# FlexRay

Méréstechnika és
Információs Rendszerek
Tanszék


FlexRay™

# Felhasznált irodalom

- **FlexRay Consortium** anyagai (www.flexray.com)
  - FlexRay - Protocol Specification V2.1.rev A és 3.0.1
- D. Paret:
  ***FlexRay and its Applications.***
  ***Real Time Multiplexed Network***
  Whiley, 2012. (Eredeti francia kiadás: 2011.)
  ISBN 978111997956 2
- D. Paret:
  ***Multiplexed Networks for Embedded Systems.***
  ***CAN, LIN, Flexray, Safe-by-Wire...***
  Whiley, 2007. (Eredeti francia kiadás: 2005.)
  ISBN 978-0-470-03416-3
- A rajzok egy része a Vector Group FlexRay posztere alapján készült.

# FlexRay Consortium (2000-2010)

- 2000-ben megalakult.
  - Autógyártók: BMW AG, Daimler Chrysler AG
  - Félvezetőgyártók: Philips Semiconductors (ma NXP), Motorola GmbH (ma Freescale Semiconductor)
- 2003-ban kibővült.
  - Részegységgyártó: Robert Bosch GmbH
  - Autógyártók: General Motors Co., Volkswagen AG
- A fentiek alkották a konzorcium magját (Core Partners).
- 2010-ben megszűnt a konzorcium.

# Konzorciumi tagok

- **Core Partners (7 tag):**
  BMW, Bosch, Daimler, Freescale Semiconductor, General Motors, NXP Semiconductors, Volkswagen.
- **Premium Associate Members (2007-ben 24 tag):**
  3SOFT, Austriamicrosystems AG, C&C group, Continental AG Hannover, DECOMSYS, Delphi Corporation, Denso, EADS, Elmos Semiconductor AG, Fiat, Ford Motor Company, HONDA Motor Co., Mentor Graphics, National Instruments, NISSAN MOTOR CO., Ltd., PSA Peugeot Citroën, Renault, Renesas Technology Corp., Toyota Motor Corporation, TTTech Automotive GmbH, TÜV NORD Mobilität GmbH & Co. KG, IFM, Tyco Electronics Corporation, TZM, Vector-Informatik.
- **Associate Members (2007-ben 73 tag)**, többek között:
  Agilent Technologies Inc., AMI Semiconductor, Analog Devices, ARC Seibersdorf Research GmbH, Atmel Corporation, CANway technology GmbH, dSPACE GmbH, Esterel Technologies, FTZ - Research and Technology Association, Fujitsu Microelectronics Europe GmbH, Hitachi, Ltd., HYUNDAI KIA MOTORS, LeCroy, Mitsubishi Electric, Mitsubishi Motors Corporation, NEC Corporation, NEC Electronics Europe, NIPPON SEIKI CO., LTD., Siemens VDO Automotive, Suzuki Motor Corporation, TDK, Telemotive, Texas Instruments, The SKF Group, Toyota Tsusho Electronics Corp., Xilinx, Yamaha Motor Co. Ltd. ...

# A fejlesztés motorja: DECOMSYS

- **DECOMSYS** (Dependable Computer Systems, www.decomsys.com) - is a Vienna University of Technology spin-off company founded in 1998. The founders of DECOMSYS were part of the development team of the Time-Triggered Architecture (TTA). This technology was driven forward by major companies of the European transportation industries in the two European projects Time-Triggered Architecture (TTA) and Safety-related Fault-tolerant Systems in Vehicles (X-By-Wire).
- A substantial part of the former TU-Vienna development team is now with DECOMSYS working on FlexRay. The lessons learned from TTA at the university and in the European projects now prove very valuable in the development of FlexRay underscoring the successful technology transfer from a research project to an industry product of highest quality for mass production. As a development partner of the FlexRay consortium DECOMSYS offers tools, chip design services, engineering services and training for the development of distributed fault-tolerant applications based on the FlexRay system.
- (Source: www.flexray.com)

# Az utolsó konzorciumi specifikációk

- **FlexRay™ Specifications Version 3.0.1**
  - FlexRay™ Protocol Specification Version 3.0.1
  - FlexRay™ Protocol Conformance Test Specification Version 3.0.1
  - FlexRay™ Electrical Physical Layer Specification Version 3.0.1
  - FlexRay™ Electrical Physical Layer Conformance Test Specification Version 3.0.1
  - FlexRay™ Electrical Physical Layer Application Notes Version 3.0.1
- **FlexRay™ Specifications Version 2.1**
  - FlexRay™ Requirements Specification V2.1
  - FlexRay™ Protocol Specification V2.1 Rev.A
  - FlexRay™ Protocol Specification V2.1 Rev. A Errata V1
  - FlexRay™ Protocol Conformance Test Specification V2.1.1
  - FlexRay™ Protocol Conformance Test Specification V2.1.2
  - FlexRay™ Electrical Physical Layer Specification V2.1 Rev B
  - FlexRay™ Electrical Physical Layer Specification V2.1 Rev B Errata sheet Version 2.0
  - FlexRay™ Electrical Physical Layer Application Notes V2.1 Rev B
  - FlexRay™ Electrical Physical Layer Conformance Test Specification V2.1 Rev. A
  - FlexRay™ Electrical Physical Layer Conformance Test Specification v2.1 Rev. A Errata Sheet 2
  - FlexRay™ Electrical Physical Layer Conformance Test Specification V2.1 Rev. B
  - FlexRay™ Electrical Physical Layer Conformance Test Specification V2.1 Rev. B Errata 1
  - FlexRay™ Physical Layer EMC Measurement Specification V2.1
  - FlexRay™ Physical Layer Common Mode Choke EMC Evaluation Specification V2.1
  - FlexRay™ Electrical Physical Layer Conformance Test Specification V2.1 Rev. B Heterogeneous Tests
- **FlexRay™ Informative Specifications**
  - FlexRay™ Preliminary Node-Local Bus Guardian Specification V2.0.9
  - FlexRay™ Preliminary Central Bus Guardian Specification V2.0.9

# Nemzetközi szabvány

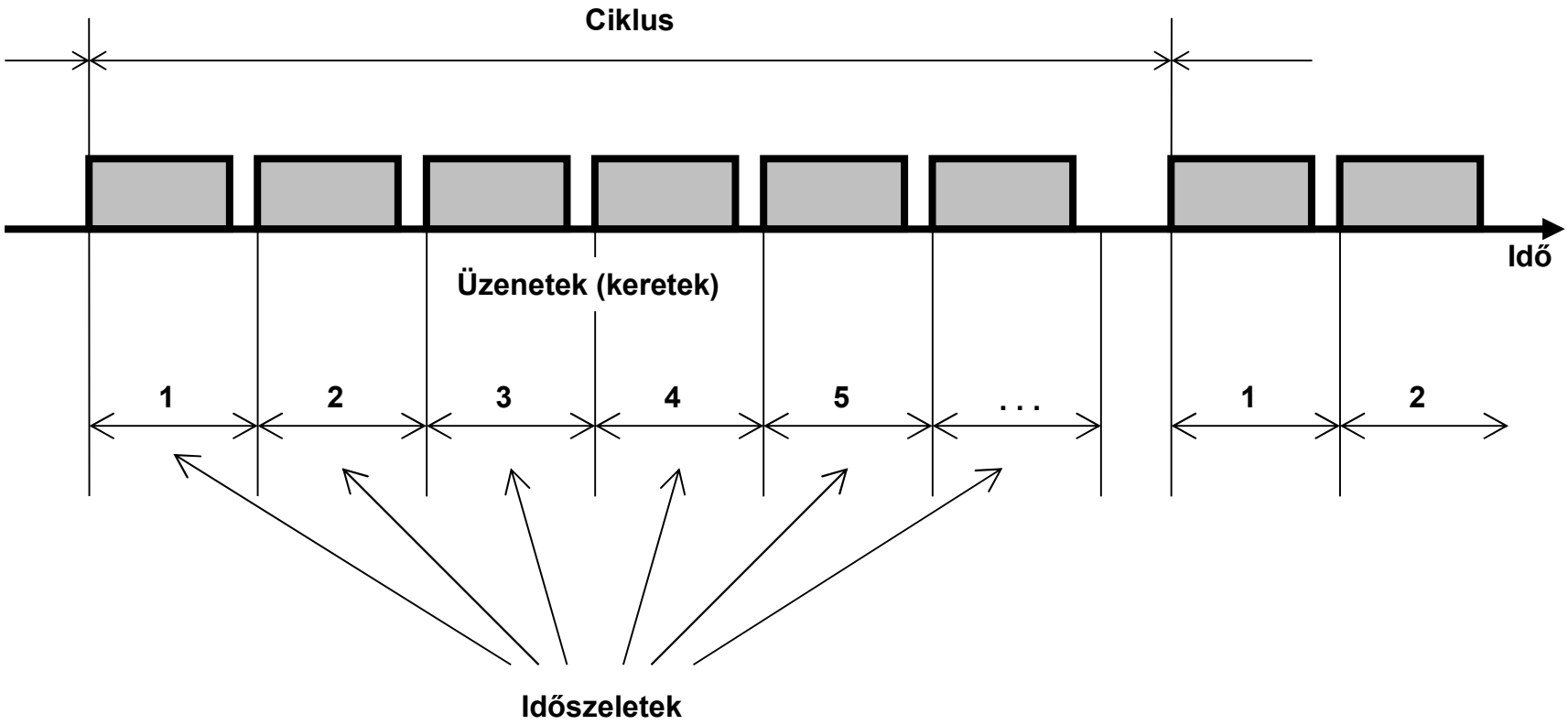
- Felajánlották az ISO-nak szabványosításra.
- FlexRay™ Specifications Version 2.1 és 3.0.1

- Autóipari alkalmazásokra találták ki, más alkalmazásokra nem gondoltak.

# Nemzetközi szabvány: ISO 17458

- ISO 17458-1:2013 Road vehicles -- FlexRay communications system – Part 1: **General information and use case definition**
- ISO 17458-2:2013 Road vehicles -- FlexRay communications system – Part 2: **Data link layer specification**
- ISO 17458-3:2013 Road vehicles -- FlexRay communications system – Part 3: **Data link layer conformance test specification**
- ISO 17458-4:2013 Road vehicles -- FlexRay communications system – Part 4: **Electrical physical layer specification**
- ISO 17458-5:2013 Road vehicles -- FlexRay communications system – Part 5: **Electrical physical layer conformance test specification**

# Alapelv



# Bit rates

- Standard bit rates
  - 10 Mbit/s (*gdBit* = 100 ns)
  - 5 Mbit/s (*gdBit* = 200 ns)
  - 2.5 Mbit/s (*gdBit* = 400 ns)

- Mindhármat tudnia kell egy FlexRay hálózatnak.

# Parameter prefix conventions

- <variable> ::= <prefix_1> [<prefix_2>] Name
- <prefix_1>::= a | c | v | g | p | z
- <prefix_2>::= d | s

- a Auxiliary Parameter
- c Protocol Constant
- v Node Variable
- g Cluster Parameter
- p Node Parameter
- z Local SDL Process Variable

- d Time Duration
- s Set

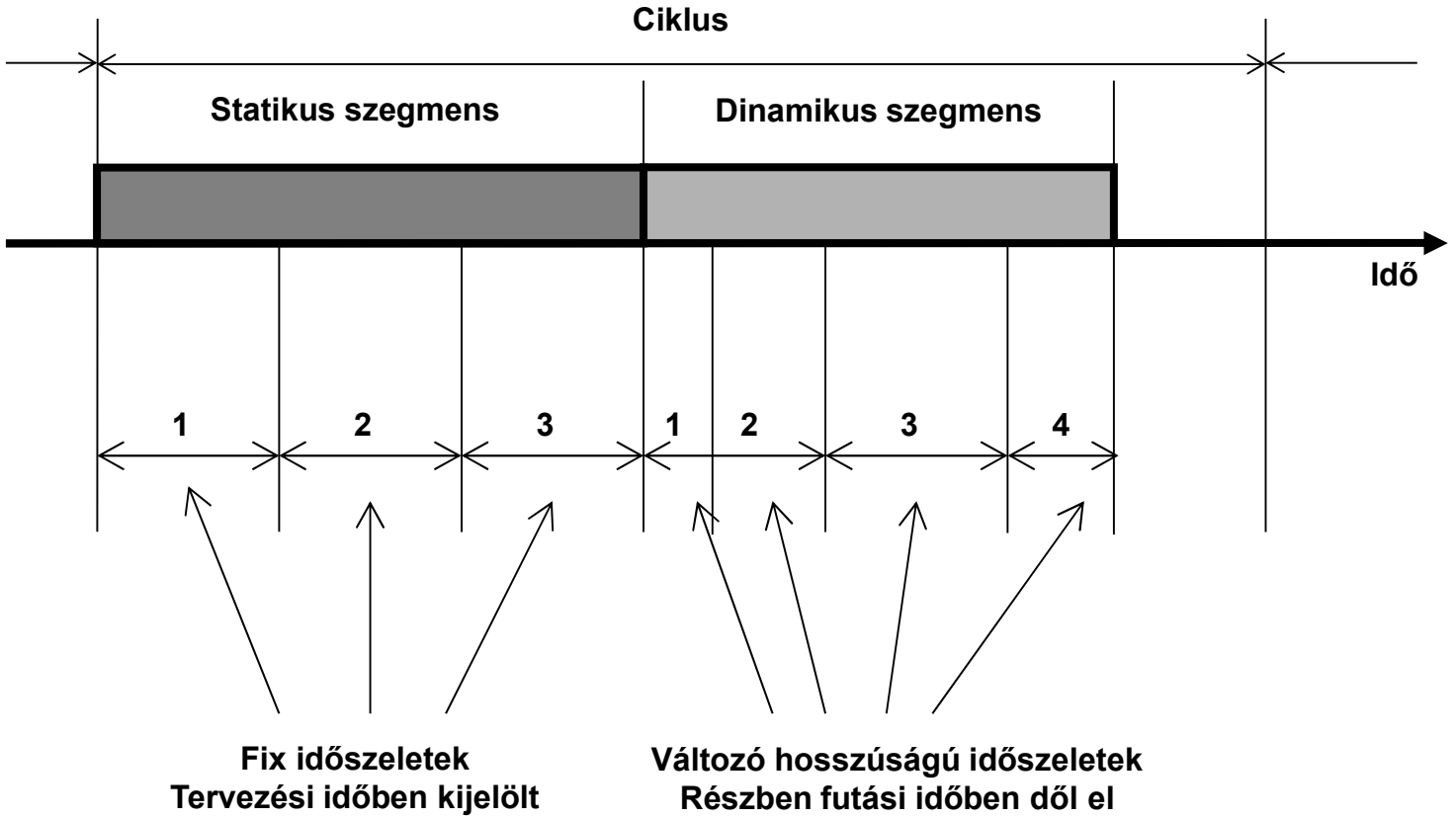
Példák:

***gdBit***

***gdStaticSlot***

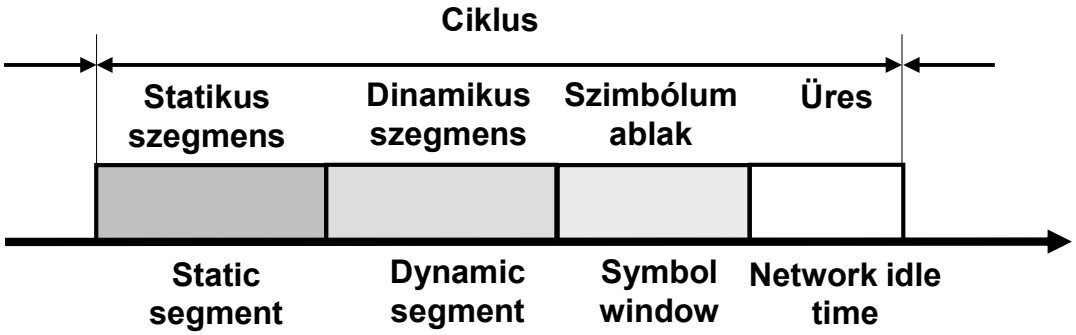
- g: a teljes klaszterre érvényes paraméter
- d: időtartam

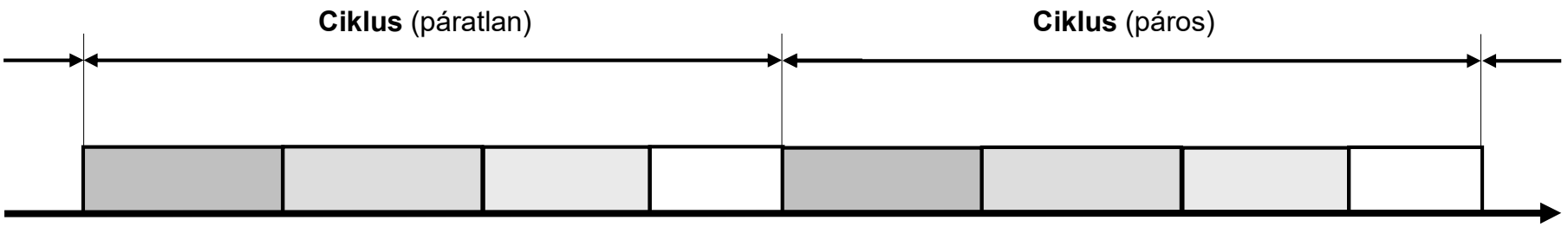
# Szegmensek




**Időszeletenként egy üzenet**

# FlexRay TDMA structure

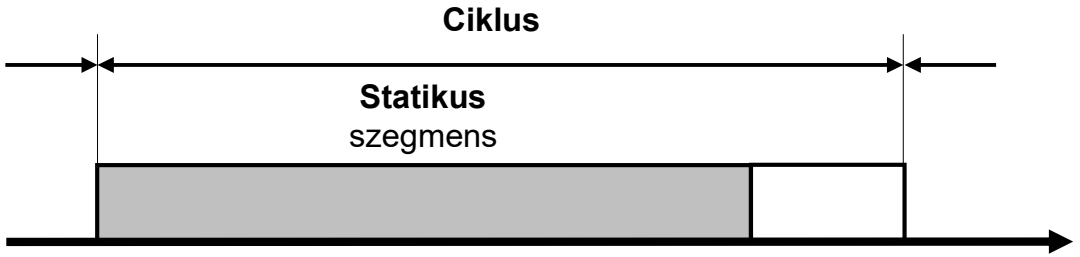


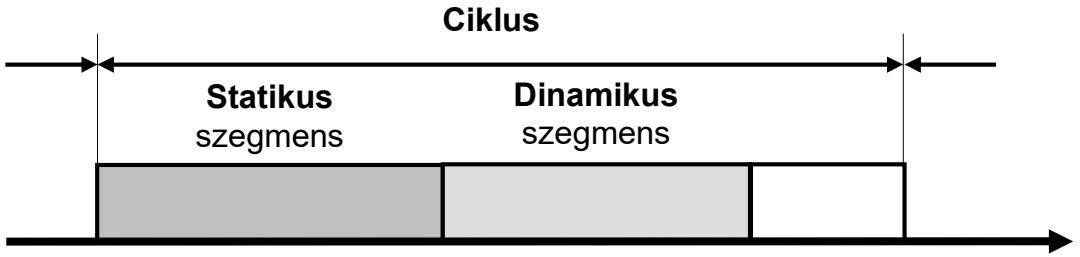

Az időszinkron miatt párba szervezik a ciklusokat. (Lásd később!)

# FlexRay TDMA configurations

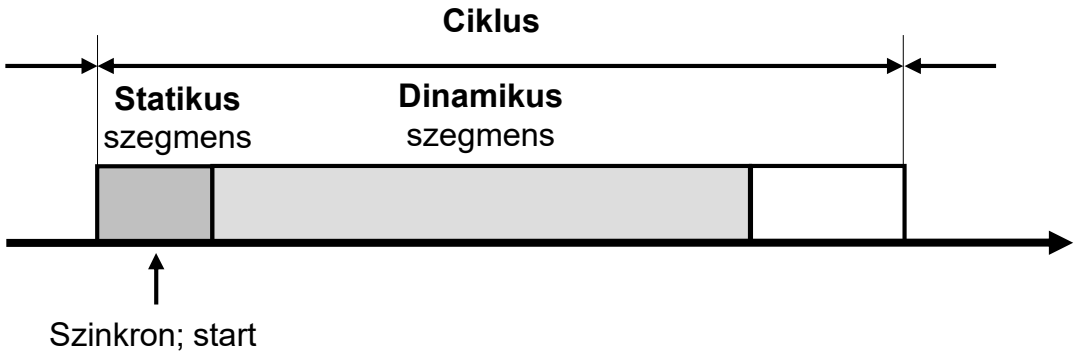
**Static** configuration



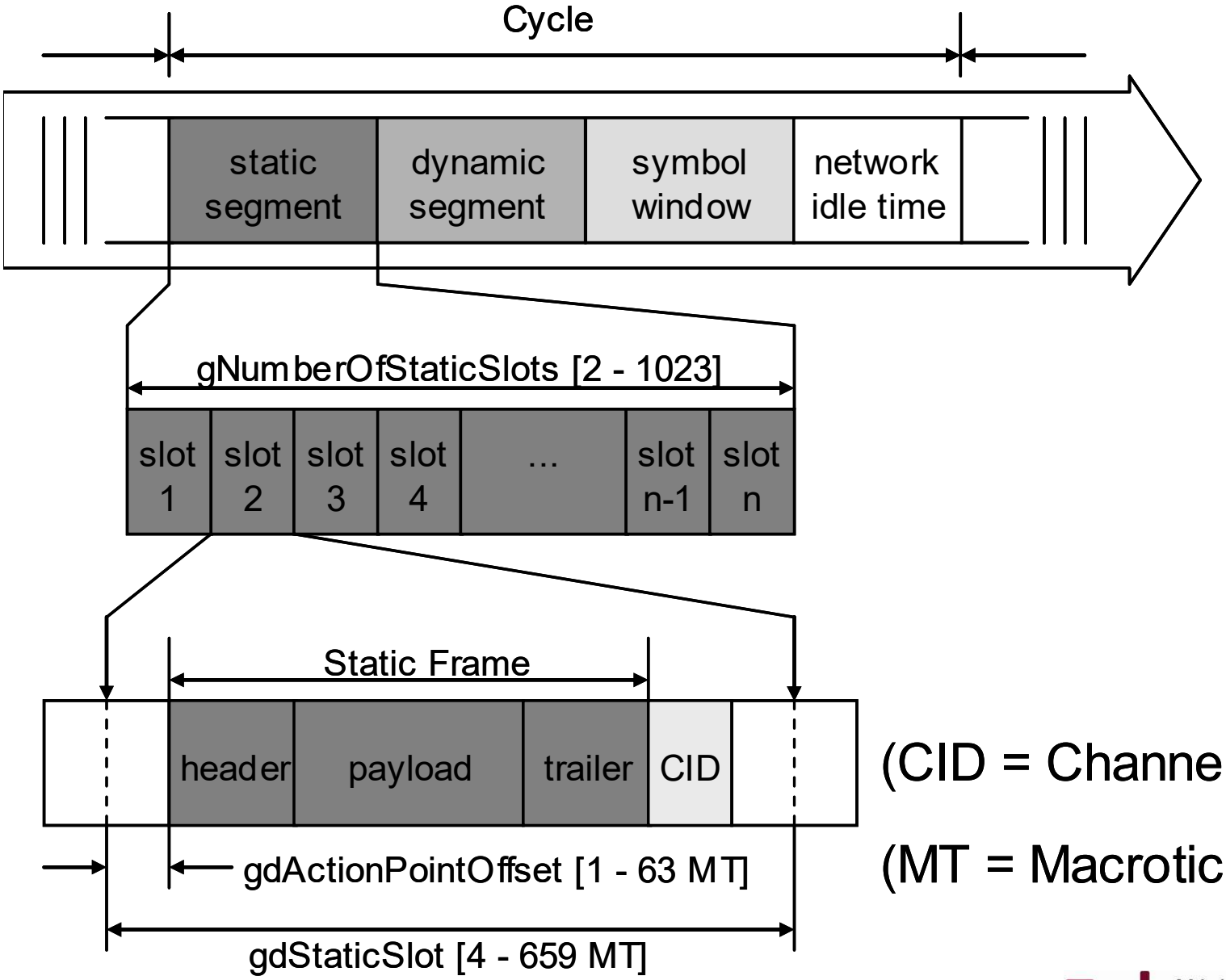

**Mixed** configuration




**Dynamic** configuration



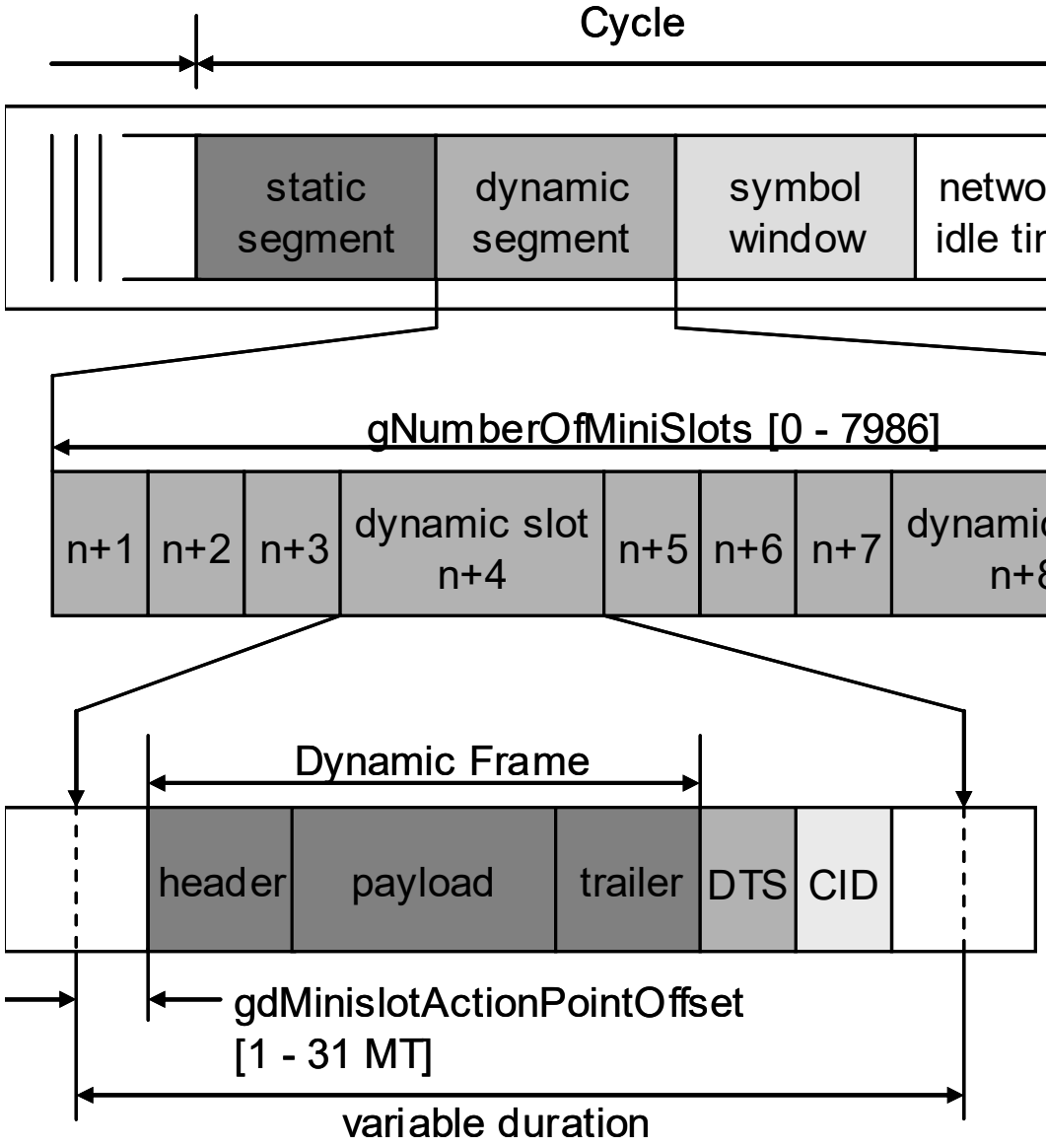
# Static segment




(CID = Channel Idle Delimiter)

(MT = Macrotick)

# Dynamic segment

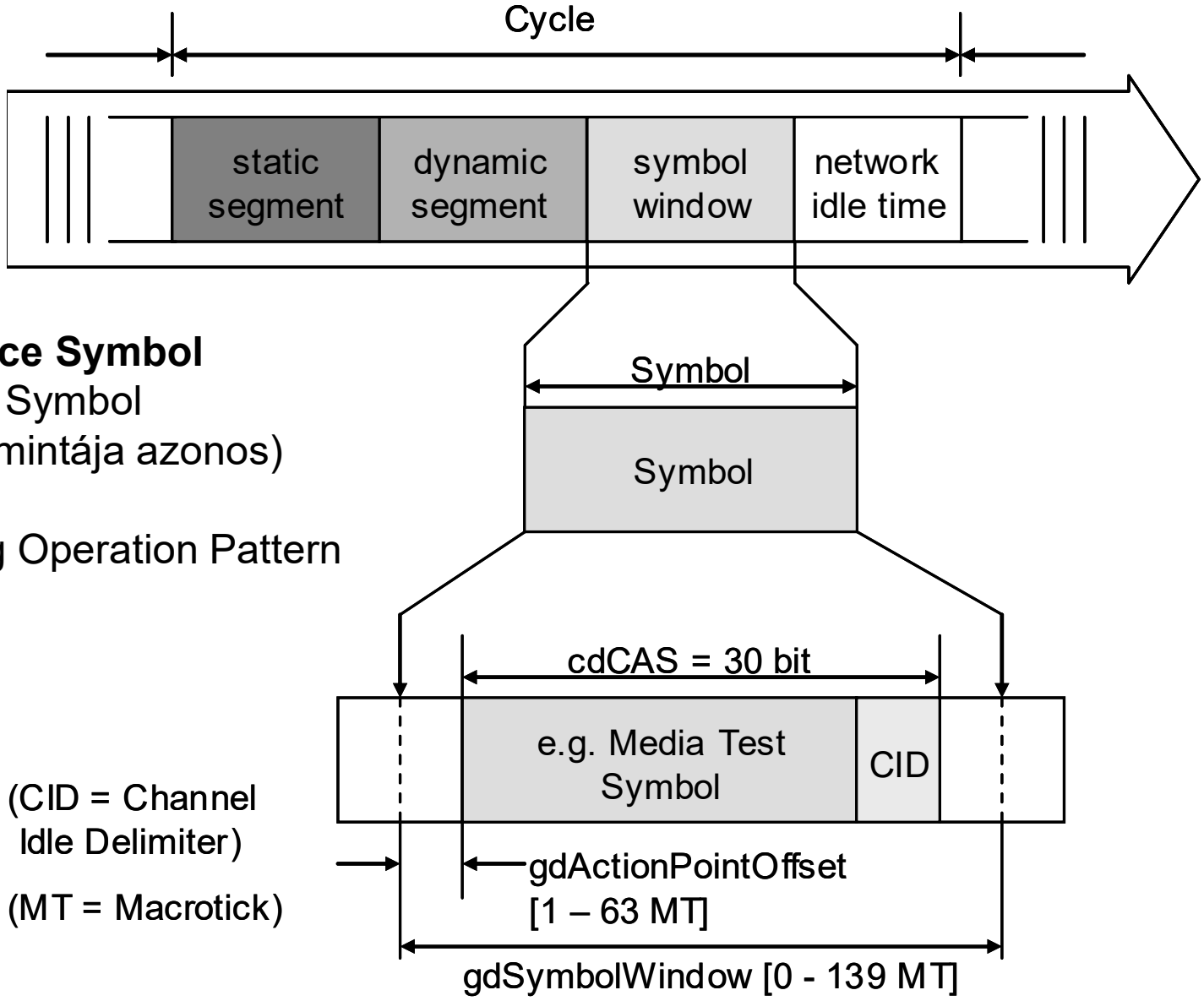



(DTS = Dynamic Trailing Sequence)

(CID = Channel Idle Delimiter)

(MT = Macrotick)

# Symbol window

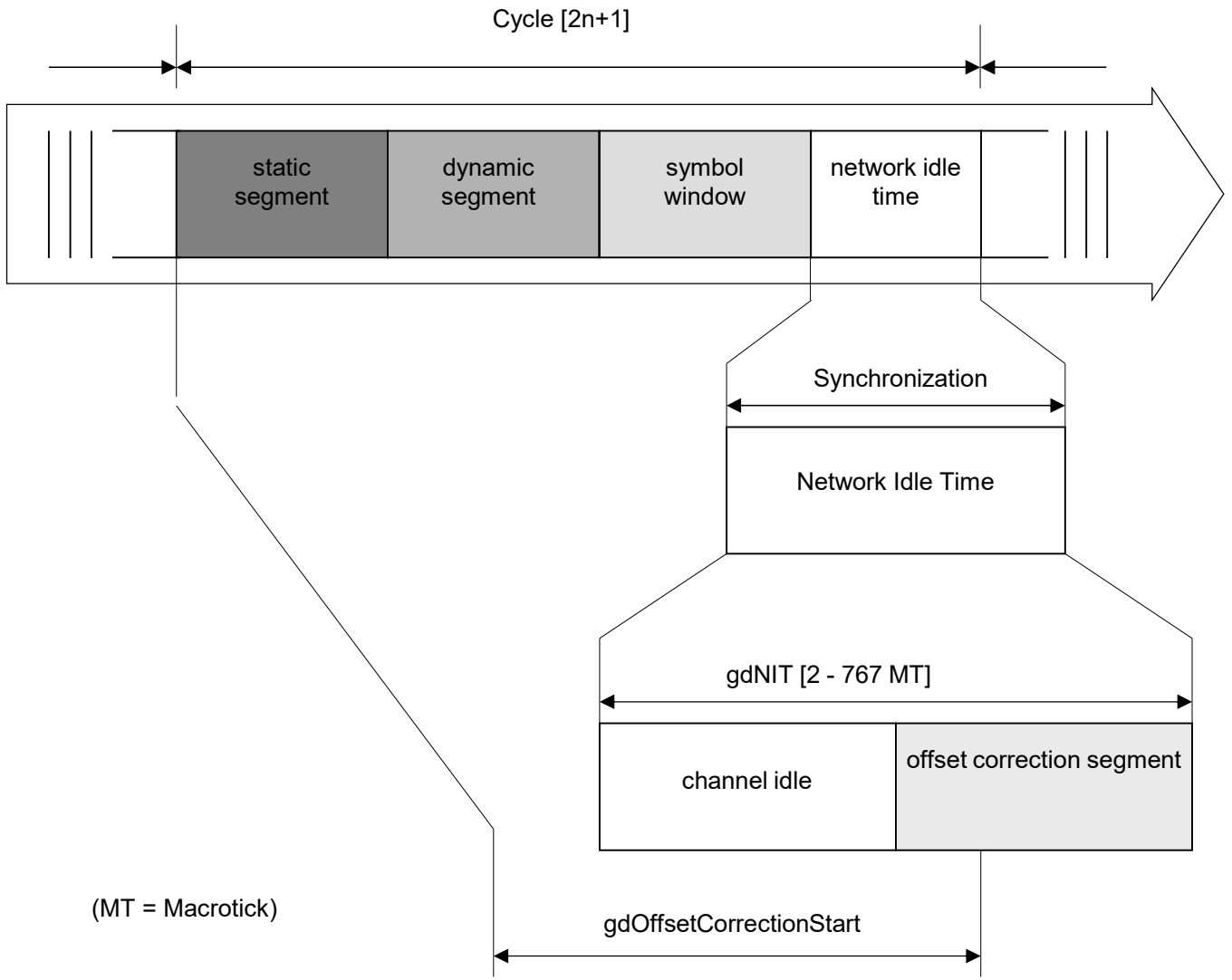



**CAS – Collision Avoidance Symbol**
MTS – Media Access Test Symbol
(CAS és MTS bitmintája azonos)
WUS – Wakeup Symbol
WUDOP – Wakeup During Operation Pattern

(CID = Channel Idle Delimiter)

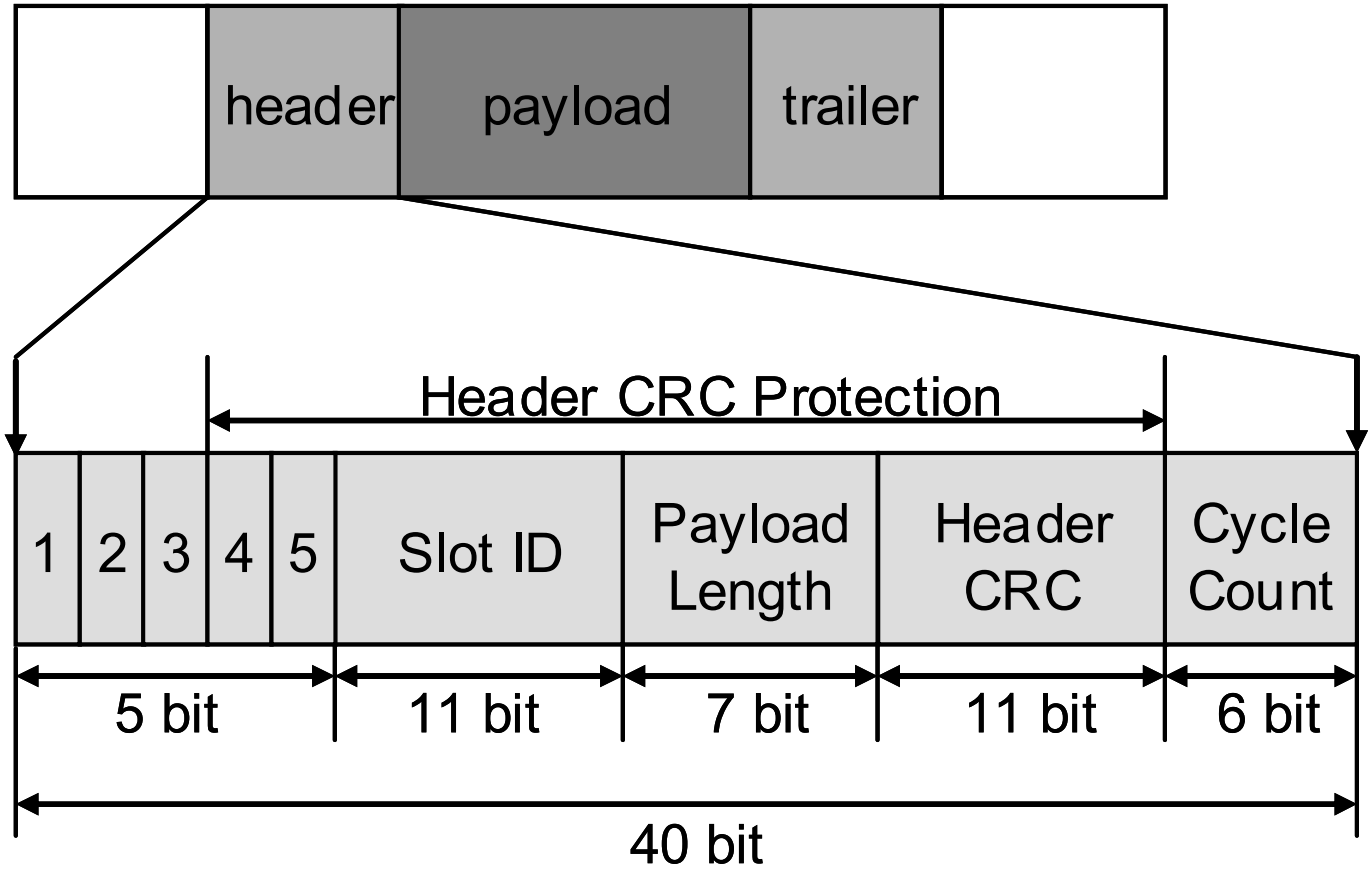
(MT = Macrotick)

# Network Idle Time (NIT)



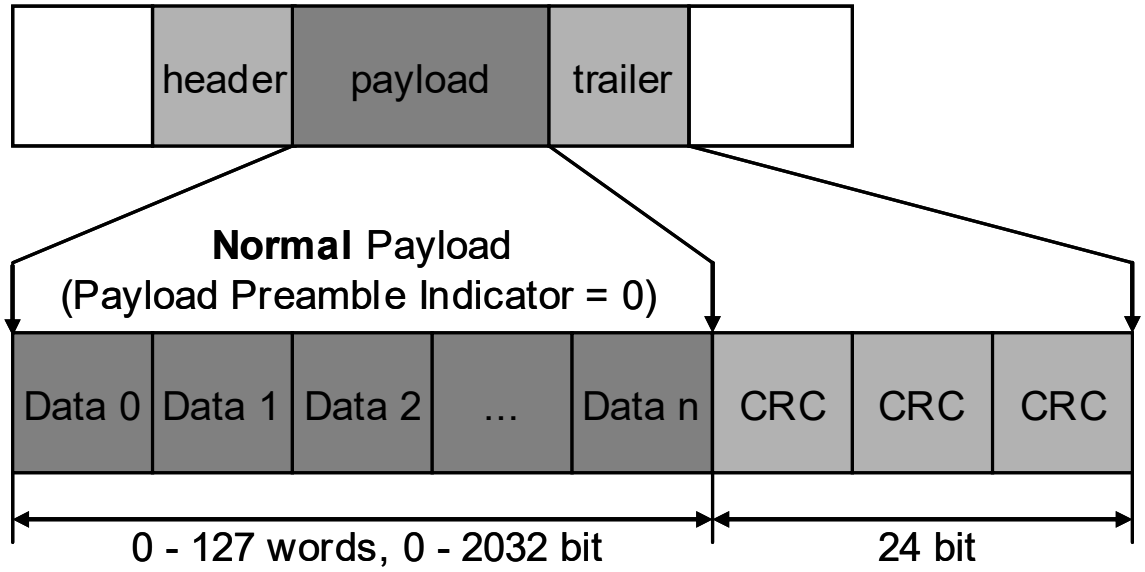

(A Vector Group FlexRay posztere alapján)

# Frame Format – Header

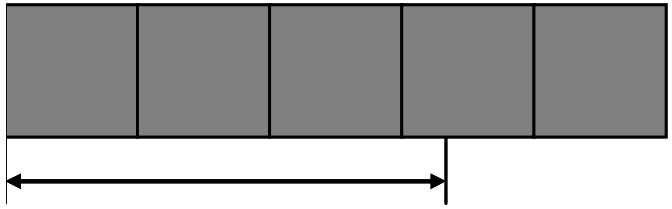



| | | | |
|---|---|---|---|
| 5: | Startup Frame Indicator | [0]: Normal | [1]: Startup Frame |
| 4: | Sync Frame Indicator | [0]: Normal | [1]: Sync Frame |
| 3: | Null Frame Indicator | [0]: Normal | [1]: Null Frame |
| 2: | Payload Preamble Indicator | [0]: Normal | [1]: Special Payload |
| 1: | Reserved | [0] | |

# Frame Format – Payload, CRC

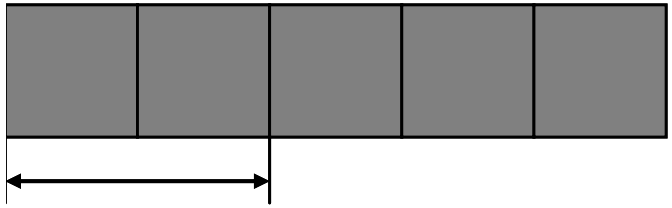



**Special** Payload (Payload Preamble Indicator = 1)
**Static Frame**



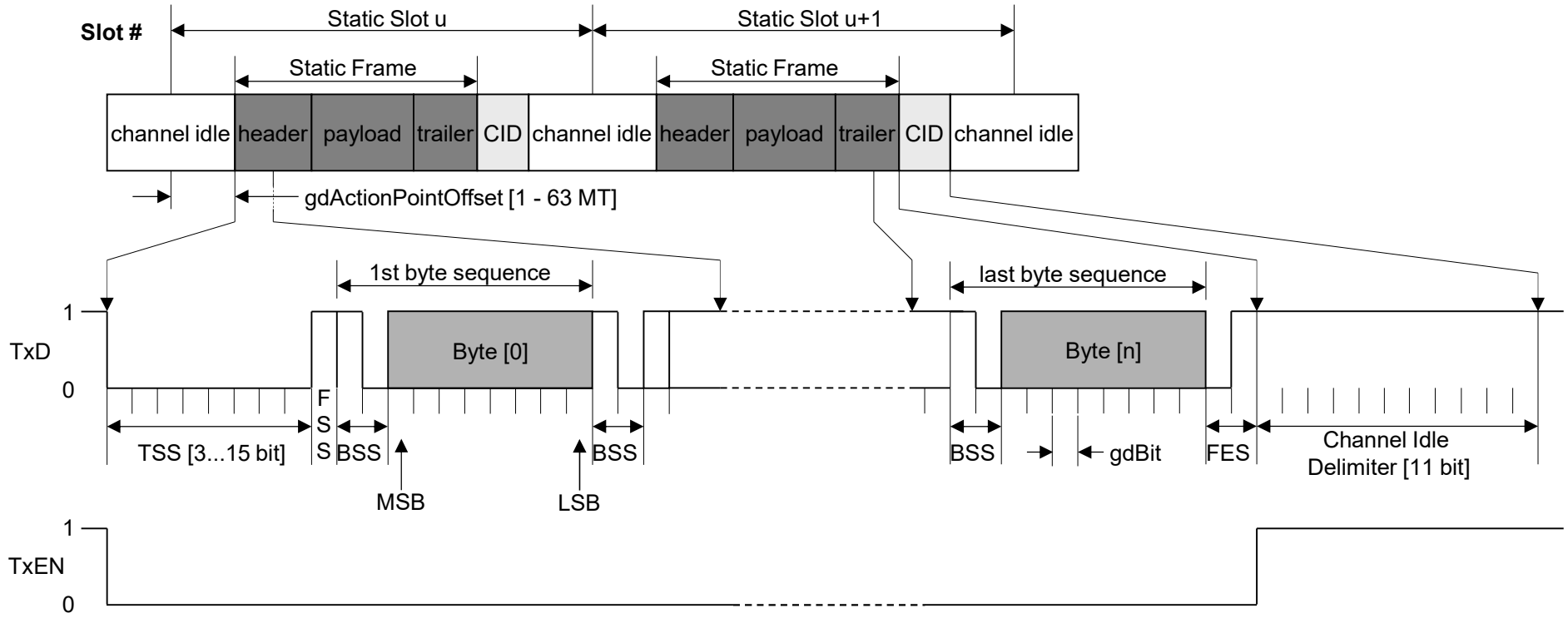
**NW Management Vector**
gNetworkManagementVectorLength [0 – 12 byte]

**Special** Payload (Payload Preamble Indicator = 1)
**Dynamic Frame**



**Message ID**
[2 byte]

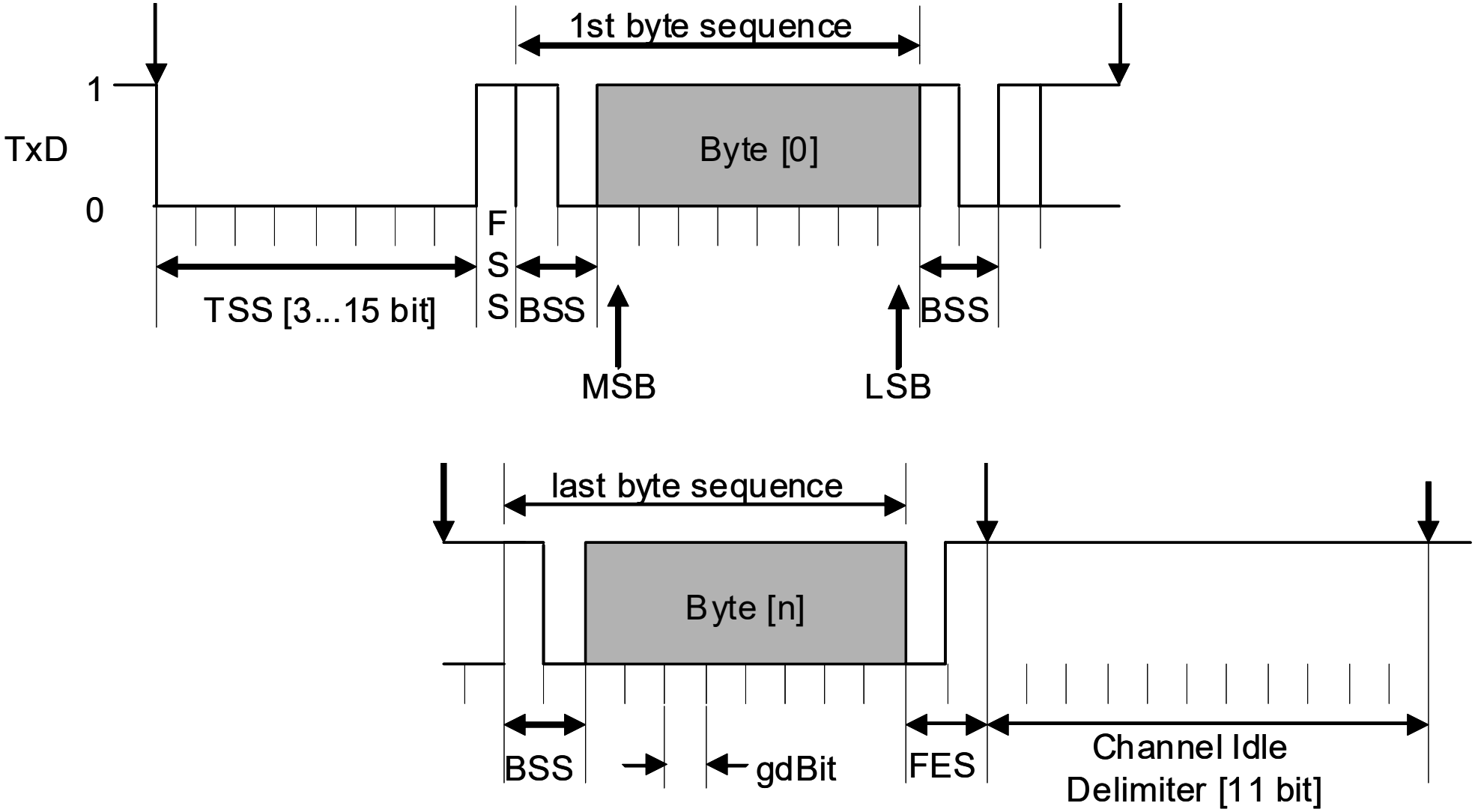
# Frame Coding – Static Slot



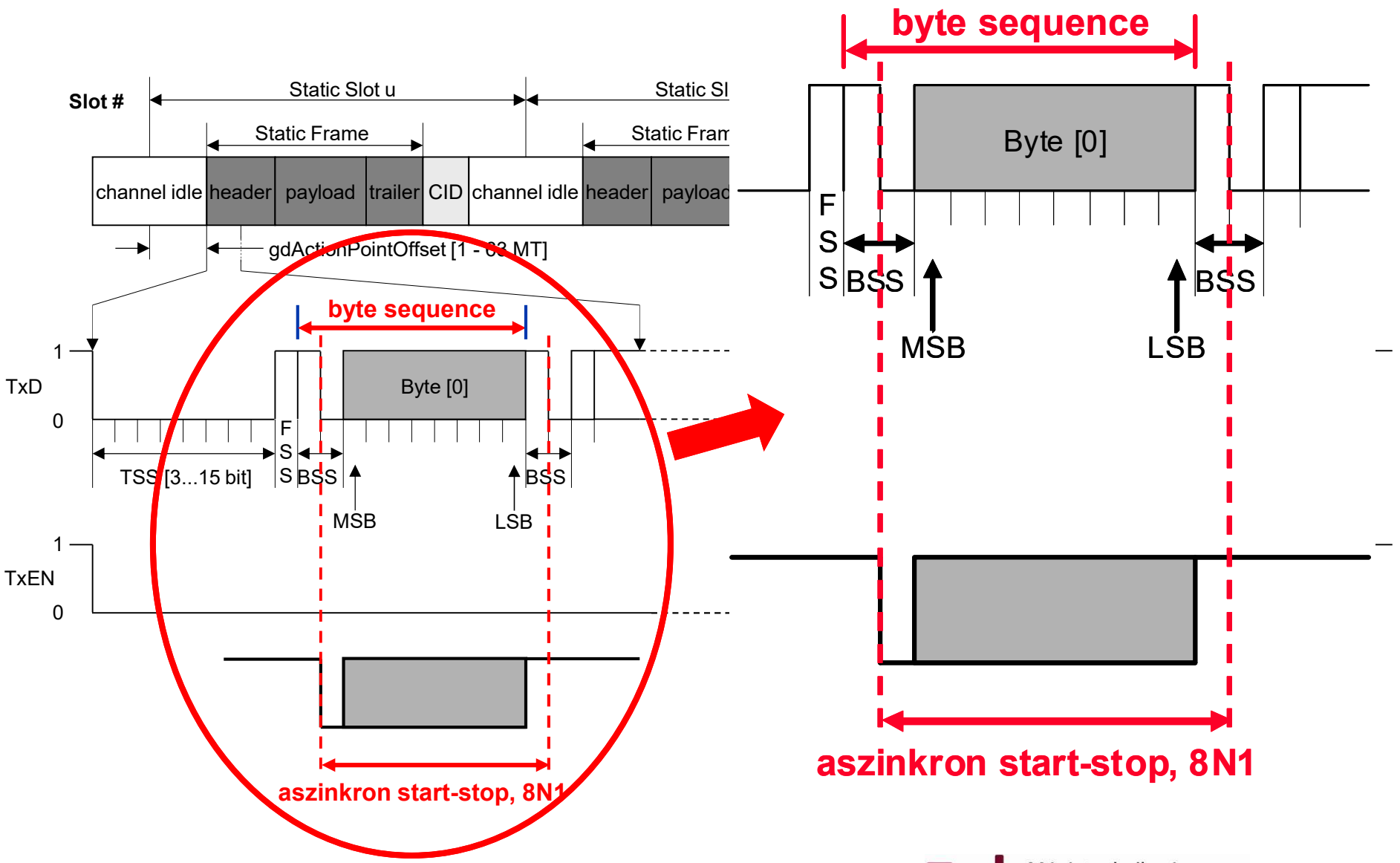

TSS = Transmission Start Sequence
FSS = Frame Start Sequence
BSS = Byte Start Sequence
FES = Frame End Sequence

(A Vector Group FlexRay posztere alapján)

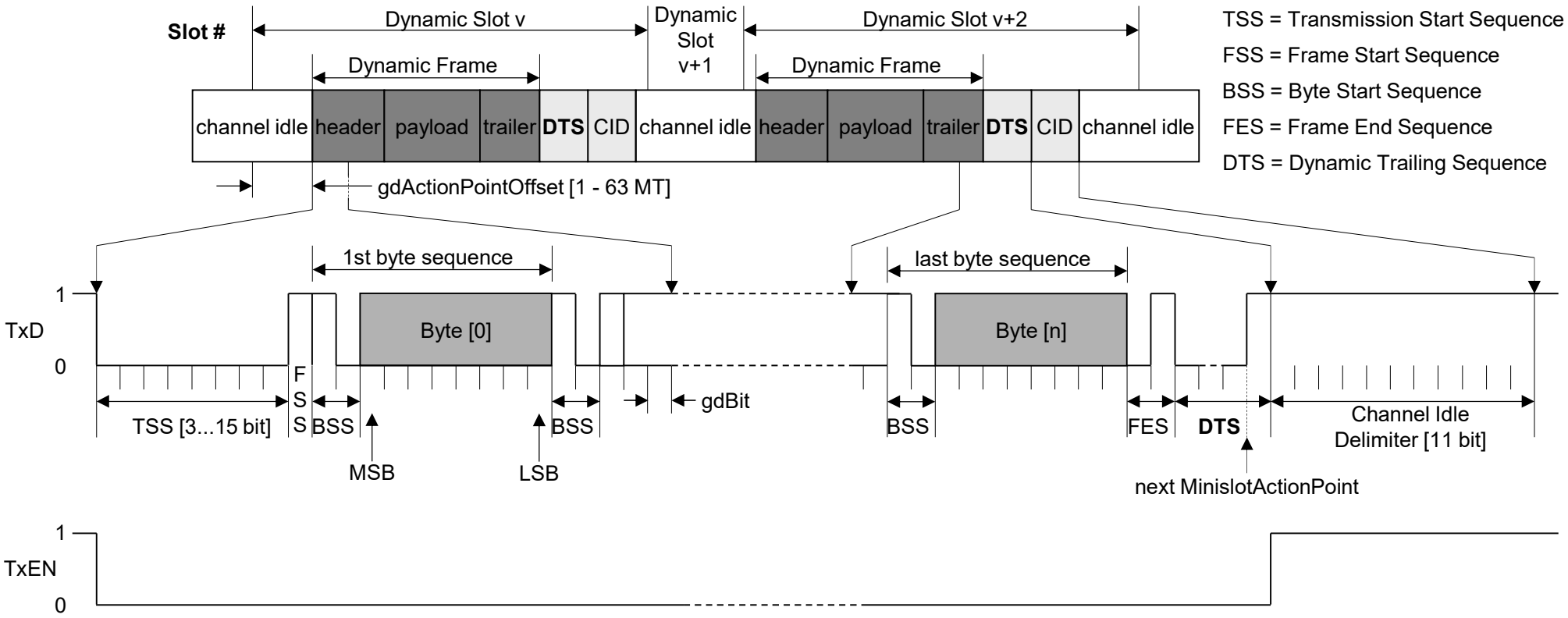
# Frame Coding – Static Slot



# Frame Coding – Static Slot

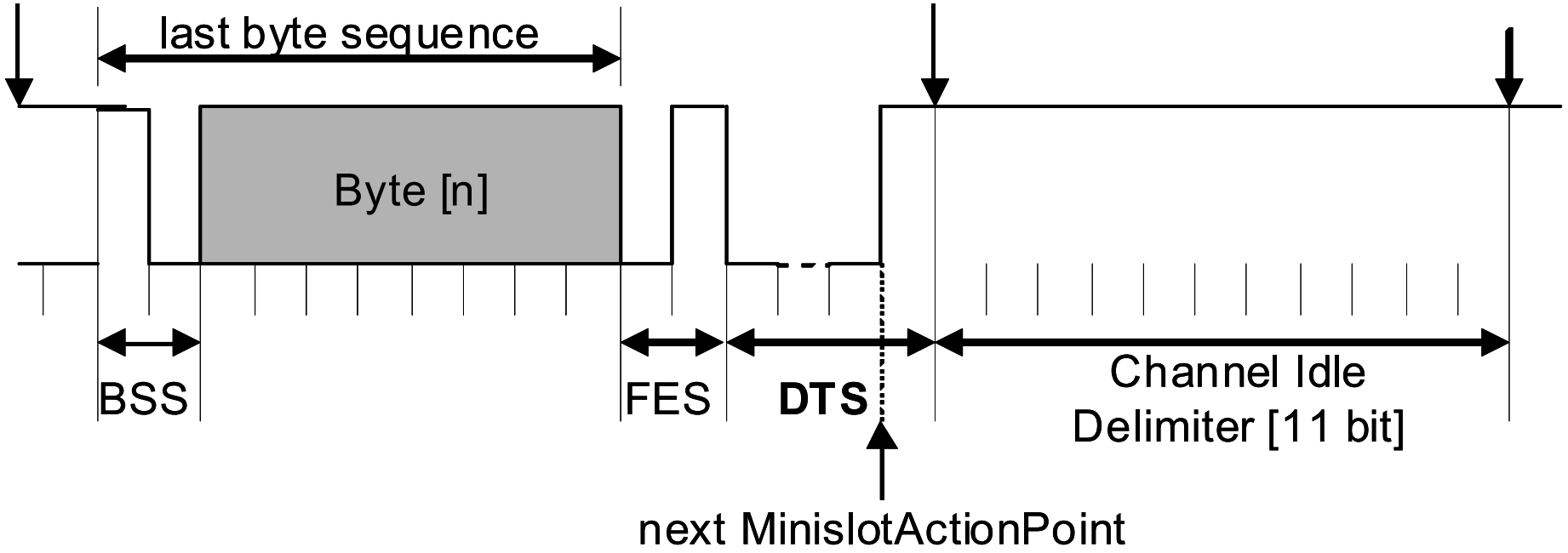


# Frame Coding – Dynamic Slot



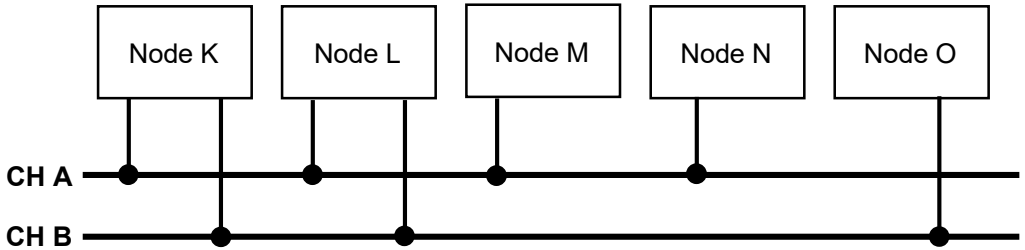

(A Vector Group FlexRay posztere alapján)

# Frame Coding – Dynamic Slot




DTS = Dynamic Trailing Sequence

# FlexRay Bus Access – Example (1/3)



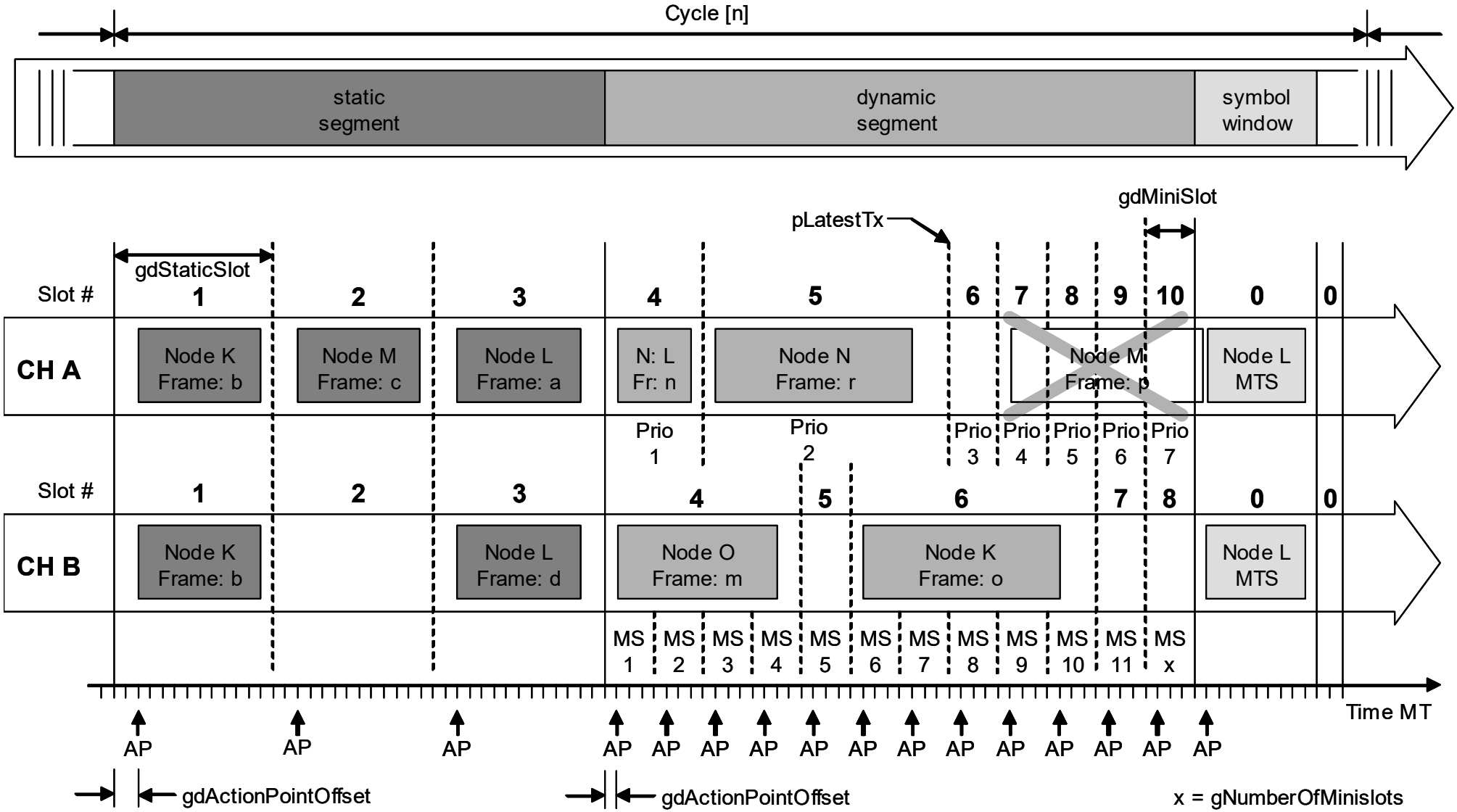

| | Slot | ECU | Channel | Tx |
|---|---|---|---|---|
| **Static segment** | 1 | Node K | A | Frame: b |
| | | | B | Frame: b |
| | 2 | Node M | A | Frame: c |
| | | | B | * |
| | 3 | Node L | A | Frame: a |
| | | | B | Frame: d |
| **Dynamic segment** | 4 Prio 1 | Node L | A | Frame: n |
| | | Node O | B | Frame: m |
| | 5 Prio 2 | Node N | A | Frame: r |
| | | | B | * |
| | 6 Prio 3 | | A | * |
| | | Node K | B | Frame: o |
| | 7 Prio 4 | Node M | A | Frame: p |
| | | | B | * |

Egyidejűleg mindkét csatornán ugyanaz a keret; redundancia, hibatűrő továbbítás.

Egyidejűleg a két csatornán különböző keretek; hatékony sávszélesség-használat.

* Üres slot; későbbi bővítésre fenntartva.

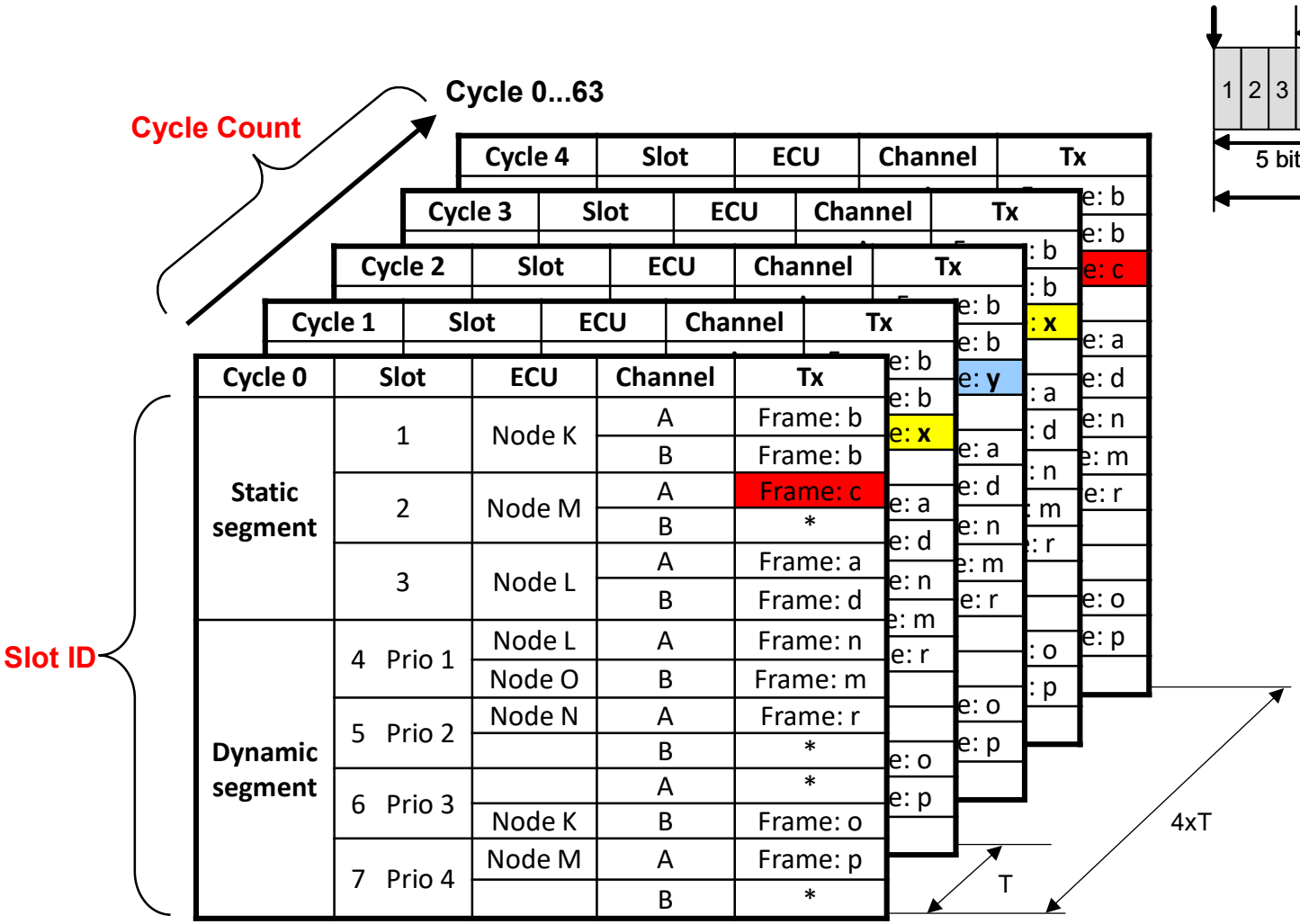
# FlexRay Bus Access – Example (2/3)

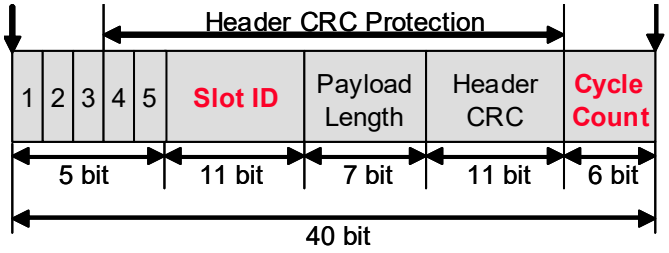


# FlexRay Bus Access – Example (3/3)

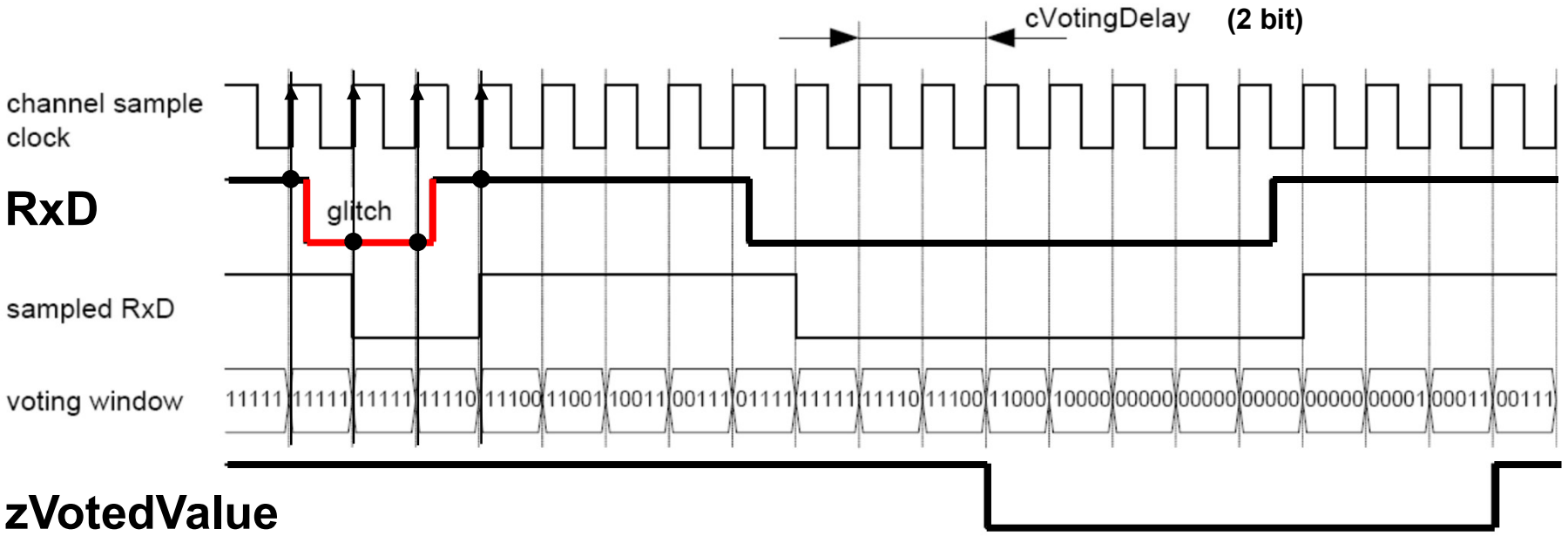
- Static segment
  - fix időzítés
  - azonos időzítés mindkét csatornán
  - az összes (be)ütemezett keretet elküldik
- Dynamic segment
  - rugalmas időzítés
  - különböző lehet az időzítés a két csatornán
  - a kereteket igény szerint továbbítják
  - a minislotok egyfajta hordozók a kerettovábbításokhoz
  - az adást be kell fejezni a dinamikus szegmens végén (a „p” keretet már nem továbbíthatják ebben a ciklusban)

# Cycle Multiplexing – Example



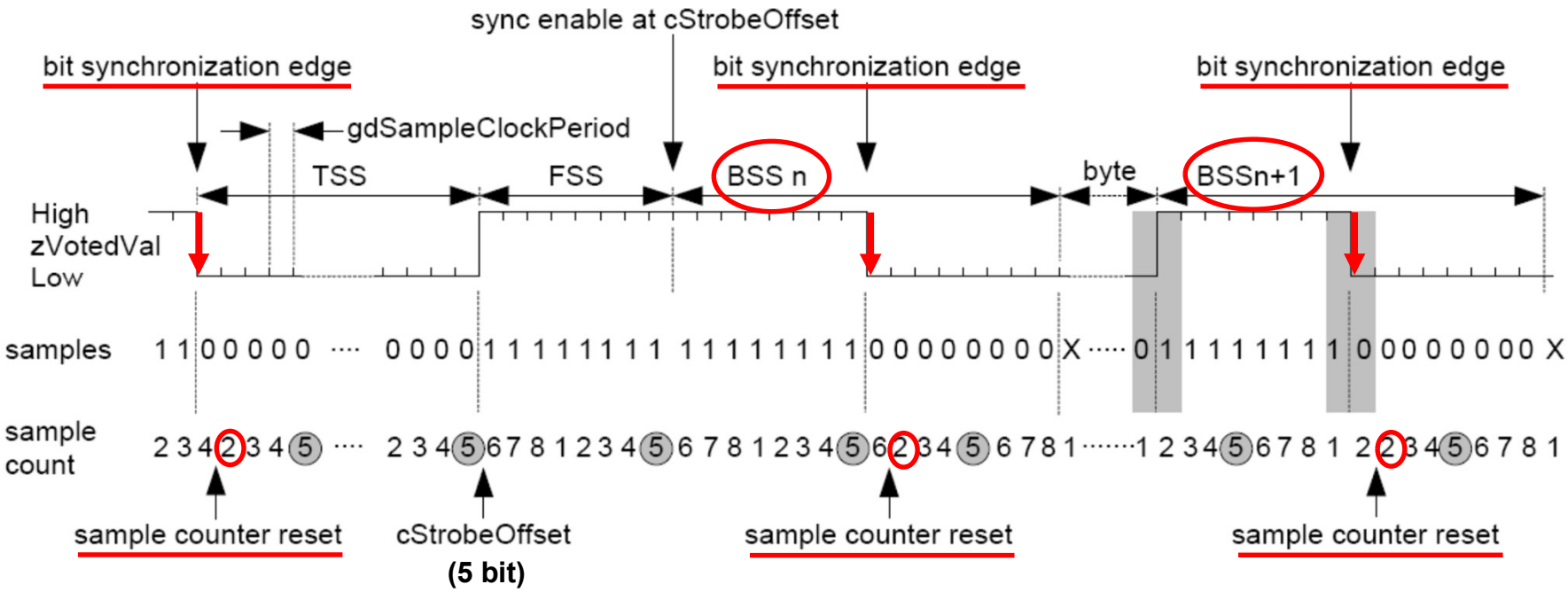



# Sampling and majority voting



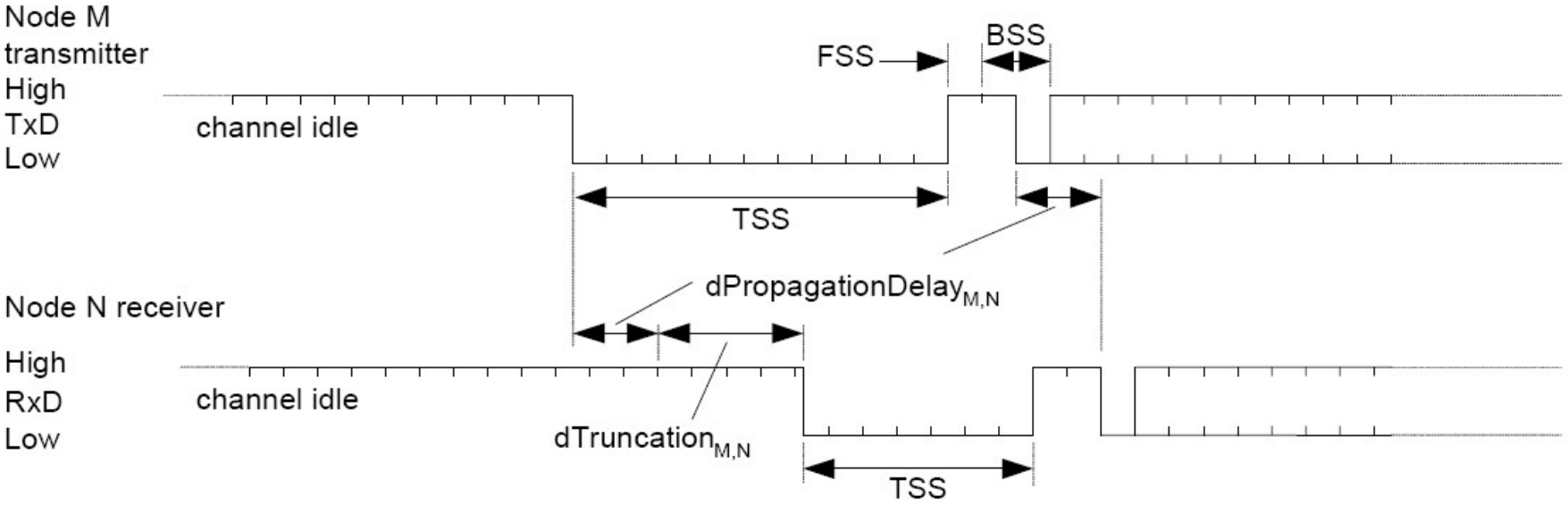

FlexRay Communications System
Protocol Specification
Version 3.0.1
Fig. 3-8

# Bit clock alignment and bit strobing



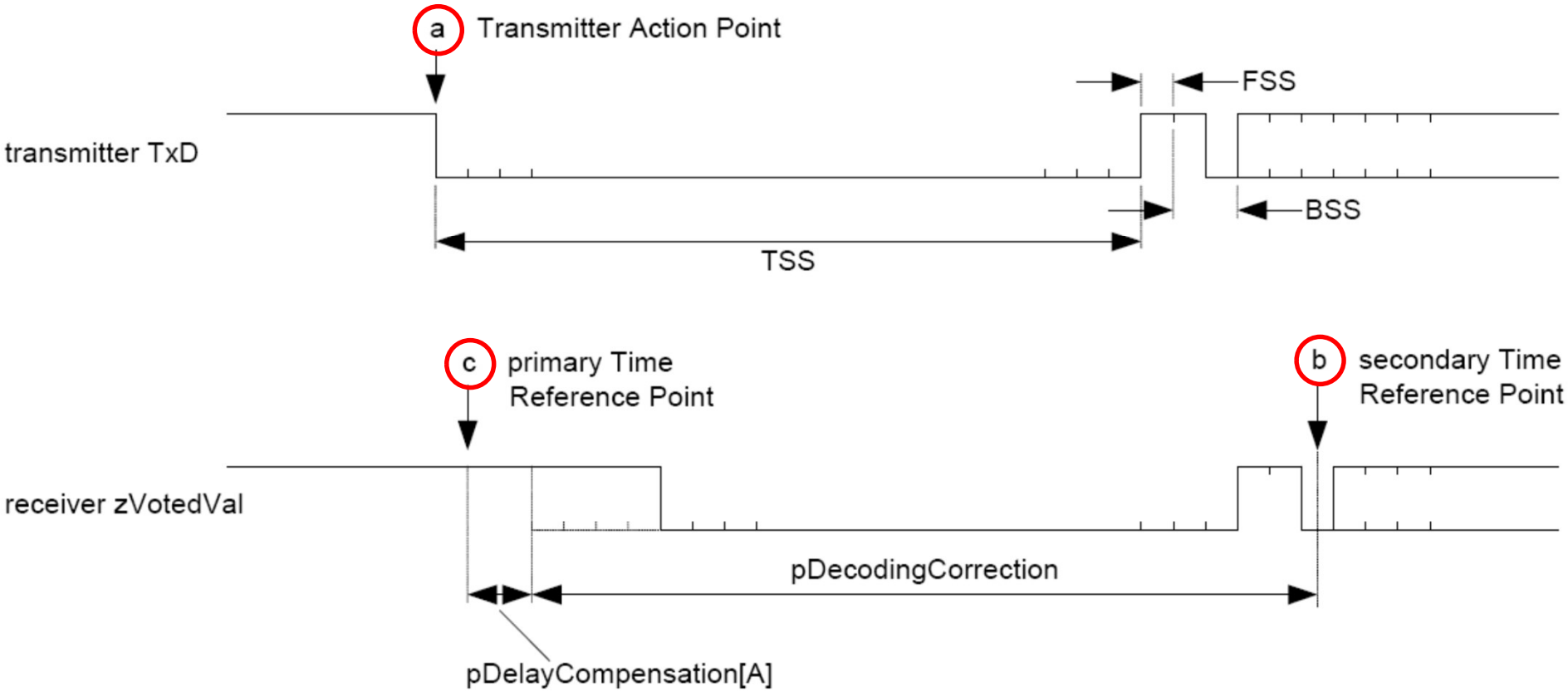

FlexRay Communications System
Protocol Specification
Version 3.0.1
Fig. 3-9

# TSS truncation and propagation



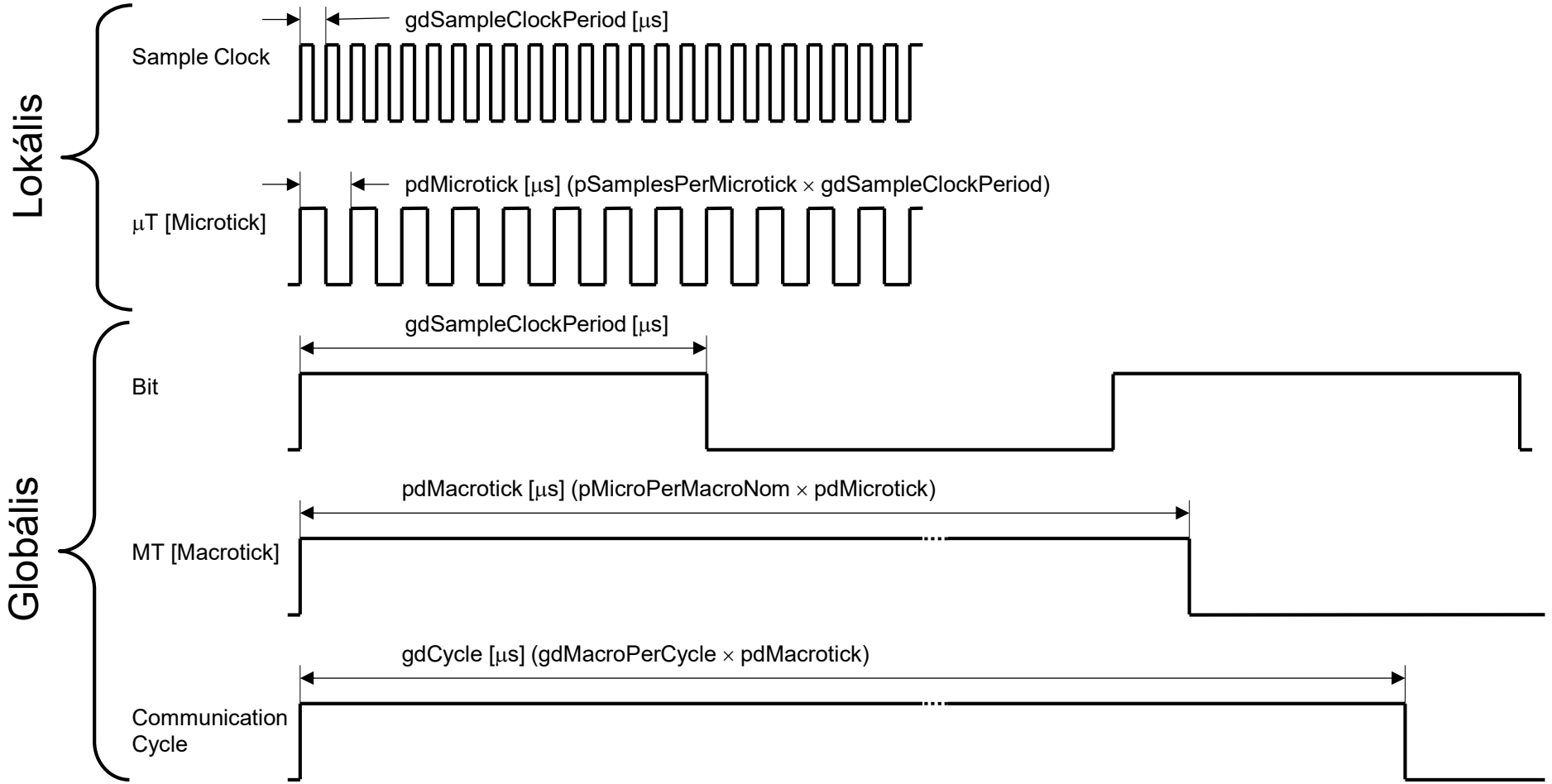

FlexRay Communications System
Protocol Specification
Version 3.0.1
Fig. 3-10

# Time reference point definitions



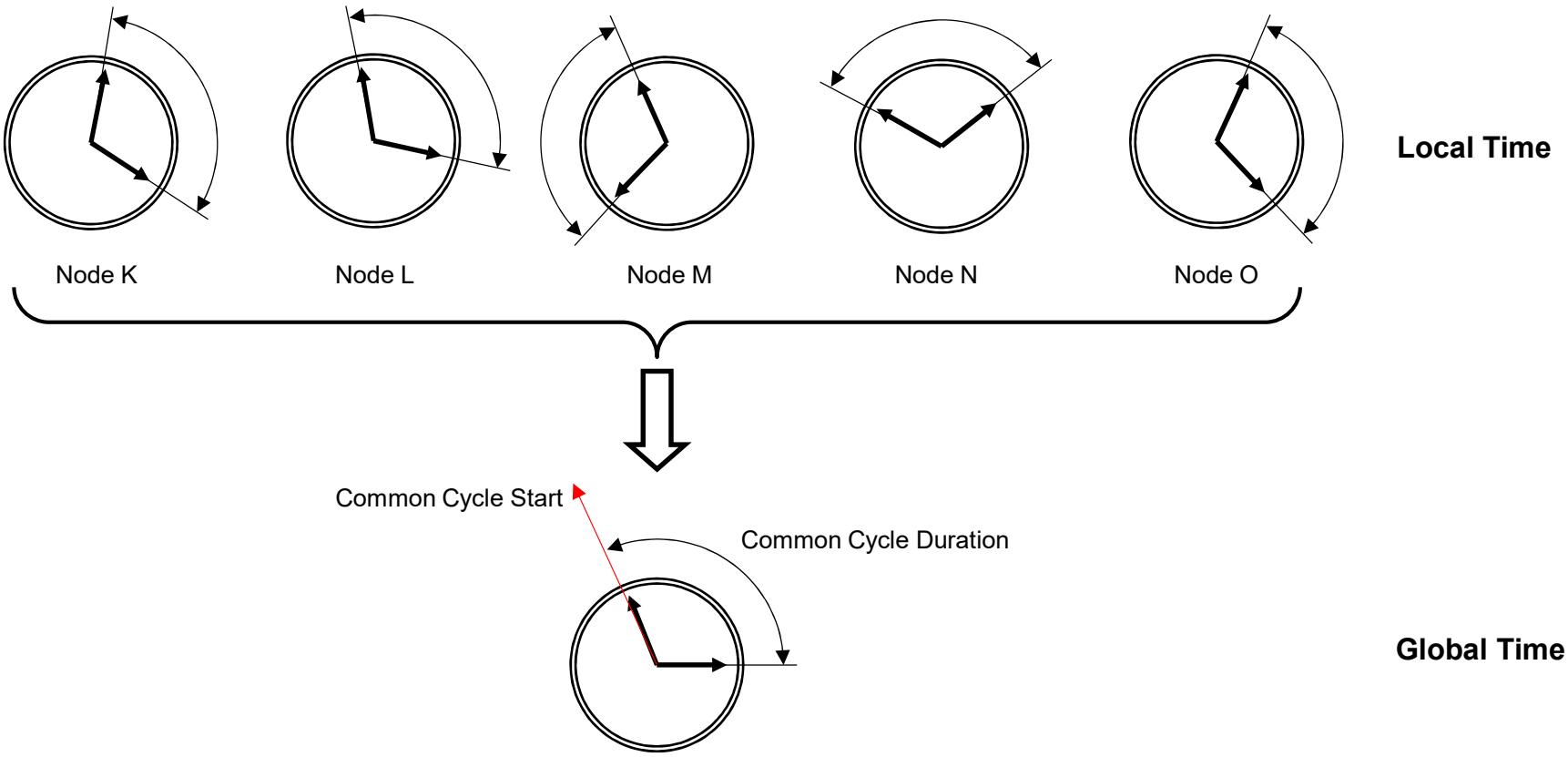

FlexRay Communications System
Protocol Specification
Version 3.0.1
Fig. 3-11

# FlexRay Timing Hierarchy



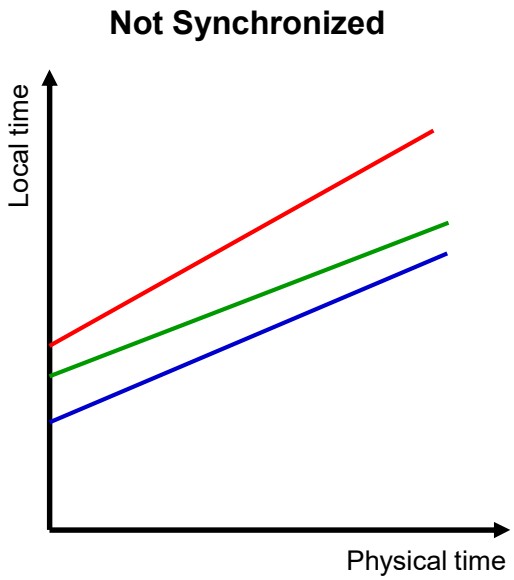

(A Vector Group FlexRay posztere alapján)

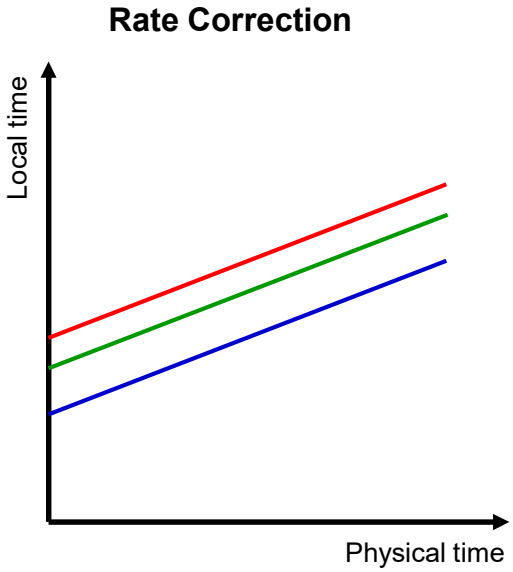
# Common Time Base

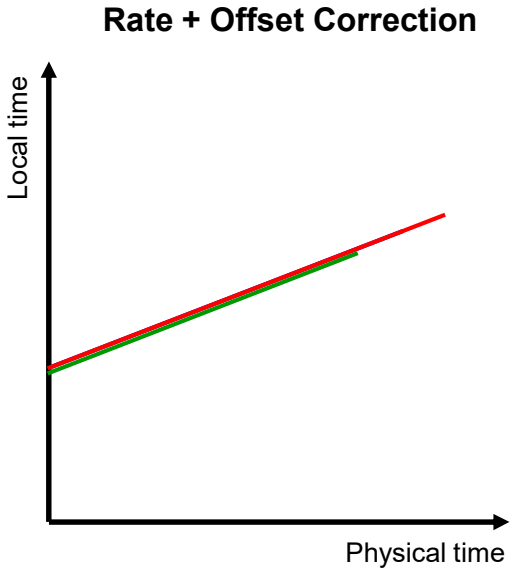



(A Vector Group FlexRay posztere alapján)

# Cluster Synchronization – Corrections

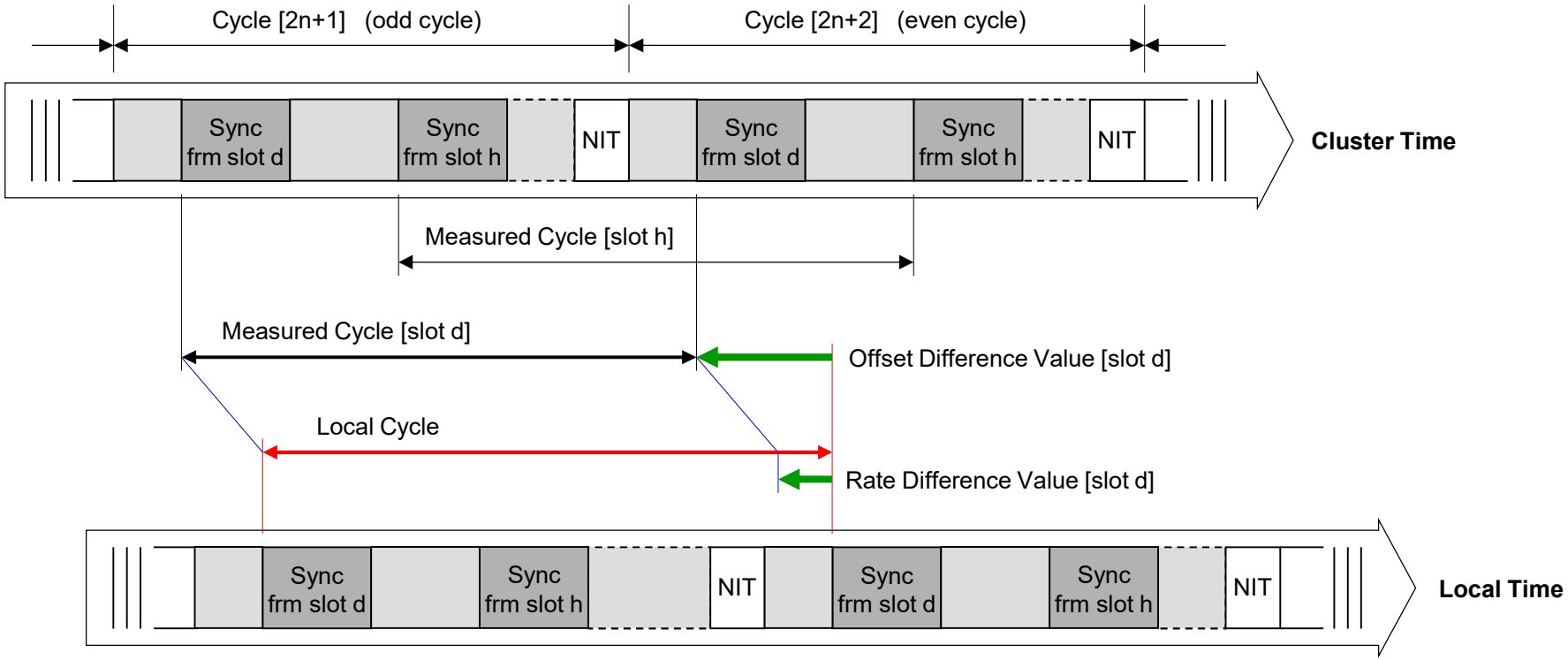


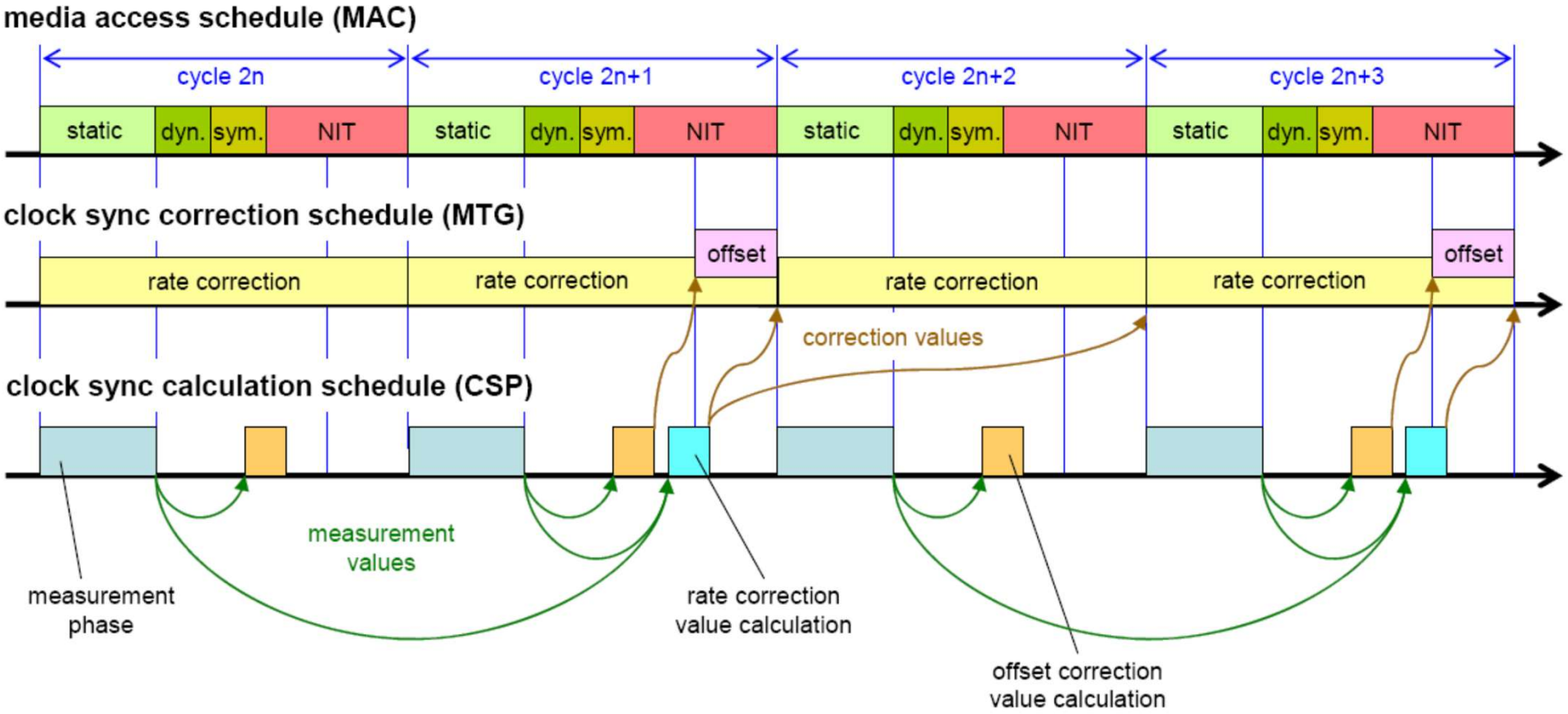

(A Vector Group FlexRay posztere alapján)

# Cluster Synchronization – Measured Principle




(A Vector Group FlexRay posztere alapján)

# Synchronization

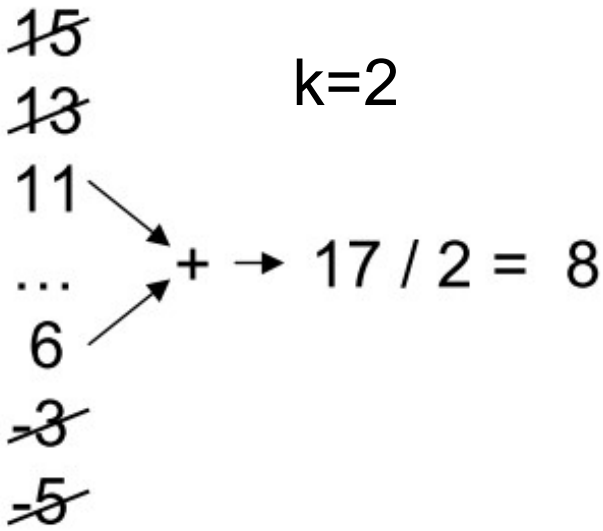



Timing relationship between clock synchronization, media access schedule, and the execution of clock synchronization functions.

FlexRay Communications System
Protocol Specification
Version 3.0.1
Fig. 8-3

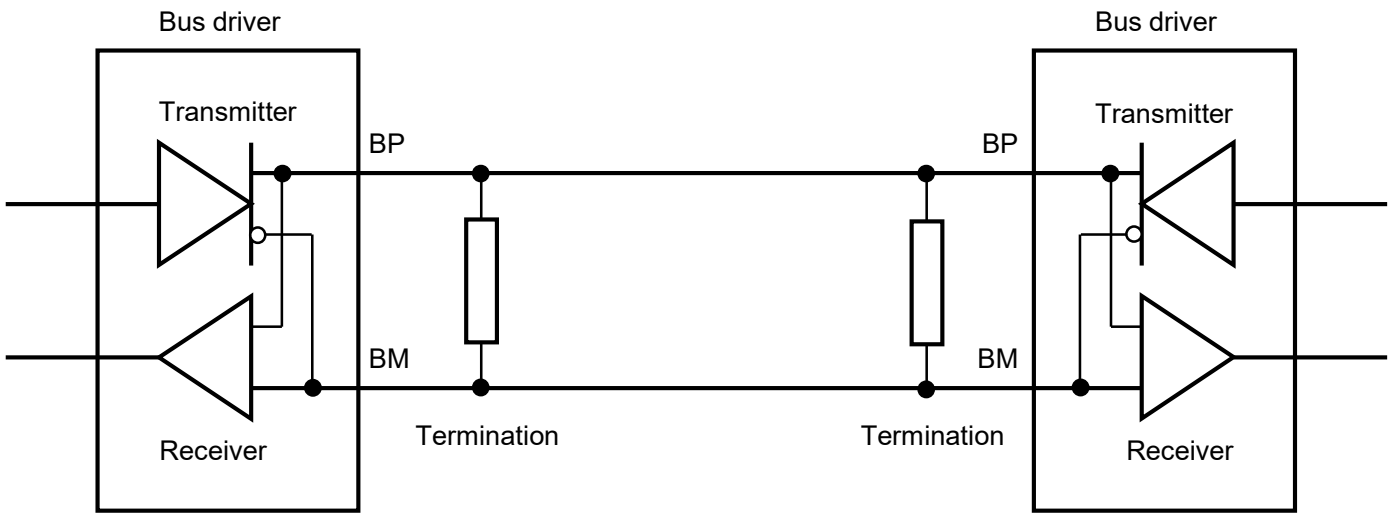
# Fault-tolerant midpoint algorithm (FTM)

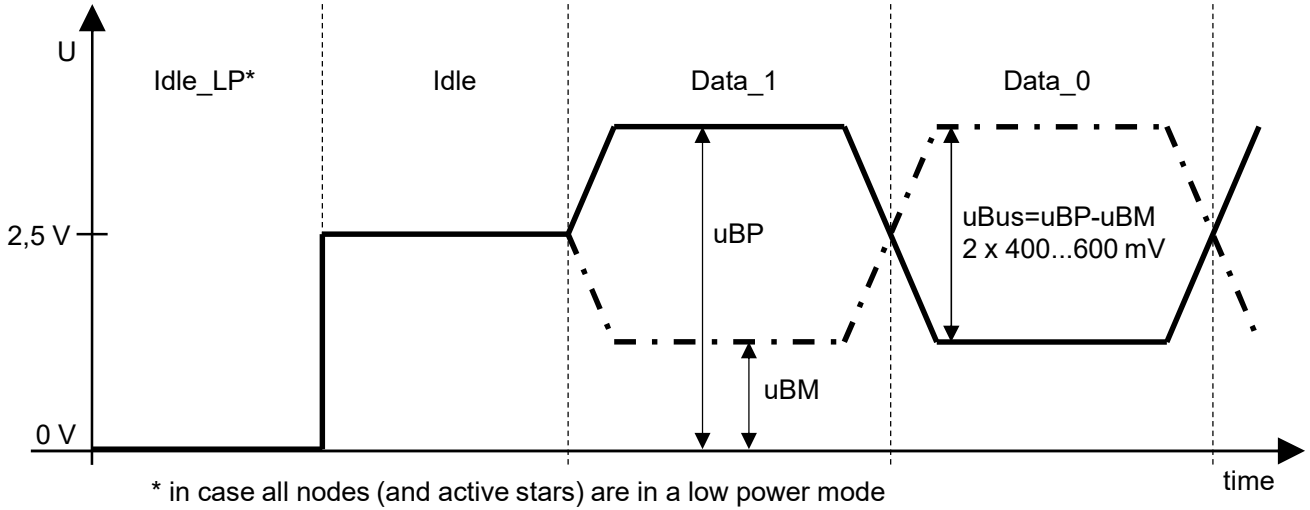
| Number of values | k |
|---|---|
| 1 - 2 | 0 |
| 3 - 7 | 1 |
| > 7 | 2 |




„Byzantine faults”

# Physical Layer




* in case all nodes (and active stars) are in a low power mode

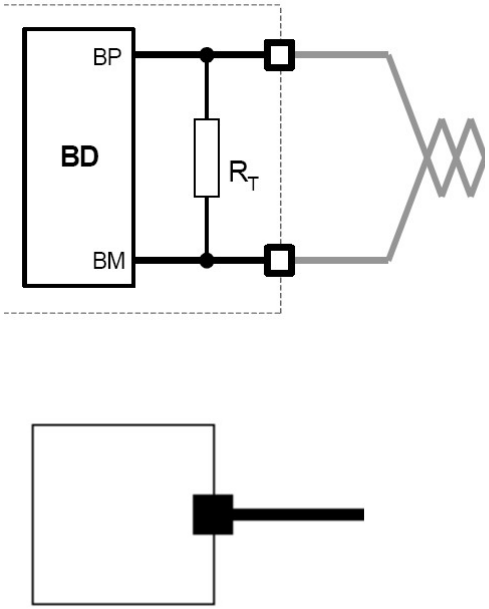
Mindkét bit domináns (nincs recessive állapot).

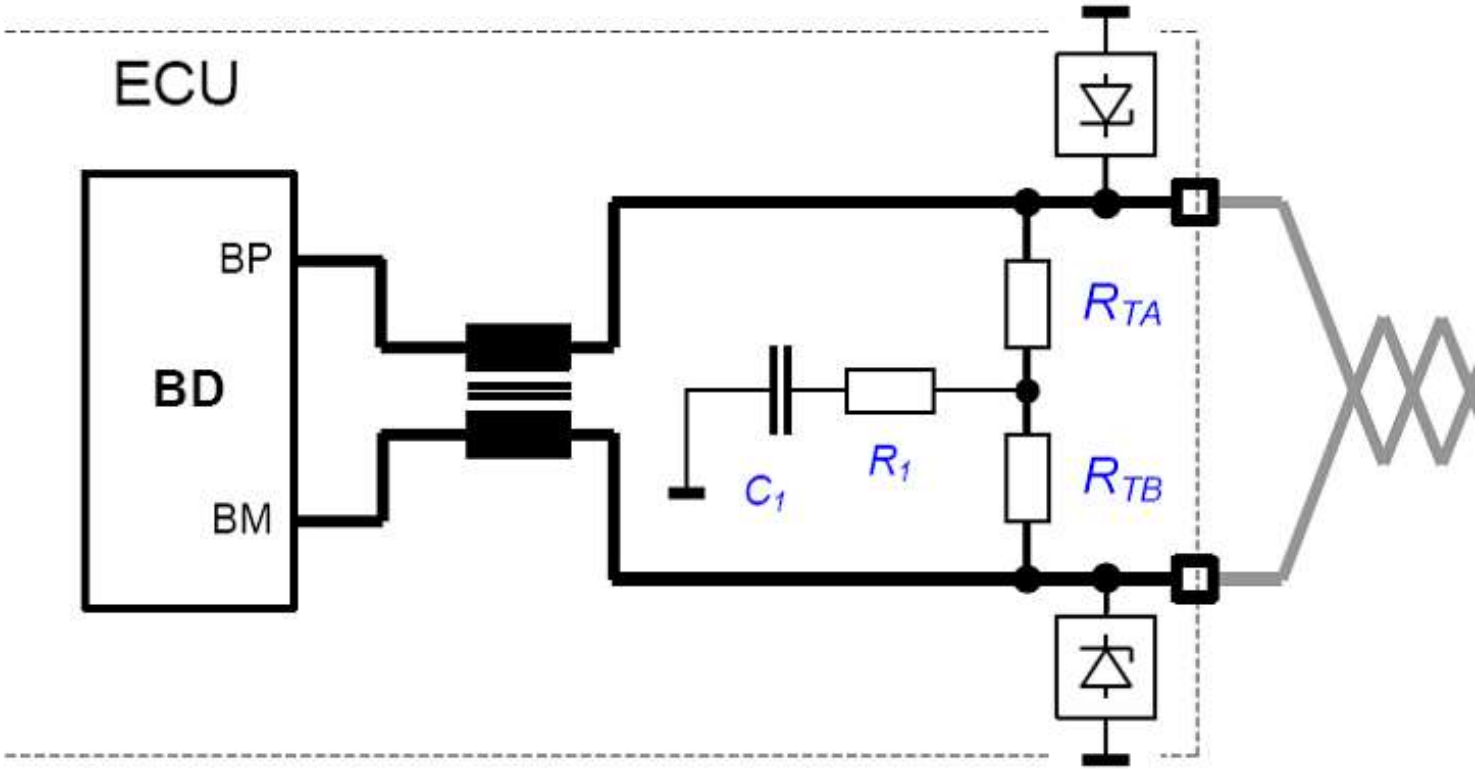
# Cable, connector

- Kábeltípus: nem specifikált
  - Kábelparaméterek:
    - Differential mode impedance @ 10 MHz: **$Z_0$ = 80...110 Ω**
    - Specific line delay: **$T_0$ = 3.4...10 ns/m**

- Csatlakozó: nem specifikált
  - Paraméterek:
    - ...

# (Split) termination



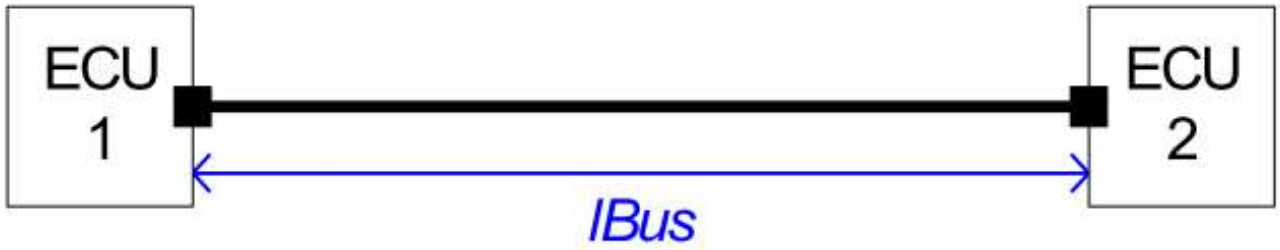




ECU with split termination
+ common mode choke
+ ESD protection diodes

FlexRay Communications System
Electrical Physical Layer Specification
Version 3.0.1
Fig. 4-1, 4-2

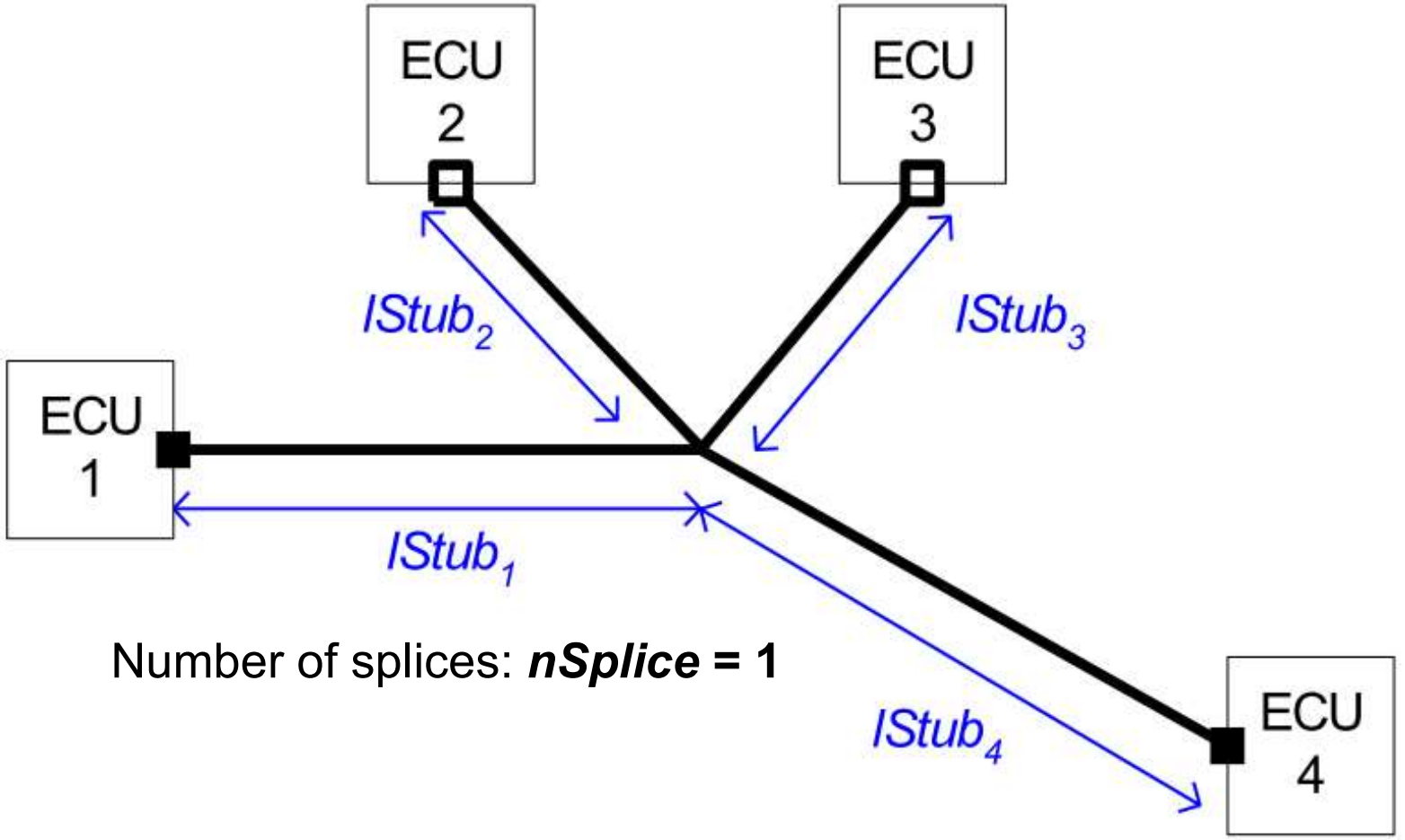
FlexRay Communications System
Electrical Physical Layer Application Notes
Version 3.0.1
Fig. 2-3

# Network topology – Point-to-point




FlexRay Communications System
Electrical Physical Layer Specification
Version 3.0.1
Fig. 5-1

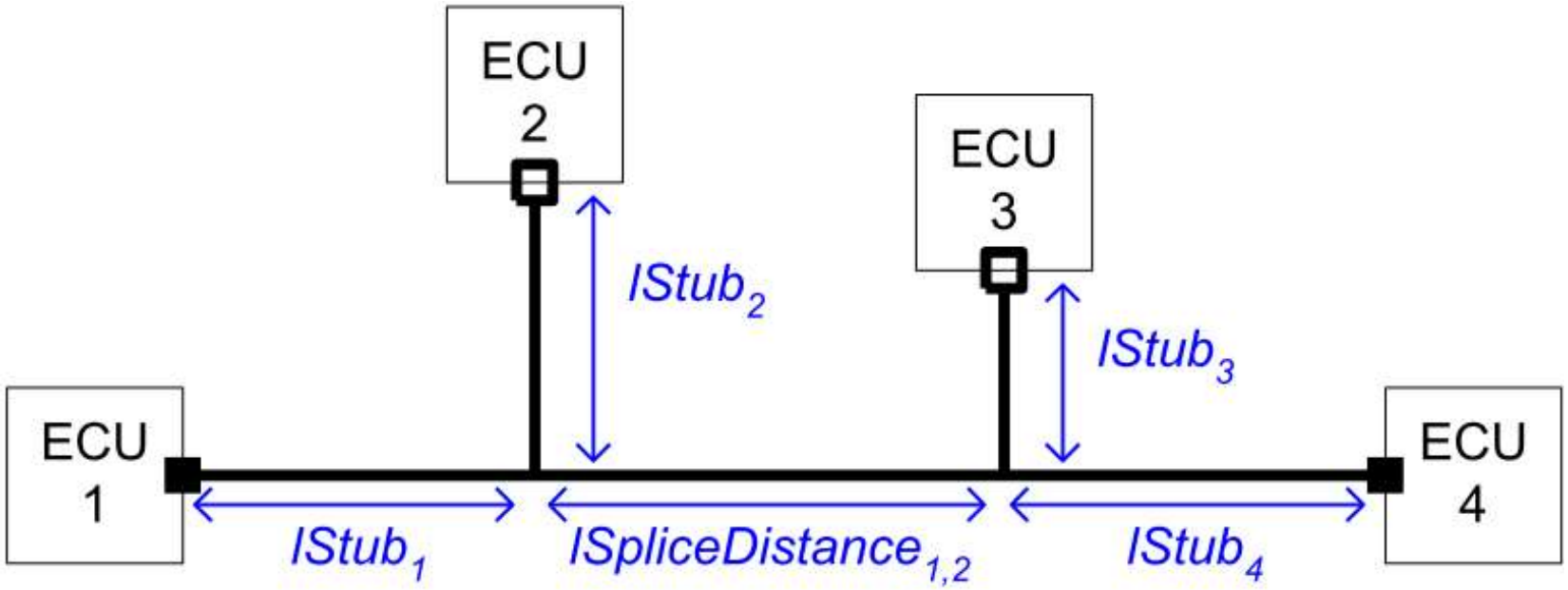
# Network topology – Passive star




Number of splices: ***nSplice* = 1**

FlexRay Communications System
Electrical Physical Layer Specification
Version 3.0.1
Fig. 5-2

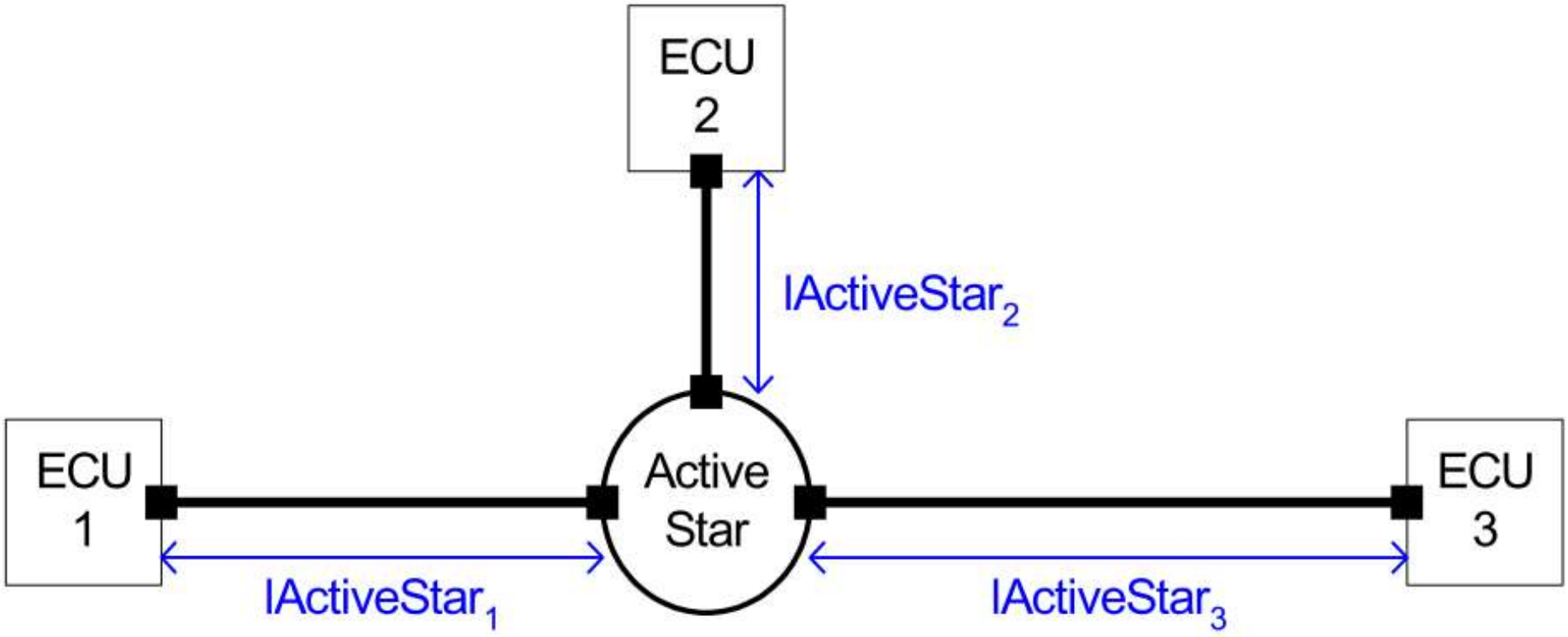
# Network topology – Linear passive bus




Number of splices: ***nSplice* = 2**

FlexRay Communications System
Electrical Physical Layer Specification
Version 3.0.1
Fig. 5-3

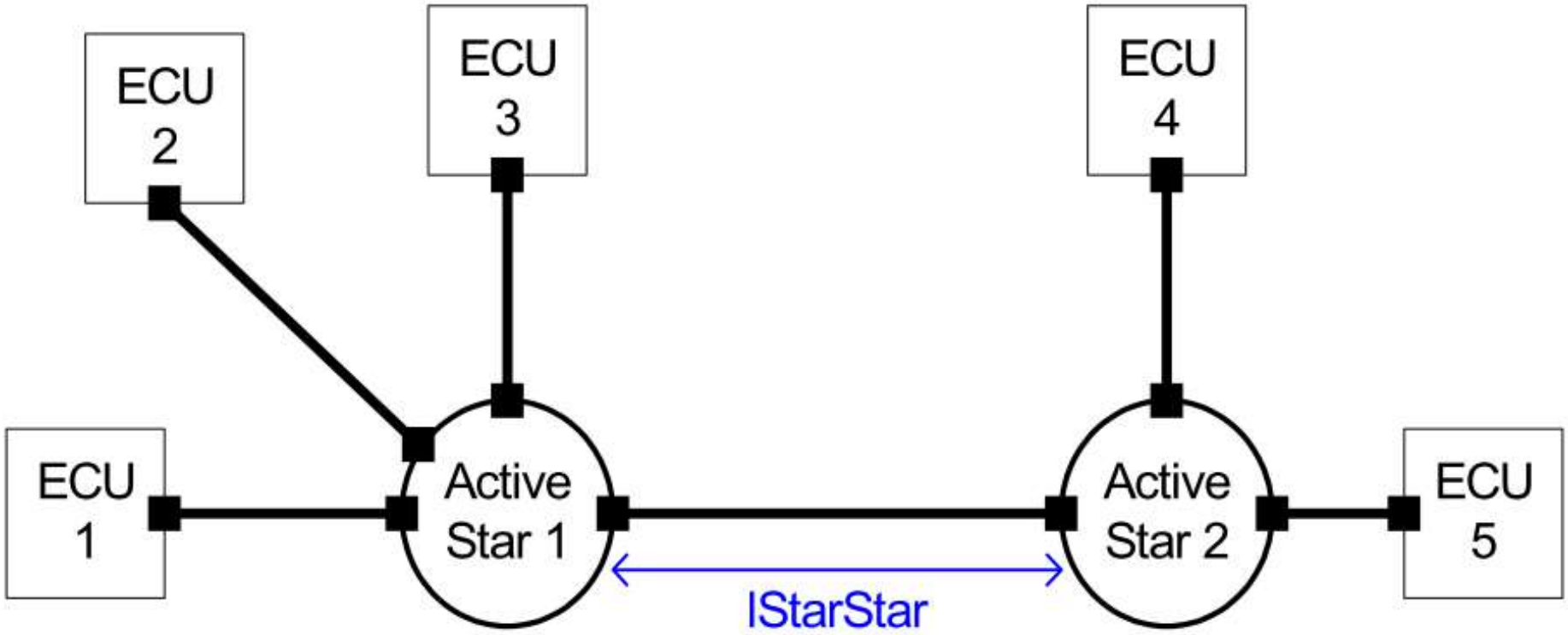
# Network topology – Active star network




Number of branches at an active star: ***nActiveBranches* = min. 2**

FlexRay Communications System
Electrical Physical Layer Specification
Version 3.0.1
Fig. 5-4

# Network topology – Cascaded active stars



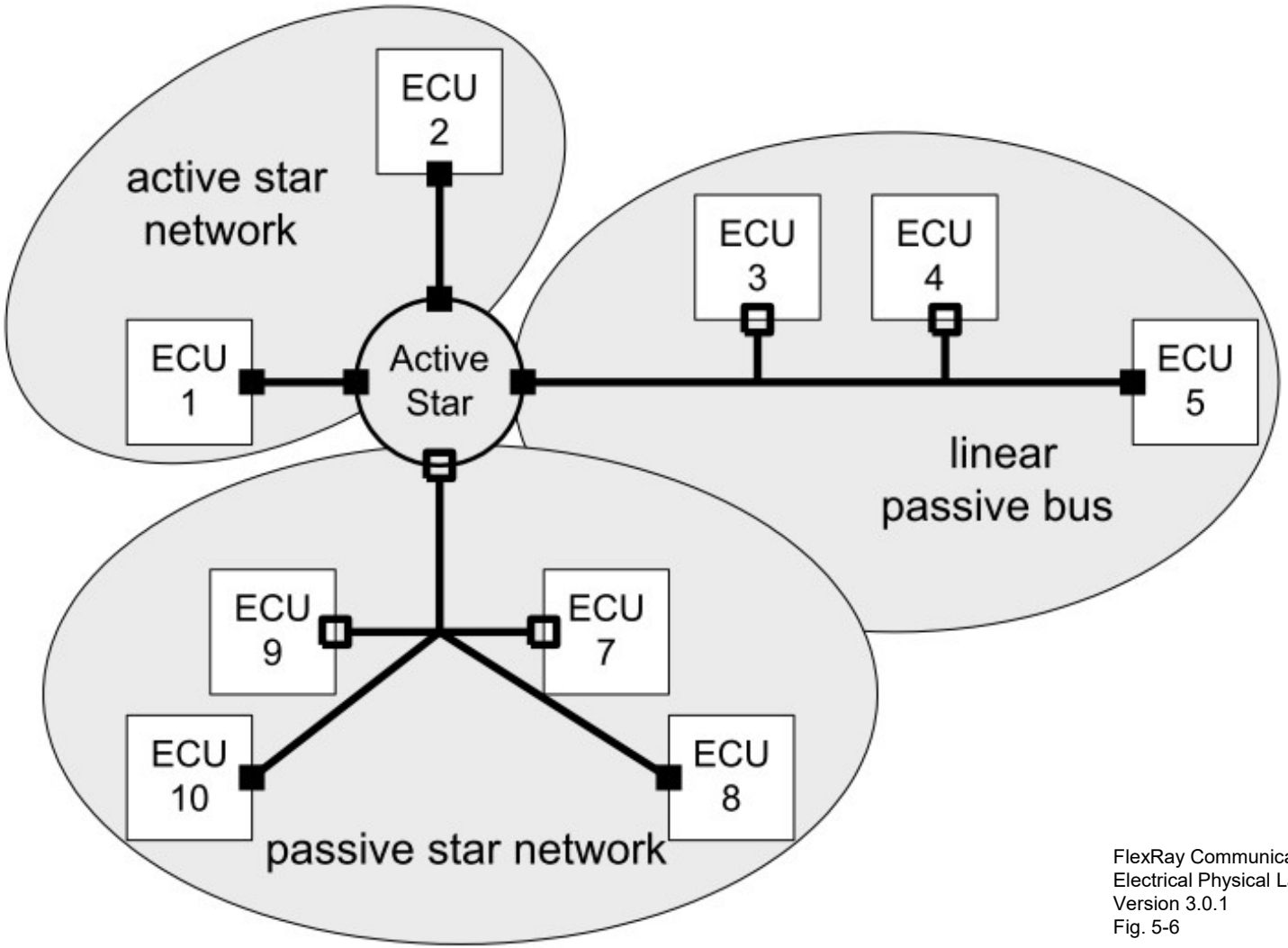

Number of active stars on the signal path from an ECU M to an ECU N:

$nStarPath_{M,N}$ = 0...2 **(2.5 Mbit/s, 5 Mbit/s)**

$nStarPath_{M,N}$ = 0...1 **(10 Mbit/s)**

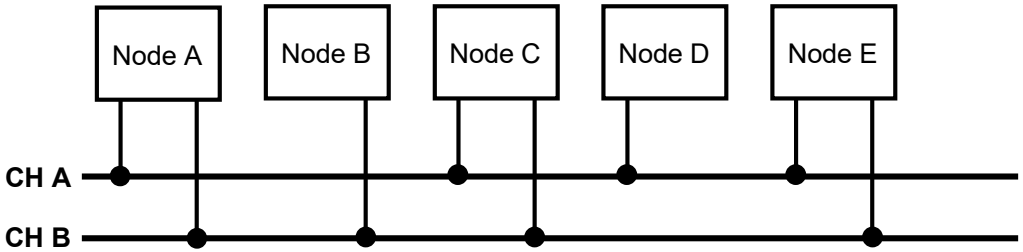
FlexRay Communications System
Electrical Physical Layer Specification
Version 3.0.1
Fig. 5-5

# Network topology – Hybrid topologies

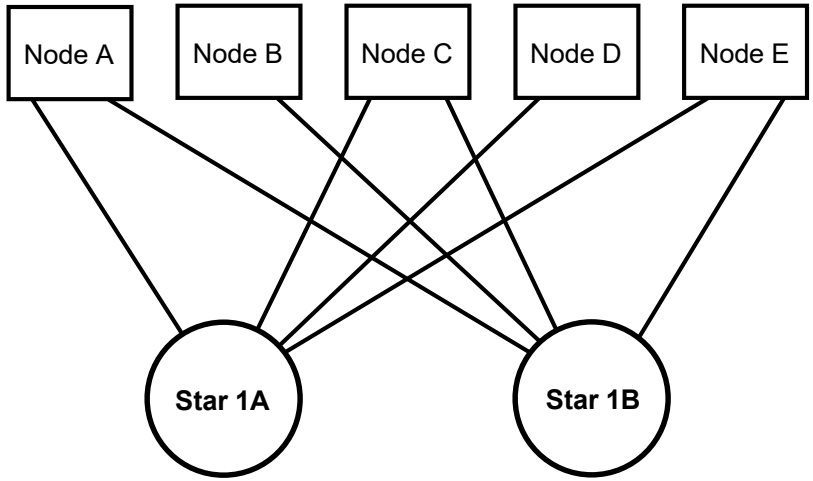



FlexRay Communications System
Electrical Physical Layer Specification
Version 3.0.1
Fig. 5-6

# Network topology – Dual channel topologies

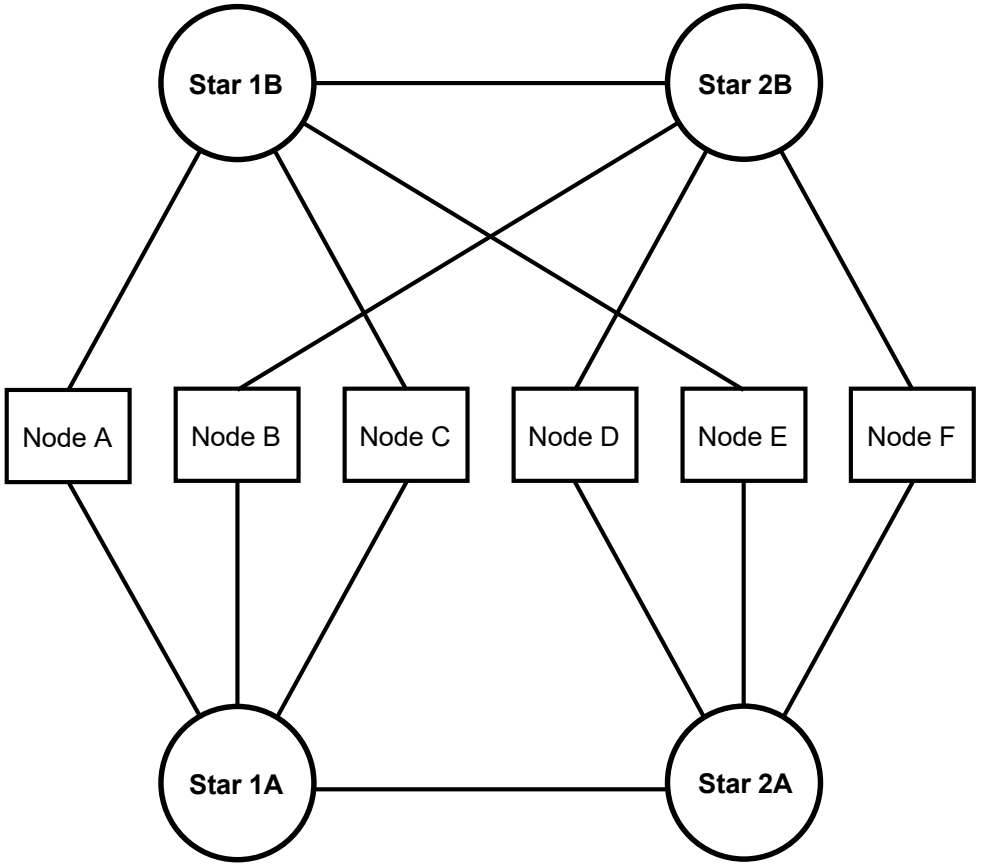



Dual channel bus configuration




Dual channel single star configuration

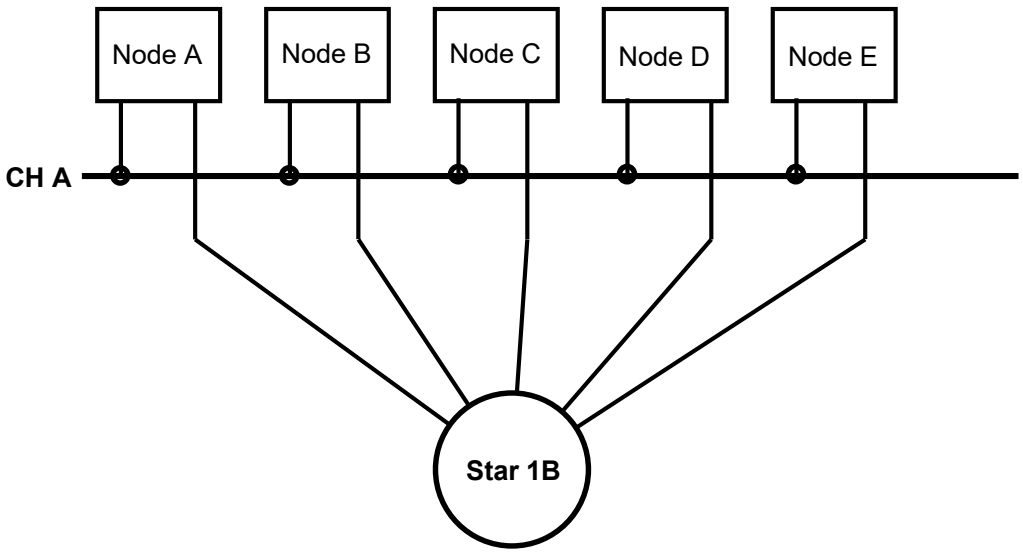
# Network topology – Dual channel topologies



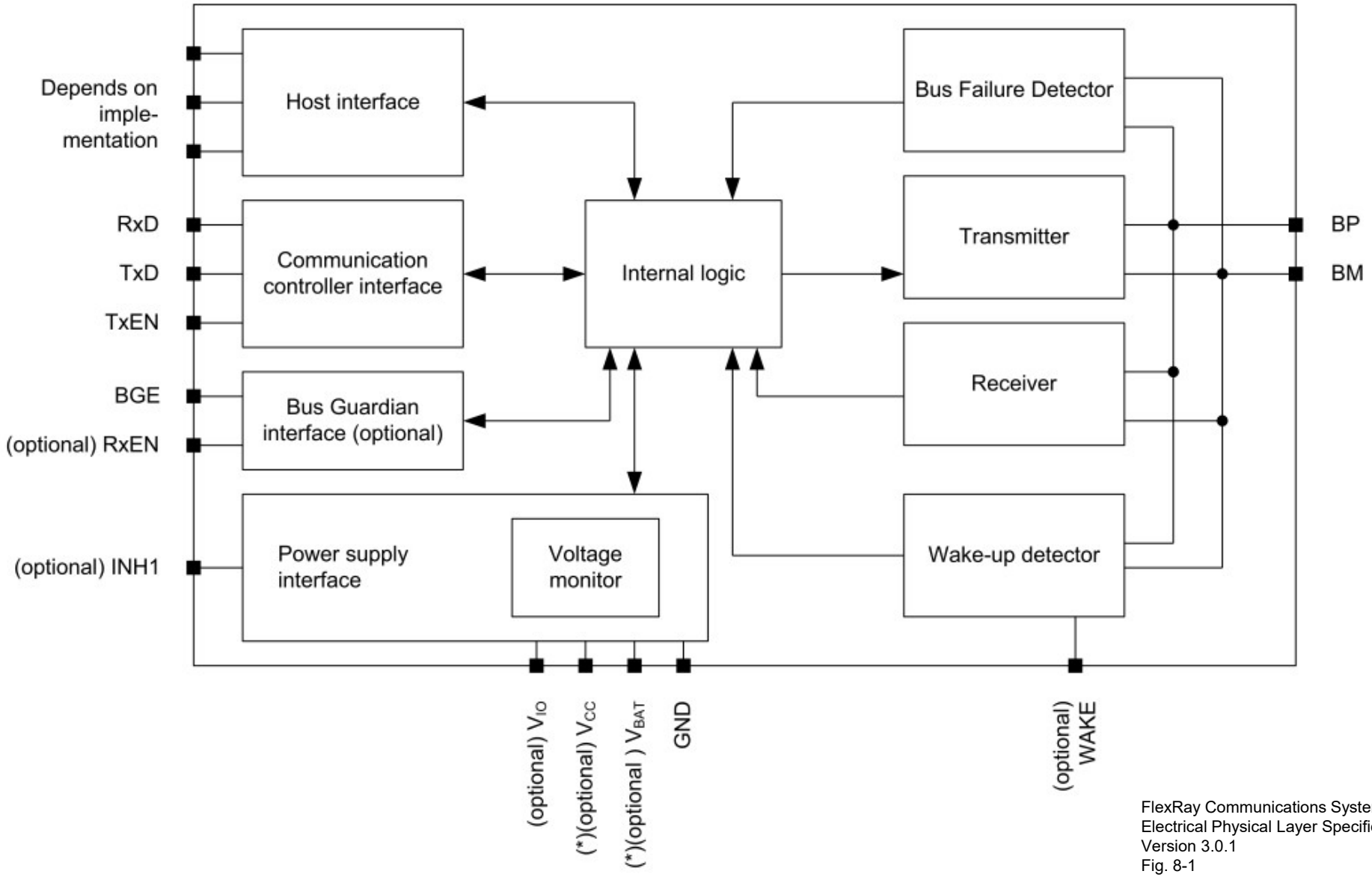

Dual channel cascaded star configuration

# Network topology – Dual channel topologies

## Dual channel hybrid configuration

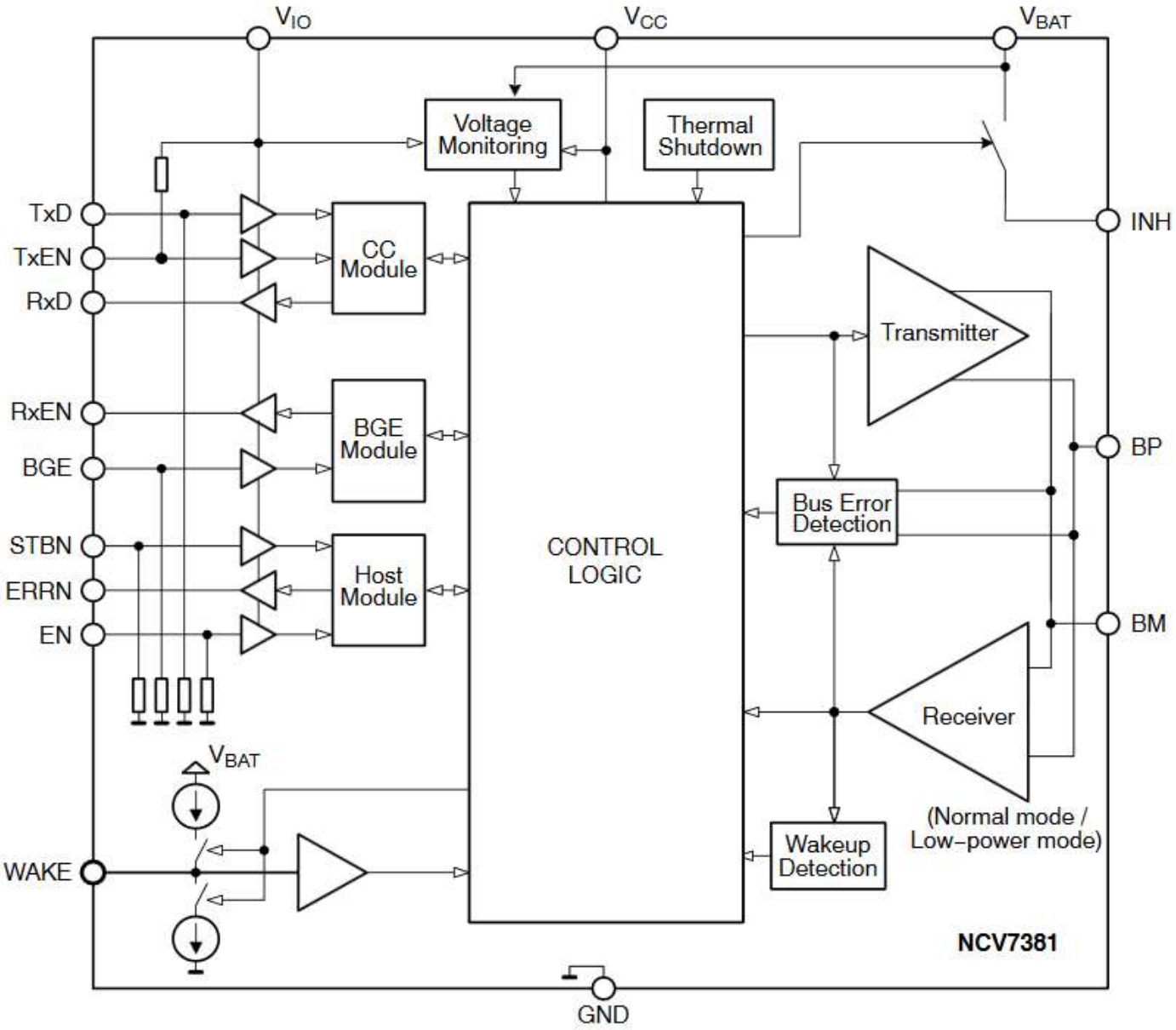


# Electrical Bus Driver




FlexRay Communications System
Electrical Physical Layer Specification
Version 3.0.1
Fig. 8-1

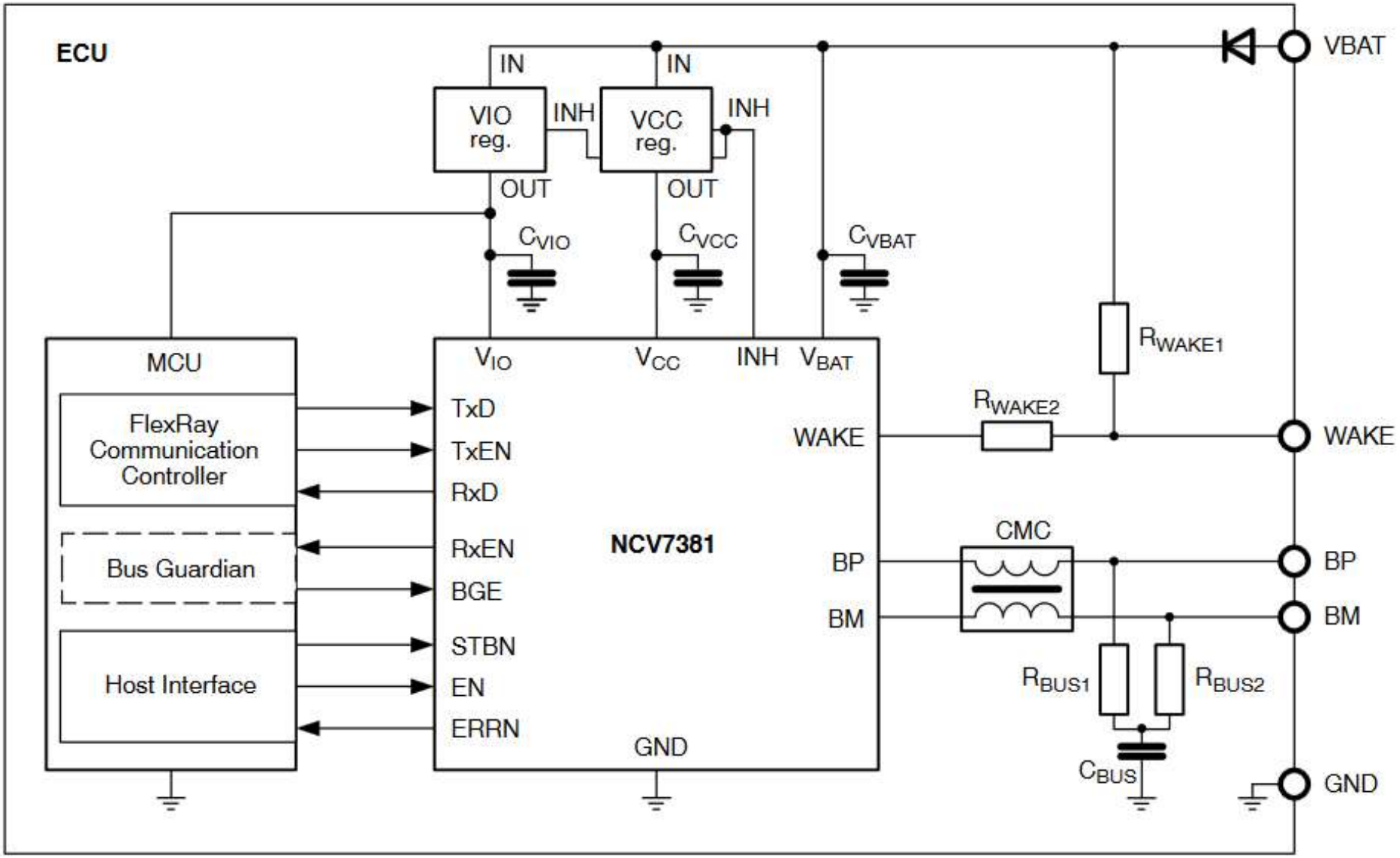
# FlexRay transceiver: NCV7381



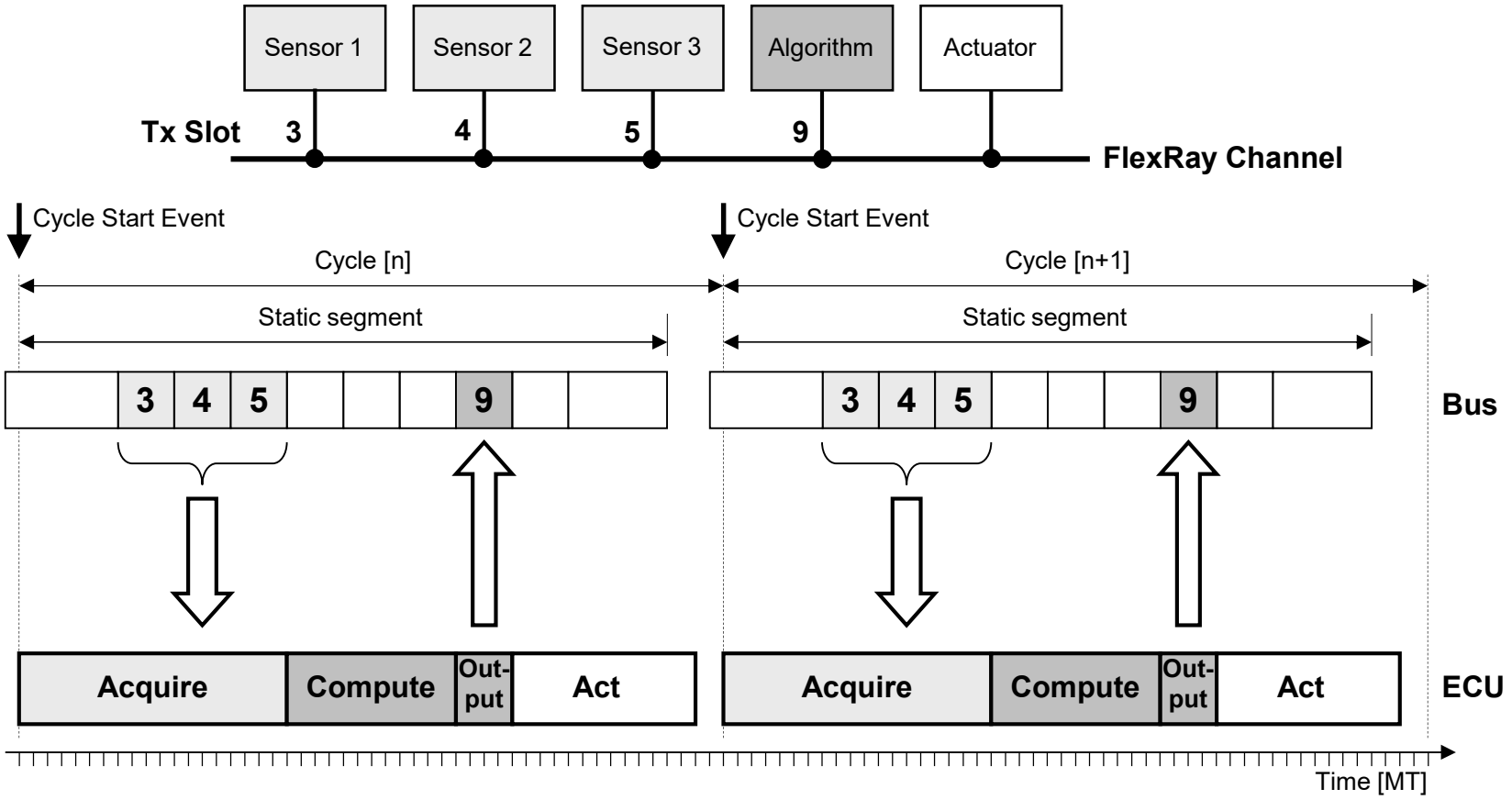
# FlexRay transceiver: NCV7381

| Pin Number | Pin Name | Pin Type | Pin Function |
|---|---|---|---|
| 1 | INH | high–voltage analog output | External regulator control output |
| 2 | EN | digital input | Mode control input; internal pull–down resistor |
| 3 | $V_{IO}$ | supply | Supply voltage for digital pins level adaptation |
| 4 | TxD | digital input | Data to be transmitted; internal pull–down resistor |
| 5 | TxEN | digital input | Transmitter enable input; when High transmitter disabled; internal pull–up resistor |
| 6 | RxD | digital output | Receive data output |
| 7 | BGE | digital input | Bus guardian enable input; when Low transmitter disabled; internal pull–down resistor |
| 8 | STBN | digital input | Mode control input; internal pull–down resistor |
| 9 | RxEN | digital output | Bus activity detection output; when Low bus activity detected |
| 10 | ERRN | digital output | Error diagnosis and status output |
| 11 | $V_{BAT}$ | supply | Battery supply voltage |
| 12 | WAKE | high–voltage analog input | Local wake up input; internal pull up or pull down (depends on voltage at pin WAKE) |
| 13 | GND | ground | Ground connection |
| 14 | BM | high–voltage analog input/output | Bus line minus |
| 15 | BP | high–voltage analog input/output | Bus line plus |
| 16 | $V_{CC}$ | supply | Bus driver core supply voltage; 5 V nominal |

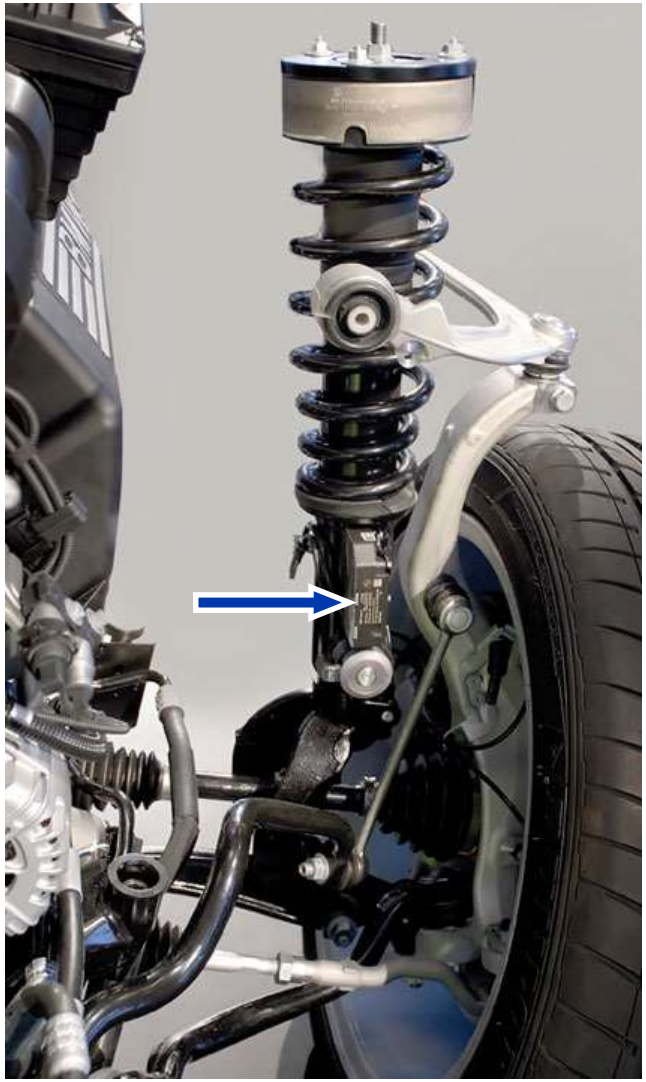
# FlexRay transceiver: NCV7381



# Application Example



# FlexRay 1st application: BMW X5 (2006)

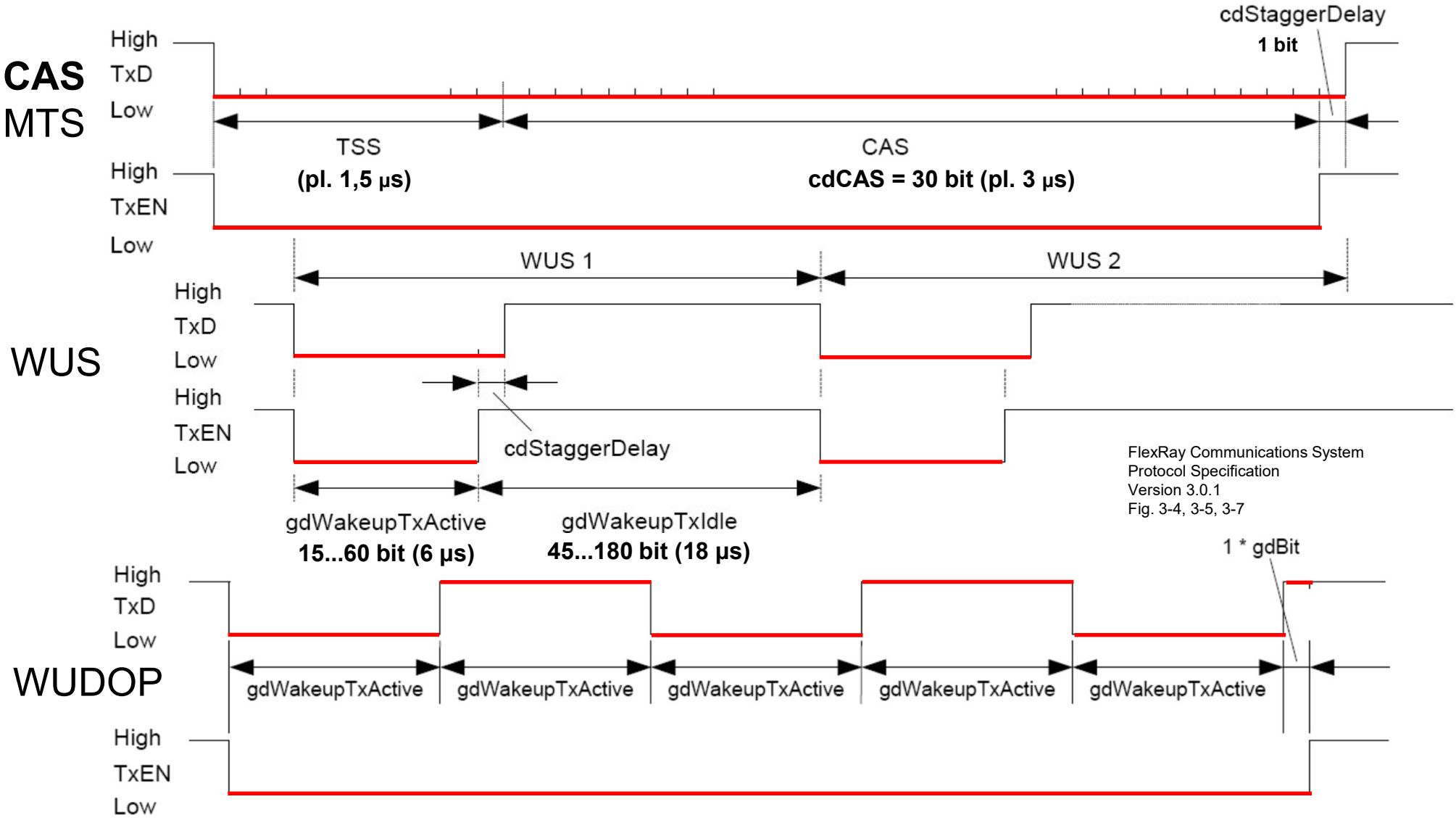


Dampers (shock absorbers) on the new BMW X5 have their valves electronically adjusted via FlexRay bus commands (note the module mounted on the strut). A soft response (low damping) is for bumpy roads and a stiff ride is provided for higher speed cornering. Swivel motors also adjust suspension anti-roll bar response.

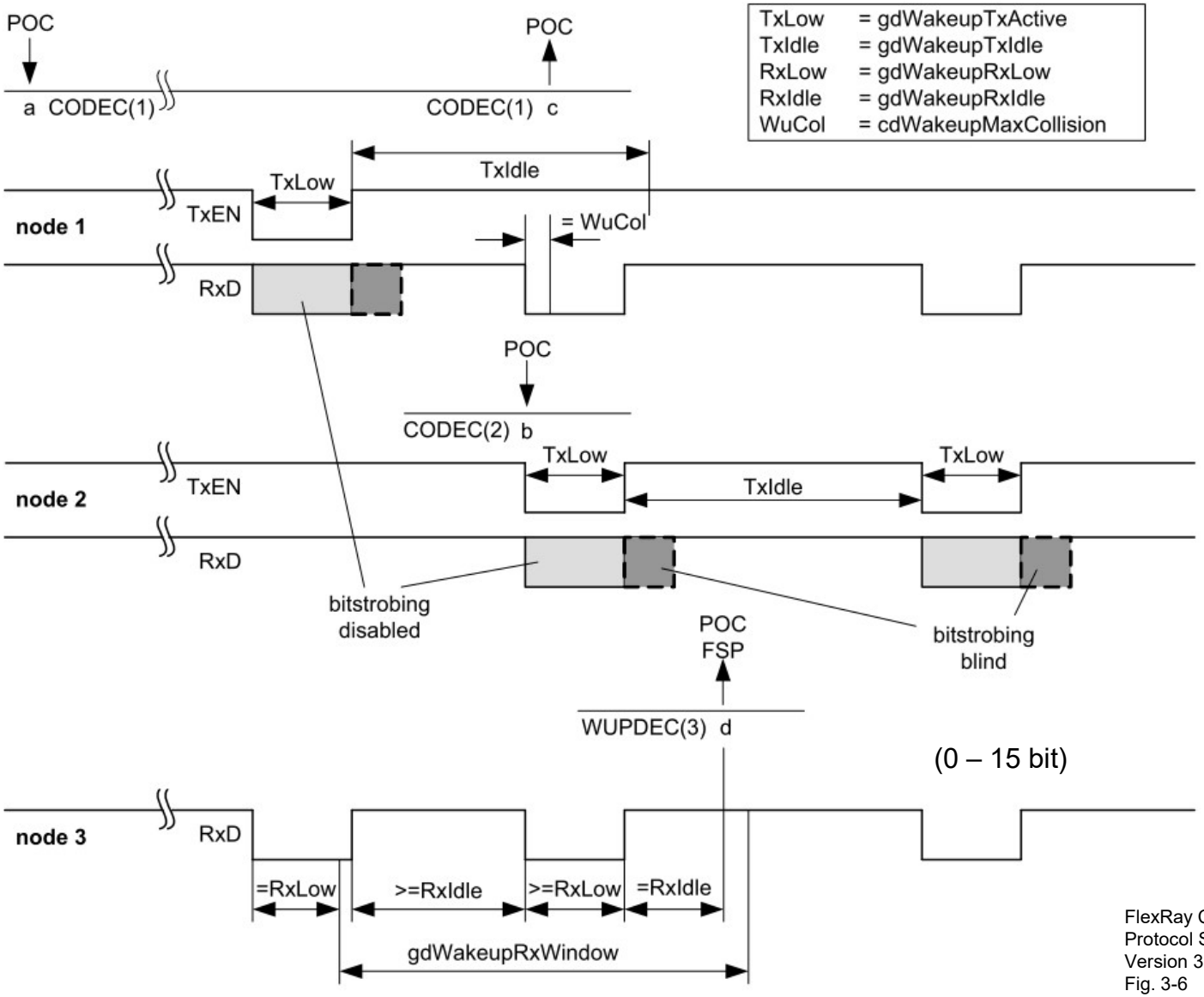
Source:
**FlexRay hits the road**
By Josef Berwanger and Anton Schedl
BMW Group, and Christopher Temple, Freescale Semiconductor
http://www.automotivedesignline.com/
194400425;jsessionid=0WJCMUH50YIMQQSNDLRCKH0CJUNN2JVN

# Wakeup + Startup

# Symbol encoding



# Wakeup symbol collision & wakeup pattern reception

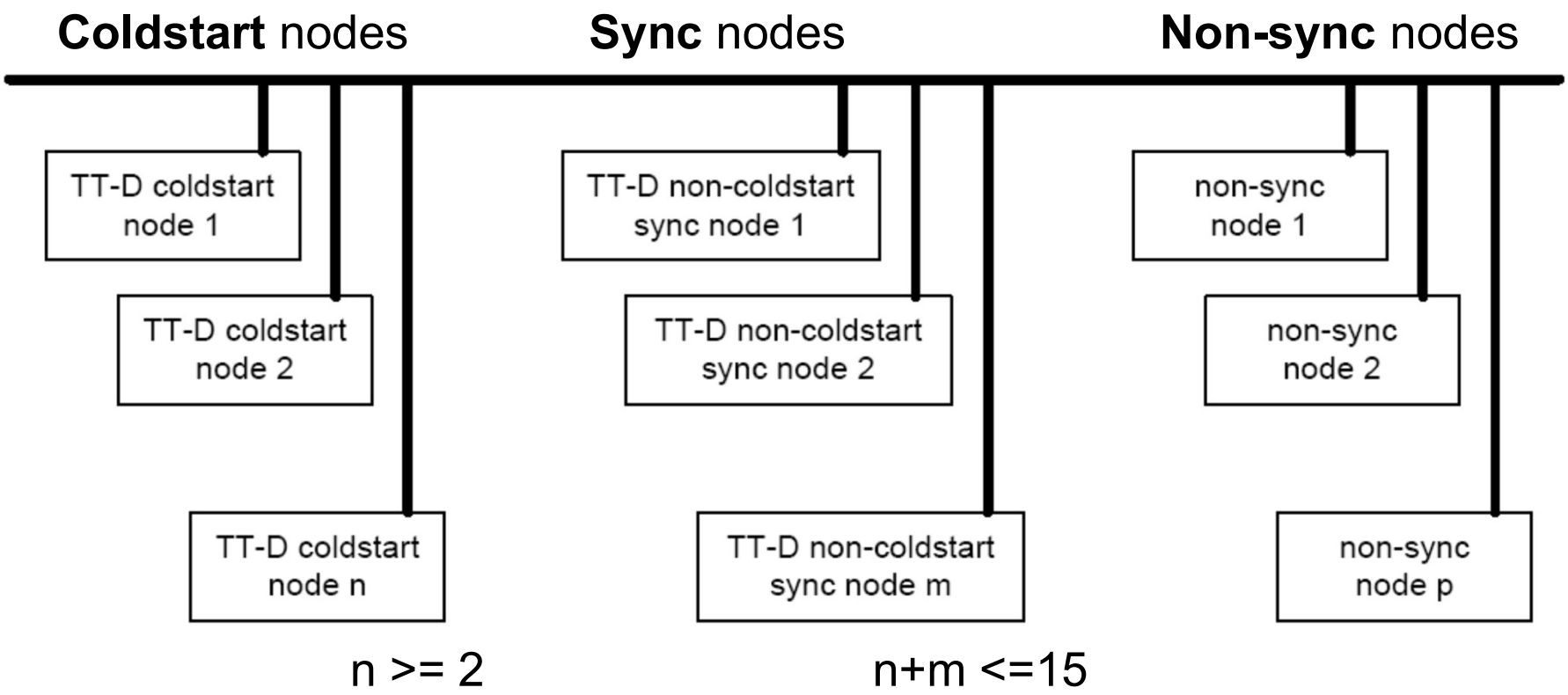



FlexRay Communications System
Protocol Specification
Version 3.0.1
Fig. 3-6

# Node-ok

- **Sync** node
  - Részt vesz a szinkronizálásban.
- **Coldstart** node (egyúttal **sync** node is)
  - Részt vesz a hálózati működés elindításában.
- **Non-sync** node
  - „Közönséges” node (se nem sync, se nem coldstart).

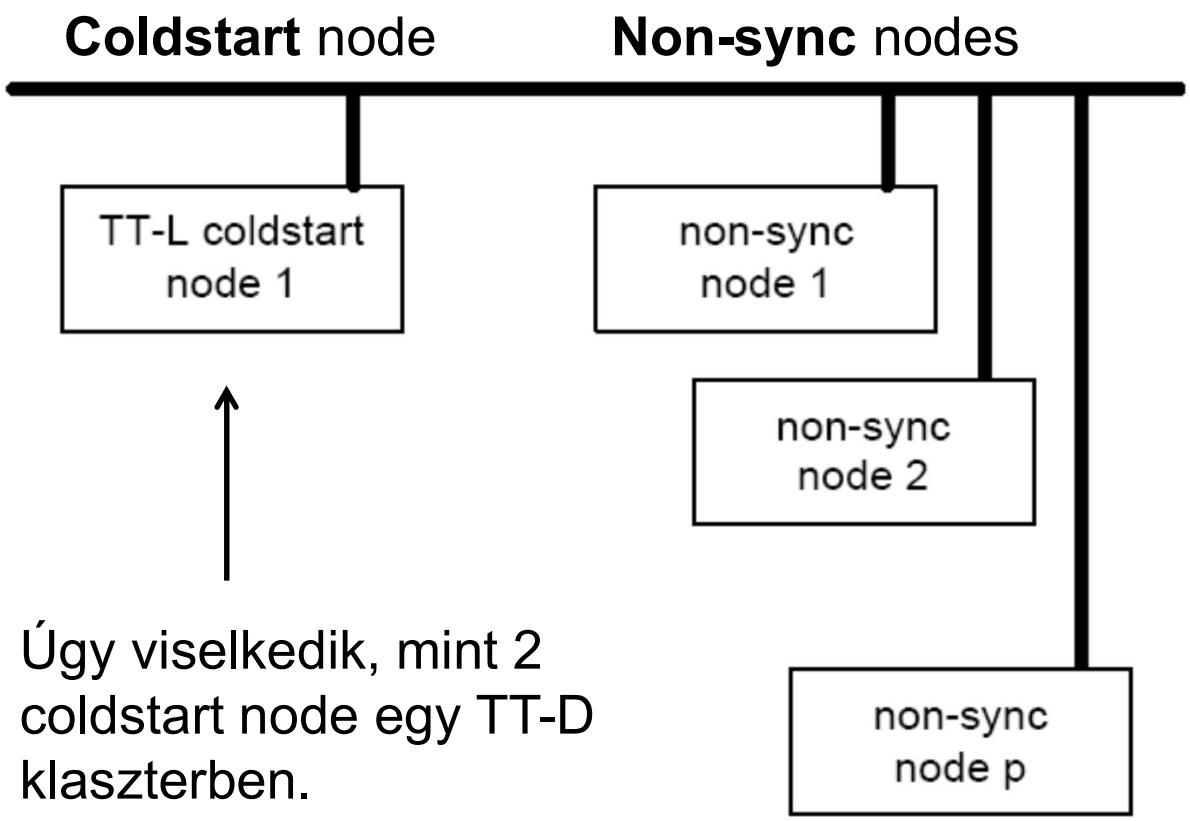
# Synchronization methods: TT-D (Local Distributed)




- Elosztott (nincs „singe point of failure”)
- Hibatűrő (fault-tolerant)

FlexRay Communications System
Protocol Specification
Version 3.0.1
Fig. 1-1

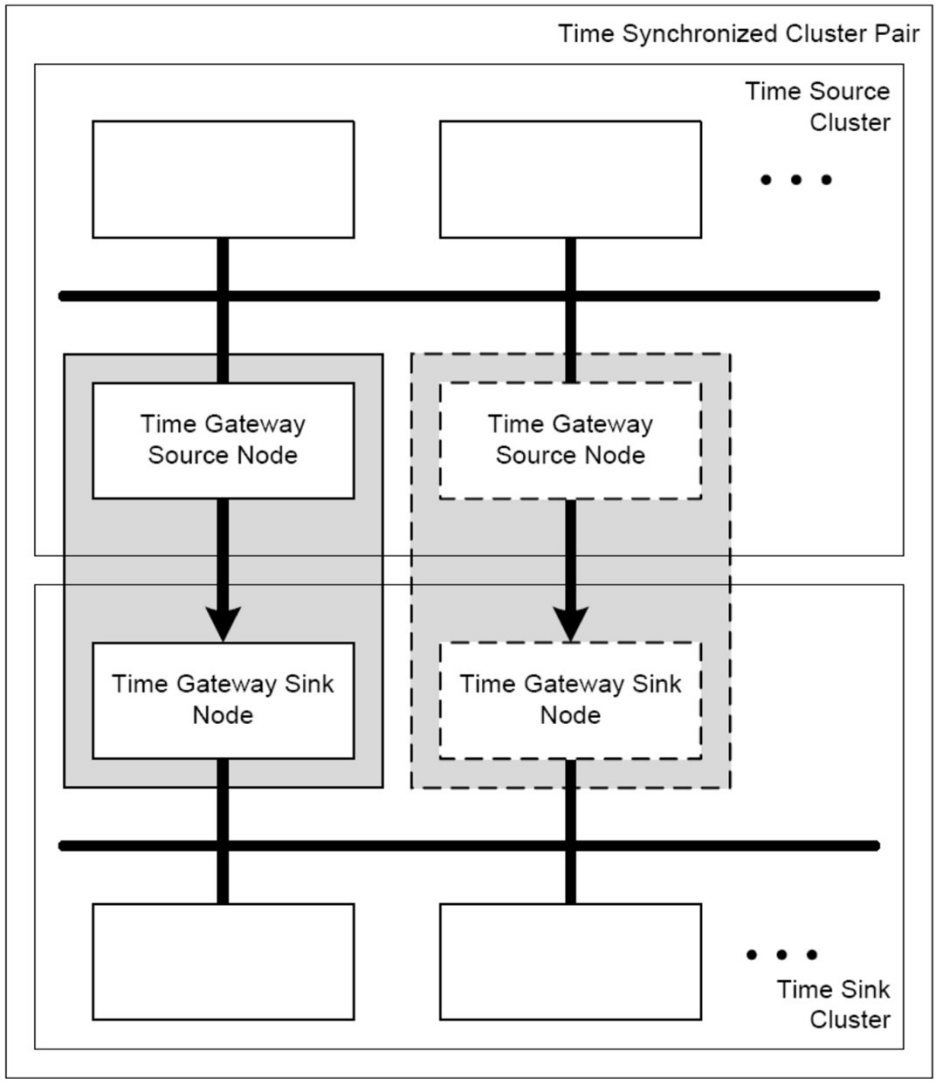
# Synchronization methods: TT-L (Local Master)

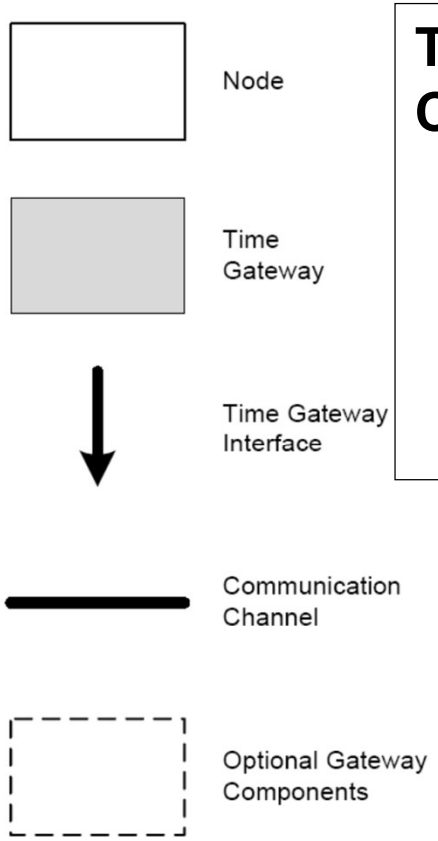



Úgy viselkedik, mint 2 coldstart node egy TT-D klaszterben.

FlexRay Communications System
Protocol Specification
Version 3.0.1
Fig. 1-2

# Synchronization methods: TT-E (External)




**Time Synchronized Cluster Pair:**

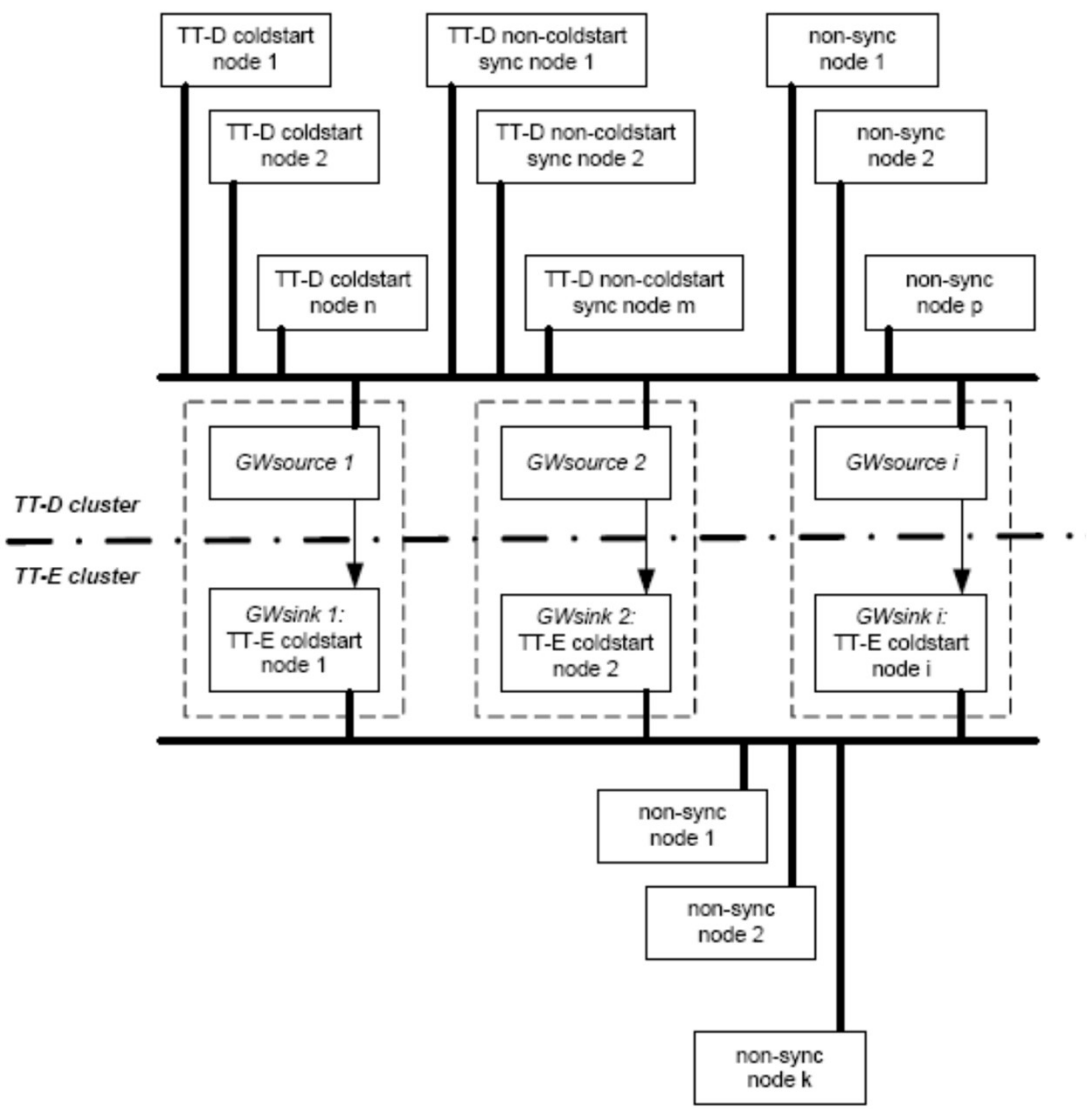
**Time Source** Cluster

↓

**Time Sink** Cluster

FlexRay Communications System
Protocol Specification
Version 3.0.1
Fig. 1-3

# TT-D + TT-E cluster

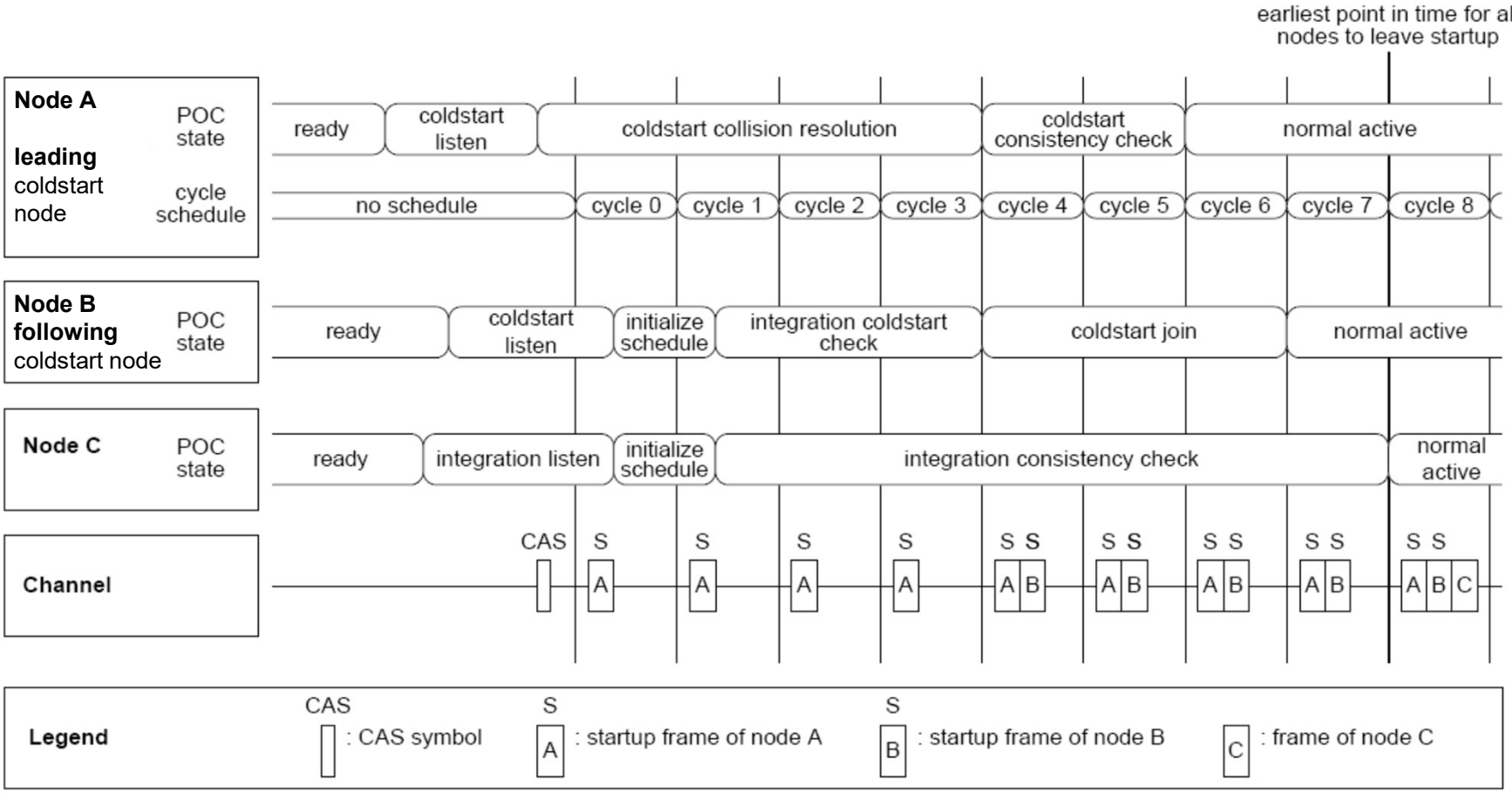



TT-D cluster
(Time Source)

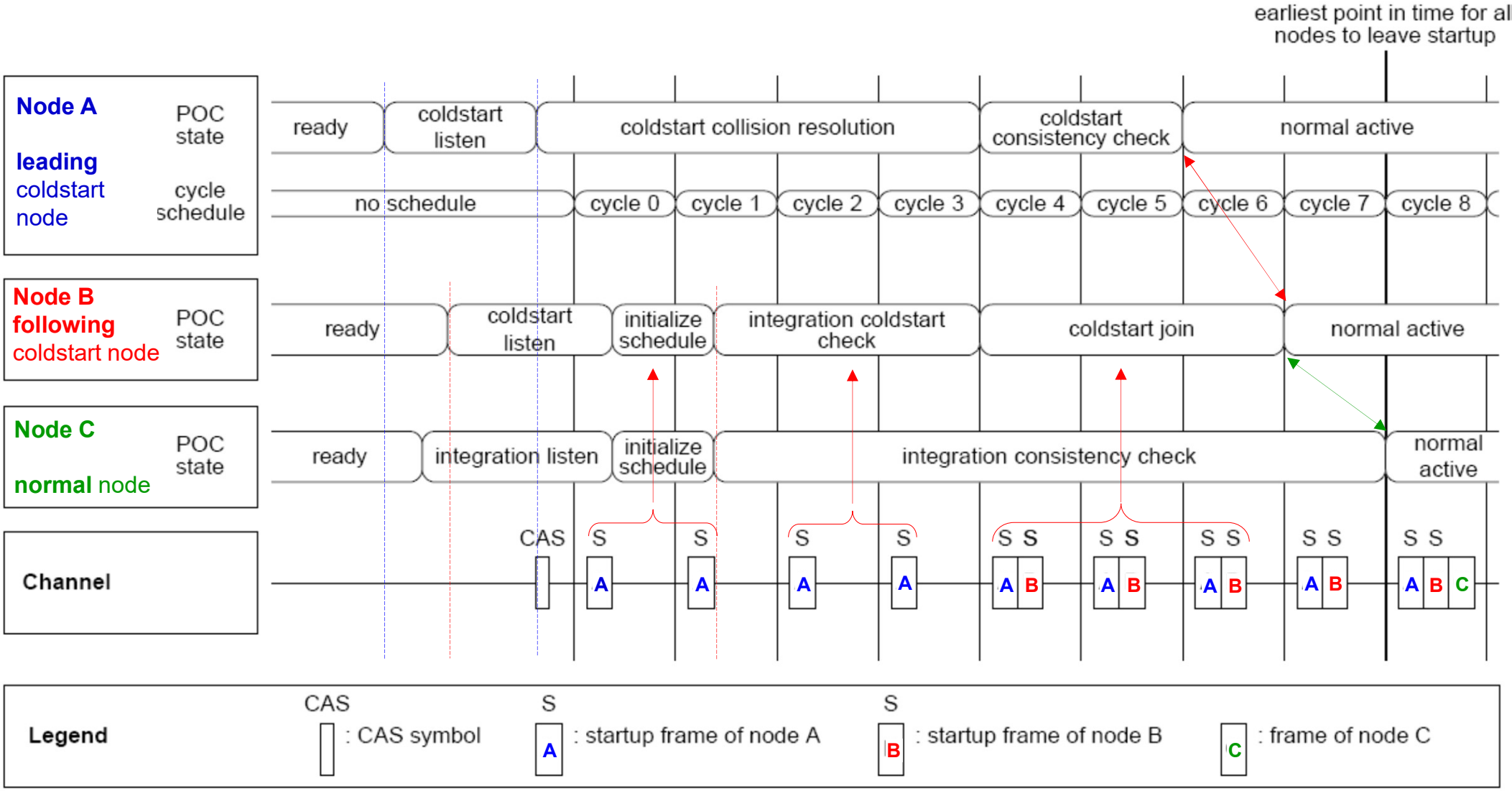
TT-E cluster
(Time Sink)

FlexRay Communications System
Protocol Specification
Version 3.0.1
Fig. 1-4

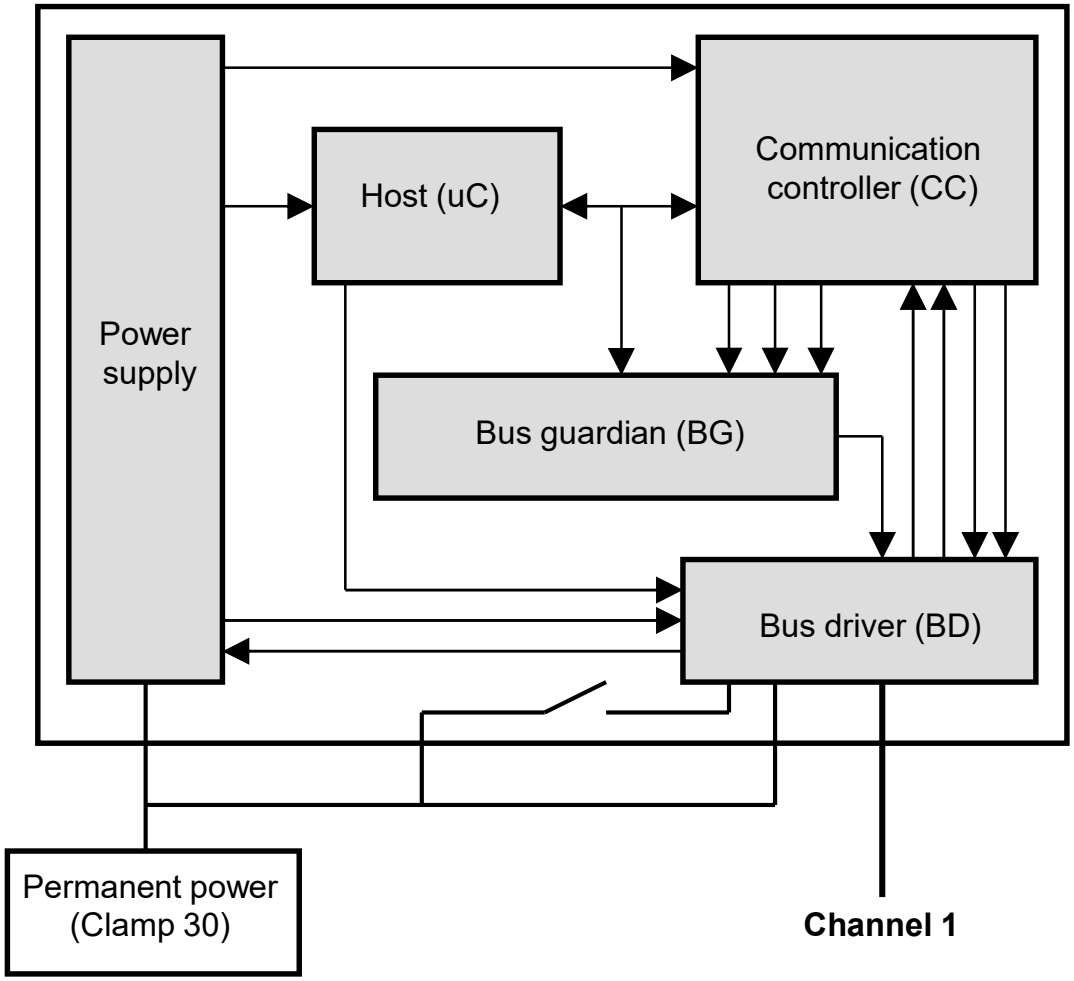
# Example of state transitions for a fault-free startup




FlexRay Communications System
Protocol Specification
Version 3.0.1
Fig. 7-9


earliest point in time for all nodes to leave startup
Node A
leading coldstart node
POC state
cycle schedule
ready
coldstart listen
coldstart collision resolution
coldstart consistency check
normal active
no schedule
cycle 0
cycle 1
cycle 2
cycle 3
cycle 4
cycle 5
cycle 6
cycle 7
cycle 8
Node B
following coldstart node
POC state
ready
coldstart listen
initialize schedule
integration coldstart check
coldstart join
normal active
Node C
normal node
POC state
ready
integration listen
initialize schedule
integration consistency check
normal active
Channel
CAS
S
A
B
C
Legend
: CAS symbol
: startup frame of node A
: startup frame of node B
: frame of node C

# ECU architecture – single channel




FlexRayInternational Workshop
16thand17thApril, 2002
Munich
The electrical physical layer
Mr. Bernd Elend -Philips Semiconductors

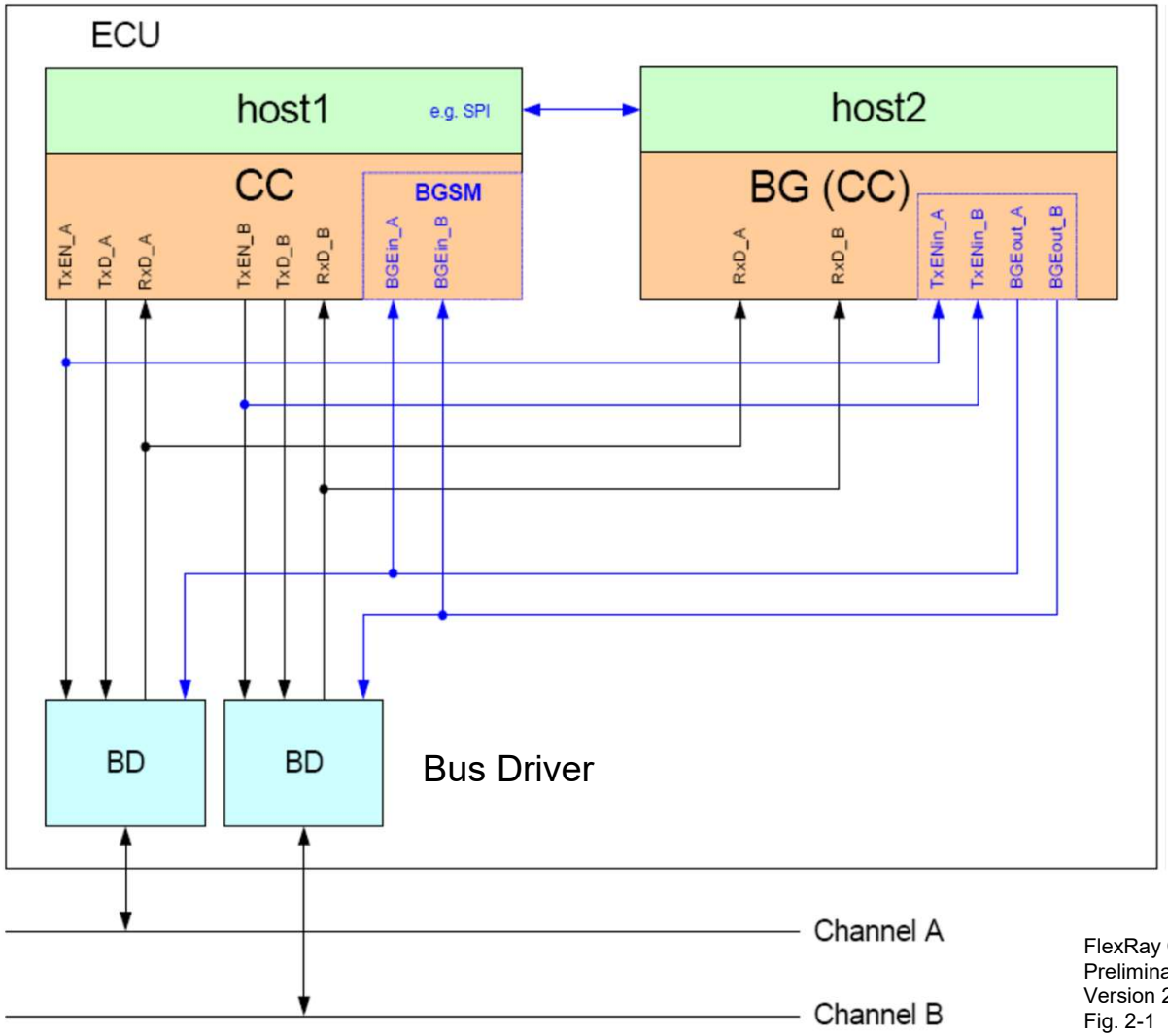
# Node-Local Bus Guardian

**CC**
Communication Controller

**BGSM**
Bus Guardian Schedule Monitoring

**Input:**
- RxD_A
- RxD_B
- BGEin_A
- BGEin_B

**Output:**
- TxD_A
- TxD_B
- TxEN_A
- TxEN_B



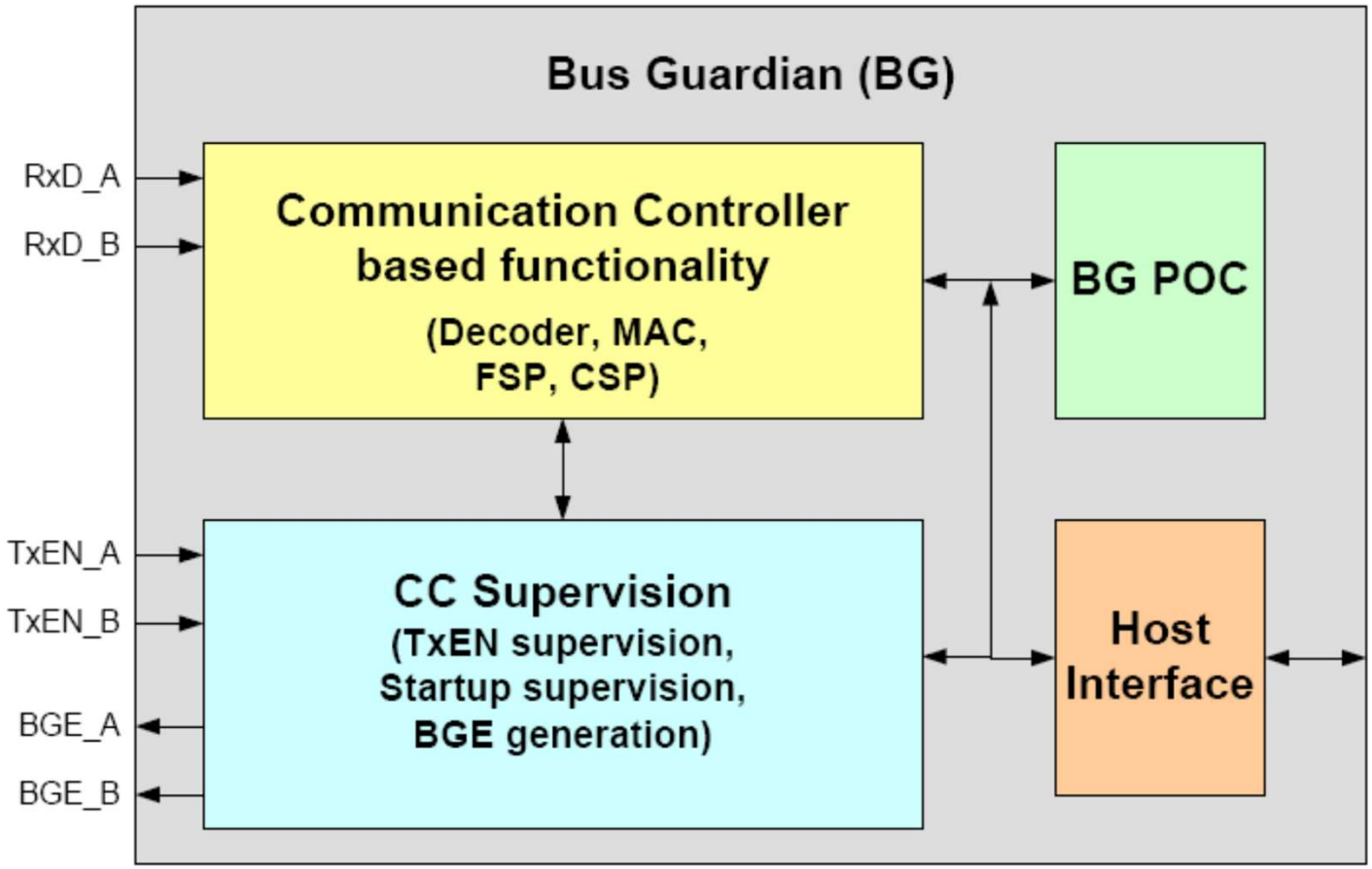

**BG**
Bus Guardian

**Input:**
- RxD_A
- RxD_B
- TxENin_A
- TxENin_B

**Output:**
- BGEout_A
- BGEout_B

FlexRay Communication System
Preliminary Node-Local Bus Guardian Specification
Version 2.0.9
Fig. 2-1

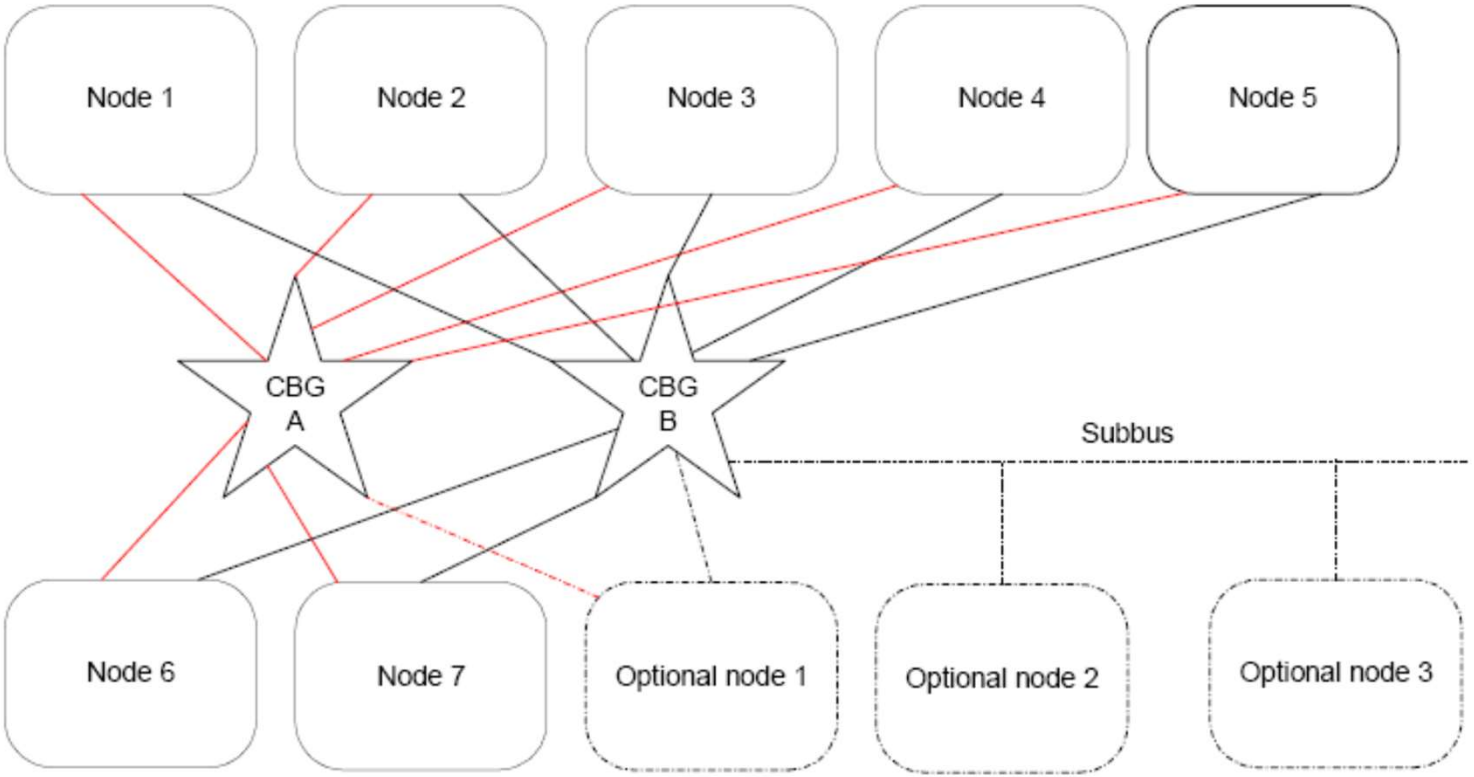
# Bus Guardian block diagram




**P**rotocol
**O**peration
**C**ontrol

FlexRay Communication System
Preliminary Node-Local Bus Guardian Specification
Version 2.0.9
Fig. 2-2

# Central Bus Guardian (CBG)




FlexRay Communications System
Preliminary Central Bus Guardian Specification
Version 2.0.9
Fig. 1-1

# Vége