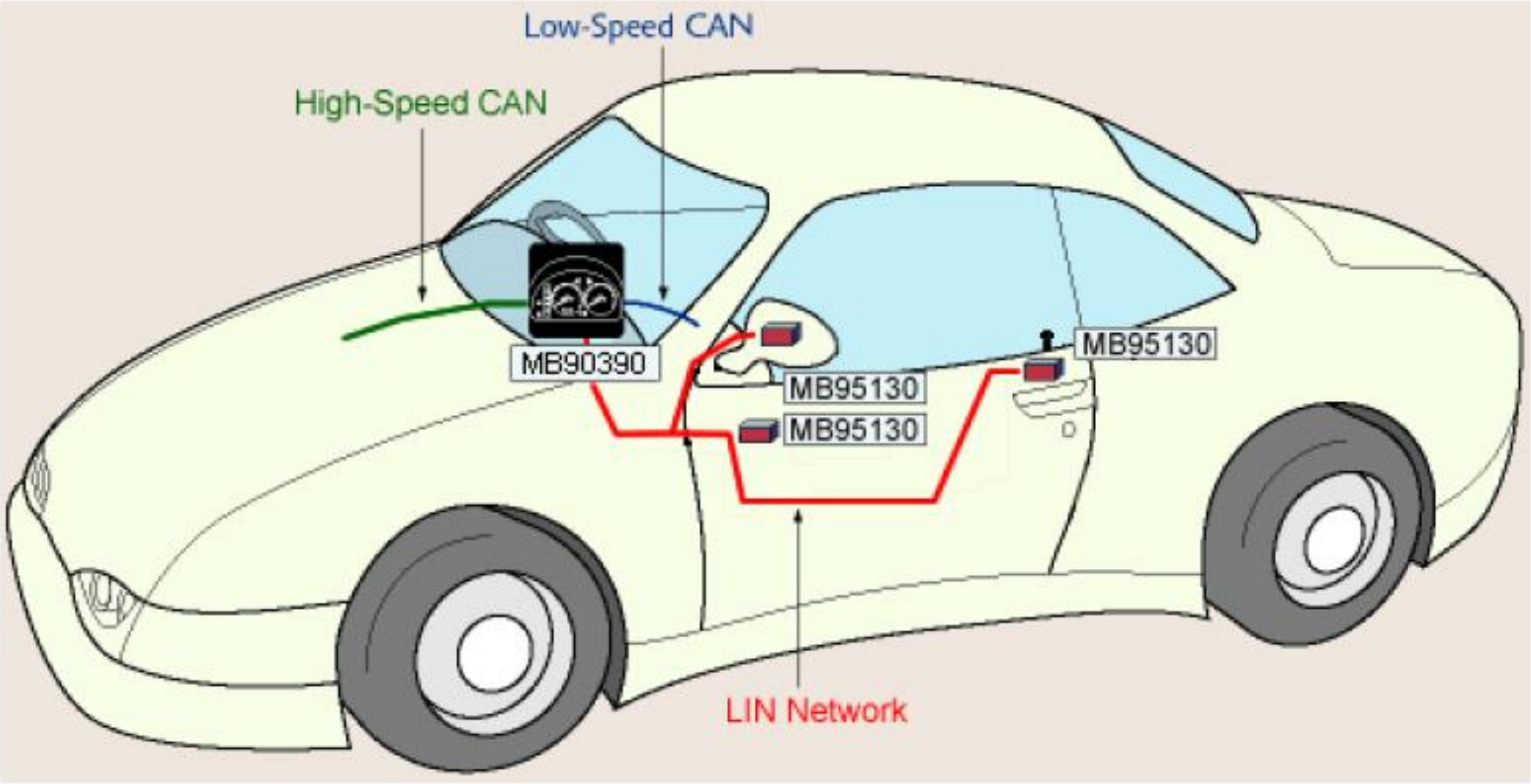
Automotive Bus Technology

Agenda

- Introduction.
- Basic Concepts.
- Frame Formats.
- Error Detections.
- Error Handling.
- CAN protocol Versions.

Introduction

- How it all began …



Introduction

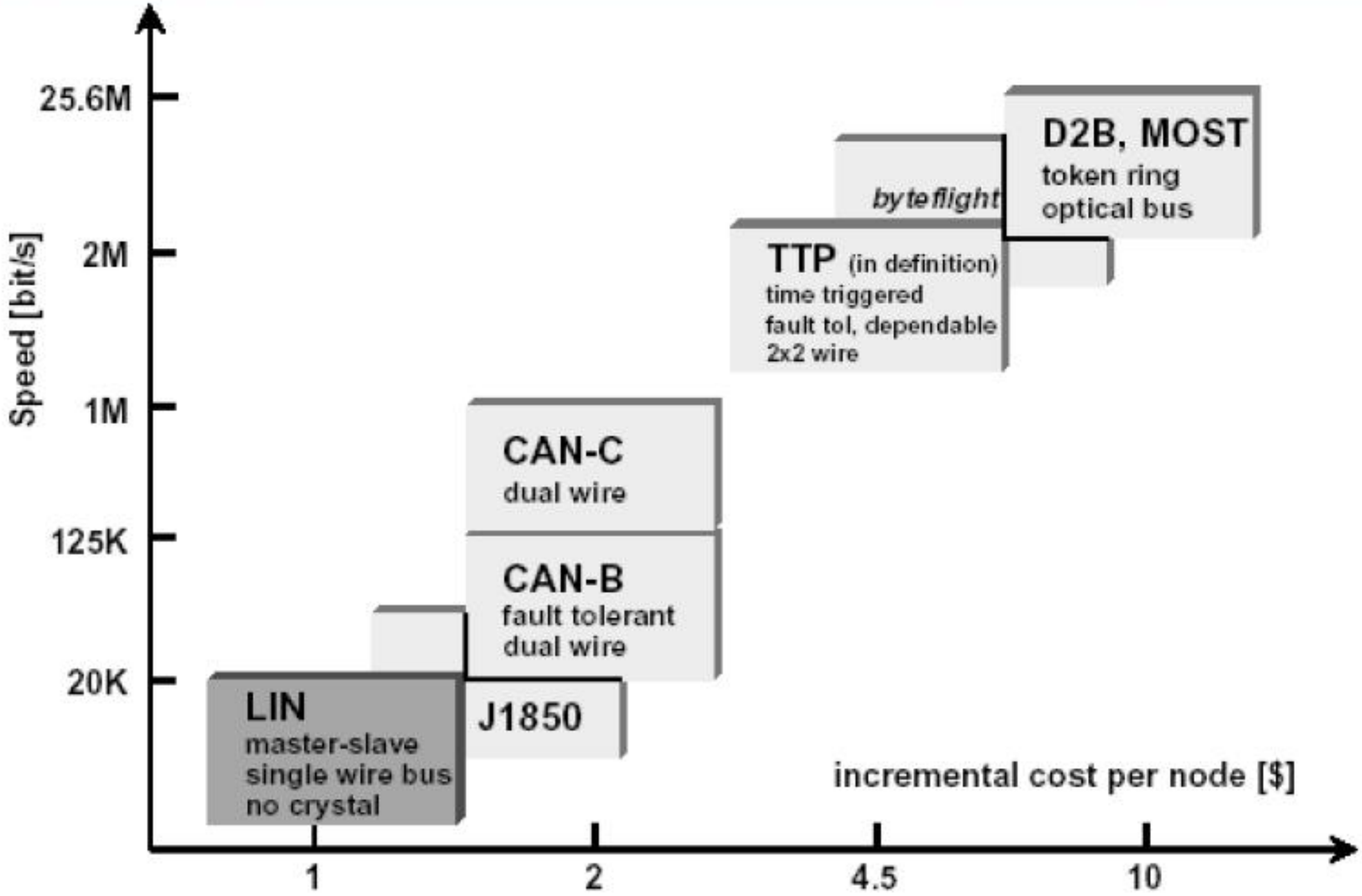
Each type requires specific features:

- Conventional body and powertrain applications use protocols with known real-time properties
  - CAN
- Multimedia applications, calling for protocols that should provide high bandwidth and speed and even wireless interconnection.
  - Bluetooth
  - MOST
  - Firewire

Introduction

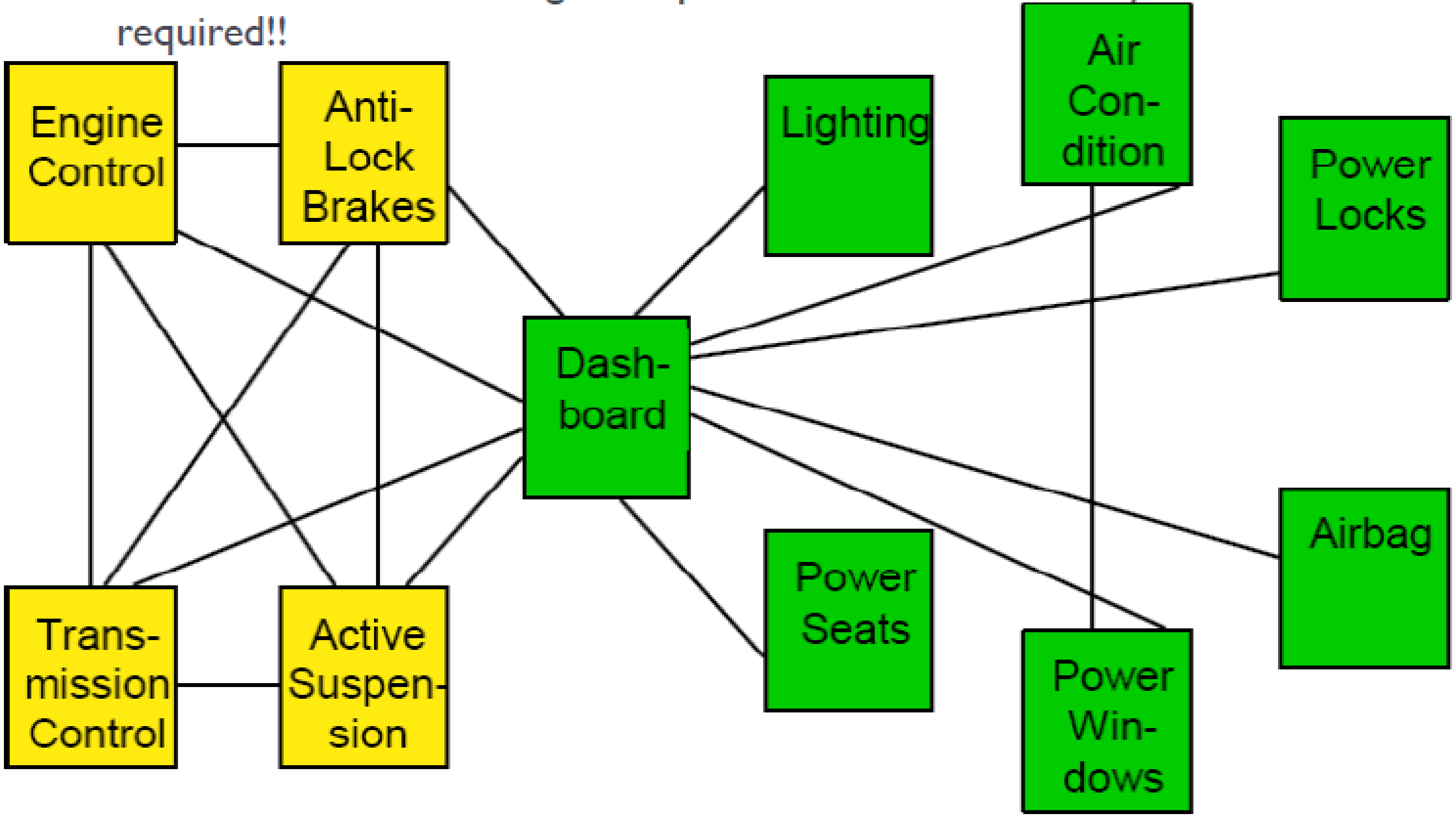
- Safety critical applications, needing protocols that are fault tolerant and reliable. X-by-wire is an emerging market that calls for protocols like
  - TTP/C (Time-Triggered Protocol classified as a SAE type C network)
  - FlexRay
  - TT-CAN (Time Triggered CAN).
- Mechatronic type applications such as smart sensors and actuators, or even complex ECUs with simple communication needs. These applications are addressed by protocols like
  - LIN
  - TTP/A
  - other OEM (Original Equipment Manufacturer) specific protocols.

Introduction



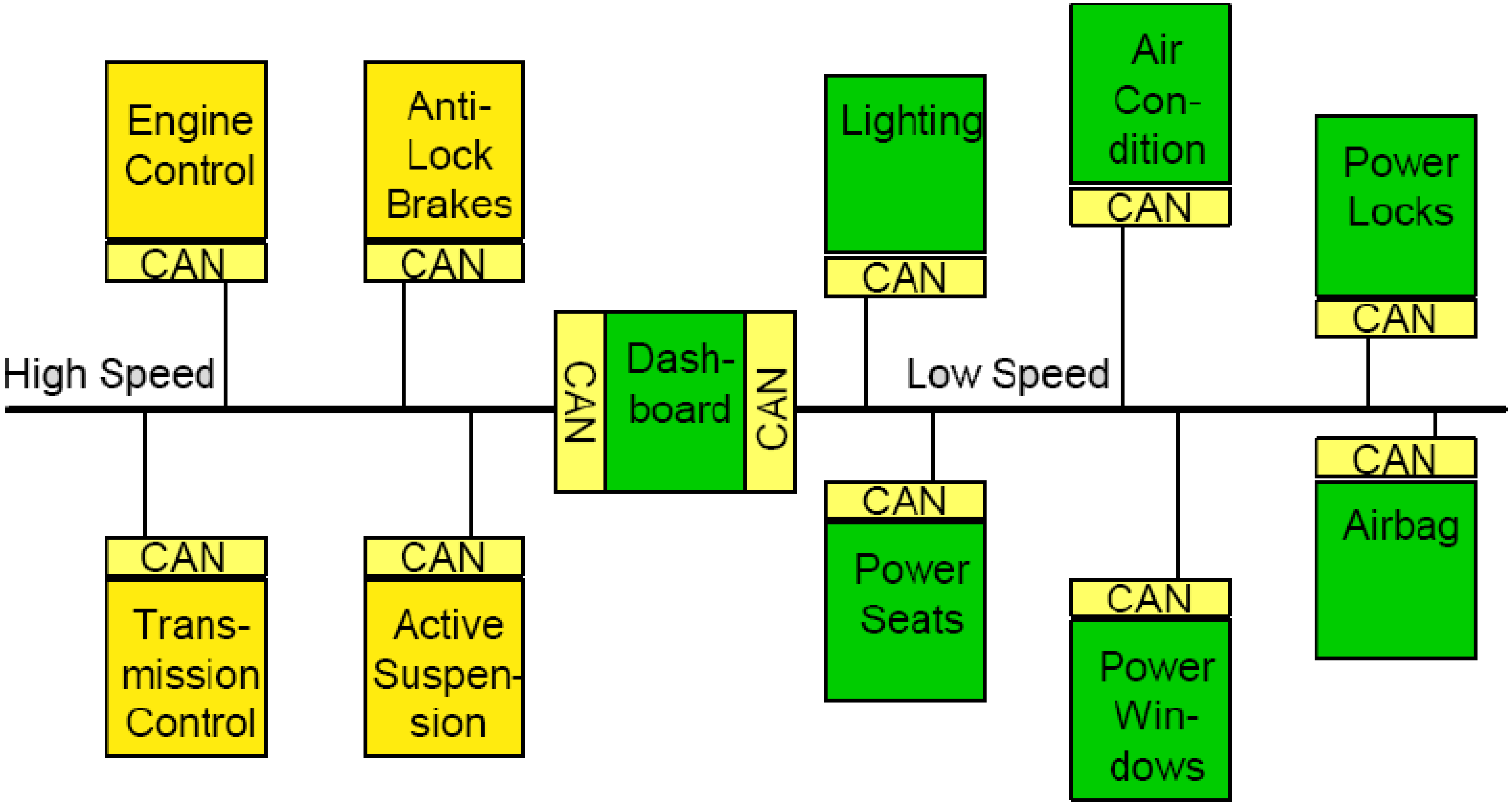
Introduction

- How it all began …
  - Discrete Interconnection of different systems (point to point wiring)
  - Network cable with a length of up to several miles and many connectors was required!!



Introduction

- How it all began …



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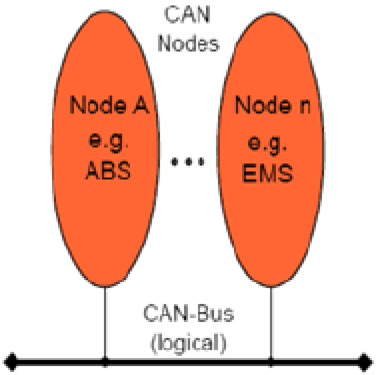
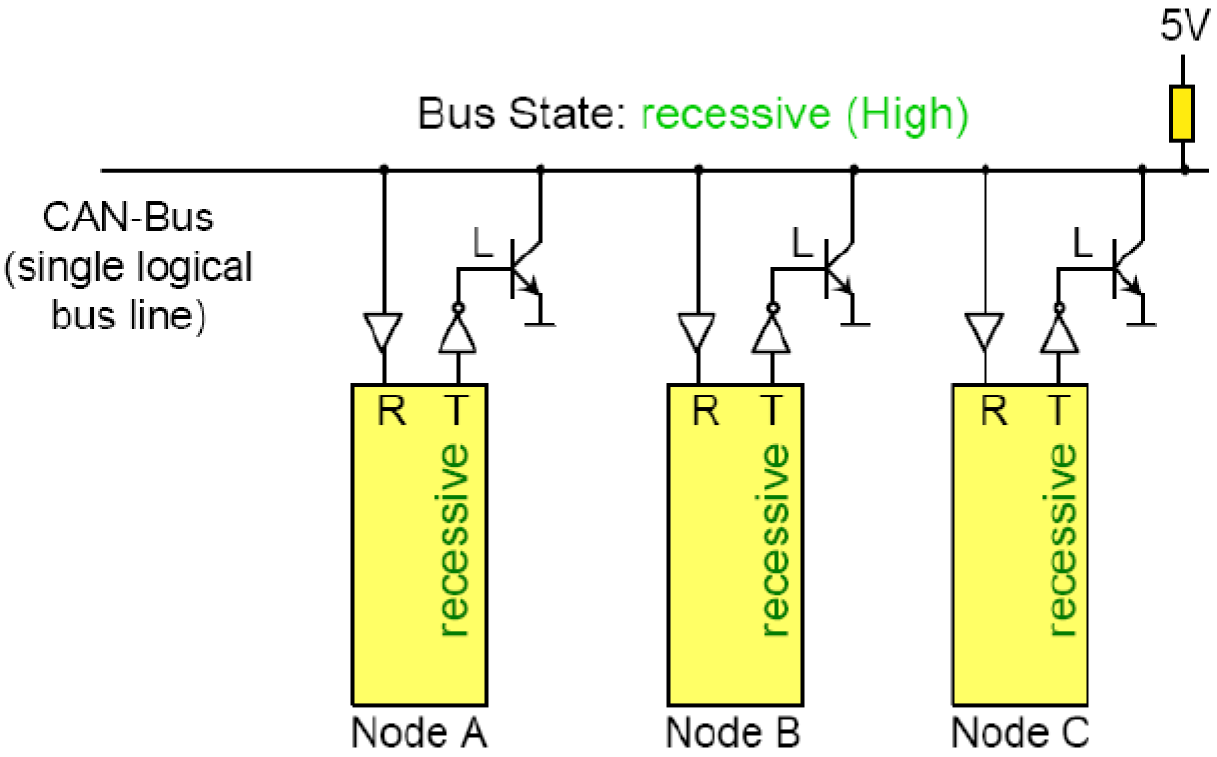
Basic Concepts

- Multi-Master Concept.
- Number of Nodes is not limited by protocol
- No Node addressing
  - Message ID specifies contents and priority.
- Easy connection/disconnection of nodes.
- Broadcast/Multicast capability.
- CAN Network Speed:
  - **Low Speed CAN** baud rates from 40 Kbit/s to 125 Kbits/sec
  - **High Speed CAN** baud rates from 40 Kbit/s to 1 Mbits/sec, depending on cable length



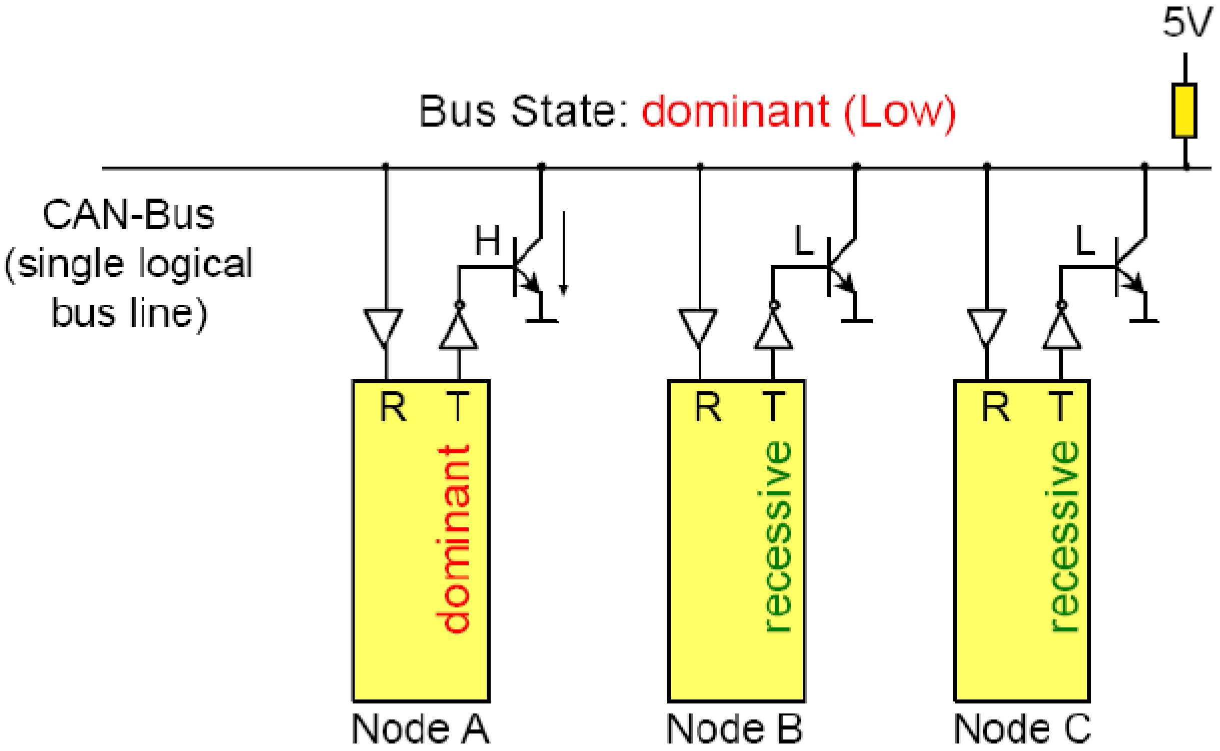
Basic Concepts

- CAN Bus Characteristics - Wired-AND



Basic Concepts

- CAN Bus Characteristics - Wired-AND

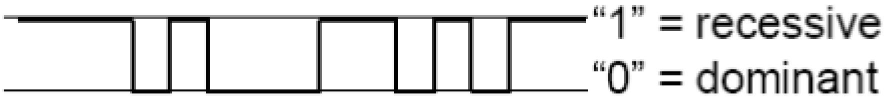


Basic Concepts

- CAN Bus Characteristics - Wired-AND

Recessive Vs Dominant

Two logic states
possible on the bus:
"1" = recessive
"0" = dominant



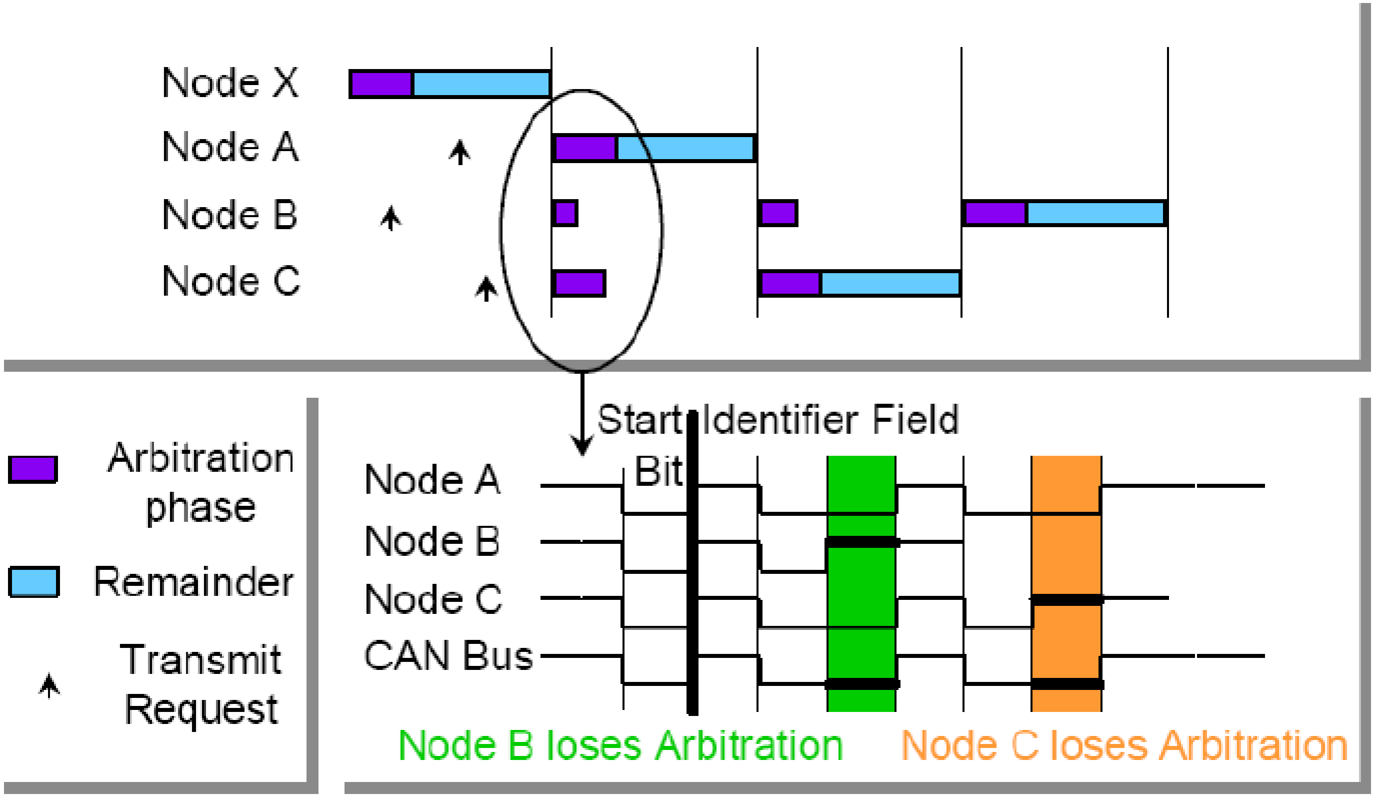
A	B	C	BUS
D	D	D	D
D	D	R	D
D	R	D	D
D	R	R	D
R	D	D	D
R	D	R	D
R	R	D	D
R	R	R	R

As soon as one node nodes transmits
a dominant bit (zero):
Bus is in the dominant state.

Only if all nodes transmit
recessive bits (ones):
Bus is in the recessive state.

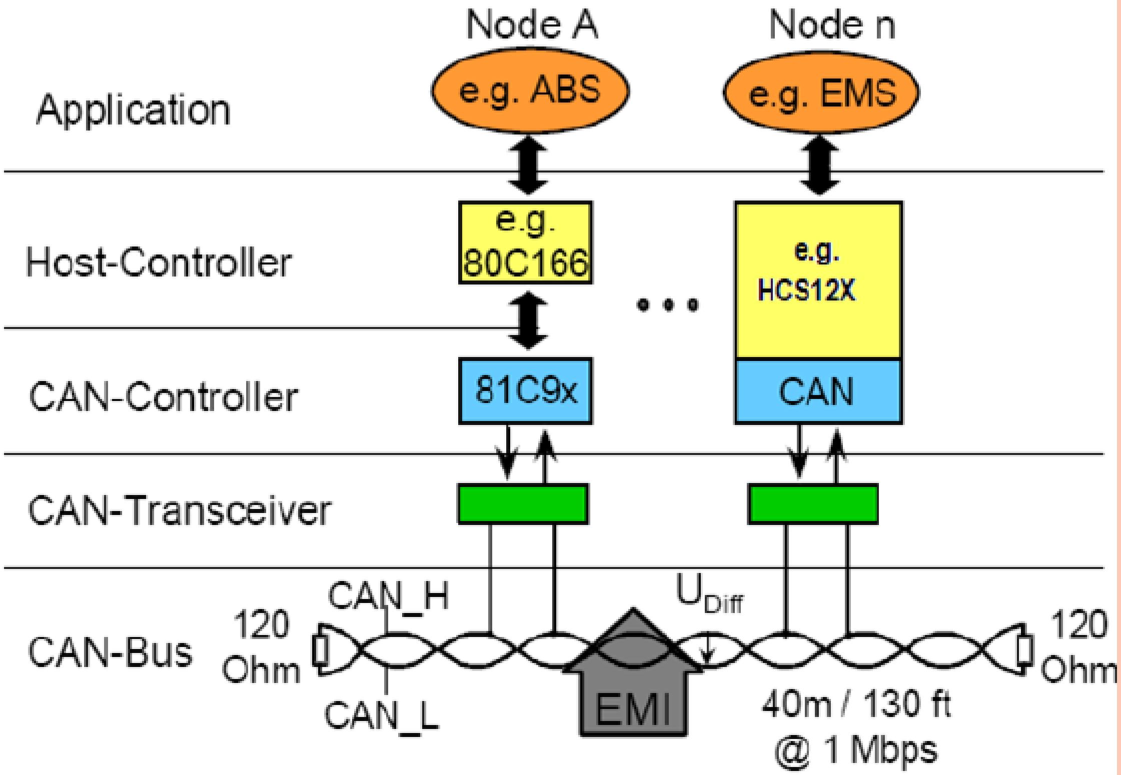
Basic Concepts

- Bus Access and Arbitration



Basic Concepts

- Sophisticated Error Detection/ Handling
- NRZ and Bit Stuffing for Synchronization
- Bus Access via CSMA/CD



CSMA/CD→ Carrier Sense Multiple Access / Collision Detection

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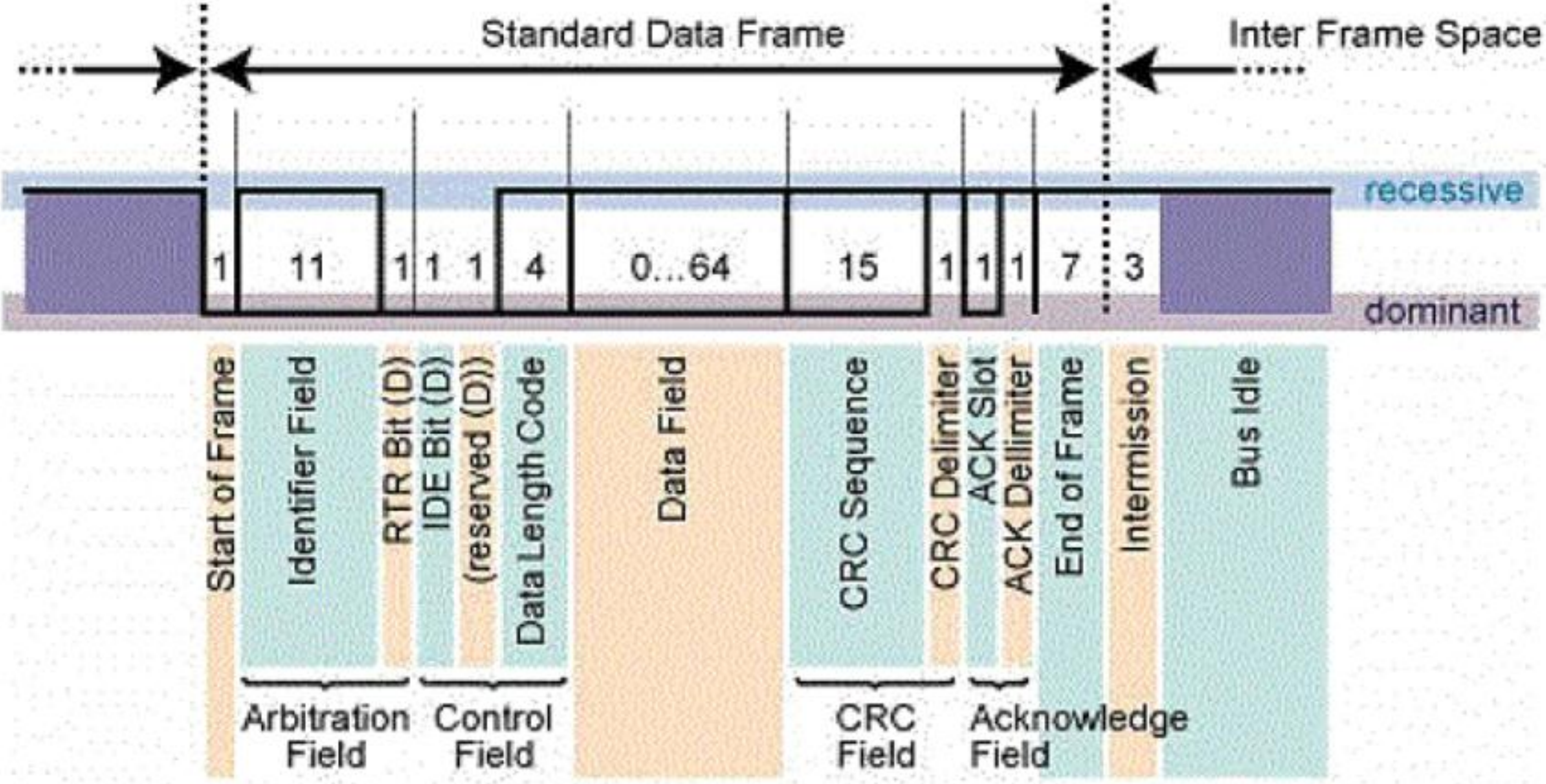
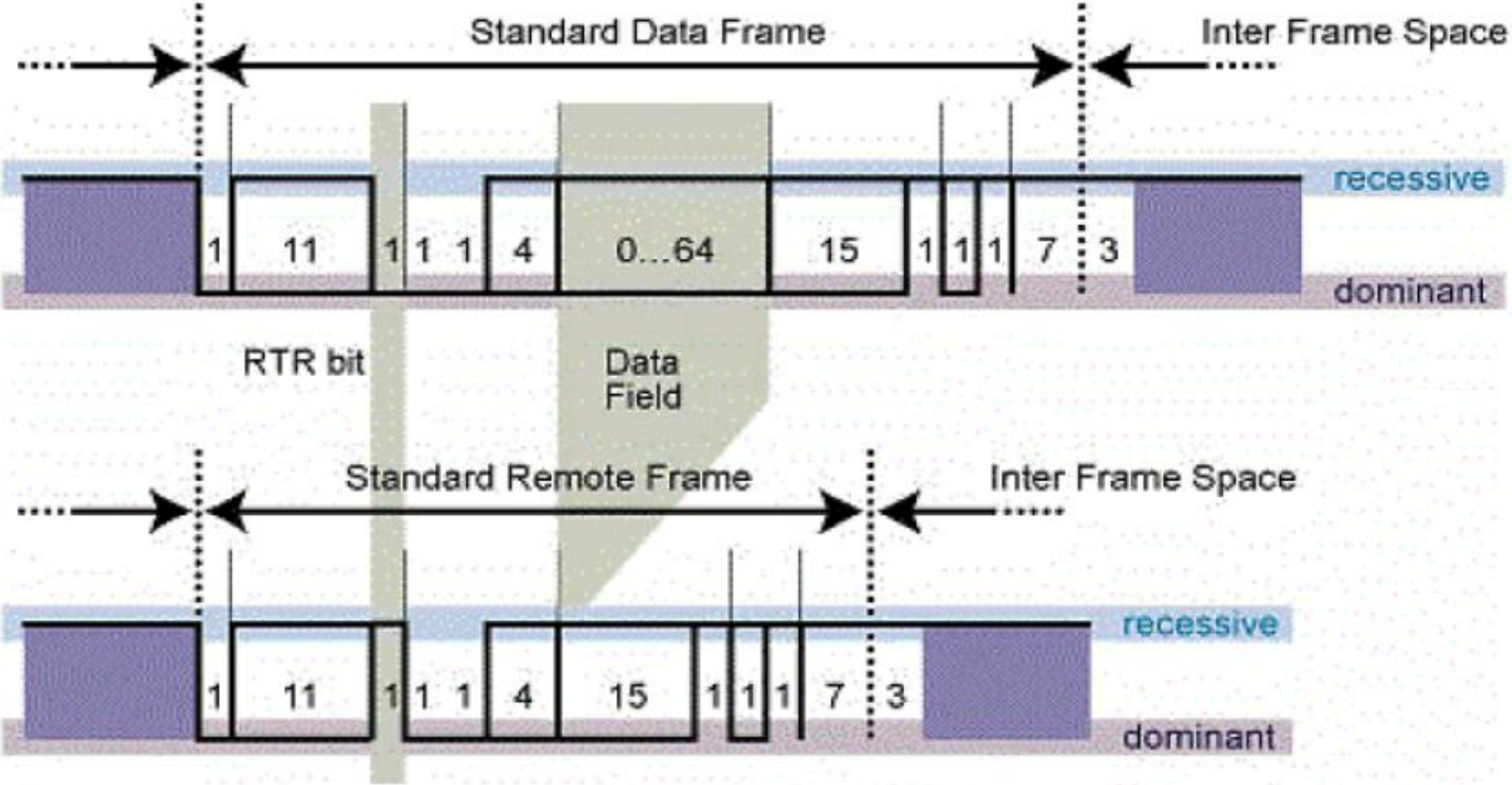
Frame Formats “Ref: http://esd.cs.ucr.edu/webres/can20.pdf”

- Data Frame
- Remote Frame
- Error Frame
- Overload Frame
- Inter-Frame Space
- Message vs. Signal

Frame Formats- Data Frame

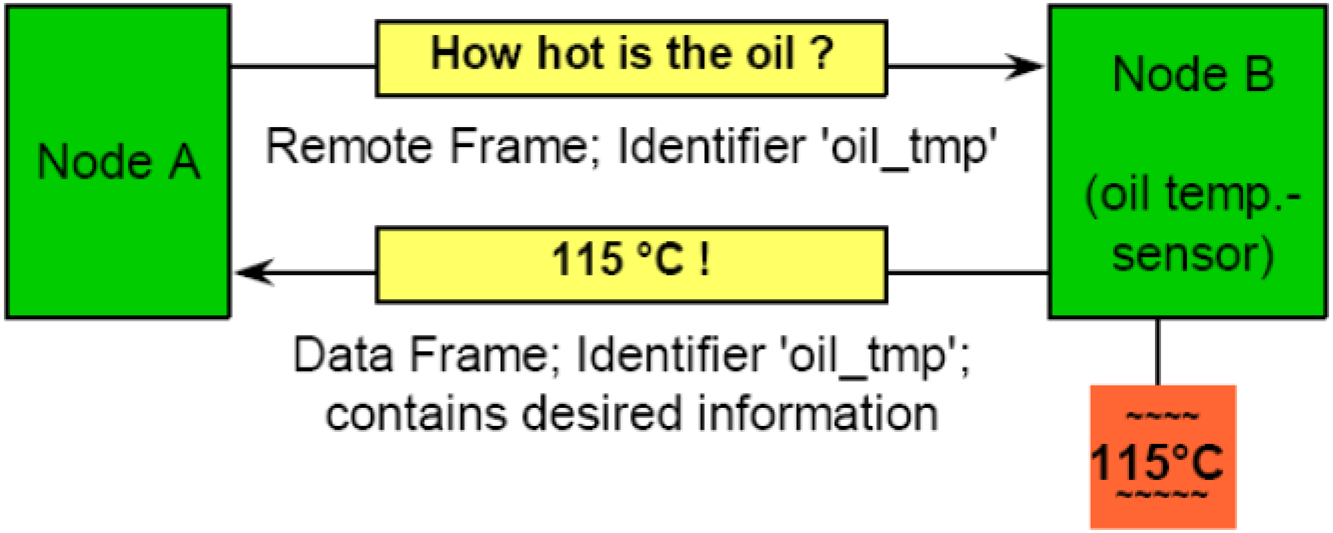


Frame Formats- Remote Frame



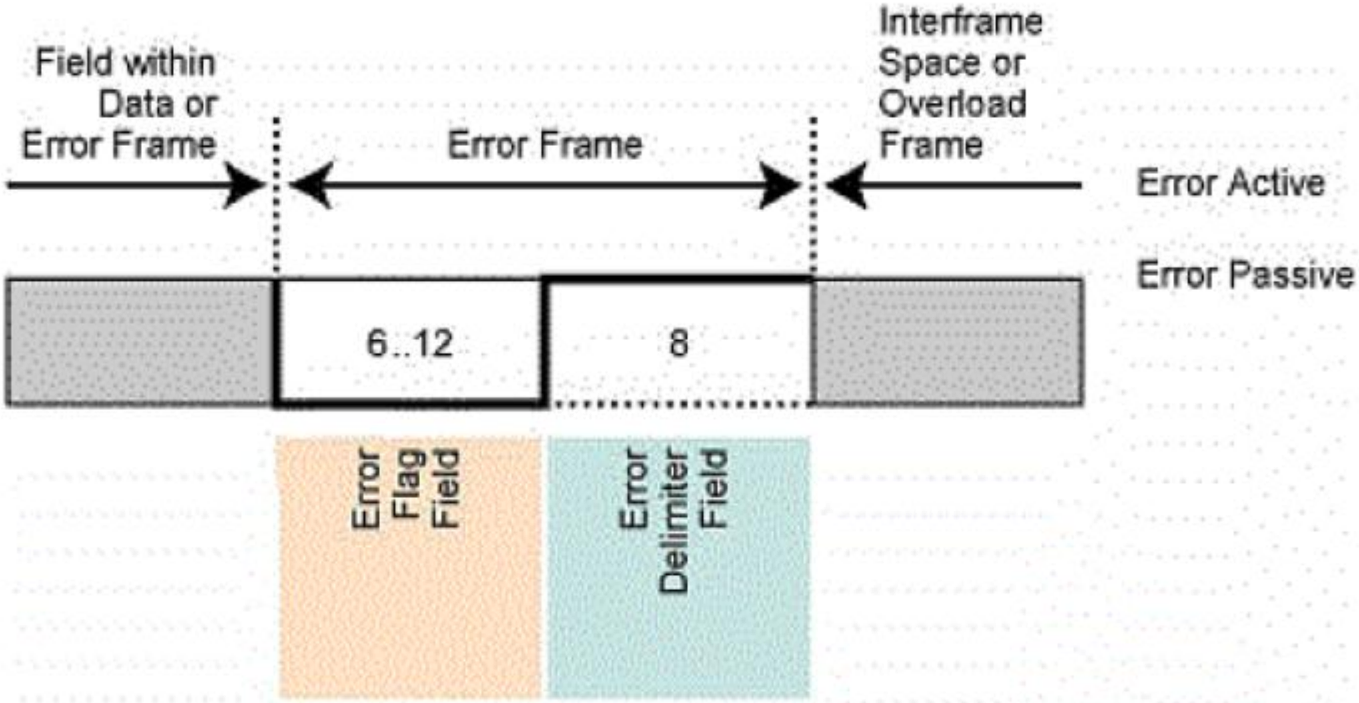
Frame Formats- Remote Frame

- Remote Frame Scenario

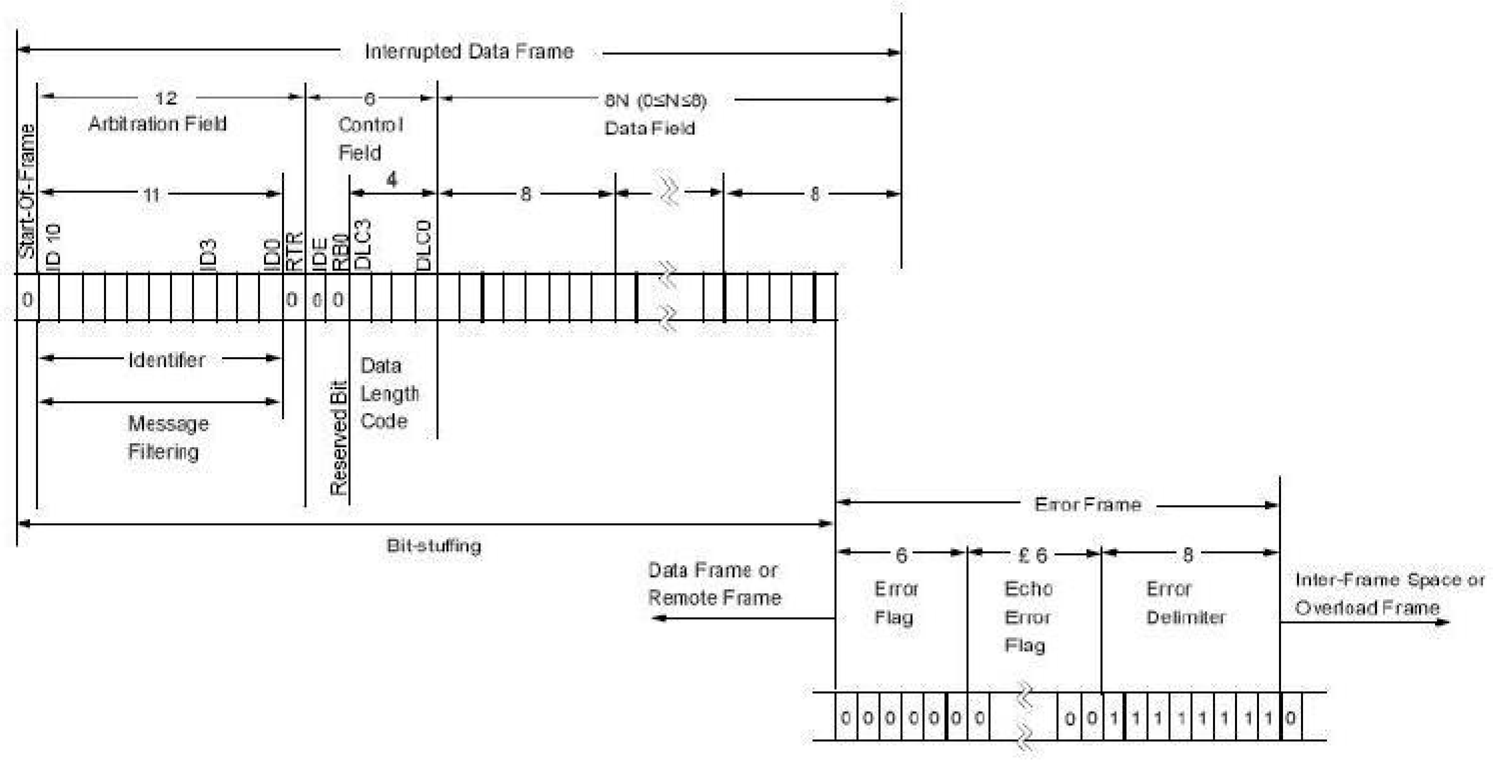

Node A
How hot is the oil ?
Node B
(oil temp.-
sensor)
Remote Frame; Identifier 'oil_tmp'
115 °C !
Data Frame; Identifier 'oil_tmp';
contains desired information
~~~~
115°C
~~~~~

Frame Formats- Error Frame

- Active Error Frame

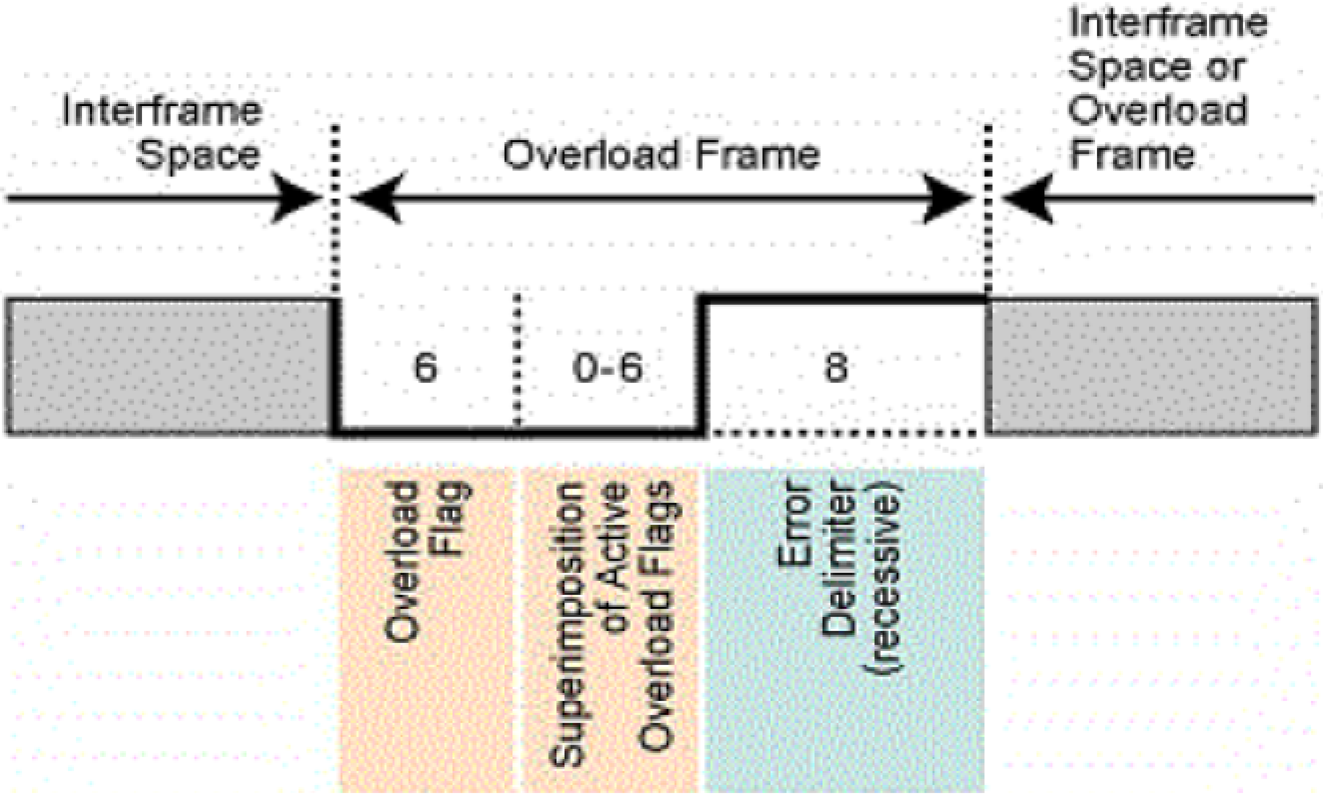


Frame Formats- Error Frame



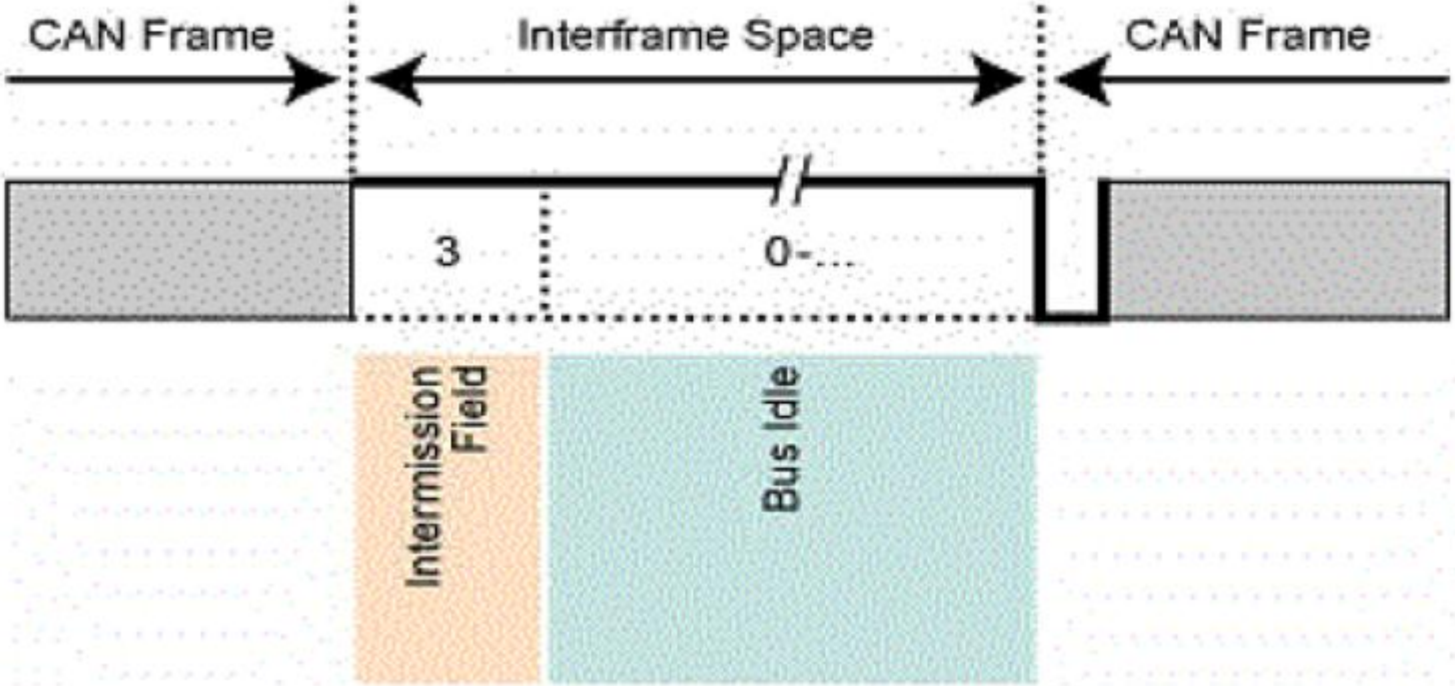
Frame Formats- Overload Frame

- Overload Frame used to delay next CAN message


Interframe Space
Overload Frame
Interframe Space or Overload Frame
6
0-6
8
Overload Flag
Superimposition of Active Overload Flags
Error Delimiter (recessive)

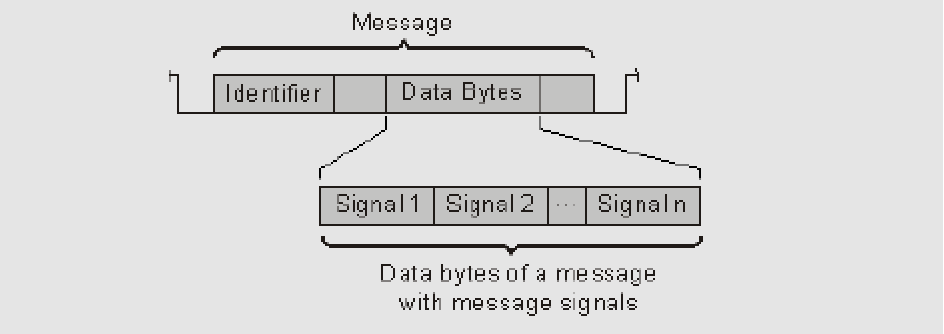
Frame Formats- Inter-frame Space

- Separates a frame (of whatever type) from a following Data or Remote frame



Frame Formats- Message vs. Signal

- Messages are transmitted between Network Nodes over the bus.
- The data bytes of any message is divided into Signals.
- Signals represent a physical value.
- For example, one data byte could be divided into 3 signals as:
  - 4 bits that represent the vehicle speed => e.g: Named SpeedSig
  - 2 bits that represent the gear position => e.g: Named GearPosSig
  - 2 bits that represent the light status => e.g: Named LightStatSig



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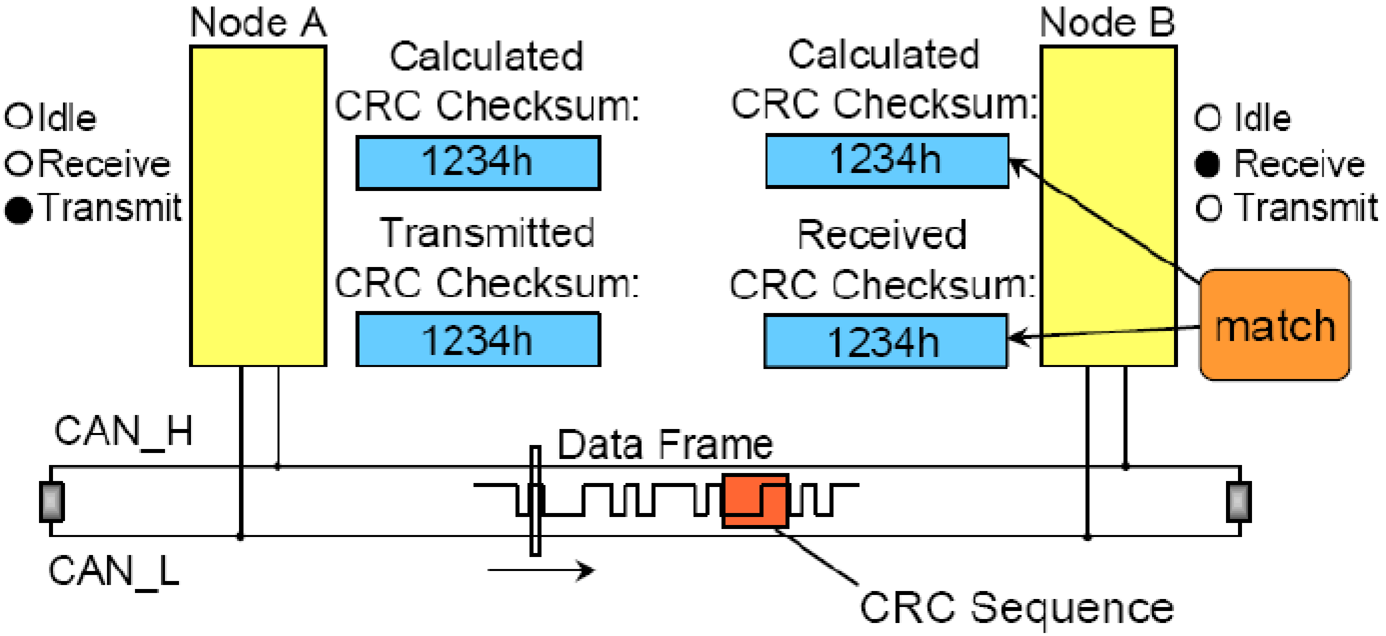
Error Detection

- CRC Error
- ACK Error
- Form Error
- Bit Error
- Stuff Error

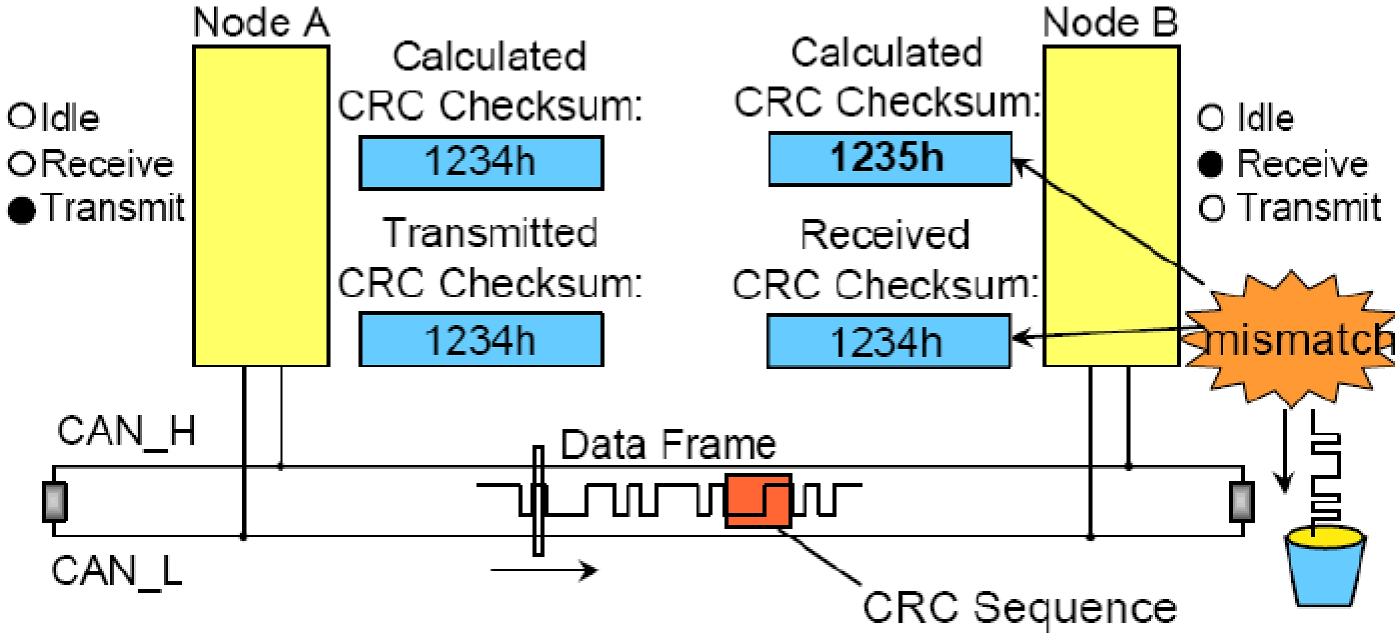
Error Detection- CRC Error

- Calculated and Received checksum must match



Error Detection- CRC Error

- Otherwise frame wasn't received correctly (CRC Error)



Error Detection- Acknowledge

- A frame must be acknowledged by at least one other node, otherwise ACK Error

[redacted]

Node A
○ Idle
○ Receive
● Transmit

Recessive
TX
Dominant

Node B
○ Idle
● Receive
○ Transmit

Recessive
TX
Dominant

CAN Bus
○ Idle
● Active

Recessive
Dominant

[redacted]

Error Detection- Frame Check

- No Dominant Bits allowed in
  - CRC Delimiter
  - ACK Delimiter
  - End of Frame
  - Inter-frame space

Otherwise Form Error is generated

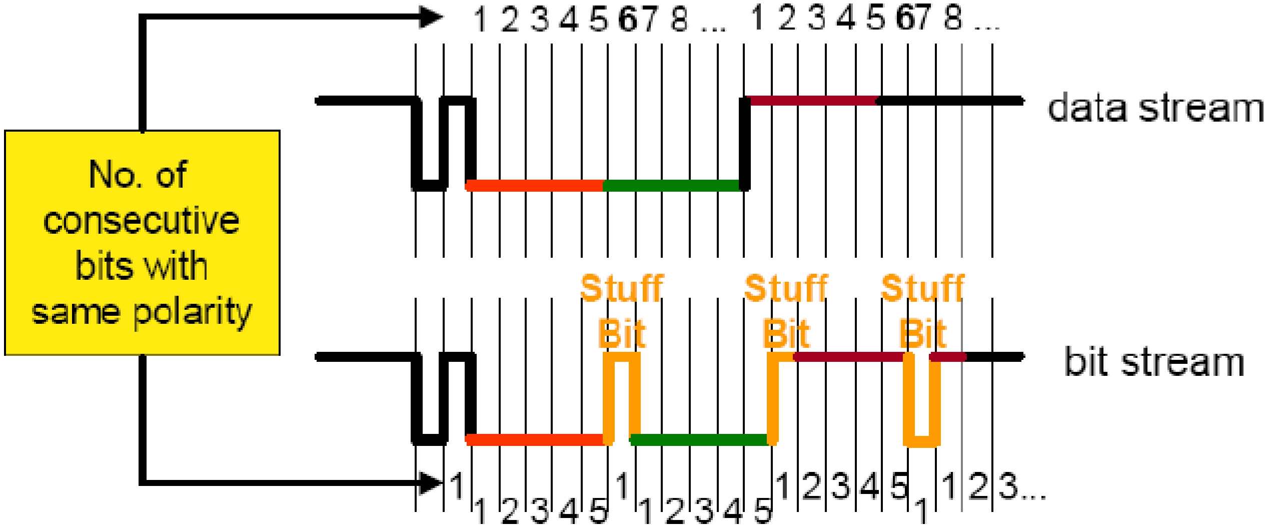
Error Detection- Bit Monitoring

- A transmitted bit must be correctly read back from CAN bus, otherwise Bit Error
- Dominant bits may overwrite recessive bits only in the Arbitration field and in the Acknowledge slot.

Error Detection- Bit Stuffing

- Six consecutive bits with same polarity are not allowed between start of frame and CRC Delimiter

Otherwise Bit Stuffing Error



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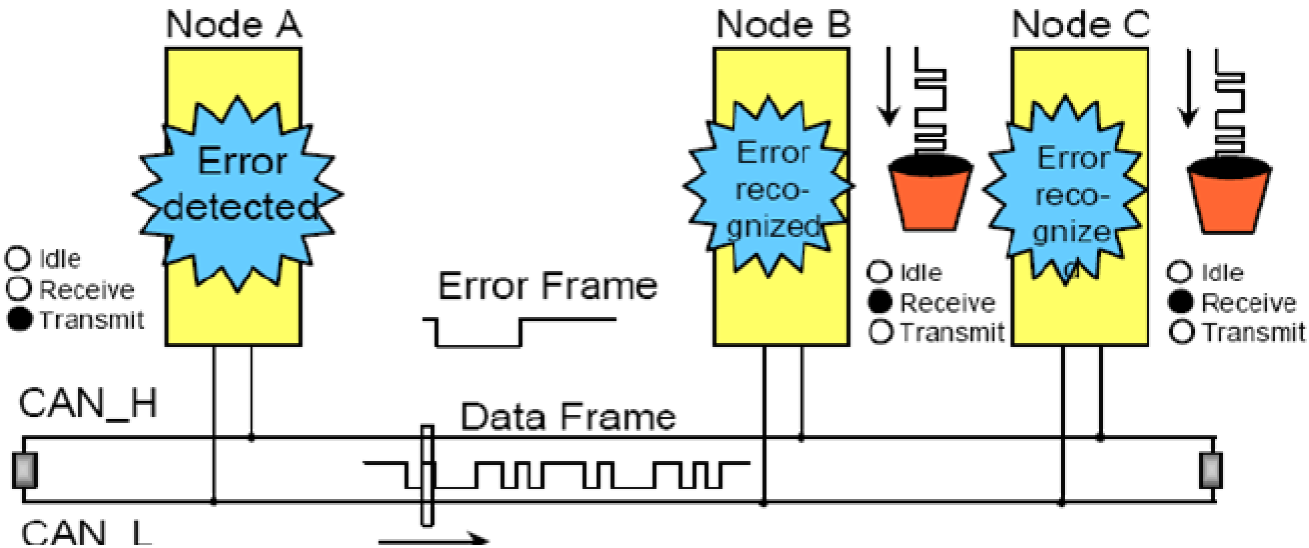
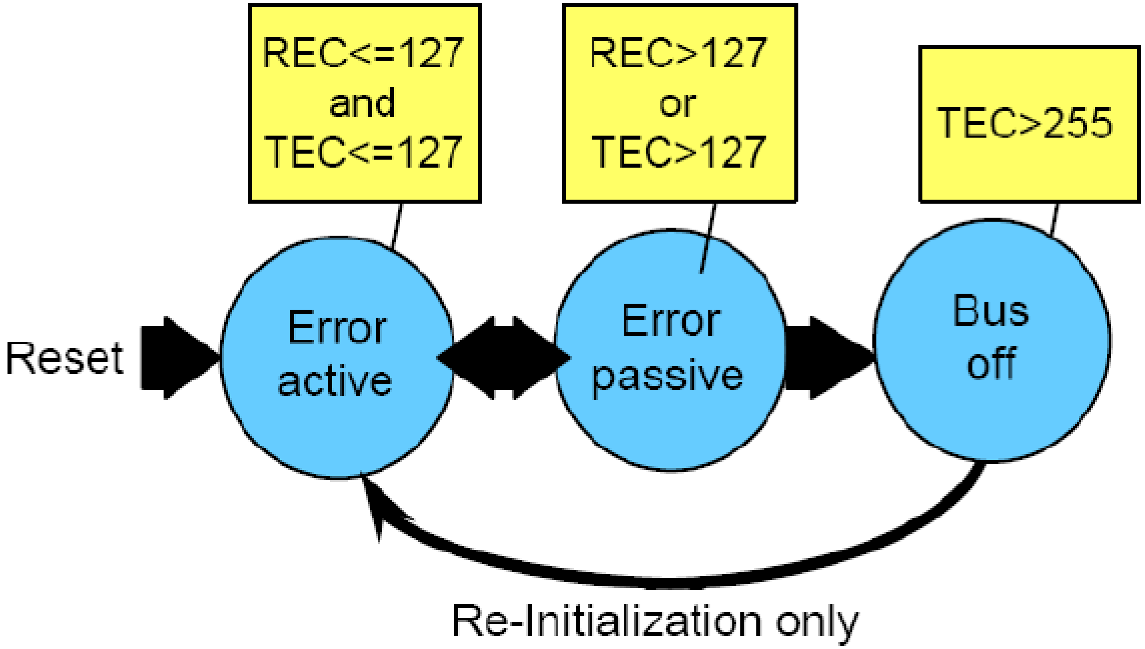
Error Handling

- Detected errors are made public to all other nodes via Error Frames.
- The transmission of the erroneous message is aborted and the frame is repeated as soon as possible.



Error Handling

- Each Node is either in Error Active, Error Passive or Bus off state.



faulty nodes withdraw from the bus automatically (Bus off State)

Undetected Errors

- Imagine a vehicle equipped with CAN
  - Running 2000 hr/year
  - At CAN bus speed of 500 Kbps
  - With 25% bus load

=> This will result in 1 undetected error every 1000 years!!

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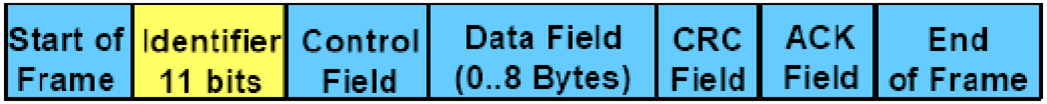
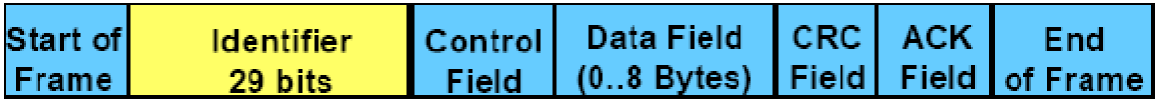
CAN protocol versions

- Two CAN protocol versions available:
  - V2.0A (Standard) - 11 bit Message ID's - 2048 ID's available.



Start of Frame	Identifier 11 bits	Control Field	Data Field (0..8 Bytes)	CRC Field	ACK Field	End of Frame

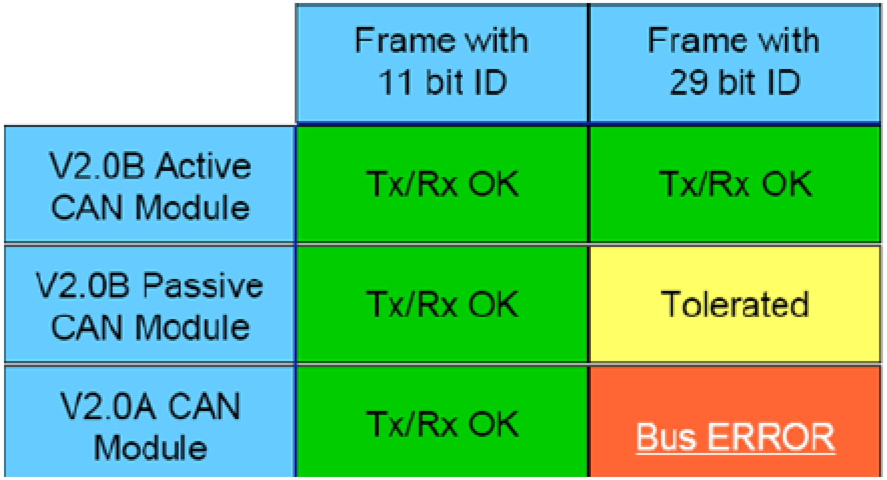
  - V2.0B (Extended) - 29 bit Message ID's - more than 536 Million ID's available



Start of Frame	Identifier 29 bits	Control Field	Data Field (0..8 Bytes)	CRC Field	ACK Field	End of Frame

CAN protocols versions

- Three types of CAN modules available (all handles 11 bit ID's)
  - 2.0A- Considers 29 bit ID as an error.
  - 2.0B Passive - Ignores 29 bit ID messages
  - 2.0B Active- Handles both 11 and 29 bit ID Messages



	Frame with 11 bit ID	Frame with 29 bit ID
V2.0B Active CAN Module	Tx/Rx OK	Tx/Rx OK
V2.0B Passive CAN Module	Tx/Rx OK	Tolerated
V2.0A CAN Module	Tx/Rx OK	Bus ERROR

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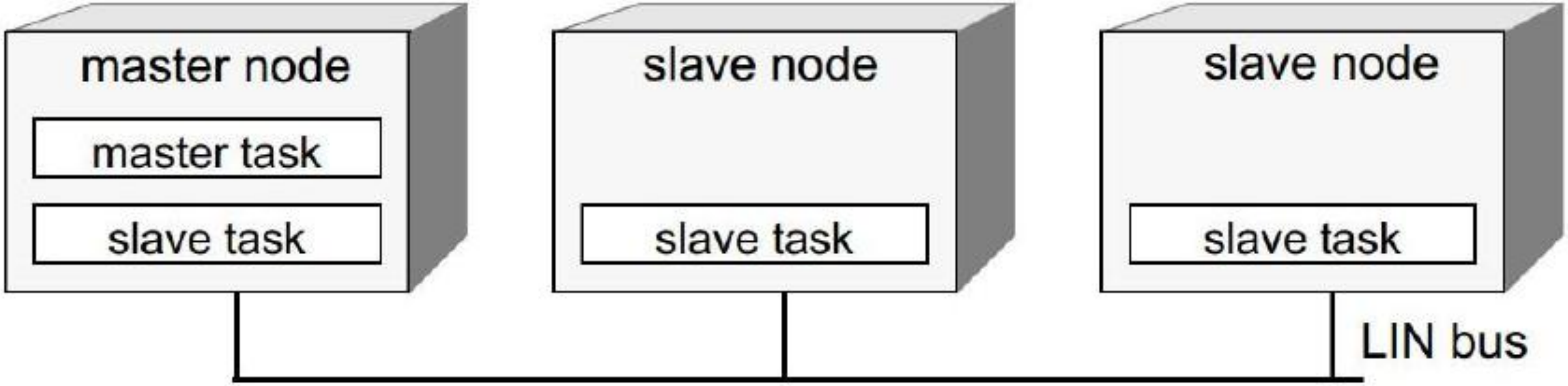
Basic Concepts

“http://www7.informatik.uni-erlangen.de/~dulz/fkom/06/Material/3/LIN%20Specification%20Package.pdf”

- The LIN is a SCI/UART-based serial
- Single-Master / Multi Slave Concept.
- Number of Nodes is limited up to 16 slaves
- No Node addressing
  - Message ID specifies contents and priority.
- Broadcast/Multicast capability.
- LIN Network Speed:
  - LIN baud rates up to 20 Kbit/s

Basic Concepts



Basic Concepts

- LIN is a Time Triggered communication protocol designed to support automotive networks in conjunction with Controller Area Network (CAN)
- No collision detection exists in LIN, therefore all messages are initiated by the master with at most one slave replying for a given message identifier.

Basic Concepts

- The LIN bus is connected between smart sensor or actuators and an Electronic Control Unit (ECU) which is often a gateway with CAN bus.
- Enables cost-effective communication with sensors and actuators when all the features of CAN are not required.
- The main features of this protocol (compared to CAN) are low cost and low speed and used for short distance networks.

Basic Concepts

- The master is typically a moderately powerful microcontroller, whereas the slaves can be less powerful, cheaper micro-controllers or dedicated ASICs.
- The LIN is a single wire 12V bus connection, in which the communication protocol is based upon ISO 9141 NRZ-standard.
- An important feature of LIN is the synchronization mechanism that allows the clock recovery by slave nodes without quartz or ceramics resonator.
- Only the master node will be using the oscillating device. Nodes can be added to the LIN network without requiring hardware or software changes in other slave nodes.

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- Introduction.
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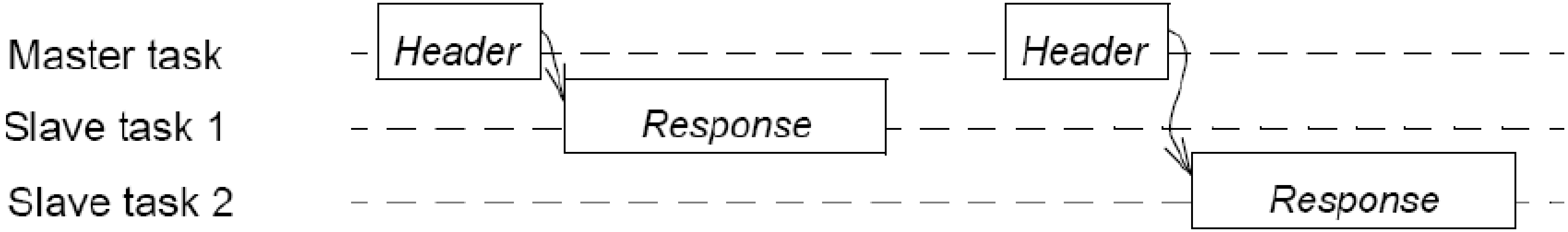
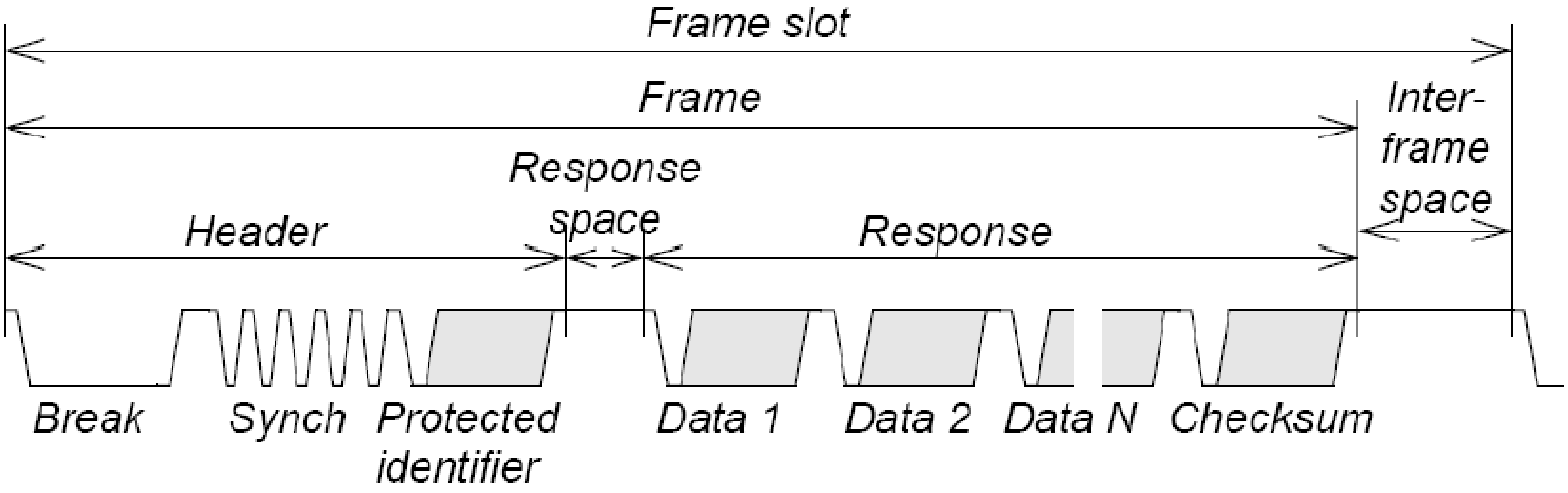
Frame Formats

- A frame consists of a header (provided by the master task) and a response (provided by a slave task)
- The slave tasks interested in the data associated with the identifier receives the response, verifies the checksum and uses the data transported



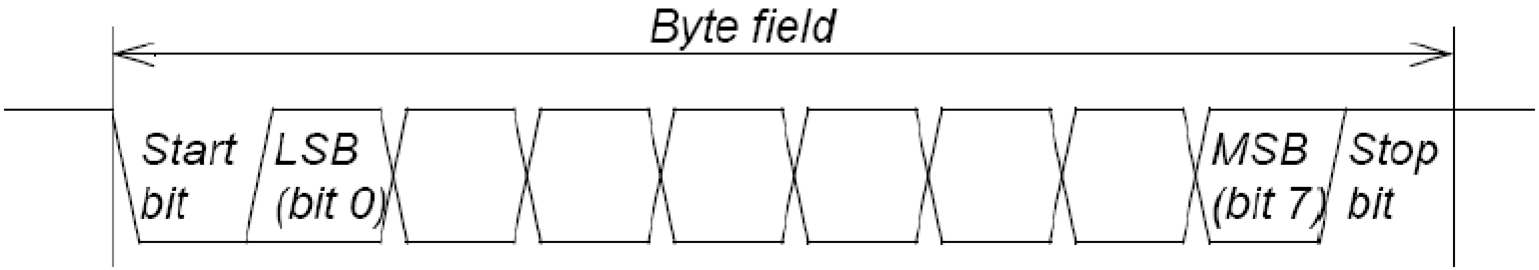
Frame Formats

- Frame Structure



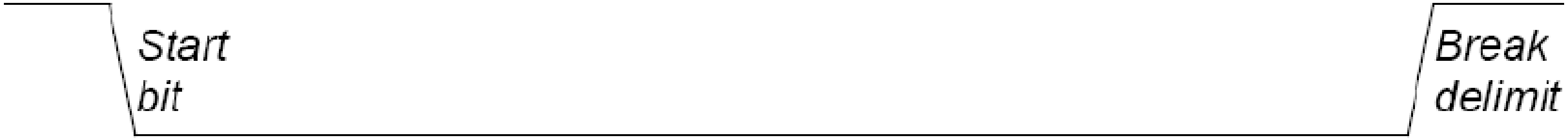
Frame Formats

- Frame Structure
- Structure of a Byte field
  - The LSB of the data is sent first and the MSB last.
  - The start bit is encoded as a bit with value zero (dominant) and the stop bit is encoded as a bit with value one (recessive)



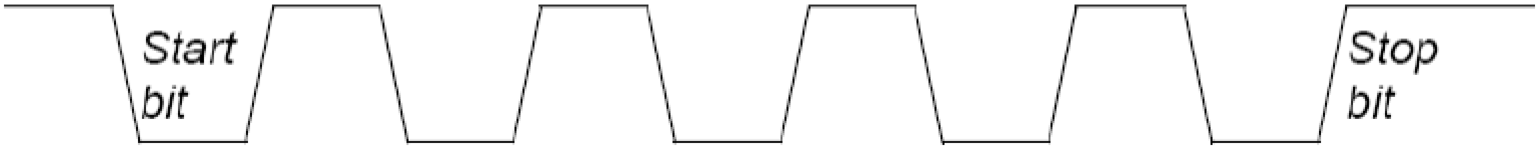
Frame Formats

- Break:
  - The break symbol is used to signal the beginning of a new frame
  - A break is always generated by the master task and it shall be at least 13 bits of dominant value, including the start bit, followed by a break delimiter



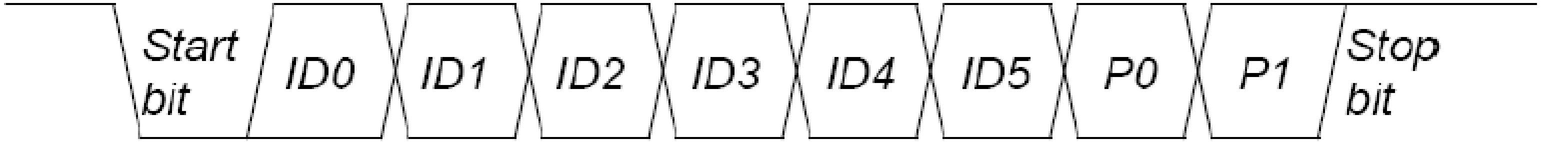
Frame Formats

- Synch Byte:
  - Synch is a byte field with the data value 0x55
  - A slave task shall always be able to detect the break/synch symbol sequence



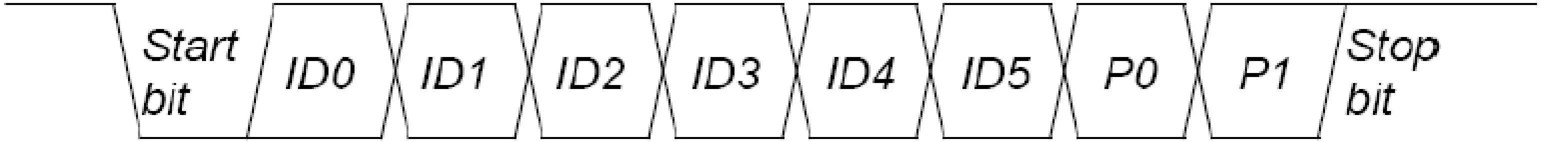
Frame Formats

- Protected Identifier
- Identifier:
  - Six bits are reserved for the identifier (ID), values in the range 0 to 63 can be used
  - The identifiers are split in four categories:
  - Values 0 to 59 (0x3b) are used for signal-carrying frames
  - 60 (0x3c) and 61 (0x3d) are used to carry diagnostic data
  - 62 (0x3e) is reserved for user-defined extensions
  - 63 (0x3f) is reserved for future protocol enhancements



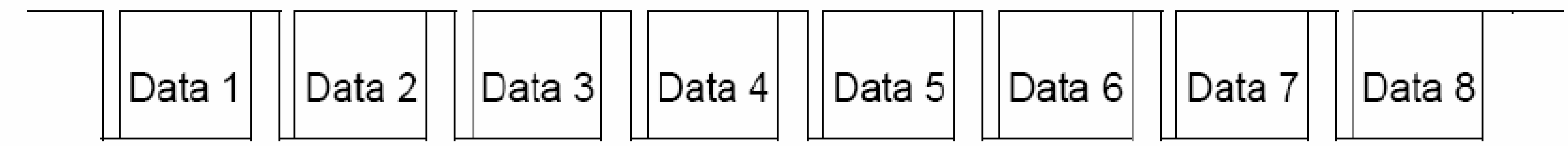
Frame Formats

- Parity:
  - The parity is calculated on the identifier bits
  - $P0 = ID0 \oplus ID1 \oplus ID2 \oplus ID4$
  - $P1 = (ID1 \oplus ID3 \oplus ID4 \oplus ID5)$



Frame Formats

- Data:
  - A frame carries between one and eight bytes of data
  - A data byte is transmitted in a byte field
  - For data entities longer than one byte, the entity LSB is contained in the byte sent first and the entity MSB in the byte sent last (little-endian)



Data 1 Data 2 Data 3 Data 4 Data 5 Data 6 Data 7 Data 8

Frame Formats

- Checksum:
  - The checksum contains the inverted eight bit sum with carry 6 over all data bytes or all data bytes and the protected identifier
  - Checksum calculation over the data bytes only is called classic checksum and it is used for communication with LIN 1.3 slaves
  - Checksum calculation over the data bytes and the protected identifier byte is called enhanced checksum and it is used for communication with LIN 2.0 slaves
  - Identifiers 60 (0x3c) to 63 (0x3f) shall always use classic checksum

REFERENCES

- CAN specification V 2.0 [BOSCH]
- LIN specification Package V 2.0
- Eng : Mohamed El Sherbiny

Automotive Bus

Questions & Discussions