SAE J1939

Serial Control and Communications Vehicle Network

Presented by
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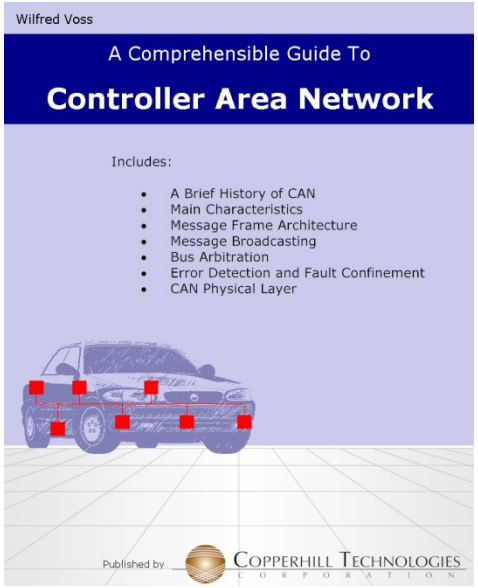
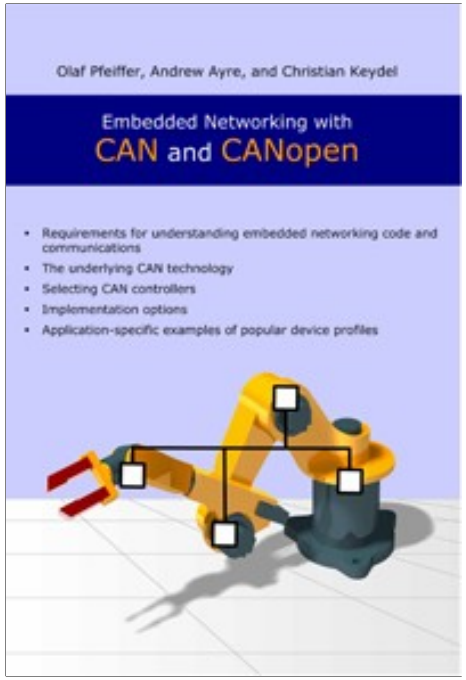
http://www.canseminar.com/Tutorials.html/

Literature

Literature on Controller Area Network, CANopen and SAE J1939

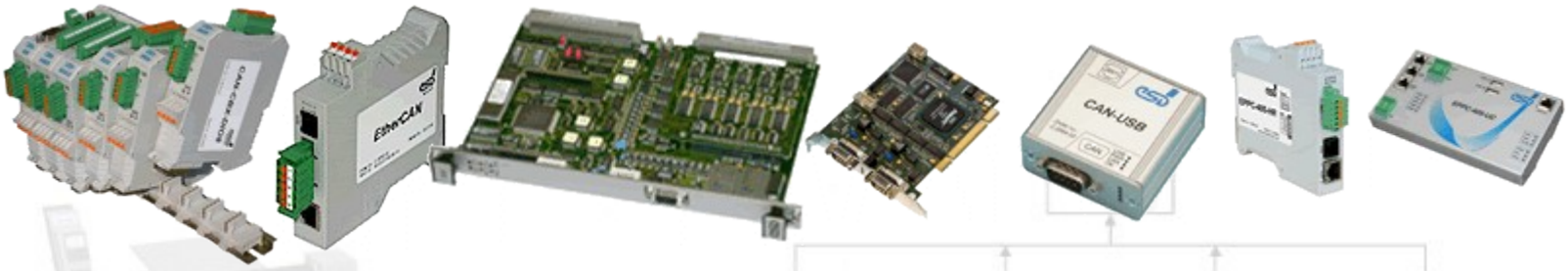




SAE J1939

Serial Control and Communications Vehicle Network

esd Product Line



esd electronics provides:

· CAN Hardware Interfaces – PCI, cPCI, VME, PMC, PC104, ISA, and more

· CAN Gateways – USB, EtherNet, Bluetooth, IEEE488, and more

· CAN Converters – CANopen, DeviceNet, Profibus, and more

· CAN Embedded Controllers

· Drivers and APIs for various operating systems

· Free CAN Analyzer software – included with driver

esd electronics, Inc.

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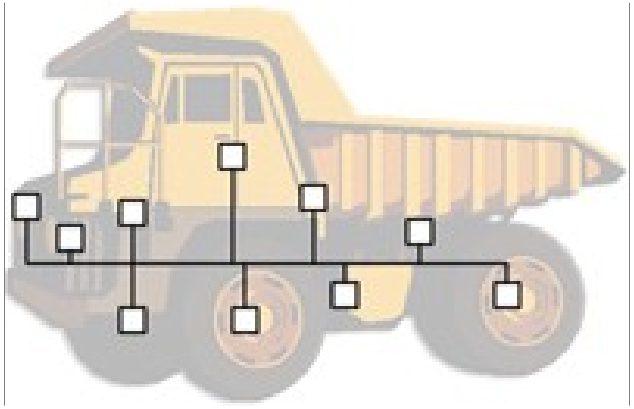
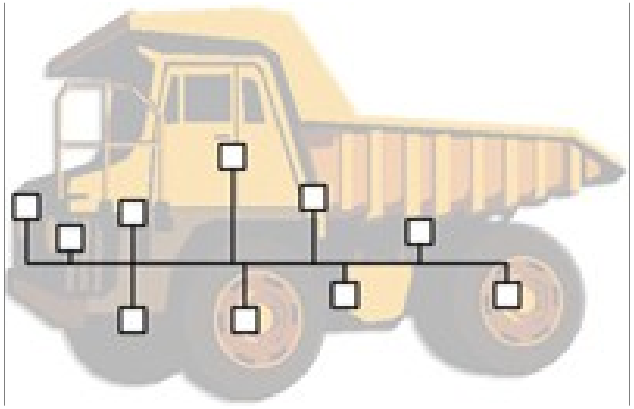
What is SAE J1939 – General Aspects



- Higher-layer protocol based on Controller Area Network (CAN)
- Provides serial data communications between Electronic Control Units (ECU) in any kind of heavy duty vehicles.
- Protocol features based on J1708 (RS485) + J1587
- Ingenious protocol design with very little protocol overhead
- Driven by data, not myriad of functions as other HLPs
- Takes full advantage of all CAN features
- Detailed documentation only available through SAE

SAE J1939 Applications

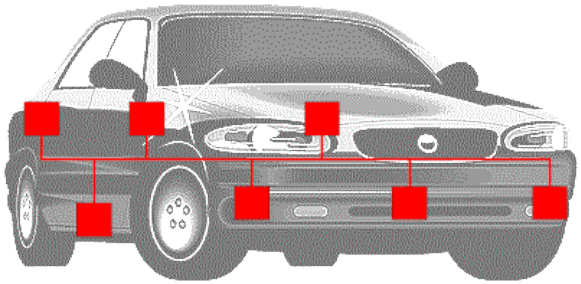


J1939-based protocols are used in:

- Diesel power-train applications
- In-Vehicle networks for trucks and buses
- Agriculture and forestry machinery (ISO 11783)
- Truck-Trailer connections
- Military vehicles (MiLCAN)
- Fleet management systems
- Recreational vehicles
- Marine navigation systems (NMEA2000)

What is CAN – General Aspects

· Serial Network Technology for Embedded Solutions



· Originally designed by Bosch for automotive industry

· Became very popular in industrial automation

· Network technology established among micro-controllers

· Well suited for high speed/real-time applications

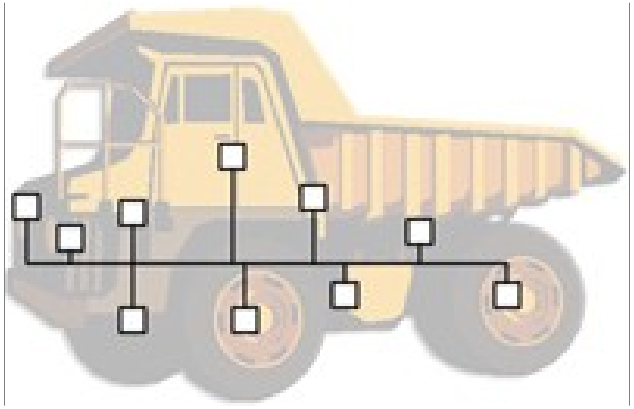
· Replaces expensive Dual-Port RAM technology

· Excellent error detection and fault confinement

· Extremely reliable

· Max. baud rate of 1 MBit/sec – SAE J1939 uses 250 kBit/sec

SAE J1939 – Quick Reference



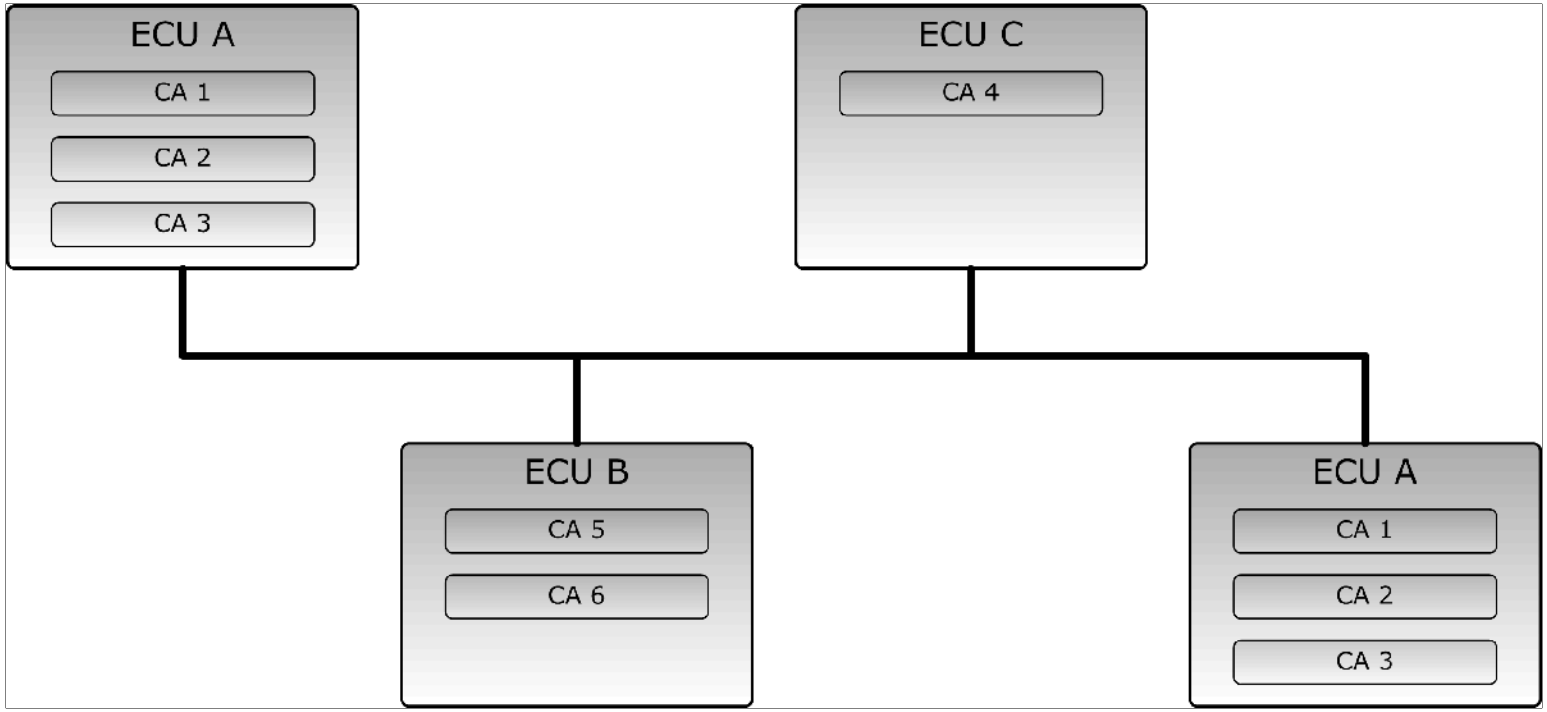
J1939 takes advantage of CAN features such as:

- Maximum reliability
- Excellent error detection & fault confinement
- Collision-free bus arbitration

J1939 Specifics:

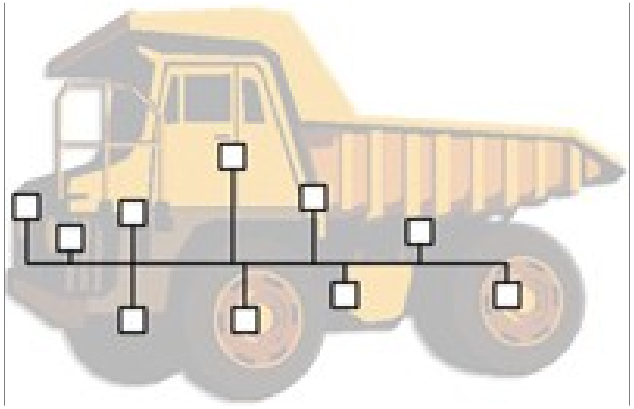
- Shielded twisted pair wire
- Max. network length of 40 meters (~120 ft.)
- Standard baud rate of 250 kBit/sec
- Uses 29-Bit Message ID
- Max. 30 nodes (ECUs) in a network

SAE J1939 – Quick Reference



SAE J1939
Serial Control and Communications Vehicle Network

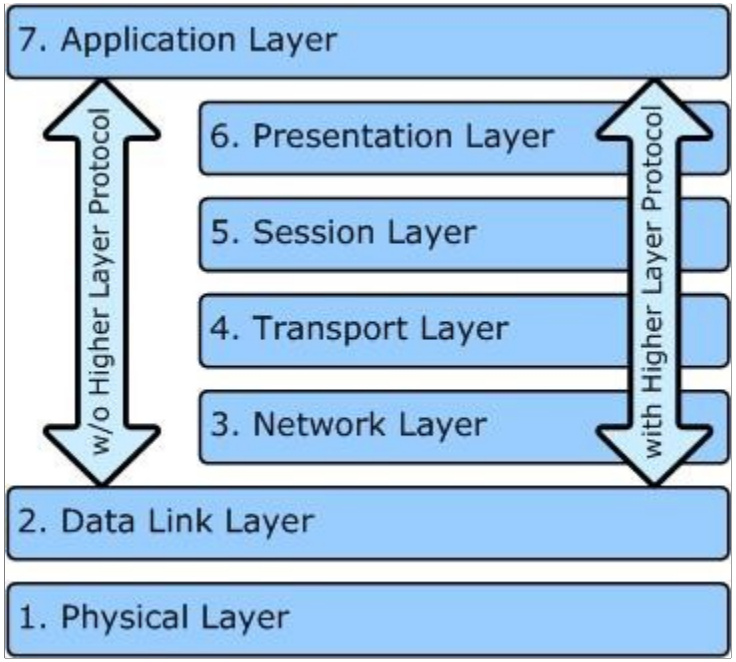
SAE J1939 – Quick Reference



J1939 Specifics:

- Does **not** support Master/Slave or Client/Server configuration
- Does **not** support node monitoring
- Features Address Claiming immediately after network start-up
- Allows “Plug&Play” feature
- Allows segmentation of messages larger than 8 bytes

SAE J1939 – Standards Collection



SAE J1939 Standards Collection scheme is based on the ISO/OSI 7-Layer Model

SAE J1939 – Standards Collection

J1939
Recommended Practice for a Serial Control and Communications Vehicle Network

J1939-01
Recommended Practice for Control And Communications Network for On-Highway Equipment

J1939-02
Agricultural and Forestry Off-Road Machinery Control and Communication Network

J1939-11
Physical Layer - 250k bits/s, Twisted Shielded PairJ1939-13Off-Board Diagnostics Connector

J1939-15
Reduced Physical Layer, 250k bits/sec, Un-Shielded Twisted Pair (UTP)

J1939-21
Data Link Layer

J1939-31
Network Layer

J1939-71
Vehicle Application Layer

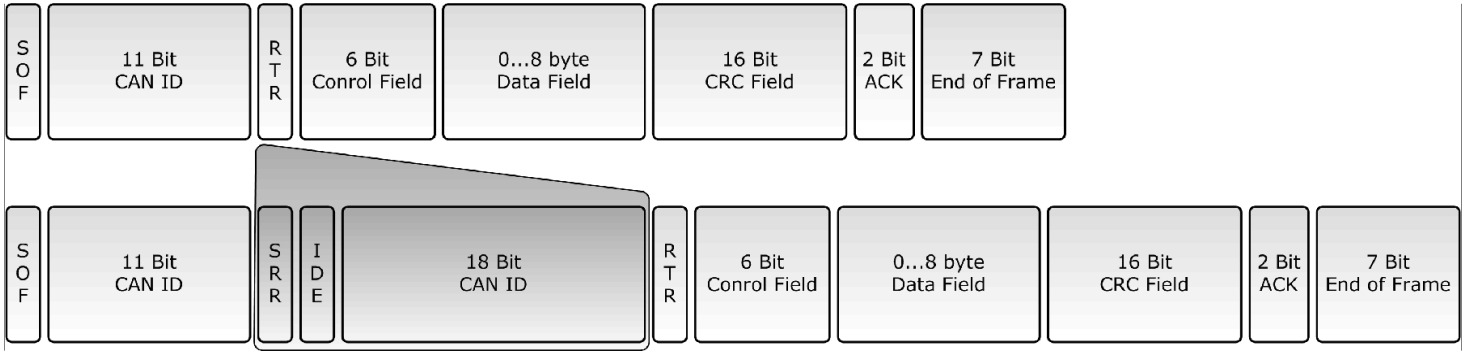
J1939-73
Application Layer – Diagnostics

J1939-74
Application - Configurable Messaging

J1939-75
Application Layer - Generator Sets and Industrial

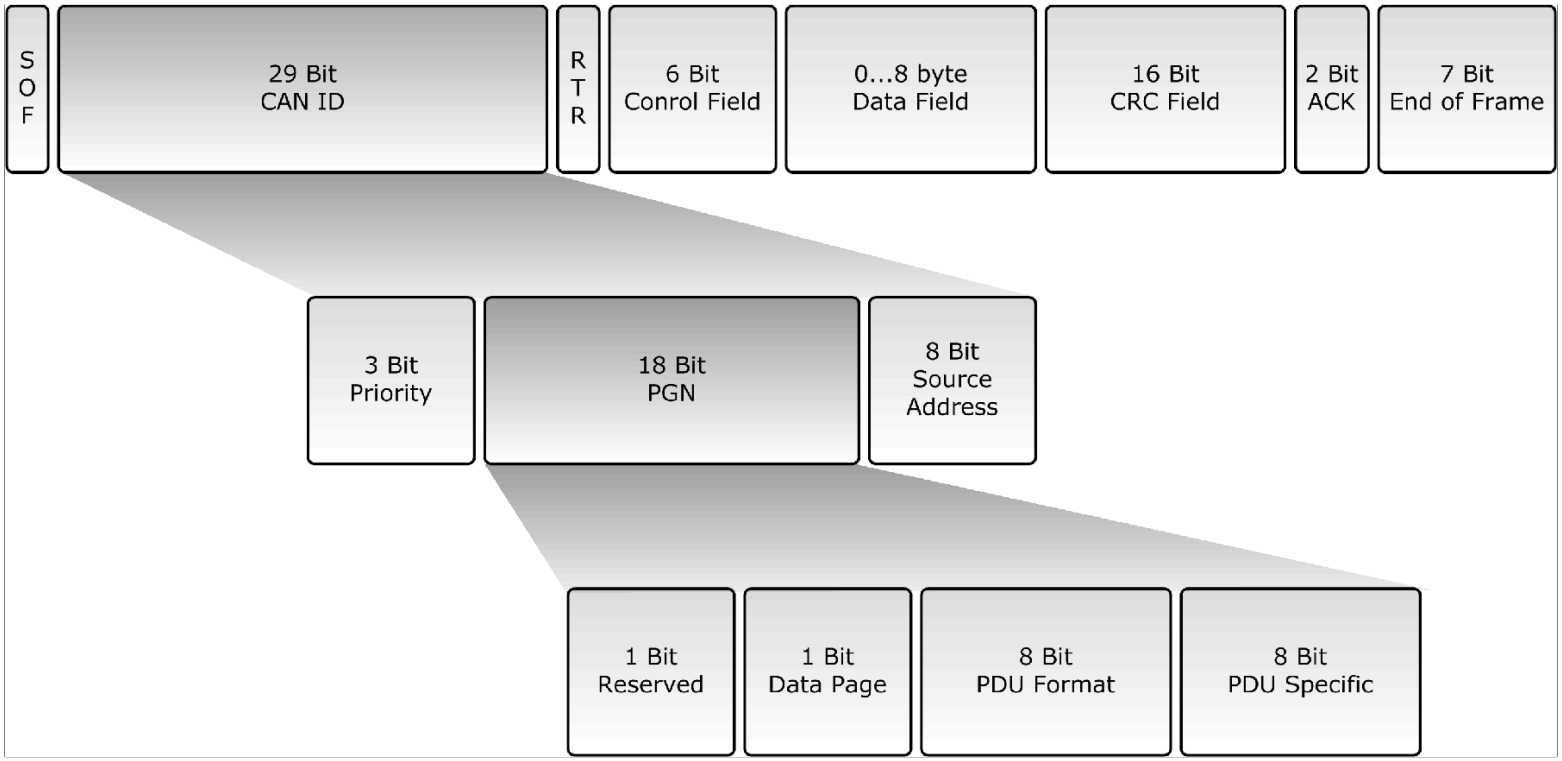
J1939-81
Network Management

SAE J1939 – Message Format (J1939/21)



- CAN Standard 2.0A was extended to 2.0B to allow a 29-Bit Identifier according to J1708 and J1587.
- IDE Bit indicates 11-Bit or 29-Bit Message Identifier
- Both formats can co-exist on the same CAN bus
- MilCAN uses J1939 29-Bit Message ID and CANopen 11-Bit Message ID
- J1939/21 also defines the segmentation of messages larger than 8 bytes.

SAE J1939 – Message Format



SAE J1939 – Parameter Group Number

SAE J1939
Serial Control and Communications Vehicle Network

- Parameters embedded in the 29-Bit message identifier are divided into three sections:
  - Priority
  - PGN (Parameter Group Number)
  - 8 Bit Source Address
- PGN identifies the Parameter Group (PG)
- PGs point to information of parameter assignments within 8 byte CAN data field, repetition rate and priority
- 8672 different Parameter Groups per page – 2 pages are available

SAE J1939 – Parameter Group Number

Priority

- First three bits represent priority during arbitration process
- Provides eight priority levels
- A value of 0 (000) = highest priority;
  a value of 8 (111) = lowest priority
- High priority messages assigned to time critical data such as torque
  control data from transmission to engine
- Lower level priorities suitable for non-time-critical data such as engine configuration data

R

- Reserved for future purposes
- Should always be set to 0 when transmitting messages

SAE J1939 – Parameter Group Number

DP – Data Page

- Page selector for PDU (Protocol Data Unit) Format (PF) field
- Currently at 0, pointing to Page 0
- Page 1 for future purposes

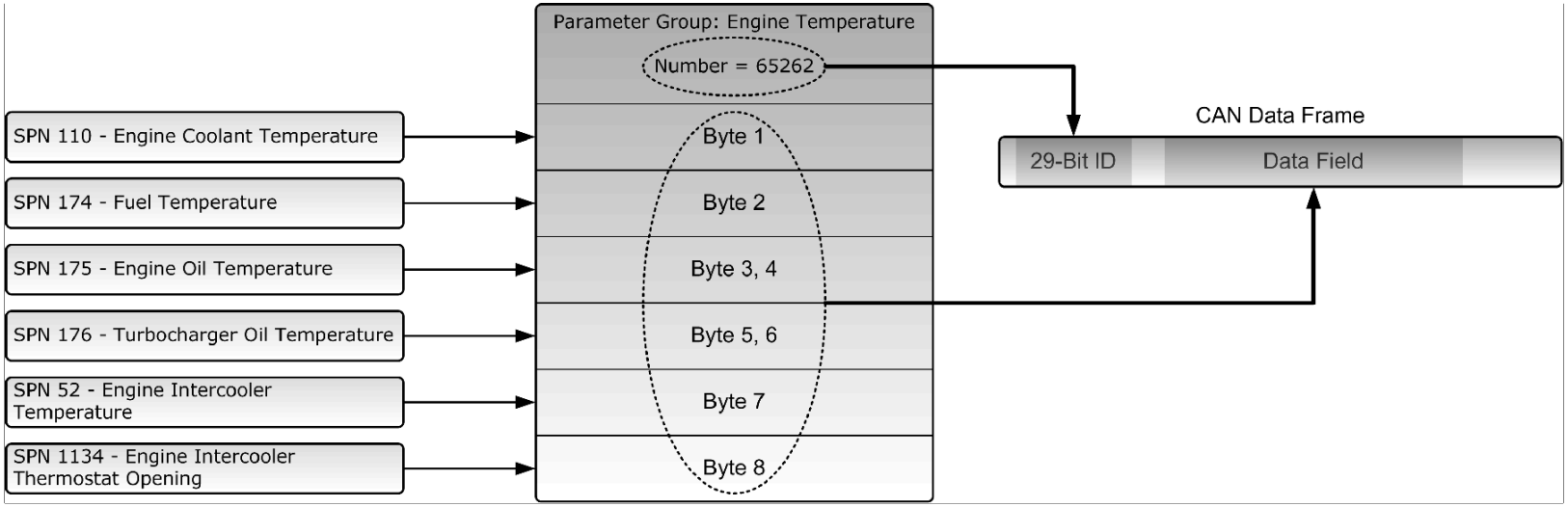
PDU Format (PF)

- PF = 0 - 239 (PDU1) indicates a destination address in PS
- PF = 240 - 255 (PDU2) indicates extension to PDU Format (PF)

PDU Specific (PS)

- Content interpreted according to information in PDU Format (PF)

SAE J1939 – PGNs and SPNs



SAE J1939 – PGNs and SPNs

PGN 65262	**Engine Temperature**
Transmission Rate	1 sec
Data Length	8 bytes
Data Page	0
PDU Format (PF)	254
PDU Specific (PS)	238
Default Priority	6
PG Number	65262 (FEEEhex)

Description of Data			**SPN**
Byte	1	Engine Coolant Temperature	110
	2	Fuel Temperature	174
	3, 4	Engine Oil Temperature	175
	5, 6	Turbocharger Oil Temperature	176
	7	Engine Intercooler Temperature	52
	8	Engine Intercooler Thermostat Opening	1134

SAE J1939 – PGNs and SPNs

SPN 110 **Engine Coolant Temperature**

Temperature of liquid engine cooling system

Data Length	1 Byte
Resolution	1 deg C / Bit
Offset	-40 deg C
Data Range	-40 to 210 deg C
Type	Measured
Reference	PGN 65262

SAE J1939 – PGN Range

DP	PGN Range (hex)	Number of PGNs	SAE or Manufacturer Assigned	Communication
0	000000 – 00EE00	239	SAE	PDU1 = Peer-to-Peer
0	00EF00	1	MF	PDU1 = Peer-to-Peer
0	00F000 – 00FEFF	3840	SAE	PDU2 = Broadcast
0	00FF00 – 00FFFF	256	MF	PDU2 = Broadcast
1	010000 – 01EE00	239	SAE	PDU1 = Peer-to-Peer
1	01EF00	1	MF	PDU1 = Peer-to-Peer
1	01F000 – 01FEFF	3840	SAE	PDU2 = Broadcast
1	01FF00 – 01FFFF	256	MF	PDU2 = Broadcast

SAE = Assigned by SAE

MF = Manufacturer Specific – Proprietary Messages

SAE J1939 – Proprietary Parameter Groups

Proprietary Parameter Groups and their numbers are designed using the exact same structure as Parameter Group and their numbers defined by the SAE.

Parameter Group Name	**Proprietary A**
Parameter Group Number	61184 (00EF00hex)
Definition	Proprietary PG using the PDU1 Format for Peer-to-Peer communication.
Transmission Rate	Manufacturer Specific
Data Length	0 – 1785 bytes (multi-packet supported)
Extended Data Page (R)	0
Data Page	0
PDU Format	239
PDU Specific	8 bit Destination Address – Manufacturer Assigned
Default Priority	6
Data Description	Manufacturer Specific

SAE J1939 – Communication Methods

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Destination Specific Communications:

- Use PDU1 (PF values 0 to 239)
- Destination address required

Broadcast Communications:

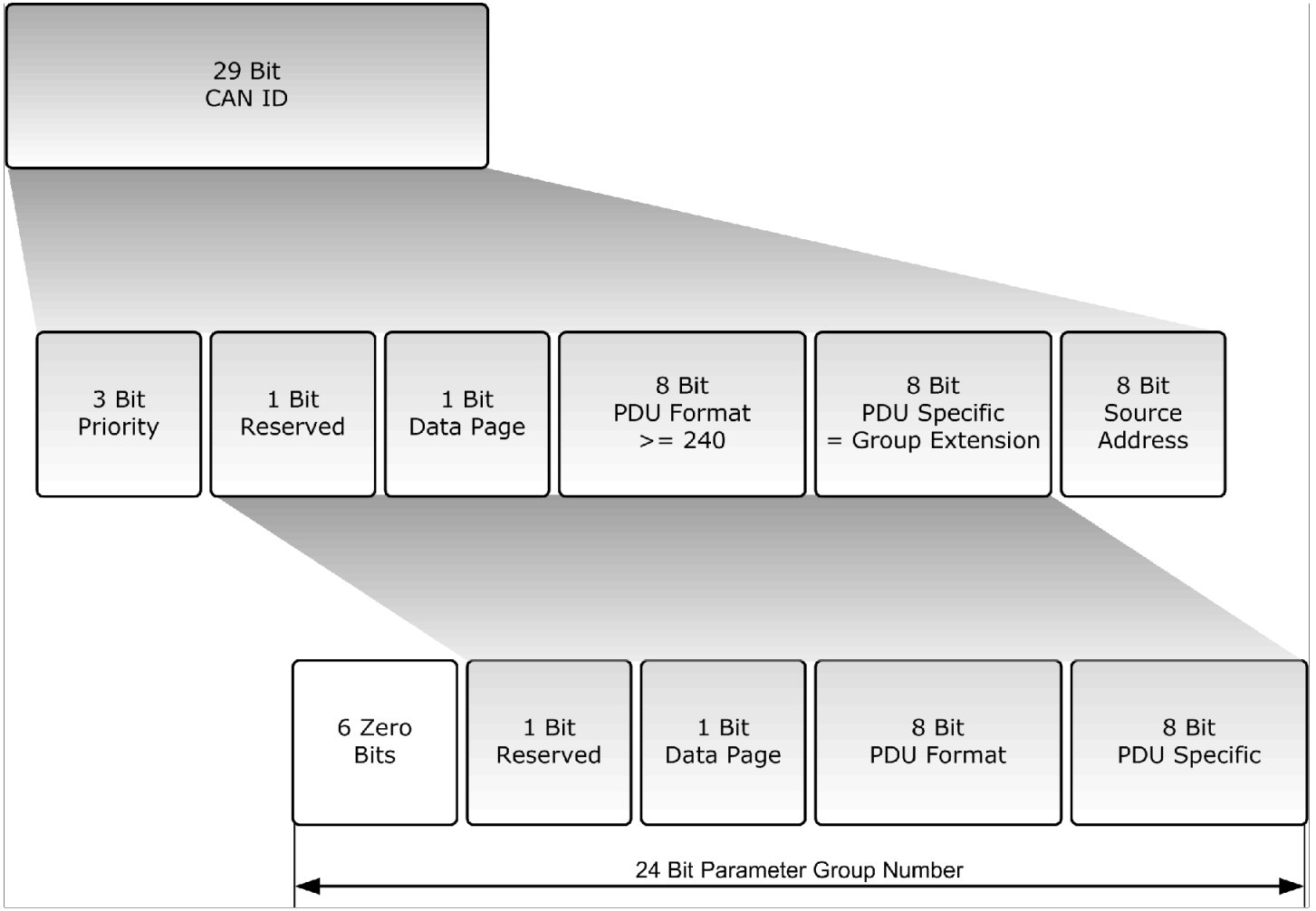
- Use PDU2 (PF values 240 to 255)
- Sending a message from single or multiple sources to single destination.
- Sending a message from single or multiple sources to multiple destinations.

Proprietary Communications*:

- Use either PDU1 or PDU2
- CAN be either Destination Specific or Broadcast
- Use proprietary PGNs

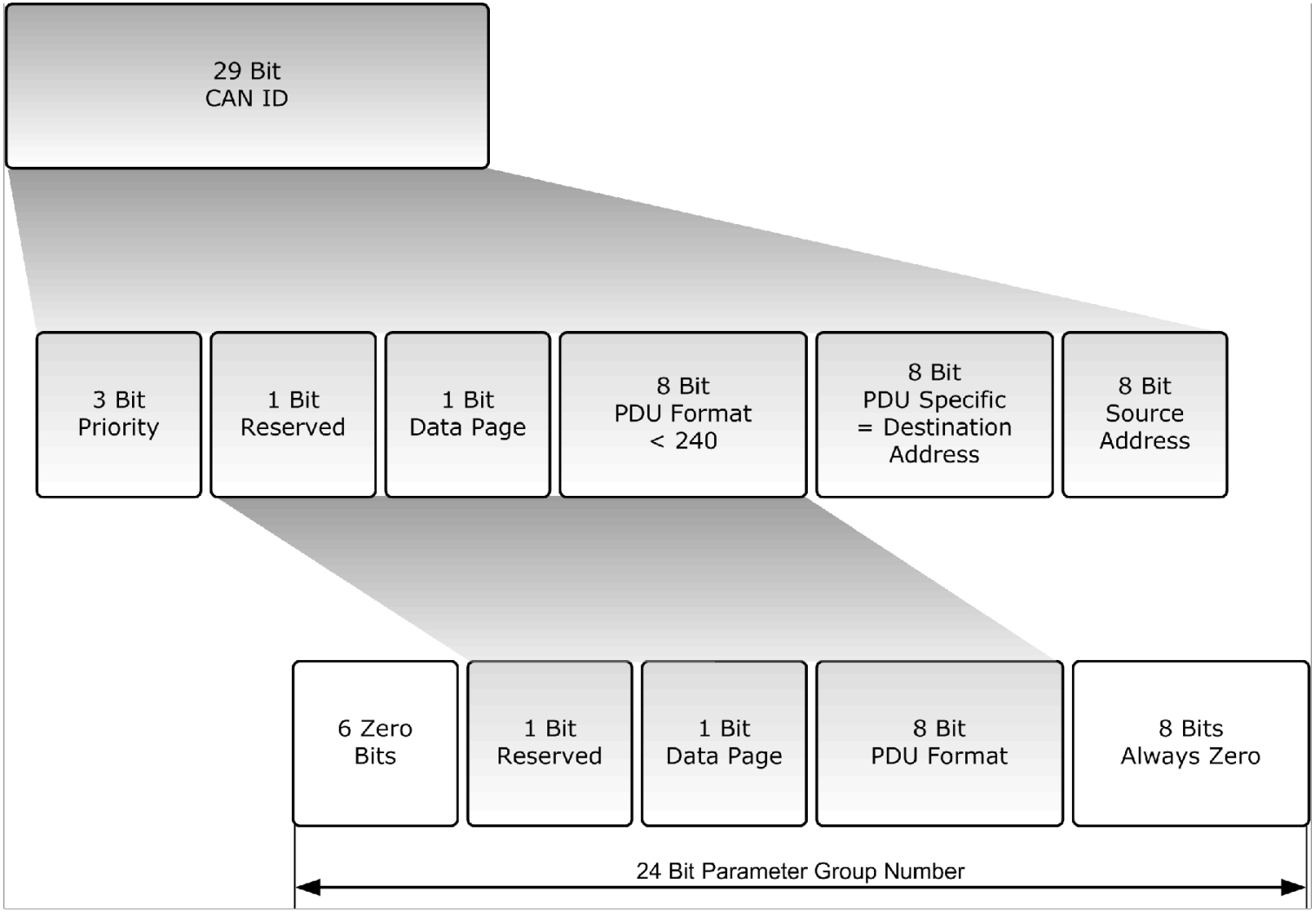
* According to SAE J1939:
"Where it is important to communicate proprietary information." Duh!

SAE J1939 – Parameter Group Number



Broadcast Communication

SAE J1939 – Parameter Group Number



Destination Specific Communication

SAE J1939 – Source Address

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- Source Address = Last 8 bits of 29-Bit message identifier
- Source address = Adress of transmitting ECU (node)
- A total of 254 addresses available
- Every address must be unique within the network
- ECUs cannot share addresses
- PGNs are independent of source address
- Every ECU is allowed to transmit any message

Note: The CAN standard in itself does not support node (ECU) addresses, only message IDs.

SAE J1939 – Message Types

1. Command

Ordinary PGN – Supports both, PDU1 and PDU2

2. Request

Specifically Assigned PGN (00EA00hex)

PDU1 Only (Peer-to-Peer)

Destination Address 255 = Global Destination Address

3. Broadcast/Response

Ordinary PGN – Supports both, PDU1 and PDU2

4. Acknowledgement

Specifically Assigned PGN (00E800hex)
PDU1 Only (Peer-to-Peer)
Destination Address 255 = Global Destination Address

5. Group Functions

Specifically Assigned PGNs
Used for proprietary functions, network management and multi-packet functions.

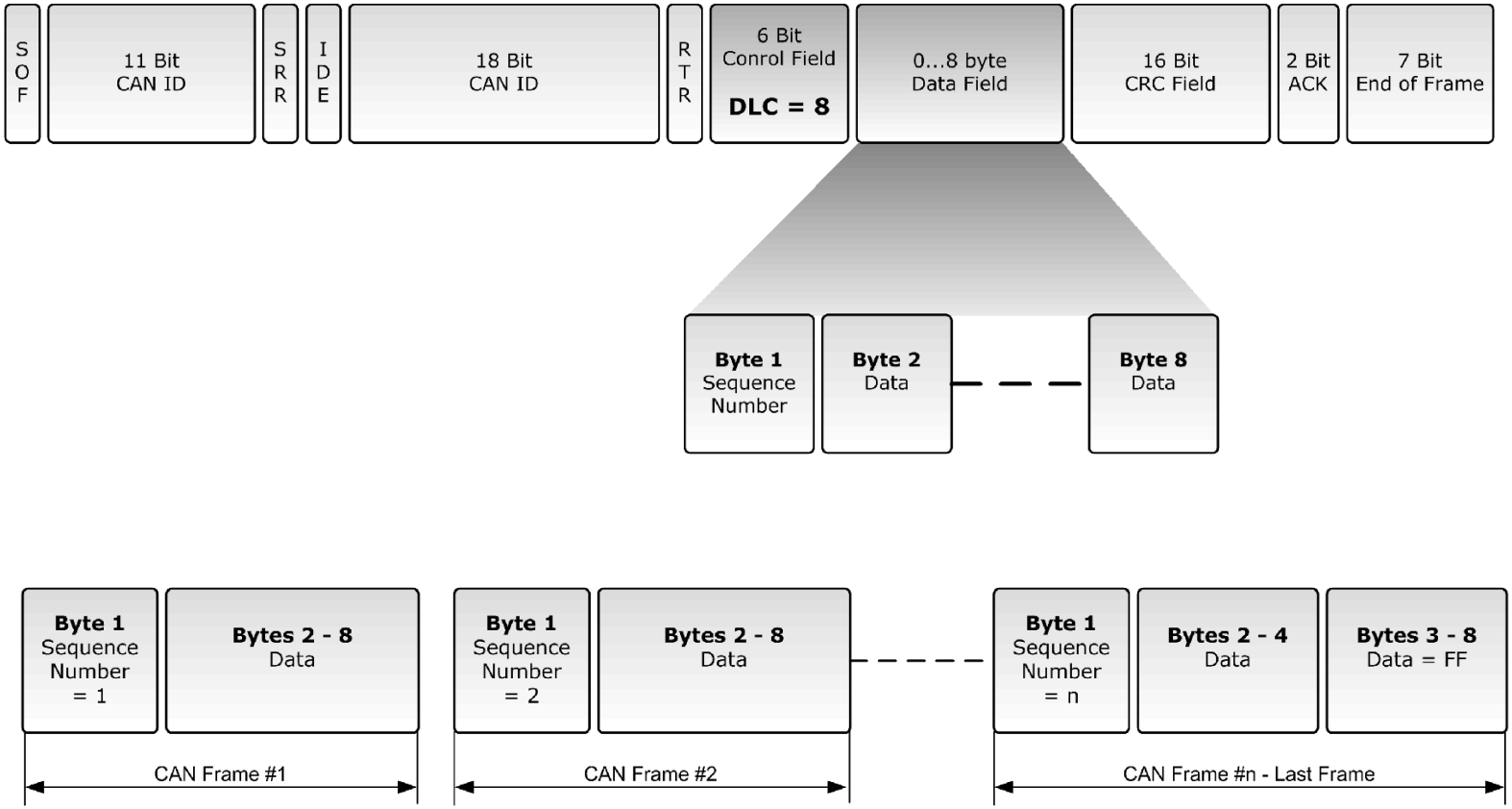
SAE J1939 – Request Message

Parameter Group Name	Request
Parameter Group Number	59904 (00EA00hex)
Definition	Requests a Parameter Group from a single device or all devices in the network.
Transmission Rate	User defined (no more than 2 to 3 times a second is recommended)
Data Length	3 bytes (CAN DLC = 3)
Extended Data Page (R)	0
Data Page	0
PDU Format	234
PDU Specific	Destination Address (Global or Specific)
Default Priority	6
Data Description	Byte 1, 2, 3 = Requested Parameter Group Number

SAE J1939 – Acknowledgement Message

Parameter Group Name	Acknowledgement
Parameter Group Number	59392 (00E800hex)
Definition	Provides handshake between transmitting and responding nodes.
Transmission Rate	Upon reception of a command or request.
Data Length	8 bytes (as described in the following)
Extended Data Page (R)	0
Data Page	0
PDU Format	232
PDU Specific	Destination Address (Global = 255)
Default Priority	6
Data Description	Bytes 1…8 = Positive Acknowledgement, Negative Acknowledgement, Access Denied or Cannot Respond

SAE J1939 – Multi-Packet Transport



Supports Peer-to-Peer and Broadcast

SAE J1939 – Broadcast Announce Message

BAM!

In order to broadcast a multi-packet message a node must first send a *Broadcast Announce Message* (BAM). A BAM message contains the following components:

- Parameter Group Number of the multi-packet message
- Size of the multi-packet message
- Number of packages

The *Broadcast Announce Message* (BAM) is embedded in the Transport Protocol – Connection Management (TP.CM) PGN 60416 and the actual data transfer is handled by using the Data Transfer PGN 60160.

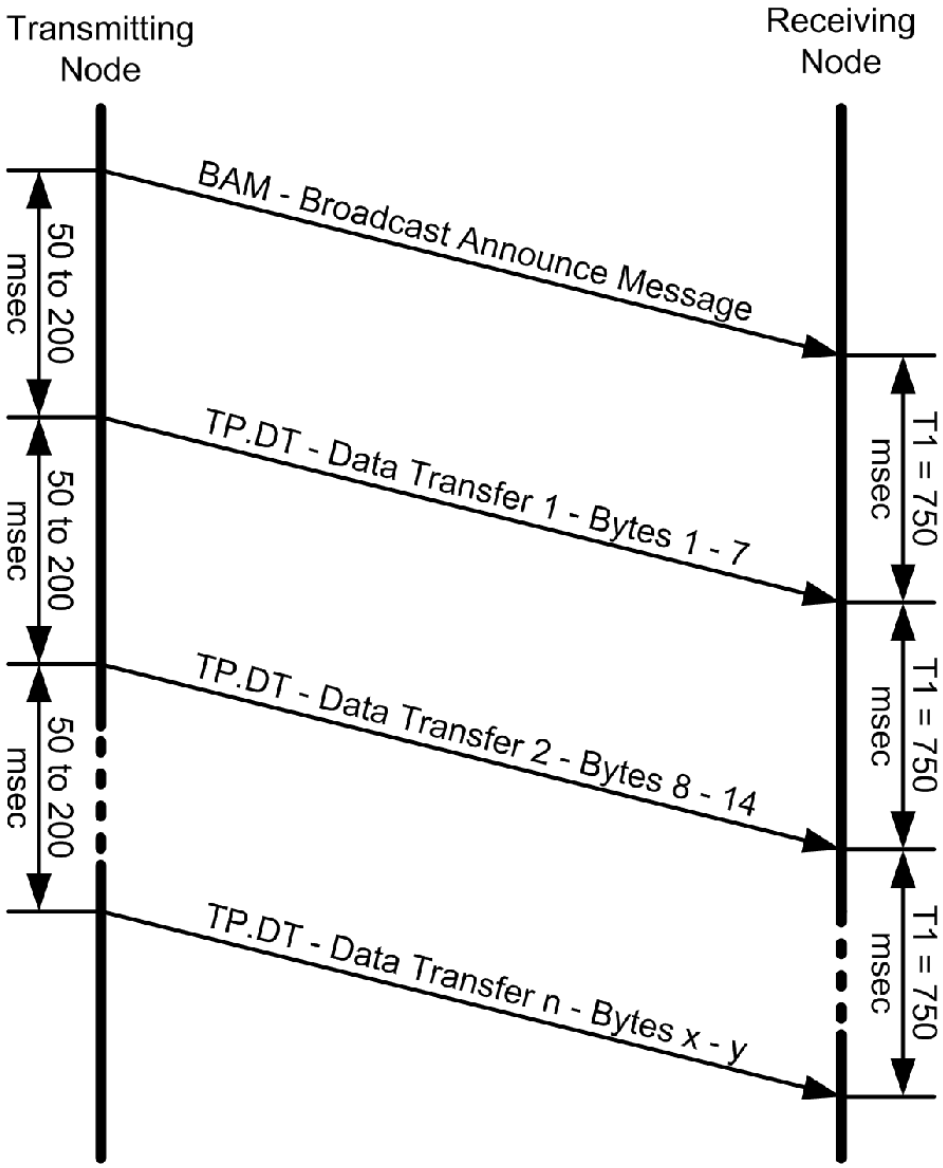
SAE J1939 – Transport Protocol

Parameter Group Name	**Transport Protocol – Connection Management (TP.CM)**
Parameter Group Number	60416 (00EC00hex)
Definition	Used for Communication Management flow-control (e.g. Broadcast Announce Message).
Transmission Rate	According to the Parameter Group Number to be transferred
Data Length	8 bytes
Extended Data Page (R)	0
Data Page	0
PDU Format	236
PDU Specific	Destination Address (= 255 for broadcast)
Default Priority	7
Data Description	(For Broadcast Announce Message only)
Byte	1 - Control Byte = 32
	2,3 – Message Size (Number of bytes)
	4 – Total number of packages
	5 – Reserved (should be filled with FFhex)
	6-8 – Parameter Group Number of the multi-packet message (6=LSB, 8=MSB)

SAE J1939 – Transport Protocol

Parameter Group Name	**Transport Protocol – Data Transfer (TP.DT)**
Parameter Group Number	60160 (00EB00hex)
Definition	Data Transfer of Multi-Packet Messages
Transmission Rate	According to the Parameter Group Number to be transferred
Data Length	8 bytes
Extended Data Page (R)	0
Data Page	0
PDU Format	235
PDU Specific	Destination Address
Default Priority	7
Data Description	
Byte	1 – Sequence Number (1 to 255)
	2-8 - Data

SAE J1939 – Broadcast Data Transfer



SAE J1939 – Flow Control

Transport Protocol

Connection Management (TP.CM) – PGN 00EC00hex

The TP.CM Data can be:

· Connection Mode Request to Send – TP.CM_RTS

· Connection Mode Clear To Send – TP.CM_CTS

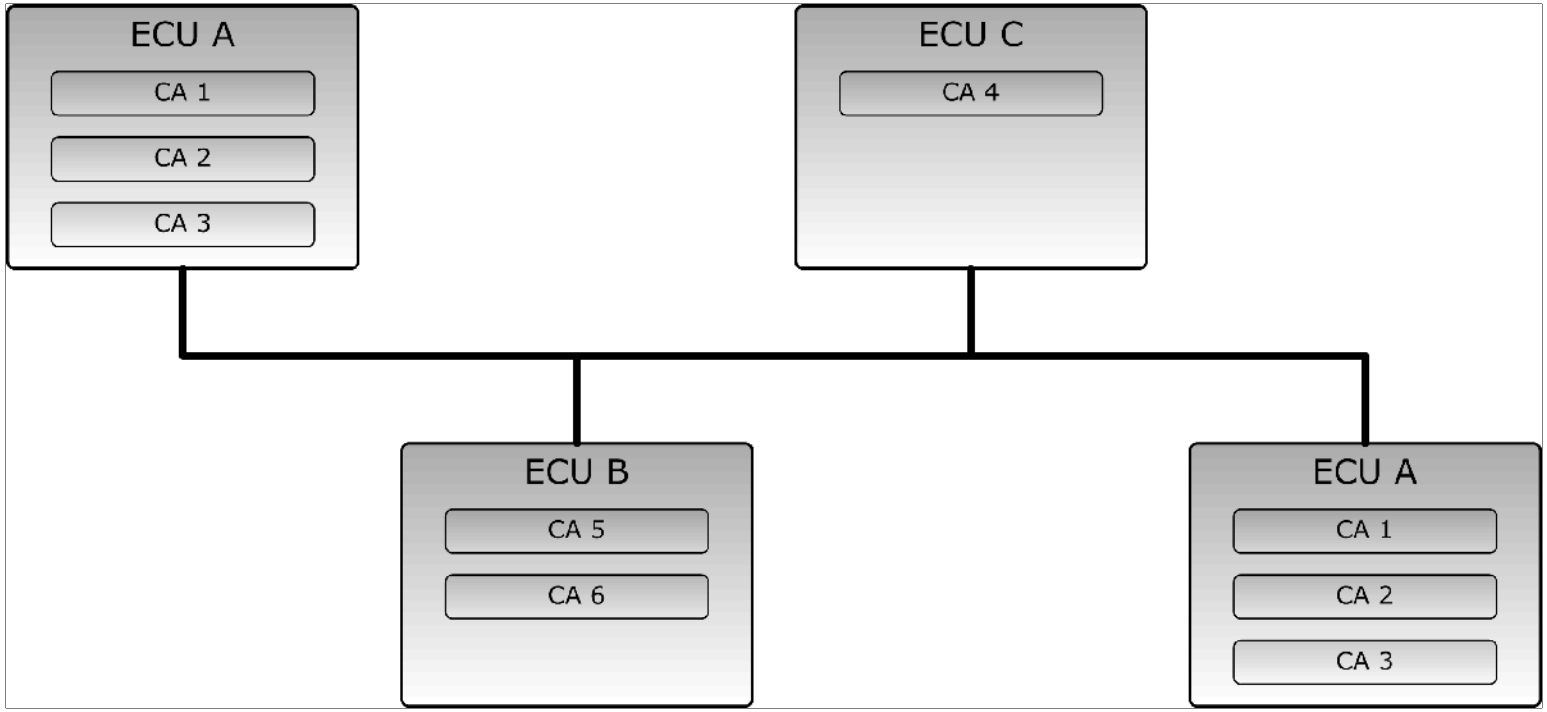
· End of Message Acknowledgement – TP.CM_EndOfMsgACK

· Connection Abort – TP.Conn_Abort

SAE J1939 – Network Management

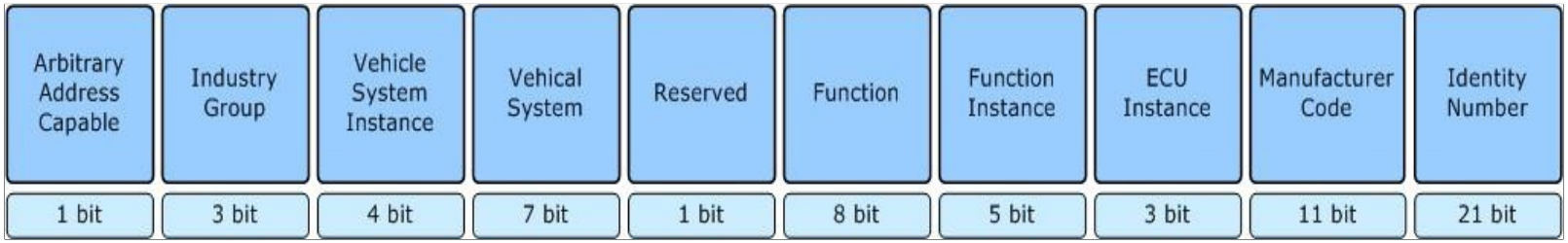
- Network Management defined in SAE J1939/81
- Handles automatic allocation of node addresses (Plug & Play) per Address Claiming procedure
- Address Claiming not supported per default in any other HLP
- J1939 Network Management allows to identify ECUs and their primary function.
- Node monitoring is not defined in J1939 – must be application specific
- J1939 does not support Master/Slave or Client/Master - must be application specific

SAE J1939 – ECUs and CAs



SAE J1939
Serial Control and Communications Vehicle Network

SAE J1939 – Address and NAME



- SAE J1939 defines 64 bit NAME to uniquely identify each ECU
- Each ECU must hold at least one name and one address for identification purposes
- ECU address defines the source or destination for messages
- ECU name indicates ECU main function performed at ECU address
- Function instance indicator used when multiple ECUs with same main function share the same network

SAE J1939 – Address Claiming

- 64 bit NAME to uniquely identify nodes (ECUs)
- Necessitates unreasonable resources to maintain standard communications
- Each ECU utilizes an 8 bit address to identify the source of a message or to access (destination address) another ECU in the network
- Address Claim Procedure:
  - Designed to assign addresses to ECUs right after the network startup
  - Assuring that assigned address is unique to ECU
- SAE J1939 Standard defines Preferred Addresses to commonly used devices in order to minimize the rate of multiple devices demanding the same address

SAE J1939
Serial Control and Communications Vehicle Network

SAE J1939 – Preferred Addresses

Industry Group	Preferred Address Range
Global (Applies to all industry groups)	0 – 84 Assigned 85 – 127 Reserved 248, 252 - 255 Reserved
Industry Group #1 – On-Highway Equipment	128 – 160 Dynamic 161 – 247 Assigned
Industry Group #2 – Agricultural and Forestry Equipment	128 – 207 Dynamic 208 – 247 Reserved
Industry Group #3 – Construction Equipment	128 - 207 Dynamic 208 – 247 Reserved
Industry Group #4 – Marine Equipment	128 – 207 Dynamic 208 – 247 Reserved
Industry Group #5 – Industrial, Process Control, Stationary Equipment	128 – 207 Dynamic 208 – 247 Reserved

SAE J1939 – Address Claiming

Two possible scenarios:

Sending an Address Claimed message (Standard)

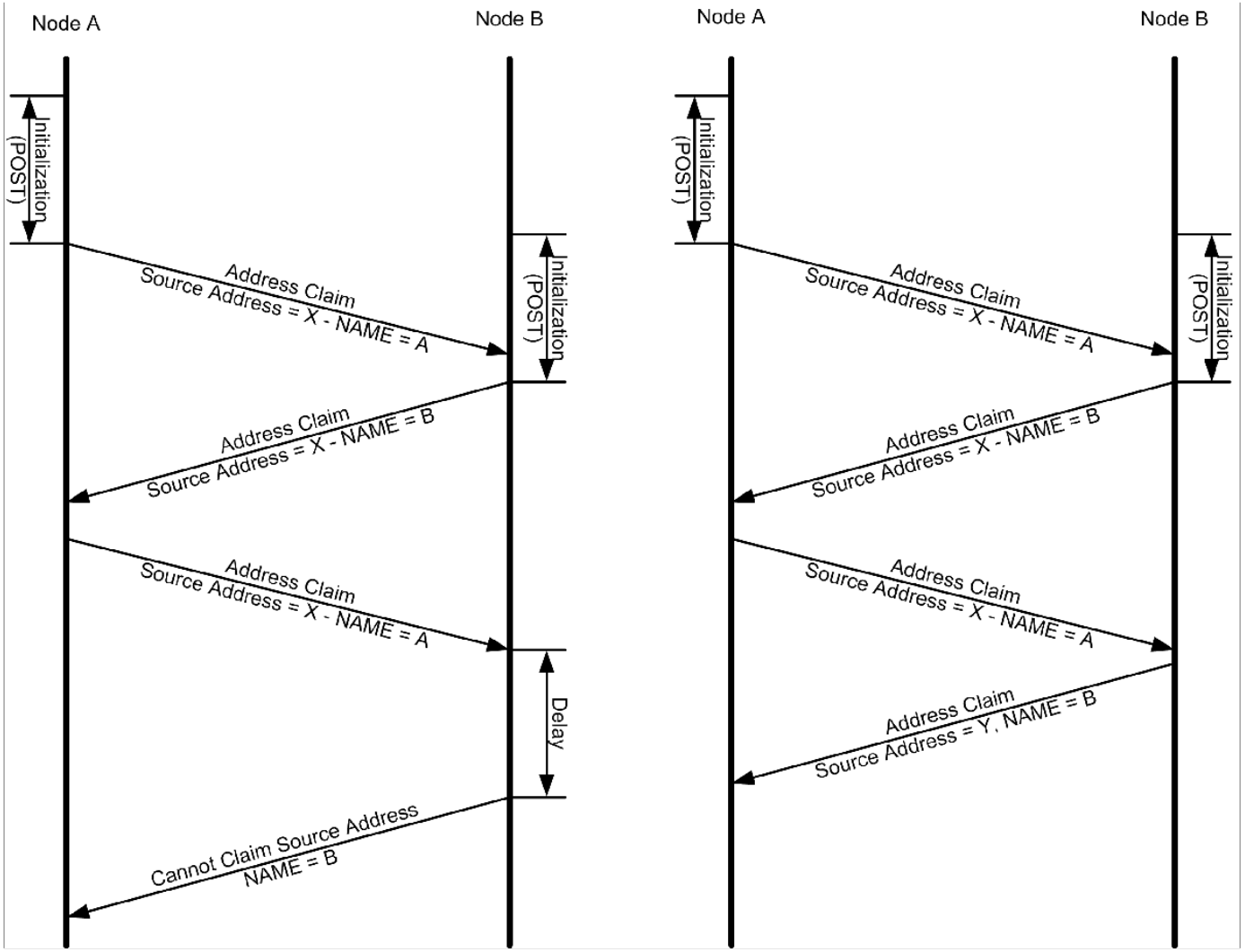
- ECU sends Address Claimed message into the CAN bus
- ECUs receiving address claim will record & verify claimed address with internal address table
- In case of address conflict ECU with lowest NAME value will succeed
- Remaining ECUs must claim different address or stop transmitting to network

Request for Address Claimed message

- Necessary procedure for ECUs powering up late (e.g. trailers, diagnostics tools, etc.)
- Used to determine and claim available address or to find out which ECUs are currently on the network

SAE J1939 – Address Claiming

Two possible address claim scenarios:



SAE J1939 – Address Claiming

· Node A starts initialization and Power-On Self Test (POST) some time ahead of node B.

· While node B is going through initialization and POST, node A sends out it address claim message.

· Node B, after having finished initialization and POST, attempts to claim the same source address as node A

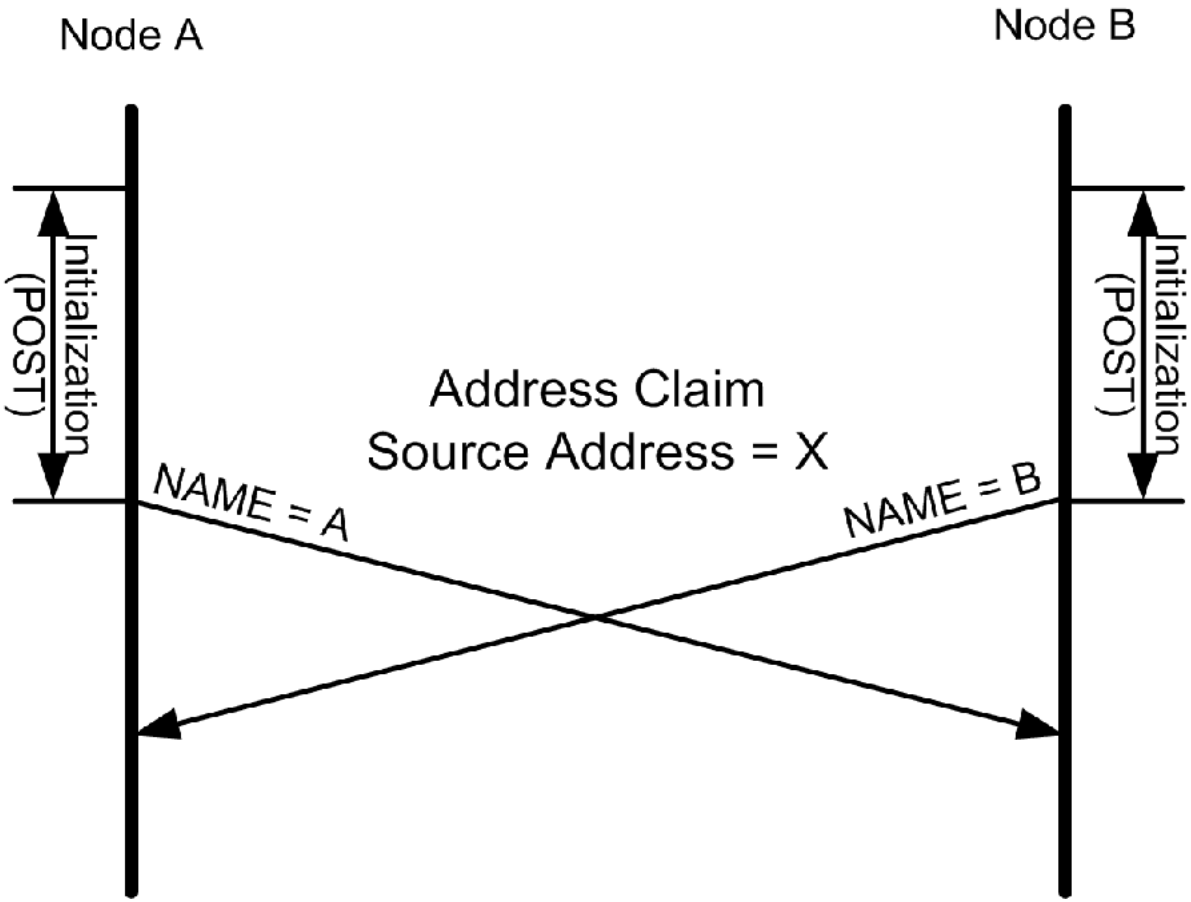
· In response node A, having determined that its NAME has higher priority, resends the address claim message.

· Node B receives the address claim message, determines that node A's name has higher priority.

· In the left scenario, node B sends a *Cannot Claim* message. In the right scenario it claims another address by sending another *Address Claim* message.

SAE J1939 – Address Claiming

CAN Message Collision is possible!



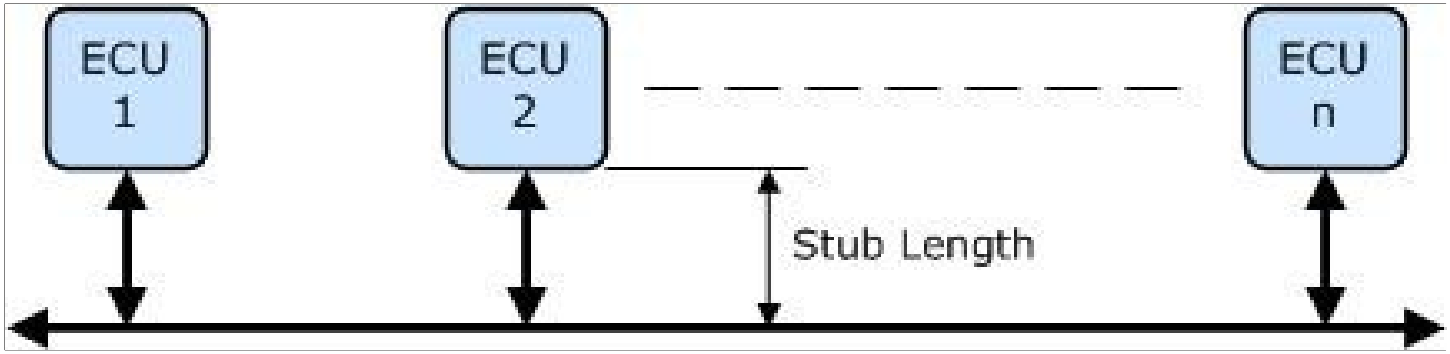
SAE J1939 – Address Management Messages

Message	PGN	PF	PS	SA	Data Length	Data
Request for Address Claimed	59904	234	DA	SA**1)**	3 bytes	PGN 60928
Address Claimed	60928	238	255	SA	8 bytes	NAME
Cannot Claim Source Address	60928	238	255	254	8 bytes	NAME
Commanded Address	65240	254	216	SA	9**2)**	NAME, new SA

1) In case no address has been claimed as of yet the source address could be set to 254.

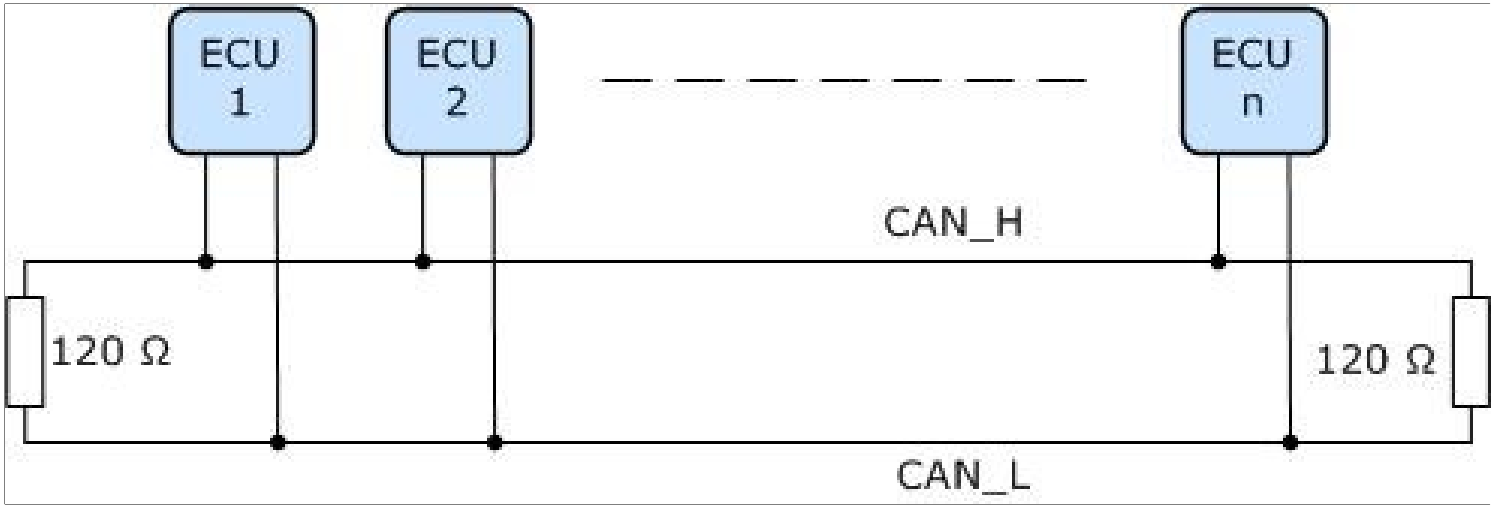
2) The commanded address, since it is longer than 8 bytes, is sent using the Transport Protocol as described in chapter *Transport Protocol*.

SAE J1939 – Network Topology



- ECUs in a J1939 network segment are connected by a single, linear, shielded twisted pair of wires
- Wiring topology of the network should be as straight as possible to minimize electrical reflections:
  - Short stub lengths
  - Avoiding complex network structures

SAE J1939 – Network Topology



- Each bus segment should be terminated by resistors, typically 120 Ω
- Termination resistors should always be on both ends of the bus
- Dividing network into sub-networks may be necessary (e.g. for truck and trailer)
- Segmentation requires bridges

J1939/13 Off-Board Diagnostic Connector

J1939/13 defines a standard connector for diagnostic purpose.

The connector is a Deutsch HD10 - 9 – 1939 (9 pins, round connector).

J1939 Online Forum

http://www.j1939forum.com

J1939Forum.com is the Online meeting place where to find additional information on SAE J1939 and get help with issues related to SAE J1939.

Literature

Literature on Controller Area Network, CANopen and SAE J1939