UNIVERSIDAD PONTIFICIA
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MADRID
INSTITUTO DE POSTGRADO
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# COMUNICACIONES MOVILES Y FIJAS

**Sadot Alexandres**



## Wireless & Mobile Communications

**Fuente: Prof. Magda El Zarki Dept. of ICS-UC, Irvine**

## Fixed Communications

**Fuente: William Stalling – Data and Computer Communications**

## Aplicaciones

**Fuente:TCN (Train Communications Networking)**

# Aplicaciones
# Cap 4: TCN WTB-MVB



## Wire Train Bus

This is the train bus standardized by IEC
for interconnecting rail vehicles

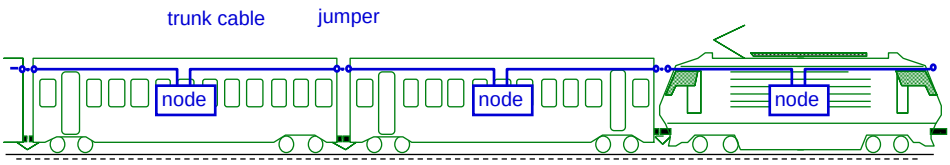
## WTB Outline

1. Applications in rail vehicles
2. Physical layer
    1. Electrical RS 485
    2. Middle-Distance
    3. Fibre Optics
3. Device Classes
4. Frames and Telegrams
5. Medium Allocation
6. Summary



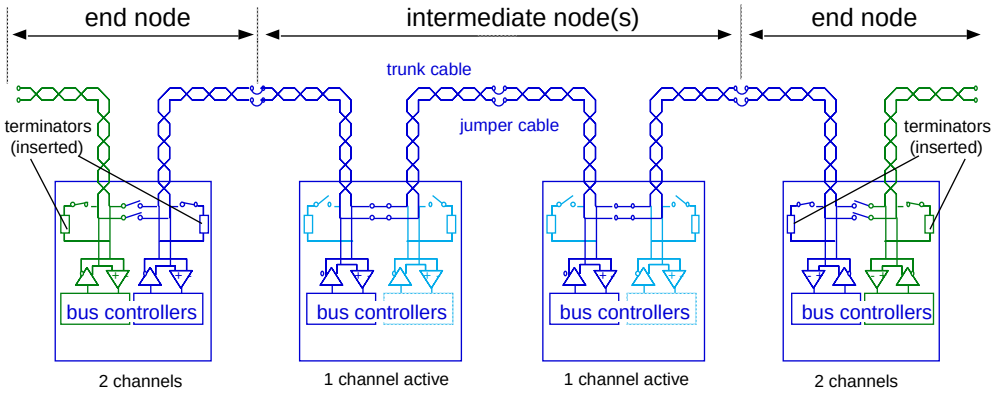
## Wire Train Bus

Train Communication Network




| | |
|---|---|
| data rate: | 1'000'000 bit/second |
| data period: | 25 ms |
| covered distance: | 860 m |
| number of devices: | 32 nodes |
| configuration: | "inauguration" assigns each node its address and orientation |
| experience: | based on DB-bus, FS-ETR450 and SBB Huckepack |

## WTB Structure




distance: 860 m (22 UIC vehicles) and supports up to 32 nodes.

medium: shielded, twisted wire pair at 1 Mbit/s with Manchester II encoding

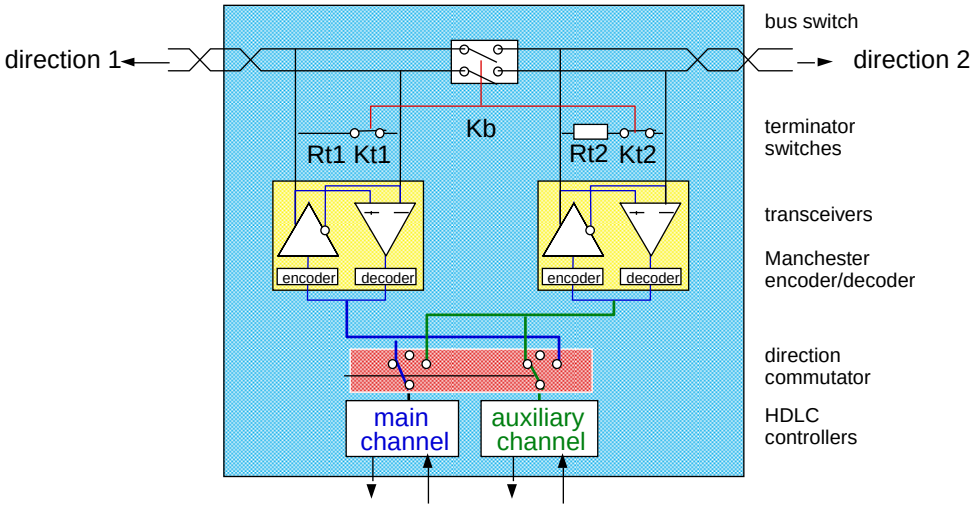
control: one master (any node may become back-up master)

link protocol: standard HDLC (IEC 3309) controllers.



## Train Bus Node

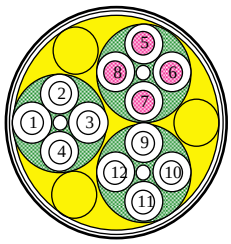
For the purpose of train inauguration, each node has two independent channels, a main and an auxiliary (HDLC) channel




One channel is connected to each direction in an end node

## UIC Cable

A 12-wire cable installed in all international coaches.

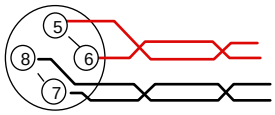



Current assignment:

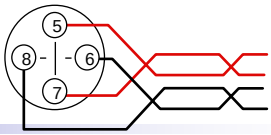
| | |
|---|---|
| 1-2: | Power amplifier input circuit |
| 3-4: | Telephone connection train guard-engine driver |
| 5-6: | Remote control of end stage |
| 7-8: | Remote control for priority announcements |
| 9: | Remote control of door closing |
| 10: | Switching on of train lightning |
| 11: | Switching off of train lightning |
| 12: | Common negative wire |
| 13: | Cable screening |

Advantage: smooth transition with older coaches
Problems: how to free a pair of wires, bandwidth, exposure, wiring.

DB coaches use wires 9,10,11 and 12 for overriding the emergency brake.



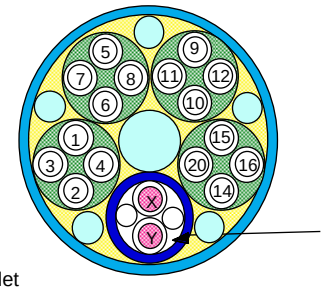

SNCF, ÖBB, SBB, ... twist the wires the other way






## UIC Data Cable

The UIC discarded the previous idea of decommissioning existing UIC lines and introduced an additional shielded wire pair in the jumper for the Train Bus:




according to UIC 558 leaflet

However, SNCF and DB could not agree whether to introduce an additional wire pair into the UIC-cable or into the EP-brake cable.

The EP cable equips SNCF coaches, but few international coaches have it. However, all recent freight vehicles have it.

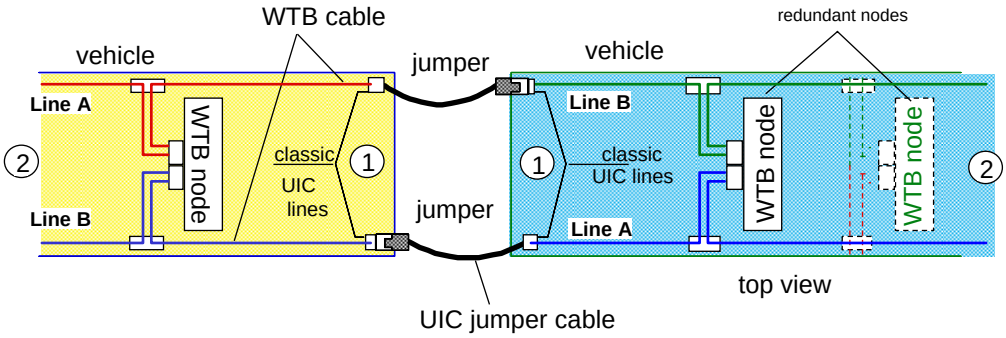
ERRI tested which medium is better for transmitting data, with no clear superiority.

## WTB Wiring

Uses jumper cables or automatic couplers between vehicles.

Fritting (voltage pulses) is used to overcome oxydation of contacts

Since there are normally two jumpers, the wiring is basically redundant:




There may be more than one node per vehicle (e.g. in locomotives)

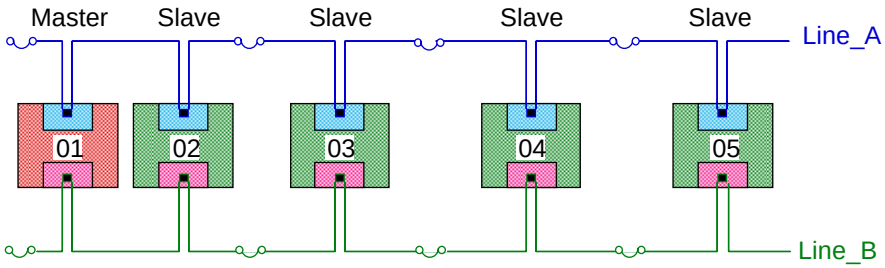
The labelling of the redundant lines (A or B) applies to one vehicle only.

The UIC specified a new cable ( 18 pole) compatible with the 13-pole UIC connector



## WTB Redundancy

The WTB provides physical layer and bus mastership redundancy.

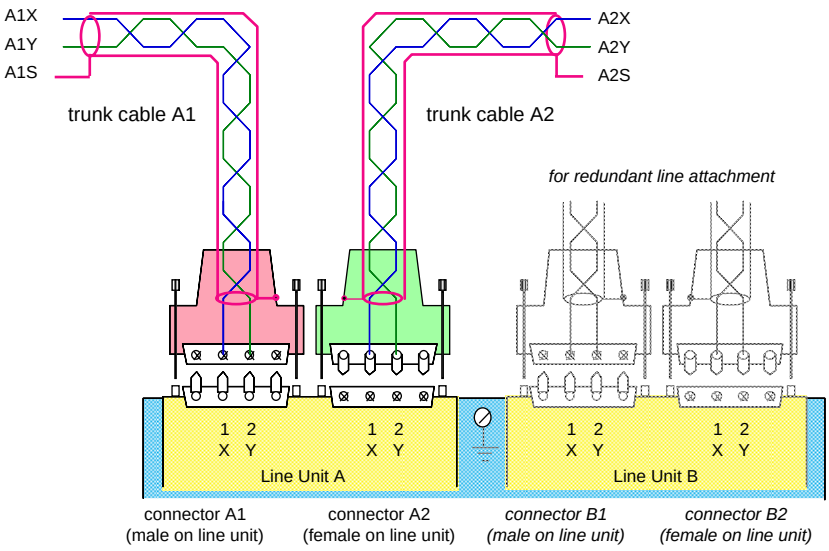



The WTB medium is basically redundant.
A node sends on both lines simultaneously.
A node receives from one line, but monitors the other line.
A signal quality supervision controls switchover.

In case of master failure, another node can take over as master.

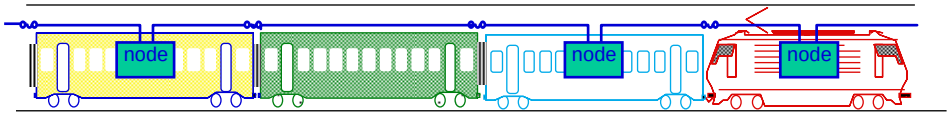
In applications where the master is tied to certain applications (strong master), its neighbour node can act as reserve master.

## WTB Connectors






## WTB transmission technology




conduction vehicle
(not equipped, no power or damaged node)

WTB is designed to cover 860 m with 22 vehicles (max. 32 nodes) without repeaters to address retrofit passenger (conduction only) vehicles and short freight trains.

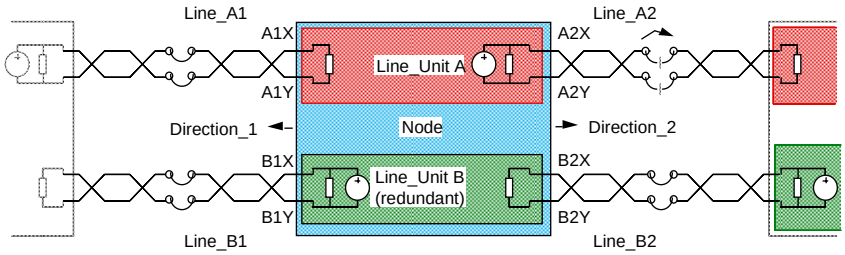
Signal attenuation is high (20,0 dB at 1 MHz), reflections occur in the jumper cable

Signal levels must be kept low to reduce electromagnetic emission

To overcome oxydation on contacts, a fritting pulse is applied to clean the contacts when vehicles are put together.

# Fritting

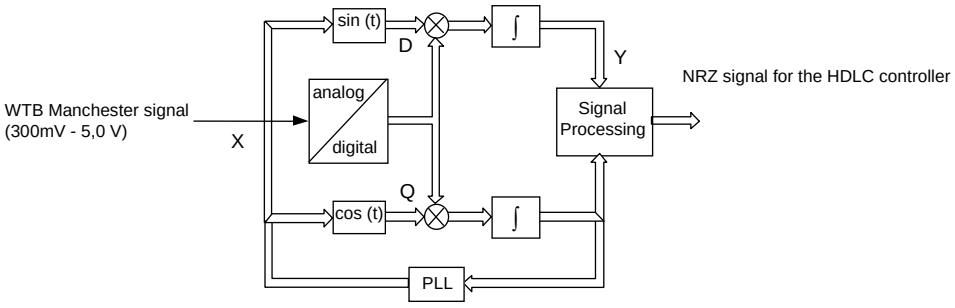
Fritting consists in applying a breakdown voltage between the wires to overcome oxidation in contacts




Fritting is applied by the End Nodes over the Auxiliary Channel, either continuously or when several attempts to detect additional nodes failed.



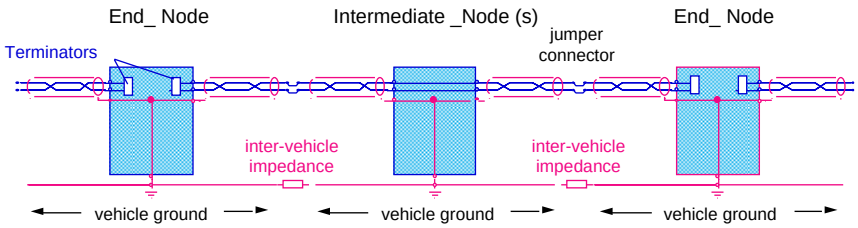
# WTB decoder technology



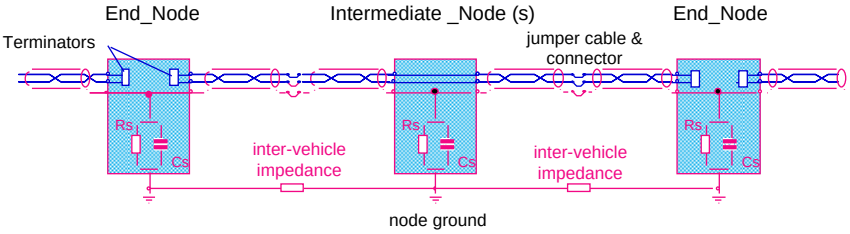

- **The high attenuation requires a decoder with a high dynamic range**
- **To this effect, WTB uses a simple Digital Signal Processor, integrated in a dedicated chip (SDSP).**
- **The decoder operates with two phase-locked loops, requiring the frames to carry a preamble**.

# Shielding Concept

Grounded shield




Continuous shield

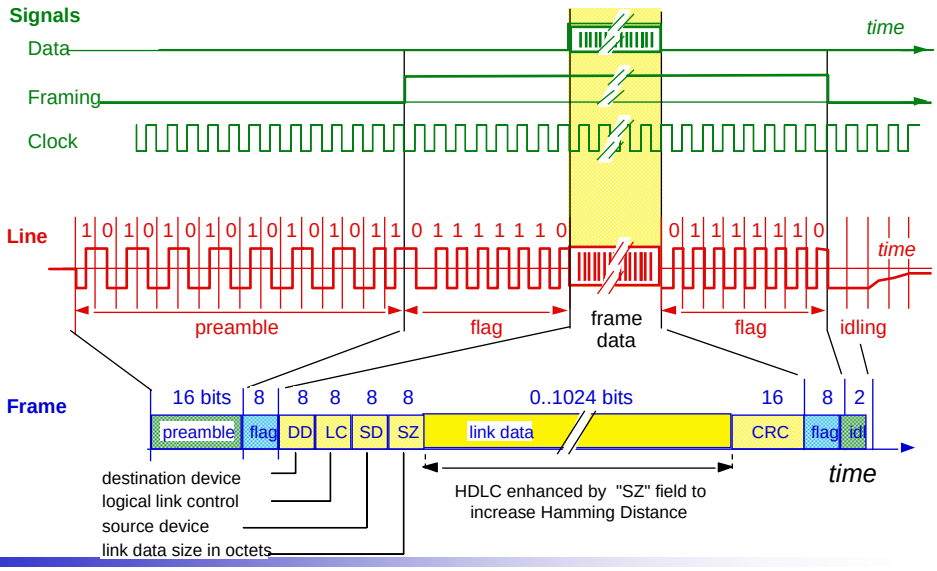



**Both shieldings acceptable depending on the application (UIC favorizes grounded shield)**

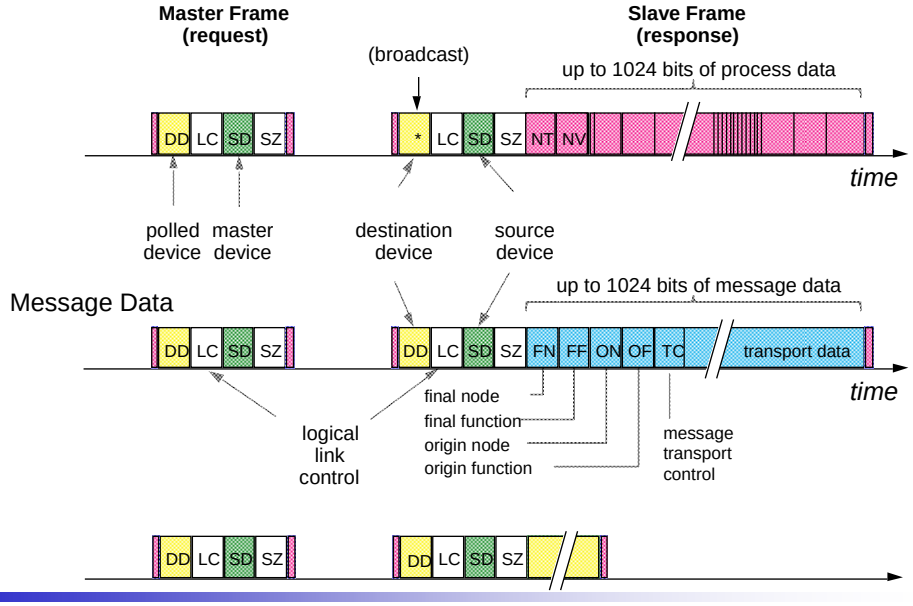


# WTB Signal Encoding

Frames use the HDLC format (ISO 3309), encoded as a Manchester signal.

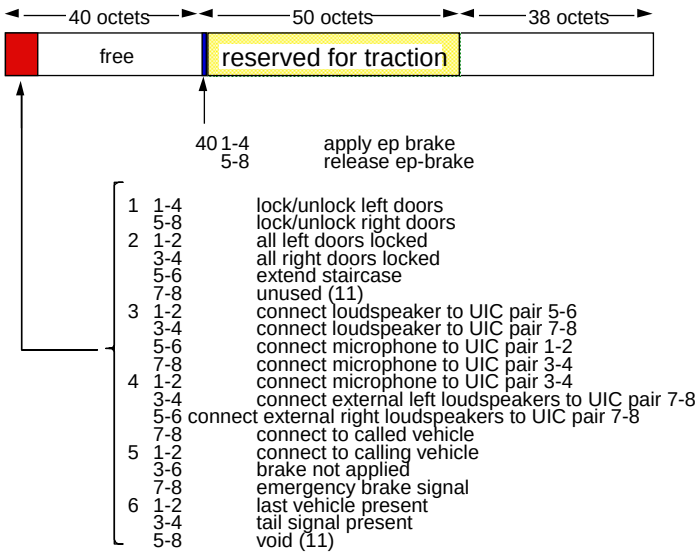


# WTB Telegrams






# UIC556 - Definition Of Regular Variables



## WTB Medium Access

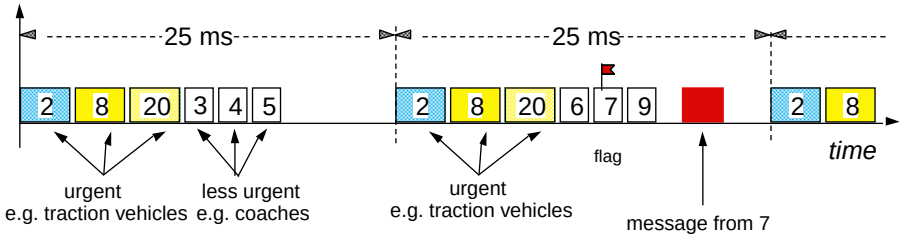
The WTB is controlled by one node acting as a master.

The master polls the other (slave) nodes regularly for process data.

The individual period depends on the vehicle type.
(for instance, traction vehicles are polled more often than passenger coaches)

Between periodic phases, the master polls the slaves for possible message data.

A slave requests to transmit message data by raising a flag during the periodic poll:






## Wire Train Bus

| | |
|---|---|
| Topography: | auto-configurable bus |
| Medium: | electrical: shielded, twisted wire pair |
| Covered distance: | 860 m, total 32 devices |
| Communication chip | standard HDLC controller<br>Statistical Digital Signal Processor for decoding |
| Processor participation | dedicated communication processor recommended |
| Medium redundancy: | fully duplicated for availability |
| Signalling: | Manchester II + delimiters |
| Gross data rate | 1,0 Mbit/s |
| Response Time | typical 100 µs |
| Basic Period | 25 ms |
| Address space | 6 bits |
| Frame size (useful data) | 1024 bits (variable) |
| Integrity | HDLC Frame Check Sequence + Manchester + Size |
| Inauguration | allocation of addresses, node orientation<br>topography distribution |
| Master redundancy | fast inauguration |

# Multifunction Vehicle Bus

This is the data bus standardized by IEC
for interconnecting standard equipment
on-board rail vehicles

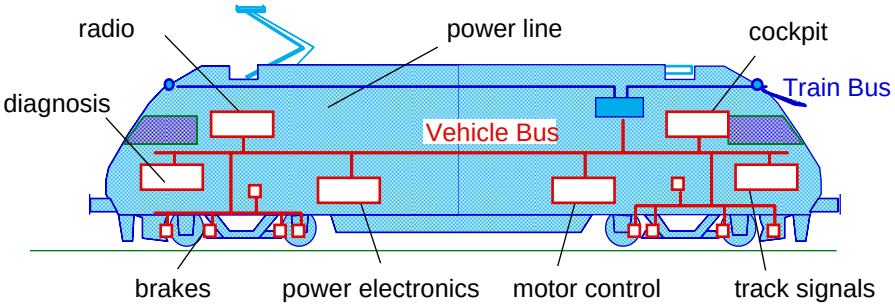


## MVB Outline

1. Applications in rail vehicles
2. Physical layer
    1. Electrical RS 485
    2. Middle-Distance
    3. Fibre Optics
3. Device Classes
4. Frames and Telegrams
5. Medium Allocation
6. Clock Synchronization
7. Fault-tolerance concept
8. Integrity Concept
9. Summary

## Multifunction Vehicle Bus in Locomotives

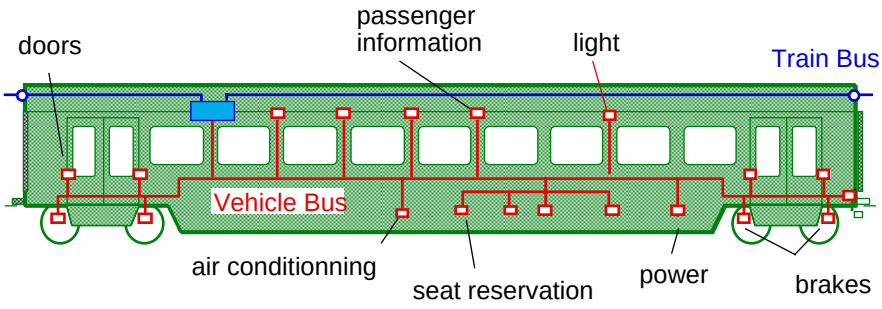
standard communication interface for all kind of on-board equipment




| | |
|---|---|
| data rate | 1'500'000 bits/second |
| delay | 0,001 second |
| medium | twisted wire pair, optical fibres |
| number of stations | up to 255 programmable stations<br>up to 4095 simple sensors/actuators |
| status | > 600 vehicles in service in 1998 |



## Multifunction Vehicle Bus in Coaches




covered distance: > 50 m for a 26 m long vehicle
< 200 m for a train set

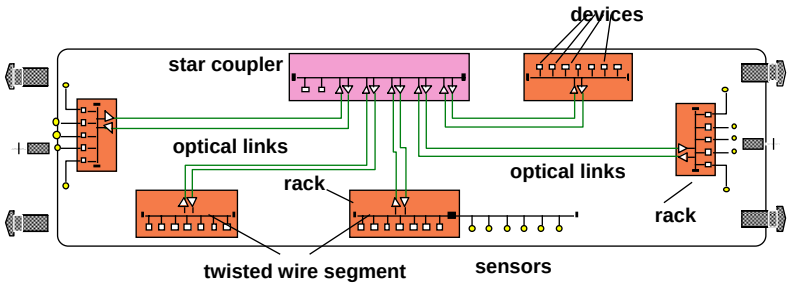
diagnostics and passenger information require relatively long, but infrequent messages

## MVB Physical Media

- OGF optical fibres; (2000 m)
- EMD shielded, twisted wires with transformer coupling; (200 m)
- ESD wires or backplane with or without galvanic isolation. (20 m)

Media are directly connected by repeaters (signal regenerators)

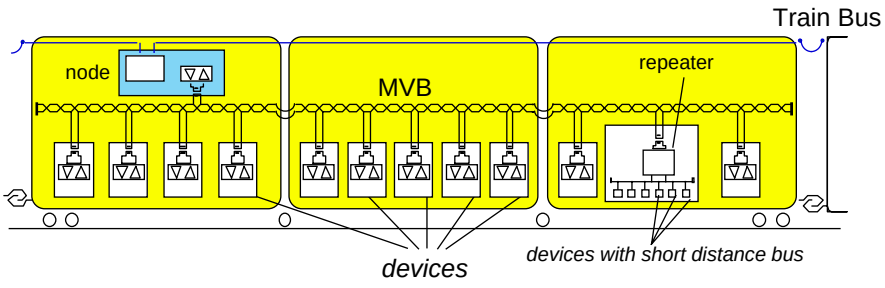
All media operate at the same speed of 1,5 Mbit/s.






## MVB Covered Distance

The MVB can span several vehicles in a multiple unit train configuration:

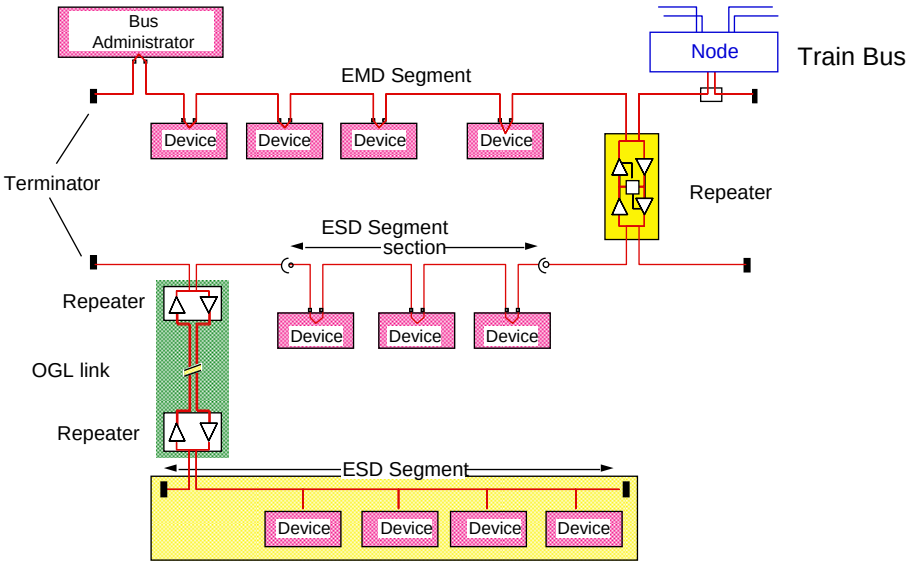



The number of devices under this configuration amounts to 4095.

MVB can serve as a train bus in trains with fixed configuration, up to a distance of:

> 200 m (EMD medium or ESD with galvanic isolation) or
> 2000 m (OGF medium).

## MVB Topography




all MVB media operate at same speed, segments are connected by repeaters.



## MVB Outline

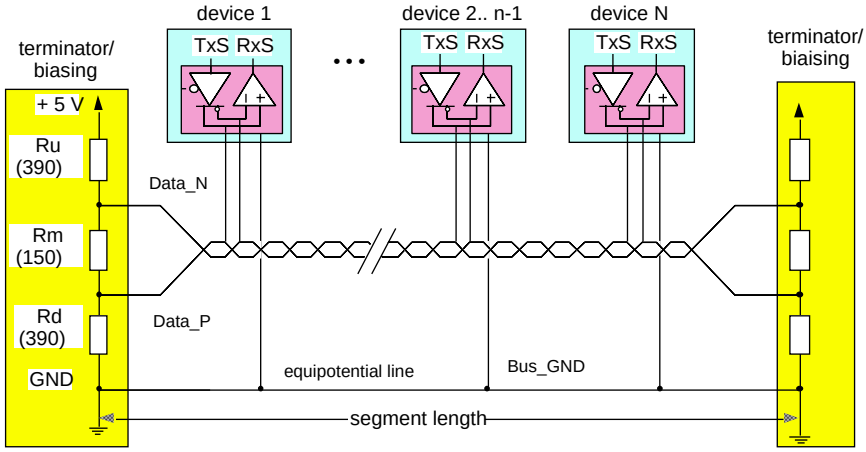
1. Applications in vehicles
2. Physical layer
    1. ESD (Electrical, RS 485)
    2. EMD (Transformer-coupled)
    3. OGF (Optical Glas Fibres)
3. Device Classes
4. Frames and Telegrams
5. Medium Allocation
6. Clock Synchronization
7. Fault-tolerance concept
8. Integrity Concept
9. Summary

## ESD (Electrical Short Distance) RS485

Interconnects devices over short distances (- 20m) without galvanic separation

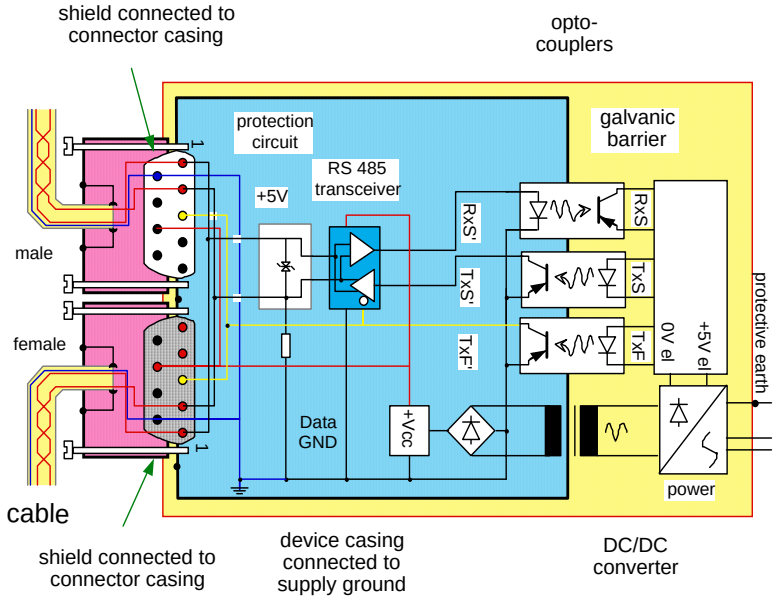
Based on proven RS-485 technology (Profibus)

Main application: connect devices within the same cabinet.

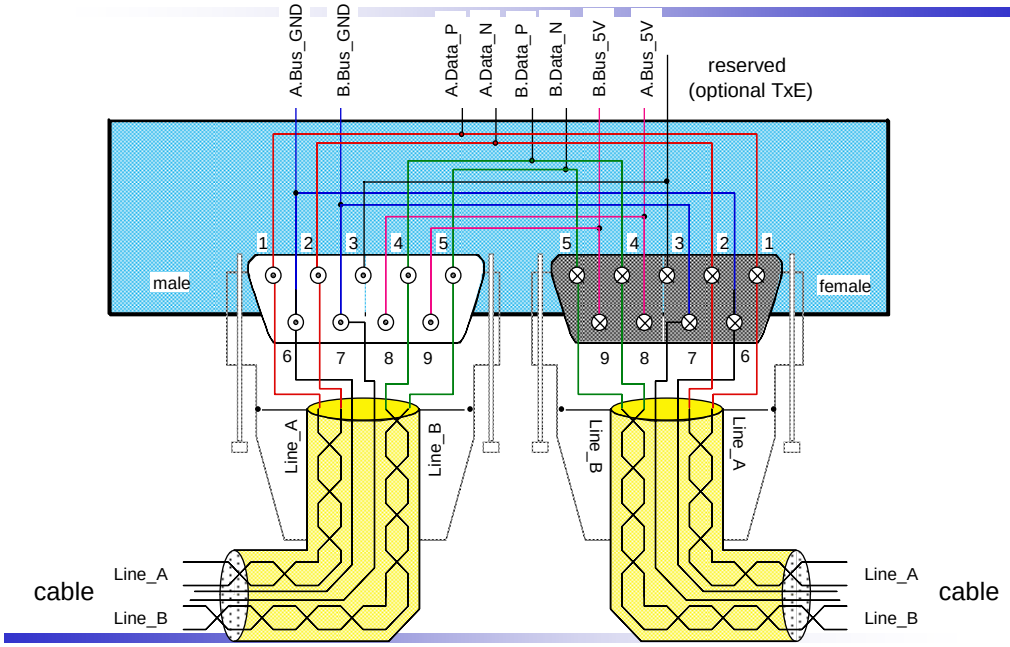





## ESD Device with Galvanical Isolation



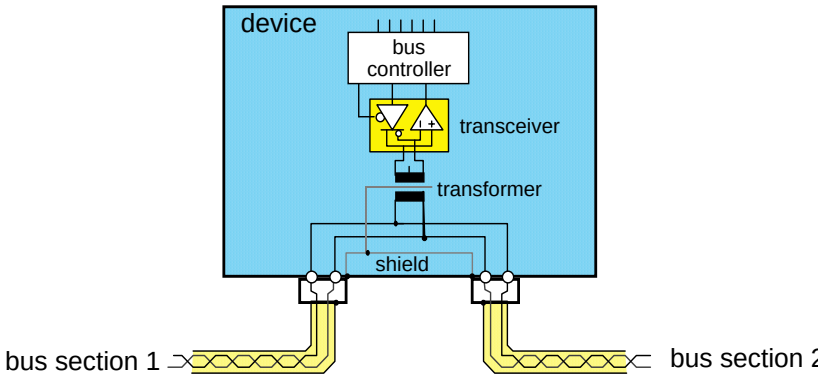
## ESD Connector for Double-Line Attachment



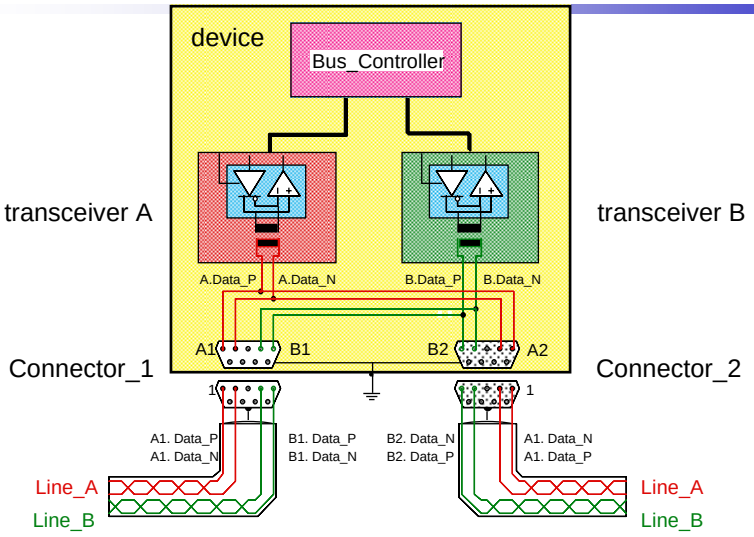



## EMD (Electrical Medium Distance) - Single Line Attachement

- Connects up to 32 devices over distances of 200 m.
- Transformer coupling to provide a low cost, high immunity galvanic isolation.
- Standard 120 Ohm cable, IEC 1158-2 line transceivers can be used.
- 2 x 9-pin Sub-D connector
- Main application: street-car and mass transit



# EMD Device with Double Line Attachment

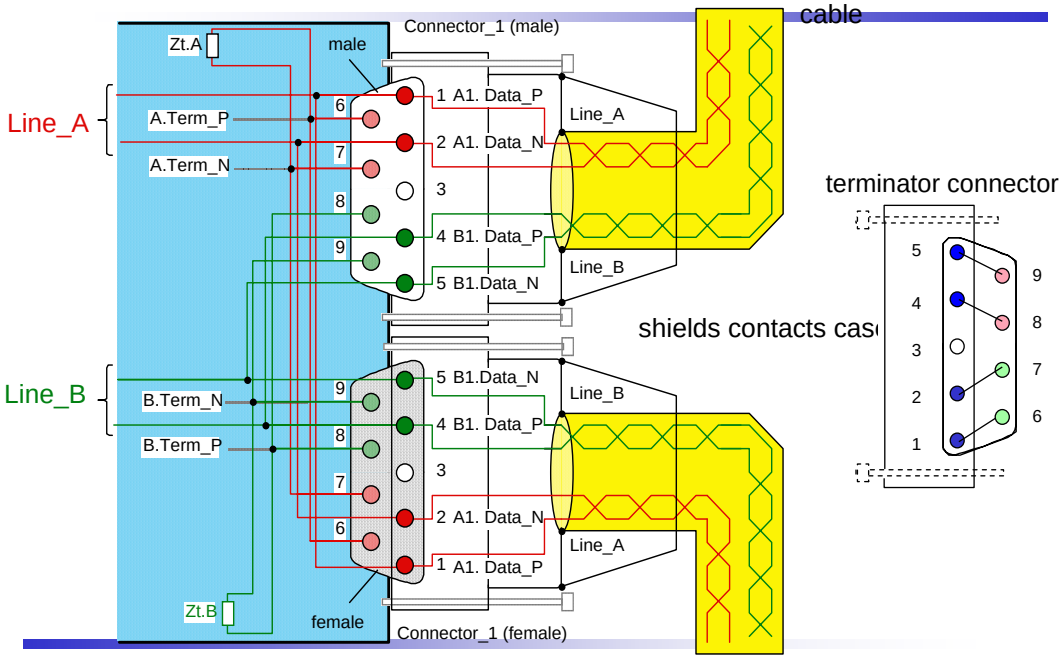



Carrying both redundant lines in the same cable eases installation

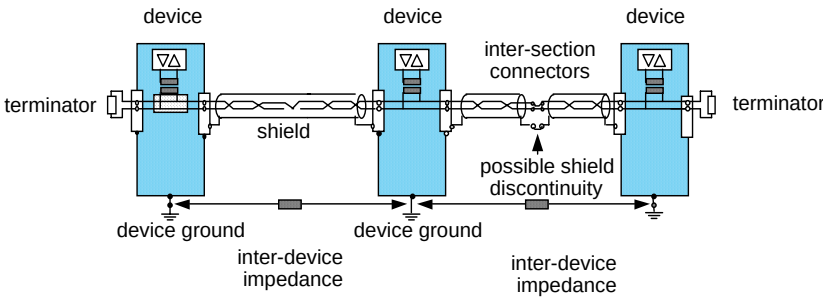
it does not cause unconsidered common mode failures in the locomotive environment (most probable faults are driver damage and bad contact)



# EMD Connectors for Double-Line Attachment



## EMD Shield Grounding Concept




Shields are connected directly to the device case

Device cases should be connected to ground whenever feasible

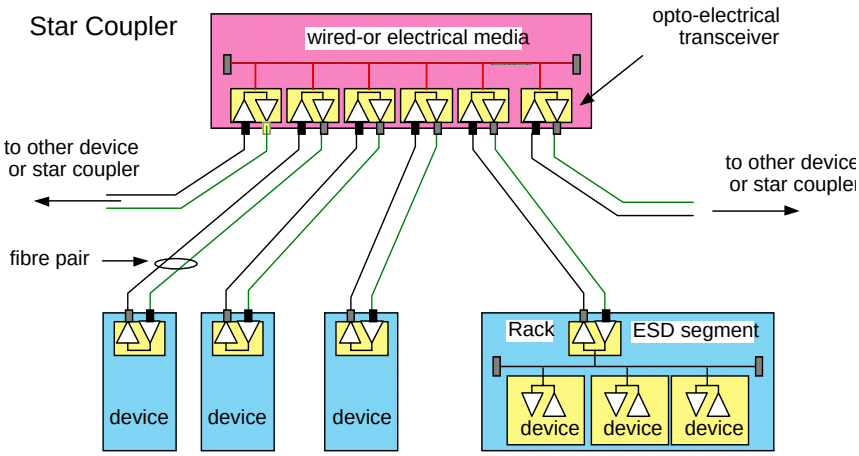


## OGF (Optical Glas Fibre)

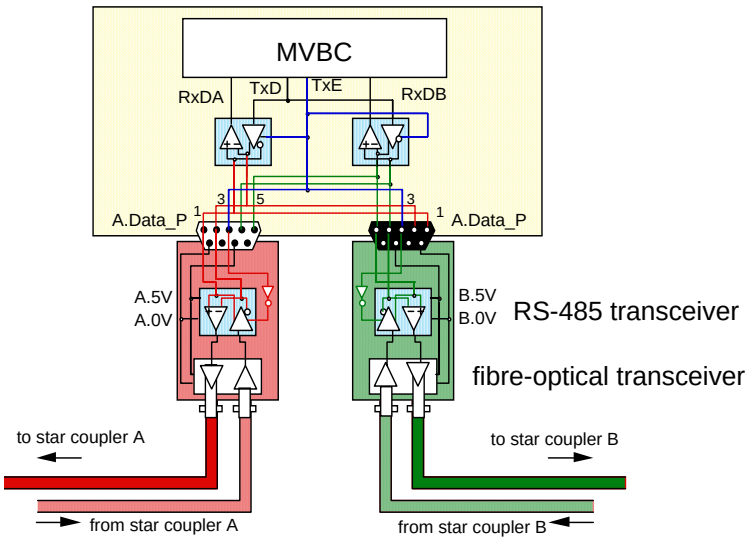
Covers up to 2000 m

Proven 200µm silica clad fibre

Main application: locomotive and critical EMC environment



## OGF to ESD adapter

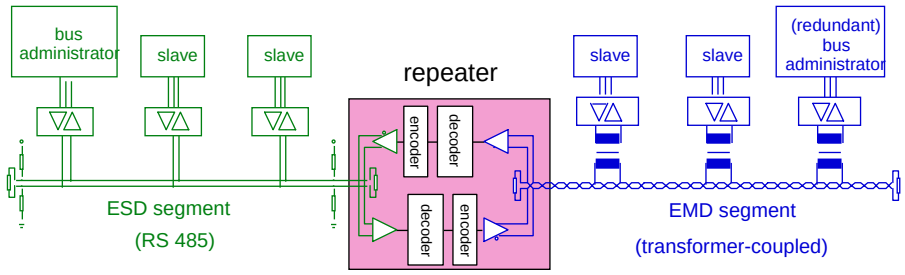



Double-line ESD devices can be connected to fibre-optical links by adapters



## MVB Repeater: the Key Element

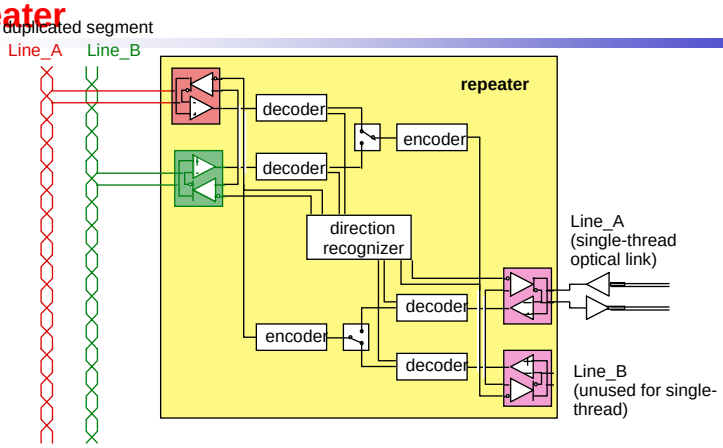
A repeater is used at a transition from one medium to another.




The repeater:

- decodes and reshapes the signal (knowing its shape)
- recognizes the transmission direction and forward the frame
- detects and propagates collisions

# MVB Repeater




- ï recognizes the transmission direction and forward the frame
- ï decodes and reshapes the signal (knowing its shape)
- ï jabber-halt circuit to isolate faulty segments
- ï detects and propagates collisions
- ï increases the interframe spacing when it becomes smaller than 3 µs
- ï can be used with all three media: ESD, EMD and OGF
- ï includes the End Delimiter in the direction fibre to trafo, removes it the other way
- ï handles redundancy (transition between single-thread and double-thread)



# MVB Outline

1. Applications in vehicles
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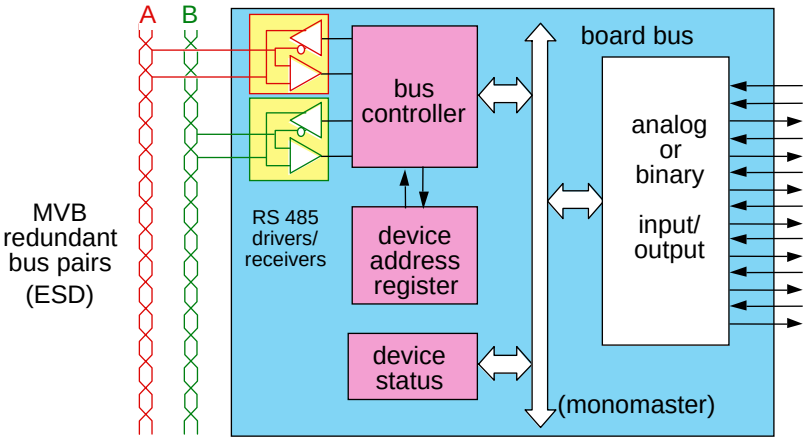
## MVB Class 1 Device




Class 1 or field devices are simple connections to sensors or actuators.

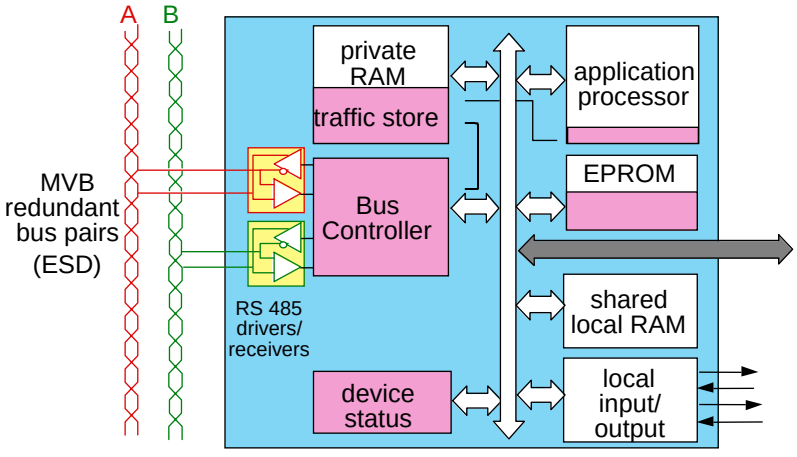
They do not require a microcontroller.

They do not participate in message data communication.

The Bus Controller manages both the input/output and the bus.



## MVB Class 2-3 Device




- Class 2 and higher devices have a processor and may exchange messages.
- Class 2 devices are configurable I/O devices (but not programmable)
- The Bus Controller communicates with the Application Processor through a shared memory, the traffic store, which holds typically 256 ports.

# MVB Class 4-5 Device

Class 4 devices present the functionality of a Programming and Test station

Class 4 devices are capable of becoming Bus Administrators.

To this effect, they hold additional hardware to read the device status of the other devices and to supervise the configuration.

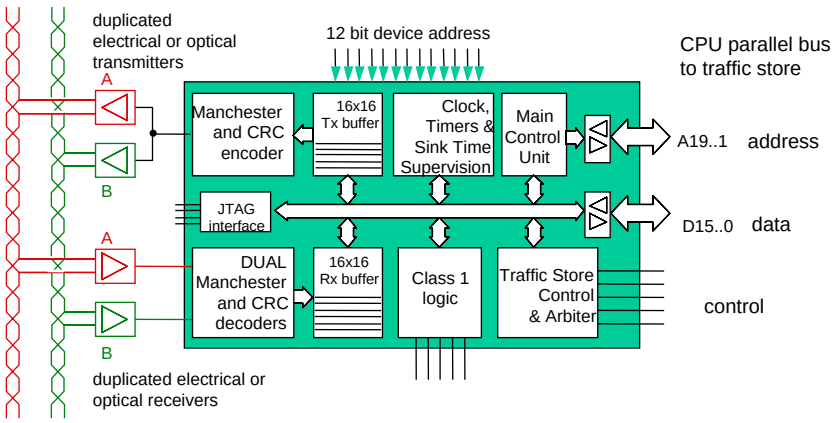
They also have a large number of ports, so they can supervise the process data transmission of any other device.

Class 5 devices are gateways with several link layers (one or more MVB, WTB).

The device classes are distinguished by their hardware structure.



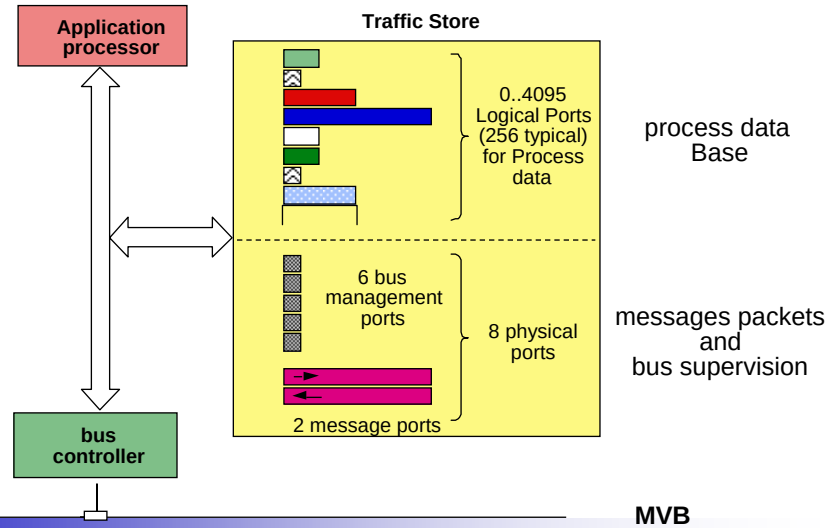
# MVBC - bus controller ASIC




- Automatic frame generation and analysis
- Adjustable reply time-out
- Up to 4096 ports for process data
- 16KByte.. 1MByte traffic store
- Freshness supervision for process data
- In Class 1 mode: up to 16 ports
- Bit-wise forcing
- Time and synchronization port
- Bus administrator functions
- Bookkeeping of communication errors
- Hardware queueing for message data
- Supports 8 and 16-bit processors
- Supports big and lirttle endians
- 24 MHz clock rate
- HCMOS 0.8 µm technology
- 100 pin QFP

## MVB Bus Interface

The interface between the bus and the application is a shared memory, the *Traffic Store*, where Process Data are directly accessible to the application.






## MVB Outline

1. Applications in vehicles
2. Physical layer
    1. Electrical RS 485
    2. Middle-Distance
    3. Fibre Optics
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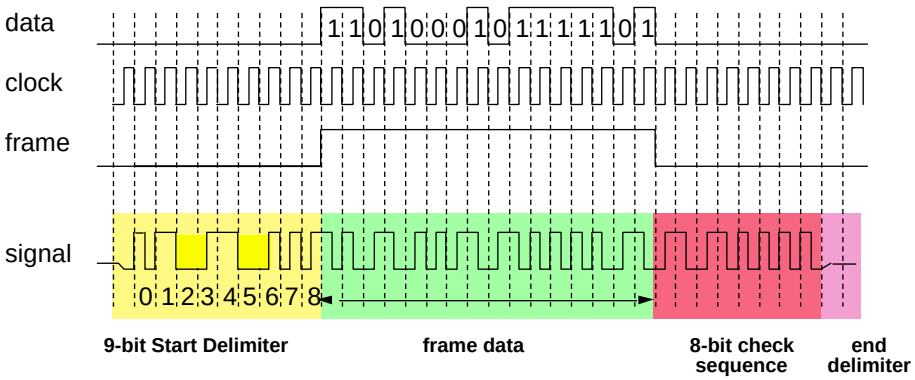
4. Frames and Telegrams
5. Medium Allocation
6. Clock Synchronization
7. Fault-tolerance concept
8. Integrity Concept
9. Summary

## MVB Manchester Encoding



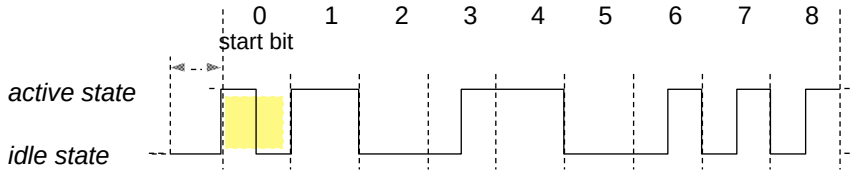

The Manchester-coded frame is preceded by a Start Delimiter containing non-manchester signals to provide transparent synchronization.



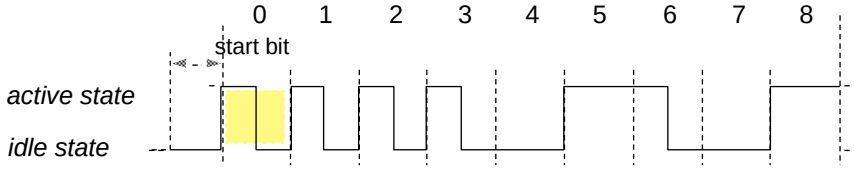
## MVB Frame Delimiters

Different delimiters identify master and slave frames:

**Master Frame Delimiter**




**Slave Frame Delimiter**

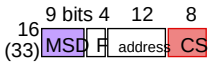



This prevents mistaking the next master frame when a slave frame is lost.

# MVB Frames Formats

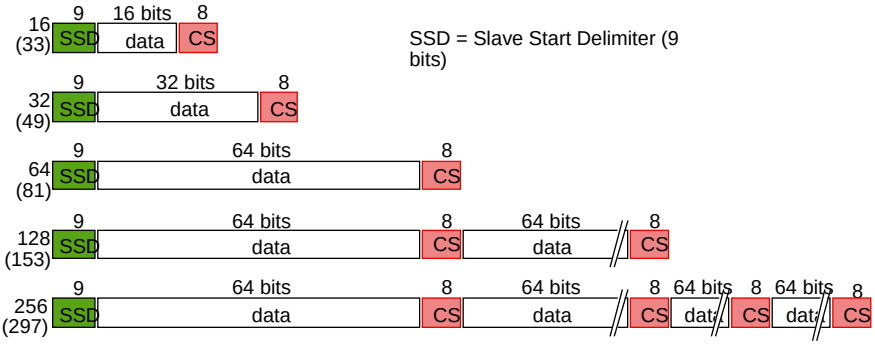
The MVB distinguishes two kinds of frames:

**master frames issued by the master**




MSD = Master Start Delimiter (9 bits)
CS = Check Sequence (8 bits)
F = F_code (4 bits)

**slave frames sent in response to master frames**



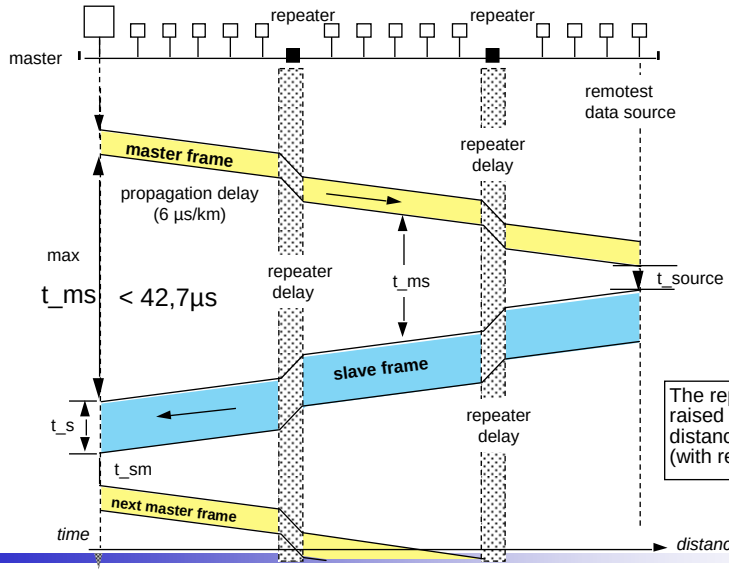

SSD = Slave Start Delimiter (9 bits)

useful (total) size in bits



# MVB Distance Limits

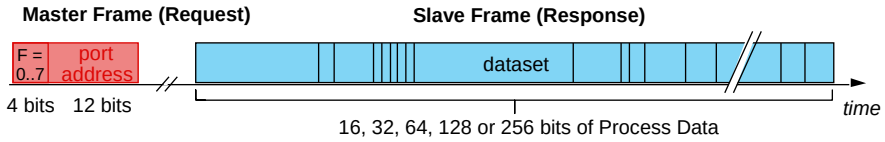
The distance is limited by the maximum allowed *reply delay* of 42,7 µs between a master frame and a slave frame.



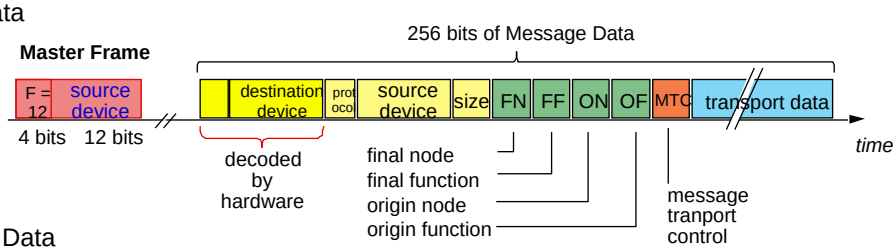

The reply delay time-out can be raised up to 83,4 µs for longer distances
(with reduced troughput).

# MVB Telegrams

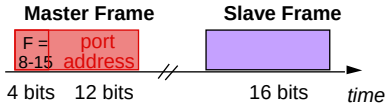
Process Data




Message Data




Supervisory Data

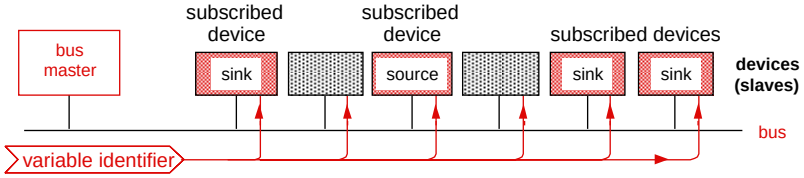



Telegrams are distinguished by the F_code in the Master Frame

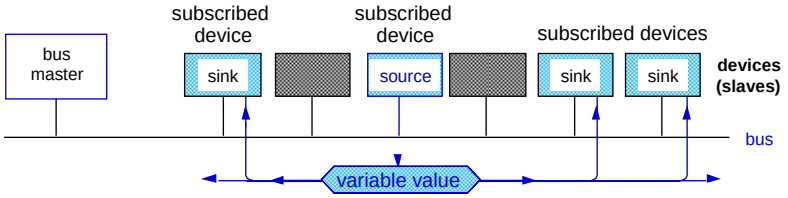


# Source-adressed broadcast

Phase1: The bus master broadcasts the identifier of a variable to be transmitted:




Phase 2: The device which sources that variable responds with a slave frame containing the value, all devices subscribed as sink receive that frame.



# MVB F_code Summary

| Master Frame | | | Slave Frame | | | |
|---|---|---|---|---|---|---|
| F_code | address | request | source | size | response | destination |
| 0 | | | | 16 | | |
| 1 | | | single | 32 | | all |
| 2 | logical | Process_Data | device | 64 | Process_Data | devices |
| 3 | | | subscribed | 128 | (application | subscribed |
| 4 | | | as | 256 | -dependent) | as |
| 5 | | reserved | source | - | | sink |
| 6 | | reserved | | - | | |
| 7 | | reserved | | - | | |
| 8 | all devices | Master_Transfer | Master | 16 | Master_Transfer | Master |
| 9 | device | General_Event | >= 1devices | 16 | Event_Identifier | Master |
| 10 | device | reserved | - | - | | |
| 11 | device | reserved | - | - | | |
| 12 | device | Message_Data | single device | 256 | Message_Data | selected device |
| 13 | group | Group_Event | >= 1devices | 16 | Event_Identifier | Master |
| 14 | device | Single_Event | single device | 16 | Event_Identifier | Master |
| 15 | device | Device_Status | single device | 16 | Device_Status | Master or monitor |



# MVB Outline

## Master Operation

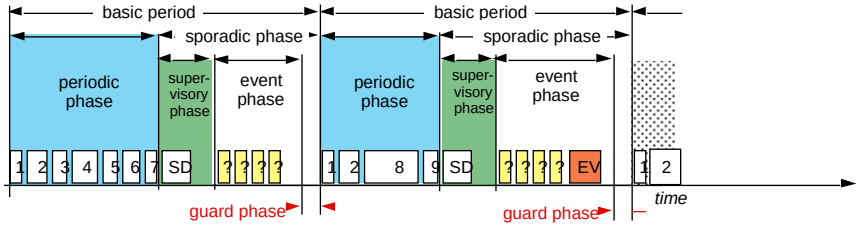
The Master performs four tasks:

1) Periodic Polling of the port addresses according to its Poll List

2) Attend Aperiodic Event Requests

3) Scan Devices to supervise configuration

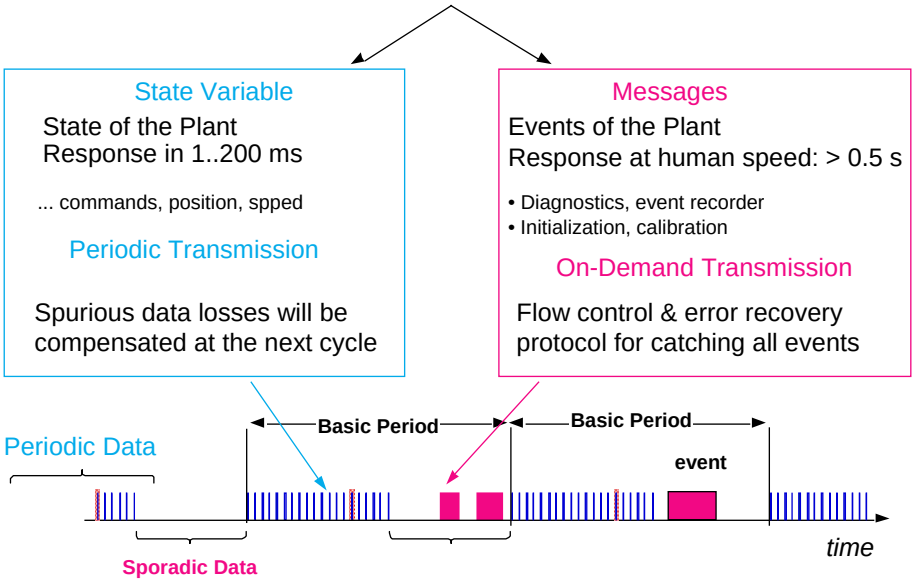
4) Pass Mastership ordently (last period in turn)



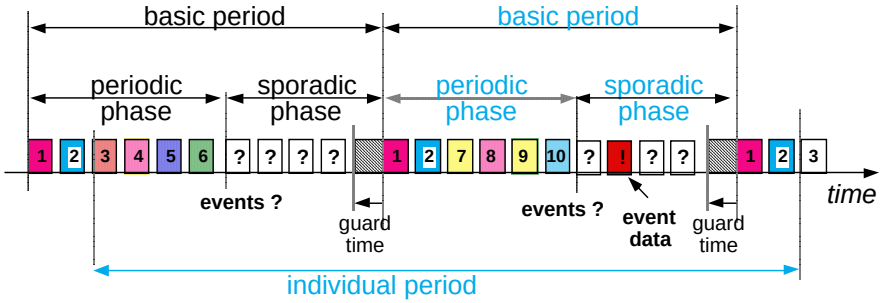

The Administrator is loaded with a configuration file before becoming Master



## Bus Traffic



## MVB Medium Access




A basic period is divided into a periodic and a sporadic phase.

During the periodic phase, the master polls the periodic data in sequence.

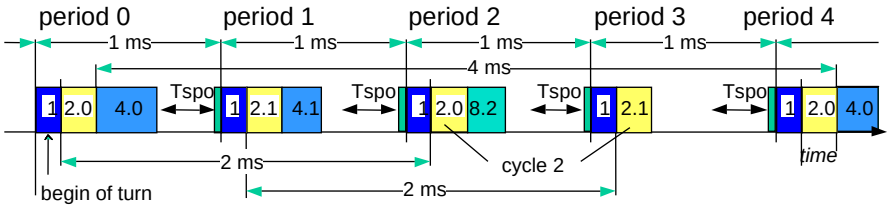
Periodic data are polled at their individual period (a multiple of the basic period).

Between periodic phases, the Master continuously polls the devices for events.

Since more than one device can respond to an event poll, a resolution procedure selects exactly one event.



## MVB Bus Administrator Configuration




The Poll List is built knowing:

- the list of the port addresses, size and individual period
- the reply delay of the bus
- the list of known devices (for the device scan
- the list of the bus administrators (for mastership transfer)

# MVB Event Resolution (1)

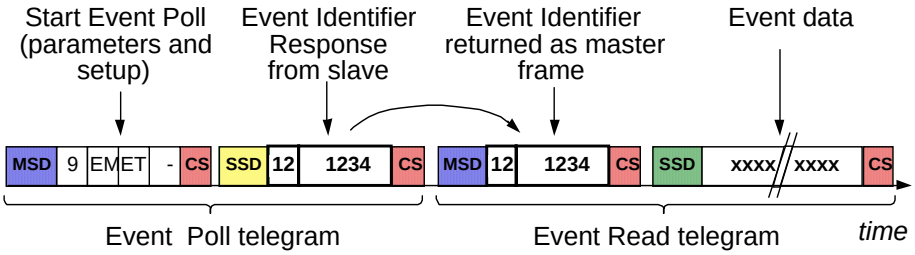
To scan events, the Master issues a General Event Poll (Start Poll) frame.

If no device responds, the Master keeps on sending Event Polls until a device responds or until the guard time before the next periodic phase begins.

A device with a pending event returns an Event Identifier Response.

If only one device responds, the Master reads the Event Identifier (no collision).

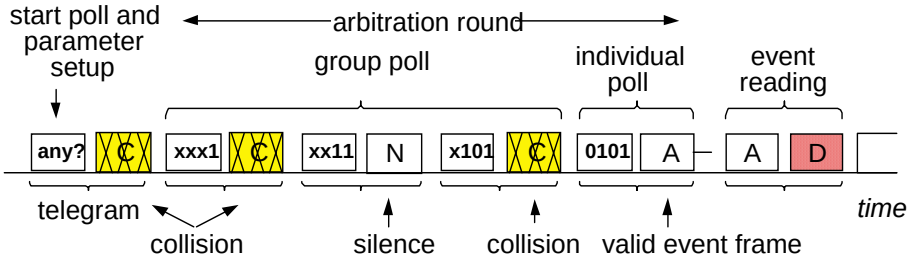
The Master returns that frame as an Event Read frame to read the event data






# MVB Event Resolution (2)

If several devices respond to an event poll, the Master detects the collision and starts event resolution

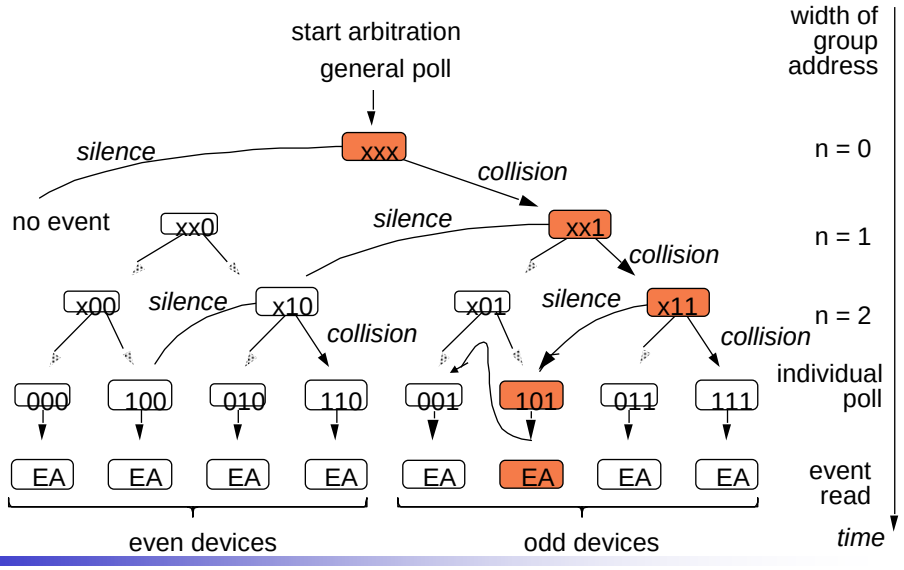



The devices are divided into groups on the base of their physical addresses. The Master first asks the devices with an odd address if they request an event.

- *If only one response comes, the master returns that frame to poll the event.*
- *If there is no response, the master asks devices with an even address.*
- *If collision keeps on, the master considers the 2nd bit of the device address.*

## MVB Event Resolution (3)

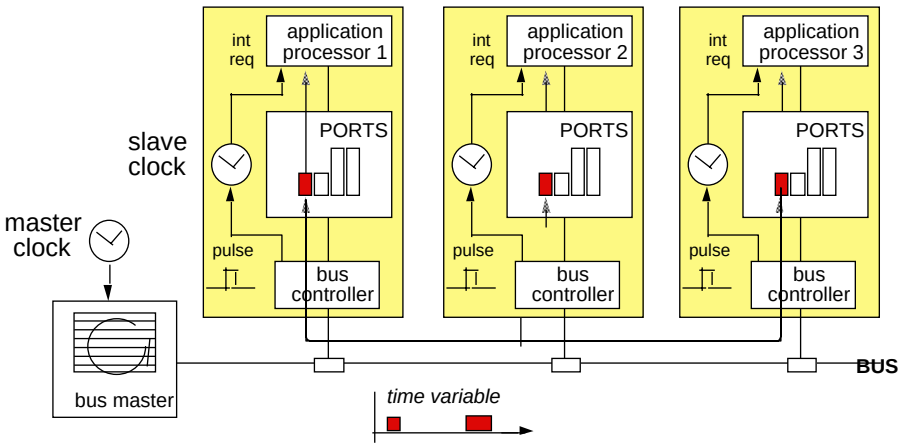
*Example with a 3-bit device address:*



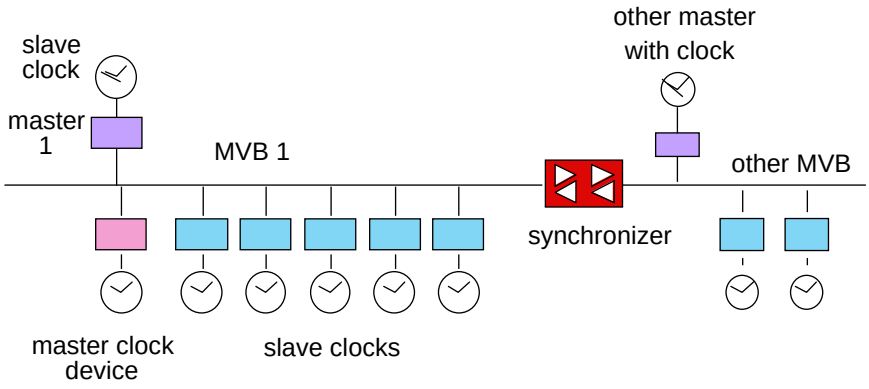



## MVB Time Distribution

At fixed intervals, the Master broadcasts the exact time as a periodic variable. When receiving this variable, the bus controllers generate a pulse which can resynchronize a slave clock or generate an interrupt request.



## MVB Slave Clock Synchronization




The clock does not need to be generated by the Master.

The clock can synchronize sampling within 100 µs across several bus segments.



## MVB Outline

# MVB Fault-tolerance Concept

**Transmission Integrity**

MVB rather stops than provides false data.
The probability for an undetected transmission error (residual error rate) is low enough to transmit most safety-critical data.

This is achieved through an extensive error detection scheme.

**Transmission Availability**

MVB continues operation is spite of any single device error. In particular, configurations without single point of failure are possible.

This is achieved through a complete duplication of the physical layer.

**Graceful Degradation**

The failure of a device affects only that device, but not devices which do not depend on its data (retro-action free).

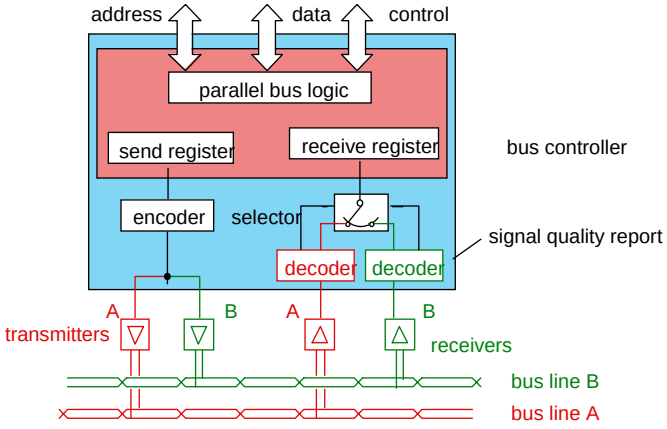
**Configurability**

Complete replication of the physical layer is not mandatory.
When requirements are slackened, single-thread connections may be used and mixed with dual-thread ones.



# MVB Basic Medium Redundancy

The bus is duplicated for availability (not for integrity)

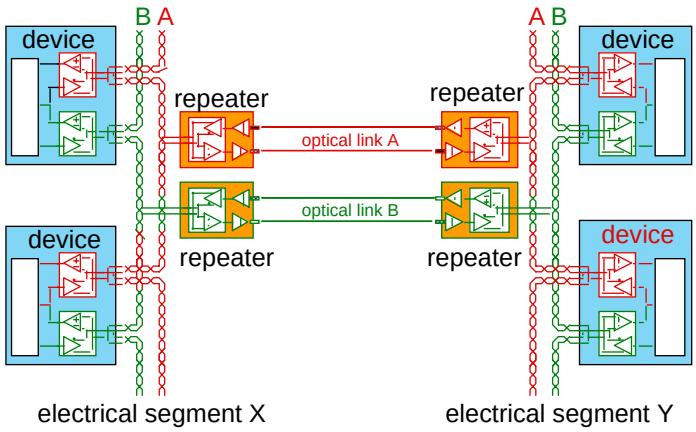



A frame is transmitted over both channels simultaneously.
The receiver receives from one channel and monitors the other.
Switchover is controlled by signal quality and frame overlap.
One frame may go lost during switchover

## MVB Medium Redundancy

The physical medium may be fully duplicated to increase availability.

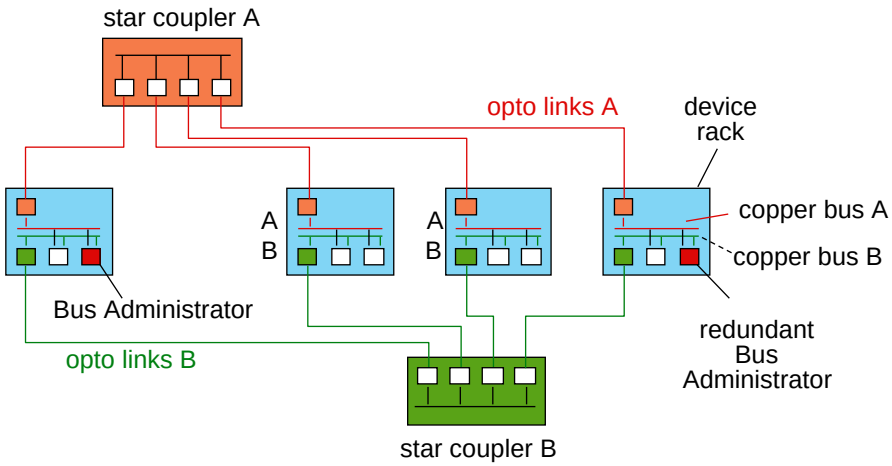
Principle: send on both, receive on one, supervise the other




Duplicated and non-duplicated segments may be connected



## MVB Double-Line Fibre Layout



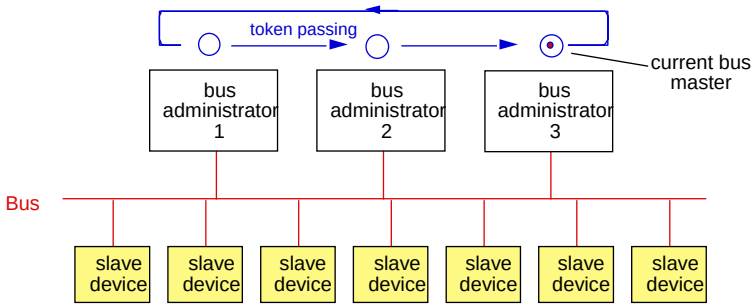

The failure of one device cannot prevent other devices from communicating.
Optical Fibres do not retro-act.

## MVB Master Redundancy

A centralized bus master is a single point of failure.

To increase availability, the task of the bus master may be assumed by one of several *Bus Administrators*

The current master is selected by token passing:




If a bus administrator detects no activity, it enters an arbitration procedure. If it wins, it takes over the master's role and creates a token.

To check the good function of all administrators, the current master offers mastership to the next administrator in the list every 4 seconds.



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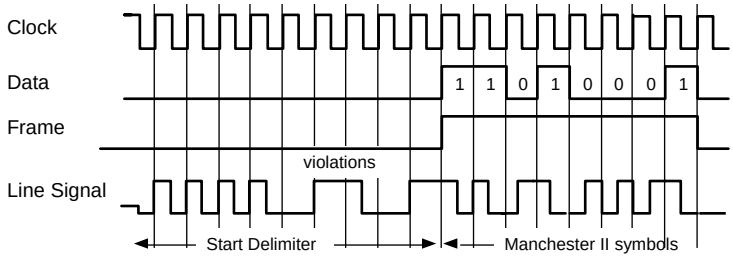
# MVB Transmission Integrity (1)

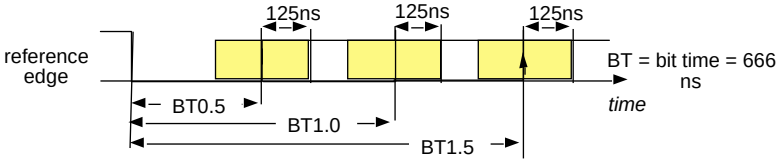
1) Manchester II encoding

Double signal inversion necessary to cause an undetected error, memoryless code




2) Signal quality supervision

Adding to the high signal-to-noise ratio of the transmission, signal quality supervision rejects suspect frames.






# MVB Transmission Integrity (2)

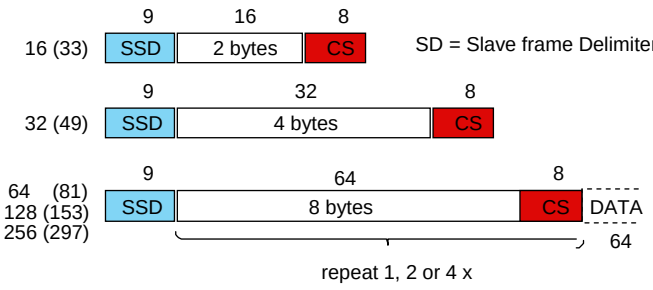
3) A check octet according to TC57 class FT2 for each group of up to 64 bits, provides a Hamming Distance of 4 (8 if Manchester coding is considered):

(Residual Error Rate $< 10^{-15}$ under standard disturbances)

**Master Frame**

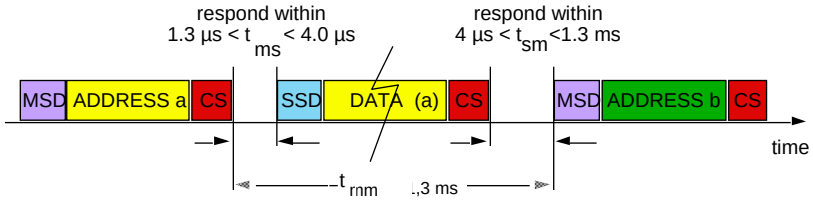

*useful (total) size in bits*

**Slave Frame**

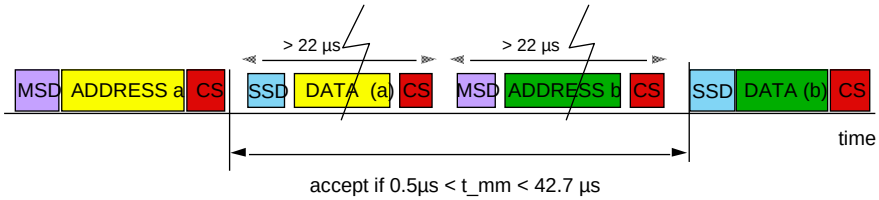


# MVB Transmission Integrity (3)

4) Different delimiters for address and data against single frame loss:




5) Response time supervision against double frame loss:




6) Configuration check: size at source and sink ports must be same as frame size.



# MVB Safety Concept

**Data Integrity**

Very high data integrity, but nevertheless insufficient for safety applications (signalling)
Increasing the Hamming Distance further is of no use since data falsification becomes more likely in a device than on the bus.

**Data Transfer**

- critical data transmitted periodically to garantee timely delivery.
- obsolete data are discarded by sink time supervision.
- error in the poll scan list do not affect safety.

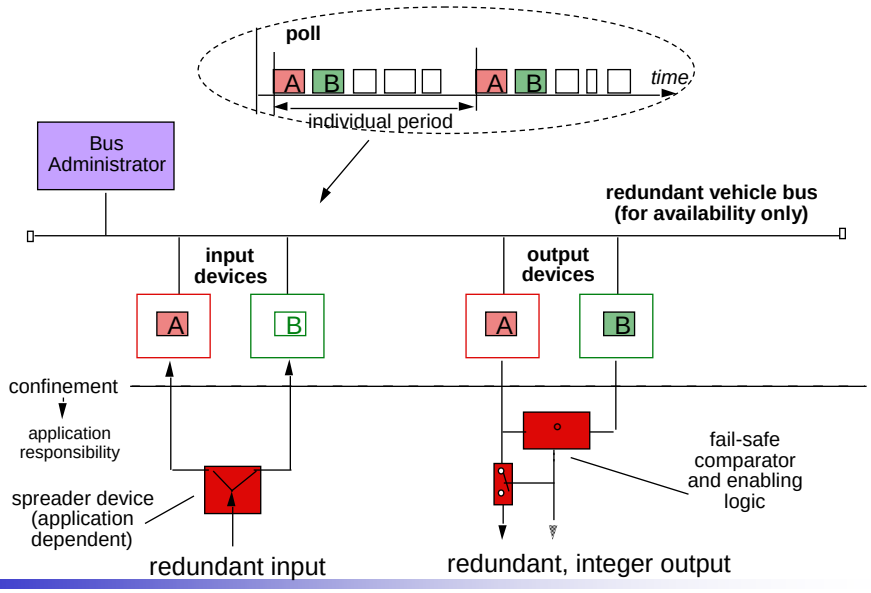
**Device Redundancy**

Redundant plant inputs A and B transmitted by two independent devices.
Diverse A and B data received by two independent devices and compared.
The output is disabled if A and B do not agree within a specified time.

**Availability**

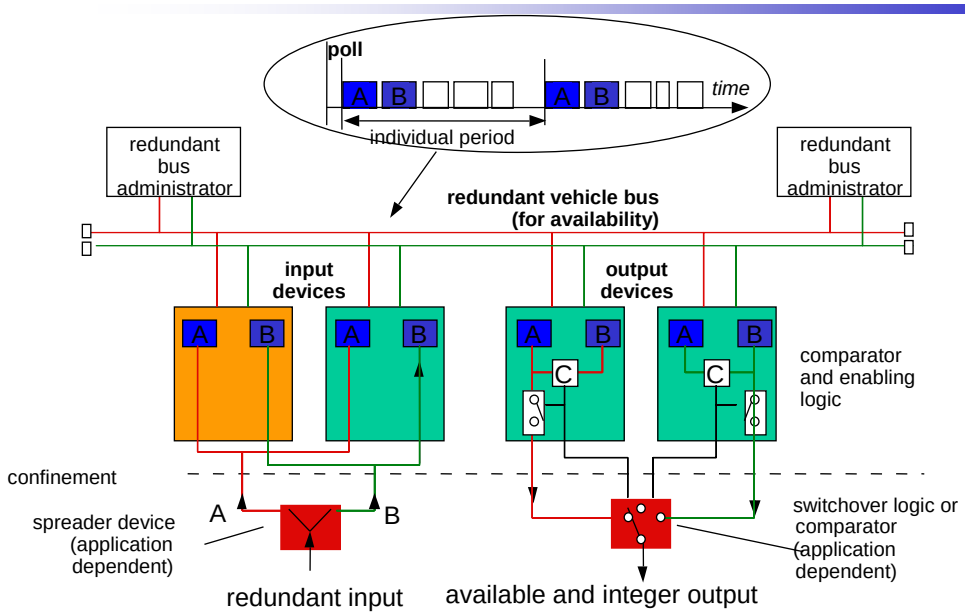
Availability is increased by letting the receiving devices receive both A and B. The application is responsible to process the results and switchover to the healthy device in case of discrepancy.

## MVB Integer Set-up






## MVB Integer and Available Set-up



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## MVB Summary

| | |
|---|---|
| Topography: | bus (copper), active star (optical fibre) |
| Medium: | copper: twisted wire pair<br>optical: fibres and active star coupler |
| Covered distance: | OGF: 2000 m, total 4096 devices<br>EMD: 200 m copper with transformer-coupling<br>ESD: 20 m copper (RS485) |
| Communication chip | dedicated IC available |
| Processor participation | none (class 1), class 2 uses minor processor capacity |
| Interface area on board | 20 cm2 (class 1), 50 cm2 (class 2) |
| Additional logic | RAM, EPROM , drivers. |
| Medium redundancy: | fully duplicated for availability |
| Signalling: | Manchester II + delimiters |
| Gross data rate | 1,5 Mb/s |
| Response Time | typical 10 µs (<43 µs) |
| Address space | 4096 physical devices, 4096 logical ports per bus |
| Frame size (useful data) | 16, 32, 64, 128, 256 bits |
| Integrity | CRC8 per 64 bits, HD = 8, protected against sync slip |

## MVB Components

Bus Controllers:

- BAP 15 (Texas Instruments, obsolete)
- MVBC01 (VLSI, in production, includes master logic
- MVBC02 (E2S, in production, includes transformer coupling)

Repeaters:

- REGA (in production)
- MVBD (in production, includes transformer coupling)

Medium Attachment Unit:

- OGF: fully operational and field tested (8 years experience)
- ESD: fully operational and field tested (with DC/DC/opto galvanic separation)
- EMD: lab tested, first vehicles equipped

Stack:

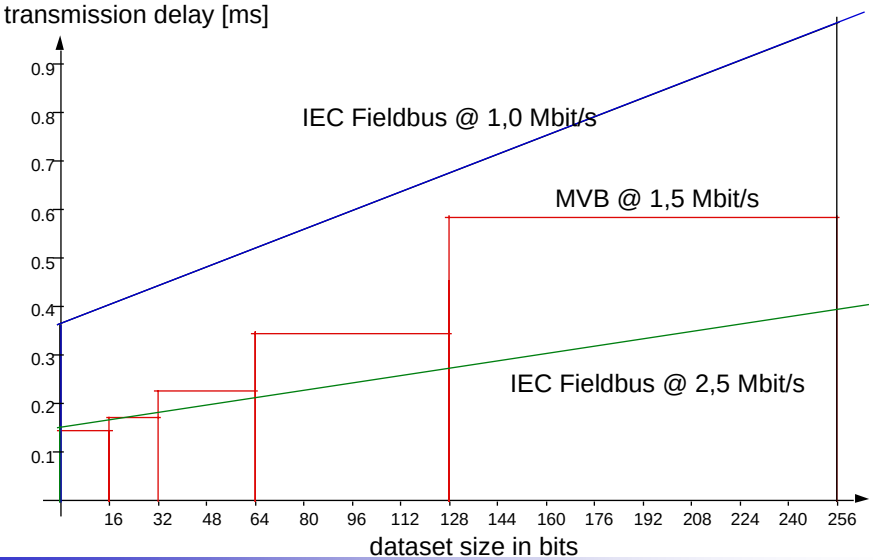
- Link Layer stack for Intel 186, i196, i960, 166, 167, Motorola 68332, under DOS, Windows, VRTX,...

Tools:

- Bus Administrator configurator
- Bus Monitor, Download, Upload, remote settings

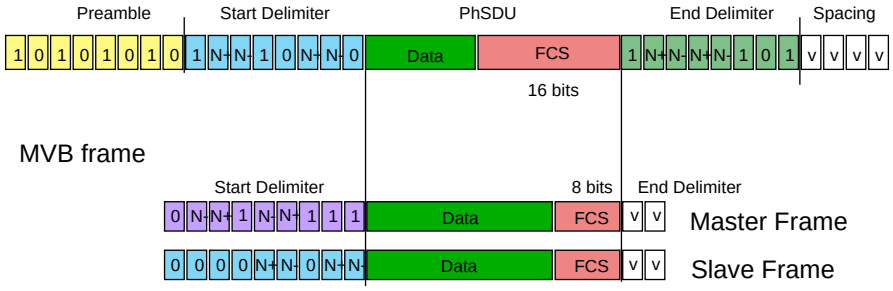


## MVB Throughput (raw data)



# MVB & IEC 61158-2 Frames

IEC 61158-2 frame




IEC65 frames have a lesser efficiency (-48%) then MVB frames

To compensate it, a higher speed (2,5 Mbit/s) would be needed.