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# Middleware and Communication Protocols for Dependable Systems TI-MICO

***The Communication Systems for advanced automotive control applications***

Version: 18.11.2014

# Abstract

The **FlexRay** protocol provides flexibility and determinism by combining a scalable **static** and **dynamic** message transmission, incorporating the advantages of familiar synchronous and asynchronous protocols

**Sources:**

***”FlexRay Requirements Specification”*, Version 2.1, 19-dec-2005 (115 pages).**

***”FlexRay Protocol Specification”,* Version 3.0.1, Oct. 2010 (341 pages).**

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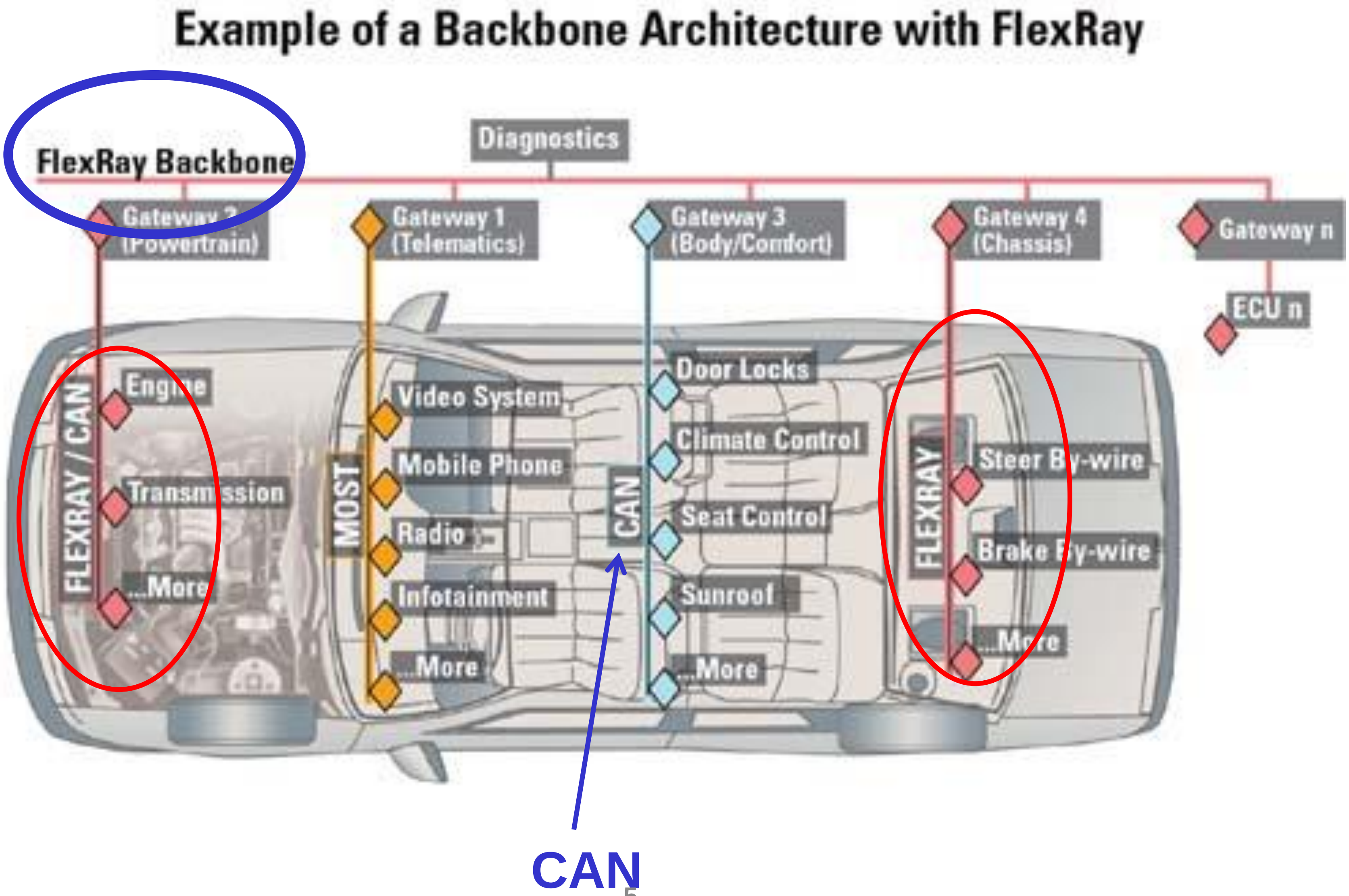
# Context

- Demand for a bus system with **high data rate** for automotive applications
- **Deterministic** and **fault-tolerant** bus system for advanced automotive control applications
- Support from the bus system for **distributed control systems**
- Support for both **event** and **time-triggered** communication
- Limited number of different communication systems within vehicles

# FlexRay Consortium Goals

- Develop an advanced communication technology for high-speed control applications in vehicles
- Make the technology available in the market place for everyone
- Drive the technology as a ***defacto* standard**
- **FlexRay standardized by ISO in 2013**
  - **ISO 17458: 2013 Road vehicles -- FlexRay communications system (part 1 – 5).**

# FlexRay Architecture Example



# FlexRay – Core Partners

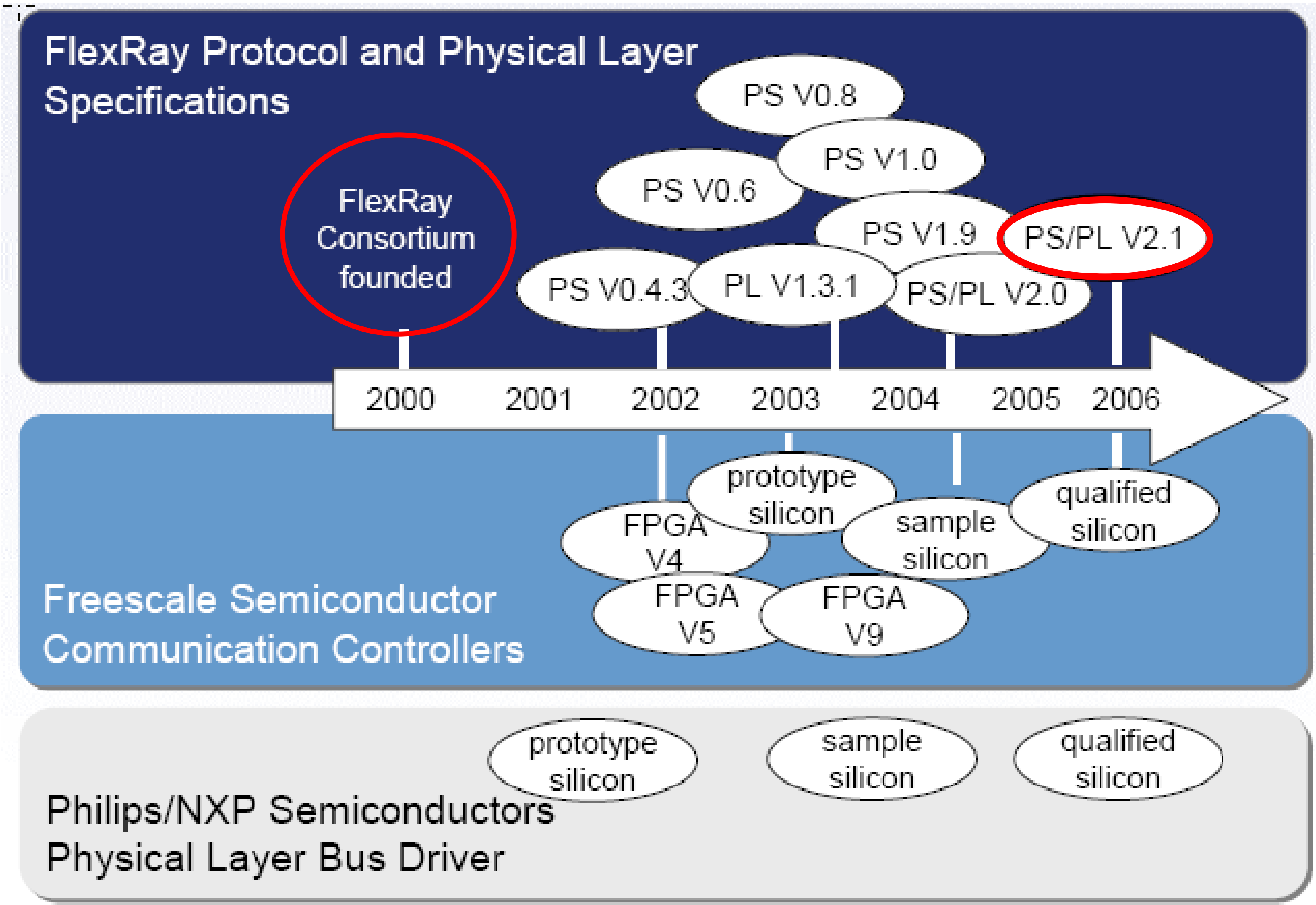
**The seven FlexRay Consortium Core Partners:**

- **BMW**
- **Daimler**
- **Volkswagen**
- **General Motors**
- **Bosch**
- **Freescale (Motorola)**
- **NXP (Philips) Semiconductors**

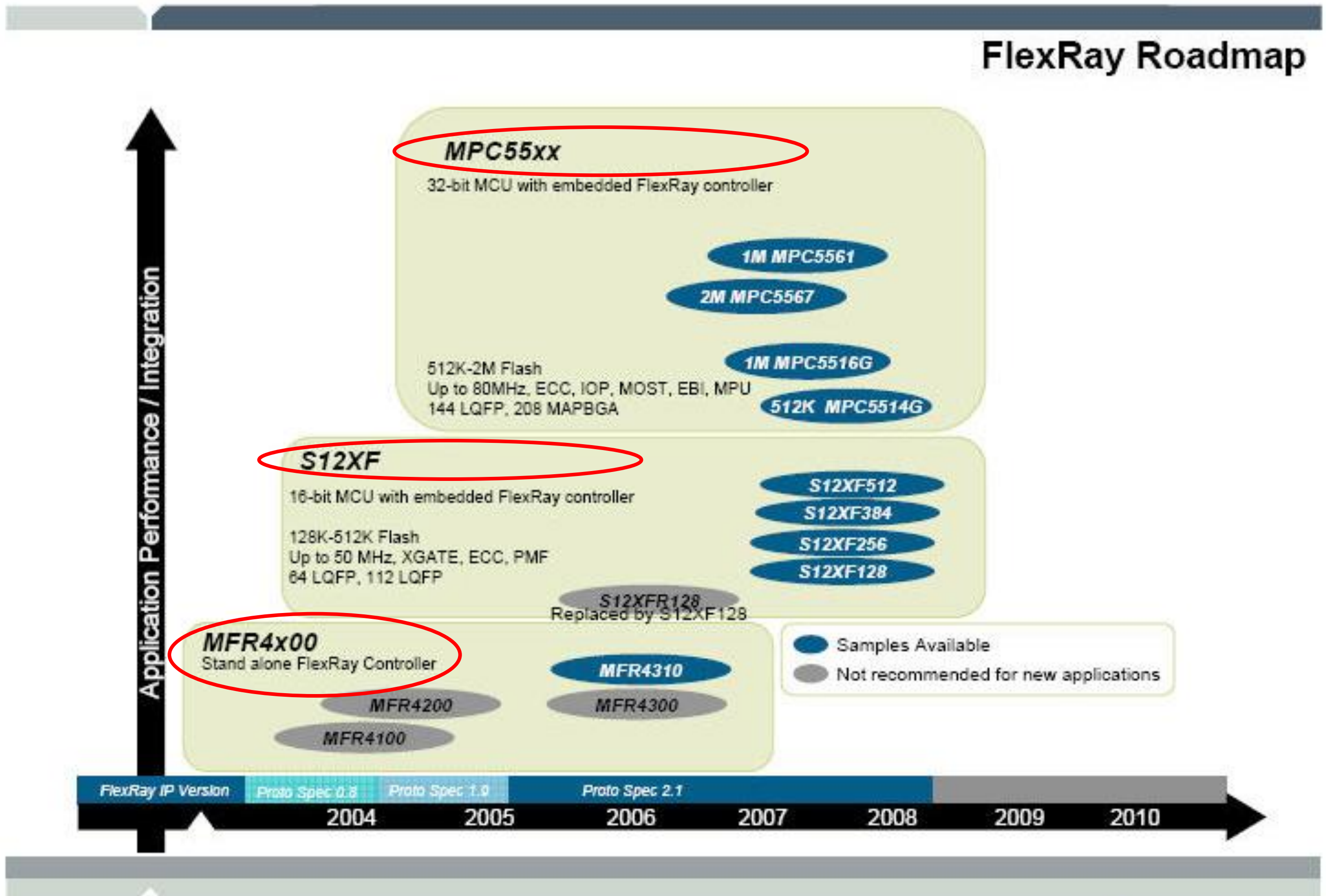
**Consortium time 2000-2010:**

**Goal: Development of FlexRay standards.**

# FlexRay History



# Freescale's FlexRay Roadmap



# FlexRay News (2006)

TTAutomotive

Stronger involvement of TTAutomotive in FlexRay Consortium

## TTAutomotive Gains Premium Associate Member Status in FlexRay Consortium

Vienna, Austria – October 12, 2006

**TTAutomotive, TTTech's subsidiary for FlexRay™ solutions, has become a premium associate member of the FlexRay consortium. As a premium associate member, TTAutomotive will play an active role in support of the development of FlexRay as the standard bus protocol for distributed automotive applications. TTAutomotive has in-depth know-how in the domain of time-triggered solutions and protocols.**

The FlexRay consortium has seven core partners – BMW, Bosch, DaimlerChrysler, Freescale, General Motors, Philips and Volkswagen – as well as members from the automotive, semiconductor and electronic systems industries. The consortium drives the development of communication systems that support the needs of future in-car control applications.

# FlexRay usage in Cars

- The first series production vehicle with FlexRay was at the end of **2006** in the BMW X5, enabling a new and fast adaptive damping system.
- Full use of FlexRay was introduced in **2008** in the new BMW 7 Series (F01), the world's first production vehicle to fully use the FlexRay system.

# General FlexRay Requirements

- **One or two channel solutions must be supported**
- **An electrical and optical physical layer must be supported**
- **Redundant physical links is optional. A mix of non-redundant and redundant physical links must be supported**
- **Wake-up of nodes and stars via the communication system**
- **A baud-rate from 500 Kbit/s up to 10 Mbit/s**

# Basic Features

- Synchronous and asynchronous data transmission
- High net data rate of up to 10 Mbit/sec
- Deterministic data transmission, guaranteed message latency and message jitter
- Support of redundant transmission channels
- Fault tolerant and time triggered services implemented in hardware
- Fast error detection and signaling
- Support of a fault tolerant synchronized global time base
- Error containment on the physical layer through an independent "Bus Guardian"
- Support of optical and electrical physical layer
- Support for bus, star and multiple star topologies

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# FlexRay Node Architecture (1)

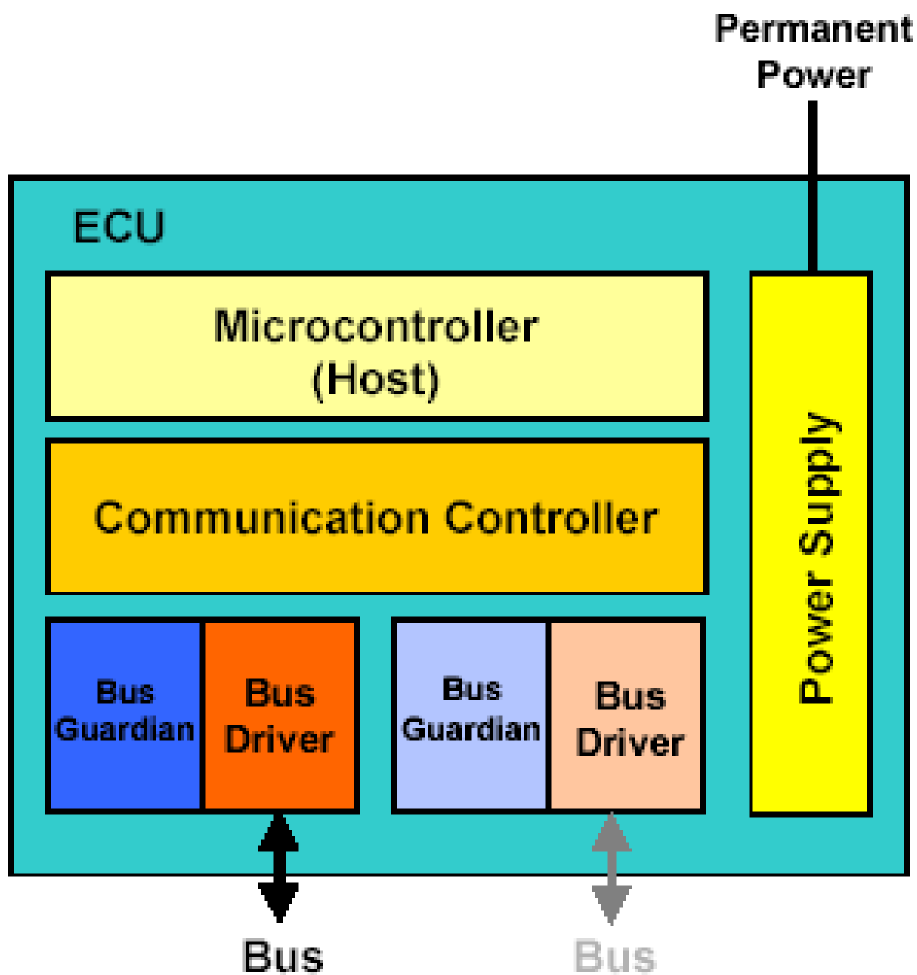
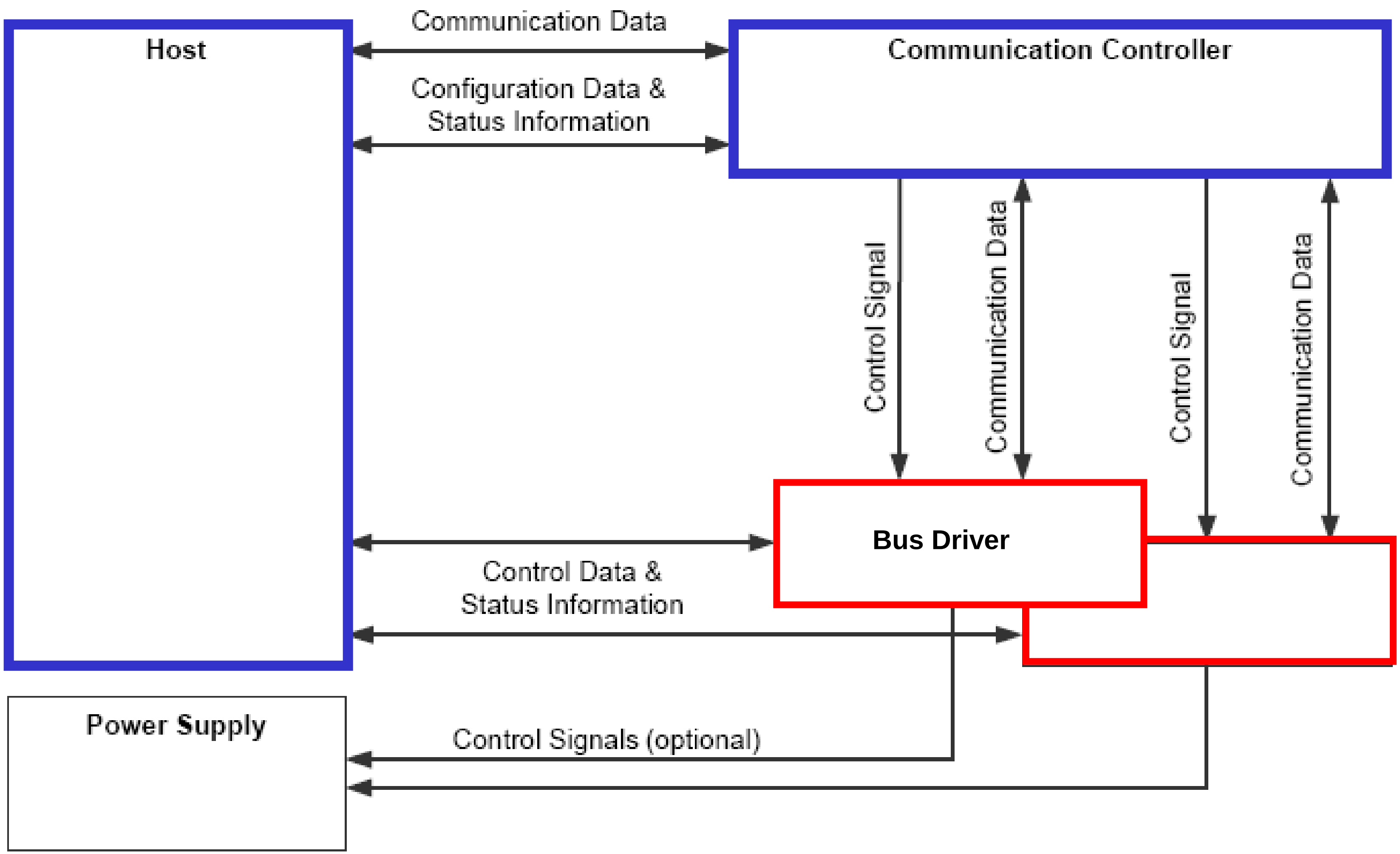



Figure 2: Architecture of a node (ECU).

**ECU= Electronic Control Unit**

# FlexRay Node Architecture (2)



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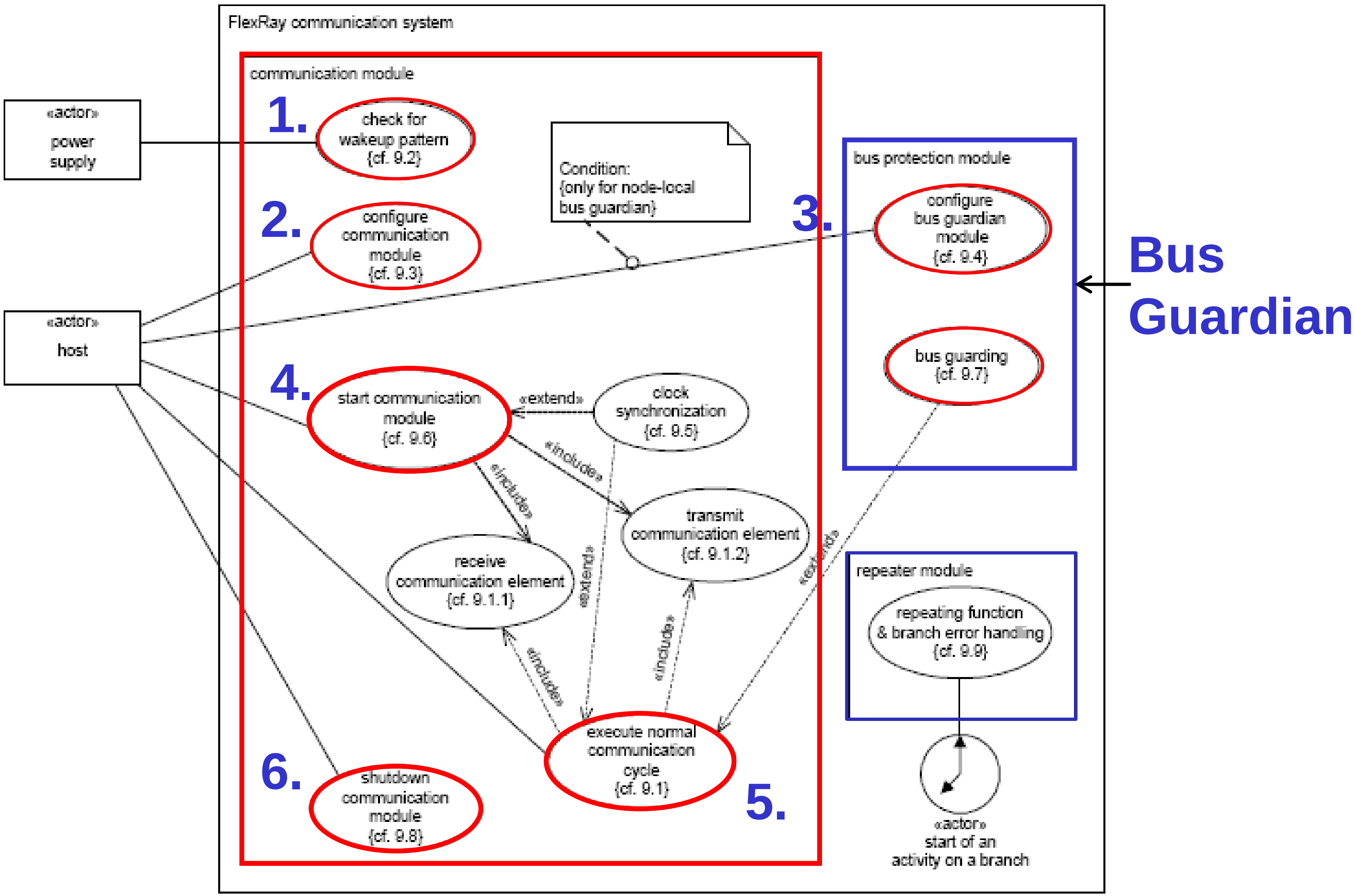
# Use Cases for the FlexRay Communication System




Source: FlexRay Req. spec.

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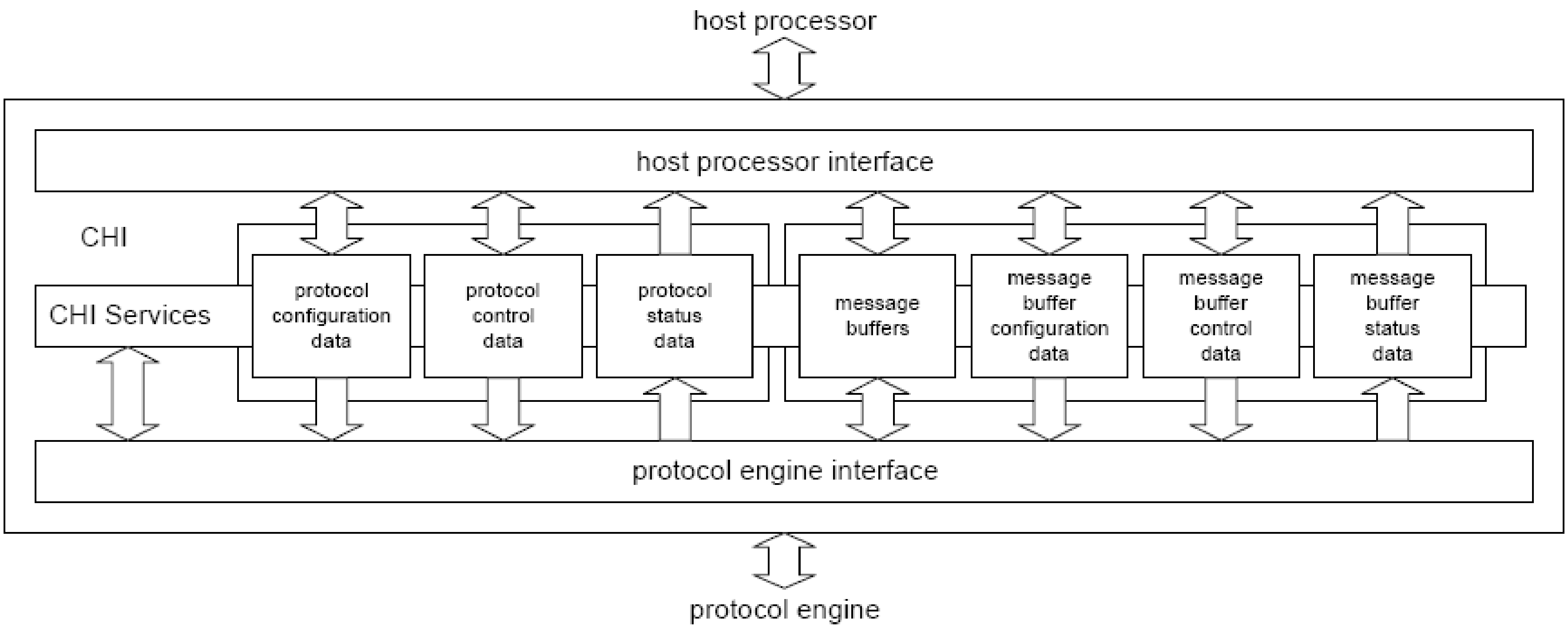
# Host Processor Interface



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# FlexRay Communication Controller

Product information

BOSCH

## E-Ray - the FlexRay Communication Controller IP-Module

The E-Ray Module is the FlexRay Communication Controller IP-module from Bosch that can be integrated as stand-alone device or as part of an ASIC. It is described in VHDL on RTL level, prepared for synthesis. The E-Ray Module performs communication according to the FlexRay protocol specification v2.1. The bit rate can be programmed to values up to 10 MBit/s. For connection to the physical layer additional Bus Driver (BD) hardware is required.

***Features***

→ Conform with Protocol Specification v2.1

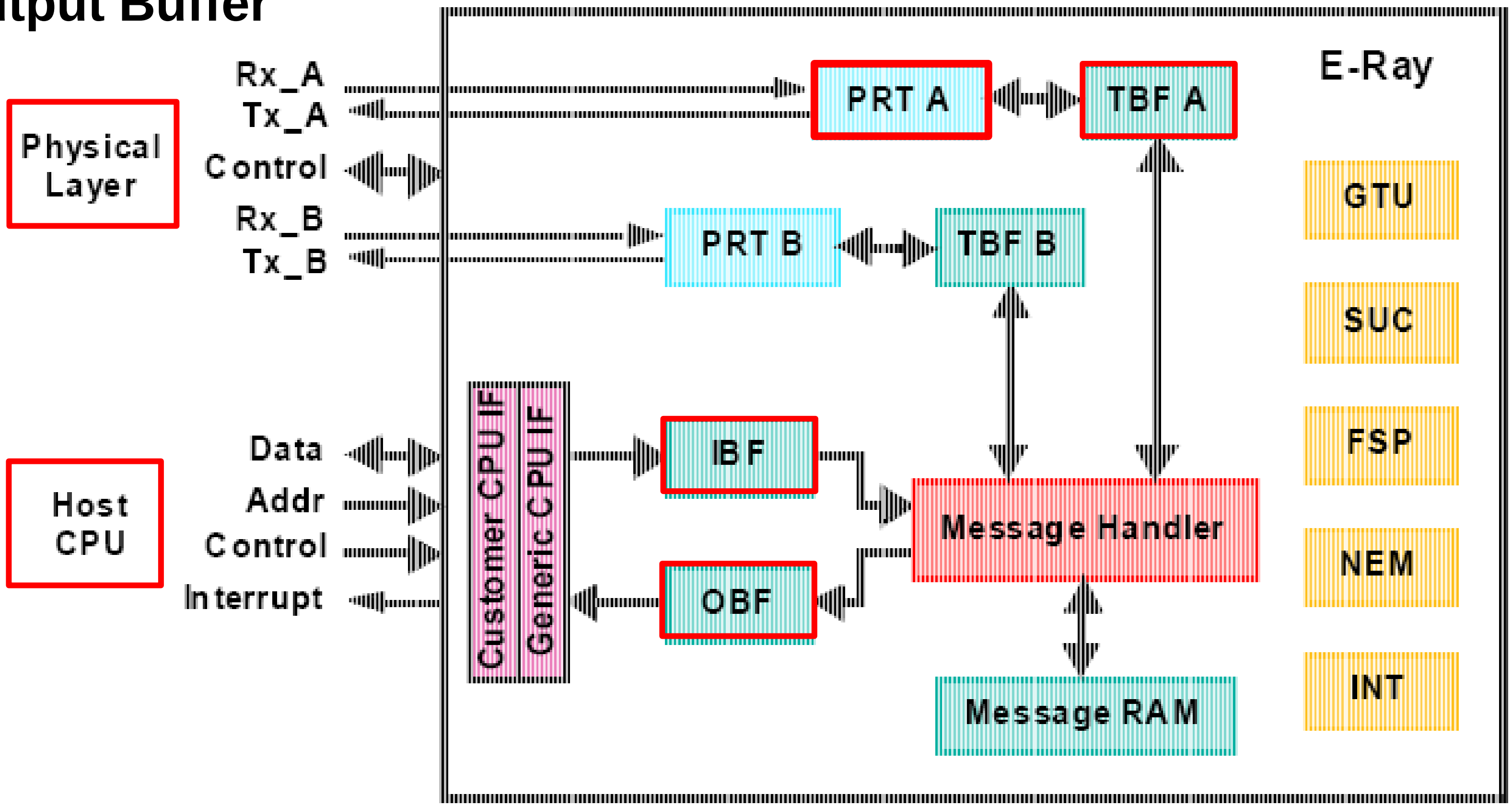
→ Data rates of up to 10 MBit/s on each channel

→ Configurable Message RAM supports
- Up to 128 Message Buffers
- Up to maximum payload of 254 Bytes
- Different payload lengths possible

**http://www.semiconductors.bosch.de/pdf/bosch_product_info_E-Ray_ip_v11.pdf**

# E-Ray FlexRay Controller Block Diagram

**PRT A: Protocol Communication Controller (Protocol Finit State Machine)**
**TBF A: Transient Buffer RAM**
**IBF: Input Buffer**
**OBF: Output Buffer**




**Source: www.bosch.de**

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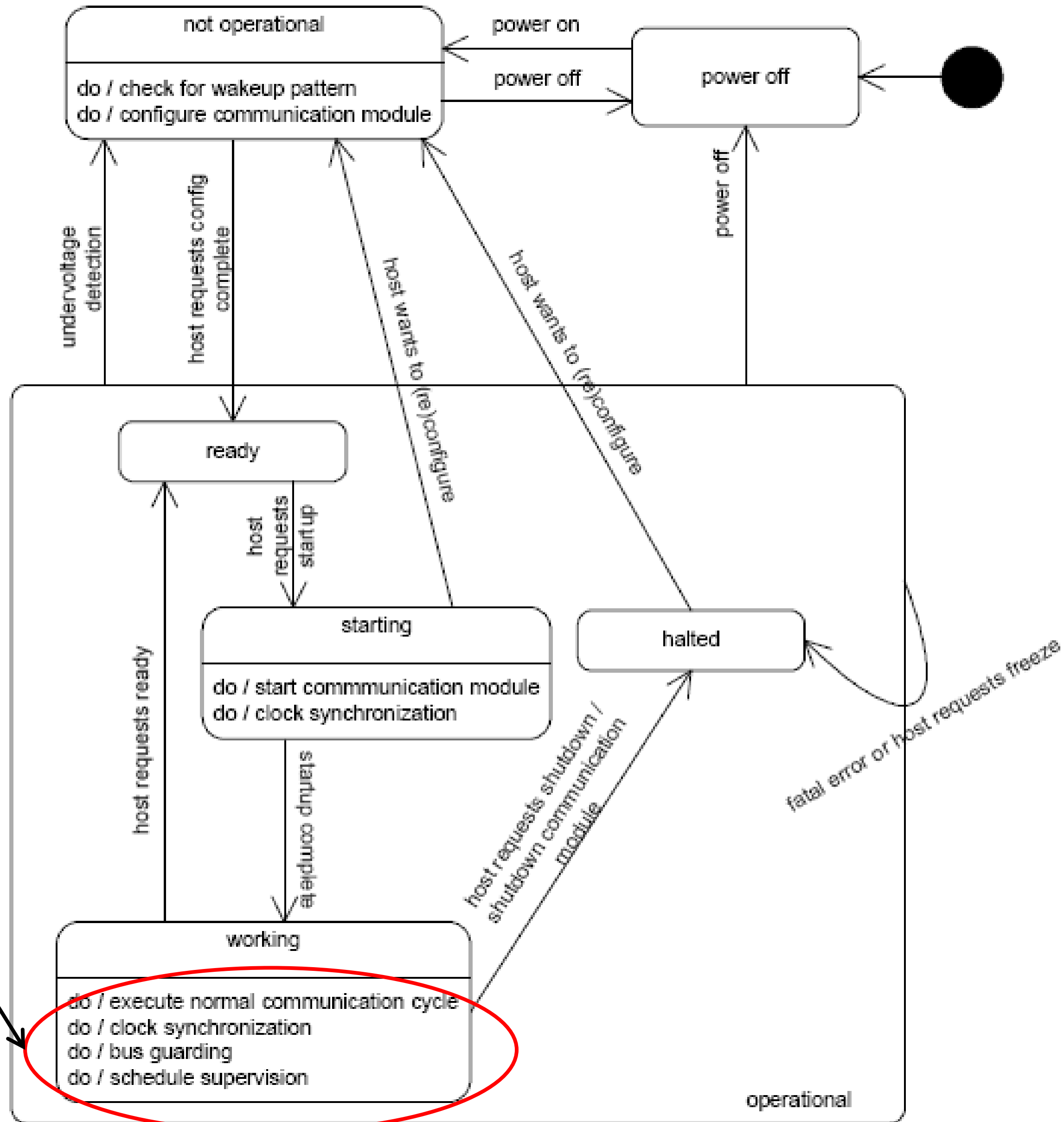
# State Model of a Communication Module




**Notice: Relations to Use Case Diagram**

**Source: FlexRay Req. spec.**

# Topologies - Bus & Star

- Bus
  - passive medium
  - no active components within the channel
  - most automotive experience here
  - automotive costs
- Star
  - best suited technology for high speed networks
  - different degrees of intelligence possible
    - with/without protocol knowledge
    - can protect against concurrent media access
    - limits the error domain of not correctly working sub networks

# Passive Bus Topology

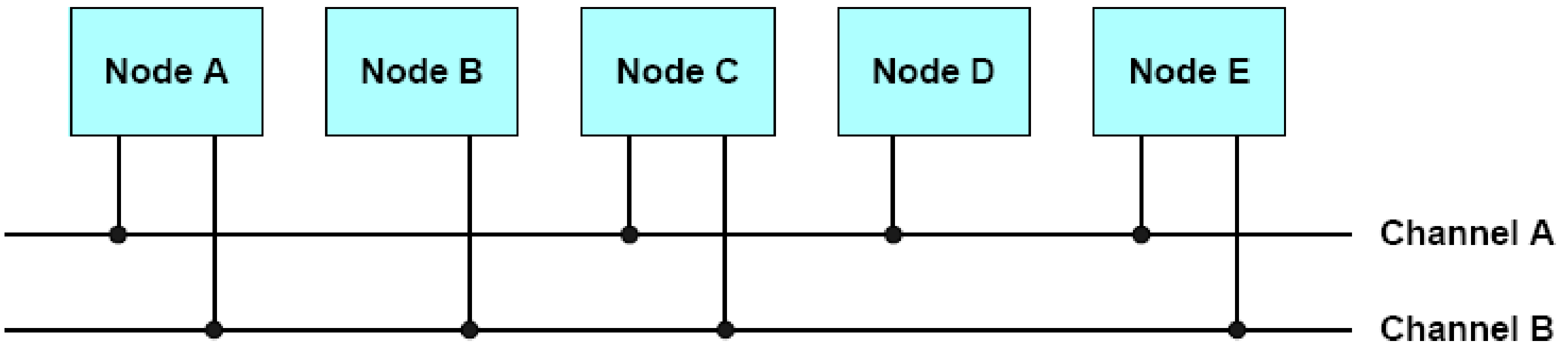



Figure 1-1: Dual channel bus configuration.

# Active Star Toplogy

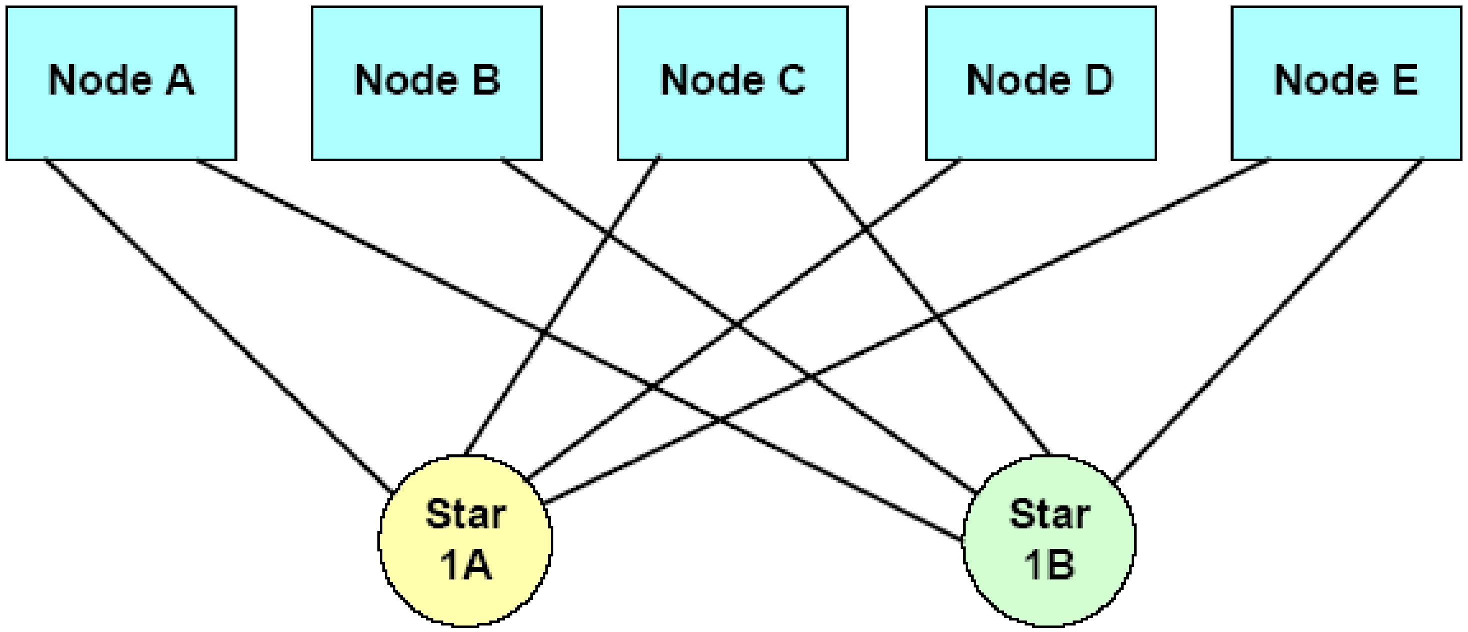



Figure 1-2: Dual channel single star configuration.

# Active Star Component

- **A branch has to be deactivated if a faulty signal is detected**
- **A deactivated branch shall be fail-silent and should be reactivated if the fail condition is no longer available**

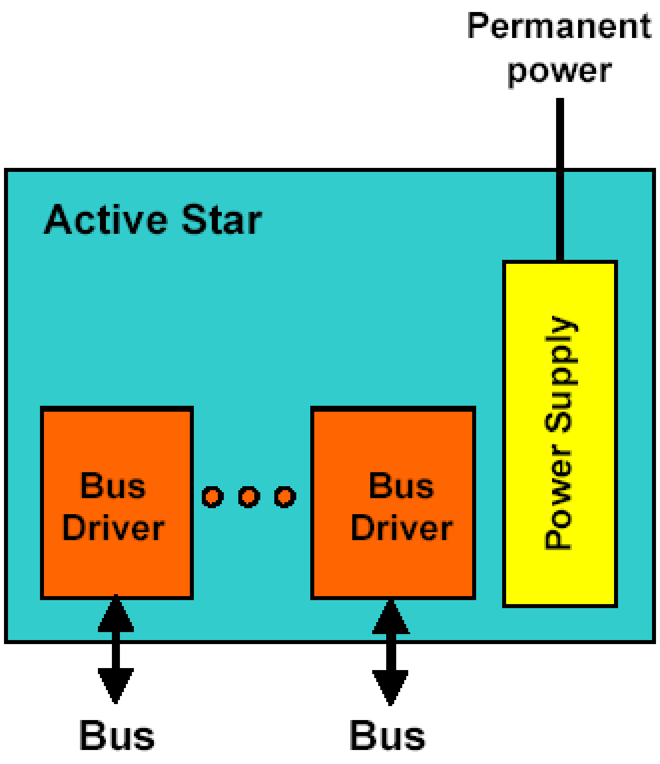



Figure 16: Block chart of an electrical active star.

# Hybrid Topology

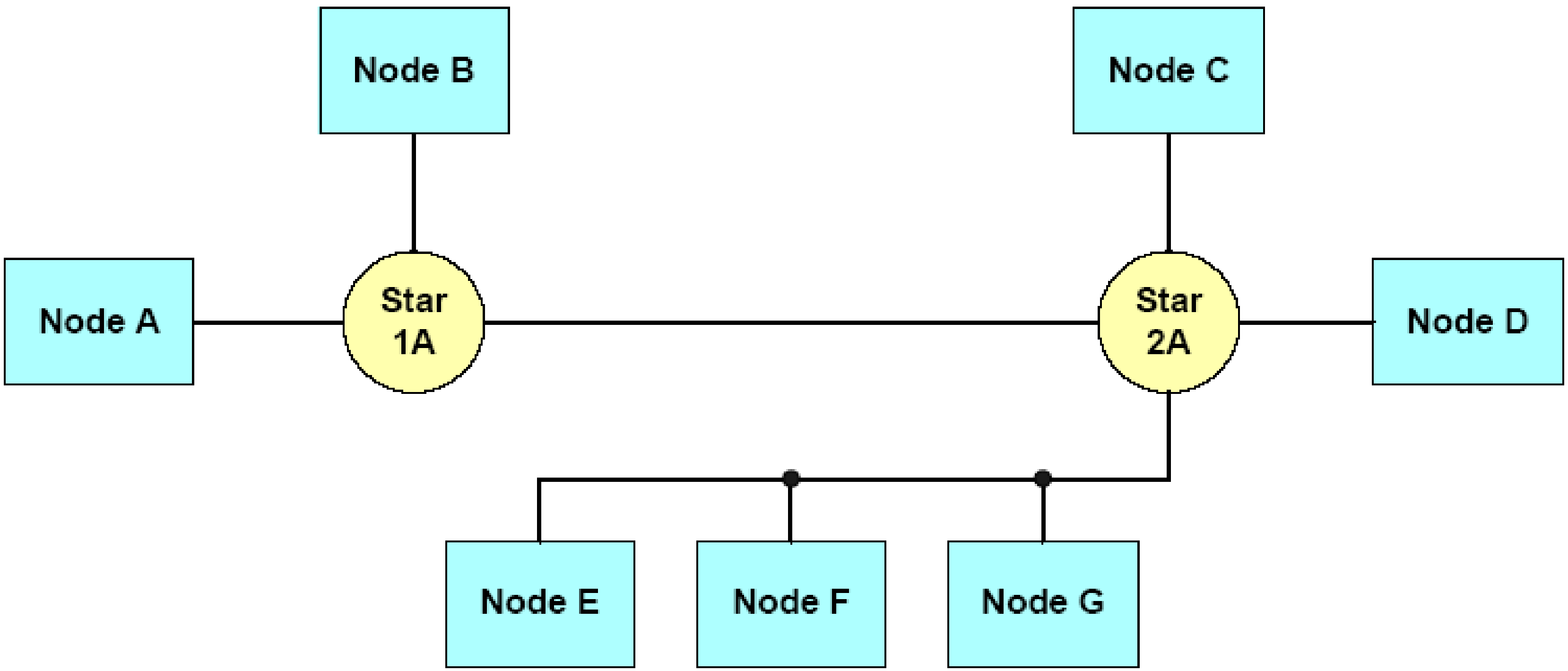
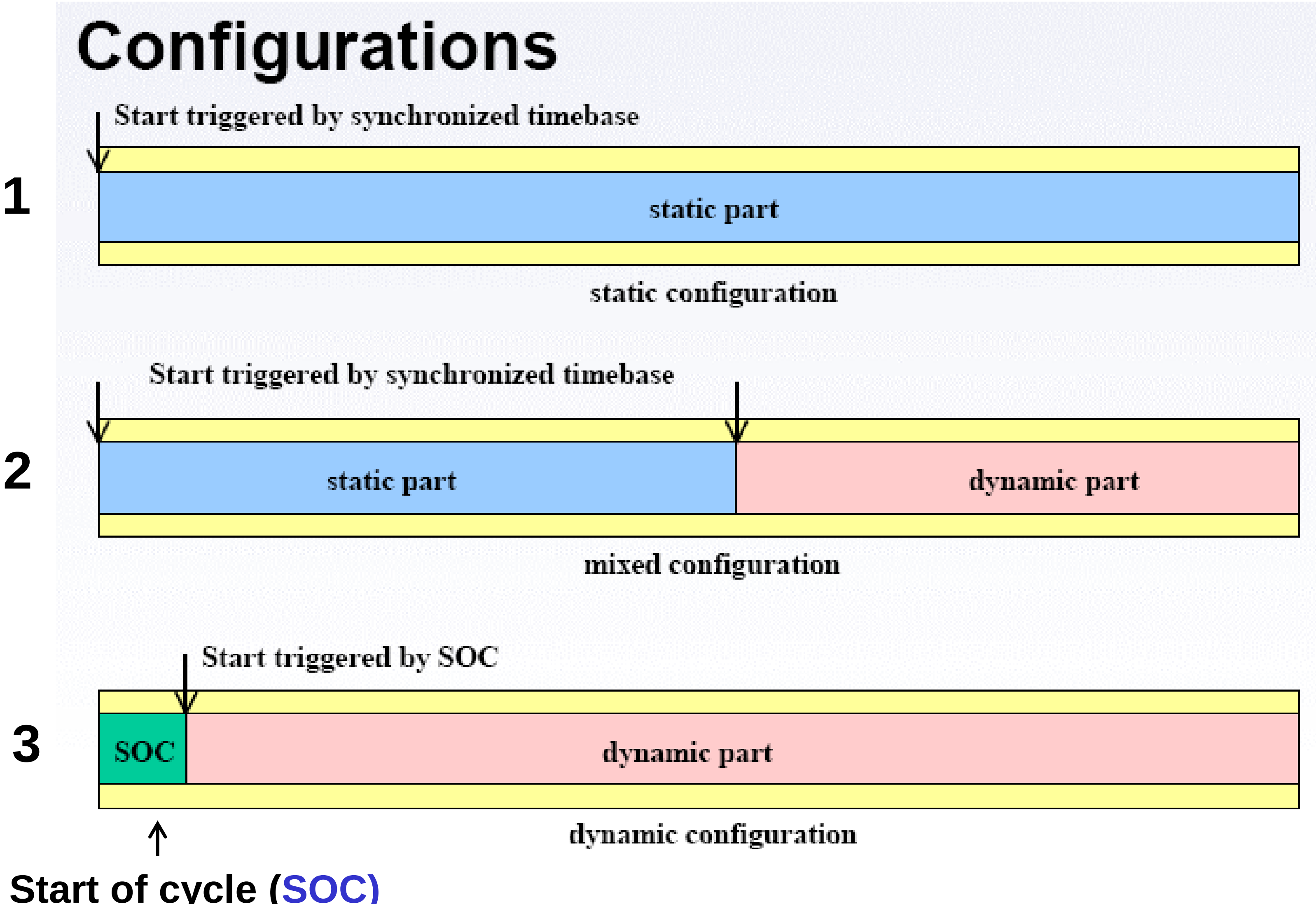



Figure 1-5: Single channel hybrid example.

# Static and Dynamic Segments

- **Static message segment**
  - **state message semantic**
  - deterministic communication behavior
  - **periodic statically scheduled** message transfer is a benefit for automotive applications, especially **distributed control loops** with replication
  - required support for distributed control and closed-loop control functions
- **Dynamic message segment**
  - spontaneous (**event**) message transfer e.g.
  - for burst transmissions
  - for diagnostic information
  - for ad hoc messages in general

# 3 Possible FlexRay Configurations

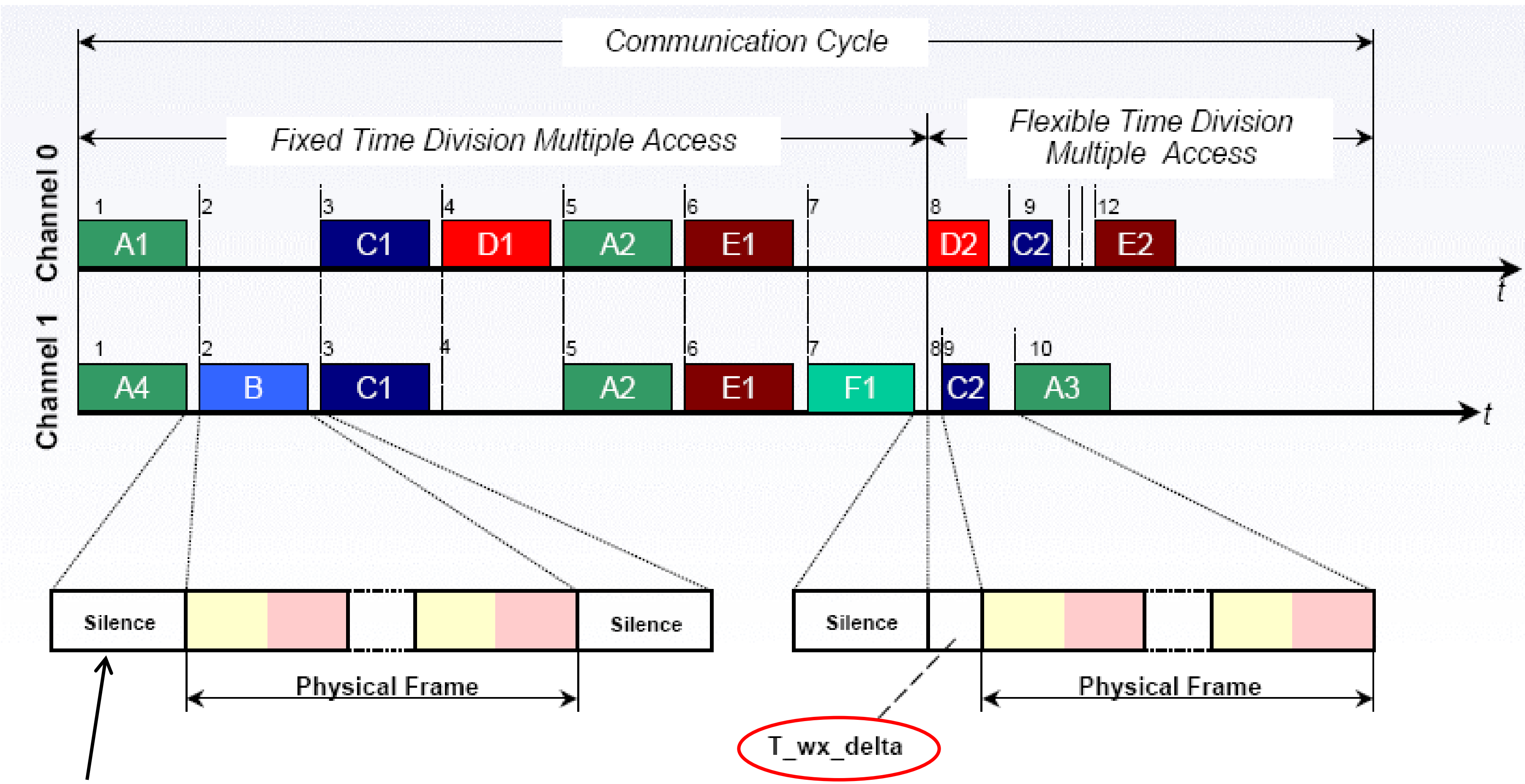


# Frame Transfer

Communication Cycle consisting of two possible segments

- **Static:**
  - Divided in timeslots (**TDMA**)
  - The slot length is **defined off-line** and therefore fixed during runtime
- **Dynamic:**
  - Has a start delimiter: Start of cycle (**SOC)**
    - **Used in pure dynamic cases**
  - **Dynamic frame length**
  - **Media is accessed via timers and priorities**

# FlexRay Communication Cycle




**Inter frame gap**

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# Communication Scheme (Bus Guardians)

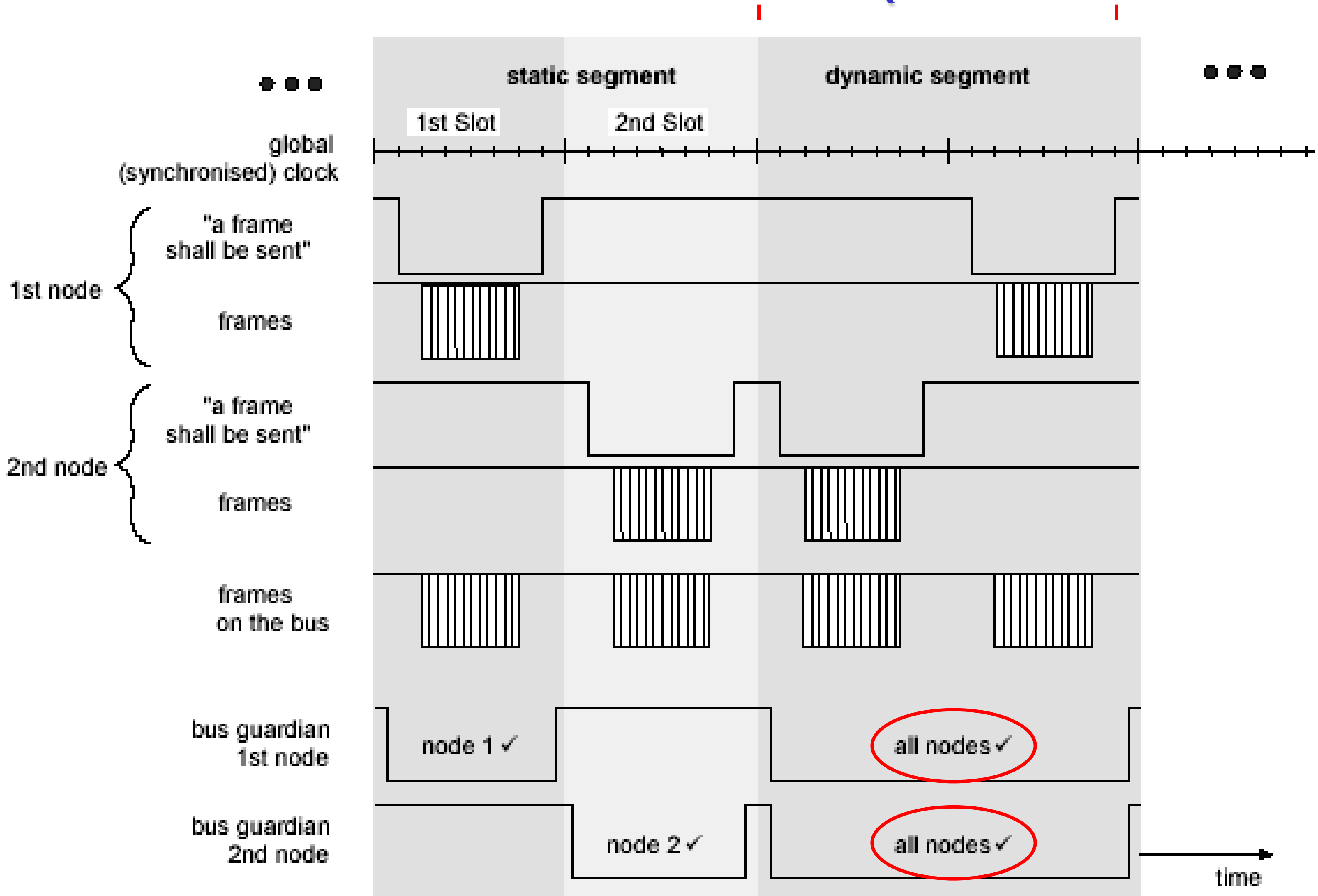



Figure 6: Typical communication scheme of two FlexRay nodes.

# Mixed Topology Example

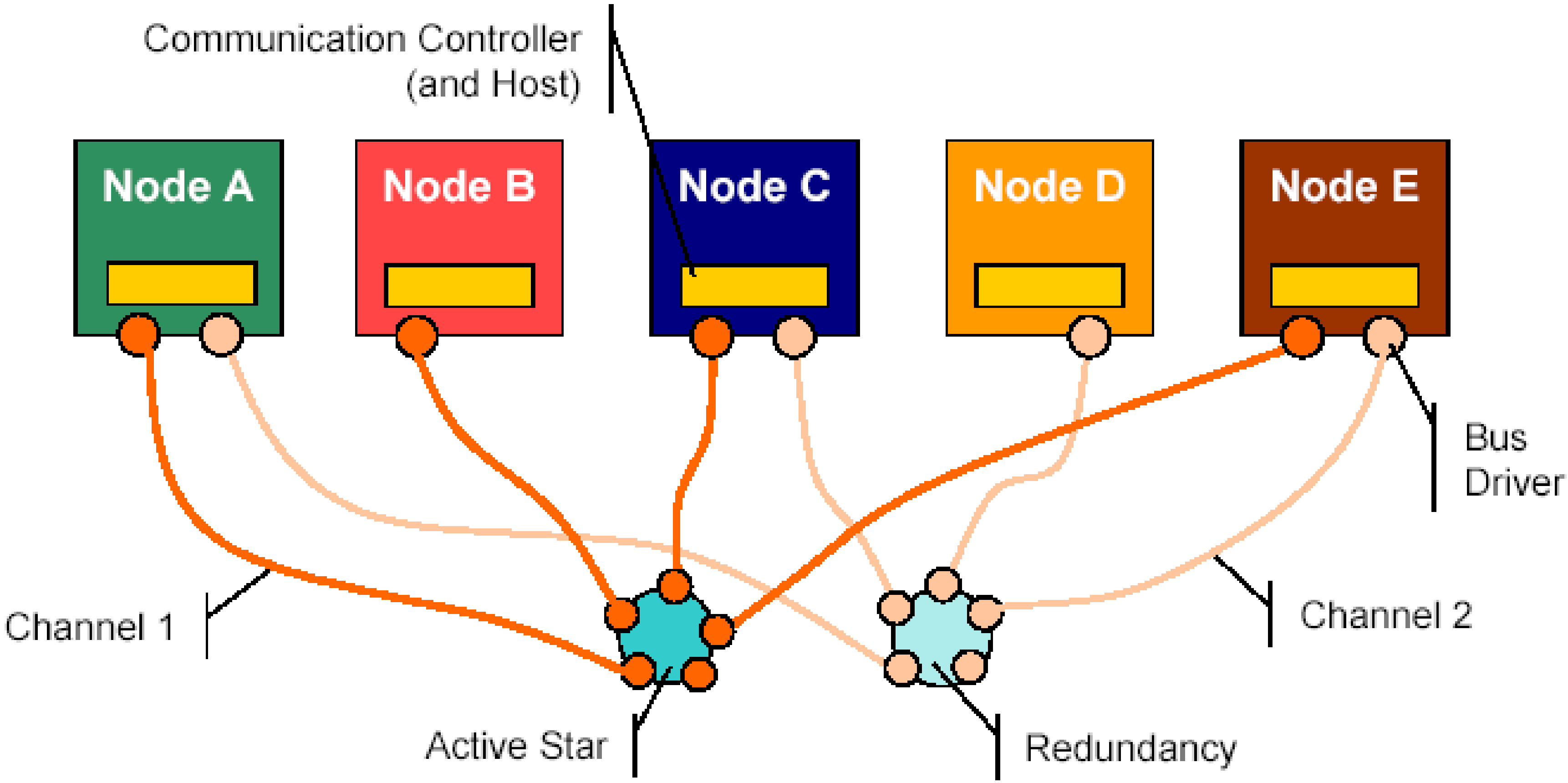
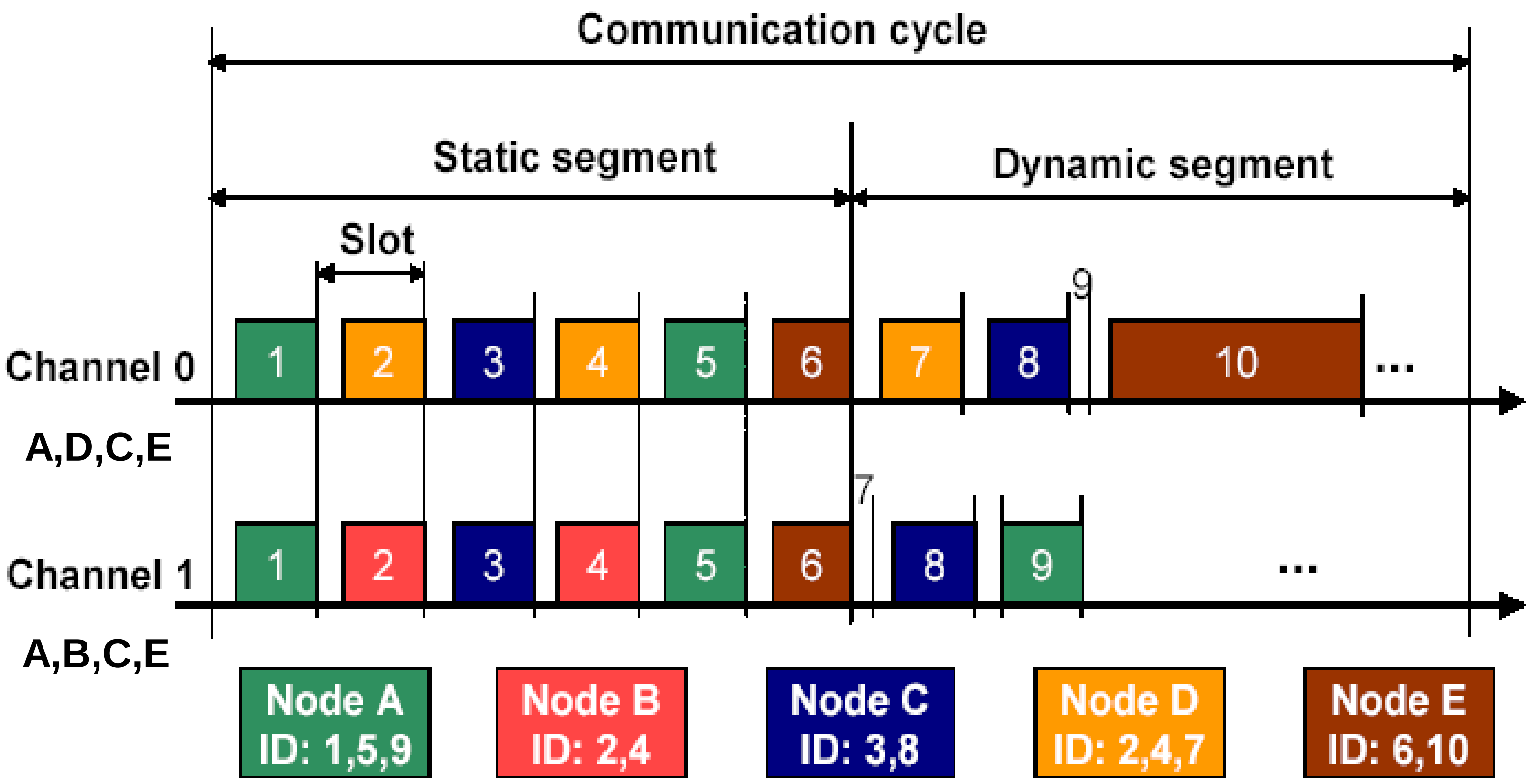



**Figure 3: Possible network configurations.**

**A node can either be connected to both channels (for redundancy) or only to one of the channels**

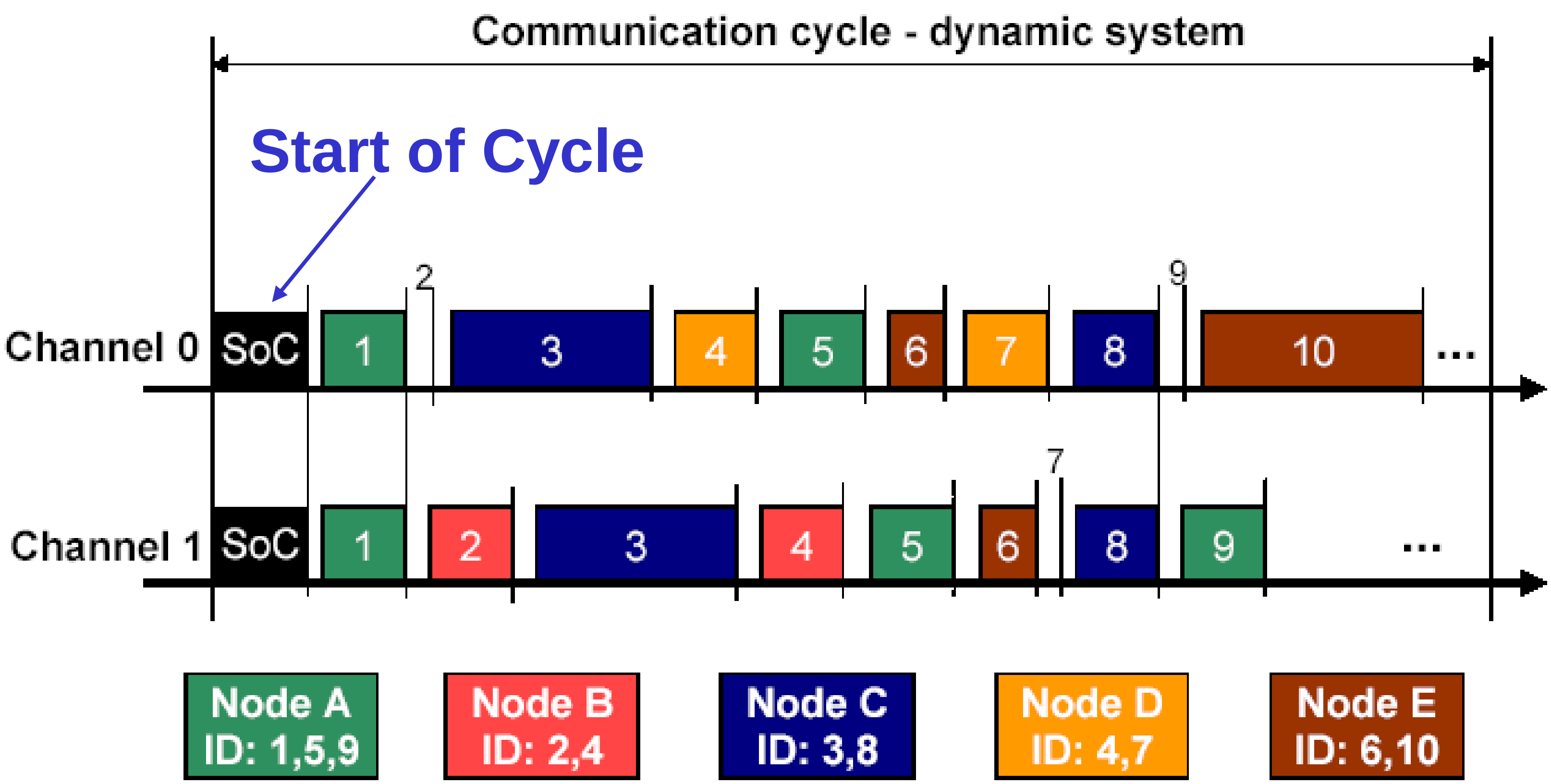
# Frame Transfer Example 1.

**Communication cycle with both static and dynamic segments**



# Frame Transfer Example 2.

## Communication cycle in a pure dynamic system



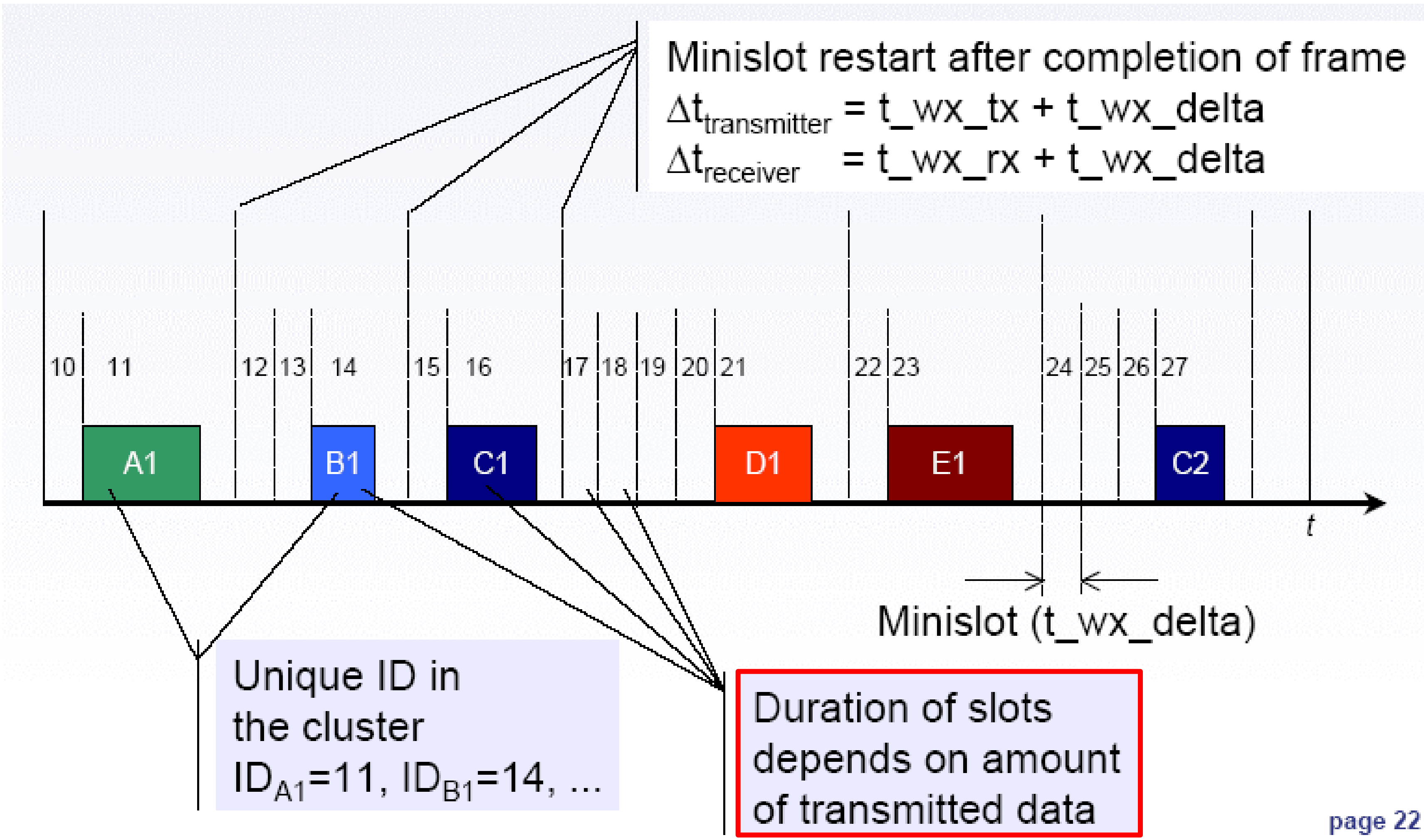
# Static Part Characteristics (1)

- Structure
  - static part divided into static slots of equal duration
  - slot duration defined on a per cluster basis
  - Slot timing identical on both channels
  - each slot identified by an unique slot ID
  - slot start determined by global time
- Configuration
  - static bandwidth allocation
    - slot assigned statically on a per channel basis to a node for transmission
    - specific (time) slots reserved for each node
    - static configuration eliminates run-time contention
  - up to 16 slots assignable per node

# Static Part Characteristics (2)

- Transmission
  - frames transmitted in slots where frame ID matches slot ID
  - all frames have equal length
  - frame content may match or differ within one slot on different channels
  - "Data Update" Bit is set if data was updated since previous cycle
  - slot remains empty if no frame is configured for it
- Bus Guardian interaction
  - access enabled for transmission during assigned slots
  - access disabled for transmission during unassigned slots

# Dynamic Part – Minislotting



# Dynamic Part Characteristics (1)

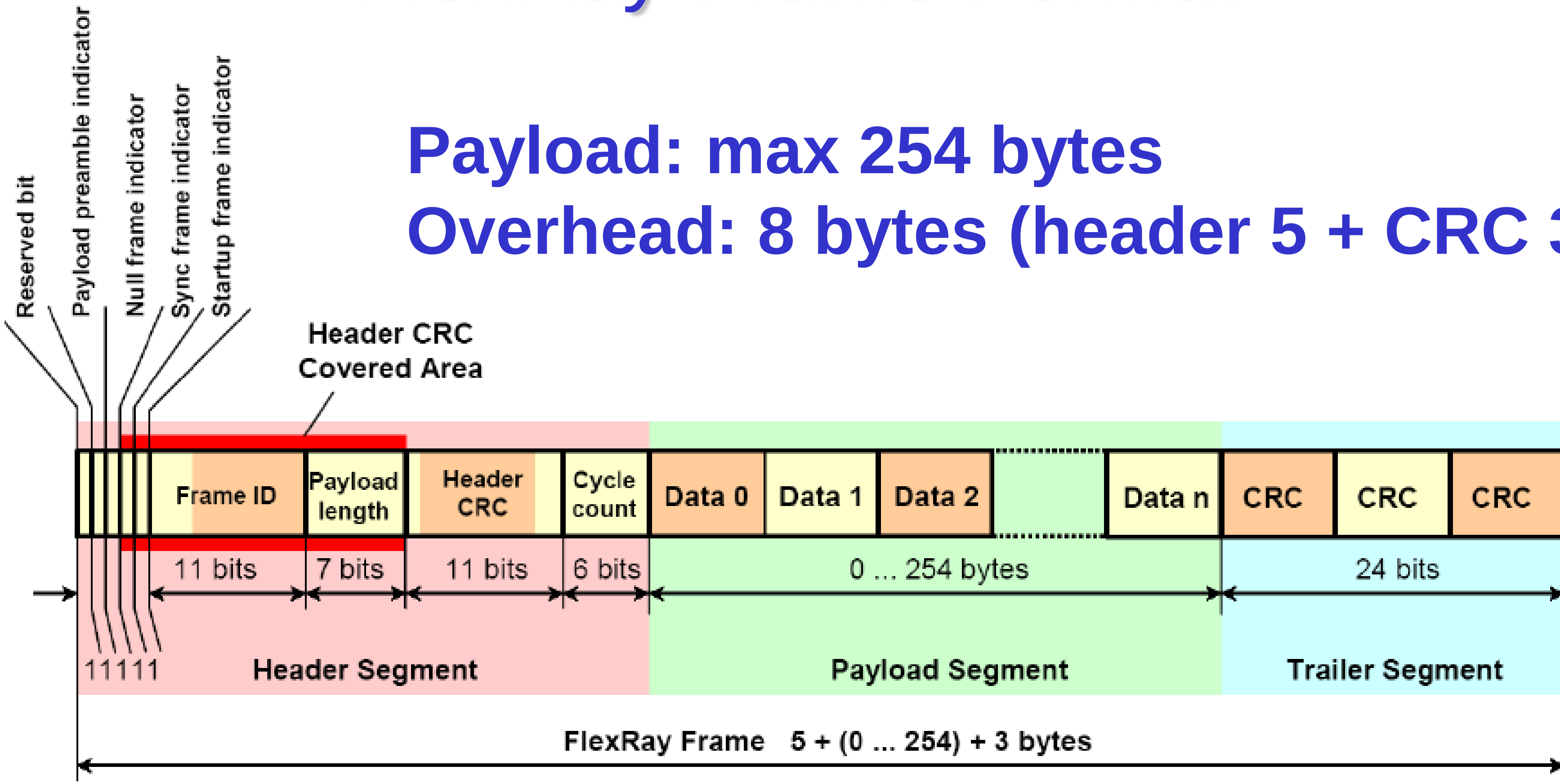
- Structure
  - dynamic bandwidth allocation for each node
    FTDMA - Flexible Time Division Media Access
  - unique IDs matching the (mini-)slot number
    ⇒ no collision, no concurrent transmission
  - if available bandwidth is smaller than sum of all frames to be transmitted those with the higher IDs wait for the next communication cycle
  - start of dynamic part
    - in mixed configuration: based on the global time
    - pure dynamic mode: triggered by SOC

# Dynamic Part Characteristics (2)

- Configuration
  - only 'new' data is transmitted
  - can be reconfigured during normal operation
  - channel sharing allowed for dual and single channel nodes
  - no sync frames allowed
  - to prevent interaction with static part frame IDs are larger than $ID_{max,static}$
- Transmission
  - can be different on both channels
  - determined by minislot counter derived from local clock
- Bus Guardian interaction
  - no protection within dynamic part
  - static part protected against dynamic part
    - BG treats dynamic part like one large static transmission slot

# FlexRay Frame Format

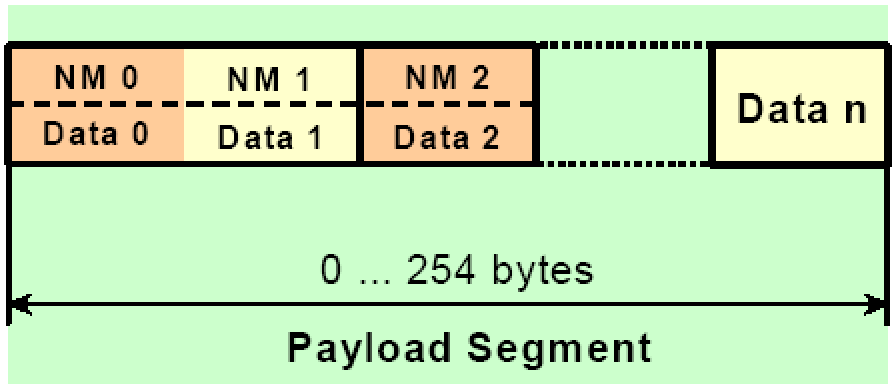
**Payload: max 254 bytes**
**Overhead: 8 bytes (header 5 + CRC 3)**



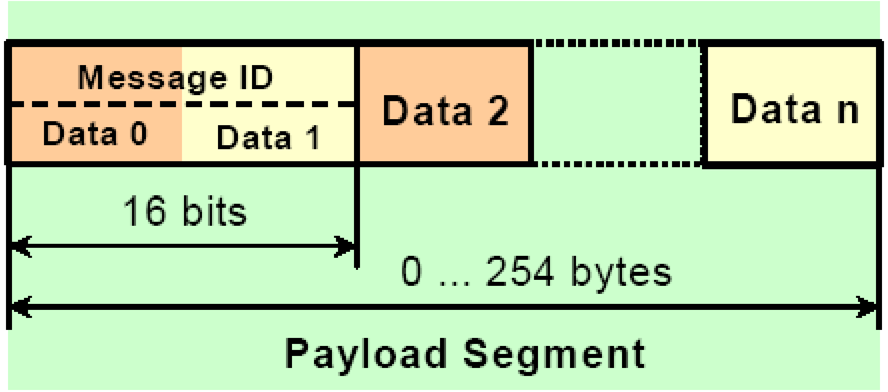

**Frame ID (11 bits):** The frame ID defines the slot in which the frame should be transmitted. A frame ID is used no more than once on each channel in a communication cycle.

# FlexRay Frame Format (2)

**Network Management Vector**




**The message ID is an application determinable number that identifies the contents of the data segment**



# AUTOSAR

**TTAutomotive Joins AUTOSAR, Vienna, Austria – November 29, 2005**

**AUTOSAR is the acronym for AUTomotive Open System ARchitecture.**

**TTAutomotive, TTTech's subsidiary for FlexRayTM solutions, has joined the AUTOSAR development partnership as a premium member.**

**TTAutomotive will focus on FlexRay software modules that comply with AUTOSAR specifications to advance FlexRay-based Time-Triggered Architecture (TTA) in the automotive industry.**

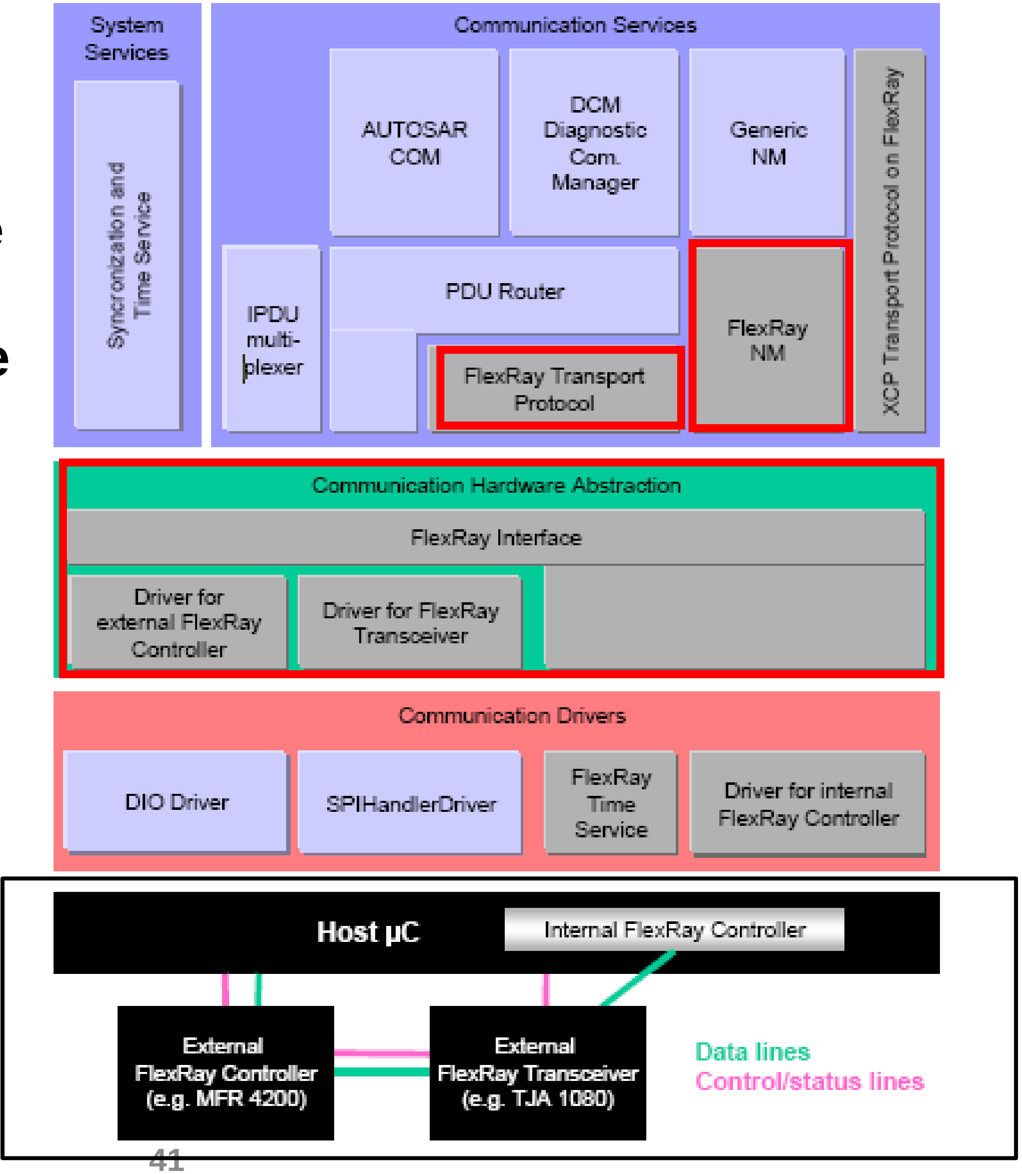
**The development partnership's mission is to establish an industrial standard for off-the-shelf software components, in order to provide cost-optimized, best-in-class solutions to the automotive industry.**
**The architecture is characterized by standardized, non-proprietary, and clearly defined interfaces.**

# AUTOSAR FlexRay Communication Stack

**Task:**

**- Provide a uniform interface to the FlexRay network**

**- Hide protocol and message properties from the application**



# Summary

- FlexRay is “the de facto standard” for high performance bus systems for the automotive market
- FlexRay supports both static and dynamic communication
- Future for car makers:
  - the AUTOSAR initiative (supporting CAN, LIN, FlexRay)

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# References


[FlexRay2005]

*”FlexRay Requirements Specification”*, Version 2.1, 19-dec.-2005

[FlexRay2010]

*”FlexRay Communications System Protocol Specification”* Version 3.0.1, October 2010

[FlexRay-tools]

http://www.ttautomotive.com/

[Autosar]

http://www.autosar.org

[ISO-Standard] *ISO 17458: 2013 Road vehicles FlexRay communications system (part 1 – 5).*

http://www.iso.org/iso/catalogue_detail.htm?csnumber=59804