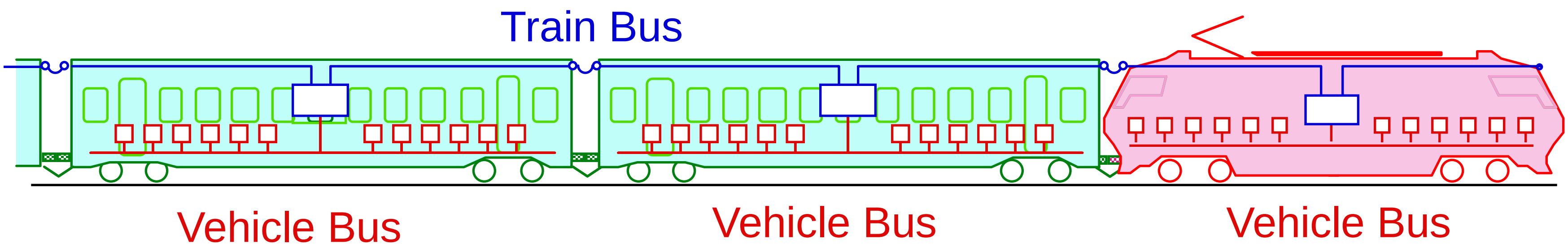
The IEC Train Communication Network
IEC 61375
Introduction



- History
- Choices
- Train Bus
- Vehicle Bus
- Architecture
- Real-Time Protocols
- Standardization in IEC
- Product development and installed base

International Electrotechnical Commission

IEC (International Electrotechnical Commission)
TC9 (Electrical Traction Equipment)
in collaboration with UIC (Union Internationale des Chemins de Fer)
set up WG22 (Working Group 22), to define a
Train Communication Network

railways operators:

Chinese Railways
DB (Germany)
FS (Italy)
JRRI (Japan)
NS (Netherlands)
RATP (France)
SNCF (France)
PKN (Poland)

grouped in the UIC
(Union Internationale
des Chemins de Fer)

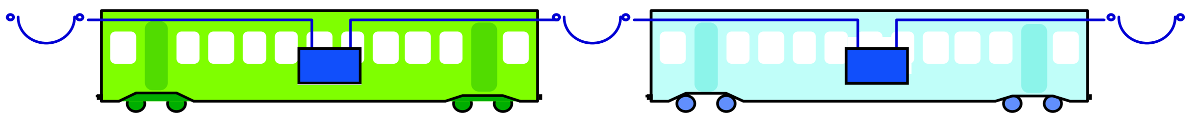
manufacturers:

Adtranz (CH, DE, SE)
ANSALDO (IT)
CAF (E)
Ercole Marelli Trazione/Firema
GEC-Alsthom (F, GB, B)
Mitsubishi (JP)
Siemens (GB, DE)
Toshiba (JP)
Westinghouse Signals (GB)

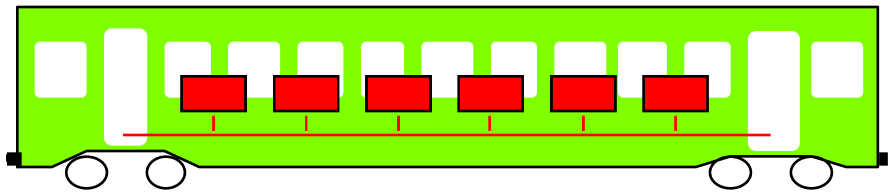
Working Group 22 task

TC9 created WG22 in 1988 to define interfaces between programmable equipments, with the aim of achieving plug-compatibility:

1) between vehicles



2) between equipment aboard a vehicle:



Working Group 22 Method of Work

Establish the user's requirements (especially UIC)

Study existing solutions (Profibus, LON, FIP, MIL 1553, CAN, ...)

Build on railways proven solutions supported by railways manufacturers

Implement before standardize

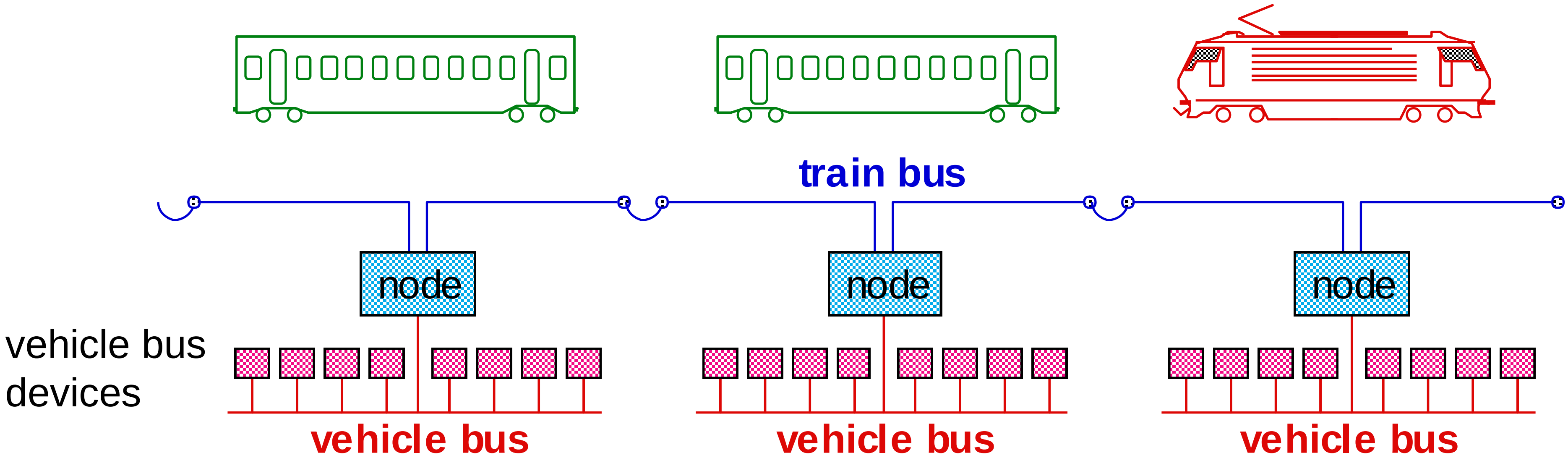
Solve intellectual property issues

Ensure fair access to the technology

Test on full scale

Define a Conformance test

Two-level Architecture



The Train Communication Network consists of:

- a Train Bus which connects the vehicles (Interface 1) and of
- a Vehicle Bus which connects the equipments within a vehicle (Interface 2).

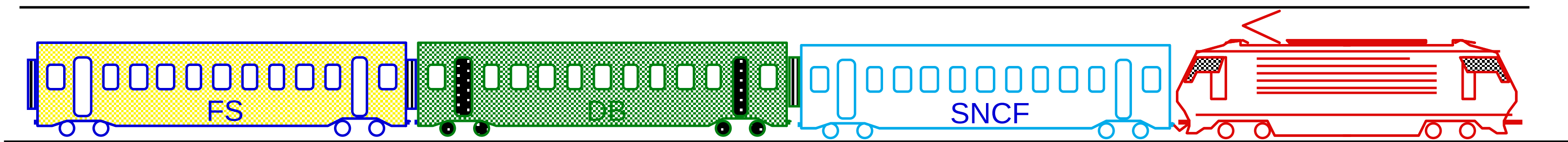
Vehicle and train bus are interconnected by a node acting as gateway

Type of Trains

WG22 distinguishes two main kinds of trains:

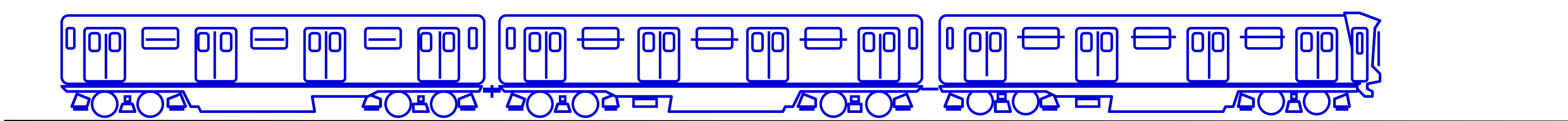
Open Trains Example: international passenger trains.

composed of vehicles frequently coupled and uncoupled in operation
train bus is automatically reconfigured during revenue service



Closed Train Sets Example: TGV, ICE, Metro, Suburban trains.

composed of vehicles not separable in operation.
train bus is configured off-line by driver or in the works



Technical Requirements (1989..today)

Topology	Two-level hierarchy: Train bus connecting Vehicle Busses.
Span	• Train bus: 850 m (1000m) , 32 nodes. • Vehicle bus: 200 m, 32 stations, 256 simple devices.
Medium	Twisted wire pair or optical fiber (no coax). A version of the train bus shall use the existing UIC or EP lines.
Operation	Train bus: automatic configuration of the train bus in less than 1 second, with left-right identification.
Traffic	• time-critical, short process data (traction control, train control,...) transmited periodically with a deterministic delay of <100 ms from end to end of the train bus, resp. <50 ms on the vehicle bus. • less time-critical messages (diagnostic, passenger information,...) transmitted on demand with reliable flow control and error recovery from end to end.
Reliability	Comply with railways environment, especially IEC 571. Redundant configuration possible to increase availability.

TCN Bus Candidates for Train and Vehicle Bus

Bus	Positive	Negative
IEC/ISA SP50	emerging international field bus standard	not commercially available - still in hot debate, complex higher layers.
FIP	field bus, deterministic, integer, supported by EdF, ENEL	national standard, uncertain future, few implementations, costly chips.
Profibus	process bus, cheap coupling, integer, large support in Germany	national standard, uncertain future. Slow, few stations, complex higher layers.
MIL 1553	railways and aerospace experience	costly (transformers, chips, tools). Insufficient integrity (parity).
ARINC 625	aerospace experience	costly (transformers, chips, tools).
Bitbus	simple, widespread	slow, dependency on Intel. Manufacturer not willing to open the software.
BRELNET, ITDC, **EKENET**	railways experience	manufacturer does not desire to open it.
Factor	(deterministic Ethernet) railways experience	chips discontinued, not open.
Tornad*	relies on standards	costly stations, manufacturer not willing to open the physical level, no support
CAN, A-BUS	simple, cheap, vehicle experience	slow, weak, non-deterministic.
LON	good concept of higher layers, tools, hierarchical architecture.	slow, non-deterministic, unsafe.

Use of Commercial Networks

Theory:

Use of commercially widely available components and software reduce development costs and guarantee long-term availability

Reality:

There are not many railways-graded network components on the market.

Commercial components must be customized to the application.

Large volume sellers have little concern for the small railways market

Companies in the computer business are less stable than railways firms.

Life-time is 5 years for commercial components, 15 years for industrial products, but 30 years for railways - what about the last 15 years ?

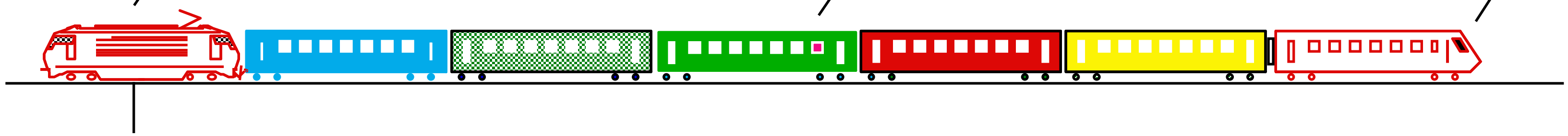
Therefore:

WG22 decided to select only busses which have been railways-proven and which are supported by in-house manufacturing capability.

Evaluation Results

- Evaluated busses: BRELNET, CD450, DIN 43322, Profibus, Modiac, IEC Field bus, Tornad, Tornad*, FIP, Factor, Arlic, Ekenet, Bitbus, CAN, ARINC 1553, MICAS, ITDC, ISA SP50.
- Only FIP, ARINC 1553, MIL 1553 and MICAS have fast, deterministic response (1 ms)
- Most busses failed because of insufficient integrity or lack of redundancy.
- Only LON supported a two-level hierarchy (network layer), but lacked real-time response.
- Only MICAS met the technical requirements and was already in use in railways. Its modified version was renamed MVB.
- The WTB is a modification of DIN 43322, taking over the CD450 experience.
- The communication software was designed especially for the TCN, to support a large number of small and simple stations.

Train Bus Traffic



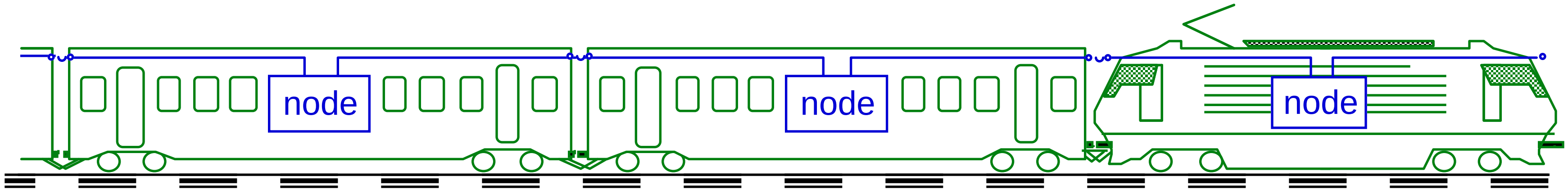
Vehicles of different types communicate over the train bus for the purpose of:

1)	telecontrol	traction control:	remote, multiple traction,...
		vehicle control:	lights, doors, heating, tilting, ...
2)	diagnostics	equipment failures, maintenance information	
3)	passenger comfort	next station, disturbances, connections. seat reservation	

NOT included: passenger private communications, video.

Wire Train Bus (WTB)

standard communication interface between vehicles



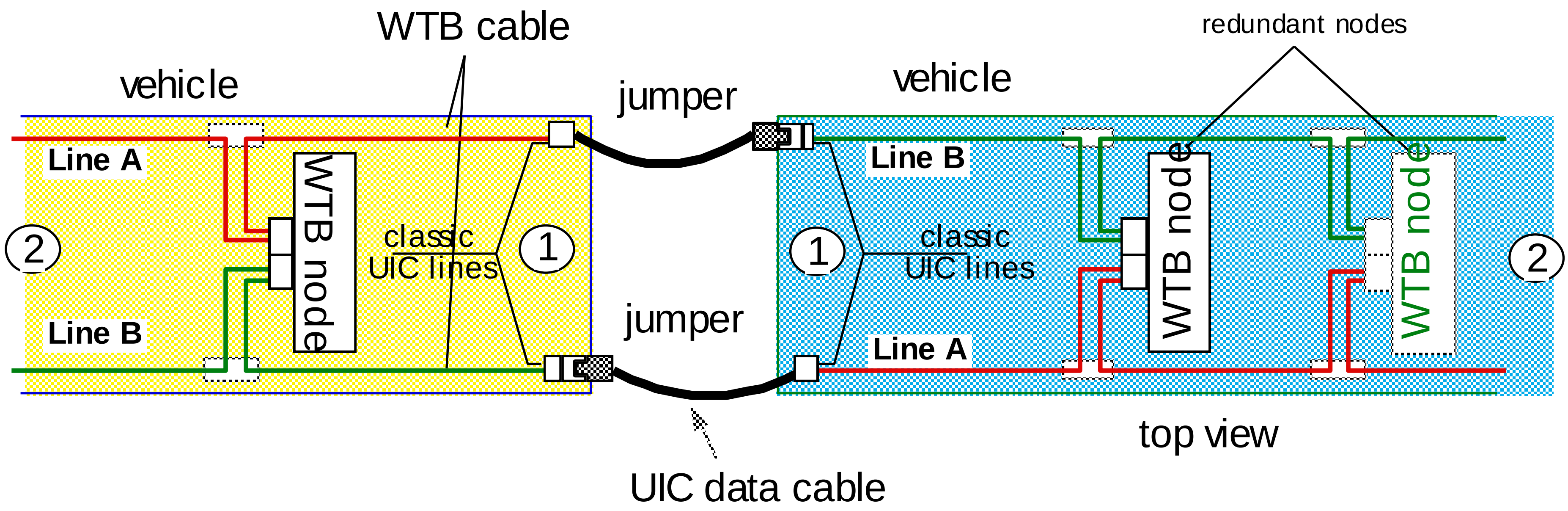
main application	open trains with variable composition such as UIC trains
covered distance	860 m
number of nodes	32
data rate	1'000'000 bit/second over shielded, twisted wires
response time	25 ms
inauguration	assigns to each node its sequential address and orientation
experience	based on DB-bus, FS-ETR450 and SBB Huckepack
status	fully tested on ERRI train, vehicles in operation

WTB Wiring

Uses jumper cables or automatic couplers between vehicles.

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

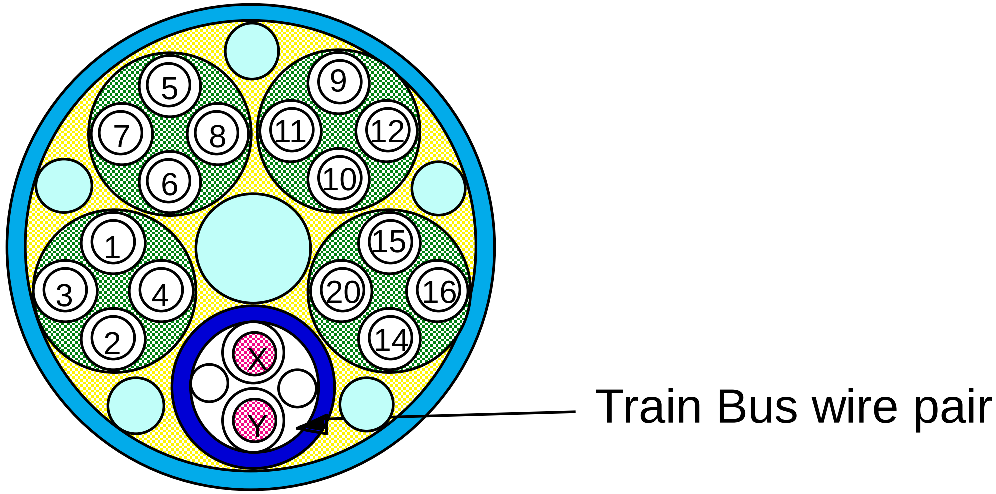
Since there are normally two jumpers, the wiring is basically redundant:



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

WTB - New UIC Cable

The UIC discarded the previous idea of decommissioning existing UIC lines and agreed to introduce an additional shielded wire pair for the Train Bus:



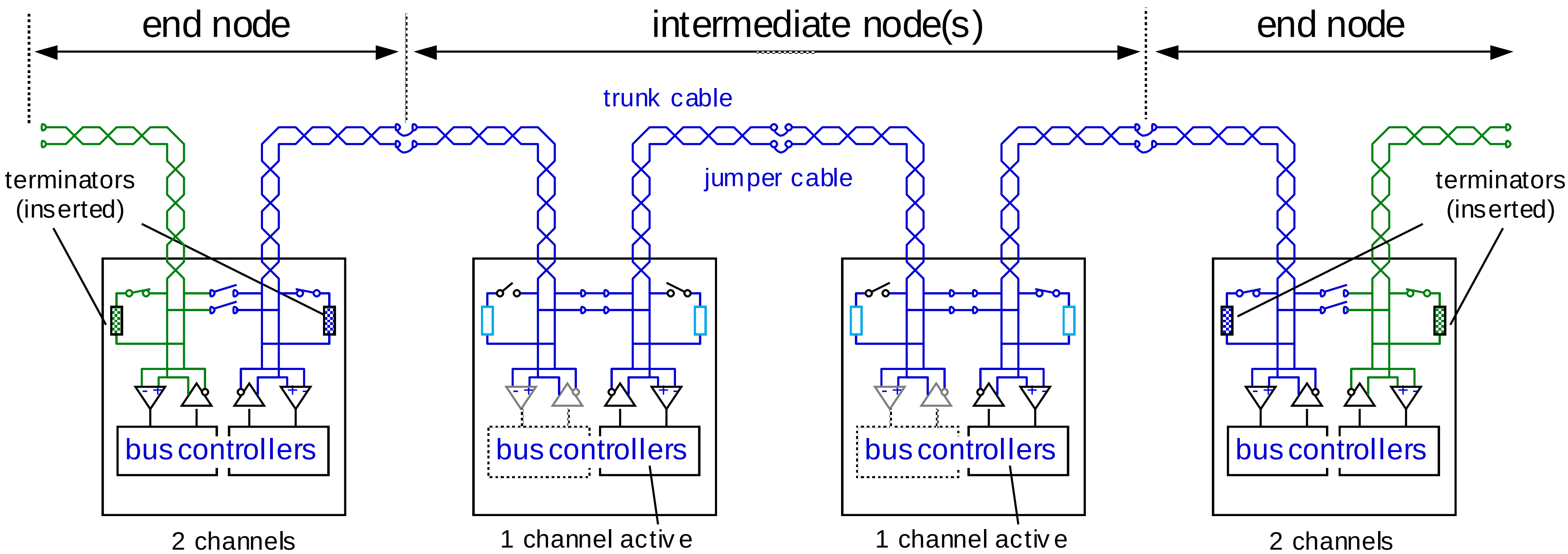
according to UIC 558 leaflet

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 both media for transmitting data, with no clear superiority.

WTB Nodes Setup and Inauguration



Autonumbering of nodes and election of the master within 1,0 s.

All nodes know their position in the bus and distinguish right from left.

All nodes are informed of the characteristics of all other nodes before regular operation.

In case of master failure, any other node takes over.

WTB: The Vehicle Interface

WG22 specified the Wire Train Bus as the standard interface for plug-compatibility between equipment located on different vehicles.

WTB is intended primarily for open trains (trains with variable composition), such as UIC international trains.

WTB considers the requirements of operators, of manufacturers and of the UIC 5R Pilot Group, expressed in leaflet UIC556.

Process Data exchanged over WTB are specified in UIC leaflet 556, to permit vehicles of different origin to communicate without ambiguity.

Diagnostics messages exchanged over WTB are defined in UIC leaflet 557.

WTB Data Definition - UIC 556 leaflet

octet	bit	
4	1-4	lock/unlock ep brake
0	5-8	lock/unlock right doors

octet	bit	
1	1-4	lock/unlock left doors
	5-8	lock/unlock right doors
2	1-2	all left doors locked
	3-4	all right doors locked
	5-6	extend staircase
	7-8	unused (11)
3	1-2	connect loudspeaker to UIC pair 5-6
	3-4	connect loudspeaker to UIC pair 7-8
	5-6	connect microphone to UIC pair 1-2
	7-8	connect microphone to UIC pair 3-4
4	1-2	connect microphone to UIC pair 3-4
	3-4	connect external right loudspeakers to UIC pair 7-8
	5-6	connect external left loudspeakers to UIC pair 7-8
	7-8	connect to called vehicle
5	1-2	connect to calling vehicle
	3-6	brake not applied
	7-8	emergency brake signal
6	1-2	last vehicle present
	3-4	tail signal present
	5-8	void (11)

UIC leaflet 556 defines the semantics of the exchanged variables

What makes WTB so special ?

WTB was designed specially for variable consist (UIC) trains.

WTB has unique features in industry:

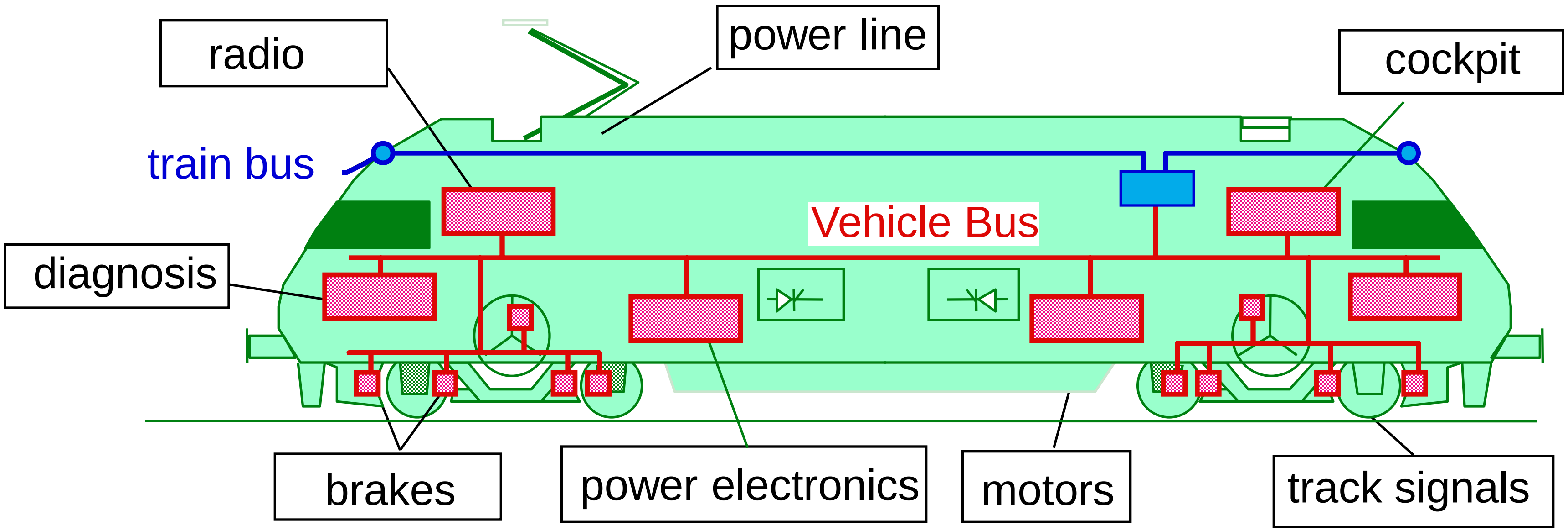
- autonumbering of nodes (inauguration) and self-configuration
- failure recovery over two independent lines
- fritting to overcome oxidation of contacts
- long transmission distance without repeater (860 m) over bad quality cables (jumpers, connectors, discontinuities)
- operation without previous commissioning
- close following of UIC 556/ UIC557 leaflets

The WTB features cost some overhead:

- two hardware channels and fritting voltage sources
- special digital signal processor for Manchester decoding
- unique link layer for inauguration

Multifunction Vehicle Bus (MVB)

standard communication interface for all kind of on-board equipment



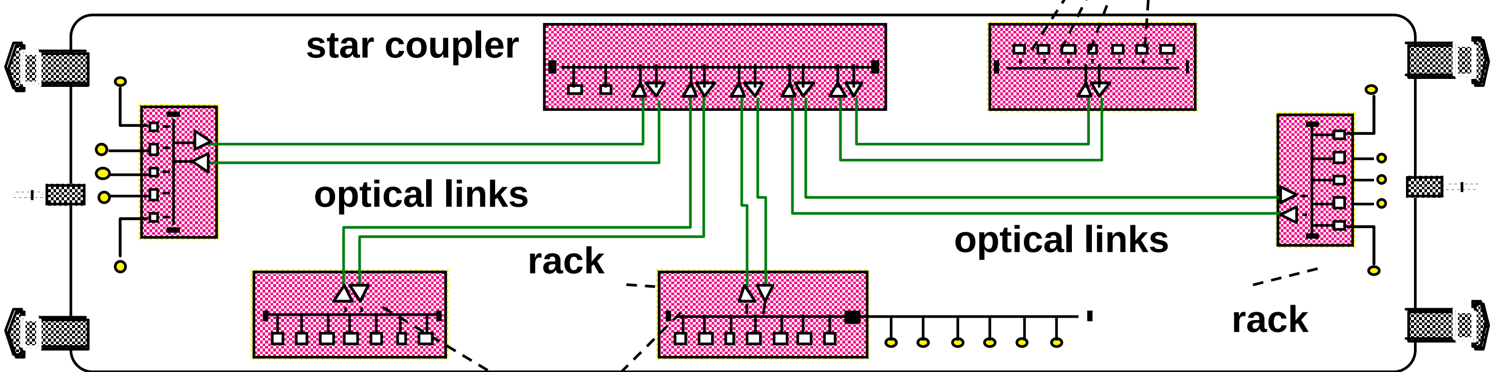
data rate	1'500'000 bits/second
delay	0,001 second
medium	twisted wire pair, optical fibres
number of stations	up to 255 programmable stations up to 4096 simple sensors/actuators
status	> 600 vehicles in service

MVB Physical Media

- OGF optical fibers (2000 m)
- EMD shielded, twisted wires with transformer coupling (200 m)
- ESD backplane bus or twisted wires according to RS485 (20 m)

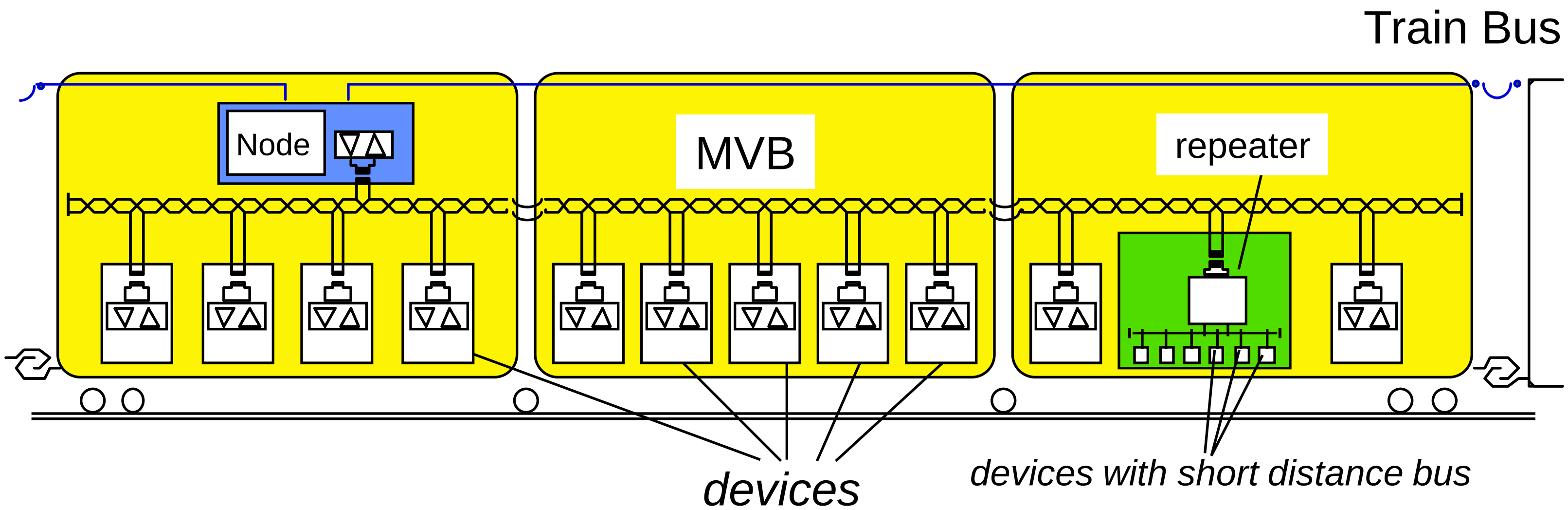
Media are directly connected by repeaters (signal regenerators)

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



MVB In Closed Train Sets

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



The number of devices under this configuration amounts to 4095.

The MVB can serve as a train bus in trains with fixed configuration, up to a distance of 200 m (EMD medium) or 2000 m (OGF medium).

MVB: The Equipment Interface

WG22 specified the Multifunction Vehicle Bus as the standard interface to provide plug-compatibility between equipment on board the same vehicle.

The data traffic on the MVB is being defined in WG22's Application Subgroup.

Each type of equipment is accessed in a standard way, to read its characteristics, set-up its parameters and download it with new programs.

The MVB paves the way to interchangeability of equipment and simplified maintenance procedures.

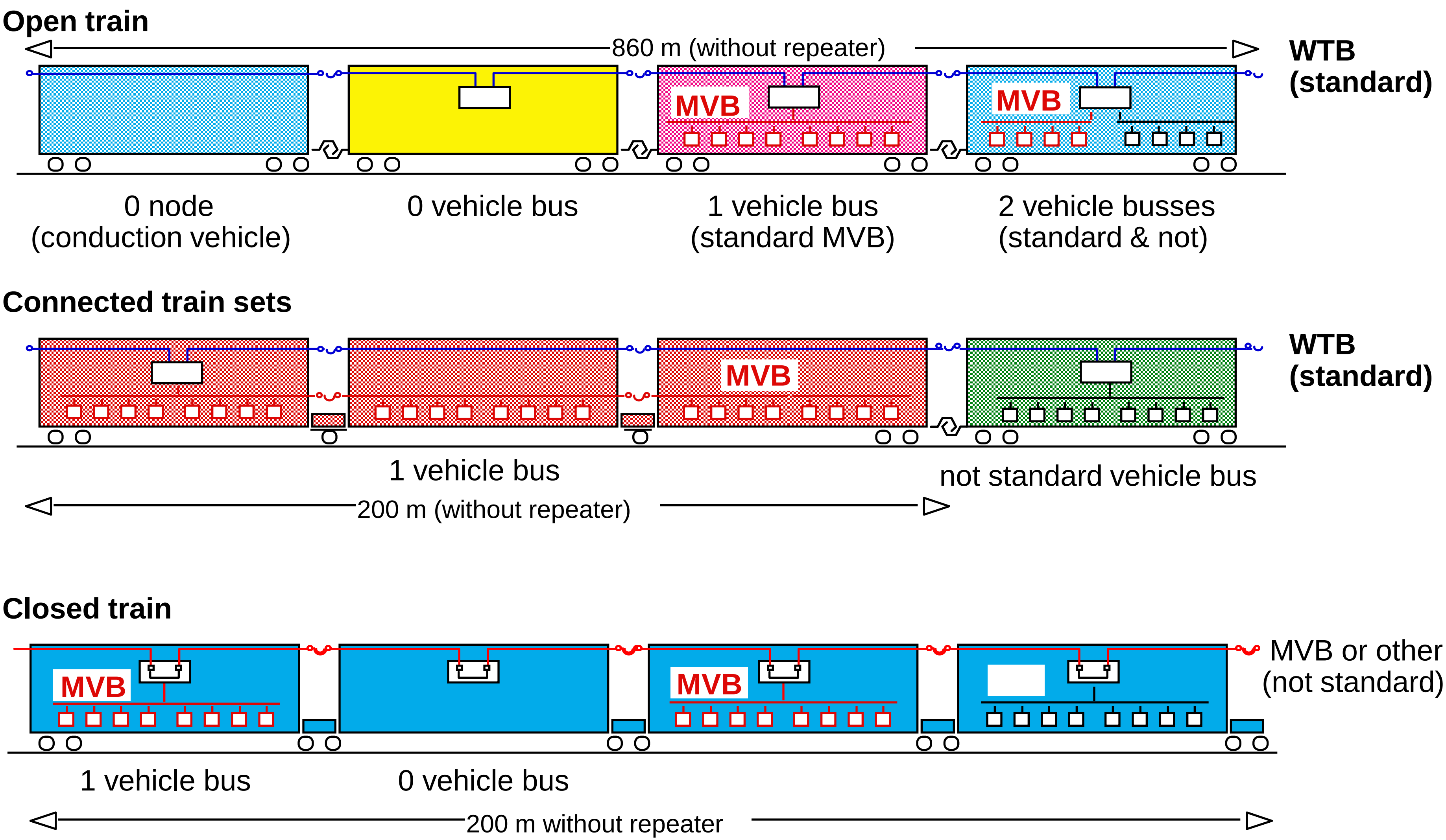
The MVB is important for:

- small equipment manufacturers (reduce network diversity)
- assemblers (wider choice of suppliers, commissioning)
- railways operators (reduce maintenance costs and spare parts)

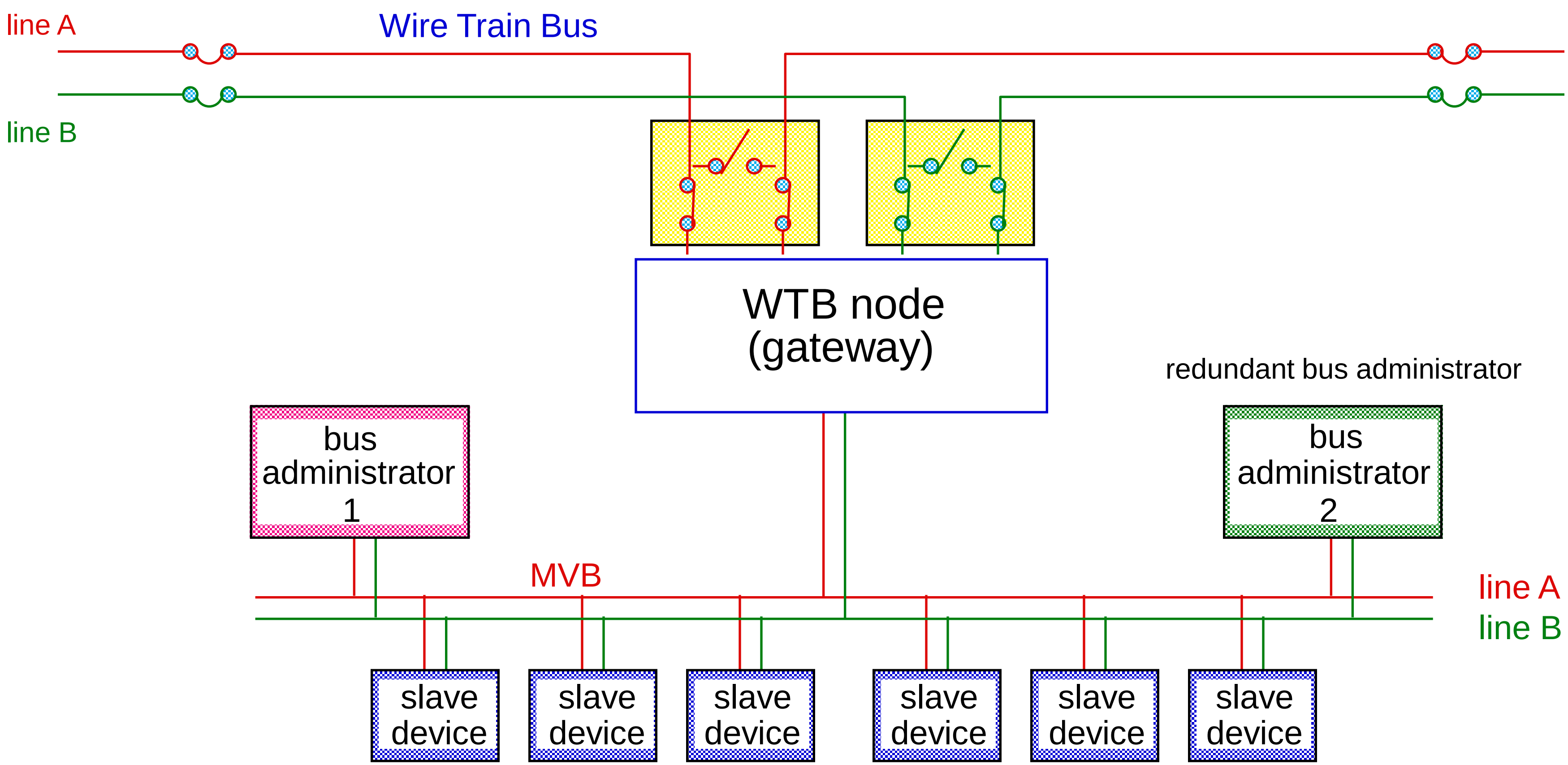
Differences WTB - MVB

Characteristics	WTB: Train Bus	MVB: Vehicle Bus
Topography	open bus, 860m	terminated bus, 300m (2000m)
Configuration	connectable on the track	fixed, pre-configured in works
Symmetry	right/left, front/rear recognition	no orientation
Addressing	relative to master	absolute (physical or logical)
Configuration	at each composition change	at installation time
Number of stations	32, one (two) per vehicle	256 in the same vehicle
Media	Shielded Twisted Pair (UIC cable)	240 um fibre & STP & RS-485
Connector	4 x sub-D	optical: ST; STP: 2 x sub-D
Redundancy	line always duplicated	line duplicated by default
Gross data rate	1.0 Mb/s	1.5 Mb/s
Hamming Distance	4	4 (8 on optical fibre)
Medium Access	cyclic (n x 25 ms) and sporadic	cyclic (n x 1 ms) and sporadic
Mastership	master selected at startup, backups	rotating master, backups
Link Control	source-addressed broadcast	source-addressed broadcast
Device classes	Intelligent nodes	Intelligent and simple devices

TCN architectures



TCN Availability Concept

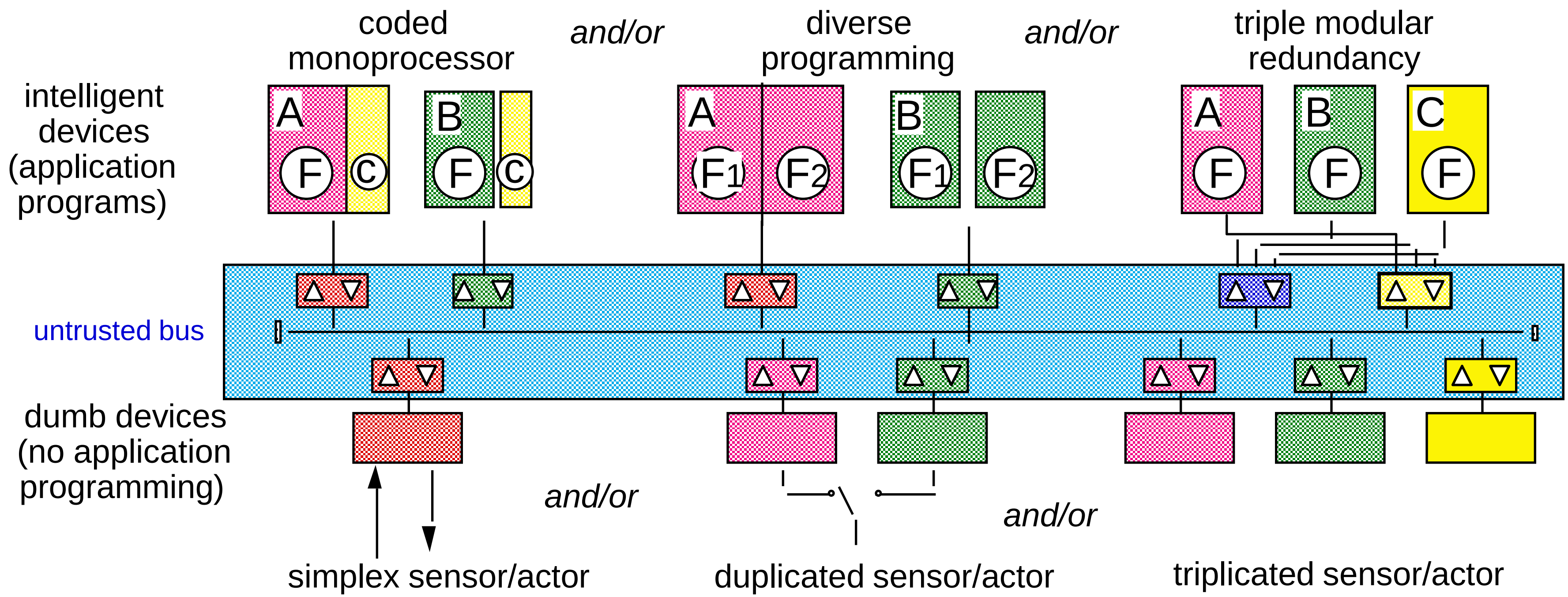


All media are by default redundant (send on both, receive from one, check other)

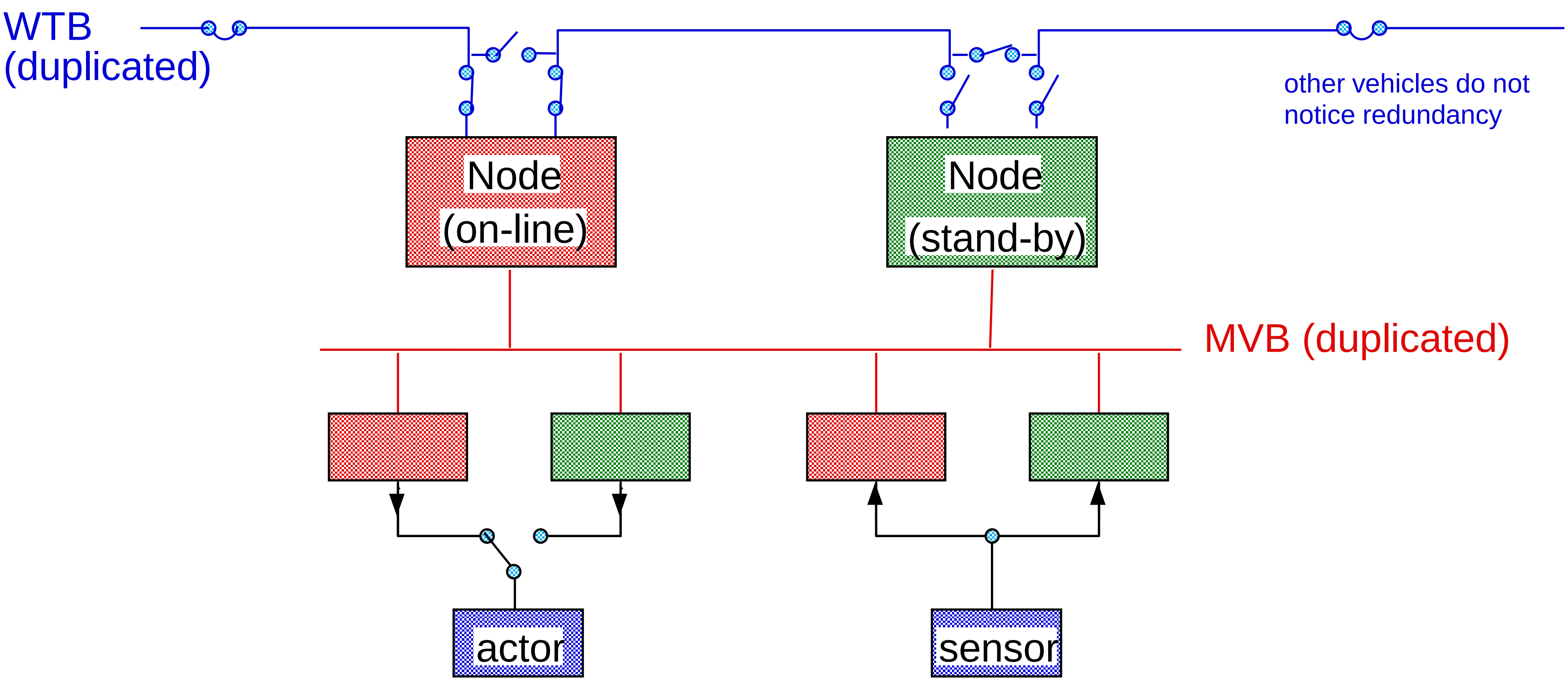
On MVB, bus mastership is assumed by alternating bus administrators
On WTB, any node can assume mastership upon a failure

TCN Integrity Concept

- MVB complies with IEC 570-5 integrity class FT2 (10^{-15} with er = 10^{-6})
- WTB has an enhanced HDLC encoding allowing a HD of 4 against sync slips
- several mechanisms check data plausibility (configuration, timeliness, indefinite)
- undetected errors in devices are more likely than on the bus
- for this reason, safety protocols developed for 2/3, 1/2 or coded processors, provide time-stamping, authentication and value check over cyclic services.



TCN Fault-Tolerance Concept



TCN allows substitution of MVB devices

Messages are re-routed to the on-line unit at switchover time.

Stand-by WTB nodes takes over through a new inauguration

TCN Bus Traffic

Variables

short and urgent data items carrying the trains's state

... motor current, axle speed, operator's commands,...

Variables are refreshed periodically, no retransmission protocol is needed in case of transmission error.

Periodic Transmission
as Process Data

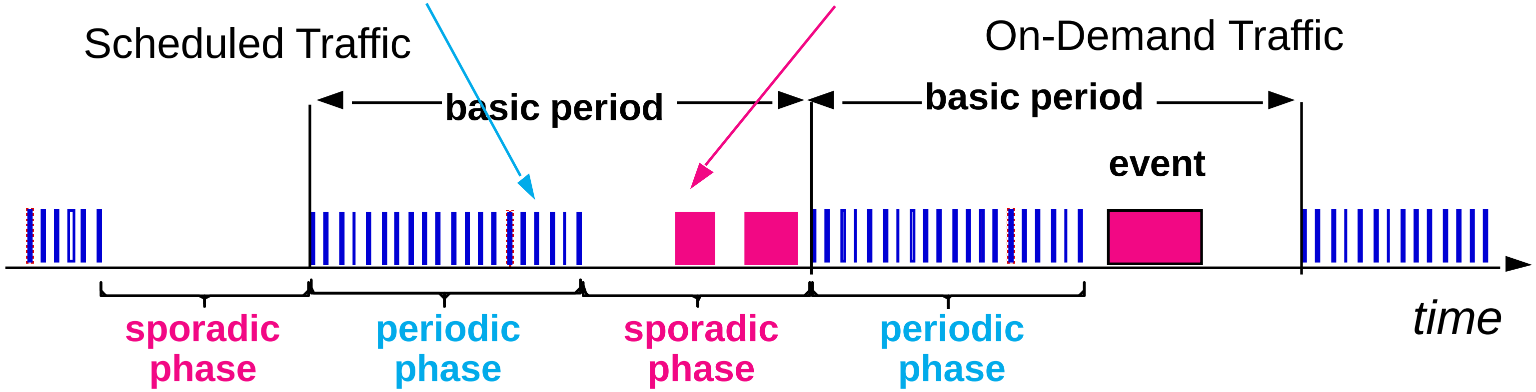
Messages

infrequent, sometimes lengthy messages reporting events, for:

- Users: diagnostics, status
- System: initialisation, down-loading, ...

Messages represent state changes which may not get lost : a protocol recovers transmission errors.

Sporadic Transmission
as Message Data

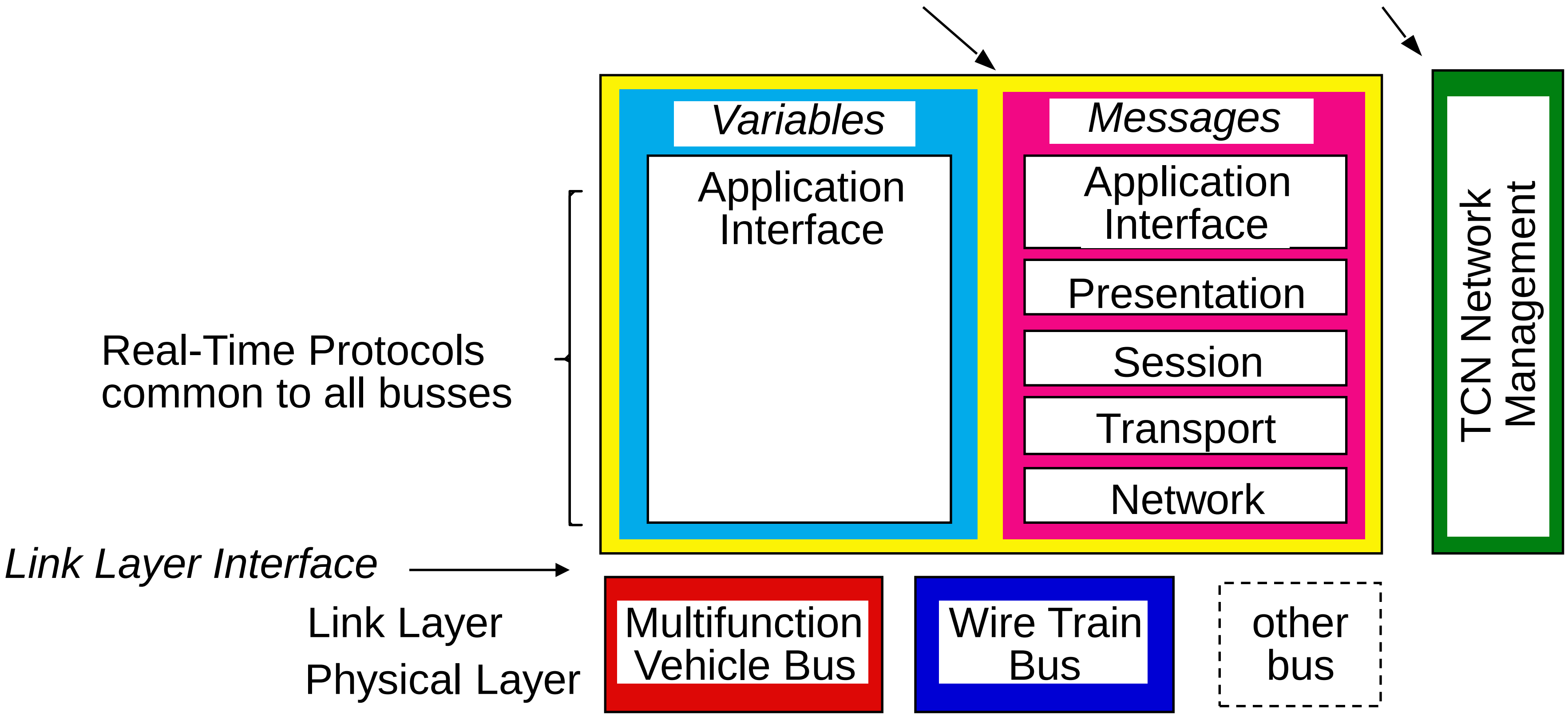


Real-Time Protocols stack

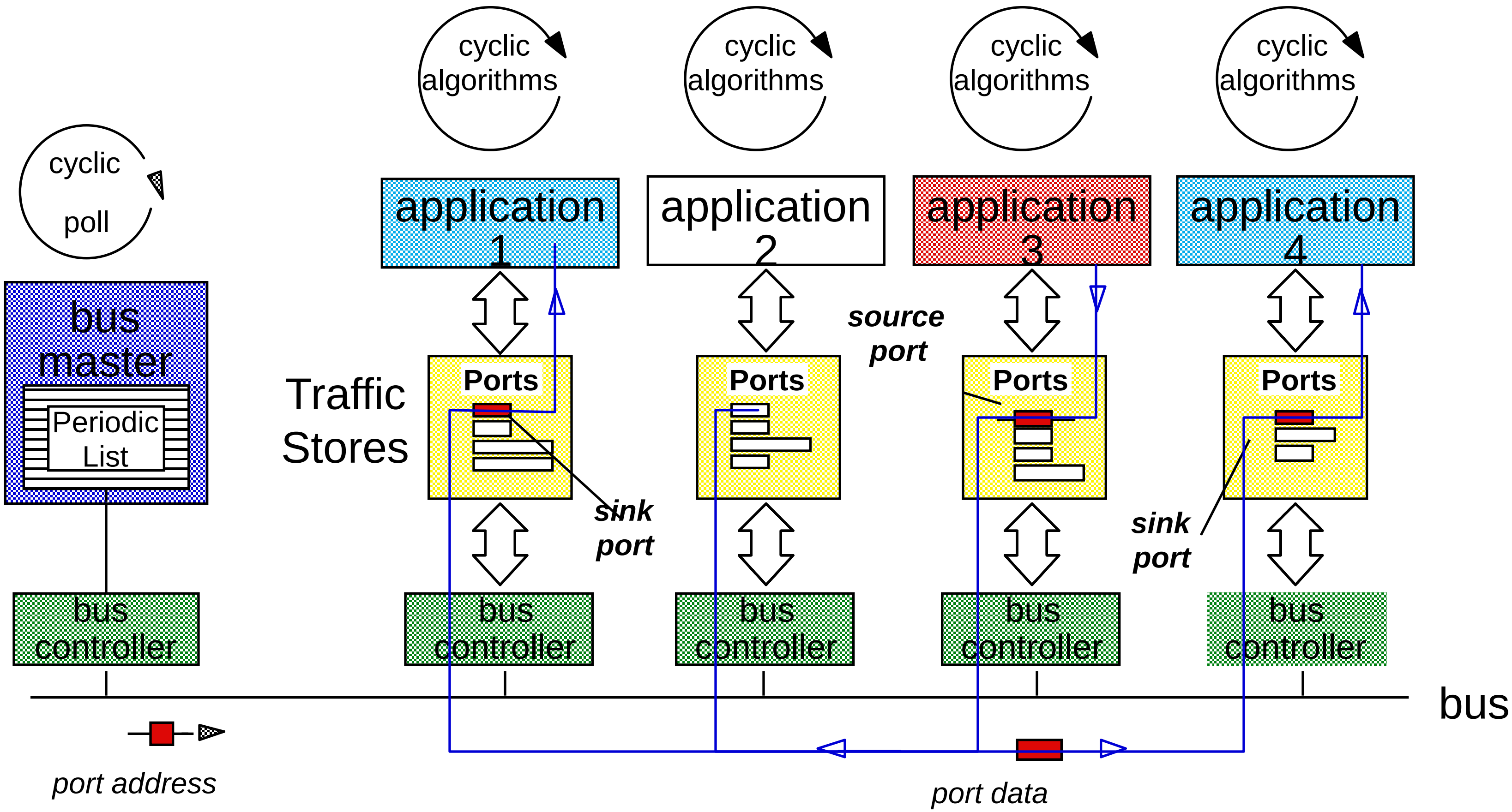
All busses of the TCN obey to the same operation principles.

The Train Communication Network follows the OSI model.

All busses share common Real-Time Protocols and Network Management.



Process Data Exchange: Determinism and Real-Time



Determinism is a concept stretching from application to application.

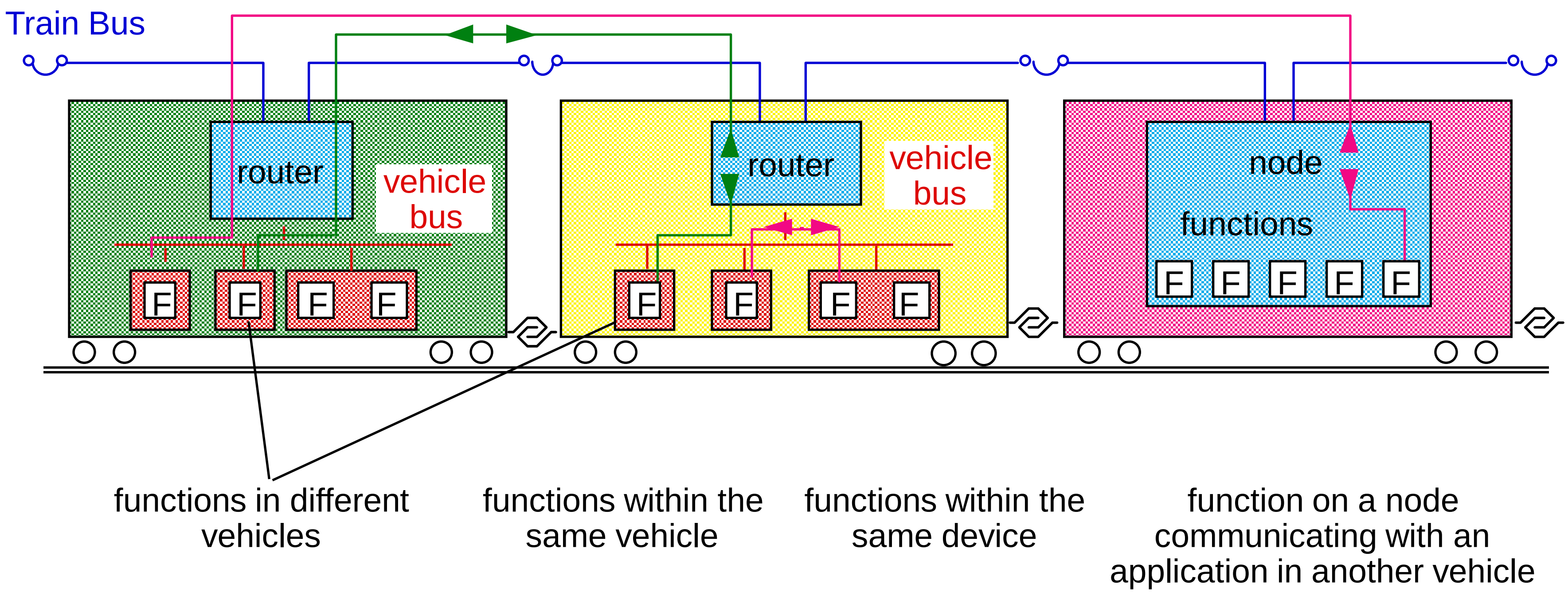
TCN provides a deterministic transmission by cyclic, source-addressed broadcast

Applications are supposed to operate cyclically to be deterministic.

TCN supplies a freshness information to detect stale data

Message Exchange and Application Interface

Functions communicate the same when located in the same or different vehicles



A defined application interface ensures that applications can be written independently from the communication system

Message Data: Demand-driven traffic

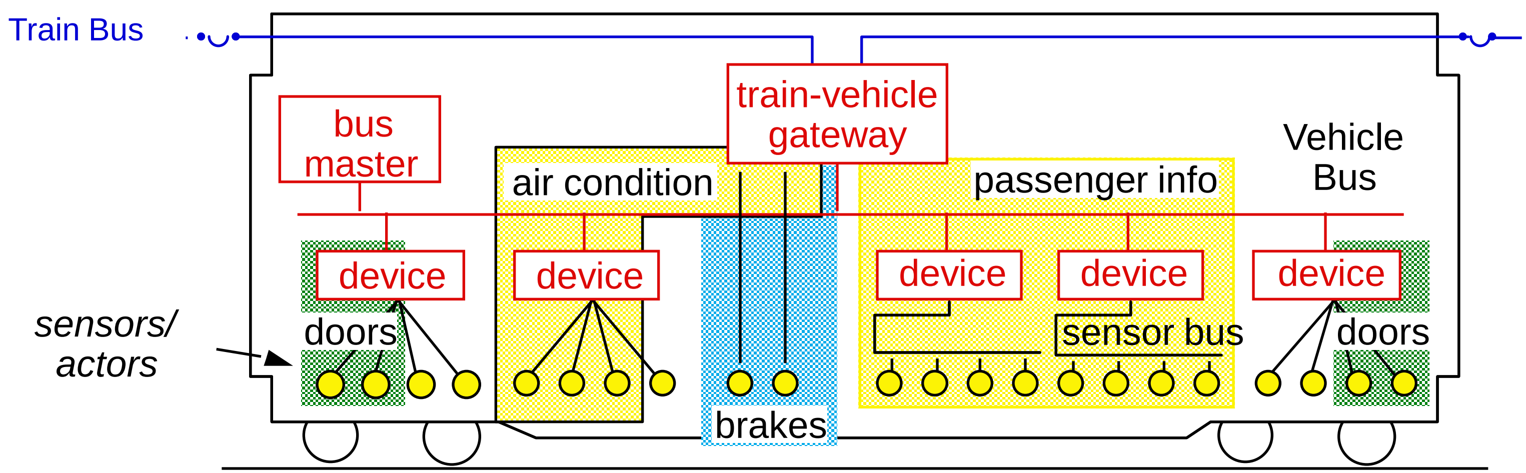
The entities exchanging messages are called Application Functions.

Each vehicle supports a number of standardized Application Functions.

The train bus accesses a vehicle without knowing its internal structure.

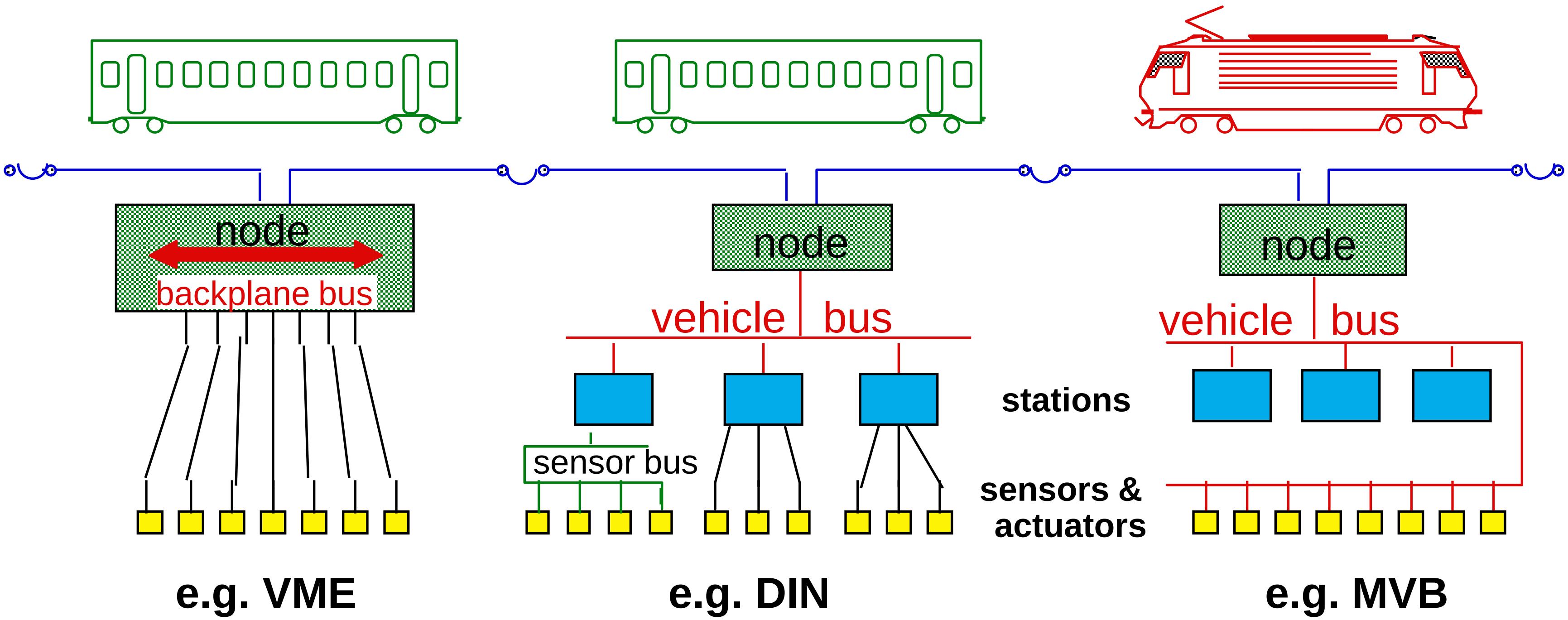
The Application accesses *functions* rather than *devices*.

Functions are implemented by one or several vehicle bus devices, or by a node.



The gateway deduces the device from the function and routes messages.

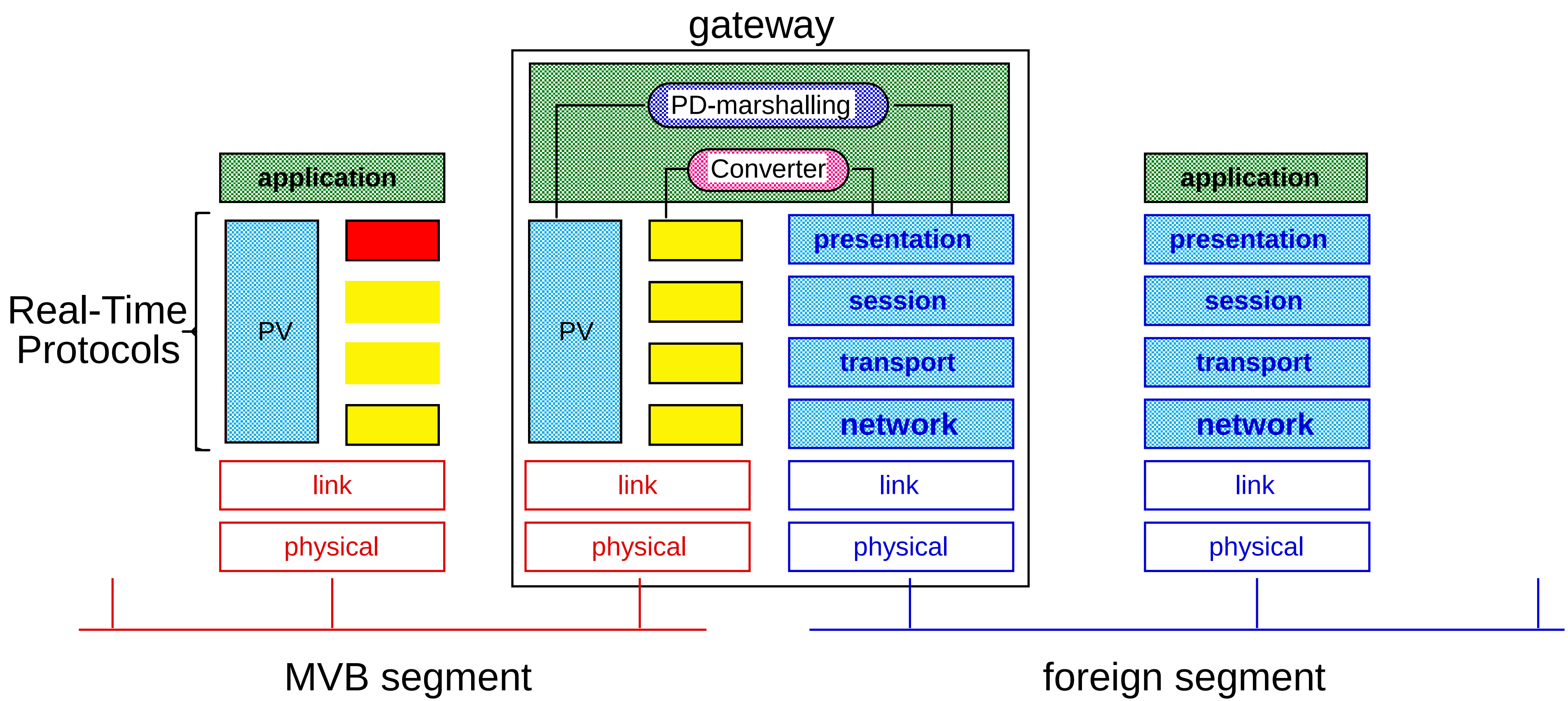
Supporting Different Vehicle Structures



Condition: all devices use the TCN's Real-Time Protocols

But: where interoperability is needed, only one type of bus shall be used

Gateways: including foreign devices

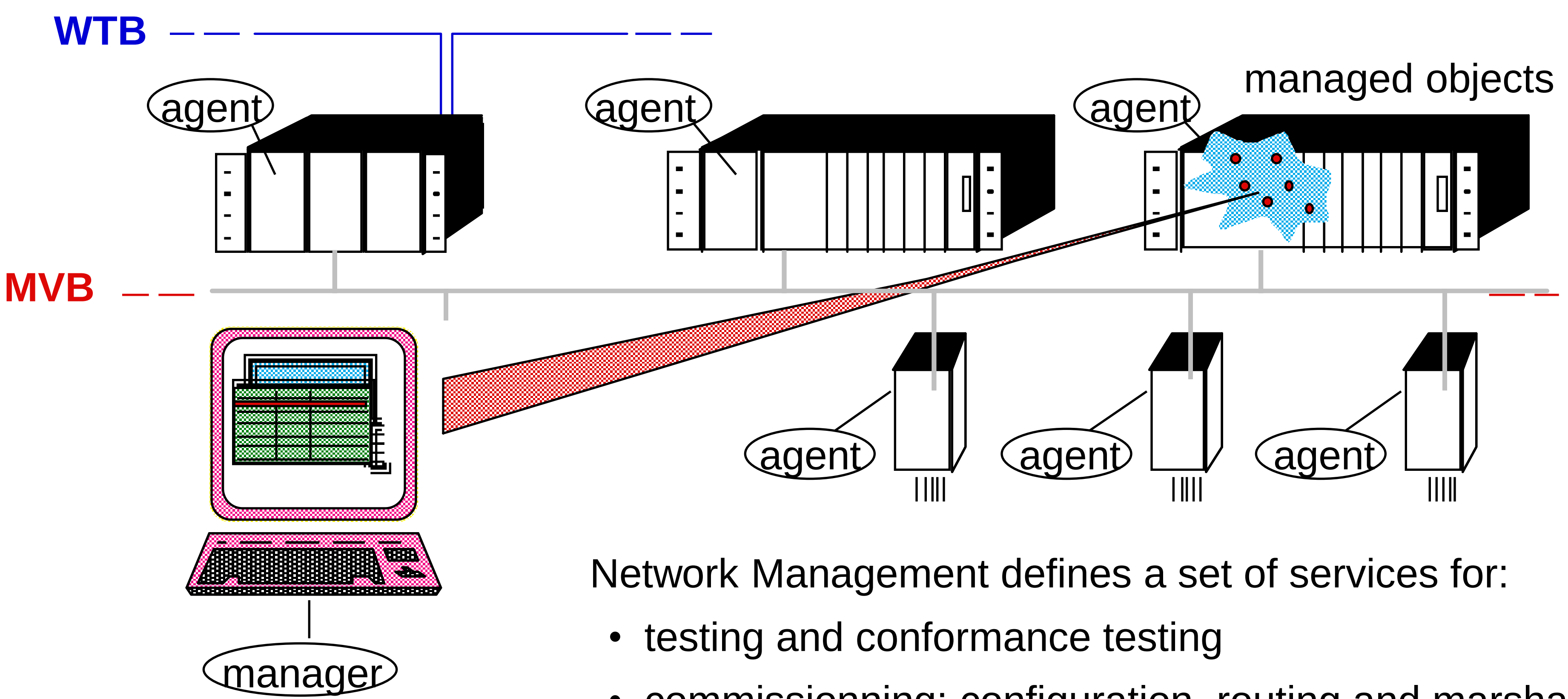


The protocol conversion requires a common object address space

The important is a common data representation and semantics

Therefore, a standard object description is needed.

TCN Network Management



Network Management defines a set of services for:

- testing and conformance testing
- commissionning: configuration, routing and marshalling
- operation: error and performance monitoring
- maintenance: evaluation of error reports

Conformance Test

Theory:

the TCN is specified in such detail that implementations by different teams, with only the standard documents as a base, are compatible.

Reality:

Whatever the level of detail, there will be ambiguities and incompatibilities between implementations.

Therefore:

The first implementation of the TCN has been done jointly by teams of several firms, to ensure that the core specifications are usable.

A user group should act as a forum to provide feedback to the standard.

Only one software written in a general language (C) should be used as a reference (also for the standard document).

This software must be made available to all parties under fair conditions.

Conformance testing will be needed when different implementations arise.

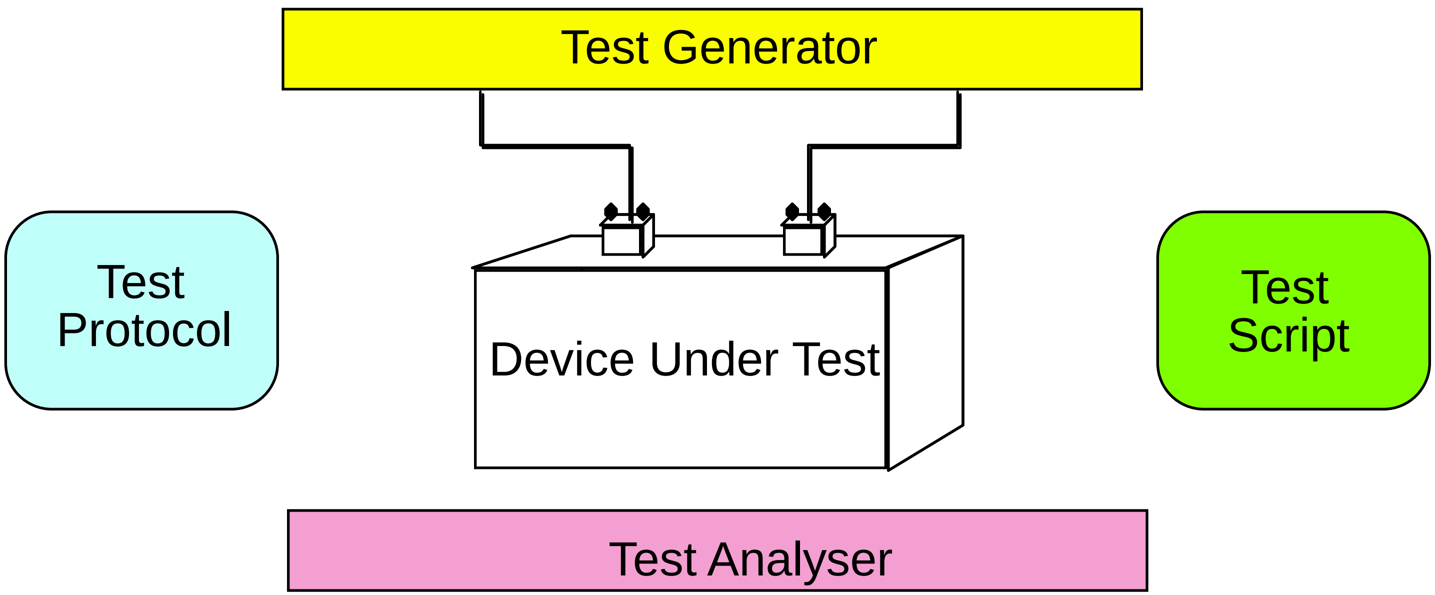
There is currently no incentive to have different implementations.

TCN Conformance Test

The guidelines for Conformance Test, developed at the request of TC9 in Frankfurt, allow to test a device's conformity with the TCN.

These tests have been successfully applied to the ERRI test train.

Conformance Testing gives a manufacturer the confidence that his product can interoperate with products of other manufacturers



IEC Status

The Train Communication Network became an International Standard in 1999.

The document was published in September 1999, consisting of the following parts:

1 General
2 Real-Time Protocols
3 Multifunction Vehicle Bus
4 Wire Train Bus
5 Network Management
Annex A: Tutorial
Annex B: Guidelines for Conformance Test

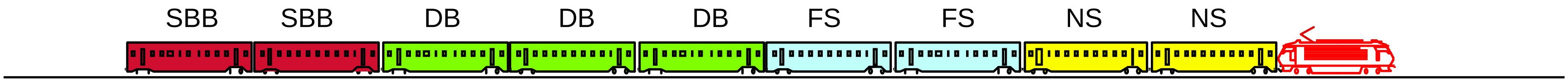
UIC and UITP strongly support TCN.

Meanwhile, several firms implement products based on the draft documents.

TCN is now the rule in international bidding.

UIC / ERRI test train

The European Railways Research Institute (ERRI) conducted a full-scale test of the TCN (at a cost of some 3 Mio US$).



A composition of the Interlaken-Amsterdam train, consisting of coaches of Germany, Switzerland, Italy and Netherlands served for the tests.

It entered revenue service in May 1994 and served until September 1995.

The result of these tests have been considered in the TCN documents

The ERRI lab test served as a validation and conformance testing tool.

Lessons learned from the ERRI Test Train

- operational problems were underestimated, the test had to be lengthened by 1/2 year.
- before installing the TCN, the electrical wiring must be harmonised (battery polarity, connector wiring, earthing, etc..)
- the WTB is more limited by reflections from cabling and connectors than by signal attenuation, decoding by a digital signal processor was a must.
- initially, recovery from individual node failures was neglected (domino-effect). Handling degraded mode situations make the bulk of the software.
- back-up mode (old UIC lines and WTB running in parallel) caused "mirror effect". The application, not the network, must care for this and other "tail-bitings".
- for trouble-shooting, means must be introduced to supervise the bus and bring it in a defined state (like assign mastership to various nodes in sequence)
- most of the difficult work was in the application programs (mapping server, etc...)

Joint Development Project

Five firms joined forces to develop the Train Communication Network

- †Siemens Verkehrssysteme (D),
- †Ercole Marelli Trazione - Firema (I),
- †AEG Schienenfahrzeuge (D),
- †ABB Henschel (D) and
- †ABB Verkehrssysteme (CH)

(AEG Schienenfahrzeuge, ABB Henschel and ABB Verkehrssysteme = ADtranz)

(all five) = Joint Development Project JDP

Development was shared among the companies.

Communication software was ported to different platforms (Intel, Motorola,..).

The operation of the train bus node has been demonstrated.

Custom Integrated Circuits are being developed by different companies.

The JDP prototype is used in the ERRI Train Bus Tests.

There are currently some 20 TCN products available from third parties.

TCN Components Available

1) MVB integrated circuits: available freely from silicon manufacturer

2) WTB nodes or Medium Attachment Unit (3 manufacturers)

3) MVB subprint with or without a processor (PBI, IP bus)

4) MVB attachment to PC-card (2 manufacturers)

5) MVB repeater (2 ASICs)

6) tools for configuration and monitoring

7) communication stack (Real-Time Protocols) and documentation.

language: "C" or ADA, ported to:

Intel 186 Intel 196 Intel 166 Intel 960 Motorola 68040 DOS/Windows

The commercial conditions can be negociated directly with any JDP company, since all are in possession of the rights.

JDP is considering general distribution and support by independent companies.

JDP field a commitment to IEC to supply all customers under fair conditions

TCN Tools

Adtranz: MicTools4.2

system configurator
application-level bus analyzer
programming environment in function block language
display and diagnostics editor

DUAGON: DT4

test system for data traffic
MVB API (Windows 95)
D104: same API for vehicle (PC104 board)

i.pro.m: CATAI

capture, design and simulation of the TCN
node emulation and software application interface development
network implementation using IPTCN network
network integration and commissioning
devices and network testing

TCN Openness

IEC required that all components necessary to implement the TCN be commercially available to all parties.

- There are no intellectual property rights on the TCN
- The product manufacturers were required to file a committment to make their technology available under reasonable conditions
- Even so, the documents were written so that a third party can implement a compatible TCN without insider knowledge
- The MVB integrated circuit was built out of the standard document only
- The software has been ported to several platforms

Stability

Theory:

Standards are stable and are not modified afterwards.

Reality:

Computer software is not stable.
ASICs technologies become obsolete.
Bugs and new requirements require corrections and modifications.
Every porting to a new platform causes changes.

Therefore:

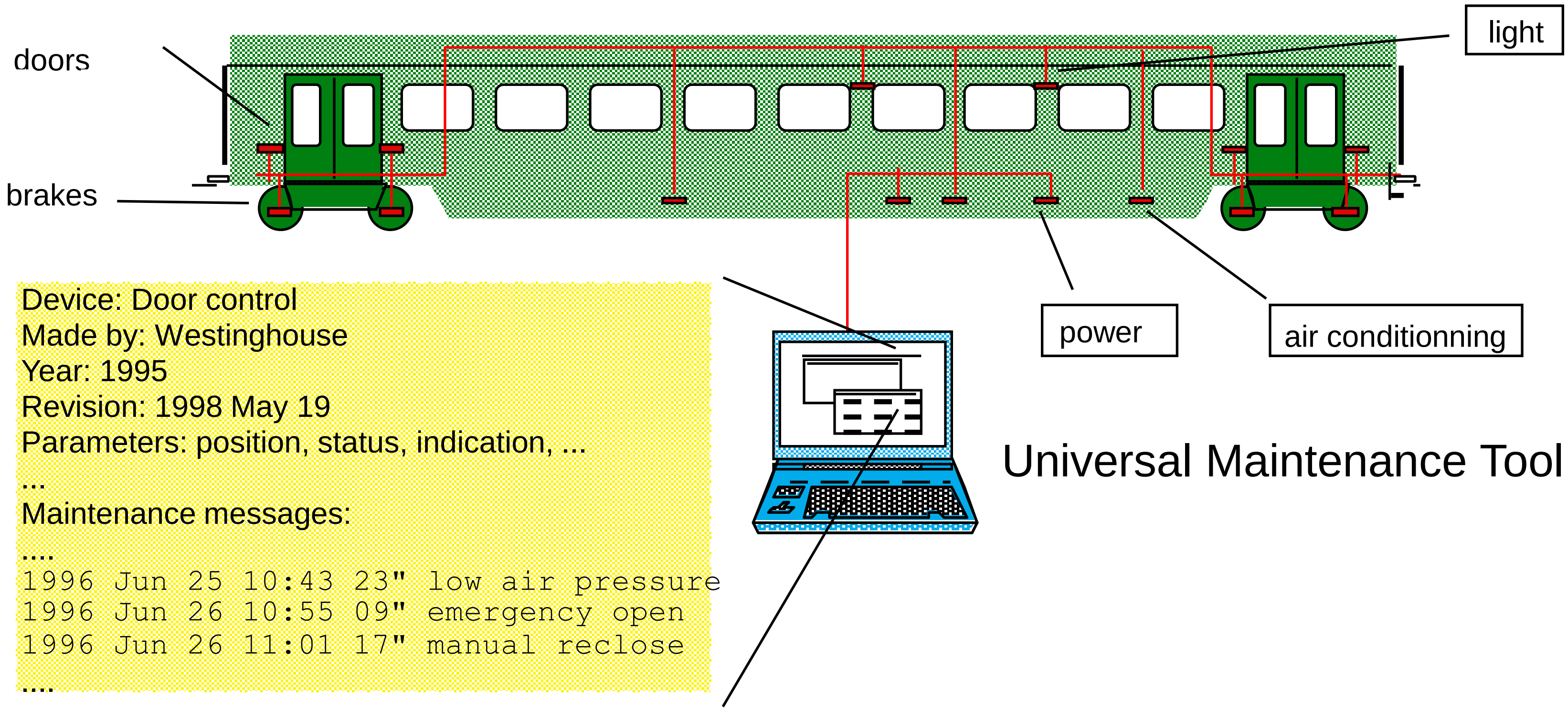
An entity must distribute and maintain the TCN over the years.

This entity must have an interest in the application and a commitment towards the railways industry and users.

Even if parts of the TCN make use of commercial components, maintenance must anyhow be done for the other components.

Only railways manufacturers can bring this stability

ROSIN - WP04 Application Subgroup



A 3 years project of the 4th European program finances the standardisation of the application interface among other TCN applications (total 5 Mio ECUs)

Goal: vehicle functions are standardized, but can be implemented in different way.

railways companies and manufacturers can access the on-board equipment over Internet

Vehicle Functions

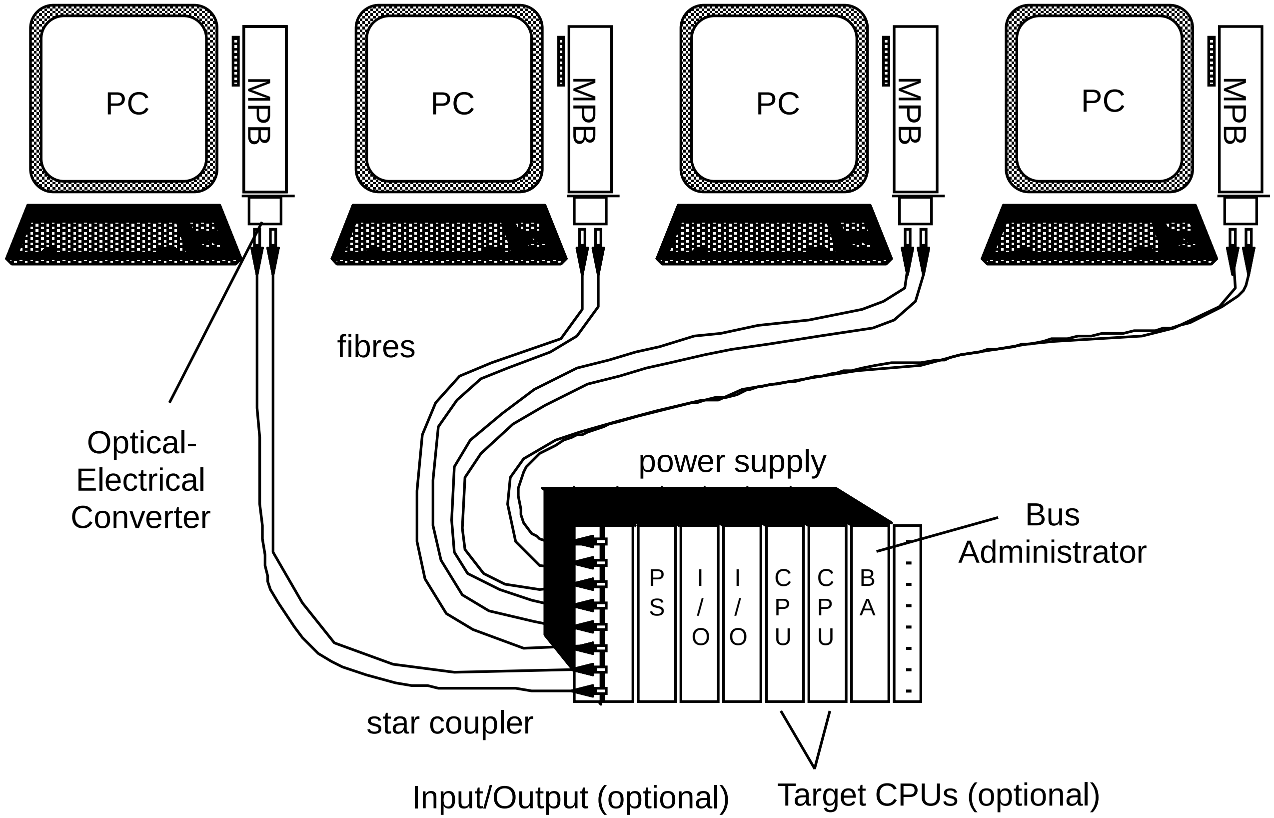
- doors
- traction
- braking & antiskid
- automatic train control
- signalling, localisation
- radio
- control & command
- driver display
- energy
  - electric (static converter)
  - pneumatic
  - hydraulic
- diagnostics
  - on-line
  - depot
- log
- fire
- de-icing
- tilting
- active suspension
- lights and other utilities
- air condition
- passenger information
  - audio,
  - entertainment
  - advertisement
- toilet
- seat reservation

- are identifiable equipment modules (such as doors, air-condition or a whole vehicle), made of electromechanical, hydraulic, pneumatic, ... parts;
- are implemented by one or several programmable devices, which implement one or several functions;
- may include simple sensors and actors, scattered over the train;
- may consist of subfunctions in a hierarchical fashion;
- may communicate with other functions.

Suppliers using TCN

Holec	Automation
Ansaldo	Automation
AEG	Automation
Knorr Electronic	Brakes
Westinghouse Brakes	Brakes
IFE	Doors
Deuta	MMI
Hagenuk	HVAC
Selectron Lyss	WC
Sécheron	Tachometer
Faiveley	Slip/Skid Control, Doors
duagon	TCN Products and Consulting
i.pro.m	TCN Products and Consulting

Consulting and Support



TCN Starterkits (PC based), training and consultancy are available from:

duagon (Switzerland) and
i.pro.m (Italy)

TCN Projects in Italy

Italian Railways Technical Headquarter in Florence fully support TCN and issued, after an experimental period, two specification documents to be used as technical part of contracts:

ST FS n° 308514: Nodo di Comunicazione tra Bus di Veicolo e Bus di Treno della rete TCN/TCN*
ST FS n° 308031: Telecomando per la trazione

FS is leading an ERRI group in charge to extend the UIC 556 leaflet to the locomotives.

Rolling stock	Manufacturer	Description
E402B FS	Ansaldo-Siemens	40 locomotives 6 MW (option: 50)
E412 FS	Adtranz Italy (formerly:Tecnomasio	20 locomotives 6 MW
E464 FS	Adtranz Italy (formerly:Tecnomasio	50 locomotives 3 MW (option 50+ 50+ 50+ 50+ 50)
TAF FS	Breda-Ansaldo-Firema (consortium)	50 trains (each train has 4 vehicles, 2 motor coaches and 2 coaches)
ETR500 FS	BREDA-Adtranz-Ansaldo-Firema	60 ETR500 Multitensione (double voltage 3000DC/15.000 AC)
Z1 FS	COSTAMASNAGA	35 international coaches

TCN Projects of Siemens

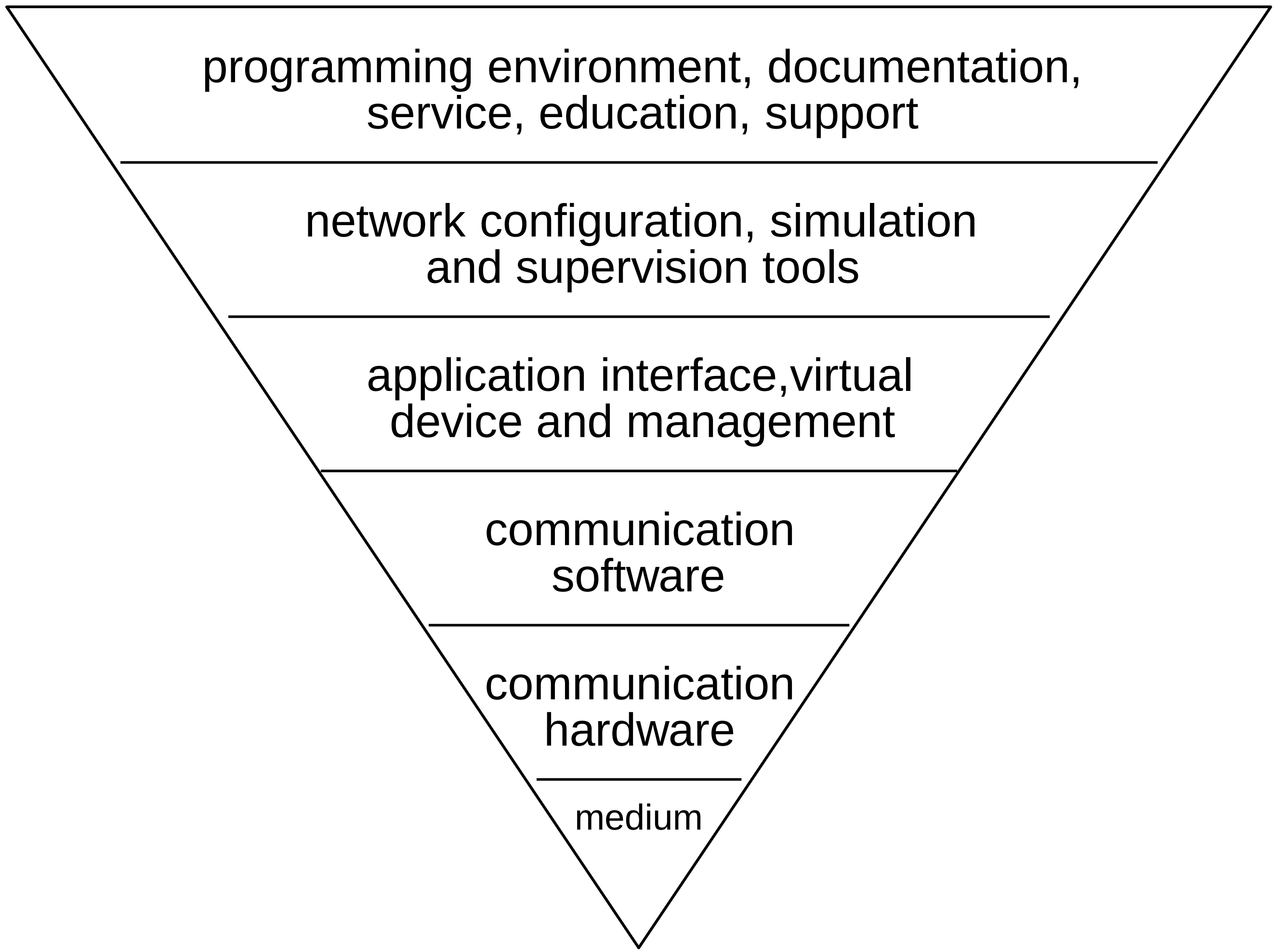
Project	Vehicle Type	Client	Pieces of trains
BR152	locomotive	DB	119 + 100 options
ICT	7-units EMU	DB	32 + 40 options
	5-units EMU	DB	11
ICT-VT	4-units DMU	DB	20
ICE3	8-units EMU	DB	50 + 50 options
ICE3	8-uniits EMU	NS	6
CDT	7-units EMU	CD	10
Pendoluso	6-units EMU	CP	10
Prague	5-units EMU	Metro	22
Puerto Rico	twin-car	Mass Transit	32
Double-decker			
	trailer car with cab	ÖBB	10 + 27 (options)
	trailer cab	ÖBB	50 + 150 (options)

(Siemens VT, August 1996)

TCN Reference List of ADtranz

Vehicle	Country	Systems	Bus Type	Delivery
SBB Lok 460-1,2,3	Switzerland	119	MVB	1991-95
RhB Ge 4/4 III	Switzerland	9	MVB	1993-12
ÖBB Rh 1822	Austria	5	MVB	1992
NSB IC70 EMU	Norway	12	MVB	1992-2
ESL (channel tunnel)	France / United Kingdom	37	MVB	1992-12
BLS 465	Switzerland	8	MVB	1994-7
VR Sr2	Finland	20	MVB	1994-12
BR Class 92	United Kingdom	46	MVB	1993-12
QR-SMU	Australia	12	MVB	1994-1
FS ETR 500	Italy	50	MVB	1995
IR WAG & WAP	India	33	MVB	1995
ERRI - TCN test	Europe	1	WTB+MVB	1994
LRV, Magdeburg	Germany	20	WTB+MVB	1994
LRV, Mannheim	Germany	69	WTB+MVB	1994
RH1163	Austria	20	DVB	1994
LRV, Bielefeld	Germany	20	MVB	1994
VR Sr2	Finnland	20	MVB	1994
MAV 2000	Ungary	5	WTB	1994
GFM	Switzerland	4	MVB	1994
MOB 7000	Switzerland	4	MVB	1995
BAM	Switzerland	2	MVB	1995
FS ETR500	Italy	50	MVB	1996
FS E 412	Italy	20	MVB	1995
ET 474	Germany	45	WTB+MVB	1996
NSB EL 18	Norway	22	MVB	1996
ET 423	Germany	100	WTB+MVB	1997
BR 101	Germany	145	WTB+MVB	1996
Regio Shuttle	Germany	17	WTB+MVB	1997
Torino Ceres	Italy	7	WTB+MVB	1996
Gardemoen	Norway	6+33+9	WTB+MVB	1996+1997+1998
Metro Stockholm	Schweden	8+14+24	WTB+MVB	1996+1997+1998
OSE	Greece	15	WTB+MVB	1997

What makes a network railways-graded ?



Any bus introduced in railways will soon become a dedicated solution
Synergies come from the *community* which uses the bus

Conclusions

- The Train Communication Network was adopted as an International Standard in 1999.
- TCN was adopted as on-board network by the IEEE Vehicular Society as IEEE Std 1473
- TCN is supported by the International Railways Union (UIC) and the International Union of Public Transport (UITP)
- TCN is supported by a strong manufacturer group rooted in railways, including Adtranz, Firema, Siemens.
- TCN is the base of the European Union ROSIN project
- Hundreds of vehicles of different manufacturers operate with TCN.
- Parts are available from third parties, TCN is free of intellectual property rights.
- There is currently no alternative to the IEC Train Communication Network

The most important for a bus is the community which supports it