Overview

LIN Local Interconnect Network Training

- History and Expectation
- Technical Features
- The ISO/OSI reference model and LIN
- Frames
- Message Frames
- Communication concept of LIN
- Command and Extended Frames
- Sleep mode and wake-up signal
- Error and Exception handling

History and Expectation

Time

Growth expectations

– 3 … 10 LIN nodes per vehicle
– 1.2 billion LIN nodes per year world wide

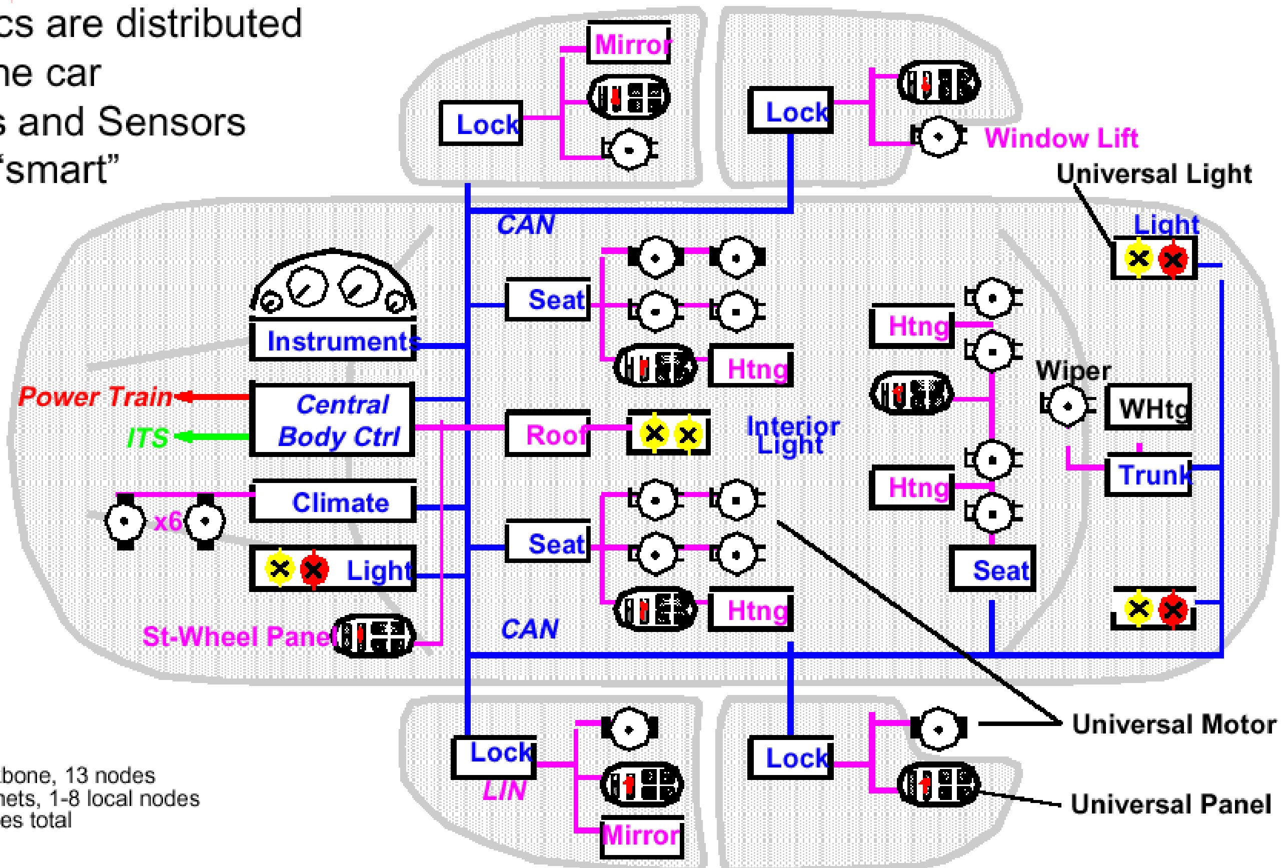
2001 - first application under development start in car production

Jul. 1999 First specification draft released

1998 - LIN Consortium is initiated as a workgroup (5 car manufactures + 1 semiconductor supplier + 1 tool provider)

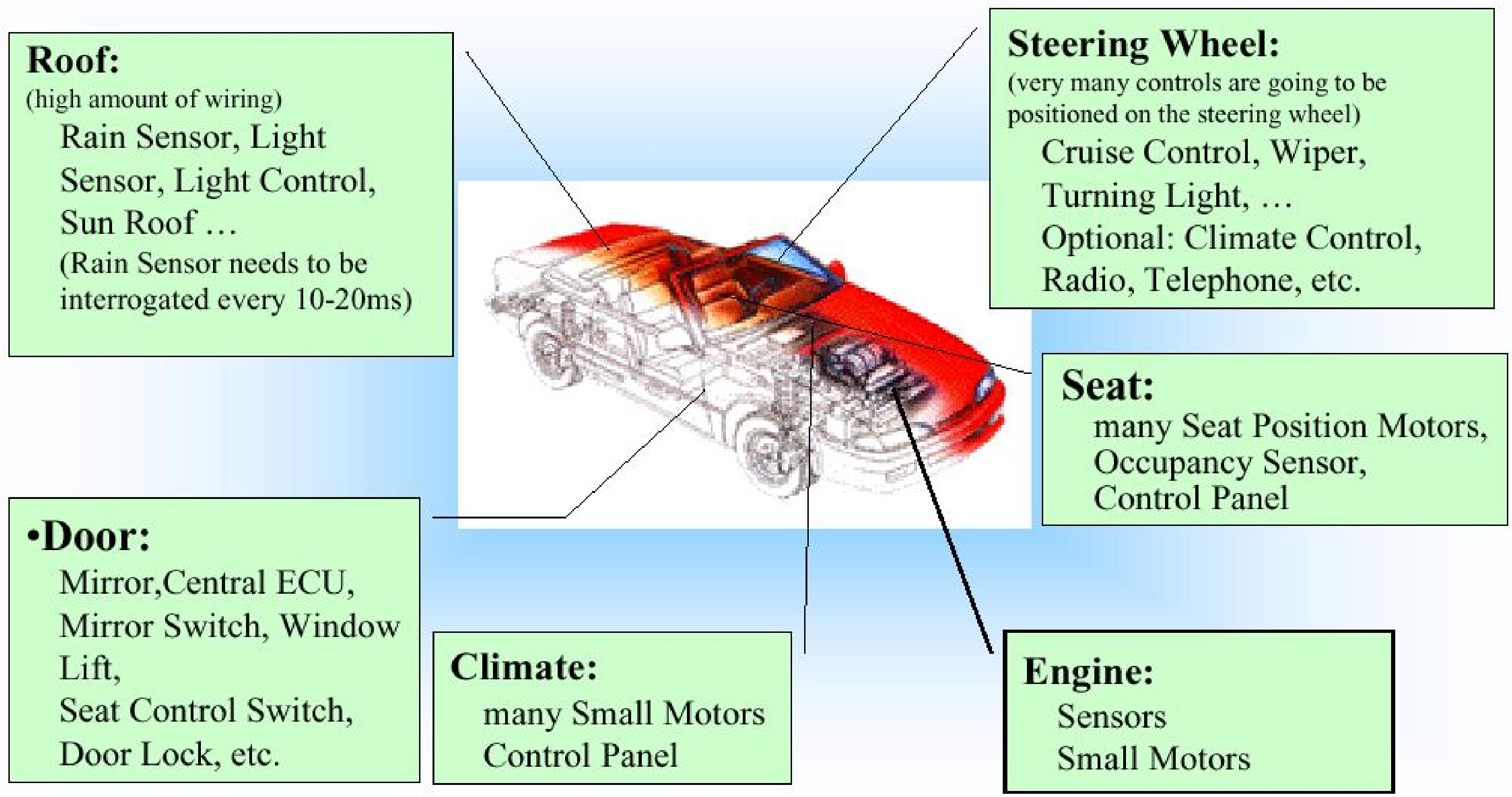
Typical example for LIN in automobiles (1)

- Electronics are distributed all over the car
- Actuators and Sensors become "smart"

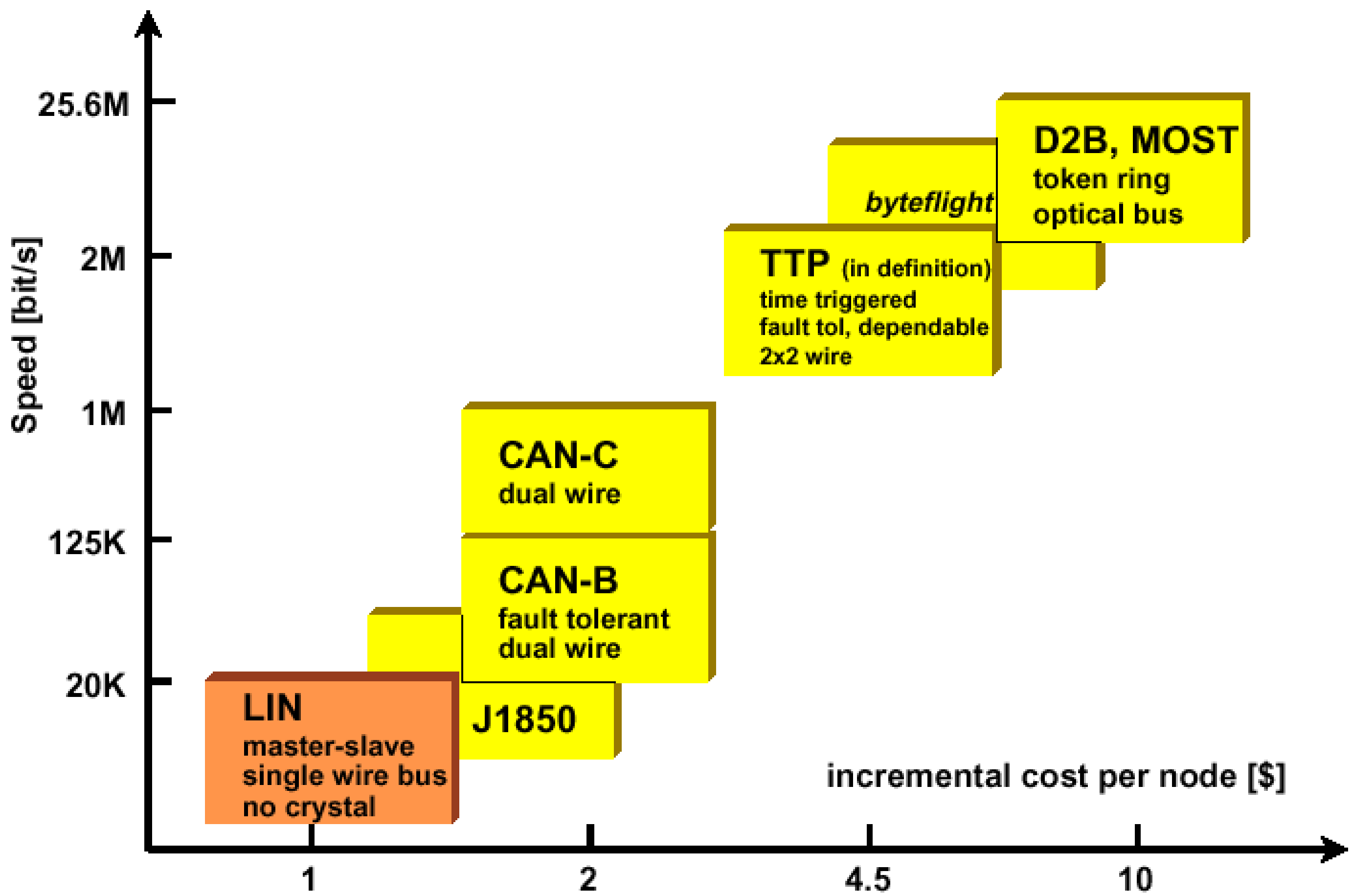


1 backbone, 13 nodes
8 subnets, 1-8 local nodes
52 nodes total

Typical example for LIN in automobiles (2)



Automotive Bus Systems



Overview

LIN Local Interconnect Network Training

- History and Expectation
- Technical Features
- The ISO/OSI reference model and LIN
- Frames
- Message Frames
- Communication concept of LIN
- Command and Extended Frames
- Sleep mode and wake-up signal
- Error and Exception handling

Technical Features(1)

- **Sub-Bus as a extension to CAN to provide connection to local network clusters**

- **Low cost single-wire implementation**
(cheaper than CAN but does not have the same reliability level as CAN)

- **Low cost silicon implementation based on common UART/SCI interface hardware**
(almost any microcontroller has necessary hardware on chip)

- **Single Master / Multiple Slave concept**

(no Arbitration is necessary)

Technical Features(2)

- **Self synchronization without quartz or ceramics resonators in slave node**

(significant cost reduction of hardware platform)

- **Speed up to 20kbit/s**

limited by the EMI of single wire transmission. Recommended Bit Rates:

Slow: 2400 bit/sec

Medium: 9600bit/sec

Fast: 19200 bit/sec

- **Guarantee of latency times for signal transmission**

- **Hot plug-in / plug-out**

Overview

LIN Local Interconnect Network Training

- History and Expectation
- Technical Features
- <u>The ISO/OSI reference model and LIN</u>
- Frames
- Message Frames
- Communication concept of LIN
- Command and Extended Frames
- Sleep mode and wake-up signal
- Error and Exception handling

The ISO/OSI reference model and LIN (1)

7	Application Layer	All
6	Presentation Layer	People
5	Session Layer	Seem
4	Transport Layer	To
3	Network Layer	Need
2	Data Link Layer	Data
1	Physical Layer	Processing

7	**Application Layer**	Applications, operating system
6	**Presentation Layer**	Conversion of data formats
5	**Session Layer**	Task synchronization, buffers, connection setup and monitoring, access rights control
4	**Transport Layer**	Address conversion, routing, segmentation
3	**Network Layer**	Setup of logical connection, transport protocol
2	**Data Link Layer**	Transmission security, frame setup, error management
1	**Physical Layer**	Electrical / mechanical characteristics: Transmission medium, wiring, connectors, encoding, signals

The ISO/OSI reference model and LIN (3)

2 **Data Link Layer**

LLC- Logical Link Control

is concerning with Message Filtering and Recovery Management

→ **Acceptance Filtering, Recovery Management, Time Base Synchronization, Message Validation**

MAC - Medium Access Control

is supervised by a management entity called Fault Confinement

→ **Data Encapsulation/Decapsulation, Error Detection, Error Signaling, Serialization/Deserialization**

1 **Physical Layer**

→ **Bit Timing, Bit synchronization, Line Driver/Receiver**

Overview

LIN Local Interconnect Network Training

- History and Expectation
- Technical Features
- The ISO/OSI reference model and LIN
- Frames
- Message Frames
- Communication concept of LIN
- Command and Extended Frames
- Sleep mode and wake-up signal
- Error and Exception handling

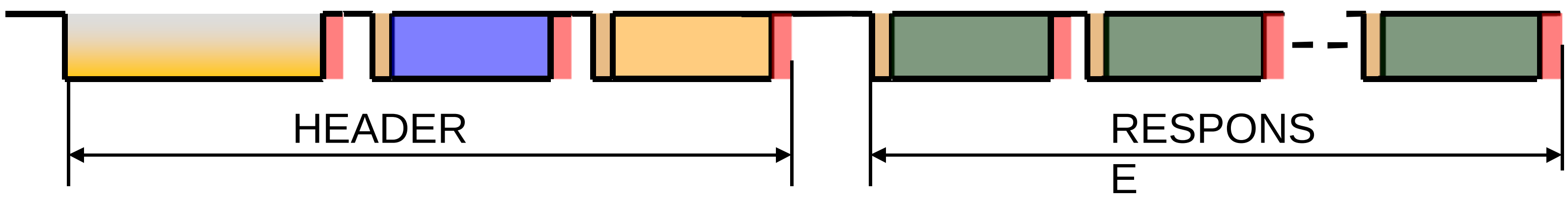
Frames (1)

- **Frame: "Envelope" for transmission data**

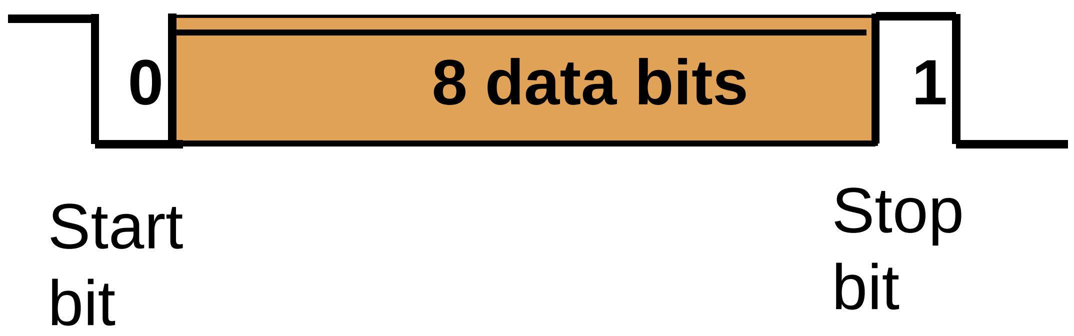
- **3 different frame types :**
  - **Message Frames:** used for regular data transmission
  - **Command Frames:** used for software updates, network configuration, and diagnostic purposes
  - **Extended Frames:** are reserved to allow the embedding of user-defined message formats and future LIN formats into the current LIN protocol without violating the current LIN specification

Frames (2)

➢ Frame: Formats



➢ Byte Fields Formats: transmission with LSB first

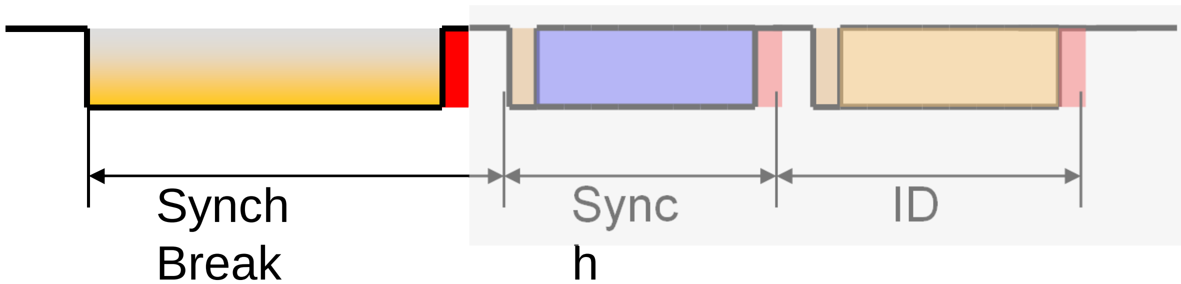


Overview

LIN Local Interconnect Network Training

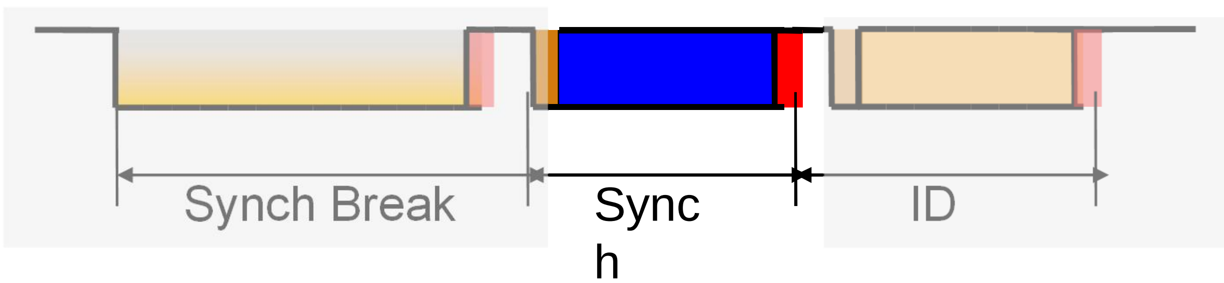
- History and Expectation
- Technical Features
- The ISO/OSI reference model and LIN
- Frames
- Message Frames
- Communication concept of LIN
- Command and Extended Frames
- Sleep mode and wake-up signal
- Error and Exception handling

Message Frames: Header(1)



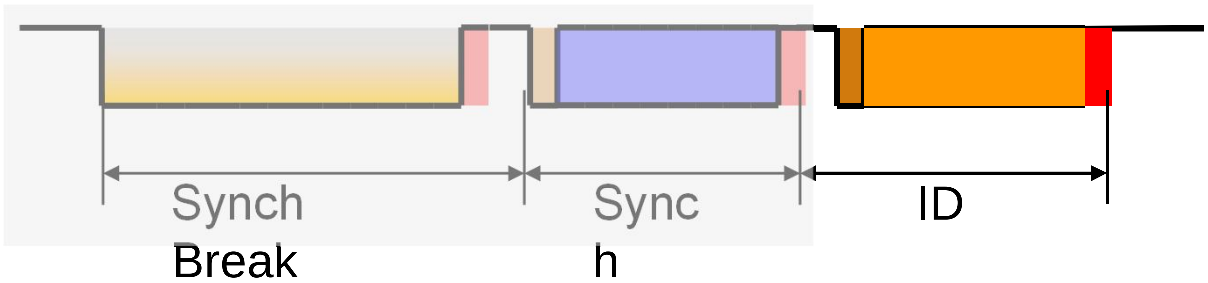
- **Synchronization break field**
  - **identify the beginning of a message frame**
  - **consists of 2 parts:**
    - "dominant" bus value with a minimum duration of $\mathbf{T_{SYNBRK}}$ (13 bits)
    - "recessive" bus value with a minimum duration of $\mathbf{T_{SYNDEL}}$ (1bit)

Message Frames: Header(2)

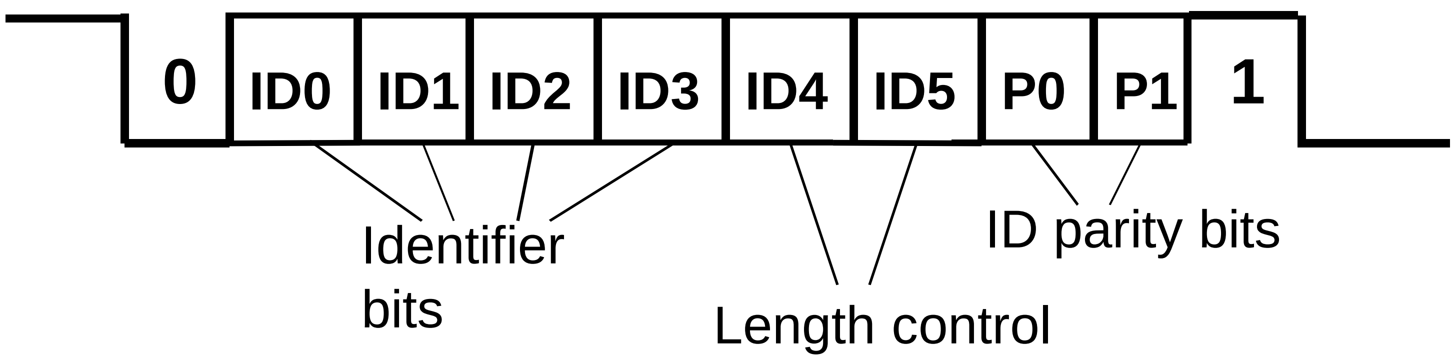


- **Synchronization field**
  - **contains the information for clock synchronization**
  - **consists of pattern: “0x55”**

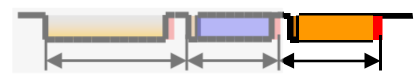
Message Frames: Header(3)



- Identifier field: contains the content and length of message



Message Frames: Header(4)



- ID0 - ID5 IDENTIFIER $\Rightarrow$ 64 (2^6) identifiers divided in four subsets of 16 identifiers with 2, 4, 8 data fields.

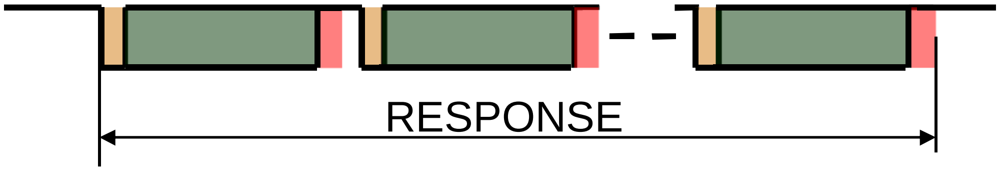
ID5	ID4	N_{DATA} (number of data fields) [byte]
0	0	2
0	1	2
1	0	4
1	1	8

- PO - P1 are the parity check bits of identifier

$$P0 = ID0 \oplus ID1 \otimes ID2 \oplus ID4 \text{ (even parity)}$$

$$P1 = \overline{ID1 \oplus ID3 \otimes ID4 \oplus ID5} \text{ (odd parity)}$$

Message Frames: Response Fields



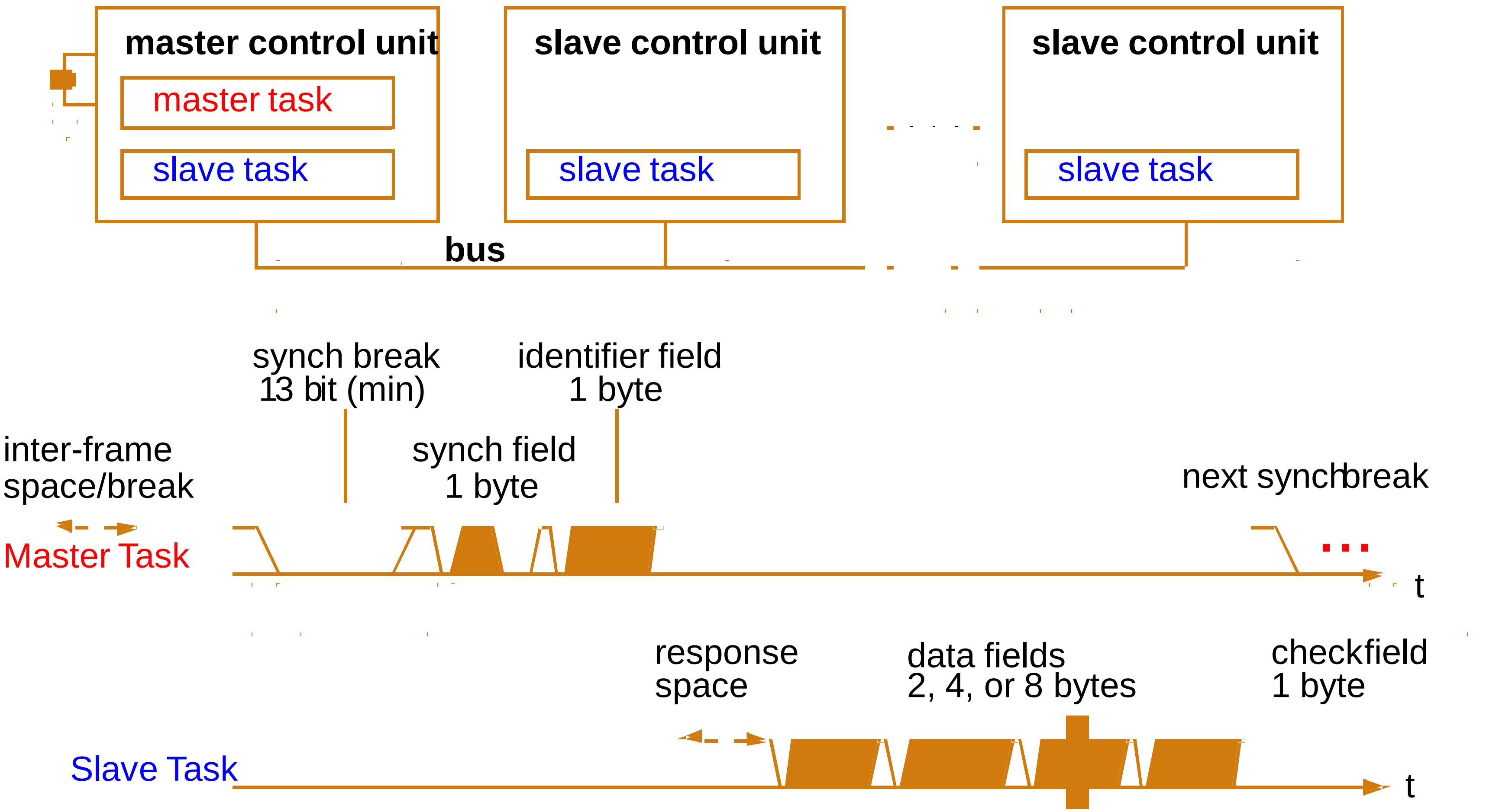
- Contains the data field and the checksum
  - DATA field consists of BYTE fields
  - CHECKSUM field contains the inverted modulo-256 sum over all data bytes calculated by “add with carry”

Overview

LIN Local Interconnect Network Training

- History and Expectation
- Technical Features
- The ISO/OSI reference model and LIN
- Frames
- Message Frames
- Communication concept of LIN
- Command and Extended Frames
- Sleep mode and wake-up signal
- Error and Exception handling

Communication Concept of LIN(1)



Communication Concept of LIN(2)

Master Task

- Has control the whole Bus and Protocol:
    - sends the header of a message
    - monitors data bytes and check sum byte and evaluates them on consistency
    - receives WakeUpBreak from a slave node when the bus is inactive and they request some action
    - serves as a reference with it’s clock base (stable clock necessary)

Communication Concept of LIN(3)

Slave Task

- Is one of 2-16 members on a bus and receives or transmits data when the appropriate ID is sent by the master:
  - waits for Synch Break
  - synchronize on Synch Byte
  - snoops for ID. According to ID slave determine what to do: receive data, transmit data or do nothing
  - when transmitting sends 2, 4, or 8 data bytes and the checksum byte

Overview

LIN Local Interconnect Network Training

- History and Expectation
- Technical Features
- The ISO/OSI reference model and LIN
- Frames
- Message Frames
- Communication concept of LIN
- Command and Extended Frames
- Sleep mode and wake-up signal
- Error and Exception handling

Command and Extended Frames: Command Frames

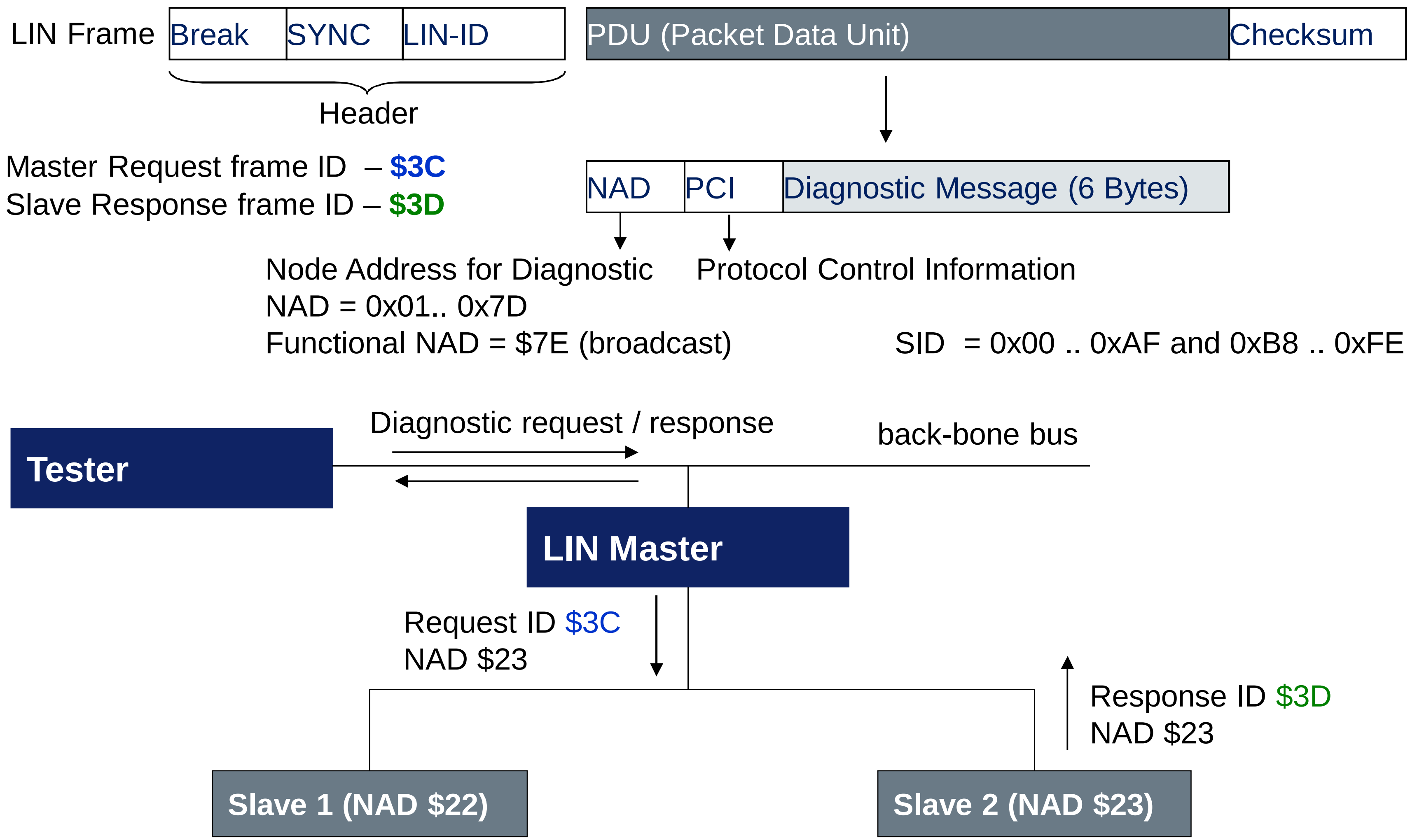
- are used to broadcast general command requests for service purposes from the master to all bus participants:
  - ID = 0x3C(0x3C)   “Master request frame” to send commands and data from the master to the slave node
  - ID = 0x3D(0x7D)   “Slave response frame” that triggers one node to send data to the master node
- first data byte of a command frame containing the values from 0x00 to 0x7F are reserved:
  - SLEEP MODE command - used to broadcast the sleep mode to all bus nodes: ID = 0x3C and DATA(0)=0x00

Command and Extended Frames: Extended Frames

- are reserved to allow the embedding of user-defined message formats and future LIN formats into LIN protocol without violating the current LIN specification:
  - ID = 0x3E(0xFE) user defined extended frame
  - ID = 0x3F(0xBF) future LIN extension

- the identifier can be followed by an arbitrary number of LIN bytes fieldc

Transport protocol -Diagnostic communication on LIN



TP-Protocol Control Information

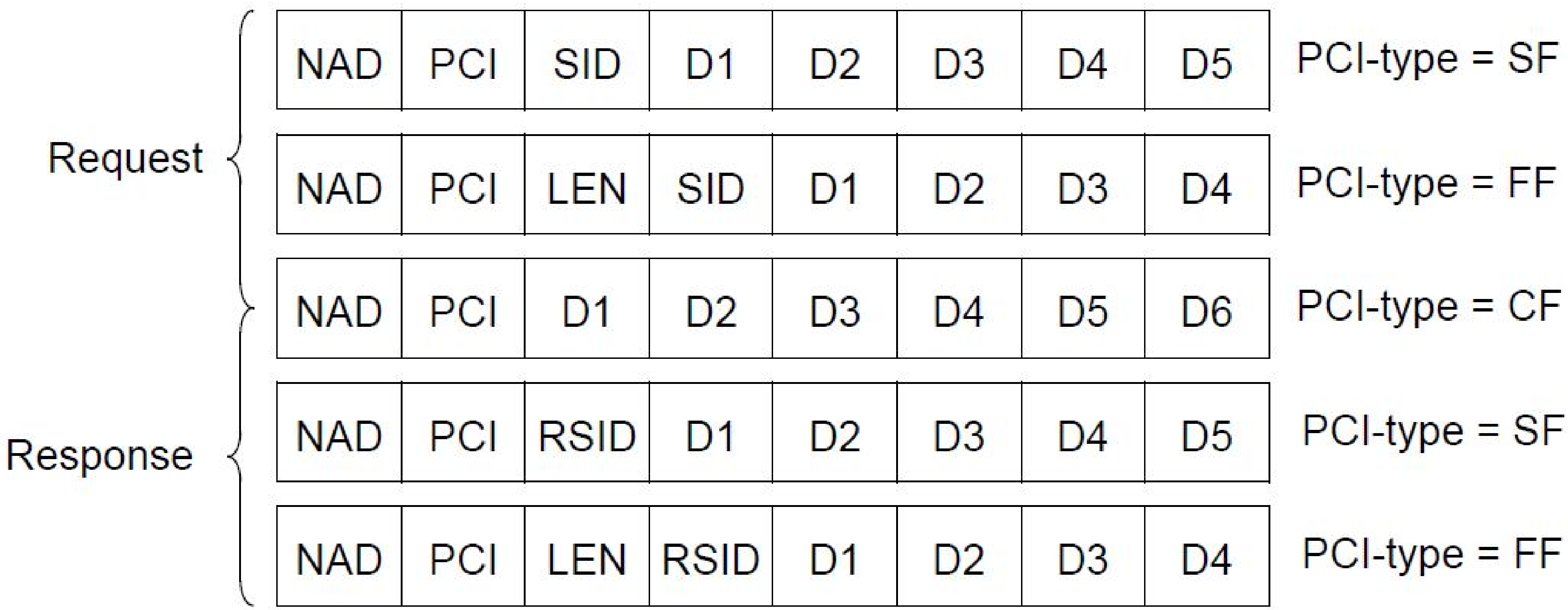


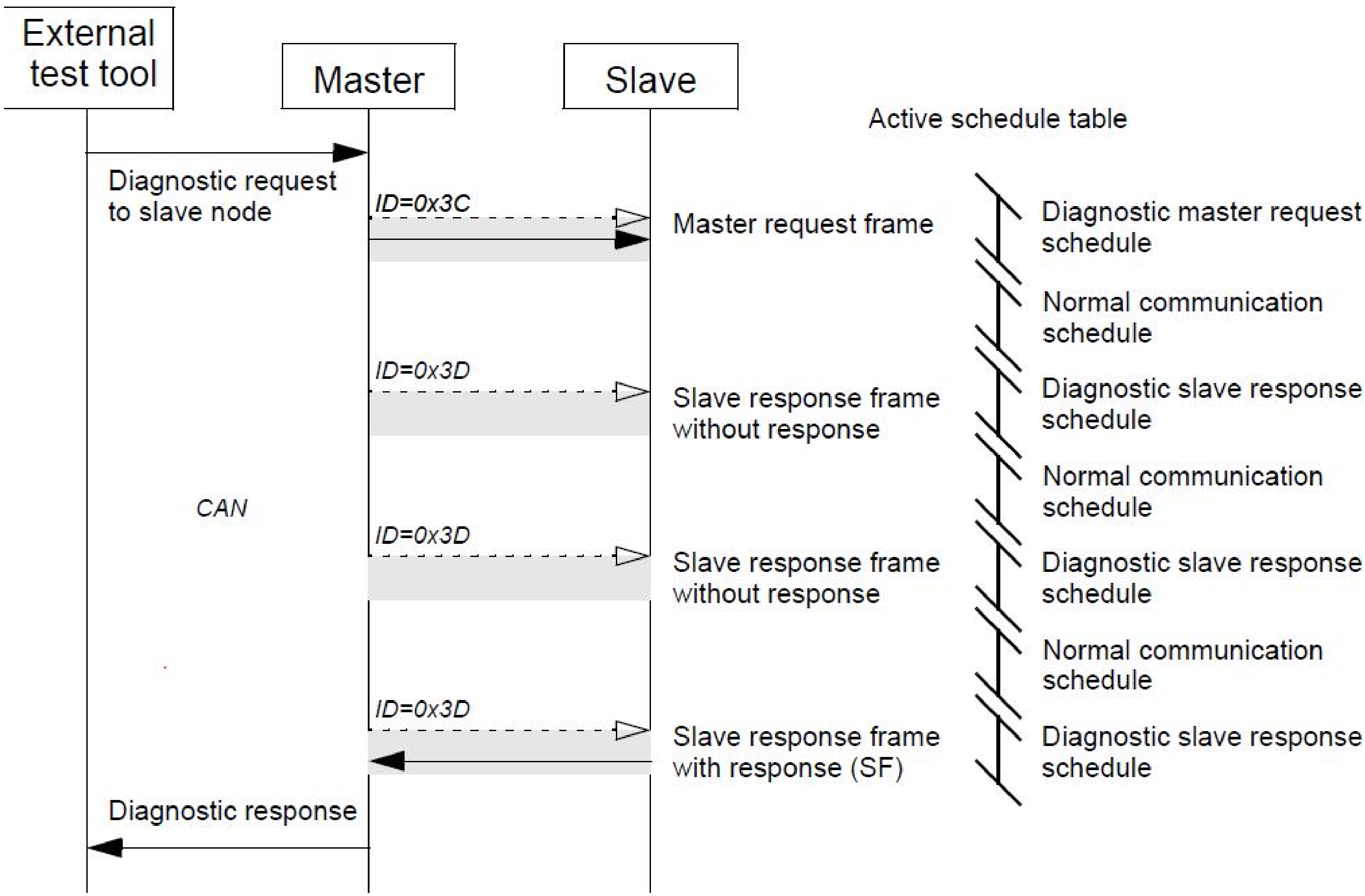
Figure 3.2: PDUs supported by the LIN transport layer.

TP-Protocol Control Information

Type	PCI type				Additional information			
	B7	B6	B5	B4	B3	B2	B1	B0
SF	0	0	0	0	Length			
FF	0	0	0	1	Length/256			
CF	0	0	1	0	Frame counter			

Table 3.1: Structure of the PCI byte.

TP-Protocol Control Information



Overview

LIN Local Interconnect Network Training

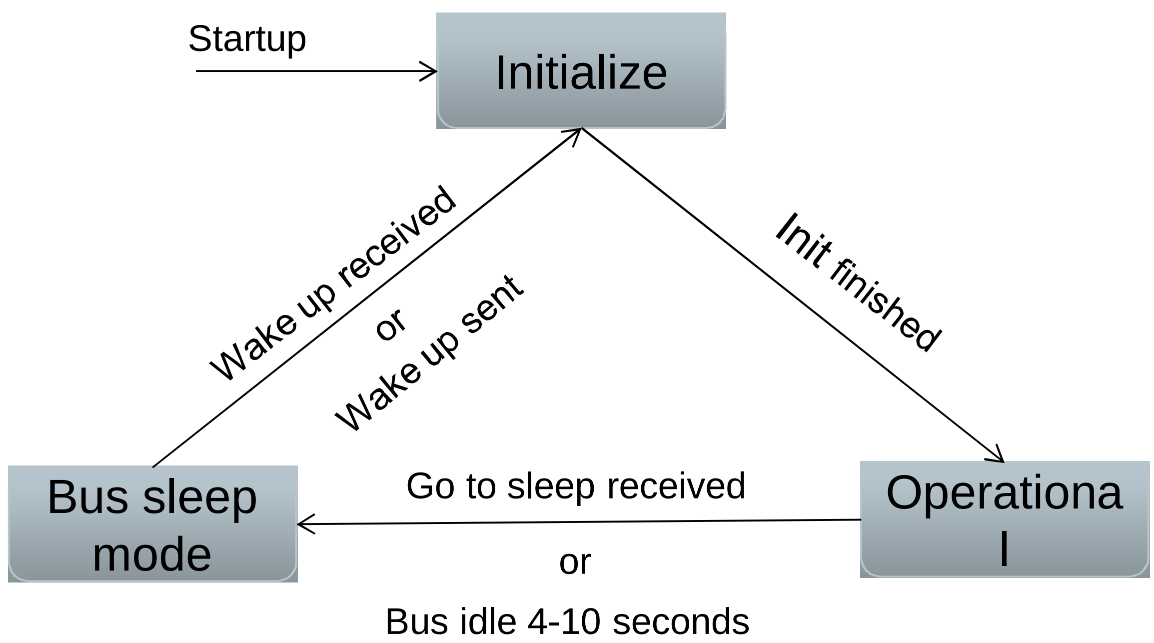
- History and Expectation
- Technical Features
- The ISO/OSI reference model and LIN
- Frames
- Message Frames
- Communication concept of LIN
- Command and Extended Frames
- Sleep mode and wake-up signal
- Error and Exception handling

Network management

→ Refers to:

- Wake-up
- Go to sleep

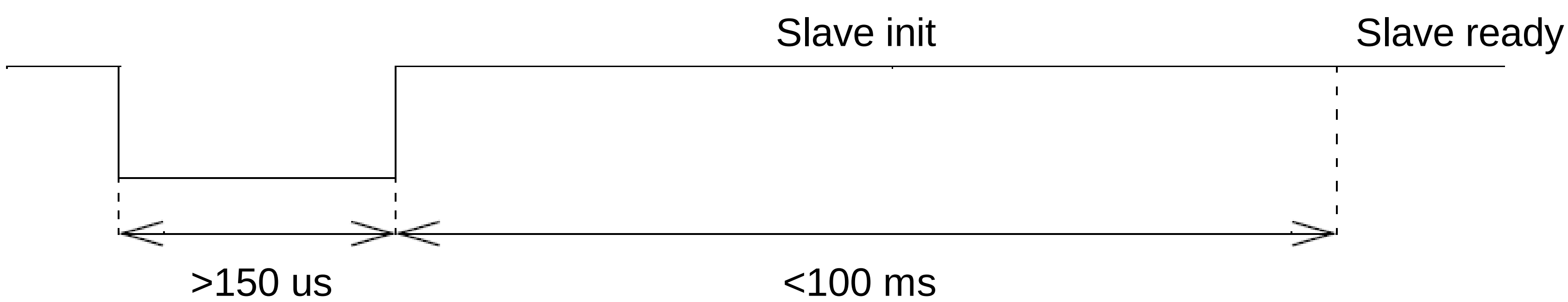
→ Slave communication state diagram:



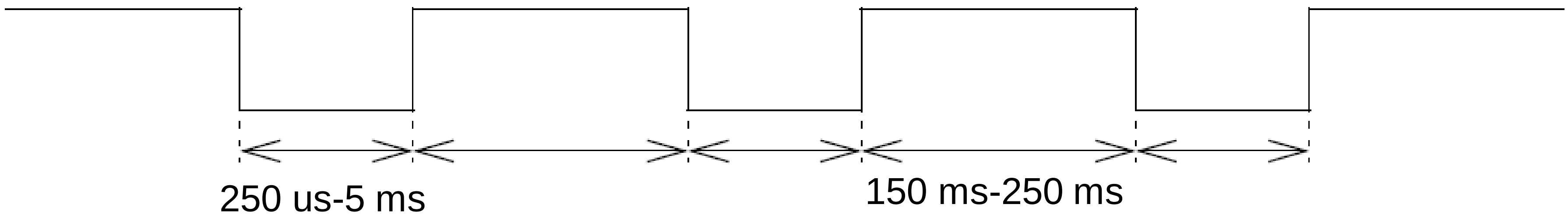
Network management

→ **Wake up**:

- Force the bus to dominant state for 250 us – 5ms
- Can be sent by any LIN node

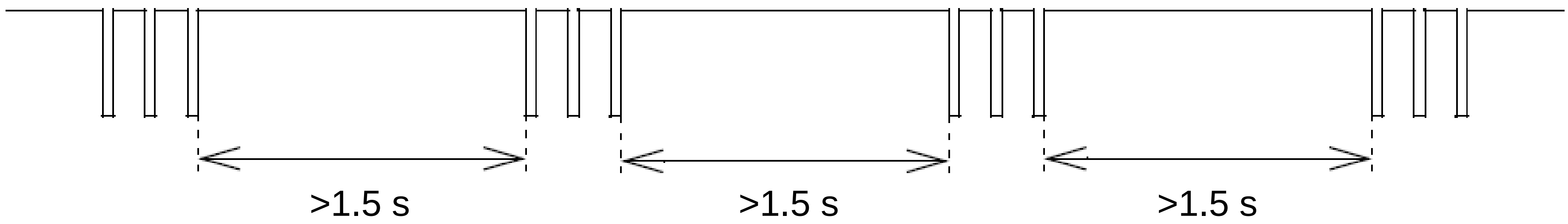


- More wake up can be requested



Network management

- After 3 failing wake up requests: minimum 1.5s wait time



→ **Go to sleep**:

- Done by:
  - Master request frame

0	0xFF	0xFF	0xFF	0xFF	0xFF	0xFF	0xFF

  - Bus idle 4-10 seconds

Overview

LIN Local Interconnect Network Training

- History and Expectation
- Technical Features
- The ISO/OSI reference model and LIN
- Frames
- Message Frames
- Communication concept of LIN
- Command and Extended Frames
- Sleep mode and wake-up signal
- Error and Exception handling

Error and exception handling

- **Possible error types:**
  - **Bit Error**
  - **Checksum Error**
  - **Identifier Parity Error**
  - **Slave Not Responding Error**

Error and exception handling(1)

Bit Errors

- **Error description**

  The bit actually appearing on the bus is different that the one transmitted

- **Method of detection**

  Sending unit monitors the bus while transmitting. A BIT_ERROR has to be detected at that bit time.

- **Fault Confinement**

  This error is detected by - master task in master

  - slave task in slave

  while reading back its own transmission

Error and exception handling(2)

Checksum Errors

- **Error description**

  The inverted modulo-256 sum over all received data bytes does not match with the receive checksum byte

- **Method of detection**

  The sum of the inverted modulo-256 sum over all received data bytes and the checksum byte does not result in 0xFF

- **Fault Confinement**

  This error is detected by:

  - slave task in master when expecting or reading data from the bus

  -slave task in slave while reading from the bus

Error and exception handling(3)

Identifier-Parity Errors

- **Error description**

  The parity identifier bits does not match with the correct calculated values

- **Method of detection**

  ☝ **Typical LIN slave application do not distinguish between an unknown but valid identifier and a corrupted identifier**

- **Fault Confinement**

  This error is detected by - master task in master while reading back its own transmission

  - slave task in slave while reading from the bus

Error and exception handling(4)

Slave-Not-Responding Errors

- **Error description**

  The message frame is not fully completed within maximum length

- **Method of detection**

  A slave task waits the entire message upon transmission of the new header

- **Fault Confinement**

  This error is detected by - slave task in master when expecting or reading data from the bus

  - slave task in slave while reading from the bus only when a slave expects a message from another slave

Error and exception handling(5)

Inconsistent-Synch-Field Errors

- **Error description**

  Synch field is different than the pattern 0x55

- **Method of detection**

  Slave task detects edges of Synch field outside the given tolerance

- **Fault Confinement**

  This error is detected only by slave task in slave

Error and exception handling(6)

Causes for message errors

- Local Disturbance of Ground Potential
- Local Disturbance of Supply Voltage
- Global Electric Disturbance of the Bus Signal
- Unsynchronized Time Base