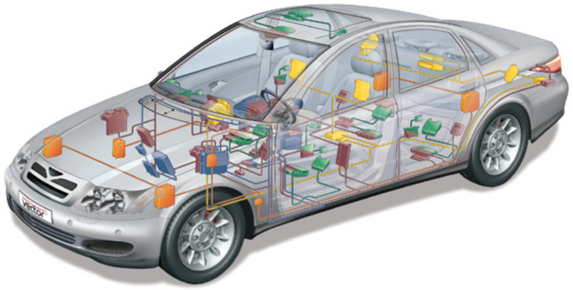
Slide 1



LIN (Local Interconnected Network)

Fundamentals of the LIN Protocol

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Vector Informatik GmbH

LOCAL INTERCONNECT NETWORK

www.lin-subbus.org

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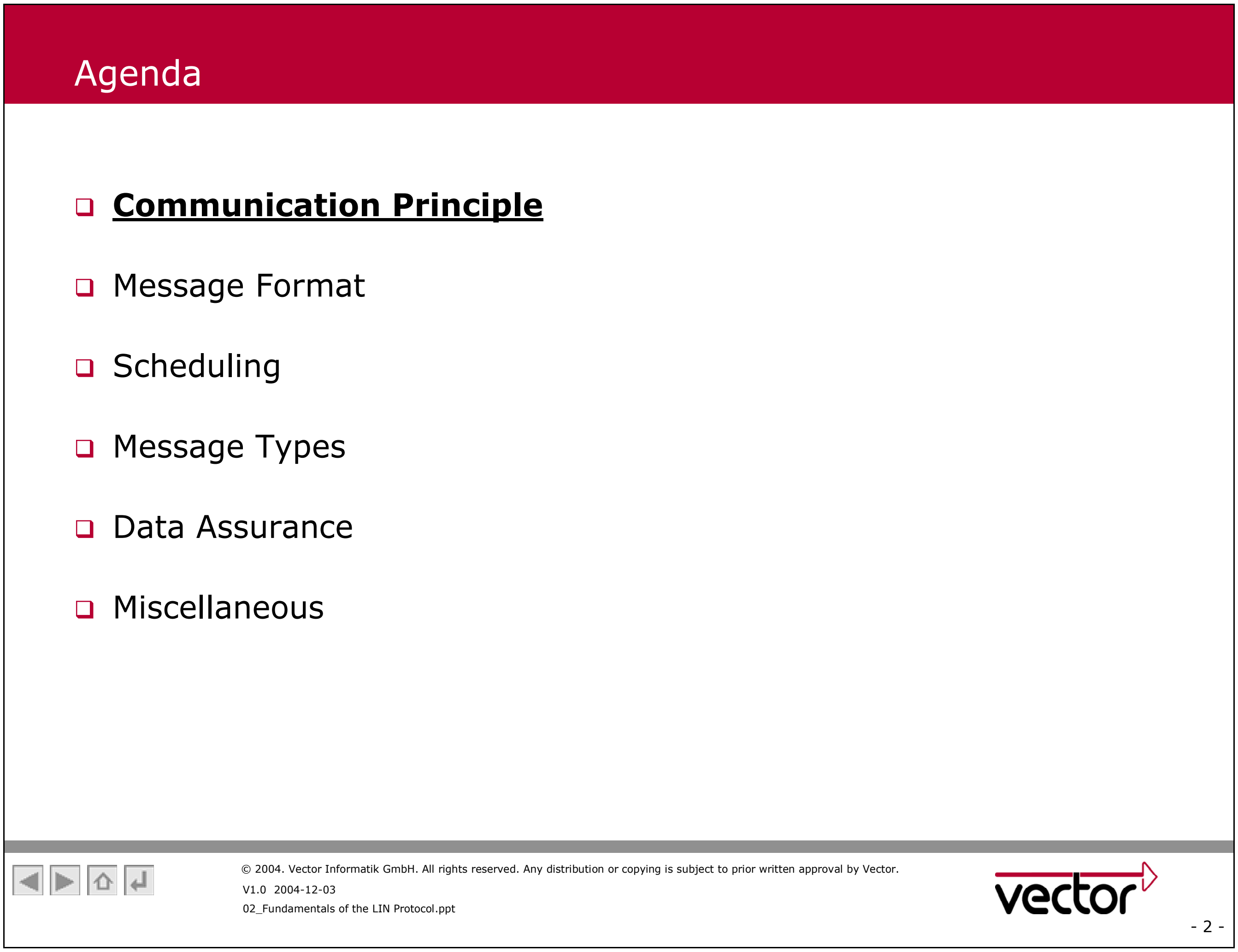
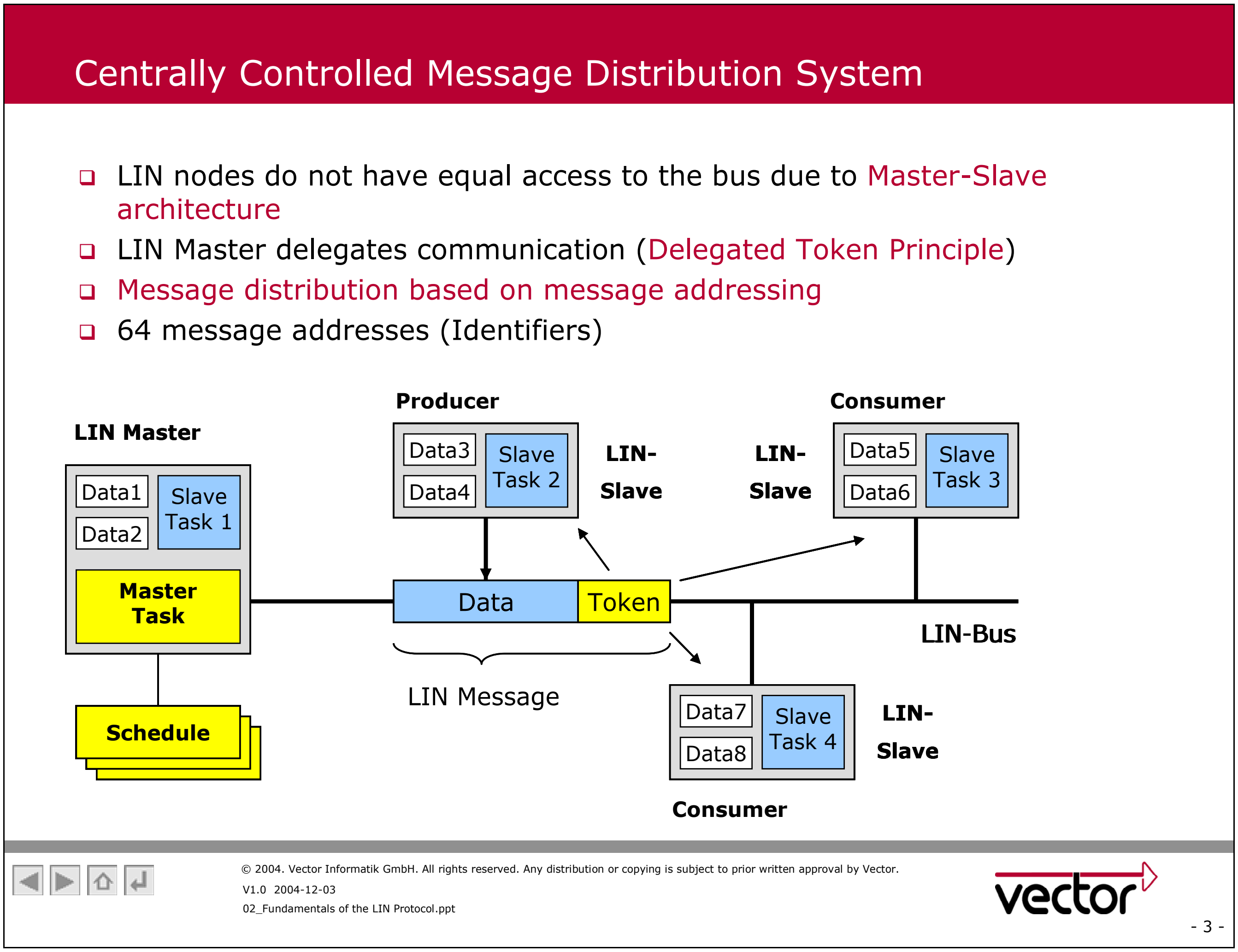
Slide 2



Agenda

- □ **Communication Principle**
- □ Message Format
- □ Scheduling
- □ Message Types
- □ Data Assurance
- □ Miscellaneous



Centrally Controlled Message Distribution System

- LIN nodes do not have equal access to the bus due to Master-Slave architecture
- LIN Master delegates communication (Delegated Token Principle)
- Message distribution based on message addressing
- 64 message addresses (Identifiers)

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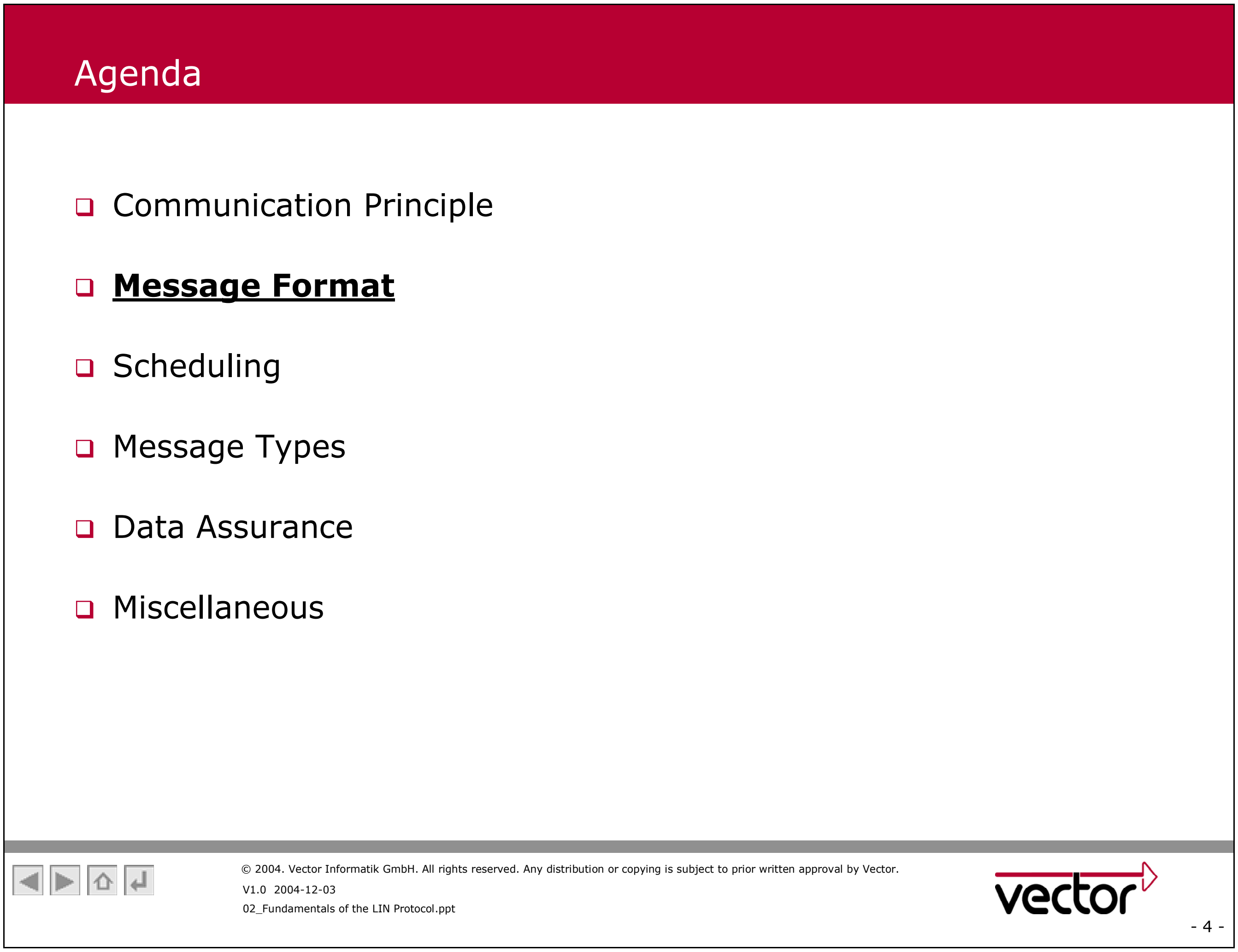
The LIN network is based on a Master-Slave architecture. One network node is chosen to control all communication. This is the LIN Master. The LIN Master performs the role of a bus arbiter with the help of the so-called “Master Task” and “LIN Schedule”.

The LIN Schedule sets the send time point of the LIN message to be transmitted. According to the LIN Schedule, the LIN Master places special messages referred to as Tokens on the bus at specified time points. A Token can be understood as a Request, and it contains a message address. This is evaluated by the LIN Slaves. A LIN Slave has three alternatives for reacting to the Token: Send data, receive data, ignore data.

Token and data together are referred to as the LIN message. Up to 64 LIN messages may be defined. Because of its message addressing method, each LIN message is available to be received by any LIN node even by the LIN Master if it has a Slave Task. The LIN network is therefore a centrally-controlled message distribution system.



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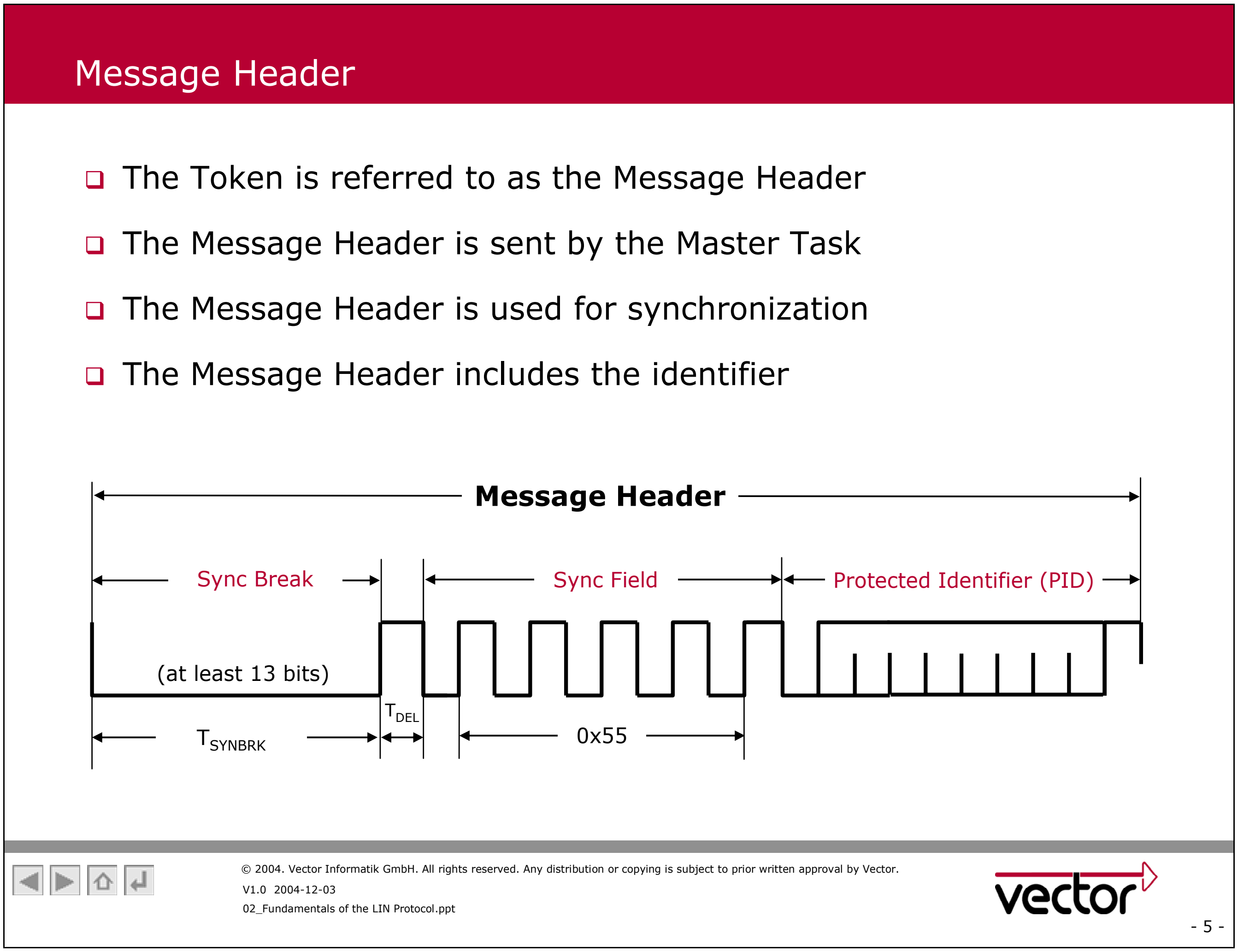

Message Header

- The Token is referred to as the Message Header
- The Message Header is sent by the Master Task
- The Message Header is used for synchronization
- The Message Header includes the identifier

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The Token is referred to as the Message Header in a LIN network. The entire Message Header is transmitted by the LIN Master. It is made up of the Sync Break, Sync Field and PID (Protected Identifier). Both the Sync Field and Sync Byte are used for initial synchronization. The PID is comprised of the message address (Identifier) and two parity bits. According to the message address the LIN nodes decide what they do immediately after the Message Header (send, receive or ignore the message response).

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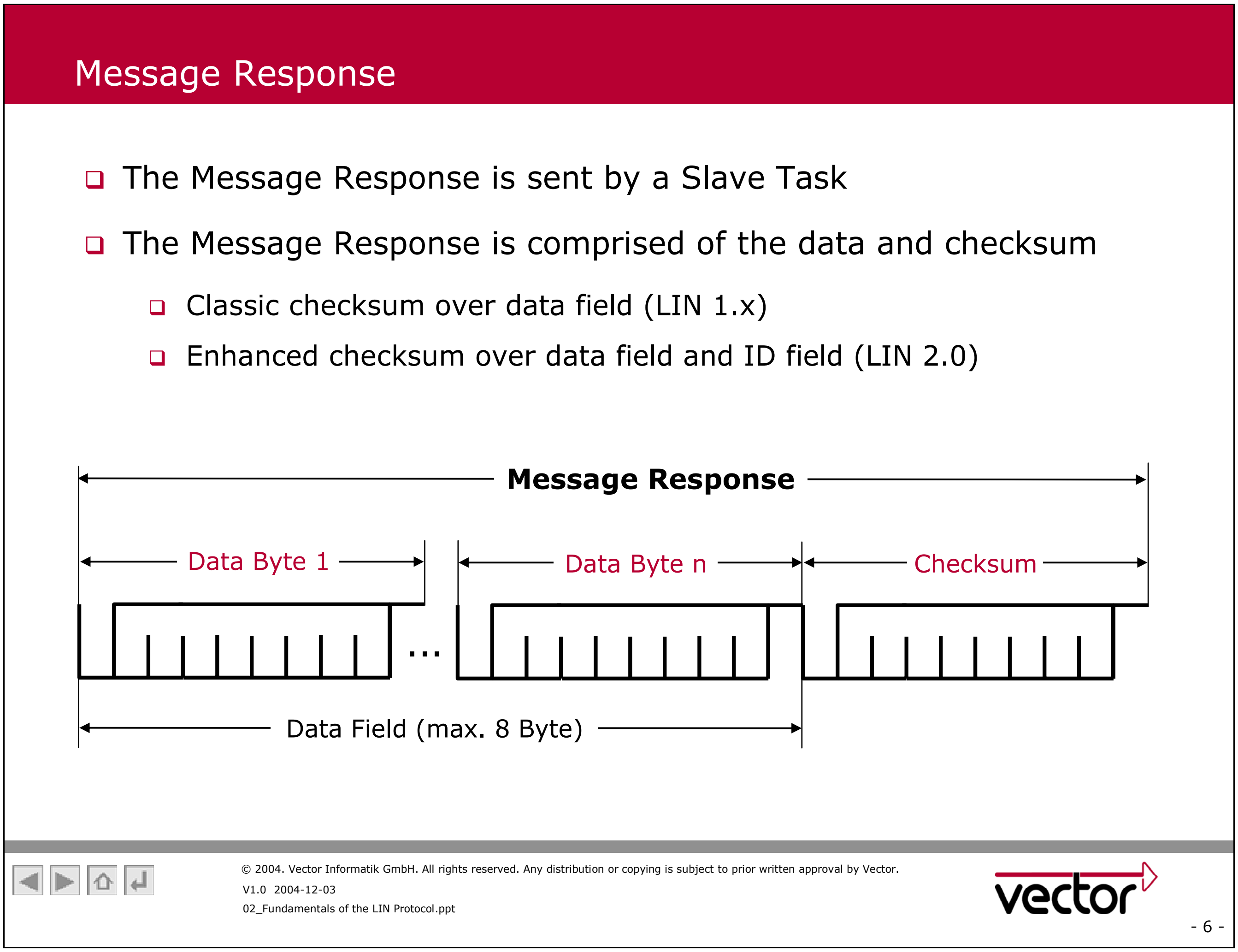

Message Response

- ❑ The Message Response is sent by a Slave Task
- ❑ The Message Response is comprised of the data and checksum
  - ❑ Classic checksum over data field (LIN 1.x)
  - ❑ Enhanced checksum over data field and ID field (LIN 2.0)

Message Response
Data Byte 1
…
Data Byte n
Checksum
Data Field (max. 8 Byte)

The message response is sent by a Slave-Task delegated for this purpose based on the message address. A maximum of eight data bytes may be transmitted with a message response. It should be noted that byte transmission begins with the LSB. Transmitting a word the transmission begins with the low byte (Little Endian transmission, Intel mode). In principle a message response may be received and accepted by all Slaves-Tasks.

The data bytes are protected with the help of a checksum. Checksum formation is based on Modulo-2 arithmetic and Carry Bit over all data bytes. The individual data bytes are added by Modulo-2 arithmetic. Overflow bits are carried. Finally the result is inverted.

Two different checksums exist: Classic and Enhanced checksums. With the Classic checksum only the data bytes are protected. With the Enhanced checksum the data bytes and the identifier are protected. For LIN 1.3 conformant LIN nodes the message responses to be transmitted are always equipped with the Classic checksum, since the Enhanced checksum is unknown in LIN 1.3. It should be noted that LIN messages with identifiers 60 and 61 (Diagnostics) are always protected with the Classic checksum.

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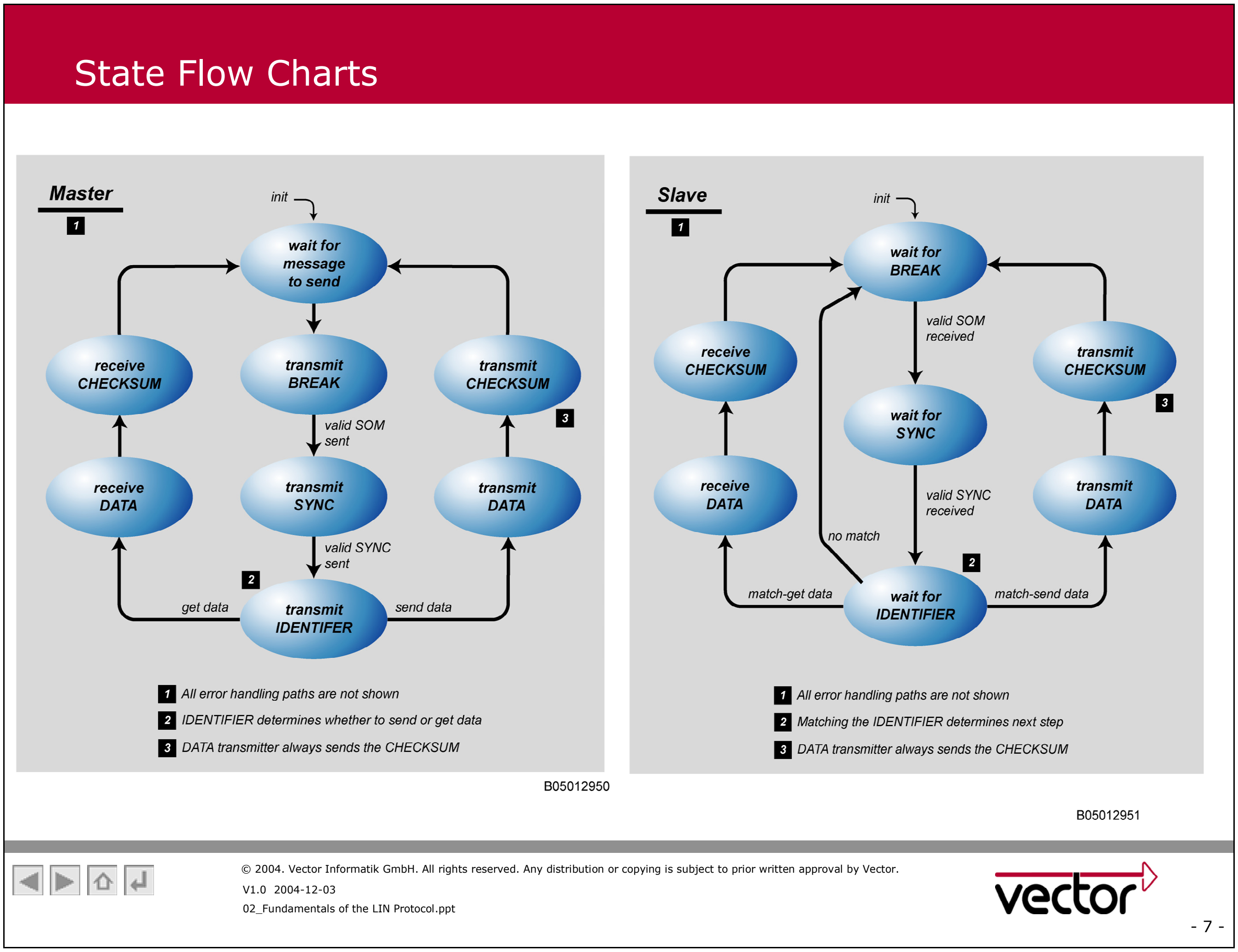

State Flow Charts

Master

1

init

wait for message to send

receive CHECKSUM

transmit BREAK

transmit CHECKSUM

valid SOM sent

3

receive DATA

transmit SYNC

transmit DATA

valid SYNC sent

2

get data

transmit IDENTIFER

send data

1 All error handling paths are not shown

2 IDENTIFIER determines whether to send or get data

3 DATA transmitter always sends the CHECKSUM

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Slave

1

init

wait for BREAK

valid SOM received

receive CHECKSUM

transmit CHECKSUM

wait for SYNC

3

receive DATA

transmit DATA

valid SYNC received

no match

2

match-get data

wait for IDENTIFIER

match-send data

1 All error handling paths are not shown

2 Matching the IDENTIFIER determines next step

3 DATA transmitter always sends the CHECKSUM

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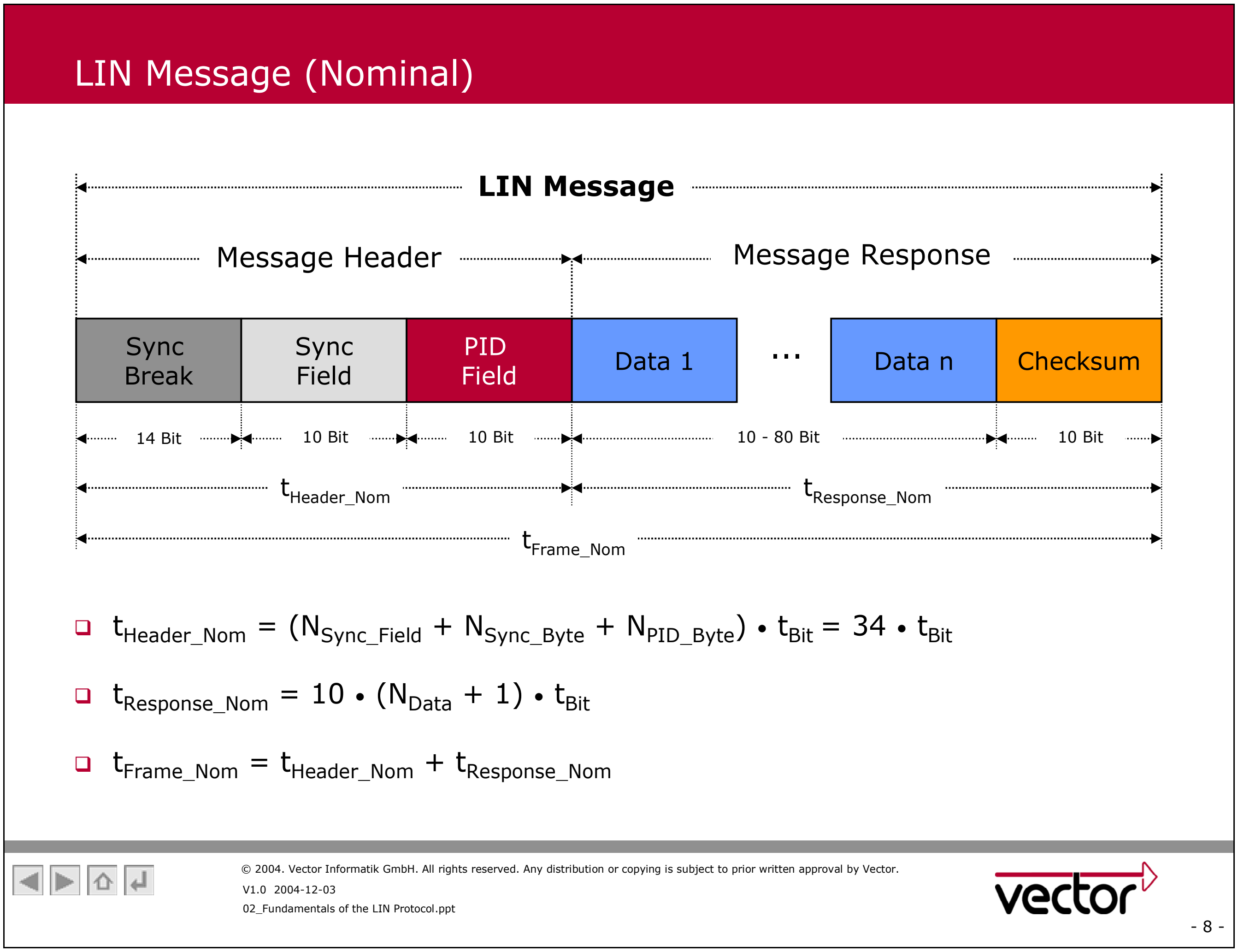
Slide 8



LIN Message (Nominal)

LIN Message

Message Header

Message Response

Sync Break	Sync Field	PID Field	Data 1	...	Data n	Checksum
14 Bit	10 Bit	10 Bit	10 - 80 Bit			10 Bit

t_{Header_Nom}

$t_{Response\_Nom}$

t_{Frame_Nom}

- $t_{Header\_Nom} = (N_{Sync\_Field} + N_{Sync\_Byte} + N_{PID\_Byte}) \bullet t_{Bit} = 34 \bullet t_{Bit}$
- $t_{Response\_Nom} = 10 \bullet (N_{Data} + 1) \bullet t_{Bit}$
- $t_{Frame\_Nom} = t_{Header\_Nom} + t_{Response\_Nom}$

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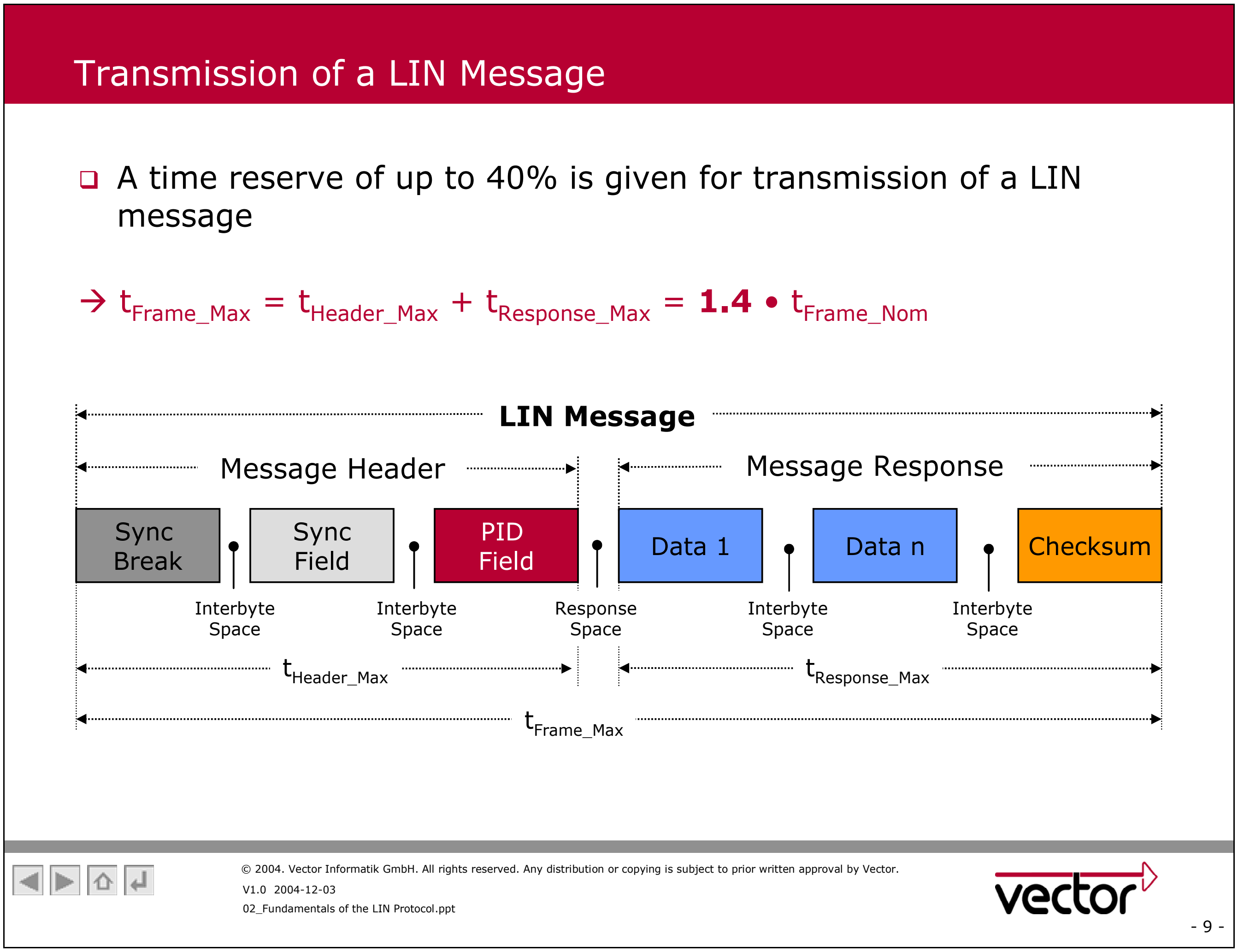
The LIN message is made up of the Message Header and Message Response. The Message Header is always sent by the LIN Master. It contains synchronization information (Sync Field and Sync Byte), the message address and two parity bits (Protected Identifier - PID). The Message Response contains a maximum of eight data bytes and a checksum.

LIN message transmission is based on the SCI interface. A SCI character is made up of eight data bits framed by a start bit and a stop bit. If the Sync Break must be 13 dominant bits and be terminated by a recessive bit, then the LIN Message Header has a nominal length of 34 bits. The length of the Message Response includes the number of data bytes and the checksum: Min. 20 bits (one data byte), max. 90 bits (eight data bytes).

In the case of transmission of eight data bytes the LIN message has a nominal length of 124 bits (Message Header: 34 bits, Message Response: 90 bits). The shortest LIN message contains 54 bits (Message Header: 34 bits, Message Response: 20 bits).



Transmission of a LIN Message

- A time reserve of up to 40% is given for transmission of a LIN message

$\rightarrow t_{Frame\_Max} = t_{Header\_Max} + t_{Response\_Max} = \mathbf{1.4} \bullet t_{Frame\_Nom}$

LIN Message

Message Header

Message Response

Sync Break

Sync Field

PID Field

Data 1

Data n

Checksum

Interbyte Space

Interbyte Space

Response Space

Interbyte Space

Interbyte Space

t_{Header_Max}

$t_{Response\_Max}$

t_{Frame_Max}

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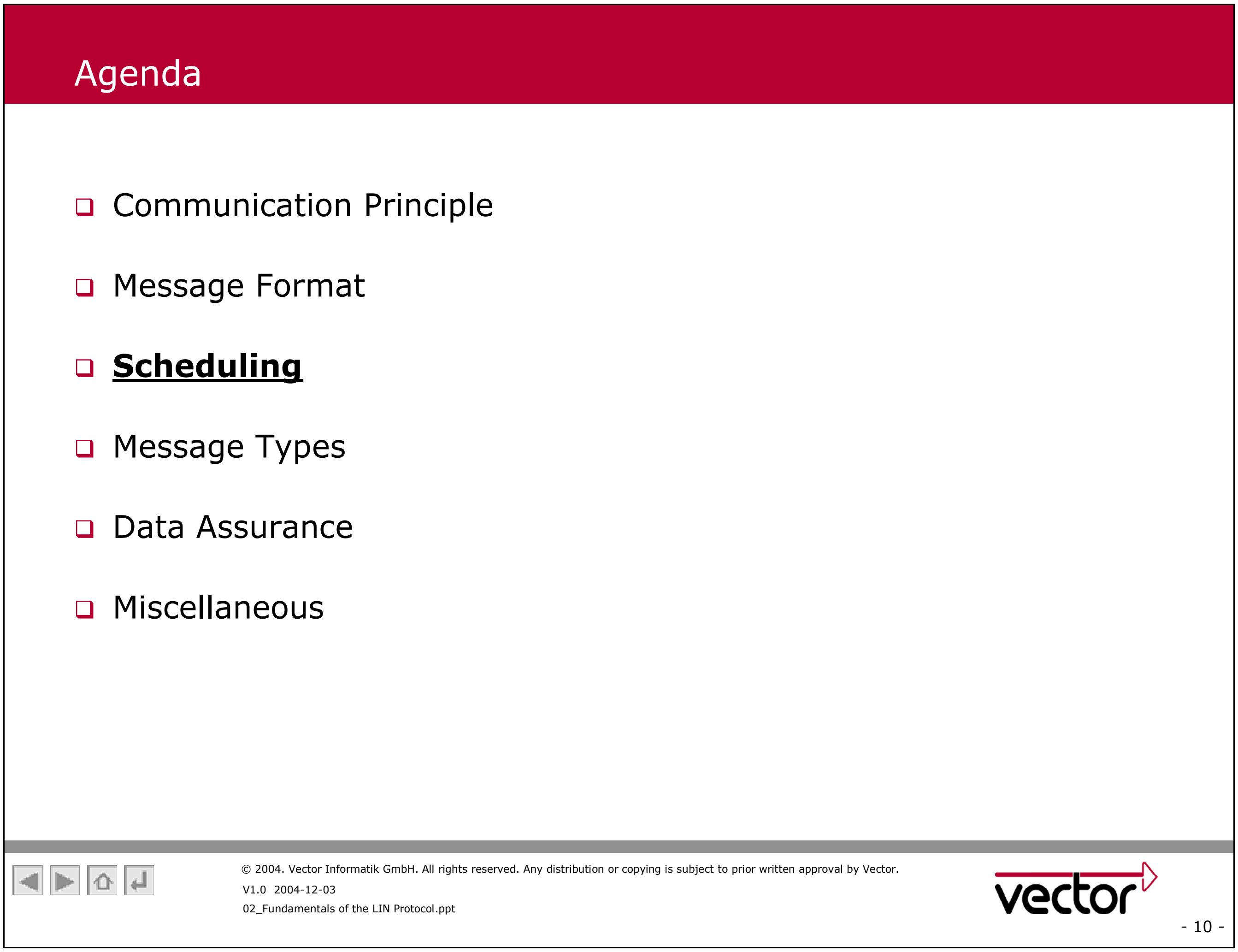
A time reserve of up to 40 % is given for transmission of a LIN message. This is a very important piece of information, above all for the dimensioning of a LIN network. This reserve compensates for the fact that very low-performance controller chips might be used or the LIN Task might not be executed immediately.

In other words, the LIN node is allowed to delay the start of the next UART character. However, the sum of all delay times may not exceed the time reserve of 40 %. Differentiation is made between two types of delay times: Interbyte Space and Response Space. The Response Space is located between the Message Header and Message Response, and the Interbyte Space between any two UART characters.



Agenda

- ❑ Communication Principle
- ❑ Message Format
- ❑ **<u>Scheduling</u>**
- ❑ Message Types
- ❑ Data Assurance
- ❑ Miscellaneous

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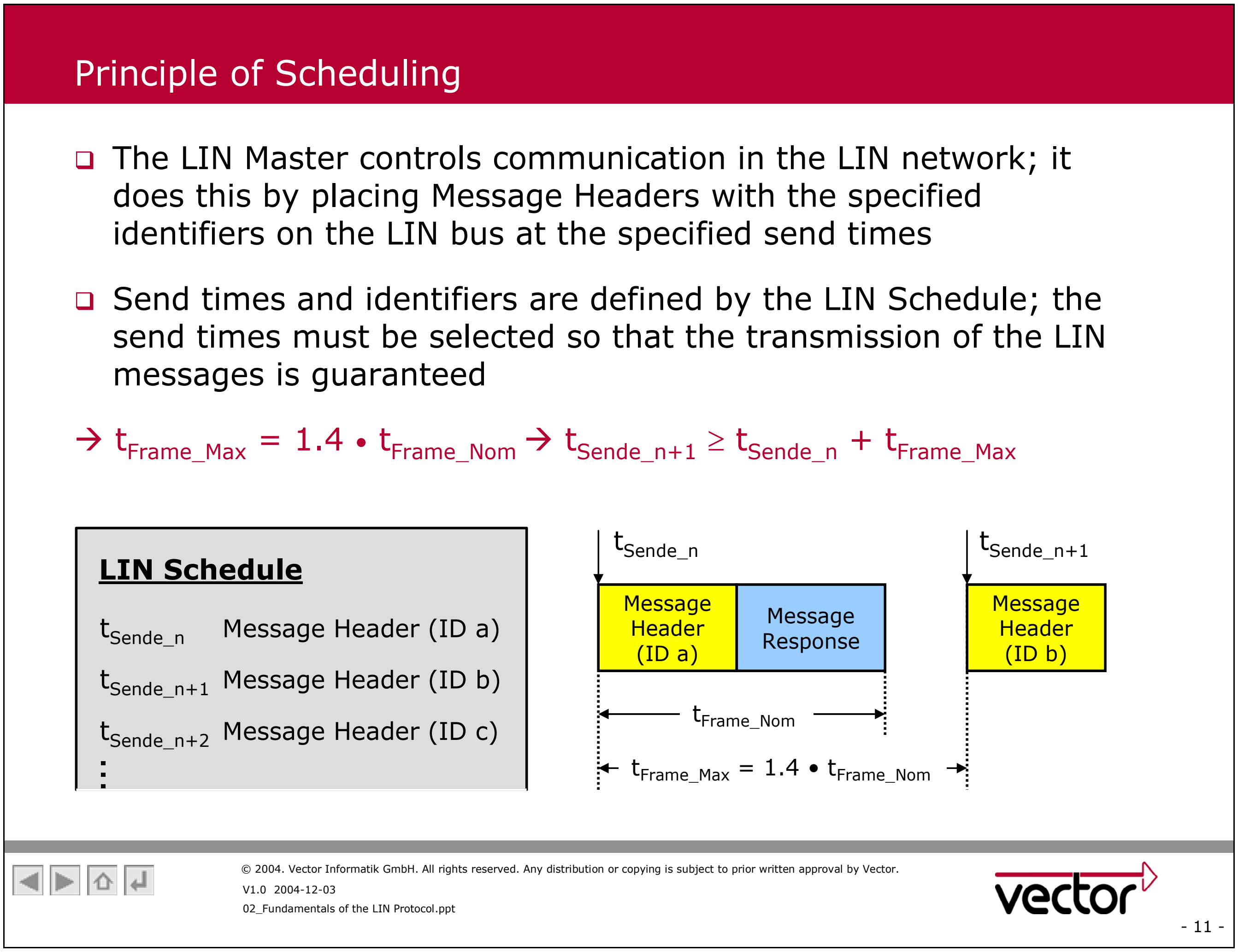

Principle of Scheduling

- The LIN Master controls communication in the LIN network; it does this by placing Message Headers with the specified identifiers on the LIN bus at the specified send times
- Send times and identifiers are defined by the LIN Schedule; the send times must be selected so that the transmission of the LIN messages is guaranteed

$\rightarrow t_{Frame\_Max} = 1.4 \bullet t_{Frame\_Nom} \rightarrow t_{Sende\_n+1} \geq t_{Sende\_n} + t_{Frame\_Max}$

LIN Schedule

t_{Sende_n}	Message Header (ID a)
t_{Sende_n+1}	Message Header (ID b)
t_{Sende_n+2}	Message Header (ID c)
⋮	

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In a LIN network the LIN Master controls communications. This involves the LIN Master transmitting very specific Message Headers at defined time points. The LIN Master takes both the send time and identifier from the so-called LIN Schedule. The send times in the LIN Schedule must be selected such that sufficient time is available for transmission of the LIN messages. 40 % additional time according to the nominal time must always be permitted for transmission of a LIN message.

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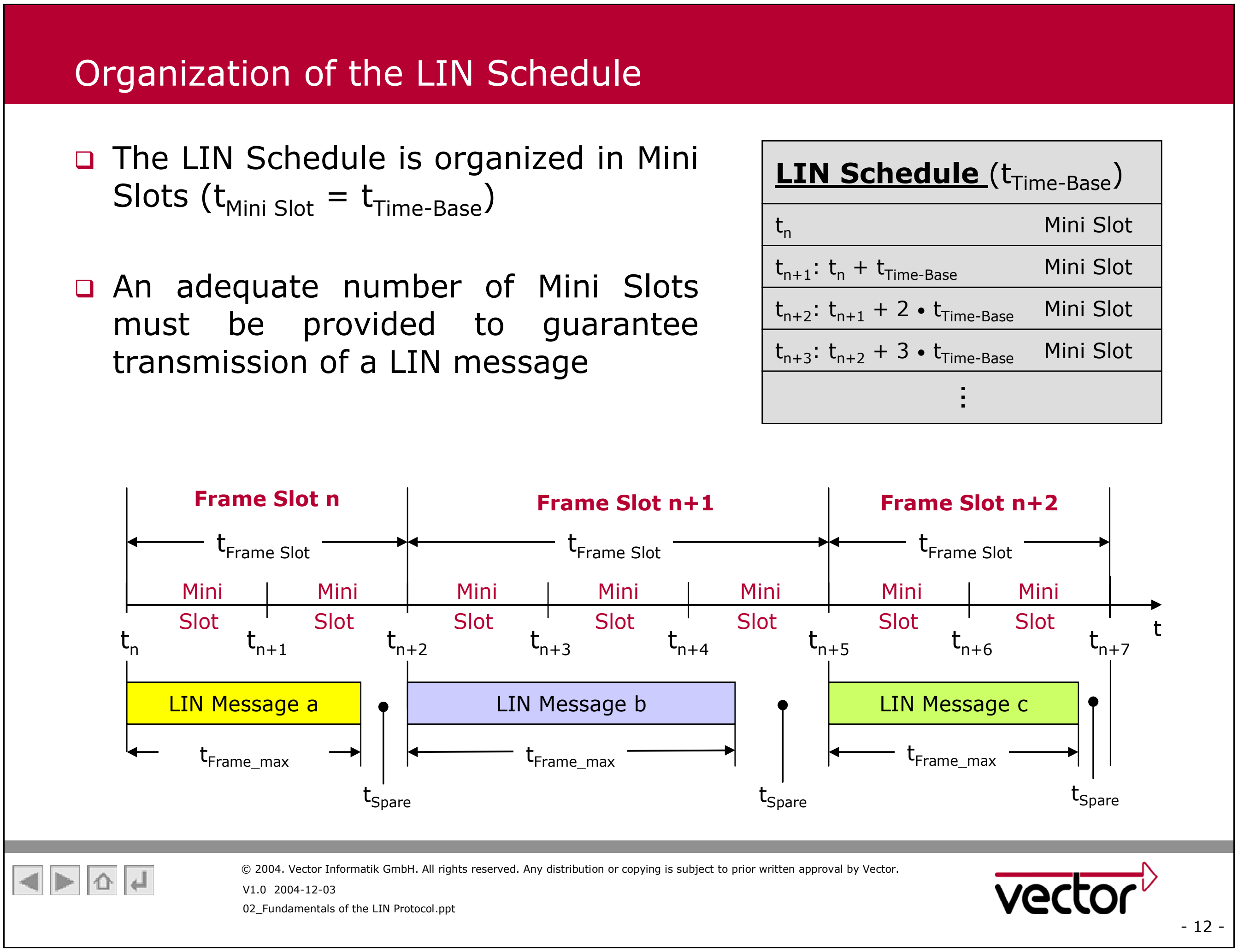

Organization of the LIN Schedule

- ❑ The LIN Schedule is organized in Mini Slots ($t_{\text{Mini Slot}} = t_{\text{Time-Base}}$)
- ❑ An adequate number of Mini Slots must be provided to guarantee transmission of a LIN message

LIN Schedule ($t_{\text{Time-Base}}$)	
t_n	Mini Slot
t_{n+1}: $t_n + t_{\text{Time-Base}}$	Mini Slot
t_{n+2}: $t_{n+1} + 2 \bullet t_{\text{Time-Base}}$	Mini Slot
t_{n+3}: $t_{n+2} + 3 \bullet t_{\text{Time-Base}}$	Mini Slot
⋮	

The LIN Schedule is organized in Mini Slots. The length of these Mini Slots correspond to the underlying time base of the LIN Schedule (e.g. 5 msec), and it represents the smallest time resolution for processing the LIN Schedule. While sending a LIN message enough Mini Slots must be provided to guarantee transmission of the specific LIN message. The sum of the necessary Mini Slots is referred to as the Frame Slot.

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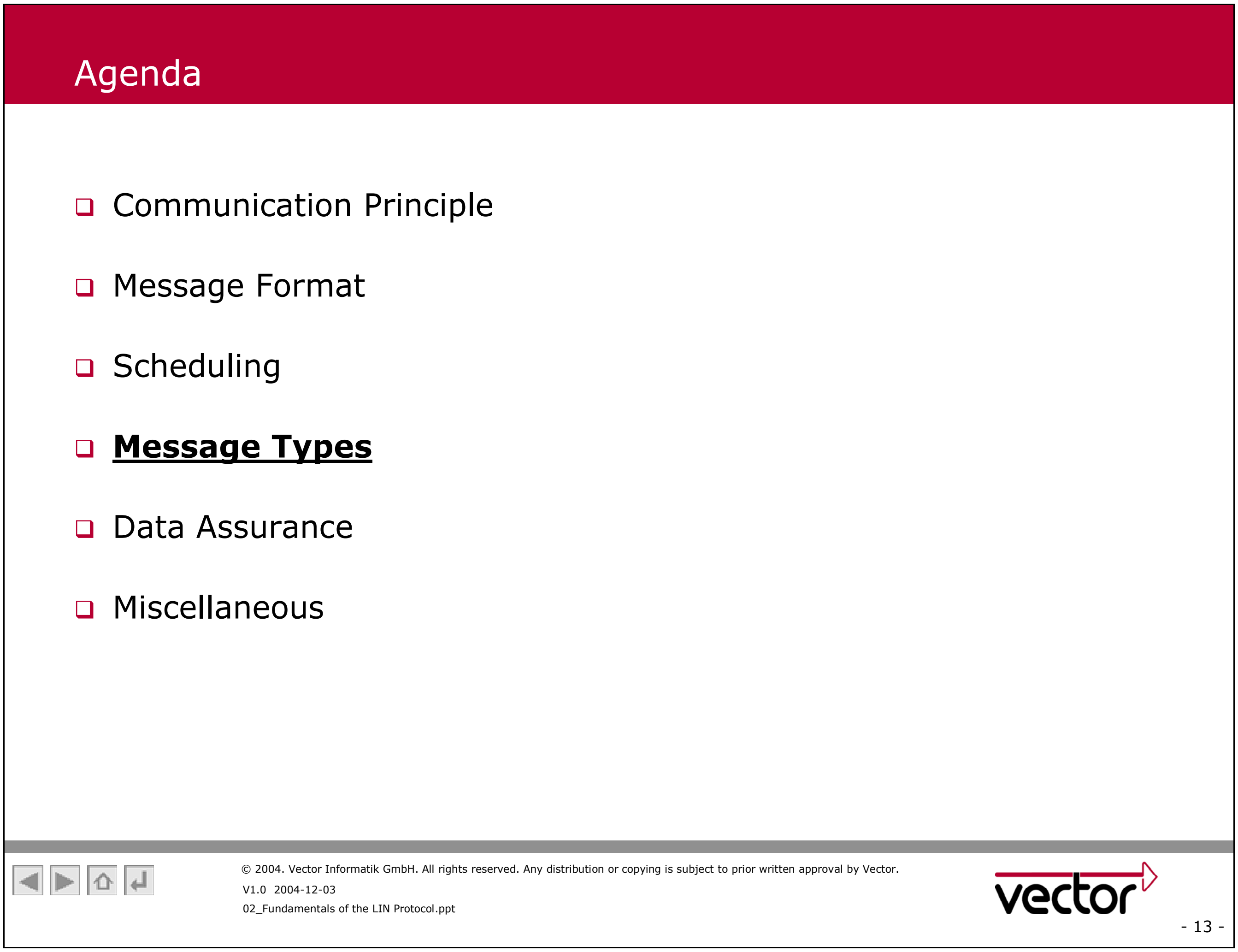

Agenda

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- ❑ **Message Types**
- ❑ Data Assurance
- ❑ Miscellaneous

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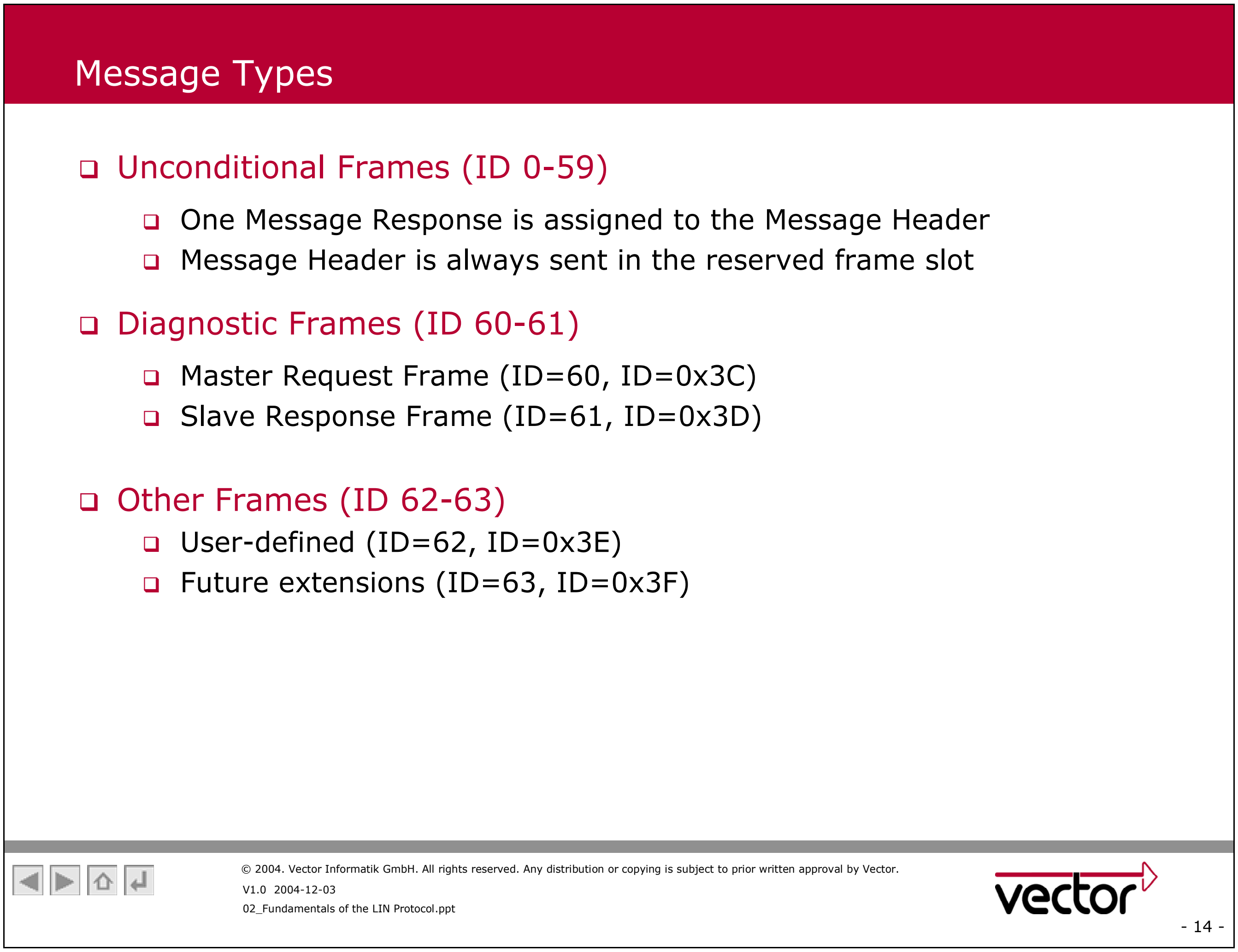

Message Types

- Unconditional Frames (ID 0-59)
  - One Message Response is assigned to the Message Header
  - Message Header is always sent in the reserved frame slot
- Diagnostic Frames (ID 60-61)
  - Master Request Frame (ID=60, ID=0x3C)
  - Slave Response Frame (ID=61, ID=0x3D)
- Other Frames (ID 62-63)
  - User-defined (ID=62, ID=0x3E)
  - Future extensions (ID=63, ID=0x3F)

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Various frame types are available for data transmission in a LIN network: Unconditional Frame, Event Triggered Frame, Sporadic Frame and Diagnostic Frame.

The Unconditional Frame is characterized in that there is exactly one sender of the Message Response.

The Event Triggered Frame is characterized in that there are multiple senders of the Message Response. Several unconditional frames from different LIN Slaves can be assigned to one event triggered frame. The first data byte of such an unconditional frame must contain the PID.

The Message Response is only sent by the LIN Slave if a signal it contains has actually changed. Due to its event-orientation collisions are not excluded and must be resolved by the LIN master.

In a Sporadic Frame Slot different Unconditional Frames from different LIN Slaves can be transmitted. The Message Header in the Sporadic Frame Slot of an Unconditional Frame is sent by the LIN Master if it knows that a signal it contains may have changed.

Two special LIN messages are used for diagnostics in a LIN network. The Master Request Frame with identifier ID=0x3C and the Slave Response Frame with identifier ID=0x3D.
The identifiers 0x3D and 0x3F are reserved and not used in the actual specification.

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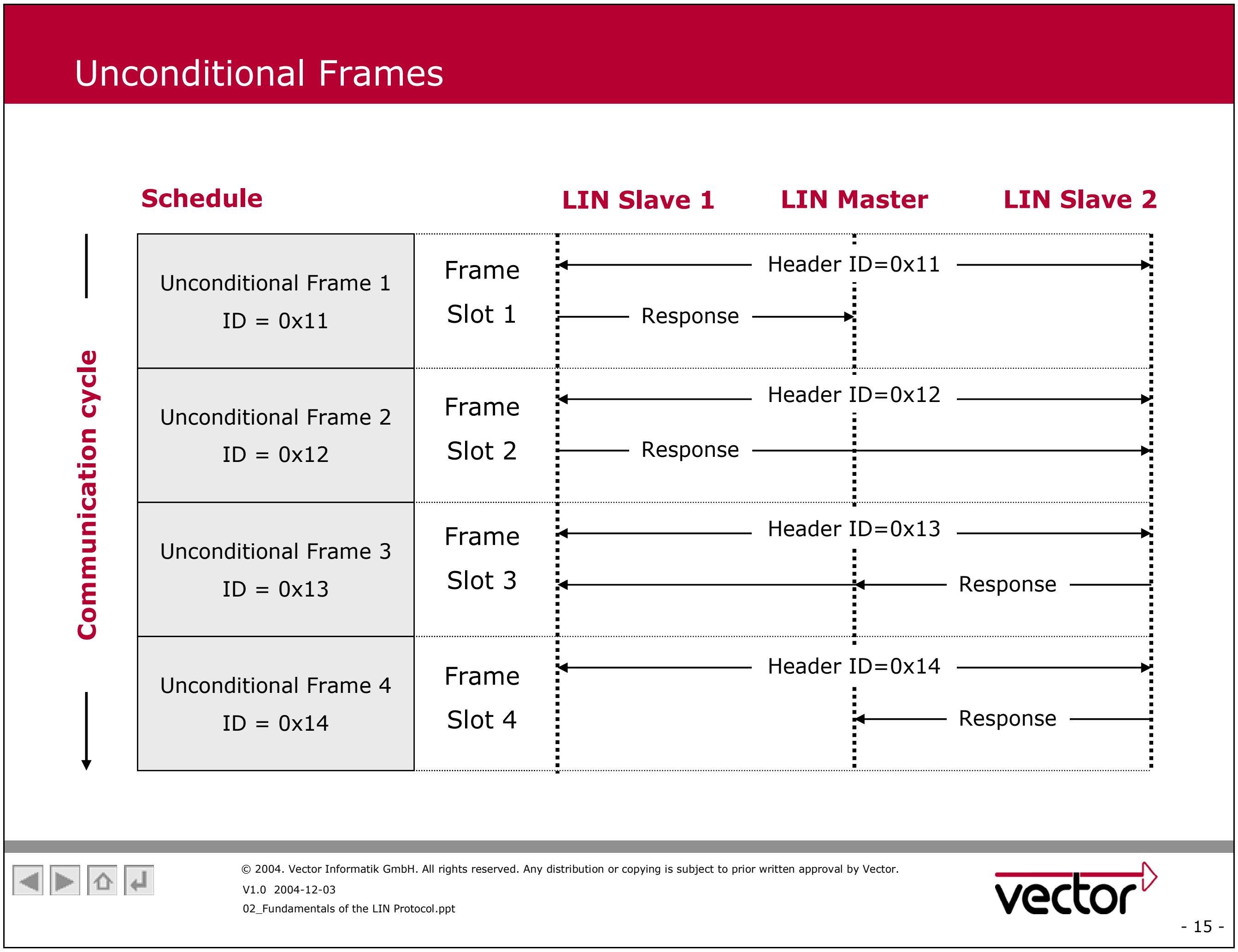

Unconditional Frames

Schedule

LIN Slave 1 LIN Master LIN Slave 2

Communication cycle

Unconditional Frame 1
ID = 0x11

Frame Slot 1

Header ID=0x11

Response

Unconditional Frame 2
ID = 0x12

Frame Slot 2

Header ID=0x12

Response

Unconditional Frame 3
ID = 0x13

Frame Slot 3

Header ID=0x13

Response

Unconditional Frame 4
ID = 0x14

Frame Slot 4

Header ID=0x14

Response

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vector

A sufficiently large frame slot is provided for transmission of an Unconditional Frame. The Unconditional Frame belonging to a frame slot may be transmitted once or multiple times per communication cycle depending on the application. The frame slot must be large enough to be able to send the Message Header and the Message Response. There is exactly one sender for the Message Response. Due to message addressing the Message Response is available for every LIN Slave to receive.

In the example four different Unconditional Frames are sent sequentially according to the entries in the Schedule. One frame slot is available for transmission of each Unconditional Frame. At the beginning of the frame slot the LIN Master sends the Message Header. The relevant LIN Slave sends the Message Response. Once all four frame slots have been processed, or all four Unconditional Frames have been transmitted, execution of the Schedule is repeated.

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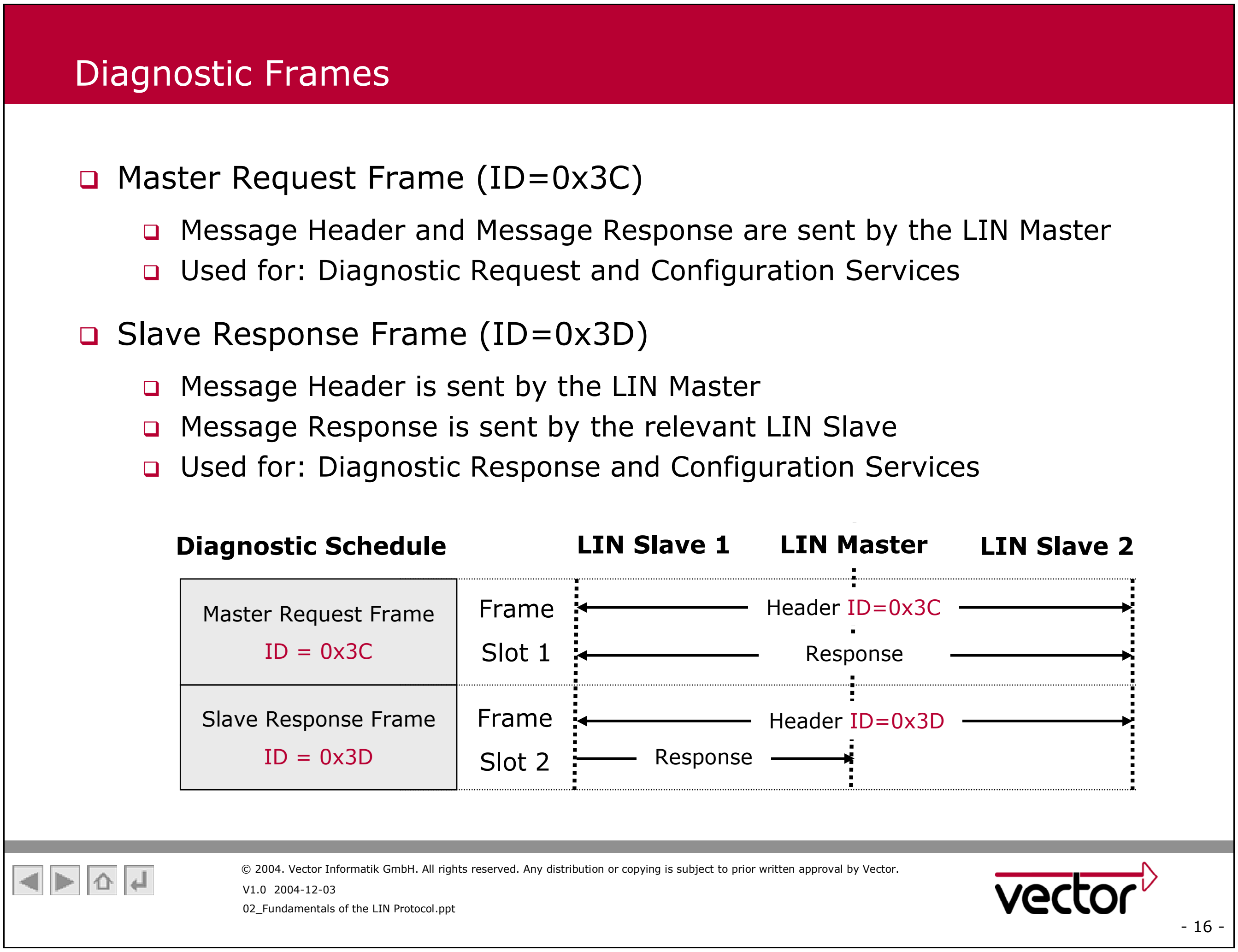

Diagnostic Frames

- ❑ Master Request Frame (ID=0x3C)
  - ❑ Message Header and Message Response are sent by the LIN Master
  - ❑ Used for: Diagnostic Request and Configuration Services
- ❑ Slave Response Frame (ID=0x3D)
  - ❑ Message Header is sent by the LIN Master
  - ❑ Message Response is sent by the relevant LIN Slave
  - ❑ Used for: Diagnostic Response and Configuration Services

Diagnostic Schedule
LIN Slave 1
LIN Master
LIN Slave 2
Master Request Frame
ID = 0x3C
Frame Slot 1
Header ID=0x3C
Response
Slave Response Frame
ID = 0x3D
Frame Slot 2
Header ID=0x3D
Response

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Diagnostic handling in a LIN network is performed with the help of two special LIN messages: Master Request Frame and Slave Response Frame. The Master Request Frame is characterized in that the LIN Master sends both the Message Header and the Message Response. The Message Header of the Master Request Frame is always sent with the identifier ID=0x3C. The Master Request Frame is used for the so-called Diagnostic Request. This may consist of several Master Request Frames. This is called a segmented Diagnostic Request.

The Slave Response Frame is characterized in that the LIN Master sends the Message Header, and a LIN Slave sends the Message Response. The Message Header of the Slave Response Frame is always sent with the identifier ID=0x3D. The Slave Response Frame is used for the so-called Diagnostic Response. The Diagnostic Response may consist of several Slave Response Frames. In that case one speaks of a segmented Diagnostic Response.

The Diagnostic Schedule is used for diagnostics. It must contain two frame slots: One for the Master Request Frame, and one for the Slave Response Frame. The number of repeats depends on the diagnostic implementation itself. For a segmented Diagnostic Request the Slave Response Frame is suppressed, and for a segmented Diagnostic Response the Master Request Frame is suppressed.

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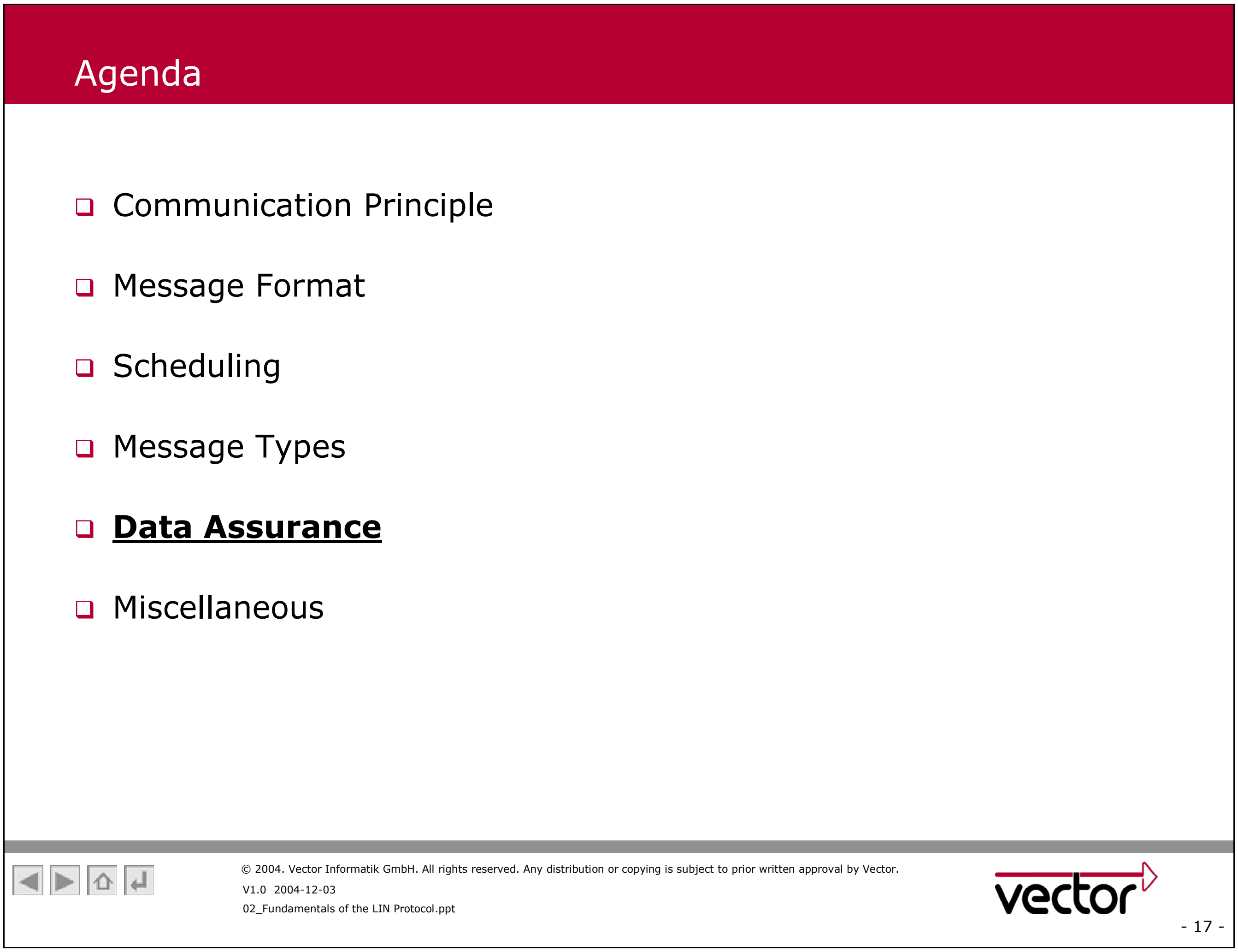

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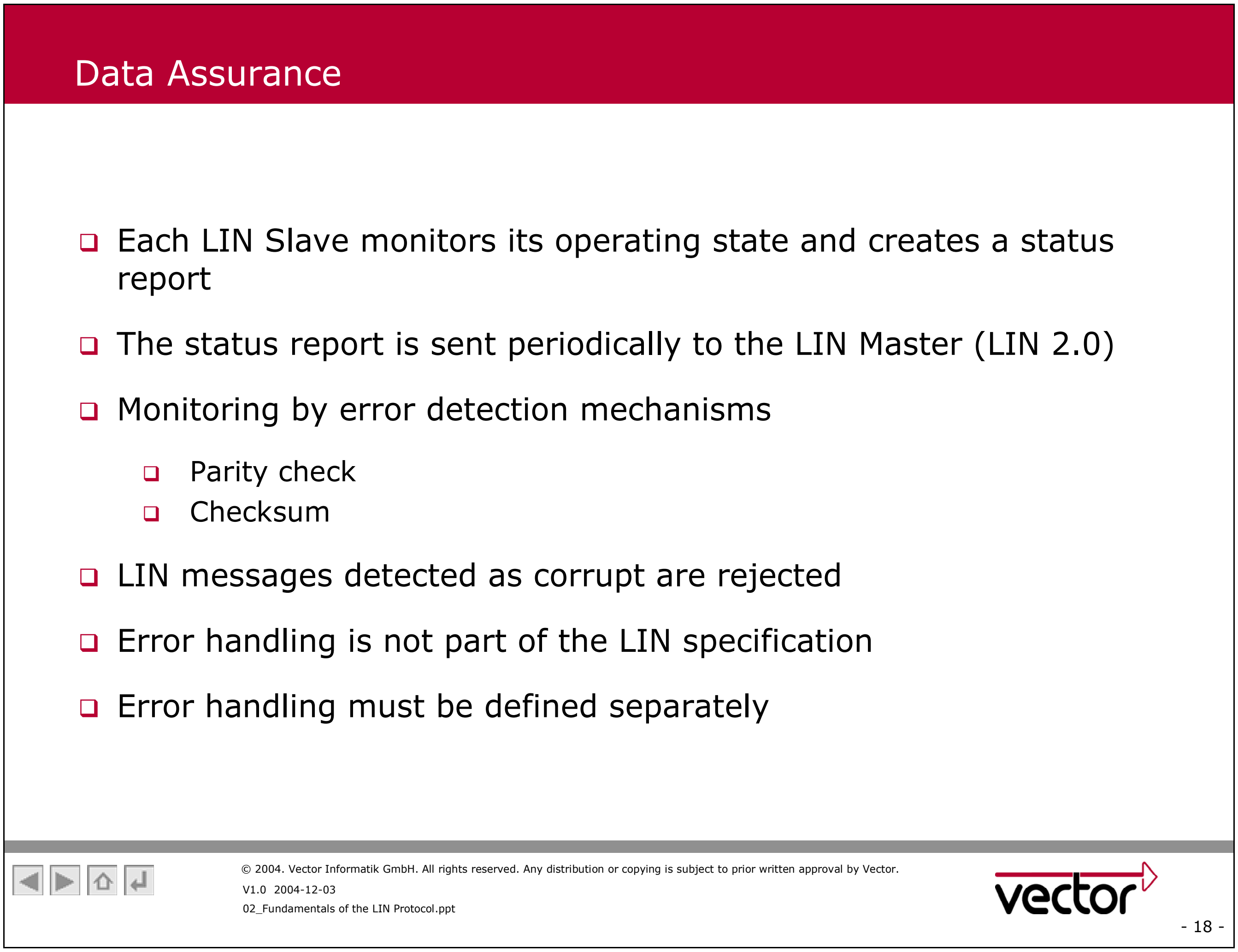

Data Assurance

- ❑ Each LIN Slave monitors its operating state and creates a status report
- ❑ The status report is sent periodically to the LIN Master (LIN 2.0)
- ❑ Monitoring by error detection mechanisms
  - ❑ Parity check
  - ❑ Checksum
- ❑ LIN messages detected as corrupt are rejected
- ❑ Error handling is not part of the LIN specification
- ❑ Error handling must be defined separately

In a LIN network a LIN Slave has the task of monitoring its own operating state (since LIN 2.0). This involves the LIN Slave checking, with the help of parity and checksum checks, to determine whether the send and receive messages were transmitted correctly. The user is free to implement additional error detection mechanisms. It is conceivable that the user might want to implement a check to determine whether there is any bus activity at all, and if yes whether the expected Message Response is transmitted and whether it satisfies the defined time requirements.
The results of monitoring are recorded in a status report. This is provided to the LIN Master. The LIN Master evaluates the status report. This entire process is also referred to as Status Management.
LIN messages detected as incorrect are rejected by the LIN Slave.
Important: Error handling is not part of the LIN specification and must be defined by the user. This generally takes into account the special constraints of the application area.

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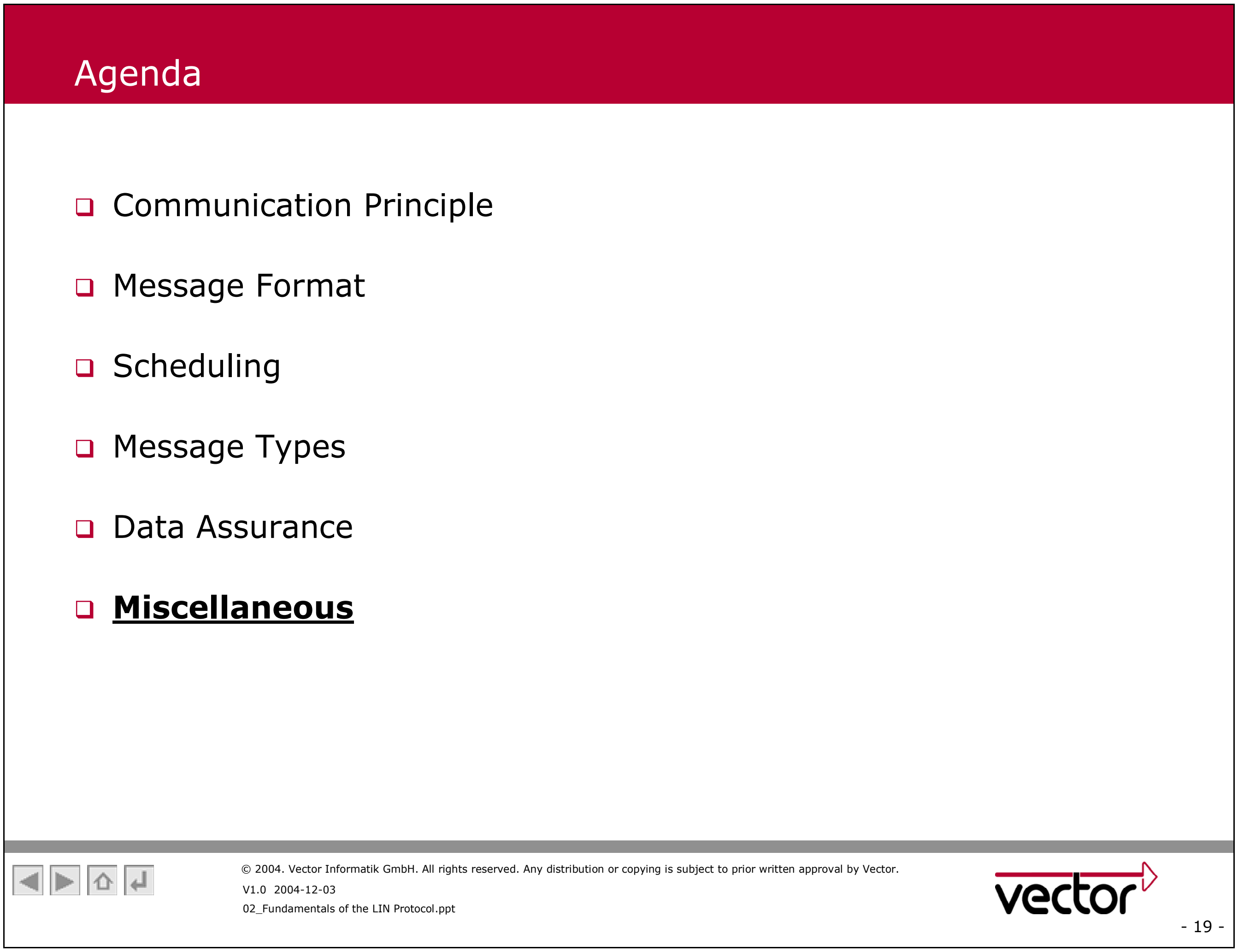

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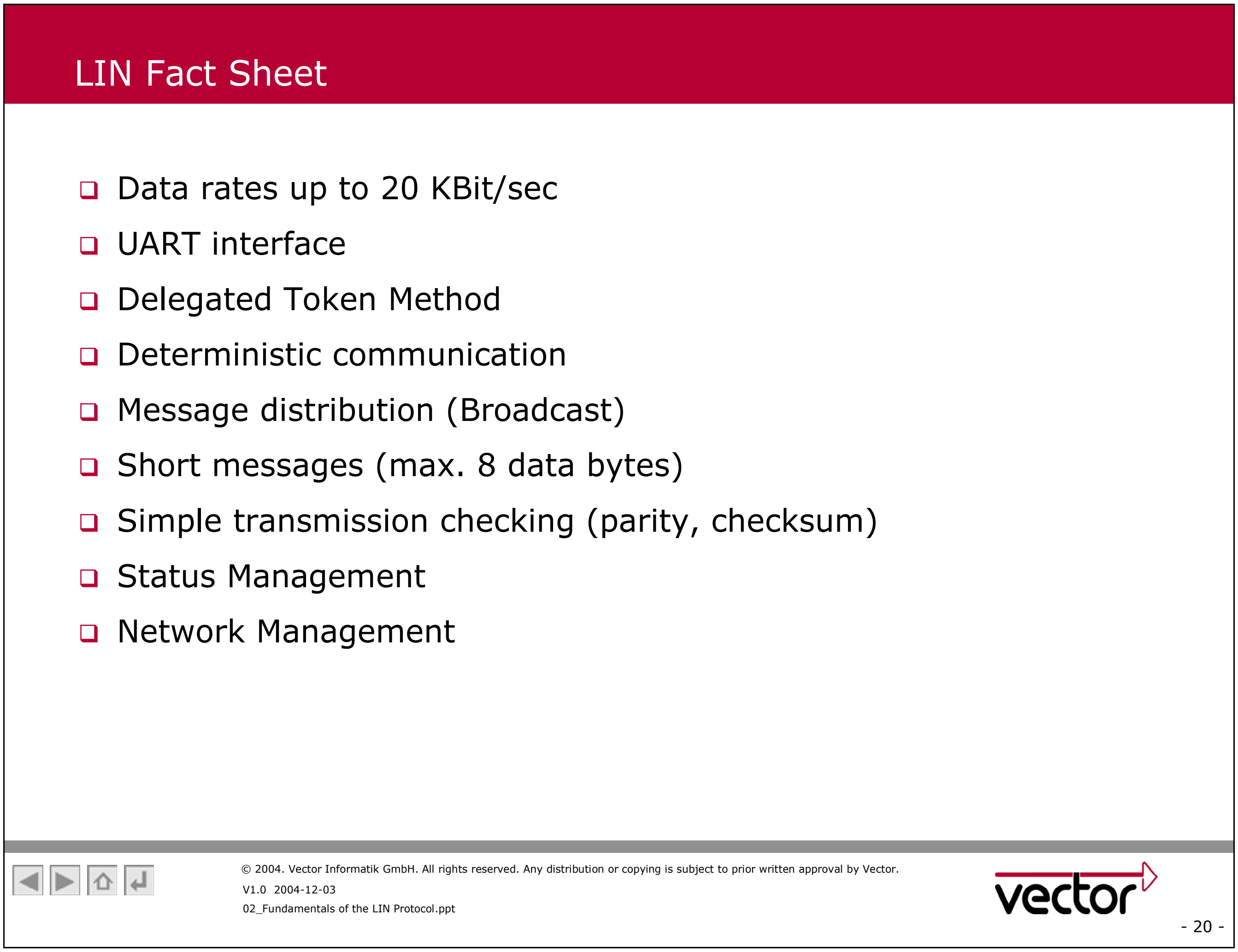

LIN Fact Sheet

- Data rates up to 20 KBit/sec
- UART interface
- Delegated Token Method
- Deterministic communication
- Message distribution (Broadcast)
- Short messages (max. 8 data bytes)
- Simple transmission checking (parity, checksum)
- Status Management
- Network Management

LIN on the Internet

- Internet
  - http://www.vector-informatik.com/
  - http://www.lin-subbus.org

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