CAN in Automation (CiA)

Holger Zeltwanger

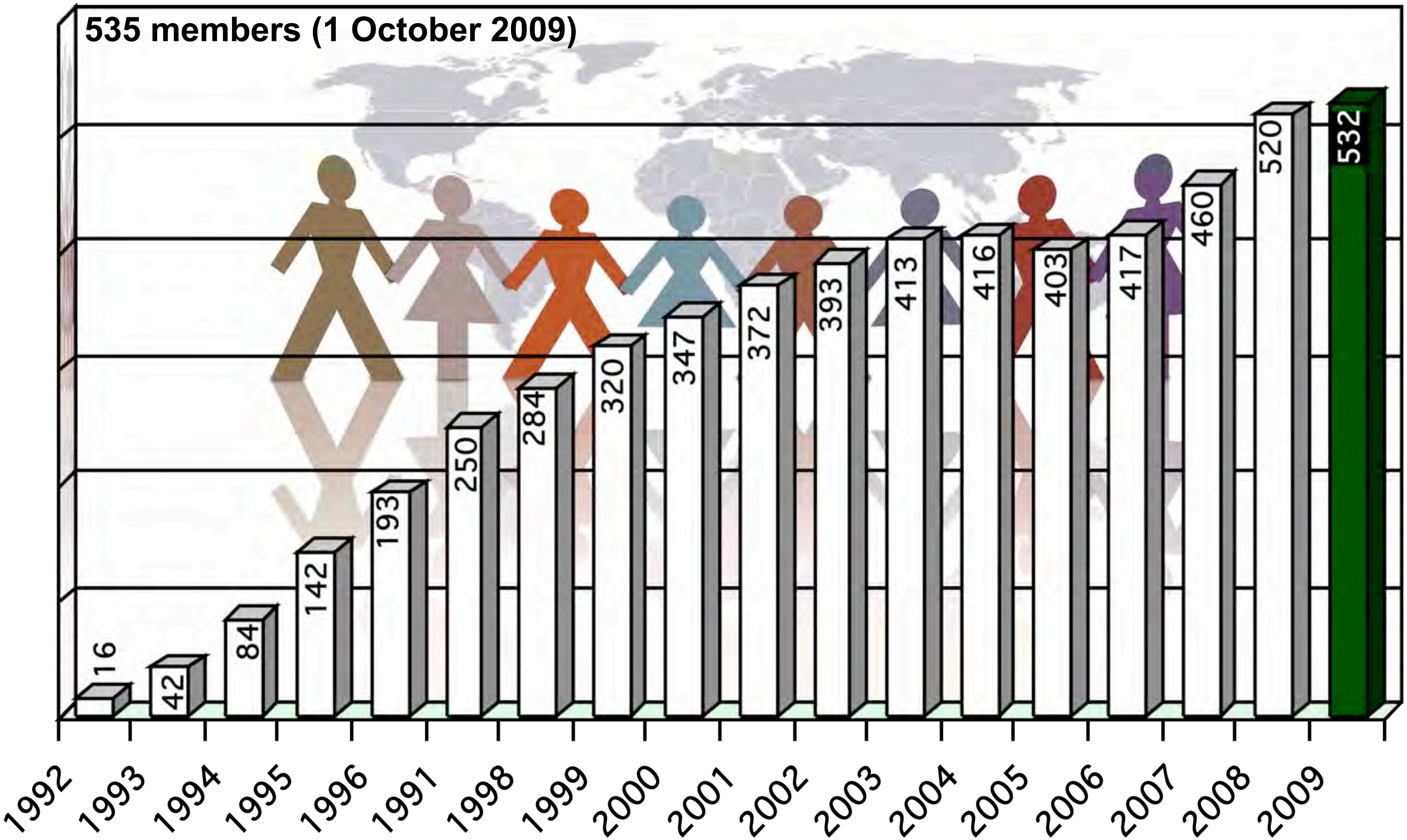
The social network

The non-profit CiA association is the social network for CAN newcomers and experts.

It provides technical, educational, publishing services for the benefit of users and manufacturers.

CiA is an absolute independent organization.

CiA members 1992 - 2009

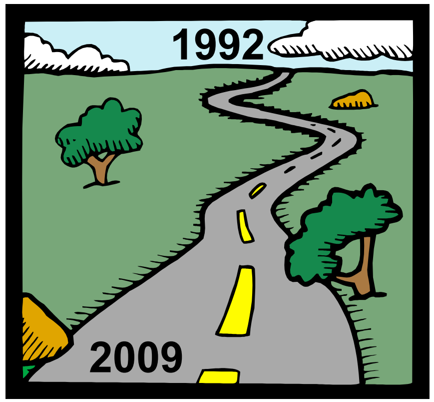


CiA worldwide

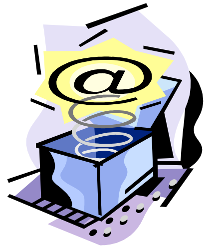
CiA history milestones

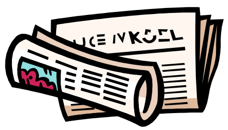
- 1992-03-05: Formation of CiA e.V. by

  Berghof, ***ESD***, *W. Gaiser*, ***G.i.N.***, *LP Elektronik*, ***MEN***, *Technology Partnership*, ***H. Zeltwanger***
- 1992-06-01: First issue of the CAN Newsletter published
- 1992-10-05: First joint CiA booth at Interkama in Duesseldorf
- 1992-11-23: First release of CiA 102 physical layer specification
- 1993-05-03: First release of CiA 200 series (CAN Application Layer)
- 1994-09-13 First international CAN Conference (iCC) in Wiesbaden
- 1994-11-28: First release of CiA 301 (CANopen) communication profile
- 1998-11-06: First iCC in United States of America
- 1999-02-26: CANopen conformance test tool released
- 2000-01-01: Formation of CiA GmbH (commercial arm of CiA)
- **2002-01-22: First CANtech conference in Moscow**
- 2004-03-01: First CANopen Product Guide on CD-ROM
- 2005-06-06: First CAN seminar in China
- 2008-04-01: New office facility in Nuremberg
- 2009-01-01: Representative in India



Services for non-members

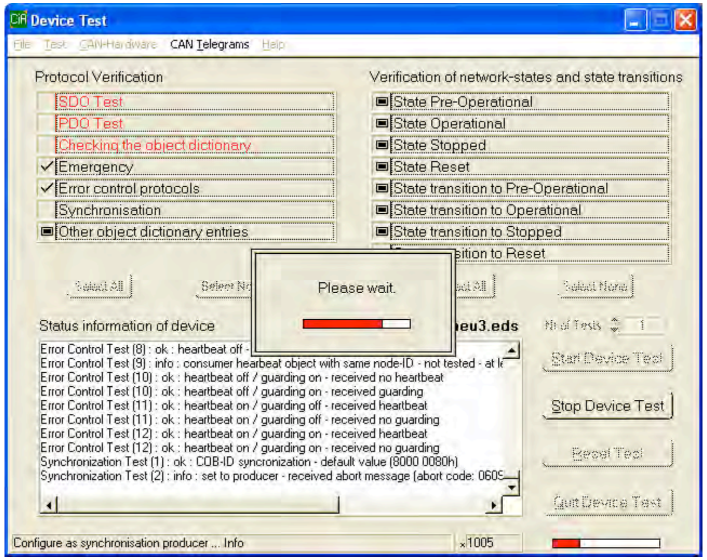




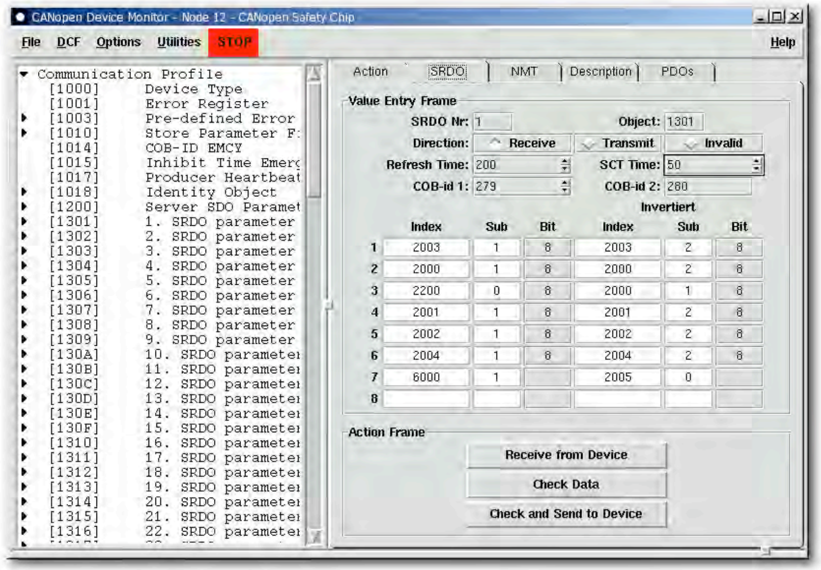
- Website (basic information for newcomers)
- Hotline (technical, marketing and product information)
- CAN Newsletter (free-of-charge subscription)
- CANopen product guide (free-of-charge subscription)
- CAN/CANopen specification and excerpt download
- CANschool (technical training for newcomers)
- Dedicated seminars (technical training for experts)
- In-house seminars (customer-specific training)
- Review of proprietary protocols and profiles
- CANopen device test and certification

Products provided by CiA

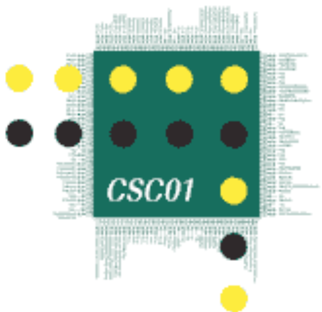
- CANopen conformance testing tool



- CANopen Safety configuration tool



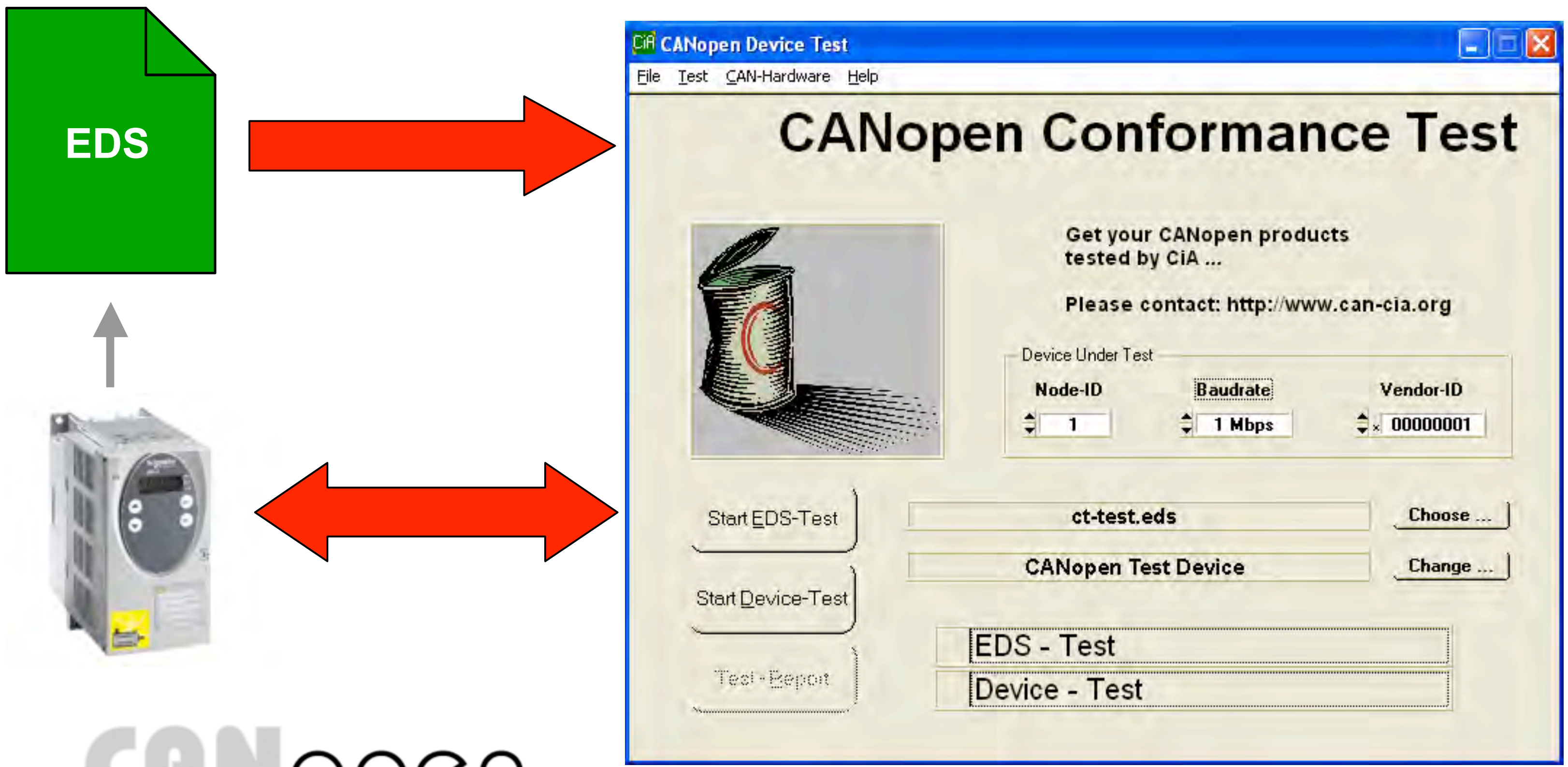
- CANopen Safety Chip (CSC01/02)



TÜV certified ● SIL 3 (IEC 61508)

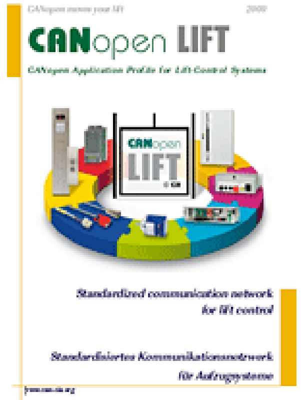
- CSC01/02 starter-kit

CANopen certification



CANopen certified by CiA

CiA 417 demonstrator



CANopen

Lift control units **Boehnke + Partner**

Lift drive **Control Techniques**

Pos. sensor **Baumer**

Car door unit **Siemens**

Panel(s) **Masora**

CANopen

Lift control units **Weber Lifttechnik**

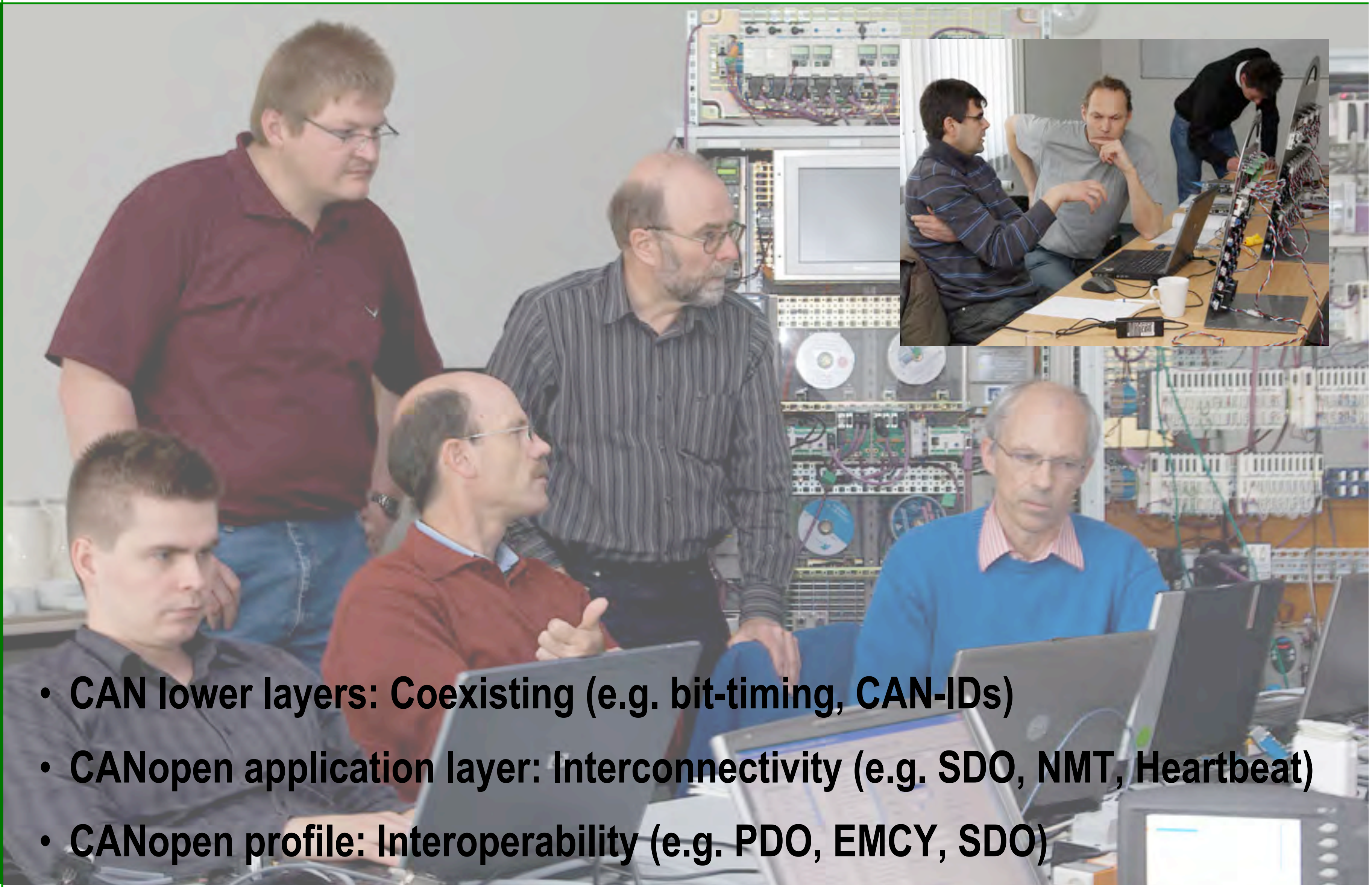
Lift drive **Ziehl-Abegg**

Pos. sensor **Pepperl + Fuchs**

Car door unit **Siemens**

Panel(s) **Schaefer**

CANopen plug-fests



- CAN lower layers: Coexisting (e.g. bit-timing, CAN-IDs)
- CANopen application layer: Interconnectivity (e.g. SDO, NMT, Heartbeat)
- CANopen profile: Interoperability (e.g. PDO, EMCY, SDO)

Membership benefits

Individual advantages:

- Creating and influencing specifications published by CiA
- Exclusive information on new CAN technology and market trends
- Information on CiA work draft specification
- Participation in joint marketing activities (e.g. demonstrators or plug-fests)
- Development of partnership with other CiA members
- Reduced fees for CiA events including in-house seminars
- Reduced prices for some CiA publications
- Free-of-charge CANopen vendor-ID assignment and license for CANopen® and CiA®
- Reduced prices for CANopen product certification

General advantages:

- Development of the CAN markets in general
- Development of specific CAN markets by region, by application, or by high-layer protocols
- Company and product neutral information platform for manufacturers and users
- Platforms for information exchange on experiences and knowledge (social network)
- Supporting international standardization of CAN technology

Community trade mark


Eingetragen / Registered 05/06/2009

No 007092273

HABM – HARMONISIERUNGSAMT FÜR DEN BINNENMARKT
MARKEN, MUSTER UND MODELLE

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Diese Eintragungsurkunde wird für die unten angegebene Gemeinschaftsmarke ausgestellt. Die betreffenden Angaben sind in das Register für Gemeinschaftsmarken eingetragen worden.

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CANopen®

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Eingetragen / Registered 27/05/2009

No 007109846

Der Präsident / The President

Wubbo de Boer

HLP history

- *1991:CAN Kingdom*
- *1992:CAN Application Layer (CAL)*
- *1994:Smart Distributed System (SDS)*
- 1994:DeviceNet
- **1994: SAE J1939**
- **1995: EN 50325-4 (CANopen)**
- 1997:OSEK-*COM*/NM
- 1999:ISO 11992-1/-2/-3
- 2000:NMEA 2000
- 2002:ISO 11783 series (ISOBUS)
- **2004: ISO 14229/15765 (Diagnostic)**
- 2007: Arinc 825

Device compatibility levels

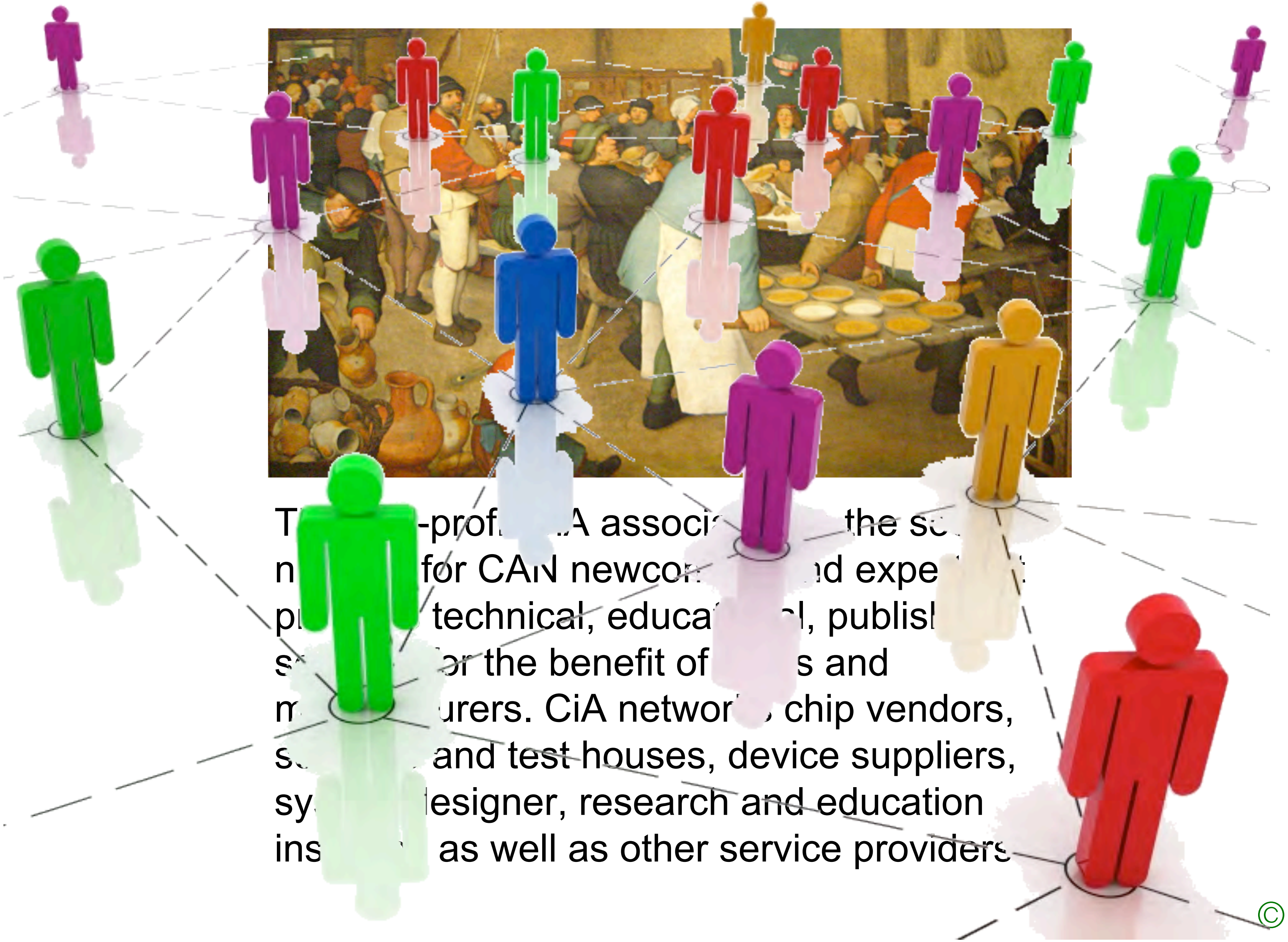
	Incompatible	Tolerating	Coexisting	Inter-connectible	Inter-workable	Inter-operable	Inter-changeable
Dynamic behavior							x
Application functionality						x	x
Parameter semantics						x	x
Data type					x	x	x
Data access				x	x	x	x
Communication profile				x	x	x	x
Higher-level protocols			x	x	x	x	x
Lower-level protocols		x	x	x	x	x	x

Application objects

Communication objects

Based on IEC TR 62390

CiA networks not only nodes!



T -prof A associ the s
n for CAN newco d expe
p technical, educa l, publis
s for the benefit of s and
m urers. CiA networ chip vendors,
s and test houses, device suppliers,
sy designer, research and education
ins as well as other service providers

Questions and answers

CAN

J1939-based networks

Protocols and applications

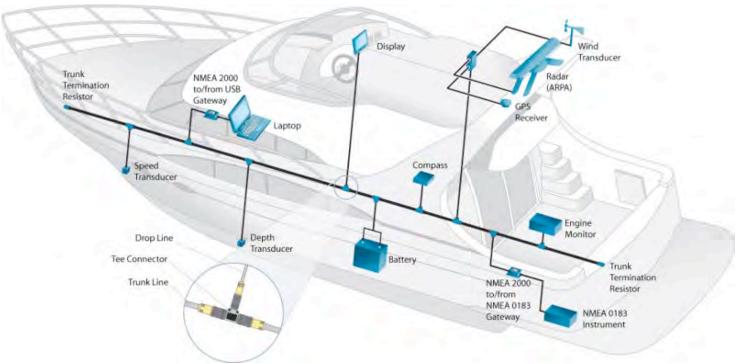
Holger Zeltwanger

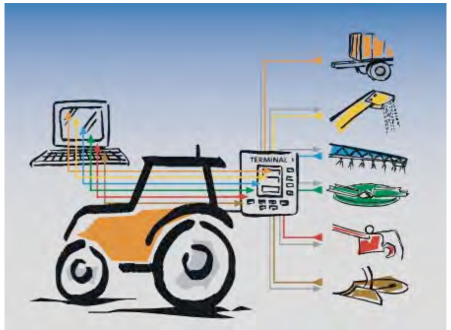
J1939 protocol families

- SAE J1939 for on-highway trucks and buses
- SAE J1939 for off-highway Diesel-engine powered vehicles
- ISO 11992 for truck/trailer communication
- ISO 11783 for agriculture and forestry vehicles
- NMEA2000 for ships and vessels
- RV-C for recreation vehicles

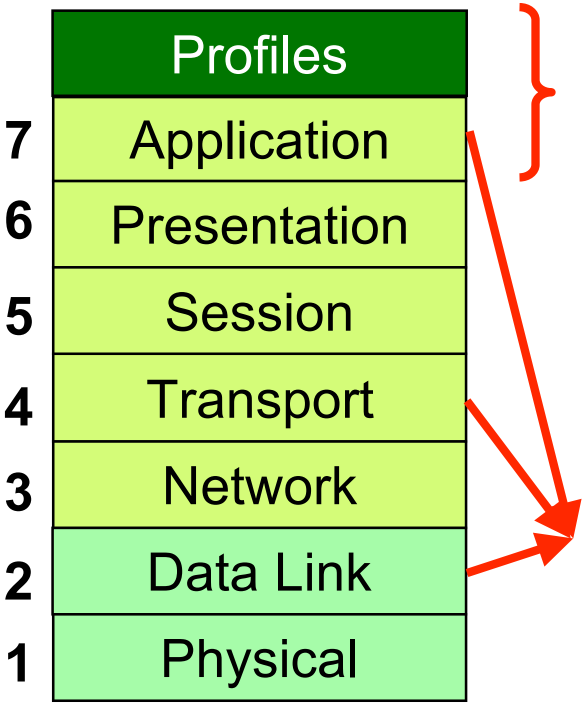
Main features

- CAN data link layer using data frames with 29-bit identifier
- Peer-to-peer and broadcast communication
- Transport protocol for up to 1785 byte
- Network management
- Definition of parameters and parameter groups





J1939 reference model



J1939-81: Network management
J1939-71: Vehicle application layer
J1939-73: Application layer - Diagnostics
J1939-74: Application - Configurable messaging
J1939-75: Application layer - Generator sets and industrial

J1939-31: Network layer

J1939-21: Data link layer

J1939-11: Twisted shielded pair (250 kbit/s)
J1939-13: Off-board diagnostic (OBD) connector
J1939-15: Un-shielded twisted par (250 kbit/s)

J1939-01: Recommended practice for control and communication network for on-highway equipment
J1939-02: Agricultural and forestry off-road machinery control and communication network
J1939-03: On-board diagnostics implementation guide
J1939-05: Marine stern drive and inboard spark-ignition engine on-board diagnostics implementation guide
J1939-82: Compliance - truck and bus
J1939-84: OBD communications compliance test cases for heavy-duty components and vehicles

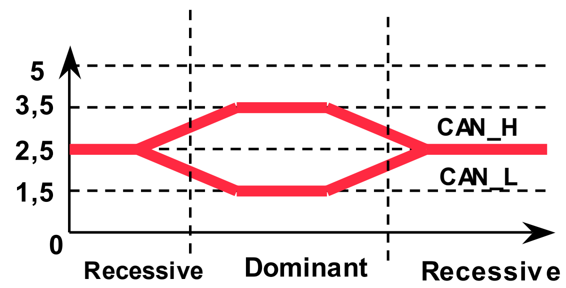
J1939 physical layers

J1939-11 (250 kbit/s)

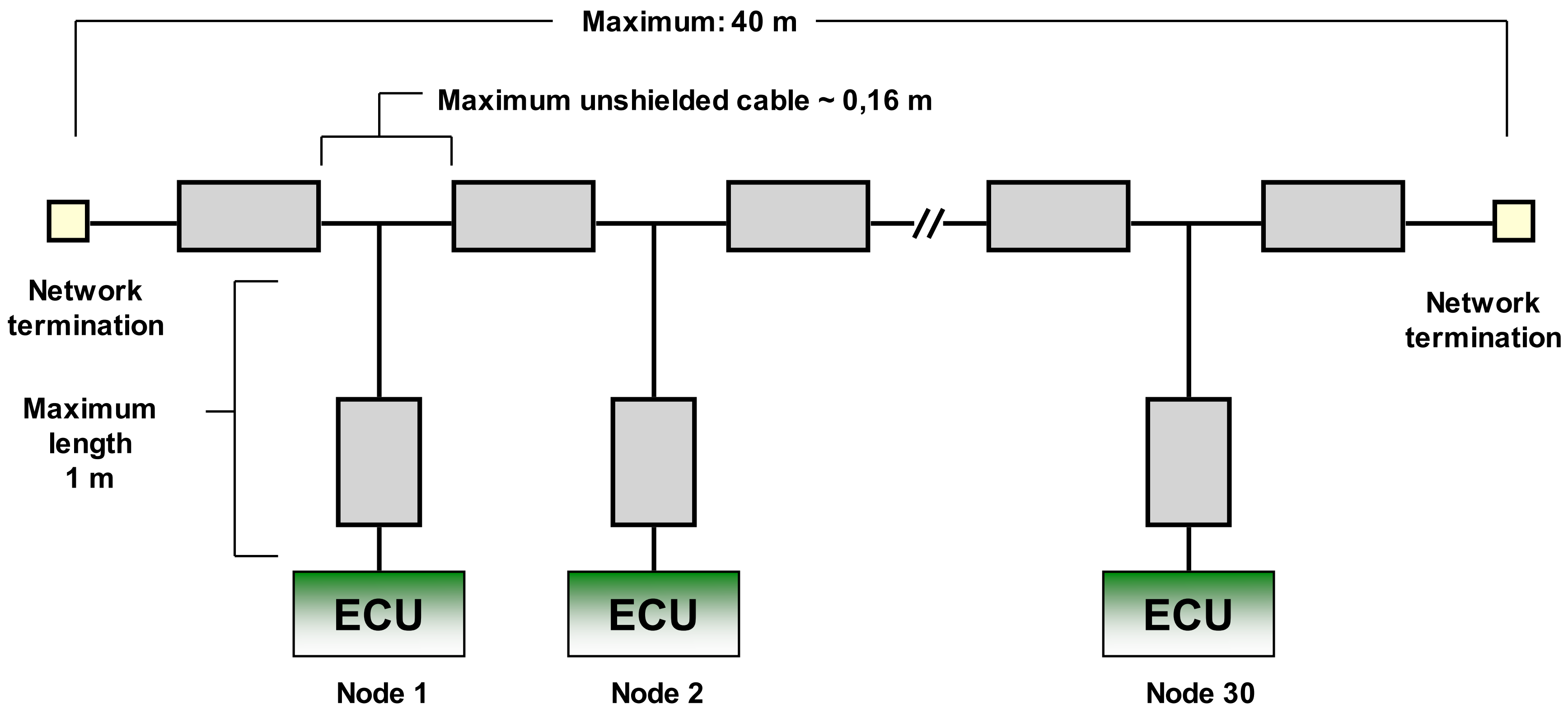
- The communication media is a shielded, twisted pair cable with a drain that requires a termination resistor at each end.
- Network connections are made using a 3-pin, unshielded connector. The three pins are defined as CAN_H, CAN_L, and shield.
- The physical layer is compliant to ISO 11898-2.
- 30 nodes per segment are allowed.

J1939-15 (250 kbit/s)

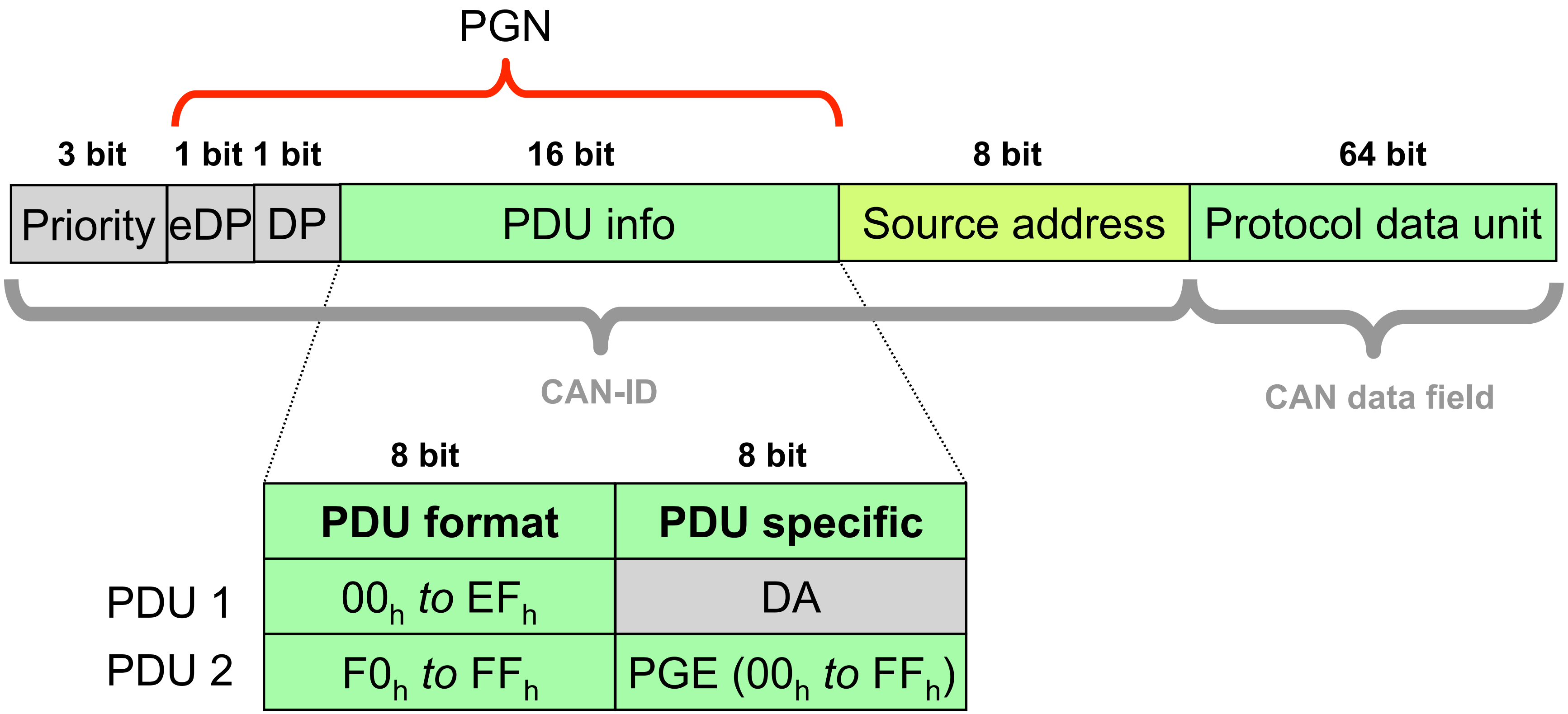
- The communication media is a twisted, non-shielded quad. The media is terminated with a current sourcing and sinking bias network.
- Network connections are made using a 4-pin, unshielded connector. The four pins are defined as CAN_H, CAN_L, Power, and Ground.
- The physical layer is compliant to ISO 11898-2.
- 30+ nodes per segment are allowed.



J1939/11 topology

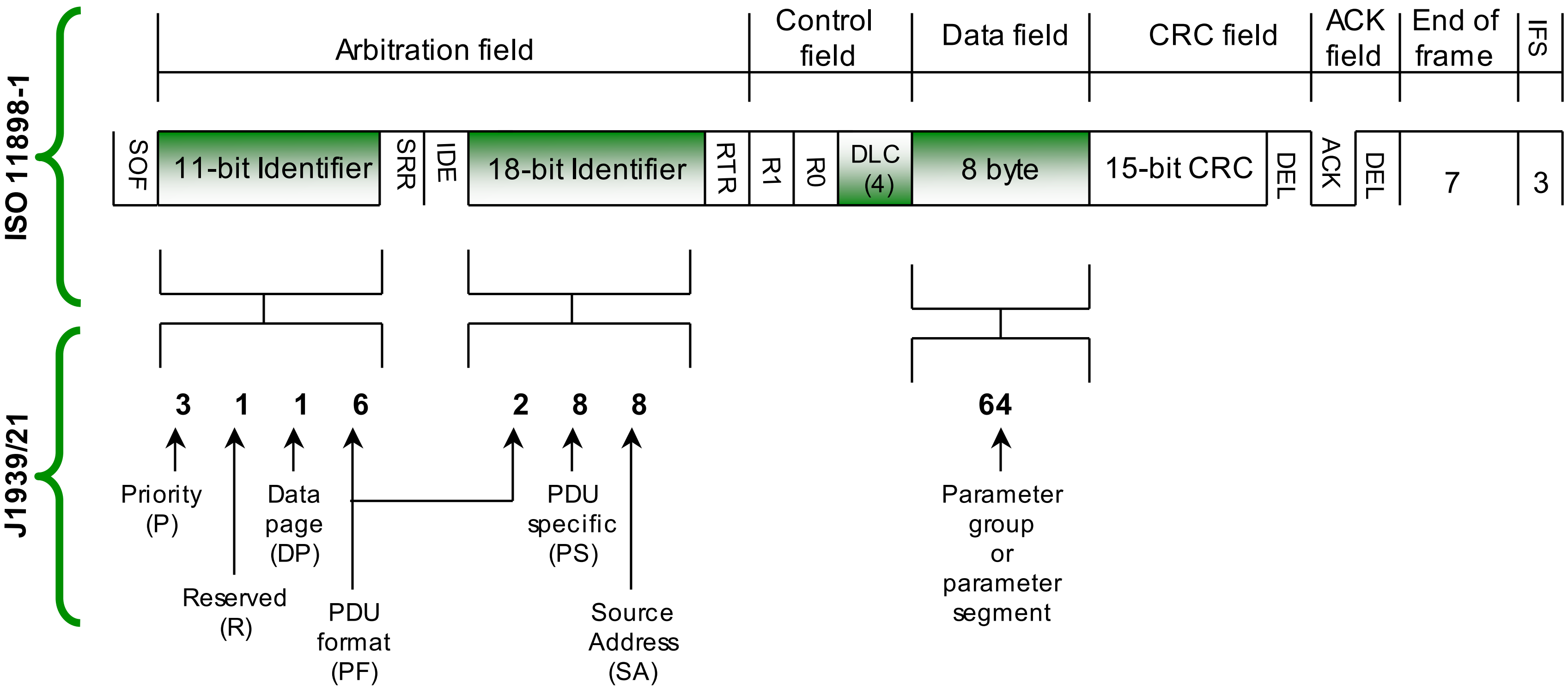


J1939 message format



DA = Destination address
DP = Data page
eDP = extended data page
PDU = Protocol data unit
PGE = Parameter group extension
PGN = Parameter group number

"Data link layer"



PDU format <240 (peer-to-peer), PDU specific contains target address (255 = global)

PDU format ≥240 (broadcast), PDU format and PDU specific contains a part of PGN

PDU = Protocol data unit PGN = Parameter group number

Transport protocols

Transport protocols are provided with the following features:

- Connection-oriented, point-to-point (RTS/CTS)
- Connectionless broadcast (BAM)
- Up to 1792 byte may be sent

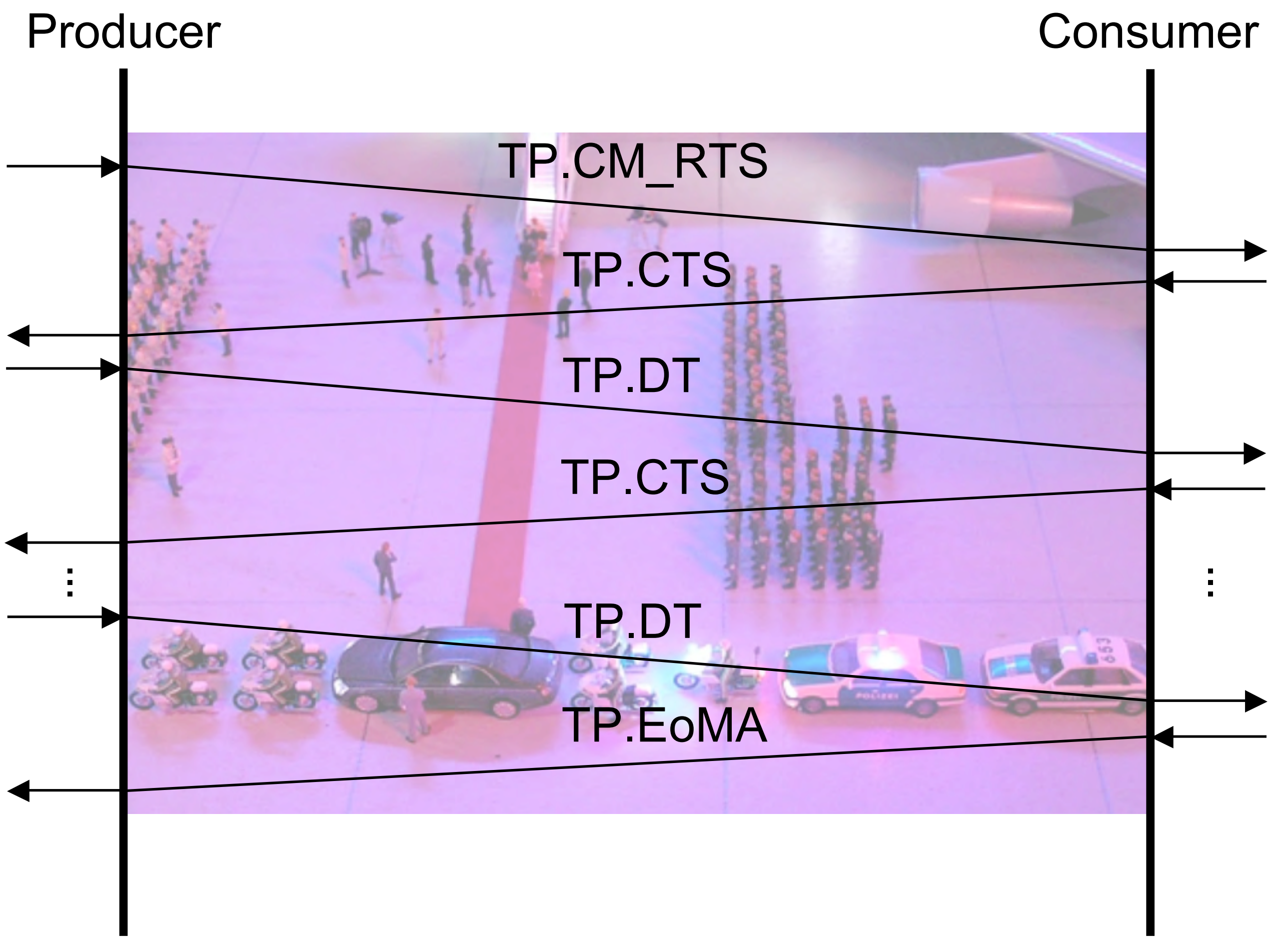
Receiver controls flow of message:

- May temporarily stop by sending CTS with #packets = 0, continuing to send every 0,55 s
- May close with End-of-Message ACK

Time will close connection if values exceed the following:

- 250 ms between packets
- 1250 ms after CTS message sent
- 1250 ms and no CTS or ACK sent after last packet
- 550 ms no CTS after CTS(0) sent

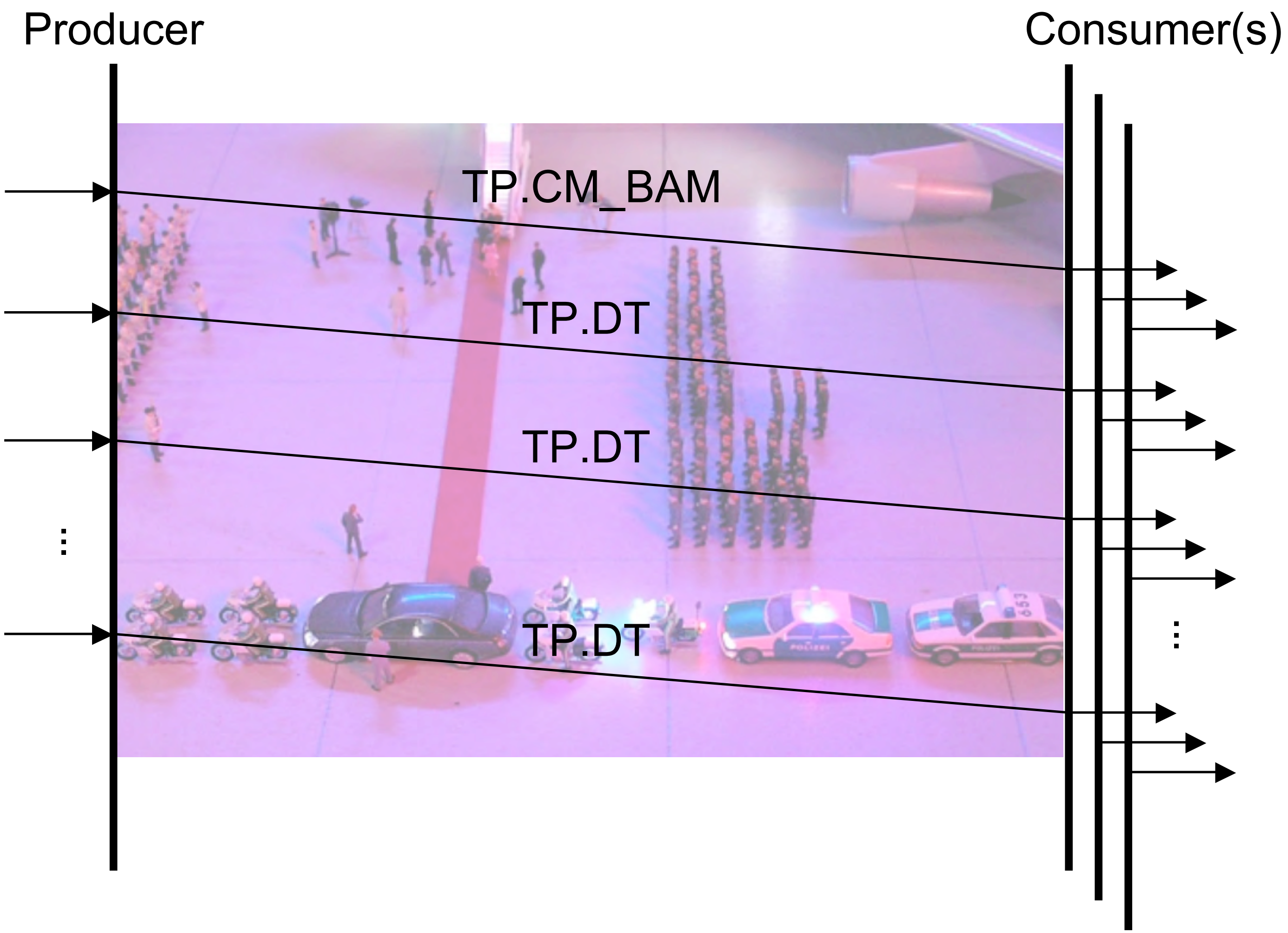
RTS/CTS protocol



RTS = request to send

CTS = clear to send

BAM protocol



BAM = broadcast announce message   DT = data transmission

Network layer (/31)

Scope of network layer

- Minimum of two segments (tractor and implement buses)
- Virtual terminals and gateway-to-management computers nodes on implement bus.

Repeater - data rate, protocol, and address space same on both sides

Bridge - protocol, address space same; media, data rates differ

Router - protocol same; address space, data rates, media may differ

Gateways - data exchanged between different networks

- Provision is made for bridges that have the ability to dynamically select a source address and provide sub-network nodes with addresses. This feature is being developed for on-highway trailer bridges applications.
- *Bridge capabilities:*
  - “Filter unless asked”
  - “Pass unless asked”

Parameter definition

Parameters defined by the following:

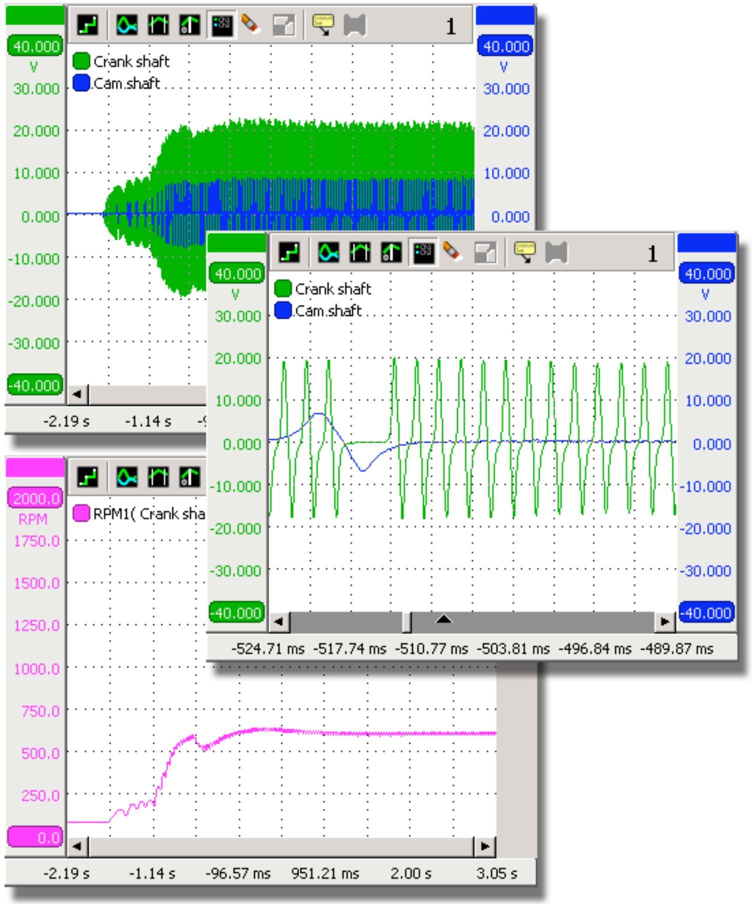
- Data length
- Resolution, offset
- Type
- Range
- SPN (suspect parameter number)

Parameters grouped by common:

- Function
- Update rate
- Subsystem

Message specifics defined by the following:

- Repetition rate or by request
- Data length
- Parameters
- PGN
- Priority, control or informational values



Engine temperature

Transmission repetition rate:	1 s
Data length:	8 byte
PGN	$FEEE_h$
PDU format	254
PDU specific	238
Default priority	6

PG:		
	1	Engine coolant temperature
	2	Fuel temperature
	3,4	Engine oil temperature
	5,6	Turbo oil temperature
	7	Engine inter-cooler temperature
	8	Not used (reserved)

Ambient conditions

MESSAGE

3.3.35 AMBIENT CONDITIONS

Transmission repetition rate:	1 s
Data length:	8 byte
PGN	$FEF5_h$

Byte:	1	Barometer pressure
	2,3	Cab interior temperature
	4,5	Ambient air temperature
	6	Air inlet temperature
	7,8	Road surface temperature

PARAMETER GROUP (PG)

3.2.5.43 *Barometric pressure*- Absolute air pressure of the atmosphere

Data Length:	1 byte
Resolution:	0,5 kPa/bit gain, 0 kPa offset
Data Range:	0 kPa to + 125 kPa (0 psi to + 18,1 psi)
SPN:	108
Type:	Measured

3.2.5.11 *Cab interior temperature*- Temperature of air inside the part of the vehicle encloses the driver and vehicle operating controls.

Data Length:	2 byte
Resolution:	0,03125 °C/bit gain, -273 °C offset
Data Range:	-273 C to + 1735.0 C
SPN:	170
Type:	Measured

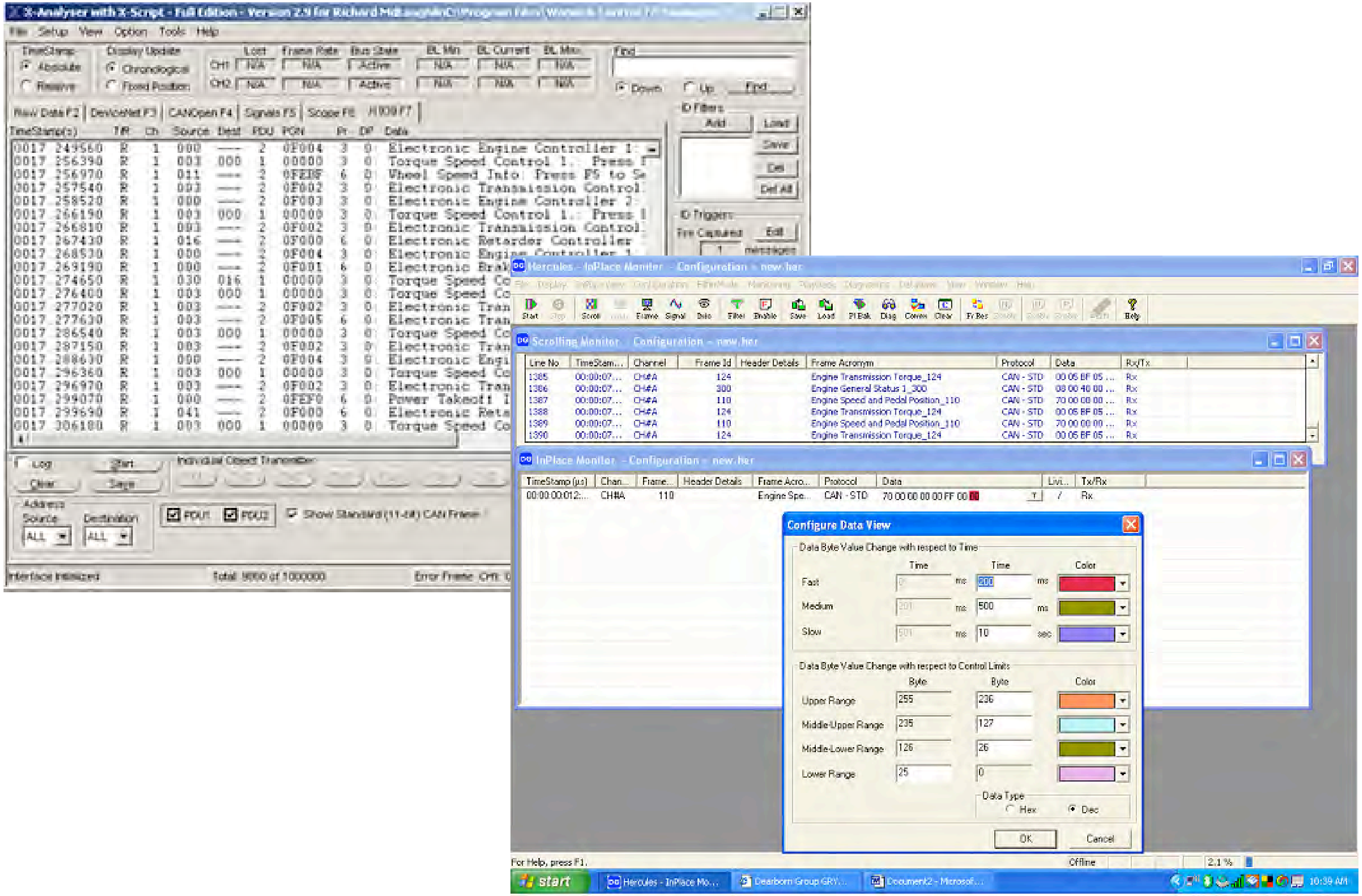
3.2.5.12 *Ambient air temperature*- Temperature of air surrounding vehicle

Data Length:	2 byte
Resolution:	0,03125 °C/bit gain, -273 °C offset
Data Range:	-273 °C to + 1735,0 °C
SPN:	171
Type:	Measured

4.2.5.13 *Air inlet temperature*- Temperature of air entering vehicle air induction system

Data Length:	1 byte
Resolution:	1 °C/bit gain, -40 °C offset
Data Range:	-40 °C + 210 °C
SPN:	172
Type:	Measured

J1939 analyzing tool



Diagnostics (/73)

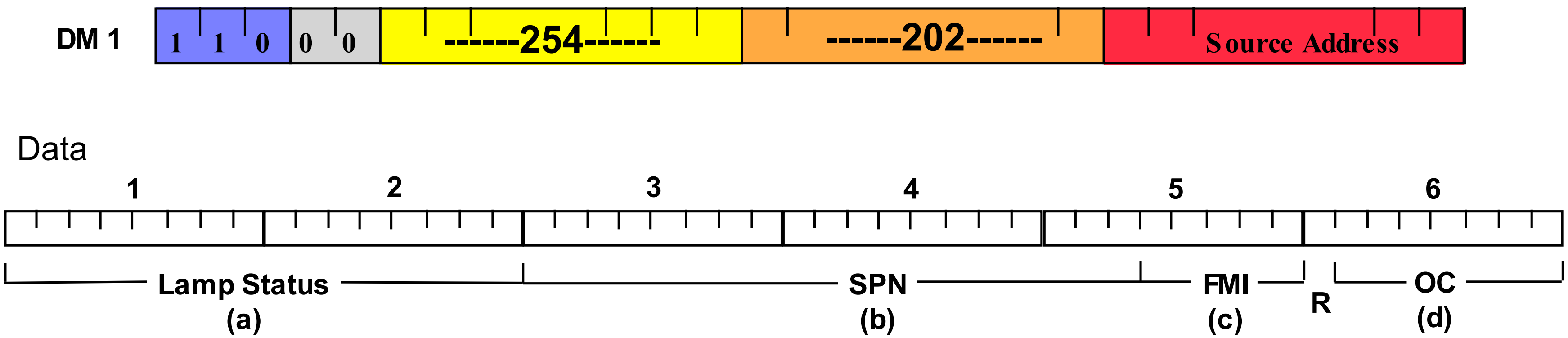
- **Requirements for service tool access:**
  - Security
  - Connectors
  - Diagnostic status message support
  - Diagnostic test support

- **Diagnostic trouble code (DTC)**
  - Suspect parameter number (SPN)
  - Failure mode identifier (FMI)
  - Occurrence count (OC)

Diagnostic message

Active diagnostic trouble codes (DM 1)

- Transmitted when DTC becomes active fault
- Update rate 1 second



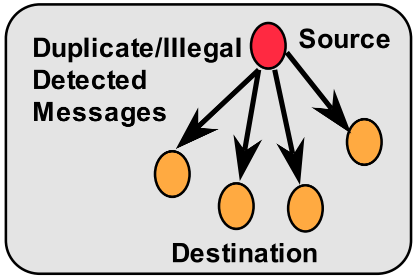
If more than one DTC occurs - data pattern = a,b,c,d,b,c,d,b,c,d,…
(Transport protocol is probably used)

Module naming (/81)

- The network management specification defines, how all modules on a given link arbitrate for their source addresses.

- It is specified that no two modules on a system have the same name and instance number.
  - Globally “address claimed” request (allows any device to compile a list of devices and their names)
  - Optional ability of devices to do dynamic addressing
  - No central network management device defined within the system

NM message



PDU1 Request	P P P	R G	-------234------	Destination Address	Source Address

Data	PGN lsb 1	PGN 2	PGN msb 3
	00	EE	00

NM .Address Claimed	1 1 1	0 0	------238------	------255------	Source Address

Data	Name 1 - 8

or

NM .Cannot Claim Address	1 1 1	0 0	------238------	------255------	------254------

Data	Name 1 - 8

Network management

Source/destination addresses:

- 0 *to* 253 — Valid ECU addresses
- 254 — Zero (not used as ECU source address)
- 255 — Global (not used as ECU source address)

Each device type has a preferred address, but has to register itself on the J1939 network by means of the “address claiming procedure”.

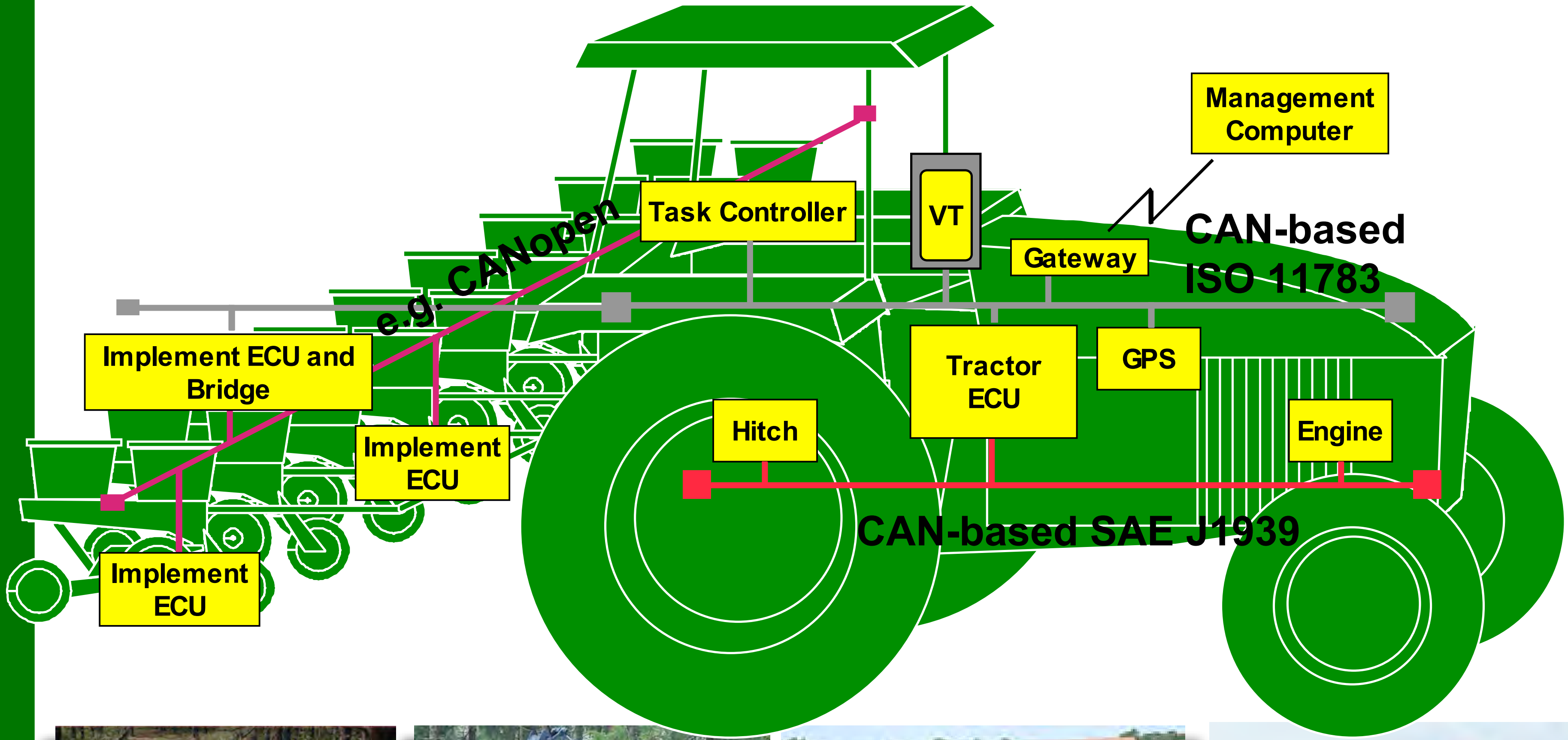
The device sends its PG address-claim:

21 bit	11 bit	3 bit	5 bit	8 bit	1 bit	7 bit	3 bit	4 bit	1 bit
ID number	Manufacturer code	ECU instance	Function instance	Function	r	Vehicle system	IG	VS instance	AAC

ID = identifier IG = industry group VS = vehicle system AAC = arbitrary address capable

ATTENTION: The address claiming procedure in J1939 may lead to CAN bus-off condition!

ISO 11783 or ISOBUS

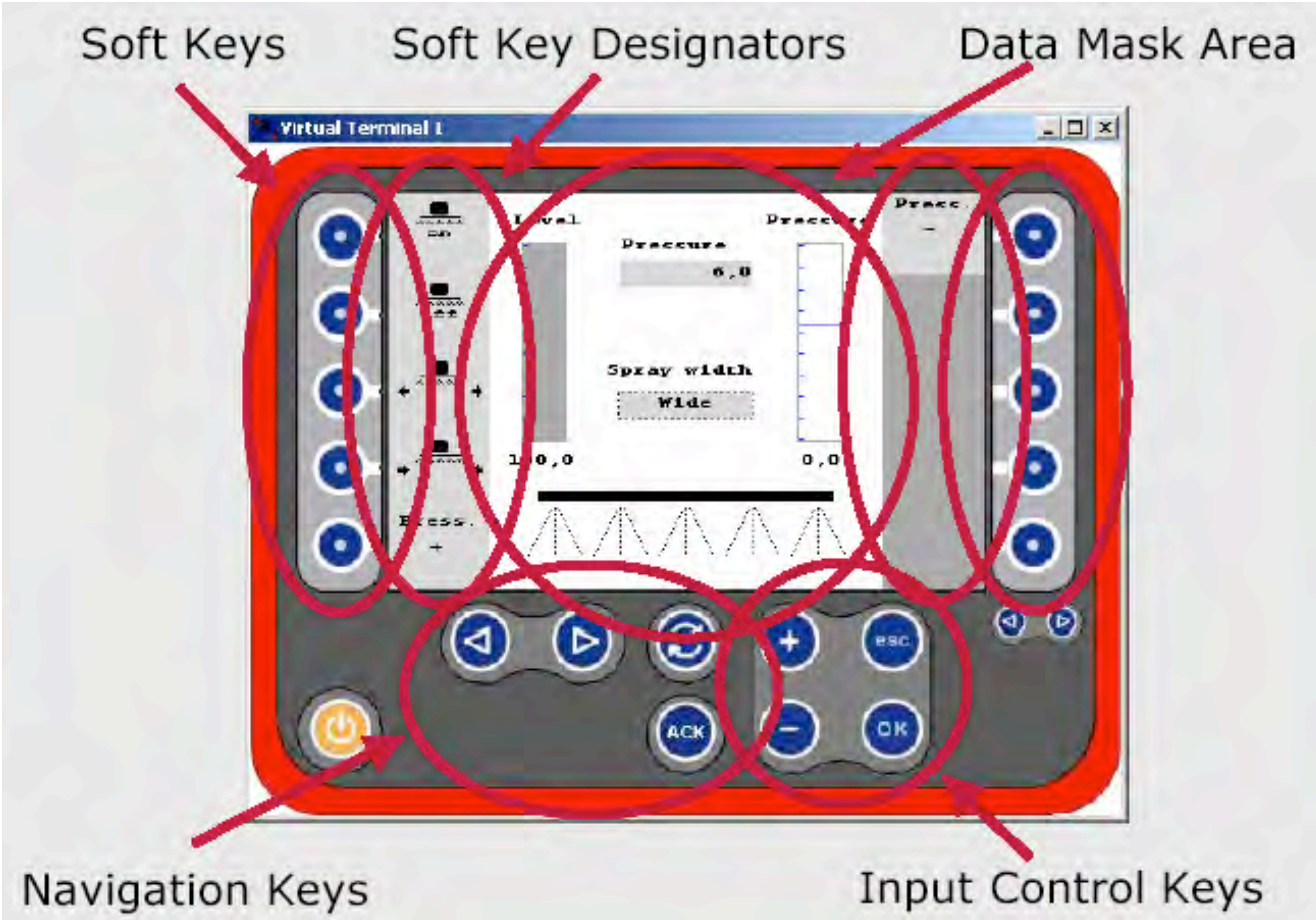


ISO 11783 documents

Part	Title	Status
1	General standard for mobile data communication	DIS
2	**Physical layer**	**IS**
3	**Data link layer**	**IS**
4	**Network layer**	**IS**
5	**Network management**	**IS** (DIS)
6	**Virtual terminal**	**IS**
7	**Implement message layer**	**IS**
8	Power train messages	DIS
9	**Tractor ECU**	**IS**
10	Task controller & management computer interface	DIS
11	Data dictionary	DIS
12	Diagnosis	DIS
13	File server	DIS
14	Sequence control	DIS

IS = international standard **(F)DIS = (final) draft international standard**

Virtual terminal



Network interconnection

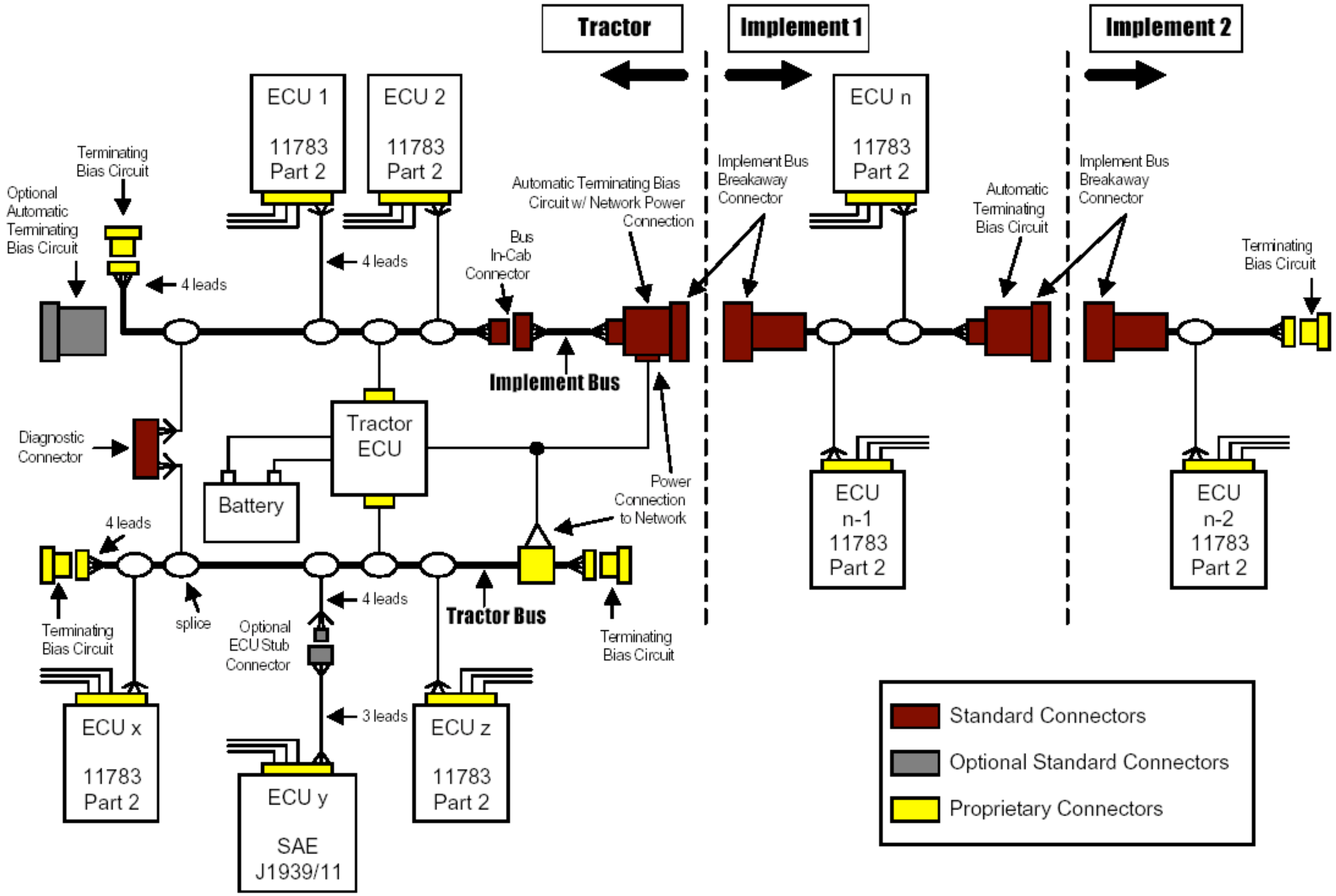
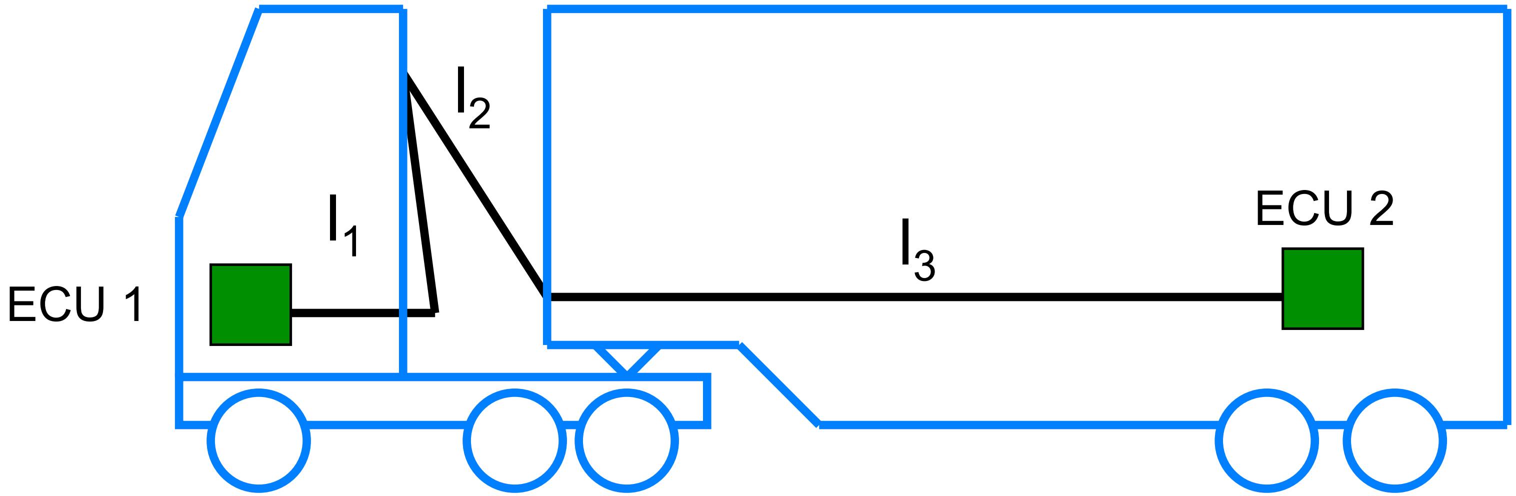


FIGURE B.1 - EXAMPLE NETWORK INTERCONNECTION

ISO truck/trailer interface

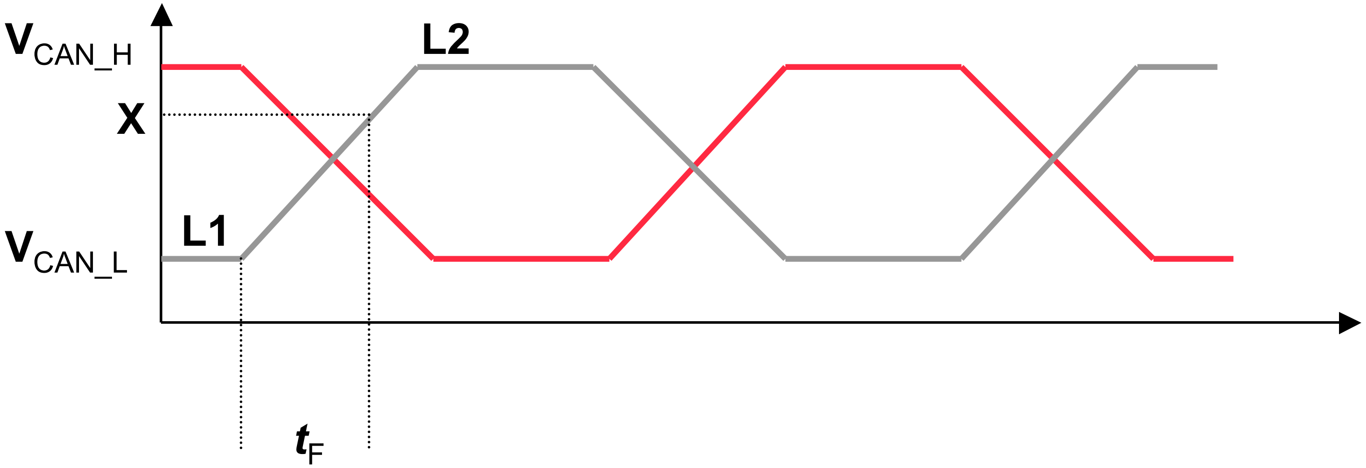


$l_{max} = l_1$ (15 m) + l_2 (7 m) + l_3 (18 m) = 40 m

ISO 11992-1

ISO 11992-1 bus level

For 24-V nominal voltage systems bus voltage is min. 0 V and max. 32 V
For 12-V nominal voltage systems bus voltage is min. 0 V and max. 16 V



$$X = V_{CAN\_L1} + 0.63 \times (V_{CAN\_L2} - V_{CAN\_L1})$$

ISO 11992 parameter groups

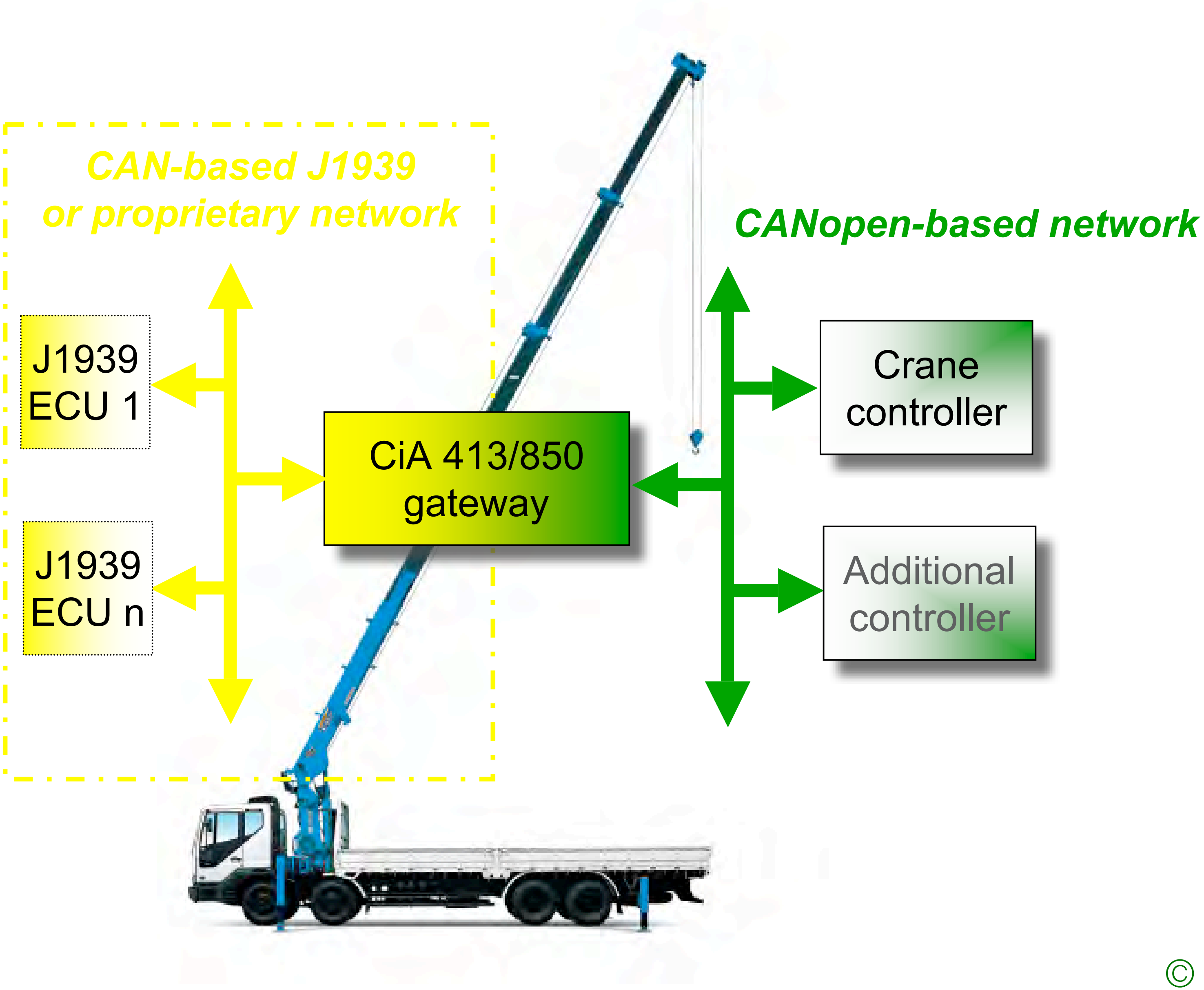
- **Braking and running gear equipment (part 2)**

Example:	Actual percentage of retarder peak torque	
	Data length:	1 byte
	Resolution:	1 %/bit gain, -125 % offset
	Data range:	-125 % to + 125 %
	Type:	Measured

- **Other equipment (part 3)**

Example:	Maximum vehicle speed limit	
	Data length:	1 byte
	Resolution:	1 km/h/bit gain, 0 km/h offset
	Data range:	0 km/h to 250 km/h
	Type:	Measured

J1939-to-CANopen gateway



Questions and answers

Arinc 825 - CAN in aircrafts

Holger Zeltwanger

CiA Managing Director

Introduction into Arinc 825

- The Arinc 825 standard (General standardization of CAN bus protocol for airborne use) was mainly driven by Airbus and Boeing. It defines a communication standard for airborne systems using CAN, which has been identified by both leading air-framers as an important baseline network for their future transport aircraft.
- Arinc 825 was developed by the CAN Technical Working Group of the Airlines Electronic Engineering Committee (AEEC) Aircraft Network Infrastructure and Security Subcommittee that included members from Airbus, Boeing, Rockwell Collins, GE Aerospace and Stock Flight Systems and was published November 15, 2007.
- Aside from large transport aircraft, Arinc 825 is suitable for general aviation as well as for military aircraft. Compatibility between the established CANaerospace standard and Arinc 825 is given.
- Arinc 825 constitutes the framework for all other Arinc standards based on CAN. An example for an Arinc 825 based standard is the Arinc 826 data-load standard, which was published in 2008.

Arinc 825 objectives

Arinc 825 was designed to be used as a primary or ancillary network for general aviation, air transport and military aircraft.

- Minimal cost of implementation and cost of change over time
- Maximum *interoperability* and *interchangeability* of CAN-connected ECUs
- Configuration flexibility: easy addition, deletion, and modification of bus nodes, without undue impact to other ECUs
- Interconnection of systems
- Easy connections of local CAN networks to other airplane networks
- Traffic to easily cross system and network boundaries for both parametric and block data transfers
- Integrated error detection and error signaling
- System level functions such as on-board data load and airplane health management can be implemented

Arinc 825 definitions

Layered architecture compliant to OSI reference model

- Physical layer - bus topology, transceiver requirements, transmission rates, cabling, connectors, pin-assignment, installation rules, etc.
- Data link layer - Use of CAN-ID field, message prioritization, bandwidth management
- Network and transport layers - logical communication channels, transport protocol, etc.
- Application layer - communication services (anyone-to-many and peer-to-peer communication), etc.

Communication profile and device/application/interface profile

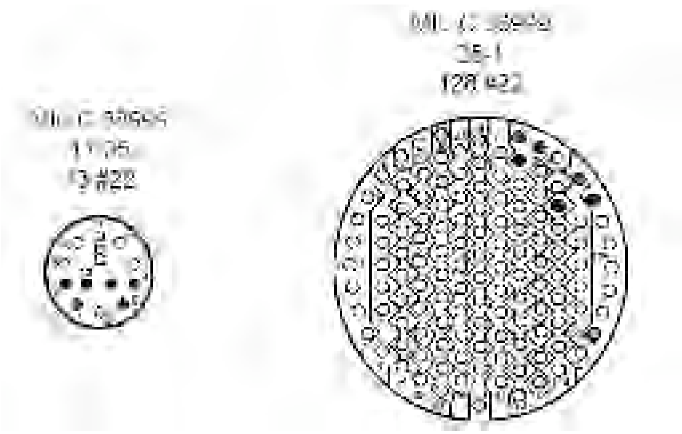
- Gateway to Ethernet-based networks (Arinc 664)
- Network quality indication support
- Payload data formats, physical units, axis and sign conventions
- Node service concept
- Test and maintenance support

Arinc 825 physical layer

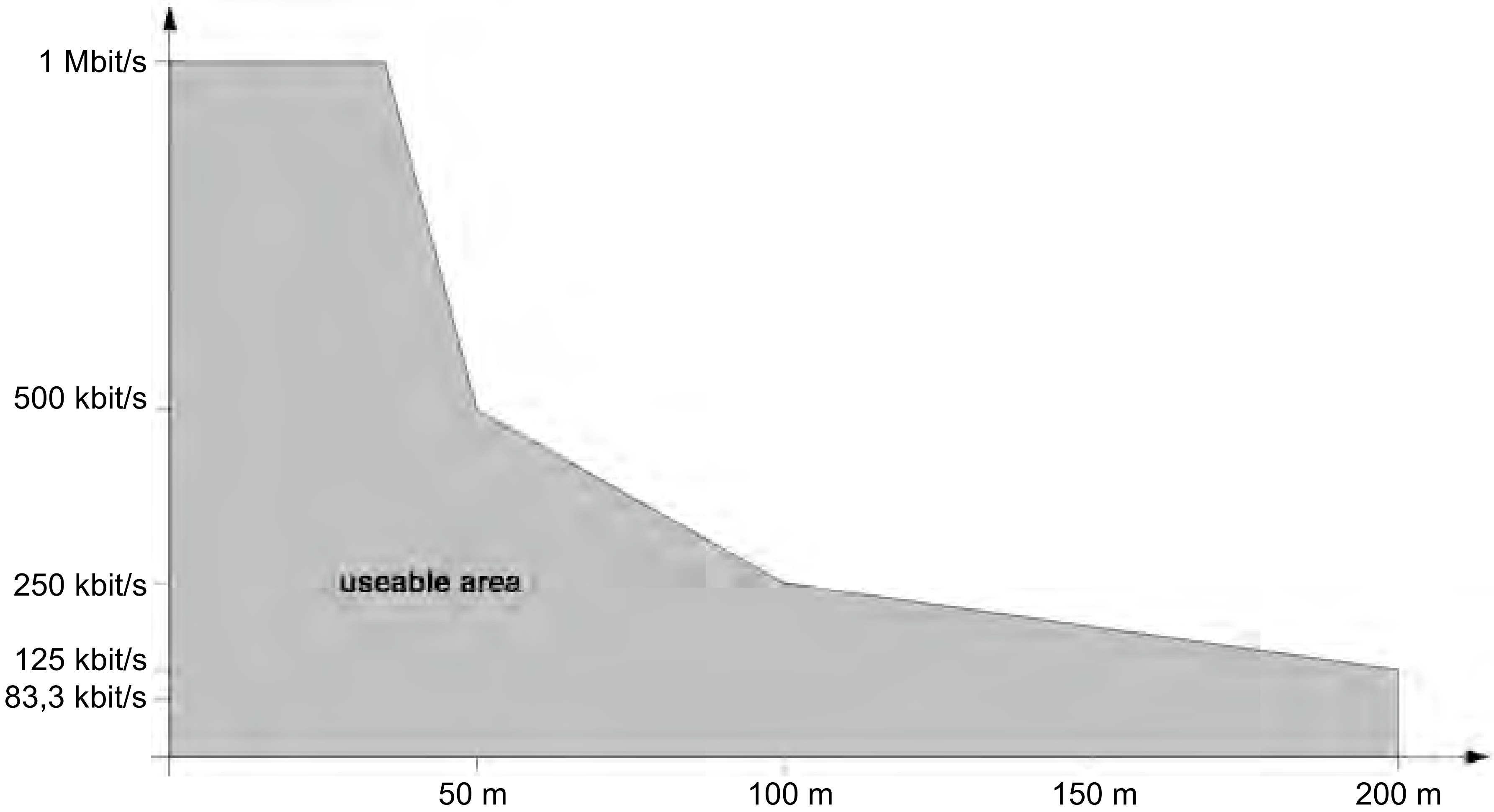
In order to ensure connectivity and reliable communication, Arinc 825 specifies the electrical characteristics, bus transceiver requirements and data rates with the corresponding tolerances.

- Transceiver chips shall be compliant to ISO 11898-2/(5)
- The bit-timing (e.g. oscillator accuracy and sample-point) is specified for the following data-rates:

  1 Mbit/s, 500 kbit/s, 250 kbit/s, 125 kbit/s, and 88,3 kbit/s
- Recommendations to avoid electromagnetic interference (EMI) problems
- *MIL-C-38999* connectors and pin-assignment specification

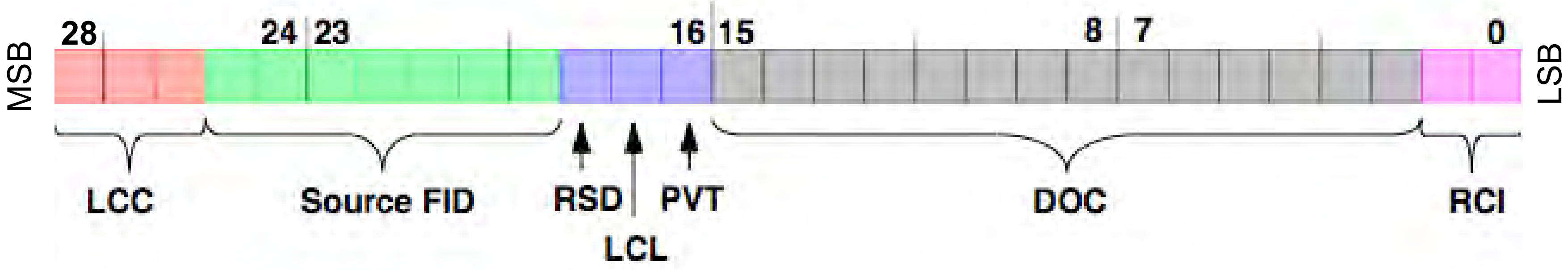


Arinc 825 network length



Arinc 825 data link layer (1)

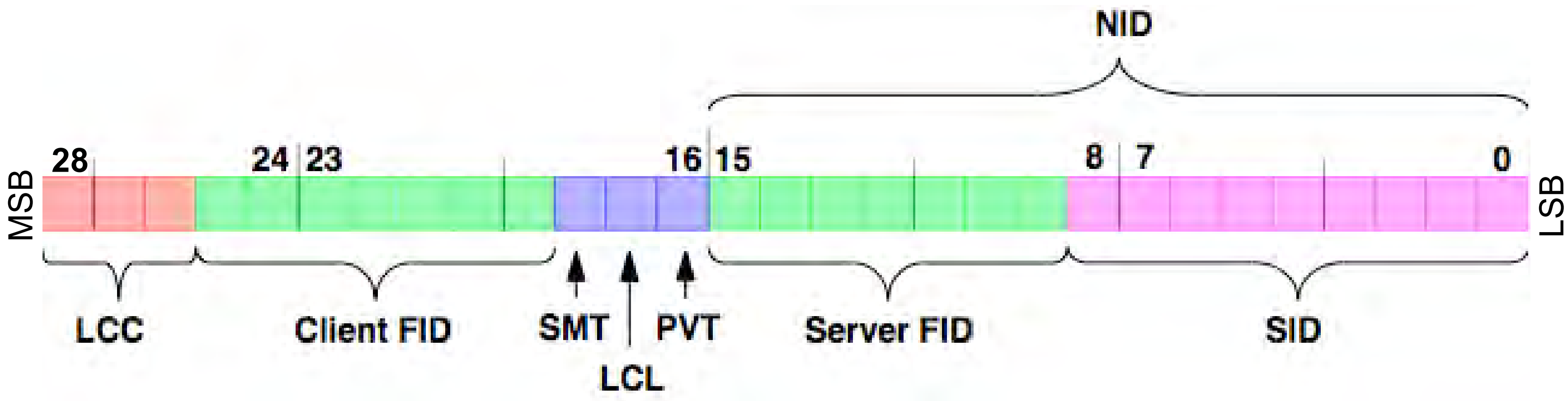
CAN-ID structure for one-to-many communication



- LCC = Logical communication channel (indicates higher-layer services)
- FID = Function code identifier (identifies the source of the message)
- RSD = reserved
- LCL = Local (indicates that message destination is the local bus segment only)
- PVT = Private (indicates that the message is for special use only)
- DOC = Data object code (identifies the message payload)
- RCI = Redundancy channel identifier (identifies one of four redundant sources)

Arinc 825 data link layer (2)

CAN-ID structure for peer-to-peer communication



- The Node-ID (NID) allows to address 512 different nodes (SID) in each of the 128 different functions (Server FID).
- FID (indicates pre-defined and user-defined functions)

> *Peer-to-peer communication allows individual nodes on a CAN network or across network domains to establish client/server type interactions, called node services. Both connectionless as well as connection-oriented communication (compare to UDP/IP versus TCP/IP) is supported.*

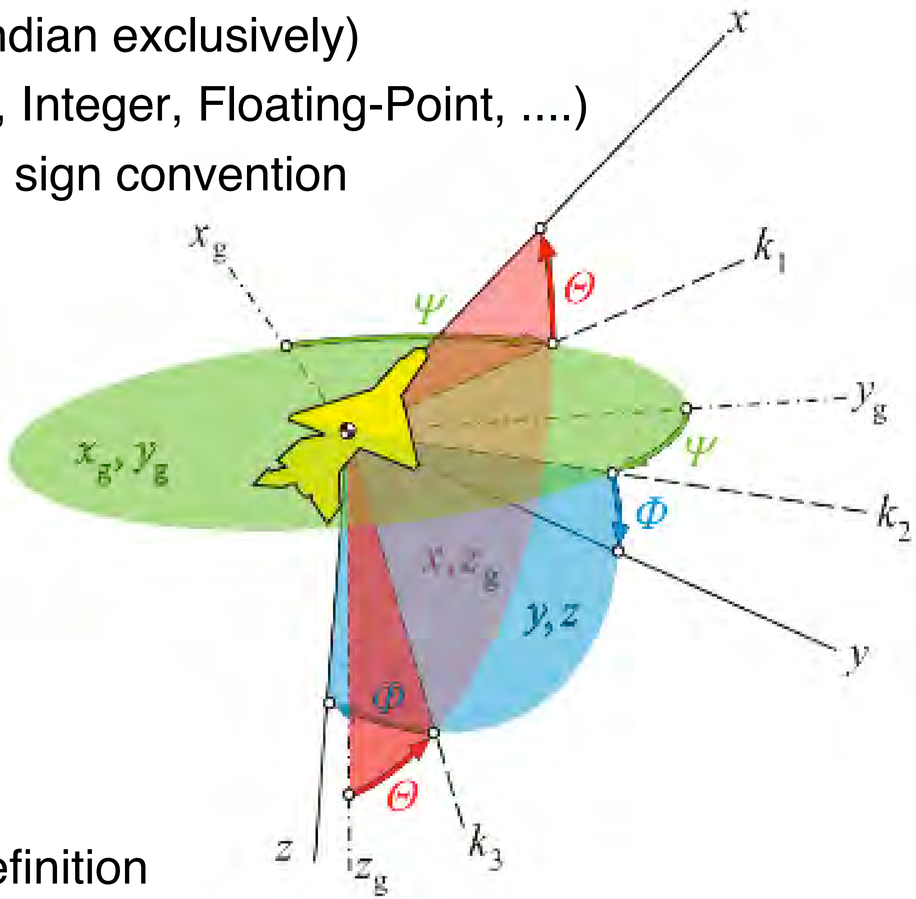
LCC coding

Channel Number	Channel Acronym	Description	LCC Bits	Message Priority
0	EEC	Emergency Event Channel	000	Highest
1		Reserved	001	
2	NOC	Normal Operation Channel	010	
3		Reserved	011	
4	NSC	Node Service Channel	100	
5	UDC	User-Defined Channel	101	
6	TMC	Test and Maintenance Channel	110	
7	FMC	CAN Base Frame Migration Channel	111	Lowest

Payload definitions

In order to provide a high-degree of compatibility (inter-workable), Arinc 825 specifies:

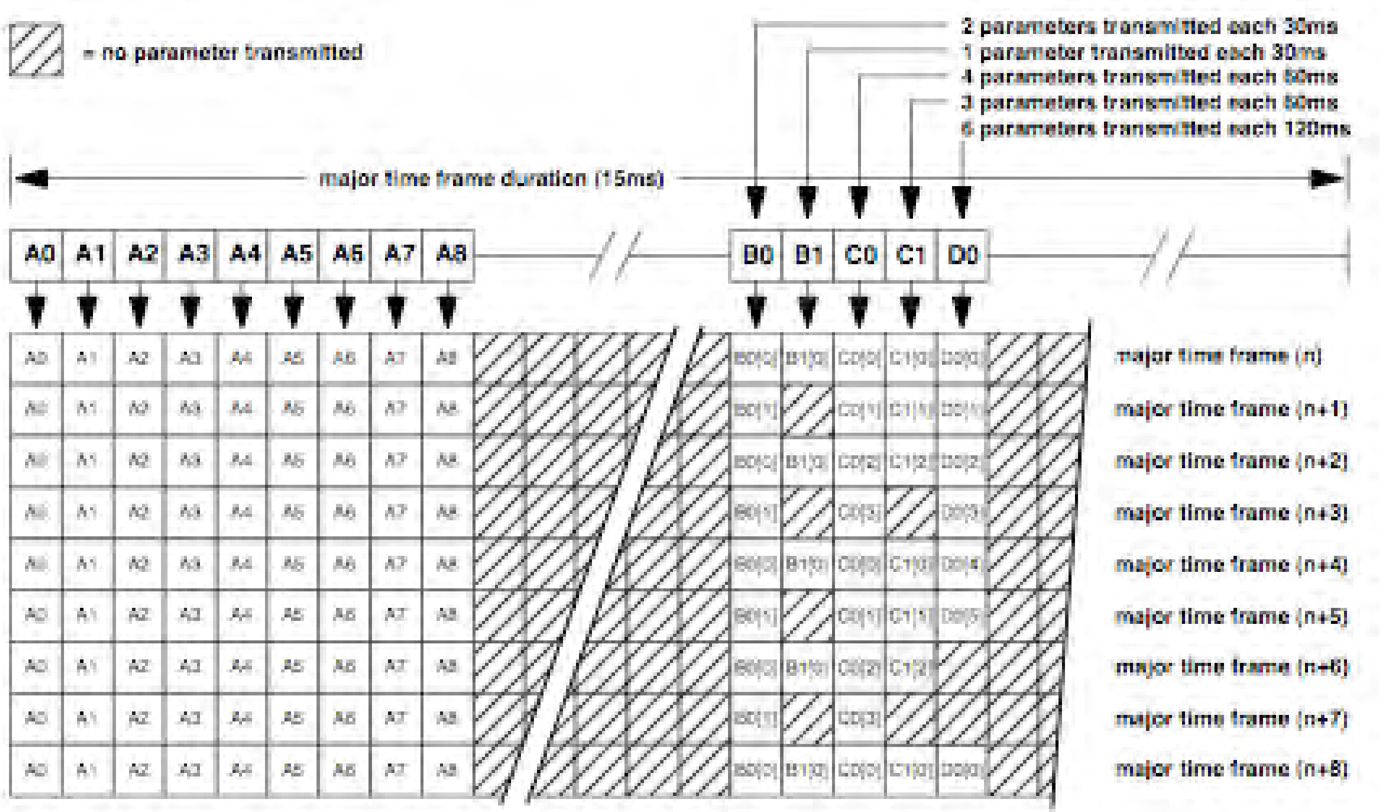
- Data endian definition (Big endian exclusively)
- Data type definition (Boolean, Integer, Floating-Point, ...)
- Aeronautical axis system and sign convention



- Engineering (physical) unit definition
- Aircraft function definition (flight state, air data, etc.)

Message scheduling

- The Arinc 825 bandwidth management concept provides a straightforward means of computing the bus-load based on the number of messages in a network segment and adjusting their transmission rates.
- The target of this concept is the minimization of peak load scenarios and transmission jitter caused by the CAN arbitration method.



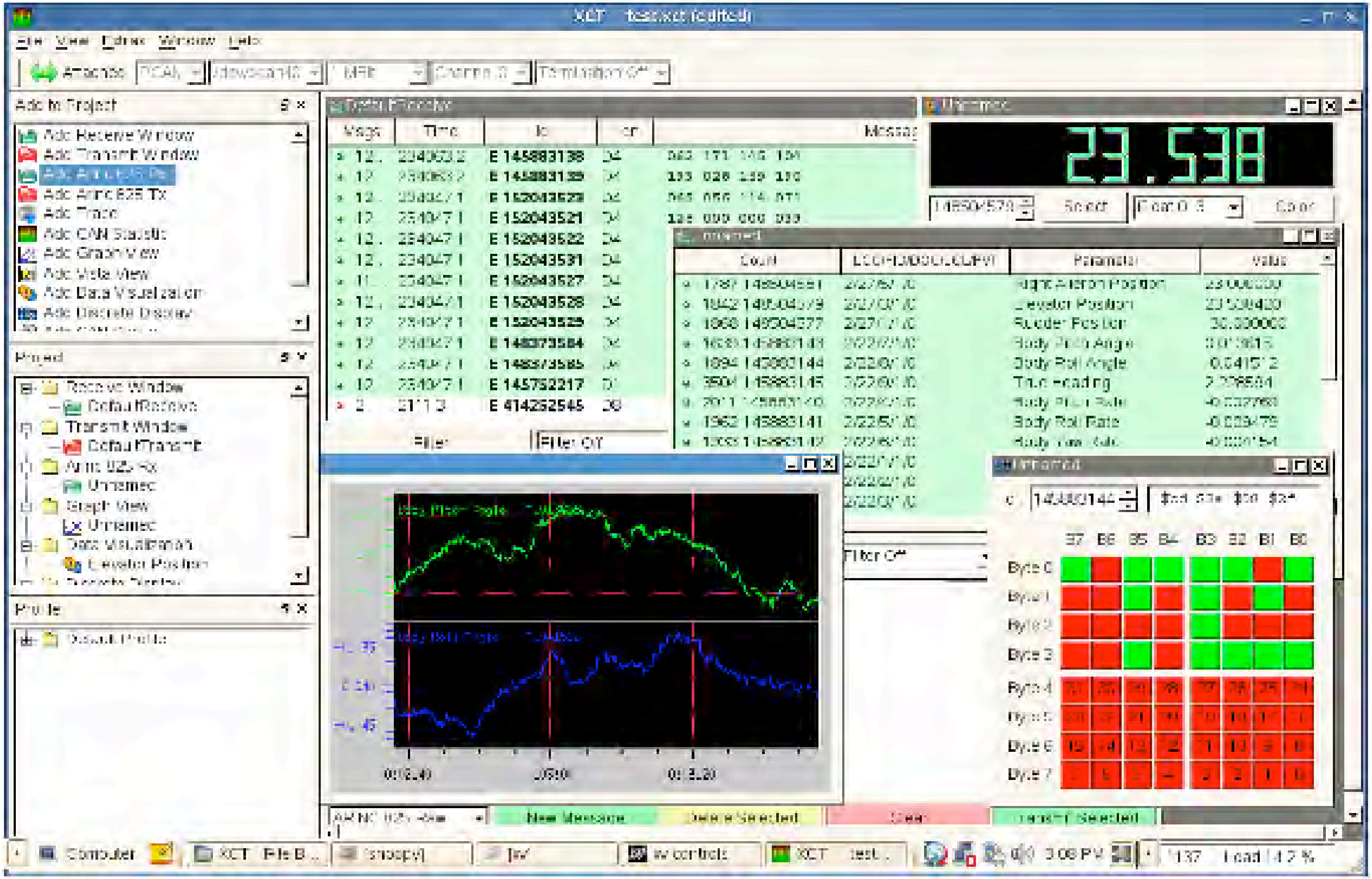
Arinc 825 system database

- Arinc 825 specifies a system database for the description of entire networks.
- The database uses XML files and describes the network traffic in detail.
- The database provide a valuable means for specification and verification of Arinc 825 systems and allow to detect potential network problems at an early stage.
- Arinc 825 test tools must be able to read the XML files and display the network data accordingly.

Arinc 825 tool

- Software tool for Linux/X86, Solaris/SPARC and Windows XP/Vista
- Runs in combination with the Arinc 825 PMC module by ICS
- Real-time data visualization in raw and Arinc 825 XML formats
- Displays CAN error frames and “listen-only” (no ACK) mode
- Displays Arinc 825 bus status, error and statistics functions
- Real-time data recording and playback of Arinc 825 data
- Triggers on CAN-ID and/or message payload content
- CAN raw bit-stream recording capability
- Synthetic Arinc 825 signal generation
- Arinc 825 node service interface support
- Arinc 825 database editor with consistency checking
- Standardized XCT project configuration file format supporting Arinc 825 network specification, integration and ground/flight test

Tool screen shot



Aircraft system architecture

General system architecture requirements:

• Arinc 825 (CAN-based) networks needs to be integrated with Arinc 624 (Ethernet-based networks).

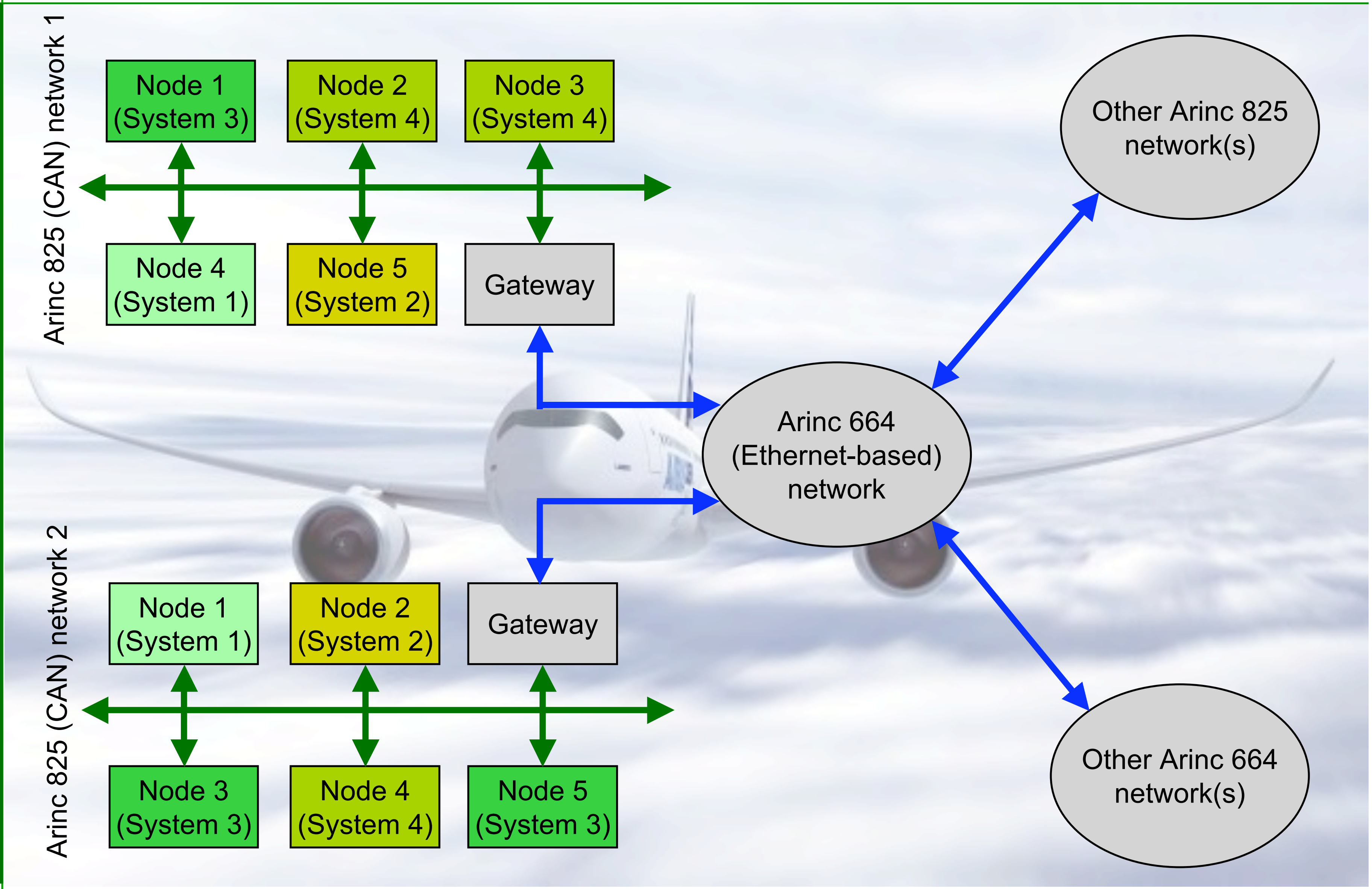
• Arinc 825 addresses the access to and data flow over CAN and also across network boundaries (domains).

• Arinc 825 supports the data-flow across domains through gateways.

• Cross-domain communication is accomplished by logical communication channel definitions, individual station addressing capabilities and one-to-many/peer-to-peer communication mechanisms.

• Arinc 825 also gives design guidelines for the implementation of gateways for cross-domain communication with respect to bandwidth capacity differences.

System architecture example



Questions and answers