error Signaling shall transfer the rest of the entries in the queue (but always maximum 5 entires in this case). The sequence will continue in this manner until the Emergency Queue is empty.

6.5.9.4 Case 4 – Status and History Entries

The CN may also send StatusResponse frames containing both Status and History Entries. In this case the History Entries shall be located in the frame after the Status Entries. As shown in the examples above the Status Entries contain static information and the History Entries are taken from the Emergency Queue.

The MN shall be aware that the number of Status Entries and History Entries as well as the frame length of the StatusResponse can vary at every frame.

6.5.10 Object descriptions

6.5.10.1 Object 1001h : ERR_ErrorRegister_U8

The object ERR_ErrorRegister_U8 is compatible to the object ‘error register’ of the standard communication profile CiA DS 301.

Index	1001_h	Object Type	VAR
Name	ERR_ErrorRegister_U8		
Data Type	UNSIGNED8	Category	M
Value Range	0..255	Access	ro
Default Value	0	PDO Mapping	Opt

- **Value Interpretation**

Bit	M/O	Description
0	M	Generic error This bit shall be set to 1_b if the Static Error Bit Field or the Status Entries in the StatusResponse frame show one or more errors. If this bit is 0_b the MN only needs to evaluate the History Entries of the StatusResponse frame.
1	O	Current
2	O	Voltage
3	O	Temperature
4	O	Communication error
5	O	Device profile specific
6	O	Reserved (always 0)
7	O	Manufacturer specific

6.5.10.2 Object 1003_h: ERR_History_ADOM

Sub-index 0 contains the number of actual errors/events that are recorded in the array starting at sub-index 1. Every new error/event is stored at sub-index 1, the older ones move down the list.

Object ERR_History_ADOM shall not be cleared upon initialisation during an NMTResetConfiguration, NMTResetCommunication or NMTResetNode.

Note: This facilitates reading the error history after the CN performed an NMTReset following an error.

Index	1003_h	Object Type	ARRAY
Name	ERR_History_ADOM		
Data Type	DOMAIN	Category	O

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	0 .. 254	Access	rw
Default Value	0	PDO Mapping	Opt

When writing to this sub-index only value 0 is allowed (clear history). All other values will be rejected with an error code.

- **Sub-Index 01_h – FE_h : ErrorEntry_DOM**

Sub-Index	01_h – FE_h		
Name	ErrorEntry_DOM		
--	--	Category	O
Value Range	see Tab. 94	Access	ro
Default Value	-	PDO Mapping	No

6.6 Program Download

In this chapter, a common method for downloading a program to a device via its object dictionary is specified. Here only the mechanism for performing the program download is specified, not the structure of program data or the data structure. The specified mechanism can be used for downloading complete programs to devices (e.g. if a device only provides a kind of POWERLINK bootstrap loader) or only parts of a program (e.g. specific tasks of real-time systems). The data structure of the transferred program data must be specified by the manufacturer (e.g. INTEL-HEX format or binary format).

Further specifications for the program download are given in specific device profiles (e.g. in CiA DS-405 for the download of PLC programs).

Programmability of a CN is indicated by NMT_NodeAssignment_AU32[sub-index] Bit 6.

6.6.1 Object Dictionary Entries on the CN

6.6.1.1 Object 1F50$_h$: PDL_DownloadProgData_ADOM

PDL_DownloadProgData_ADOM holds downloaded programs. It allows the access to up to 254 programs.

Index	1F50$_h$	Object Type	ARRAY
Name	PDL_DownloadProgData_ADOM		
Data Type	DOMAIN	Category	O

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	00$_h$ .. FE$_h$	Access	rw
Default Value	-	PDO Mapping	No

- **Sub-Index 01$_h$: Program**

Sub-Index	01$_h$		
Name	Program		
--	--	Category	Cond
Value Range	DOMAIN	Access	cond
Default Value	-	PDO Mapping	No

Sub-index 1 is the program access point of a device that is reserved for the firmware of the device holding the device communication profile. Therefore no common program download to this sub-index is allowed.

If the download fails, the device responds with an Abort SDO Transfer (error code 0606 0000$_h$).

If the device does not support firmware download via SDO Write by Index this sub-index shall not be present.

Note: The firmware may also be downloaded to a device by FTP or SDO File Write transfer.

If the device supports reading of the program the access shall be rw otherwise wo.

- **Sub-Index 02$_h$ .. FE$_h$: Program**

Sub-Index	02$_h$ .. FE$_h$		
Name	Program		
--	--	Category	O
Value Range	DOMAIN	Access	cond
Default Value	-	PDO Mapping	No

Program sub-indices provide access to additional programs in a device.

If the device supports reading of the program the access shall be rw otherwise wo.

6.6.1.2 Object 1F51$_h$: PDL_ProgCtrl_AU8

PDL_ProgCtrl_AU8 is specified for controlling the execution of stored programs:

Index	$1F51_h$	Object Type	ARRAY
Name	PDL_ProgCtrl_AU8		
Data Type	UNSIGNED8	Category	Cond

PDL_ProgCtrl_AU8 shall be implemented if PDL_DownloadProgData_ADOM is supported by the device.

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	01_h .. FE_h	Access	rw
Default Value	01_h	PDO Mapping	No

- **Sub-Index 01_h: ProgCtrl**

Sub-Index	01_h		
Name	ProgCtrl		
--	--	Category	M
Value Range	0 .. 2 (refer Tab. 100)	Access	rw
Default Value	-	PDO Mapping	No

ProgCtrl controls the program holding the device communication profile to be accessed by PDL_DownloadProgData_ADOM[1].

On write access program execution will be commanded, on read access the current execution state of the program may be queried. The following values are defined:

	Write Access	Read Access
0	stop program	program stopped
1	start program	program running
2	reset program	program stopped

Tab. 100 PDL_ProgCtrl_AU8 sub-index value interpretation

If the action is not possible, the device shall responds with an Abort SDO Transfer (error code 0800 0024_h).

- **Sub-Index 02_h .. FE_h: ProgCtrl**

Sub-Index	02_h .. FE_h		
Name	ProgCtrl		
--	--	Category	Cond
Value Range	0 .. 2 (refer Tab. 100)	Access	rw
Default Value	-	PDO Mapping	No

ProgCtrl sub-indices control the additional programs to be accessed via the PDL_DownloadProgData_ADOM sub-indices 02_h .. FE_h. The respective sub-index shall be implemented if the corresponding sub-index of PDL_DownloadProgData_ADOM is provided by the device.

6.6.1.3 Object $1F52_h$: PDL_LocVerApplSw_REC

PDL_LocVerApplSw_REC is defined to support verification of the version of the program holding the device communication profile to be accessed via PDL_DownloadProgData_ADOM[1] [21].

[21] Note that the object NMT_ManufactDevName_VS can be regarded as a version number of a fixed program of a non-programmable node or as a firmware (like boot block and operating system) version number of a programmable node. Hence, a separate object for re-programmable application software is defined.

Index	$1F52_h$	Object Type	RECORD
Name	PDL_LocVerApplSw_REC		
Data Type	PDL_LocVerApplSw_TYPE	Category	Cond

PDL_LocVerApplSw_REC shall be implemented if PDL_DownloadProgData_ADOM is supported by the device.

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	2	Access	const
Default Value	2	PDO Mapping	No

- **Sub-Index 01_h: ApplSwDate_U32**

Sub-Index	01_h		
Name	ApplSwDate_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	rw
Default Value	-	PDO Mapping	No

ApplSwDate_U32 shall contain the number of days since January 1, 1984.

- **Sub-Index 02_h: ApplSwTime_U32**

Sub-Index	02_h		
Name	ApplSwTime_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	rw
Default Value	-	PDO Mapping	No

ApplSwTime_U32 shall contain the number of ms since midnight.

Note that the date and time are only supported for the default application program. Dates and times of additional programs 2 to 254 are not supported. In case of two or more programs, one possibility could be to store the latest update time and date of any of the programs 2 to 254 in the objects PDL_MnExpAppSwDateList_AU32 and PDL_MnExpAppSwTimeList_AU32.

6.6.1.4 Object 0427_h: PDL_LocVerApplSw_TYPE

Index	0427_h	Object Type	DEFSTRUCT
Name	PDL_LocVerApplSw_TYPE		
Sub-Index	Component Name	Value	Data Type
00h	NumberOfEntries	02h	
01h	ApplSwDate_U32	0007h	UNSIGNED32
02h	ApplSwTime_U32	0007h	UNSIGNED32

6.6.2 Object Dictionary Entries on the MN

Two MN located objects are specified for verification of the version of the application software at the CNs.

In programmable devices the objects shall be compared to PDL_LocVerApplSw_REC reflecting the version of the downloaded program holding the device communication profile accessible via PDL_DownloadProgData_ADOM[1].

In non-programmable devices the objects may be used to store verification data to be compared to NMT_ManufactSwVers_VS.

6.6.2.1 Object 1F53$_h$: PDL_MnExpAppSwDateList_AU32

PDL_MnExpAppSwDateList_AU32 holds the expected Application SW date to be compared to the actual value on the CN in order to verify the Application SW.

Index	1F53$_h$	Object Type	ARRAY
Name	PDL_MnExpAppSwDateList_AU32		
Data Type	UNSIGNED32	Category	Cond

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	01$_h$ .. FE$_h$	Access	rws
Default Value	FE$_h$	PDO Mapping	No

- **Sub-Index 01$_h$ .. FE$_h$: AppSwDate**

Sub-Index	01$_h$ .. FE$_h$		
Name	AppSwDate		
--	--	Category	O
Value Range	UNSIGNED32	Access	rws
Default Value	0	PDO Mapping	No

Each sub-index in the array corresponds to the CN with the Node ID equal to the sub-index. The sub-index value is valid only if there is a CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bits 0, 1 and 5.

AppSwDate contains the number of days since January 1, 1984.

PDL_MnExpAppSwDateList_AU32 shall be implemented by MNs if the MN supports program verification.

PDL_MnExpAppSwDateList_AU32 may be implemented by CNs to hold latest update date of additional programs to be accessed via PDL_DownloadProgData_ADOM sub-indices 02$_h$ .. FE$_h$.

6.6.2.2 Object 1F54$_h$: PDL_MnExpAppSwTimeList_AU32

PDL_MnExpAppSwTimeList_AU32 holds the expected Application SW time to be compared to the actual value on the CN in order to verify the Application SW.

Index	1F54$_h$	Object Type	ARRAY
Name	PDL_MnExpAppSwTimeList_AU32		
Data Type	UNSIGNED32	Category	Cond

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	01$_h$ .. FE$_h$	Access	rws
Default Value	FE$_h$	PDO Mapping	No

- **Sub-Index 01$_h$ .. FE$_h$: AppSwTime**

Sub-Index	01$_h$ .. FE$_h$		
Name	AppSwTime		
--	--	Category	O
Value Range	UNSIGNED32	Access	rws
Default Value	0	PDO Mapping	No

Each sub-index in the array corresponds to the CN with the Node ID equal to the sub-index. The sub-index value is valid only if there is a CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bits 0, 1 and 5.

AppSwTime contains the number of milliseconds after midnight (00:00).

PDL_MnExpAppSwTimeList_AU32 shall be implemented by MNs if the MN supports program verification.

PDL_MnExpAppSwTimeList_AU32 may be implemented by CNs to hold latest update time of additional programs to be accessed via PDL_DownloadProgData_ADOM sub-indices 02_h .. FE_h.

6.7 Configuration Management

The configuration of a device may be stored locally on the device in a non-volatile memory or centrally on the MN performing the Configuration Manager function.

The Configuration Manager is an optional application residing on the MN. It may configure network devices at network boot-up. Support of Configuration Manager functions shall be indicated by device description entry D_CFM_ConfigManager_BOOL.

For this it has to know the (application dependent) parameter values. This information may be provided by a Device Configuration File for each device. This file is stored on the MN. In order to reduce memory consumption Concise Configuration Storage may be applied.

POWERLINK defines a XML based Device Description (XDD) and Device Configuration (XDC) file format. The file format is described in detail in a separate paper (POWERLINK XML Specification).

6.7.1 Device Description

The Device Description File provides information about the device's basic communication and functional properties.

POWERLINK employs XDD Files for Device Description. These files shall be provided by the manufacturer of the device.

XDD files may be stored locally on the device or centrally on the MN.

6.7.1.1 Local Storage on the Device

With some devices it may be possible to store the Device Description File (XDD) locally on the device. Local XDD File storage has some advantages:

- The manufacturer does not have the problem of distributing the XDD File via data carrier.
- Management of different XDD File versions for different software versions is less error prone, if they are stored together.
- The complete network settings may be stored on the network. This makes the task of analyzing or reconfiguring a network easier for tools and more transparent for the users.

The object CFM_StoreDevDescrFile_DOM contains the XDD File. The format of the file is described by object CFM_StoreDevDescrFormat_U16.

The XDD File is downloaded from a Configuration Tool to the device by writing the file as a domain to CFM_StoreDevDescrFile_DOM. The file is uploaded by reading CFM_StoreDevDescrFile_DOM.

6.7.1.2 Central Storage on the MN

For those devices which are not able to store their XDD Files, the Configuration Manager on the MN may take over this task. The objects CFM_StoreDevDescrFileList_ADOM and CFM_DevDescrFileFormatList_AU8 are defined at the Configuration Manager to hold the file information.

The device XDD File is downloaded from a Configuration Tool to the Configuration Manager by writing the file as a domain to CFM_StoreDevDescrFileList_ADOM with the sub-index equal to the device's Node ID.

The file is uploaded to a tool by reading CFM_StoreDevDescrFileList_ADOM with the sub-index equal to the device's Node ID.

6.7.2 Device Configuration Storage

Device Configuration provides application specific setup values.

6.7.2.1 Device Configuration File Storage

Centralized storage of device configuration is performed by the Configuration Manager on the MN. Data is stored in the form of a Device Configuration File (XDC).

XDC Storage is managed by the the objects CFM_StoreDcfList_ADOM and CFM_DcfStorageFormatList_AU8. CFM_StoreDcfList_ADOM holds the XDC Files and CFM_DcfStorageFormatList_AU8 provides information about the files' storage format. Each sub-index of the ARRAYs points to the Node ID of the device to which the XDC belongs.

The XDC is downloaded from a Configuration Tool to the Configuration Manager by writing the XDC File as a domain to CFM_StoreDcfList_ADOM with the sub-index equal to the device's Node ID.

The XDC is uploaded from the Configuration Manager to a Tool by reading the object CFM_StoreDcfList_ADOM with the sub-index equal to the device's Node ID.

6.7.2.2 Concise Configuration Storage

The Concise Device Configuration does not contain all of the information contained in the XDC. The information to be stored consists of the parameter values of the object dictionary entries. The information is stored by a stream assigning data values to the particular objects and sub-indices. (See Tab. 102)

It is recommended that Concise Configuration Storage is used when complete XDC storage is not possible.

The concise configuration of a device is downloaded from a Configuration Tool to the Configuration Manager by writing the stream as a domain to CFM_ConciseDcfList_ADOM with the sub-index equal to the device's Node ID.

The concise DCF of a device is uploaded from the Configuration Manager to a Tool by reading the object CFM_ConciseDcfList_ADOM with the sub-index equal to the device's Node ID.

6.7.2.3 Check Configuration Process

POWERLINK defines the object CFM_VerifyConfiguration_REC. If a device supports saving of parameters in non-volatile memory, the MN or a configuration tool may use this object to verify the configuration after a device is reset and to check whether a reconfiguration is necessary. The configuration tool shall store configuration date, time and ID in CFM_VerifyConfiguration_REC and shall store the same values in the respective sub-indices of CFM_ExpConfDateList_AU32, CFM_ExpConfTimeList_AU32 and CFM_ExpConfIdList_AU32.

Now the configuration tool orders the device to save its configuration by writing the signature "save" to NMT_StoreParam_REC.AllParam_U32.

After a reset the device restores the last configuration and the signature automatically or by request.

The Configuration Manager compares the signature in CFM_VerifyConfiguration_REC to the respective sub-indices of CFM_ExpConfDateList_AU32, CFM_ExpConfTimeList_AU32 and/or CFM_ExpConfIdList_AU32 and decides if a reconfiguration is necessary or not.

6.7.2.4 Request Configuration

In some applications there might be situations where it is necessary to configure CNs during run-time – for example, if a CN fails and re-boots. The NMT master will recognize this and inform the application (see chapter 7.4.2.2.1.2). With the object CFM_ConfCNRequest_AU32 the NMT master application is able to tell the Configuration Manager to configure that CN.

Another example is the connection of a new machine part with several devices. The application needs the ability to start the Configuration Manager at least for the new nodes.

Configuration may be also requested by the target CN itself or by a tool residing on another CN.

To initiate the configuration process of a single CN, the requester writes the signature "conf" to the sub-index equal to the CN's Node ID.

A SDO Write Request to sub-index FF_h is used to start an overall re-configuration of all CNs on the system. This function enables simple applications to request the Configuration Management without knowing the actual project configuration.

6.7.3 Object Dictionary Entries

6.7.3.1 Object 1020$_h$: CFM_VerifyConfiguration_REC

CFM_VerifyConfiguration_REC holds device local Configuration date and time.

Index	1020$_h$	Object Type	RECORD
Name	CFM_VerifyConfiguration_REC		
Data Type	CFM_VerifyConfiguration_TYPE	Category	M

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	2 .. 4	Access	const
Default Value	-	PDO Mapping	No

- **Sub-Index 01$_h$: ConfDate_U32**

Sub-Index	01$_h$		
Name	ConfDate_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	rws, valid on reset
Default Value	0	PDO Mapping	No

ConfDate_U32 holds the local configuration date. It contains the number of days since January 1, 1984.

- **Sub-Index 02$_h$: ConfTime_U32**

Sub-Index	02$_h$		
Name	ConfTime_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	rws, valid on reset
Default Value	0	PDO Mapping	No

ConfDate_U32 holds the local configuration time. It contains the number of ms since midnight.

- **Sub-Index 03$_h$: ConfId_U32**

Sub-Index	03$_h$		
Name	ConfId_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rws
Default Value	0	PDO Mapping	No

ConfId_U32 holds a configuration ID value.

The value shall be created by a configuration tool in a manufacturer specific way.

In a POWERLINK network it should be identical only on those nodes, that have an identical HW and configuration besides some node specific objects like POWERLINK Node ID (NMT_EPLNodeID_REC.NodeID_U8), SerialNumber (NMT_IdentityObject_REC.SerialNo_U32) etc. Otherwise ConfId_U32 should be unique for each node in an Ethernet POWERLINK network segment.

- **Sub-Index 04h: VerifyConfInvalid_BOOL**

Sub-Index	04h		
Name	VerifyConfInvalid_BOOL		
Data Type	BOOLEAN	Category	O
Value Range	BOOLEAN	Access	ro
Default Value	TRUE	PDO Mapping	No

VerifyConfInvalid_BOOL enables temporary local modifications of configuration parameters for test purpose while maintaining the bootability of the network.

VerifyConfInvalid_BOOL = FALSE indicates that the configuration was not modified since the last storage of ConfId_U32 (sub-index 03h).

A change of a parameter defined in this specification which is stored in permanent memory shall set VerifyConfInvalid_BOOL to TRUE. It may be set also by the application.

VerifyConfInvalid_BOOL shall be set to FALSE upon writing a value > 0 to ConfId_U32.

A configuration tool or an application may use this information to display a warning if the configuration of a node was modified.

6.7.3.2 Object 1021h: CFM_StoreDevDescrFile_DOM

CFM_StoreDevDescrFile_DOM holds the device local Device Description File.

Index	1021h	Object Type	VAR
Name	CFM_StoreDevDescrFile_DOM		
Data Type	DOMAIN	Category	O
Value Range	DOMAIN	Access	ro or rws
Default Value	-	PDO Mapping	No

The object is read-only if the Device Description File stored by CFM_StoreDevDescrFile_DOM is unchangable.
Otherwise a Device Description File may be downloaded from a configuration tool by writing the file as a domain to CFM_StoreDevDescrFile_DOM. Reading the object uploads to the tool.

The availability of a Device Description File at CFM_StoreDevDescrFile_DOM is indicated by CFM_StoreDevDescrFormat_U16. If no data had been stored (CFM_StoreDevDescrFormat_U16 = FFh), a SDO Read Request to CFM_StoreDevDescrFile_DOM is aborted with the error code E_CFM_DATA_SET_EMPTY.

6.7.3.3 Object 1022h: CFM_StoreDevDescrFormat_U16

CFM_StoreDevDescrFormat_U16 holds the format of the Device Description File stored by CFM_StoreDevDescrFile_DOM.

Index	1022h	Object Type	VAR
Name	CFM_StoreDevDescrFormat_U16		
Data Type	UNSIGNED16	Category	Cond
Value Range	refer Tab. 101	Access	ro or rws
Default Value	-	PDO Mapping	No

The object shall be implemented if CFM_StoreDevDescrFile_DOM is implemented.

The object is read-only if the Device Description File stored by CFM_StoreDevDescrFile_DOM is unchangable.

CFM_StoreDevDescrFormat_U16 describes the format of the storage. This allows the use of compressed formats. The device may always store the file in a compressed format internally. The CFM_StoreDevDescrFormat_U16 object describes the external behavior.

Valid values are:

Value	Format
00h	XML XDD format as defined in separate paper, not compressed
01_h to FE_h	reserved
FF_h	no Device Description File available

Tab. 101 Device description file and device configuration storage formats

6.7.3.4 Object $1F20_h$: CFM_StoreDcfList_ADOM

CFM_StoreDcfList_ADOM holds XDC files for configured CNs. The object may be implemented on the MN only, if object CFM_DcfStorageFormatList_AU8 is implemented.

Index	$1F20_h$	Object Type	ARRAY
Name	CFM_StoreDcfList_ADOM		
Data Type	DOMAIN	Category	Cond

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	ro
Default Value	254	PDO Mapping	No

- **Sub-Index 01_h .. FE_h: CNDcf**

Sub-Index	01_h .. FE_h		
Name	CNDcf		
--	--	Category	Cond
Value Range	DOMAIN	Access	rws
Default Value	-	PDO Mapping	No

Each sub-index in the array corresponds to the CN with the Node ID equal to the sub-index. The sub-index value is valid only if there is a CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] bits 0 and 1.

A XDC is downloaded from a Configuration Tool to the Configuration Manager by writing the XDC File to the respective CFM_StoreDcfList_ADOM sub-index. The tool uploads the XDC by reading the sub-index.

The availability of XDC data at a CFM_StoreDcfList_ADOM sub-index is indicated by the corresponding CFM_DcfStorageFormatList_AU8 sub-index. If no data is stored (CFM_DcfStorageFormatList_AU8.CNDcfFormat[sub-index] = FF_h), a SDO Read Request to the CFM_StoreDcfList_ADOM sub-index is aborted with the error code E_CFM_DATA_SET_EMPTY.

6.7.3.5 Object $1F21_h$: CFM_DcfStorageFormatList_AU8

CFM_DcfStorageFormatList_AU8 holds the format of the XDC files for configured CNs. The object may be implemented on the MN only.

Index	1F21h	Object Type	ARRAY
Name	CFM_DcfStorageFormatList_AU8		
Data Type	UNSIGNED8	Category	O

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	ro
Default Value	254	PDO Mapping	No

- **Sub-Index 01h .. FEh: CNDcfFormat**

Sub-Index	01h .. FEh		
Name	CNDcfFormat		
--	--	Category	Cond
Value Range	refer Tab. 101	Access	rws
Default Value	FFh	PDO Mapping	No

CNDcfFormat describes the format of the storage. This allows the use of compressed formats. The device may always store the file in a compressed format internally. The CNDcfFormat object describes the external behavior.

Each sub-index in the array corresponds to the CN with the Node ID equal to the sub-index. The sub-index value is valid only if there is a CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bits 0 and 1.

If no data is stored (CNDcfFormat[sub-index] = FFh), a SDO Read Request to the CFM_StoreDcfList_ADOM sub-index is aborted with the error code E_CFM_DATA_SET_EMPTY.

6.7.3.6 Object 1F22h: CFM_ConciseDcfList_ADOM

CFM_ConciseDcfList_ADOM holds Concise Configuration data for configured CNs. The object may be implemented on the MN only.

Index	1F22h	Object Type	ARRAY
Name	CFM_ConciseDcfList_ADOM		
Data Type	DOMAIN	Category	O

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	ro
Default Value	254	PDO Mapping	No

- **Sub-Index 01h .. FEh: CNConciseDcfData**

Sub-Index	01h .. FEh		
Name	CNConciseDcfData		
--	--	Category	O
Value Range	DOMAIN	Access	rws
Default Value	-	PDO Mapping	No

The content of CNConciseDcfData is a stream with the following structure:

Number of supported entries		UNSIGNED32
Item 1	Index 1	UNSIGNED16
	Sub-index 1	UNSIGNED8
	Data size of parameter 1	UNSIGNED32
	Data of parameter 1	DOMAIN
Item 2	Index 2	UNSIGNED16
	Sub-index 2	UNSIGNED8
	Data size of parameter 2	UNSIGNED32
	Data of parameter 2	DOMAIN
:::::::		
Item n	Index n	UNSIGNED16
	Sub-index n	UNSIGNED8
	Data size of parameter n	UNSIGNED32
	Data of parameter n	DOMAIN

Tab. 102 Concise DCF stream format

The Data Size is measured in octets (i.e. UNSIGNED16 has size 2; size of BOOL is given as 1).

Each sub-index in the array corresponds to the CN with the Node ID equal to the sub-index. The sub-index value is valid only if there is a CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] bits 0 and 1.

Device configuration is uploaded from a Configuration Tool to the Configuration Manager by writing the stream as domain to the respective CNConciseDcfData sub-index. Reading the stream uploads to a tool.

An empty data set is written by the following concise stream:

Number of supported entries	0 (UNSIGNED32)

If no data has been stored, a SDO Read Request will return a valid concise stream with the following content:

Number of supported entries	0 (UNSIGNED32)

6.7.3.7 Object 1F23$_h$: CFM_StoreDevDescrFileList_ADOM

CFM_StoreDevDescrFileList_ADOM holds Device Description Files of configured CNs. The object may be implemented on the MN only, if object CFM_DevDescrFileFormatList_AU8 is implemented.

Index	1F23$_h$	Object Type	ARRAY
Name	CFM_StoreDevDescrFileList_ADOM		
Data Type	DOMAIN	Category	Cond

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	ro
Default Value	254	PDO Mapping	No

- **Sub-Index 01_h .. FE_h: CNDevDescrFile**

Sub-Index	01_h .. FE_h		
Name	CNDevDescrFile		
--	--	Category	O
Value Range	DOMAIN	Access	rws
Default Value	-	PDO Mapping	No

Each sub-index in the array corresponds to the CN with the Node ID equal to the sub-index. The sub-index value is valid only if there is a CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] bits 0 and 1.

A Device Description File is downloaded from a Configuration Tool to the Configuration Manager by writing the file to the respective CFM_StoreDevDescrFileList_ADOM sub-index. Reading the the sub-index uploads to the tool.

The availability of a Device Description File at a CFM_StoreDevDescrFileList_ADOM sub-index is indicated by the corresponding CFM_DevDescrFileFormatList_AU8 sub-index. If no data had been stored (CFM_DevDescrFileFormatList_AU8. CNDevDescrFileFormat [sub-index] = FF_h), a SDO Read Request to the CFM_StoreDevDescrFileList_ADOM sub-index is aborted with the error code E_CFM_DATA_SET_EMPTY.

6.7.3.8 Object $1F24_h$: CFM_DevDescrFileFormatList_AU8

CFM_DevDescrFileFormatList_AU8 holds the format of the Device Description Files for configured CNs. The object may be implemented on the MN only.

Index	$1F24_h$	Object Type	ARRAY
Name	CFM_DevDescrFileFormatList_AU8		
Data Type	UNSIGNED8	Category	O

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	ro
Default Value	254	PDO Mapping	No

- **Sub-Index 01_h .. FE_h: CNDevDescrFileFormat**

Sub-Index	01_h .. FE_h		
Name	CNDevDescrFileFormat		
--	--	Category	Cond
Value Range	refer Tab. 101	Access	rws
Default Value	FF_h	PDO Mapping	No

CNDevDescrFileFormat describes the format of the storage. This allows the usage of compressed formats. The device may always store the file in a compressed format internally. The object describes the external behavior.

Each sub-index in the array corresponds to the CN with the Node ID equal to the sub-index. The sub-index value is valid only if there is a CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] bits 0 and 1.

A sub-index is implemented if the corresponding sub-index of CFM_StoreDevDescrFileList_ADOM is implemented.

6.7.3.9 Object $1F25_h$: CFM_ConfCNRequest_AU32

CFM_ConfCNRequest_AU32 is used to request configuration data by a CN from the Configuration Manager under runtime conditions. The object may be implemented on the MN only.

Index	$1F25_h$	Object Type	ARRAY
Name	CFM_ConfCNRequest_AU32		
Data Type	UNSIGNED32	Category	O

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	ro
Default Value	254	PDO Mapping	No

- **Sub-Index 01_h .. FE_h: CNConfigurationRequest**

Sub-Index	01_h .. FE_h		
Name	CNConfigurationRequest		
--	--	Category	O
Value Range	UNSIGNED32	Access	wo
Default Value	0	PDO Mapping	No

Each sub-index in the array corresponds to the CN with the Node ID equal to the sub-index. The sub-index value is valid only if there is a CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] bits 0 and 1.

To initiate the configuration process, the CN writes the signature “conf” to the respective sub-index.

Signature	MSB			LSB
ISO 8859 (“ASCII”)	f	n	o	c
hex	66_h	$6E_h$	$6F_h$	63_h

Tab. 103 CNConfigurationRequest write access signature

If no data had been stored, a SDO Write Request to 01_h to FE_h is aborted with the error code E_CFM_DATA_SET_EMPTY.

A SDO Write Request to sub-index FF_h returns without error.

6.7.3.10 Object $1F26_h$: CFM_ExpConfDateList_AU32

CFM_ExpConfDateList_AU32 holds a list of expected Configuration dates of configured CNs. The object may be implemented on the MN only.

Index	$1F26_h$	Object Type	ARRAY
Name	CFM_ExpConfDateList_AU32		
Data Type	UNSIGNED32	Category	O

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	ro
Default Value	254	PDO Mapping	No

- **Sub-Index 01h .. FEh: CNConfigurationDate**

Sub-Index	01h .. FEh		
Name	CNConfigurationDate		
--	--	Category	O
Value Range	UNSIGNED32	Access	rws
Default Value	0	PDO Mapping	No

Each sub-index in the array corresponds to the CN with the Node ID equal to the sub-index. The sub-index value is valid only if there is a CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] bits 0 and 1.

Each sub-index holds the configuration date of the respective CN. It contains the number of days since January 1, 1984. It is evaluated in conjunction with the corresponding CFM_ExpConfTimeList_AU32 sub-index.

6.7.3.11 Object 1F27h: CFM_ExpConfTimeList_AU32

CFM_ExpConfTimeList_AU32 holds a list of expected Configuration times of configured CNs. The object may be implemented on the MN only.

Index	1F27h	Object Type	ARRAY
Name	CFM_ExpConfTimeList_AU32		
Data Type	UNSIGNED32	Category	O

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	ro
Default Value	254	PDO Mapping	No

- **Sub-Index 01h .. FEh: CNConfigurationTime**

Sub-Index	01h .. FEh		
Name	CNConfigurationTime		
--	--	Category	Cond
Value Range	UNSIGNED32	Access	rws
Default Value	0	PDO Mapping	No

Each sub-index in the array corresponds to the CN with the Node ID equal to the sub-index. The sub-index value is valid only if there is a CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] bits 0 and 1.

Each Sub-index holds the configuration time of the respective CN. It contains the number of ms since midnight. It is evaluated in conjunction with the corresponding CFM_ExpConfDateList_AU32 sub-index.

A sub-index is implemented if the corresponding sub-index of CFM_ExpConfDateList_AU32 is implemented.

6.7.3.12 Object 1F28h: CFM_ExpConfIdList_AU32

CFM_ExpConfIdList_AU32 holds a list of expected Configuration IDs of configured CNs. The object may be implemented on the MN only.

Index	1F28h	Object Type	ARRAY
Name	CFM_ExpConfIdList_AU32		
Data Type	UNSIGNED32	Category	O

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	ro
Default Value	254	PDO Mapping	No

- **Sub-Index 01h .. FEh: CNConfigurationId**

Sub-Index	01h .. FEh		
Name	CNConfigurationId		
--	--	Category	Cond
Value Range	UNSIGNED32	Access	rws
Default Value	0	PDO Mapping	No

Each sub-index in the array corresponds to the CN with the Node ID equal to the sub-index. The sub-index value is valid only if there is a CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] bits 0 and 1.

Each Sub-index holds the configuration ID of the respective CN.

6.7.3.13 Object 0435h: CFM_VerifyConfiguration_TYPE

Index	0435h	Object Type	DEFSTRUCT
Name	CFM_VerifyConfiguration_TYPE		
Sub-Index	Component Name	Value	Data Type
00h	NumberOfEntries	04h	
01h	ConfDate_U32	0007h	UNSIGNED32
02h	ConfTime_U32	0007h	UNSIGNED32
03h	ConfId_U32	0007h	UNSIGNED32
04h	VerifyConfInvalid_BOOL	0001h	BOOLEAN

6.8 Input from a Programmable Device

6.8.1 Basics

In a network a programmable node can be characterised as a process having input and output variables. The set of variables will be arguments of the program and hence their values will not be determined until after the programm is written. The arguments must be handled as variables located in the object dictionary.

The definition of such parameters depends on the programming system (e.g. IEC61131-3) and can not be standardised here. It can be assumed, however, that there exists a set of network variables with the logic attribute EXTERN.

Compiling/Linking (or interpreting) a program including EXTERN variables requires relocation information. Within POWERLINK devices this information is the index (and sub-index) of the variable. Most programming systems use the mechanism of a resource definition, used to assign the POWERLINK attributes (index, sub-index, rw, assignment of POWERLINK data type to local data type, etc.) to the corresponding symbolic names (variable name in the program). The resource definition may be created by the user with a simple editor, or, more conveniently using a configuration tool. On systems with a disk-based file system a direct exchange via the DCF format is possible.

Variable names must meet the rules of the underlying programming system. POWERLINK imposes no system-specific restrictions on variable names: correct naming is the responsibility of the programmer/manufacturer.

Defining EXTERN variables requires a rule for distributing the indices, called “dynamic index assignment”.

6.8.2 Dynamic index assignment

The index area used for dynamic index assignment is dependent on the device. Each data type and direction (Input/Output) has its own area, called a segment. Segments must not overlap. Variables of the same data type are gathered in an array. If all elements of an array are defined (sub-index 01_h to FE_h), the next free object of the area is allocated.

In order to allow programmable devices the use of a process image, they may implement a conversion formula to calculate the offset of a variable in the process image directly from the index and sub-index.

Definition of the abstract object segment (also called dynamic channel):

A segment is a range of indices in the object dictionary with the following attributes:

- **Data type**

  The data type of the objects which can be defined in this segment.

- **Direction**

  The direction flag distinguishes between inputs and outputs. The values are ‘wo’ for outputs and ‘ro’ for inputs. The distinction is important to enable the correct mapping of the variable into a receive PDO (wo) or transmit PDO (ro). This does not affect the access possibilities via SDO.

- **Index range**

  The range of indices with start index and end index.

- **PIOffset**

  The offset in the process image, where the first object of this segment is allocated.

  For byte and multi-byte variables the PIOffset is a 32-bit unsigned offset value.

  For Boolean variables it is the offset and additionally the address difference between two Boolean variables counted in bits. If Boolean variables are packed in bytes one bit after the other, the value is 1. If Booleans are each stored in a byte cell, the value is 8.

- **Maximum count**

  The maximum number of variables in this segment.

Some devices distinguish strictly between different segments in the process image for different data types. For these devices the PIOffset of the first segment will be 0, the PIOffset of the second segment will be the maximum count of the first segment multiplied by the data type size of the first segment and so on. If the result does not exactly meet the physical configuration, the device software is free to map the segments into the object dictionary in a logical fashion using internal segment descriptors/offsets.

Some devices mix different data types in the same segment. For these devices all PIOffset attributes will have the value 0. Configuration Tools that allocate space in the process image by assigning indices must ensure that under these circumstances indices are omitted to avoid overlapping. (For special applications there may be a feature to explicitly overlap variables – for example, to aid debuggers interpreting memory cells as different data types.)

Any mixed form of these two device types is possible.

6.8.3 Object dictionary entries

The network variables are accessed via the entries described by the segments. In some applications it is desirable to read or write the complete process image as one block:

6.8.3.1 Object 1F70$_h$: INP_ProcessImage_REC

INP_ProcessImage_REC provides access to process image segments.

Index	1F70$_h$	Object Type	RECORD
Name	INP_ProcessImage_REC		
Data Type	INP_ProcessImage_TYPE	Category	O

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	2	Access	const
Default Value	2	PDO Mapping	No

- **Sub-Index 01$_h$: SelectedRange_U32**

Sub-Index	01$_h$		
Name	SelectedRange_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	rw
Default Value	0	PDO Mapping	No

Defines the process image segment to be accessed. After writing to SelectedRange_U32 the corresponding data can be read from or written to the addressed area with ProcessImageDomain_DOM as an unstructured stream of bytes.

The structure of SelectedRange_U32 is as follows:

MSB			**LSB**
31	**16**	**15**	**0**
Data length		Object segment	

Tab. 104 Structure of SelectedRange_U32

The Object Segment to be addressed is given by the Index. If several Segments are overlapping, the same memory area can be addressed with each of the indices.

The Data Length gives the maximum size of the transfer in bytes. If the value is 0, the complete segment is to be accessed.

- **Sub-Index 02$_h$: ProcessImageDomain_DOM**

Sub-Index	02$_h$		
Name	ProcessImageDomain_DOM		
Data Type	DOMAIN	Category	M
Value Range	DOMAIN	Access	rw
Default Value	0	PDO Mapping	No

Holds the data of the segment addressed by SelectedRange_U32 as an unstructured stream of bytes.

6.8.3.2 Object 0428$_h$: INP_ProcessImage_TYPE

Index	0428$_h$	Object Type	DEFSTRUCT
Name	INP_ProcessImage_TYPE		
Sub-Index	Component Name	Value	Data Type
00$_h$	NumberOfEntries	02$_h$	
01$_h$	SelectedRange_U32	0007$_h$	UNSIGNED32
02$_h$	ProcessImageDomain_DOM	000F$_h$	DOMAIN

7 Network Management (NMT)

7.1 NMT State Machine

7.1.1 Overview

The NMT state machine determines the behaviour of the communication function unit (see 2.2.1). The coupling of the application state machine to the NMT state machine is device dependent and falls into the scope of device profiles.

Both MN and CN start up by common initialisation process. At the end of this process, the node specific POWERLINK Node ID is evaluated in order to decide, if the node is setup to be an MN or a CN. The further process differentiates between an MN specific branch and a CN specific one.

The common initialisation process is described by 7.1.2. The paragraph also handles PowerOn, PowerOff and reset levels common to MN and CN.

The MN specific branch is described by Tab. 105, the CN specific one by 7.1.4. Only one of these branches shall be executed on a node.

7.1.2 Common Initialisation NMT State Machine

In Fig. 72 the initialisation of the NMT state machine, common to MN and CN is shown. Fig. 72 also displays PowerOn, PowerOff and common reset levels that affect both MN and CN.

The common initialisation NMT state machine is the nodes upper layer NMT state machine. The MN and CN specific NMT state machines are nested into this state machine. Only one of these nested state machines shall be executed on a node. PowerOff and Reset displayed by the upper layer machine affect each of the nested state machines.

7.1.2.1 States

7.1.2.1.1 NMT_GS_POWERED

All the states handled by this paragraph are states that are valid when the device is powered, e.g. they shall be regarded to be sub-states of the super-state NMT_GS_POWERED.

NMT_GS_POWERED shall be entered on PowerOn (NMT_GT1). It shall be left on PowerOff (NMT_GT3).

NMT_GS_POWERED is a super-state that will not be signalled over the network by an individual NMT state value.

7.1.2.1.1.1 NMT_GS_INITIALISATION

After system start, the node attains the state NMT_GS_INITIALISATION. The node automatically shall enter this state, an NMT command shall not be necessary. In the state NMT_GS_INITIALISATION, the network functionality shall be initialised.

NMT_GS_INITIALISATION and its sub-states are node internal states only. They will not be signalled over the network by NMT state.

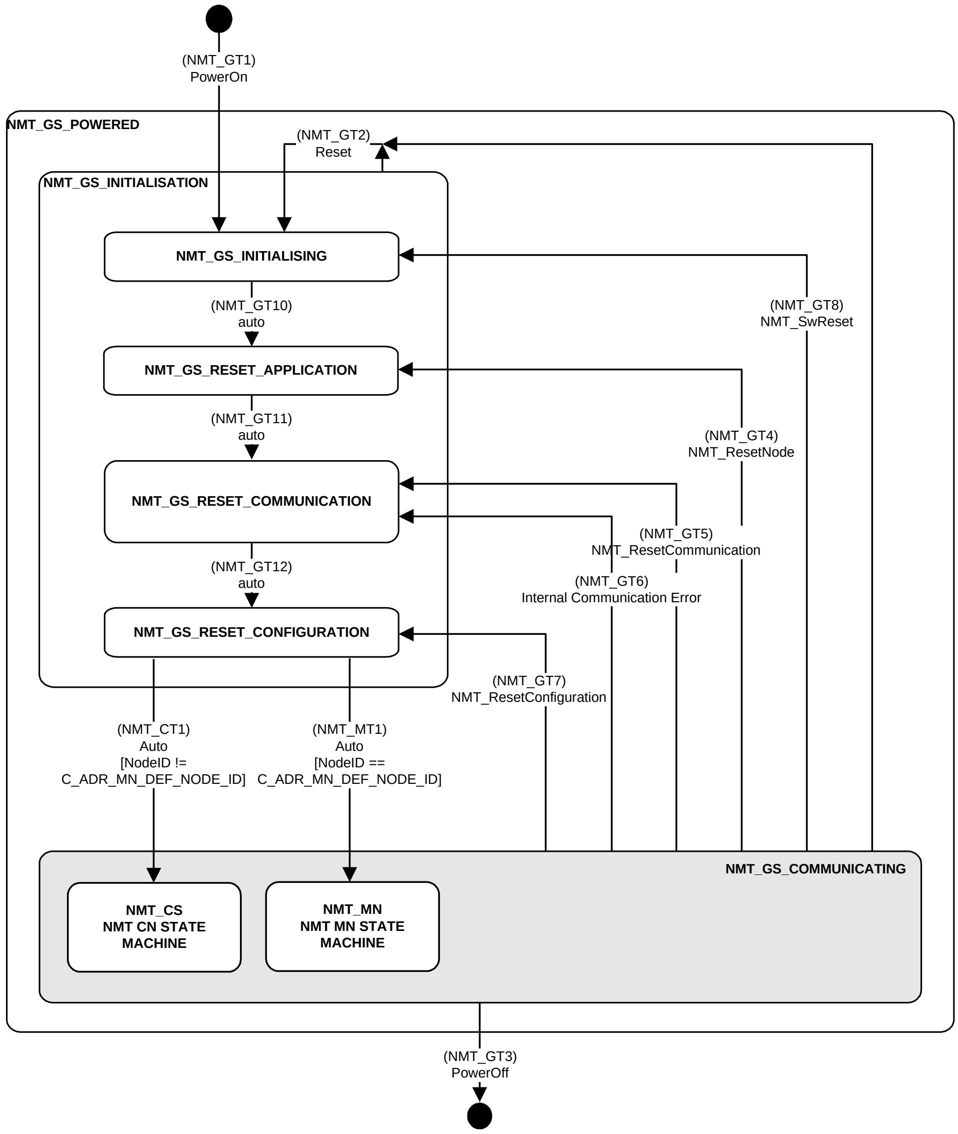


Fig. 72. Common initialisation NMT state machine

7.1.2.1.1.1.1 Sub-states

The state NMT_GS_INITIALISATION is divided into four sub-states in order to enable a complete or partial reset of a node (see Fig. 72).

- **NMT_GS_INITIALISING**

  This is the first sub-state the POWERLINK node shall enter after Power On (NMT_GT1), hardware resp. software Reset (NMT_GT2) or the reception of an NMTSwReset (NMT_GT8) command. After finishing the basic node initialisation, the POWERLINK node shall autonomously enter the sub-state NMT_GS_RESET_APPLICATION (NMT_GT10).

- **NMT_GS_RESET_APPLICATION**

  In this sub-state, the parameters of the manufacturer-specific profile area and of the standardised device profile area shall be set to their PowerOn values. After setting the PowerOn values, the sub-state NMT_GS_RESET_COMMUNICATION shall be entered autonomously (NMT_GT11).

  NMT_GS_RESET_APPLICATION shall be entered upon the reception of an NMTResetNode command from all sub-states of NMT_GS_COMMUNICATING, e.g. the NMT MN resp. CN state machine.

- **NMT_GS_RESET_COMMUNICATION**

  In this sub-state the parameters of the communication profile area (except ERR_History_ADOM) shall be set to their PowerOn values.

  NMT_GS_RESET_COMMUNICATION shall be entered upon the recognition of an internal communication error or the reception of an NMTResetCommunication command from all sub-states of NMT_GS_COMMUNICATING, e.g. the MN resp. CN NMT state machine.

  PowerOn values are the last stored parameters. If no stored configuration is available or if the Reset was preceded by a restore default command (object NMT_RestoreDefParam_REC), the PowerOn values shall be set to the default values according to the communication and device profile specifications.

- **NMT_GS_RESET_CONFIGURATION**

  In this sub-state the configuration parameters set in the object dictionary are used to generate the active device configuration. The node shall examine its Node ID in order to decide if it's configured to be an MN or a CN. If the node is equal to C_ADR_MN_DEF_NODE_ID , the node shall enter the MN NMT state machine (NMT_MT1), otherwise the CN NMT state machine shall be entered (NMT_CT1).

  NMT_GS_RESET_CONFIGURATION shall be entered upon the reception of an NMTResetConfiguration command from all substates of NMT_GS_COMMUNICATING.

  This sub-state is used to re-configure devices which do not support storing of communication parameters.

7.1.2.1.1.2 NMT_GS_COMMUNICATING

When leaving the state NMT_GS_INITIALISATION (NMT_MT1 resp. NMT_CT1) the super-state NMT_GS_COMMUNICATING will be entered. NMT_GS_COMMUNICATING includes the MN NMT state machine (refer 7.1.3) as well as the CN NMT state machine (refer 7.1.4).

There shall be a transition from NMT_GS_COMMUNICATING to NMT_GS_INITIALISATION if an NMTSwReset (NMT_GT8), NMTResetNode (NMT_GT4), NMTResetCommunication (NMT_GT5) or NMTResetConfiguration (NMT_GT7) command is received or an internal communication error occurs (NMT_GT6).

NMT_GS_COMMUNICATING is a super-state that won't be signalled over the network by an individual NMT state value.

7.1.2.2 Transitions

(NMT_GT1)	PowerOn [ ] / start basic node initialisation
	On PowerOn, NMT_GS_INITIALISATION sub-state NMT_GS_INITIALISING shall be entered autonomously. NMT_GT1, NMT_GT2 and NMT_GT8 are equivalent transitions, triggered by different reset sources.
(NMT_GT2)	Reset [ ] / start basic node initialisation
	After Hardware or local software Reset, NMT_GS_INITIALISATION sub-state NMT_GS_INITIALISING shall be entered autonomously. NMT_GT1, NMT_GT2 and NMT_GT8 are equivalent transitions, triggered by different reset sources.
(NMT_GT3)	PowerOff [ ]
	POWERLINK node was powered off in NMT_GS_POWERED
(NMT_GT4)	NMTResetNode [ ] / start application initialisation
	If an NMTResetNode command is received in NMT_GS_COMMUNICATING, NMT_GS_INITIALISATION sub-state NMT_GS_RESET_APPLICATION shall be entered.
(NMT_GT5)	NMTResetCommunication [ ] / start communication initialisation
	If an NMTResetCommunication command is received in NMT_GS_COMMUNICATING, NMT_GS_INITIALISATION sub-state NMT_GS_RESET_COMMUNICATION shall be entered.

(NMT_GT6)	Internal Communication Error [ ] / start communication initialisation
	If an Internal Communication Error is recognized in NMT_GS_COMMUNICATING, NMT_GS_INITIALISATION sub-state NMT_GS_RESET_COMMUNICATION shall be entered.
(NMT_GT7)	NMTResetConfiguration [ ] / activate device configuration
	If an NMTResetConfiguration command is received in NMT_GS_COMMUNICATING, NMT_GS_INITIALISATION sub-state NMT_GS_RESET_CONFIGURATION shall be entered. If parameters of the object dictionary concerning the device's cycle configuration (node assigment and timing) are changed, the modification shall take effect after the NMTResetConfiguration command is received.
(NMT_GT8)	NMTSwReset [ ] / start basic node initialisation
	If an NMTSwReset command is received in NMT_GS_COMMUNICATING, NMT_GS_INITIALISATION sub-state NMT_GS_INITIALISING shall be entered. NMT_GT1, NMT_GT2 and NMT_GT8 are equivalent transitions, triggered by different reset sources.
(NMT_GT10)	Auto [basic node initialisation completed] / start application initialisation
	NMT_GS_INITIALISATION sub-state NMT_GS_INITIALISING completed, NMT_GS_INITIALISATION sub-state NMT_GS_RESET_APPLICATION shall be entered autonomously.
(NMT_GT11)	Auto [application initialisation completed] / start communication initialisation
	NMT_GS_INITIALISATION sub-state NMT_GS_RESET_APPLICATION completed, NMT_GS_INITIALISATION sub-state NMT_GS_RESET_COMMUNICATION shall be entered autonomously.
(NMT_GT12)	Auto [communication initialisation completed] / start configuration setup
	NMT_GS_INITIALISATION sub-state NMT_GS_RESET_COMMUNICATION completed, NMT_GS_INITIALISATION sub-state NMT_GS_RESET_CONFIGURATION shall be entered autonomously.
(NMT_MT1)	Auto [configuration setup completed, Node ID = C_ADR_MN_DEF_NODE_ID] / start observing network traffic
	If NMT_GS_INITIALISATION sub-state NMT_GS_RESET_CONFIGURATION is completed and Node ID configuration is equal to the default MN address (C_ADR_MN_DEF_NODE_ID), state NMT_MS_NOT_ACTIVE shall be entered autonomously, e.g. the MN NMT state machine shall be entered.
(NMT_CT1)	Auto [communication initialisation completed, Node ID not equal to C_ADR_MN_DEF_NODE_ID] / start observing network traffic
	If NMT_GS_INITIALISATION sub-state NMT_GS_RESET_CONFIGURATION is completed and Node ID configuration is not equal to the default MN address (C_ADR_MN_DEF_NODE_ID), state NMT_CS_NOT_ACTIVE shall be entered autonomously, e.g. the CN NMT state machine shall be entered.

Tab. 105 Common initialisation NMT state transitions

7.1.3 MN NMT State Machine

7.1.3.1 Overview

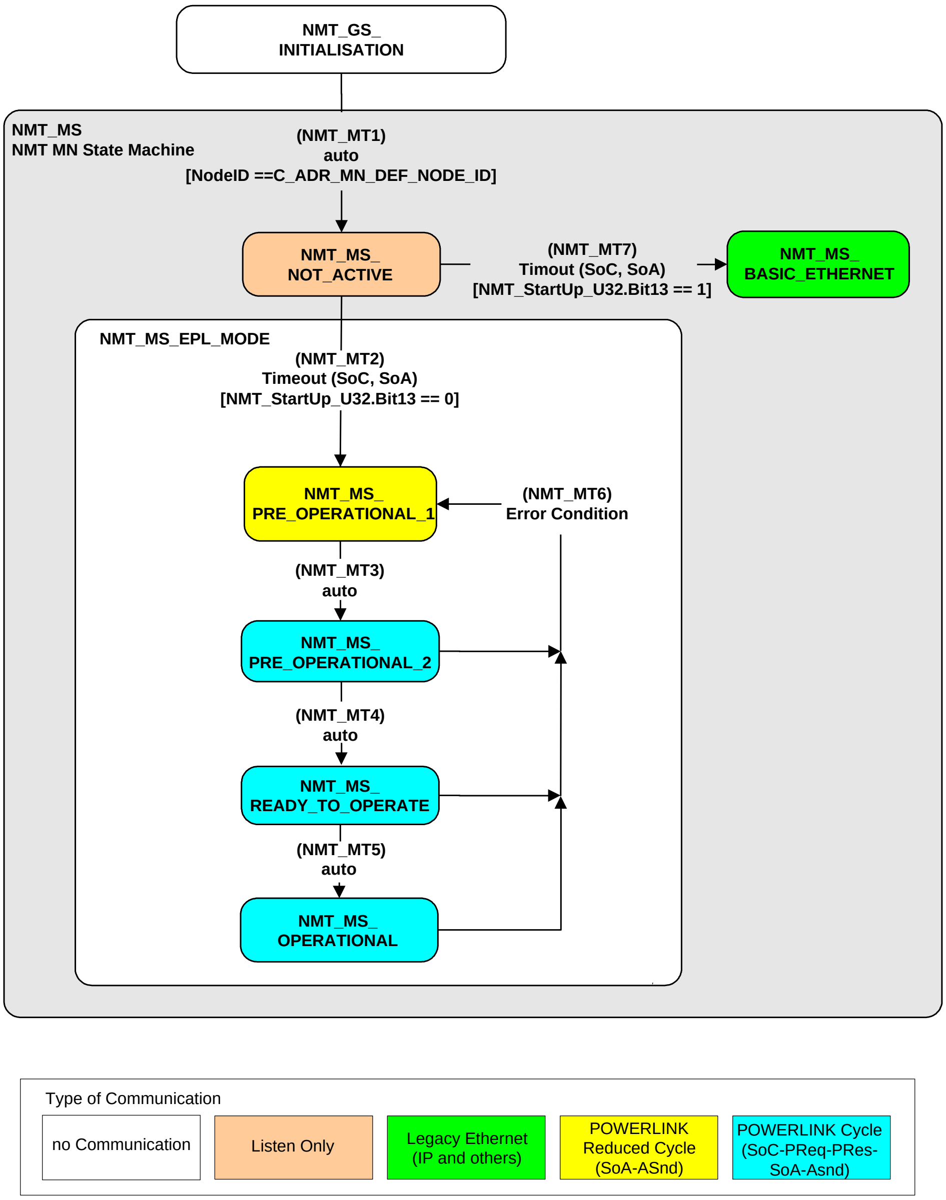


Fig. 73. NMT state diagram of an MN

The MN NMT state machine shall be regarded to be hosted by the common initialisation NMT state machine (7.1.2). The MN NMT state machine represents a sub-state of the super-states NMT_GS_POWERED (7.1.2.1.1) and NMT_GS_COMMUNICATING (7.1.2.1.1.2). The transitions defined by these states shall be valid at the MN NMT state machine.

7.1.3.2 States

The current state of the MN shall define the current state of the POWERLINK network.

7.1.3.2.1 NMT_MS_NOT_ACTIVE

The MN shall observe network traffic in NMT_MS_NOT_ACTIVE in order to ensure, that there is no other MN active on the network.

Reception of a SoC or a SoA frame indicates that there is another MN active. On SoC or SoA, the node shall freeze boot-up. An error shall be signalled to the MN application and the current MN state shall be maintained.

The node shall be not authorised to send any frame in NMT_MS_NOT_ACTIVE.

Depending on NMT_StartUp_U32.Bit13 the transition to NMT_MS_PRE_OPERATIONAL_1 (NMT_MT2) or NMT_MS_BASIC_ETHERNET (NMT_MT7) shall be triggered, if there are no SoA or SoC frames received inside the time interval defined by index NMT_BootTime_REC.MNWaitNoAct_U32.

A node that does not support MN mode shall stay in state NMT_MS_NOT_ACTIVE. An error message E_NMT_BA1_NO_MN_SUPPORT shall be issued to the application.

7.1.3.2.2 NMT_MS_EPL_MODE

NMT_MS_EPL_MODE is a super-state that is not signalled over the network by an individual NMT state value.

7.1.3.2.2.1 NMT_MS_PRE_OPERATIONAL_1

In the state NMT_MS_PRE_OPERATIONAL_1, the MN shall start executing the reduced POWERLINK cycle.

Communication in NMT_MS_PRE_OPERATIONAL_1 shall be robust to collisions. Collisions shall be resolved by CSMA/CD.

After entering NMT_MS_PRE_OPERATIONAL_1, the MN shall transmit a sequence of C_DLL_PREOP1_START_CYCLES SoA frames, not assigning the asynchrous slot to any node including the MN. This start sequence allows collisions pending from pre-NMT_MS_EPL_MODE phase to be resolved.

It shall identify the configured nodes (index NMT_NodeAssignment_AU32[Node ID].Bit1) and may check their identification. Identification check completion may be delayed if application SW or configuration data have to be downloaded by the node.

Identified nodes shall be cyclically accessed via StatusRequest.

There is no PDO exchange in NMT_MS_PRE_OPERATIONAL_1.

The transition from NMT_MS_PRE_OPERATIONAL_1 to NMT_MS_PRE_OPERATIONAL_2 (NMT_MT3) may be triggered if all mandatory CNs have been successfully identified.

It’s recommended, that the MN has completed it’s configuration in NMT_MS_PRE_OPERATIONAL_1.

Refer 7.4.1.3 for further information about NMT_MS_PRE_OPERATIONAL_1.

7.1.3.2.2.2 NMT_MS_PRE_OPERATIONAL_2

In the state NMT_MS_PRE_OPERATIONAL_2, the MN shall start executing the isochronous POWERLINK cycle.

It shall start polling the identified CNs, that are in state NMT_CS_PRE_OPERATIONAL_2 and that are not marked as AsyncOnly CNs, by Preq frames in order to start PDO transfer, synchronisation and heartbeat. The transmitted Preq frames may differ to the PDO mapping requirements. The data shall be declared invalid by not setting the RD flag.

The received Pres frames from the polled CNs shall be ignored.

Identified async-only CNs (index NMT_NodeAssignment_AU32[Node ID].Bit8) shall be cyclically accessed via StatusRequest.

Configured but unidentified CNs shall be searched for via SoA IdentRequest frames.

The MN state transition from NMT_MS_PRE_OPERATIONAL_2 to NMT_MS_READY_TO_OPERATE (NMT_MT4) shall be triggered when all mandatory CNs have signalled to be in state NMT_CS_READY_TO_OPERATE and the MN has completed its configuration.

Refer 7.4.1.4 for further information about NMT_MS_PRE_OPERATIONAL_2.

7.1.3.2.2.3 NMT_MS_READY_TO_OPERATE

In NMT_MS_READY_TO_OPERATE, the MN shall execute the isochronous POWERLINK cycle.

When entering NMT_MS_READY_TO_OPERATE, the MN shall start transmitting PDO data to the identified isochronous CNs according to the requirements of the PDO mapping. The transmitted data shall be declared invalid by resetting the RD flag. The length of the Preq frames shall be equal to the configured Preq payload size of the respective CN (index NMT_MNPReqPayloadLimitList_AU16[Node ID]).

PDO data received from the CNs shall be ignored.

Identified async-only CNs shall be cyclically accessed via SoA StatusRequest frames.

Configured but unidentified CNs shall be searched via SoA IdentRequest frames.

The MN state transition from NMT_MS_READY_TO_OPERATE to NMT_MS_OPERATIONAL (NMT_MT5) shall be triggered if all mandatory CNs transmit their Pres frames with correct frame length and timing.

Refer 7.4.1.5 for further information about NMT_MS_READY_TO_OPERATE.

7.1.3.2.2.4 NMT_MS_OPERATIONAL

NMT_MS_OPERATIONAL is the normal operating state of the POWERLINK MN. The MN shall execute the isochronous POWERLINK cycle.

The MN shall transmit PDO data to the identified isochronous CNs according to the requirements of the PDO mapping. The transmitted data may be declared valid by setting the RD flag, if requested by the application. The length of the Preq frames shall be equal to the configured Preq payload size of the respective CN.

The MN may transmit NMTStartNode commands to force CNs state transition from NMT_CS_READY_TO_OPERATE to NMT_CS_OPERATIONAL. The NMTStartNode transmission is controlled by index NMT_StartUp_U32.Bits1 and NMT_StartUp_U32.Bit3.

Identified Async-only CNs shall be cyclically accessed via SoA StatusRequest frames.

Configured but unidentified CNs shall be searched for via SoA IdentRequest frames.

All mandatory CNs shall be in NMT_CS_OPERATIONAL and free of POWERLINK protocol relevant errors. If a mandatory CN is lost, if it has a state not equal to NMT_CS_OPERATIONAL or if it has signalled an error, the MN shall change over to NMT_MS_PRE_OPERATIONAL_1 (NMT_MT6).

The error reaction of the MN is controlled by index NMT_StartUp_U32.Bit4 and NMT_StartUp_U32.Bit6.

Refer 7.4.1.6 for further information about NMT_MS_OPERATIONAL.

7.1.3.2.3 NMT_MS_BASIC_ETHERNET

In NMT_MS_BASIC_ETHERNET the MN may perform Legacy Ethernet communication according to IEEE 802.3. There is no POWERLINK specific network traffic control. The CSMA/CD collision handling shall control the network access. The node is allowed to transmit autonomously.

Any Legacy Ethernet protocol may be applied. Asnd frames may be transmitted by the MN in state NMT_MS_BASIC_ETHERNET.

To leave NMT_MS_BASIC_ETHERNET, NMT_MS_EPL_MODE has to be enabled by setting NMT_StartUp_U32.Bit13 to 0_b and the device has to be reset by NMTResetCommunication or another reset command.

Support of NMT_MS_BASIC_ETHERNET is optional. Support shall be indicated by D_NMT_MNBasicEthernet_BOOL.

7.1.3.3 Transitions

(NMT_MT1)	Refer Tab. 105
(NMT_MT2)	Timeout (SoC, SoA) [NMT_StartUp_U32.Bit13 = 0_b] / enable POWERLINK reduced cycle communication
	If NMT_MS_EPL_MODE is enabled by NMT_StartUp_U32.Bit13 = 0_b and the node does not receive any SoA or SoC frame during a definable timeout interval after entering the NMT_MS_NOT_ACTIVE state, the node shall change over to NMT_MS_PRE_OPERATIONAL_1. Timeout defined by NMT_BootTime_REC.MNWaitNoAct_U32
(NMT_MT3)	Auto [All mandatory CNs identified] / enable isochronous POWERLINK cycle communication, invalid PDO, dummy Preq allowed
	If the node has identified all mandatory CNs, the node shall change to NMT_MS_PRE_OPERATIONAL_2. The state transition may be delayed by the application.
(NMT_MT4)	Auto [MN configuration completed, all mandatory CNs in NMT_CS_READY_TO_OPERATE] / invalid PDO, configured Preq, Pres
	If the MN has completed its configuration and if all mandatory CNs are in state NMT_CS_READY_TO_OPERATE, the node shall change to the state NMT_MS_READY_TO_OPERATE. The state transition may be delayed by the application.
(NMT_MT5)	Auto [The isochronous communication is error free] / enable configured Preq and Pres, start operation
	If all mandatory CNs transmit their Pres frames with correct frame length and timing, the MN shall change to the state NMT_MS_OPERATIONAL. The state transition may be delayed by the application
(NMT_MT6)	Auto [Mandatory CN lost, mandatory CN not in NMT_CS_OPERATIONAL, error] / enable POWERLINK reduced cycle communication
	If the MN detects errors of a mandatory CN, it shall change over to NMT_MS_PRE_OPERATIONAL_1
(NMT_MT7)[22]	Timeout (SoC, SoA) [NMT_StartUp_U32.Bit13 = 1_b] / enable Legacy Ethernet communication
	If NMT_StartUp_U32.Bit13 is set, the MN shall change over to NMT_MS_BASIC_ETHERNET

Tab. 106 MN specific state transitions

Refer Fig. 72 and Tab. 105 for state transitions defined by the common Initialisation NMT state, which have to be applied to the MN NMT state machine.

[22] optional transition (cf. 7.1.3.2.3)

7.1.4 CN NMT State Machine

The CN NMT state machine shall be regarded to be hosted by the common initialisation NMT state machine (7.1.2). The CN NMT state machine represents a sub-state of the super-states NMT_GS_POWERED (7.1.2.1.1) and NMT_GS_COMMUNICATING (7.1.2.1.1.2). The transitions defined by these states shall be valid at the CN NMT state machine.

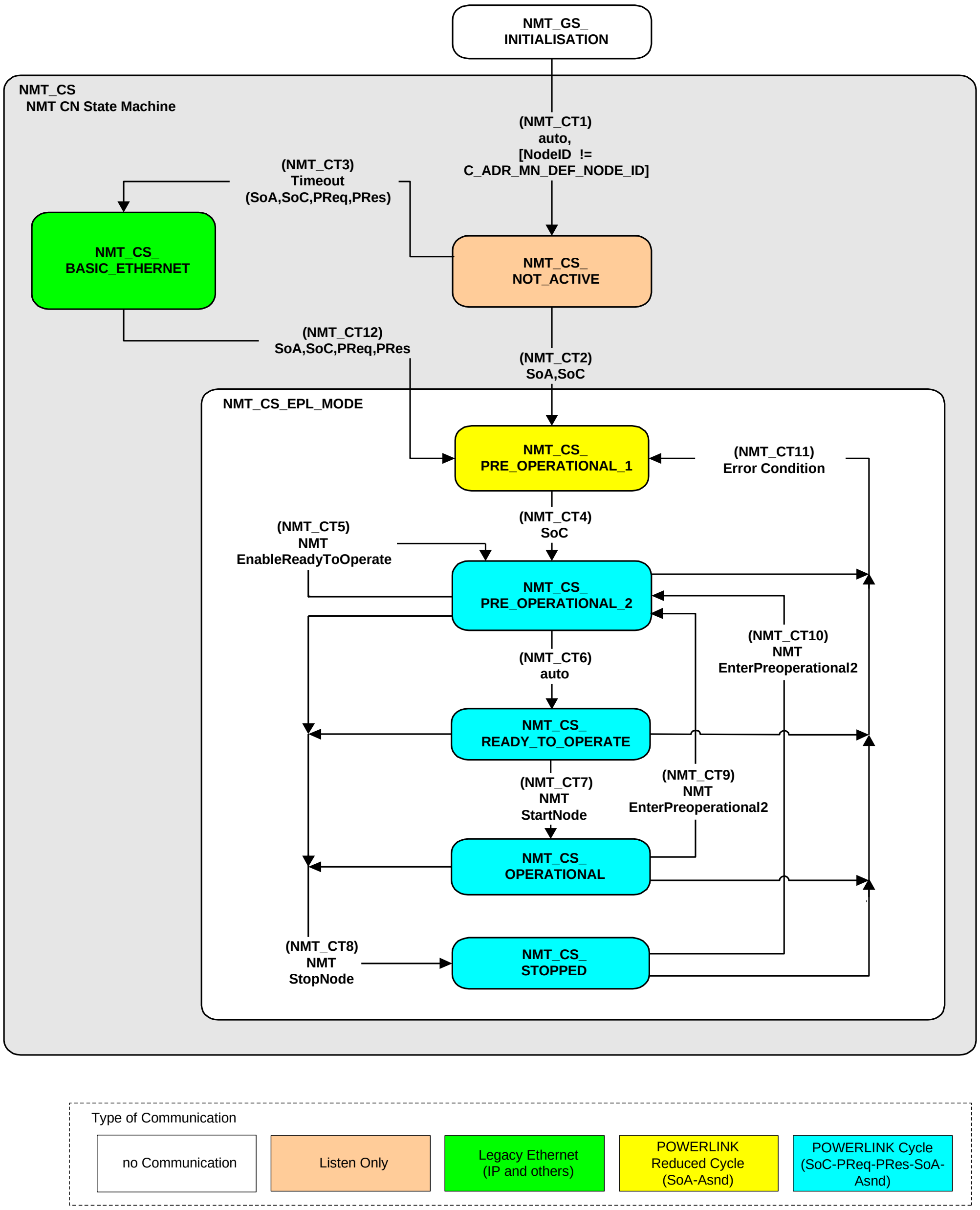


Fig. 74. State diagram of a CN

7.1.4.1 States

7.1.4.1.1 NMT_CS_NOT_ACTIVE

NMT_CS_NOT_ACTIVE is a non-permanent state which allows a starting node to recognize the current network state.

The CN shall observe network traffic. The node shall be not authorised to send frames autonomously. There shall be no Legacy Ethernet frame transmission allowed at NMT_CS_NOT_ACTIVE. The node shall be able to recognize NMTReset commands sent via Asnd.

The transition from NMT_CS_NOT_ACTIVE to NMT_CS_PRE_OPERATIONAL_1 shall be triggered by a SoA or SoC frame being received.

The transition from NMT_CS_NOT_ACTIVE to NMT_CS_BASIC_ETHERNET shall be triggered by timeout for SoC, Preq, Pres and SoA frames.

7.1.4.1.2 NMT_CS_EPL_MODE

NMT_CS_EPL_MODE is a super-state that won't be signalled over the network by an individual NMT state value.

7.1.4.1.2.1 NMT_CS_PRE_OPERATIONAL_1

In the state NMT_CS_PRE_OPERATIONAL_1, the CN shall send a frame only if the MN has authorised it to do so by a SoA AsyncInvite command.

In NMT_CS_PRE_OPERATIONAL_1 the node shall be identified by the MN via IdentRequest (see **7.3.3.2**). If required the CN shall download its configuration data from a configuration server. Both processes may be completely or partially shifted to NMT_CS_PRE_OPERATIONAL_2, if the MN is not in NMT_MS_PRE_OPERATIONAL_1 resp. leaves NMT_MS_PRE_OPERATIONAL_1 before the CN has completed its configuration.

Communication in NMT_CS_PRE_OPERATIONAL_1 shall be robust to collisions. Collisions shall be resolved by CSMA/CD.

The transition from NMT_CS_PRE_OPERATIONAL_1 to the following state shall be triggered by a SoC frame being received (see Fig. 74).

There is no PDO communication in NMT_CS_PRE_OPERATIONAL_1.

7.1.4.1.2.2 NMT_CS_PRE_OPERATIONAL_2

In the state NMT_CS_PRE_OPERATIONAL_2, the CN shall wait for the configuration to be completed.

The node is queried by the MN via Preq. The received PDO data may be invalid, they may differ to the PDO mapping requirements.

The PDO data received from the MN via Preq and from other CNs and the MN via Pres shall be ignored by the CN.

The transmitted Pres frames may differ to the PDO mapping requirements. The data shall be declared invalid by not setting the RD flag.

Async-only CNs shall not be queried by the MN via Preq and thus shall not respond via Pres.

Both types of CN shall respond to AsyncInvite commands via SoA. If not invited by the MN, there shall be no Ethernet frame transmission allowed at the NMT_CS_PRE_OPERATIONAL_2 state.

Precondition for the transition from NMT_CS_PRE_OPERATIONAL_2 to NMT_CS_READY_TO_OPERATE shall be the reception of an NMTEnableReadyToOperate command. The transition shall be triggered if the application is ready for operation. The maximum transition time from reception of NMTEnableReadyToOperate until the CN is in NMT_CS_READY_TO_OPERATE may be given by D_NMT_CNPreOp2ToReady2Op_U32.

The transition from NMT_CS_PRE_OPERATIONAL_2 to NMT_CS_PRE_OPERATIONAL_1 shall be triggered by an error recognition (see 4.7.7).

The transition from NMT_CS_PRE_OPERATIONAL_2 to NMT_CS_STOPPED shall be triggered by reception of NMT state command NMTStopNode (see 7.3.1.2.1).

7.1.4.1.2.3 NMT_CS_READY_TO_OPERATE

With the state NMT_CS_READY_TO_OPERATE, the CN shall signal its readiness to operation to the MN.

The node may participate in cyclic frame exchange. Cyclic nodes shall respond via Pres when queried via Preq by the MN.

Async-only CNs shall not be queried by the MN via Preq and thus shall not respond via Pres.

Both types of CN shall respond to AsyncInvite commands via SoA. If not invited by the MN, there shall be no Ethernet frame transmission allowed at the NMT_CS_READY_TO_OPERATE state.

The RD flag shall be set to 0, regardless if valid process data is available.

The length of the Pres payload shall be less or equal to the configured limit (Object NMT_CycleTiming_REC.PresActPayloadLimit_U16). The transmitted data shall correspond to the requirements defined by the PDO mapping (see 6.4.4).

The transition from NMT_CS_READY_TO_OPERATE to NMT_CS_OPERATIONAL shall be triggered by the reception of NMT state command NMTStartNode (see 7.3.1.2.1)

The transition from NMT_CS_READY_TO_OPERATE to NMT_CS_PRE_OPERATIONAL_1 shall be triggered by an error recognition (see 4.7.7).

The transition from NMT_CS_READY_TO_OPERATE to NMT_CS_STOPPED shall be triggered by reception of NMT state command NMTStopNode (see 7.3.1.2.1).

7.1.4.1.2.4 NMT_CS_OPERATIONAL

NMT_CS_OPERATIONAL is the normal operating state of a CN.

The CN may participate in cyclic frame exchange. A cyclic CN shall respond via Pres when queried via Preq by the MN.

An Async-only CN isn’t queried by the MN via Preq and thus does not respond via Pres.

Both types of CN shall respond to AsyncInvite commands via SoA. If not invited by the MN, there is no Ethernet frame transmission allowed at the NMT_CS_OPERATIONAL state.

The CN may perform surveillance of other nodes using the NMT guarding mechanism (7.3.5).

The PDO data received from the MN via Preq and from other CNs and the MN via Pres shall be interpreted if selected by the CN application.

The RD flag is controlled by the application. Temporary clearing the RD flag is allowed if PDO data are not valid. The length of the Pres payload shall be less or equal to the configured limit (Object NMT_CycleTiming_REC.PresActPayloadLimit_U16). The transmitted data shall correspond to the requirements defined by the PDO mapping (see 6.4.4).

The transition from NMT_CS_OPERATIONAL to NMT_CS_PRE_OPERATIONAL_2 shall be triggered by the reception of NMT state command NMTEnterPreOperational2 (see 7.3.1.2.1).

The transition from NMT_CS_OPERATIONAL to NMT_CS_PRE_OPERATIONAL_1 shall be triggered by an error recognition(see 4.7.7).

The transition from NMT_CS_OPERATIONAL to NMT_CS_STOPPED shall be triggered by reception of NMT state command NMTStopNode (see 7.3.1.2.1).

7.1.4.1.2.5 NMT_CS_STOPPED

In the NMT_CS_STOPPED state, the node shall be largely passive. NMT_CS_STOPPED shall be used for controlled shutdown of a selected CN while the system is still running.

The node shall not participate in cyclic frame exchange, but still observes SoA frames.

It shall not be queried by the MN via Preq.

The node shall not respond via Pres when queried by the MN via Preq.

The node shall respond to AsyncInvite commands via SoA. If not invited by the MN, there is no Ethernet frame transmission allowed at the NMT_CS_STOPPED state.

The transition from NMT_CS_STOPPED to NMT_CS_PRE_OPERATIONAL_2 shall be triggered by the reception of NMT state command NMTEnterPreOperational2 (see 7.3.1.2.1)

The transition from NMT_CS_STOPPED to NMT_CS_PRE_OPERATIONAL_1 shall be triggered by an error recognition (see 4.7.7).

7.1.4.1.3 NMT_CS_BASIC_ETHERNET

In the NMT_CS_BASIC_ETHERNET state the node may perform Legacy Ethernet communication according to IEEE 802.3. There is no POWERLINK specific network traffic control. The CSMA/CD collision handling shall control the network access. The node is allowed to transmit autonomiously.

Any Legacy Ethernet protocol may be applied.

Asnd frames may be transmitted by a CN in state NMT_CS_BASIC_ETHERNET.

To avoid disturbance of POWERLINK network traffic when the node is in NMT_CS_BASIC_ETHERNET , the node shall recognize SoC, Preq, Pres and SoA frames. On the reception of such a frame, the CN shall immediately stall any autonomous frame transmission and change over to. NMT_CS_PRE_OPERATIONAL_1.

7.1.4.2 Transitions

(NMT_CT1)	Refer Tab. 105
(NMT_CT2)	SoA, SoC [ ] / enable POWERLINK reduced cycle communication
	If a SoA or SoC frame is received in NMT_CS_NOT_ACTIVE, the node shall change over to the state NMT_CS_PRE_OPERATIONAL_1.
(NMT_CT3)	Timeout (SoC, Preq, Pres and SoA) [ ] / enable Legacy Ethernet communication
	If the node does not receive any SoC, Preq, Pres or SoA frame during a definable timeout interval after entering the NMT_CS_NOT_ACTIVE state, the node shall change over to NMT_CS_BASIC_ETHERNET. The timeout interval shall be defined by Object NMT_CNBasicEthernetTimeout_U32.
(NMT_CT4)	SoC [ ] / enable POWERLINK cycle communication, not valid, dummy Pres allowed
	If the node receives a SoC frame in NMT_CS_PRE_OPERATIONAL_1, the node shall change over to NMT_CS_PRE_OPERATIONAL_2.
(NMT_CT5)	NMTEnableReadyToOperate [] / enable transition to NMT_CS_READY_TO_OPERATE
	The CN is free to change over to NMT_CS_READY_TO_OPERATE after configuration and synchronisation is completed
(NMT_CT6)	Auto [application is ready and NMTEnableReadyToOperate was received] / enable configured Pres, not valid
	The CN shall automatically change over to NMT_CS_READY_TO_OPERATE
(NMT_CT7)	NMTStartNode [configuration valid] / enable configured Pres, start operation
	If the CN receives the NMTStartNode command in NMT_CS_READY_TO_OPERATE, it shall change over to NMT_CS_OPERATIONAL
(NMT_CT8)	NMTStopNode [ ] / freeze cyclic communication
	If the node receives an NMTStopNode command in NMT_CS_PRE_OPERATIONAL_2, NMT_CS_READY_TO_OPERATE or NMT_CS_OPERATIONAL, it shall change over to NMT_CS_STOPPED.
(NMT_CT9)	NMTEnterPreoperational2 [ ] / reset RD flag in Pres, dummy Pres only
	If the node receives the NMTEnterPreoperational2 command in NMT_CS_OPERATIONAL, it shall change over to NMT_CS_PRE_OPERATIONAL_2
(NMT_CT10)	NMTEnterPreoperational2 [ ] / re-enable POWERLINK cycle communication, dummy Pres only
	If the node receives the NMTEnterPreoperational2 command in NMT_CS_STOPPED, it shall change over to NMT_CS_PRE_OPERATIONAL_2.
(NMT_CT11)	Error condition [ ] / enable POWERLINK reduced cycle communication
	If the node recognizes an error condition (refer 4.7.7) in NMT_CS_PRE_OPERATIONAL_2, NMT_CS_READY_TO_OPERATE, NMT_CS_OPERATIONAL or NMT_CS_STOPPED, the node shall change over to NMT_CS_PRE_OPERATIONAL_1
(NMT_CT12)	SoC, Preq, Pres or SoA [ ] / stall autonomous frame transmission
	If a SoC, Preq, Pres or SoA frame is received in NMT_CS_BASIC_ETHERNET, the node shall change over to NMT_CS_PRE_OPERATIONAL_1. ***It's extremely important that the node immediately stops any autonomous frame transmission, when it recognizes a SoC, Preq, Pres or SoA frame.***

Tab. 107 CN specific state transitions

Refer Fig. 72 and Tab. 105 for state transitions defined by the common Initialisation NMT state, that have to applied to the CN NMT state machine.

7.1.4.3 States and Communication Object Relation

Tab. 108 shows the relation between communication states and communication objects. Services on the listed communication objects may only be executed if the devices involved in the communication are in the appropriate communication states.

		NMT_GS_INITIALISATION	NMT_CS_NOT_ACTIVE	NMT_CS_PRE_OPERATIONAL_1	NMT_CS_PRE_OPERATIONAL_2	NMT_CS_READY_TO_OPERATE	NMT_CS_OPERATIONAL	NMT_CS_STOPPED	NMT_CS_BASIC_ETHERNET
POWERLINK controlled network traffic									
	SoC	-	R/S	R/S	R	R	R	-	R/S
	Preq	-	-	-	R	R	R	-	R/S
	PDO reception	-	-	-	-	(x)¹	x	-	-
	Pres receive	-	-	-	-	R	R	-	R/S
	Pres transmit	-	-	-	(T)	T	T	-	-
	PDO transmission	-	-	-	-	(x)²	x	-	-
	SoA	-	R/S	R	R	R	R	R	R/S
	IdentRequest	-	-	x	x	x	x	x	-
	StatusRequest	-	-	x	x	x	x	x	-
	NMTRequestInvite	-	-	x	x	x	x	x	-
	UnspecifiedInvite	-	-	x	x	x	x	x	-
	Reception of asynchronous frames	-	R	R	R	R	R	R	R
	SDO reception	-	-	x	x	x	x	x	-
	NMT Command	-	(x)³	(x)⁴	(x)⁴	(x)⁴	(x)⁴	(x)⁴	(x)³
	other protocols	-	-	x	x	x	x	x	-
	Transmission, assigned by SoA	-	-	T	T	T	T	T	-
	SDO transmission	-	-	x	x	x	x	x	-
	NMTRequest transmission	-	-	x	x	x	x	x	-
	IdentResponse	-	-	x	x	x	x	x	-
	StatusResponse	-	-	x	x	x	x	x	-
	other protocols	-	-	x	x	x	x	x	-
Network traffic not controlled by POWERLINK									
	Legacy Ethernet reception	-	-	-	-	-	-	-	R
	UDP/IP reception	-	-	-	-	-	-	-	(x)⁵
	SDO reception (UDP/IP)	-	-	-	-	-	-	-	(x)⁵
	POWERLINK-Asnd reception	-	-	-	-	-	-	-	(x)⁵
	SDO reception (POWERLINK-Asnd)	-	-	-	-	-	-	-	(x)⁵
	Legacy Ethernet transmission	-	-	-	-	-	-	-	T
	UDP/IP, autonomiously sent	-	-	-	-	-	-	-	(x)⁵
	SDO transmission (UDP/IP)	-	-	-	-	-	-	-	(x)⁵
	POWERLINK-Asnd, autonomiously sent	-	-	-	-	-	-	-	(x)⁵
	SDO transmission (POWERLINK-Asnd)	-	-	-	-	-	-	-	(x)⁵

R *frame accepted*
R/S *frame accepted, triggers state transition*
T *frame transmitted*
(T) *dummy Pres only*
x *frame data interpreted resp. transmitted*
(x)¹ *frame data may be interpreted*
(x)² *data invalidated by resetting the RD flag*
(x)³ *only selected NMT commands accepted, shall cause state transition, refer 7.3.1.2.1*
(x)⁴ *may cause state transition, refer 7.3.1.2.1*
(x)⁵ *depends on protocol support*
- *no frame handling*

Tab. 108 States and communication objects

7.1.4.4 Relationship to other state machines

The CN NMT state machine is commanded by the MN NMT state machine via NMT commands.

The NMT state machines are operating in close relationship to the cycle state machines (refer 4.2.4.5 resp. 4.2.4.6).

7.2 NMT Object Dictionary Entries

NMT Object Dictionary hosts entries defining node internal parameters that control the isochronous POWERLINK cycle. These internal parameters shall not be changed when the isochronous POWERLINK cycle is in operation.

Modifications of the respective OD entries shall be restricted to the OD data handling but shall not immediately influence the internal parameter set controlling the current POWERLINK cycle. To make POWERLINK cycle relevant OD entries valid, the device shall be set to NMT_GS_RESET_CONFIGURATION by NMTResetConfiguration, a more powerful NMT reset command or a HW reset.

OD entries that require a such type handling are indicated by the access type supplement “valid on reset”.

7.2.1 NMT General Objects

Most of the objects decribed by this paragraph apply to all nodes.

Some sub-indices of objects otherwise mandatory to the MN may not be implemented on the MN. Refer to the Category entry to identify unsupported items on the MN (Category = No).

7.2.1.1 Identification

7.2.1.1.1 Object 1000$_h$: NMT_DeviceType_U32

Contains information about the device type. The object describes the type of device and its functionality.

The value shall be setup by the device firmware during system initialisation.

Index	1000$_h$	Object Type	VAR
Name	NMT_DeviceType_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	const
Default Value	-	PDO Mapping	No

- **Value Interpretation**

Byte:	MSB			LSB
	Additional Information		Device Profile Number	

Tab. 109 NMT_DeviceType_U32 value interpretation

NMT_DeviceType_U32 is composed of a 16-bit field which describes the device profile that is used and a second 16-bit field which gives additional information about optional functionality of the device.

The Additional Information parameter is device profile specific. Its specification does not fall within the scope of this document, it is defined in the appropriate device profile. The value 0000$_h$ indicates a device that does not follow a standardised device profile.

For multiple device modules the Additional Information parameter contains FFFF$_h$ and the device profile number referenced by object 1000$_h$ is the device profile of the first device in the Object Dictionary. All other devices of a multiple device module identify their profiles at objects 67FF$_h$ + x * 800$_h$ with x = internal number of the device (0 – 7). These entries describe the device type of the preceding device.

7.2.1.1.2 Object 1008$_h$: NMT_ManufactDevName_VS

Contains the manufacturer device name.

If implemented, it shall be setup by the device firmware during system initialisation.

Remark: In the device description file (see separate paper) the sub element “productName” of element “DeviceIdentity” must be equal to NMT_ManufactDevName_VS.

Index	1008_h	Object Type	VAR
Name	NMT_ManufactDevName_VS		
Data Type	VISIBLE_STRING	Category	O
Value Range	-	Access	const
Default Value	-	PDO Mapping	No

7.2.1.1.3 Object 1009_h: NMT_ManufactHwVers_VS

Contains the manufacturer hardware version description.

Remark: In the device description file (see separate paper) the sub element "version" (with attribute "versionType" set to "HW") of element "DeviceIdentity" must be equal to NMT_ManufactHwVers_VS.

Index	1009_h	Object Type	VAR
Name	NMT_ManufactHwVers_VS		
Data Type	VISIBLE_STRING	Category	O
Value Range	-	Access	const
Default Value	-	PDO Mapping	No

7.2.1.1.4 Object $100A_h$: NMT_ManufactSwVers_VS

Contains the manufacturer software version description.

Remark: In the device description file (see separate paper) the sub element "version" (with attribute "versionType" set to "FW") of element "DeviceIdentity" must be equal to NMT_ManufactSwVers_VS.

Index	$100A_h$	Object Type	VAR
Name	NMT_ManufactSwVers_VS		
Data Type	VISIBLE_STRING	Category	O
Value Range	-	Access	const
Default Value	-	PDO Mapping	No

7.2.1.1.5 Object 1018_h: NMT_IdentityObject_REC

The object at index 1018_h contains general information about the device.

The values shall be setup by the device firmware during system initialisation.

Index	1018_h	Object Type	RECORD
Name	NMT_IdentityObject_REC		
Data Type	IDENTITY	Category	M

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	1 .. 4	Access	const
Default Value	-	PDO Mapping	No

- **Sub-Index 01_h: VendorId_U32**

Sub-Index	01_h		
Name	VendorId_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	const
Default Value	-	PDO Mapping	No

The sub-index provides the manufacturer-specific vendor ID.

The POWERLINK vendor ID is equal to the CANopen vendor ID.

Note: A CANopen vendor ID can be obtained from CAN in Automation (CiA).

- **Sub-Index 02$_h$: ProductCode_U32**

Sub-Index	02$_h$		
Name	ProductCode_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	const
Default Value	-	PDO Mapping	No

The manufacturer-specific Product code identifies a specific device version. The value shall be equal to the device description entry D_NMT_ProductCode_U32.

- **Sub-Index 03$_h$: RevisionNo_U32**

Sub-Index	03$_h$		
Name	RevisionNo_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	const
Default Value	-	PDO Mapping	No

The manufacturer-specific revision number consists of a major revision number and a minor revision number. The major revision number identifies a specific device behaviour. If the device functionality is expanded, the major revision has to be incremented. The minor revision number identifies different versions with the same device behaviour. The value shall be equal to the device description entry D_NMT_RevisionNo_U32.

31	**16**	**15**	**0**
major revision number		minor revision number	
MSB			LSB

Tab. 110 Structure of Revision number

- **Sub-Index 04$_h$: SerialNo_U32**

Sub-Index	04$_h$		
Name	SerialNo_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	const
Default Value	-	PDO Mapping	No

The sub-index provides the Serial Number of the device.

7.2.1.1.6 Object 1F82$_h$: NMT_FeatureFlags_U32

Feature Flags indicate communication profile specific properties of the device given by it’s design.

The object shall be setup by the device firmware during system initialisation.

Index	1F82$_h$	Object Type	VAR
Name	NMT_FeatureFlags_U32		
Data Type	UNSIGNED32	Category	M
Value Range	-	Access	const
Default Value	-	PDO Mapping	No

- **Value Interpretation**

Octet	Bit	Name	TRUE	FALSE
0	0	Isochronous	device may be isochronously accessed via PReq, it may be operated as isochronous CN (see 4.2.2.2.1)	device does not support isochronous access via PReq, it may be exclusively used as async-only CN (see 4.2.2.2.2)
			D_NMT_Isochronous_BOOL	
	1	SDO by UDP/IP	device supports	device does not support
			SDO communication via UDP/IP frames (see 6.3.3.1) D_SDO_SupportUdpIp_BOOL	
	2	SDO by Asnd	device supports	device does not support
			SDO communication via POWERLINK ASnd frames (see 6.3.3.1) D_SDO_SupportASnd_BOOL	
	3	SDO by PDO	device supports	device does not support
			SDO communication via container embedded in PDO communication (see 6.3.3.1) D_SDO_SupportPDO_BOOL	
	4	NMT Info Services	device supports	device does not support
			NMT Info Services (see 7.3.4) *Note: Device description entries are defined for each service.*	
	5	Extended NMT State Commands	device supports	device does not support
			reception of Extended NMT State Commands (see 7.3.1.2.2) D_NMT_ExtNmtCmds_BOOL	
	6	Dynamic PDO Mapping	device supports	device does not support
			dynamic PDO mapping (see 6.4.2) D_PDO_DynamicMapping_BOOL	
	7	NMT Services by UDP/IP	device supports	device does not support
			NMT Services by UDP/IP (see 7.3.8) D_NMT_ServiceUdpIp_BOOL	
1	8	Configuration Manager	device supports	device does not support
			Configuration manager functions (see 6.7) D_CFM_ConfigManager_BOOL	
	9	Multiplexed Access	CN device supports	CN device does not support
			Multiplexed isochronous access (see 4.2.4.1.1.1) D_DLL_CNFeatureMultiplex_BOOL	
	10	Node ID setup by SW	device supports	device does not support
			Node ID setup by SW (see 7.2.1.3.1) D_NMT_NodeIDBySW_BOOL	
	11	MN Basic Ethernet Mode	MN device supports	MN device does not support
			Basic Ethernet Mode (see 7.1.3.2.3) D_NMT_MNBasicEthernet_BOOL	
	12	Routing Type 1 Support	device supports	device does not support
			Routing Type 1 functions (see 9.1) D_RT1_RT1Support_BOOL	
	13	Routing Type 2 Support	device supports	device does not support
			Routing Type 2 functions (see 9.2) D_RT2_RT2Support_BOOL	
	14	SDO Read/Write All by Index	device supports	device does not support
			SDO commands Read and Write All by Index (see 6.3.2.4.2) D_SDO_CmdReadAllByIndex_BOOL, D_SDO_CmdWriteAllByIndex_BOOL	
	15	SDO Read/Write Multiple Parameter by Index	device supports	device does not support
			SDO commands Read and Write Multiple Parameter by Index (see 6.3.2.4.2) D_SDO_CmdReadMultParam_BOOL,	

Octet	Bit	Name	TRUE	FALSE
			D_SDO_CmdWriteMultParam_BOOL	
2	16	reserved	Used by EPSG DS302-B [2]	
	17	reserved	Used by EPSG DS302-A [1]	
	18	reserved	Used by EPSG DS302-C [3]	
	19	reserved	Used by EPSG DS302-D [4]	
	20	reserved	Used by EPSG DS302-E [5]	
	21	reserved	Used by EPSG DS302-F [6]	
	22 .. 23	reserved	--	--
3	24 .. 31	reserved	--	--

Tab. 111 NMT_FeatureFlags_U32 interpretation

7.2.1.1.7 Object 1F83h: NMT_EPLVersion_U8

The index holds the POWERLINK communication profile version that is implemented by device.

The value shall be setup by the device firmware during system initialisation.

Index	1F83h	Object Type	VAR
Name	NMT_EPLVersion_U8		
Data Type	UNSIGNED8	Category	M
Value Range	-	Access	const
Default Value	-	PDO Mapping	No

- **Value Interpretation**

High Nibble	Low Nibble
POWERLINK Main Version	POWERLINK Sub Version

Tab. 112 NMT_EPLVersion_U8 encoding

7.2.1.2 Parameter Storage

7.2.1.2.1 Object 1010h: NMT_StoreParam_REC

This object supports the saving of parameters in non volatile memory. By read access the device provides information about its saving capabilities.

Index	1010h	Object Type	RECORD
Name	NMT_StoreParam_REC		
Data Type	NMT_ParameterStorage_TYPE	Category	O

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	01h .. 7Fh	Access	const
Default Value	-	PDO Mapping	No

NumberOfEntries is implemetation specific.

- **Sub-Index 01_h: AllParam_U32**

Sub-Index	01_h		
Name	AllParam_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	rw
Default Value	-	PDO Mapping	No

Refers to all parameters that can be stored on the device.

- **Sub-Index 02_h: CommunicationParam_U32**

Sub-Index	02_h		
Name	CommunicationParam_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rw
Default Value	-	PDO Mapping	No

Refers to communication related parameters (Index 1000_h .. $1FFF_h$: manufacturer specific communication parameters).

- **Sub-Index 03_h: ApplicationParam_U32**

Sub-Index	03_h		
Name	ApplicationParam_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rw
Default Value	-	PDO Mapping	No

Refers to application related parameters (Index 6000_h .. $9FFF_h$: manufacturer specific application parameters).

- **Sub-Index 04_h .. $7F_h$: ManufacturerParam_*XXh*_U32**

Sub-Index	04h .. 7Fh		
Name	ManufacturerParam_XXh_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rw
Default Value	-	PDO Mapping	No

ManufacturerParam_*XXh*_U32 provide means to store manufacturer specific lists of data.

To allow access by name "*_XXh*" is replaced with a name index. For example, the name index is "*_04h*" if the sub-index is 04_h. The name index is incremented up to "*_7Fh*" corresponding to sub-index $7F_h$.

- **Value Interpretation of Sub-Index 01_h .. $7F_h$**

In order to avoid storage of parameters by mistake, storage is only executed when a specific signature is written to the appropriate sub-index. The signature is „save“.

Signature	MSB			LSB
ISO 8859 ("ASCII")	e	v	a	s
hex	65_h	76_h	61_h	73_h

Tab. 113 NMT_StoreParam_REC storage write access signature

On reception of the correct signature in the appropriate sub-index the device stores the parameter and then confirms the SDO transmission. If the storing fails, the device responds with an Abort SDO Transfer.

If a wrong signature is written, the device refuses to store it and responds with Abort SDO Transfer.

On read access to the appropriate sub-index the device provides information about its storage functionality with the following format:

	UNSIGNED32		
	MSB		LSB
bits	31 .. 2	1	0
	reserved (=0)	0/1	0/1

Tab. 114 NMT_StoreParam_REC storage read access structure

bit	value	meaning
31 .. 2	0	Reserved (=0_b)
1	0	Device does not save parameters autonomously
	1	Device saves parameters autonomously
0	0	Device does not save parameters on command
	1	Device saves parameters on command

Tab. 115 NMT_StoreParam_REC structure of read access

Autonomous saving means that a device stores the storable parameters in a non-volatile memory without user request.

7.2.1.2.2 Object 1011_h: NMT_RestoreDefParam_REC

With this object the default values of parameters according to the communication or device profile are restored. By read access the device provides information about its capabilities to restore these values. Several parameter groups are distinguished:

Index	1011_h	Object Type	RECORD
Name	NMT_RestoreDefParam_REC		
Data Type	NMT_ParameterStorage_TYPE	Category	O

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	01_h .. $7F_h$	Access	const
Default Value	-	PDO Mapping	No

NumberOfEntries is implemetation specific.

- **Sub-Index 01_h: AllParam_U32**

Sub-Index	01_h		
Name	AllParam_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	rw, cf. Validation information
Default Value	-	PDO Mapping	No

Refers to all parameters that can be stored on the device.

- **Sub-Index 02h: CommunicationParam_U32**

Sub-Index	02_h		
Name	CommunicationParam_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rw, cf. Validation information
Default Value	-	PDO Mapping	No

Restore communication default parameters, refers to communication related parameters (Index 1000_h .. $1FFF_h$: manufacturer specific communication parameters).

- **Sub-Index 03h: ApplicationParam_U32**

Sub-Index	03_h		
Name	ApplicationParam_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rw, cf. Validation information
Default Value	-	PDO Mapping	No

Restore application default parameters, refers to application related parameters (Index 6000_h – $9FFF_h$ manufacturer specific application parameters).

- **Sub-Index 04_h .. $7F_h$: ManufacturerParam_XXh_U32**

Sub-Index	04_h .. $7F_h$		
Name	ManufacturerParam_*XXh*_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rw, cf. Validation information
Default Value	-	PDO Mapping	No

Restore manufacturer defined default parameters. Manufacturers may restore their individual choice of parameters.

To allow access by name "*_XXh*" is replaced with a name index. For example, the name index is "*_04h*" if the sub-index is 04_h. The name index is incremented up to "*_7Fh*" corresponding to sub-index $7F_h$.

- **Sub-Index 01_h – $7F_h$ Value Interpretation**

In order to avoid the restoring of default parameters by mistake, restoring is only executed when a specific signature is written to the appropriate sub-index. The signature is „load".

Signature	MSB			LSB
ISO 8859 ("ASCII")	d	a	o	l
hex	64_h	61_h	$6F_h$	$6C_h$

Tab. 116 NMT_RestoreDefParam_REC restoring write access signature

On reception of the correct signature in the appropriate sub-index the device restores the default parameters and then confirms the SDO transmission. If the restoring failed, the device responds with an Abort SDO Transfer. If a wrong signature is written, the device refuses to restore the defaults and responds with an Abort SDO Transfer.

On read access to the appropriate sub-index the device provides information about its default parameter restoring capability with the following format:

	UNSIGNED32	
	MSB	LSB
bits	31 .. 1	0
	reserved (=0)	0/1

Tab. 117 NMT_RestoreDefParam_REC restoring default values read access structure

bit number	value	meaning
31 .. 1	0	reserved (=0)
0	0	Device does not restore default parameters
	1	Device restores parameters

Tab. 118 NMT_RestoreDefParam_REC structure of restore read access

- **Validation Information**

Following a restore-default-parameter SDO command the objects initially keep their current values and are set to their default values after the device is reset (NMTResetNode for sub-index 01_h, 03_h .. $7F_h$, NMTResetCommunicationsufficient for sub-index 2_h) or power cycled.

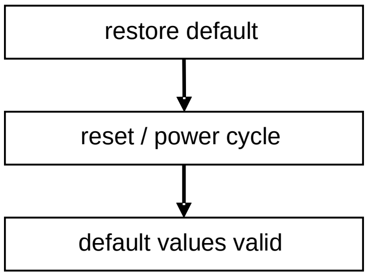


Fig. 75. NMT_RestoreDefParam_REC restore procedure

7.2.1.3 Communication Interface Description

7.2.1.3.1 Object $1F93_h$: NMT_EPLNodeID_REC

The object stores the devices's POWERLINK Node ID.

Index	$1F93_h$	Object Type	RECORD
Name	NMT_EPLNodeID_REC		
Data Type	NMT_EPLNodeID_TYPE	Category	M

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	2,3	Access	const
Default Value	depends on presence of Sub-Index 03_h	PDO Mapping	No

- **Sub-Index 01_h: NodeID_U8**

Sub-Index	01_h		
Name	NodeID_U8		
Data Type	UNSIGNED8	Category	M
Value Range	1 .. 240, 253, 254	Access	ro
Default Value	-	PDO Mapping	No

The sub-index holds the device's actual Node ID. NodeID_U8 may be provided by hardware settings (dip switch etc.) or set up by software.

- **Sub-Index 02h: NodeIDByHW_BOOL**

Sub-Index	02h		
Name	NodeIDByHW_BOOL		
Data Type	BOOLEAN	Category	M
Value Range	BOOLEAN	Access	ro
Default Value	-	PDO Mapping	No

The sub-index displays the Node ID setup mode of the device. It shall be setup during system initialisation.

- On devices, that setup the POWERLINK Node ID exclusively by HW, the object sub-index be set to TRUE.
- On devices, that setup the POWERLINK Node ID exclusively by SW, the object sub-index be set to FALSE.
- On devices, that enable SW POWERLINK Node ID setup by a special HW setup, the sub-index shall be set to FALSE, if POWERLINK Node ID setup by SW is enabled.

  If SW POWERLINK Node ID setup is enabled by a Node ID HW switch, it's recommended to use Node ID setup = 0.

The ability to define the POWERLINK Node ID by SW shall be indicated in the object dictionary entry NMT_FeatureFlags_U32 Bit 10 and in the device description by D_NMT_NodeIDBySW_BOOL. HW setup ability is indicated in the device description by D_NMT_NodeIDByHW_BOOL .

- **Sub-Index 03h: SWNodeID_U8**

Sub-Index	03h		
Name	SWNodeID_U8		
Data Type	UNSIGNED8	Category	Cond
Value Range	1 .. 240, 253, 254	Access	cond, valid on reset
Default Value	-	PDO Mapping	No

The sub-index may be used to setup the Node ID by SW.

If the device supports Node ID setup by SW (NMT_FeatureFlags_U32 Bit 10 is set and D_NMT_NodeIDBySW_BOOL is true), the sub-index shall be mandatory. Access shall be rws. Activation of the setting shall be indicated by sub_index 02h.

If the device does not support Node ID setup by SW, the sub-index shall be optional. If implemented, access shall be ro.

7.2.1.3.2 Object 1030h .. 1039h : NMT_InterfaceGroup_*Xh*_REC

The following objects are used to configure and retrieve parameters of the network interfaces (physical or virtual) via SDO. Each interface has one entry. The InterfaceGroup_REC object is a subset of the Interface Group RFC1213.

POWERLINK interfaces shall be described by the low order objects (e.g. 1030h, 1031h, …).

Index	1030h .. 1039h	Object Type	RECORD
Name	NMT_InterfaceGroup_*Xh*_REC		
Data Type	NMT_InterfaceGroup_TYPE	Category	1030h: M 1031h .. 1039h: O

To allow access by name "*_Xh*" is replaced with a name index. For example, the name index is "*_0h*" if the object index is 1030h. The name index is incremented up to "*_9h*" corresponding to object index 1039h.

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	9	Access	const
Default Value	9	PDO Mapping	No

- **Sub-Index 01_h: InterfaceIndex_U16**

Sub-Index	01_h		
Name	InterfaceIndex_U16		
Data Type	UNSIGNED16	Category	M
Value Range	1..10	Access	ro
Default Value	-	PDO Mapping	No

Interface index of the physical interface. This number is the index number subtracted by $102F_h$. The POWERLINK node that adds an interface generates the respective value.

The interface identified by a particular value of this index is the same interface as identified by the same value of NWL_IpAddrTable_*Xh*_REC.IfIndex_U16.

- **Sub-Index 02_h: InterfaceDescription_VSTR**

Sub-Index	02_h		
Name	InterfaceDescription_VSTR		
Data Type	VISIBLE_STRING	Category	M
Value Range	-	Access	const
Default Value	-	PDO Mapping	No

A textual string containing information about the interface. This string should include the name of the manufacturer, the product name and the version of the hardware interface.

The value shall be setup by the device firmware during system initialisation.

- **Sub-Index 03_h: InterfaceType_U8**

Sub-Index	03_h		
Name	InterfaceType_U8		
Data Type	UNSIGNED8	Category	M
Value Range	1 – other 6 – ethernet-csmacd 7 – iso88023-csmacd see RFC1213 Interface Group object if Type for further numbers	Access	const
Default Value	6 – ethernet-csmacd	PDO Mapping	No

The type of interface, distinguished according to the physical/link protocol(s) immediately ‘below’ the network layer in the protocol stack.

The value shall be setup by the device firmware during system initialisation.

- **Sub-Index 04_h: InterfaceMtu_U16**

Sub-Index	04_h		
Name	InterfaceMtu_U16		
Data Type	UNSIGNED16	Category	M
Value Range	UNSIGNED16	Access	const
Default Value	-	PDO Mapping	No

The size of the largest datagram which can be sent/received on the interface, specified in octets. This size also includes the header of the data link layer.

Example: for Ethernet this is the size of the largest frame including MAC addresses, EtherType and checksum at the end of the frame.

The value shall be setup by the device firmware during system initialisation.

- **Sub-Index 05_h: InterfacePhysAddress_OSTR**

Sub-Index	05_h		
Name	InterfacePhysAddress_OSTR		
Data Type	OCTET_STRING	Category	M
Value Range	-	Access	const
Default Value	-	PDO Mapping	No

The interface's address at the protocol layer immediately 'below' the network layer in the protocol stack, e.g. the MAC address of an Ethernet interface. For interfaces which do not have such an address (e.g. a serial line), this object should contain an octet string of zero length.

The value shall be setup by the device firmware during system initialisation. It shall be read from the hardware.

- **Sub-Index 06_h: InterfaceName_VSTR**

Sub-Index	06_h		
Name	InterfaceName_VSTR		
Data Type	VISIBLE_STRING	Category	M
Value Range	-	Access	ro
Default Value	-	PDO Mapping	No

A user reference name for the interface. This name shall be the name used by the device driver to access the interface (e.g. for Linux "eth0").

- **Sub-Index 07_h: InterfaceOperStatus_U8**

Sub-Index	07_h		
Name	InterfaceOperStatus_U8		
Data Type	UNSIGNED8	Category	M
Value Range	0 – Down 1 – Up	Access	ro
Default Value	-	PDO Mapping	No

The current operational state of the interface.

- **Sub-Index 08_h: InterfaceAdminState_U8**

Sub-Index	08_h		
Name	InterfaceAdminState_U8		
Data Type	UNSIGNED8	Category	M
Value Range	0 – Down 1 – Up	Access	rws
Default Value	Up	PDO Mapping	No

The current administration state (Down/Up) of the interface.

The value shall not be set to "Down" if this is the only interface that is "Up".

- **Sub-Index 09_h: Valid_BOOL**

Sub-Index	09_h		
Name	Valid_BOOL		
Data Type	BOOLEAN	Category	M
Value Range	BOOLEAN	Access	rws
Default Value	-	PDO Mapping	No

Specifies whether or not the data of this object is valid. If the value is TRUE the data of this object is valid. If the value is FALSE the data of this object is invalid.

- **Sub-Index 0A$_h$:**

  Used by EPSG DS302-E [5]

7.2.1.3.3 Object 1F9A$_h$: NMT_HostName_VSTR

Provides the node's DNS hostname.

The Object shall be supported only if IP is supported by the device. (refer 5.1)

Index	1F9A$_h$	Object Type	VAR
Name	NMT_HostName_VSTR		
Data Type	VISIBLE_STRING32	Category	Cond
Value Range	see 5.1.4	Access	rws
Default Value	-	PDO Mapping	No

7.2.1.4 Node List

7.2.1.4.1 Object 1F81h: NMT_NodeAssignment_AU32

This object assigns nodes to the NMT Master (MN).

On the CN the object is conditional. It shall be supplied if one of the following the ARRAY type objects are implemented by the CN: NMT_MultiplCycleAssign_AU8, NMT_ConsumerHeartbeatTime_AU32, or NMT_PresPayloadLimitList_AU16.

Each sub-index in the array corresponds to the node with the Node ID equal to the sub-index.

Available Node IDs may be restricted by the device description entries D_NMT_MaxCNNumber_U8 and D_NMT_MaxCNNodeID_U8 (cf 4.5). Sub-Indices corresponding to invalid Node IDs shall be set to 0.

The sub-index equal to the MN's Node ID C_ADR_MN_DEF_NODE_ID shall represent the MN.

The object should be set by the system configuration. It should be equal on all nodes providing this object.

On the MN, the object controls the identification of CNs. If the object is modified in state NMT_MS_PRE_OPERATIONAL_1, the identification process shall be restarted.

Index	1F81h	Object Type	ARRAY
Name	NMT_NodeAssignment_AU32		
Data Type	UNSIGNED32	Category	MN: M CN: Cond

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	rws, valid on reset
Default Value	254	PDO Mapping	No

- **Sub-Index 01h .. FEh: NodeAssignment**

Sub-Index	01h .. FEh		
Name	NodeAssignment		
--	--	Category	M
Value Range	Bit field, see below	Access	rws, valid on reset
Default Value	0	PDO Mapping	No

- **NodeAssignment Value Interpretation**

Octet	Bit[23]	Value	Description	Property	Evaluate
0	0	0_b	Node with this ID does not exist, Bits 1 to 30 above are not used.	MN, CN	MN, CN
		1_b	Node with this ID exists.		
	1	0_b	Node with this ID is not a CN, Bits 2 .. 7, 9, 13 .. 30 are not used.	MN, CN	MN, CN
		1_b	Node with this ID is a CN. After configuration (with Configuration Manager) the Node will be set to state NMT_CS_OPERATIONAL.		
	2	0_b	On detection of a booting CN inform the application but do NOT automatically configure and start the node.	CN	MN
		1_b	On detection of a booting CN inform the application and continue the process “START_CN” (see 7.4.2.2.4)		
	3	0_b	Optional CN.	CN	MN, CN
		1_b	Mandatory CN.		
	4	0_b	The CN node may be reset by the NMTSwReset, NMTResetNode, NMTResetCommunication or NMTResetConfiguration command independent of its state. Hence no checking of its state needs to be performed prior to NMT Reset Communication.	CN	MN
		1_b	MN must not send any of the reset commands listed above to this node if it notices that the CN is in NMT_CS_OPERATIONAL state.		
	5	0_b	Application software version verification for this node is not required.	CN	MN
		1_b	Application software version verification for this node is required.		
	6	0_b	Automatic application software update (download) is not allowed.	CN	MN
		1_b	Automatic application software update (download) is allowed.		
	7	---	Reserved (0_b).	---	---
1	8	0_b	Isochronously accessed node	MN, CN	MN, CN
		1_b	AsyncOnly node		
	9	0_b	continuously accessed CN	CN	MN, CN
		1_b	multiplexed CN		
	10	0_b	device is not a Router Type 1	MN, CN	MN, CN
		1_b	device is a Router Type 1		
	11	0_b	device is not a Router Type 2	MN, CN	MN, CN
		1_b	device is a Router Type 2		
	12	0_b	MN does not transmit Pres	MN	MN, CN
		1_b	MN transmits Pres		
	13	---	Reserved (0_b), used by EPSG DS302-B [2]	---	---
	14	---	Reserved (0_b), used by EPSG DS302-C [3]	---	---
	15	---	Reserved (0_b), used by EPSG DS302-E [5]	---	---
2	16 .. 23	---	Reserved (00_h).	---	---
3	24 .. 30	---	Reserved ($000\ 0000_b$).	---	---

[23] Bit 0 and further bits may be used to control allocation of memory for depending OD entries

Octet	Bit[23]	Value	Description	Property	Evaluate
	31	0_b	Bit 0 .. 30 not valid	MN, CN	MN, CN
		1_b	Bit 0 .. 30 valid		

Tab. 119 NMT_NodeAssignment_AU32 interpretation

Bits that control a feature that is not supported by the implementation are ro.

Bit 31 may be used to control memory allocation for Node list array sub-indices located on the MN and the CN.

7.2.1.5 Timing

The indices described by this paragraph control the timing behavior of the POWERLINK network traffic. They are common for MN and CN as well. Additional values, that are provided by the MN implementation only, are listed in 7.2.2.3.

7.2.1.5.1 Object 1006_h: NMT_CycleLen_U32

This object defines the communication cycle time interval in µs. This period defines the SYNC interval.

The object should be set by the system configuration.

Index	1006_h	Object Type	VAR
Name	NMT_CycleLen_U32		
Data Type	UNSIGNED32	Category	M
Value Range	refer below	Access	rws, valid on reset
Default Value	-	PDO Mapping	No

Communication cycle period setup values shall be limited by the device description entries D_NMT_CycleTimeMin_U32 and D_NMT_CycleTimeMax_U32. Both limits shall be multiples of D_NMT_CycleTimeGranularity_U32. Between the limits, values may be taken from the continuum (D_NMT_CycleTimeGranularity_U32 = 1) or stepwise setup may be applied (D_NMT_CycleTimeGranularity_U32 > 1).

To avoid incompatible step sizes that lead to a huge cycle time, D_NMT_CycleTimeGranularity_U32 should be a multiple of the two base granularities 100 µs or 125 µs.

7.2.1.5.2 Object $1F98_h$: NMT_CycleTiming_REC

NMT_CycleTiming_REC provides node specific timing parameters, that influence the POWERLINK cycle timing.

Index	$1F98_h$	Object Type	RECORD
Name	NMT_CycleTiming_REC		
Data Type	NMT_CycleTiming_TYPE	Category	M

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	MN: 9; CN: 8 .. 9	Access	const
Default Value	MN: 9, CN: -	PDO Mapping	No

- **Sub-Index 01h: IsochrTxMaxPayload_U16**

Sub-Index	01h		
Name	IsochrTxMaxPayload_U16		
Data Type	UNSIGNED16	Category	M
Value Range	36 .. C_DLL_ISOCHR_MAX_PAYL	Access	const
Default Value	-	PDO Mapping	No

Provides the device specific upper limit for payload data size in octets of isochronous messages to be transmitted by the device.

On all nodes, the sub-index limits the size of the Pres frame issued by the node (sub-index PresActPayloadLimit_U16, refer below). Additionally on the MN, the size of transmitted Preq messages (object NMT_MNPReqPayloadLimitList_AU16) is affected.

The limit shall be setup by the device firmware during system initialisation.

- **Sub-Index 02h: IsochrRxMaxPayload_U16**

Sub-Index	02h		
Name	IsochrRxMaxPayload_U16		
Data Type	UNSIGNED16	Category	M
Value Range	36 .. C_DLL_ISOCHR_MAX_PAYL	Access	const
Default Value	-	PDO Mapping	No

Provides the device specific upper limit for payload data size in octets of isochronous messages to be received by the device.

On all nodes, the sub-index limits the size of the Pres frames received by the node (object NMT_PresPayloadLimitList_AU16, see 7.2.1.5.5). Additionally on the CN, the size of the received Preq message (sub-index PreqActPayloadLimit_U16, refer below) is affected.

The limit shall be setup by the device firmware during system initialisation.

- **Sub-Index 03h: PresMaxLatency_U32**

Sub-Index	03h		
Name	PresMaxLatency_U32		
Data Type	UNSIGNED32	Category	CN: M MN: -
Value Range	UNSIGNED32	Access	const
Default Value	-	PDO Mapping	No

Provides the maximum time in ns, that is required by the CN to respond to Preq.

The value shall be setup by the device firmware during system initialisation.

- **Sub-Index 04$_h$: PreqActPayloadLimit_U16**

Sub-Index	04$_h$		
Name	PreqActPayloadLimit_U16		
Data Type	UNSIGNED16	Category	CN: M MN: -
Value Range	36 .. sub-index 02$_h$	Access	rws, valid on reset *)
Default Value	-	PDO Mapping	No

Provides the configured Preq payload data slot size in octets expected by the CN. The payload data slot size plus headers gives the size of the Preq frame. The data slot may be filled by PDO data up to this limit.

Note: This results in a fixed frame size regardless of the size of PDO data used.

*) The current value of PreqActPayloadLimit_U16 shall be used for checking the mapping at activation.

Note: The new mapping is active immediately. If the mapping is active but the mapped data are larger than frame size the received frame shall be ignored. See 6.4.8.2
However the frame size shall change to the current version of PreqActPayloadLimit_U16 after a reset configuration only.

The MN holds a list of node specific Preq payload data slot values to be transmitted in object NMT_MNPReqPayloadLimitList_AU16.

- **Sub-Index 05$_h$: PresActPayloadLimit_U16**

Sub-Index	05$_h$		
Name	PresActPayloadLimit_U16		
Data Type	UNSIGNED16	Category	CN: M MN: O
Value Range	36 .. sub-index 01$_h$	Access	rws, valid on reset *)
Default Value	-	PDO Mapping	No

Provides the configured Pres payload data slot size in octets sent by the CN. The payload data slot size plus headers gives the size of the Pres frame. The data slot may be filled by PDO data up to this limit.

Note: This results in a fixed frame size regardless of the size of PDO data used

*) The current value of PresActPayloadLimit_U16 shall be used for checking the mapping at activation.

Note: The new mapping is active immediately. If the mapping is active but the mapped data are larger than the frame size the RD flag shall be reset. See 6.4.8.2
However the frame size shall change to the current version of PresActPayloadLimit_U16 after a reset configuration only.

The Pres payload values expected to be received by the node are listed in object NMT_PresPayloadLimitList_AU16.

- **Sub-Index 06$_h$: AsndMaxLatency_U32**

Sub-Index	06$_h$		
Name	AsndMaxLatency_U32		
Data Type	UNSIGNED32	Category	CN: M MN: -
Value Range	UNSIGNED32	Access	const
Default Value	-	PDO Mapping	No

Provides the maximum time in ns, that is required by the CN to respond to SoA.

The value shall be setup by the device firmware during system initialisation.

- **Sub-Index 07_h: MultiplCycleCnt_U8**

Sub-Index	07_h		
Name	MultiplCycleCnt_U8		
Data Type	UNSIGNED8	Category	M
Value Range	UNSIGNED8	Access	rws, valid on reset
Default Value	0	PDO Mapping	No

This sub-index describes the length of the multiplexed cycle in multiples of the POWERLINK cycle.

The MultiplCycleCnt_U8 value shall be upper limited by the MN's device description entry D_NMT_MNMultiplCycMax_U8. It shall be equal in all nodes of the segment.

If MultiplCycleCnt_U8 is zero, there is no support of multiplexed cycle on the network.

Note: A value of one is a valid value despite the fact that this does not result in a multiplexing.

- **Sub-Index 08_h: AsyncMTU_U16**

Sub-Index	08_h		
Name	AsyncMTU_U16		
Data Type	UNSIGNED16	Category	M
Value Range	C_DLL_MIN_ASYNC_MTU .. see below	Access	rws, valid on reset
Default Value	C_DLL_MIN_ASYNC_MTU	PDO Mapping	No

This sub-index describes the maximum asynchronous frame size in octets. The value applies to Asnd frames as well as to UDP/IP and other legacy Ethernet type frames. For this reason the value describes the length of the complete Ethernet frame minus 14 octets Ethernet header and 4 octets checksum.

AsyncMTU_U16 is upper limited by the NMT_InterfaceGroup_*Xh*_REC.InterfaceMTU_U16 values of all devices in the segment. This limit shall be 18 octets less than the minimum InterfaceMTU_U16 value provided by any node in the segment. AsyncMTU_U16 may grow up to C_DLL_MAX_ASYNC_MTU.

AsyncMTU_U16 shall be equal in all nodes of the segment.

Sub-Index 08_h shall be valid in all NMT states.

- **Sub-Index 09_h: Prescaler_U16**

Sub-Index	09_h		
Name	Prescaler_U16		
Data Type	UNSIGNED16	Category	MN: M, CN: O
Value Range	0, 1 .. 1000	Access	rws, valid on reset
Default Value	2	PDO Mapping	No

This sub-index configurates the toggle rate of the SoC PS flag. The value provides the number of cycles that have to be completed to toggle the flag by the MN.

If Prescaler_U16 is 0, there shall be no toggling of the SoC PS flag.
If Prescaler_U16 is 1 the flag shall be toggled every cycle, if its value is 2 every 2^{nd} cycle and so on.

Prescaler_U16 shall be equal in all nodes of the segment.

- **Sub-Index $0A_h$:**

Used by EPSG DS302-C [3]

- **Sub-Index $0B_h$:**

Used by EPSG DS302-C [3]

- **Sub-Index $0C_h$:**

Used by EPSG DS302-C [3]

- **Sub-Index 0Dh:**

  Used by EPSG DS302-C [3]

- **Sub-Index 0Eh:**

  Used by EPSG DS302-C [3]

- **Sub-Index 0Fh:**

  Used by EPSG DS302-E [5]

7.2.1.5.3 Object 1F9Bh: NMT_MultiplCycleAssign_AU8

This object assigns nodes to the particular POWERLINK cycles of the multiplexed cycle period defined by NMT_CycleTiming_REC.MultiplCycleCnt_U8. The value shall be equal in all nodes of the segment.

Index	1F9Bh	Object Type	ARRAY
Name	NMT_MultiplCycleAssign_AU8		
Data Type	UNSIGNED8	Category	Cond

The index shall be supported if the node supports Multiplexing (see NMT_FeatureFlags_U32, D_DLL_CNFeatureMultiplex_BOOL resp. D_DLL_MNFeatureMultiplex_BOOL) and is valid only if NMT_CycleTiming_REC.MultiplCycleCnt_U8 is not zero.

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	0 .. 254	Access	rws, valid on reset
Default Value	-	PDO Mapping	No

- **Sub-Index 01h – FEh: CycleNo**

Sub-Index	01h – FEh		
Name	CycleNo		
--	--	Category	O
Value Range	0 .. NMT_CycleTiming_REC. MultiplCycleCnt_U8	Access	rws, valid on reset
Default Value	0	PDO Mapping	No

Each sub-index in the array corresponds to the node with the Node ID equal to the sub-index. The sub-index value is valid only if there is a multiplexed node assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bits 0, 1 and 9.

CycleNo defines the POWERLINK cycle index in the multiplexed cycle, when the respective node shall be accessed. If CycleNo is zero, the node shall be accessed continuously (see 4.2.4.4).

7.2.1.5.4 Object 1016h: NMT_ConsumerHeartbeatTime_AU32

The consumer heartbeat time defines the expected heartbeat cycle time (see 7.3.5). Monitoring starts after the reception of the first heartbeat. If the consumer heartbeat time is 0 the corresponding entry is not used. The time must be a multiple of 1ms.

Index	1016_h	Object Type	ARRAY
Name	NMT_ConsumerHeartbeatTime_AU32		
Data Type	UNSIGNED32	Category	O

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	1 .. D_NMT_MaxHeartbeats_U8	Access	rws
Default Value	-	PDO Mapping	No

Number of Entries, e.g. number of guard channels, may be limited by the device description entry D_NMT_MaxHeartbeats_U8.

- **Sub-Index 01_h – FE_h: HeartbeatDescription**

Sub-Index	01_h – FE_h		
Name	HeartbeatDescription		
--	--	Category	O
Value Range	UNSIGNED32	Access	rws
Default Value	0	PDO Mapping	No

- **Sub-Index 01_h – FE_h Value Description**

	UNSIGNED32			
	MSB			**LSB**
Bits	**31-24**	**23-16**	**15-0**	
Value	reserved (value: 00h)	Node ID	heartbeat time	
Encoded as	-	UNSIGNED8	UNSIGNED16	

Tab. 120 HeartbeatDescription value interpretation

If an attempt is made to configure several non-zero consumer heartbeat times for the same Node ID the device aborts the SDO download with abort code E_NMT_INVALID_HEARTBEAT.

7.2.1.5.5 Object $1F8D_h$: NMT_PresPayloadLimitList_AU16

This object holds a list of the expected Pres payload data slot size in octets for each configured node that is isochronously accessed, e.g. via Preq / Pres frame exchange. The payload data slot size is a measure for the configured size of the Pres frame. The data slot may be filled by PDO data up to this limit.

Index	$1F8D_h$	Object Type	ARRAY
Name	NMT_PresPayloadLimitList_AU16		
Data Type	UNSIGNED16	Category	MN: M CN: O

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	rws, valid on reset
Default Value	254	PDO Mapping	No

- **Sub-Index 01_h – FE_h: PresPayloadLimit**

Sub-Index	01_h .. FE_h		
Name	PresPayloadLimit		
--	--	Category	M
Value Range	36 .. C_DLL_ISOCHR_MAX_PAYL, 0, $FFFF_h$	Access	rws, valid on reset
Default Value	36	PDO Mapping	No

Each sub-index in the array corresponds to the node with the Node ID equal to the sub-index. The sub-index value is valid only if there is an isochronous node assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bits 0 and 8.

Sub-index C_ADR_MN_DEF_NODE_ID indicates the payload size of the Pres frame issued by the MN.

A CN shall support the object only if it listens to Pres messages issued by another node (cross traffic). If the value of NMT_PresPayloadLimitList_AU16 [Node ID] equals 0, the node does not listen to the Pres of that Node ID. If the value equals $FFFF_h$, the Pres payload limit of this node equals NMT_CycleTiming_REC.IsochrRxMaxPayload_U16.

Values should be equal on all nodes of the segment.

7.2.1.6 NMT Service Interface

7.2.1.6.1 Object $1F9E_h$: NMT_ResetCmd_U8

NMT_ResetCmd_U8 may be used to initiate the reset of a node.

Index	$1F9E_h$	Object Type	VAR
Name	NMT_ResetCmd_U8		
Data Type	UNSIGNED8	Category	M
Value Range	NMTInvalidService, NMTResetNode, NMTResetConfiguration, NMTResetCommunication, NMTSwReset	Access	rw
Default Value	NMTInvalidService	PDO Mapping	No

Setting NMT_ResetCmd_U8 to the NMT Command ID NMTResetNode, NMTResetConfiguration, NMTResetCommunication or NMTSwReset (see App. 3.7) shall trigger the node internal generation of a respective NMT command to itself.

On read access, NMT_ResetCmd_U8 will always show NMTInvalidService.

If applied in NMT_CS_EPL_MODE or NMT_MS_EPL_MODE, resets by NMT_ResetCmd_U8 may violate the NMT rules and stimulate DLL and NMT Guarding errors.

7.2.1.7 NMT Diagnostics

7.2.1.7.1 Object 1F8C$_h$: NMT_CurrNMTState_U8

The index holds the node's current NMT state.

Index	1F8C$_h$	Object Type	VAR
Name	NMT_CurrNMTState_U8		
Data Type	UNSIGNED8	Category	M
Value Range	see App. 3.6	Access	ro
Default Value	NMT_CS_NOT_ACTIVE resp. NMT_MS_NOT_ACTIVE	PDO Mapping	No

An overview list containing the NMT states of all nodes in the segment is provided by MN object NMT_MNNodeCurrState_AU8.

7.2.2 NMT MN Objects

The NMT Master provides services for controlling the network behavior of nodes. Only one NMT Master can exist in an Ethernet POWERLINK Network. In POWERLINK the NMT Master is located in the MN.

The NMT Master Control Settings activate the MN functions and define the boot behavior and error reactions.

7.2.2.1 MN Start Up Behavior

Hint: MN and CN startup timing should be well balanced. System power up sequence should be considered.

7.2.2.1.1 Object 1F80$_h$: NMT_StartUp_U32

This object configures the boot behavior of a device that is able to become the MN.

Object NMT_StartUp_U32 is a configuration object. Internal state transitions must not change this object.

The object should be set by the system configuration.

The object controls the verification of CNs. If the object is modified in state NMT_MS_PRE_OPERATIONAL_1 after start of verification, verification process shall be restarted.

Index	$1F80_h$	Object Type	VAR
Name	NMT_StartUp_U32		
Data Type	UNSIGNED32	Category	M
Value Range	Bit field, see below	Access	rws, valid on reset
Default Value	-	PDO Mapping	No

- **NMT_StartUp_U32 Value Interpretation**

Octet	Bit	Value	Description
0	0	---	Reserved (0_b).
	1	0_b	Start only explicitly assigned CNs (if Bit 3 = 0_b).
		1_b	Perform the service NMTStartNode with broadcast addressing (if Bit 3 = 0_b).
	2	0_b	Automatically enter state NMT_MS_OPERATIONAL.
		1_b	Do not automatically enter state NMT_MS_OPERATIONAL. Application will decide when to enter the state.
	3	0_b	Allow to start up the CNs (i.e. to send NMTStartNode).
		1_b	Do not allow to send NMTStartNode; the application may start the CNs.
	4	0_b	On error event from guarding a mandatory CN deal with the CN individually.
		1_b	On error event from guarding a mandatory CN perform NMTResetNode with broadcast addressing. Refer to Bit 6 and NMT_NodeAssignment_AU32 Bit 3.
	5	---	Reserved (0_b).
	6	0_b	On error event from guarding a mandatory CN deal with the CN according to Bit 4.
		1_b	On error event from guarding a mandatory CN send NMTStopNode with broadcast addressing. Ignore Bit 4.
	7	0_b	Automatically enter state NMT_MS_PRE_OPERATIONAL_2.
		1_b	Do not automatically enter NMT_MS_PRE_OPERATIONAL_2. Application will decide when to enter the state.
1	8	0_b	Automatically enter state NMT_MS_READY_TO_OPERATE.
		1_b	Do not automatically enter NMT_MS_READY_TO_OPERATE. Application will decide when to enter the state.
	9	0_b	The identification of the CNs shall be limited to verification of the respective NMT_MNDeviceTypeIdList_AU32 sub-index.
		1_b	The identification of the CNs shall be completely checked.
	10	0_b	The SW-Version of the CNs shall not be checked.
		1_b	The SW-Version of the CNs shall be checked. If the check fails, the CN’s SW has to be updated.
	11	0_b	The Configuration of the CNs shall not be checked.
		1_b	The Configuration of the CNs shall be checked. If the check fails, the CN’s configuration has to be updated.
	12	0_b	In case of error event return automatically from NMT_MS_OPERATIONAL to NMT_MS_PRE_OPERATIONAL_1.
		1_b	Do not return to NMT_MS_PRE_OPERATIONAL_1. Application will decide whether to enter the state.
	13	0_b	NMT_MS_EPL_MODE activation: in NMT_MS_NOT_ACTIVE observe the network and change over to NMT_MS_PRE_OPERATIONAL_1 if there is no other MN detected
		1_b	NMT_MS_BASIC_ETHERNET released: from NMT_MS_NOT_ACTIVE change over to NMT_MS_BASIC_ETHERNET
	14	---	Reserved (0_b), used by EPSG DS302-A [1]
	15	---	Reserved (0_b)
2 – 3	16 – 31	---	Reserved (00 00_h)

Tab. 121 NMT_StartUp_U32 interpretation

7.2.2.1.2 Object 1F89$_h$: NMT_BootTime_REC

This object describes time interval values to be used by the MN when it starts the network.

It gives the maximum time, in µs, the master will wait for all mandatory CNs before signaling an error. If the time is zero (0), it will wait indefinitely.

Hint: MN and CN startup timing should be well balanced. System power up sequence should be considered.

Index	1F89$_h$	Object Type	RECORD
Name	NMT_BootTime_REC		
Data Type	NMT_BootTime_TYPE	Category	M

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	9	Access	const
Default Value	9	PDO Mapping	No

- **Sub-Index 01$_h$: MNWaitNotAct_U32**

Sub-Index	01$_h$		
Name	MNWaitNotAct_U32		
Data Type	UNSIGNED32	Category	M
Value Range	>=250	Access	rws, valid on reset
Default Value	1 000 000	PDO Mapping	No

This sub-index describes the time interval in µs that the MN shall remain in state NMT_MS_NOT_ACTIVE and listen for POWERLINK frames on the network before it changes over to NMT_MS_PRE_OPERATIONAL_1.

- **Sub-Index 02h: MNTimeoutPreOp1_U32**

Sub-Index	02$_h$		
Name	MNTimeoutPreOp1_U32		
Data Type	UNSIGNED32	Category	M
Value Range	0, 50 000 – 5 000 000	Access	rws, valid on reset
Default Value	500 000	PDO Mapping	No

This sub-index describes the time interval in µs that the MN shall wait in state NMT_MS_PRE_OPERATIONAL_1 for all mandatory CNs to be identified via the IdentRequest / IdentResponse mechanism before it signals an error to the application.

If the timeout value is zero (0), there shall be no timeout for CN identification.

- **Sub-Index 03$_h$: MNWaitPreOp1_U32**

Sub-Index	03$_h$		
Name	MNWaitPreOp1_U32		
Data Type	UNSIGNED32	Category	O
Value Range	0, 50 000 – 5 000 000	Access	rws, valid on reset
Default Value	500 000	PDO Mapping	No

This sub-index describes the time interval in µs that the MN shall remain in state NMT_MS_PRE_OPERATIONAL_1.

If the wait value is zero (0), NMT_MS_PRE_OPERATIONAL_1 shall be left as soon as all mandatory CNs have been identified.

- **Sub-Index 04h: MNTimeoutPreOp2_U32**

Sub-Index	04h		
Name	MNTimeoutPreOp2_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	rws, valid on reset
Default Value	500 000	PDO Mapping	No

This sub-index describes the time interval in µs that the MN shall wait in state NMT_MS_PRE_OPERATIONAL_2 for all mandatory CNs to complete the initialisation of the error signaling and to be in state NMT_CS_READY_TO_OPERATE before it signals an error to the application.

For all optional CNs this sub-index describes the time interval in µs that the MN shall wait after sending the NMT command NMTEnableReadyToOperate to a CN before BOOT_STEP2 returns with an error.

If the timeout value is zero (0), there shall be no timeout, i.e. the MN will wait indefinitely.

- **Sub-Index 05h: MNTimeoutReadyToOp_U32**

Sub-Index	05h		
Name	MNTimeoutReadyToOp_U32		
Data Type	UNSIGNED32	Category	M
Value Range	0, 50 000 – 5 000 000	Access	rws, valid on reset
Default Value	500 000	PDO Mapping	No

This sub-index describes the time interval in µs that the MN shall wait in state NMT_MS_READY_TO_OPERATE for all mandatory CNs to be in state NMT_CS_OPERATIONAL before it signals an error to the application.

If the timeout value is zero (0), there shall be no timeout, i.e. the MN will wait indefinitely.

- **Sub-Index 06h: MNIdentificationTimeout_U32**

Sub-Index	06h		
Name	MNIdentificationTimeout_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rws, valid on reset
Default Value	500 000	PDO Mapping	No

This sub-index describes the time interval in µs that the MN shall wait in the CHECK_IDENTIFICATION state of the boot process until a device must be able to reply to an Ident Request message before an error is signaled to the application.

If the timeout value is zero (0), there shall be no timeout, i.e. the MN will wait indefinitely.

- **Sub-Index 07h: MNSoftwareTimeout_U32**

Sub-Index	07h		
Name	MNSoftwareTimeout_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rws, valid on reset
Default Value	500 000	PDO Mapping	No

This sub-index describes the time interval in µs that the MN shall wait after the software update in the CHECK_SOFTWARE state until a device must be able to reply to an Ident Request message before an error is signaled to the application.

If the timeout value is zero (0), there shall be no timeout, i.e. the MN will wait indefinitely.

- **Sub-Index 08$_h$: MNConfigurationTimeout_U32**

Sub-Index	08$_h$		
Name	MNConfigurationTimeout_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rws, valid on reset
Default Value	500 000	PDO Mapping	No

This sub-index describes the time interval in µs that the MN shall wait after the configuration of a CN was updated in the CHECK_CONFIGURATION state until a device must be able to reply to an Ident Request message before an error is signaled to the application.

If the timeout value is zero (0), there shall be no timeout, i.e. the MN will wait indefinitely.

- **Sub-Index 09$_h$: MNStartCNTimeout_U32**

Sub-Index	09$_h$		
Name	MNStartCNTimeout_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rws, valid on reset
Default Value	500 000	PDO Mapping	No

This sub-index describes the time interval in µs that the MN shall wait for a CN in the START_CN state to switch over to NMT_CS_OPERATIONAL before an error is signaled to the application.

If the timeout value is zero (0), there shall be no timeout, i.e. the MN will wait indefinitely.

- **Sub-Index 0A$_h$**

  Used by EPSG DS302-A [1]

- **Sub-Index 0B$_h$**

  Used by EPSG DS302-A [1]

- **Sub-Index 0C$_h$**

  Used by EPSG DS302-A [1]

7.2.2.2 NMT Master Network Node Lists

The Network List consists of objects that give information about which CNs must be managed, how they should be booted and information concerning requested actions on Error events.

7.2.2.2.1 Object 1F84$_h$: NMT_MNDeviceTypeIdList_AU32

This object holds a list of the expected NMT_DeviceTypeId_U32 value for each configured CN.

The object should be set by the system configuration. It shall be filled with the NMT_DeviceType_U32 object dictionary entry of the respective device.

It may be used by the verification of CNs. If the object is modified in state NMT_MS_PRE_OPERATIONAL_1 after start of verification, verification process shall be restarted.

Index	1F84$_h$	Object Type	ARRAY
Name	NMT_MNDeviceTypeIdList_AU32		
Data Type	UNSIGNED32	Category	M

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	rws, valid on reset
Default Value	254	PDO Mapping	No

- **Sub-Index 01_h .. FE_h: CNDeviceTypeId**

Sub-Index	01_h .. FE_h		
Name	CNDeviceTypeId		
--	--	Category	M
Value Range	UNSIGNED32	Access	rws, valid on reset
Default Value	0	PDO Mapping	No

Each sub-index in the array corresponds to the node with the Node ID equal to the sub-index. The sub-index value is valid only if there is a node assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bit 0.

Sub-index C_ADR_MN_DEF_NODE_ID may represent the MN.

On Boot-Up, the CN's NMT_DeviceType_U32 value is reported to the MN via IdentResponse. The MN shall compare the received value with the respective CNDeviceTypeId sub-index value. The Boot-Up for that device is only continued when the two values are equal.

If the value in CNDeviceTypeId is 0, this read access only gives information about the mere existence of a device with this Node ID. There is no comparison to the reported NMT_DeviceType_U32 value.

For multi-device-modules the application may perform additional checks.

7.2.2.2.2 Object $1F85_h$: NMT_MNVendorIdList_AU32

This object holds a list of the expected NMT_IdentityObject_REC.VendorId_U32 value for each configured CN.

The object should be set by the system configuration. It shall be filled with the NMT_IdentityObject_REC.VendorId_U32 object dictionary entry of the respective device.

It may be used by the verification of CNs. If the object is modified in state NMT_MS_PRE_OPERATIONAL_1 after start of verification, verification process shall be restarted.

Index	$1F85_h$	Object Type	ARRAY
Name	NMT_MNVendorIdList_AU32		
Data Type	UNSIGNED32	Category	O

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	rws, valid on reset
Default Value	254	PDO Mapping	No

- **Sub-Index 01_h – FE_h: CNVendorId**

Sub-Index	01_h .. FE_h		
Name	CNVendorId		
--	--	Category	M
Value Range	UNSIGNED32	Access	rws, valid on reset
Default Value	0	PDO Mapping	No

Each sub-index in the array corresponds to the node with the Node ID equal to the sub-index. The sub-index value is valid only if there is a node assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bit 0.

Sub-index C_ADR_MN_DEF_NODE_ID may represent the MN.

On Boot-Up, the CN's NMT_IdentityObject_REC.VendorId_U32 value is reported to the MN via IdentResponse. The MN compares the received value with the respective CNVendorId sub-index value. The Boot-Up for that device is only continued when the two values are equal.

If the value in CNVendorId is 0, this read access only gives information about the mere existence of a device with this Node ID. There is no comparison with the reported NMT_IdentityObject_REC.VendorId_U32 value.

For multi-device-modules the application may perform additional checks.

7.2.2.2.3 Object 1F86$_h$: NMT_MNProductCodeList_AU32

This object holds a list of the expected NMT_IdentityObject_REC.ProductCode_U32 value for each configured CN.

The object should be set by the system configuration. It shall be filled with the D_NMT_ProductCode_U32 device descrition entry of the respective device.

It may be used by the verification of CNs. If the object is modified in state NMT_MS_PRE_OPERATIONAL_1 after start of verification, verification process shall be restarted

Index	1F86$_h$	Object Type	ARRAY
Name	NMT_MNProductCodeList_AU32		
Data Type	UNSIGNED32	Category	O

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	rws, valid on reset
Default Value	254	PDO Mapping	No

- **Sub-Index 01$_h$ – FE$_h$: CNProductCode**

Sub-Index	01$_h$ .. FE$_h$		
Name	CNProductCode		
--	--	Category	M
Value Range	UNSIGNED32	Access	rws, valid on reset
Default Value	0	PDO Mapping	No

Each sub-index in the array corresponds to the node with the Node ID equal to the sub-index. The sub-index value is valid only if there is a node assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bit 0.

Sub-index C_ADR_MN_DEF_NODE_ID may represent the MN.

On Boot-Up, the CN’s NMT_IdentityObject_REC.ProductCode_U32 value is reported to the MN via IdentResponse. The MN compares the received value with the respective CNProductCode sub-index value. The Boot-Up for that device is only continued when the two values are equal.

If the value in CNProductCode is 0, this read access only gives information about the mere existence of a device with this Node ID. There is no comparison with the reported NMT_IdentityObject_REC.ProductCode_U32 value.

For multi-device-modules the application may perform additional checks.

7.2.2.2.4 Object 1F87$_h$: NMT_MNRevisionNoList_AU32

This object holds a list of the expected NMT_IdentityObject_REC.RevisionNo_U32 value for each configured CN.

The object should be set by the system configuration. It shall be filled with the D_NMT_RevisionNo_U32 device descrition entry of the respective device.

It may be used by the verification of CNs. If the object is modified in state NMT_MS_PRE_OPERATIONAL_1 after start of verification, verification process shall be restarted

Index	$1F87_h$	Object Type	ARRAY
Name	NMT_MNRevisionNoList_AU32		
Data Type	UNSIGNED32	Category	O

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	rws, valid on reset
Default Value	254	PDO Mapping	No

- **Sub-Index 01_h – FE_h: CNRevisionNo**

Sub-Index	01_h .. FE_h		
Name	CNRevisionNo		
--	--	Category	M
Value Range	UNSIGNED32	Access	rws, valid on reset
Default Value	0	PDO Mapping	No

Each sub-index in the array corresponds to the node with the Node ID equal to the sub-index. The sub-index value is valid only if there is a node assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bit 0.

Sub-index C_ADR_MN_DEF_NODE_ID may represent the MN.

On Boot-Up, the CN's NMT_IdentityObject_REC.RevisionNo_U32 is reported to the MN via IdentResponse. The MN compares the received value with the respective CNRevisionNo sub-index value. The Boot-Up for that device is only continued when the two values are equal.

If the value in CNRevisionNo is 0, this read access only gives information about the mere existence of a device with this Node ID. There is no comparison with the reported NMT_IdentityObject_REC.RevisionNo_U32 value.

For multi-device-modules the application may perform additional checks.

7.2.2.2.5 Object $1F88_h$: NMT_MNSerialNoList_AU32

This object holds a list of the expected NMT_IdentityObject_REC.SerialNo_U32 value for each configured CN.

The object should be set by the system configuration.

It may be used by the verification of CNs. If the object is modified in state NMT_MS_PRE_OPERATIONAL_1 after start of verification, verification process shall be restarted

Index	$1F88_h$	Object Type	ARRAY
Name	NMT_MNSerialNoList_AU32		
Data Type	UNSIGNED32	Category	O

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	rws, valid on reset
Default Value	254	PDO Mapping	No

- **Sub-Index 01h – FEh: CNSerialNo**

Sub-Index	01h .. FEh		
Name	CNSerialNo		
--	--	Category	M
Value Range	UNSIGNED32	Access	rws, valid on reset
Default Value	0	PDO Mapping	No

Each sub-index in the array corresponds to the node with the Node ID equal to the sub-index. The sub-index value is valid only if there is a node assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bit 0.

Sub-index C_ADR_MN_DEF_NODE_ID may represent the MN.

On Boot-Up, the CN's NMT_IdentityObject_REC.SerialNo_U32 is reported to the MN via IdentResponse. The MN compares the received value with the respective CNSerialNo sub-index value. If the values are different a warning is issued.

If the value in CNSerialNo is 0, this read access only gives information about the mere existence of a device with this Node ID. There is no comparison with the reported NMT_IdentityObject_REC.SerialNo_U32 value.

For multi-device-modules the application may perform additional checks.

7.2.2.3 Timing

The indices described by this paragraph shall be implemented by the MN only. They control the timing behavior of the POWERLINK network traffic. They are supplemetal to the the objects described by 7.2.1.4.

7.2.2.3.1 Object 1F8Ah: NMT_MNCycleTiming_REC

This object holds timing parameter use by the MN only to control the POWERLINK cycle.

Index	1F8Ah	Object Type	RECORD
Name	NMT_MNCycleTiming_REC		
Data Type	NMT_MNCycleTiming_TYPE	Category	M

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	1 .. 4	Access	ro
Default Value	-	PDO Mapping	No

- **Sub-Index 01h: WaitSoCPReq_U32**

Sub-Index	01h		
Name	WaitSoCPReq_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	rws, valid on reset
Default Value	1000	PDO Mapping	No

The sub-index provides a time interval in ns between end of SoC transmission and begin of the next frame transmission (Preq or PresMN). This wait interval enables the CN first accessed after SoC to complete it's SoC handling.

WaitSoCPReq_U32 shall be set to the maximum of D_NMT_MNSoC2PReq_U32D_NMT_MNSoC2PReq_U32 and the D_NMT_CNSoC2PReq_U32 values of all configured isochronous CNs (cf. NMT_NodeAssignment_AU32[sub-index] Bits 0, 1 and 8).

WaitSoCPReq_U32 handling may be implemented in 2 ways (see 4.2.4.3):

a. delayed transmision of 1st Preq following SoC by MN, sub-index provides time interval between the end of the SoC transmission and the start of the first Preq

b. Transmission of the 1st Preq to the non existing node addressed by C_ADR_DUMMY_NODE_ID. The Pres frame receive timeout shall be set to WaitSoCPReq_U32. Timeout error handling (see 4.7.6.2, 4.7.6.3) shall be disabled for this dummy message.

- **Sub-Index 02h: AsyncSlotTimeout_U32**

Sub-Index	02_h		
Name	AsyncSlotTimeout_U32		
Data Type	UNSIGNED32	Category	O
Value Range	>=250	Access	rws, valid on reset
Default Value	100 000	PDO Mapping	No

The sub-index describes the worst case time interval in ns between the end of the SoA transmission and the begin of the reception of an Asnd frame issued by a CN.

- **Sub-Index 03h:**

Used by EPSG DS302-B [2]

- **Sub-Index 04h: MinRedCycleTime_U32**

Sub-Index	04_h		
Name	MinRedCycleTime_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	rws, valid on reset
Default Value	-	PDO Mapping	No

The minimum reduced cycle time (MinRedCycleTime_U32) holds the minimum time between SoA frames in the reduced cycle.

MinRedCycleTime_U32 shall be set to the maximum of D_NMT_MinRedCycleTime_U32 of the CNs.

7.2.2.3.2 Object 1F8B$_h$: NMT_MNPReqPayloadLimitList_AU16

This object holds a list of the Preq payload data slot size in octets for each configured node that is isochronously accessed, e.g. via Preq / Pres frame exchange. The payload data slot size is a measure for the configured size of the Preq frame. The data slot may be filled by PDO data up to this limit.

Index	$1F8B_h$	Object Type	ARRAY
Name	NMT_MNPReqPayloadLimitList_AU16		
Data Type	UNSIGNED16	Category	M

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	rws, valid on reset
Default Value	254	PDO Mapping	No

- **Sub-Index 01_h – FE_h: CNPReqPayload**

Sub-Index	01_h .. FE_h		
Name	CNPReqPayload		
--	--	Category	M
Value Range	36 .. C_DLL_ISOCHR_MAX_PAYL	Access	rws, valid on reset
Default Value	36	PDO Mapping	No

Each sub-index in the array corresponds to the CN with the Node ID equal to the sub-index. The sub-index value is valid only if there is an isochronous CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bits 0, 1 and 8.

7.2.2.3.3 Object $1F92_h$: NMT_MNCNPResTimeout_AU32

This object holds a list of all configured CNs in [ns] with PollRequest to PollResponse timeouts (see 4.7.6.2, 4.7.6.3).

The object should be set by the system configuration.

Index	$1F92_h$	Object Type	ARRAY
Name	NMT_MNCNPResTimeout_AU32		
Data Type	UNSIGNED32	Category	M

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	rws, valid on reset
Default Value	254	PDO Mapping	No

- **Sub-Index 01_h – FE_h: CNPResTimeout**

Sub-Index	01_h .. FE_h		
Name	CNPResTimeout		
--	--	Category	M
Value Range	UNSIGNED32	Access	rws, valid on reset
Default Value	25 000	PDO Mapping	No

Each sub-index in the array corresponds to a CN with the Node ID equal to the sub-index. The sub-index value is valid only if there is an isochronous CN assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bits 0, 1 and 8.

This parameter describes the POWERLINK node specific timeout values in ns. Whenever a PollRequest frame is sent to a CN this timer is started. (refer 4.7.6.1.1)

7.2.2.3.4 Object 1F9Cₕ: NMT_IsochrSlotAssign_AU8

This object assigns nodes to a particular isochronous slot. The isochronous POWERLINK cycle can be divided into communication slots each consisting of Preq and Pres message for a particular node (see slot 1 to n in Fig. 76).

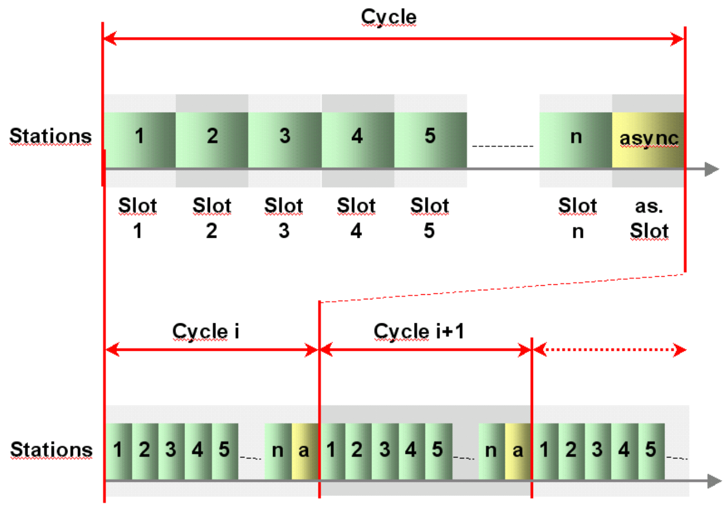


Fig. 76. POWERLINK communication slots

The object 1F9C$_h$ can be used to request fast processing nodes first and give slower nodes enough time for the SoC processing for example.

Index	1F9C$_h$	Object Type	ARRAY
Name	NMT_IsochrSlotAssign_AU8		
Data Type	UNSIGNED8	Category	O

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	1 .. 254	Access	rws, valid on reset
Default Value	254	PDO Mapping	No

Sub-index 0 may be used to limit the number of isochronous slots per cycle to be checked by the cycle producing in the DLL_MS.

- **Sub-Index 01h – Feh: NodeId**

Sub-Index	01$_h$-FE$_h$		
Name	NodeId		
--	--	Category	O
Value Range	0 .. 254	Access	rws, valid on reset
Default Value	0	PDO Mapping	No

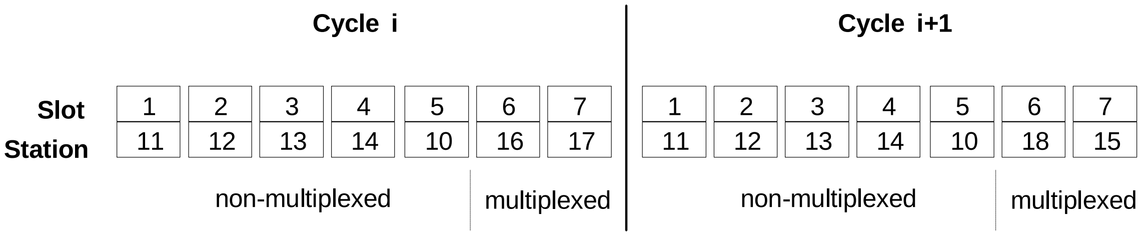
Each sub-index in the array corresponds to an individual communication slot which is equal to the sub-index. The slot shall only be used if there is an isochronous node with the Node ID assigned by index NMT_NodeAssignment_AU32[sub-index] Bits 0, 1, 8 and 9. Value 0 indicates that there is no particular node assigned to the communication slot.

The sub-indices can also be used for the slot assignment of multiplexed nodes. If multiplexed and non-multiplexed nodes shall be assigned to particular communication slots, it must be ensured that all the isochronous non-multiplexed stations are configured on the lower sub-indices of object 1F9Ch. Care has also to be taken that the multiplex slots are mapped to the communication slots in ascending order. That means the first multiplexed node assigned to object 1F9Ch must be configured in the first multiplex slot in object 1F9Bh and so on.

Gaps in the NMT_IsochrSlotAssign_AU8 are allowed as unused communication slots are skipped.

Example:

Let's assume nodes 10 to 14 are non-multiplexed nodes and nodes 15-18 are multiplexed nodes. Furthermore node 10 is a slow processing node which must be shifted away from the cycle beginning. The slot diagram for the isochronous cycle will look as follows:



The above example results in the following setup of object NMT_IsochrSlotAssign_AU8:

Index	1F9C$_h$									
sub-index	0	1	2	3	4	5	6	7	8	9
value	9	11	12	13	14	10	16	17	18	15

The setup of object 1F9Bh NMT_MultiplCycleAssign_AU8 for the multiplexed nodes 15 to 18 must look as follows:

Index	1F9Bh								
sub-index	10	11	12	13	14	15	16	17	18
value	0	0	0	0	0	2	1	1	2

7.2.2.4 CN NMT State Surveillance

The objects described by this paragraph are used by the MN surveillance of the CN NMT states as described at 7.1.4.

7.2.2.4.1 Object 1F8Eh: NMT_MNNodeCurrState_AU8

This object holds a list of the current NMT states of the configured nodes.

Index	1F8Eh	Object Type	ARRAY
Name	NMT_MNNodeCurrState_AU8		
Data Type	UNSIGNED8	Category	M

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	254	Access	const
Default Value	254	PDO Mapping	No

- **Sub-Index 01h – FEh: CurrState**

Sub-Index	01h .. FEh		
Name	CurrState		
--	--	Category	M
Value Range	see App. 3.6	Access	ro
Default Value	NMT_CS_NOT_ACTIVE resp. NMT_MS_NOT_ACTIVE	PDO Mapping	No

Each sub-index in the array corresponds to the node with the Node ID equal to the sub-index. The sub-index value is valid only if there is a node assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bit 0.

Sub-index C_ADR_MN_DEF_NODE_ID indicates the current state of the MN state machine. It holds values described by Tab. 105.

The individual states of the nodes may be locally accessed via NMT_CurrNMTState_U8.

7.2.2.4.2 Object 1F8Fh: NMT_MNNodeExpState_AU8

This object holds a list of the expected NMT states of the configured nodes in accordance with the CNs' boot-up behavior and the NMT state commands transmitted by the MN. See 7.1.4.

The sub-indices of NMT_MNNodeExpState_AU8 should be equal to those of NMT_MNNodeCurrState_AU8 expect for an interval of C_NMT_STATE_TOLERANCE after an NMT state command to the respective CN.

Index	1F8Fh	Object Type	ARRAY
Name	NMT_MNNodeExpState_AU8		
Data Type	UNSIGNED8	Category	O

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	254	Access	const
Default Value	254	PDO Mapping	No

- **Sub-Index 01_h – FE_h: ExpState**

Sub-Index	01_h .. FE_h		
Name	ExpState		
--	--	Category	M
Value Range	see App. 3.6	Access	ro
Default Value	NMT_CS_NOT_ACTIVE resp. NMT_MS_NOT_ACTIVE	PDO Mapping	No

Each sub-index in the array corresponds to the node with the Node ID equal to the sub-index. The sub-index value is valid only if there is a node assigned to the Node ID by index NMT_NodeAssignment_AU32[sub-index] Bit 0.

Sub-index C_ADR_MN_DEF_NODE_ID indicates the current state of the MN state machine. It holds values described by Tab. 105.

7.2.2.5 NMT Service Interface

7.2.2.5.1 Object $1F9F_h$: NMT_RequestCmd_REC

NMT_RequestCmd_REC may be used by a diagnostic node outside of the POWERLINK segment connected via a router to initiate an NMT command by the MN.

Index	$1F9F_h$	Object Type	RECORD
Name	NMT_RequestCmd_REC		
Data Type	NMT_RequestCmd_TYPE	Category	M

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	3 .. 4	Access	const
Default Value	-	PDO Mapping	No

- **Sub-Index 01_h: Release_BOOL**

Sub-Index	01_h		
Name	Release_BOOL		
Data Type	BOOLEAN	Category	M
Value Range	BOOLEAN	Access	rw
Default Value	FALSE	PDO Mapping	No

Writing TRUE to Release_BOOL shall trigger the positioning of the NMT command described by sub-indices 02_h to 04_h to the transmission queues of the MN.

Release_BOOL shall be automatically reset to FALSE by the MN, when queuing of the NMT services has been completed.

- **Sub-Index 02h: CmdID_U8**

Sub-Index	02h		
Name	CmdID_U8		
Data Type	UNSIGNED8	Category	M
Value Range	see.App. 3.7	Access	rw
Default Value	NMTInvalidService	PDO Mapping	No

CmdID_U8 indicates the requested NMT service. It is equivalent to the NMTRequestedCommandID entry of the NMTRequest Frame NMT Service Slot (see 7.3.6.1)

- **Sub-Index 03h: CmdTarget_U8**

Sub-Index	03h		
Name	CmdTarget_U8		
Data Type	UNSIGNED8	Category	M
Value Range	UNSIGNED8	Access	rw
Default Value	C_ADR_INVALID	PDO Mapping	No

CmdTarget_U8 indicates POWERLINK address of the target node of the requested NMT service. It is equivalent to the NMTRequestedCommandTarget entry of the NMTRequest Frame NMT Service Slot (see 7.3.6.1)

- **Sub-Index 04h: CmdData_DOM**

Sub-Index	04h		
Name	CmdData_DOM		
Data Type	DOMAIN	Category	Cond
Value Range	DOMAIN	Access	rw
Default Value	-	PDO Mapping	No

CmdData_DOM provides data specific to the requested NMT service. It is equivalent to the NMTRequestedCommandData entry of the NMTRequest Frame NMT Service Slot (see 7.3.6.1)

CmdData_DOM shall be supported if extended NMT State Command Services are supported by the MN, support shall be indicated by the object dictionary index NMT_FeatureFlags_U32 Bit 5.

7.2.3 NMT CN Objects

7.2.3.1 CN StartUp Behaviour

Hint: MN and CN startup timing should be well balanced. System power up sequence should be considered.

7.2.3.1.1 Object 1F99h: NMT_CNBasicEthernetTimeout_U32

Provide the time in µs to be applied before changing from NMT_CS_NOT_ACTIVE to NMT_CS_BASIC_ETHERNET.

Index	1F99h	Object Type	VAR
Name	NMT_CNBasicEthernetTimeout_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	rws, valid on reset
Default Value	5 000 000	PDO Mapping	No

Value 0 shall mean, never change to NMT_CS_BASIC_ETHERNET. If not 0, the value shall be greater than NMT_CycleLen_U32.

To avoid erroneous change over to NMT_CS_BASIC_ETHERNET at system startup, NMT_CNBasicEthernetTimeout_U32 should be greater than the MN’s NMT_BootTime_REC.MNWaitNotAct_U32.

Note: It is the responsibility of the user resp. configuration tool to set an appropriate value.

7.2.4 NMT Object Types

7.2.4.1 Object 0023$_h$: IDENTITY

Index	0023$_h$	Object Type	DEFSTRUCT
Name	IDENTITY		
Sub-Index	Component Name	Value	Data Type
00h	NumberOfEntries	04$_h$	
01h	VendorId_U32	0007$_h$	UNSIGNED32
02h	ProductCode_U32	0007$_h$	UNSIGNED32
03h	RevisionNo_U32	0007$_h$	UNSIGNED32
04h	SerialNo_U32	0007$_h$	UNSIGNED32

7.2.4.2 Object 0429$_h$: NMT_ParameterStorage_TYPE

Index	0429$_h$	Object Type	DEFSTRUCT
Name	NMT_ParameterStorage_TYPE		
Sub-Index	Component Name	Value	Data Type
00$_h$	NumberOfEntries	7F$_h$	
01$_h$	AllParam_U32	0007$_h$	UNSIGNED32
02$_h$	CommunicationParam_U32	0007$_h$	UNSIGNED32
03$_h$	ApplicationParam_U32	0007$_h$	UNSIGNED32
04$_h$ .. 7F$_h$	ManufacturerParam_*XXh*_U32	0007$_h$	UNSIGNED32

7.2.4.3 Object 042Bh: NMT_InterfaceGroup_TYPE

Index	042B$_h$	Object Type	DEFSTRUCT
Name	NMT_InterfaceGroup_TYPE		
Sub-Index	Component Name	Value	Data Type
00$_h$	NumberOfEntries	09$_h$	
01$_h$	InterfaceIndex_U16	0006$_h$	UNSIGNED16
02$_h$	InterfaceDescription_VSTR	0009$_h$	VISIBLE_STRING
03$_h$	InterfaceType_U8	0005$_h$	UNSIGNED8
04$_h$	InterfaceMtu_U16	0006$_h$	UNSIGNED16
05$_h$	InterfacePhysAddress_OSTR	000A$_h$	OCTET_STRING
06$_h$	InterfaceName_VSTR	0009$_h$	VISIBLE_STRING
07$_h$	InterfaceOperStatus_U8	0005$_h$	UNSIGNED8
08$_h$	InterfaceAdminState_U8	0005$_h$	UNSIGNED8
09$_h$	Valid_BOOL	0001$_h$	BOOLEAN

7.2.4.4 Object 042C$_h$: NMT_CycleTiming_TYPE

Index	042C$_h$	Object Type	DEFSTRUCT
Name	NMT_CycleTiming_TYPE		
Sub-Index	Component Name	Value	Data Type
00$_h$	NumberOfEntries	09$_h$	
01$_h$	IsochrTxMaxPayload_U16	0006$_h$	UNSIGNED16
02$_h$	IsochrRxMaxPayload_U16	0006$_h$	UNSIGNED16
03$_h$	PresMaxLatency_U32	0007$_h$	UNSIGNED32
04$_h$	PreqActPayloadLimit_U16	0006$_h$	UNSIGNED16
05h	PresActPayloadLimit_U16	0006$_h$	UNSIGNED16

06_h	AsndMaxLatency_U32	0007_h	UNSIGNED32
07_h	MultiplCycleCnt_U8	0005h	UNSIGNED8
08_h	AsyncMTU_U16	0006_h	UNSIGNED16
09_h	Prescaler_U16	0006_h	UNSIGNED16

7.2.4.5 Object $042E_h$: NMT_BootTime_TYPE

Index	$042E_h$	Object Type	**DEFSTRUCT**
Name	NMT_BootTime_TYPE		
Sub-Index	Component Name	Value	Data Type
00_h	NumberOfEntries	05_h	
01_h	MNWaitNotAct_U32	0007_h	UNSIGNED32
02_h	MNTimeoutPreOp1_U32	0007_h	UNSIGNED32
03_h	MNWaitPreOp1_U32	0007_h	UNSIGNED32
04_h	MNTimeoutPreOp2_U32	0007_h	UNSIGNED32
05_h	MNTimeoutReadyToOp_U32	0007_h	UNSIGNED32
06_h	MNIdentificationTimeout_U32	0007_h	UNSIGNED32
07_h	MNSoftwareTimeout_U32	0007_h	UNSIGNED32
08_h	MNConfigurationTimeout_U32	0007_h	UNSIGNED32
09_h	MNStartCNTimeout_U32	0007_h	UNSIGNED32

7.2.4.6 Object $042F_h$: NMT_MNCycleTiming_TYPE

Index	$042F_h$	Object Type	DEFSTRUCT
Name	NMT_MNCycleTiming_TYPE		
Sub-Index	Component Name	Value	Data Type
00_h	NumberOfEntries	02_h	
01_h	WaitSoCPReq_U32	0007_h	UNSIGNED32
02_h	AsyncSlotTimeout_U32	0007_h	UNSIGNED32

7.2.4.7 Object 0439_h: NMT_EPLNodeID_TYPE

Index	0439_h	Object Type	DEFSTRUCT
Name	NMT_EPLNodeID_TYPE		
Sub-Index	Component Name	Value	Data Type
00_h	NumberOfEntries	02_h	
01_h	NodeID_U8	0005_h	UNSIGNED8
02_h	NodeIDByHW_BOOL	0001_h	BOOLEAN
03_h	SWNodeID_U8	0005_h	UNSIGNED8

7.2.4.8 Object $043A_h$: NMT_RequestCmd_TYPE

Index	$043A_h$	Object Type	DEFSTRUCT
Name	NMT_RequestCmd_TYPE		
Sub-Index	Component Name	Value	Data Type
00_h	NumberOfEntries	04_h	
01_h	Release_BOOL	0001_h	BOOLEAN
02_h	CmdID_U8	0005_h	UNSIGNED8
03_h	CmdTarget_U8	0005_h	UNSIGNED8
04_h	CmdData_DOM	$000F_h$	DOMAIN

7.3 Network Management Services

POWERLINK Network Management (NMT) is node-oriented and follows a master/slave relationship.

The function of the NMT master is carried out by the MN.

CNs are administrated as NMT slaves by the master. An NMT slave is uniquely identified in the network by its POWERLINK Node ID.

According to the definition, Network Management is directed from the NMT master (MN) to the NMT slaves (CNs).

POWERLINK defines five categories of NMT services:

- **NMT State Command Services**

  The MN uses NMT State Command Services to control the CN state machine(s).

- **NMT Managing Command Services**

  The MN uses NMT Managing Command Services to access NMT data items of the CN(s) in a fast coordinated way.

- **NMT Response Services**

  NMT Response Services indicate the current NMT state of a CN to the MN.

- **NMT Info Services**

  NMT Info Services are used to transmit NMT information from the MN to a CN.

- **NMT Guard services**

  NMT Guard Services are used by the MN and CNs to detect failures in a POWERLINK network.

A CN may request NMT command and info services to be issued by the MN (NMTRequest, see 7.3.6).

In NMT_CS_EPL_MODE, a CN shall ignore NMT command services that are not issued by the MN. In NMT_CS_BASIC_ETHERNET NMT command services shall be accepted regardless their source node.

7.3.1 NMT State Command Services

The MN controls the state of the CN via NMT State Command Services. The state transitions are defined by the CN state machine (see 7.1.4).

POWERLINK distinguishes between implicit and explicit NMT State Commands.

7.3.1.1 Implicit NMT State Command Services

At system startup, the reception or the timeout of SoA, PReq, PRes or SoC frames trigger CN state machine transitions from the state NMT_CS_NOT_ACTIVE to the next states. In NMT_CS_PRE_OPERATIONAL_1 the reception of SoC triggers the transition to NMT_CS_PRE_OPERATIONAL_2. SoA, PReq, PRes or SoC are used to synchronise a CN with the current network mode after system start or reset. (see 7.1.4).

In Basic Ethernet Mode, the reception of POWERLINK SoA, PReq, PRes or SoC will trigger a change over to NMT_CS_EPL_MODE. (see 7.1.4).

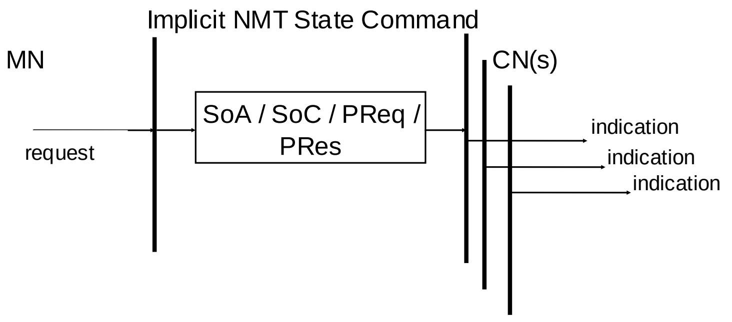


Fig. 77. Implicit NMT state command service protocol

SoA, PReq, PRes or SoC acting as shown above are termed implicit NMT state commands. They are valid regardless of their data content and without further extensions.

Tab. 122 displays implicit NMT state commands in relation to the current CN state when the command is received. SoA and SoC reception or timeouts not mentioned in the table do not trigger state transitions.

Current State	**Implicit NMT State Command**	**Destination State**
NMT_CS_NOT_ACTIVE	SoA, SoC	NMT_CS_PRE_OPERATIONAL_1
	Timeout (SoA, PReq, PRes, SoC)	NMT_CS_BASIC_ETHERNET
NMT_CS_PRE_OPERATIONAL_1	SoC	NMT_CS_PRE_OPERATIONAL_2
NMT_CS_BASIC_ETHERNET	SoA, PReq, PRes, SoC	NMT_CS_PRE_OPERATIONAL_1

Tab. 122 Implicit NMT state commands

An NMT Response Service (see 7.3.3) requested by the implicit NMT State Command shall indicate the current state.

7.3.1.1.1 Implicit NMT State Command Transmission

Implicit NMT State Command services (7.3.1.1) do not require explicit NMT frame transmission by the MN. Regular SoA, PReq, PRes and SoC frames (refer 4.6.1.1) can be valid Implicit NMT State Commands on their own.

SoA, PRes and SoC frames cannot be sent directly to a single node – they are multicast. The CN decides according to its own current state whether a received implicit NMT State command is active (i.e. is to be carried out).

7.3.1.2 Explicit NMT State Command Services

An explicit NMT State Command shall be transmitted by the MN in the ASnd frame.

The target CN shall be addressed via the ASnd Destination field. The ASnd frame shall be either unicast to one CN or broadcast to all CNs (using the POWERLINK broadcast address C_ADR_BROADCAST). A command sent via broadcast shall be ignored at the transmitting MN.

Special broadcast NMT commands may be sent to selected groups of CNs (see 7.3.1.2.2).

The explicit NMT State Command services shall be identified by ASnd ServiceID = NMT_COMMAND.

Fig. 78 shows the protocol used to implement the explicit NMT State Command Services.

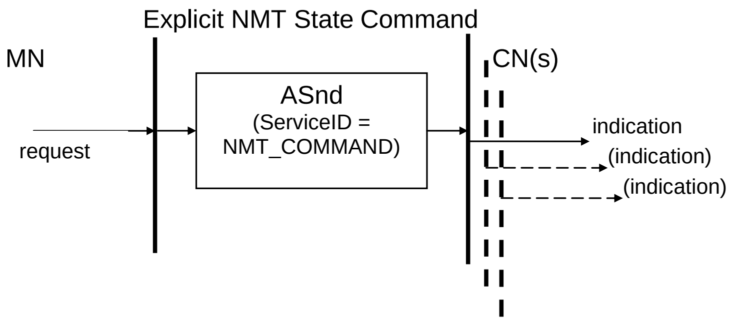


Fig. 78. Explicit NMT state command service protocol

The ASnd ServiceID value of explicit NMT State Command Services shall be NMT_COMMAND. The specific NMT State Command identification and its data shall be located in the ASnd Payload field, called NMT Service Slot in the following.

	Bit Offset							
Octet offset [24]	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	NMTCommandID							
1	Reserved							
2 .. n	NMTCommandData							

n ≤ C_DLL_MAX_PAYL_OFFSET – 4

Tab. 123 NMT state command service, NMT managing command service and NMT info service structure of the NMT Service Slot field

Field	**Abbr.**	**Description**	**Value**
NMTCommandID	cid	Qualifies the NMT state command.	Tab. 125, Tab. 126
NMTCommandData	cdat	0..C_DLL_MAX_PAYL_OFFSET – 6 octets of NMT command-specific data to be issued by the MN. The lower layer is responsible for padding.	

Tab. 124 NMT Service Slot fields of explicit NMT state command services

7.3.1.2.1 Plain NMT State Command

The Plain NMT State Command shall be unicast to a specific CN or broadcast to all CNs.

Plain NMT State Commands shall ignore NMTCommandData.

The following Plain NMT State Commands are defined:

[24] Octet offset is measured from the begin of the ASnd Payload field. The offset relative to the beginning of the Ethernet frame is 18 octets.

NMTCommandID	Initial state	Destination state
NMTStartNode	NMT_CS_READY_TO_OPERATE	NMT_CS_OPERATIONAL
NMTStopNode	NMT_CS_PRE_OPERATIONAL_2	NMT_CS_STOPPED
	NMT_CS_READY_TO_OPERATE	
	NMT_CS_OPERATIONAL	
NMTEnterPreOperational2	NMT_CS_OPERATIONAL	NMT_CS_PRE_OPERATIONAL_2
	NMT_CS_STOPPED	
NMTEnableReadyToOperate	NMT_CS_PRE_OPERATIONAL_2	NMT_CS_PRE_OPERATIONAL_2
NMTResetNode	NMT_CS_NOT_ACTIVE / NMT_MS_NOT_ACTIVE	NMT_GS_INITIALISATION sub-state NMT_GS_RESET_APPLICATION
	NMT_CS_PRE_OPERATIONAL_1 / NMT_MS_PRE_OPERATIONAL_1	
	NMT_CS_PRE_OPERATIONAL_2 / NMT_MS_PRE_OPERATIONAL_2	
	NMT_CS_READY_TO_OPERATE / NMT_MS_READY_TO_OPERATE	
	NMT_CS_OPERATIONAL / NMT_MS_OPERATIONAL	
	NMT_CS_STOPPED	
	NMT_CS_BASIC_ETHERNET	
NMTResetCommunication	NMT_CS_NOT_ACTIVE / NMT_MS_NOT_ACTIVE	NMT_GS_INITIALISATION sub-state NMT_GS_RESET_COMMUNICATION
	NMT_CS_PRE_OPERATIONAL_1 / NMT_MS_PRE_OPERATIONAL_1	
	NMT_CS_PRE_OPERATIONAL_2 / NMT_MS_PRE_OPERATIONAL_2	
	NMT_CS_READY_TO_OPERATE / NMT_MS_READY_TO_OPERATE	
	NMT_CS_OPERATIONAL / NMT_MS_OPERATIONAL	
	NMT_CS_STOPPED	
	NMT_CS_BASIC_ETHERNET	
NMTResetConfiguration	NMT_CS_NOT_ACTIVE / NMT_MS_NOT_ACTIVE	NMT_GS_INITIALISATION sub-state NMT_GS_RESET_CONFIGURATION
	NMT_CS_PRE_OPERATIONAL_1 / NMT_MS_PRE_OPERATIONAL_1	
	NMT_CS_PRE_OPERATIONAL_2 / NMT_MS_PRE_OPERATIONAL_2	
	NMT_CS_READY_TO_OPERATE / NMT_MS_READY_TO_OPERATE	
	NMT_CS_OPERATIONAL / NMT_MS_OPERATIONAL	
	NMT_CS_STOPPED	
	NMT_CS_BASIC_ETHERNET	
NMTSwReset	NMT_CS_NOT_ACTIVE / NMT_MS_NOT_ACTIVE	NMT_GS_INITIALISATION sub-state NMT_GS_INITIALISING
	NMT_CS_PRE_OPERATIONAL_1 / NMT_MS_PRE_OPERATIONAL_1	
	NMT_CS_PRE_OPERATIONAL_2 / NMT_MS_PRE_OPERATIONAL_2	
	NMT_CS_READY_TO_OPERATE / NMT_MS_READY_TO_OPERATE	
	NMT_CS_OPERATIONAL / NMT_MS_OPERATIONAL	
	NMT_CS_STOPPED	
	NMT_CS_BASIC_ETHERNET	

Tab. 125 Plain NMT state commands

All commands listed in Tab. 125 are mandatory. The commands shall be only acted on if the CN is in the appropriate initial state (see Tab. 125); otherwise the command is ignored and an entry made in the CN error log.

7.3.1.2.1.1 NMT Reset Commands to the MN

NMTSwReset, NMTResetNode, NMTResetConfiguration and NMTResetCommunication addressed to the MN as unicast may be requested by a diagnostic node (refer 7.3.6). Since MN resets will affect the complete network they shall be forwarded to all nodes. The requested command shall be performed by the MN in the following way:

1. route the command to all CNs.
2. perform the requested reset.

7.3.1.2.2 Extended NMT State Command

Extended NMT State Commands are used to access groups of CNs.

The Asnd frame transporting the command is broadcast to all CNs.

The “NMTCommand Specific Data” field contains a POWERLINK Node List according to the POWERLINK Node List Format (see 7.3.1.2.3). The POWERLINK Node List indicates the validity of the command for the individual nodes (i.e. whether the node acts on the command). Node IDs to which the command is addressed are indicated by 1_b. Nodes that have to ignore the command are indicated by 0_b.

Tab. 126 lists the Extended NMT State Commands. Initial State, Destination State and the validity of the commands at the initial states are identical to the respective plain commands (see Tab. 125).

NMTCommandID	M/O
NMTStartNodeEx	O
NMTStopNodeEx	O
NMTEnterPreOperational2Ex	O
NMTEnableReadyToOperateEx	O
NMTResetNodeEx	O
NMTResetCommunicationEx	O
NMTResetConfigurationEx	O
NMTSwResetEx	O

Tab. 126 Extended NMT state commands

Support of Extended NMT State Commands is optional. Support shall be indicated by the object dictionary index NMT_FeatureFlags_U32 Bit 5 and D_NMT_ExtNmtCmds_BOOL. The Flags don’t differentiate particular Extended NMT State Commands. They indicate support of all Extended NMT State Commands defined by this specification.

7.3.1.2.3 POWERLINK Node List Format

The POWERLINK Node List is transmitted by the NMTCommandData field.

The POWERLINK Node List format assigns one bit for each POWERLINK Node ID. The Node ID assignment is given in Tab. 127.

	Bit offset							
Octet offset [25]	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	7	6	5	4	3	2	1	-
1	15	14	13	12	11	10	9	8
2	23	22	21	20	19	18	17	16
3	31	30	29	28	27	26	25	24
4	39	38	37	36	35	34	33	32
5	47	46	45	44	43	42	41	40
6	55	54	53	52	51	50	49	48
7	63	62	61	60	59	58	57	56
8	71	70	69	68	67	66	65	64
9	79	78	77	76	75	74	73	72
10	87	86	85	84	83	82	81	80
11	95	94	93	92	91	90	89	88
12	103	102	101	100	99	98	97	96
13	111	110	109	108	107	106	105	104
14	119	118	117	116	115	114	113	112
15	127	126	125	124	123	122	121	120
16	135	135	133	132	131	130	129	128
17	143	142	141	140	139	138	137	136
18	151	150	149	148	147	146	145	144
19	159	158	157	156	155	154	153	152
20	167	166	165	164	163	162	161	160
21	175	174	173	172	171	170	169	168
22	183	182	181	180	179	178	177	176
23	191	190	189	188	187	186	185	184
24	199	198	197	196	195	194	193	192
25	207	206	205	204	203	202	201	200
26	215	214	213	212	211	210	209	208
27	223	222	221	220	219	218	217	216
28	231	230	229	228	227	226	225	224
29	239	238	237	236	235	234	233	232
30	247	246	245	244	243	242	241	240
31	-	254	253	252	251	250	249	248

Tab. 127 POWERLINK node list: Node ID to bit assignment

7.3.2 NMT Managing Command Services

The MN uses NMT Managing Command Services to configure NMT-relevant entries in the database of the CN. These commands do not directly influence the state machine of the CN.

NMT Managing Commands are transmitted in an ASnd frame by the MN. They are unicast to a single CN or broadcast to all CNs (using the POWERLINK broadcast address C_ADR_BROADCAST).

The services are identified by ASnd ServiceID set to NMT_COMMAND.

Fig. 79 shows the protocol used to implement the NMT Managing Command Services.

[25] Octet offset is measured from the beginning of NMTCommandData. The offset relative to the Ethernet frame is 20 octets.

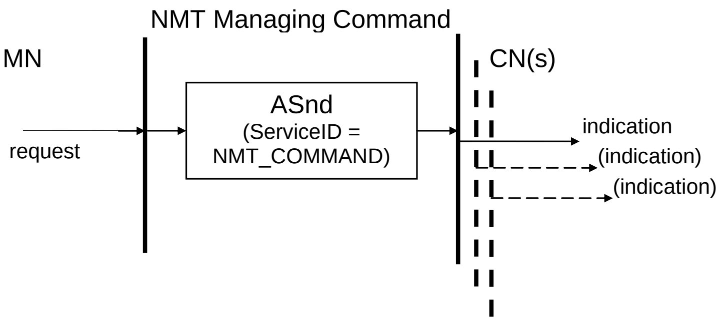


Fig. 79. NMT managing command service protocol

The ASnd ServiceID value of NMT Managing Command Services is NMT_COMMAND. The specific NMT Managing Command identification and its data are located in the ASnd Payload field.

Field	Abbr.	Description	Value
NMTCommandID	cid	qualifies the NMT Managing Command.	Tab. 129
NMTCommandData	cdat	0..C_DLL_MAX_PAYL_OFFSET – 6 octets of NMT managing command-specific data to be issued by the MN. The lower layers are responsible for padding.	

Tab. 128 NMT Service Slot fields of NMT managing command services

The following NMT Managing Command Services are defined:

NMTCommandID	M/O	Short description
NMTNetHostNameSet	O	Sets hostname of an individual CN.
NMTFlushArpEntry	O	Clears local MAC and IP address list at all CNs.

Tab. 129 NMT managing command services

Support of particular NMT Managing Command Services shall be indicated by specific device description entries (see 7.3.2.1.1, 7.3.2.1.2)

7.3.2.1 Service Descriptions

7.3.2.1.1 NMTNetHostNameSet

NMTNetHostNameSet sets the hostname of the CN.

NMTCommandID is NMTNetHostNameSet.

	Bit Offset							
Octet offset [26]	7	6	5	4	3	2	1	0
0 .. 31	HostName							

Tab. 130 NMTCommandData structure of NMTNetHostNameSet

Field	Abbr.	Description	Value
HostName	hn	May be used to modify CN’s local DNS hostname	

Tab. 131 NMTCommandData data fields of NMTNetHostNameSet

The NMTNetHostNameSet command is addressed unicast to an individual CN.

After execution of NMTNetSetHostName command, the modified hostname is published by the CN. Publishing is carried out in the following manner:

1. The CN indicates an ASnd Transmission Request using the RS bits of the Pres frame or a StatusResponse ASnd frame using the priority level C_DLL_ASND_PRIO_NMTRQST.
2. The MN assigns the asynchronous phase to the CN via an SoA frame. (RequestedServiceID = NMT_REQUEST_INVITE).

[26] Octet offset is measured from the beginning of NMTCommandData. The offset relative to the Ethernet frame is 20 octets.

3. The CN requests an IdentRequest to itself using the NMTRequest ASnd frame (see 7.3.6).
4. The MN transmits an SoA (RequestedServiceID = IDENT_REQUEST) to the requesting CN.
5. The CN publishes its modified HostName via an IdentResponse ASnd frame.

Support shall be indicated by D_NMT_NetHostNameSet_BOOL.

7.3.2.1.2 NMTFlushArpEntry

NMTFlushArpEntry removes the entries for a CN from the address tables of all other CNs. The entry to be eliminated is indicated by the Node ID of the CN to be removed.

NMTCommandID is NMTFlushArpEntry.

	Bit Offset							
Octet offset [27]	7	6	5	4	3	2	1	0
0	Node ID							

Tab. 132 NMTFlushArpEntry ASnd service slot structure

Field	Abbr.	Description	Value
Node ID	nid	Identifies the node whose ARP entry is to be deleted. Using C_ADR_BROADCAST flushes all ARP entries.	

Tab. 133 NMTCommandData data fields of NMTFlushArpEntry

The NMTFlushArpEntry command is broadcast to all CNs.

Support shall be indicated by D_NMT_FlushArpEntry_BOOL.

7.3.3 NMT Response Services

NMT Response Services are used by the MN to query NMT information from the CN, e.g. current state, error and setup data.

7.3.3.1 NMT State Response

The CNs shall signal their state to the MN via NMT State Response services.

CNs that communicate isochronously via PReq / PRes shall use the PRes frame to indicate their current state.

Fig. 80 shows the protocol used to implement the NMT State Response Service from isochronously communicating CNs. The service is mandatory on the MN and every CN device, that is able to communicate isochronously.

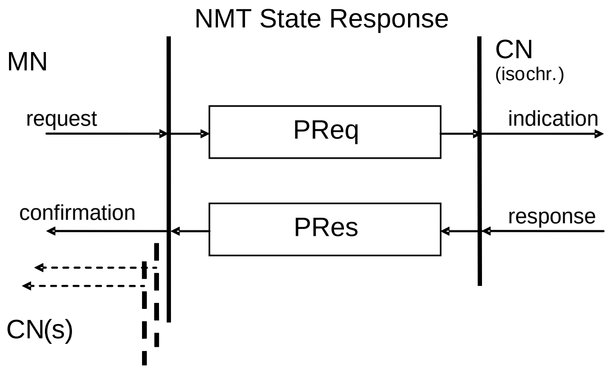


Fig. 80. NMT state response service protocol (isochronous CN)

The MN shall receive the NMT State Response. CNs may receive NMT State Response if configured to do so.

CNs which do not communicate isochronously (i.e. Async-only CNs or ioschronous CNs in state NMT_CS_PRE_OPERATIONAL_1) shall signal their state via StatusResponse and IdentResponse

[27] Octet offset is measured from the beginning of NMTCommandData. The offset relative to the Ethernet frame is 20 octets.

ASnd frames. Isochronous CNs in NMT_CS_PRE_OPERATIONAL_2, NMT_CS_READY_TO_OPERATE or NMT_CS_OPERATIONAL may be triggered by the MN to respond via StatusResponse and IdentResponse ASnd frames.

Fig. 81 shows the protocol used to implement the NMT Response Service from CNs that are not communicating isochronously. The service is mandatory on the MN and every CN device.

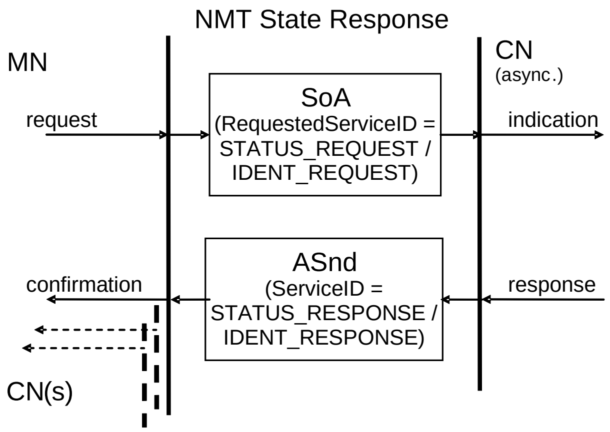


Fig. 81. NMT state response service protocol (async-only CN)

The MN shall receive the NMT State Response. CNs may receive the NMT State Response if configured to do so and if the NMT State Response is transmitted via an IdentResponse ASnd frame.

NMT State Response shall use the following data fields of the PRes, StatusResponse or IdentResponse frames:

- NMTState

  NMTState shall report the current NMT state of the CN.

  If the NMT state reponse requesting message triggers a CN NMT state transition, the pre-transition state shall be reported. No response shall be issued if the CN is in state NMT_CS_NOT_ACTIVE when receiving the request.

- Exception New (EN)

  EN shall report unread entries at the CN emergency queue (see 6.5.2).

- Exception Clear (EC)

  EC shall be used by Error Signaling management (see 6.5.2). EC shall be operated by StatusResponse and IdentResponse only.

Refer to 4.6.1.1.4, 7.3.3.2.1 and 7.3.3.3.1 for detailed information about frame format.

7.3.3.2 IdentResponse Service

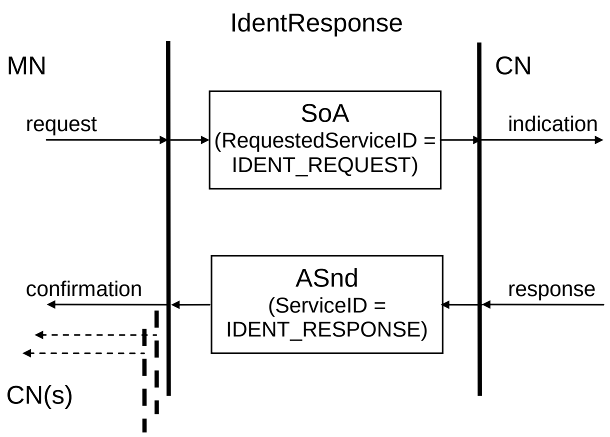


Fig. 82. IdentResponse service protocol

The IdentResponse service is used by the MN to identify configured but unrecognized CNs at system startup or after loss of communication. The service may be used after start-up to query a CN's setup information.

Fig. 82 shows the protocol that is used to implement the IdentResponse service. The service is mandatory on the MN and every CN device.

ASnd frames transporting IdentResponses are broadcast. The MN shall receive IdentResponses; CNs may receive IdentResponses if configured to do so.

The IdentResponse service may be initiated by a CN via the NMT Request mechanism (see 7.3.6). The NMTRequestedCommandID field of the NMT requesting ASnd frame shall be set to IDENT_REQUEST.

7.3.3.2.1 IdentResponse Frame

The IdentResponse service frames are identified by ASnd ServiceID set to IDENT_RESPONSE.

	Bit Offset							
Octet Offset [28]	**7**		**5**	**4**	**3**	**2**	**1**	**0**
0	res	res	res	res	res	res	res	res
1	res[29]	res[30]	PR			RS		
2	NMTState							
3	Reserved							
4	EPLVersion							
5	Reserved							
6 .. 9	FeatureFlags							
10 .. 11	MTU							
12 .. 13	PollInSize							
14 .. 15	PollOutSize							
16 .. 19	ResponseTime							
20 .. 21	Reserved							
22 .. 25	DeviceType							
26 .. 29	VendorID							
30 .. 33	ProductCode							
34 .. 37	RevisionNumber							
38 .. 41	SerialNumber							
42 .. 49	VendorSpecificExtension1							
50 .. 53	VerifyConfigurationDate							
54 .. 57	VerifyConfigurationTime							
58 .. 61	ApplicationSwDate							
62 .. 65	ApplicationSwTime							
66 .. 69	IPAddress							
70 .. 73	SubnetMask							
74 .. 77	DefaultGateway							
78 .. 109	HostName							
110 .. 157	VendorSpecificExtension2							

Tab. 134 NMT Service Slot structure of IdentResponse

[28] Octet Offset is measured from the begin of the ASnd Payload field. The offset relative to the beginning of the Ethernet frame is 18 octets.

[29] *Used by EPSG DS302-A [1]*

[30] *Used by EPSG DS302-A [1]*

Field	Abbr	Description	Value
Priority	PR	Flags: Indicates the priority of the requested asynchronous frame. (see 4.2.4.1.2.3)	
RequestToSend	RS	Flags: Indicates the number of pending requests to send at the CN. The value C_DLL_MAX_RS indicates C_DLL_MAX_RS or more requests, 0 indicates no pending request.	0 – C_DLL_MAX_RS
NMTState	stat	Reports the current status of the CN's NMT state machine.	
EPLVersion	eplv	Indicates the POWERLINK Version to which the CN conforms. coding of entry (see Tab. 112)	
FeatureFlags	feat	Reports the device's feature flags (NMT_FeatureFlags_U32)	
MTU	mtu	Reports the largest packet-size of the ISO/OSI network layer that can be transmitted over the network. See NMT_MNCycleTiming_REC.AsyncMTU_U16	C_DLL_MIN_ASYNC_MTU – C_DLL_MAX_ASYNC_MTU
PollInSize	pis	Reports the actual CN setting for Preq data block size (NMT_CycleTiming_REC.PreqActPayloadLimit_U16).	
PollOutSize	pos	Reports the actual CN setting for Pres data block size (NMT_CycleTiming_REC.PresActPayloadLimit_U16).	
ResponseTime	rst	Reports the time required by the CN to respond to Preq (NMT_CycleTiming_REC.PresMaxLatency_U32).	
DeviceType	dt	Reports the CN's Device type (NMT_DeviceType_U32).	
VendorID	vid	Reports the CN's Vendor ID, index (NMT_IdentityObject_REC.VendorId_U32)	
ProductCode	prdc	Reports the CN's Product Code, index (NMT_IdentityObject_REC.ProductCode_U32)	
RevisionNumber	rno	Reports the CN's Revision Number, (NMT_IdentityObject_REC.RevisionNo_U32).	
SerialNumber	sno	Reports the CN's Serial Number, (NMT_IdentityObject_REC.SerialNo_U32).	
VendorSpecific-Extension1	vex1	May be used for vendor specific purpose, to be filled with zeros if not in use.	
Verify-ConfigurationDate	vcd	Reports the CN's Configuration date (CFM_VerifyConfiguration_REC.ConfDate_U32).	
Verify-ConfigurationTime	vct	Reports the CN's Configuration time (CFM_VerifyConfiguration_REC.ConfTime_U32).	
ApplicationSW-Date	ad	Reports the CN's Application SW date (PDL_LocVerApplSw_REC.ApplSwDate_U32 on programmable device or date portion of NMT_ManufactSwVers_VS on non-programmable device).	
ApplicationSW-Time	at	Reports the CN's Application SW time (PDL_LocVerApplSw_REC.ApplSwTime_U32 on programmable device or time portion of NMT_ManufactSwVers_VS on non-programmable device).	
IPAddress	ipa	Reports the current IP address value of the CN (NWL_IpAddrTable_Xh_REC.Addr_IPAD).	
SubnetMask	snm	Reports the current IP subnet mask value of the CN (NWL_IpAddrTable_Xh_REC.NetMask_IPAD).	
DefaultGateway	gtw	Reports the current IP default gateway value of the CN (NWL_IpAddrTable_Xh_REC.DefGateway_IPAD).	
HostName	hn	Reports the current DNS hostname of the CN (NMT_HostName_VSTR). Unused bytes of the hostname shall be set to 0h in the IdentResponse.	

Field	Abbr	Description	Value
VendorSpecific-Extension2	vex2	May be used for vendor specific purpose, to be filled with zeros if not in use.	

Tab. 135 NMT Service Slot data fields of IdentResponse

If the respective object dictionary entry is not implemented by the device, the data field shall be set to 0 resp. empty string.

7.3.3.3 StatusResponse Service

The StatusResponse service is used by the MN to query the current status of CNs that are not communicating isochronously.

Fig. 83 shows the protocol used to implement the StatusResponse Service. The service is mandatory on the MN and every CN device.

ASnd frames transporting StatusResponses are broadcast. The MN shall receive StatusResponses; CNs may receive StatusResponses if configured to do so.

The StatusResponse service can be initiated by a CN via the NMT Request mechanism (7.3.6). The NMTRequestedCommandID entry of the NMT requesting ASnd frame is set to STATUS_REQUEST.

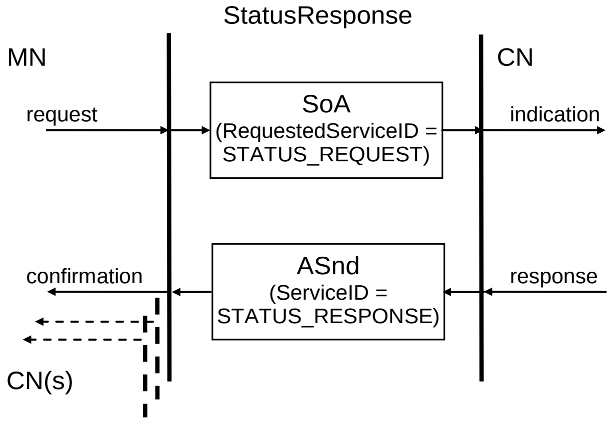


Fig. 83. StatusResponse service protocol

7.3.3.3.1 StatusResponse Frame

The StatusResponse service frames are identified by ASnd ServiceID set to STATUS_RESPONSE.

	Bit Offset							
Octet offset [31]	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	res	res	res	EN	EC	res	res	res
1	res[32]	res[33]	PR			RS		
2	NMTState							
3 .. 5	Reserved							
6 .. 13	StaticErrorBitField							
14 .. 14+n*20	List of Errors / Events (see 6.5.8) 20 Byte / Entry , minimum n=2							

n (2-14) : Number of error/event entries

Tab. 136 NMT Service Slot structure of StatusResponse

[31] Octet Offset is measured from the begin of the ASnd Payload field. The offset relative to the beginning of the Ethernet frame is 18 octets.

[32] *Used by EPSG DS302-A [1]*

[33] *Used by EPSG DS302-A [1]*

Field	Abbr	Description	Value
ExceptionNew	EN	Flag: Error signaling (see 6.5.2).	
ExceptionClear	EC	Flag: Error signaling (see 6.5.2).	
Priority	PR	Flags: indicates the priority of the requested asynchronous frame. (see 4.2.4.1.2.3).	
RequestToSend	RS	Flags: indicates the number of pending requests to send at the CN. The value C_DLL_MAX_RS indicates C_DLL_MAX_RS or more requests, 0 indicates no pending request.	0 – C_DLL_MAX_RS
NMTState	stat	Reports the current status of the CN's NMT state machine.	
StaticErrorBitfield	seb	Specific bits are set to indicate pending errors at the CN (see 6.5.8.1 for encoding of errors in the bit field).	
ErrorCodeList	el	Contains a list of errors, that have occurred at the CN. Each Error Code has a size of 20 octets (see 6.5.8.2). The lower layer is responsible for padding. Maximum size of ErrorCodeList is device specific. It is indicated by D_NMT_ErrorEntries_U32.	

Tab. 137 NMT Service Slot data fields of StatusResponse

7.3.4 NMT Info Services

NMT Info Services are used to transmit complex status information in the form of bundles as well as to distribute system-relevant setup information from the MN to the CNs.

All NMT Info services are transmitted via ASnd by the MN.

The target CNs are unicast via the ASnd Destination field to one CN or broadcast to all CNs.

NMT Info Services are identified by ASnd ServiceID = NMT_COMMAND.

Fig. 84 shows the protocol used to implement the NMT Info services.

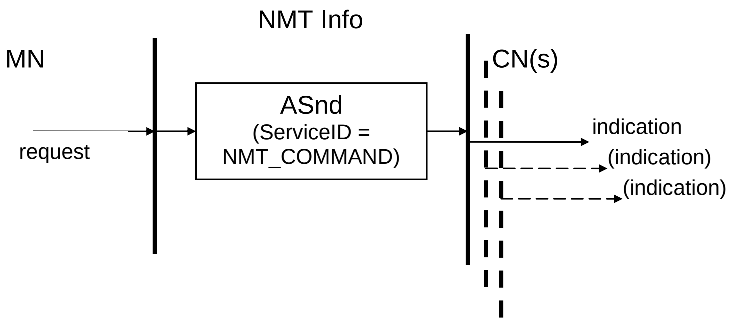


Fig. 84. NMT info service protocol

The particular NMT Info services including their data are located in the NMT Service Slot.

The NMT Info Services use the following parameters of the NMT Service slot:

Field	Abbr.	Description	Value
NMTCommandID	cid	qualifies the NMT Info service.	Tab. 139
NMTCommandData	cdat	0..C_DLL_MAX_PAYL_OFFSET – 4 octets of NMT Info Service-specific data to be issued by the MN. The lower layers are responsible for padding.	

Tab. 138 NMT Service Slot data fields of NMT managing info services

The following NMT Info services are defined:

NMTCommandID	Producer		Consumer		Short description
	MN	CN	MN	CN	
NMTPublishConfiguredNodes	Y	Y	Y	Y	Provides CNs declared in the configuration of the MN.
NMTPublishActiveNodes	Y	N	Y	Y	Provides CNs that have been identified by the MN.
NMTPublishPreOperational1	Y	N	Y	Y	Provides active CNs in the state NMT_CS_PRE_OPERATIONAL_1.
NMTPublishPreOperational2	Y	N	Y	Y	Provides active CNs in the state NMT_CS_PRE_OPERATIONAL_2.
NMTPublishReadyToOperate	Y	N	Y	Y	Provides CNs in the state NMT_CS_READY_TO_OPERATE.
NMTPublishOperational	Y	N	Y	Y	Provides CNs in the state NMT_CS_OPERATIONAL.
NMTPublishStopped	Y	N	Y	Y	Provides CNs in the state NMT_CS_STOPPED.
NMTPublishNodeStates	Y	N	Y	Y	Provides current NMT states
NMTPublishEmergencyNew	Y	N	Y	Y	Provides active CNs with the exception new flag (EN) set.
NMTPublishTime	Y	Y	Y	Y	Provides the system time.

Tab. 139 NMT info services

In the object dictionary support shall be indicated by Index NMT_FeatureFlags_U32 Bit 4. The flags do not differentiate particular NMT Info Services. They indicate support of at least one NMT Info Services defined by this specification.

Support of particular NMT Info Services shall be indicated by specific device description entries (see 7.3.4.1.1 to 7.3.4.1.10).

7.3.4.1 Service Descriptions

7.3.4.1.1 NMTPublishConfiguredNodes

Using the NMTPublishConfiguredNodes service, the MN or a CN may publish a list of nodes configured in its configuration.

The NMTPublishConfiguredNodes service uses the POWERLINK Node List format (see 7.3.1.2.3). Node IDs that correspond to configured CNs are indicated by 1_b.

Information to be published is obtained from NMT_NodeAssignment_AU32 sub-index Bit 1.

Support shall be indicated by D_NMT_PublishConfigNodes_BOOL.

7.3.4.1.2 NMTPublishActiveNodes

Using the NMTPublishActiveNodes service, the MN may publish a list of the active nodes.

Information to be published is obtained from NMT_MNNodeCurrState_AU8 sub-indices. CNs in the states NMT_CS_PRE_OPERATIONAL_1, NMT_CS_PRE_OPERATIONAL_2, NMT_CS_READY_TO_OPERATE, NMT_CS_OPERATIONAL and NMT_CS_STOPPED are regarded active.

The NMTPublishActiveNodes service uses the POWERLINK Node List format (see 7.3.1.2.3). Node IDs that correspond to active CNs are indicated by 1_b.

The MN itself is regarded to be ever active.

Support shall be indicated by D_NMT_PublishActiveNodes_BOOL.

7.3.4.1.3 NMTPublishPreOperational1

Using the NMTPublishPreOperational1 service, the MN may publish a list of nodes in the state NMT_CS_PRE_OPERATIONAL_1 resp. NMT_MS_PRE_OPERATIONAL_1.

The NMTPublishPreOperational1 service uses the POWERLINK Node List format (see 7.3.1.2.3). Node IDs that correspond to active nodes in the state NMT_CS_PRE_OPERATIONAL_1 or NMT_MS_PRE_OPERATIONAL_1 are indicated by 1_b.

Information to be published is obtained from NMT_MNNodeCurrState_AU8 sub-indices.

Support shall be indicated by D_NMT_PublishPreOp1_BOOL.

7.3.4.1.4 NMTPublishPreOperational2

Using the NMTPublishPreOperational2 service, the MN may publish a list of nodes in the state NMT_CS_PRE_OPERATIONAL_2 resp. NMT_MS_PRE_OPERATIONAL_2.

The NMTPublishPreOperational2 service uses the POWERLINK Node List format (see 7.3.1.2.3). Node IDs that correspond to active nodes in the state NMT_CS_PRE_OPERATIONAL_2 or NMT_MS_PRE_OPERATIONAL_2 are indicated by 1_b.

Information to be published is obtained from NMT_MNNodeCurrState_AU8 sub-indices.

Support shall be indicated by D_NMT_PublishPreOp2_BOOL.

7.3.4.1.5 NMTPublishReadyToOperate

Using the NMTPublishReadyToOperate service, the MN may publish a list of nodes in the state NMT_CS_READY_TO_OPERATE resp. NMT_MS_READY_TO_OPERATE.

The NMTPublishReadyToOperate service uses the POWERLINK Node List format (see 7.3.1.2.3). Node IDs that correspond to active nodes in the state NMT_CS_READY_TO_OPERATE or NMT_MS_READY_TO_OPERATE are indicated by 1_b.

Information to be published is obtained from NMT_MNNodeCurrState_AU8 sub-indices.

Support shall be indicated by D_NMT_PublishReadyToOp_BOOL.

7.3.4.1.6 NMTPublishOperational

Using the NMTPublishOperational service, the MN may publish a list of nodes in the state NMT_CS_OPERATIONAL resp. NMT_MS_OPERATIONAL.

The NMTPublishOperational service uses the POWERLINK Node List format (see 7.3.1.2.3). Node IDs that correspond to active CNs in the state NMT_CS_OPERATIONAL or NMT_MS_OPERATIONAL are indicated by 1_b.

Information to be published is obtained from NMT_MNNodeCurrState_AU8 sub-indices.

Support shall be indicated by D_NMT_PublishOperational_BOOL.

7.3.4.1.7 NMTPublishStopped

Using the NMTPublishStopped service, the MN may publish a list of CNs in the state NMT_CS_STOPPED.

The NMTPublishStopped service uses the POWERLINK Node List format (see 7.3.1.2.3). Node IDs that correspond to active CNs in the state NMT_CS_STOPPED are indicated by 1_b.

Information to be published is obtained from NMT_MNNodeCurrState_AU8 sub-indices.

Support shall be indicated by D_NMT_PublishStopped_BOOL.

7.3.4.1.8 NMTPublishNodeStates

Using the NMTPublishNodeStates service, the MN may publish the current NMT states of the POWERLINK nodes as listed in NMT_MNNodeCurrState_AU8 (7.2.2.4.1).

	Bit Offset							
Octet Offset [34]	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	reserved							
1 .. 254	NMTState							

Tab. 140 NMTCommandData structure of NMTPublishNodeStates

Field	Abbr.	Description	Value
NMTState	stat	Current NMT state of POWERLINK Nodes Octet Offset = POWERLINK Node ID	

Tab. 141 NMTCommandData data fields of NMTPublishNodeStates

[34] Octet offset is measured from the beginning of NMTCommandData. The offset relative to the Ethernet frame is 20 octets.

The octet offset not corresponding to a node configured by index NMT_NodeAssignment_AU32[sub-index] Bits 1 and 2 shall be set to NMT_GS_OFF.

Support shall be indicated by D_NMT_PublishNodeState_BOOL.

7.3.4.1.9 NMTPublishEmergencyNew

Using the NMTPublishEmergencyNew service, the MN may publish a list of nodes with the Exception New flag (EN) set.

The NMTPublishEmergencyNew service uses the POWERLINK Node List format (see 7.3.1.2.3). Node IDs that correspond to nodes with the EN flag set are indicated by 1_b.

Support shall be indicated by D_NMT_PublishEmergencyNew_BOOL.

7.3.4.1.10 NMTPublishTime

Using the NMTPublishTime service, the MN or a CN publishes date and time.

	Bit Offset							
Octet Offset [35]	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0 .. 5	DateTime							

Tab. 142 NMTCommandData structure of NMTPublishTime

Field	Abbr.	Description	Value
DateTime	dt	Current RTC time value of the MN coded as TIME_OF_DAY.	

Tab. 143 NMTCommandData data fields of NMTPublishTime

Support shall be indicated by D_NMT_PublishTime_BOOL

7.3.5 NMT Guard Services

MN and CNs may detect failures in an Ethernet POWERLINK-based network using NMT Guard Services. NMT Guard services are optional.

Local errors in a node may for example lead to a reset or change of state. The definition of such local errors is not within the scope of this specification.

7.3.5.1 Guarding CNs

Ethernet POWERLINK may use a guard mechanism to monitor nodes. The MN queries the CNs and receives their replies.

In order to query isochronously-addressed CNs in the POWERLINK Mode, the guard mechanism uses the ioschronous PReq / PRes message exchange.

The supervising node monitors the reception of PRes frames from the monitored node. If the PRes frames do not arrive in time, the supervising node informs its application.

Due to the multicast transmission of the PRes frame, CNs are able to monitor other CNs.

If the MN transmits PRes, it may be monitored by the CNs too.

The monitoring time is configurable via the object dictionary entry NMT_ConsumerHeartbeatTime_AU32.

7.3.5.1.1 Guarding Async-Only CNs

An asynchronous channel is allocated to nodes which are not addressed isochronously. They are queried by the MN via a StatusRequest SoA telegram and respond with a StatusResponse ASnd message. If no StatusResponse is received within the monitoring time, the MN informs its application.

The guarded CN is the only one that receives the StatusRequest, other CNs shall ignore it. They shall not rely on a StatusRequest frequency satisfying their guard time requirements regarding the respective CN. That’s why, no guarding of async-only CNs by other CNs is possible.

Hint: StatusRequest and StatusResponse transmission is affected by the asynchronous scheduling mechanism. The timing severely influenced by the sum of asynchronous transmission requests in the

[35] Octet offset is measured from the beginning of NMTCommandData. The offset relative to the Ethernet frame is 20 octets.

system. That's why, NMT_ConsumerHeartbeatTime_AU32 of async-only CNs shall be set to large values.

7.3.5.2 Guarding the MN

The CNs may control the function of the MN by timeout-monitoring the SoC frames (see 7.3.1.1). If a CN does not receive any frames, it changes to the state NMT_CS_PRE_OPERATIONAL_1. This transition is signalled to the CN's application.

7.3.6 Request NMT Services by a CN

A CN may request the execution of explicit NMT State Commands, NMT Management Commands, NMT Info Services, IdentResponse and StatusResponse services at the MN.

1. The CN indicates an NMTRequest using the RS bits of the PRes frame or a StatusResponse ASnd Frame using the priority level C_DLL_ASND_PRIO_NMTRQST.
2. The MN assigns the asynchronous phase to the CN via SoA (RequestedServiceID = NMT_REQUEST_INVITE).
3. The CN requests the desired service using the ASnd NMTRequest frame (ServiceID = NMT_REQUEST).

The service is mandatory on the MN.

7.3.6.1 NMTRequest Frame

NMTRequests are transmitted by a CN via ASnd upon assignment of the asynchronous phase via an NMTRequestInvite SoA frame.

The NMTRequest frames are identified by ASnd ServiceID = NMT_REQUEST.

	Bit Offset							
Octet offset [36]	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0	NMTRequestedCommandID							
1	NMTRequestedCommandTarget							
2 .. n	NMTRequestedCommandData							

n ≤ C_DLL_MAX_PAYL_OFFSET – 4

Tab. 144 NMT Service Slot structure of NMTRequest

Field	Abbr.	Description	Value
NMTRequested-CommandID	rcid	The NMT service to be issued by the MN by its NMTCommandID value. StatusResponse and IdentResponse services are indicated by the SoA RequestedServiceID values STATUS_REQUEST and IDENT_REQUEST.	
NMTRequested-CommandTarget	rct	Indicates the target node of the requested NMT command.	
NMTRequested-CommandData	rcd	0..C_DLL_MAX_PAYL_OFFSET – 6 octets of NMT command-specific data to be issued by the MN. The lower layers are responsible for padding.	

Tab. 145 NMT Service Slot data fields of an NMTRequest frame

The NMTRequest ASnd frame is unicast to the MN.

7.3.6.1.1 Invalid NMTRequests

If the CN requests an NMT service not supported by the MN, the MN responds with a unicast ASnd frame with ServiceID = NMT_COMMAND to the requesting CN.

The NMTCommandID NMTInvalidService is used:

[36] Octet offset is measured from the begin of the ASnd Payload field. The offset relative to the beginning of the Ethernet frame is 18 octets.

This special service is mandatory. It must not influence the state machine of the CNs and must not transport any data to the CN.

7.3.7 NMT Services via Object Dictionary

7.3.7.1 NMT Reset Commands

The NMT Command Services NMTSwReset, NMTResetNode, NMTResetConfiguration, and NMTResetCommunication may be initiated by writing the respective NMTServiceID to NMT_ResetCmd_U8.

NMT Reset via NMT_ResetCmd_U8 should be applied to CNs in NMT_CS_BASIC_ETHERNET only. If applied to nodes in NMT_CS_EPL_MODE or NMT_MS_EPL_MODE, resets by NMT_ResetCmd_U8 may violate the NMT rules and stimulate DLL and NMT Guarding errors. Use NMT Request via Object Dictionary (see 7.3.7.2) instead.

7.3.7.2 NMT Requests to the MN

NMT Requests may be posted to the MN by writing to NMT_RequestCmd_REC.

The objects sub-indices shall be mapped to the NMT Service Slot of a virtual NMTRequest Frame (see 7.3.6.1):

NMT_RequestCmd_REC.CmdID_U8	→	NMTRequested-CommandID
NMT_RequestCmd_REC.CmdTarget_U8	→	NMTRequested-CommandTarget
NMT_RequestCmd_REC.CmdData_DOM	→	NMTRequested-CommandData

The NMT Request shall be triggered by writing TRUE to NMT_RequestCmd_REC.Release_BOOL.

The NMT Services via Object Dictionary mechanism does not provide a response channel. Therefore, only Explicit NMT State Command Services (see 7.3.1.2) may by requested via Object Dictionary.

7.3.8 NMT Services via UDP/IP

NMT requests coming from a diagnostic node outside of the POWERLINK segment via a router may be hosted by UDP/IP frames. Hosting shall be in accordance to the POWERLINK compliant UDP/IP format (see 4.6.1.2).

The NMT Services via UDP/IP mechanism does not provide a response channel. Therefore, only Explicit NMT State Command Services (see 7.3.1.2) may by requested via UDP/IP.

Support of NMT Services via UDP/IP by an MN is optional. Support shall be indicated by object dictionary entry NMT_FeatureFlags_U32 Bit 7 and D_NMT_ServiceUdpIp_BOOL.

7.4 Boot-up Managing Node

7.4.1 NMT_MS dependant Network Boot-up

7.4.1.1 Overview

When a POWERLINK Node starts after PowerOn (NMT_GT1), Reset (NMT_GT2) or NMTSwReset (NMT_GT8), the state machine will begin to execute according to the NMT state diagram of a POWERLINK node (see 7.1.2) and will attain the NMT_GS_INITIALISATION state automatically. After completion of the initialisation, the node will enter the super state NMT_GS_COMMUNICATING. In this super state the node will perform as either a Managing Node (MN) or Controlled Node (CN) depending on the configured Node ID. The state NMT_GS_INITIALISATION is reachable from every state within the super state after processing the NMT command service NMTResetNode (NMT_GT4), NMTResetCommunication (NMT_GT5), NMTResetConfiguration (NMT_GT7), NMTSwReset (NMT_GT8) or after internal errors (NMT_GT6).

7.4.1.2 NMT_MS_NOT_ACTIVE

There shall be only one active MN on a POWERLINK network.The purpose of the state NMT_MS_NOT_ACTIVE is to enable a potential MN to detect whether the bus is already managed by another MN.

Detecting SoC or SoA during this state indicates to the potential MN that the network already has an active MN.

The state NMT_MS_NOT_ACTIVE is entered from the NMT_GS_INITIALISATION state (NMT_MT1).

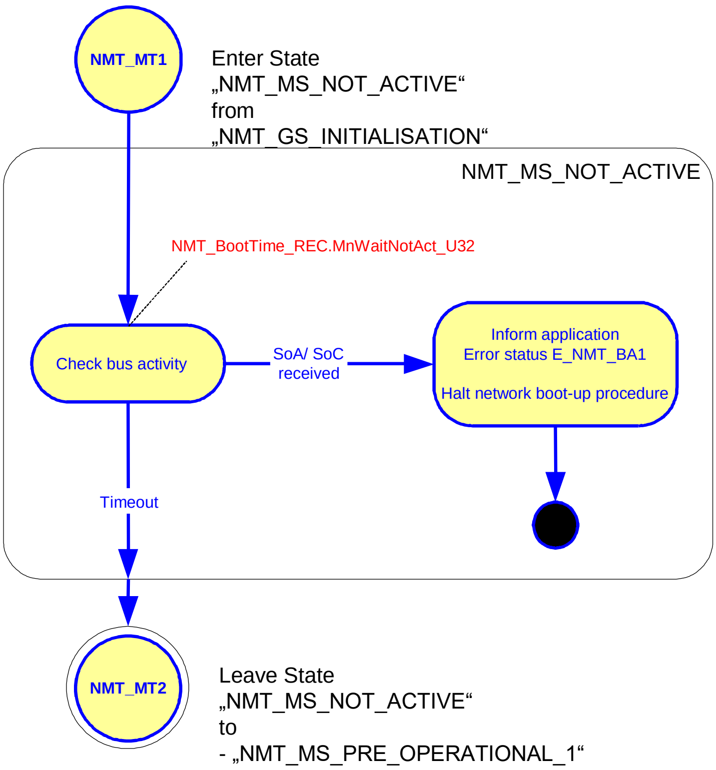


Fig. 85. State NMT_MS_NOT_ACTIVE

In the state NMT_MS_NOT_ACTIVE the MN proceeds as follows:

- Check for bus activity. Reception of SoC or SoA frames indicates that another MN is currently managing the network. In case of the reception of SoA or SoC frames, the error
  - E_NMT_BA1 (see 7.4.3.1)

  shall be signalled to the MN application.

  The current MN state shall be maintained. The MN shall halt network boot-up procedure.
- If the potential MN does not detect either SoC or SoA frames within a time interval defined by index NMT_BootTime_REC.MNWaitNoAct_U32, it shall transition from NMT_MS_NOT_ACTIVE to NMT_MS_PRE_OPERATIONAL_1.

7.4.1.3 NMT_MS_PRE_OPERATIONAL_1

In the state NMT_MS_PRE_OPERATIONAL_1 the MN assumes bus master-ship. It will attempt to reach all configured CNs and examine their configuration versions. The MN communicates with the CN using the Reduced POWERLINK Cycle (SoA and Asnd frames) (see 4.2.4.2). In case of communication errors such as frame losses, the MN signals the error to the application. If the error was caused by a mandatory node, the MN shall remain in this state.

This state is entered from the NMT_MS_NOT_ACTIVE (NMT_MT2) or the NMT_MS_OPERATIONAL (NMT_MT6) state.

The steps of the network boot process in NMT_MS_PRE_OPERATIONAL_1 are as follows:

- If the state was entered from NMT_MS_NOT_ACTIVE (NMT_MT2), all nodes of the network will be reset using the NMT command service NMTResetNode.
- Initiate boot process BOOT_STEP1 for all configured CNs.
  Configured CNs are identified by:
  - NMT_NodeAssignment_AU32[1..254].Bit0
  - NMT_NodeAssignment_AU32[1..254].Bit1
- If mandatory CNs are booted sequentially, the boot process shall not be halted in case of an error associated with the particular CN. The MN shall continue to attempt to contact all configured but not responding CNs.
- If an application SW update of one or more nodes was done, the MN must send out the NMT command
  - NMTSwReset

  to all CNs and restart the BOOT_STEP1 for all configured CNs.
- When the BOOT_STEP1 process has been successfully terminated for all mandatory CNs, the MN may switch to the state NMT_MS_PRE_OPERATIONAL_2
  Mandatory CNs are identified by :
  - NMT_NodeAssignment_AU32[1..254].Bit3
- The MN can switch to the state NMT_MS_PRE_OPERATIONAL_2 either automatically or under control of the application. The transition policy is defined by:
  - NMT_StartUp_U32.Bit7.

  If the waiting time interval
  - NMT_BootTime_REC.MnWaitPreOp1_U32

  has not expired, the MN waits in this state until the waiting time expires.
- If BOOT_STEP1 has not been processed successfully for all mandatory CNs, the MN shall signal the error
  - E_NMT_BPO1 (see 7.4.3.2)

  to the MN application.

  In this case the MN shall halt the network boot-up procedure and maintain its current state.
- If optional CNs answered with IdentResponse successfully, but could not finish BOOT_STEP1 without errors, the application will be notified. In this case the network boot procedure for these particular CNs shall be restarted.

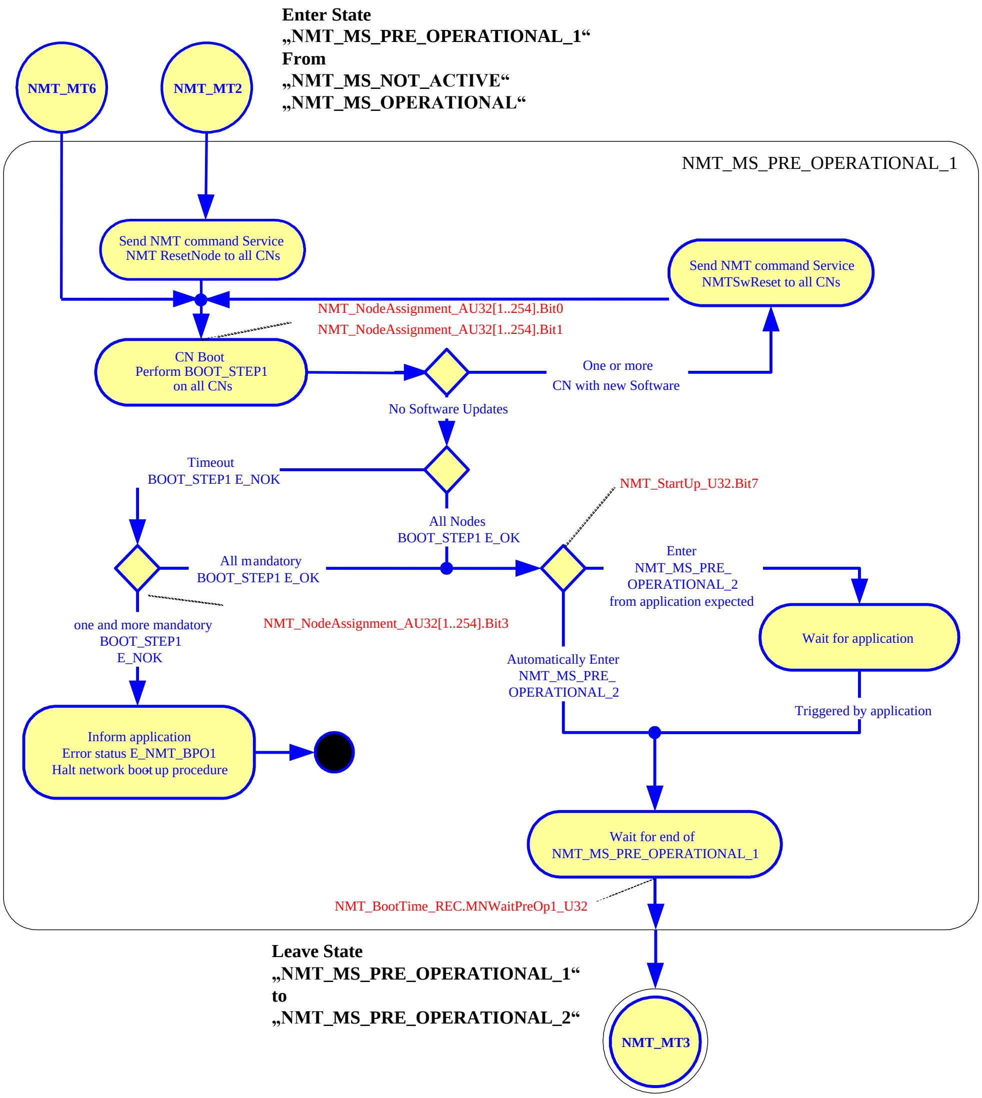


Fig. 86. Detail state NMT_MS_PRE_OPERATIONAL_1

7.4.1.4 NMT_MS_PRE_OPERATIONAL_2

In the state NMT_MS_PRE_OPERATIONAL_2 the MN will initiate isochronous communication with the CNs and insure their transition from NMT_CS_PRE_OPERATIONAL_2 to NMT_CS_READY_TO_OPERATE.

When all mandatory CNs have reached the NMT_CS_READY_TO_OPERATE state, the MN will change to the state NMT_MS_READY_TO_OPERATE.

In case of an error associated with the mandatory CNs, the MN will signal the error to the application. In this case the MN shall halt the network boot-up procedure and maintain its current state.

The NMT_MS_PRE_OPERATIONAL_2 state is entered from the NMT_MS_PRE_OPERATIONAL_1 (NMT_MT3) state.

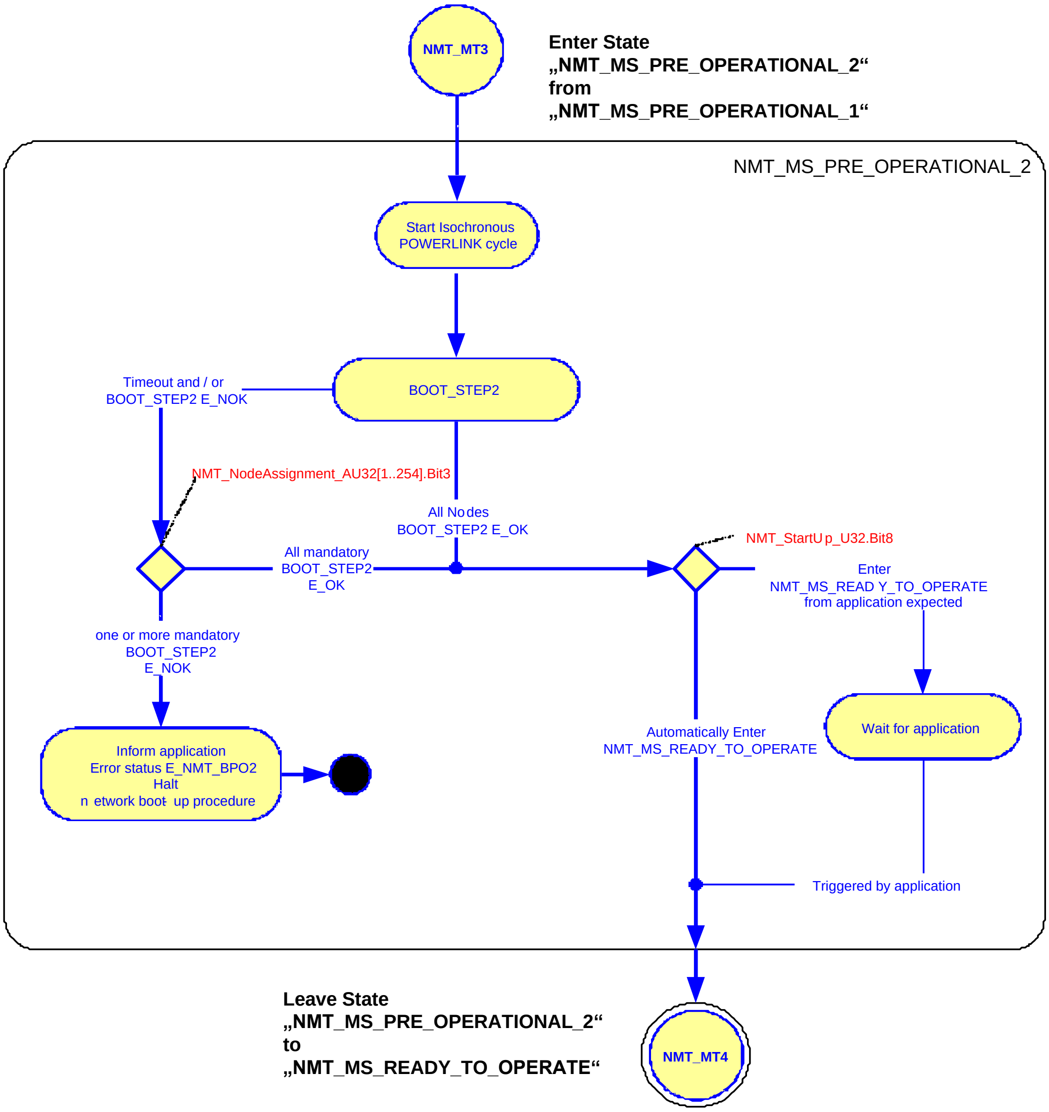


Fig. 87. Detail state NMT_MS_PRE_OPERATIONAL_2

The network boot steps and tasks in the NMT_MS_PRE_OPERATIONAL_2 state are as follows:

- Start isochronous POWERLINK Cycle with SoC /SoA frames to synchronise the CNs to the MN POWERLINK Cycle.
- Start process BOOT_STEP2 for all configured CNs. Configured CNs are identified by:
  - NMT_NodeAssignment_AU32[1..254].Bit0
  - NMT_NodeAssignment_AU32[1..254].Bit1
- After the BOOT_STEP2 process is successfully terminated for all mandatory CNs (all mandatory CNs are in the NMT_CS_READY_TO_OPERATE state), the MN itself shall switch to the state NMT_MS_READY_TO_OPERATE direct or after application trigger, depending on the following object:
  - NMT_StartUp_U32.Bit8

  Mandatory CNs are identified by:
  - NMT_NodeAssignment_AU32[1..254].Bit3

In case of errors or timeout condition during the BOOT_STEP2 process of one or more mandatory CN, the error

  - E_NMT_BPO2 (see 7.4.3.3)

  shall be signaled to the application.

- Errors of optional CNs in BOOT_STEP2 shall be signaled to the application. The network boot-up process for these CNs shall be restarted.

- Keep trying to engage previous boot-up processes for all configured optional CNs.

7.4.1.5 NMT_MS_READY_TO_OPERATE

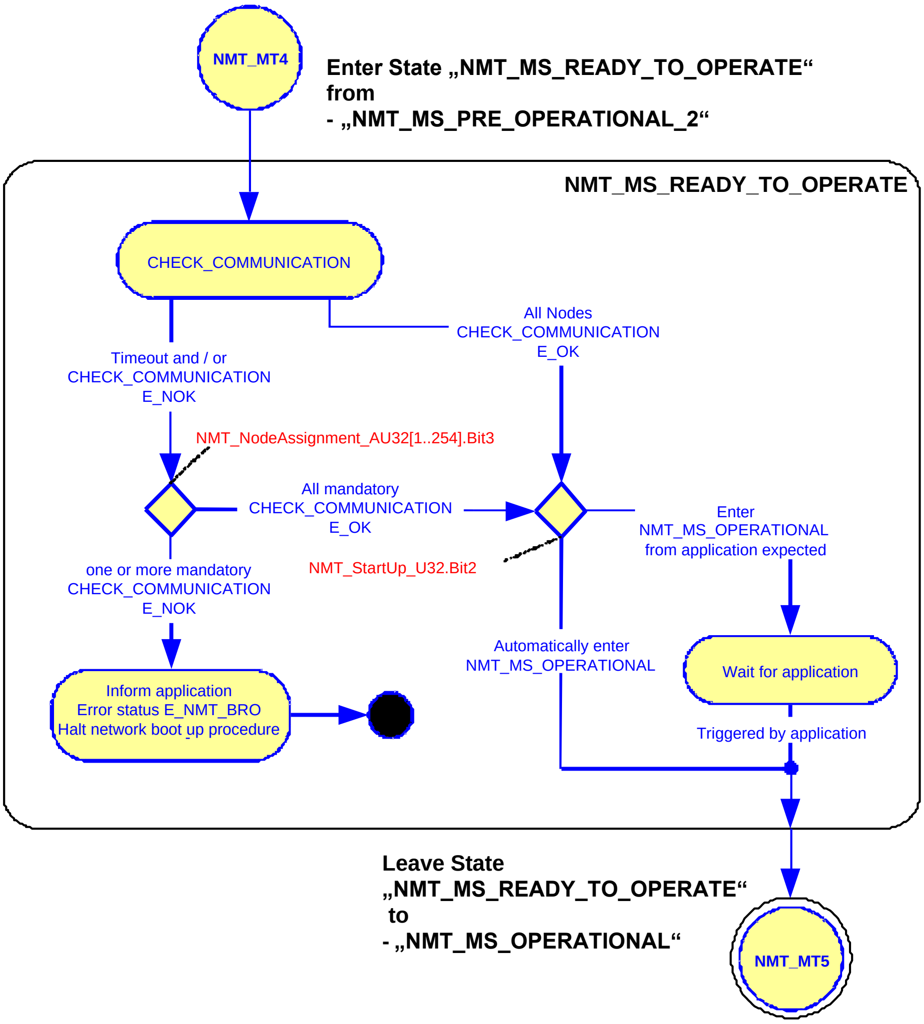


Fig. 88. Detail state NMT_MS_READY_TO_OPERATE

The purpose of the network boot process in NMT_MS_READY_TO_OPERATE state is to start and check the isochronous communication with all identified isochronous CNs. The length of the isochronous frames shall be checked against the configured values of NMT_PresPayloadLimitList_AU16.

If isochronous communication with all mandatory CNs operates correctly, the MN may enter the NMT_MS_OPERATIONAL state.

In case of communication or configuration errors within one or more mandatory CNs, the MN signals the error to the application and shall remain in this state.

This NMT state is entered from the NMT_MS_PRE_OPERATIONAL_2 state (NMT_MT4).

In the state NMT_MS_READY_TO_OPERATE the MN proceeds as follows:

- Start process CHECK_COMMUNICATION for all configured CN.
  Configured CNs are identified by:
  - NMT_NodeAssignment_AU32[1..254].Bit0
  - NMT_NodeAssignment_AU32[1..254].Bit1
- After the CHECK_COMMUNICATION process is terminated successfully for all mandatory CNs, the MN shall switch to the state NMT_MS_OPERATIONAL direct or after the application trigger. The transition policy is defined by:
  - NMT_StartUp_U32.Bit2

  Mandatory CNs are identified by:

- NMT_NodeAssignment_AU32[1..254].Bit3

If the CHECK_COMMUNICATION process of one or more mandatory CN failed, the error:

- E_NMT_BRO (see 7.4.3.4)

shall be signaled to the application.

The current MN state shall be maintained. The MN shall halt the network boot-up procedure.

- Errors of optional CNs during the CHECK_COMMUNICATION process shall be signaled to the application. The boot process for these CN shall be halted. The restart of the boot-up process for these CNs may be triggered by the application.
- Keep trying to engage previous boot processes for all configured optional CNs.

7.4.1.6 NMT_MS_OPERATIONAL

In the state NMT_MS_OPERATIONAL, the MN forces all CNs that are in the state NMT_CS_READY_TO_OPERATE to the state NMT_CS_OPERATIONAL.

In the NMT_MS_OPERATIONAL state the MN continues isochronous communication with all identified isochronous CNs.

The MN can force each CN to NMT_CS_OPERATIONAL either individually, with the NMTStartNode unicast command, or all CNs, with the NMTStartNode broadcast command. After all identified CNs are in the state NMT_CS_OPERATIONAL, the MN shall start the process OPERATIONAL for all identified CNs.

In case of communication errors of mandatory nodes, the sub-state ERROR_TREATMENT of the network boot-up procedure is entered. Finally the MN enters the state NMT_MS_PRE_OPERATIONAL_1.

The NMT_MS_OPERATIONAL state is entered from the NMT_MS_READY_TO_OPERATE state (NMT_MT5).

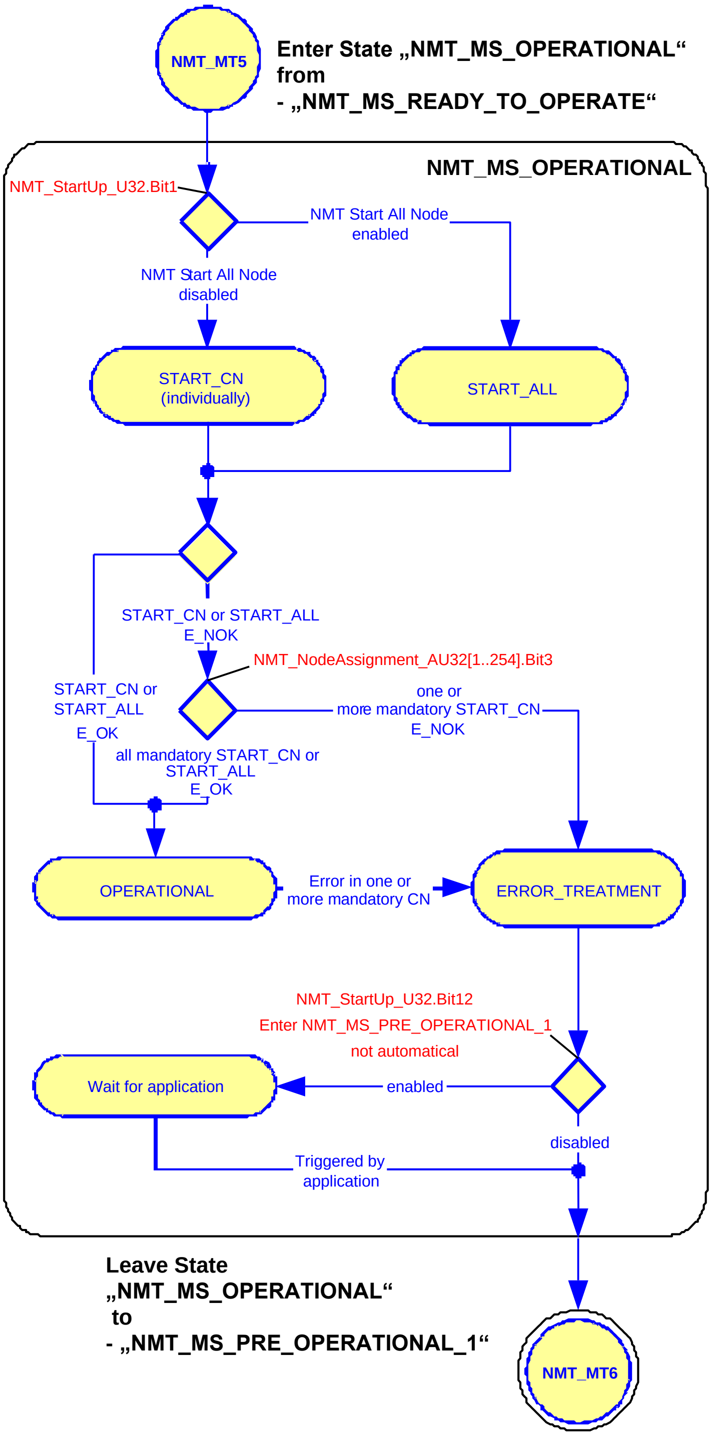


Fig. 89. Detail state NMT_MS_OPERATIONAL

The network boot steps and tasks of the NMT_MS_OPERATIONAL state are as follows:

- Start process START_ALL or START_CN either for all CNs or individually depending on the following object:
  - NMT_StartUp_U32.Bit1

  Configured CNs are identified by:
  - NMT_NodeAssignment_AU32[1..254].Bit0
  - NMT_NodeAssignment_AU32[1..254].Bit1,
- In case of errors of mandatory nodes during START_CN or START_ALL, the MN shall start the ERROR_TREATMENT process. Finally the MN enters state NMT_MS_PRE_OPERATIONAL_1 direct or after application trigger, depending on the following object:

- NMT_StartUp_U32.Bit12

If START_ALL or START_CN for all mandatory nodes finished successfully, the MN shall enter the boot-up sub-state OPERATIONAL.

- In case of communication errors during OPERATIONAL of one or more mandatory node, the MN shall enter the ERROR_TREATMENT sub-state. Finally the MN shall enter NMT_MS_PRE_OPERATIONAL_1 direct or after the application trigger, depending on the following object:
  - NMT_StartUp_U32.Bit12
- Errors of optional CNs during the START_CN, START_ALL or OPERATIONAL process shall be signaled to the application. The boot process for these CN shall be halted. The restart of the boot-up process for these CNs may be triggered by the application.
- Keep trying to engage previous boot processes for all configured optional CNs.

7.4.2 MN Boot-up Procedure on CN Level

7.4.2.1 Overview

The previous chapter describes how the MN performs the network boot-up. This chapter describes how the MN manages the boot-up procedure for a single CN.

On network level, optional and mandatory CNs are handled differently. On CN level the handling is the same.

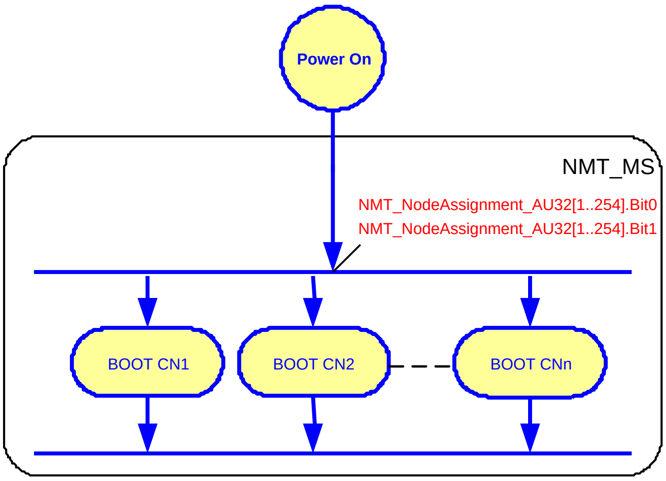


Fig. 90. Overview of the boot process in NMT super-state NMT_MS

7.4.2.2 Boot-up of optional and mandatory CNs

Optional CNs are able to link in the network everytime. For the consistency and errorless working of the network it is important to run the complete boot process also for the optional nodes. Therefore the optional CNs must be booted-up without any impact on the MN NMT state. Errors during the boot-up process of optional CNs do not cause an NMT state change of the MN. The application shall be informed about the errors.

The mandatory CN boot process correlates directly to the MN NMT states. Only if all mandatory CNs reach the same target NMT state within a sub-state of the boot process, the MN will proceed with the boot process.

The MN force all CNs into a specific NMT state. Fig. 91 shows the dependencies between the MN NMT state and the boot process actions. Optional CNs are able to be linked to the network later, even if the MN is already in the NMT_MS_OPERATIONAL state .

It is possible to carry out the boot steps of one NMT state in parallel for all nodes or in serial i.e. one CN after the other. For optional nodes, even boot steps of different NMT states can be carried out in parallel for different CNs as there must not be a common NMT state for all optional nodes in the network.

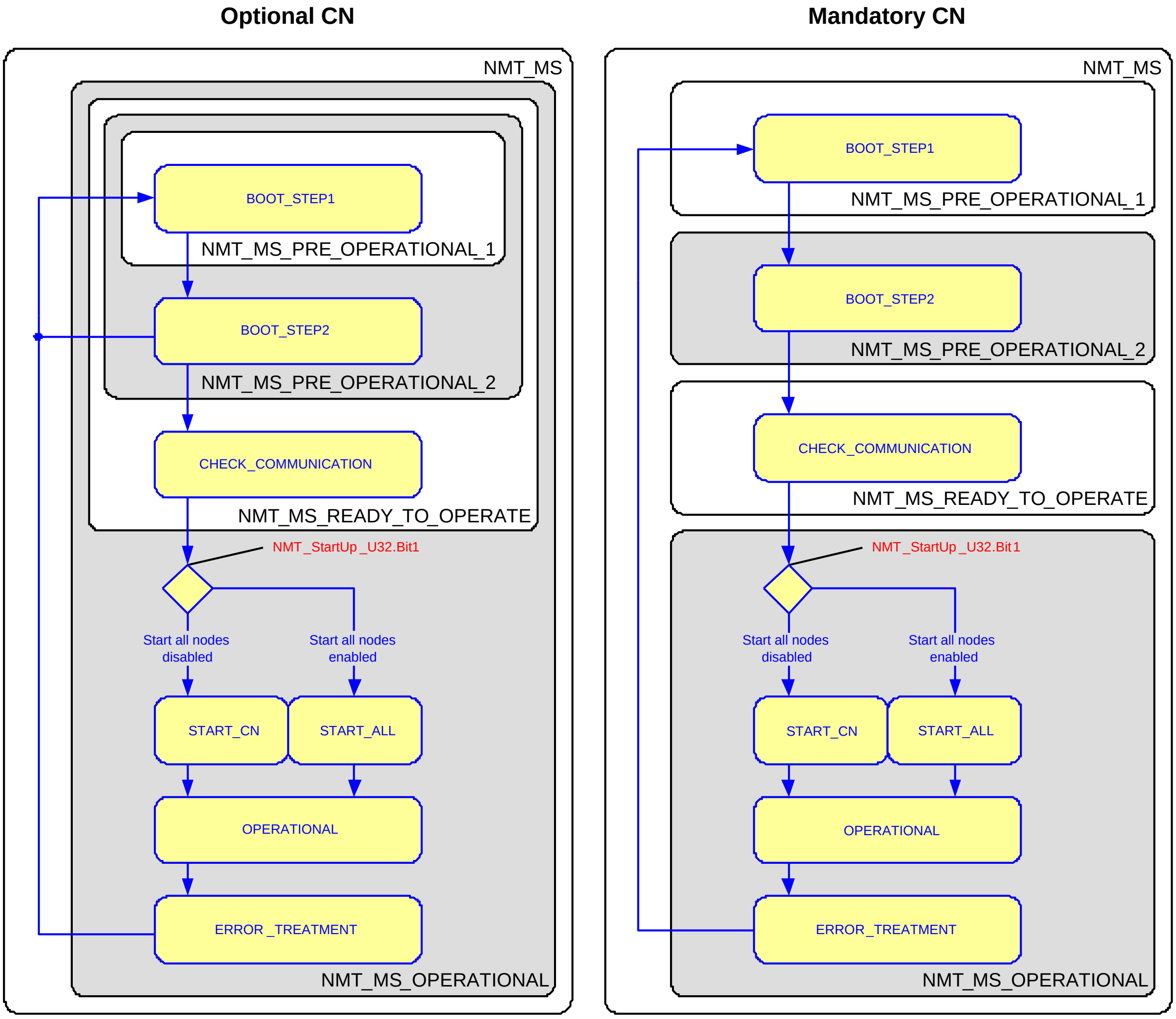


Fig. 91. Network boot process dependencies to the NMT_MS for optional and mandatory CNs

7.4.2.2.1 BOOT_STEP1

The BOOT_STEP1 process is started for all configured CNs. The purpose of the BOOT_STEP1 process is to check the identification of the configured CNs and to check the CN's software and configuration.

The BOOT_STEP1[Node ID] returns E_OK after all checks or updates are terminated successfully. If one of the checks or updates fails, BOOT_STEP1[Node ID] returns E_NOK.

The following steps are performed in BOOT_STEP1:

- Check Identification (see chapter 7.4.2.2.1.1)
- Check Software (see chapter 7.4.2.2.1.2)
- Check Configuration (see chapter 7.4.2.2.1.3)

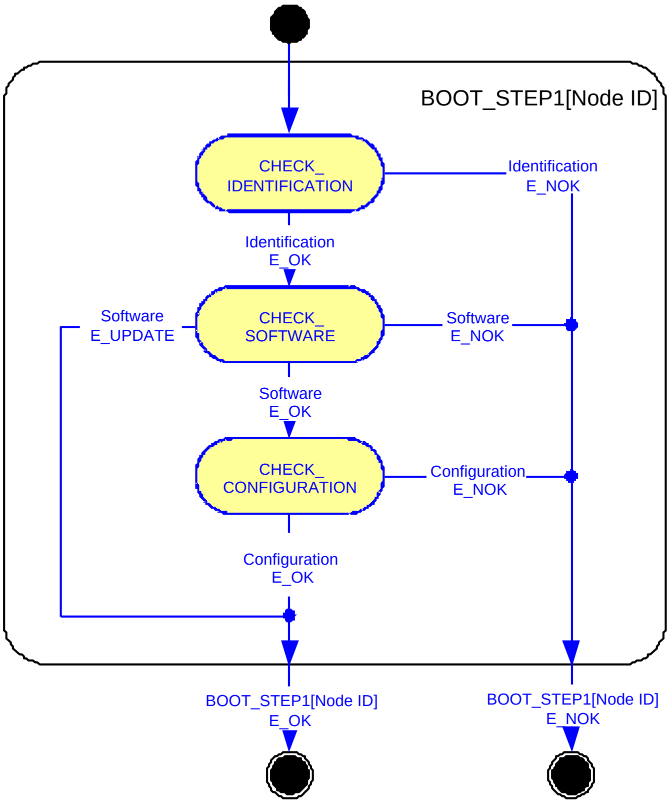


Fig. 92. Sub-state BOOT_STEP1

7.4.2.2.1.1 CHECK_IDENTIFICATION

The purpose of the CHECK_IDENTIFICATION state is to check the identification of a CN. CHECK_IDENTIFICATION [Node ID] returns E_OK after all identifications are finished successfully. If one of the identifications fails, CHECK_IDENTIFICATION [Node ID] returns E_NOK.

In the sub-state CHECK_IDENTIFICATION the MN proceeds as follows:

- Request IdentResponse from the CN (see 7.3.3.2). In case of a timeout, the error E_NMT_BPO1_GET_IDENT is set and CHECK_IDENTIFICATION[Node ID] is finished with E_NOK.
- Check the device type of the CN against the following object:
  - NMT_MNDeviceTypeIdList_AU32[Node ID].

  If the device type checking fails, the Error Status E_NMT_BPO1_DEVICE_TYPE is set and CHECK_IDENTIFICATION[Node ID] finished with E_NOK, otherwise the next step is performed.
- If the boot-up process of a CN shall not continue automatically, the boot process waits for an application trigger to continue. Otherwise the boot process is continued immediately. The switching policy depends on
  - NMT_NodeAssignment_AU32[1..254].Bit2
  - If identification check is not required depending on NMT_StartUp_U32.Bit9, CHECK_IDENTIFICATION[Node ID] returns E_OK.

  If the Identification check is required, it is based on the following objects:
  - NMT_MNVendorIdList_AU32[Node ID]
  - NMT_MNProductCodeList_AU32[Node ID]
  - NMT_MNRevisionNoList_AU32[Node ID]

  If the identification check fails, CHECK_IDENTIFICATION[Node ID] returns E_NOK and error E_NMT_BPO1_VENDOR_ID, E_NMT_BPO1_PRODUCT_CODE or E_NMT_BPO1_REVISION_NO is set, otherwise the boot process continues.
- The CN serial number is checked based on the following object:

- NMT_MNSerialNoList_AU32[Node ID].

If the identification check fails, the error E_NMT_BPO1_SERIAL_NO is set and CHECK_IDENTIFICATION[Node ID] returns E_NOK. Otherwise CHECK_IDENTIFICATION[Node ID] returns E_OK.

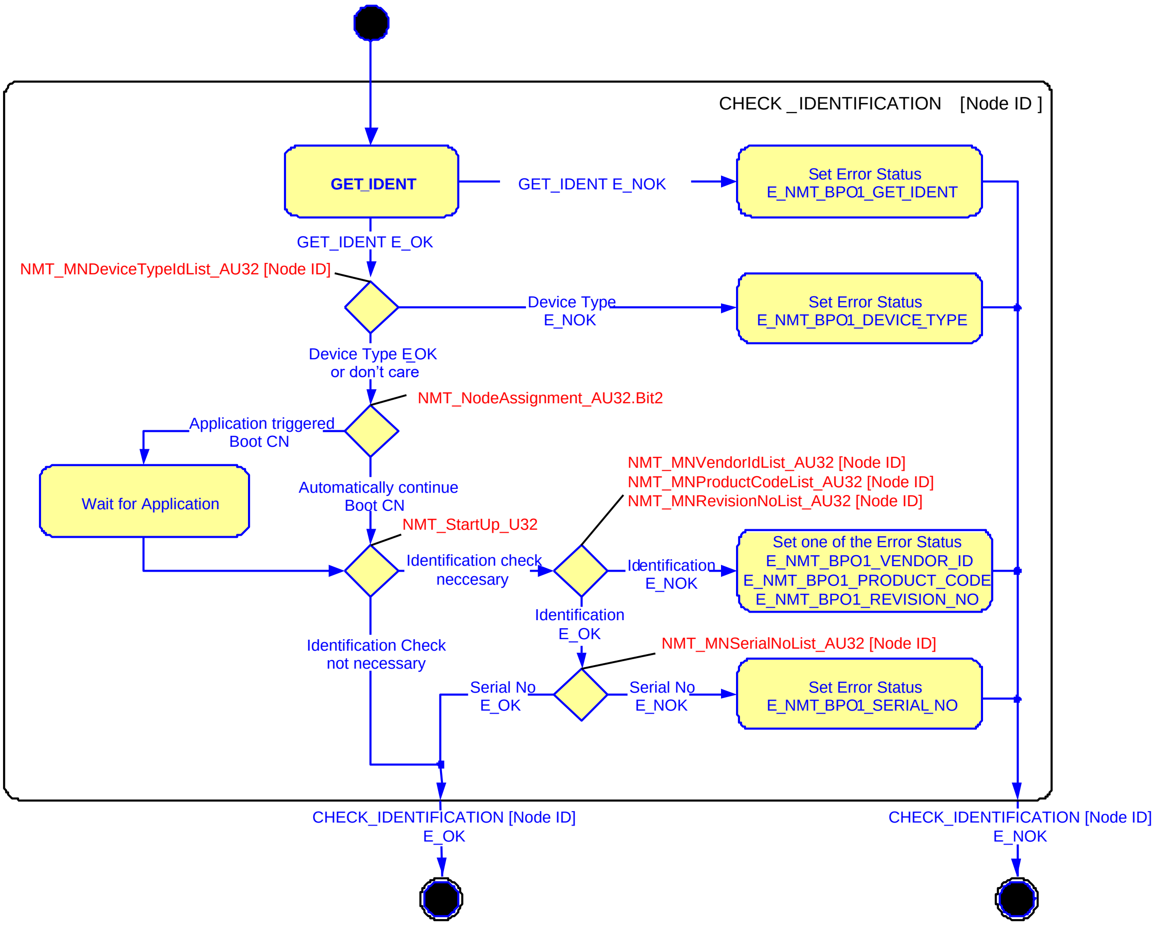


Fig. 93. Sub-state CHECK_IDENTIFICATION[Node ID]

7.4.2.2.1.2 CHECK_SOFTWARE

The purpose of CHECK_SOFTWARE is to check and update the CN software, if required.
The update process itself shall be done by the application. The application signals the result of the update process to the boot-up process.
CHECK_SOFTWARE [Node ID] returns E_OK after all software checks and updates are finished successfully. If an error occurred, CHECK_SOFTWARE [Node ID] returns E_NOK.

In the process CHECK_SOFTWARE[Node ID] the MN proceeds as follows:

- If software version check is not required (depending on the following object:
  - NMT_StartUp_U32.Bit10,
  - NMT_NodeAssignment_AU32[Node ID].Bit5),

  CHECK_SOFTWARE[Node ID] returns E_OK, otherwise the reported CN software version is checked against objects
  - PDL_MnExpAppSwDateList_AU32[Node ID],
  - PDL_MnExpAppSwTimeList_AU32[Node ID]

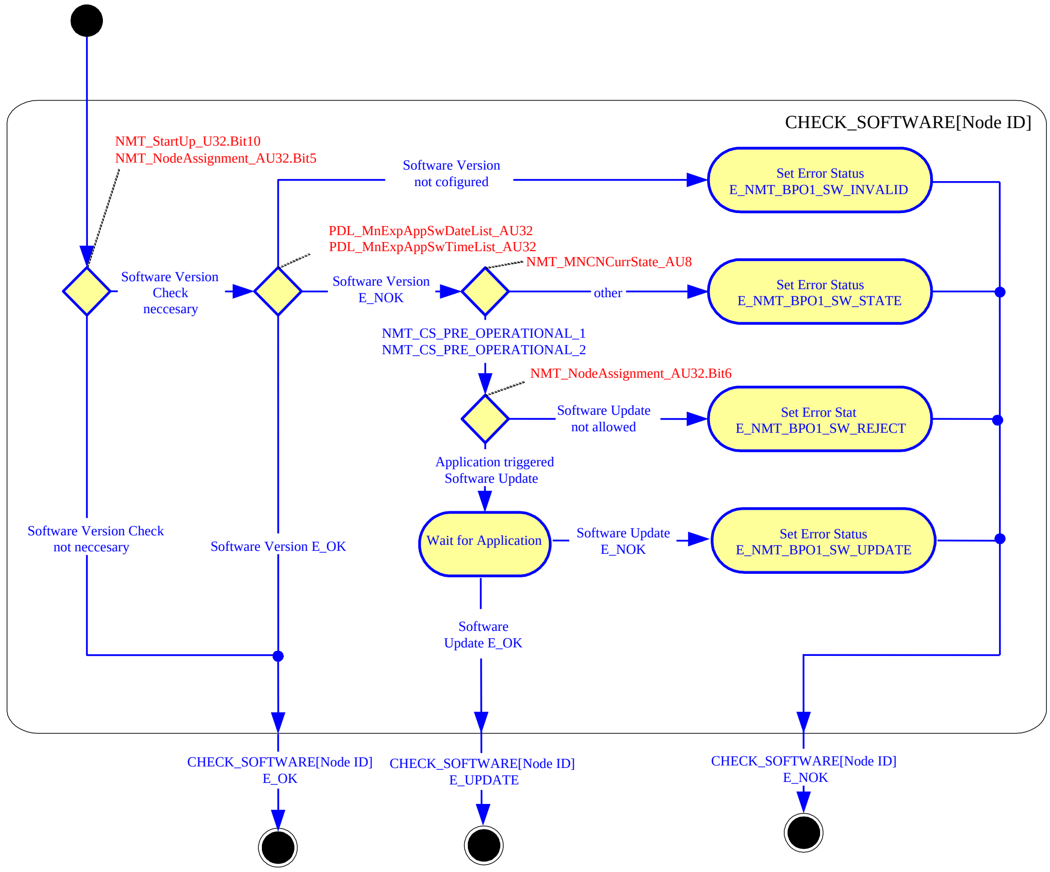


Fig. 94. Sub-state CHECK_SOFTWARE[Node ID]

- If the checking of the software version is not possible because the software version information on the MN is not configured (corresponding node sub-index of PDL_MnExpAppSwDateList_AU32 or PDL_MnExpAppSwTimeList_AU32 not found), the error E_NMT_BPO1_SW_INVALID is set and CHECK_SOFTWARE[Node ID] returns E_NOK. If the received software version matches the expected one, CHECK_SOFTWARE[Node ID] returns E_OK, otherwise the process continues with the NMT state check of the CN.
- If the current NMT state of the CN is not equal to NMT_CS_PREOPERATIONAL_1 or NMT_CS_PREOPERATIONAL_2 (check based on object
  - NMT_MNNodeCurrState_AU8),

  The error E_NMT_BPO1_SW_STATE is set and CHECK_SOFTWARE[Node ID] returns E_NOK, otherwise the next step is proceeded.
- If software update is not allowed (depending on the setting of object
  - NMT_NodeAssignment_AU32[Node ID].Bit6),

  the error E_NMT_BPO1_SW_REJECT is set and CHECK_SOFTWARE[Node ID] returns E_NOK. If the software update is allowed, the application shall be informed. Continue of the boot-up process shall be triggered by the application update return code.
- The software update itself is always part of the application. Any protocol (SDO, FTP, …) is allowed to be used for the application software update. A successful completion of the update is signalled by the application with the event E_OK.
- If there was an error during the application software update, the application will signal this to the boot-up process by returning E_NOK. In case of a software update error, the boot step returns E_NOK.
- Running BOOT_STEP1 for an optional CN while the MN is already in NMT_MS_PRE_OPERATIONAL_2 or higher, the NMTSwReset command shall be sent to the CNs individually after leaving CHECK_SOFTWARE with E_UPDATE.

7.4.2.2.1.3 CHECK_CONFIGURATION

The purpose of CHECK_CONFIGURATION is to check the configuration of a CN and to update the configuration if necessary. CHECK_CONFIGURATION [Node ID] returns E_OK, if the configuration fits, otherwise CHECK_ CONFIGURATION [Node ID] returns E_NOK.

The steps of CHECK_CONFIGURATION[Node ID] are as follows:

- If configuration verification is not required (configured by object
    - NMT_StartUp_U32.Bit11),

  CHECK_CONFIGURATION returns E_OK, otherwise the configuration is checked against objects
    - CFM_ExpConfDateList_AU32[Node ID]
    - CFM_ExpConfTimeList_AU32[Node ID]

  If the configuration date and time received within the IdentResponse of the CN is correct, CHECK_CONFIGURATION[Node ID] returns E_OK. Otherwise the boot-up process continues with the next step.
- After the configuration update is finished successfully, the MN shall request an IdentResponse from the updated CN (see 7.3.3.2). If a timeout occurs, the error E_NMT_BPO1_GET_IDENT is set and CHECK_CONFIGURATION[Node ID] returns E_NOK, otherwise the boot-up process continues with the next step.
- Configuration date and time is checked against objects
    - CFM_ExpConfDateList_AU32[Node ID]
    - CFM_ExpConfTimeList_AU32[Node ID]

  If the configuration check fails, the error E_NMT_BPO1_CF_VERIFY is set and CHECK_CONFIGURATION[Node ID] returns E_NOK, otherwise it returns E_OK.

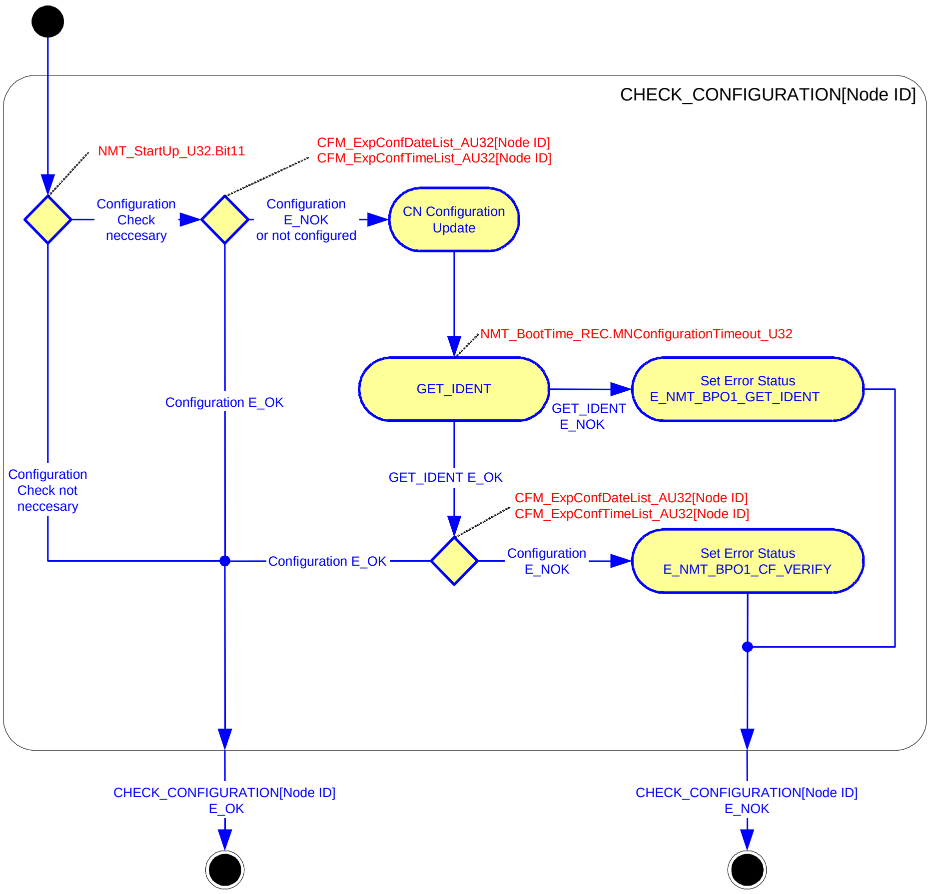


Fig. 95. Sub-state CHECK_CONFIGURATION[Node ID]

7.4.2.2.1.3.1 GET_IDENT

The purpose of the sub-state GET_IDENT is to request the IdentResponse from a CN. GET_IDENT [Node ID] returns E_OK, if the CN answers within a timeout interval, otherwise GET_IDENT [Node ID] returns E_NOK. The timeout interval depends on the actual boot-up state.

GET_IDENT[Node ID] proceeds as follows:

- Request IdentResponse from the CN.
- The IdentRequest will be repeated until the CN responds with its Ident Response or a timeout occurs (timeout value passed by the caller of this sub state).

- If the CN answers with its IdentResponse, GET_IDENT[Node ID] returns E_OK.
- If the CN does not respond within the configured timeout interval, GET_IDENT[Node ID] returns E_NOK.

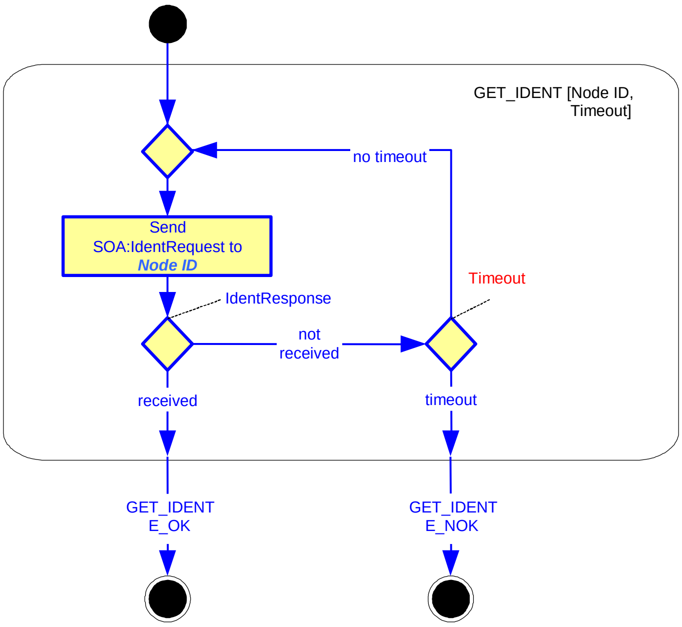


Fig. 96. Sub-state GET_IDENT[Node ID]

7.4.2.2.2 BOOT_STEP2

The purpose of BOOT_STEP2 is to send the NMT command NMTEnableReadyToOperate to a CN and to check the CN's NMT state change to NMT_CS_READY_TO_OPERATE. Furthermore the initialisation of the error signaling shall be completed in BOOT_STEP2.

BOOT_STEP2 [Node ID] returns E_OK, if the initialisation of the error signaling is completed and the CN NMT state is NMT_CS_READY_TO_OPERATE.
BOOT_STEP2 [Node ID] returns E_NOK, if the initialisation of the error signaling is not completed or the CN NMT state did not change from NMT_CS_PRE_OPERATIONAL_2 to NMT_CS_READY_TO_OPERATE state within a timeout interval (see MNTimeoutPreOp2_U32).

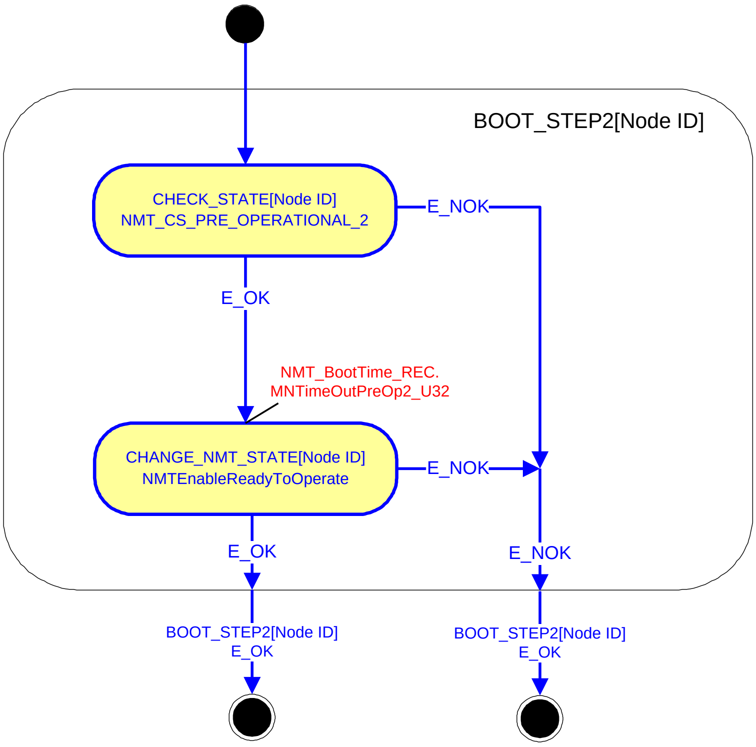


Fig. 97. Sub-state BOOT_STEP2[Node ID]

BOOT_STEP2[Node ID] proceeds as follows:

- Verify that the CN is in state NMT_CS_PRE_OPERATIONAL_2 by CHECK_STATE.
- Start the process CHANGE_NMT_STATE to send the NMT command NMTEnableReadyToOperate to the CN and to check the NMT state change of the CN.
- Check for the end of the initialisation of the error signaling.

7.4.2.2.3 CHECK_COMMUNICATION

The purpose of CHECK_COMMUNICATION[Node ID] is to check the communication with a CN after start of the isochronous POWERLINK cycle in the NMT state NMT_MS_READY_TO_OPERATE. CHECK_COMMUNICATION[Node ID] will return E_OK, if the Pres frame checking of isochronous CNs returnes no error. Otherwise CHECK_ COMMUNICATION [Node ID] returns E_NOK.

CHECK_COMMUNICATION[Node ID] proceeds as follows:

- Check the received CN Pres:
  - No loss of frame occurs
  - The payload length is less or equal than the length configured in object
    - NMT_PresPayloadLimitList_AU16 [Node ID].
  - The frame receive time is less or equal than the time configured in object
    - NMT_MNCNPResTimeout_AU32[Node ID].
- CHECK_COMMUNICATION[Node ID] returns E_NOK, if the communication with the CN fails or the expected parameter values do not fit. Otherwise CHECK_COMMUNICATION[Node ID] returns E_OK.

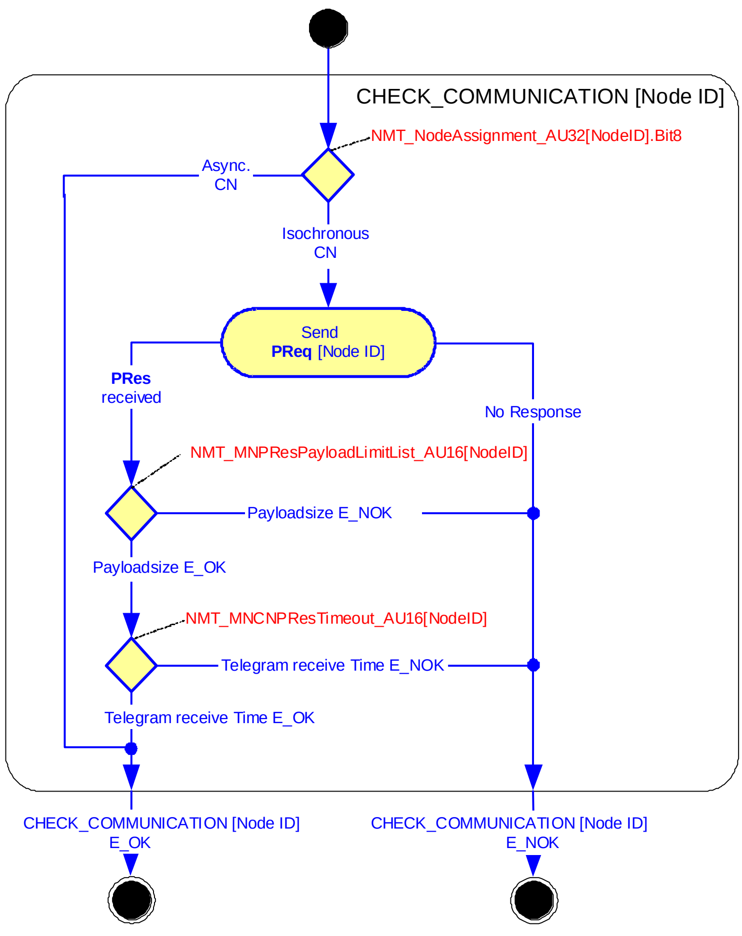


Fig. 98. Sub-state CHECK_COMMUNICATION[Node ID]

7.4.2.2.4 START_CN

In the sub-state START_CN[Node ID] the MN sends NMTStartNode to an individual CN. START_CN[Node ID] returns E_OK, if the CN changes its state to NMT_CS_OPERATIONAL within a timeout interval, otherwise E_NOK will be returned.

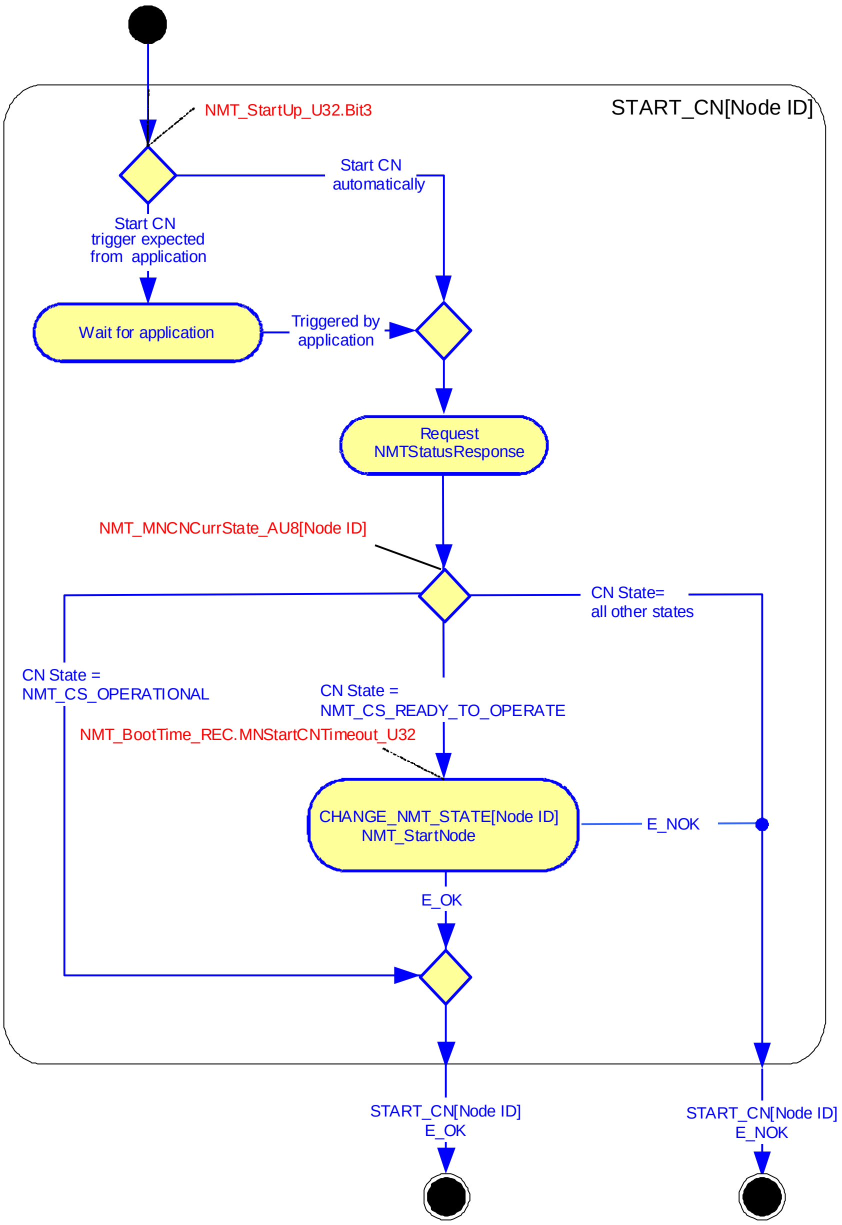


Fig. 99. Sub-state START_CN[Node ID]

START_CN[Node ID] proceeds as follows:

- START_CN[Node ID] starts immediately or after the application trigger, depending on object
  - NMT_StartUp_U32.Bit3.
- The MN checks the current state of the CN. If the CN is in the state NMT_CS_OPERATIONAL, START_CN[Node ID] returns E_OK.
- If the CN is in the state NMT_CS_READY_TO_OPERATE the boot-up procedure enters the sub-state CHANGE_NMT_STATE[Node ID] to send NMTStartNode to the CN and control its state change.
- If CHANGE_NMT_STATE[Node ID] returns E_OK, START_CN[Node ID] returns E_OK.

- If the CN is in a wrong state (neither NMT_CS_OPERATIONAL nor NMT_CS_READY_TO_OPERATE) or if CHANGE_NMT_STATE[Node ID] returns E_NOK, START_CN[Node ID] returns E_NOK, too.

7.4.2.2.5 START_ALL

In the sub-state START_ALL, NMTStartNode is sent to all CNs as broadcast. START_ALL returns E_OK, if all CNs change their state to NMT_CS_OPERATIONAL within a timeout interval, otherwise START_ALL returns E_NOK.

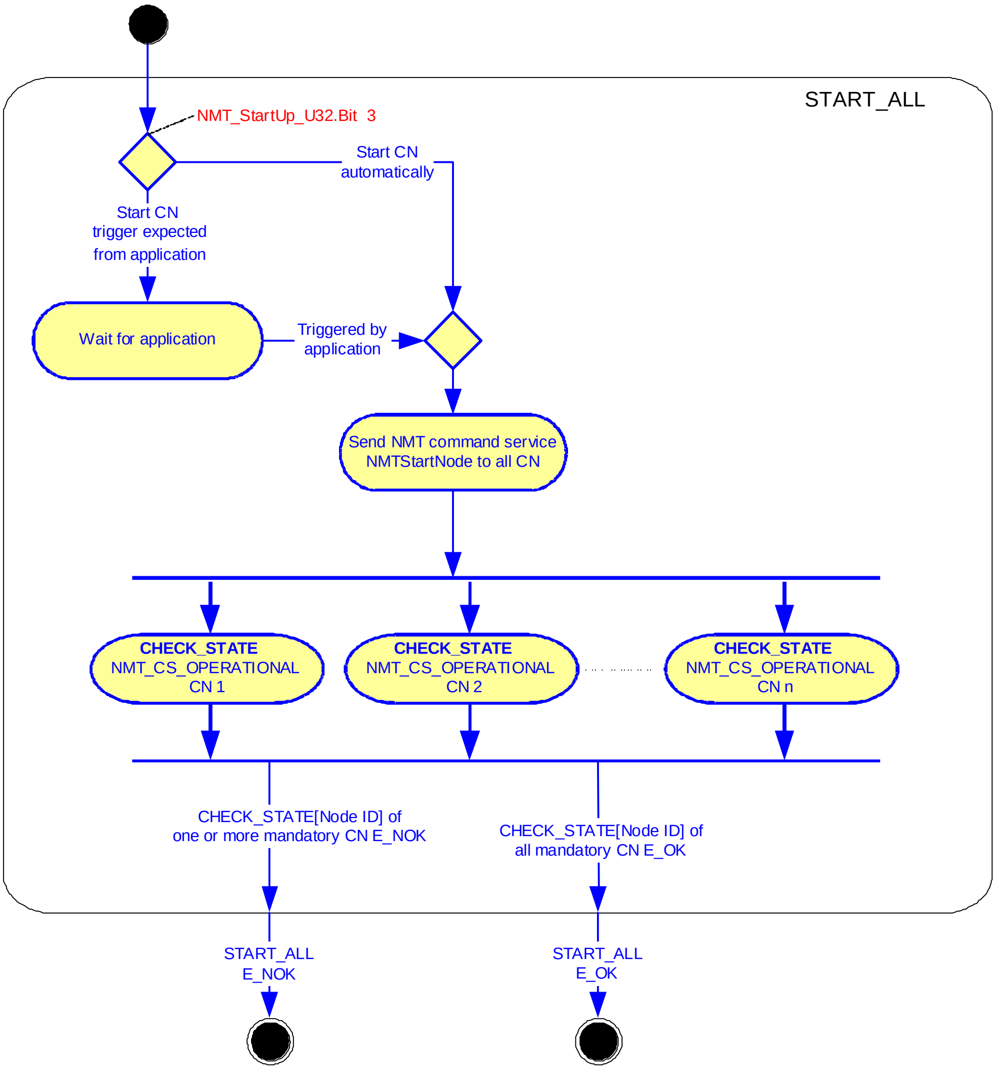


Fig. 100. Sub-state START_ALL

START_ALL proceeds as follows:

- START_ALL proceeds immediately or after the application trigger, depending on the following object:
    - NMT_StartUp_U32.Bit3.
    - After transmission of the broadcast NMT command NMTStartNode, the MN starts the sub-state CHECK_STATE for all identified CNs. If all CNs are in the state NMT_CS_OPERATIONAL, START_ALL returns E_OK. If one or more mandatory CNs caused an error in CHECK_STATE, START_ALL returns E_NOK.

7.4.2.2.6 CHECK_STATE

The purpose of CHECK_STATE is to check the current NMT state of a CN.

CHECK_STATE returns E_OK, if the current CN state is already equal to the expected state. It returns E_NOK, if the CN did not switch to the target state within a timeout interval.

If the CN is in an unexpected state, CHECK_STATE returns E_NOK.

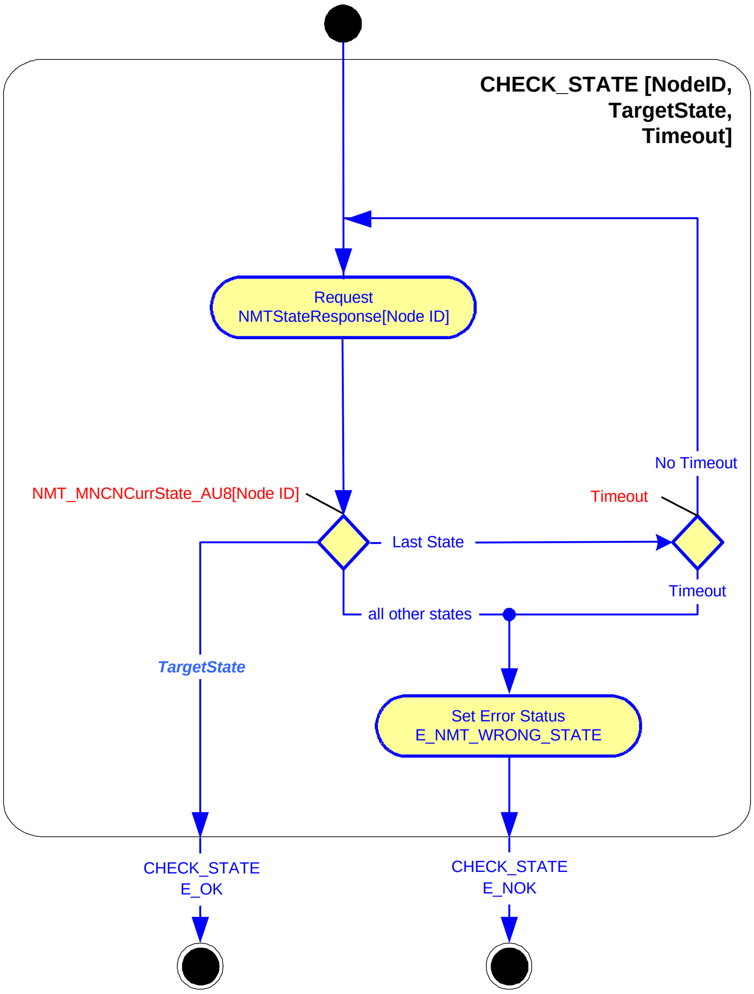


Fig. 101. Sub-state CHECK_STATE

CHECK_STATE proceeds as follows:

- If the CN state equals to the target state, CHECK_STATE returns E_OK.
- If the CN state corresponds to the last state, the CN state is further checked within a time interval until the state changes to the target state or a timeout occurs.
  For a state change to NMT_CS_READY_TO_OPERATE the timeout is configured via object NMT_BootTime_REC.MNTimeoutPreOp2_U32.
  In all other cases the timeout is defined by C_NMT_STATE_TOLERANCE.
  In case of a timeout CHECK_STATE returns E_NOK.
- If the CN is in an unexpected state, CHECK_STATE returns E_NOK.

7.4.2.2.7 CHANGE_NMT_STATE

CHANGE_NMT_COMMAND sends a NMT command to a particular CN. The resulting NMT state change is checked. Before checking the status, the MN waits for C_NMT_STATE_TOLERANCE cycles to allow the CN's NMT state change.

CHANGE_NMT_STATE returns E_OK, if the CN state is equal to the target state. Otherwise E_NOK will be returned.

If the CN state is not in an expected state, CHANGE_NMT_STATE returns with status E_NOK.

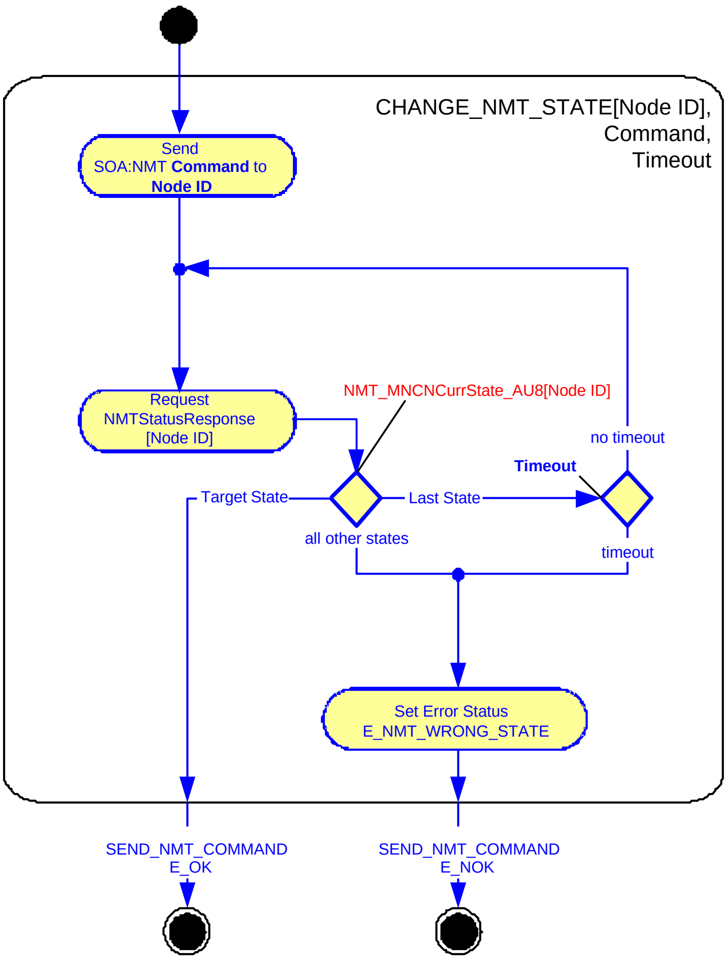


Fig. 102. Sub-state CHANGE_NMT_STATE

7.4.2.2.8 OPERATIONAL

In the OPERATIONAL state, the MN supervises all CNs that are in NMT_CS_OPERATIONAL state. If a mandatory CN generates an error such as response timeouts or wrong NMT states, the ERROR_TREATMENT substate shall be entered.

Errors of optional nodes in state OPERATIONAL are reported to the application. The boot-up of these optional CNs shall be restarted after sending the NMT command NMTResetNode.

7.4.2.2.9 ERROR_TREATMENT

In the sub-state ERROR_TREATMENT the MN will, depending on the NMT_StartUp_U32.Bit4 and NMT_StartUp_U32.Bit6, either send a NMTResetNode or a NMTStopNode to all CNs or it shall handle errors on CN in an application specific manner.

Errors of optional CNs do not have any influence on the MN or the other CNs.

The steps of the ERROR_TREATMENT process are as follows:

- Depending on the following bits:
  - NMT_StartUp_U32.Bit6
  - NMT_StartUp_U32.Bit4

the errors are treated different. For optional nodes these bits are always ignored as only the individual CN error treatment is allowed.

- If NMT_StartUp_U32.Bit6 is true, the NMT command NMTStopNode shall be transmitted to all CNs
- If NMT_StartUp_U32.Bit4 is true, the NMT command NMTResetNode shall be transmitted to all CNs. If NMT_StartUp_U32.Bit4 is false, errors are treated individually by the application.

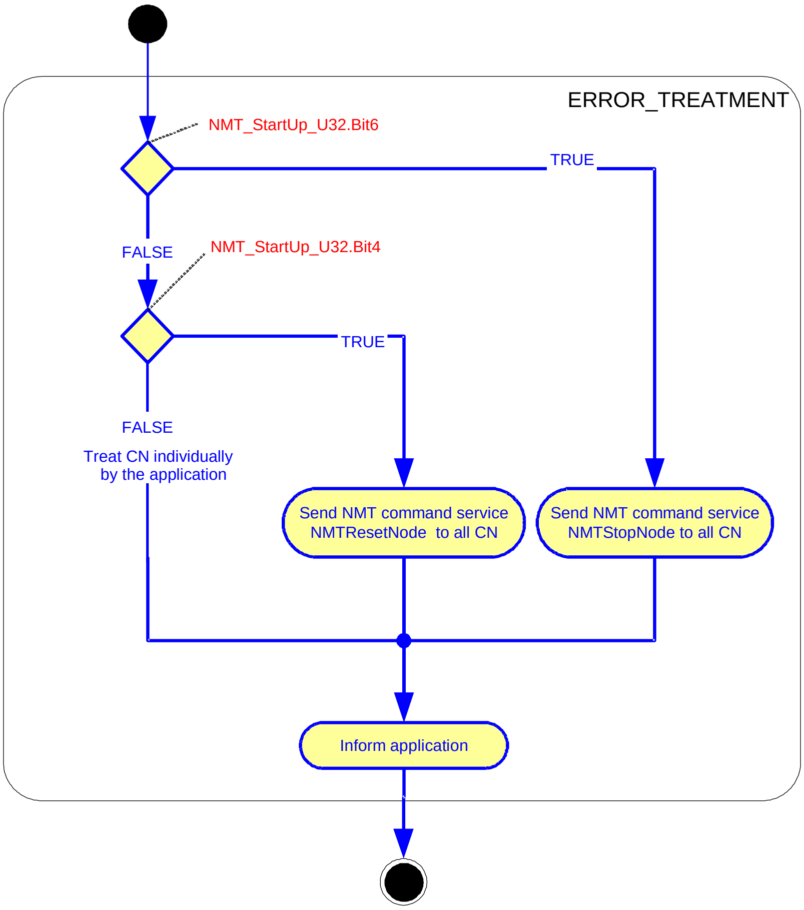


Fig. 103. Sub-state ERROR_TREATMENT

7.4.3 Boot-up Errors

7.4.3.1 Bus activity

- **Error Source**

  The device is configured as an MN and detects another MN (SoC, IdentRequest, …).

- **Handling**

  The MN shall halt the boot procedure. The error is logged in the error history.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_NMT_BA1	XXXX	

7.4.3.2 BOOT_STEP1 failed

- **Error Source**

  Boot process in the NMT_MS_PRE_OPERATIONAL_1 state failed. One or more mandatory CNs failed.

- **Handling**

  The MN shall stop the boot-up procedure. The error is logged in the error history.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_NMT_BPO1	XXXX	

7.4.3.3 BOOT_STEP2 failed

- **Error Source**

  Boot process in the NMT_MS_PRE_OPERATIONAL_2 state failed. One or more of the mandatory configured CNs failed.

- **Handling**

  The MN shall stop the boot-up procedure. The error is logged in the error history.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_NMT_BPO2	XXXX	

7.4.3.4 Boot-up in NMT_MS_READY_TO_OPERATE failed

- **Error Source**

  The process CHECK_COMMUNICATION in the NMT_MS_READY_TO_OPERATE state failed because of the reception of at least one incorrect or missing Pres.

- **Handling**

  The MN shall stop the boot-up procedure and log the error in the error history.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_NMT_BRO	XXXX	

7.4.3.5 Get Ident failed

- **Error Source**

  No response on an Ident Request was received.

- **Handling**

  Log the error in the error history.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_NMT_BPO1_GET_IDENT	XXXX	

7.4.3.6 Device Type Invalid

- **Error Source**

  Actual device type of the CN (value of object NMT_DeviceType_U32 reported via IdentResponse) did not match the expected device type configured on the MN via object NMT_MNDeviceTypeIdList_AU32.

- **Handling**

  Log the error in the error history.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_NMT_BPO1_DEVICE_TYPE	XXXX	

7.4.3.7 Vendor ID invalid

- **Error Source**

  Vendor ID reported via IdentResponse of the CN did not match the expected vendor ID configured on the MN via object NMT_MNVendorIdList_AU32.

- **Handling**

  Log the error in the error history.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_NMT_BPO1_VENDOR_ID	XXXX	

7.4.3.8 Configuration failed

- **Error Source**

  Configuration update failed.

- **Handling**

  Log the error in the error history.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_NMT_BPO1_CF_VERIFY	XXXX	

7.4.3.9 Product Code invalid

- **Error Source**

  Product Code reported via IdentResponse of the CN did not match the expected product code configured on the MN via object NMT_MNProductCodeList_AU32.

- **Handling**

  Log the error in the error history.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_NMT_BPO1_PRODUCT_CODE	XXXX	

7.4.3.10 Revision number invalid

- **Error Source**

  Revision number reported via IdentResponse of the CN did not match the expected revision number configured on the MN via object NMT_MNRevisionNoList_AU32.

- **Handling**

  Log the error in the error history.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_NMT_BPO1_REVISION_NO	XXXX	

7.4.3.11 Serial number invalid

- **Error Source**

  Serial number reported via IdentResponse of the CN did not match the expected serial number configured on the MN via object NMT_MNSerialNoList_AU32.

- **Handling**

  Log the error in the error history.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_NMT_BPO1_SERIAL_NO	XXXX	

7.4.3.12 NMT state invalid

- **Error Source**

  Reported CN NMT state does not match the expected NMT state.

- **Handling**

  Log the error in the error history.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_NMT_WRONG_STATE	XXXX	

7.4.3.13 Invalid Software

- **Error Source**

  Software version information for a certain CN not available on the MN.

- **Handling**

  Log the error in the error history.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_NMT_BPO1_SW_INVALID	XXXX	

7.4.3.14 Invalid NMT state for SW update

- **Error Source**

  Software update failed due to wrong NMT state of the target CN.

- **Handling**

  Log the error in the error history.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_NMT_BPO1_SW_STATE	XXXX	

7.4.3.15 SW update not allowed

- **Error Source**

  Software update of a CN not allowed.

- **Handling**

  Log the error in the error history.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_NMT_BPO1_SW_REJECT	XXXX	

7.4.3.16 SW update failed

- **Error Source**

  An error occurred during the application SW update process.

- **Handling**

  Log the error in the error history.

- **Registration**

  History Entry Object ERR_History_ADOM:

Mode	Profile	Error Code	Timestamp	Additional Information
3_h	002_h	E_NMT_BPO1_SW_UPDATE	XXXX	

7.4.4 Minimal Boot-up MN

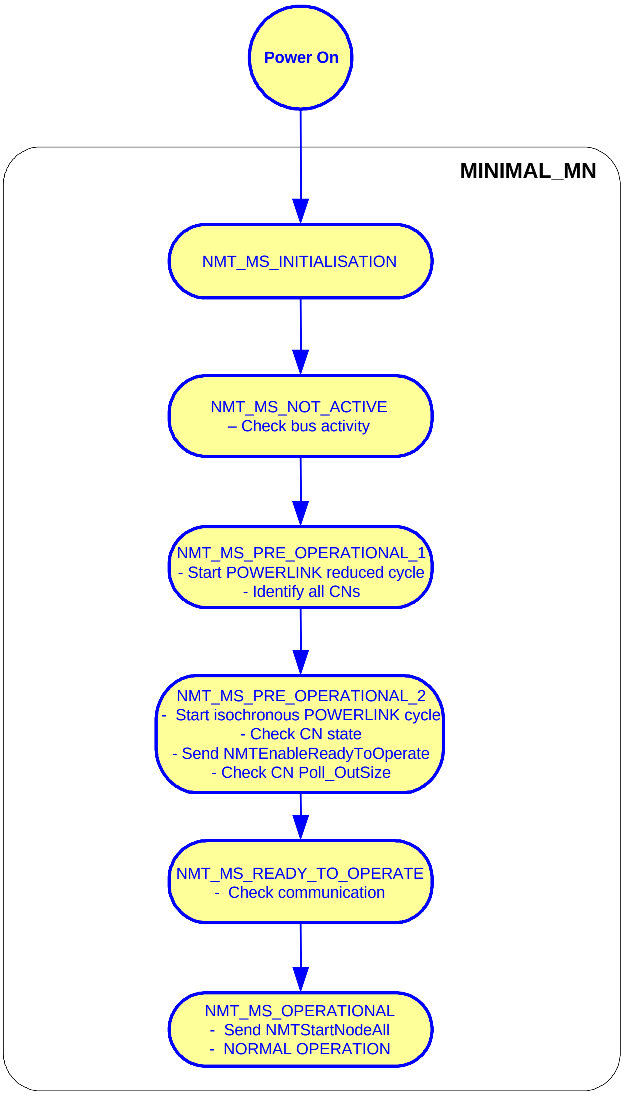
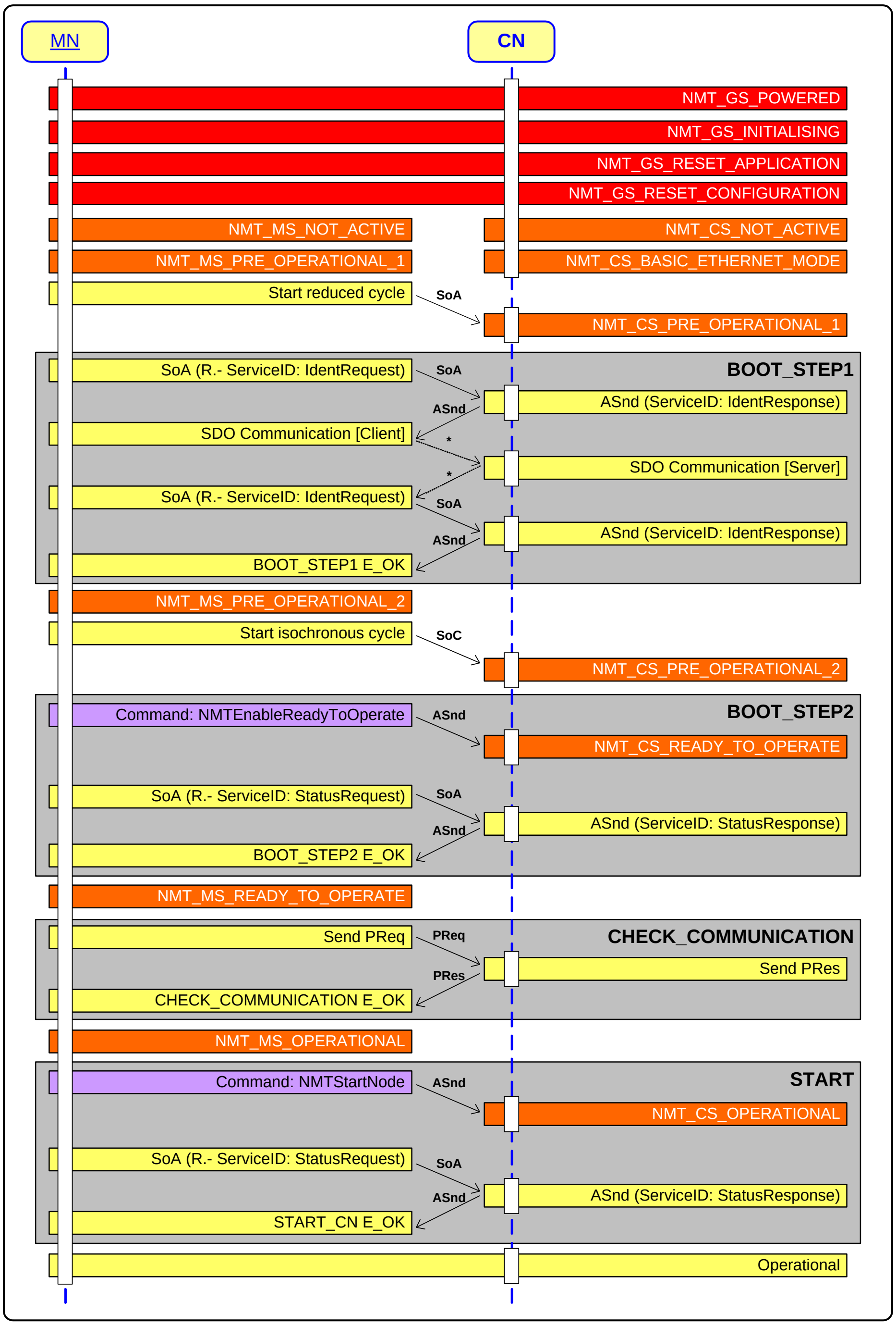


Fig. 104. Minimal NMT boot-up process

Fig. 104 depicts a minimal MN boot-up, which allows to implement a simple NMT state machine on low-cost MNs. Only small applications should use this type of boot-up as there is no error treatment or configuration checking. The minimal MN boot-up guarantees only that all devices reach the operational state and that no device violates the POWERLINK cycle.

7.4.5 Example Boot-up Sequence

In this example a typical boot-up with a single CN and without boot-up errors is depicted. The example also shows a configuration update of the CN in BOOT_STEP1.



* Operation is done several times

Fig. 105. Boot procedure example for a single CN

7.4.6 Application Notes

- It is permitted to boot-up one device after another (sequential boot-up) or all in parallel. If the sequential boot-up procedure is implemented, it must be ensured that a particular boot step is still performed for all devices even if an error of a mandatory node occurred within that boot step. The reaction of the boot-up process upon an error within a mandatory node shall be delayed until the boot step was finished for all the other devices, too.

- The defined processes shall give an overview to the boot-up, they do not define a specific API. The main purpose is to have common rules for the MN boot-up procedure and to give CNs the knowledge, what they have to expect on boot-up.
- The same procedure, except for the error handling, will be used if an optional CN has to be booted while the rest of the system is already running, e.g. after a reset or error. In that case the NMT command NMTStartNode may always be sent individually.

8 Diagnostics

8.1 Diagnostic Object Dictionary Entries

8.1.1 Object 1101_h: DIA_NMTTelegrCount_REC

The object's sub-indices count cycles, synchronous and asynchronous frames, SDO telegrams and StatusRequests since NMT_GS_RESET_COMMUNICATION. The counters shall be reset in NMT_GS_RESET_COMMUNICATION.

The application may provide additional means to reset the conters.

Index	1101_h	Object Type	RECORD
Name	DIA_NMTTelegrCount_REC		
Data Type	DIA_NMTTelegrCount_TYPE	Category	O

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	8	Access	const
Default Value	8	PDO Mapping	No

- **Sub-Index 01_h: IsochrCyc_U32**

Sub-Index	01_h		
Name	IsochrCyc_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

This sub-index holds the number of transmitted (MN) or received (CN) SoC frames.

- **Sub-Index 02_h: IsochrRx_U32**

Sub-Index	02_h		
Name	IsochrRx_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

This sub-index holds the number of received Preq and Pres frames.

- **Sub-Index 03_h: IsochrTx_U32**

Sub-Index	03_h		
Name	IsochrTx_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

This sub-index holds the number of transmitted Preq and Pres frames.

- **Sub-Index 04h: AsyncRx_U32**

Sub-Index	04h		
Name	AsyncRx_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

This sub-index holds the number of received asynchronous frames (POWERLINK Asnd, IP frames etc., but not SoA).

- **Sub-Index 05h: AsyncTx_U32**

Sub-Index	05h		
Name	AsyncTx_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

This sub-index holds the number of transmitted asynchronous frames (POWERLINK Asnd, IP frames etc., but not SoA).

- **Sub-Index 06h: SdoRx_U32**

Sub-Index	06h		
Name	SdoRx_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

This sub-index holds the number of received SDO telegrams via UDP/IP or POWERLINK Asnd.

- **Sub-Index 07h: SdoTx_U32**

Sub-Index	07h		
Name	SdoTx_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

This sub-index holds the number of transmitted SDO telegrams via UDP/IP or POWERLINK Asnd.

- **Sub-Index 08h: Status_U32**

Sub-Index	08h		
Name	Status_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

This sub-index holds the number of received StatusRequest SoA telegrams.

8.1.2 Object 1102$_h$: DIA_ERRStatistics_REC

The object's sub-indices count events which occurred in the Error Signaling module. When reaching their maximum value the counters shall continue with 0.

Index	1102$_h$	Object Type	RECORD
Name	DIA_ERRStatistics_REC		
Data Type	DIA_ERRStatistics_TYPE	Category	O

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	7	Access	const
Default Value	7	PDO Mapping	No

- **Sub-Index 01$_h$: HistoryEntryWrite_U32**

Sub-Index	01$_h$		
Name	HistoryEntryWrite_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

This sub-index holds the number of entries written to the error history (see 6.5.1).

- **Sub-Index 02$_h$: EmergencyQueueWrite_U32**

Sub-Index	02$_h$		
Name	EmergencyQueueWrite_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

This sub-index holds the number of successful write actions to the emergency queue. Write actions which can not be performed because the queue is full shall not be counted here.

- **Sub-Index 03$_h$: EmergencyQueueOverflow_U32**

Sub-Index	03$_h$		
Name	EmergencyQueueOverflow_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

This sub-index holds the number of write actions to the emergency queue which could not be done because the queue was full.

- **Sub-Index 04$_h$: StatusEntryChanged_U32**

Sub-Index	04$_h$		
Name	StatusEntryChanged_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

This sub-index holds the number of changes in the StatusEntries.

- **Sub-Index 05$_h$: StaticErrorBitFieldChanged_U32**

Sub-Index	05$_h$		
Name	StaticErrorBitFieldChanged_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

This sub-index holds the number of changes in the Static Error Bit Field.

- **Sub-Index 06$_h$: ExceptionResetEdgePos_U32**

Sub-Index	06$_h$		
Name	ExceptionResetEdgePos_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

This sub-index holds the number of detected 0 to 1 transitions of the bit ER.

- **Sub-Index 07$_h$: ExceptionNewEdge_U32**

Sub-Index	07$_h$		
Name	ExceptionNewEdge_U32		
Data Type	UNSIGNED32	Category	O
Value Range	UNSIGNED32	Access	ro
Default Value	0	PDO Mapping	No

This sub-index holds the number of all generated transitions on the bit EN.

8.1.3 Diagnostics Object Types

8.1.3.1 Object 0437$_h$: DIA_NMTTelegrCount_TYPE

Index	0437$_h$	Object Type	DEFSTRUCT
Name	DIA_NMTTelegrCount_TYPE		
Sub-Index	Component Name	Value	Data Type
00$_h$	NumberOfEntries	08$_h$	
01$_h$	IsochrCyc_U32	0007$_h$	UNSIGNED32
02$_h$	IsochrRx_U32	0007$_h$	UNSIGNED32
03$_h$	IsochrTx_U32	0007$_h$	UNSIGNED32
04$_h$	AsyncRx_U32	0007$_h$	UNSIGNED32
05$_h$	AsyncTx_U32	0007$_h$	UNSIGNED32
06$_h$	SdoRx_U32	0007$_h$	UNSIGNED32
07$_h$	SdoTx_U32	0007$_h$	UNSIGNED32
08$_h$	Status_U32	0007$_h$	UNSIGNED32

8.1.3.2 Object 0438_h: DIA_ERRStatistics_TYPE

Index	0438_h	Object Type	DEFSTRUCT
Name	DIA_ERRStatistics_TYPE		
Sub-Index	Component Name	Value	Data Type
00_h	NumberOfEntries	07_h	
01_h	HistoryEntryWrite_U32	0007_h	UNSIGNED32
02_h	EmergencyQueueWrite_U32	0007_h	UNSIGNED32
03_h	EmergencyQueueOverflow_U32	0007_h	UNSIGNED32
04_h	StatusEntryChanged_U32	0007_h	UNSIGNED32
05_h	StaticErrorBitFieldChanged_U32	0007_h	UNSIGNED32
06_h	ExceptionResetEdgePos_U32	0007_h	UNSIGNED32
07_h	ExceptionNewEdge_U32	0007_h	UNSIGNED32

9 Routing

A POWERLINK Router is a coupling element in a network that allows IP communication between a POWERLINK segment and any other datalink layer protocol carrying IP e.g. legacy Ethernet, POWERLINK etc.

9.1 Routing Type 1

A POWERLINK Router Type 1 is a coupling element in a network that allows IP communication between a POWERLINK network and any other datalink layer protocol carrying IP e.g. Legacy Ethernet, POWERLINK etc. It enables the communication between two networks using IP and ICMP. Other network layer protocols besides IP cannot be coupled via the Routing Type 1. MN and CNs may have router functionality implemented. A POWERLINK Router runs an application that forwards IP and ICMP datagrams from the POWERLINK network to an external network and vice versa. Fig. 106 illustrates the black box model of the POWERLINK Router.

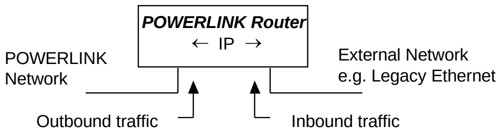


Fig. 106. POWERLINK router, black box model

Traffic from the external network to the POWERLINK network is called inbound traffic. The traffic from the POWERLINK network to the external network e.g. Legacy Ethernet is called outbound traffic.

Routing Type 1 is optional. Support shall be indicated by D_RT1_RT1Support_BOOL.

9.1.1 Core Tasks of a POWERLINK Router

This section describes some relevant application scenarios in more detail. Possible application scenarios for the use of a POWERLINK Router are listed below. Only scenarios for communication paths that involve a POWERLINK Router are listed.

- Diagnostics, Remote Maintenance, Monitoring
- Alarm Messages
- Software Download
- Configuration / Engineering
- Secure Access
- SDO communication

Each data transmission that originates from the POWERLINK network and terminates out-side of it (including inside the router), falls within the responsibility of the POWERLINK Router. The same applies for traffic that originates from the external network and terminates inside the POWERLINK network.

There are several use cases that require the above mentioned traffic pattern. While they can all be subsumed under the view that they require the functionality of the POWERLINK Router, they will be outlined below because each use case has its own peculiarities. In any case, the coupling by means of a POWERLINK Router is only possible on layer 3, because the POWERLINK Router only handles data link frames that contain IP and ICMP packets. Fig. 107 illustrates these use cases.

1. Access from the Factory Floor network (e. g., for diagnostics)
2. Access from the Company Network (e. g., for inventory purposes)
   In this scenario, additional security effort may be necessary, which may require further processing in the data path POWERLINK Router <-> company network.
3. Remote Access (e. g., for remote maintenance)
   Strict security aspects should be taken into account. These are outside the scope of this document.
4. POWERLINK inter-segment communication (e. g., for exchange of manufacturing service data)

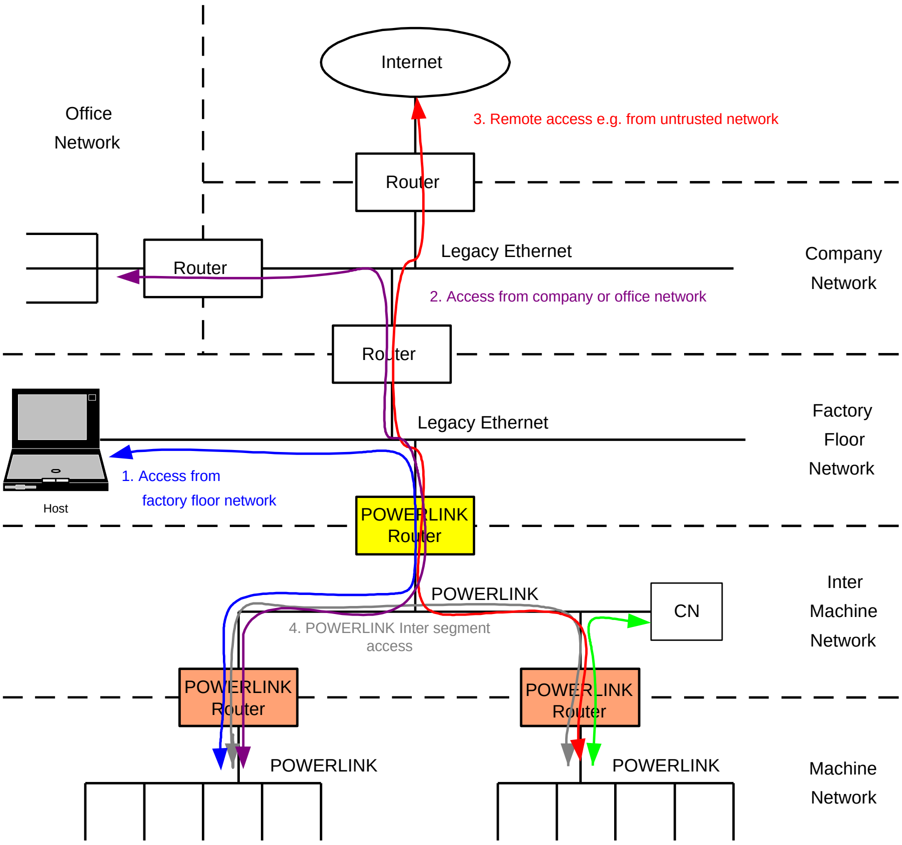


Fig. 107. Possible communication relations via a POWERLINK router

A POWERLINK Router shall provide at least one interface of type POWERLINK. In Fig. 107 that is the POWERLINK Router (yellow) between Factory Floor and Inter Machine Network and the POWERLINK Routers (orange) between Inter Machine and Machine Network. The other routers do not contain a POWERLINK interface and are therefore outside the scope of this specification.

9.1.2 Reference Model

The reference model of the POWERLINK Router is shown below.

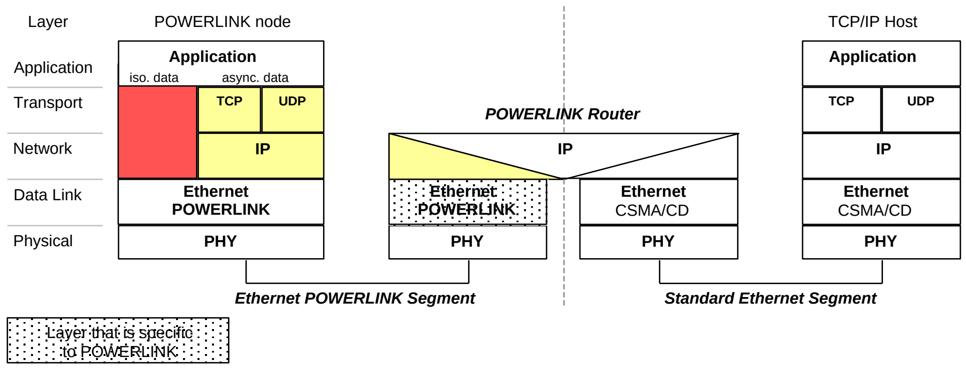


Fig. 108. POWERLINK router reference model

9.1.3 Data Link Layer

A POWERLINK Router shall at least provide two interfaces. One interface to the POWERLINK and a second interface to the external network. IP operates on top of the data link layer – e.g. POWERLINK, Legacy Ethernet.

9.1.3.1 DLL POWERLINK Interface

The Interface of the POWERLINK Router to the POWERLINK network shall behave exactly like a POWERLINK CN (see 4.2.2.2).

9.1.3.2 DLL interface to the external network

Depending on the application requirements, the interface to the external network can be chosen. Any datalink layer protocol that can embed IP may be used. Legacy Ethernet, POWERLINK, X.25, etc. may be used for the interface connecting to the external network.

9.1.4 Network Layer

The POWERLINK Router connects a POWERLINK network to an external network only via the Internet Protocol (IP). Therefore, the router's tasks on this layer are basically the same as that of any other standard IP router, as described in RFC 1812. These include the routing or forwarding and Network Address Translation (NAT) described in 9.1.4.2. If other protocols are used, they shall be encapsulated in IP to communicate via the POWERLINK Router.

9.1.4.1 Communication between POWERLINK and the external network

The POWERLINK Router shall forward the following types of packets:

- The POWERLINK Router shall forward only the IP and ICMP packets from the external network that are addressed and permitted (see 9.1.5) to the POWERLINK network. How the IP datagrams are sent on the POWERLINK network, depends on the POWERLINK network state – see 9.1.4.2.
- The POWERLINK Router shall forward only the IP and ICMP packets from the POWERLINK network that are addressed to the external network.

The ICMP datagrams supported by the POWERLINK Router are given in 9.1.4.2.1.

9.1.4.2 IP Coupling

The main difference between an IP router using only Legacy Ethernet and a POWERLINK Router is that the POWERLINK Router forwards IP and ICMP packets depending on the current POWERLINK network state. Note, that the POWERLINK Router accesses the POWERLINK network in the same way a CN does, because a POWERLINK Router runs only the IP coupling application.

- In the NMT_CS_EPL_MODE state, the POWERLINK Router shall forward the respective IP and ICMP packets to and from the asynchronous phase. The POWERLINK Router shall respect the network access rules of the POWERLINK network, i.e. it's only allowed to send, when invited by the MN.
- In the NMT_CS_BASIC_ETHERNET state, the POWERLINK Router shall access the POWERLINK network like an IEEE802.3 compliant node using CSMA/CD. There is no cycle time interval in basic ethernet mode.

Since a POWERLINK network uses fixed IP addresses, supporting only IP routing would limit the flexibility of the system. This restriction is removed using IP routing and Network Address Translation (NAT).

9.1.4.2.1 IP Routing

Forwarding an IP datagram generally requires the router to choose the relevant local interface and the address of the next-hop router resp. (for the final hop) of the destination host. This choice depends upon a route database within the router. The route database is called routing table RT1_IpRoutingTable_XXh_REC.

Ipv4 routing is specified in RFC 1812. Nothing should prevent a POWERLINK Router from implementing standard IP routing procedures, but it is recommended that the following points be considered:

A router's functionality, as given in RFC 1812 (Requirements for IP Version 4 Routers) is rather extensive and complex, even if only mandatory functions are implemented. A considerable fraction of these functions are neither required nor of meaningful use for a typical POWERLINK Router application scenario. It seems therefore sensible to define the POWERLINK Router's functionality with reference to RFC 1812 and explicitly list the functions that vary from RFC1812.

- The POWERLINK Router shall use static routing. The POWERLINK Router may not support any dynamic routing algorithms like RIP or OSPF. Especially for the interface to the POWERLINK network, the POWERLINK Router should be aware of the limited bandwidth. Therefore, the POWERLINK Router shall not use dynamic routing algorithms on the POWERLINK network.
- The POWERLINK Router shall not support IP multicasting.
- The POWERLINK Router shall support IP fragmentation. IP datagrams larger than the MTU of the respective network shall be fragmented.
- The POWERLINK Router may not support MTU discovery. The MTU of the POWERLINK network is given in NMT_CycleTiming_REC.AsyncMTU_U16. The POWERLINK Router shall not send frames longer than the respective Layer 2 MTU limit. However, it may receive and process frames addressed to it exceeding this limit.
- The POWERLINK Router shall use the standard ARP (RFC 826) protocol to find out the IP to MAC address relation – see 5.1.3
- Traffic precedence features (Layer 2 priority (IEEE 802.1Q-1999) as well as Layer 3 IP TOS) may be supported.
- The typical location for a POWERLINK Router is comparable to what RFC 1812 calls a "fringe router", i. e., it connects a local network to a network of another hierarchy.
- The POWERLINK Router shall support the following ICMP messages: Echo Request/Reply, Destination Unreachable, Redirect, Time Exceeded, Parameter Problem, Address Mask Request
- The POWERLINK Router need not support the following options: Time Stamp, Source Route, Record Route.

9.1.4.2.1.1 Configuration

Routers shall be manageable by POWERLINK SDO and optionally by the Simple Network Management Protocol version 3 (SNMPv3).

9.1.4.2.1.1.1 SNMP

The POWERLINK Router may support SNMPv3 RFC 3410-3418 on non-POWERLINK interfaces. If so the following standard MIBs for management shall be supported.

- The System, Interface, IP, ICMP, and UDP groups of MIB-II "Management Information Base of TCP/IP-Based Internets: MIB-II", RFC 1213 shall be implemented.
- If the router implements TCP (e.g., for Telnet) then the TCP group of MIB-II "Management Information Base of TCP/IP-Based Internets: MIB-II", STD 16, RFC1213 shall be implemented
- The IP Forwarding Table MIB "IP Forwarding Table MIB", RFC 1354 shall be implemented.

9.1.4.2.1.1.2 SDO

The functionality, which can be configured and retrieved via SDO, is a subset of that provided by SNMP. For the POWERLINK Router configuration and diagnostics the relevant objects from MIB-II RFC 1213 and RFC 1354 are mapped to SDO – see 9.1.7. Objects, which are not accessible via SDO, can be accessed via SNMP.

9.1.4.2.2 Network Address Translation (NAT)

NAT allows POWERLINK nodes within a POWERLINK network to transparently communicate with hosts in the external network. Basic NAT and NAPT are two varieties of NAT. Since POWERLINK nodes have fixed IP addresses, each POWERLINK Router shall implement Basic NAT which is specified in:

- RFC 2663 – IP Network Address Translator (NAT) Terminology and Considerations
- RFC 3022 – Traditional IP Network Address Translator (Traditional NAT) – extends RFC 1631

With Basic NAT, a block of external IP addresses are set aside for translating IP addresses of POWERLINK nodes in the POWERLINK network. POWERLINK nodes that must be addressed from the external network, shall be configured in the NAT table RT1_NatTable_XXh_REC. The NAT table contains the POWERLINK IP EplIpAddr_IPAD to external IP ExtIpAddr_IPAD address translation. For datagrams outbound from the POWERLINK network, the source IP address EplIpAddr_IPAD shall be translated to the associated ExtIpAddr_IPAD called Source-NAT. For inbound packets, the destination IP address ExtIpAddr_IPAD shall be translated to the associated EplIpAddr_IPAD, called Destination-NAT. Independent from inbound or outbound IP telegrams, the related fields such as IP, TCP, UDP and ICMP header checksums shall be corrected. This kind of NAT is also called bidirectional NAT or 1to1 NAT (see RFC 2663). Fig. 109 illustrates an example for bidirectional NAT.

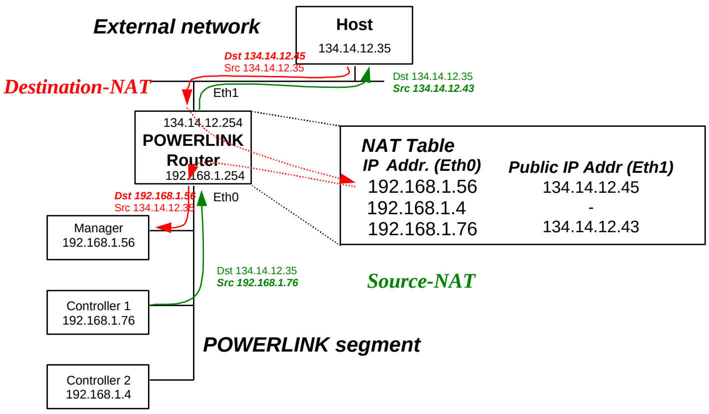


Fig. 109. Symmetrical n-to-n NAT

The visibility of POWERLINK nodes to the external network can be controlled by bidirectional NAT. Therefore, nodes that should not be accessed from the external network, can be concealed. POWERLINK nodes that are not configured in the NAT table may not communicate with nodes in the external network i.e. the packets are dropped.

In more detail POWERLINK differentiates between Source-NAT where the source address is changed and Destination-NAT where the destination address is changed. Fig. 110 illustrates the general NAT architecture.

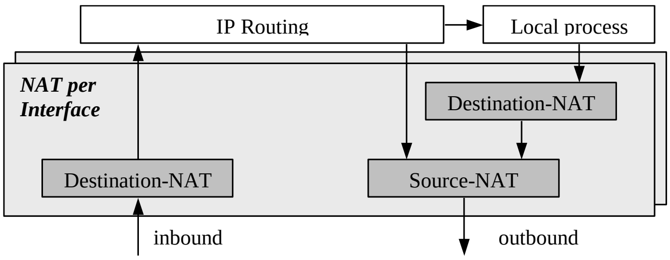


Fig. 110. NAT architecture

For outbound IP datagrams, that is from the POWERLINK network to the external network we shall use Source-NAT (S-NAT). S-NAT changes the source address of the IP / ICMP packet. This is done in the output chain, just before it is finally sent out. This is an important detail, since it means that anything else on the Router itself (routing, packet filtering) will see the packet unchanged.

For inbound IP datagrams, that is from the external network to the POWERLINK network we shall use Destination-NAT (D-NAT). D-NAT changes the destination address of the IP / ICMP packet. D-NAT is done in the input chain, just as the packet comes in. This means that anything else on the Router itself (routing, packet filtering) will see the packet going to its `real' destination.

The following figure illustrates the interaction between a POWERLINK network and an external network. It is presented for informative purpose only.

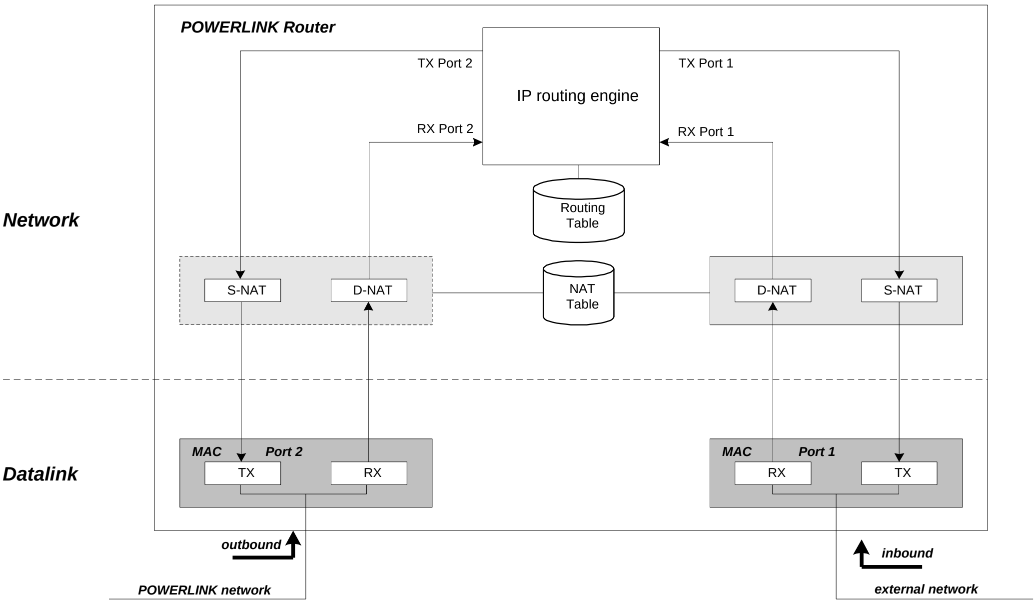


Fig. 111. Integration of NAT in the POWERLINK router

If bidirectional NAT is configured for a POWERLINK-host a host on the external network who wants to communicate with that POWERLINK-host it looks as if the POWERLINK-host is on the same network like itself.

External addresses of the NAT table are in the subnet of the external network:

On the interface to the external network the POWERLINK Router shall behave like a host, accepting all external IP addresses *ExtIpAddr_IPAD* listed in the NAT table RT1_NatTable_XXh_REC. Note, that the POWERLINK Router must respond to an ARP request, requesting one of the external IP addresses *StaticExtIpAddr_IPAD* listed in the NAT table. Therefore this interface does not obtain the IP packet like a router does i.e. the packet is addressed to the router if it is not in the subnet.

- External addresses of the NAT table are not in the subnet of the direct connected external network:

  The interface to the external Network is addressed like a router.

- In every case:

  The interface of the POWERLINK Router to the POWERLINK network shall act like a router.

Additional information about NAT is given in http://www.netfilter.org, RFC 2993 – Architectural Implications of NAT and RFC 3027 – Protocol Complications with the IP Network Address Translator.

9.1.4.2.2.1 Configuration

Network address translation shall be manageable by POWERLINK SDO and optionally by SNMPv3.

9.1.4.2.2.1.1 SNMP

The POWERLINK Router MIB specifies the managed objects to configure NAT. Therefore the NAT Group of the POWERLINK Router MIB shall be implemented.

9.1.4.2.2.1.2 SDO

The RT1_NatTable_*XXh*_REC object specifies the NAT table.

9.1.5 Security

Connecting a POWERLINK network via the POWERLINK Router to an external network (e.g. a LAN) enables the communication with other resources and services. This presents an enormous benefit to the entire system. On the other hand a POWERLINK Router represents a security risk, giving hackers, crackers and intruders the opportunity to access nodes in the POWERLINK network. The POWERLINK Router is the best place to add security mechanisms to protect a POWERLINK network, since the POWERLINK Router connects an un-trusted network with the trusted POWERLINK network.

Security mechanisms consist of rules and restriction but also must ensure availability and ease of use. Therefore, security must always be used at the right level. When applying security, a risk assessment must typically be performed. The risk assessment shows the level of security that must be supported. A risk assessment examines the following questions.

- Which network is connected to the POWERLINK network (trusted or un-trusted) ?
- Must we cope with accidental “attacks/errors” (handling errors) ?
- Must we cope with “evil-minded” malicious attacks (hackers, crackers, intruders, sabotage) ?
- ...

Depending on the result of the risk assessment, the appropriate mechanisms, listed below, must be used.

- Secrecy
- Integrity
- Authentication and Authorisation
- Availability of the information

This specification for the POWERLINK Router assumes that:

- The POWERLINK Router is connected to a trusted network (e. g. the factory floor network). Note that additional security considerations must be taken if the factory floor network is connected to the office network or –even harder – to the internet.
- The POWERLINK Router does not protect the POWERLINK network against evil minded attacks such as ICMP attacks, spoofing, etc..

The security assumption stated above, requires that a POWERLINK Router shall provide a basic security level. The basic security level is achieved using a Packet Filter (stateless Firewall). For higher security demands stateful Firewalls, VPN servers and Intrusion Detection systems must be considered. However, this is outside the scope of this specification.

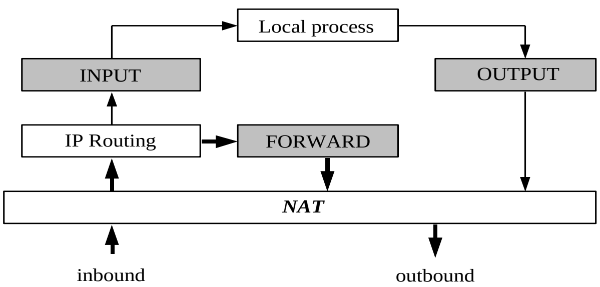
Support of Routing Type 1 security features is optional. Support shall be indicated by D_RT1_RT1SecuritySupport_BOOL.

9.1.5.1 Packet Filter – Firewall

A Packet Filter is a firewall element that analyses and controls inbound and outbound traffic of the datalink-, network and transport layers. A firewall in the sense of a Packet Filter physically decouples an un-trusted network from a trusted network. This enables a global point of security control. The Packet Filter functionality shall be implemented on the POWERLINK Router since the POWERLINK Router separates both networks.

In an effort to protect the POWERLINK network from various risks, both accidental and malicious, a Packet Filter should be deployed at a network’s ingress points – the POWERLINK Router. A Packet Filter maintains the access between the interfaces through Access Control Lists (ACLs).

This specification defines the filter entries and the tables that shall be implemented. Fig. 112 illustrates the involved tables that represent also the position where the IP datagrams shall be evaluated.



The bold arrows present the route between POWERLINK and external network.

Fig. 112. Filter tables of the packet filter

The INPUT table RT1_AclInTable_Xh_REC shall contain the filter entries for packets that are addressed to the POWERLINK Router itself. The FORWARD table RT1_AclFwdTable_*XXh*_REC shall contain the filter entries for packets routed through the POWERLINK Router. The OUTPUT table RT1_AclOutTable_*Xh*_REC shall contain the filter entries for packets locally generated. Each table shall have its default policy (RT1_SecurityGroup_REC.InTablePolicy_U8, RT1_SecurityGroup_REC.FwdTablePolicy_U8, RT1_SecurityGroup_REC.OutTablePolicy_U8).

9.1.5.1.1 ACL – Filter Entries

An Access Control List is a sequential list of permit and deny conditions known as a rule. The list defines the connections permitted to pass through the POWERLINK Router as well as connections that are denied. ACL's act as a basic method of limiting access to the POWERLINK network.

A POWERLINK Router can support the following optional filter entries:

Datalink Layer Ethernet MAC frames (DIX2):

- Source MAC address (*SrcMac_MAC*) of the Ethernet MAC header.

A POWERLINK Router shall support the following filter entries:

Network Layer

- Source IP address (*SrcIp_IPAD*) field of the IP header / Source IP network mask (*SrcMask_IPAD*)
- Destination IP address (*DstIp_IPAD*) field of the IP header / Destination IP network mask (*DstMask_IPAD*)
- Protocol (*Protocol_U8*) field of the IP header.

Transport Layer if the Protocol is either UDP or TCP

- Source L4 Port (*SrcPort_U16*) of the TCP or UDP header.
- Destination L4 Port (*DstPort_U16*) of the TCP or UDP header.

9.1.5.1.2 Filter strategy

A firewall rule specifies criteria for a packet, and a target. A target specifies what do with this packet if the rule matches. A rule matches if all specified entries from the assessed packet match the corresponding entry of the current rule. If the packet does not match, the next rule in the respective table is examined; if it does match, then the target (*Target_U8*) of the rule is executed, which is either ACCEPT or DROP. ACCEPT means to let the packet through. DROP means to drop the packet on the floor.

If no rule matches, it shall be up to the policy of the respective table (RT1_SecurityGroup_REC.InTablePolicy_U8, RT1_SecurityGroup_REC.FwdTablePolicy_U8, RT1_SecurityGroup_REC.OutTablePolicy_U8) to process the packet.

9.1.5.1.3 Configuration

The security settings and the ACLs shall be manageable by POWERLINK SDO and optionally by SNMPv3.

9.1.5.1.3.1 SNMP

The POWERLINK Router MIB specifies the managed objects to configure the Packet Filter. Therefore the Security Group of the POWERLINK Router MIB shall be implemented.

9.1.5.1.3.2 SDO

The following objects shall be implemented to configure the Packet Filter:

- *RT1_SecurityGroup_REC*
- *RT1_AclFwdTable_XXh_REC*
- *RT1_AclInTable_Xh_REC*
- *RT1_AclOutTable_Xh_REC*

9.1.6 Additional Services of a POWERLINK Router

Besides the data transport service between the POWERLINK and the normal Ethernet network, the POWERLINK Router may offer extended services. These are:

- Precision Time Protocol (IEEE 1588) boundary clock functionality,
- BOOTP/DHCP Relay,
- Address Allocation DHCP (Option 82),

- Enhanced security mechanisms such as IEEE 802.1X-2001 Port-Based Network Access Control Virtual Private Network (VPN) Server, Intrusion Detection.
- DNS Server / Cache

9.1.7 Object description

9.1.7.1 Object 1E80$_h$: RT1_EplRouter_REC

RT1_EplRouter_REC specifies attributes for POWERLINK Router configuration. This object shall only be implemented for routing type 1.

Index	1E80$_h$	Object Type	RECORD
Name	RT1_EplRouter_REC		
Data Type	RT1_EplRouter_TYPE	Category	Conditional

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	2	Access	ro
Default Value	2	PDO Mapping	No

- **Sub-Index 01$_h$: EnableNat_BOOL**

Sub-Index	01$_h$		
Name	EnableNat_BOOL		
Data Type	BOOLEAN	Category	M
Value Range	BOOLEAN	Access	rws
Default Value	TRUE	PDO Mapping	No

Enables or disables the Network Address Translation on the POWERLINK Router.

- **Sub-Index 02$_h$: EnablePacketFiltering_BOOL**

Sub-Index	02$_h$		
Name	EnablePacketFiltering_BOOL		
Data Type	BOOLEAN	Category	M
Value Range	BOOLEAN	Access	rws
Default Value	TRUE	PDO Mapping	No

Depending on the value of EnablePacketFiltering_BOOL, the Packet Filer on the POWERLINK Router is enabled or disabled.

9.1.7.2 Object 1E90$_h$ .. 1ECF$_h$: RT1_IpRoutingTable_*XXh*_REC

The RT1_IpRoutingTable_*XXh*_REC object is a subset of RFC1354, which defines the routers forwarding table. The routing table shall have 64 entries that may be configured via SDO.

To allow access by name "_*XXh*" shall be replaced by a name index. Name index shall be "_*00h*" if object index is 1E90$_h$. It shall be incremented up to "_*3Fh*" corresponding to object index 1ECF$_h$. This object shall only be implemented for routing type 1.

Index	1E90h .. 1ECFh	Object Type	RECORD
Name	RT1_IpRoutingTable_XXh_REC		
Data Type	RT1_IpRoutingTable_TYPE	Category	Conditional

- **Sub-Index 00h: NumberOfEntries**

Sub-Index	00h		
Name	NumberOfEntries		
Value Range	7	Access	ro
Default Value	7	PDO Mapping	No

- **Sub-Index 01h: IpForwardDest_IPAD**

Sub-Index	01h		
Name	IpForwardDest_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	-	PDO Mapping	No

The destination IP address of this route. An entry with a value of 0.0.0.0 is considered a default route. This object may not take a Multicast (Class D) address value. Any assignment (implicit or otherwise) of an instance of this object to a value x must be rejected if the bitwise logical-AND of x with the value of the corresponding instance of the IpForwardMask_IPAD object is not equal to x.

- **Sub-Index 02h: IpForwardMask_IPAD**

Sub-Index	02h		
Name	IpForwardMask_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	0.0.0.0	PDO Mapping	No

Indicate the mask to be logical-ANDed with the destination address before being compared to the value in the IpForwardDest_IPAD field. For those systems that do not support arbitrary subnet masks, an agent constructs the value of the IpForwardMask_IPAD by reference to the IP Address Class. Any assignment (implicit or otherwise) of an instance of this object to a value x must be rejected if the bitwise logical-AND of x with the value of the corresponding instance of the IpForwardDest_IPAD object is not equal to IpForwardDest_IPAD.

- **Sub-Index 03h: IpForwardNextHop_IPAD**

Sub-Index	03h		
Name	IpForwardNextHop_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	-	PDO Mapping	No

On remote routes, the address of the next system en route; Otherwise, 0.0.0.0.

- **Sub-Index 04h: IpForwardType_U8**

Sub-Index	04h		
Name	IpForwardType_U8		
Data Type	UNSIGNED8	Category	M
Value Range	Other (1), -- not specified invalid (2), -- logically deleted local (3), -- local interface remote (4), -- remote destination	Access	rws
Default Value	invalid (2)	PDO Mapping	No

The type of route. Note that local(3) refers to a route for which the next hop is the final destination; remote(4) refers to a route for which the next hop is not the final destination. Setting this object to the value invalid(2) has the effect of invalidating the corresponding entry in the IpForwardTable_REC object. That is, it effectively disassociates the destination identified with said entry from the route identified with said entry. It is an implementation-specific matter as to whether the agent removes an invalidated entry from the table. Accordingly, management nodes must be prepared to receive tabular information from agents that corresponds to entries not currently in use. Proper interpretation of such entries requires examination of the relevant IpForwardType_U8 object.

- **Sub-Index 05h: IpForwardAge_U32**

Sub-Index	05h		
Name	IpForwardAge_U32		
Data Type	UNSIGNED32	Category	M
Value Range	UNSIGNED32	Access	ro
Default Value	-	PDO Mapping	No

The number of seconds since this route was last updated or otherwise determined to be correct. Note that no semantics of `too old’ can be implied except through knowledge of the routing protocol by which the route was learned.

- **Sub-Index 06h: IpForwardItfIndex_U16**

Sub-Index	06h		
Name	IpForwardItfIndex_U16		
Data Type	UNSIGNED16	Category	M
Value Range	UNSIGNED16	Access	rws
Default Value	-	PDO Mapping	No

The IpForwardItfIndex_U16 identifies the local interface (NMT_LocItfGroup*N*_REC.-ItfIndex_U16) through which the next hop of this route should be reached.

- **Sub-Index 07h: IpForwardMetric1_S32**

Sub-Index	07h		
Name	IpForwardMetric1_S32		
Data Type	INTEGER32	Category	M
Value Range	INTEGER32	Access	rws
Default Value	-1	PDO Mapping	No

An alternate routing metric for this route. If this metric is not used, its value should be set to -1. A metric indicates the cost of using a route, which is typically the number of hops to the IP destination. Anything on the local subnet is one hop, and each router crossed after that is an additional hop. If there are multiple routes to the same destination with different metrics, the route with the lowest metric is selected.

9.1.7.3 Object 1D00h .. 1DFFh: RT1_NatTable_*XXh*_REC

This object specifies the NAT table located on the POWERLINK Router for bidirectional (1to1) NAT. The NAT table shall have 256 entries that may be configured via SDO.

To allow access by name "*_XXh*" shall be replaced by a name index. Name index shall be "*_00h*" if object index is $1D00_h$. It shall be incremented up to "*_FFh*" corresponding to object index $1DFF_h$. This object shall only be implemented for routing type 1.

Index	$1D00_h$ .. $1DFF_h$	Object Type	RECORD
Name	RT1_NatTable_*XXh*_REC		
Data Type	RT1_NatTable_TYPE	Category	Conditional

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	4	Access	ro
Default Value	4	PDO Mapping	No

- **Sub-Index 01_h: EplIpAddr_IPAD**

Sub-Index	01_h		
Name	EplIpAddr_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	-	PDO Mapping	No

StaticEplIpAddr_IPAD contains the IP address to the POWERLINK network.

- **Sub-Index 02_h: ExtIpAddr_IPAD**

Sub-Index	02_h		
Name	ExtIpAddr_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	-	PDO Mapping	No

StaticExtIpAddr_IPAD contains the IP address to the external network.

- **Sub-Index 03_h: Mask_IPAD**

Sub-Index	03_h		
Name	Mask_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	-	PDO Mapping	No

This is the Network-mask for EplIpAddr_IPAD and ExtIpAddr_IPAD. Bidirectional NAT only works for single hosts or IP-address ranges which are equal in size for source and destination. Thus only one mask is needed.

- **Sub-Index 04_h: Type_U8**

Sub-Index	04_h		
Name	Type_U8		
Data Type	UNSIGNED8	Category	M
Value Range	other (1), -- not specified invalid (2), -- logically deleted bidirectional-nat (3) – bidirectional NAT	Access	rws
Default Value	invalid (2)	PDO Mapping	No

Setting this object to the value invalid(2) has the effect of invalidating the corresponding entry in the Type_U8 object. That is, it effectively disassociates the respective entry from Table_REC. It is an implementation-specific matter as to whether the agent removes an invalidated entry from the table. Accordingly, management nodes must be prepared to receive tabular information from agents that corresponds to entries not currently in use. Proper interpretation of such entries requires examination of the relevant Type_U8.

9.1.7.4 Object 1E81$_h$: RT1_SecurityGroup_REC

The RT1_SecurityGroup_REC contains information about the security settings of the POWERLINK Router. This object shall only be implemented for routing type 1.

Index	1E81$_h$	Object Type	RECORD
Name	RT1_SecurityGroup_REC		
Data Type	RT1_SecurityGroup_TYPE	Category	Conditional

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	3	Access	const
Default Value	3	PDO Mapping	No

- **Sub-Index 01$_h$: FwdTablePolicy_U8**

Sub-Index	01$_h$		
Name	FwdTablePolicy_U8		
Data Type	UNSIGNED8	Category	M
Value Range	accept (1) drop (2) reject (3)	Access	rws
Default Value	accept	PDO Mapping	No

FwdTablePolicy_U8 specifies the default policy of the FORWARD table (RT1_AclFwdTable_*XXh*_REC).

- **Sub-Index 02$_h$: InTablePolicy_U8**

Sub-Index	02$_h$		
Name	InTablePolicy_U8		
Data Type	UNSIGNED8	Category	M
Value Range	accept (1) drop (2) reject (3)	Access	rws
Default Value	accept	PDO Mapping	No

InTablePolicy_U8 specifies the default policy of the INPUT table (RT1_AclInTable_Xh_REC).

- **Sub-Index 03$_h$: OutTablePolicy_U8**

Sub-Index	03$_h$		
Name	OutTablePolicy_U8		
Data Type	UNSIGNED8	Category	M
Value Range	accept (1) drop (2) reject (3)	Access	rws
Default Value	accept	PDO Mapping	No

OutTablePolicy_U8 specifies the default policy of the OUTPUT table (RT1_AclOutTable_*Xh*_REC).

9.1.7.5 Object 1B00$_h$ .. 1BFF$_h$: RT1_AclFwdTable_*XXh*_REC

This object specifies the Access Control List (ACL) for the FORWARD table located on the POWERLINK Router – see 9.1.5.1. The FORWARD table shall have 256 entries that may be configured via SDO.

To allow access by name "_XXh" shall be replaced by a name index. Name index shall be "_00h" if object index is $1B00_h$. It shall be incremented up to "_3Fh" corresponding to object index $1BFF_h$. This object shall only be implemented for routing type 1.

Index	$1B00_h$ .. $1BFF_h$	Object Type	RECORD
Name	RT1_AclFwdTable_XXh_REC		
Data Type	RT1_AclTable_TYPE	Category	Conditional

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	9	Access	const
Default Value	9	PDO Mapping	No

- **Sub-Index 01_h: SrcIp_IPAD**

Sub-Index	01_h		
Name	SrcIp_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	-	PDO Mapping	No

SrcIp_IPAD specifies a plain source IP address for the respective entry. A value of 0.0.0.0 and a SrcMask_IPAD of 0.0.0.0 shall indicate any IP address.

- **Sub-Index 02_h: SrcMask_IPAD**

Sub-Index	02_h		
Name	SrcMask_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	-	PDO Mapping	No

SrcMask_IPAD is the network mask to the according source IP address SrcIp_IPAD for the respective entry. A value of 0.0.0.0 for SrcIp_IPAD and a SrcMask_IPAD of 0.0.0.0 shall indicate any IP address.

- **Sub-Index 03_h: DstIp_IPAD**

Sub-Index	03_h		
Name	DstIp_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	-	PDO Mapping	No

DstIp_IPAD specifies a plain destination IP address for the respective entry. A value of 0.0.0.0 and a DstMask_IPAD of 0.0.0.0 shall indicate any IP address.

- **Sub-Index 04_h: DstMask_IPAD**

Sub-Index	04_h		
Name	DstMask_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	-	PDO Mapping	No

DstMask_IPAD is the network mask to the according destination IP address DstIp_IPAD for the respective entry. A value of 0.0.0.0 for DstIp_IPAD and a DstMask_IPAD of 0.0.0.0 shall indicate any IP address.

- **Sub-Index 05h: Protocol_U8**

Sub-Index	05h		
Name	Protocol_U8		
Data Type	UNSIGNED8	Category	M
Value Range	UNSIGNED8	Access	rws
Default Value	0	PDO Mapping	No

The protocol of the rule or the packet to check. In the Internet Protocol version 4 (Ipv4) [RFC791] there is a field, called "Protocol", to identify the next level protocol. This is an 8 bit field. The specified protocol is a numeric number listed in http://www.iana.org/assignments/protocol-numbers. The number zero is equivalent to all protocols.

- **Sub-Index 06h: SrcPort_U16**

Sub-Index	06h		
Name	SrcPort_U16		
Data Type	UNSIGNED16	Category	M
Value Range	UNSIGNED16	Access	rws
Default Value	0	PDO Mapping	No

SrcPort_U16 specifies the source port if the protocol (Protocol_U8) TCP or UDP is specified. A value of zero indicates any protocol.

- **Sub-Index 07h: DstPort_U16**

Sub-Index	07h		
Name	DstPort_U16		
Data Type	UNSIGNED16	Category	M
Value Range	UNSIGNED16	Access	rws
Default Value	0	PDO Mapping	No

DstPort_U16 contains the destination port if the protocol (Protocol_U8) TCP or UDP is specified. A value of zero indicates any protocol.

- **Sub-Index 08h: SrcMac_MAC**

Sub-Index	08h		
Name	SrcMac_MAC		
Data Type	MAC_ADDRESS	Category	M
Value Range	MAC_ADDRESS	Access	rws
Default Value	00:00:00:00:00:00	PDO Mapping	No

Match source MAC address. A value of 00:00:00:00:00:00 specifies any source MAC.

- **Sub-Index 09h: Target_U8**

Sub-Index	09h		
Name	Target_U8		
Data Type	UNSIGNED8	Category	M
Value Range	Invalid (0) accept (1) drop (2) reject (3)	Access	rws
Default Value	Invalid (0)	PDO Mapping	No

Specifies the target of the rule. If the value is zero, the entry shall be invalid. If the rule matches the target, the value is either accept, drop or reject.

9.1.7.6 Object 1ED0$_h$ .. 1EDF$_h$: RT1_AclInTable_Xh_REC

This object specifies the Access Control List (ACL) for the INPUT table located on the POWERLINK Router – see 9.1.5.1. The INPUT table shall have 16 entries that may be configured via SDO.

To allow access by name "*_Xh*" shall be replaced by a name index. Name index shall be "*_0h*" if object index is 1ED0$_h$. It shall be incremented up to "*_Fh*" corresponding to object index 1EDF$_h$. This object shall only be implemented for routing type 1.

Index	1ED0$_h$ .. 1EDF$_h$	Object Type	RECORD
Name	RT1_AclInTable_Xh_REC		
Data Type	RT1_AclTable_TYPE	Category	Conditional

- **Sub-Index 00$_h$: NumberOfEntries**

Sub-Index	00$_h$		
Name	NumberOfEntries		
Value Range	9	Access	const
Default Value	9	PDO Mapping	No

- **Sub-Index 01$_h$: SrcIp_IPAD**

Sub-Index	01$_h$		
Name	SrcIp_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	-	PDO Mapping	No

SrcIp_IPAD contains a plain source IP address for the respective entry. A value of 0.0.0.0 and a SrcMask_IPAD of 0.0.0.0 shall indicate any IP address.

- **Sub-Index 02$_h$: SrcMask_IPAD**

Sub-Index	02$_h$		
Name	SrcMask_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	-	PDO Mapping	No

SrcMask_IPAD is the network mask to the according source IP address SrcIp_IPAD for the respective entry. A value of 0.0.0.0 for SrcIp_IPAD and a SrcMask_IPAD of 0.0.0.0 shall indicate any IP address.

- **Sub-Index 03$_h$: DstIp_IPAD**

Sub-Index	03$_h$		
Name	DstIp_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	-	PDO Mapping	No

DstIp_IPAD specifies a plain destination IP address for the respective entry. A value of 0.0.0.0 and a DstMask_IPAD of 0.0.0.0 shall indicate any IP address.

- **Sub-Index 04_h: DstMask_IPAD**

Sub-Index	04_h		
Name	DstMask_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	-	PDO Mapping	No

DstMask_IPAD is the network mask to the according destination IP address DstIp_IPAD for the respective entry. A value of 0.0.0.0 for DstIp_IPAD and a DstMask_IPAD of 0.0.0.0 shall indicate any IP address.

- **Sub-Index 05_h: Protocol_U8**

Sub-Index	05_h		
Name	Protocol_U8		
Data Type	UNSIGNED8	Category	M
Value Range	UNSIGNED8	Access	rws
Default Value	0	PDO Mapping	No

The protocol of the rule or the packet to check. In the Internet Protocol version 4 (Ipv4) [RFC791] there is a field, called “Protocol”, to identify the next level protocol. This is an 8 bit field. The specified protocol is a numeric number listed in http://www.iana.org/assignments/protocol-numbers. The number zero is equivalent to all protocols.

- **Sub-Index 06_h: SrcPort_U16**

Sub-Index	06_h		
Name	SrcPort_U16		
Data Type	UNSIGNED16	Category	M
Value Range	UNSIGNED16	Access	rws
Default Value	0	PDO Mapping	No

SrcPort_U16 specifies the source port if the protocol (Protocol_U8) TCP or UDP is specified. A value of zero indicates any protocol.

- **Sub-Index 07_h: DstPort_U16**

Sub-Index	07_h		
Name	DstPort_U16		
Data Type	UNSIGNED16	Category	M
Value Range	UNSIGNED16	Access	rws
Default Value	0	PDO Mapping	No

DstPort_U16 contains the destination port if the protocol (Protocol_U8) TCP or UDP is specified. A value of zero indicates any protocol.

- **Sub-Index 08_h: SrcMac_MAC**

Sub-Index	08_h		
Name	SrcMac_MAC		
Data Type	MAC_ADDRESS	Category	M
Value Range	MAC_ADDRESS	Access	rws
Default Value	00:00:00:00:00:00	PDO Mapping	No

Match source MAC address. A value of 00:00:00:00:00:00 specifies any source MAC.

- **Sub-Index 09_h: Target_U8**

Sub-Index	09_h		
Name	Target_U8		
Data Type	UNSIGNED8	Category	M
Value Range	Invalid (0) accept (1) drop (2) reject (3)	Access	rws
Default Value	Invalid (0)	PDO Mapping	No

Specifies the target of the rule. If the value is zero, the entry shall be invalid. If the rule matches the target, the value is either accept, drop or reject.

9.1.7.7 Object $1EE0_h$ .. $1EEF_h$: RT1_AclOutTable_*Xh*_REC

This object specifies the Access Control List (ACL) for the OUTPUT table located on the POWERLINK Router – see 9.1.5.1. The routing table shall have 16 entries that may be configured via SDO.

To allow access by name "*_Xh*" shall be replaced by a name index. Name index shall be "*_0h*" if object index is $1EE0_h$. It shall be incremented up to "*_Fh*" corresponding to object index $1EEF_h$. This object shall only be implemented for routing type 1.

Index	$1EE0_h$ .. $1EEF_h$	Object Type	RECORD
Name	RT1_AclOutTable_Xh_REC		
Data Type	RT1_AclTable_TYPE	Category	Conditional

- **Sub-Index 00_h: NumberOfEntries**

Sub-Index	00_h		
Name	NumberOfEntries		
Value Range	9	Access	const
Default Value	9	PDO Mapping	No

- **Sub-Index 01h: SrcIp_IPAD**

Sub-Index	01h		
Name	SrcIp_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	-	PDO Mapping	No

SrcIp_IPAD specifies a plain source IP address for the respective entry. A value of 0.0.0.0 and a SrcMask_IPAD of 0.0.0.0 shall indicate any IP address.

- **Sub-Index 02h: SrcMask_IPAD**

Sub-Index	02h		
Name	SrcMask_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	-	PDO Mapping	No

SrcMask_IPAD is the network mask to the according source IP address SrcIp_IPAD for the respective entry. A value of 0.0.0.0 for SrcIp_IPAD and a SrcMask_IPAD of 0.0.0.0 shall indicate any IP address.

- **Sub-Index 03h: DstIp_IPAD**

Sub-Index	03h		
Name	DstIp_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	-	PDO Mapping	No

DstIp_IPAD specifies a plain destination IP address for the respective entry. A value of 0.0.0.0 and a DstMask_IPAD of 0.0.0.0 shall indicate any IP address.

- **Sub-Index 04h: DstMask_IPAD**

Sub-Index	04h		
Name	DstMask_IPAD		
Data Type	IP_ADDRESS	Category	M
Value Range	IP_ADDRESS	Access	rws
Default Value	-	PDO Mapping	No

DstMask_IPAD is the network mask to the according destination IP address DstIp_IPAD for the respective entry. A value of 0.0.0.0 for DstIp_IPAD and a DstMask_IPAD of 0.0.0.0 shall indicate any IP address.

- **Sub-Index 05h: Protocol_U8**

Sub-Index	05h		
Name	Protocol_U8		
Data Type	UNSIGNED8	Category	M
Value Range	UNSIGNED8	Access	rws
Default Value	0	PDO Mapping	No

The protocol of the rule or the packet to check. In the Internet Protocol version 4 (Ipv4) [RFC791] there is a field, called “Protocol”, to identify the next level protocol. This is an 8 bit field. The specified protocol is a numeric number listed in http://www.iana.org/assignments/protocol-numbers. The number zero is equivalent to all protocols.

- **Sub-Index 06h: SrcPort_U16**

Sub-Index	06h		
Name	SrcPort_U16		
Data Type	UNSIGNED16	Category	M
Value Range	UNSIGNED16	Access	rws
Default Value	0	PDO Mapping	No

SrcPort_U16 specifies the source port if the protocol (Protocol_U8) TCP or UDP is specified. A value of zero indicates any protocol.

- **Sub-Index 07h: DstPort_U16**

Sub-Index	07h		
Name	DstPort_U16		
Data Type	UNSIGNED16	Category	M
Value Range	UNSIGNED16	Access	rws
Default Value	0	PDO Mapping	No

DstPort_U16 contains the destination port if the protocol (Protocol_U8) TCP or UDP is specified. A value of zero indicates any protocol.

- **Sub-Index 08h: SrcMac_MAC**

Sub-Index	08h		
Name	SrcMac_MAC		
Data Type	MAC_ADDRESS	Category	M
Value Range	MAC_ADDRESS	Access	rws
Default Value	00:00:00:00:00:00	PDO Mapping	No

Match source MAC address. A value of 00:00:00:00:00:00 specifies any source MAC.

- **Sub-Index 09h: Target_U8**

Sub-Index	09h		
Name	Target_U8		
Data Type	UNSIGNED8	Category	M
Value Range	Invalid (0) accept (1) drop (2) reject (3)	Access	rws
Default Value	Invalid (0)	PDO Mapping	No

Specifies the target of the rule. If the value is zero, the entry shall be invalid. If the rule matches the target, the value is either accept, drop or reject.

9.1.7.8 Router Type I Object Types

9.1.7.8.1 Object 0430h: RT1_EplRouter_TYPE

Index	0430h	Object Type	DEFSTRUCT
Name	RT1_EplRouter_TYPE		
Sub-Index	Component Name	Value	Data Type
00h	NumberOfEntries	02h	
01h	EnableNat_BOOL	0001h	BOOLEAN
02h	EnablePacketFiltering_BOOL	0001h	BOOLEAN

9.1.7.8.2 Object 0431h: RT1_IpRoutingTable_TYPE

Index	0431h	Object Type	DEFSTRUCT
Name	RT1_IpRoutingTable_TYPE		
Sub-Index	Component Name	Value	Data Type
00h	NumberOfEntries	07h	
01h	IpForwardDest_IPAD	0402h	IP_ADDRESS
02h	IpForwardMask_IPAD	0402h	IP_ADDRESS
03h	IpForwardNextHop_IPAD	0402h	IP_ADDRESS
04h	IpForwardType_U8	0005h	UNSIGNED8
05h	IpForwardAge_U32	0007h	UNSIGNED32
06h	IpForwardItfIndex_U16	0006h	UNSIGNED16
07h	IpForwardMetric1_S32	0004h	INTEGER32

9.1.7.8.3 Object 0432h: RT1_NatTable_TYPE

Index	0432h	Object Type	DEFSTRUCT
Name	RT1_NatTable_TYPE		
Sub-Index	Component Name	Value	Data Type
00h	NumberOfEntries	04h	
01h	EplIpAddr_IPAD	0402h	IP_ADDRESS
02h	ExtIpAddr_IPAD	0402h	IP_ADDRESS
03h	Mask_IPAD	0402h	IP_ADDRESS
04h	Type_U8	0005h	UNSIGNED8

9.1.7.8.4 Object 0433h: RT1_SecurityGroup_TYPE

Index	0433h	Object Type	DEFSTRUCT
Name	RT1_SecurityGroup_TYPE		
Sub-Index	Component Name	Value	Data Type
00h	NumberOfEntries	03h	
01h	FwdTablePolicy_U8	0005h	UNSIGNED8
02h	InTablePolicy_U8	0005h	UNSIGNED8
03h	OutTablePolicy_U8	0005h	UNSIGNED8

9.1.7.8.5 Object 0434h: RT1_AclTable_TYPE

Index	0434h	Object Type	DEFSTRUCT
Name	RT1_AclTable_TYPE		
Sub-Index	Component Name	Value	Data Type
00h	NumberOfEntries	09h	
01h	SrcIp_IPAD	0402h	IP_ADDRESS

02_h	SrcMask_IPAD	0402_h	IP_ADDRESS
03_h	DstIp_IPAD	0402_h	IP_ADDRESS
04_h	DstMask_IPAD	0402_h	IP_ADDRESS
05_h	Protocol_U8	0005_h	UNSIGNED8
06_h	SrcPort_U16	0006_h	UNSIGNED16
07_h	DstPort_U16	0006_h	UNSIGNED16
08_h	SrcMac_MAC	0401_h	MAC_ADDRESS
09_h	Target_U8	0005_h	UNSIGNED8

9.1.8 POWERLINK Router MIB

The POWERLINK Router Management Information Base (MIB) specifies the managed objects which are accessible via SNMP.

9.2 Routing Type 2

A POWERLINK Router Type 2 is a coupling element that allows communication between nodes in a POWERLINK network and nodes in an CANopen network.

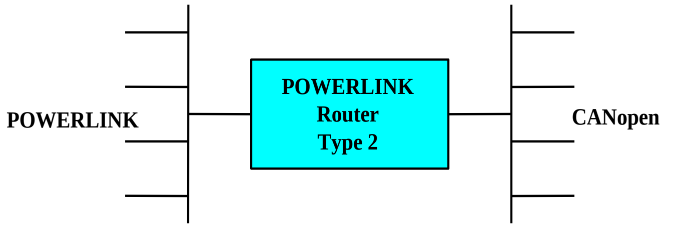


Fig. 113. POWERLINK router type 2

Routing Type 2 will provide CANopen compliant SDO communication between POWERLINK and CANopen nodes.

CANopen to CANopen cross traffic over a POWERLINK based Machine Network (see Fig. 107) will be provided.

Access from the Factory Floor Network and further IP based networks (see Fig. 107) to CANopen nodes via POWERLINK Router Type 1 and POWERLINK Router Type 2 will be possible.

POWERLINK Routing Type 2 will be specified by a separate standard.

Routing Type 2 is optional. Support shall be indicated by D_RT2_RT2Support_BOOL.

10 Indicators

Each POWERLINK node shall support:

- either two LEDs
  - a red ERROR LED
  - a green STATUS LED
- or a combination of both using one bicolor (green/red) LED called S/E LED.
  The red subfunction of the S/E LED is equivalent to the ERROR LED, the green one to the STATUS LED.

The following POWERLINK specific LEDs may be additionally used:

- per node
  - Transmit data (TX LED): yellow
- per port:
  - Receive data (RX LED): yellow
  - Ethernet Link (LINK LED): green
  - Collision (COL LED): red (recommended)
  - For the LINK LED and the COL LED, a bicolor (green/red) LED (L/C LED) may be used.

Alternative following POWERLINK specific LED may be additionally used:

- per port:
  - Ethernet Link/Data Activity (LINK/DATA ACTIVITY LED) bicolor (green/yellow) LED or
  - Ethernet Link/Data Activity (LINK/DATA ACTIVITY LED) green LED

10.1 Indicator states and flash rates

The following indicator states are distinguished:

LED on	constantly on
LED off	constantly off
LED flickering	equal on and off times with a frequency of approximately 10 Hz: on for approximately 50 ms and off for approximately 50 ms.
LED blinking	equal on and off times with a frequency of approximately 2,5 Hz: on for approximately 200 ms followed by off for approximately 200 ms.
LED single flash	one short flash (approximately 200ms) followed by a long off phase (approximately 1000 ms).
LED double flash	a sequence of two short flashes (approximately 200ms), separated by an off phase (approximately 200ms). The sequence is finished by a long off phase (approximately 1000 ms).
LED triple flash	a sequence of three short flashes (approximately 200ms), separated by an off phase (approximately 200ms). The sequence is finished by a long off phase (approximately 1000 ms).

Tab. 146 LED indicator states

10.2 Indicator Signaling

- **ERROR LED**

ERROR LED function is controlled by NMT state machine transitions.

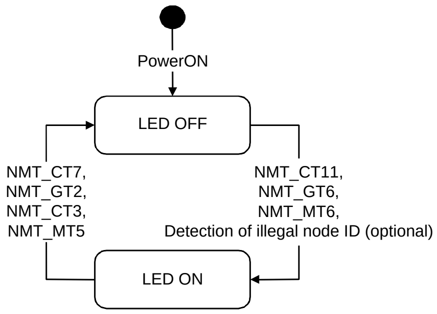


Fig. 114. ERROR LED state machine

In case of detection of an illegal Node ID switching on the error LED is optional.

Example for an illegal Node ID: Node ID setting 240 on a CN only device.

- **STATUS LED**

  STATUS LED function is controlled by NMT state machine states.

STATUS LED	State
LED off	NMT_GS_OFF, NMT_GS_INITIALISATION, NMT_CS_NOT_ACTIVE / NMT_MS_NOT_ACTIVE
LED flickering	NMT_CS_BASIC_ETHERNET
LED single flash	NMT_CS_PRE_OPERATIONAL_1 / NMT_MS_PRE_OPERATIONAL_1
LED double flash	NMT_CS_PRE_OPERATIONAL_2 / NMT_MS_PRE_OPERATIONAL_2
LED triple flash	NMT_CS_READY_TO_OPERATE / NMT_MS_READY_TO_OPERATE
LED on	NMT_CS_OPERATIONAL / NMT_MS_OPERATIONAL
LED blinking	NMT_CS_STOPPED

Tab. 147 Status LED states

- **S/E LED**

  combination of ERROR LED and STATUS LED,
  STATUS LED is dominant over the ERROR LED function, e.g. if a STATUS LED flash is required, the ERROR LED will be off during the flash

- **TX LED**

  shall be LED on, when data are currently transmitted

- **RX LED**

  shall be LED on, when data are currently received

- **LINK LED**

  shall be LED on, when etherlink link is established

- **COLLISION LED**

  shall be LED on, when an ethernet frame collision is recognized

- **LINK/DATA ACTIVITY LED**

  - **Bicolor (yellow/green) LED**

    shall be LED on green when ethernet link is established, shall be on yellow when data received or transmitted it is allowed to indicate only the TX- or RX- direction or both, the DATA ACTIVITY LED is dominant over the LINK LED

- **green LED**
  shall be LED on green when ethernet link is established, shall be flash when data received or transmitted it is allowed to indicate only the TX- or RX- direction or both, the DATA ACTIVITY LED is dominat over the LINK LED

10.3 Recommended labelling

- „BS“ or „Status“ for the STATUS LED
- „BE“ or „Error“ for the ERROR LED
- „S/E“for the S/E LED
- „Tx“ for the TX LED
- „Rx“ for the RX LED
- „L“ for the LINK LED
- „C“ for the COLLISION LED
- „L/C“ for the combined LINK LED and COL LED
- „L/A”or alternatively „LS/DA” for the LINK/DATA ACTIVITY LED

Case of labelling shall not be significant, e.g. „RUN“, „run“ and „Run“ shall be equivalent.

App. 1 Summary Object Library (normative)

App. 1.1 Object Dictionary Entries, sorted by index

Index	Name	Store	Category	Object Type
0001_h	BOOLEAN			DEFTYPE
0002_h	INTEGER8			DEFTYPE
0003_h	INTEGER16			DEFTYPE
0004_h	INTEGER32			DEFTYPE
0005_h	UNSIGNED8			DEFTYPE
0006_h	UNSIGNED16			DEFTYPE
0007_h	UNSIGNED32			DEFTYPE
0008_h	REAL32			DEFTYPE
0009_h	VISIBLE_STRING			DEFTYPE
$000A_h$	OCTET_STRING			DEFTYPE
$000B_h$	UNICODE_STRING			DEFTYPE
$000C_h$	TIME_OF_DAY			DEFTYPE
$000D_h$	TIME_DIFFERENCE			DEFTYPE
$000F_h$	DOMAIN			DEFTYPE
0010_h	INTEGER24			DEFTYPE
0011_h	REAL64			DEFTYPE
0012_h	INTEGER40			DEFTYPE
0013_h	INTEGER48			DEFTYPE
0014_h	INTEGER56			DEFTYPE
0015_h	INTEGER64			DEFTYPE
0016_h	UNSIGNED24			DEFTYPE
0018_h	UNSIGNED40			DEFTYPE
0019_h	UNSIGNED48			DEFTYPE
$001A_h$	UNSIGNED56			DEFTYPE
$001B_h$	UNSIGNED64			DEFTYPE
0023_h	IDENTITY			DEFSTRUCT
0040_h .. $005F_h$	Manufacturer Specific Complex Data Types			DEFSTRUCT
0060_h .. $007F_h$	Device Profile (0) Specific Standard Data Types			DEFTYPE
0080_h .. $009F_h$	Device Profile (0) Specific Complex Data Types			DEFSTRUCT
$00A0_h$ .. $00BF_h$	Device Profile 1 Specific Standard Data Types			DEFTYPE
$00C0_h$ .. $00DF_h$	Device Profile 1 Specific Complex Data Types			DEFSTRUCT
$00E0_h$ .. $00FF_h$	Device Profile 2 Specific Standard Data Types			DEFTYPE
0100_h .. $011F_h$	Device Profile 2 Specific Complex Data Types			DEFSTRUCT

Index	Name	Store	Category	Object Type
0120h .. 013Fh	Device Profile 3 Specific Standard Data Types			DEFTYPE
0140h .. 015Fh	Device Profile 3 Specific Complex Data Types			DEFSTRUCT
0160h .. 017Fh	Device Profile 4 Specific Standard Data Types			DEFTYPE
0180h .. 019Fh	Device Profile 4 Specific Complex Data Types			DEFSTRUCT
01A0h .. 01BFh	Device Profile 5 Specific Standard Data Types			DEFTYPE
01C0h .. 01DFh	Device Profile 5 Specific Complex Data Types			DEFSTRUCT
01E0h .. 01FFh	Device Profile 6 Specific Standard Data Types			DEFTYPE
0200h .. 021Fh	Device Profile 6 Specific Complex Data Types			DEFSTRUCT
0220h .. 023Fh	Device Profile 7 Specific Standard Data Types			DEFTYPE
0240h .. 025Fh	Device Profile 7 Specific Complex Data Types			DEFSTRUCT
0401h	MAC_ADDRESS			DEFTYPE
0402h	IP_ADDRESS			DEFTYPE
0403h	NETTIME			DEFTYPE
0420h	PDO_CommParamRecord_TYPE			DEFSTRUCT
0422h	SDO_ParameterRecord_TYPE			DEFSTRUCT
0424h	DLL_ErrorCntRec_TYPE			DEFSTRUCT
0425h	NWL_IpGroup_TYPE			DEFSTRUCT
0426h	NWL_IpAddrTable_TYPE			DEFSTRUCT
0427h	PDL_LocVerApplSw_TYPE			DEFSTRUCT
0428h	INP_ProcessImage_TYPE			DEFSTRUCT
0429h	NMT_ParameterStorage_TYPE			DEFSTRUCT
042Bh	NMT_InterfaceGroup_TYPE			DEFSTRUCT
042Ch	NMT_CycleTiming_TYPE			DEFSTRUCT
042Eh	NMT_BootTime_TYPE			DEFSTRUCT
042Fh	NMT_MNCycleTiming_TYPE			DEFSTRUCT
0430h	RT1_EplRouter_TYPE			DEFSTRUCT
0431h	RT1_IpRoutingTable_TYPE			DEFSTRUCT
0432h	RT1_NatTable_TYPE			DEFSTRUCT
0433h	RT1_SecurityGroup_TYPE			DEFSTRUCT
0434h	RT1_AclTable_TYPE			DEFSTRUCT
0435h	CFM_VerifyConfiguration_TYPE			DEFSTRUCT
0437h	DIA_NMTTelegrCount_TYPE			DEFSTRUCT

Index	Name	Store	Category	Object Type
0438h	DIA_ERRStatistics_TYPE			DEFSTRUCT
0439h	NMT_EPLNodeID_TYPE			DEFSTRUCT
043Ah	NMT_RequestCmd_TYPE			DEFSTRUCT
043Bh	DLL_MNRingRedundancy_TYPE used by EPSG DS302-A [1]			DEFSTRUCT
1000h	NMT_DeviceType_U32	-	M	VAR
1001h	ERR_ErrorRegister_U8	-	M	VAR
1003h	ERR_History_ADOM	-	O	ARRAY
1006h	NMT_CycleLen_U32	x	M	VAR
1008h	NMT_ManufactDevName_VS	-	O	VAR
1009h	NMT_ManufactHwVers_VS	-	O	VAR
100Ah	NMT_ManufactSwVers_VS	-	O	VAR
1010h	NMT_StoreParam_REC	-	O	RECORD
1011h	NMT_RestoreDefParam_REC	-	O	RECORD
1016h	NMT_ConsumerHeartbeatTime_AU32	1-254	O	ARRAY
1018h	NMT_IdentityObject_REC	-	M	RECORD
1020h	CFM_VerifyConfiguration_REC	1-3	M	RECORD
1021h	CFM_StoreDevDescrFile_DOM	x	O	VAR
1022h	CFM_StoreDevDescrFormat_U16	x	Cond	VAR
1027h	NMT_ChildIdentList_AU16 used by EPSG DS302-F [6]		Cond	ARRAY
1030h .. 1039h	NMT_InterfaceGroup_*Xh*_REC	8-9	M(1030h)/ O	RECORD
1050h	DLL_RelativeLatencyDiff_AU32 used by EPSG DS302-C [3]		Cond	ARRAY
1101h	DIA_NMTTelegrCount_REC	-	O	RECORD
1102h	DIA_ERRStatistics_REC	-	O	RECORD
1200h .. 127Fh	SDO_ServerContainerParam_*XXh*_REC	1-4	O	RECORD
1280h .. 12FFh	SDO_ClientContainerParam_*XXh*_REC	1-4	O	RECORD
1300h	SDO_SequLayerTimeout_U32	x	M	VAR
1301h	SDO_CmdLayerTimeout_U32	x	O	VAR
1302h	SDO_SequLayerNoAck_U32	x	O	VAR
1400h .. 14FFh	PDO_RxCommParam_*XXh*_REC	1-2	Cond	RECORD
1600h .. 16FFh	PDO_RxMappParam_XXh_AU64	0-254	Cond	ARRAY
1800h .. 18FFh	PDO_TxCommParam_XXh_REC	1-2	Cond	RECORD
1A00h .. 1AFFh	PDO_TxMappParam_XXh_AU64	0-254	Cond	ARRAY
1B00h .. 1BFFh	RT1_AclFwdTable_*XXh*_REC	1-9	Cond	RECORD
1C00h	DLL_MNCRCError_REC	3	MN: M CN: -	RECORD
1C01h	DLL_MNCollision_REC	3	MN: O	RECORD

Index	Name	Store	Category	Object Type
			CN: -	
1C02h	DLL_MNCycTimeExceed_REC	3	MN: O CN: -	RECORD
1C03h	DLL_MNLossOfLinkCum_U32	-	MN: Cond CN: -	VAR
1C04h	DLL_MNCNLatePResCumCnt_AU32	-	MN: Cond CN: -	ARRAY
1C05h	DLL_MNCNLatePResThrCnt_AU32	-	MN: Cond CN: -	ARRAY
1C06h	DLL_MNCNLatePResThreshold_AU32	1-254	MN: Cond CN: -	ARRAY
1C07h	DLL_MNCNLossPResCumCnt_AU32	-	MN: O CN: -	ARRAY
1C08h	DLL_MNCNLossPResThrCnt_AU32	-	MN: M CN: -	ARRAY
1C09h	DLL_MNCNLossPResThreshold_AU32	1-254	MN: M CN: -	ARRAY
1C0Ah	DLL_CNCollision_REC	3	MN: - CN: O	RECORD
1C0Bh	DLL_CNLossSoC_REC	3	MN: - CN: M	RECORD
1C0Ch	DLL_CNLossSoA_REC	3	MN: - CN: Cond	RECORD
1C0Dh	DLL_CNLossPReq_REC	3	MN: - CN: Cond	RECORD
1C0Eh	DLL_CNSoCJitter_REC	3	MN: - CN: Cond	RECORD
1C0Fh	DLL_CNCRCError_REC	3	MN: - CN: M	RECORD
1C10h	DLL_CNLossOfLinkCum_U32	-	MN: - CN: Cond	VAR
1C12h	DLL_MNCycleSuspendNumber_U32	x	MN: M CN: -	VAR
1C13h	DLL_CNSoCJitterRange_U32	x	MN: - CN: Cond	VAR
1C14h	DLL_CNLossOfSocTolerance_U32	x	MN: - CN: M	VAR
1C15h	DLL_MNLossStatusResCumCnt_AU32	-	MN: O CN: -	ARRAY
1C16h	DLL_MNLossStatusResThrCnt_AU32	-	MN: M CN: -	ARRAY
1C17h	DLL_MNLossStatusResThreshold_AU32	1-254	MN: M CN: -	ARRAY
1C40h	DLL_MNRingRedundancy_REC used by EPSG DS302-A [1]		MN: Cond CN: -	RECORD
1C80h	PDO_ErrMapVers_OSTR	-	O	VAR
1C81h	PDO_ErrShort_RX_OSTR	-	O	VAR
1D00h .. 1DFFh	RT1_NatTable_*XXh*_REC	1-4	Cond	RECORD
1E40h .. 1E49h	NWL_IpAddrTable_*Xh*_REC	(2,3,) 5	Cond (1E40h)/O	RECORD
1E4Ah	NWL_IpGroup_REC	(1,) 2	Cond	RECORD

Index	Name	Store	Category	Object Type
1E80h	RT1_EplRouter_REC	1,2	Cond	RECORD
1E81h	RT1_SecurityGroup_REC	1-3	Cond	RECORD
1E90h .. 1ECFh	RT1_IpRoutingTable_*XXh*_REC	1-4, 6,7	Cond	RECORD
1ED0h .. 1EDFh	RT1_AclInTable_Xh_REC	1-9	Cond	RECORD
1EE0h .. 1EEFh	RT1_AclOutTable_*Xh*_REC	1-9	Cond	RECORD
1F20h	CFM_StoreDcfList_ADOM	1-254	MN: Cond CN: -	ARRAY
1F21h	CFM_DcfStorageFormatList_AU8	1-254	MN: O CN: -	ARRAY
1F22h	CFM_ConciseDcfList_ADOM	1-254	MN: O CN: -	ARRAY
1F23h	CFM_StoreDevDescrFileList_ADOM	1-254	MN: Cond CN: -	ARRAY
1F24h	CFM_DevDescrFileFormatList_AU8	1-254	MN: O CN: -	ARRAY
1F25h	CFM_ConfCNRequest_AU32	-	MN: O CN: -	ARRAY
1F26h	CFM_ExpConfDateList_AU32	1-254	MN: O CN: -	ARRAY
1F27h	CFM_ExpConfTimeList_AU32	1-254	MN: O CN: -	ARRAY
1F28h	CFM_ExpConfIdList_AU32	1-254	MN: O CN: -	ARRAY
1F50h	PDL_DownloadProgData_ADOM	-	O	ARRAY
1F51h	PDL_ProgCtrl_AU8	-	Cond	ARRAY
1F52h	PDL_LocVerApplSw_REC	-	Cond	RECORD
1F53h	PDL_MnExpAppSwDateList_AU32	0-254	Cond	ARRAY
1F54h	PDL_MnExpAppSwTimeList_AU32	0-254	Cond	ARRAY
1F55h	PDL_DownloadChildProgList_AU16 used by EPSG DS302-F [6]		Cond	ARRAY
1F70h	INP_ProcessImage_REC	-	O	RECORD
1F80h	NMT_StartUp_U32	x	MN: M CN: -	VAR
1F81h	NMT_NodeAssignment_AU32	x	MN: M CN: Cond	ARRAY
1F82h	NMT_FeatureFlags_U32	-	M	VAR
1F83h	NMT_EPLVersion_U8	-	M	VAR
1F84h	NMT_MNDeviceTypeIdList_AU32	0-254	MN: M CN: -	ARRAY
1F85h	NMT_MNVendorIdList_AU32	0-254	MN: O CN: -	ARRAY
1F86h	NMT_MNProductCodeList_AU32	0-254	MN: O CN: -	ARRAY
1F87h	NMT_MNRevisionNoList_AU32	0-254	MN: O CN: -	ARRAY
1F88h	NMT_MNSerialNoList_AU32	0-254	MN: O CN: -	ARRAY
1F89h	NMT_BootTime_REC	1-9	MN: M	RECORD

Index	Name	Store	Category	Object Type
			CN: -	
1F8Ah	NMT_MNCycleTiming_REC	1,2,4	MN: M CN: -	VAR
1F8Bh	NMT_MNPReqPayloadLimitList_AU16	0-254	MN: M CN: -	ARRAY
1F8Ch	NMT_CurrNMTState_U8	-	M	VAR
1F8Dh	NMT_PresPayloadLimitList_AU16	0-254	MN: M CN: O	ARRAY
1F8Eh	NMT_MNNodeCurrState_AU8	-	MN: M CN: -	ARRAY
1F8Fh	NMT_MNNodeExpState_AU8	-	MN: O CN: -	ARRAY
1F92h	NMT_MNCNPResTimeout_AU32	0-254	MN: M CN: -	ARRAY
1F93h	NMT_EPLNodeID_REC	3	M	RECORD
1F94h	NMT_PdoNodeAssign_AU8 used by EPSG DS302-D [4]		Cond	ARRAY
1F98h	NMT_CycleTiming_REC	4,5, 7-9	M	RECORD
1F99h	NMT_CNBasicEthernetTimeout_U32	x	MN: - CN: M	VAR
1F9Ah	NMT_HostName_VSTR	x	Cond	VAR
1F9Bh	NMT_MultiplCycleAssign_AU8	0-254	Cond	ARRAY
1F9Ch	NMT_IsochrSlotAssign_AU8	0-254	O	ARRAY
1F9Eh	NMT_ResetCmd_U8	-	M	VAR
1F9Fh	NMT_RequestCmd_REC	-	MN: M CN: -	RECORD
1FA0h	NMT_PredecessorNodeNumberList_AU32 used by EPSG DS302-E [5]		Cond	ARRAY
1FA1h	NMT_PredecessorHubPortList_AU32 used by EPSG DS302-E [5]		Cond	ARRAY

App. 1.2 Object Dictionary Entries, sorted by name

Name	Index	Object Type
BOOLEAN	0001_h	DEFTYPE
CFM_ConciseDcfList_ADOM	$1F22_h$	ARRAY
CFM_ConfCNRequest_AU32	$1F25_h$	ARRAY
CFM_DcfStorageFormatList_AU8	$1F21_h$	ARRAY
CFM_DevDescrFileFormatList_AU8	$1F24_h$	ARRAY
CFM_ExpConfDateList_AU32	$1F26_h$	ARRAY
CFM_ExpConfIdList_AU32	$1F28_h$	ARRAY
CFM_ExpConfTimeList_AU32	$1F27_h$	ARRAY
CFM_StoreDcfList_ADOM	$1F20_h$	ARRAY
CFM_StoreDevDescrFile_DOM	1021_h	VAR
CFM_StoreDevDescrFileList_ADOM	$1F23_h$	ARRAY
CFM_StoreDevDescrFormat_U16	1022_h	VAR
CFM_VerifyConfiguration_REC	1020_h	RECORD
CFM_VerifyConfiguration_TYPE	0435_h	DEFSTRUCT
Device Profile (0) Specific Complex Data Types	0080_h .. $009F_h$	DEFSTRUCT
Device Profile (0) Specific Standard Data Types	0060_h .. $007F_h$	DEFTYPE
Device Profile 1 Specific Complex Data Types	$00C0_h$ .. $00DF_h$	DEFSTRUCT
Device Profile 1 Specific Standard Data Types	$00A0_h$ .. $00BF_h$	DEFTYPE
Device Profile 2 Specific Complex Data Types	0100_h .. $011F_h$	DEFSTRUCT
Device Profile 2 Specific Standard Data Types	$00E0_h$ .. $00FF_h$	DEFTYPE
Device Profile 3 Specific Complex Data Types	0140_h .. $015F_h$	DEFSTRUCT
Device Profile 3 Specific Standard Data Types	0120_h .. $013F_h$	DEFTYPE
Device Profile 4 Specific Complex Data Types	0180_h .. $019F_h$	DEFSTRUCT
Device Profile 4 Specific Standard Data Types	0160_h .. $017F_h$	DEFTYPE
Device Profile 5 Specific Complex Data Types	$01C0_h$ .. $01DF_h$	DEFSTRUCT
Device Profile 5 Specific Standard Data Types	$01A0_h$ .. $01BF_h$	DEFTYPE

Name	Index	Object Type
Device Profile 6 Specific Complex Data Types	0200_h .. $021F_h$	DEFSTRUCT
Device Profile 6 Specific Standard Data Types	$01E0_h$ .. $01FF_h$	DEFTYPE
Device Profile 7 Specific Complex Data Types	0240_h .. $025F_h$	DEFSTRUCT
Device Profile 7 Specific Standard Data Types	0220_h .. $023F_h$	DEFTYPE
DIA_ERRStatistics_REC	1102_h	RECORD
DIA_ERRStatistics_TYPE	0438_h	DEFSTRUCT
DIA_NMTTelegrCount_REC	1101_h	RECORD
DIA_NMTTelegrCount_TYPE	0437_h	DEFSTRUCT
DLL_CNCollision_REC	$1C0A_h$	RECORD
DLL_CNCRCError_REC	$1C0F_h$	RECORD
DLL_CNLossOfLinkCum_U32	$1C10_h$	VAR
DLL_CNLossPReq_REC	$1C0D_h$	RECORD
DLL_CNLossSoA_REC	$1C0C_h$	RECORD
DLL_CNLossSoC_REC	$1C0B_h$	RECORD
DLL_CNSoCJitter_REC	$1C0E_h$	RECORD
DLL_CNSoCJitterRange_U32	$1C13_h$	VAR
DLL_ErrorCntRec_TYPE	0424_h	DEFSTRUCT
DLL_CNLossOfSocTolerance_U32	$1C14_h$	VAR
DLL_MNCNLatePResCumCnt_AU32	$1C04_h$	ARRAY
DLL_MNCNLatePResThrCnt_AU32	$1C05_h$	ARRAY
DLL_MNCNLatePResThreshold_AU32	$1C06_h$	ARRAY
DLL_MNCNLossPResCumCnt_AU32	$1C07_h$	ARRAY
DLL_MNCNLossPResThrCnt_AU32	$1C08_h$	ARRAY
DLL_MNCNLossPResThreshold_AU32	$1C09_h$	ARRAY
DLL_MNCollision_REC	$1C01_h$	RECORD
DLL_MNCRCError_REC	$1C00_h$	RECORD
DLL_MNCycleSuspendNumber_U32	$1C12_h$	VAR
DLL_MNCycTimeExceed_REC	$1C02_h$	RECORD
DLL_MNLossOfLinkCum_U32	$1C03_h$	VAR
DLL_MNLossStatusResCumCnt_AU32	$1C15_h$	ARRAY
DLL_MNLossStatusResThrCnt_AU32	$1C16_h$	ARRAY
DLL_MNLossStatusResThreshold_AU32	$1C17_h$	ARRAY
DLL_MNRingRedundancy_REC used by EPSG DS302-A [1]	$1C40_h$	RECORD
DLL_MNRingRedundancy_TYPE used by EPSG DS302-A [1]	$043B_h$	DEFSTRUCT
DLL_RelativeLatencyDiff_AU32 used by EPSG DS302-C [3]	1050_h	ARRAY
DOMAIN	$000F_h$	DEFTYPE
ERR_ErrorRegister_U8	1001_h	VAR
ERR_History_ADOM	1003_h	ARRAY
IDENTITY	0023_h	DEFSTRUCT
INP_ProcessImage_REC	$1F70_h$	RECORD
INP_ProcessImage_TYPE	0428_h	DEFSTRUCT
INTEGER16	0003_h	DEFTYPE

Name	Index	Object Type
INTEGER24	0010$_h$	DEFTYPE
INTEGER32	0004$_h$	DEFTYPE
INTEGER40	0012$_h$	DEFTYPE
INTEGER48	0013$_h$	DEFTYPE
INTEGER56	0014$_h$	DEFTYPE
INTEGER64	0015$_h$	DEFTYPE
INTEGER8	0002$_h$	DEFTYPE
IP_ADDRESS	0402$_h$	DEFTYPE
MAC_ADDRESS	0401$_h$	DEFTYPE
Manufacturer Specific Complex Data Types	0040$_h$ .. 005F$_h$	DEFSTRUCT
NETTIME	0403$_h$	DEFTYPE
NMT_BootTime_REC	1F89$_h$	RECORD
NMT_BootTime_TYPE	042E$_h$	DEFSTRUCT
NMT_CNBasicEthernetTimeout_U32	1F99$_h$	VAR
NMT_ConsumerHeartbeatTime_AU32	1016$_h$	ARRAY
NMT_CurrNMTState_U8	1F8C$_h$	VAR
NMT_CycleLen_U32	1006$_h$	VAR
NMT_CycleTiming_REC	1F98$_h$	RECORD
NMT_CycleTiming_TYPE	042C$_h$	DEFSTRUCT
NMT_DeviceType_U32	1000$_h$	VAR
NMT_EPLNodeID_REC	1F93$_h$	RECORD
NMT_EPLNodeID_TYPE	0439$_h$	DEFSTRUCT
NMT_EPLVersion_U8	1F83$_h$	VAR
NMT_FeatureFlags_U32	1F82$_h$	VAR
NMT_HostName_VSTR	1F9A$_h$	VAR
NMT_IdentityObject_REC	1018$_h$	RECORD
NMT_InterfaceGroup_TYPE	042B$_h$	DEFSTRUCT
NMT_InterfaceGroup_*Xh*_REC	1030$_h$ .. 1039$_h$	RECORD
NMT_IsochrSlotAssign_AU8	1F9C$_h$	ARRAY
NMT_ManufactDevName_VS	1008$_h$	VAR
NMT_ManufactHwVers_VS	1009$_h$	VAR
NMT_ManufactSwVers_VS	100A$_h$	VAR
NMT_MNCNPResTimeout_AU32	1F92$_h$	ARRAY
NMT_MNCycleTiming_REC	1F8A$_h$	VAR
NMT_MNCycleTiming_TYPE	042F$_h$	DEFSTRUCT
NMT_MNDeviceTypeIdList_AU32	1F84$_h$	ARRAY
NMT_MNNodeCurrState_AU8	1F8E$_h$	ARRAY
NMT_MNNodeExpState_AU8	1F8F$_h$	ARRAY
NMT_MNPReqPayloadLimitList_AU16	1F8B$_h$	ARRAY
NMT_MNProductCodeList_AU32	1F86$_h$	ARRAY
NMT_MNRevisionNoList_AU32	1F87$_h$	ARRAY
NMT_MNSerialNoList_AU32	1F88$_h$	ARRAY
NMT_MNVendorIdList_AU32	1F85$_h$	ARRAY
NMT_MultiplCycleAssign_AU8	1F9B$_h$	ARRAY

Name	Index	Object Type
NMT_NodeAssignment_AU32	1F81h	ARRAY
NMT_ParameterStorage_TYPE	0429h	DEFSTRUCT
NMT_PdoNodeAssign_AU8 used by EPSG DS302-D [4]	1F94h	ARRAY
NMT_PredecessorHubPortList used by EPSG DS302-E [5]	1FA0h	ARRAY
NMT_PredecessorNodeNumberList used by EPSG DS302-E [5]	1FA1h	ARRAY
NMT_PresPayloadLimitList_AU16	1F8Dh	ARRAY
NMT_RequestCmd_REC	1F9Fh	RECORD
NMT_RequestCmd_TYPE	043Ah	DEFSTRUCT
NMT_ResetCmd_U8	1F9Eh	VAR
NMT_RestoreDefParam_REC	1011h	RECORD
NMT_StartUp_U32	1F80h	VAR
NMT_StoreParam_REC	1010h	RECORD
NWL_IpAddrTable_TYPE	0426h	DEFSTRUCT
NWL_IpAddrTable_*Xh*_REC	1E40h .. 1E49h	RECORD
NWL_IpGroup_REC	1E4Ah	RECORD
NWL_IpGroup_TYPE	0425h	DEFSTRUCT
OCTET_STRING	000Ah	DEFTYPE
PDL_DownloadProgData_ADOM	1F50h	ARRAY
PDL_LocVerApplSw_REC	1F52h	RECORD
PDL_LocVerApplSw_TYPE	0427h	DEFSTRUCT
PDL_MnExpAppSwDateList_AU32	1F53h	ARRAY
PDL_MnExpAppSwTimeList_AU32	1F54h	ARRAY
PDL_ProgCtrl_AU8	1F51h	ARRAY
PDO_CommParamRecord_TYPE	0420h	DEFSTRUCT
PDO_ErrMapVers_OSTR	1C80h	VAR
PDO_ErrShort_RX_OSTR	1C81h	VAR
PDO_RxCommParam_*XXh*_REC	1400h .. 14FFh	RECORD
PDO_RxMappParam_*XXh*_AU64	1600h .. 16FFh	ARRAY
PDO_TxCommParam_*XXh*_REC	1800h .. 18FFh	RECORD
PDO_TxMappParam_*XXh*_AU64	1A00h .. 1AFFh	ARRAY
REAL32	0008h	DEFTYPE
REAL64	0011h	DEFTYPE
RT1_AclFwdTable_*XXh*_REC	1B00h .. 1BFFh	RECORD
RT1_AclInTable_*Xh*_REC	1ED0h .. 1EDFh	RECORD
RT1_AclOutTable_*Xh*_REC	1EE0h .. 1EEFh	RECORD

Name	Index	Object Type
RT1_AclTable_TYPE	0434_h	DEFSTRUCT
RT1_EplRouter_REC	$1E80_h$	RECORD
RT1_EplRouter_TYPE	0430_h	DEFSTRUCT
RT1_IpRoutingTable_TYPE	0431_h	DEFSTRUCT
RT1_IpRoutingTable_*XXh*_REC	$1E90_h$ .. $1ECF_h$	RECORD
RT1_NatTable_TYPE	0432_h	DEFSTRUCT
RT1_NatTable_*XXh*_REC	$1D00_h$ .. $1DFF_h$	RECORD
RT1_SecurityGroup_REC	$1E81_h$	RECORD
RT1_SecurityGroup_TYPE	0433_h	DEFSTRUCT
SDO_ClientContainerParam_*XXh*_REC	1280_h .. $12FF_h$	RECORD
SDO_CmdLayerTimeout_U32	1301_h	VAR
SDO_ParameterRecord_TYPE	0422_h	DEFSTRUCT
SDO_SequLayerNoAck_U32	1302_h	VAR
SDO_SequLayerTimeout_U32	1300_h	VAR
SDO_ServerContainerParam_*XXh*_REC	1200_h .. $127F_h$	RECORD
TIME_DIFFERENCE	$000D_h$	DEFTYPE
TIME_OF_DAY	$000C_h$	DEFTYPE
UNICODE_STRING	$000B_h$	DEFTYPE
UNSIGNED16	0006_h	DEFTYPE
UNSIGNED24	0016_h	DEFTYPE
UNSIGNED32	0007_h	DEFTYPE
UNSIGNED40	0018_h	DEFTYPE
UNSIGNED48	0019_h	DEFTYPE
UNSIGNED56	$001A_h$	DEFTYPE
UNSIGNED64	$001B_h$	DEFTYPE
UNSIGNED8	0005_h	DEFTYPE
VISIBLE_STRING	0009_h	DEFTYPE

App. 2 Device Description Entries (normative)

Name	Description	Type	Category		Default	
			MN	CN	MN	CN
D_CFM_ConfigManager_BOOL	Ability of a node to perform Configuration Manager functions	BOOLEAN	O	O	N	N
D_DLL_CNLossOfSoCToleranceMax_U32	maximum value for object DLL_CNLossOfSocTolerance_U32	UNSIGNED32	-	O	-	100000
D_DLL_CNFeatureMultiplex_BOOL	node’s ability to perform control of multiplexed isochronous communication	BOOLEAN	-	O	-	N
D_DLL_ErrBadPhysMode_BOOL	Support of Data Link Layer Error recognition: Incorrect physical operation mode	BOOLEAN	O	O	N	N
D_DLL_ErrMacBuffer_BOOL	Support of Data Link Layer Error recognition: TX / RX buffer underrun / overrun	BOOLEAN	O	O	N	N
D_DLL_ErrMNMultipleMN_BOOL	Support of MN Data Link Layer Error recognition: Multiple MNs	BOOLEAN	O	-	N	-
D_DLL_FeatureCN_BOOL	node’s ability to perform CN functions	BOOLEAN	O	O	Y	Y
D_DLL_FeatureMN_BOOL	node’s ability to perform MN functions	BOOLEAN	M	M	-	-
D_DLL_MNFeatureMultiplex_BOOL	MN’s ability to perform control of multiplexed isochronous communication	BOOLEAN	O	-	Y	-
D_DLL_MNFeaturePResTx_BOOL	MN’s ability to transmit Pres	BOOLEAN	O	-	Y	-
D_NMT_BootTimeNotActive_U32	max. boot time from cold start to NMT_MS_NOT_ACTIVEresp. NMT_CS_NOT_ACTIVE [µs]	UNSIGNED32	M	M	-	-
D_NMT_CNPreOp2ToReady2Op_U32	maximum transition time of a CN from reception of NMTEnableReadyToOperate until the CN is in state NMT_CS_READY_TO_OPERATE [µs]	UNSIGNED32	-	O	-	-
D_NMT_CNSoC2PReq_U32	CN SoC handling maximum time [ns], a subsequent PReq won’t be handled before SoC handling was finished	UNSIGNED32	-	M	-	-
D_NMT_CycleTimeGranularity_U32	POWERLINK cycle time granularity [µs] Value shall be 1 µs if POWERLINK cycle time settings may be taken from a continuum. Otherwise granularity should be a multiple of the base granularity values 100 µs or 125 µs.	UNSIGNED32	O	O	1	1
D_NMT_CycleTimeMax_U32	maximum POWERLINK cycle time [µs]	UNSIGNED32	M	M	-	-
D_NMT_CycleTimeMin_U32	minimum POWERLINK cycle time [µs]	UNSIGNED32	M	M	-	-
D_NMT_EmergencyQueueSize_U32	maximum number of history entries in the Error Signaling emergency queue (see 6.5)	UNSIGNED32	O	O	0	0
D_NMT_ErrorEntries_U32	maximum number of error entries (Status and History Entries) in the StatusResponse frame (see 7.3.3.3.1) value range: 2 .. 14	UNSIGNED32	M	M	-	-
D_NMT_ExtNmtCmds_BOOL	Support of Extended NMT State Command	BOOLEAN	O	O	N	N
D_NMT_FlushArpEntry_BOOL	Support of NMT Managing Command Service NMTFlushArpEntry	BOOLEAN	O	O	N	N
D_NMT_Isochronous_BOOL	Device may be accessed isochronously	BOOLEAN	O	O	Y	Y

D_NMT_MaxCNNodeID_U8	maximum Node ID available for regular CNs the entry provides an upper limit to the Node ID available for cross traffic PDO reception from a regular CN	UNSIGNED8	O	O	239	239
D_NMT_MaxCNNumber_U8	maximum number of supported regular CNs in the Node ID range 1 .. 239	UNSIGNED8	O	O	239	239
D_NMT_MaxHeartbeats_U8	number of guard channels	UNSIGNED8	O	O	254	254
D_NMT_MinRedCycleTime_U32	Minimum reduced cycle time [µs], i.e. minimum time between SoA frames	UNSIGNED32	O	O	-	-
D_NMT_MNASnd2SoC_U32	minimum delay between end of reception of ASnd and start of transmission of SoC [ns]	UNSIGNED32	M	-	-	-
D_NMT_MNBasicEthernet_BOOL	support of NMT_MS_BASIC_ETHERNET	BOOLEAN	O	-	N	-
D_NMT_MNMultiplCycMax_U8	maximum number of POWERLINK cycles per multiplexed cycle	UNSIGNED8	O	-	0	-
D_NMT_MNPRes2PReq_U32	delay between end of PRes reception and start of PReq transmission [ns]	UNSIGNED32	M	-	-	-
D_NMT_MNPRes2PRes_U32	delay between end of reception of PRes from CNn and start of transmission of PRes by MN [ns]	UNSIGNED32	M	-	-	-
D_NMT_MNPResRx2SoA_U32	delay between end of reception of PRes from CNn and start of transmission of SoA by MN [ns]	UNSIGNED32	M	-	-	-
D_NMT_MNPResTx2SoA_U32	delay between end of PRes transmission by MN and start of transmission of SoA by MN [ns]	UNSIGNED32	M	-	-	-
D_NMT_MNSoA2ASndTx_U32	delay between end of transmission of SoA and start of transmission of ASnd by MN [ns]	UNSIGNED32	M	-	-	-
D_NMT_MNSoC2PReq_U32	MN minimum delay between end of SoC transmission and start of PReq transmission [ns]	UNSIGNED32	M	-	-	-
D_NMT_NetHostNameSet_BOOL	Support of NMT Managing Command Service NMTNetHostNameSet	BOOLEAN	O	O	N	N
D_NMT_NetTime_BOOL	Support of NetTime transmission via SoC	BOOLEAN	O	-	N	-
D_NMT_NetTimeIsRealTime_BOOL	Support of real time via NetTime in SoC	BOOLEAN	O	-	N	-
D_NMT_NodeIDByHW_BOOL	Ability of a node to support Node ID setup by HW	BOOLEAN	O	O	Y	Y
D_NMT_NodeIDBySW_BOOL	Ability of a node to support Node ID setup by SW	BOOLEAN	O	O	N	N
D_NMT_ProductCode_U32	Identity Object Product Code	UNSIGNED32	O	O	0	0
D_NMT_PublishActiveNodes_BOOL	Support of NMT Info service NMTPublishActiveNodes	BOOLEAN	O	-	N	-
D_NMT_PublishConfigNodes_BOOL	Support of NMT Info service NMTPublishConfiguredNodes	BOOLEAN	O	O	N	N
D_NMT_PublishEmergencyNew_BOOL	Support of NMT Info service NMTPublishEmergencyNew	BOOLEAN	O	-	N	-
D_NMT_PublishNodeState_BOOL	Support of NMT Info service NMTPublishNodeStates	BOOLEAN	O	-	N	-
D_NMT_PublishOperational_BOOL	Support of NMT Info service NMTPublishOperational	BOOLEAN	O	-	N	-
D_NMT_PublishPreOp1_BOOL	Support of NMT Info service NMTPublishPreOperational1	BOOLEAN	O	-	N	-
D_NMT_PublishPreOp2_BOOL	Support of NMT Info service NMTPublishPreOperational2	BOOLEAN	O	-	N	-
D_NMT_PublishReadyToOp_BOOL	Support of NMT Info service NMTPublishReadyToOperate	BOOLEAN	O	-	N	-

Name	Description	Type	Category		Default	
			MN	CN	MN	CN
D_NMT_PublishStopped_BOOL	Support of NMT Info service NMTPublishStopped	BOOLEAN	O	-	N	-
D_NMT_PublishTime_BOOL	Support of NMT Info service NMTPublishTime	BOOLEAN	O	O	N	N
D_NMT_RelativeTime_BOOL	Support of RelativeTime transmission via SoC	BOOLEAN	O	-	N	-
D_NMT_RevisionNo_U32	Identity Object Revision Number	UNSIGNED32	O	O	0	0
D_NMT_ServiceUdpIp_BOOL	Support of NMT services via UDP/IP	BOOLEAN	O	-	N	-
D_NMT_SimpleBoot_BOOL	Ability of an MN node to perform only Simple Boot Process, if not set Indivual Boot Process shall be proviced	BOOLEAN	M	-	-	-
D_NWL_Forward_BOOL	Ability of node to forward datagrams	BOOLEAN	O	O	N	N
D_NWL_ICMPSupport_BOOL	Support of ICMP	BOOLEAN	O	O	N	N
D_NWL_IPSupport_BOOL	Ability of the node cummunicate via IP	BOOLEAN	O	O	Y	Y
D_PDO_DynamicMapping_BOOL	Support of dynamic PDO mapping	BOOLEAN	O	O	Y	Y
D_PDO_Granularity_U8	minimum size of objects to be mapped [bit]	UNSIGNED8	O	O	8	8
D_PDO_MaxDescrMem_U32	maximum cumulative memory consumption of TPDO and RPDO mapping describing objects [byte]	UNSIGNED32	O	O	MAX_U32	MAX_U32
D_PDO_RPDOChannelObjects_U8	Number of supported mapped objects per RPDO channel	UNSIGNED8	O	O	254	254
D_PDO_RPDOChannels_U16	number of supported RPDO channels	UNSIGNED16	O	O	256	256
D_PDO_RPDOCycleDataLim_U32	maximum sum of data size of RPDO data to be received per cycle [Byte]	UNSIGNED32	O	O	MAX_U32	MAX_U32
D_PDO_RPDOOverallObjects_U16	maximum number of mapped RPDO objects, sum of all channels	UNSIGNED16	O	O	MAX_U16	MAX_U16
D_PDO_SelfReceipt_BOOL	node’s ability to receive PDO data transmitted by itself	BOOLEAN	O	O	N	N
D_PDO_TPDOChannelObjects_U8	maximum Number of mapped objects per TPDO channel	UNSIGNED8	O	O	254	254
D_PDO_TPDOChannels_U16	number of supported TPDO channels	UNSIGNED16	O	-	256	-
D_PDO_TPDOCycleDataLim_U32	maximum sum of data size of TPDO data to be transmitted per cycle [Byte]	UNSIGNED32	O	O	MAX_U32	MAX_U32
D_PDO_TPDOOverallObjects_U16	maximum number of mapped RPDO objects, sum of all channels	UNSIGNED16	O	O	MAX_U16	MAX_U16
D_PHY_ExtEPLPorts_U8	number of externally accessible Ethernet POWERLINK ports	UNSIGNED8	O	O	2	2
D_PHY_HubDelay_U32	network propagation delay of the hub integrated in the device in [ns]	UNSIGNED32	O	O	1000	1000
D_PHY_HubIntegrated_BOOL	indicates a hub integrated by the device	BOOLEAN	O	O	Y	Y
D_PHY_HubJitter_U32	jitter of the propagation delay caused by the integrated hub in [ns]	UNSIGNED32	O	O	50	50
D_RT1_RT1SecuritySupport_BOOL	Support of Routing Type 1 security functions	BOOLEAN	O	O	N	N
D_RT1_RT1Support_BOOL	Support of Routing Type 1 functions	BOOLEAN	O	O	N	N
D_RT2_RT2Support_BOOL	Support of Routing Type 2 functions	BOOLEAN	O	O	N	N
D_SDO_Client_BOOL	device implements a SDO client	BOOLEAN	O	O	Y	Y
D_SDO_CmdFileRead_BOOL	Support of SDO command FileRead	BOOLEAN	O	O	N	N

Name	Description	Type	Category		Default	
			MN	CN	MN	CN
D_SDO_CmdFileWrite_BOOL	Support of SDO command FileWrite	BOOLEAN	O	O	N	N
D_SDO_CmdLinkName_BOOL	Support of SDO command LinkName	BOOLEAN	O	O	N	N
D_SDO_CmdReadAllByIndex_BOOL	Support of SDO command ReadAllByIndex	BOOLEAN	O	O	N	N
D_SDO_CmdReadByName_BOOL	Support of SDO command ReadByName	BOOLEAN	O	O	N	N
D_SDO_CmdReadMultParam_BOOL	Support of SDO command ReadMultipleParam	BOOLEAN	O	O	N	N
D_SDO_CmdWriteAllByIndex_BOOL	Support of SDO command WriteAllByIndex	BOOLEAN	O	O	N	N
D_SDO_CmdWriteByName_BOOL	Support of SDO command WriteByName	BOOLEAN	O	O	N	N
D_SDO_CmdWriteMultParam_BOOL	Support of SDO command WriteMultParam	BOOLEAN	O	O	N	N
D_SDO_MaxConnections_U32	max. number of SDO connections	UNSIGNED32	O	O	1	1
D_SDO_MaxParallelConnections_U32	max. number of SDO connections between a SDO client/server pair	UNSIGNED32	O	O	1	1
D_SDO_SeqLayerTxHistorySize_U16	max. number of frames in SDO sequence layer sender history value <= 31	UNSIGNED16	O	O	5	5
D_SDO_Server_BOOL	device implements a SDO server	BOOLEAN	O	O	Y	Y
D_SDO_SupportASnd_BOOL	Support of SDO via ASnd frames	BOOLEAN	M	O	Y	N
D_SDO_SupportPDO_BOOL	Support of SDO via PDO frames	BOOLEAN	O	O	N	N
D_SDO_SupportUdpIp_BOOL	Support of SDO via UDP/IP frames	BOOLEAN	M	O	Y	N

Abbreviations in the table:

- M device description entry is mandatory
- O device description entry is optional
- \- item is irrelevant for the selected type of node (MN or CN), item may be provided if the device supports the other type, too

Comments to Default

Default values shall be used if an optional entry is not provided by the device description. If no default is indicated, zero value resp. empty string shall be applied.

Device description entry names are created according to the following rules:

Name shall be in accordance to IEC 61131-3. It consists of:

- *Device description entry identification prefix “D_”*
- *domain prefix, indicating the association of the object to a functional domain, 3 uppercase characters followed by underline*
- *name (verbally). Composed of words, each word are leaded by an uppercase character followed by lowercase characters or digits, no underlines or spaces*
- *data type postfix, indicating the data type of the object (underline followed by up to 5 uppercase characters or digits)*

App. 3 Constant Value Assignments (normative)

App. 3.1 POWERLINK Message Type Ids

Message Type	Abbr.	ID Value
Start of Cycle	SoC	01_h
PollRequest	PReq	03_h
PollResponse	PRes	04_h
Start of Asynchronous	SoA	05_h
Asynchronous Send	ASnd	06_h
Active Managing Node Indication, used by EPSG DS302-A [1]	AMNI	07_h
Asynchronous Invite, used by EPSG DS302-B [2]	Ainv	$0D_h$

ID values not listed by the table are reserved.

App. 3.2 AsyncSend Request Priorities

Priority Level	Priority Name	ID value
highest	PRIO_NMT_REQUEST	111_b
higher	available for application purpose	110_b, 101_b, 100_b
medium	PRIO_GENERIC_REQUEST	011_b
lower	available for application purpose	010_b, 001_b, 000_b

App. 3.3 ASnd ServiceIDs

Service Name	Service ID	ID Value
reserved		00h
IdentResponse	IDENT_RESPONSE	01_h
StatusResponse	STATUS_RESPONSE	02_h
NMTRequest	NMT_REQUEST	03_h
NMTCommand	NMT_COMMAND	04_h
SDO	SDO	05_h
reserved, used by EPSG DS302-C [3]		06_h
reserved		07_h .. $9F_h$
Manufacturer specific	MANUF_SVC_IDS	$A0_h$ .. FE_h
reserved		FF_h

App. 3.4 SoA RequestedServiceIDs

Service Name	Service ID	ID Value
NoService	NO_SERVICE	00_h
IdentRequest	IDENT_REQUEST	01_h
StatusRequest	STATUS_REQUEST	02_h
NMTRequestInvite	NMT_REQUEST_INVITE	03_h
reserved		04_h .. 05_h
reserved, used by EPSG DS302-C [3]		06_h
reserved		07_h .. $9F_h$
Manufacturer specific	MANUF_SVC_IDS	$A0_h$ .. FE_h
UnspecifiedInvite	UNSPECIFIED_INVITE	FF_h

App. 3.5 Object Dictionary Object Types

NULL	0000_h
DEFTYPE	0005_h
DEFSTRUCT	0006_h
VAR	0007_h
ARRAY	0008_h
RECORD	0009_h

Values not listed by the table are reserved.

App. 3.6 NMT States

	Name	Value	
MN and CN States	NMT_GS_OFF	$0000\ 0000_b$	
	NMT_GS_POWERED	$xxxx\ 1xxx_b$	Super state
	NMT_GS_INITIALISATION	$xxxx\ 1001_b$	Super state
	NMT_GS_INITIALISING	$0001\ 1001_b$	
	NMT_GS_RESET_APPLICATION	$0010\ 1001_b$	
	NMT_GS_RESET_COMMUNICATION	$0011\ 1001_b$	
	NMT_GS_RESET_CONFIGURATION	$0111\ 1001_b$	
	NMT_GS_COMMUNICATING	$xxxx\ 11xx_b$	Super state
CN States	NMT_CS_NOT_ACTIVE	$0001\ 1100_b$	
	NMT_CS_EPL_MODE	$xxxx\ 1101_b$	Super state
	NMT_CS_PRE_OPERATIONAL_1	$0001\ 1101_b$	
	NMT_CS_PRE_OPERATIONAL_2	$0101\ 1101_b$	
	NMT_CS_READY_TO_OPERATE	$0110\ 1101_b$	
	NMT_CS_OPERATIONAL	$1111\ 1101_b$	
	NMT_CS_STOPPED	$0100\ 1101_b$	
	NMT_CS_BASIC_ETHERNET	$0001\ 1110_b$	
MN States	NMT_MS_NOT_ACTIVE	$0001\ 1100_b$	
	NMT_MS_EPL_MODE	$xxxx\ 1101_b$	Super state
	NMT_MS_PRE_OPERATIONAL_1	$0001\ 1101_b$	
	NMT_MS_PRE_OPERATIONAL_2	$0101\ 1101_b$	
	NMT_MS_READY_TO_OPERATE	$0110\ 1101_b$	
	NMT_MS_OPERATIONAL	$1111\ 1101_b$	
	NMT_MS_BASIC_ETHERNET	$0001\ 1110_b$	

NMT_CS_OPERATIONAL and NMT_MS_OPERATIONAL can be easily identified by the most signifiant bit being set.

App. 3.7 NMT Commands

Name		ID Value
requestable ASnd ServiceIDs		01_h .. $1F_h$
	IdentResponse	01_h
	StatusResponse	02_h
Plain NMT State Commands		20_h .. $3F_h$
	NMTStartNode	21_h
	NMTStopNode	22_h
	NMTEnterPreOperational2	23_h
	NMTEnableReadyToOperate	24_h
	NMTResetNode	28_h
	NMTResetCommunication	29_h
	NMTResetConfiguration	$2A_h$
	NMTSwReset	$2B_h$
	NMTGoToStandby used by EPSG DS302-A [1]	$2C_h$
Extended NMT State Commands		40_h .. $5F_h$
	NMTStartNodeEx	41_h
	NMTStopNodeEx	42_h
	NMTEnterPreOperational2Ex	43_h
	NMTEnableReadyToOperateEx	44_h
	NMTResetNodeEx	48_h
	NMTResetCommunicationEx	49_h
	NMTResetConfigurationEx	$4A_h$
	NMTSwResetEx	$4B_h$
NMT Managing Commands		60_h .. $7F_h$
	NMTNetHostNameSet	62_h
	NMTFlushArpEntry	63_h
NMT Info services		80_h .. BF_h
	NMTPublishConfiguredNodes	80_h
	NMTPublishActiveNodes	90_h
	NMTPublishPreOperational1	91_h
	NMTPublishPreOperational2	92_h
	NMTPublishReadyToOperate	93_h
	NMTPublishOperational	94_h
	NMTPublishStopped	95_h
	NMTPublishNodeStates	96_h
	NMTPublishEmergencyNew	$A0_h$
	NMTPublishTime	$B0_h$
NMTInvalidService		FF_h

ID values not listed as distinctive commands are reserved

App. 3.8 General Purpose Constants

Name	Value	Unit	Description
C_ADR_BROADCAST	FFh	--	POWERLINK broadcast address
C_ADR_DIAG_DEF_NODE_ID	FDh	--	POWERLINK default address of dignostic device
C_ADR_DUMMY_NODE_ID	FCh	--	POWERLINK dummy node address
C_ADR_SELF_ADR_NODE_ID	FBh	--	POWERLINK pseudo node address to be used by a node to address itself
C_ADR_INVALID	00h	--	invalid POWERLINK address
C_ADR_MN_DEF_NODE_ID	F0h	--	POWERLINK default address of MN
C_ADR_RT1_DEF_NODE_ID	FEh	--	POWERLINK default address of router type 1
C_DLL_ASND_PRIO_NMTRQST	7	--	ASnd request priority to be used by NMT Requests
C_DLL_ASND_PRIO_STD	0	--	standard ASnd request priority
C_DLL_ETHERTYPE_EPL	88ABh	--	
C_DLL_ISOCHR_MAX_PAYL	1490	Byte	maximum size of PReq and PRes payload data, requires C_DLL_MAX_ASYNC_MTU
C_DLL_MAX_ASYNC_MTU	1500	Byte	maximum asynchronous payload in bytes including all headers (exclusive the Ethernet header)
C_DLL_MAX_PAYL_OFFSET	1499	Byte	maximum offset of Ethernet frame payload, requires C_DLL_MAX_ASYNC_MTU
C_DLL_MAX_RS	7	--	
C_DLL_MIN_ASYNC_MTU	300	Byte	minimum asynchronous payload in bytes including all headers (exclusive the Ethernet header)
C_DLL_MIN_PAYL_OFFSET	45	Byte	minimum offset of Ethernet frame payload
C_DLL_MULTICAST_AMNI	01-11-1E-00-00-05	--	POWERLINK Active Managing Node Indication, canonical form. Used by EPSG DS302-A [1]
C_DLL_MULTICAST_ASND	01-11-1E-00-00-04	--	POWERLINK ASnd multicast MAC address, canonical form
C_DLL_MULTICAST_PRES	01-11-1E-00-00-02	--	POWERLINK PRes multicast MAC address, canonical form
C_DLL_MULTICAST_SOA	01-11-1E-00-00-03	--	POWERLINK SoA multicast MAC address, canonical form
C_DLL_MULTICAST_SOC	01-11-1E-00-00-01	--	POWERLINK Soc multicast MAC address, canonical form
C_DLL_PREOP1_START_CYCLES	10	--	number of unassigning SoA frames at start of NMT_MS_PRE_OPERATIONAL_1
C_DLL_T_BITTIME	10	ns	Transmission time per bit on 100 Mbit/s network
C_DLL_T_EPL_PDO_HEADER	10	Byte	size of PReq and PRes POWERLINK PDO message header (see 4.6.1.1.3 and 4.6.1.1.4)
C_DLL_T_ETH2_WRAPPER	18	Byte	size of Ethernet type II wrapper consisting of header and checksum (see 4.6.1.1.1)
C_DLL_T_IFG	960	ns	Ethernet Interframe Gap
C_DLL_T_MIN_FRAME	5120	ns	Size of minimum Ethernet frame (without preamble and start-of-frame-delimiter)
C_DLL_T_PREAMBLE	640	ns	Size of Ethernet frame preamble plus start-of-frame-delimiter
C_ERR_MONITOR_DELAY	10		Error monitoring start delay

Name	Value	Unit	Description
C_IP_ADR_INVALID	00 00 00 00h	--	invalid IP address (0.0.0.0) used to indicate no change
C_IP_INVALID_MTU	0	Byte	invalid MTU size used to indicate no change
C_NMT_STATE_TOLERANCE	5	Cycles	maximum reaction time to NMT state commands
C_NMT_STATREQ_CYCLE	5	sec	StatusRequest cycle time to be applied to AsyncOnly CNs
C_SDO_EPL_PORT	3819	--	port to be used POWERLINK specific UDP/IP frames
C_SDO_CMDLAYERTIMEOUT	30000	ms	Command layer timeout
C_SDO_SEQULAYERNOACK	2	--	Number of acknowledge requests
C_SDO_SEQULAYERTIMEOUT	15000	ms	Sequence layer timeout

General Purpose Constant names are created according to the following rules:

Name shall be in accordance to IEC 61131-3. It consists of:

- *General Purpose Constant identification prefix “C_”*
- *domain prefix, indicating the association of the object to a functional domain,*
  3 uppercase characters followed by underline
- *name (verbally).*
  composed of words, words are separated by underline, upperchase characters only, no spaces

App. 3.9 Error Code Constants

Name	Value	Description
	816xh	HW errors
E_DLL_BAD_PHYS_MODE	8161h	
E_DLL_COLLISION	8162h	
E_DLL_COLLISION_TH	8163h	
E_DLL_CRC_TH	8164h	
E_DLL_LOSS_OF_LINK	8165h	
E_DLL_MAC_BUFFER	8166h	
	82xxh	Protocol errors
E_DLL_ADDRESS_CONFLICT	8201h	
E_DLL_MULTIPLE_MN	8202h	
	821xh	Frame size errors
E_PDO_SHORT_RX	8210h	
E_PDO_MAP_VERS	8211h	
E_NMT_ASND_MTU_DIF	8212h	
E_NMT_ASND_MTU_LIM	8213h	
E_NMT_ASND_TX_LIM	8214h	
	823xh	Timing errors
E_NMT_CYCLE_LEN	8231h	
E_DLL_CYCLE_EXCEED	8232h	
E_DLL_CYCLE_EXCEED_TH	8233h	
E_NMT_IDLE_LIM	8234h	
E_DLL_JITTER_TH	8235h	
E_DLL_LATE_PRES_TH	8236h	
E_NMT_PREQ_CN	8237h	
E_NMT_PREQ_LIM	8238h	
E_NMT_PRES_CN	8239h	
E_NMT_PRES_RX_LIM	823Ah	
E_NMT_PRES_TX_LIM	823Bh	

	$824x_h$	Frame errors
E_DLL_INVALID_FORMAT	8241_h	
E_DLL_LOSS_PREQ_TH	8242_h	
E_DLL_LOSS_PRES_TH	8243_h	
E_DLL_LOSS_SOA_TH	8244_h	
E_DLL_LOSS_SOC_TH	8245_h	
E_DLL_LOSS_STATUSRES_TH	8246_h	
	$84xx_h$	Boot-up Errors
E_NMT_BA1	8410_h	
E_NMT_BA1_NO_MN_SUPPORT	8411_h	
E_NMT_BPO1	8420_h	
E_NMT_BPO1_GET_IDENT	8421_h	
E_NMT_BPO1_DEVICE_TYPE	8422_h	
E_NMT_BPO1_VENDOR_ID	8423_h	
E_NMT_BPO1_PRODUCT_CODE	8424_h	
E_NMT_BPO1_REVISION_NO	8425_h	
E_NMT_BPO1_SERIAL_NO	8426_h	
E_NMT_BPO1_CF_VERIFY	8428_h	
E_NMT_BPO1_SW_INVALID	8429_h	
E_NMT_BPO1_SW_STATE	$842A_h$	
E_NMT_BPO1_SW_UPDATE	$842B_h$	
E_NMT_BPO1_SW_REJECT	$842C_h$	
E_NMT_BPO2	8430_h	
E_NMT_BRO	8440_h	
E_NMT_WRONG_STATE	8480_h	

Error Code Constant names are created according to the following rules:

Name shall be in accordance to IEC 61131-3. It consists of:

- *Error Code Constant identification prefix “E_”*
- *domain prefix, indicating the association of the object to a functional domain,*
  3 uppercase characters followed by underline
- *name (verbally).*
  composed of words, words are separated by underline, upperchase characters only, no spaces

App. 3.10 SDO Abort Codes

Name	Abort code	Description
	0503 0000h	reserved
	0504 0000h	SDO protocol timed out.
	0504 0001h	Client/server Command ID not valid or unknown.
	0504 0002h	Invalid block size.
	0504 0003h	Invalid sequence number.
	0504 0004h	reserved
	0504 0005h	Out of memory.
	0601 0000h	Unsupported access to an object.
	0601 0001h	Attempt to read a write-only object.
	0601 0002h	Attempt to write a read-only object.
	0602 0000h	Object does not exist in the object dictionary.
	0604 0041h	Object cannot be mapped to the PDO.
E_PDO_MAP_OVERRUN	0604 0042h	The number and length of the objects to be mapped would exceed PDO length.
	0604 0043h	General parameter incompatibility.
E_NMT_INVALID_HEARTBEAT	0604 0044h	Invalid heartbeat declaration
	0604 0047h	General internal incompatibility in the device.
	0606 0000h	Access failed due to an hardware error.
	0607 0010h	Data type does not match, length of service parameter does not match
	0607 0012h	Data type does not match, length of service parameter too high
	0607 0013h	Data type does not match, length of service parameter too low
	0609 0011h	Sub-index does not exist.
	0609 0030h	Value range of parameter exceeded (only for write access).
	0609 0031h	Value of parameter written too high.
	0609 0032h	Value of parameter written too low.
	0609 0036h	Maximum value is less than minimum value.
	0800 0000h	General error
	0800 0020h	Data cannot be transferred or stored to the application.
	0800 0021h	Data cannot be transferred or stored to the application because of local control.
	0800 0022h	Data cannot be transferred or stored to the application because of the present device state.
	0800 0023h	Object dictionary dynamic generation fails or no object dictionary is present (e.g. object dictionary is generated from file and generation fails because of a file error).
E_CFM_DATA_SET_EMPTY	0800 0024h	EDS, DCF or Concise DCF Data set empty

The abort codes not listed here are reserved.

App. 4 Data Sheet Requirements (normative)

The hardware used to implement POWERLINK devices may be spread over a broad range of amount of resources as well as calculation power. These differences result in highly different reaction times and buffer sizes affecting the POWERLINK communication timing.

In order to give a compact overview to the project engineer, each manufacturer of a POWERLINK device shall provide a short data sheet displaying critical device properties.

- For CN devices, the data sheet shall provide the following parameters:
  - POWERLINK cycle time
    - minimum value, if device supports adjustment over a continuous range
    - list of values, if device supports discrete values only
  - size of isochronous transmit buffer (maximal size of isochronous frames)
  - size of isochronous receive buffer (maximal size of isochronous frames)
  - overall buffer size available for isochronous data
  - PReq to PRes latency (CN isochronous reaction time)
  - SoA to ASnd latency (CN asynchronous reaction time)
  - maximum asynchronous MTU
  - ability to support multiplexed isochronous access
  - asynchronous SDO transfer method (UDP/IP and/or POWERLINK ASnd)
- For MN devices, the data sheet shall provide the following parameters:
  - POWERLINK cycle time
    - minimum value, if device supports adjustment over a continuous range
    - list of values, if device supports discrete values only
  - size of isochronous transmit buffer (maximal size of isochronous frames)
  - size of isochronous receive buffer (maximal size of isochronous frames)
  - overall buffer size available for isochronous data
  - minimum transmit-to-transmit gap (controls sequence of MN frame transmission)
  - minimum receive-to-transmit gap (controls sequence of MN frame transmission)
  - maximum asynchronous MTU
  - ability to support multiplexed isochronous access

For devices that support CN and MN, both parameter lists shall be independently provided.

End of File