CAN XL – THE NEXT STEP IN CAN EVOLUTION

JULY 2023

BOSCH

Agenda

1. Key Success Factors
2. Standardization
3. CAN XL Data Link Layer
4. New Functions on Layer 2
5. CAN XL Layer 1 – Transceiver
6. Compatibility ON Layer 1 & 2
7. Use Cases

CAN XL

KEY SUCCESS FACTORS

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CAN XL – Next Step in CAN Evolution

Key Success Factors

01

Bit rate up to 20 Mbit/s

just limited by selected PHY technology

CAN XL protocol targeted for high-speed CAN XL transceivers (up to 20Mbit/s), but also works with CAN FD or CAN SIC transceivers

02

Large payload size + New Functions (SDT, VCID, ...)

allows tunneling of e.g. Ethernet traffic (transparent for higher layer protocols)

All kind of payload types supported – including largest possible Ethernet frame, IPv6, ...

03

Incremental upgrade

& mixed networks (CAN FD & CAN XL)

Co-existence of “cheap” CAN FD and fast CAN XL nodes in same network

04

Extreme scalability

- wide range of bit rates configurable [up to 20 Mbit/s]
- any transceiver (Classic, FD, SIC, SIC XL) usable
- Use Cases: (1) Signal based communication
  (2) Service oriented communication (via **ETH tunnelling**)

05

Supports complex network topologies

Flexible trade-off between speed and complex networks (e.g. long stubs supported)

06

AUTOSAR support

- CAN XL: new features
- Ethernet Tunneling via CAN XL
- released in November 2022

07

Price

expected to be cheaper than 10BASE-T1S

08

Availability

- **CiA610-1 specification released in November 2021 as DSP (ISO Standardization ongoing: adopt CiA610-1 content)**
- **Samples of automotive micro controllers with CAN XL and CAN SIC XL Transceiver are available in 2023**

CAN XL

STANDARDIZATION

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CAN XL – Next Step in CAN Evolution
Why do we need CAN XL?

Background

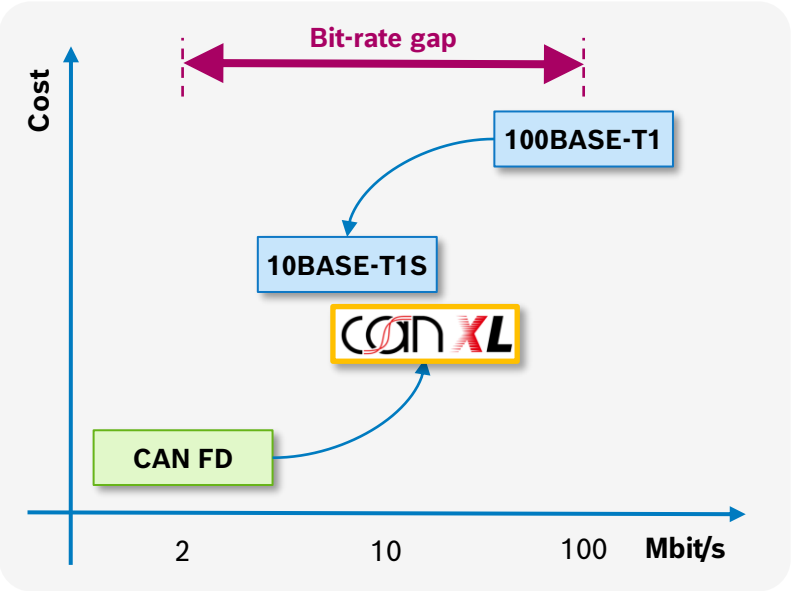
Large Bit rate gap between CAN FD and 100BASE-T1 Ethernet

Target

- Provide a superior 10 Mbit/s CAN solution with respect to
  - Price (Transceiver, Pins, Cabling, ...)
  - Safety
  - Security
  - Quality of Service

  -> initial target exceeded with max bit rate of up to 20 Mbit/s

- Preserve CAN properties:
  Arbitration, robustness, long stubs, ...



CAN XL – Next Step in CAN Evolution
Standardization Status

Technically Stable

Specification at CiA (CAN in Automation)

- CiA610-1 (OSI Layer 2, CAN XL Protocol) ➔ released
- CiA610-3 (OSI Layer 1, CAN XL Transceiver) ➔ released

ISO standardization

- ISO 11898-1 (OSI Layer 2, CAN XL Protocol) ➔ integration of CiA610-1 started
- ISO 11898-2 (OSI Layer 1, CAN XL Transceiver) ➔ integration of CiA610-3 started

CAN XL

DATA LINK LAYER

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CAN XL – Next Step in CAN Evolution
Core Properties

High Throughput

Bitrate

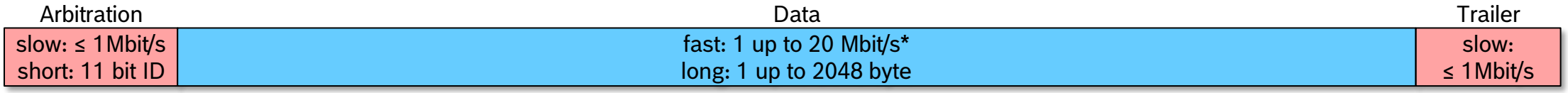
- **Arbitration** Phase: **≤ 1 Mbit/s**
- **Data** Phase: **1 … up to 20 Mbit/s,** user configured, tradeoff between bit rate & network topology

Identifier

- Priority ID (bus access priority): short (11 bit) ➔ enables high net bit rate for short payloads
- Message ID (identifies message): long (32 bit) ➔ sent in “Acceptance Field” during XL data phase

Data Field length

- Range: **1 … 2048 byte** (byte granularity)
- Enables: legacy CAN applications … transparent Ethernet frame tunneling, use of TCP/IP, and more



**depending on used Transceiver and topology

CAN XL – Next Step in CAN Evolution
New Functions on Layer 2

New Functions

Layer 2 MAC Frame contains 3 new fields

- **SDT: SDU Type (8 bit)**
  - indicates the type of the protocol embedded in the data field
  - comparable to EtherType in Ethernet
  - **CiA611-1 defines 2 SDT values for Ethernet Tunneling**
- **VCID: Virtual CAN Network ID (8 bit)**
  - allows to separate the CAN network/bus into virtual networks
  - comparable to VLAN ID in Ethernet
- **AF: Acceptance Field (32 bit)**
  - AF Field interpretation depends on SDT and supports both:
  - 1) Content based addressing (Message ID)
    2) Node based addressing (Src/Dst Address)

- Enables to run several applications or higher layer protocols on the same CAN bus
- Essential feature for Zone Architectures

- Simplifies frame filtering in RX/TX direction
- Improves Safety & Security

- Enables any type of Addressing

Layer 2 MAC frame format

Arbitration Field		Control Field								Data Field	CRC Field		ACK Field		EOF Field
Priority ID	XL	ADS	SDT	SEC	DLC	SBC	PCRC	VCID	AF	Data Bytes	FCRC	FCP	DAS	ACK	EOF

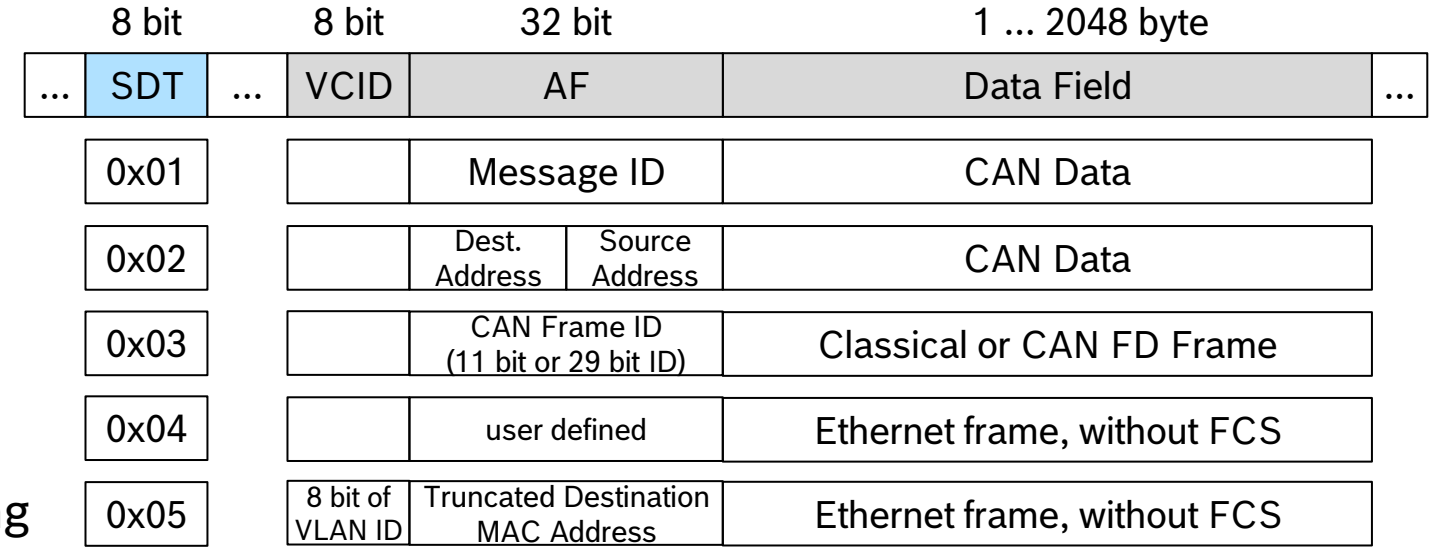
CAN XL – Next Step in CAN Evolution
SDU Type (SDT)

Definition

- Indicates the type of the protocol embedded in the data field – comparable to EtherType

CiA611-1

- specifies 5 SDU Types (SDT) in first version (specification of further values is planed)



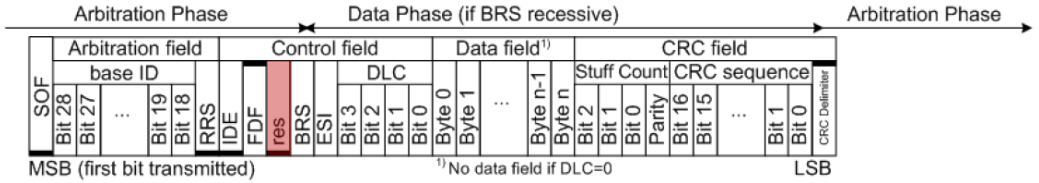
- Content Based Addressing
- Node Addressing
- Classical & FD Frame Tunneling
- IEEE 802.3 (Eth) Tunneling
- IEEE 802.3 (Eth) mapped Tunneling

CAN XL – Next Step in CAN Evolution
Compatibility to CAN FD

FD & XL Protocol are Compatible

CAN FD has the res bit for future protocol extensions

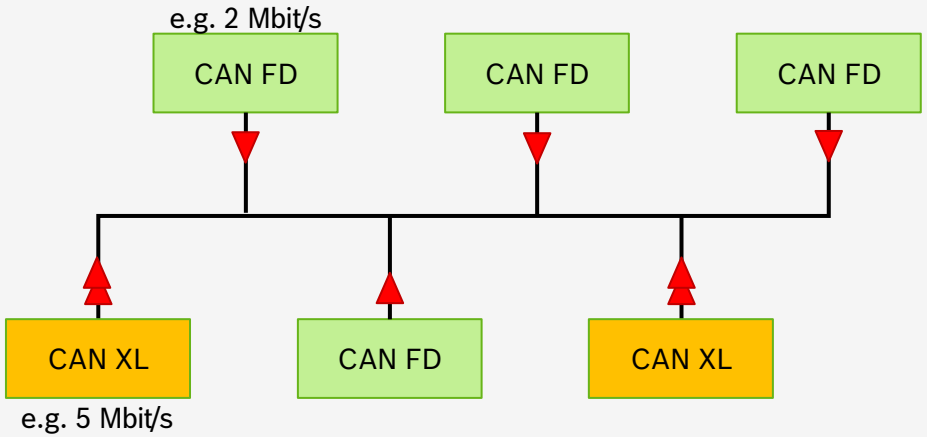
- res = 0: CAN FD node expects a CAN FD Frame
- res = 1: CAN FD node **enters** bus integration state – a passive wait state
  CAN FD node **finishes** bus integration when the CAN XL frame ends (when 11 recessive bits seen)



Compatibility of CAN FD and XL enables

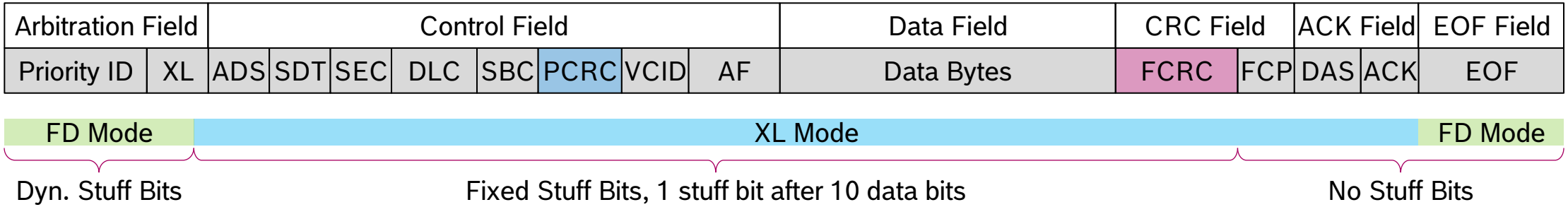
- Incremental upgrade path
- E/E Architecture design freedom: "mixed FD/XL" or "XL only" networks
- Mixed CAN FD/XL networks: 2 data bit rates on the same bus
  (CAN XL is limited to SIC mode, no Transceiver mode switch allowed)
  - right bandwidth for each bus node
  - bandwidth/price optimized endpoints

Mixed CAN FD / CAN XL network



CAN XL – Next Step in CAN Evolution

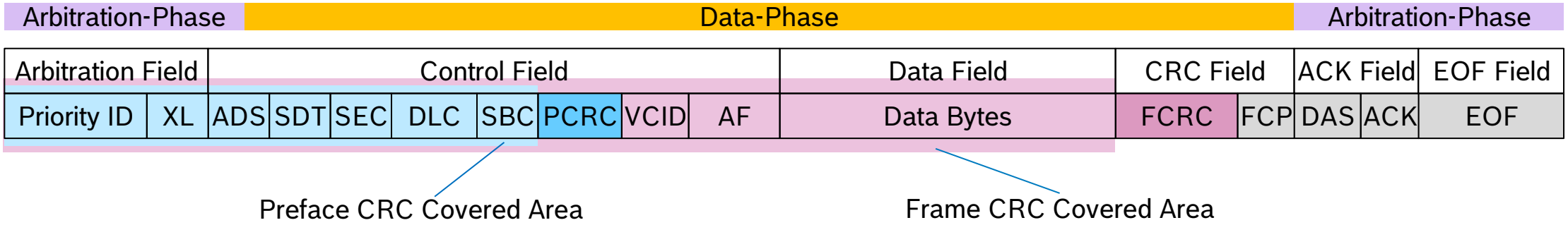
MAC Frame Format – Details[1]



- **Priority ID** 11-bit ID for bus arbitration, purpose: bus access priority
- **XL** Placeholder in this graphic for several Bits: e.g. Frame Format Switch ➔ FD to XL Format
- **ADS** Arbitration Data Sequence ➔ Bit Rate Switching from Arbitration to Data Phase
- **SDT** SDU Type (8 bit) ➔ indicates the type of the protocol embedded in the data field (comparable to EtherType in Ethernet)
- **SEC** SEC (1 bit) signals, if further Layer 2 functions added headers to the data field (e.g. Security, Fragmentation)
- **DLC** Data Length Code (11 bit)
- **SBC** Stuff Bit Count ➔ count of dynamic stuff bits in the arbitration field, safeguards against specific error types
- **PCRC** Preface CRC (13 bit) ➔ Safeguards the bits up to PCRC
- **VCID** Virtual CAN Network ID (8 bit) ➔ allows to separate the CAN Bus into virtual buses (comparable to VLAN ID in Ethernet)
- **AF** Acceptance Field (32 bit) ➔ Field for the Addressing, the interpretation of this field depends on SDT
- **Data** 1 to 2048 bytes user data
- **FCRC** Frame CRC (32 bit) ➔ Safeguards the whole frame, i.e. the bits up to the FCRC
- **FCP** Format Check Pattern ➔ Receiver checks if he is aligned to transmitted bit stream
- **DAS** Data Arbitration Sequence ➔ Bit Rate Switching from Data to Arbitration Phase
- **ACK** Positive Acknowledgement, same as in CAN FD

[1] See CiA610-1 for the exact frame format

CAN XL – Next Step in CAN Evolution
MAC Frame – CRC Concept



Preface CRC (PCRC)

- Length: 13 Bit
- Hamming Distance: 6

Frame CRC (FCRC)

- Length: 32 Bit
- Hamming Distance: 6 (outperforms FlexRay and Ethernet CRC Polynomials)

CAN XL – Next Step in CAN Evolution
Operating Modes

CAN XL has two Operating Modes

- The mode is configurable by software during runtime
- All nodes in one Bus/Network must use the same mode

Mode	Error Signaling ENABLED	Error Signaling DISABLED
Description	Errors signaled with Error Flags (identical to CAN FD behavior)	Errors are not signaled - **RX Node**: Re-Integrates after an Error (waits for the end of the current transmission) - **TX Node**: Does not check for TX errors (always transmits the full frame)
Compatibility	CAN XL is compatible to CAN FD	incompatible to CAN FD
Frames on Bus	CAN XL + CAN FD + Classical CAN	CAN XL only

➔ CAN XL is compatible to CAN FD, when Error Signaling = ENABLED

CAN XL – Next Step in CAN Evolution
Comparison of CAN Protocols

Property	Classical CAN	CAN FD	CAN XL
Data Field	[0 ... 8 byte]	[0 ... 64 byte]	[1 ... 2048 byte]
Identifier	11 bit & 29 bit	11 bit & 29 bit	11 bit
Bus Access	CSMA/CR (Arbitration)	CSMA/CR (Arbitration)	CSMA/CR (Arbitration)
Acceptance Field	–	–	32 bit (Message ID)
VCAN ID	–	–	8 bit
SDU Type	–	–	8 bit
Bit Stuffing	dynamic	dynamic fixed in CRC	dynamic (in arbitration field) fixed (in data phase)
CRC	15 bit	17 or 21 bit	PCRC: 13 bit FCRC: 32 bit (outperforms Flexray & Ethernet)
Error Signaling	ON	ON	Software Configurable: ON/OFF
Transceiver Mode Switching	Not supported	Not supported	Software Configurable: ON/OFF
Bit rate ratio: data/arb	–	Up to approx. 16.	Up to 40 (e.g. 500 kbit/s & 20 Mbit/s)
Arbitration phase bit rate Data phase bit rate	[0 ... 1 Mbit/s] –	[0 ... 1 Mbit/s] [arb. phase bit rate ... 8 Mbit/s]	[0 ... 1 Mbit/s] [2x arb. phase bit rate ... 20 Mbit/s]

CAN XL

LAYER 1 - TRANSCEIVER

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CAN XL – Next Step in CAN Evolution
Transceiver Types usable with CAN XL

- Today
  - ➔ High Speed CAN Transceiver
    1 Mbit/s in Data-Phase (realistic with existing bus topologies)
  - ➔ CAN FD Transceiver
    2 Mbit/s in Data-Phase (realistic with existing bus topologies)
  - ➔ CAN SIC Transceiver (Signal Improvement, former “Ringing Suppression”)
    5 or 8 Mbit/s in Data-Phase
- Tomorrow
  - ➔ CAN SIC XL Transceiver, according CiA610-3
    up to 20 Mbit/s in Date-Phase

➔ All transceivers: (1) usable & (2) pin compatible

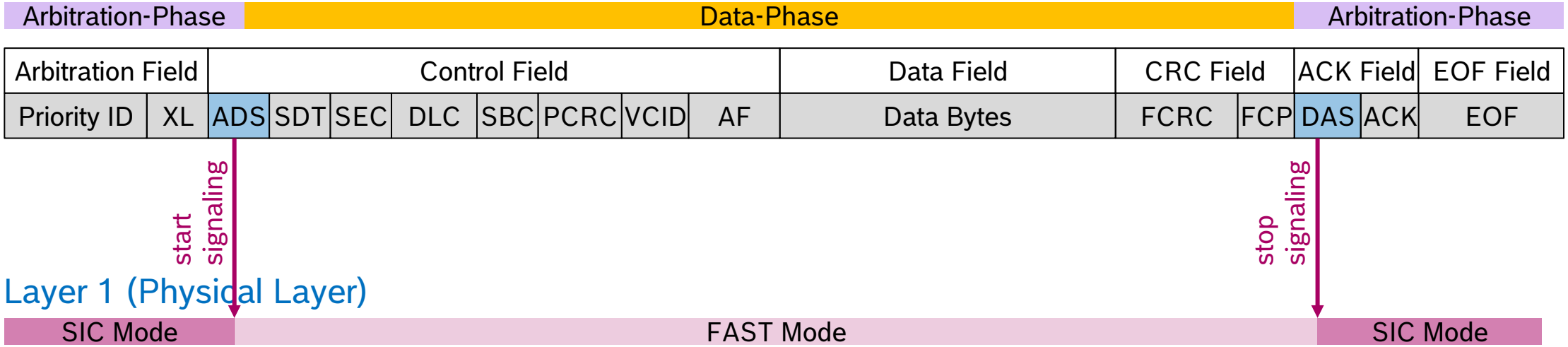
CAN XL – Next Step in CAN Evolution
CAN SIC XL Transceiver – Overview

Modes of CAN SIC XL Transceiver

- SIC Mode ➔ dominant/recessive (like a CAN SIC transceiver)
- FAST Mode ➔ **TX node**: push/pull (0/1) **RX node**: adjust threshold (➔ Error Frames not supported!)

The XL Protocol Controller signals the mode switch to the transceiver during ADS & DAS

Layer 2 (MAC)



COMPATIBILITY

ON LAYER 1 & 2

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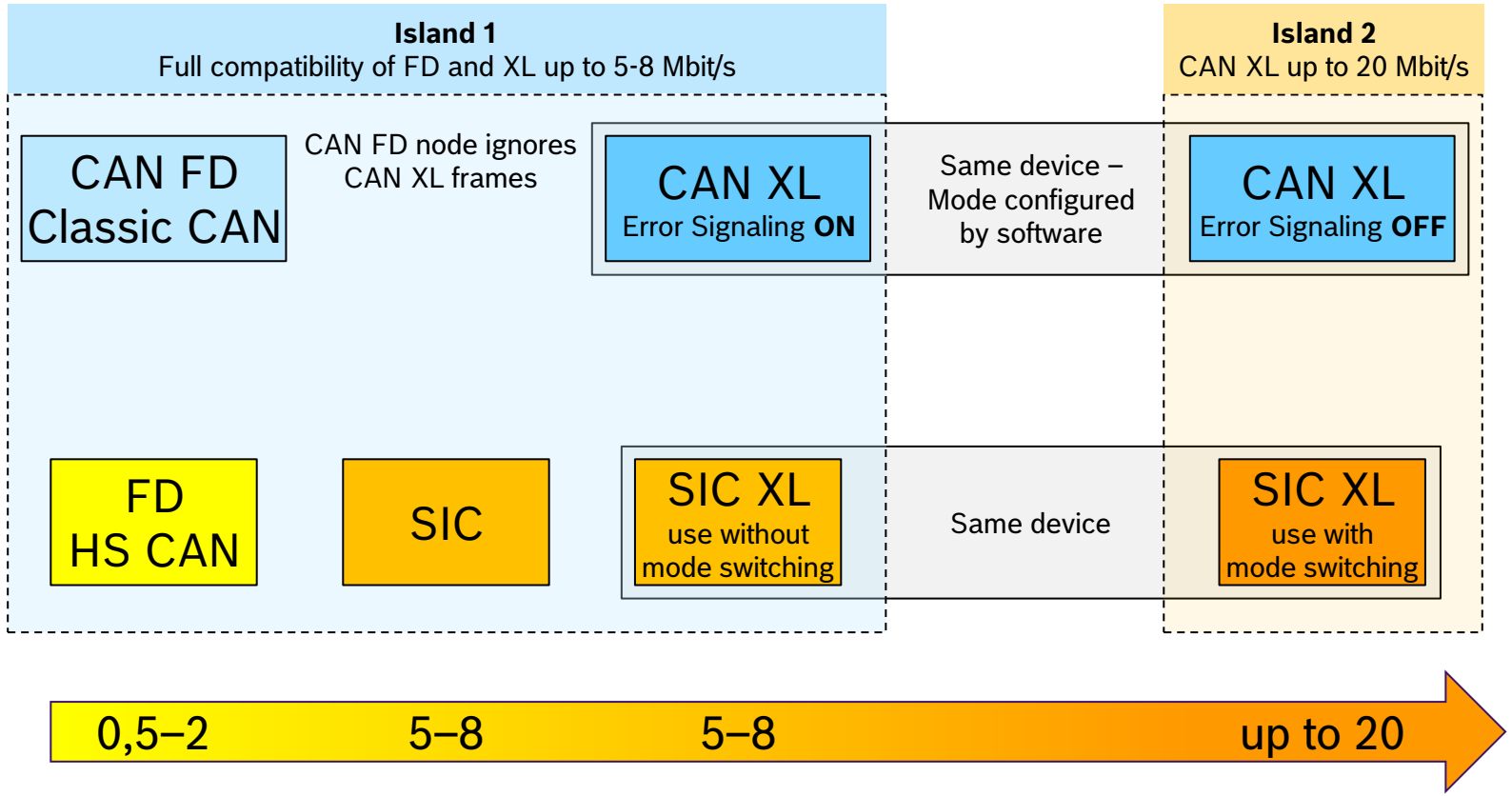
Compatibility

Extreme Flexibility and Compatibility



*depending on used Transceiver and topology

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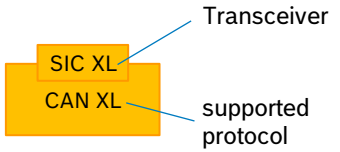
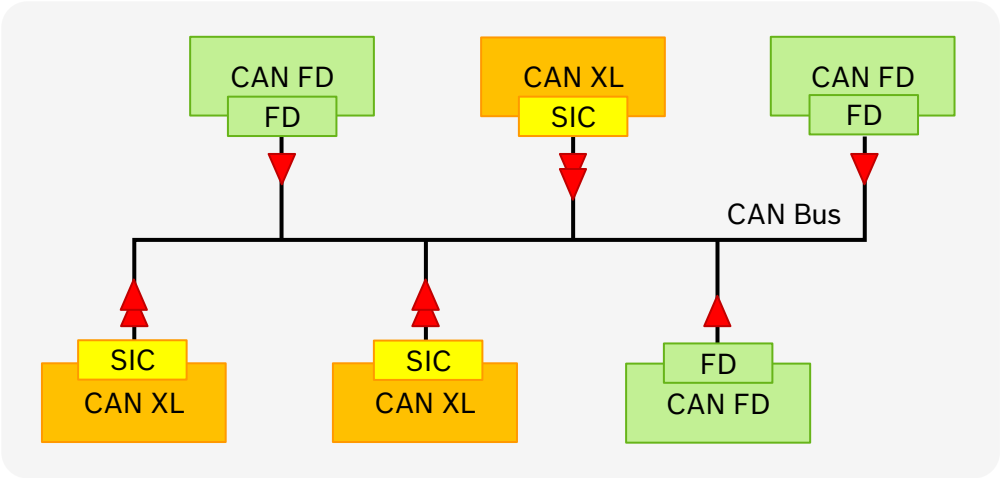
CAN XL – Next Step in CAN Evolution
Examples



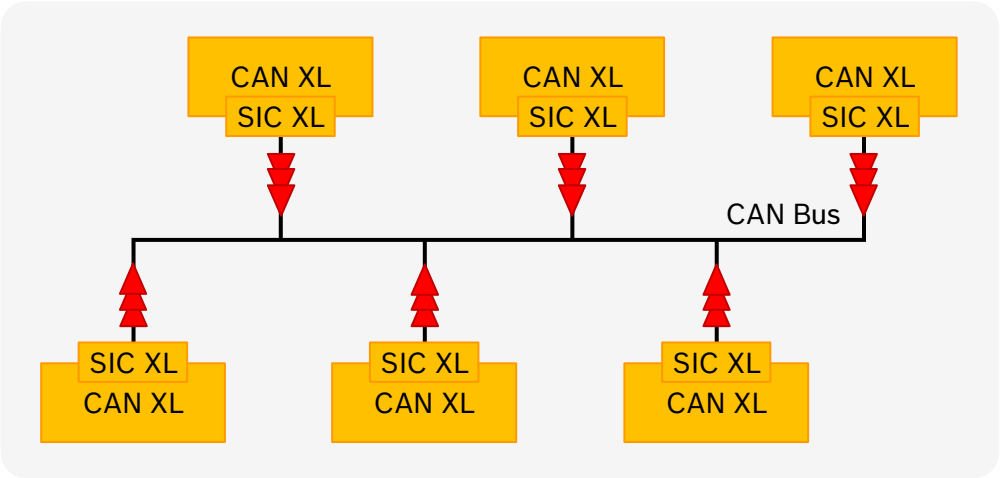
Mixed CAN FD / CAN XL Network



Bit-Rate
- Arbitration-Phase: 500 kbit/s
- FD Data-Phase: 2 Mbit/s
- XL Data-Phase: 5 to 8 Mbit/s (NO mode switch)*

Error Signaling: ENABLED

Pure CAN XL Network



Bit-Rate
- Arbitration-Phase: 650 kbit/s
- FD Data-Phase: not used
- XL Data-Phase: up to 20 Mbit/s*

Error Signaling: DISABLED

*depending on used Transceiver and topology

USE CASES

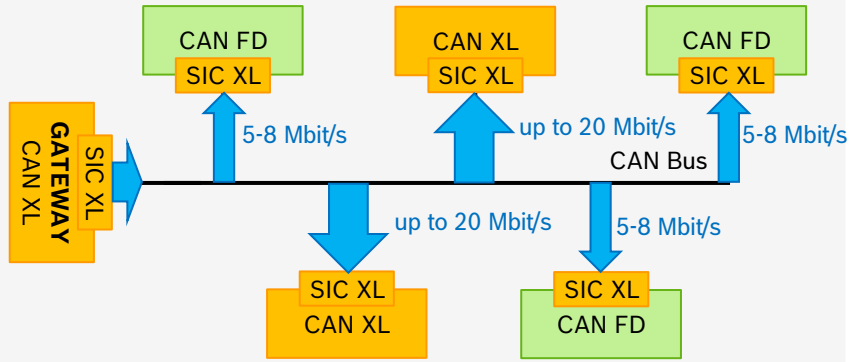
CAN XL – Next Step in CAN Evolution

Example Use Cases

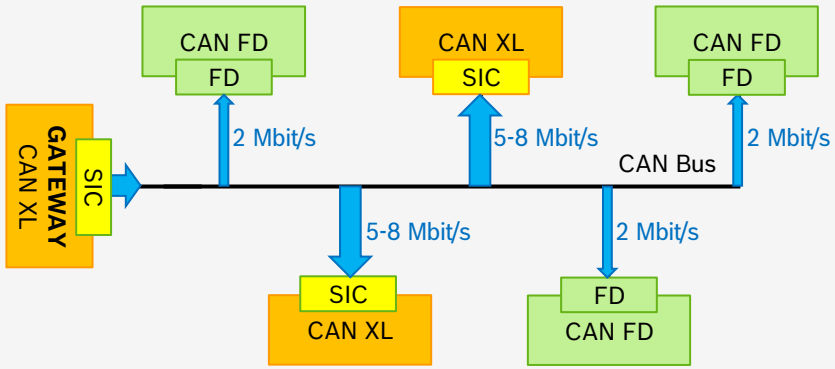
Flashing / Software updates

- Fact: Majority of new microcontrollers will support CAN XL
- **Idea**: Improve flashing times
  - **Normal operation**: pure CAN FD network
  - **Flashing operation**: CAN XL with
    (a) larger payload
    (b) bit rate only limited by transceiver type

Mixed Network (SIC XL only): speed up by factor 2-10



Mixed Network (FD & XL ECUs): speed up by factor 2-4



Pure XL ECU Network: speed up by factor 2-10