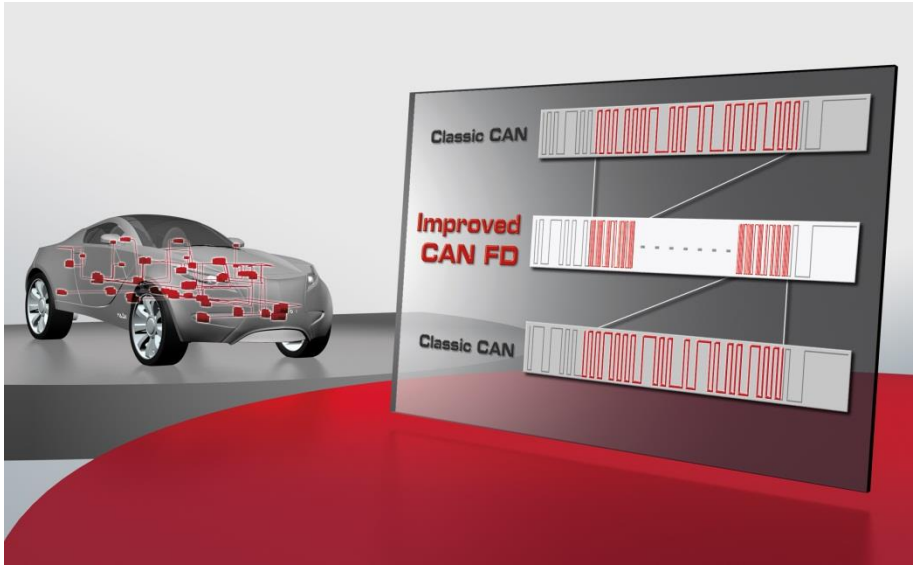
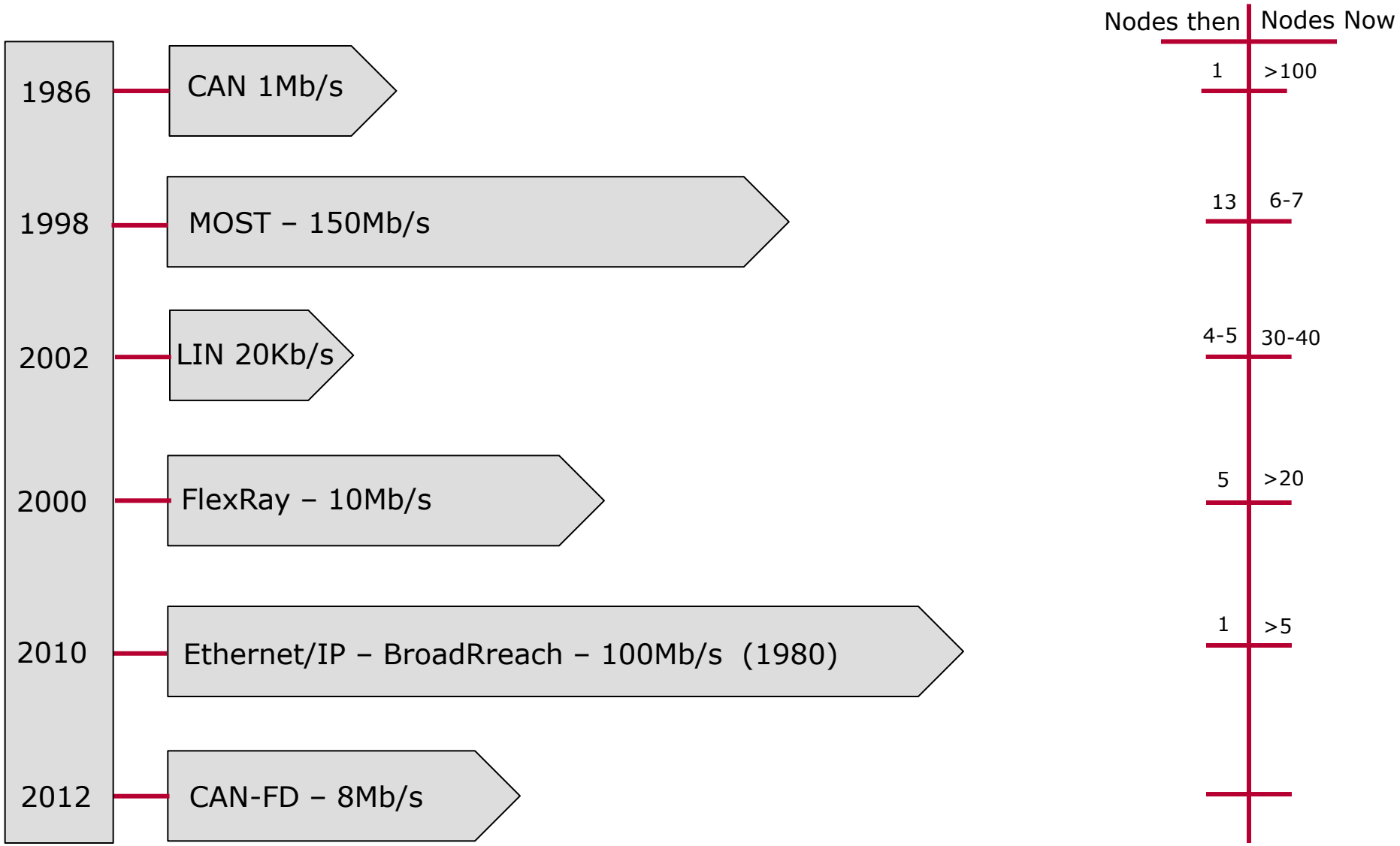


New Network Technologies & Challenges for the Future - FlexRay, CAN FD, IP

Tariq Javaid

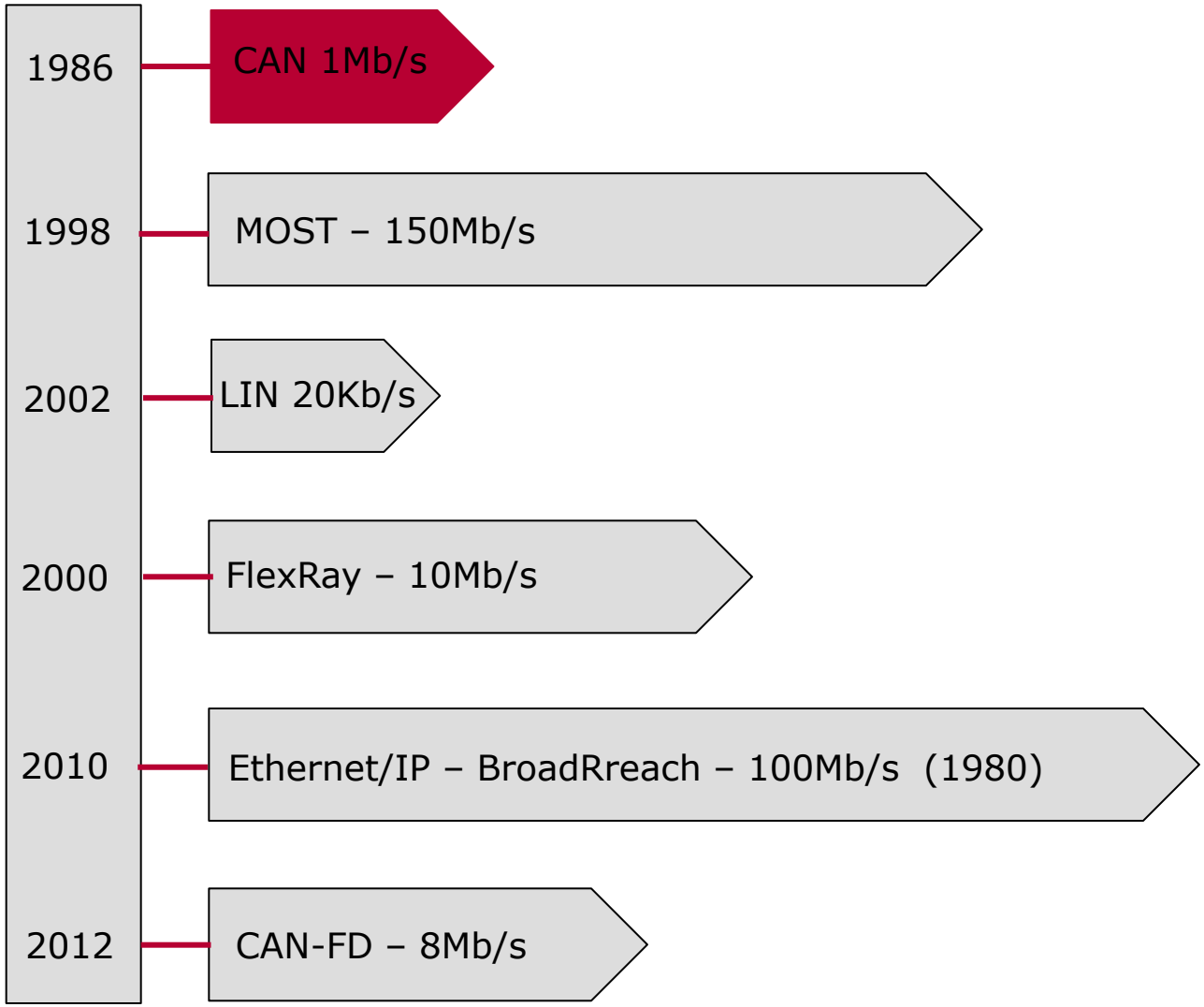
© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Automotive Networks



© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Automotive Networks

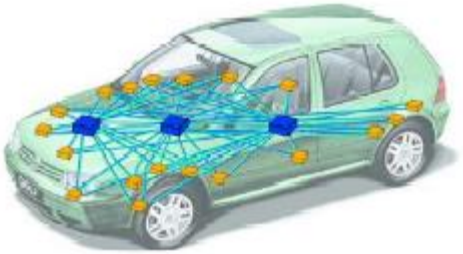


© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Why CAN?

Point-to-point networking

Each unit of information to be transported is allocated to a communication channel in the form of an electrical wire.



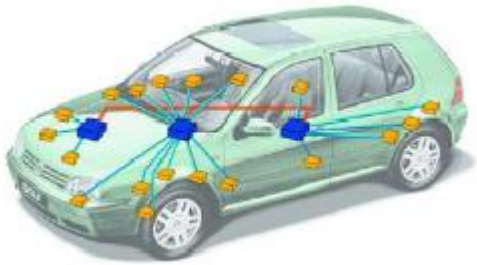
With growing demands for communication, point-to-point wiring leads to enormous wiring expense with the following primary consequences:

- High complexity and susceptibility to errors
- High cost and effort
- Space and weight problems

Bus networking

All information is transported over a single medium (bus).

→ All ECUs share the bus

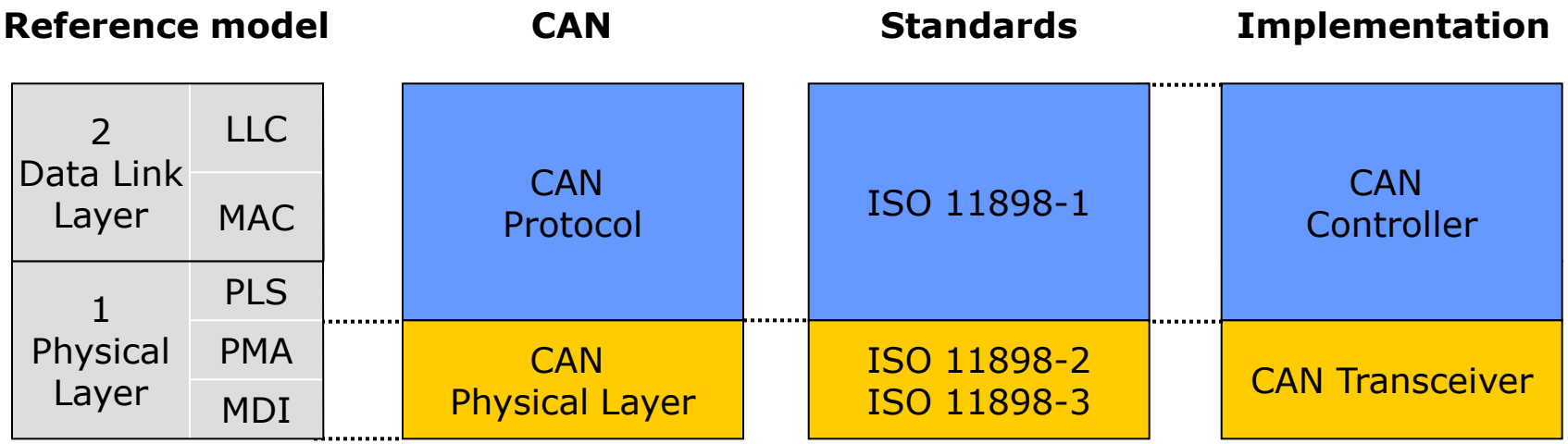


The transition from point-to-point networking to bus networking offers advantages that include:

- Reduced complexity and susceptibility to errors
- Reduced cost and effort
- Reduced space/weight requirements

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

CAN Standard & Implementation

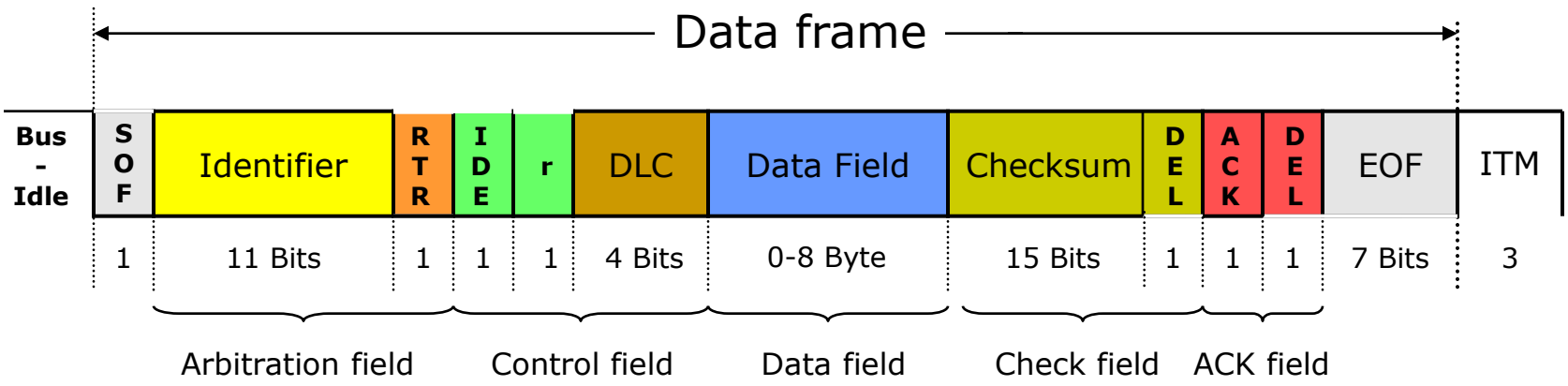


- ISO 11898-1: CAN Protocol (Event triggered)
- ISO 11898-2: High-Speed Physical Layer (up to 1 MBaud)
- ISO 11898-3: Low-Speed Physical Layer (up to 125 KBaud)

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

CAN Data Frame

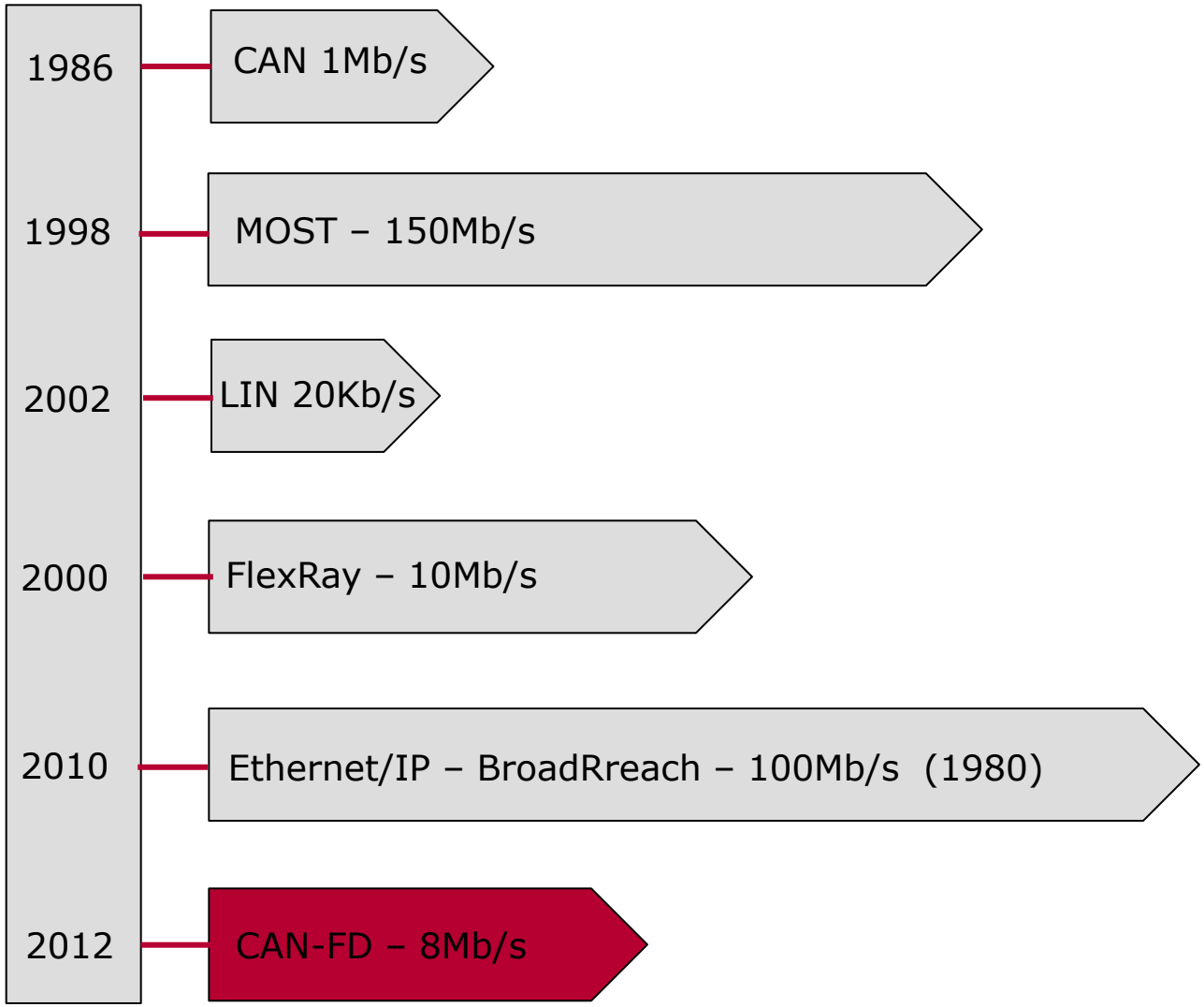
Structure



- **SOF** Start Of Frame
- **RTR** Remote Transmission Request
- **IDE** Identifier Extension
- **DLC** Data Length Code
- **ACK** Acknowledgement
- **EOF** End Of Frame

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Automotive Networks



© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Why CAN FD?

CAN networks reached practical maximums of data transfer

- Many CAN buses have reached 50%-95%+ bus load level
- CAN messages contain ≥50% overhead
  - Standard CAN 111 bits/message for 64 bits of data*
  - Extended CAN 131 bits/message for 64 bits of data*
- At most, only ~40-50% of the bandwidth is used to exchange useful data

- Current CAN bus speeds ≤ 1Mbit/s
  - Limited by physical characteristics of in-vehicle wiring
    - Most auto networks ≤ 500Kbit/s
    - J1939 networks = 250Kbit/s (500Kb/s under consideration)

* - excluding stuff bits

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Why CAN FD?

- Maximal CAN bus speed limited due to the In-Frame Response (IFR) mechanism
- ACK generation delay in CAN controller
  - Propagation delay through the transceiver
  - Propagation delay over wire

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

What is CAN FD?

Improved CAN protocol

- CAN FD is a serial communications protocol based on CAN 2.0
- Two new features added:
  - Support dual bit rates within a message
    - Arbitration-Phase – same bit rate as standard CAN
    - Data-Phase – bit rates higher than 1 Mb/s are possible (up to ~8 Mb/s)
  - Support larger data lengths than “classic” CAN
    - Up to 64 bytes/message

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

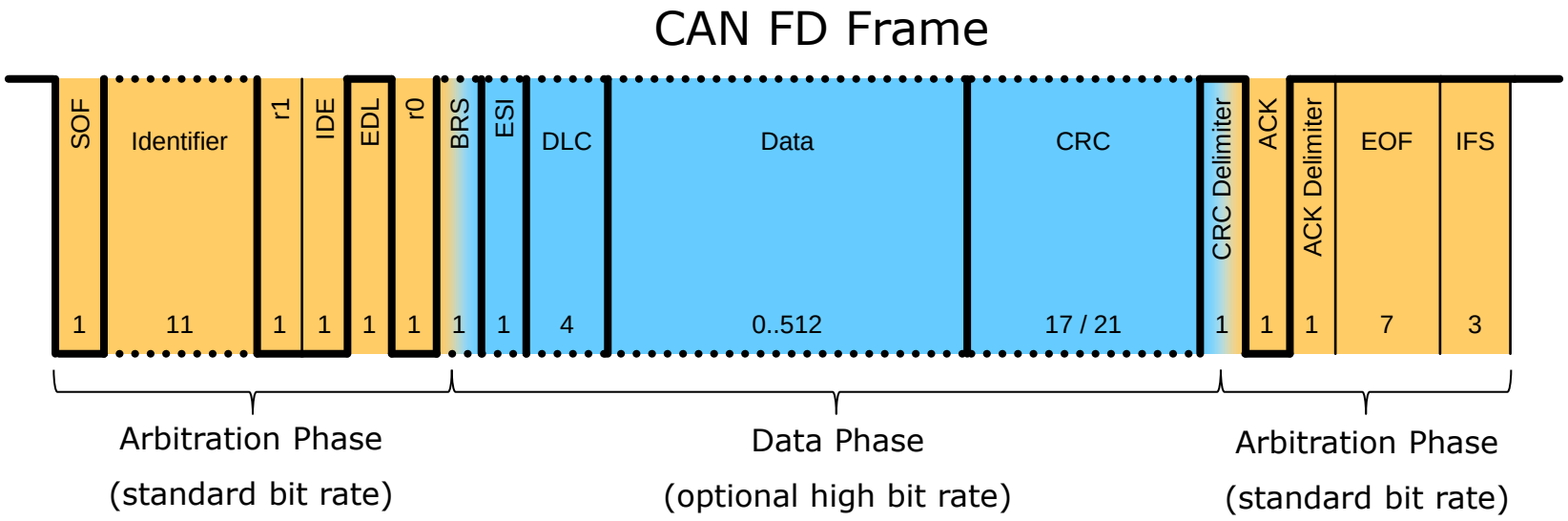
What is CAN FD?

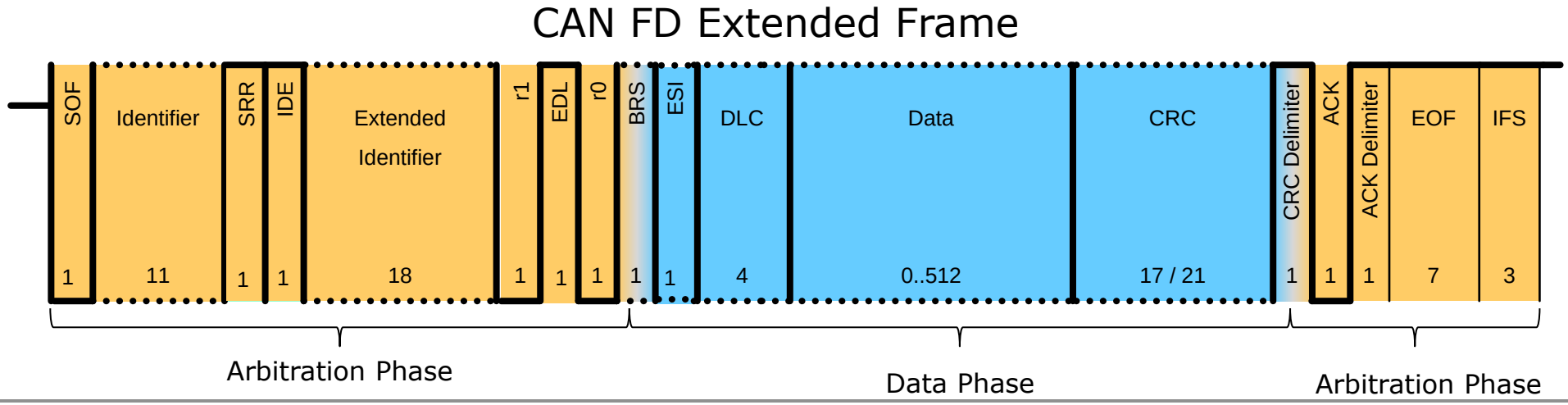
- Differences from CAN to CAN FD are limited to controller hardware
  - Existing CAN transceivers usable up to 2-8 Mbit/s
    - Component re-qualification unnecessary
  - Legacy SW usable
    - Data fields up to 8 bytes in length
  - Well known technology: Event-Triggered system
- System cost similar to standard CAN
  - Controller, crystal, transceiver, node interconnection cost

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

CAN FD Frame

- Consist of two phases – *Arbitration phase* and *Data phase*



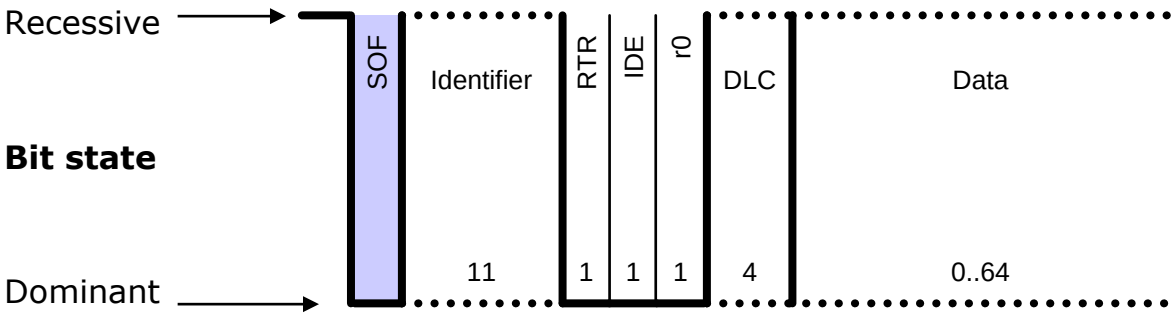


© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

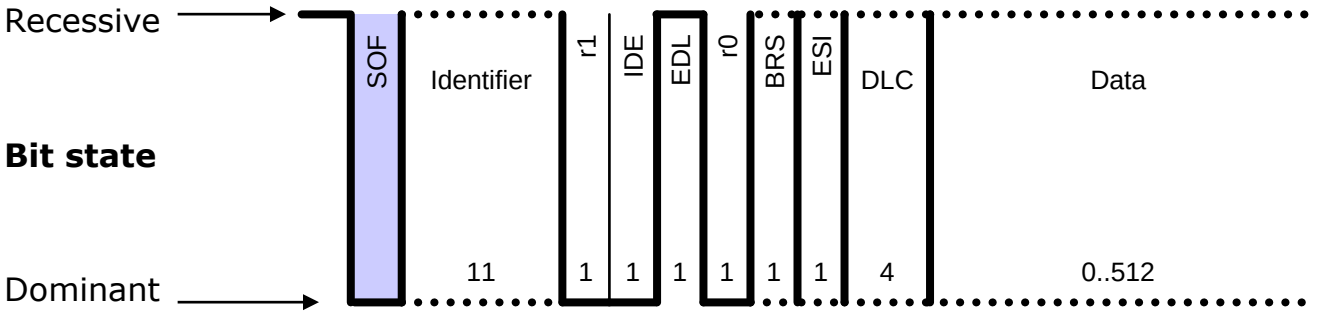
Start of Frame

- CAN and CAN FD use the same SOF – a single “dominant” bit

CAN frame



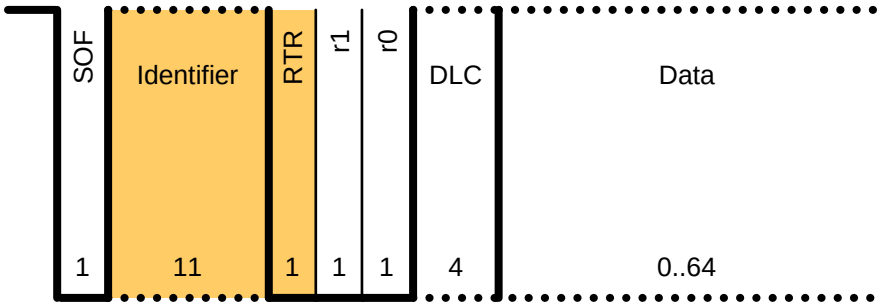
CAN FD frame



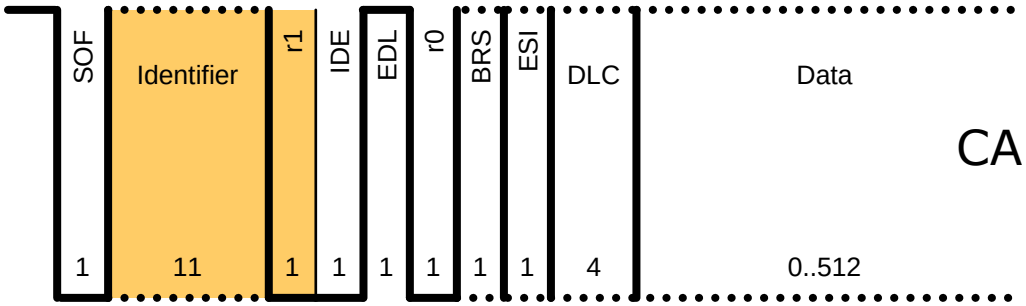
© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Arbitration Field

- Little difference between CAN and CAN FD arbitration fields
  - Both share the same addressing for Standard and Extended formats
  - CAN FD removes the RTR bit and maintains an always dominant r1 bit



CAN frame

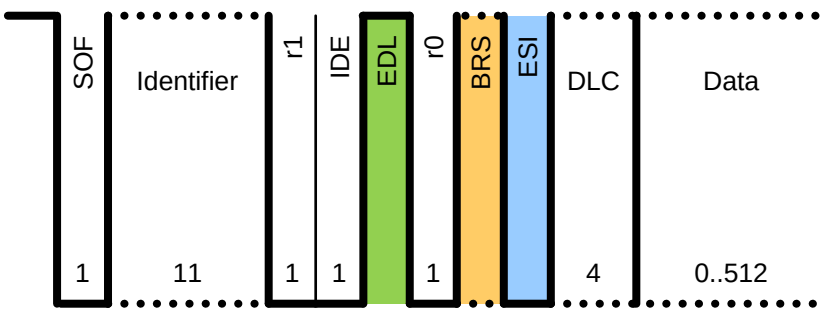


CAN FD frame

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Control Field

- CAN and CAN FD share the following bits:
  - IDE, r0 and the DLC bits



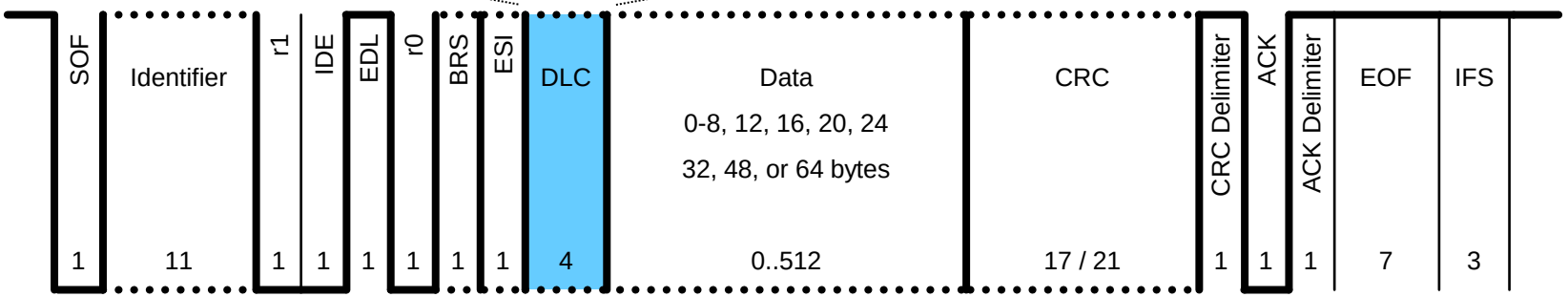
- CAN FD adds the following bits to the control field :
  - EDL – Extended Data Length
    - Determines if CAN (dominant) or CAN FD (recessive)
  - BRS – Bit Rate Switch
    - Separates Arbitration phase from Data phase in CAN FD
    - Clock rate switches when BRS is recessive
  - ESI – Error State Indicator (error active/passive)

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Control Field

- Data Length Code (DLC)
  - 4 bits used for both formats
    - For lengths ≥ 8, CAN FD uses the following DLCs:

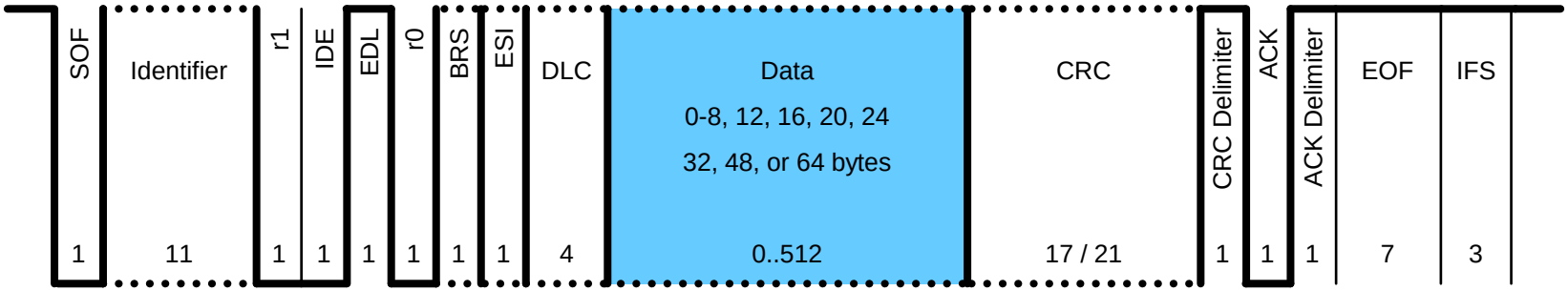
1000 = 8	1100 = 24
1001 = 12	1101 = 32
1010 = 16	1110 = 48
1011 = 20	1111 = 64



© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

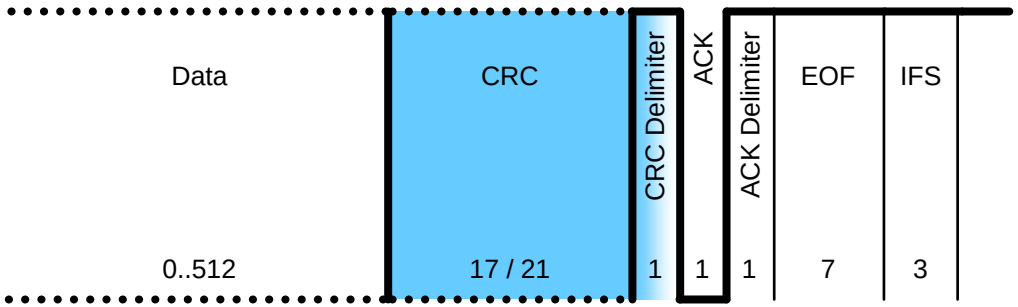
Data Field

- 0-8 bytes in CAN
- 0-8, 12, 16, 20, 24, 32, 48, or 64 bytes in CAN FD
- No data field if DLC = 0



© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

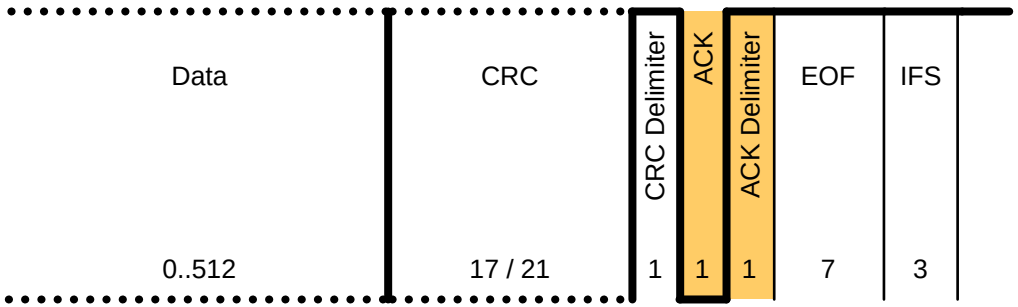
CRC Field



- Size of CRC differs based on CAN/CAN FD and length of DLC
  - 15 bits for CAN
  - 17 bits for CAN FD where data field ≤ 16 bytes
  - 21 bits for CAN FD where data field > 16 bytes
- Preceding stuff bits are included in the CAN FD CRC calculation
  - CAN does not use stuff bits in the CRC calculation
- CAN FD CRC delimiter transmitted as 1 bit, but due to phase shift, etc. receiver can accept delimiter of up to 2 bit times
  - Data Phase of CAN FD frame ends with the sample point of the first bit of the CRC delimiter

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

ACK Field



- ACK sent at the end of the CRC delimiter bit
- Slight difference in the format between CAN and CAN FD
  - CAN FD receiver recognizes up to two bit times as a valid ACK
    - 1 extra bit time allowed to compensate for transceiver phase shift and bus propagation delay due to the switch from a high data phase clock to a low arbitration phase clock

End of Frame

- Frames are delimited by a group of 7 recessive bits

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

CAN FD Controller

- Controller allows for dynamic switching between CAN – CAN FD
- Four Frame Formats:
  - CAN standard format – 11 bit identifier and fixed bit rate
  - CAN extended format - 29 bit identifier and fixed bit rate
  - CAN FD standard format – 11 bit identifier and dual bit rate
  - CAN FD extended format - 29 bit identifier and dual bit rate

- Error Frame:
  - Identical to CAN error frame
  - Error frame is always sent with arbitration bit rate
  - Controller switches automatically to arbitration bit rate

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

CAN FD Controller

- Remote Frame:
  - Remote frame in CAN standard format & in CAN extended format
  - Remote frames are **undefined** in CAN FD format
    - RTR bit removed from CAN FD bit-stream

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

CAN FD Performance

- Basic calculation principles:
  - Stuff bits excluded
  - Max CAN frame with 111 bits
  - Max CAN FD frames with 116/568 bits

Frame Type	No. Data-Bytes	Arb. Bit-Rate	Opt. Bit-Rate	Avg. Bit-Rate	Frame Duration
CAN	8	1 Mbit/s	-		111 us
CAN FD	8	1 Mbit/s	4 Mbit/s	2.3 Mbit/s	50.75 us
CAN FD	8	1 Mbit/s	8 Mbit/s	2.9 Mbit/s	39.875 us
CAN FD	64	1 Mbit/s	4 Mbit/s	3.5 Mbit/s	163.75 us
CAN FD	64	1 Mbit/s	8 Mbit/s	5.9 Mbit/s	96.375 us

- **CAN FD can decrease bus loading significantly**
- **Data/Overhead ratio increases for 64 byte significantly**

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

CAN FD Hardware

- CAN FD qualified transceiver roadmap announced
- MCU sample silicon with full CAN FD support available in 2013
  - Roadmaps presented from ST, NXP and Freescale during CAN FD Tech Day in Detroit (18th October 2012)
- Other semiconductor manufacturers are in preparation

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

CAN FD Standardization

- CAN ISO standardization
  - CAN FD integrated into existing ISO 11898**-1** **->** start 10/2012
  - Upgrade CAN conformance test ISO16845 **->** in parallel

- CAN FD upgrade for J1939 **->** ongoing

- CAN FD (8 byte) in Autosar 4.1.1 **->** approved
- CAN FD (64 byte) in Autosar **->** in preparation

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

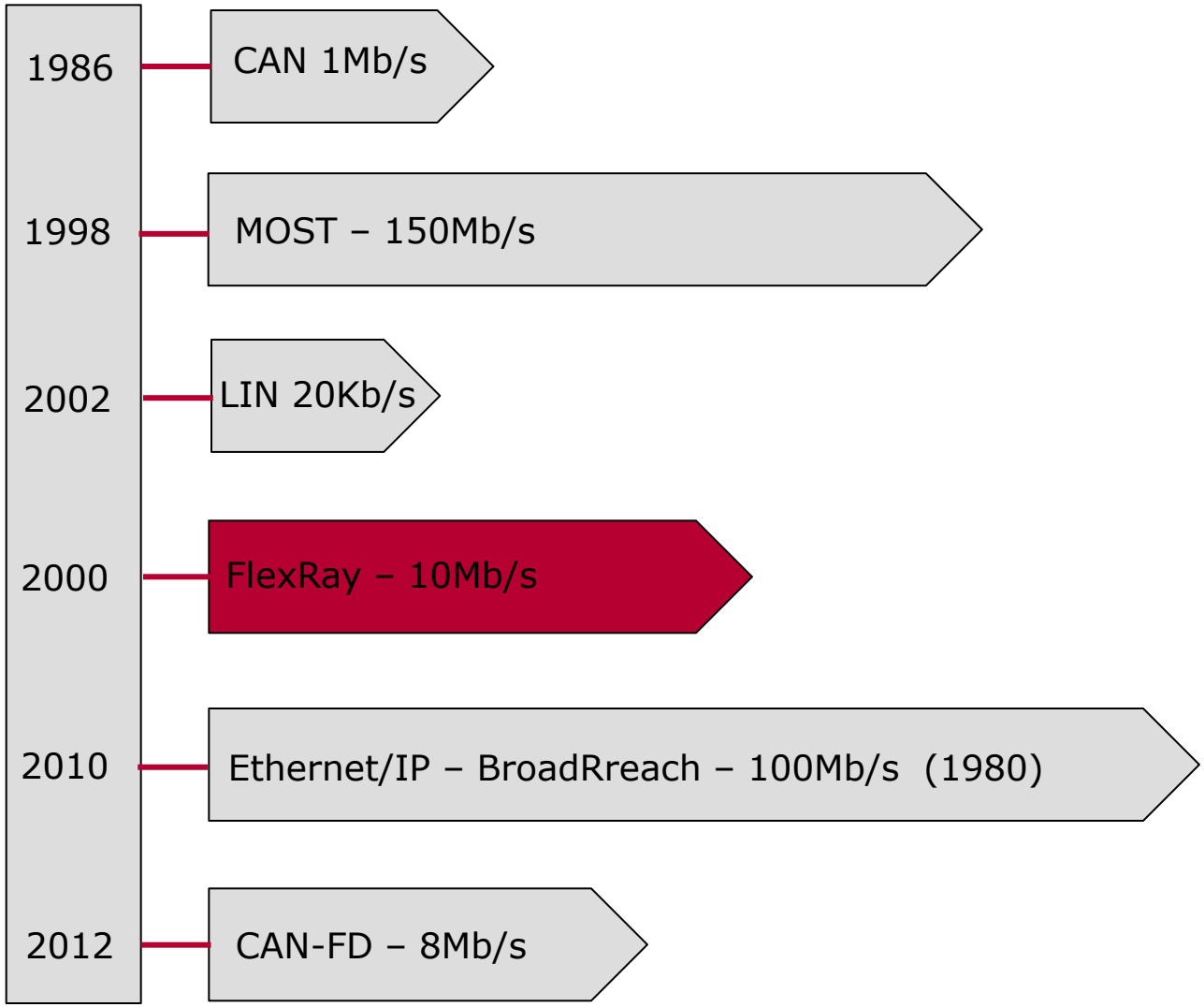
Summary

CAN FD provides a migration path compatible with CAN

- CAN 2.0 nodes and CAN FD nodes can communicate with each other as long as the CAN FD frame format is **not** used
- CAN FD nodes must meet CAN 2.0/ISO 11898-1 specifications
- Concept with mixed CAN – CAN FD networks is possible with the usage of partial network transceivers

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Automotive Networks



© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Why FlexRay?

Requirements and goals

- Transmission rate
  - Currently, requirements for applications in the powertrain and chassis areas lie in the range of 1 to 2 MBit/s.
  - Future bandwidths of 10 MBit/s are desired.
- Scalability
  - A new communication system should permit flexible expansion.
  - The installation or removal of ECUs should not necessitate any re-configuration of parameters.
- Composability
  - The components should fit together smoothly.
  - No changes to the system should be needed afterwards.
- Fault tolerance
  - Import information should be transmitted redundantly.
  - The transmission of information has to be predictable (deterministic).

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Determinism and indeterminism

- Event-driven control
  - Sending times can be influenced by external events.
  - Worst Case: All ECUs try to send at the same time.

    ➔ Indeterminism

Highway

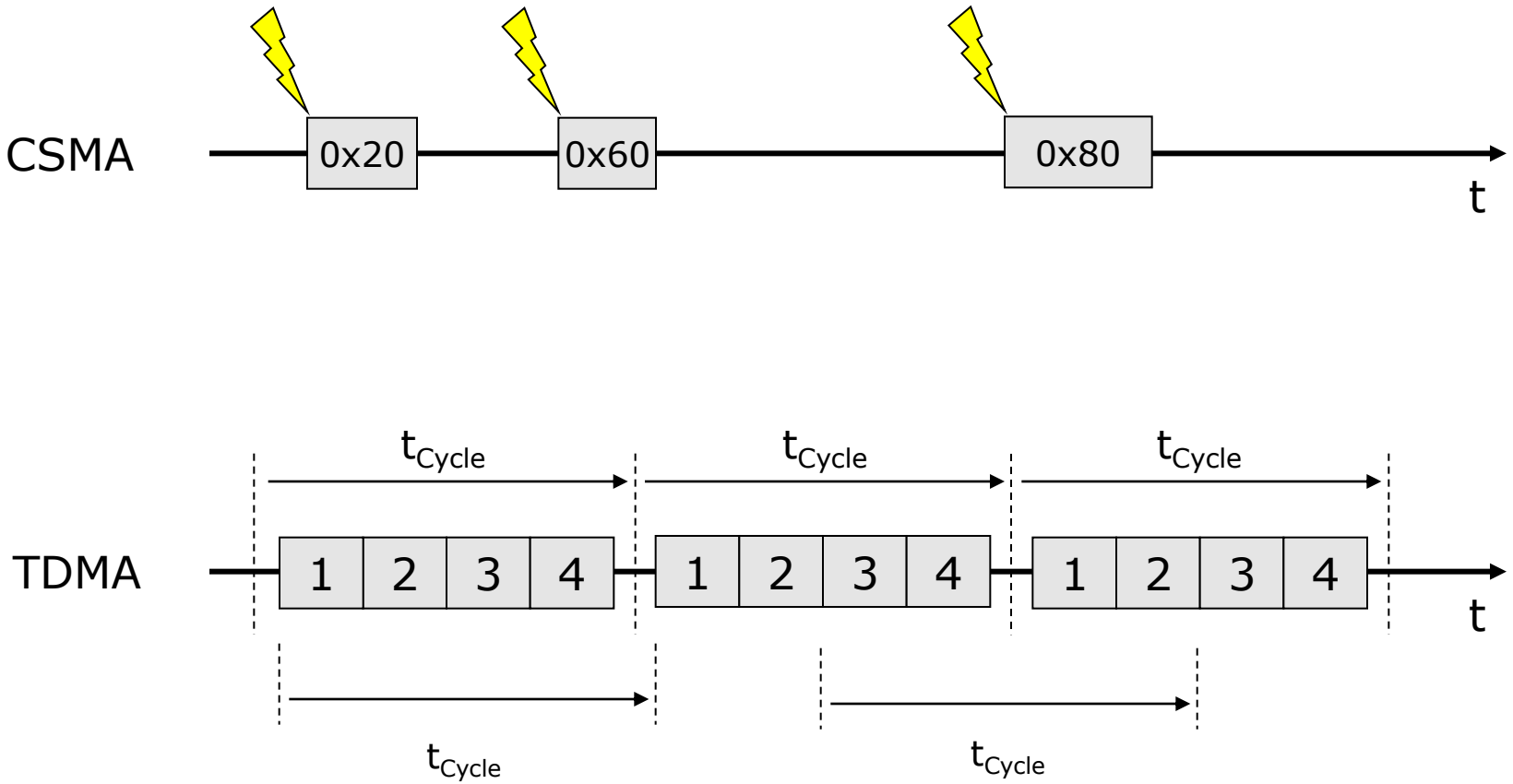
- Time-triggered control
  - Sending time is reserved beforehand and is allocated to an ECU.
  - An ECU starts sending at the same points in time (Schedule).

    ➔ Determinism

Ski lift

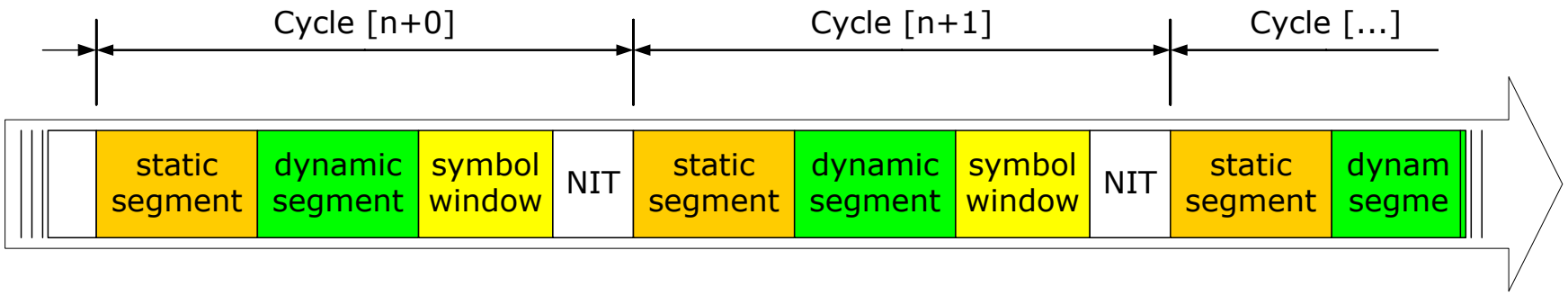
© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Event-triggered vs. time-triggered



© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

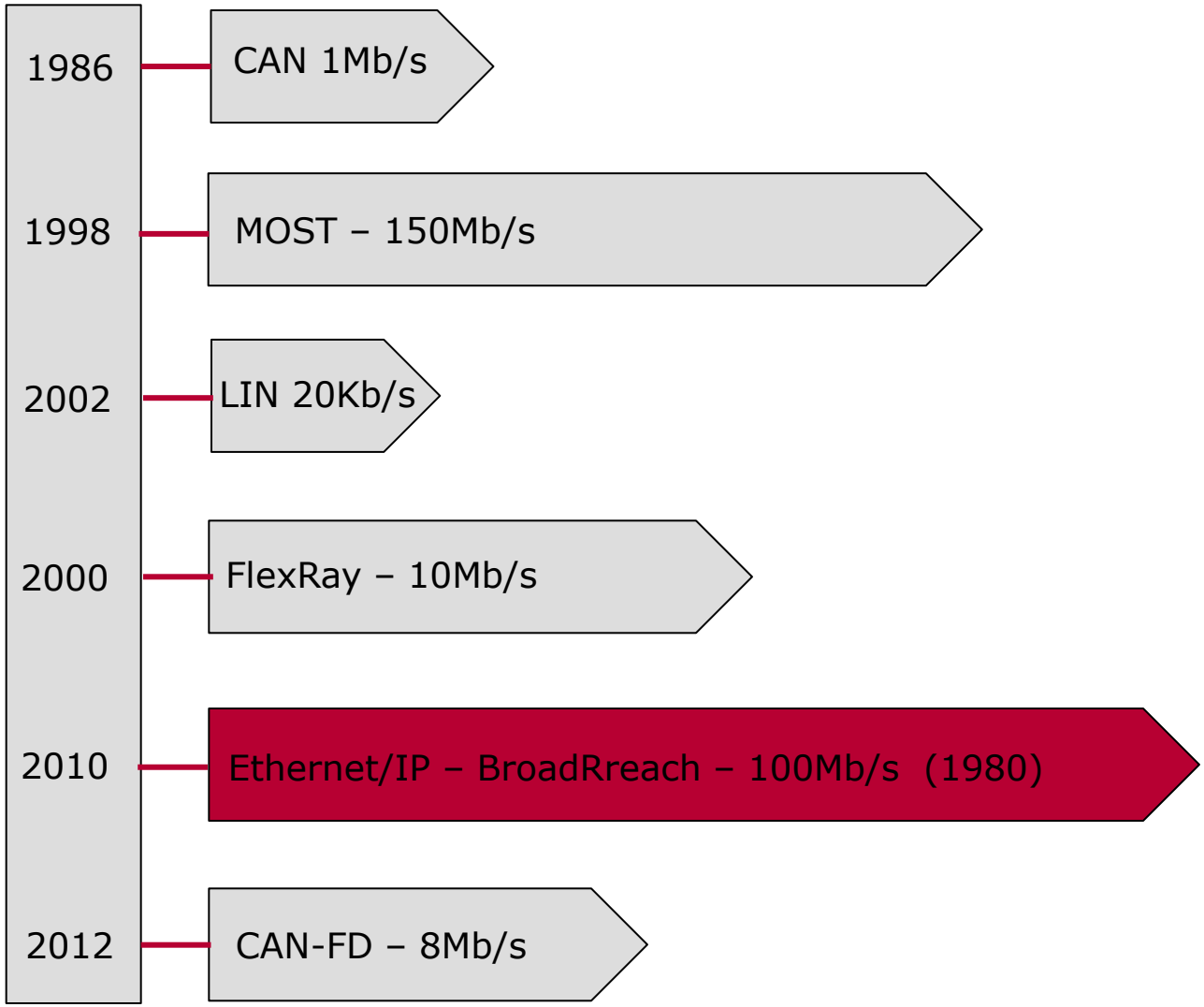
Communication Cycle



- Static Segment
  - Time window for time-synchronous data transfer
  - Bus access with TDMA (**T**ime **D**ivision **M**ultiple **A**ccess)
- Dynamic Segment (optional)
  - Time window for event-driven data transfer
  - Bus access with FTDMA (**F**lexible **T**ime **D**ivision **M**ultiple **A**ccess)
- Symbol Window (optional)
  - Optional window in which a test symbol can be transmitted in each cycle
- NIT: Network Idle Time
  - Time period for synchronization of network nodes

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Automotive Networks



© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Bandwidth Requirements in infotainment

Source – BMW AG

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Why IP?

	Ethernet	MOST
Application	Home, Office, factory, industrial control	Automotive
Standards	IEEE	Proprietary
Medium	POF, Copper	POF
Topology	Ring, hybrid, Star	Ring
Speed	10mb/s – 100gb/s	150mb/s
Volume Production	Billions	Millions
Supplier	Multiple	SMSC
Silicon Cost	Low	High

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Why IP?

- Bandwidth
  - Not limit for a long time (10/100/1000Mbit/s)
  - Fully Duplex
- Scalability/Flexibility
  - IP and Ethernet is separated in different network layers
    - Multiple physical layers available
    - Many protocols
  - Real Time vs. Non Real Time Communication
- Mature Technology
  - Available since 1980
  - Many international standards available

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Why IP?

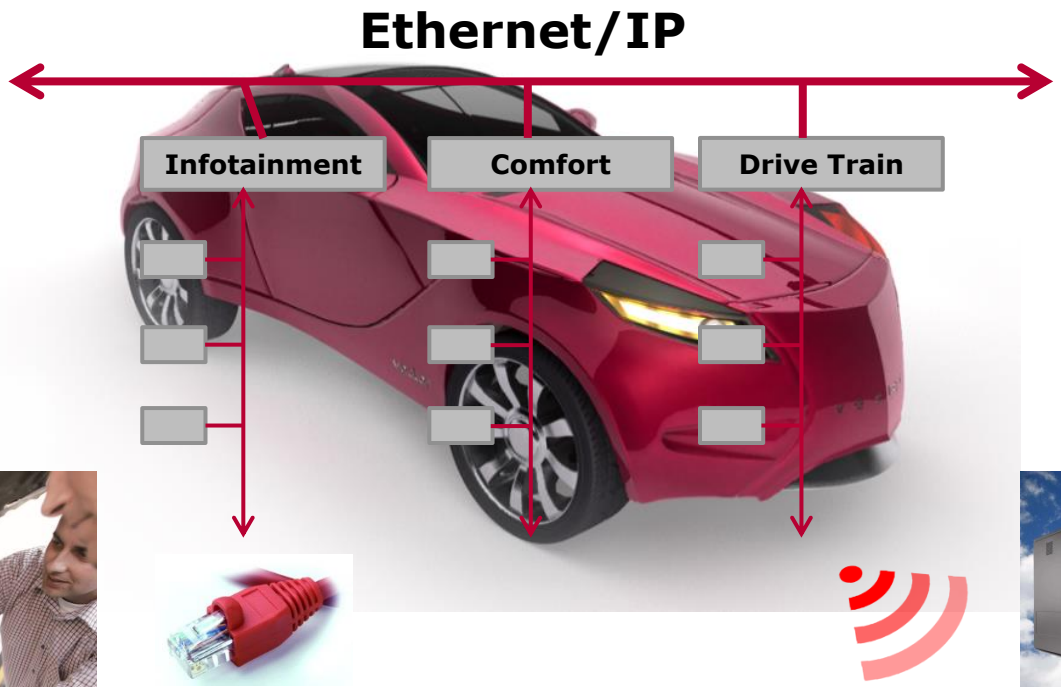
- Availability of BroadR-Reach Physical Layer
  - Full Duplex 100Mbit/s
  - Single Twisted Pair
    - Low cost, easy to handle
  - Unshielded
  - Physical layer available for automotive usage
  - Extended temperature range
  - Organisations
    - http://www.opensig.org/
  - Additional information
    - Broadcom

http://www.broadcom.com/products/Physical-Layer/BroadR-Reach-PHYs

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

IP Application Area

Networking in & outside of the car



Diagnostics/Flashing

Communication b/w Tester and ECU via IP. Fast flash and updates via the OBD Ethernet Interface.

Car in Cloud (Car2X)

Networking with IP-based devices, applications ,other cars and infrastructure .

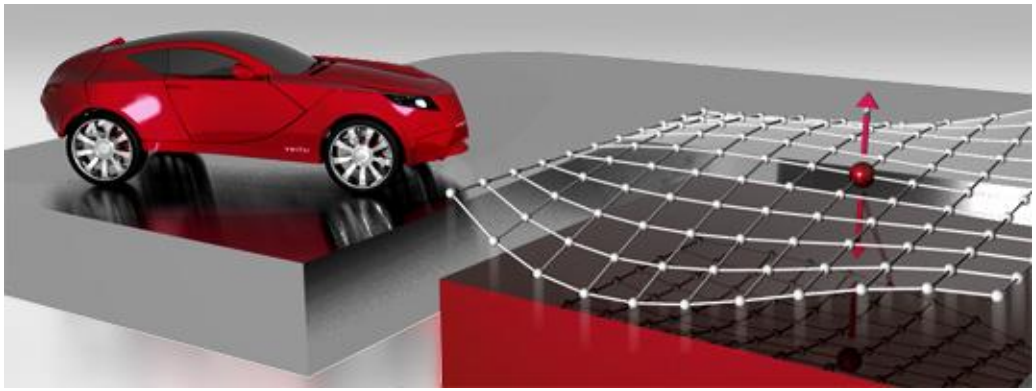
© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

IP Application Areas

High Speed Calibration

- Used for development only
- High bandwidth required
  - 100Mbit/s or 1000Mbit/s
- Low latency required
  - Function bypassing
- Standardized in ASAM MCD-1 XCP

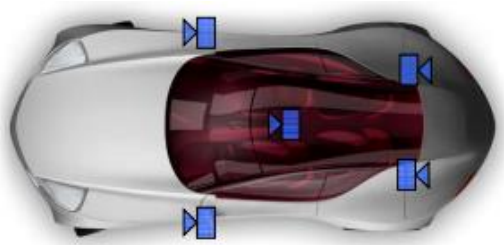
"The Universal Measurement and Calibration Protocol Family"



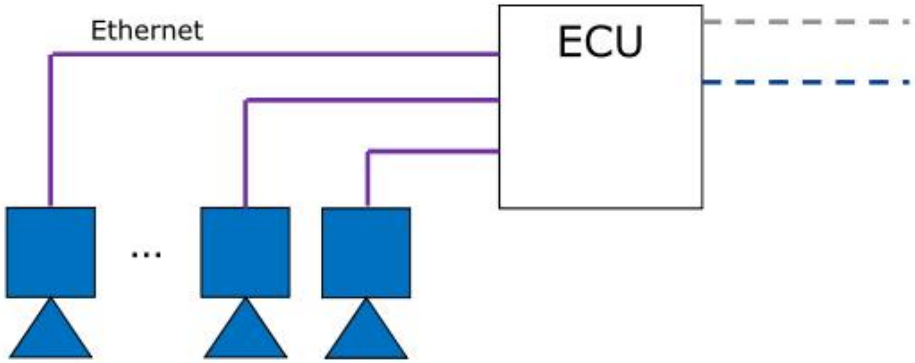
© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

IP Application Areas

Video Camera



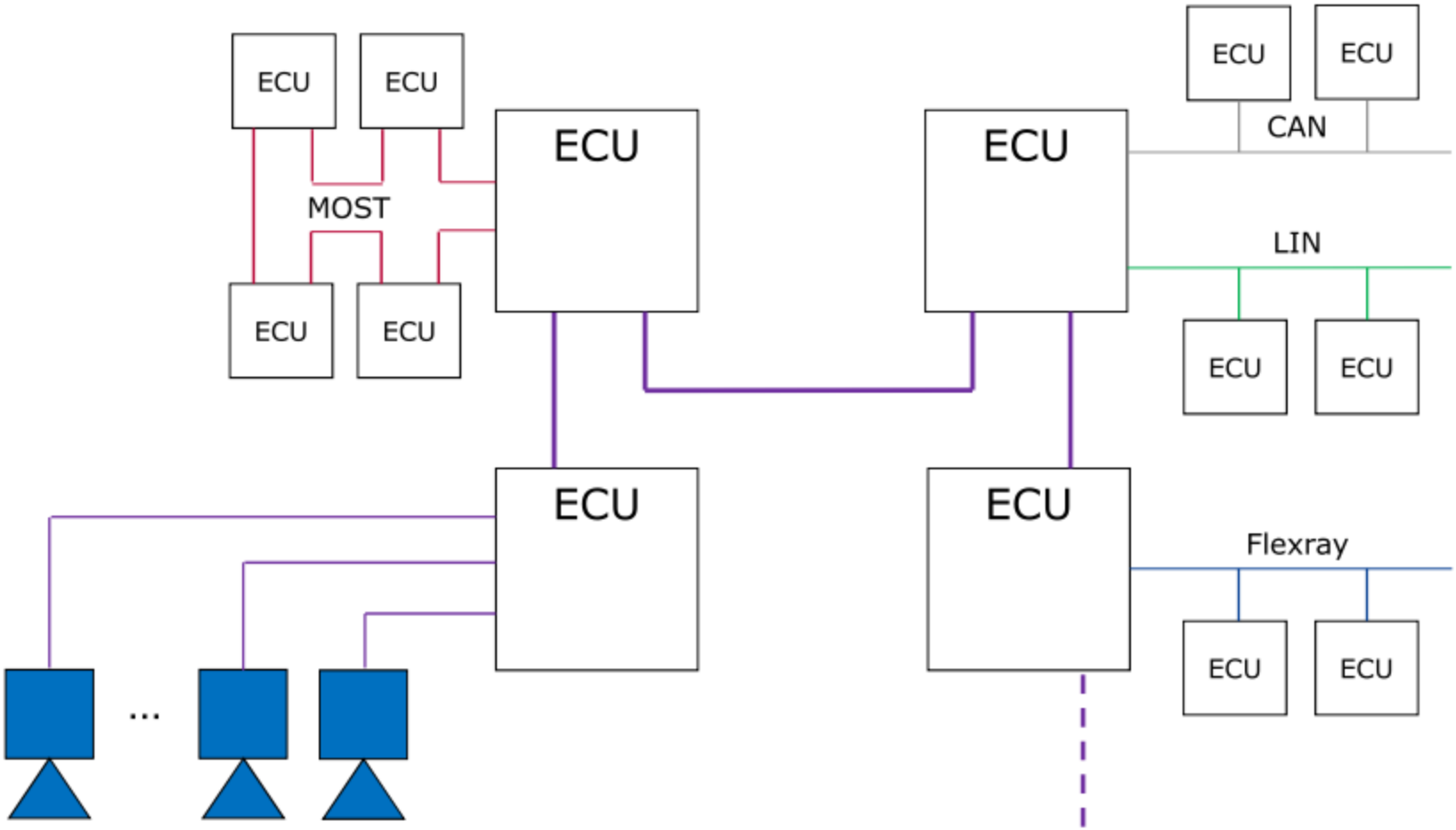
- Replace expensive shielded cable
- Using high bandwidth
- Physical layer
  - Broadcom BroadR-Reach, 100Mbit/s, full duplex, twisted pair
- Streaming on MAC layer level (AVB), time critical



© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

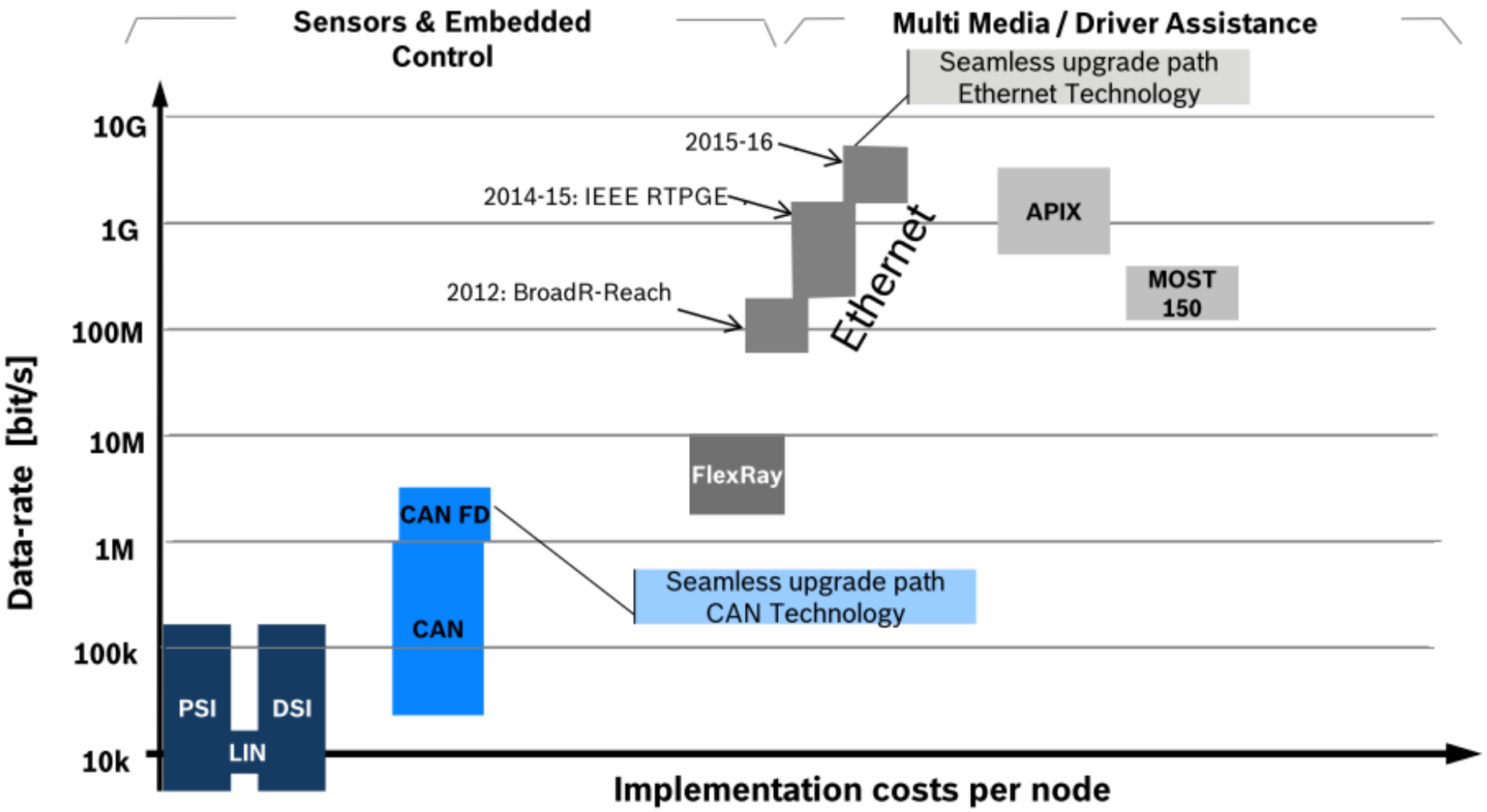
IP Application Areas

Data Backbone



© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Future Communication System Landscape



Source - Bosch

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

CANoe system

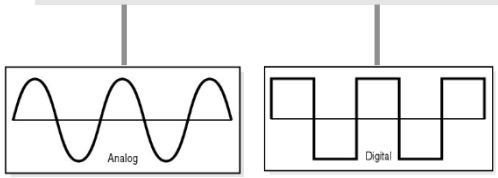
CANoe

Interfaces to acquire digital and analog Signals.

Interfaces to acquire data traffic on the bus.

I/O Interfaces:

- National Instruments
- Keithley
- IOcab
- VT System



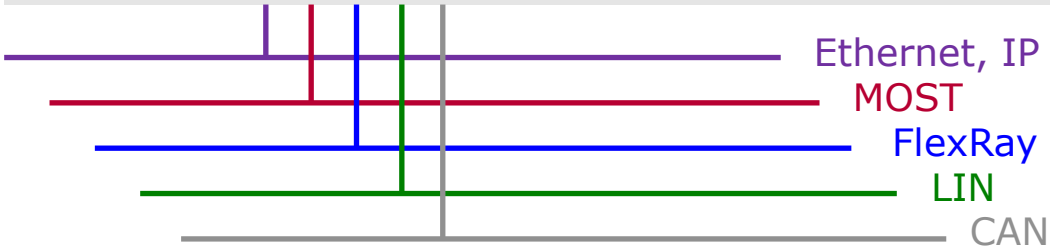
Vector Netzwerk Interfaces:

PCMCIA: CANcardXL

USB: CANcaseXL, VN1610, VN8900

Expresscard: CANcardXLe

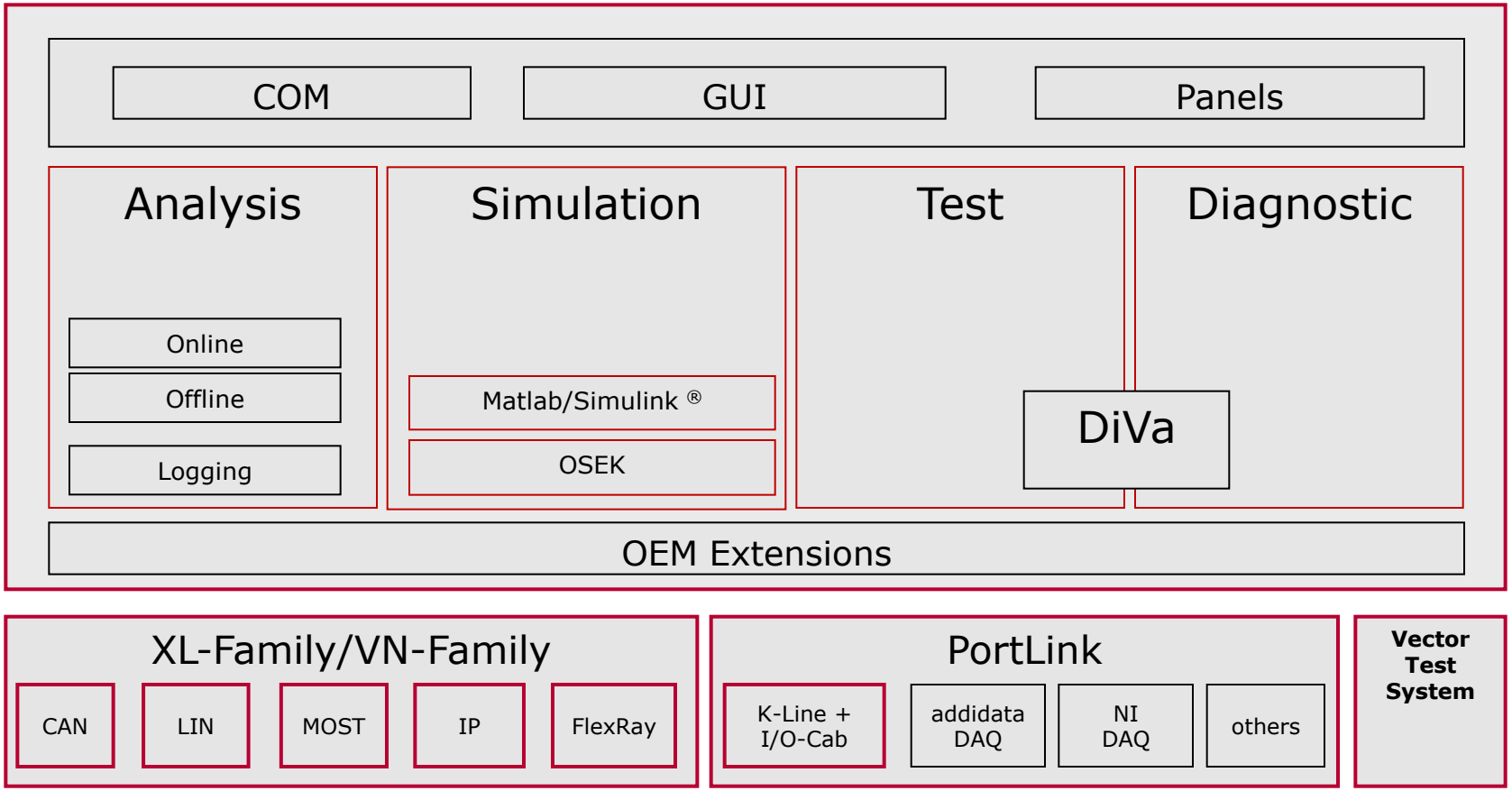
PCI, PXI, PCIe: CANboardXL, VN3300



© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Network Access

CANoe System



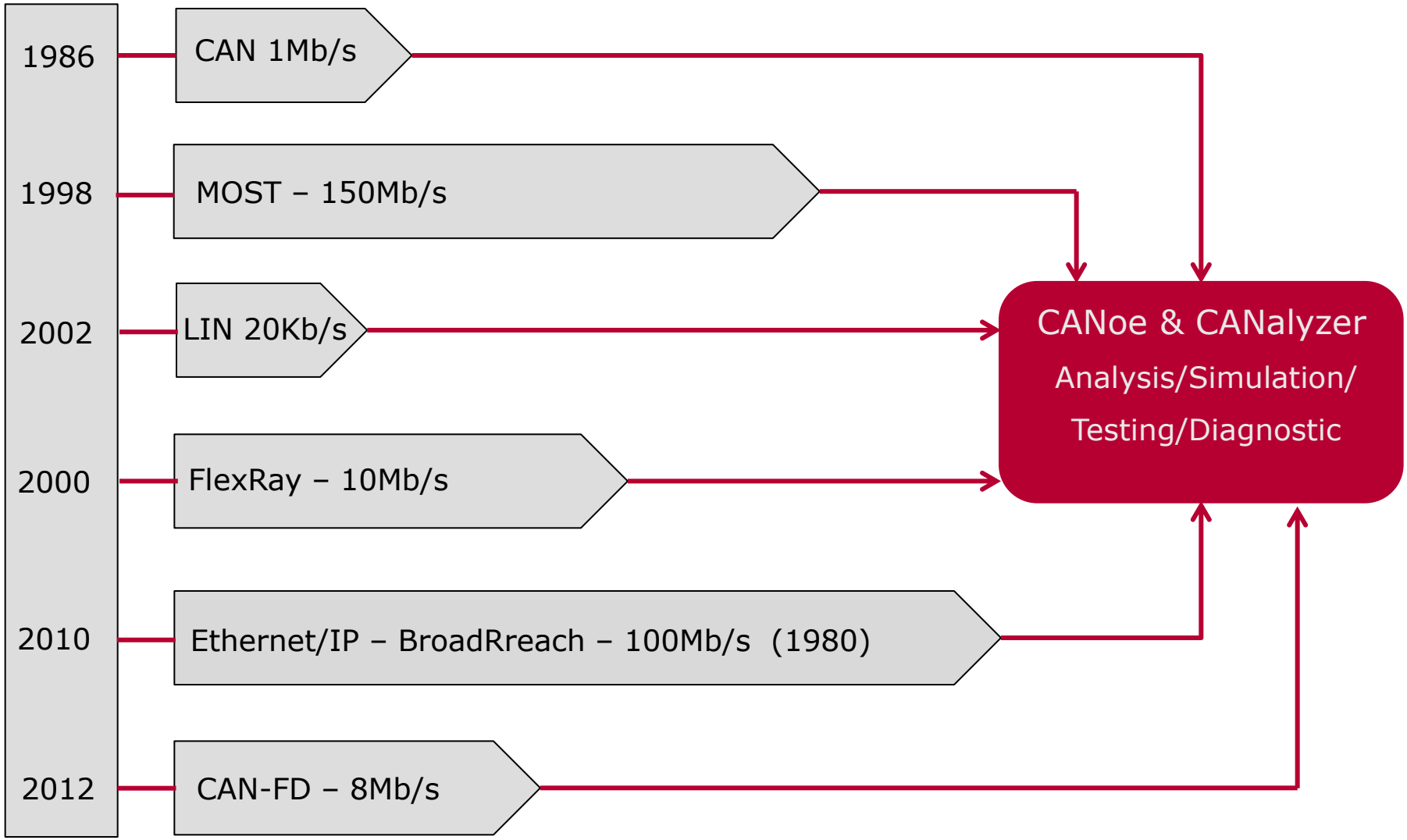
© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Demo

- CANoe simulation based on CAN
- CANoe simulation based on CAN-FD
- CANoe simulation based in FlexRay
- CANoe simulation based on IP

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Automotive Networks



© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.

Thank you for your attention.

For detailed information about Vector
and our products please have a look at:

www.vector.com

Author:

Tariq Javaid

Vector GB

© 2013 . Vector Informatik GmbH. All rights reserved. Any distribution or copying is subject to prior written approval by Vector.