Holger Zeltwanger

Next CAN generation protocols including higher-layer protocols such as CANopen FD

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- Electronic engineer (university of applied science)
- Technical journalist since 40 years
- Initiator of the CiA association
- Member of the CiA Board of Directors since 1992
- Member of ISO TC22 SC31 (data communication)
- Convenor of ISO TC22 SC31 WG3 (in-vehicle networks), elected until 2021
- Convenor of ISO TC22 SC31 WG4 (network applications), elected until 2020
- Expert in several other ISO working groups
- Expert in several IEC working groups
- Expert in several DIN working groups
- Member of SAE J1939 committee and task forces
- Member of SAE J2284 committee

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2019 CAN IN SPACE WORKSHOP

First press release

BOSCH AND INTEL JOIN IN DEVELOPMENT OF AUTOMOBILE ELECTRONICS NETWORK

DETROIT, Mich., Feb. 25, 1986 -- Robert Bosch GmbH and Intel Corp. today announced that the companies are jointly developing a high-speed communication link for interconnecting electronic control units within automobiles.

This serial communication system now in development is called the "Controller Area Network" (CAN).

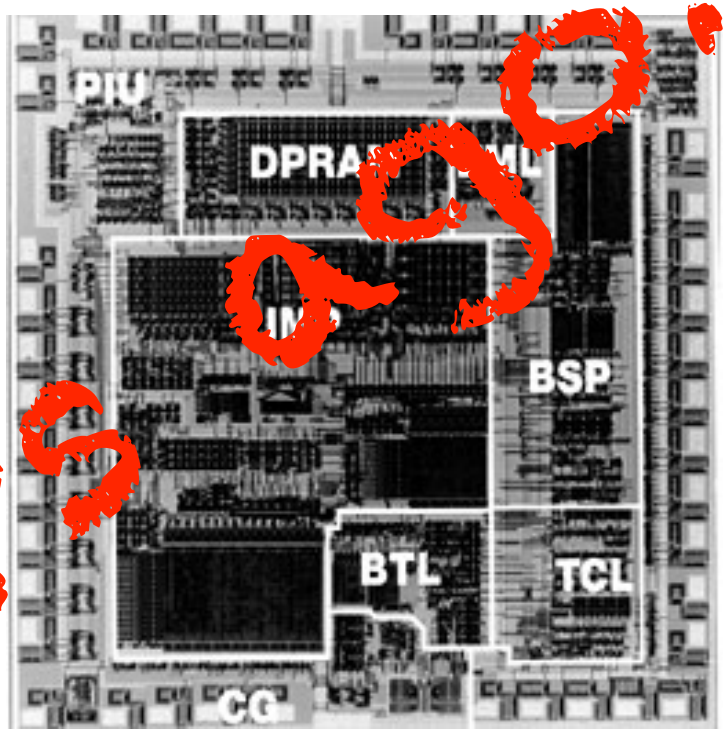
Robert Bosch defined the CAN protocol architecture and is contributing its expertise in automotive system engineering, quality and reliability.

Intel is contributing to the CAN project its knowledge of automotive market requirements and expertise in designing of high-reliability, cost-effective very-large-scale-integrated (VLSI) products.

The outcome of this cooperation will be a standard line of Intel products: a serial controller which interfaces between various microcontroller architectures and the serial bus; and microcontrollers with the protocol integrated within a single chip.

The VLSI products will be offered to the general marketplace as standard products.

33 years ago!



Intel's 82526 CAN stand-alone controller chip supported data-rates up to 1 Mbit/s

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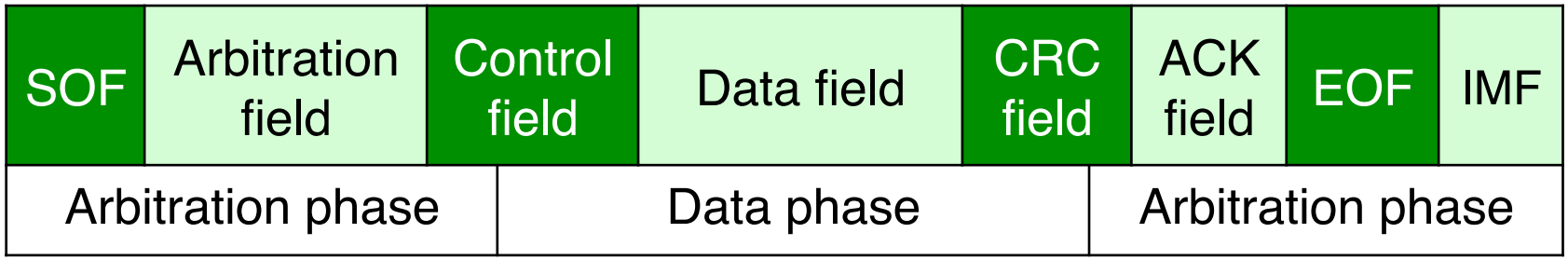
CAN FD protocols

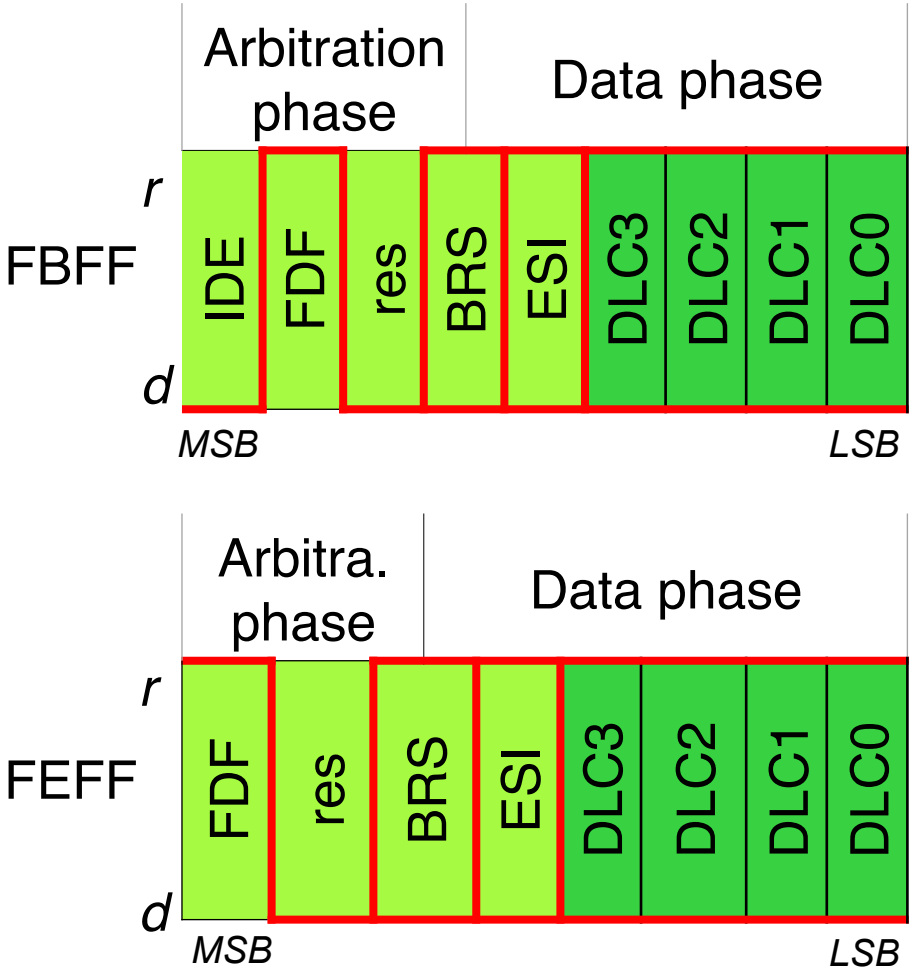


KEY
SOF = start-of-frame
CRC = cyclic redundancy check
ACK = acknowledgement
EOF = end-of-frame
IMF = intermission field

ISO 11898-1:2015 specifies the following data frame formats:

- FBFF (FD base frame format): 11-bit identifier
- FEFF (FD extended frame format): 29-bit identifier
- CBFF (CAN base frame format): 11-bit identifier
- CEFF (CAN extended frame format): 29-bit identifier

CAN FD control field



No. of data bytes	Data length code (DLC)			
	DLC 3	DLC 2	DLC 1	DLC 0
0 *to* 8	As in Classical CAN			
12	r	d	d	r
16	r	d	r	d
20	r	d	r	r
24	r	r	d	d
32	r	r	d	r
48	r	r	r	d
64	r	r	r	r

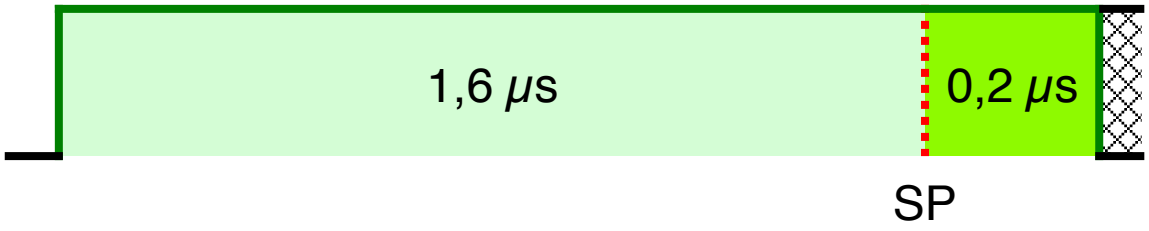
LEGEND: IDE (identifier extension), FDF (flexible data rate format), BRS (bit rate switch; recessive, if alternate bit-rate), ESI (error state indicator; recessive, if error passive)

Bit length (example)

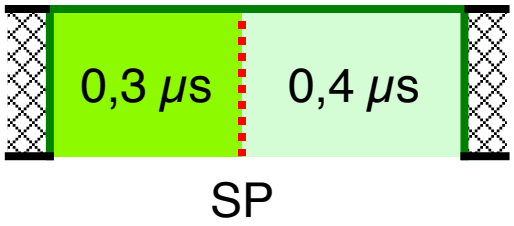
Arbitration bit rate: 500 kbit/s (2 µs per bit)
Data bit rate: 2 Mbit/s (0,5 µs per bit)

Arbitration phase SP: 80 % of bit time
Data phase SP: 60 % of bit time

BRS bit

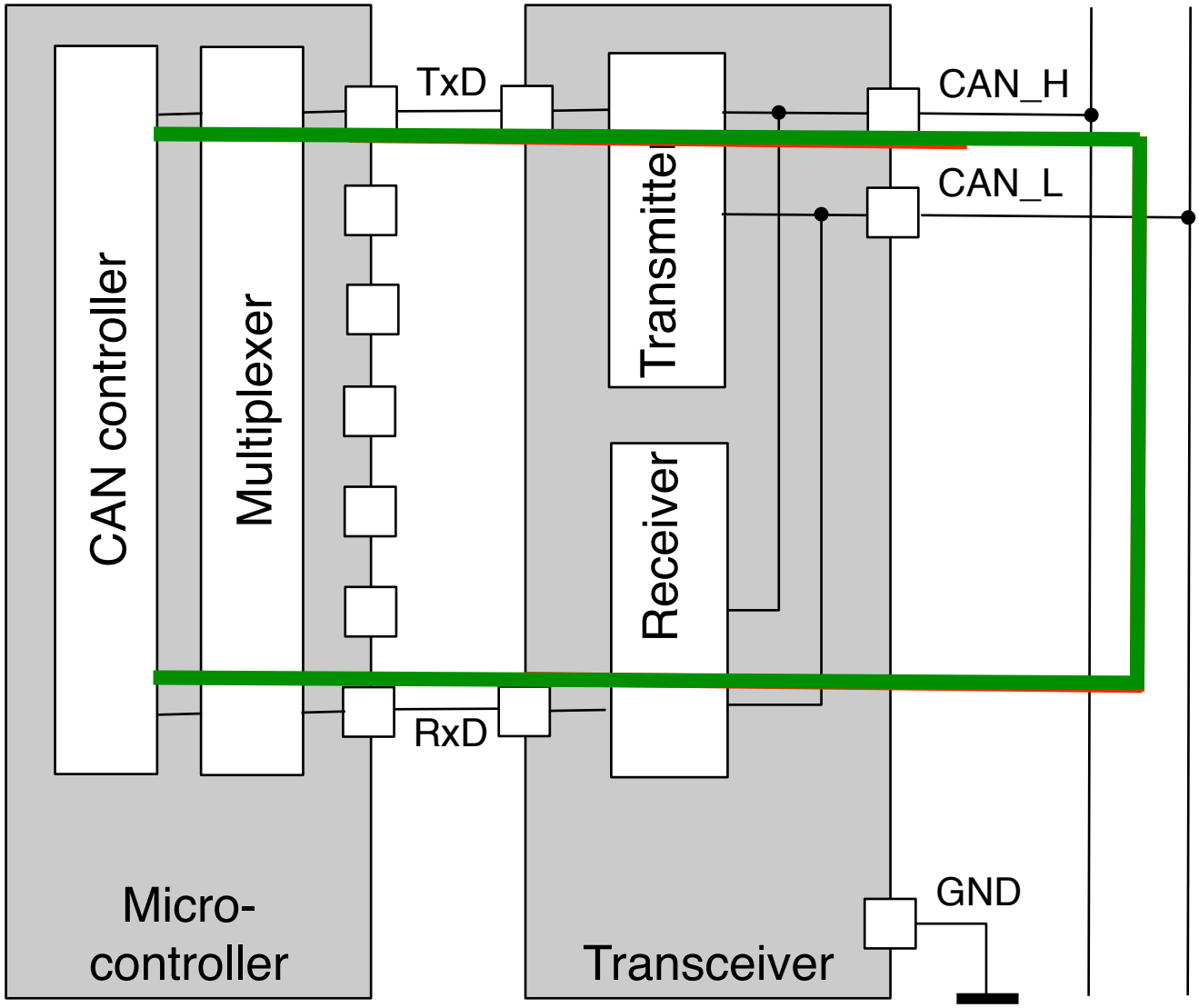


CRC delimiter



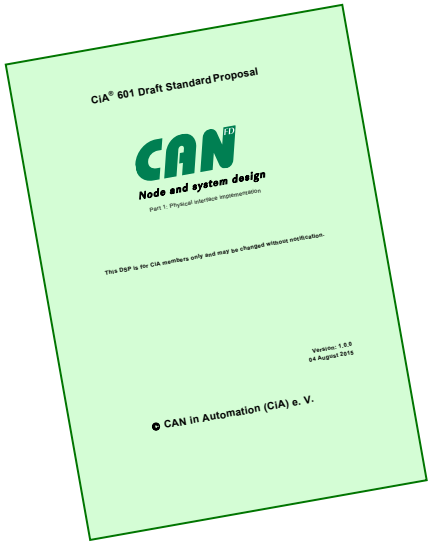
KEY
BRS: bit rate switch
CRC: cyclic redundancy check
SP: sample point

TD* compensation



* TD (transmitter delay)

CiA 601 series



CAN FD node and system design

- CiA 601-1 (version 2.0): Physical interface implementation [1]
- CiA 601-2 (version 1.0): Controller interface recommendation [2]
- CiA 601-3: System design recommendation [2]
- *CiA 601-4 (version 2.0): Signal improvement circuitry* [3]
- *CiA 601-5: Reference topology examples* [3]
- *CiA 601-6: CAN FD cable recommendation* [2]
- *CiA 110: Common-mode choke specification* [2]

1 Released as CiA Draft Standard (DS)
2 Released as CiA Draft Standard Proposal (DSP)
3 Still under development

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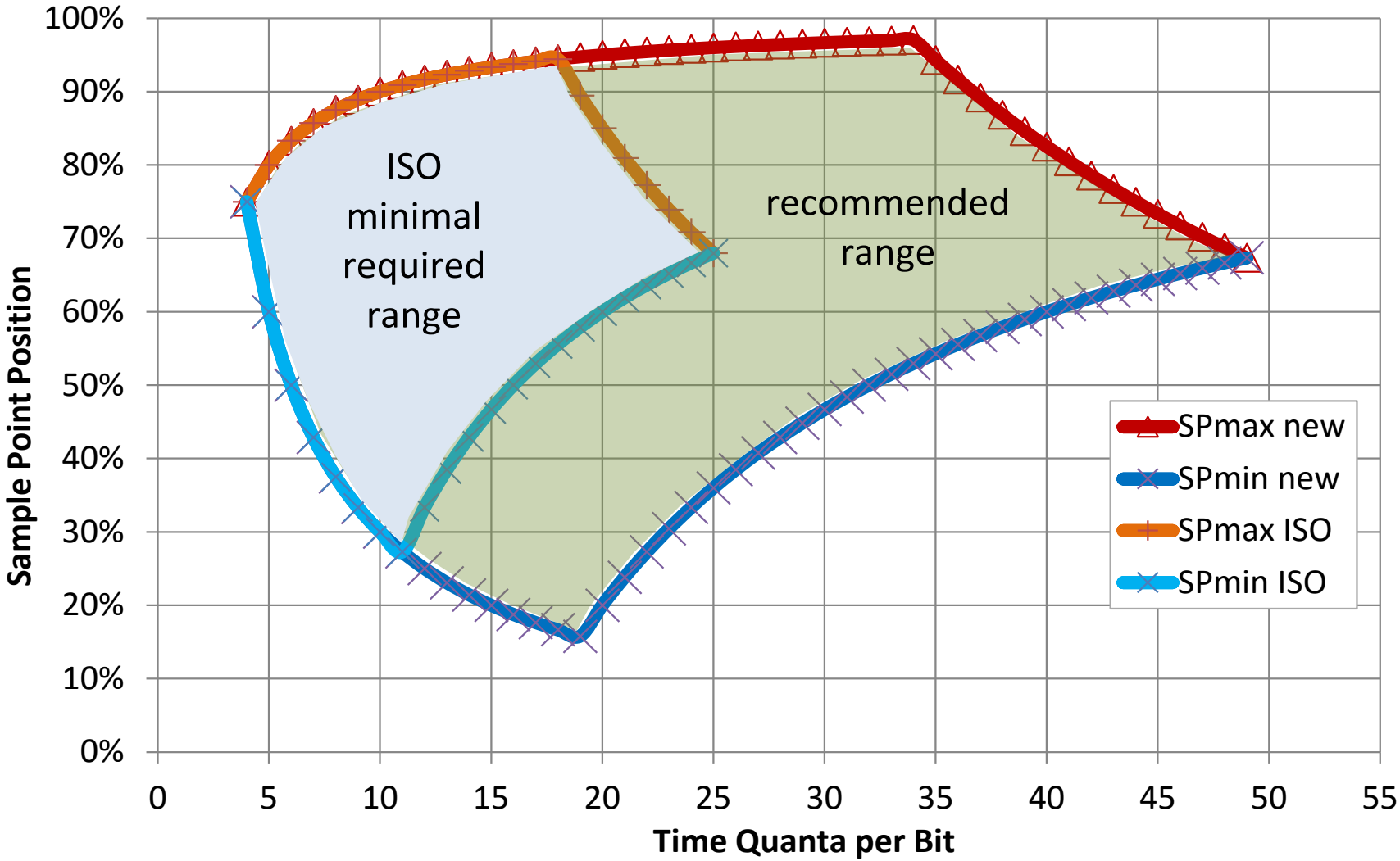
CiA 601-2 bit-timing register



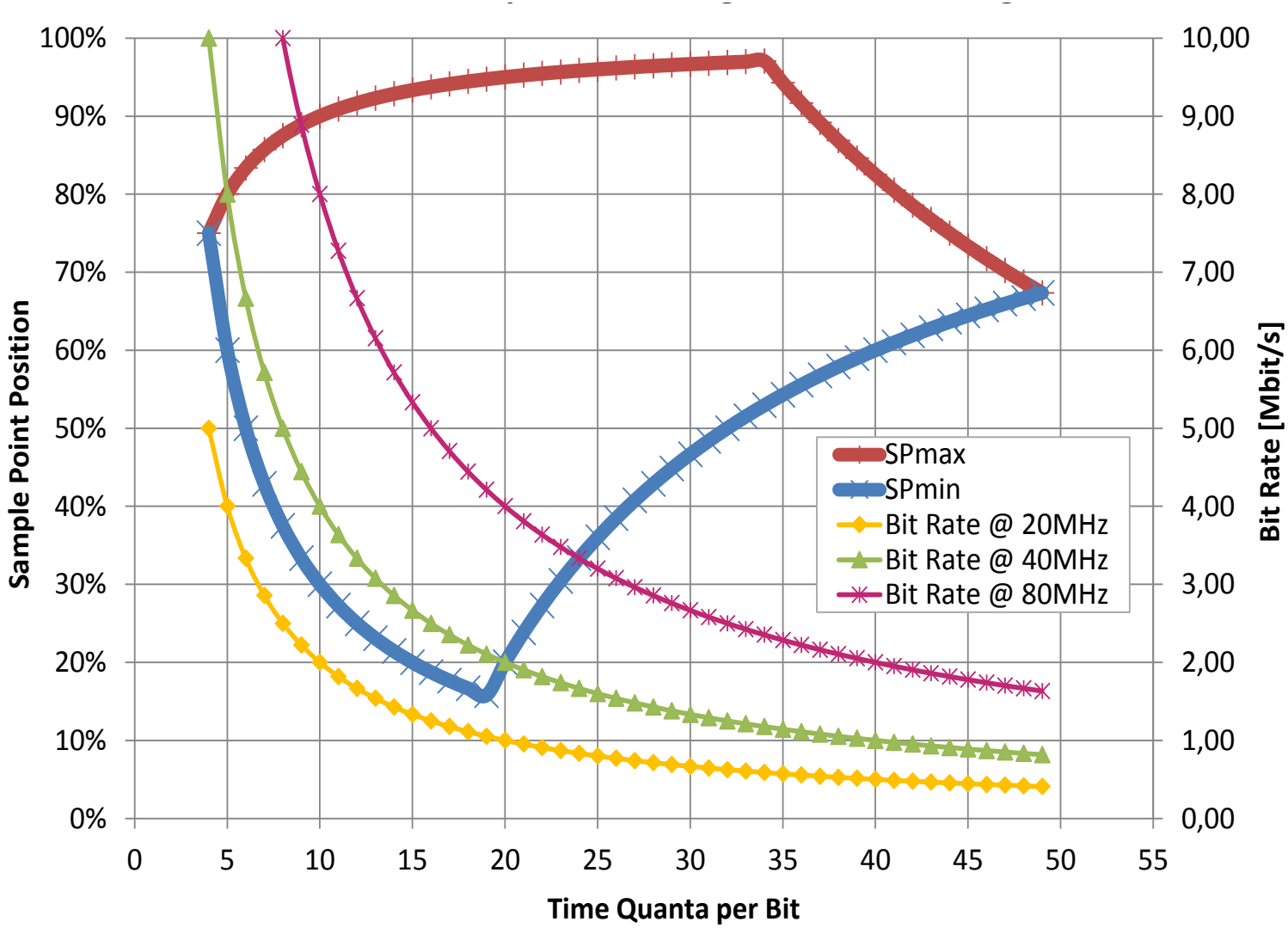
Data-phase Sample Point (SP) range with recommended register length

Bit-timing recommendations

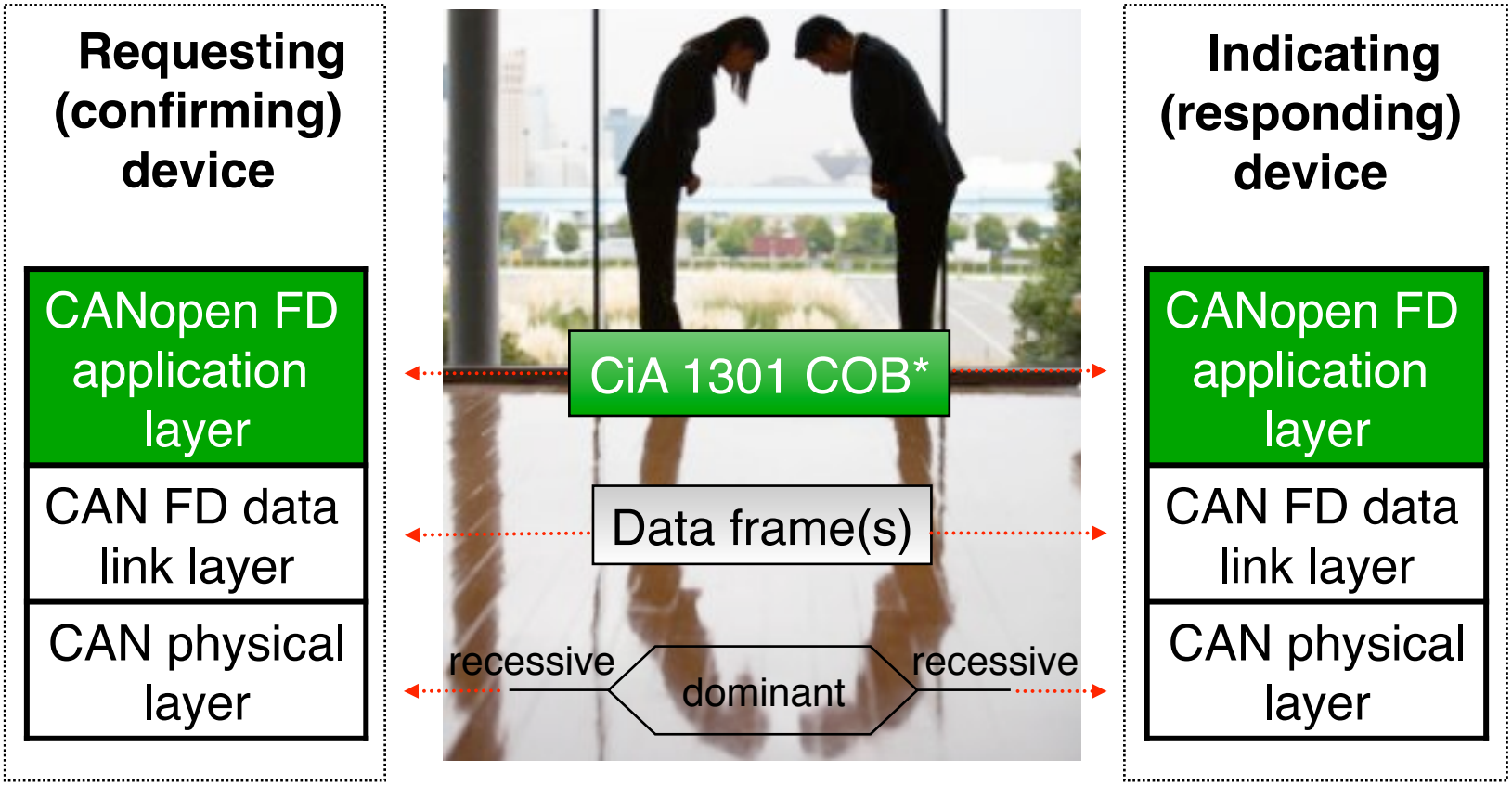
- Set $tq_A = tq_D$ (this reduces the quantization error);
- Make tq_A as short as possible (this minimizes the quantization error);
- Choose the highest available CAN clock frequency (e.g. 40 MHz or 80 MHz);
- All nodes should have the very same sample-point, in both arbitration and data-phase (but these sample-points may be different);
- SJW_A and SJW_D should be as large as possible (this makes the network more robust);
- Enable TDC for data-phase bit-rates for 1 Mbit/s and higher.

LEGEND:
tq = time quantum – SJW = synchronization jump width – TDC = transmitter delay compensation

Data-phase SP range

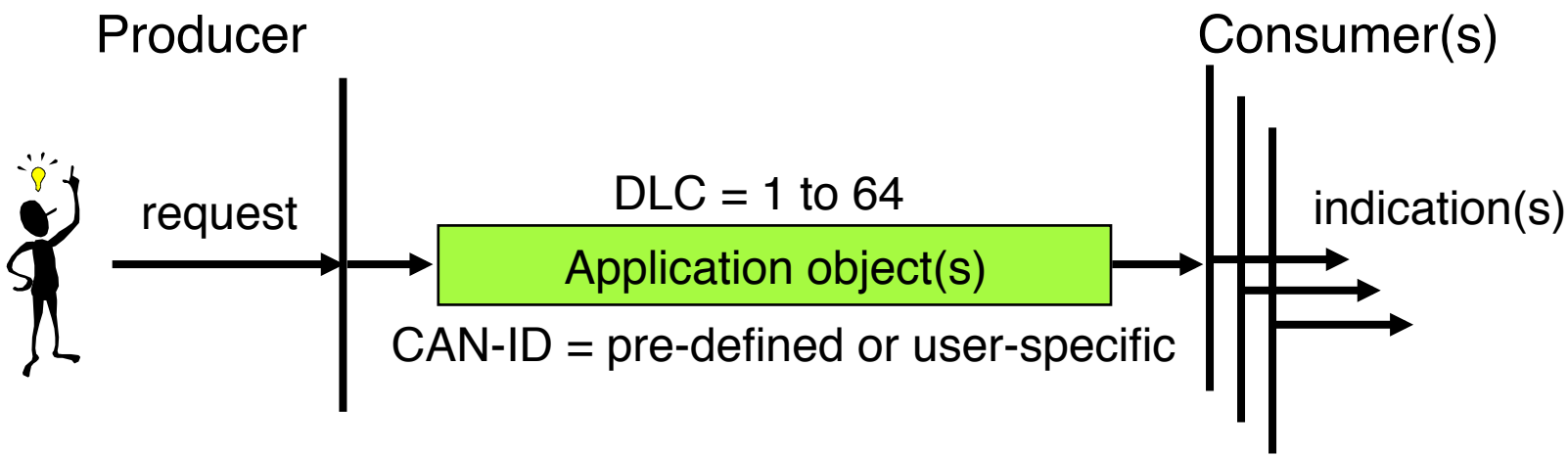


CANopen FD protocol layers



* COB = communication object

PDO with 64-byte payload



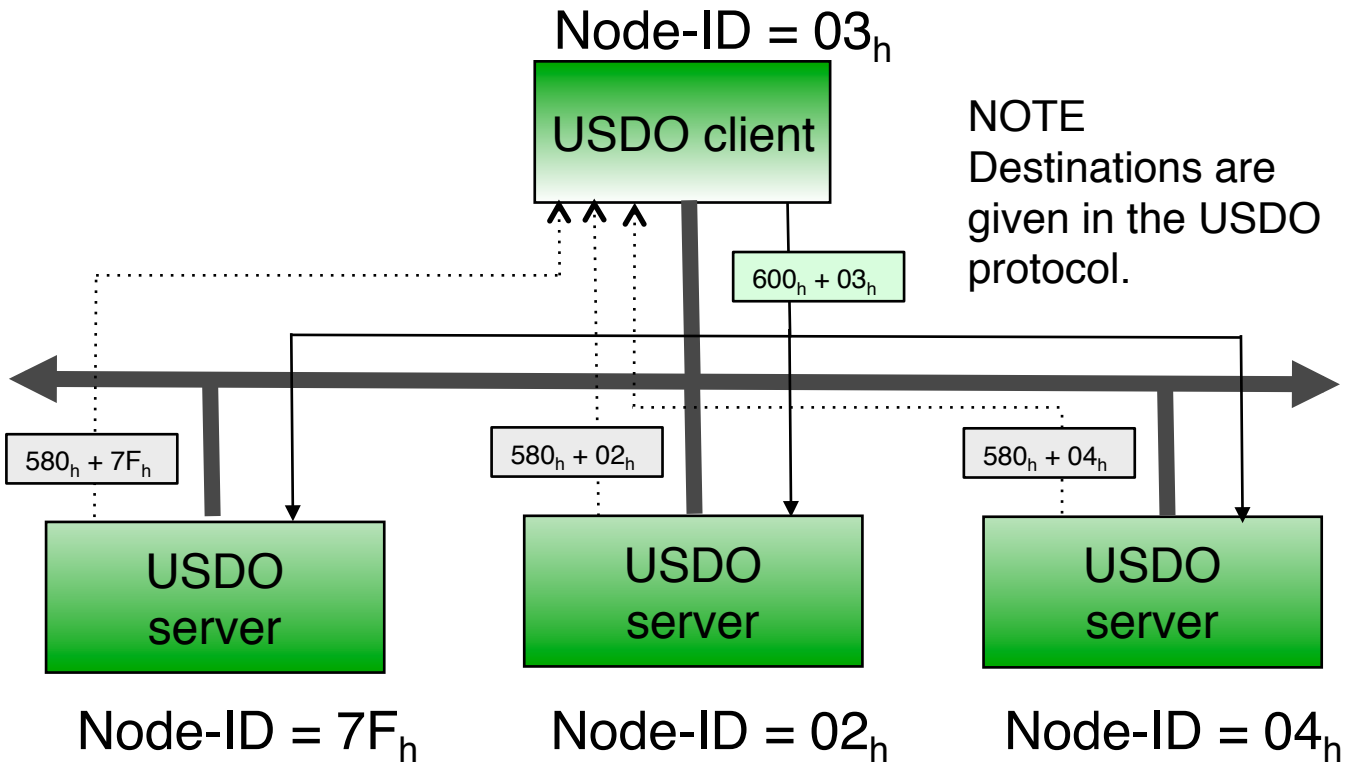
Asynchronous PDOs are triggered by a CoS event or the elapsing of the event-timer (periodically).

Asynchronous PDOs are triggered by the SYNC message (cyclically) or by the SYNC message plus a CoS event (acyclically).

NOTE PDOs shall not be requested by Classical CAN remote frames.

Universal SDO (USDO)

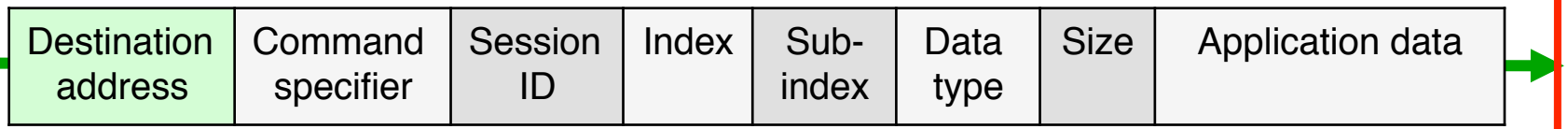
- Confirmed data transfer in unicast, (multicast), and broadcast
- Expedited and segmented data transfer
- Inherent routing capability
- Physical (net-ID and node-ID) and logical (name) addressing
- *Multiple sub-index access (not yet specified)*



USDO uni-/multi-/broad-cast

Client Server

USDO download request



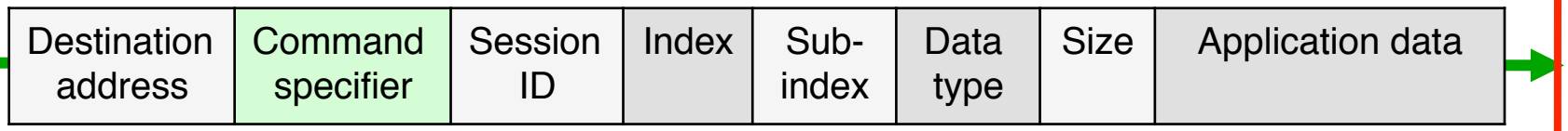
Destination address	Description
00_h	Broadcast (to all nodes)
01_h to $7F_h$	Unicast (to node with indicated node-ID)
80_h to FF_h	Multicast (to some nodes part of indicated group)

Expedited USDO download

Client

Server

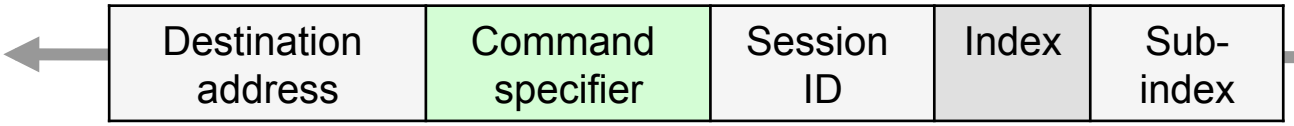
USDO download request



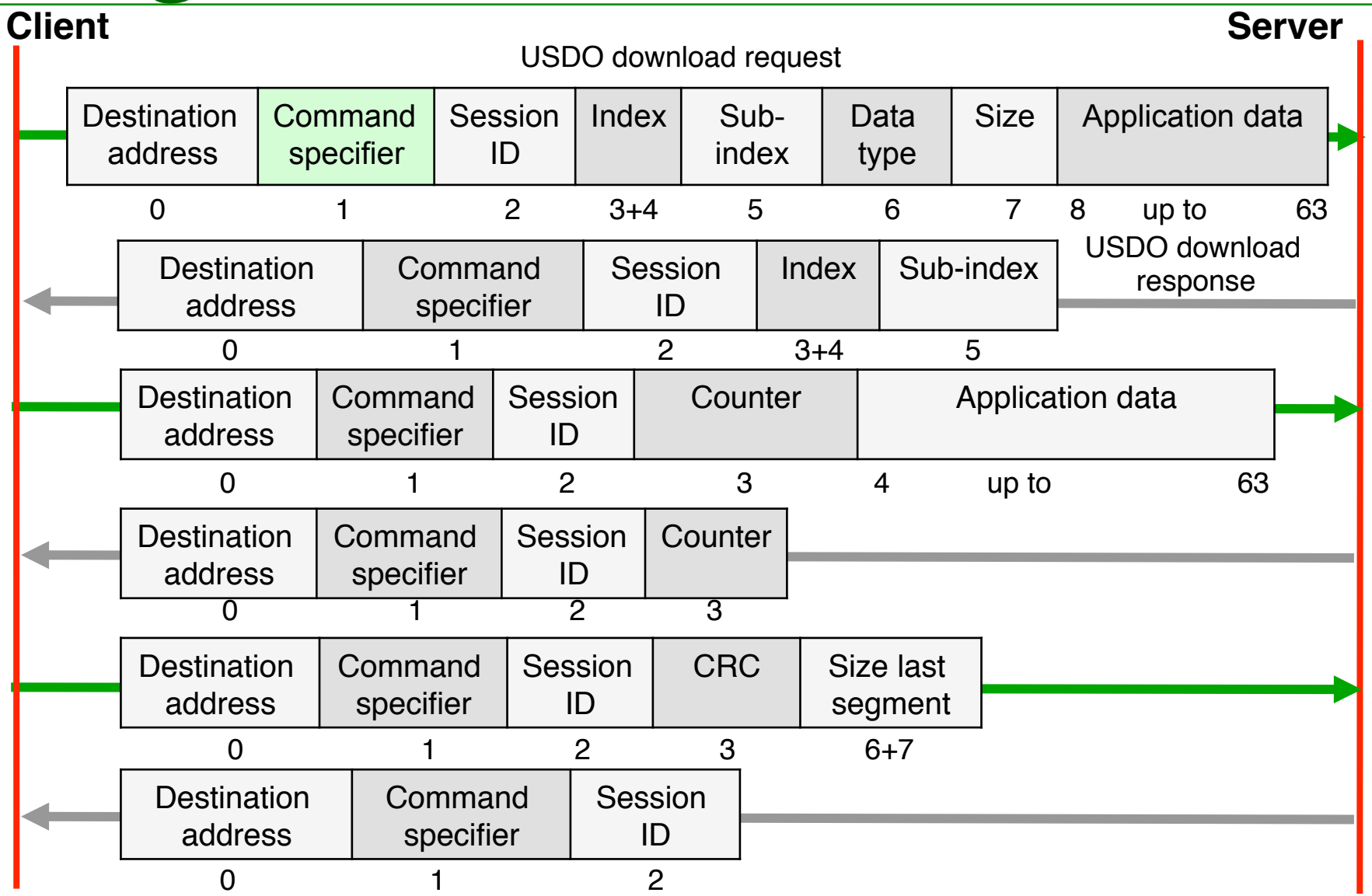
Command specifier	Description
01/02	Client/Server CS upload expedited (single frame)
03/04	Client/Server CS download expedited (single frame)

up to 63

USDO download response



Segmented USDO download

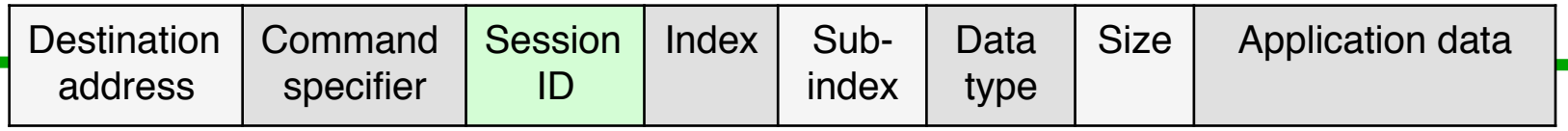


USDO Session ID

Client

Server

USDO download request



The Session ID:

- Identifies exactly one USDO transfer between one USDO server and one USDO client
- Is equal in all transactions of exactly one USDO transfer
- Differs for all currently running USDO transfers of one USDO clients to the very same USDO server
- Enables several parallel USDO accesses from one USDO client to the very same USDO server

USDO download response

USDO data type information

Client

Server

USDO download request

Destination address	Command specifier	Session ID	Index	Sub-index	Data type	Size	Application data
0	1		2	3+4	5	6	7 8

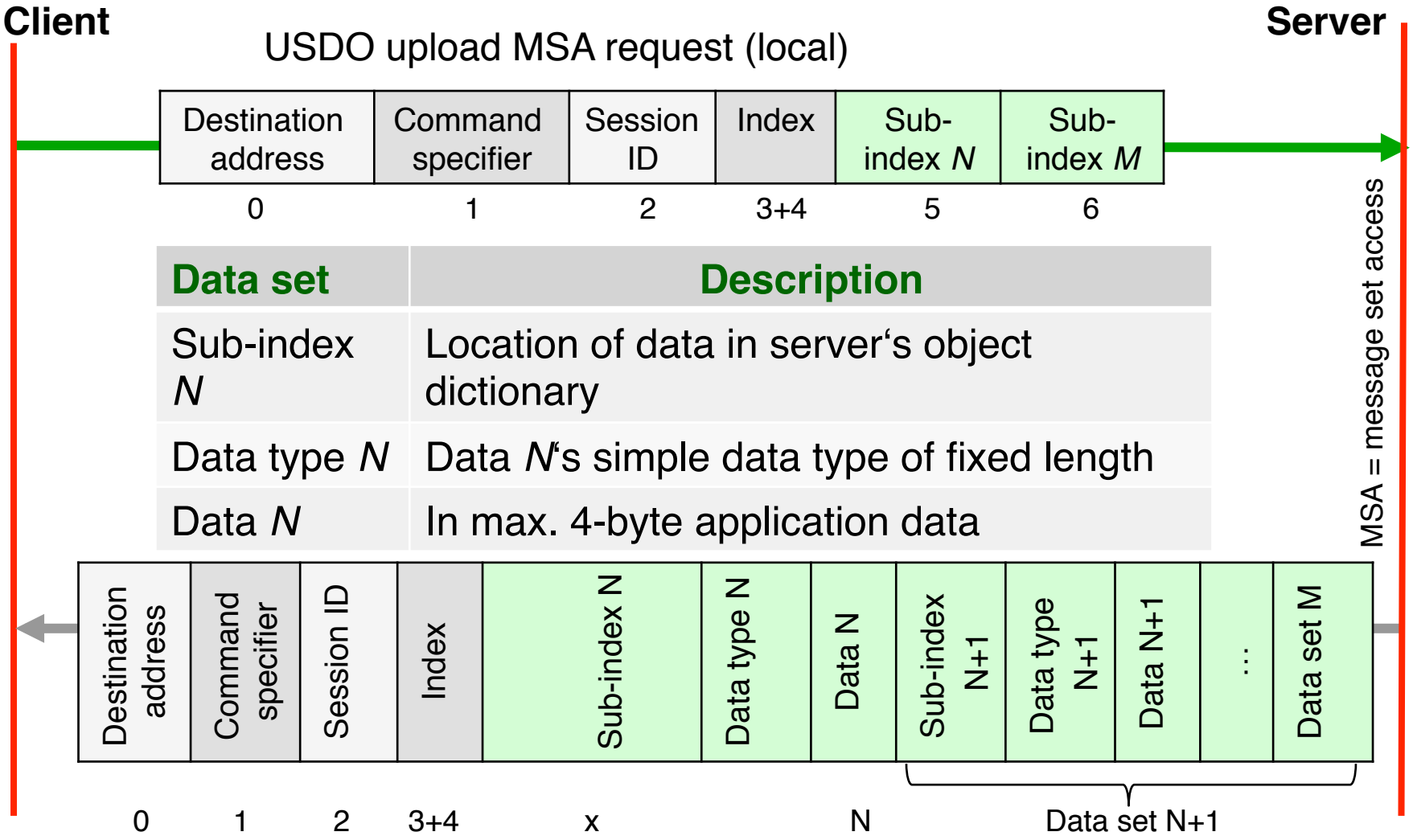
Data type	Description
01	Boolean
02	Integer8
03	Integer16
04	Integer32
...	Further simple CANopen data types according to CiA 301

up to 63

USDO download response

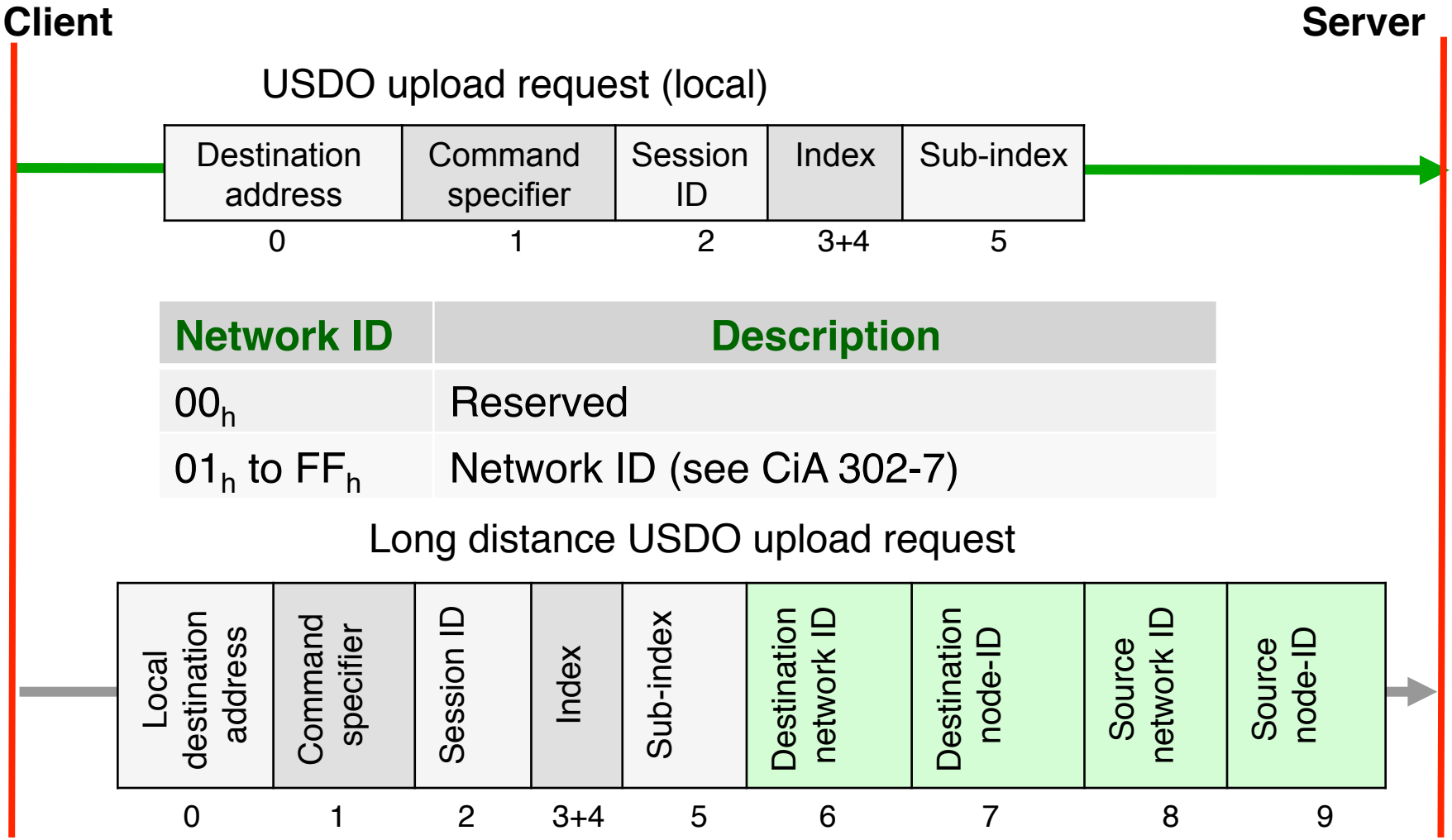
Destination address	Command specifier	Session ID	Index	Sub-index
0 5	1		2	3+4

MSA USDO upload (future)



Data set	Description
Sub-index *N*	Location of data in server's object dictionary
Data type *N*	Data *N*'s simple data type of fixed length
Data *N*	In max. 4-byte application data

Long distance USDO upload

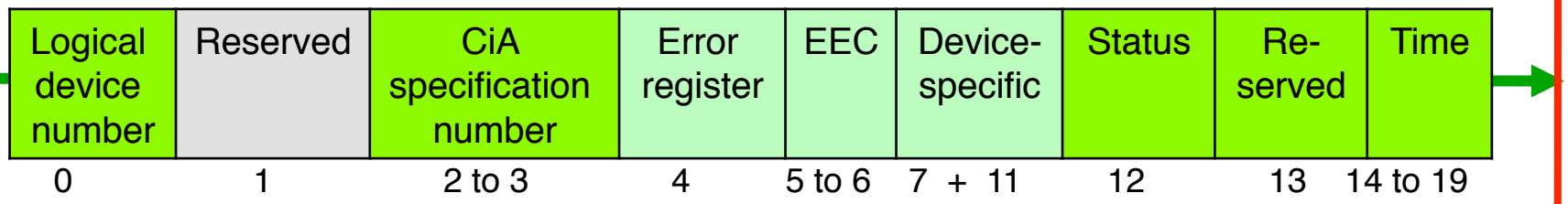


Network ID	Description
00_h	Reserved
01_h to FF_h	Network ID (see CiA 302-7)

EMCY write protocol

Producer **Consumer**

Legacy EMCY



Bit field	Description
Logical device number	Entire CANopen device or logical device to which the error is related to.
CiA specification number	Number of CiA specification that specifies the EEC.
Error register	Current content of object 1001_h.
EEC	Emergency error code, defined by CiA specification.
Device-specific	Profile- or manufacturer-specific error information
Status	Type of error (e.g. recoverable/non recoverable)
Time	Time information, based on the TIME_OF_DAY
Reserved	Always 0. Reserved for future use by CiA.

CAN XL: Requirements

- *Payload length:* As large as Ethernet frames
- *Reliability:* Equal or better than Classical CAN, CAN FD, and 10-Mbit/s Ethernet
- *Robustness:* As good as CAN FD, and better than 10-Mbit/s Ethernet
- *Bitrate:* 10+ Mbit/s in the data (high-speed) phase, up to 1 Mbit/s in the nominal (low-speed) phase
- Backwards compatibility with CAN FD

CAN XL frame format

LS phase		HS phase						LS phase	
Priority ID	XL	ADS	DLC	HCRC	Payload	FCRC	DAS	ACK	EOF
11 bit	? bit	? bit	11 bit	? bit	2048 byte	? bit	? bit	? bit	? bit

- Header CRC (HCRC): Hamming distance of 6, fixed stuff-bits
- Frame CRC (FCRC): Hamming distance of 6, to be decided, if just the HCRC is protected
- Retransmission can be enabled (for legacy applications) or disabled (for periodically transmitting nodes and for confirmed transmission)
- ACK: Introduction of a NACK bit is under discussion
- Payload: Maximum Ethernet frames (2000 byte) can be tunneled (space-holders for safety and security are under discussion)
- Number of stuff-bits can be less than in CAN FD (e.g. each 15th bit)

Planned CiA specifications

- CiA 610-1: CAN XL – Specifications and test plans – Part 1: Data link layer and physical signaling requirements
- CiA 610-2: CAN XL – Specifications and test plans – Part 2: Data link layer and physical signaling conformance test plan
- CiA 610-3: CAN XL – Specifications and test plans – Part 3: Physical media attachment sub-layer requirements
- CiA 610-4: CAN XL – Specifications and test plans – Part 4: Physical media attachment sub-layer conformance test plan
- CiA 610-5: CAN XL – Specifications and test plans – Part 5: Media independent interface requirements
- CiA 610-6: CAN XL – Specifications and test plans – Part 6: Media independent interface conformance test plan
- CiA 610-7: CAN XL – Specifications and test plans – Part 7: Higher-layer function requirements
- CiA 610-8: CAN XL – Specifications and test plans – Part 8: Higher-layer function conformance test plan

iCC 2020 (March 17 + 18)

- Official CAN XL technology launch in Baden-Baden (Germany)
- Several papers on CAN XL topics (DLL, PHY, and HLPs)
- First hardware prototypes at tabletop exhibition