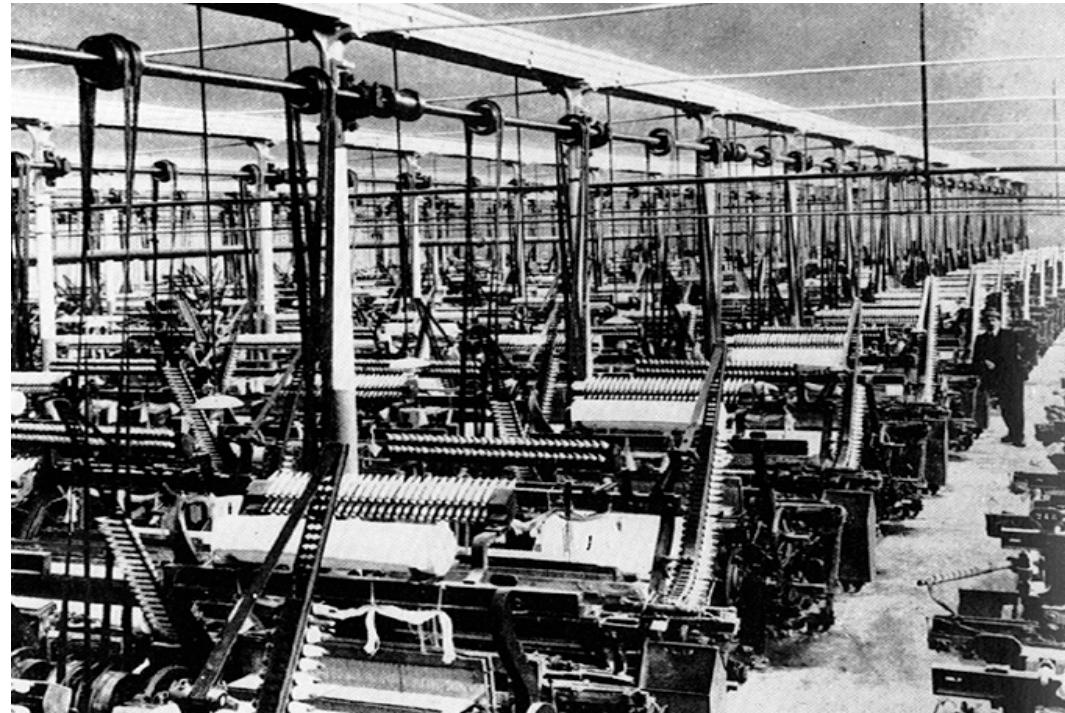


CANopen in modular machine building



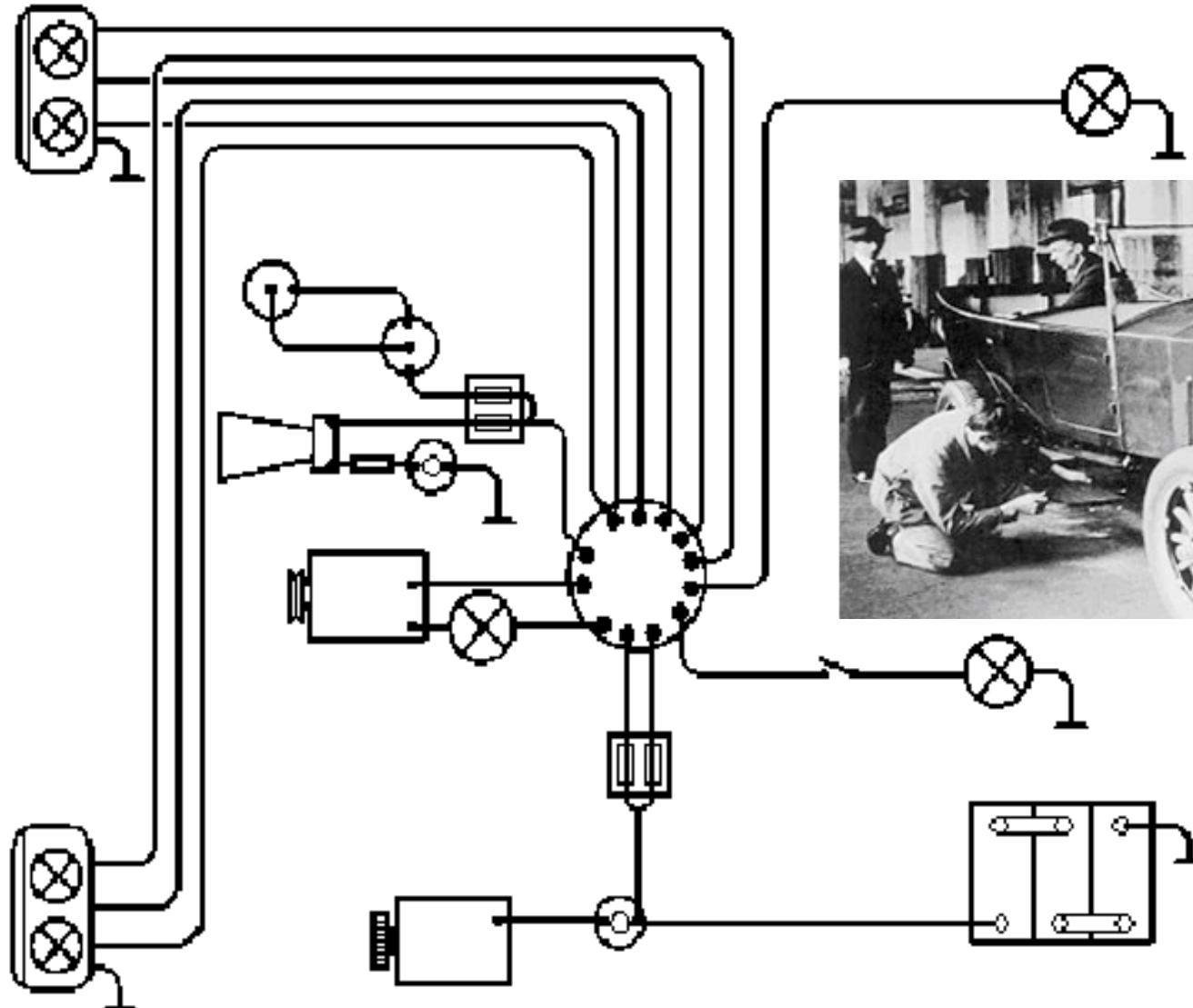
Reiner Zitzmann
(CAN in Automation)
www.can-cia.org

Agenda



- **CANopen introduction**
- **CANopen device profiles**
- **CANopen application profiles**
- **CANopen gateway solutions**

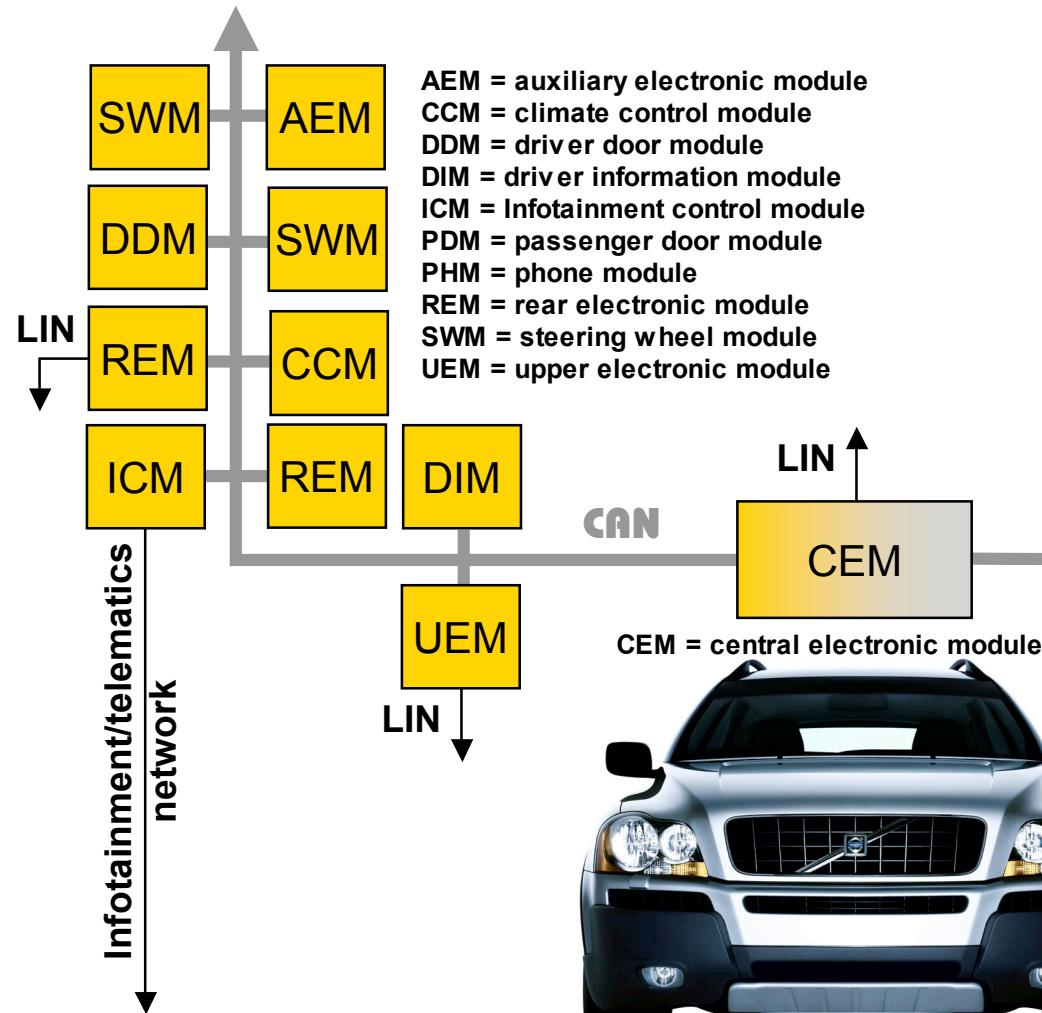
Volvo ÖV4 "Jacob" (1927)



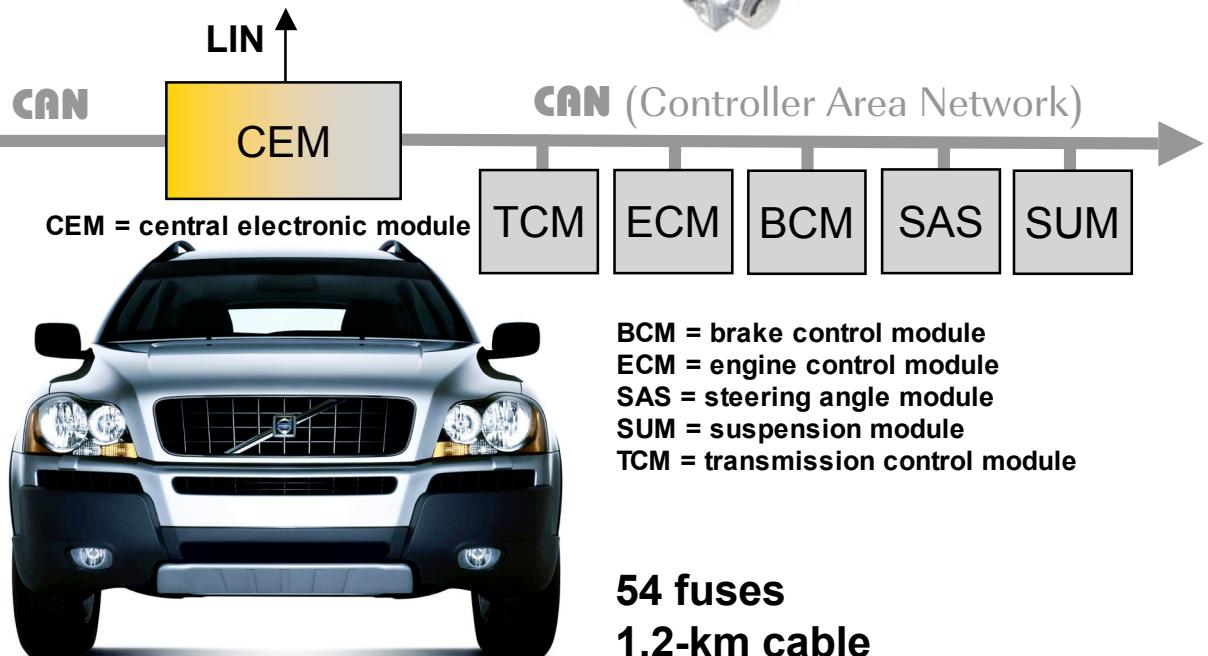
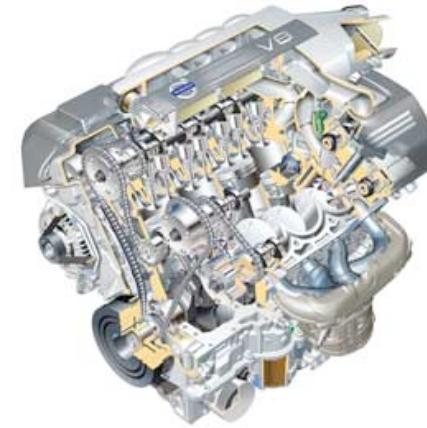
4 fuses
30-m cable

Volvo XC90 (2003)

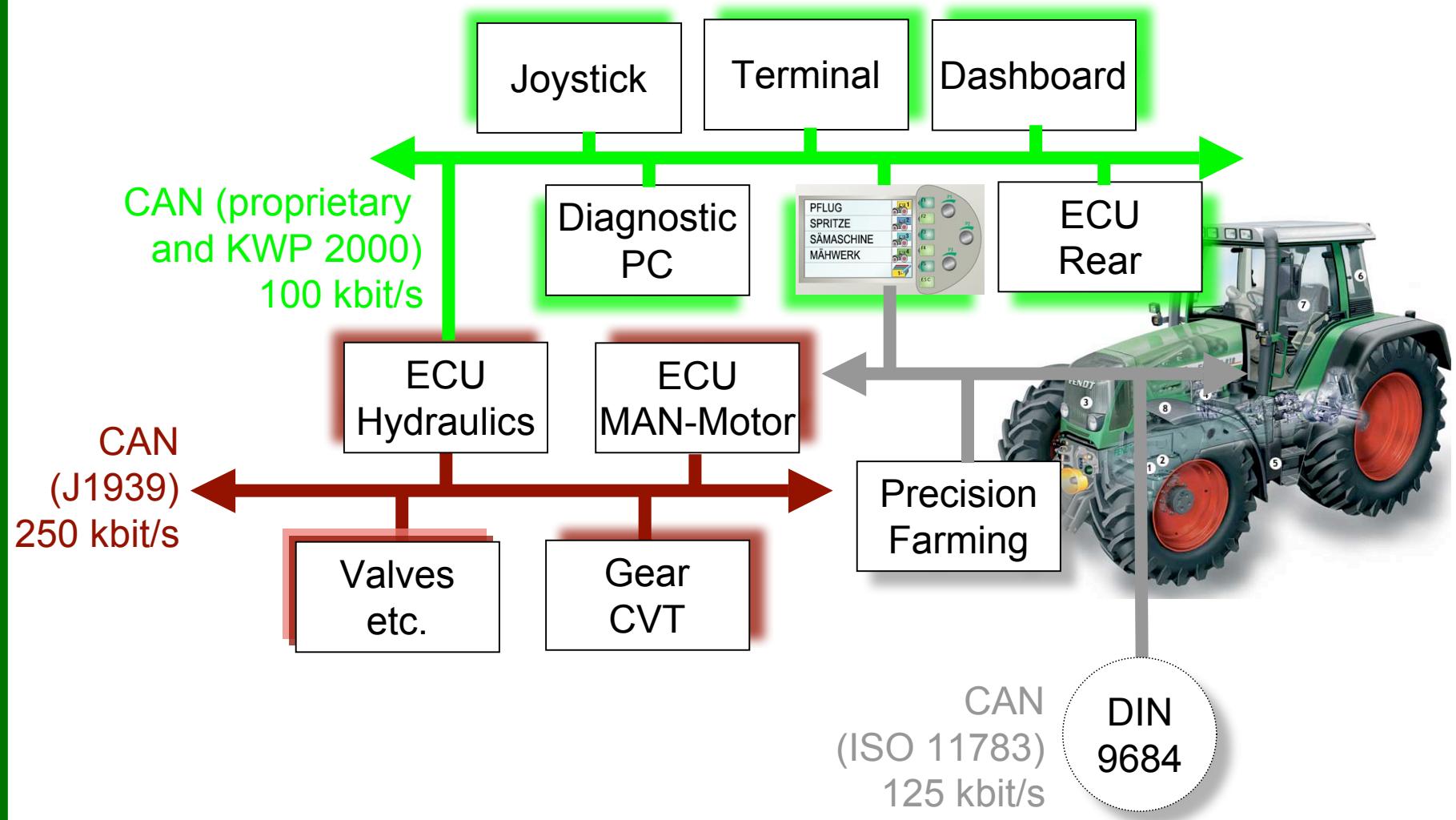
Body electronics



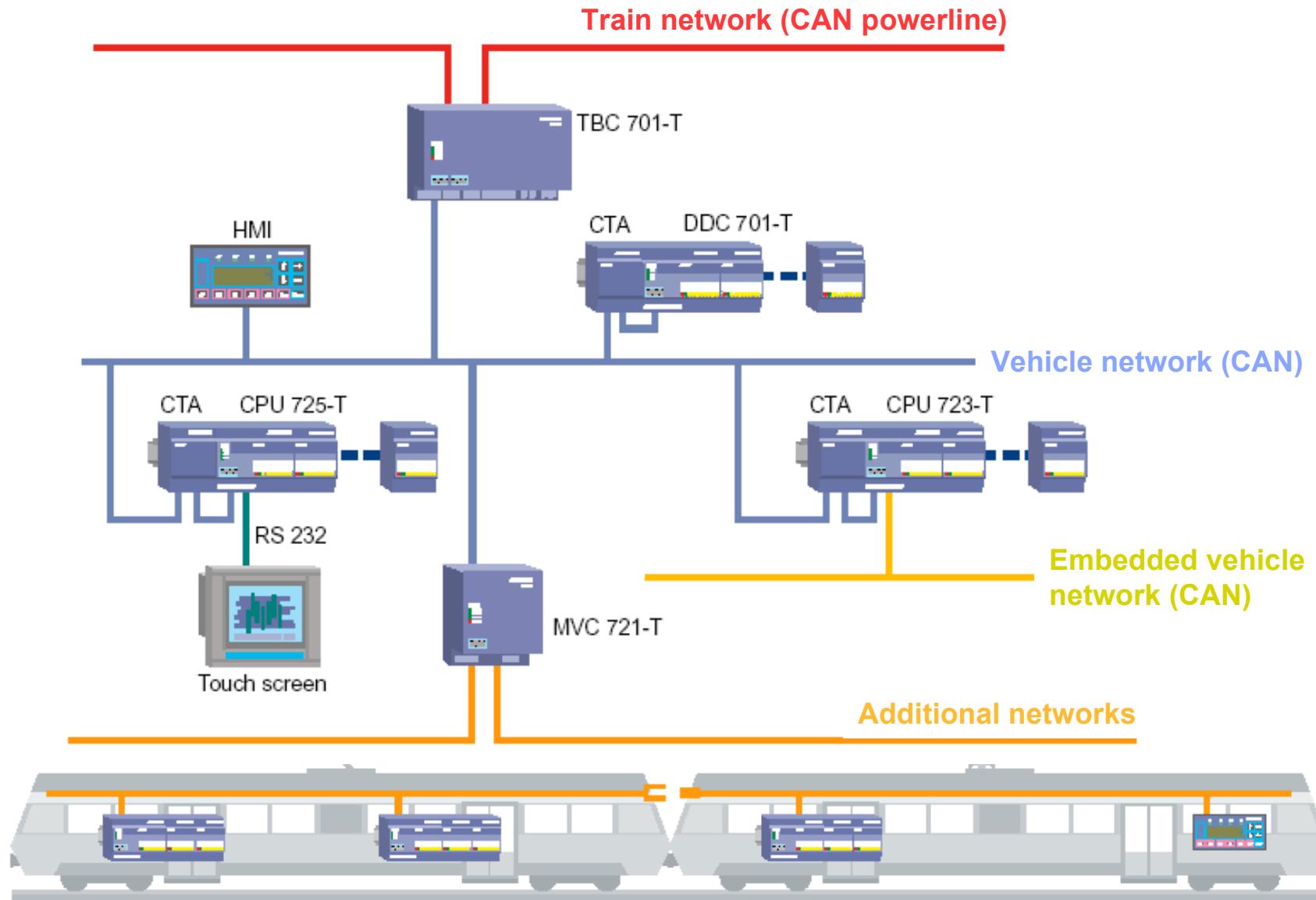
Power-train and chassis



Agriculture machine



Swiss rail vehicle architecture



CAN markets



- Passenger cars
- Truck and bus
- Truck superstructures
- Off-highway vehicles



- Rail vehicles
- Trams and metros
- Railway signaling



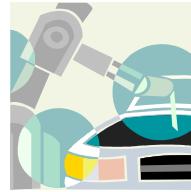
- Maritime electronics
- Off-shore (sub-sea)



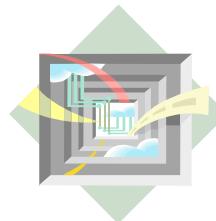
- Aircraft and helicopter
- Aerospace



- Cranes
- Excavators
- Paving machines



- Factory automation
- Production line
- Process automation



- Machine control
 - Textile machines
 - Plastic machines
 - Printing machines
 - Packaging machines
- Up-/down-stream devices



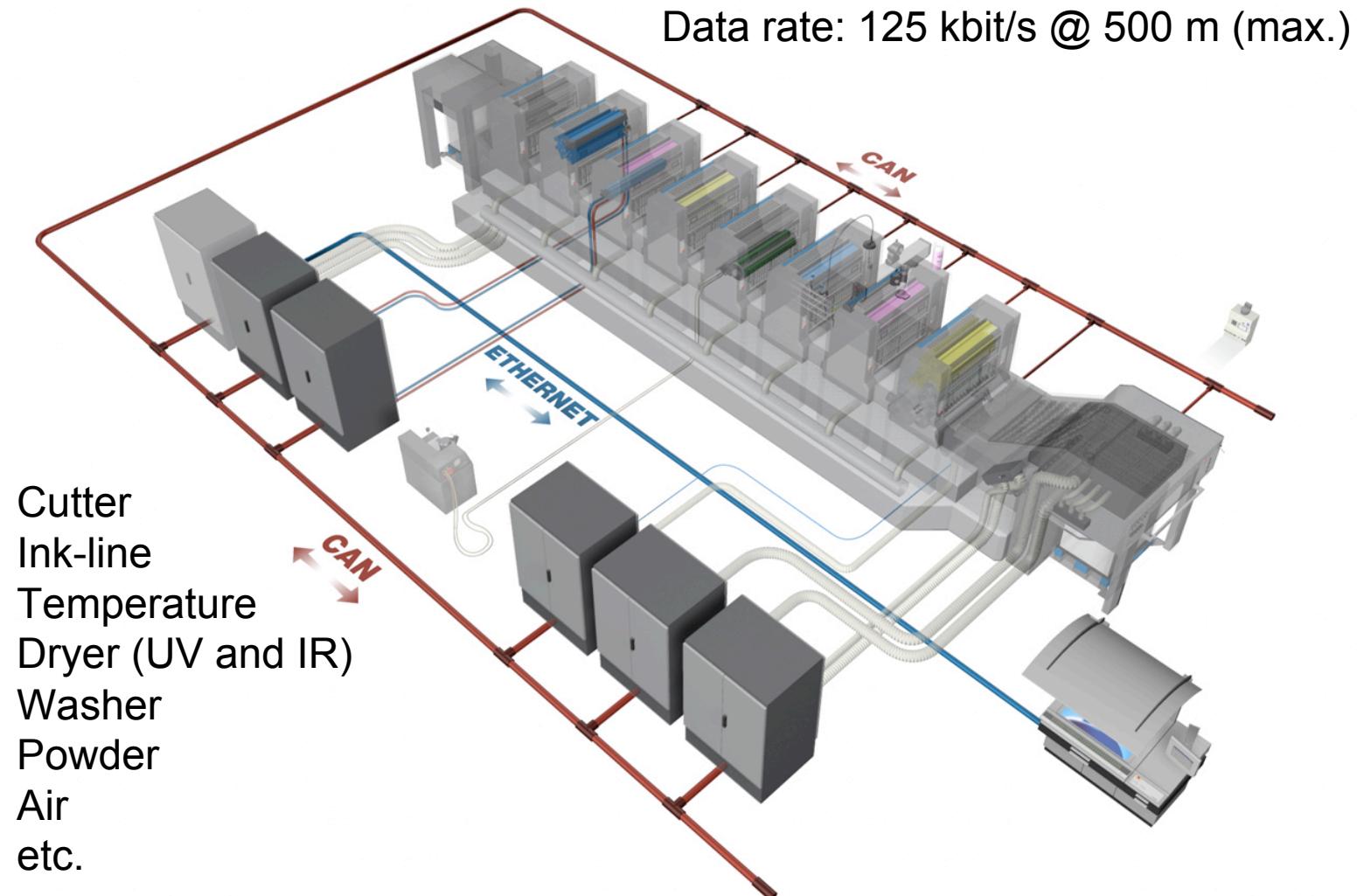
- Medical devices
- Operating room
- Intensive care



- HVAC control
 - Lift control
 - Embedded door control
-
- Embedded control

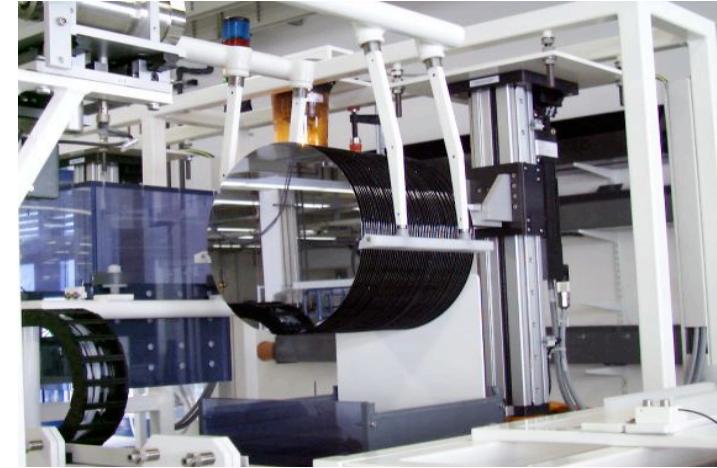
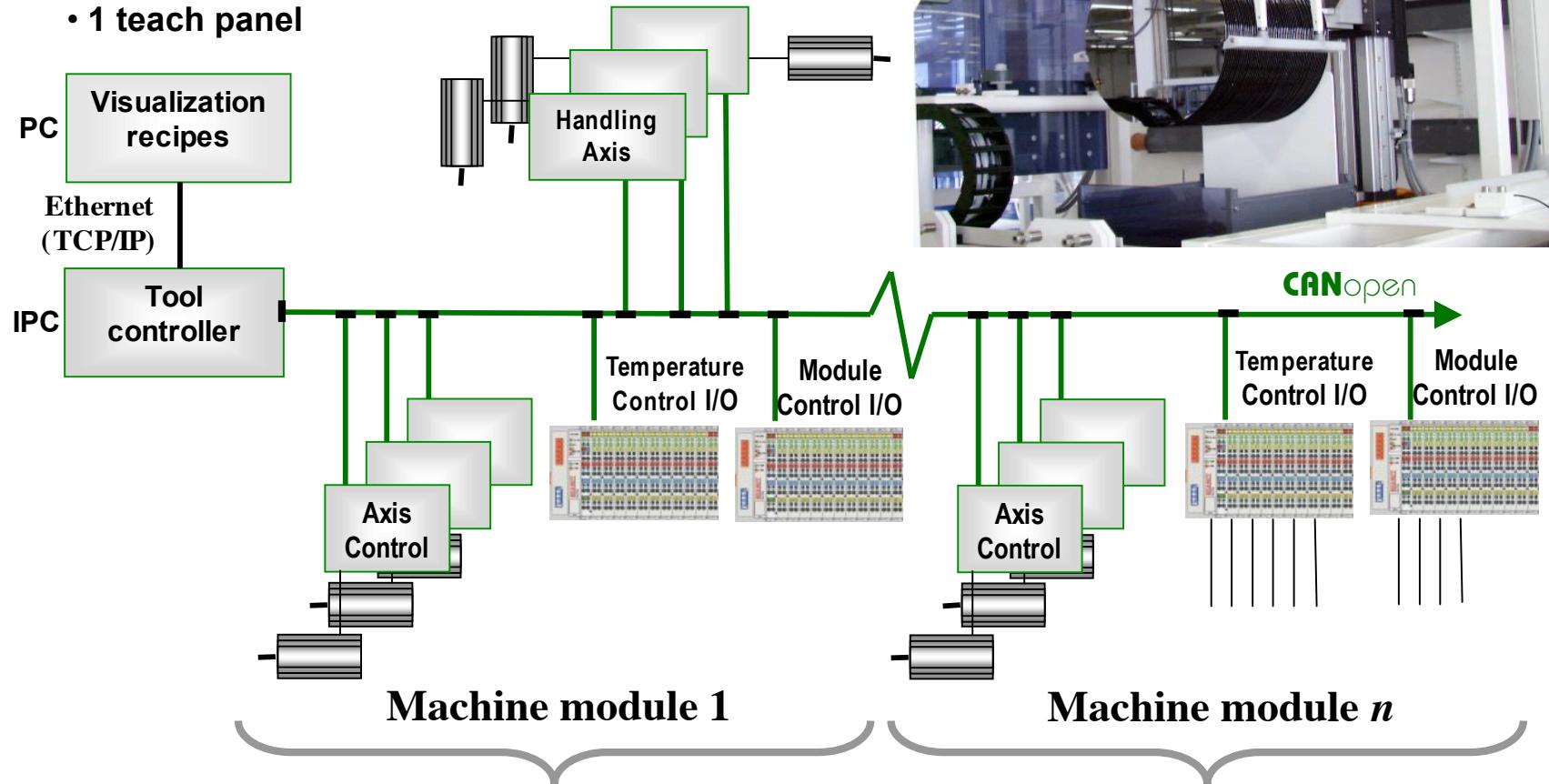


Offset printing machine

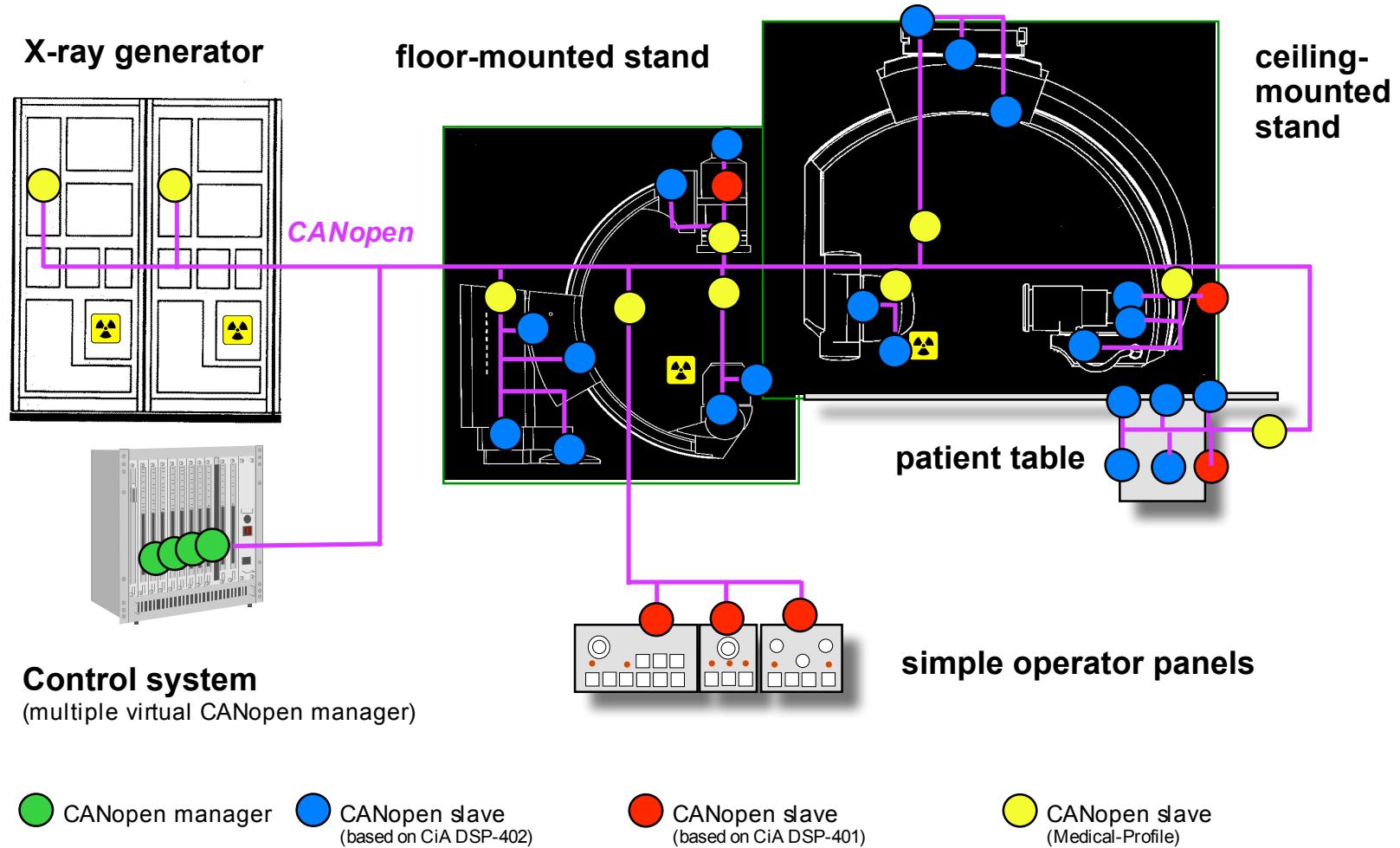


Wafer wet process

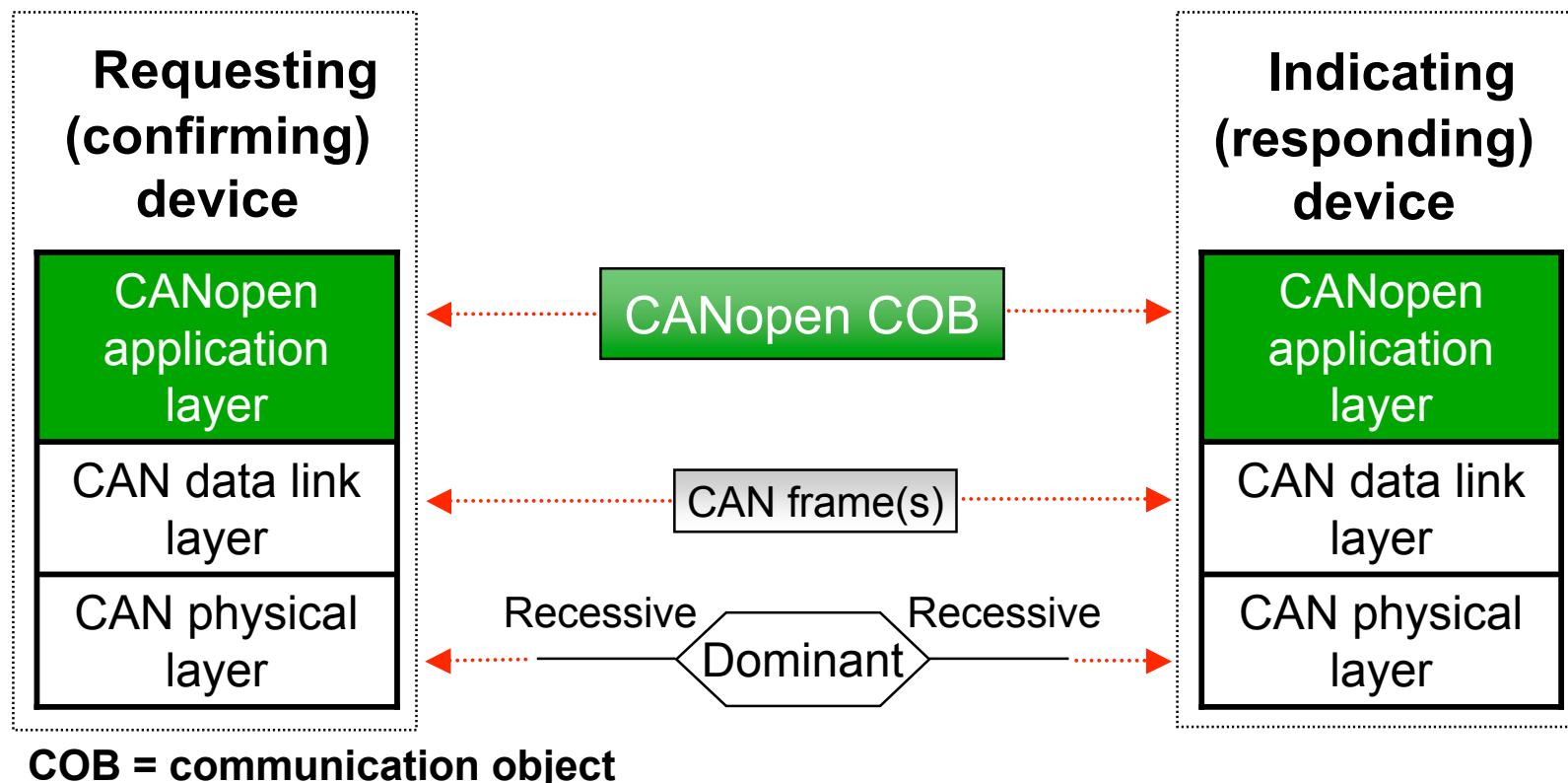
- 11 servo axis
- 14 I/O modules
- 6 valve manifolds
- 1 teach panel



X-ray angio-biplane system



CANopen application layer



CANopen history



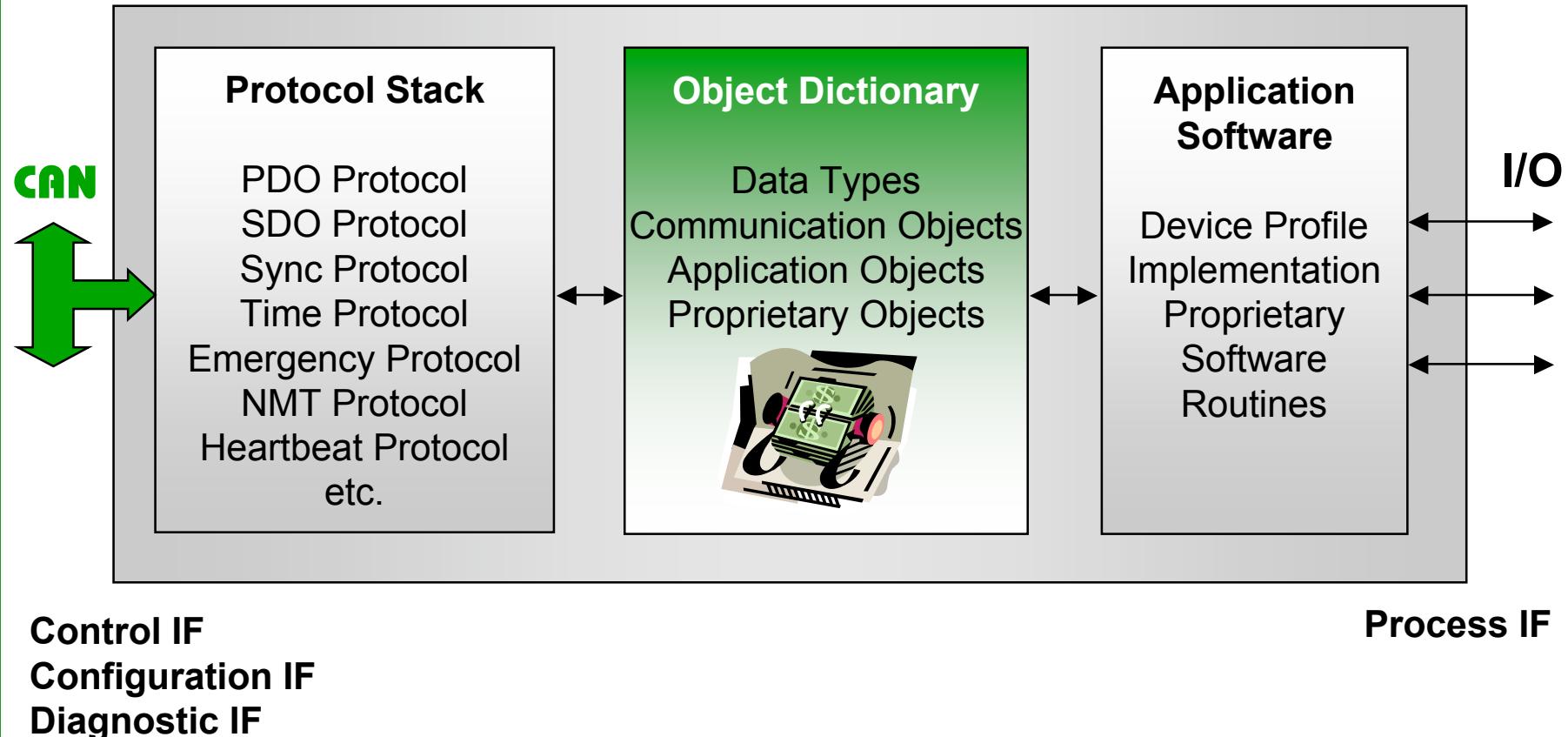
- 1993: ESPRIT project ASPIC (CAL-based communication profile)
- November 1994: CAL-based communication profile version 1.0
- January 1995: CAL-based communication profile version 1.1
- September 1995: CANopen CiA DSP 301 version 2.0
- October 1996: CiA DS 301 version 3.0
- June 1999: CiA DS 301 version 4.0
- Winter 2006: CiA DS 301 version 4.1

CANopen specifications

cia301 **cia302** **cia303** **cia304** **cia305** **cia306**
cia307 **cia308** **cia309** **cia310** **cia311** **cia312**
cia313 **cia400** **cia401** **cia402** **cia404** **cia405**
cia406 **cia408** **cia410** **cia412** **cia413** **cia414**
cia415 **cia416** **cia417** **cia418** **cia419** **cia420**
cia421 **cia422** **cia423** **cia424** **cia425** **cia426**
cia427 **cia428** **cia429** **cia430** **cia431** **cia432**
cia433 **cia434** **cia435** **cia436** **cia437** **cia438** **cia439**



Internal device structure



Object dictionary layout

Index ¹ range	Description
0000 _h	Reserved
0001 _h to 025F _h	Data types
0260 _h to 0FFF _h	Reserved
1000 _h to 1FFF _h	Communication profile area
2000 _h to 5FFF _h	Manufacturer-specific profile area
6000 _h to 9FFF _h	Standardized profile area
A000 _h to AFFF _h	Network variables
B000 _h to FFFF _h	Reserved



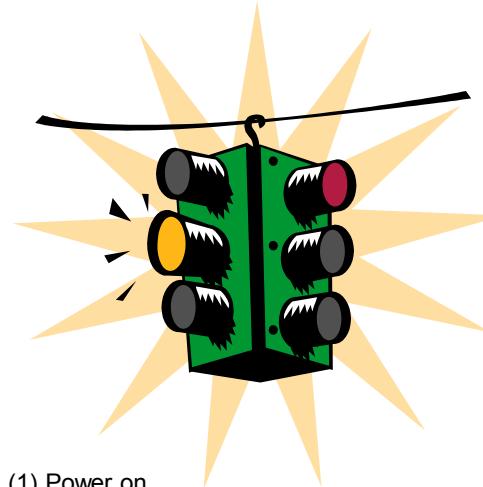
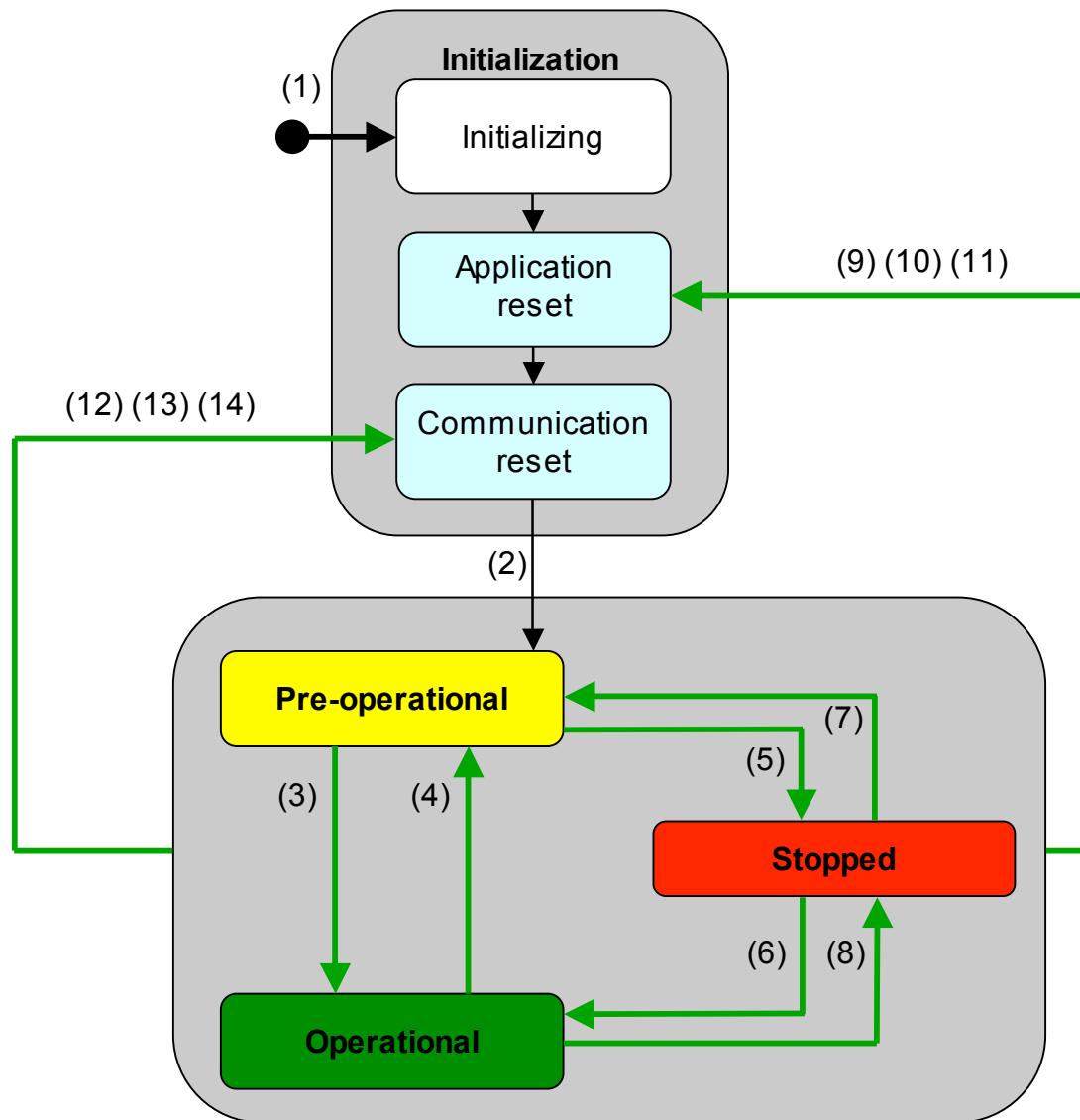
¹ 16-bit index plus 8-bit sub-index

Communication objects

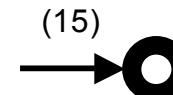
Index (hex)	Object	Name
1000	VAR	Device type
1001	VAR	Error register
1002	VAR	Manufacturer status register
1003	ARRAY	Pre-defined error field
1005	VAR	COB-ID SYNC-message
1006	VAR	Communication cycle period
1007	VAR	Synchronous window length
1008	VAR	Manufacturer device name
1009	VAR	Manufacturer hardware version
100A	VAR	Manufacturer software version
100C	VAR	Guard time
100D	VAR	Life time factor
1010	VAR	Store parameters
1011	VAR	Restore default parameters
1012	VAR	COB-ID time stamp
1013	VAR	High resolution time stamp
1014	VAR	COB-ID Emergency
1015	VAR	Inhibit Time Emergency
1016	ARRAY	Consumer Heartbeat Time
1017	VAR	Producer Heartbeat Time
1018	RECORD	Identity object
1020	ARRAY	Verify Configuration
1021	VAR	Store EDS
1022	VAR	Storage Format
1023	RECORD	OS Command
1024	VAR	OS Command Mode
1025	RECORD	OS Debugger Interface
1026	ARRAY	OS Prompt
1027	ARRAY	Module List
1028	ARRAY	Emergency Consumer
1029	ARRAY	Error Behaviour



NMT slave state machine



- (1) Power on
- (2) Automatic switch to Pre-Operational
- (3) and (6) NMT switch to Operation
- (4) and (7) NMT switch to Pre-Operational
- (5) and (8) NMT switch to Stopped
- (9), (10) and (11) NMT switch to Application Reset
- (12), (13) and (14) NMT switch to Communication Reset
- (15) Power-off or hardware reset

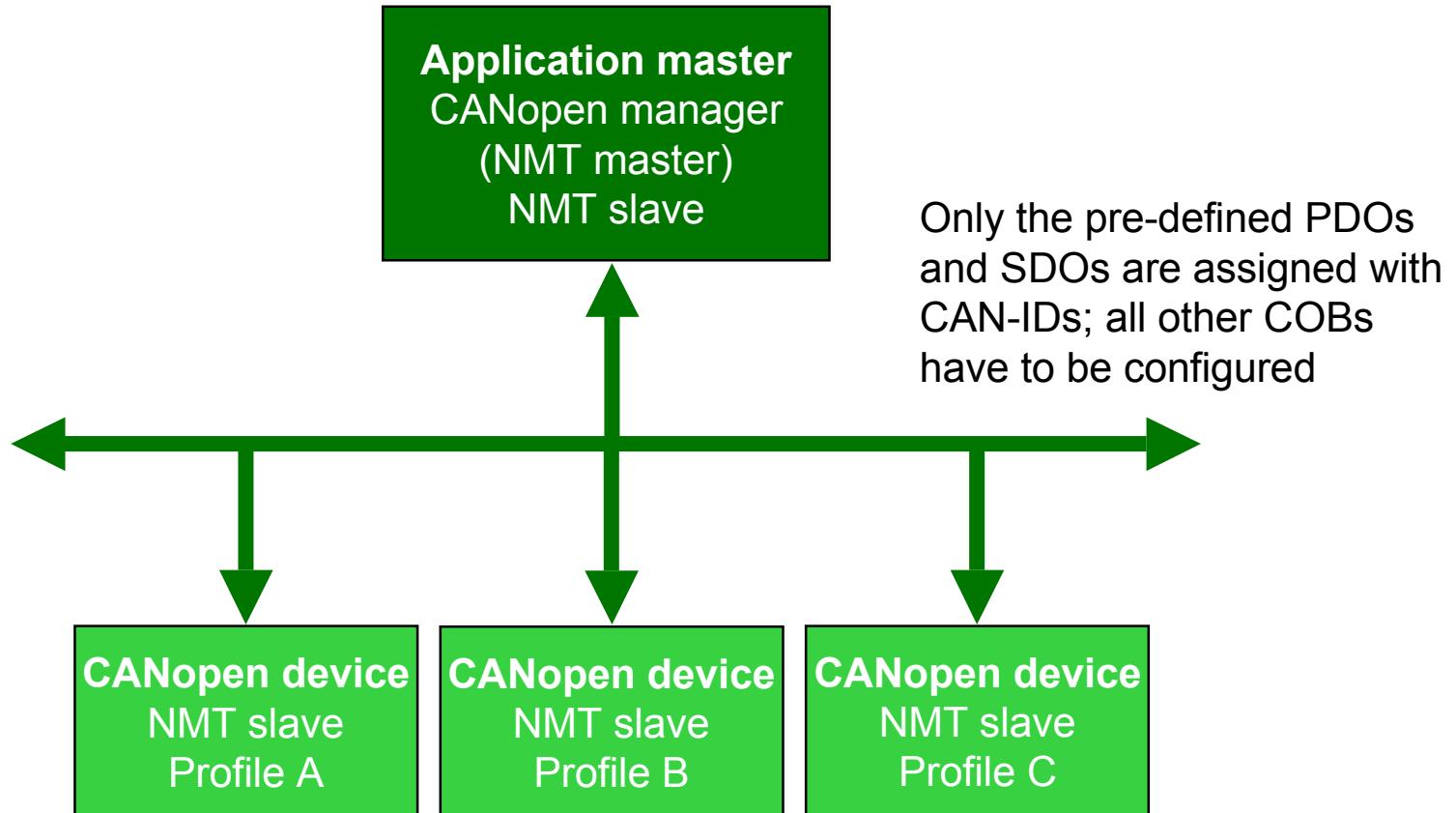


Pre-defined CAN-ID set

Object	Function code	CAN Identifier	Communication parameters at Index
NMT	0000_b	0	-
SYNC	0001_b	128 (80_h)	$1005_h, 1006_h, 1007_h$
TIME STAMP	0010_b	256 (100_h)	$1012_h, 1013_h$

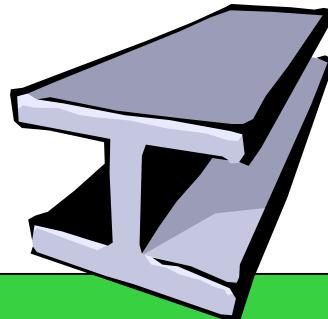
EMERGENCY	0001_b	129 (81_h) - 255 (FF_h)	$1014_h, 1015_h$
TPDO1 (tx)	0011_b	385 (181_h) - 511 ($1FF_h$)	1800_h
RPDO1 (rx)	0100_b	513 (201_h) - 639 ($27F_h$)	1400_h
TPDO2 (tx)	0101_b	641 (281_h) - 767 ($2FF_h$)	1801_h
RPDO2 (rx)	0110_b	769 (301_h) - 895 ($37F_h$)	1401_h
TPDO3 (tx)	0111_b	897 (381_h) - 1023 ($3FF_h$)	1802_h
RPDO3 (rx)	1000_b	1025 (401_h) - 1151 ($47F_h$)	1402_h
TPDO4 (tx)	1001_b	1153 (481_h) - 1279 ($4FF_h$)	1803_h
RPDO4 (rx)	1010_b	1281 (501_h) - 1407 ($57F_h$)	1403_h
SSDO (tx)	1011_b	1409 (581_h) - 1535 ($5FF_h$)	1200_h
SSDO (rx)	1100_b	1537 (601_h) - 1663 ($67F_h$)	1200_h
NMT ERROR CONTROL	1110_b	1793 (701_h) - 1919 ($77F_h$)	$1016_h, 1017_h$

Device profiles



One CANopen device may implement up to eight logical devices

CANopen device profiles



Device profile definition includes:

- Definition of 1000_h device type object
- Definition of 1029_h error behavior object and error codes
- Definition of PDO communication and mapping parameters
- Definition of device-specific data types (optional)
- Definition of standardized application objects
- Definition of device-specific application state machines (optional)

Note: Only default PDOs are allowed to be defined as valid.
All other pre-defined PDOs shall be invalid.

Collimator objects

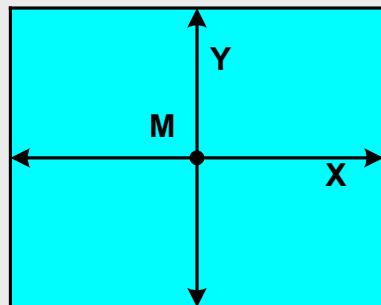
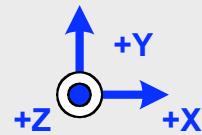
- 6000_h : Source Image Distance (SID)
- 6001_h : Source Fringe Distance (SFD)
- 6002_h : Collimator Command
- 6003_h : Collimator State
- 6010_h to $601F_h$: Symmetric Rectangular_Collimation_Set_n (SRCS)
- 6020_h to $602F_h$: Quadrangle_Collimation_Set_n (QCS)
- 6030_h to $603F_h$: Circular_Collimation_Set_n (CCS)
- 6040_h to $604F_h$: Homogeneous_Filter_Set_n (HFS)
- 6050_h to $605F_h$: Spatial_Filter_Set_n (SFS)
- 6100_h : Visualisation_Control (VC)
- 6101_h : Visualisation_State (VS)
- 6102_h : Visualisation_Duration (VD)



Shape parameters

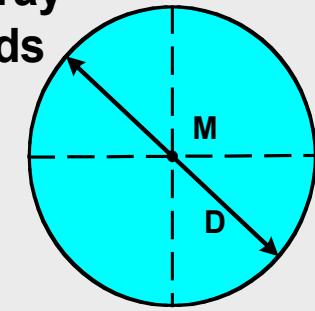
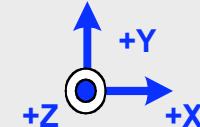
View from X-ray focus towards receptor

Z = 0 plane (i.e. Image Receptor Reference Plane)



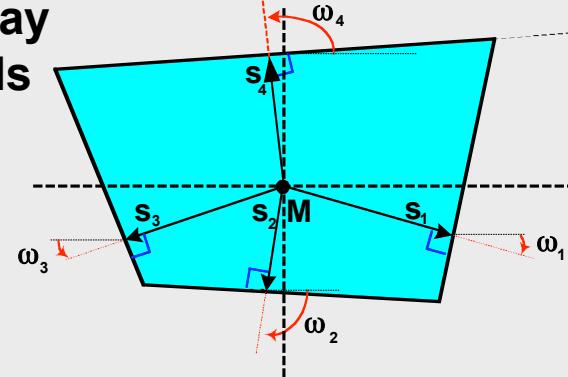
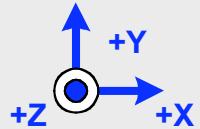
View from X-ray focus towards receptor

Z = 0 plane (i.e. Image Receptor Reference Plane)



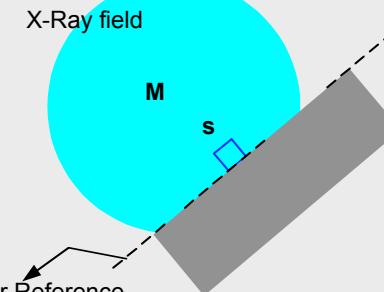
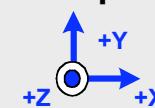
View from X-ray focus towards receptor

Z = 0 plane (i.e. Image Receptor Reference Plane)

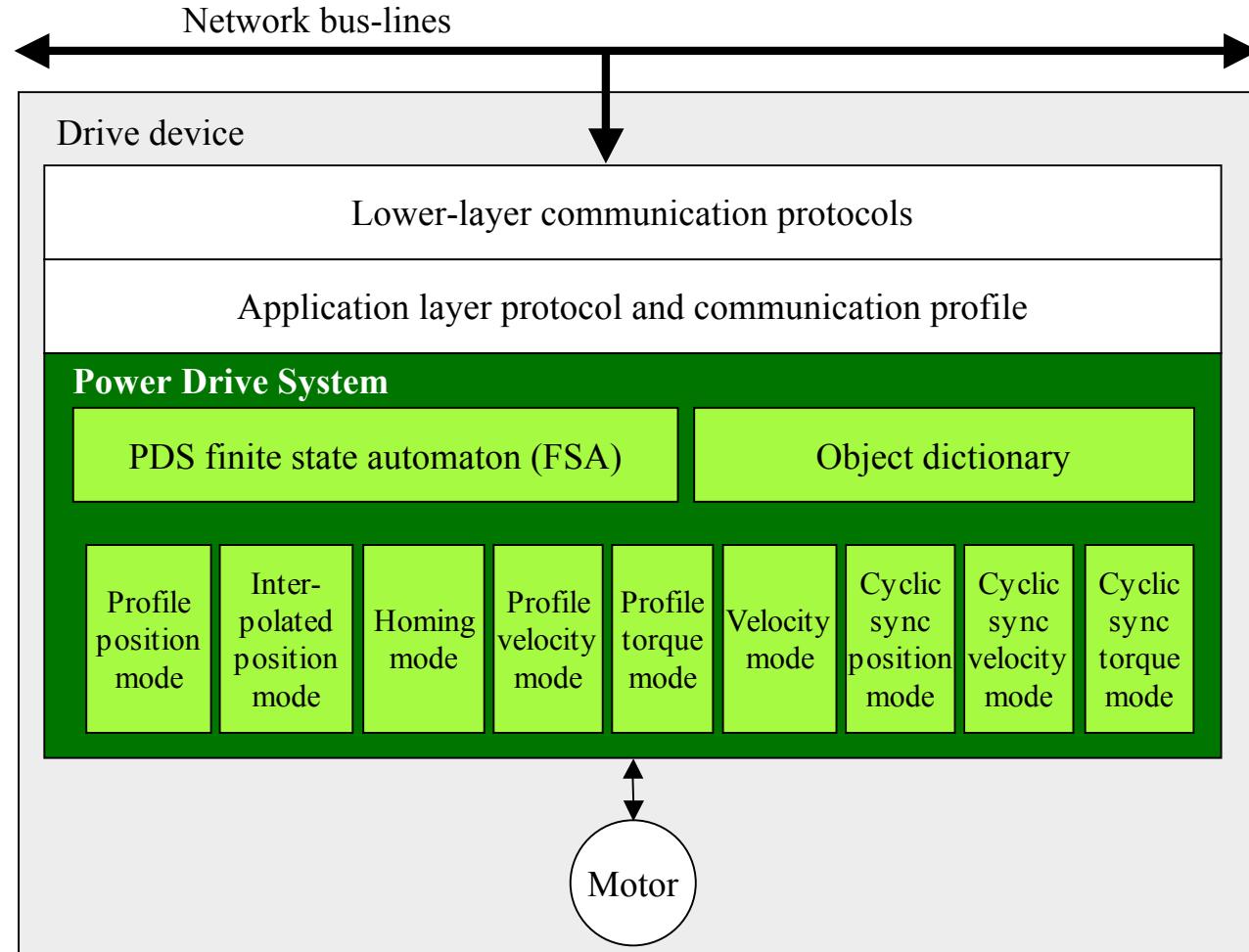


View from X-ray focus towards receptor

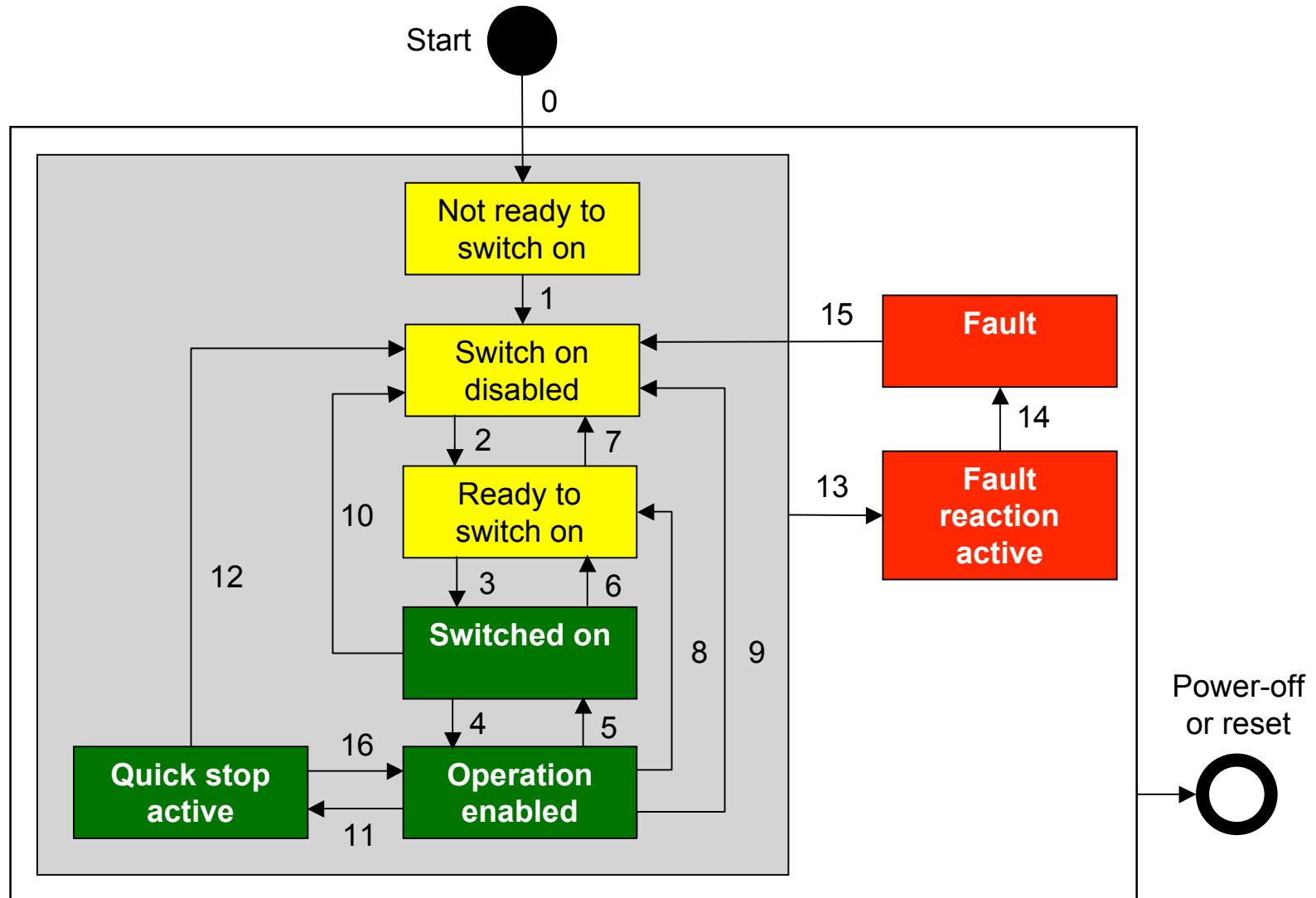
Z = 0 plane (i.e. Image Receptor Reference Plane)



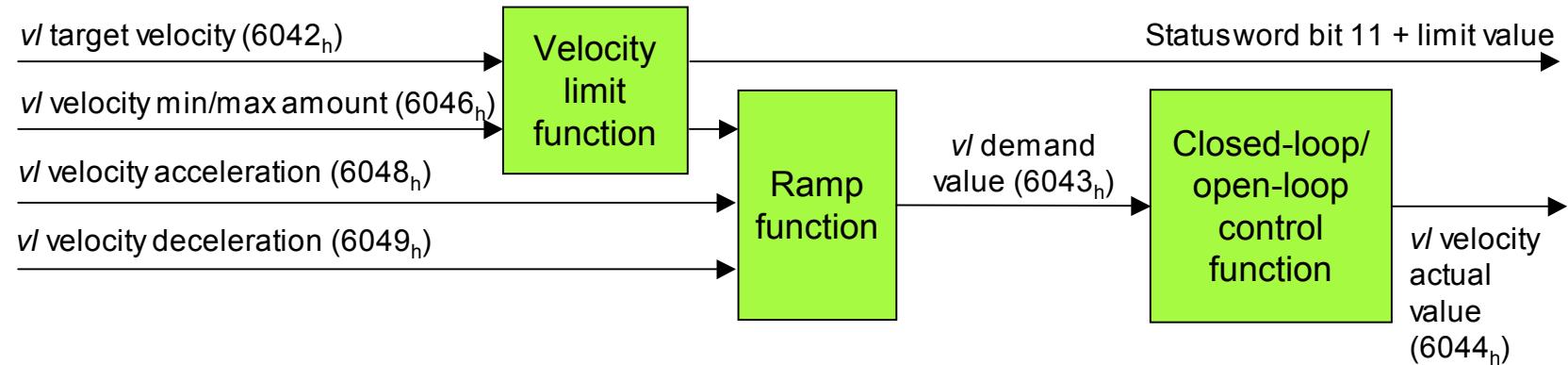
CiA 402 power drive system



CiA 402 state machine



Velocity mode (simple)



Generic RPDOs

PDO	Mapping Object Index	Mapping Object Name	M/O	Comment
1	6040_h	controlword	M	controls the state machine
2	6040 _h	controlword	O	controls the state machine
	6060 _h	modes_of_operation		and mode of operation
3	6040_h	controlword	O	controls the state machine
	607A_h	target_position		and the target position
4	6040 _h	controlword	O	controls the state machine
	6081 _h	profile_velocity		and the target velocity
5	6040_h	controlword	O	controls the state machine
	6071_h	target_torque		and the target torque
6	6040 _h	controlword	O	controls the state machine
	6042 _h	vl_target_velocity		and the nominal speed
7	6040_h	controlword	O	controls the state machine
	60FE_h	digital_outputs		and the digital outputs

Generic TPDOs

PDO	Mapping Object Index	Mapping Object Name	M/O	Comment
1	6041_h	statusword	M	shows status
2	6041 _h	statusword	O	shows status and actual
	6061 _h	modes_of_operation_display		mode of operation
3	6041_h	statusword	O	shows status and the actual position
	6064_h	position_actual_value		
4	6041 _h	statusword	O	shows status and
	606C _h	velocity_actual_value		the actual velocity
5	6041_h	statusword	O	shows status and the actual torque
	6077_h	torque_actual_value		
6	6041 _h	statusword	O	shows status and
	6044 _h	vl_control_effort		the actual speed
7	6041_h	statusword	O	shows status and the digital inputs
	60FD_h	digital_inputs		

Frequency inverter PDOs

RPDO	Mapping Object Index	Mapping Object Name	M/O	Comment
1	6040_h 6042_h	controlword nominal speed (vl)	M	controls the state machine and the nominal speed
2	6040 _h 6042 _h 6071 _h	controlword nominal speed target torque	O	controls the state machine, nominal speed, and target torque
3		manufacturer-specific	O	
4 to 16		reserved		
TPDO				
1	6041_h 6044_h	statusword current speed	M	shows status, current speed
2	6041 _h 6044 _h 6077 _h	statusword current speed current torque	O	shows status, current speed, and current torque
3		manufacturer-specific	O	
4 to 16		reserved		

Servo and stepper PDOs

RPDO	Mapping Object Index	Mapping Object Name	M/O	Comment
1	6040_h	controlword	M	controls the state machine
2	6040 _h	controlword	O	controls the state machine
	607A _h	target position (pp)		and target position
3	6040_h	controlword		controls the state machine
	60FF_h	target velocity (pv)		and the target velocity
4		manufacturer-specific	O	
5 to 16		reserved		
TPDO				
1	6041_h	statusword	M	shows status
2	6041 _h	statusword	O	shows status and
	6064 _h	current position (pp)		current position
3	6041_h	statusword	O	shows status and
	606C_h	current velocity (pv)		current velocity
4		manufacturer-specific	O	
5 to 16		reserved		

Device profile overview



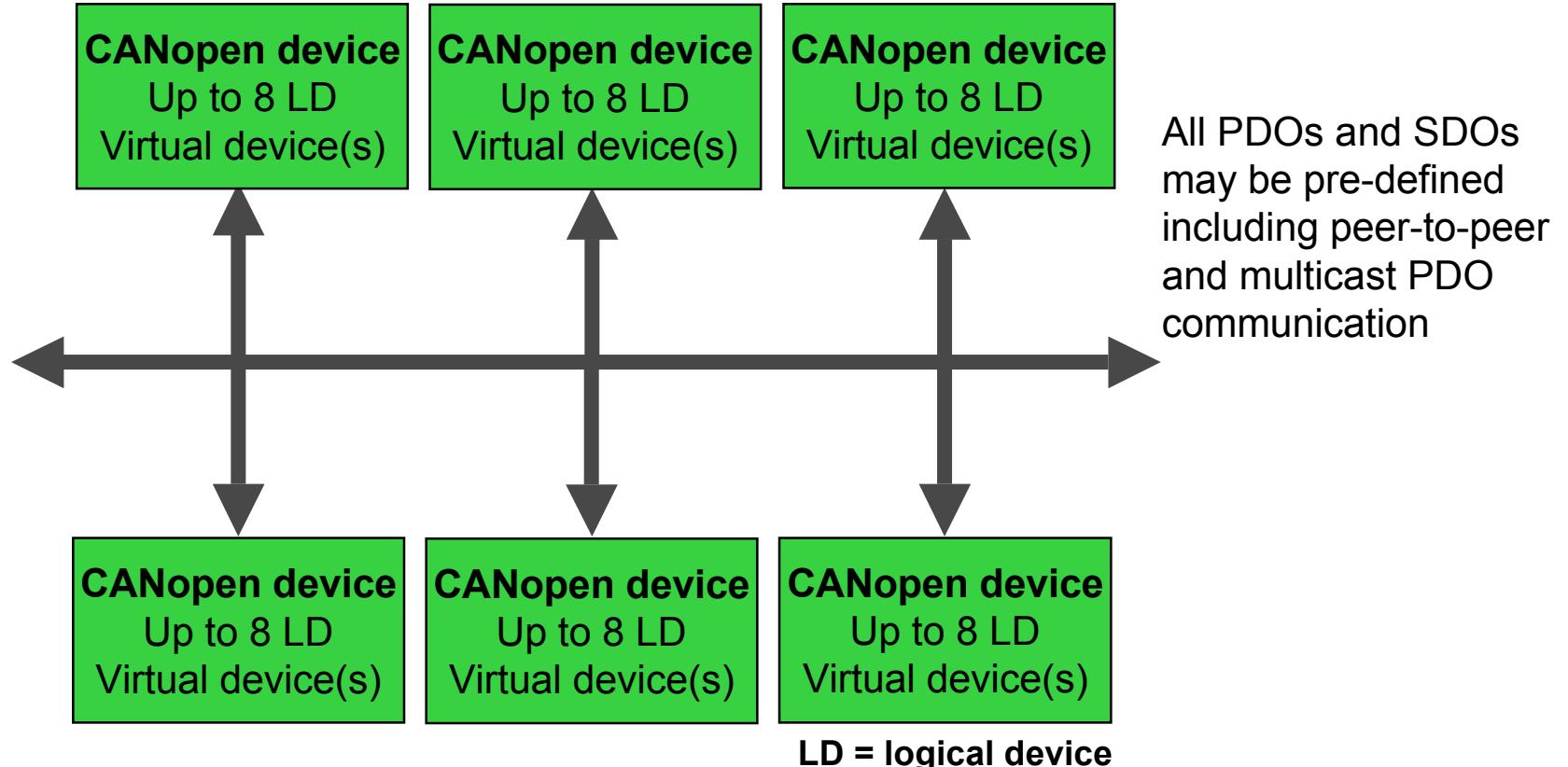
CiA 400	Framework for multi-level CANopen network architectures
CiA 401	CANopen device profile generic I/O modules
CiA 402	CANopen device profile for drives and motion control
CiA 404	CANopen device profile measurement devices and closed-loop controllers
CiA 405	CANopen interface and device profile for IEC 61131-3 programmable devices
CiA 406	CANopen device profile for encoders
CiA 408	CANopen device profile fluid power technology
CiA 410	CANopen device profile inclinometer
CiA 412	CANopen medical device profile - Part 1: General definitions, Part 2: Collimator, Part 6: Dosimeter
CiA 413	CANopen device profile truck gateway - Part 1: General definitions, Application objects for brake and running gear, Application objects for other than brake and running gear equipment, Part 5: Application objects for superstructure, Part 6: Framework for J1939-based networks
CiA 414	CANopen device profile for weaving machines - Part 1: General definitions, Part 2: Feeders
CiA 418	CANopen device profile for battery modules
CiA 419	CANopen device profile for battery charger
CiA 420	CANopen profiles for extruder downstream devices - Part 1: General definitions, Part 2: Puller, Part 3: Corrugator, Part 4: Saw, Part 5: Co-extruder, Part 6: Calibration table

[Free-of-charge on CiA's website](#)

Only for CiA members

Under development

CANopen application profile



Each logical device may implement as many virtual devices as defined

Application profiles

Application definition includes:

- Definition of 1000_h device type object
- Definition of 1029_h error behavior object and error codes
- Definition of PDO communication and mapping parameters
- Definition of application-specific data types (optional)
- Definition of standardized application objects
- Definition of device-specific application state machines (optional)

Note: An application profile may specify any number of pre-defined PDOs. These PDOs may be pre-linked not only to the NMT master device but also to any NMT slave device. An application profile compliant CANopen device is a pre-configured device and may not be used in a generic CANopen network. Generic CANopen device should be integrated only after configuration into an application profile specific network.

Application profile overview

CiA 407	CANopen application profile public transportation (EN 13149-4/5/6)
CiA 415	CANopen application profile sensor system for road construction machines
CiA 416	CANopen application profile building door control - Part 1: General definitions and node-ID claiming procedure, Part 2: Virtual device definition, Part 3: Pre-defined communication objects and detailed application object specification
CiA 417	CANopen application profile lift control systems - Part 1: General definitions and physical layer specifications, Part 2: Virtual device definition, Part 3: Predefined communication objects, Part 4: Detailed application object specification
CiA 422	CANopen application profile for municipal vehicles - Part 1: General definitions, Part 2: Virtual device definitions, Part 3: Pre-defined communication objects, Part 4: Detailed application object specification
CiA 425	CANopen application profile for medical diagnostic add-on modules - Part 1: General definitions, Part 2: Injector, Part 3: Electrocardiogram (ECG)

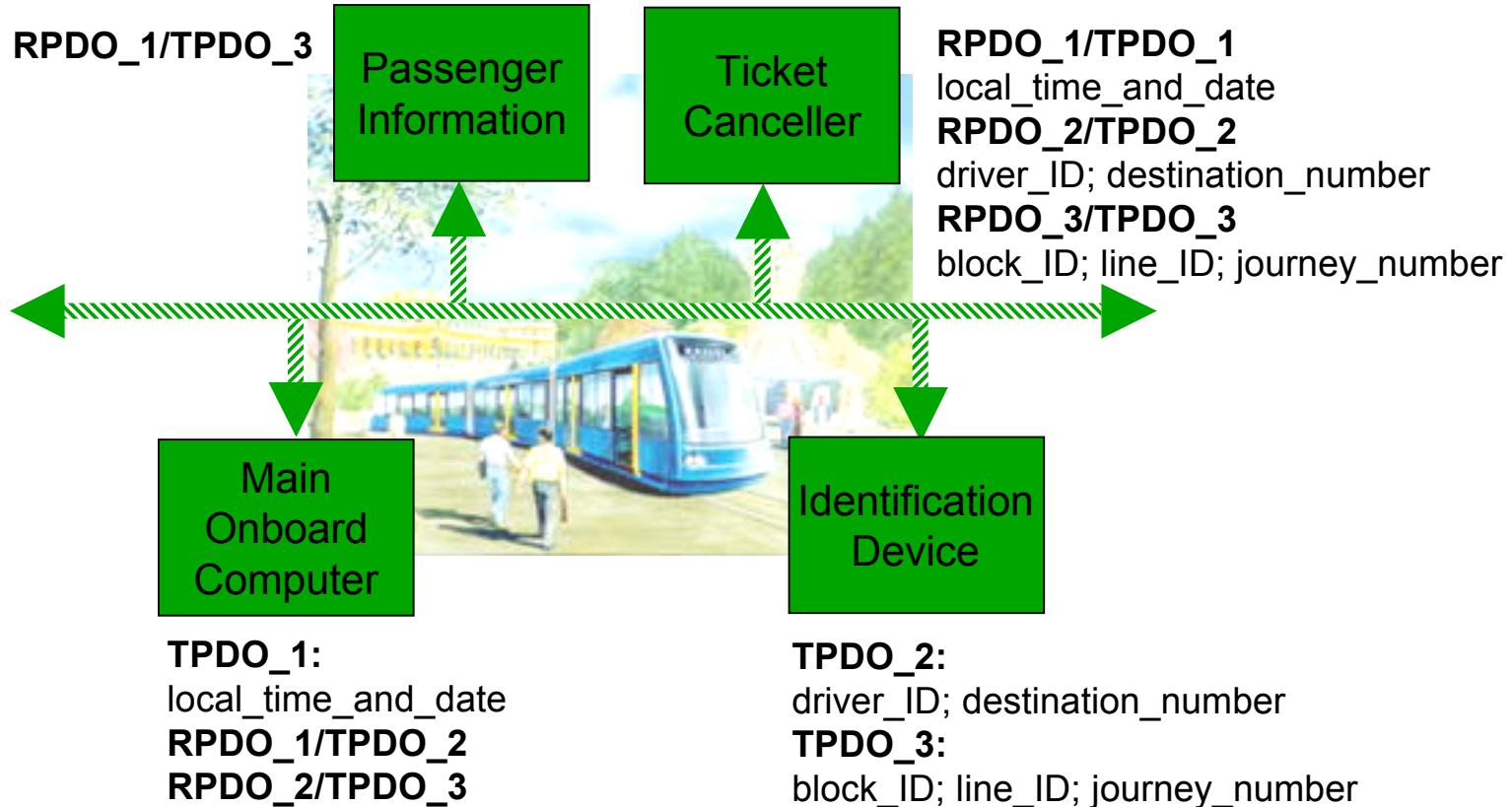
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Under development



Predefined PDO connection



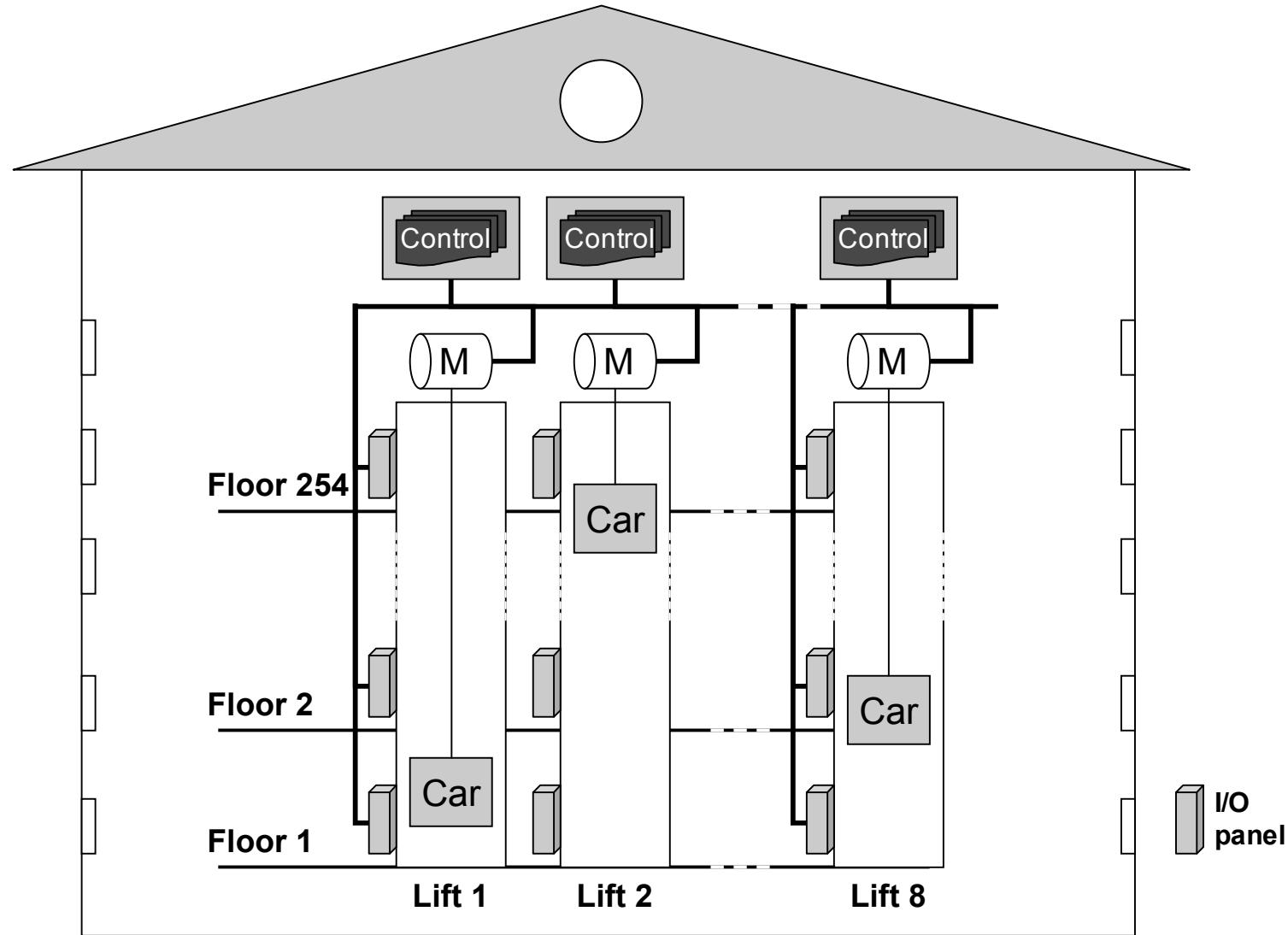
(CiA 407 minimum configuration)

Predefined PDO communication

Message No.	Main on-board comp. (01 _h)	COB-ID	Identification (02 _h)	Destination indicator (03 _h :01 _h :02 _h)	Next stop indicator (03 _h :02 _h :02 _h)	Ticket canceller (04 _h)	Ticket printer (05 _h)
1	TPDO1	181 _h	-	-	-	RPDO1	RPDO1
2	TPDO2	381 _h	-	RPDO2	-	RPDO2	RPDO2
3	TPDO3	401 _h	-	-	RPDO4	-	RPDO4
4	TPDO4	481 _h	-	-	-	-	RPDO5
5	TPDO5	501 _h	-	-	-	-	RPDO6
6	RPDO2	201 _h	TPDO1	-	-	-	-
7	RPDO3	281 _h	TPDO2	RPDO3		RPDO3	RPDO3
8	RPDO1	301 _h	TPDO3	RPDO1	-	-	-

Message No.	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
1	610E:01 _h year	610E:02 _h day	610E:03 _h month	610E:04 _h hour	610E:05 _h minute	610E:06 _h second	not transmitted	
6	6190:00 _h driver_ID							
7	6194:00 _h block_ID				6192:00 _h line_ID		6195:00 _h journey_number	

CiA 417 lift control system

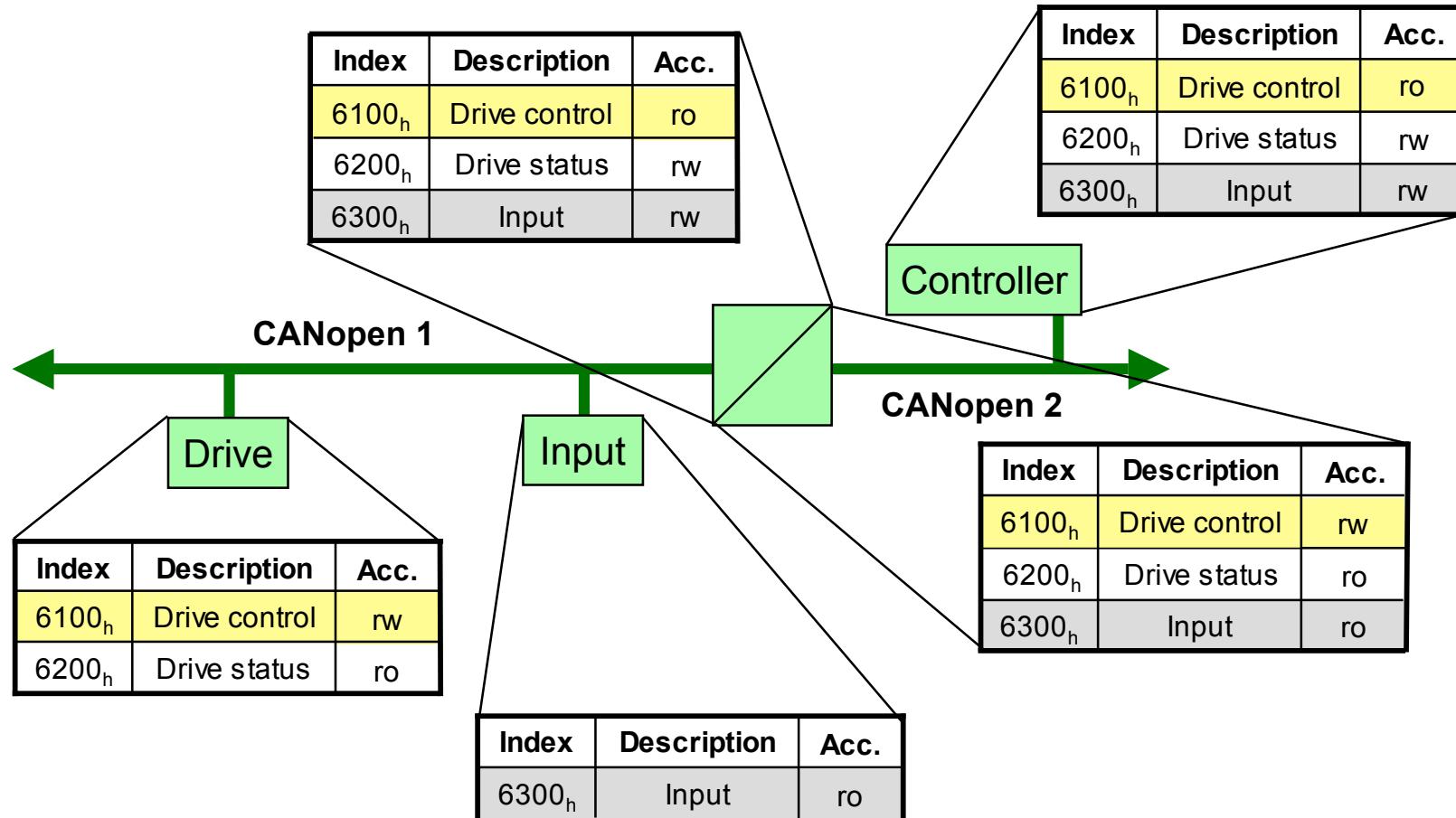


CiA 417 multiple lift control

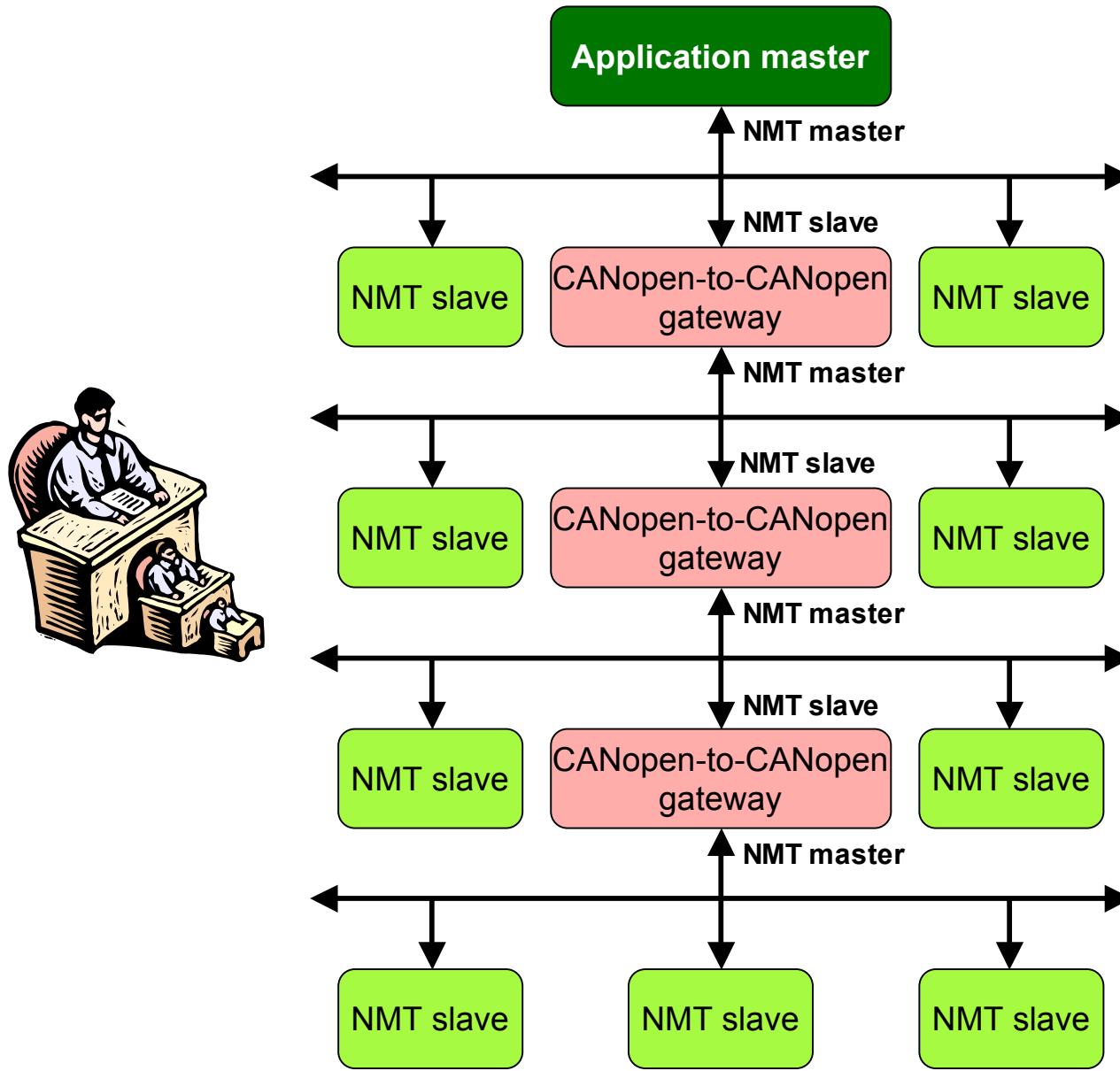
Index	Description
6000 _h to 60FF _h	Physical device
6100 _h to 67FF _h	Lift 1
6800 _h to 68FF _h	reserved
6900 _h to 6FFF _h	Lift 2
:::	
9800 _h to 98FF _h	reserved
9900 _h to 9FFF _h	Lift 8

Index	Description
6100 _h to 61FF _h	Panel input unit
6200 _h to 62FF _h	Panel output unit
6300 _h to 630F _h	Car door unit
6310 _h	Light barrier unit
6311 _h to 637F _h	reserved
6380 _h to 63FF _h	Car position unit
6400 _h to 647F _h	Car drive unit
6480 _h to 64FF _h	Load measuring unit
6500 _h to 657F _h	Sensor unit
6580 _h to 67FF _h	reserved

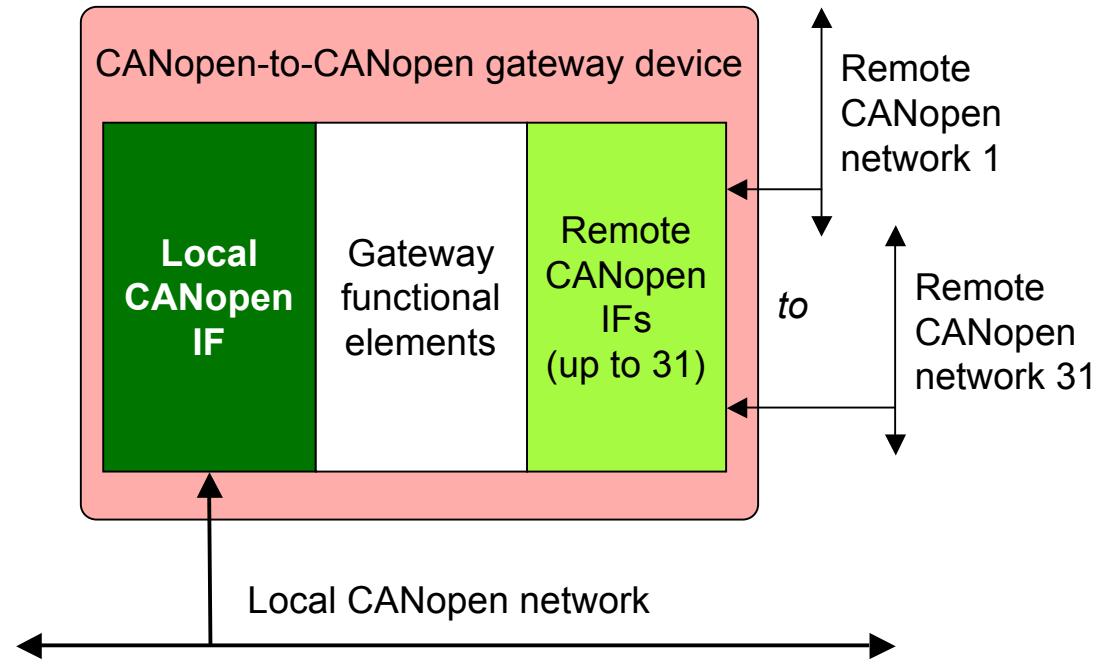
Transparent gateway



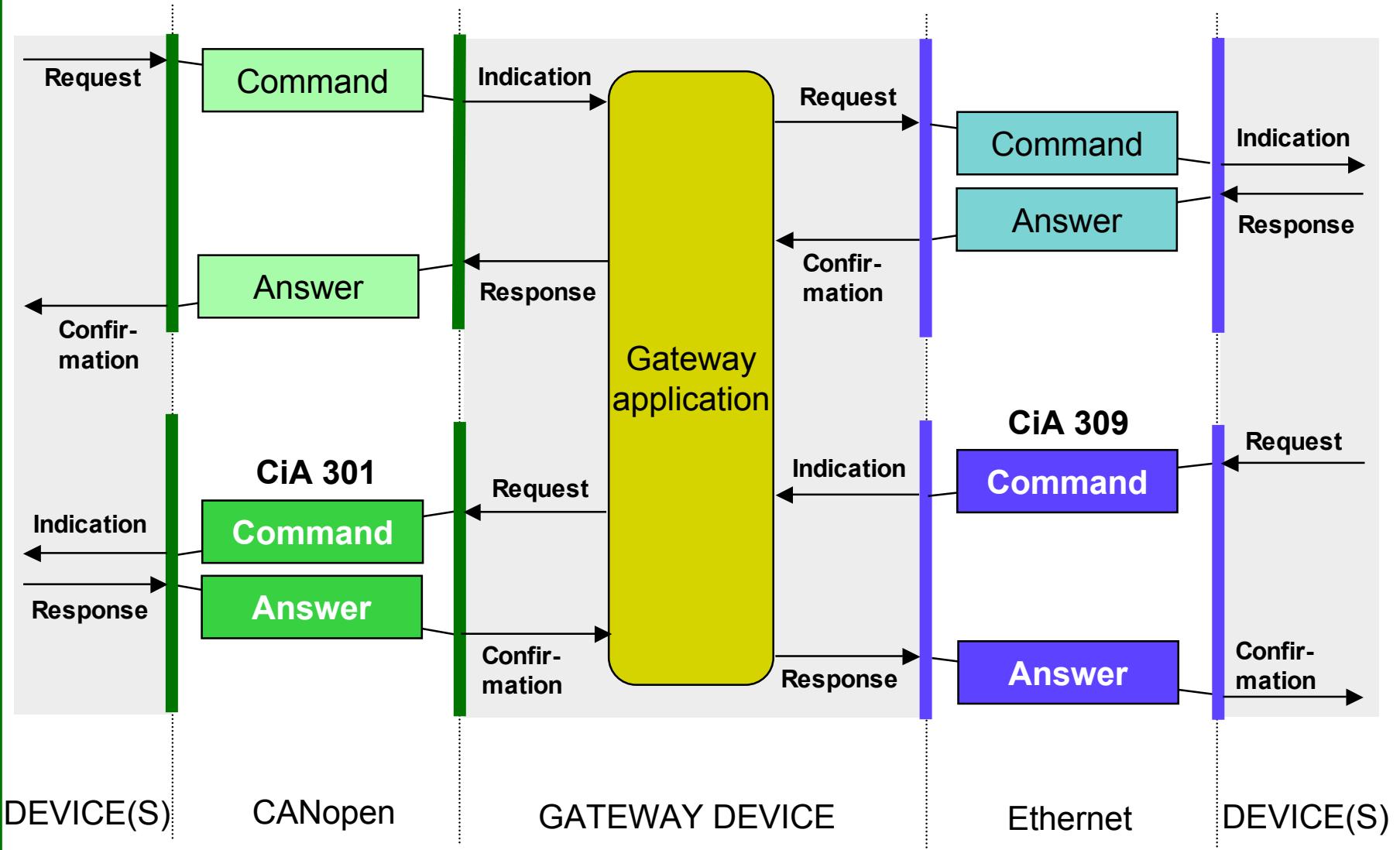
Hierarchical networks



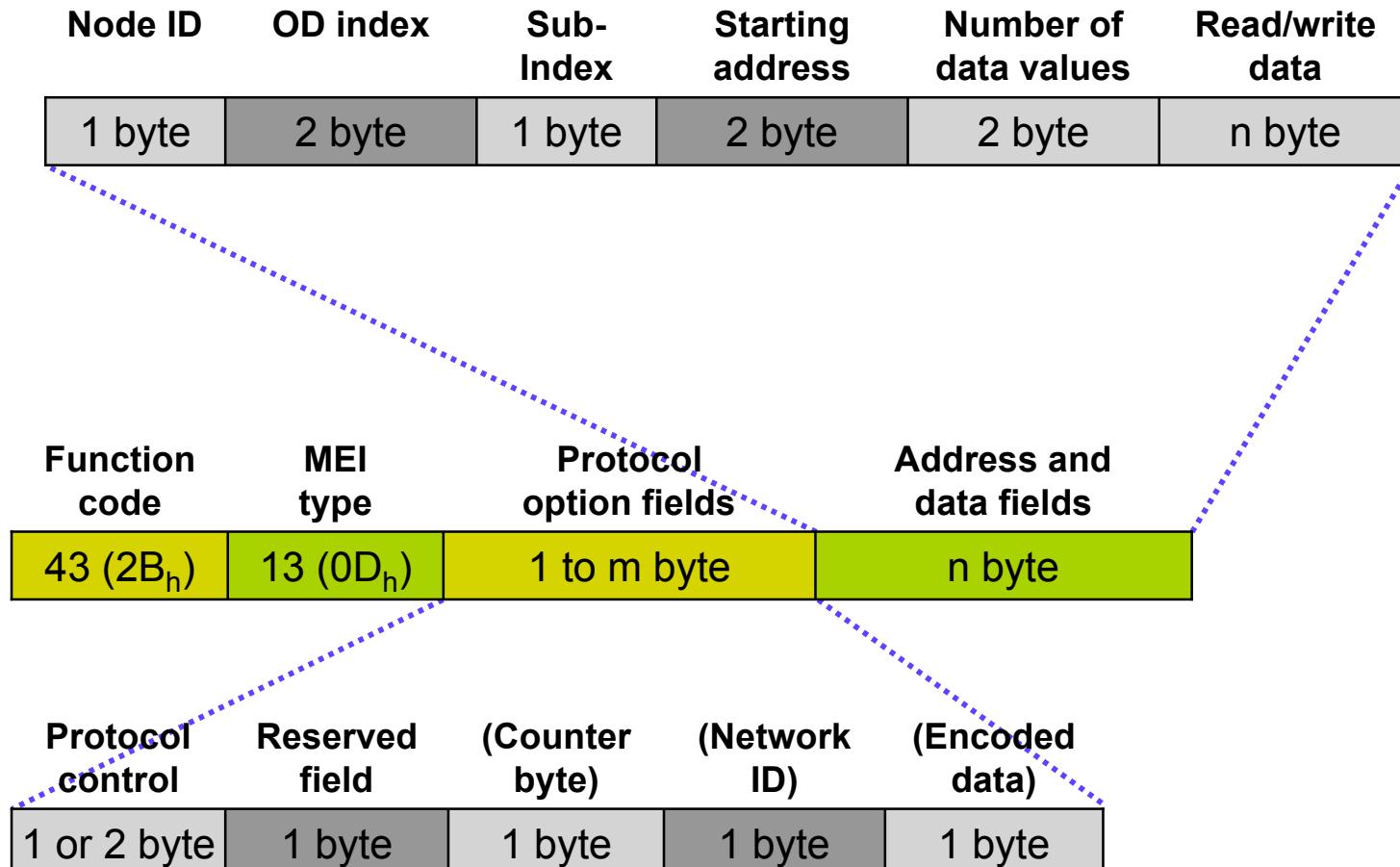
CiA 400 gateway model



CiA 309 gateway protocols



ModbusTCP protocol



Start CANopen device

Field name	Byte size and order	Example/range
Protocol control	1 byte	05 _h : specified network 01 _h : default network
Reserved field	1 byte	00 _h
[Optional] Counter byte	1 byte	not applicable
[Optional] Network ID	1 byte	1 to 255 if protocol control is 05 _h
[Optional] Encoded data	1 byte	not applicable

Field name	Byte size and order	Example/range
Node ID	1 byte	7F _h
Index	1 byte, high	FFFF _h
	1 byte, low	
Sub-index	1 byte	04 _h : start all nodes 12 _h : start one node
Starting address	1 byte, high	0000 _h
	1 byte, low	
Number of data values	1 byte, high	0000 _h : if sub-index is 04 _h 0001 _h : if sub-index is 12 _h
	1 byte, low	
Read/write data	1 byte	not applicable (if number of data values is 0000 _h) 01 _h to 7F _h : target node-ID (if number of data values is 0001 _h)

Ethernet (ASCII) protocol

```
<command-request>      ::= "["<sequence>"]" [[<net>] <node>] <command>
<sequence>             ::= UNSIGNED32
<net>                  ::= UNSIGNED8
<node>                  ::= UNSIGNED8
<command>                ::= <command-specifier> | <compound-command>
<compound-command>      ::= <command-specifier> <parameter>
<parameter>              ::= <value> | <compound-parameter>
<compound-parameter>    ::= <value> <parameter>
```

```
<command-response>     ::= "["<sequence>"]" <response>
<response>              ::= <value> | <error-string> | <emcy-list> | "OK"
<error-string>          ::= "Error:" <error code>
<error-code>             ::= <internal-error-code> | <sdo-abort-code>
<emcy-list>              ::= [<emcy1> "...<emcy254>"]
```

Start CANopen device

ASCII command

```
[ [net] node] start
```

```
1 8 start
```

ASCII answer

```
[ [net] node] start ok
```

```
1 8 start ok
```



We CANopen markets!