FlexRay – A Communications Network for Automotive Control Systems

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The FlexRay Standard

FlexRay is the next generation automotive bus to provide

- High-speed communication
- Deterministic communication
- Fault-tolerant communication

FlexRay System Components released by the FlexRay Consortium in 2005:

- FlexRay Communications System Protocol Specification Version 2.1, May 2005
- FlexRay Communications System Electrical Physical Layer Specification 2.1, May 2005
- FlexRay Bus Guardian Specification Version 2.1, December 2005

In addition:

- FlexRay Executable (Reference) Model, Version 2.1.0.2 available today from FSL
  - certified by TUEV
  - SystemC based
  - Unambiguous reference for FlexRay IP providers and tool makers

FlexRay Consortium Web site: http://www.flexray.com/
Freescale Web site: http://www.freescale.com/flexray

Evolution of Vehicle Networks

Evolution of Vehicle Networks (1)

- CAN
  - 1st car use 2002; widely adopted in automotive products
  - CAN-B (ISO 11898-3): 125kbps, VUL=1.5V, VUH=3.5V
  - CAN-B (SAE J2411): 33kbps, VUL=0V, VUH=4.1V
  - CAN-C (SAE J2284): 500kbps, designed limit of 1 Mbps rarely implemented today
- Byteflight
  - 1st car use for airbag in 2004
  - 10Mbps
  - Time-triggered + Flexibility
- FlexRay
  - 1st car use for Chassis application in 2006
  - 10Mbps
  - Time-triggered + Flexibility + safety concept

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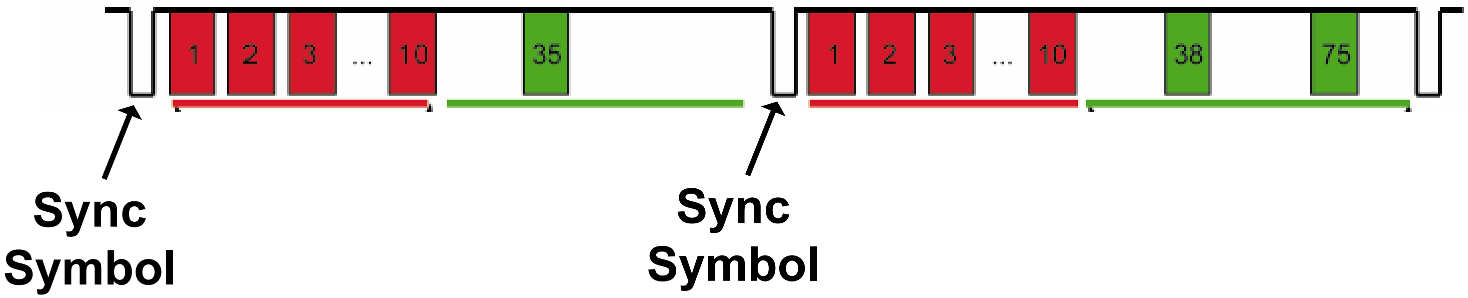
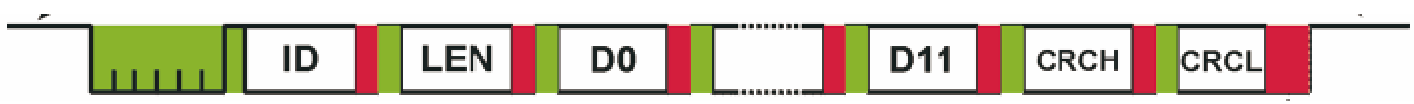
Byteflight Data Transfer Overview

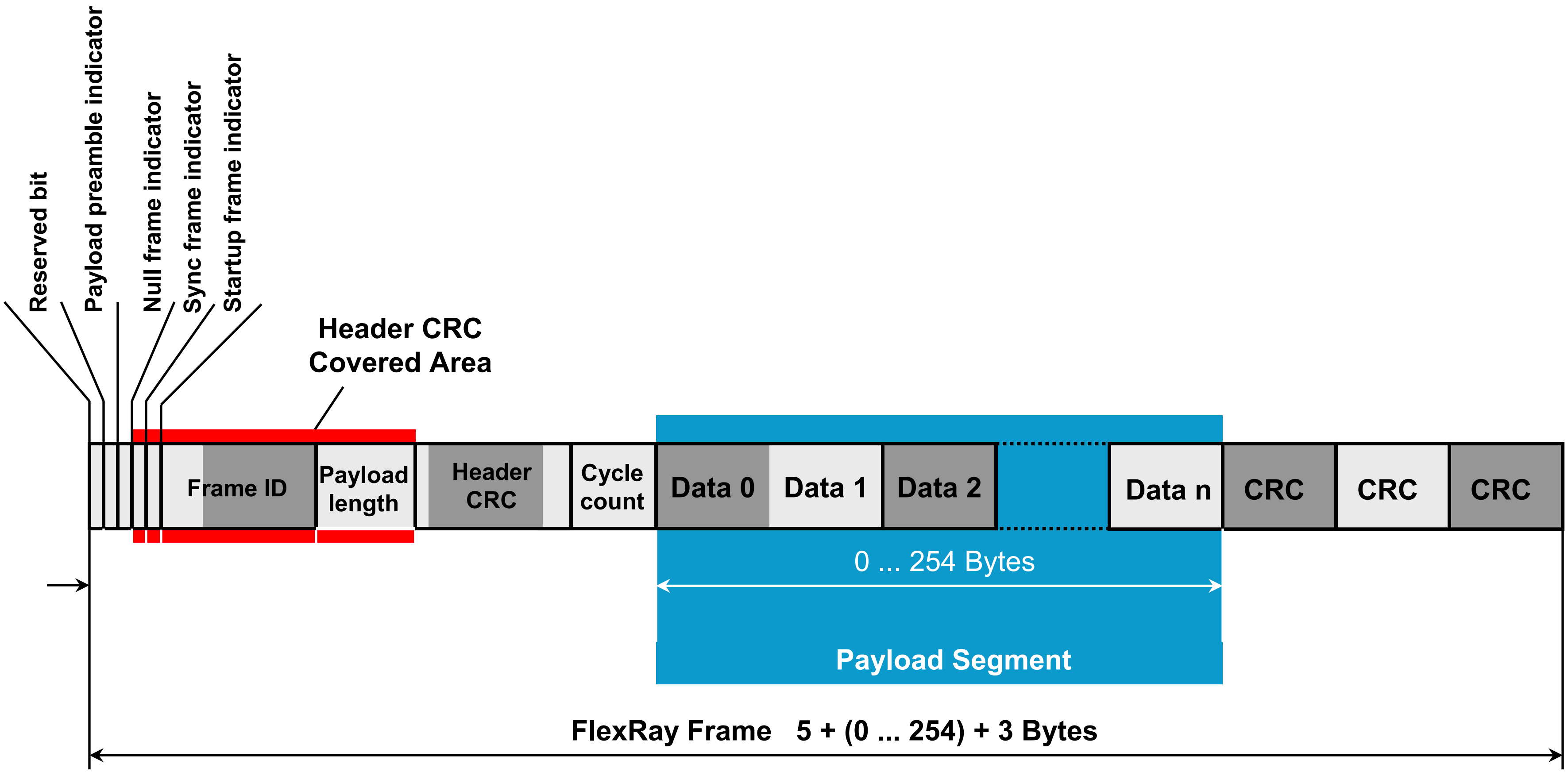


- Master clock
- Cycle starts w/ Sync symbol
- Fixed time slots for high priority communication
- Rest of bandwidth is allocated to low priority communication



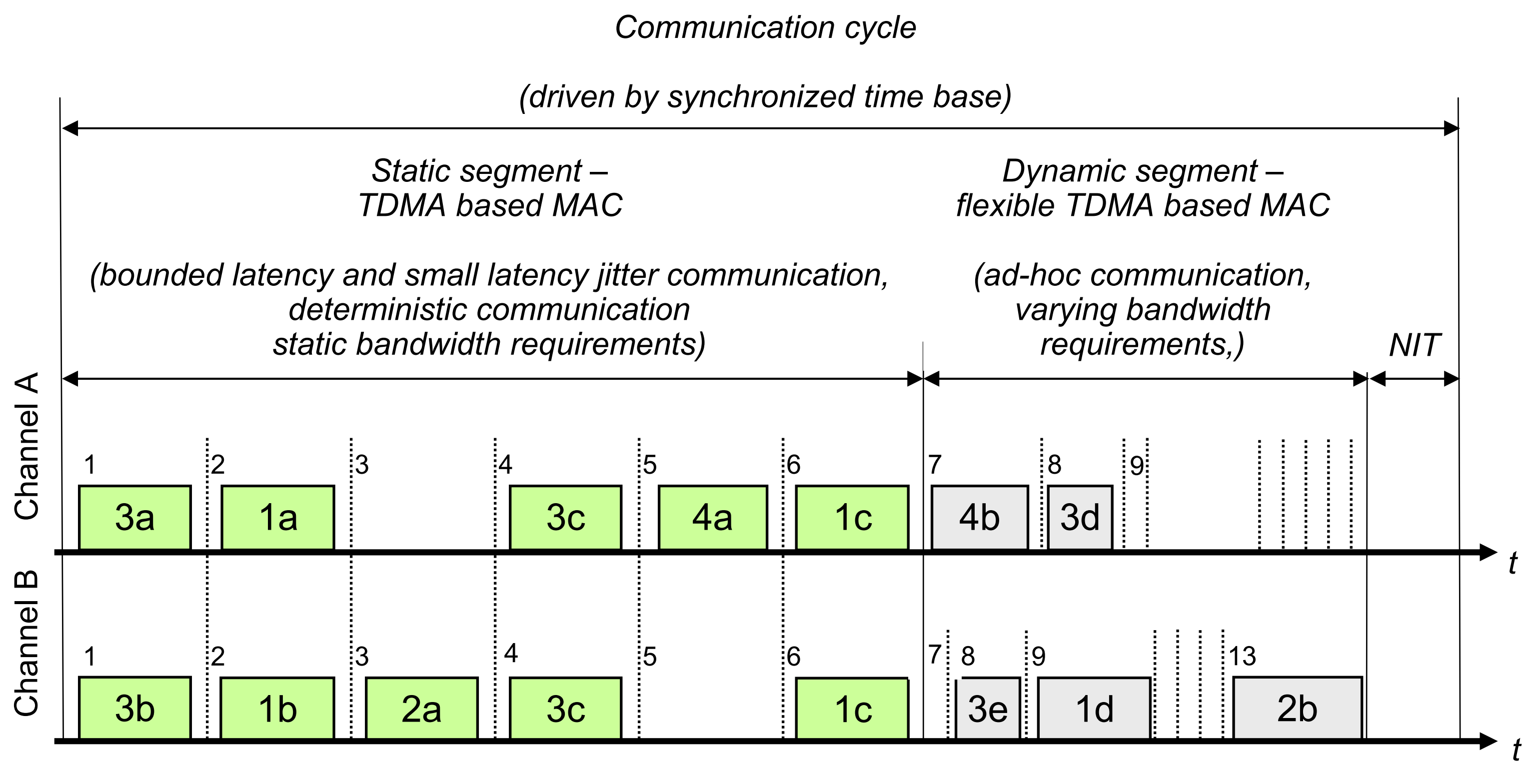
- Frame format: 6bit Sync, ID Byte, 12 message Bytes, 2 CRC Bytes

FlexRay Data Transfer Overview



- 254 bytes, 8 Bytes overhead (5 header incl. header CRC, 3 frame CRC) plus start/stop bits

FlexRay Data Transfer Overview



Example of a FlexRay communication cycle showing the static and the dynamic segment.

Evolution of Vehicle Networks: Issues Resolved

CAN →	byteflight →	FlexRay
Unpredictable latency	TDMA + Bandwidth Allocation Flexibility	TDMA + Bandwidth Allocation Flexibility + Fault tolerance concept

Evolution of Vehicle Networks (Overview)

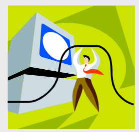
Feature	CAN	TTP	byteflight	FlexRay
Message transmission	asynchronous	synchronous	synchronous and asynchronous	synchronous and asynchronous
Message identification	message identifier	time slot	message identifier	time slot
Data rate	1 Mbps gross	2 Mbps gross	10 Mbps gross	10 Mbps gross
Bit encoding	NRZ with bit stuffing	modified frequency modulation (MFM)	NRZ with start/stop bits	NRZ with start/stop bits
Physical Layer	transceiver up to 1 Mbps	not defined	optical transceiver up to 10 Mbps	10Mbps with differential signalling
Clock synchronization	not provided	distributed, in µs range	by master, in 100 ns range	distributed, in µs range
Temporal composability	not supported	supported	supported for high priority messages	supported
Latency Jitter	bus load dependent	constant for all messages	constant for high priority messages according t_cyc	constant for all messages
Error containment	not provided	provided with special physical layer	provided by optical fiber and transceiver	provided with special physical layer
Babbling idiot avoidance	not provided	only by independent bus guardian	provided via star coupler	provided via star coupler or bus
Extensibility	excellent in non-time critical applications	only if extension planned in original design	extension possible for high priority messages with effect on bandwidth	separation of functional and structural domain
Flexibility	flexible bandwidth for each node	only one message per node and TDMA cycle	flexible bandwidth for each node	multiple slots per node, dynamic

Fault Tolerance

FlexRay and Functional Safety

- Safety requirements
  - Depend on application area (brake, steering, driver assist)
  - Lead to redundancy of system components
  - Degree of redundancy must be calibrated by field data on failure probability
- FlexRay provides the infrastructured to design reliable (safety-critical) communications systems
  - Deterministic System Design
  - Static Segments
  - Dual channel - scalable system fault-tolerance
  - Bus Guardian
  - Interconnect topologies: centralized or bus

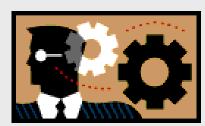
Fault-Tolerance Overview



Topological flexibility (single versus dual channel, mixed connectivity)

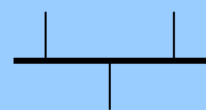
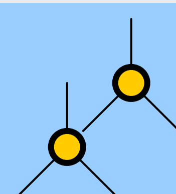
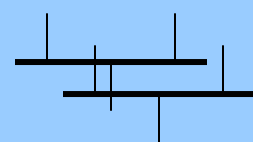
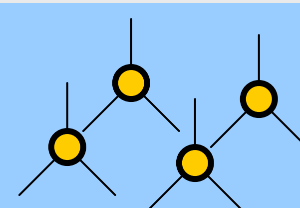
Scalable fault-tolerance to support fault-tolerant and non fault-tolerant systems

Fault-tolerant clock synchronization also usable in a non fault-tolerant way



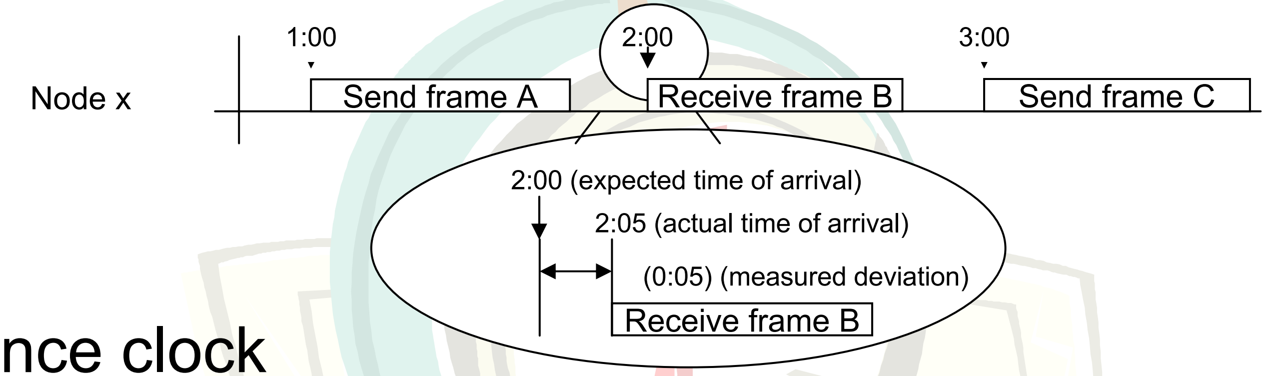
Conceptual separation of functional and structural domain

Topological Flexibility

Optional BG	Bus	Multiple star	@ 10MBit
Single channel			reduced wire-harness, experience, cost
Dual channel			tolerates one faulty channel
mixed topologies	passive medium, most experience, cost efficient	allows for high data rates, increases error containment	electrical & optical physical layer

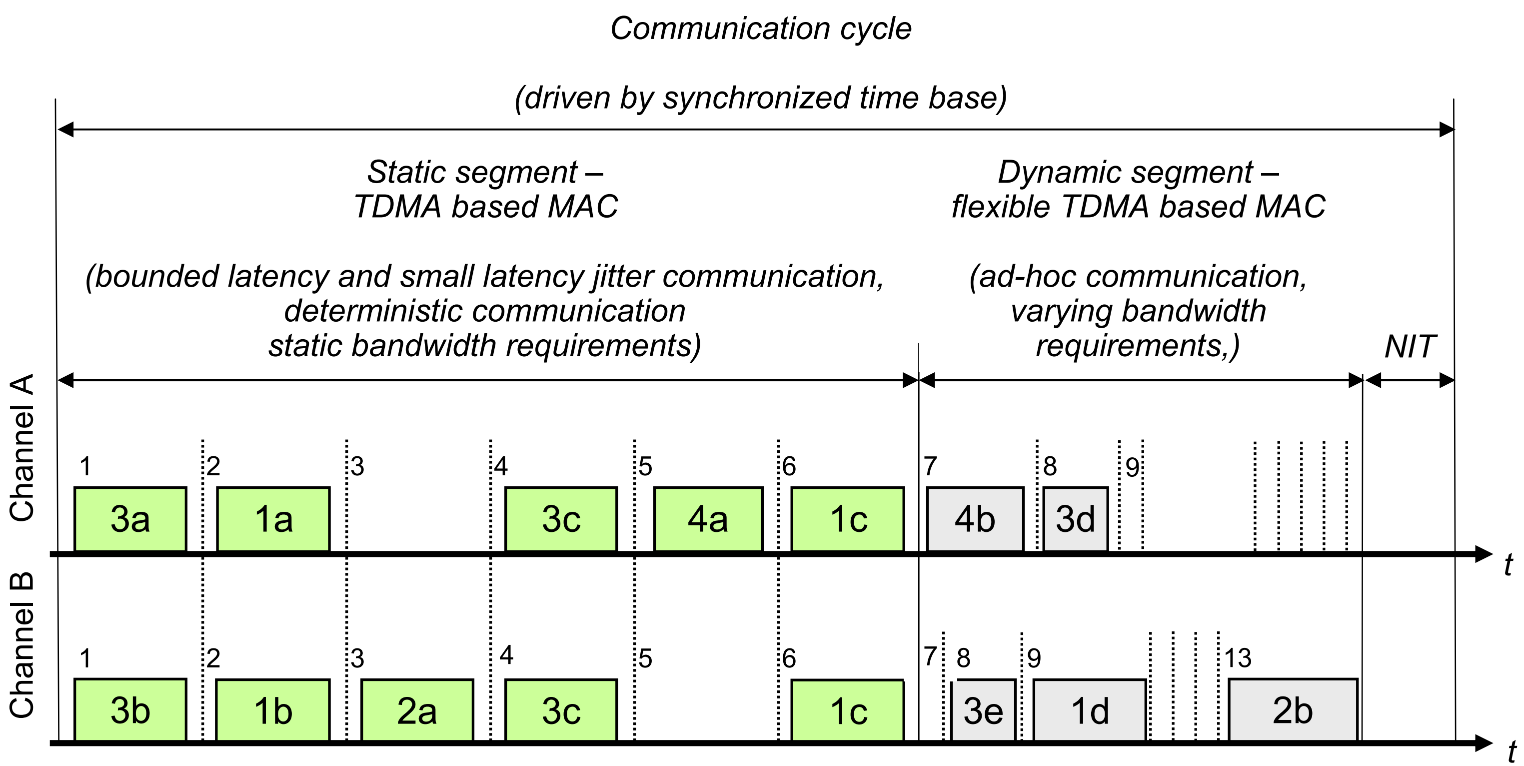
Clock Synchronization Principle

- Exchanging Deviations
  - Implicit exchange of clock deviations via exchange of (sync) frames



- Reference clock
  - No single physical reference clock exists
  - Each node calculates deviation in respect to a virtual reference clock
  - Virtual reference clock established using distributed fault-tolerant clock synchronization algorithm (fault-tolerant midpoint)
  - Combined use of offset correction and rate correction

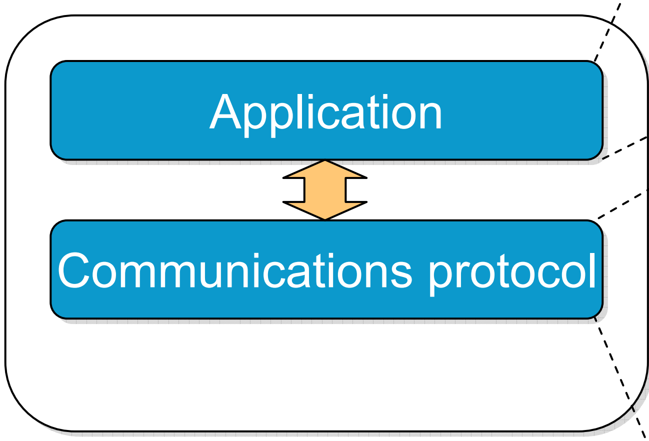
Separation of Functional & Structural Domain



Example of a FlexRay communication cycle showing the static and the dynamic segment.

Functionality Beyond FlexRay

- Low Protocol Overhead
  - Services to support application safety are left to the application software (eg. membership services)
  - AutOsar must complement FlexRay link layer (in the controller)



Application related fault-tolerance (such as message agreement)

Application related error handing (such as system diagnosis)

-> Functional or structural view

Communication rel. fault-tolerance (such as clock-synchronization)

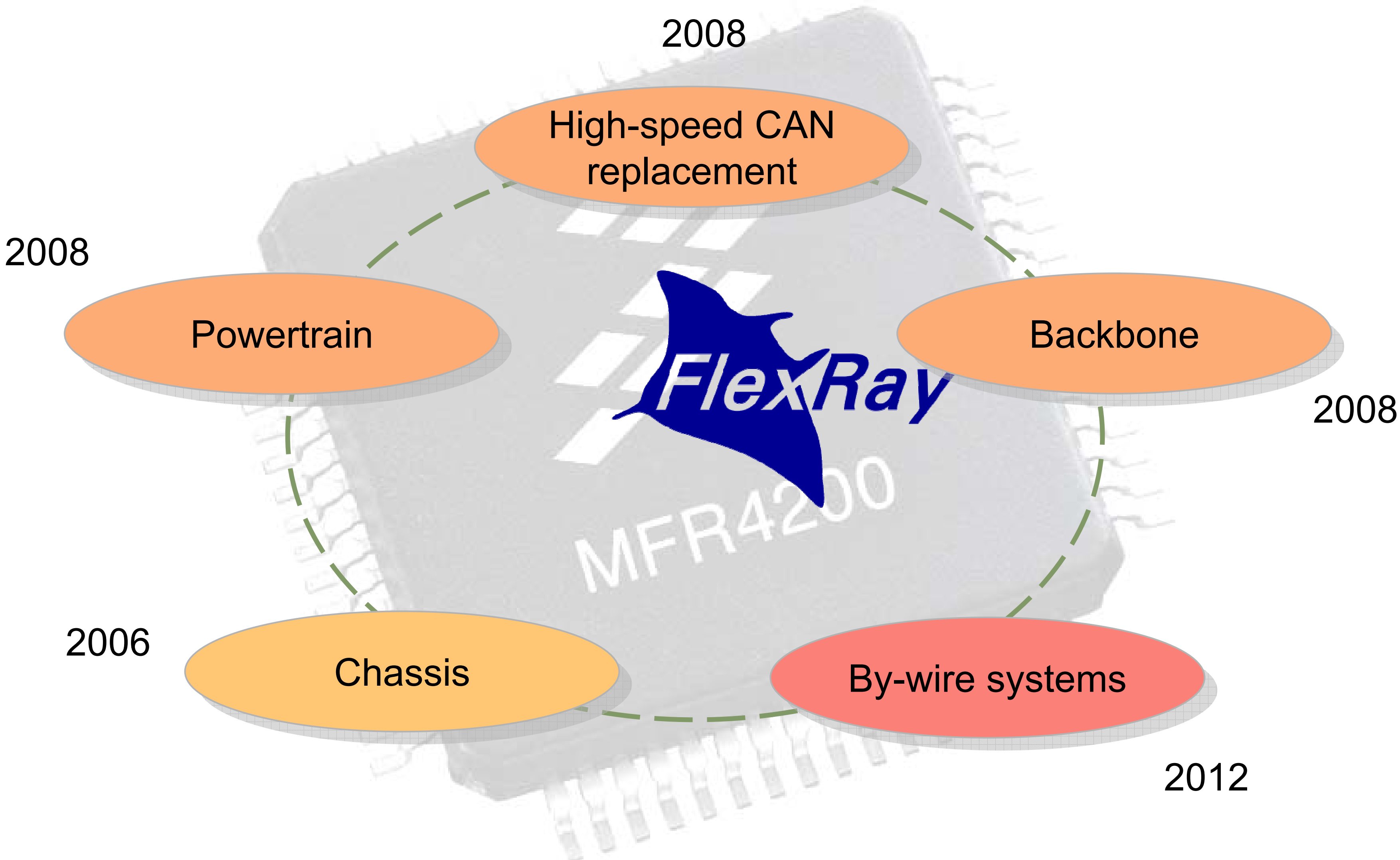
Communication rel. error handing (loss of synchronization)

Error signaling to application

-> Functional view

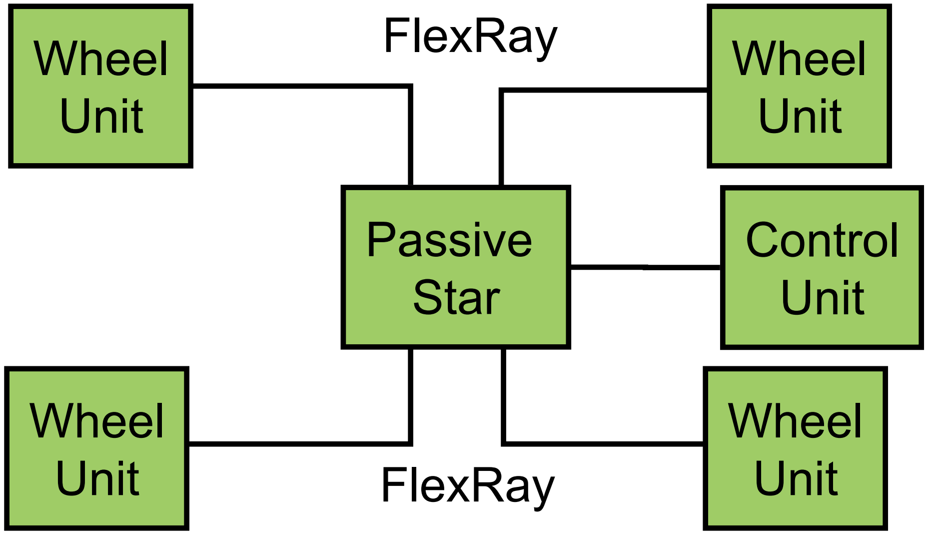
Applications

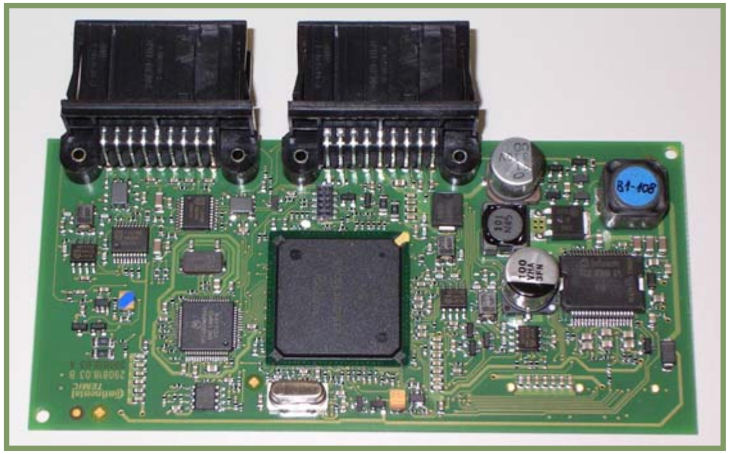
Application Domain Examples



Example: Chassis Applications

- Adaptive Suspension System
  - Distribution of control algorithm between 4 wheel nodes and 1 control unit
  - Passive star topology @ 10Mbps
  - Single channel
  - Fail silent strategy





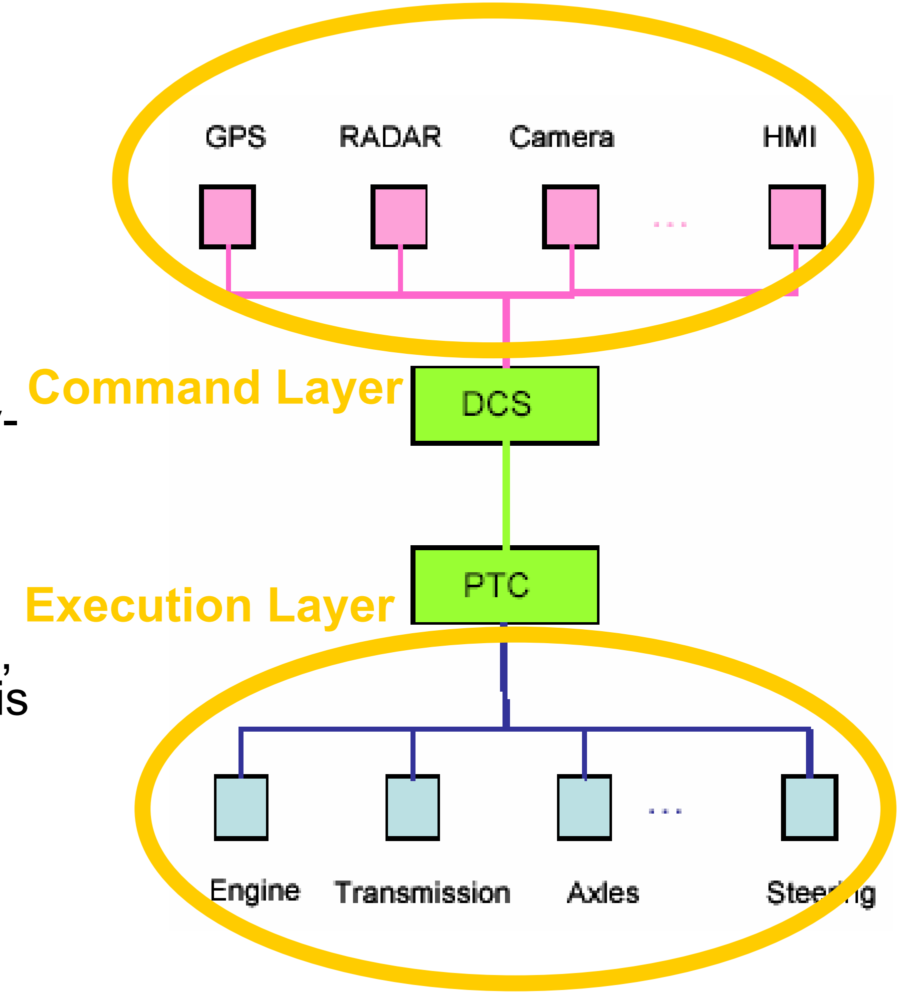
FlexRay ECU based on MPC563 and MFR4200.

Trends in Chassis Electronics

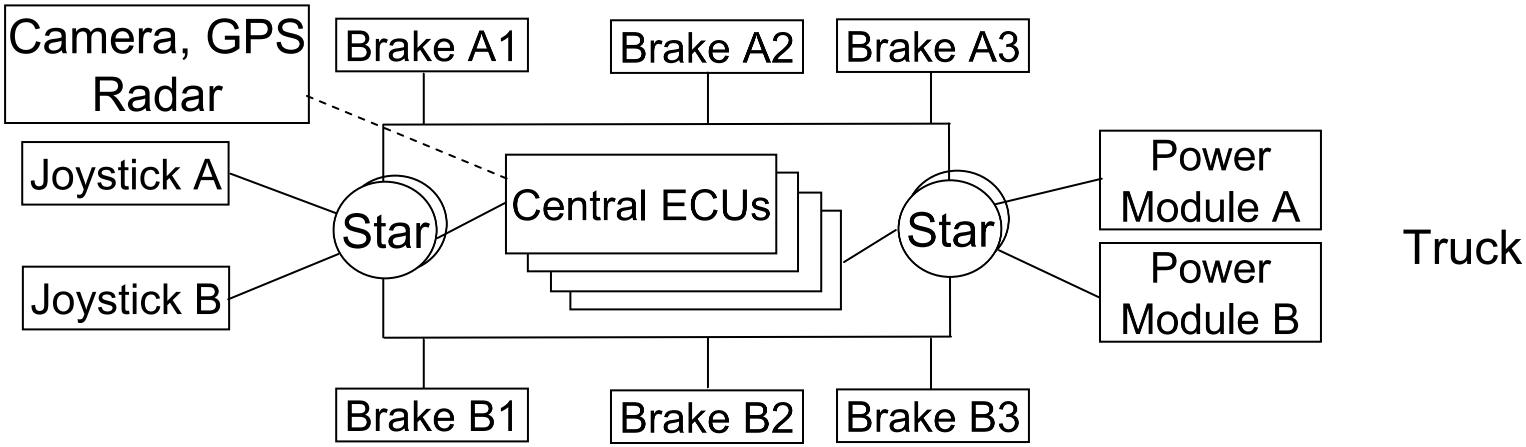
- Current state:
  - Longitudinal dynamics only (ABS and Traction control)
- Future:
  - Networking of Longitudinal & Lateral Dynamics & Driver Assistance
- Challenge:
  - Flexible architecture w/
    - > ABS, DSC in basic configuration
    - > Active Steering, electric brake management, ACC as options
  - FlexRay provides a feasible backbone w/ separation of structure and function
    - > No change of ECU code at change of option package
    - > All ECUs have FlexRay slots assigned according to platform plan

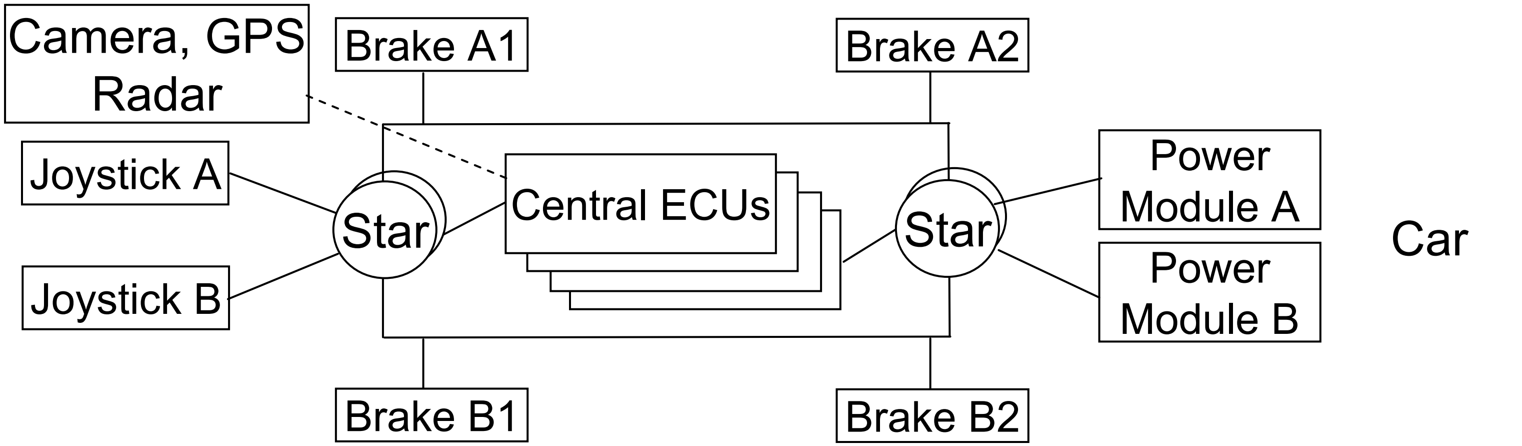
Example: X-by-Wire

- European funded project SPARC (Secure Propulsion Using Advanced Redundant Control)
  - Execution layer (steering system, braking system, power pack (engine & transmission), energy system) uses FlexRay as bus architecture
  - Implementation of steer-by-wire system, brake-by-wire system, shift-by-wire system, engine-by-wire system, load separation module and energy management
  - The platform is equipped with two independently working FlexRay Buses, each consisting of two channels. One is assigned to the communication between the HMI and the DCS, the other bus is used for communication between the PTC and the execution (mechatronic) layer, i.e. the lower part of the hourglass.



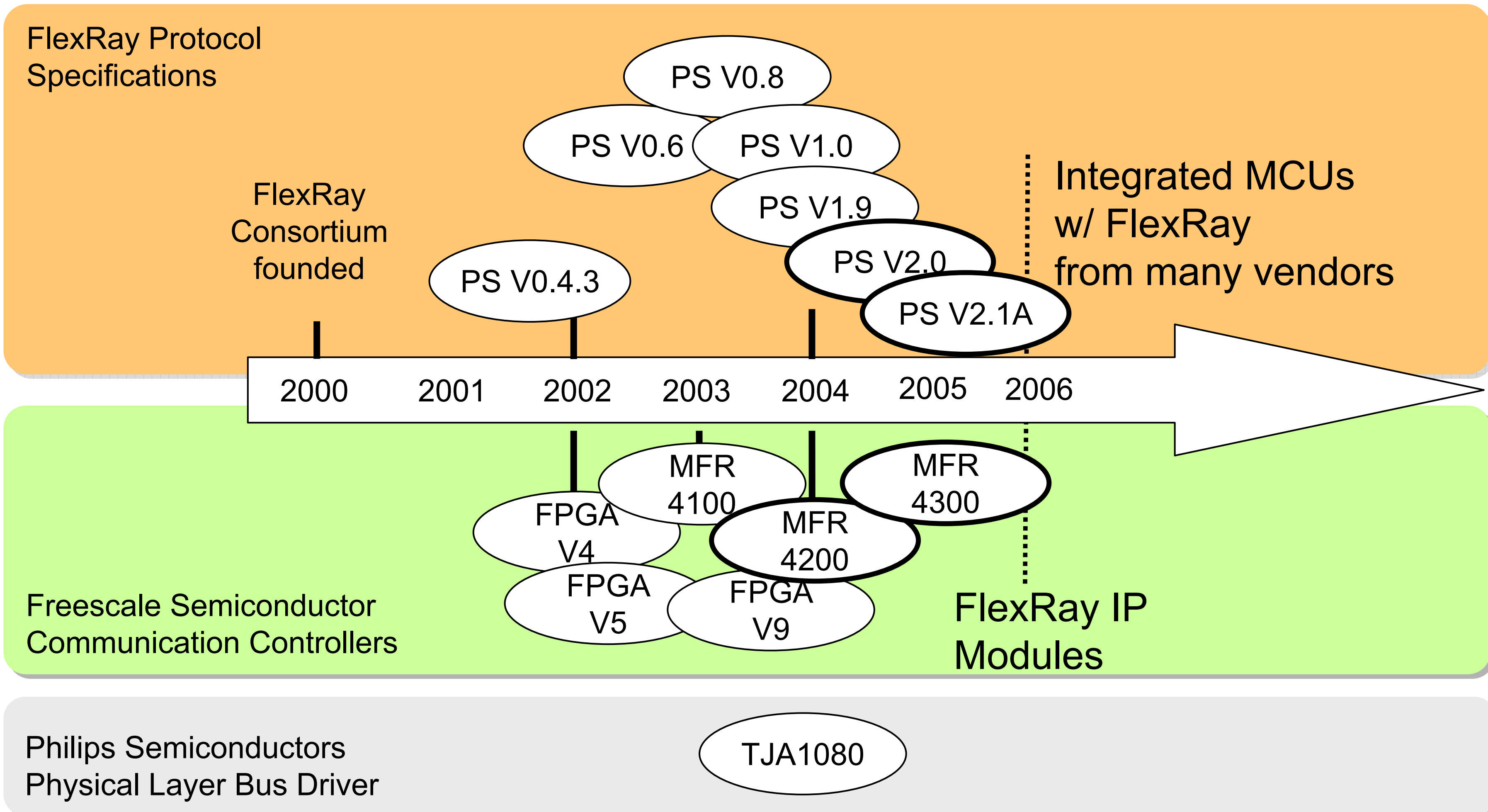
SPARC Architecture





FlexRay Product History

FlexRay Implementations Roadmap



Summary

- FlexRay is the next generation communication backbone for automotive applications
  - Qualified Controller and Physical Network Interface products exist
  - Automotive mass-production SOP 2006
  - Reference Model to explore systems architecture
- Safety critical applications like by-wire systems will use mechanisms built into FlexRay to support fault tolerance
  - No technical limits for state-of-the-art systems
  - Full flexibility for emerging systems architectures for ‘affordable’ safety in vehicles
- FlexRay market will develop in non-safety-critical application first

Thank you

for your attention

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