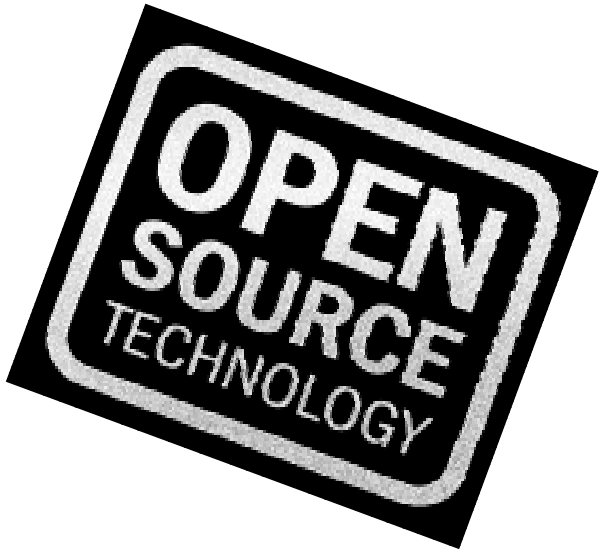
openPOWERLINK

Open Source Industrial Ethernet

CLT2010

Version V1.02 13.03.2010



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Limitations of Ethernet

- Non-determinism, because of collisions
- Carrier Sense Multiple Access/Collision Detection (CSMA/CD):
  retransmission after random time,
  transmission is not guaranteed

➔Possible solution: classic fieldbusses
like CAN, Profibus, LON, etc.

Limitation of classic fieldbusses

- Classic fieldbusses have a low bandwidth that is not sufficient for the higher demands of contemporary applications (e.g. for firmware updates)
- CAN: max. 1 Mbit/s
- LON: max. 78 kbit/s
- Profibus-DP: max. 12 Mbit/s
- Profibus-PA: max. 31.25 kbit/s

➔Solution: Industrial Ethernet
like POWERLINK, EtherCAT, Sercos III, Profinet IRT

Applications of Microcontroller Networks

- Central/decentral control or
  data capturing of decentral processes
- Data exchange between sensors and actuators
- Data capturing over large distances (>1km)
- Reducing the complexity of the wiring
- Typical applications:
  - industrial automation
  - automotive engineering, shipbuilding
  - building control, alarm systems
  - power plants
  - measurement engineering
  - ...

What is POWERLINK?

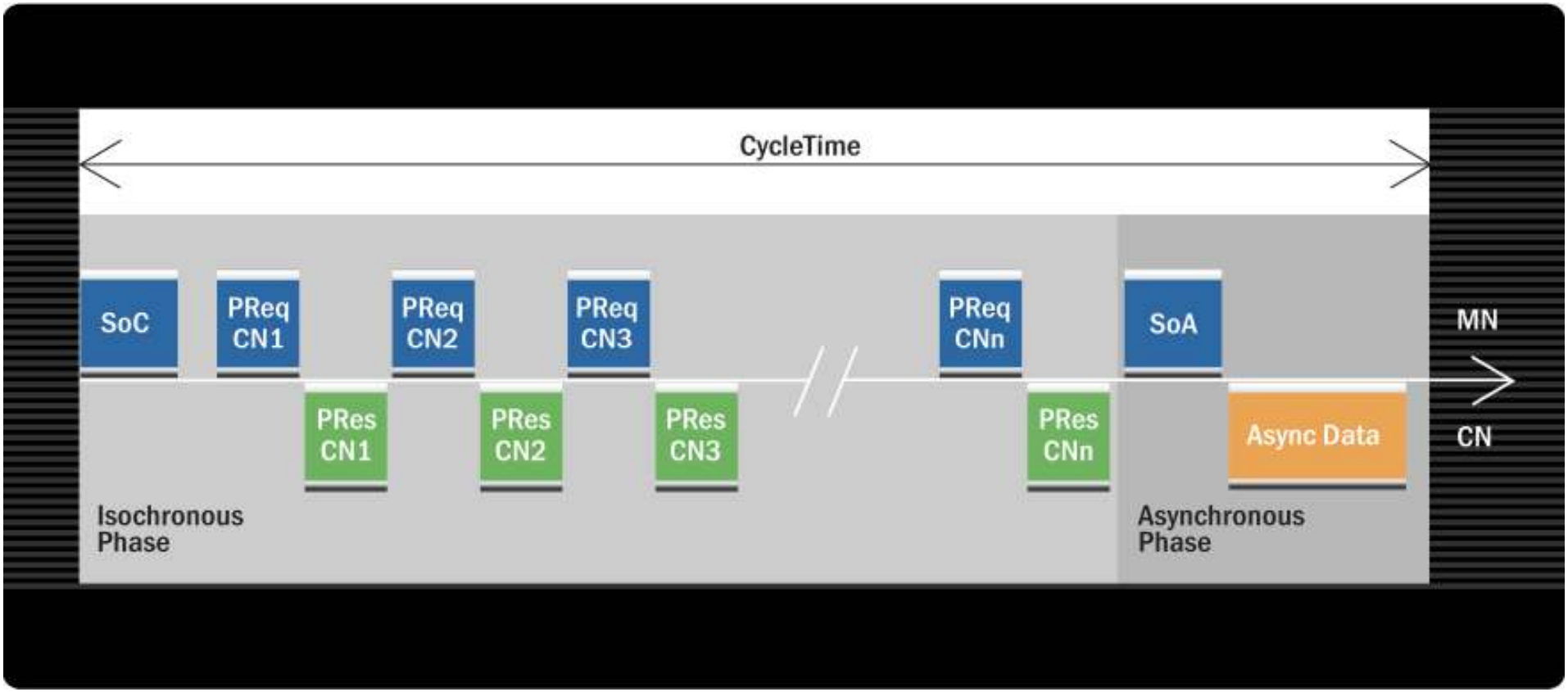
- *Industrial Ethernet* Fieldbus Protocol
- Based on IEEE 802.3u Fast Ethernet
- CANopen over Ethernet
- Real-time capable via slot communication
- Master-Slave Protocol
- Master = Managing Node (MN)
- Slave = Controlled Node (CN)
- Hot plugging
- Direct cross-traffic

What is openPOWERLINK?

- Open Source implementation of POWERLINK
- Development done by SYS TEC electronic GmbH
- Currently supported target platforms:
  - Linux
  - Windows
  - bare-metal (OS-less)
- License: BSD
- Pure software-based solution on standard Ethernet controllers, but hardware-acceleration possible

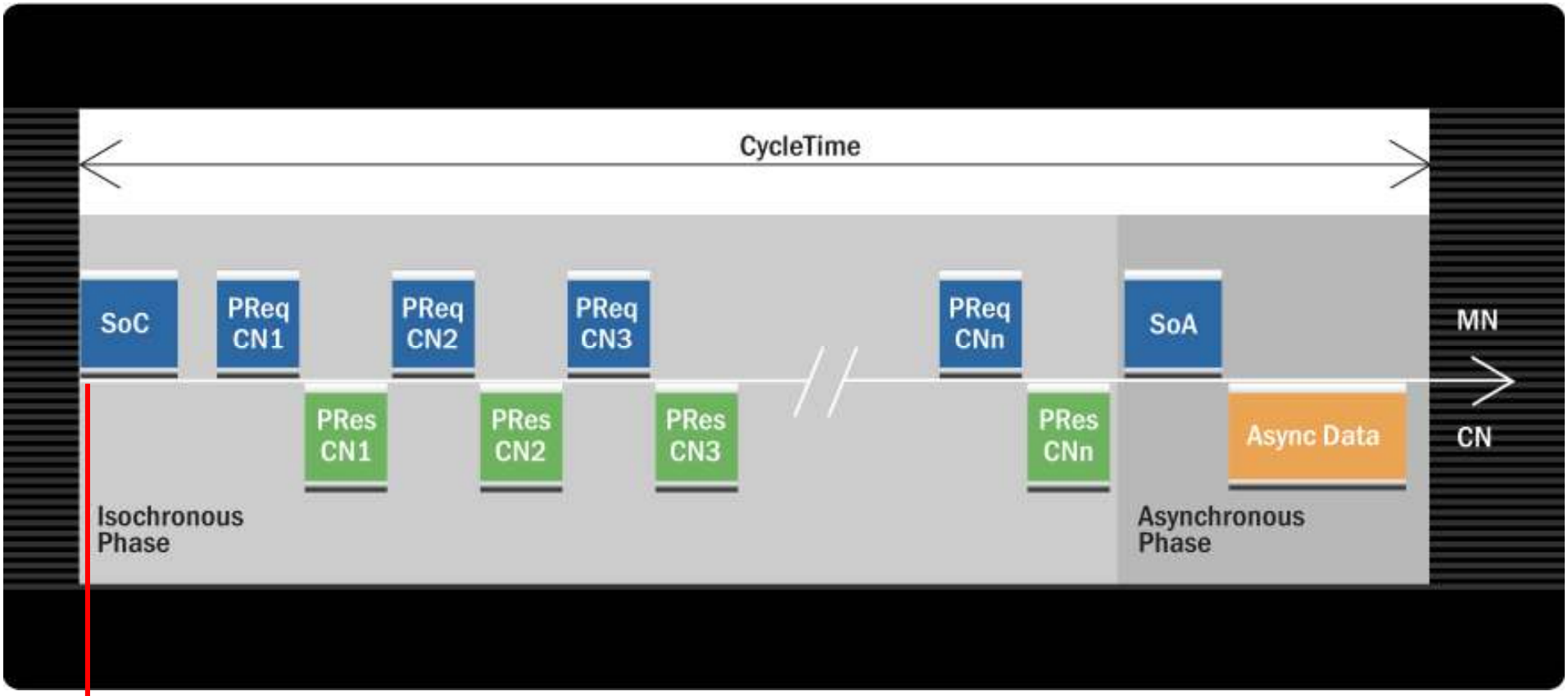
How does POWERLINK work?

Slot Communication Network Management



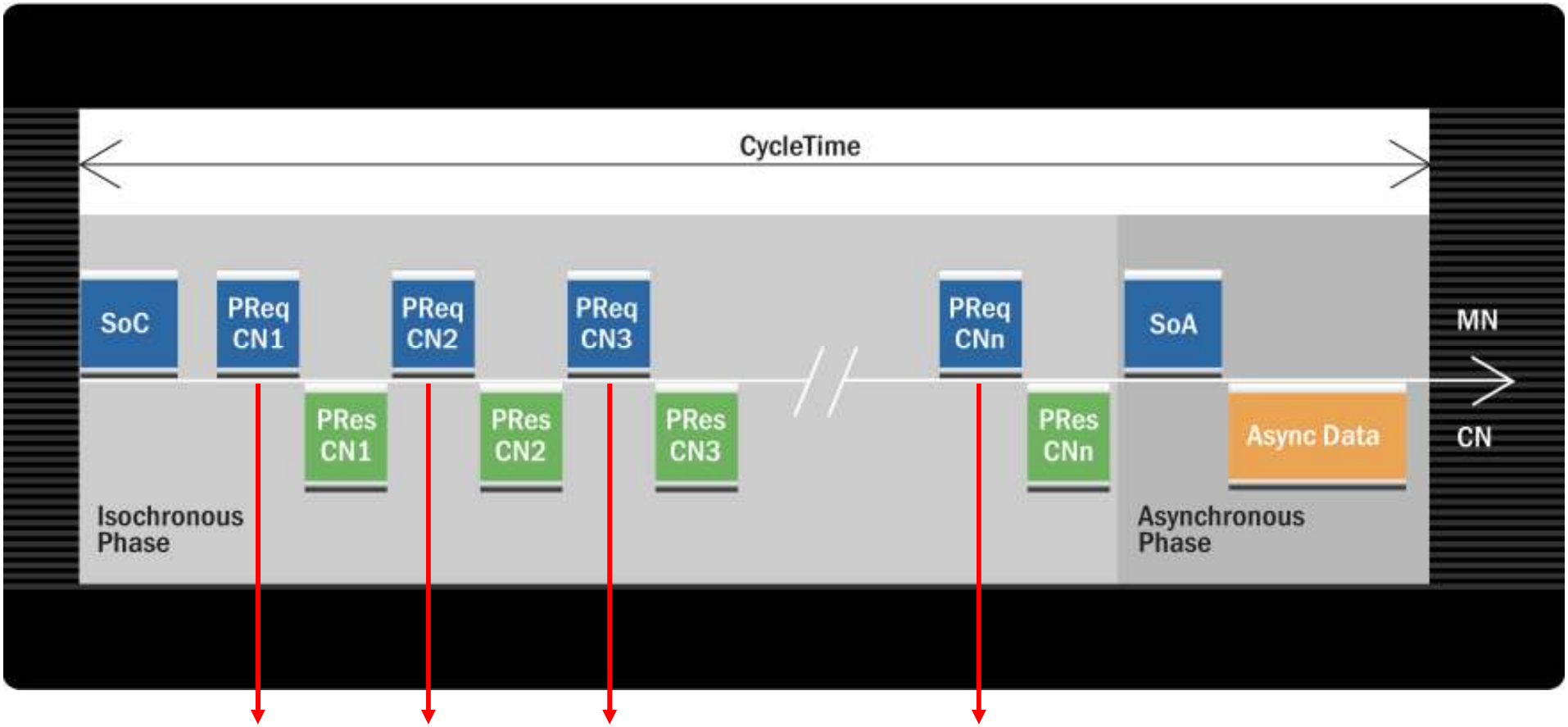
Demo (Wireshark)

SoC Frame



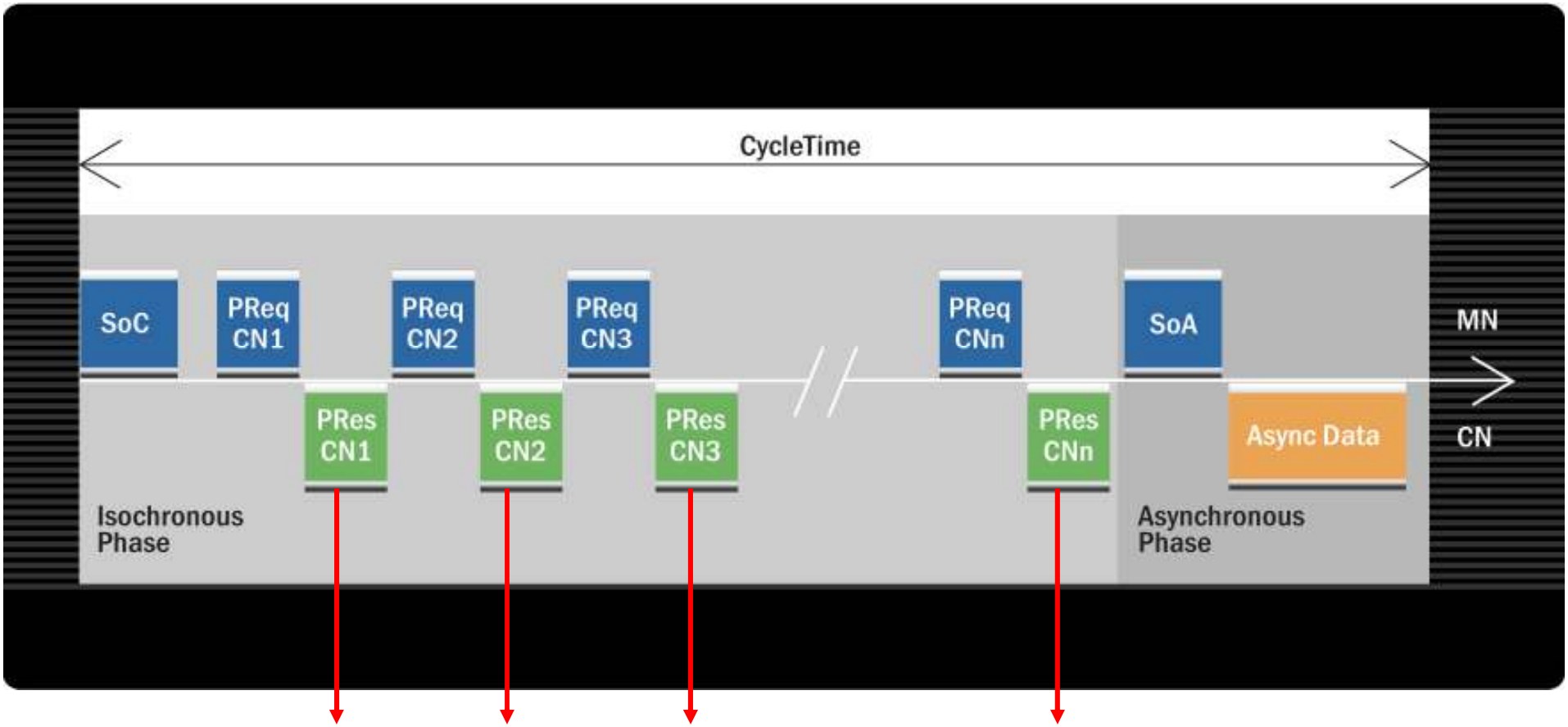
SoC: Start of Cycle synchronization event

PReq Frame



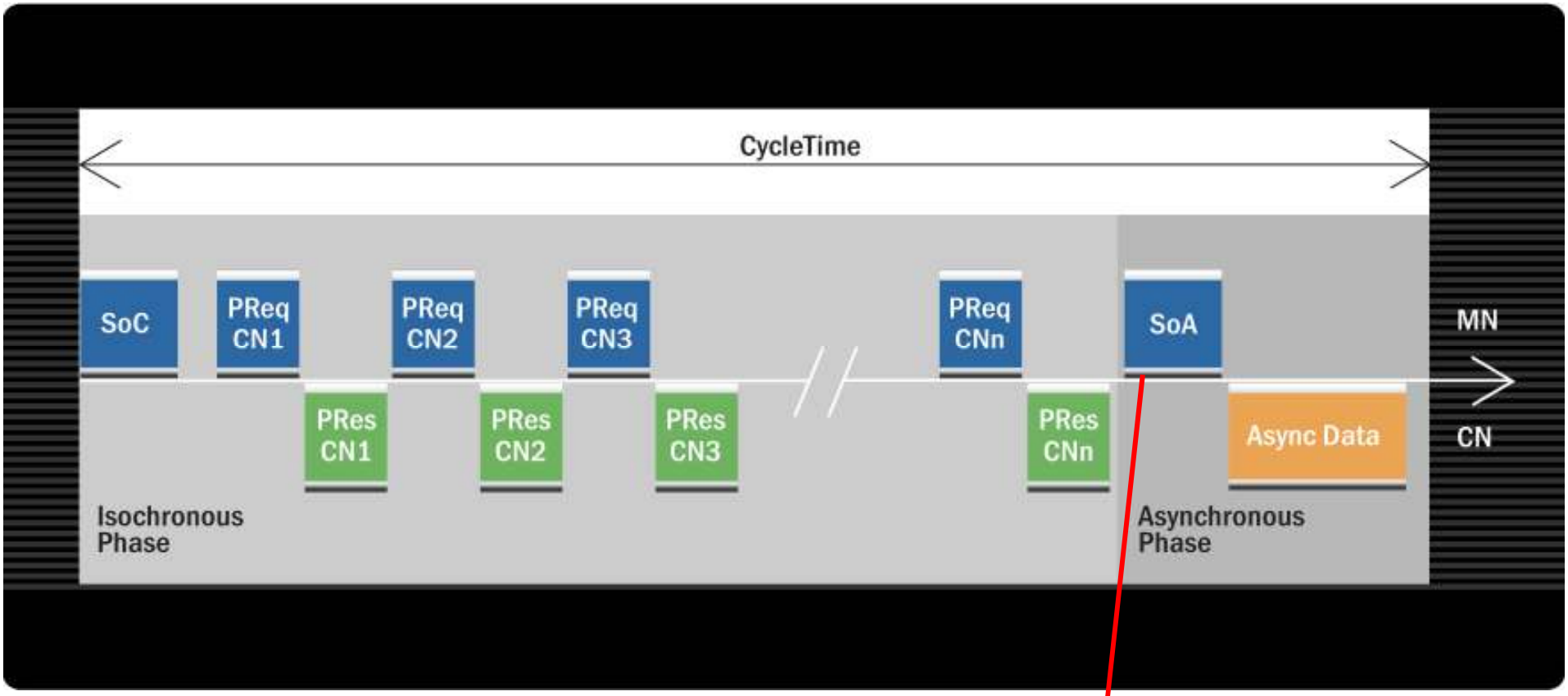
PReq: Poll Request from MN for specific CN contains PDO payload

PRes Frame



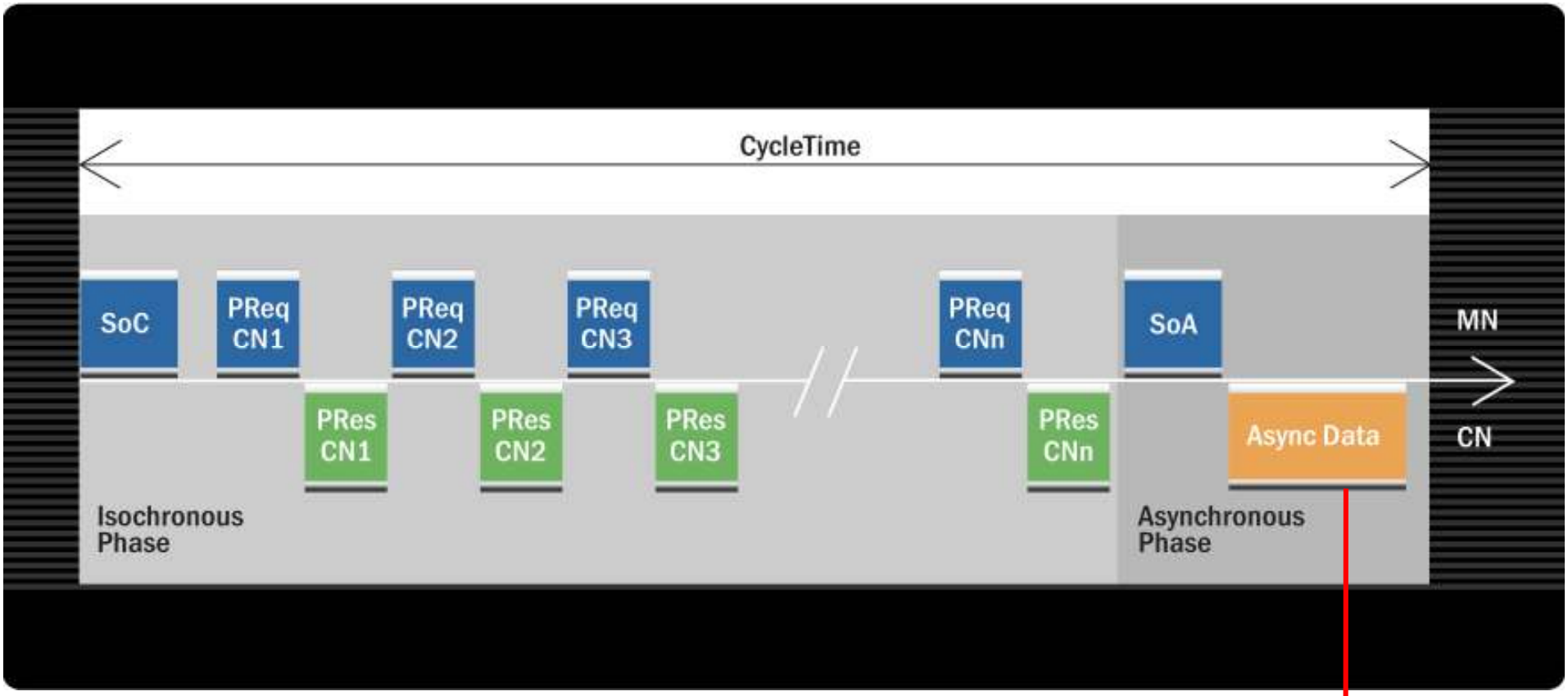
PRes: Poll Response from CN / MN
contains PDO payload and current NMT state

SoA Frame



SoA: Start of Asynchronous
assigns asynchronous phase to specific node

ASnd Frame

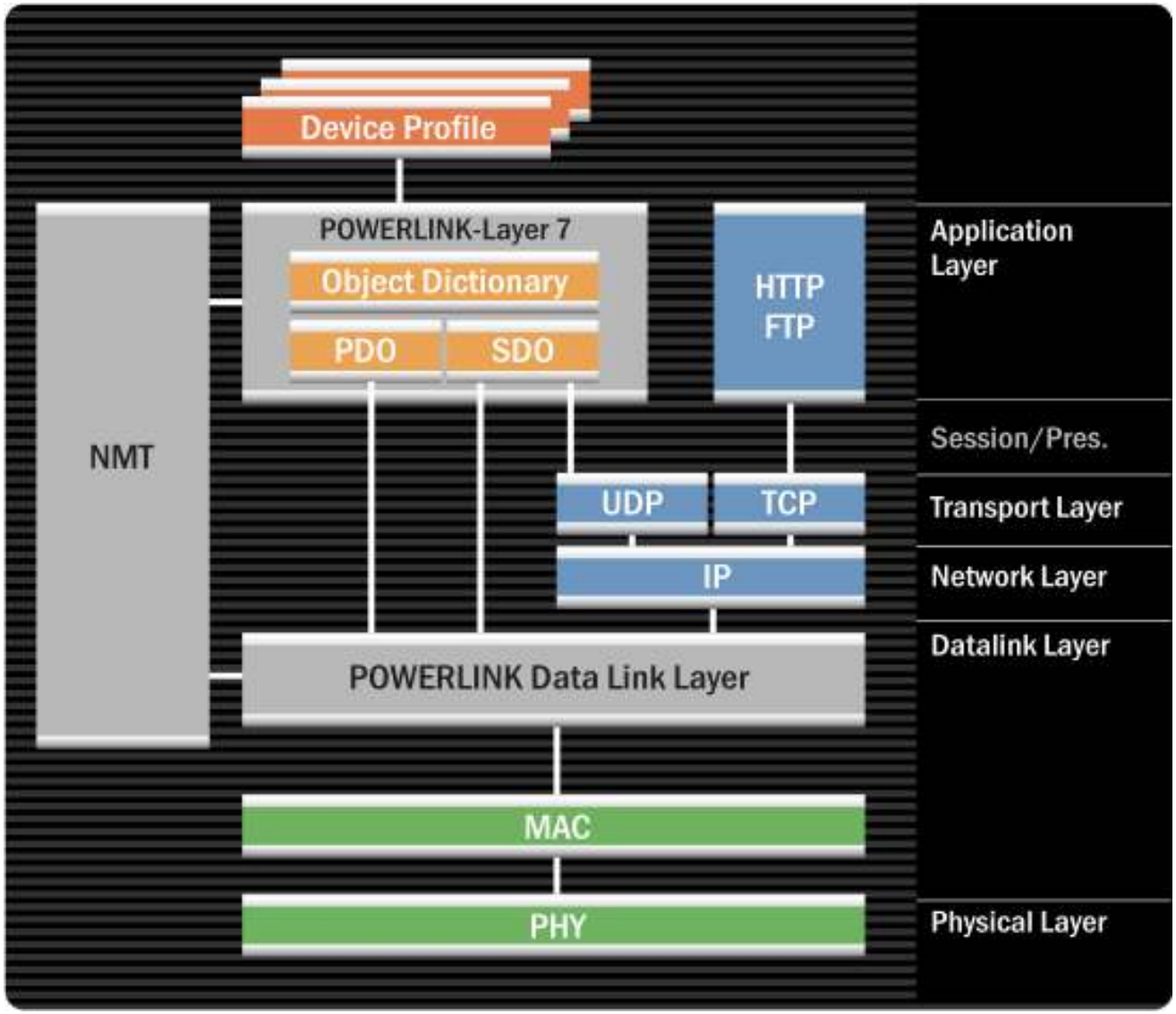


ASnd: Asynchronous Send

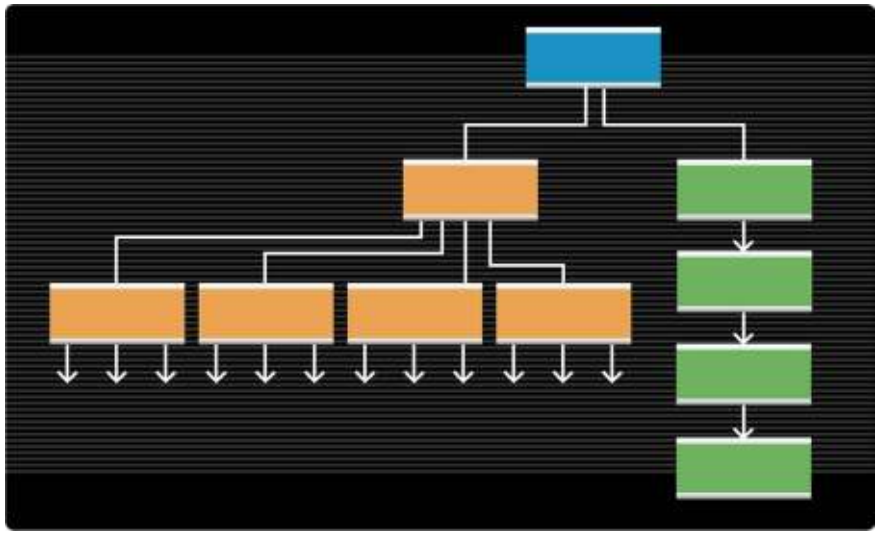
TCP/IP

NMT commands, SDO, IdentResponse, StatusResponse

OSI Model


Device Profile
POWERLINK-Layer 7
Object Dictionary
PDO
SDO
NMT
HTTP
FTP
UDP
TCP
IP
POWERLINK Data Link Layer
MAC
PHY
Application Layer
Session/Pres.
Transport Layer
Network Layer
Datalink Layer
Physical Layer

Topology



Possible Topologies:

- Star
- Line (daisy chain)
- Tree
- Mixed

Connectors:

- RJ45
- M12

Equipment:

- Hubs
- Switches

Node Addressing Scheme

- Unique Node-ID for each node in the network
- Node-ID of MN: 240 = 0xF0
- Node-ID of CNs: 1 – 239
- Node-ID of Gateway: 254
- Node-ID of diagnostic device: 253

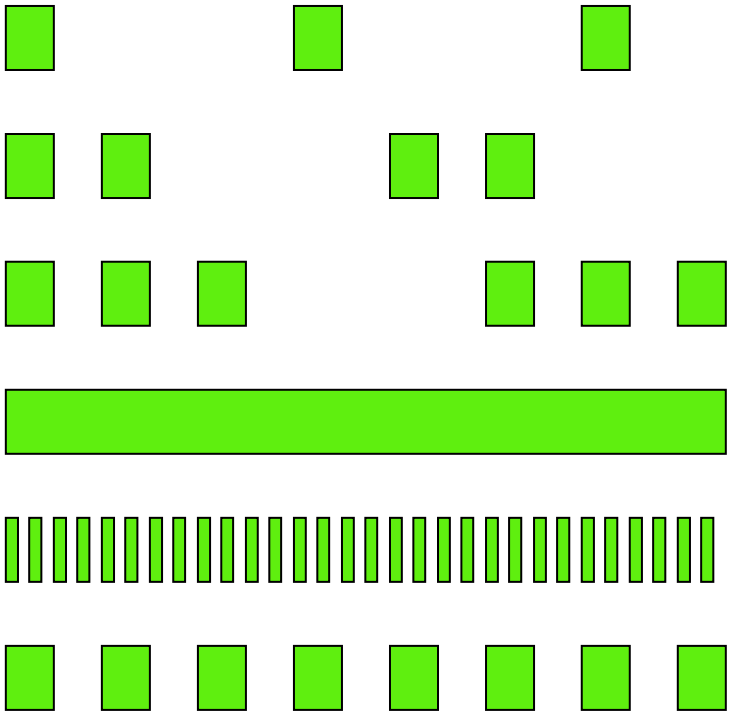
CN 48 = 0x30

Performance

- 0.1 µs system synchronization
- 100 µs cycle time
- up to 240 nodes in one network
  - 480 synchronized axes
  - 460.000 digital I/O data points
- Unlimited extension
  - 100 m between any two nodes
  - Larger distances using fiber optics

NMT States and Status LED

- Initialising
- Reset Application
- Reset Communication
- Reset Configuration
- Not Active
- Pre Operational 1
- Pre Operational 2
- Ready-To-Operate
- Operational
- *Basic Ethernet*
- *Stopped*



Boot-up Demo

Object Dictionary (3)

- Access rights: ro, rw, wo, const
- Device and application profiles of CANopen are used
- Overall layout according to specification:

Index	**Object**
0x0001 – 0x0FFF	Declaration of Data Types (formalism)
0x1000 – 0x1FFF	Communication Profile Area
0x2000 – 0x5FFF	Manufacturer Specific Profile Area
0x6000 – 0x9FFF	Standardised Device Profile Area
0xA000 – 0xBFFF	Standardised Interface Profile Area
0xC000 – 0xFFFF	Reserved for further use

Object Dictionary (4)

- XML Device Description (XDD):
  - Describes the structure of the OD (including default values) of a device type (e.g. I/O module from manufacturer ABC)
  - Is the basis for configuration tools
- XML Device Configuration (XDC):
  - Contains the current configuration of the OD of a specific device (e.g. I/O module at the left drive in the machine)
  - Generated by configuration tools
  - Concise Device Configuration (CDC): binary form of XDC
  - Used by the Configuration Manager (CFM) to configure the nodes in the network at run-time

OD Communication Profile

- 0x1000: NMT_DeviceType_U32
- 0x1006: NMT_CycleLen_U32
- 0x1018: NMT_IdentityObject_REC
  (VendorID, ProductCode, RevisionNo, SerialNo)
- 0x1400 .. 0x14FF: PDO_RxCommParam_XXh_REC
- 0x1600 .. 0x16FF: PDO_RxMappParam_XXh_AU64
- 0x1800 .. 0x18FF: PDO_TxCommParam_XXh_REC
- 0x1A00 .. 0x1AFF: PDO_TxMappParam_XXh_AU64
- 0x1CXX: Error counters
- 0x1F82: NMT_FeatureFlags_U32
- 0x1F98: NMT_CycleTiming_REC

CANopen Device/Application Profiles

- CiA 401: Generic I/O modules
- CiA 402: Drives and motion control
- CiA 404: Measuring devices and closed-loop controllers
- CiA 406: Encoders (rotating and linear)
- CiA 417: Lift control systems
- CiA 422: Municipal Vehicles (e.g. garbage trucks)
- CiA 445: RFID reader
- CiA 447: Special-purpose car add-on devices (e.g. in taxis)

Process Data Object (PDO)

- For exchange of process data between actuators, sensors and control
- Abstraction layer between source and sink (virtual cabling via variable mapping)
- Up to 1490 Bytes per Ethernet frame
- Structure is stored in OD and can be configured via SDO
- Communication model: Producer-Consumer(s)
- Cyclically transmitted in isochronous phase
- Direct cross-traffic between CNs is possible

PDO Mapping

Master to slave

Managing Node 0xF0

Process Variables:

0x2001/1	Output 1, 8 Bit, 0xAB
0x2001/2	Output 2, 8 Bit, 0xCD

Controlled Node 0x02

Process Variables:

0x6200/1	Output 1, 8 Bit, 0xCD
0x6200/2	Output 2, 8 Bit, 0xAB

Tx PDO Mapping Parameter:

0x1A00/0	NrOfEntries: 2
0x1A00/1	1. Mapped Object: 0x00800000012001LL
0x1A00/2	2. Mapped Object: 0x00800100022001LL

Rx PDO Mapping Parameter:

0x1600/0	NrOfEntries: 2
0x1600/1	1. Mapped Object: 0x00800000026200LL
0x1600/2	2. Mapped Object: 0x00800100016200LL

Tx PDO Communication Parameter:

0x1800/0	NrOfEntries: 2
0x1800/1	NodeID: 0x02
0x1800/2	MappingVersion: 0x00

Rx PDO Communication Parameter:

0x1400/0	NrOfEntries: 2
0x1400/1	NodeID: 0x00
0x1400/2	MappingVersion: 0x00

Resulting PReq frame to Node 0x02:

SrcNodeId	DstNodeId	MappingVersion	PDO Length	PDO Payload
0xF0	0x02	0x00	3	0xAB 00 CD

openCONF Demo

Service Data Object (SDO)

- For configuration of the nodes, to get access to remote ODs
- Transported in asynchronous phase via ASnd frames or encapsulated in UDP datagrams
- Transportation in isochronous phase via container in PDO is possible too, but currently not implemented
- Consists of 2 Layers:
  - Sequence Layer: Peer-to-Peer transport stream with acknowledgement
  - Command Layer: Client-Server communication

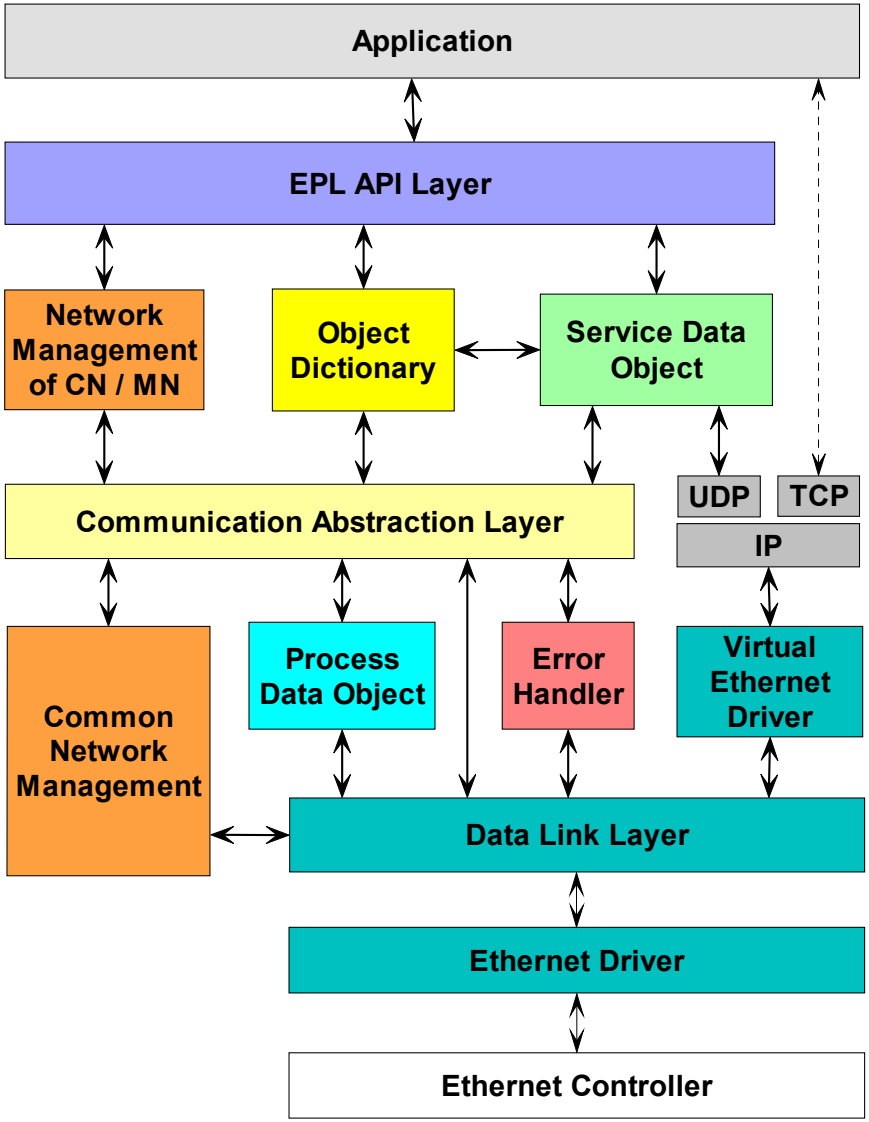
SDO Aborts

- SDO transfers can be aborted by both parties
- Common SDO abort codes
  - 0x05040000L: Timeout occurred
  - 0x06010000L: Unsupported access of object
  - 0x06010001L: Read of write-only object
  - 0x06010002L: Write to read-only object
  - 0x06020000L: Object does not exist
  - 0x06090011L: sub-index does not exist
  - 0x08000000L: General error

openPOWERLINK

- Implements Communication profile EPSG DS 1.1.0
- Data link layer and NMT state machine for Controlled and Managing Nodes
- SDO via UDP and EPL ASnd frames
- Dynamic PDO mapping
- User-configurable object dictionary
- Supports the EPL cycle features async-only CN and multiplexed CN
- Implemented in plain ANSI C
- Modular software structure for simple portability to different target platforms
- Supports target platforms with and without operating system
- Event driven Communication Abstraction Layer (CAL)
- Provides Generic API for user-application

Software Structure



- Low-prioritized processes
- Called: user part

- High-prioritized real-time processes
- Called: kernel part

Directory Structure

Edrv	Ethernet driver implementations
EplStack	EPL protocol stack core components
Example	Example and test projects
Include	Generic header files
Include/kernel	Header files for EPL kernel part
Include/user	Header files for EPL user part
ObjDicts	Sample Object dictionaries
SharedBuff	Shared buffer implementation for CAL and frame queues
Target/ARCH/OS/C	Target dependant files for architecture ARCH, operating system OS and compiler C

Introduction into demo project

- Makefile
- demo_main.c
  - EplApiInitialize();
  - EplApiLinkObject();
  - EplApiExecNmtCommand(kEplNmtEventSwReset);
  - EplApiShutdown();
  - AppCbEvent()
  - AppCbSync()
- Build and run the project

Extensions and future enhancements?

- Multiplexed CNs (currently only in CN stack supported)
- PResMN
- PResChaining (implementation on-going)
- Future enhancements:
  - High Availability/ Redundancy
  - Safety/ openSAFETY protocol stack

Terms and Abbreviations

- EPL: Ethernet POWERLINK
- EPSG: Ethernet POWERLINK Standardization Group
- NMT: Network Management
- OD: Object Dictionary
- PDO: Process Data Object
- SDO: Service Data Object
- CN: Controlled Node (Slave)
- MN: Managing Node (Master)

References

[1] EPSG Draft Standard 301 Ethernet POWERLINK Communication Profile Specification, Version 1.1.0, Ethernet POWERLINK Standardisation Group, 2008

[2] Ethernet POWERLINK Standardisation Group, http://www.ethernet-powerlink.org/

[3] openPOWERLINK, http://openpowerlink.sourceforge.net/

[4] openCONFIGURATOR, http://sourceforge.net/openconf

[5] CAN in Automation (CiA), http://www.can-cia.org/

The End

Any questions about POWERLINK or openPOWERLINK?

Thanks for your attention!