Ethernet POWERLINK (DRAFT)

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June 16^{th}, 2011

- Object dictionary.
- Access to device via service data (SDO).
- Commands.

NMT The network management.

- Nodes.
- Boot up

History

Ethernet Powerlink was first introduced as a proprietary protocol by B&R in the early years of this millennium. To gain wider acceptance of the B&R protocol by the market an “independent” association Ethernet Powerlink Standardization Group (EPSG) was founded in June 2003. *The focus of the group is to leverage the advantages of Ethernet for high performance Real-Time networking systems based on the Ethernet POWERLINK Real-Time protocol. Various working groups are focusing on different tasks like safety, technology, marketing, certification and end users. The EPSG is cooperating with standardization bodies and associationns, like the CAN in Automation (CiA) Group and the IEC.*[5]

Real time computing

In computer science, real-time computing (RTC), or reactive computing, is the study of hardware and software systems that are subject to a "real-time constraint" i.e., operational deadlines from event to system response. Real-time programs must execute within strict constraints on response time. [1, page 164, chapter 16]

Why is TCP/IP over Ethernet not sufficent for (fast) real time systems?

The main reason lies within the architecture:

- On the physical link layer CSMA/CD (Carrier Sense Multiple Access/Collision Detection) does not prevent random jamming of time critical messages or commands.

After a station detects a collision, it aborts its transmission, waits a random period of time, and then tries again, assuming that no other station has started transmitting in the meantime. Therefore, our model for CSMA/CD will consist of alternating contention and transmission periods, with idle periods occurring when all stations are quiet (e.g., for lack of work).[3]

The constraints to the RT-system

Let us think of a system that provides the following functionality.

- 240 Network devices in one network segment.
- Deterministic communication must be guaranteed.
- Less than 200μs cycle time.
- Based on the Ethernet framework.

In mathematics, a deterministic system is a system in which no randomness is involved in the development of future states of the system.[4] *A deterministic model will thus always produce the same output from a given starting condition or initial state.*[4]

The problem with Ethernet IEEE 802.3 in half duplex mode.

The slot time of an 100MB Ethernet is $t_{slot} \approx 5\mu s$.
It is twice the time it takes for an electronic pulse (OSI Layer 1 - Physical) to travel the length of the maximum theoretical distance between two nodes. In CSMA/CD networks such as ethernet, Network Interface Controllers (NICs) wait a minimum of the slot time (which should be a constant, NOT dependent on the individual network -ie, it is a standard across all CSMA/CD networks that use a common NIC) before transmitting, allowing time (the maximum theoretical time - slot time) for the pulse to reach the NIC that intends to send.[6]

The problem with Ethernet IEEE 802.3 in half duplex mode, cont'd

Let us say that a time critical message via package p_m of station A must fight its way through the CSMA/CD network to station B. Imagine that in coincidence all 238 stations try to send to station B. Station A might not be able to send the package and receive the proper ACK from B for more than 476 times the slot time, as every other station awaits also an acknowledge package as each acknowledgement package itself must fight its way through the CSMA/CD network. **The odds on such bad timing are very poor, but it may happen.**

$$t_{pm} > stations * 2 * t_{slot} \approx 2.4ms \gg 200\mu \qquad (1)$$

And the $200\mu s$ cycle time must include all 240 stations (not only A)!

One ring to rule them all.

Possible Solutions?

- Token Ring Network (Daisy Chain Ethernet?!?)

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- Token Ring Network (Daisy Chain Ethernet?!?)
- Ethernet in FullDuplex mode (CSMA-CD deactivated, switched Network). **One to many** or **many to one** may result in the same timing problem as with CSMA-CD as the switch must queue and deliver(divert) all messages.

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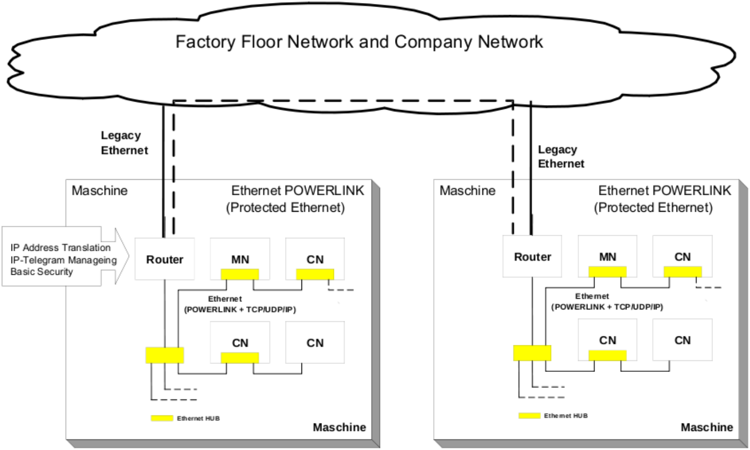
- Parallel transmission of IP-based protocols.
- Use of conventional hardware is possible.

Integration of POWERLINK into IT infrastructure.



[2, page 28, chapter]

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- Power Link mode
- Basic Ethernet mode (CSMA-CD, non deterministic)

Power Link mode.

- In POWERLINK Mode network traffic follows the set of rules given by standard for Real-time Ethernet communication ([2, EPSG 301]).
- **POWERLINK Managing Node (MN)** manages Network access.
- A **Client Node (CN)** 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. [2, page 40, chapter 4.1]

The 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.[2, page 40, chapter 4.1]

Isochrounous POWERLINK Cycle

Isochronous data exchange between nodes shall occur cyclically.
It shall be repeated in a fixed interval, called POWERLINK cycle.
Each cycle consists of several phases:

- The Isochrounous phase.

[2, page 42, chapter 4.2.1]

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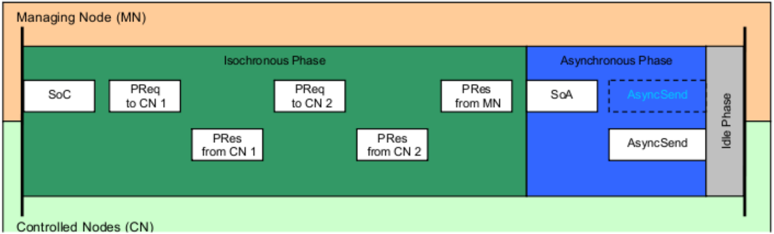
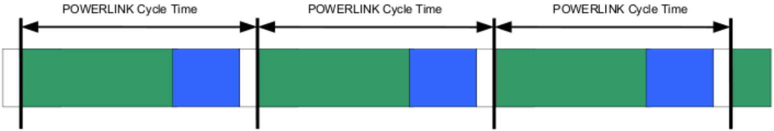
- The Idle phase.

[2, page 42, chapter 4.2.1]

Isochrounous POWERLINK Cycle



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.[2, page 42, chapter 4.1]



Frames (isochronous).

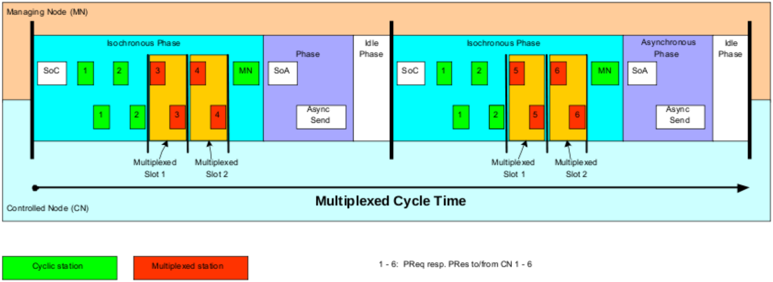
- SoC (Start of Cycle) is a mutlicast Ethernet frame generated on a periodc basis.
- PReq (Poll request, shall be sent to every configured and active NC. (unicast only).
- PRes (Poll response, The response of an accessed CN. (may be reviewed by all Nodes)

The PReq / PRes procedure shall be repeated for each configured and active isochronous CN. When all configured and active isochronous CNs have been processed, the MN may send a multicast PRes frame to all nodes. This frame is dedicated to transfer data relevant for groups of CNs. [2, page 42]

Multiplexed Timeslots

POWERLINK supports CN communication classes, that determine the cycles in which nodes are to be addressed. This leeds us to the multiplexed cycle time and we do get two types of stations.

- Cyclic stations.
- Multiplexed stations.



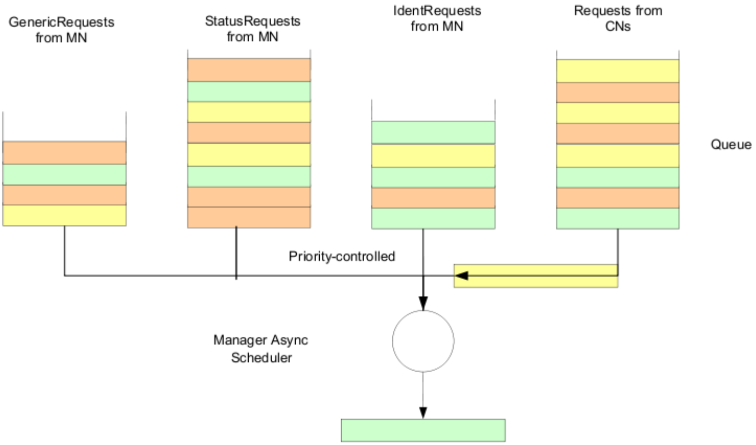
Frames (asynchronous).

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**.

- SoA Start of asynchronous send.
- ASend Asynchronous send frame.

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.[2, page 45, chapter 4.2.2.1.]

Asynchronous Scheduling.



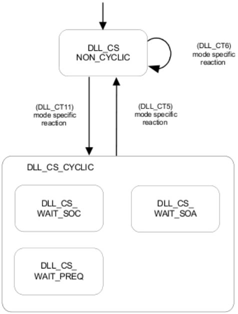
Asynchronous Transmit Priorities.

Asynchronous transmit requests may be prioritized by 3 PR bits in the PRes, the IdentResponse and StatusResponse frame.[2, page 45, chapter 4.2.] 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.

Network States (p59ff)

There are several “Cycle State Machines” defined for CN nodes and MN node. They manage the communication within a POWERLINK cycle. Each cycle state machine is bound to the NMT status (such as initialization, pre operational, operational). Example: State machine of CN (NMT_GS_INITIALISATION, NMT_CS_NOT_ACTIVE, NMT_CS_PRE_OPERATIONAL_1, NMT_CS_BASIC_ETHERNET)



Active nodes management and ID's

Each Node shall have a unique POWERLINK Node ID.

- The MN shall be configured with a list of all nodes on the network (Node ID = 240_d).
- POWERLINK Node ID $1_d - 239_d$ may be used for CN.
- The Powerlink ID is either set by the application process or is set on the device.

[2, page 69, chapter 4.5]

POWERLINK Node ID assignment.

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 adress 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

[2, page 70]

MAC addressing.

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

- `MAC Unicast` The high order bit of the MAC is 0 (unicast address, should be globally unique.)
- `MAC Multicast` For group addresses the high-order bit of the MAC address is 1. Registered nodes to group address will receive it.

	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

Integration with Ethernet.

- POWERLINK resides on top of 802.3 MAC layer.
- Messages are encapsulated in Ethernet II frames. (Ethernet type field = $88AB_h$).
- 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.

[2, page 70, chapter 4.6]

The basic POWERLINK frames.

	Bit Offset								entry defined by
Octet Offset [4]	7	6	5	4	3	2	1	0	
0 .. 5	Destination MAC Address								Ethernet 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 II

C_DLL_MIN_PAYL_OFFSET+14 ≤ n ≤ C_DLL_MAX_PAYL_OFFSET+14

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	

The start of cycle (SOC) frame.

	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	relti me	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.	

The poll request (PReq) frame.

	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 NodeID
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. An 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	

The poll response (PRes) frame.

	Bit Offset							
Octet Offset [9]	7	6	5	4	3	2	1	0
0	res	MessageType						
1	Destination							
2	Source							
3	NMTStatus							
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

PRes shall be transmitted using the multicast MAC address

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 NodeID
NMTStatus	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	

Start of asynchronous (SoA) frame.

Octet Offset [12]	Bit Offset 7	6	5	4	3	2	1	0
0	res	MessageType						
1	Destination							
2	Source							
3	NMTStatus							
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
NMTStatus	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).	

Asynchronous send (SoA) frame.

	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 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, multicast or broadcast MAC address (See 4.4).

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	

Possible sources of errors.

The data link error handling forms the basis for diagnosis. The real error source often can only be detected by analysing and interpreting multiple error symptoms. [2, page 77, chapter 4.7]

- Physical layer error sources.
  - Loss of link.

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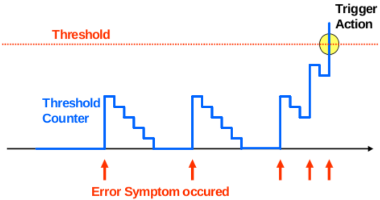
  - Timing Violation (late response).

Error handling.

There are of course a lot of strategies to deal with errors. On each node exists an error history where the occoured error symptoms are stored.
The symptoms are classified and do have a corrsponding error count. Errors detected on the MN are often to be seen more critical than some errors on the CNs. Such as Timing violations on MN's side wich are critical due to cycletime consistency compared to CRC errors of SoAs received by a CN. (Which than can be logged into CN error history and the frame beeing ignored). [2, page 81, chapter 4.7]

Error threshold counters. I



- 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.

Error threshold counters. II

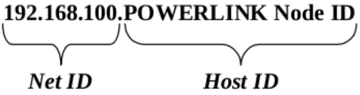
- All kinds of POWERLINK cycle,e.g. reduced and isochronous cycle, shall decrement threshold counters. Async-only and multiplexed nodes shall decrement at every cycle but not only to cycles adressing them.
- The threshold value shall be configurable.
- Immediate error reaction shall be commanded by a 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.

A lot of error handling strategies are formulated but more details woudld break the mould.

Internet Protocol

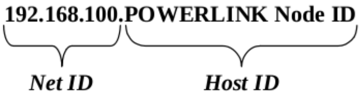
The IP (UDP and TCP) protocols are prefered for the asynchrounous phase.

- Each IP-capable POWERLINK node posseses an IPv4 address, subnet mask and default gateway.
- The private class C Net ID 192.168.100.0 shall be used for a POWERLINK network see RFC1918.



- Each IP capable POWERLINK node shall have a hostname.

Internet Protocol



- A class C network provides $254(1-254)$ IP addresses, which matches the number of valid POWERLINK Node IDs.
- The Host ID of the private class C Net ID 192.168.100.0 shall be identical to the POWERLINK Node ID.
- The last byte of the IP address (Host ID) has the same value as the POWERLINK Node ID.
- The subnet mask of a POWERLINK node shall be 255.255.255.0 This is the subnet mask of a class C net.
- The Default Gateway preset shall use the IP address 192.168.100.254. The value may be modified to another valid IP address.

UDP/IP format

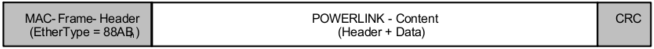
In order to enable the transmission of POWERLINK frames encapsulated in UDP/IP frames, the payload portion of the UDP/IP frame shall be leaded by a slightly modified POWERLINK frame header. [2, page 117, chapter 5.2]

	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

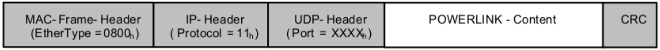
$n \geq 59$

POWERLINK embedded into Ethernet frame.

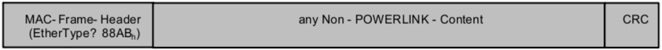
The Powerlink frame follows the rules of IEEE 802.3.



as well as the POWERLINK compliant UDP/IP frame and the



legacy ethernet frame structure.



[2, page 118, chapter 6.1]

Data type definitions.

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). Generic data types like unsigned integer, bit, boolean, time, date, strings are defined as well as MAC address, IP address and compound data types (structs, arrays, etc.).[2, page 120, chapter 6.1]

Data type definition examples.

```
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'
```

The object dictionary.

Object dictionariy structures and their entries are common to all devices. An object dictionary entry is defined by:

- Index
- Object type
- Name
- Data type
- Catagory

Further more, for static data types following on next page...

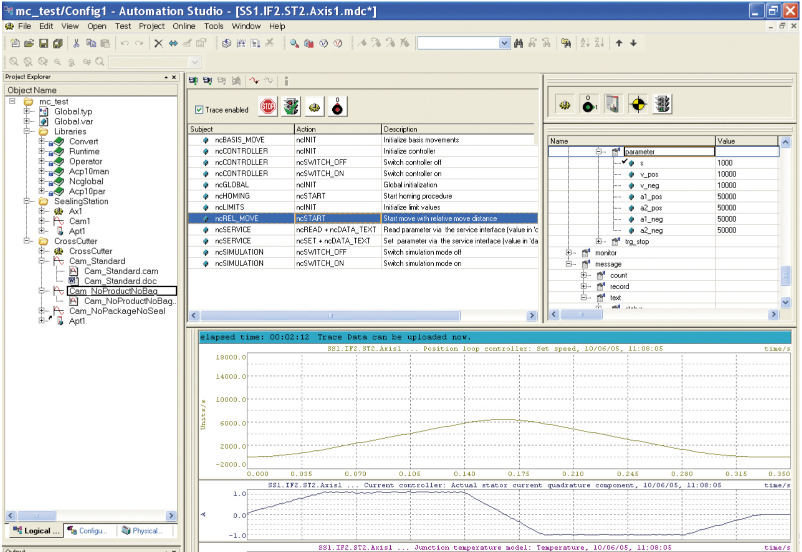
The object dictionary.

- Access (rw, wo, ro, const, cond-¿variable access controlled by device)
- Value Range
- Default Value
- PDO Mapping (Process Data Object)
- Category
- Data type

Sub indexing and complex object types.

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.

Automation Studio example.

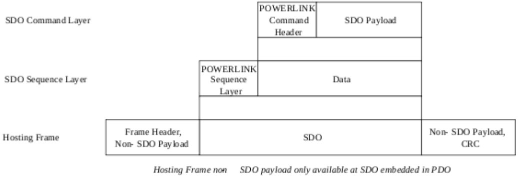


SDO layer model.

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.[2, page 131, chapter 6.3.2]

Ethernet POWERLINK provides three SDO transfer methods:

- SDO transfer via UDP/IP frames in asynchronous phase



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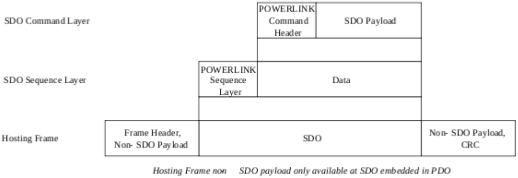
Ethernet POWERLINK provides three SDO transfer methods:

- SDO transfer via UDP/IP frames in asynchronous phase
- SDO transfer via POWERLINK ASnd frames in asynchronous phase

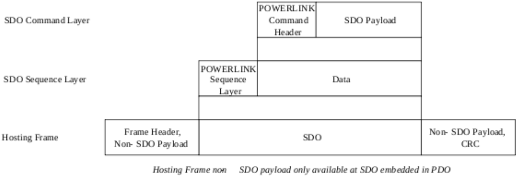


SDO layer model.

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.[2, page 131, chapter 6.3.2]

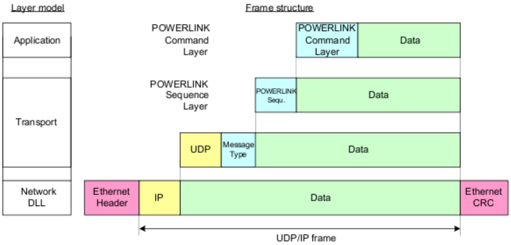
Ethernet POWERLINK provides three SDO transfer methods:

- SDO transfer via UDP/IP frames in asynchronous phase
- SDO transfer via POWERLINK ASnd frames in asynchronous phase
- SDO embedded in PDO in isochronous phas



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.[2, page 131, chapter 6.3.2]



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.[2, page 134, chapter 6.3.3]

Asynchronous SDO Command Layer. I

Tasks of the POWERLINK Command Layer:

- Addressing of the parameters, e.g. via index/sub-index or via name
- Provide additional services.
- 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

Asynchronous SDO Command Layer. II

(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.[2, page 140, chapter 6.3.2]

POWERLINK Command Layer Protocol.

The POWERLINK Command Layer is structured in the following way:

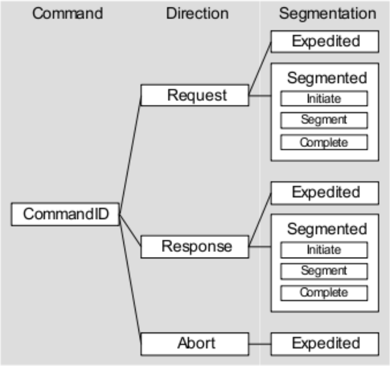
Byte Offset[16]	Bit Offset								
	7	6	5	4	3	2	1	0	
0	reserved								Fixed part
1	Transaction ID								
2	Res-ponse	Abort	Segmentation		reserved				
3	Command ID								
4 .. 5	Segment Size								
6 .. 7	reserved								
8 .. 11	Data Size (only if Segmentation = Initiate)								Variable part
(8 + 4*d) .. k-1	Command ID specific header								Command ID specific part
k .. 1465	Optional Payload Data								

k = Length of Command ID specific header; k < 1465
d: if seg = Initiate d = 1
else d = 0

For embedding of SDO in cyclic data (PollRequest and PollResponse) the first byte within POWERLINK Command Layer is reserved for Embedded Sequence Layer.

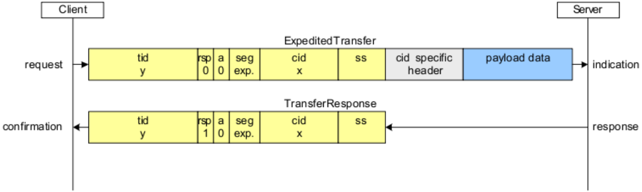
POWERLINK Command Layer .

The structure of the information in the POWERLINK Command Layer Header.



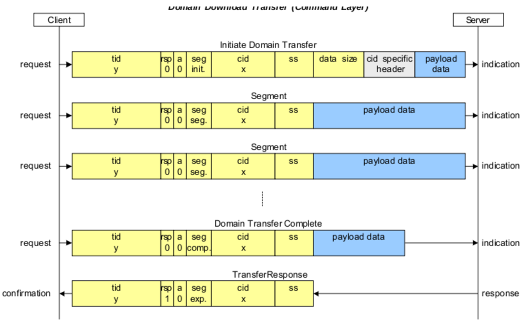
Download Protocol (Expedited download).

The download service is used by the SDO client to download data to the server (owner of the object dictionary). In an expedited download, the data identified by the cid specific header is transferred to the server.



Download Protocol (Domain download).

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 Transfer Complete frame.



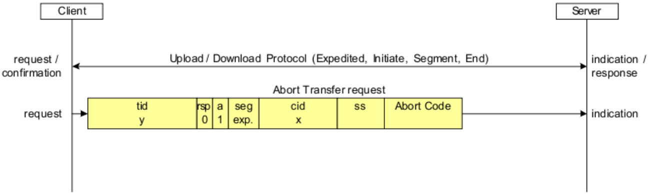
Upload protocol.

The Upload service is used by the SDO client to upload data from the server. It works analogous to the download protocol.

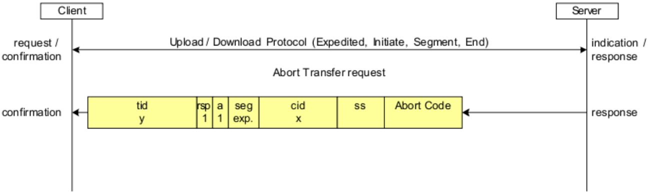
Abort and abort.

The Abort Transfer service aborts the up- or download referenced by the Transaction ID. The reason is indicated.

Abort Transfer Client → Server



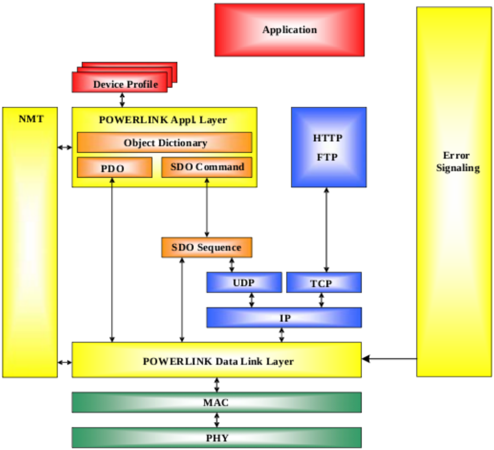
Abort Transfer Server → Client



Commands.

POWERLINK provides a set of commands to manipulate PDO's (Process Data Objects) of corresponding devices. To upload and download firmware to clients, configure them and control them. To enable file transfer, write multiple parameters by index, etc.

Reference model.



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.

Network Management Services. I

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.

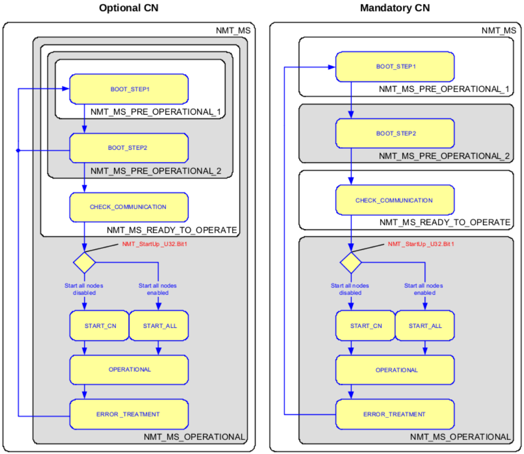
- MT State Command Services The MN uses NMT State Command Services to control the CN state machine(s).
- NMT Managing Command Services The MN uses NMT Managing Command Services to access NMT data items of the CN(s) in a fast coordinated way.
- NMT Response Services NMT Response Services indicate the 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.

Network Management Services. II

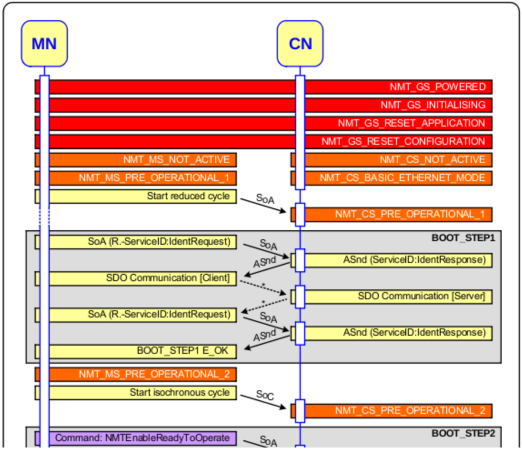
- NMT Guard services NMT Guard Services are used by the MN and CNs to detect failures in a POWERLINK network.

A CN may request NMT command and info services to be issued by the MN.

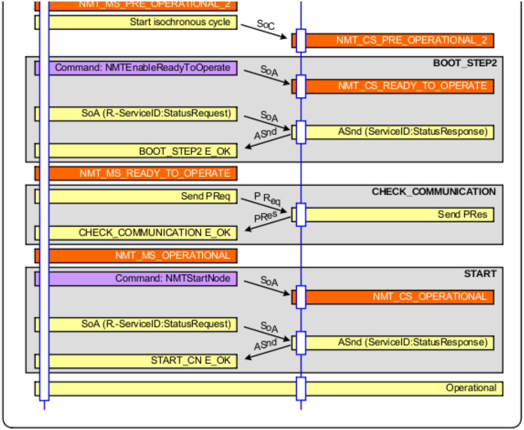
Bootup of optional and mandatory CNs.



Example Boot Up Sequence



Example Boot Up Sequence



Reference

All images are taken out of [2, EPSG 301] standard draft. It may occour that some frames do not show the proper citation, which than has been left out due to space concerns and to increase readability of the presentation. This presentation entirly depends on [2, EPSG 301].

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