Train Communication Network

IEC 61375 - 4

Wire Train Bus

This is the train bus standardized in IEC 61375
for interconnecting rail vehicles

Introduction

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

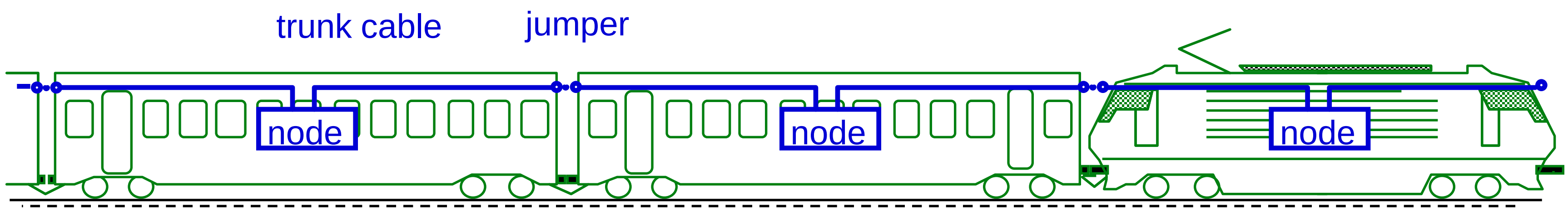
6. Clock Synchronization

7. Fault-tolerance concept

8. Integrity Concept

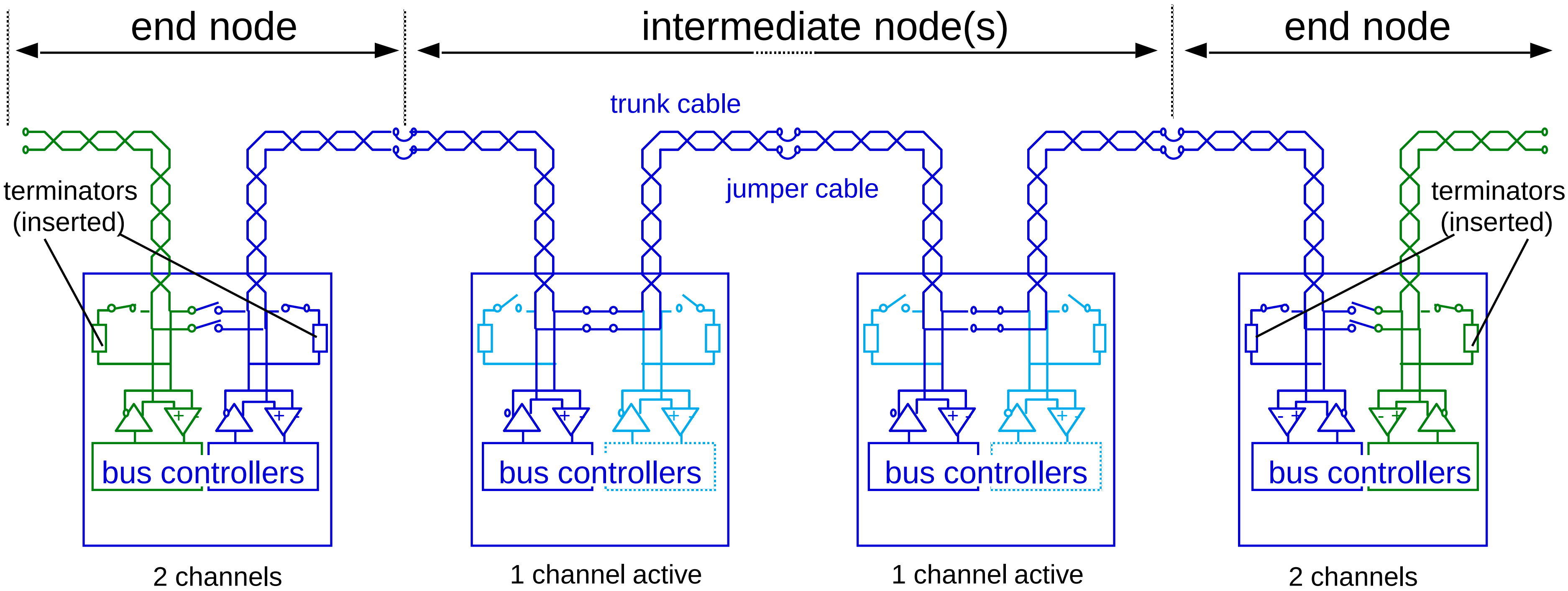
9. Summary

Wire Train Bus



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.

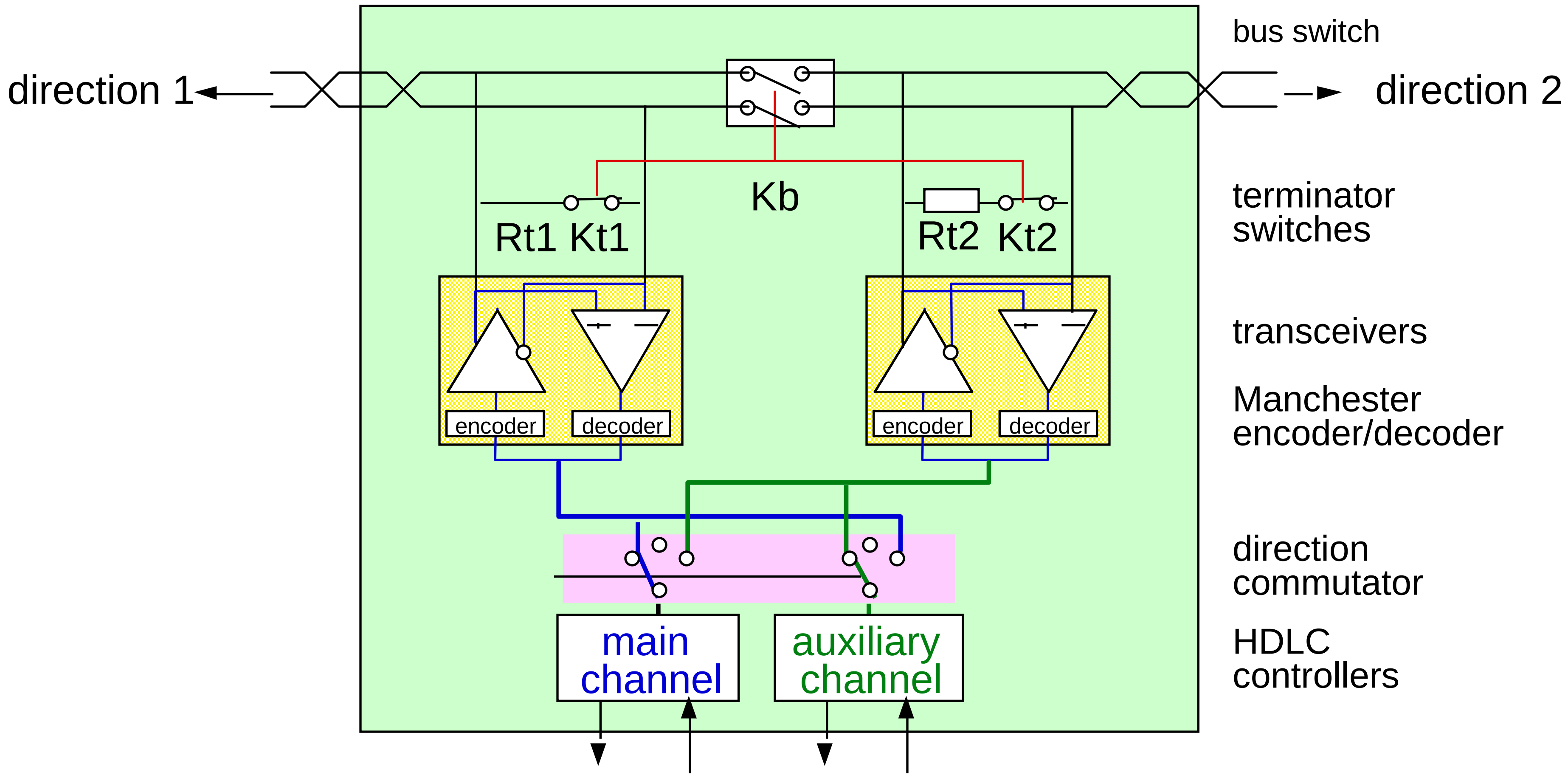
medium: shielded, twisted wire pair at 1 Mbit/s with Manchester II encoding

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

link protocol: standard HDLC (IEC 3309) controllers.

Train Bus Node

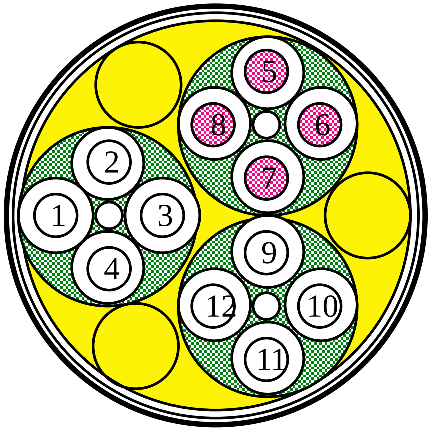
For the purpose of train inauguration, each node has two independent channels, a main and an auxiliary (HDLC) channel



One channel is connected to each direction in an end node

legacy UIC Cable

A 12-wire cable installed in all international coaches.



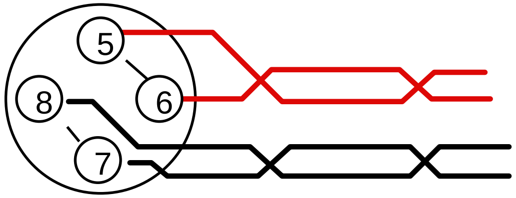
Current assignment:

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

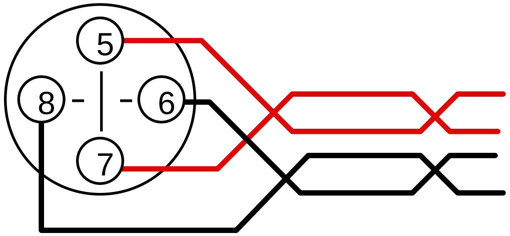
Advantage: smooth transition with older coaches

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.



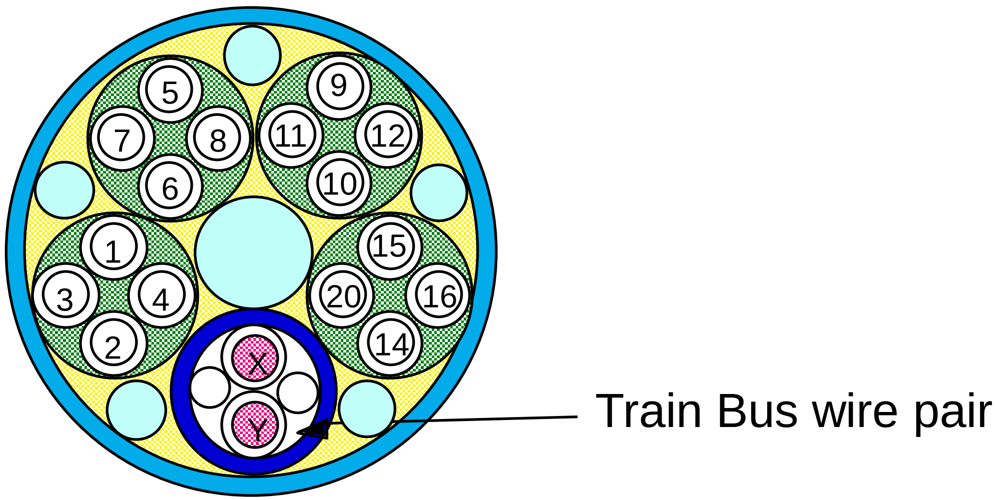
SNCF, ÖBB, SBB, ...
twist the wires the other way



could not be used for data transmission at the required speed

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.

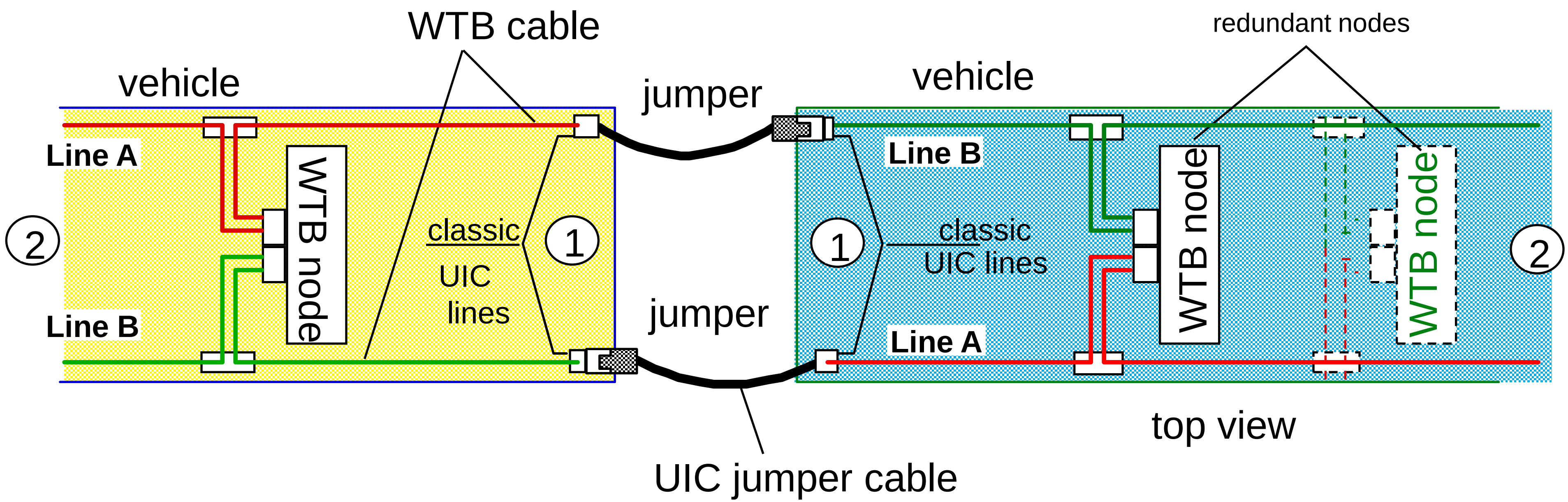
ERRI tested which medium is better for transmitting data, with no clear superiority.

WTB Wiring

Uses jumper cables or automatic couplers between vehicles.

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

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



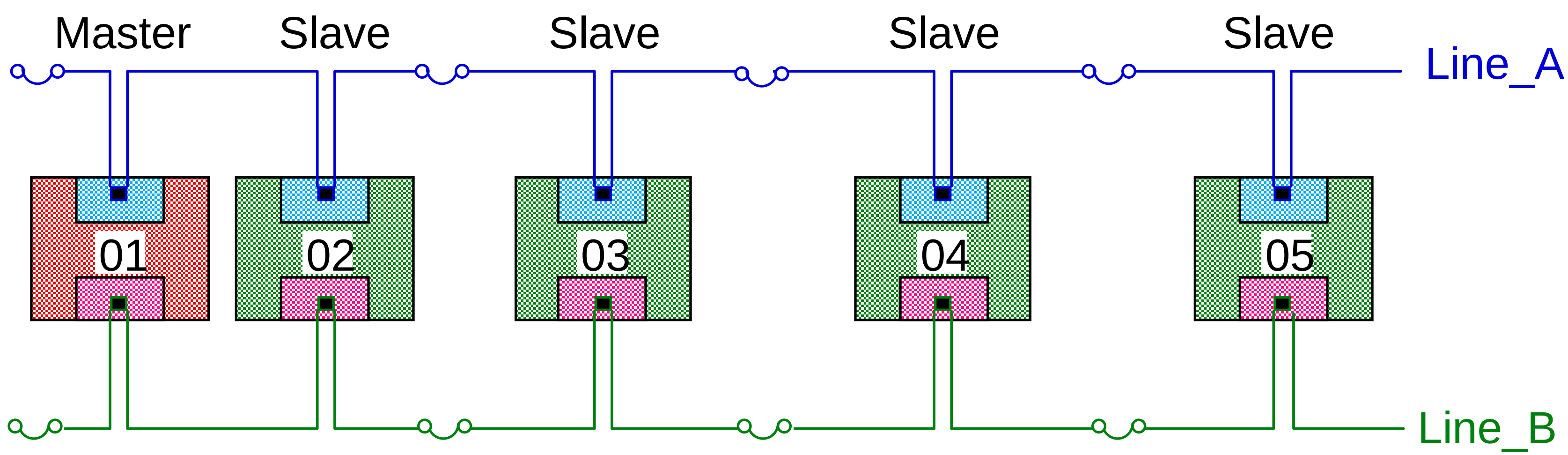
There may be more than one node per vehicle (e.g. in locomotives)

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.

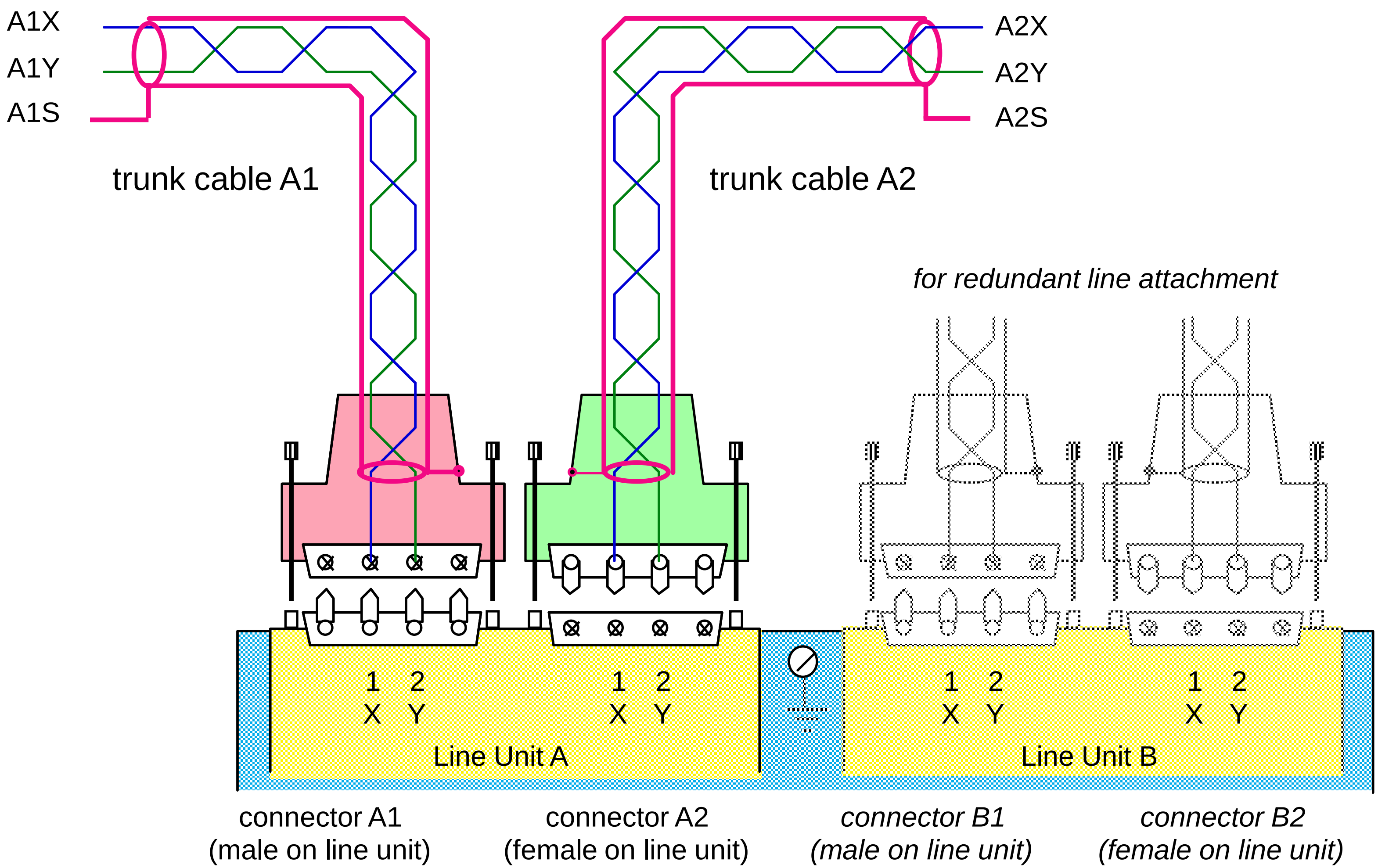


The WTB medium is basically redundant.
A node sends on both lines simultaneously.
A node receives from one line, but monitors the other line.
A signal quality supervision controls switchover.

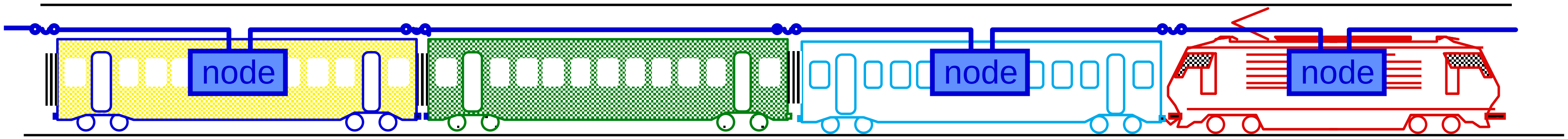
In case of master failure, another node can take over as master.

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.

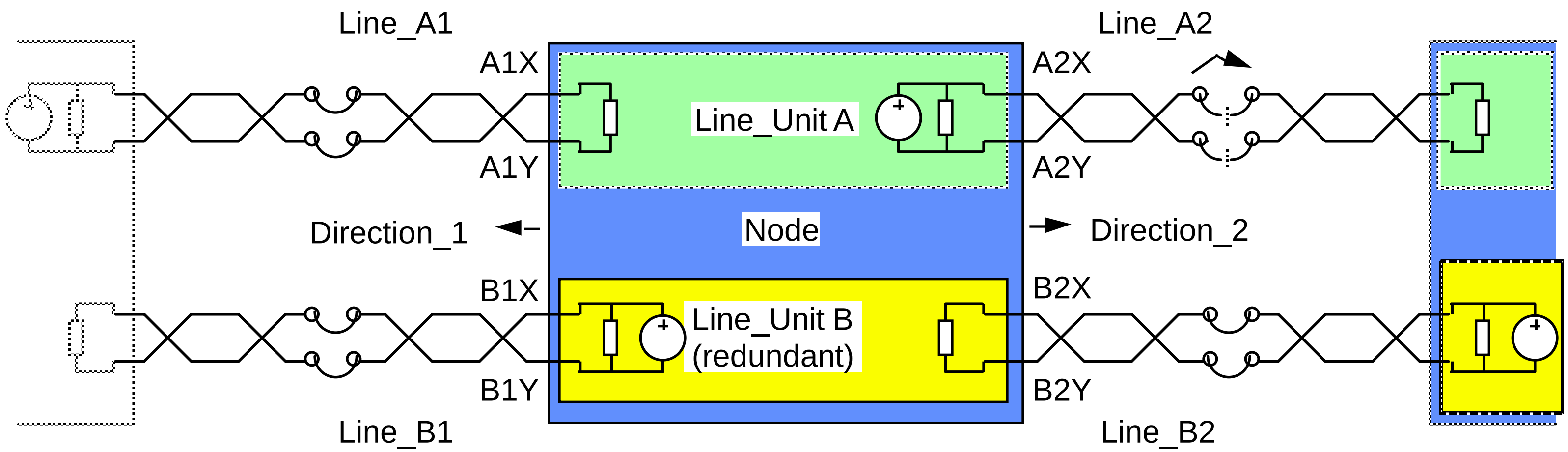
Signal attenuation is high (20,0 dB at 1,0 MHz), reflections occur in the jumper cable

Signal levels must be kept low to reduce electromagnetic emission

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

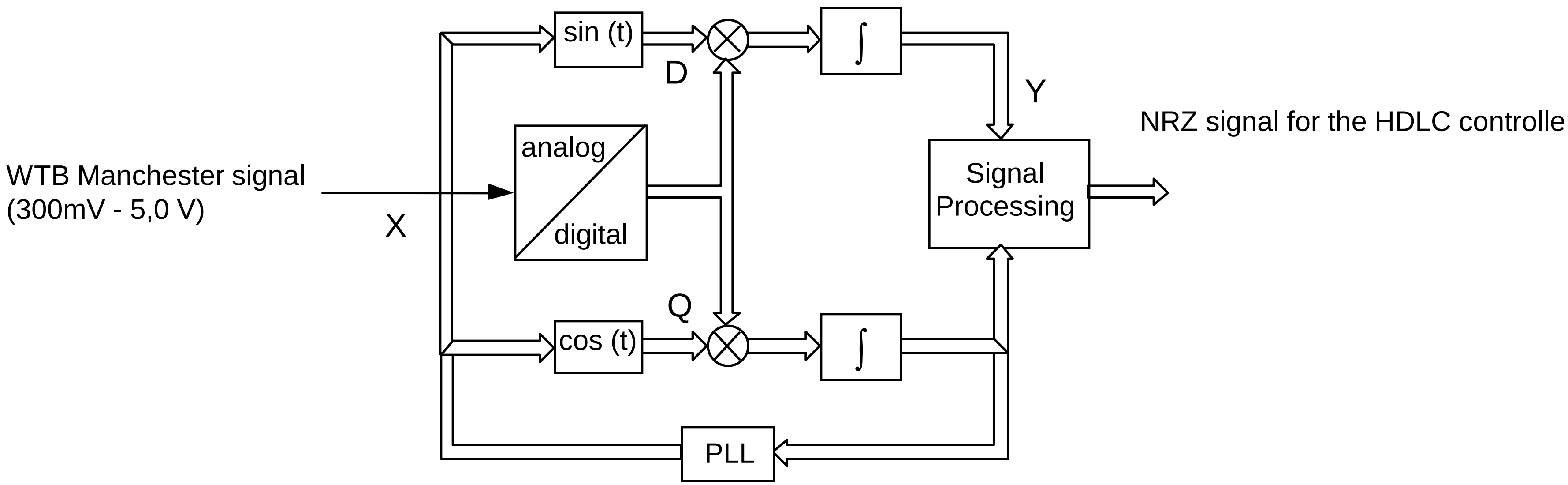
Fritting

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.

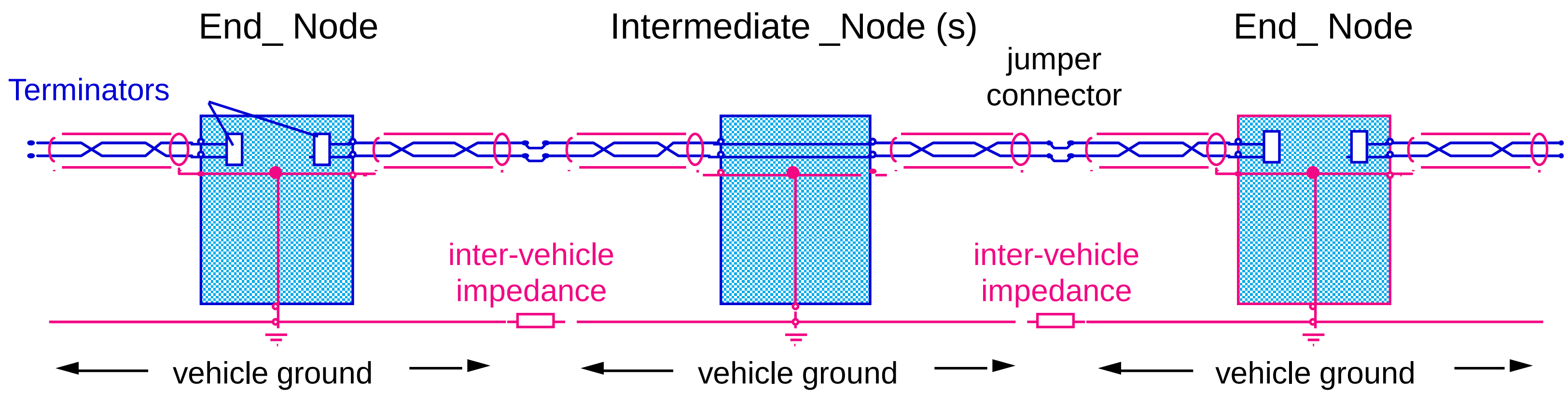
WTB decoder technology



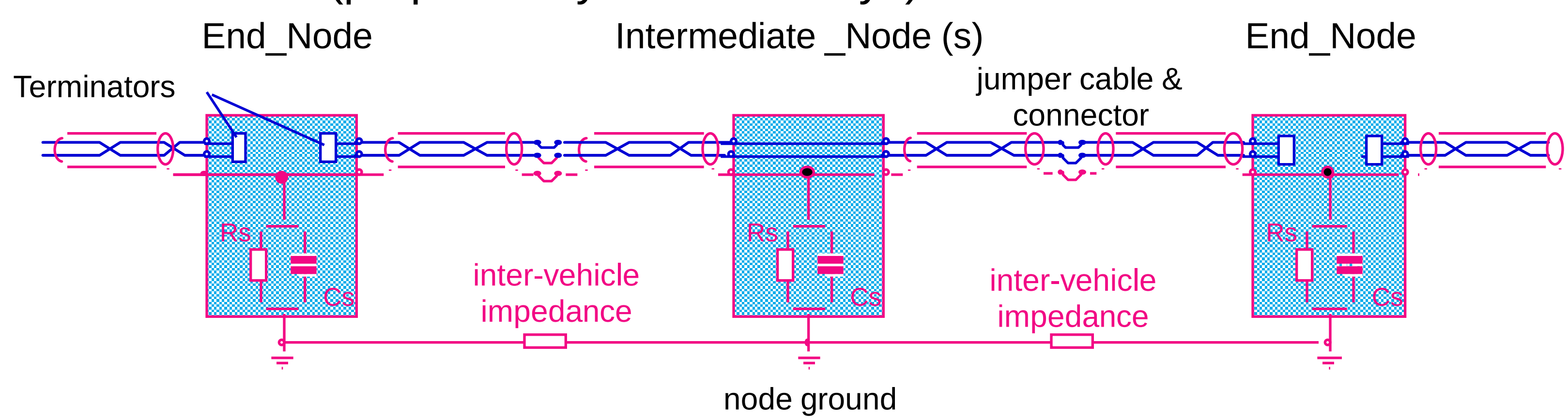
- The high attenuation requires a decoder with a high dynamic range
- To this effect, WTB uses a simple Digital Signal Processor, integrated in a dedicated chip (SDSP).
- The decoder operates with two phase-locked loops, requiring the frames to carry a preamble.

Shielding Concept

Grounded shield (recommended by UIC)



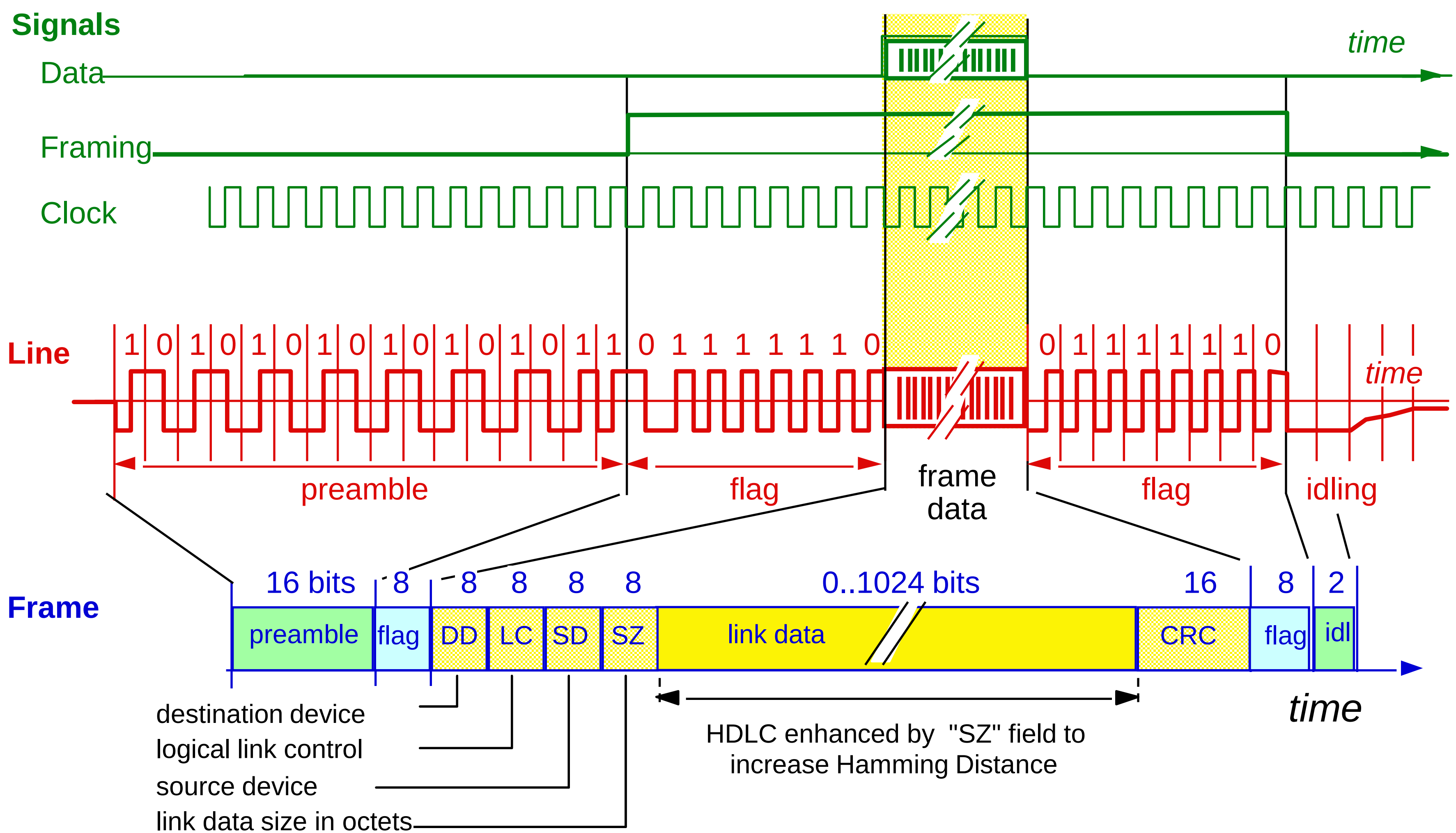
Continuous shield (proposed by some railways)



Both shielding schemes are acceptable depending on the application

WTB Signal Encoding

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



WTB Medium Access

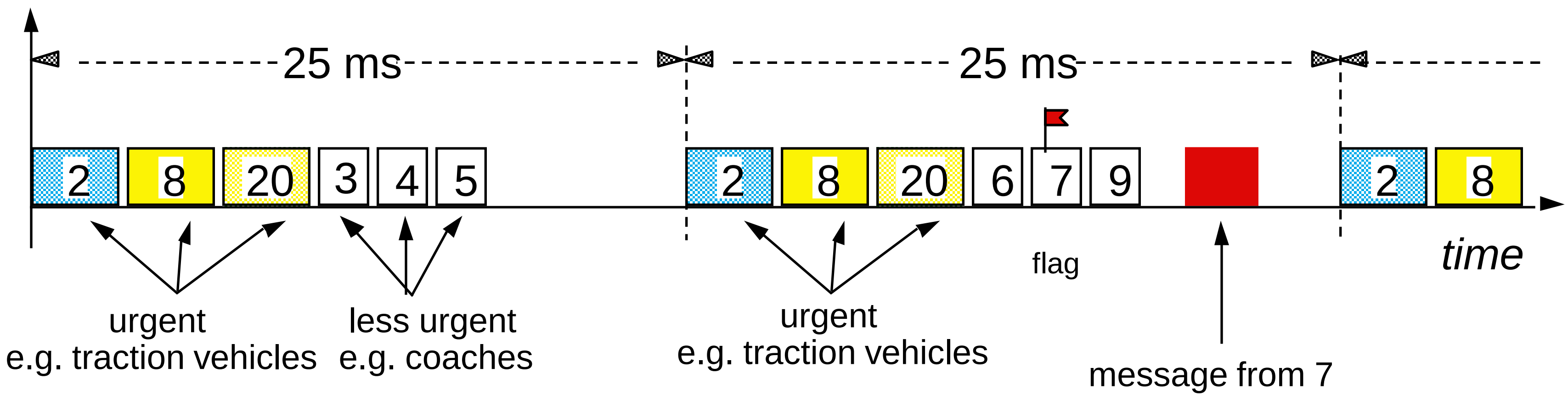
The WTB is controlled by one node acting as a master.

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

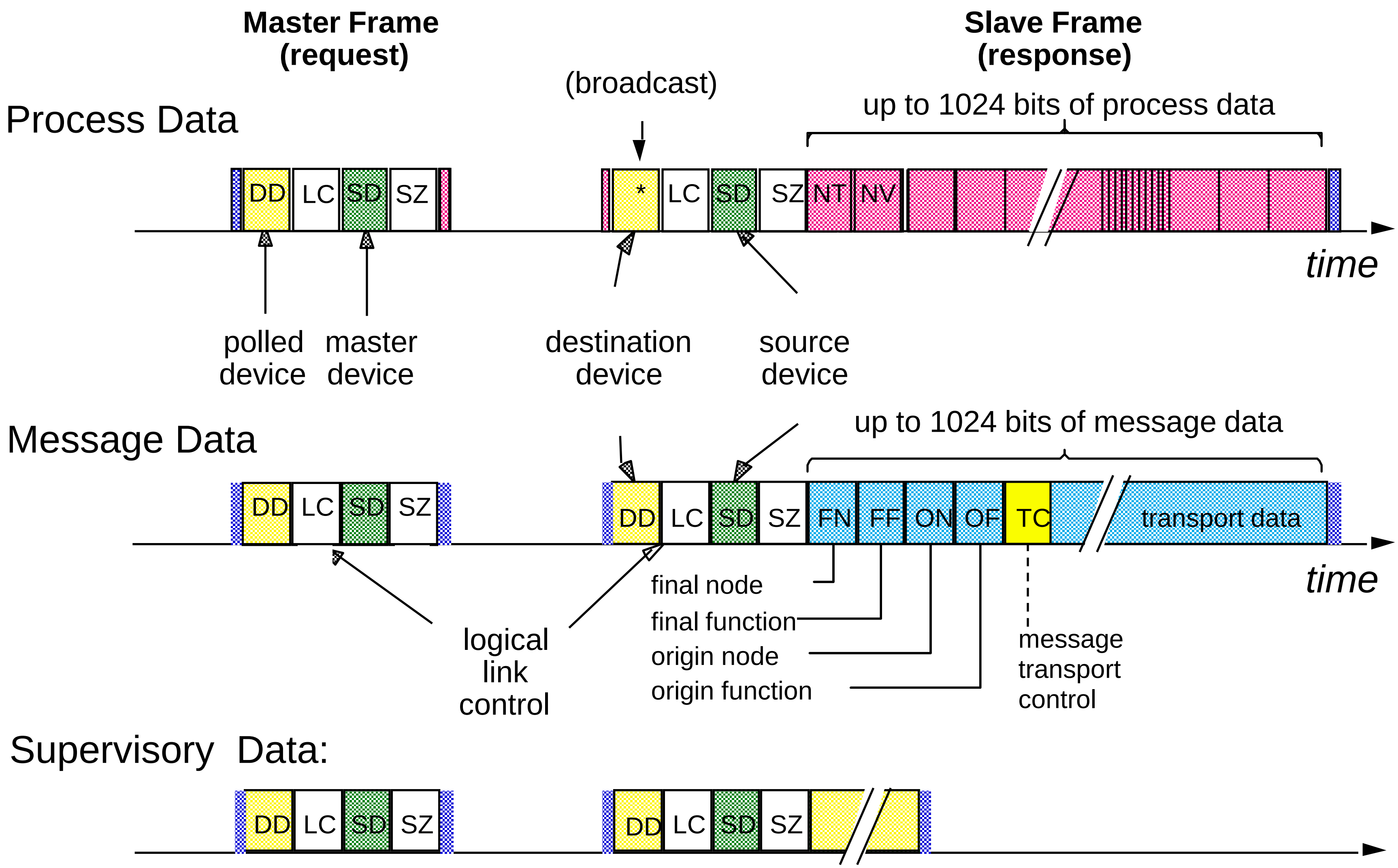
The individual period depends on the vehicle type.
(for instance, traction vehicles are polled more often than passenger coaches)

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:



WTB Telegrams



Beyond Data Transfer

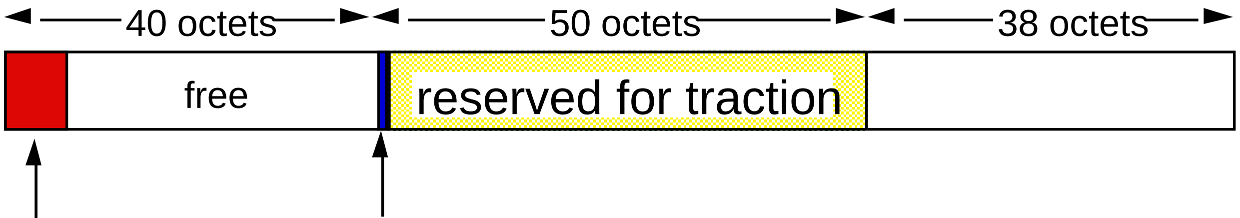
WTB uses the three data exchanges for three types of data:
- periodic, deterministic process variables packed in datasets
- event-driven messages for diagnostics and network management
- supervisory data for WTB management

The content of the first two data types is defined in standard documents.

Especially,
the periodic data protocol and interfaces is defined in IEC 61375-2
the railways-specific data are specified in the UIC leaflet 556;

the message protocol and interfaces is defined in IEC 61375-2 (RTP)
the railways-specific diagnostics data are defined in the UIC 557 leaflets.

UIC556 - Definition Of Regular Variables



40	1-4	apply ep brake
	5-8	release ep-brake

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 left loudspeakers to UIC pair 7-8
	5-6	connect external right 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)

traction data are defined in companions UIC documents

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 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 topography distribution
Master redundancy	fast inauguration

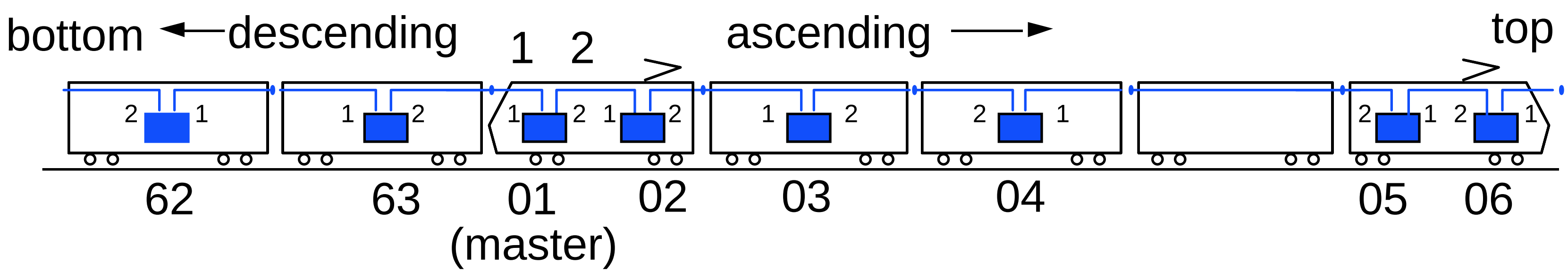
Wire Train Bus Inauguration

The inauguration allocates to each node its address and orientation and of the characteristics of all nodes present on the bus.

Train Bus Node Addresses

At each change in composition (train shortening, lengthening, recovery,...), the *inauguration* assigns each node its address and direction.

Nodes are addressed by their position with respect to the master:

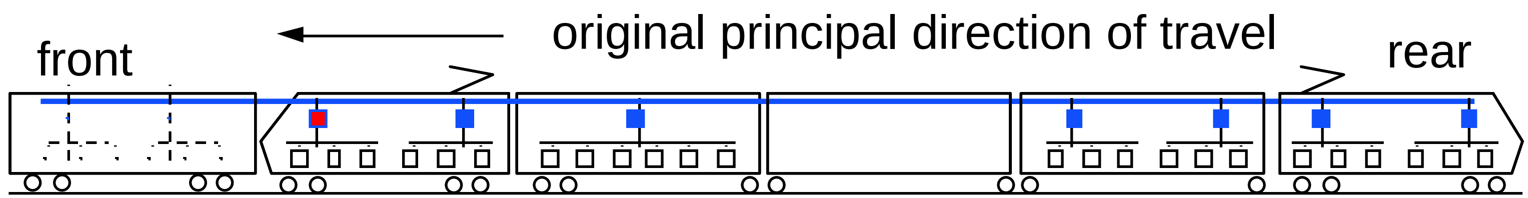


Direction 1 of the master node is arbitrarily called "bottom", direction 2 "top", irrespectively of the travel direction(avoids confusion with front, rear).

Each node receives its position address, the direction of the master, and whether it is below or above the master.

The master numbers the nodes sequentially in both directions.
Up to 62 nodes may be numbered. The master is always 01.

Application Vehicle Numbering

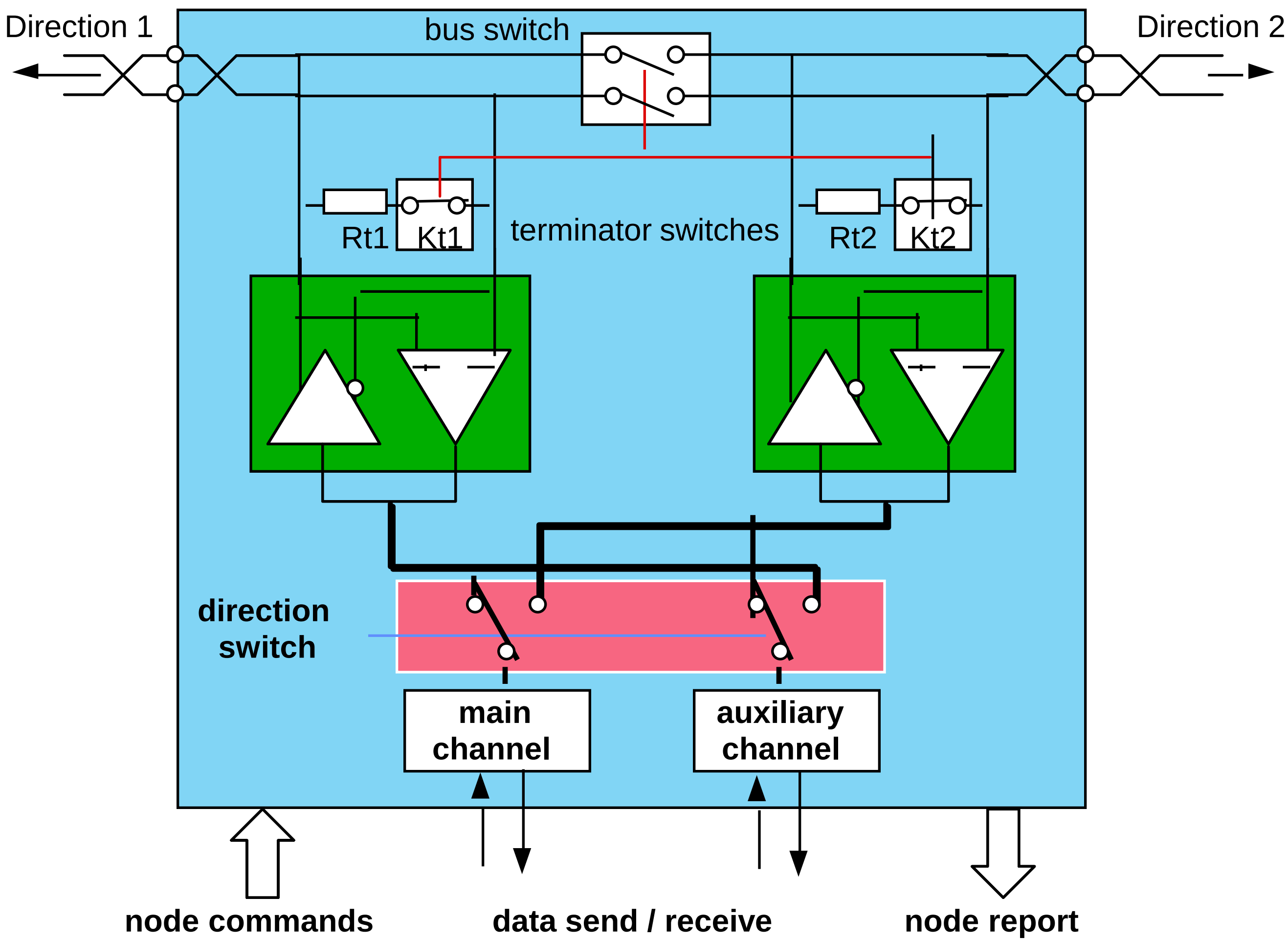


TCN (nodes)	62 63	01 02	03	no node	04 05	06 07
UIC forwards	01	02	03	04	05	06
UIC backwards	06	05	04	03	02	01

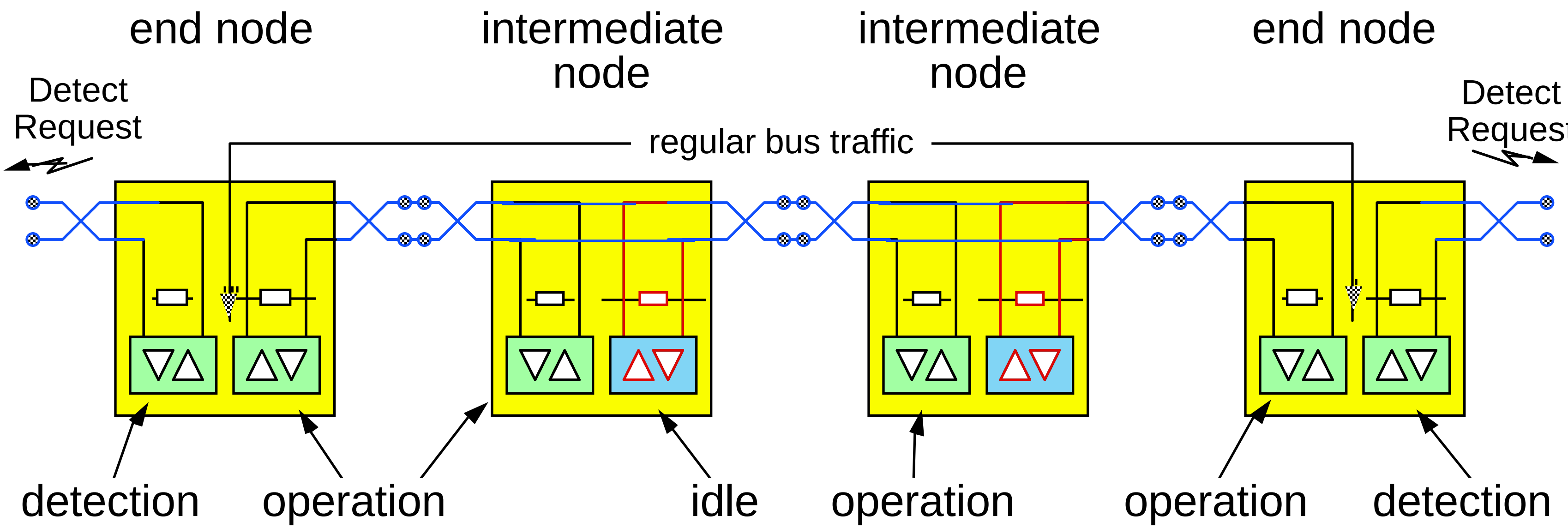
The application may operate with different addresses, e.g. vehicle addresses, especially if there is more than one node per vehicle or vehicles with no node. The application deduces its own addresses from the node addresses.

The translation is done by *amapping module*

Node Structure For Inauguration



End Nodes And Intermediate Nodes

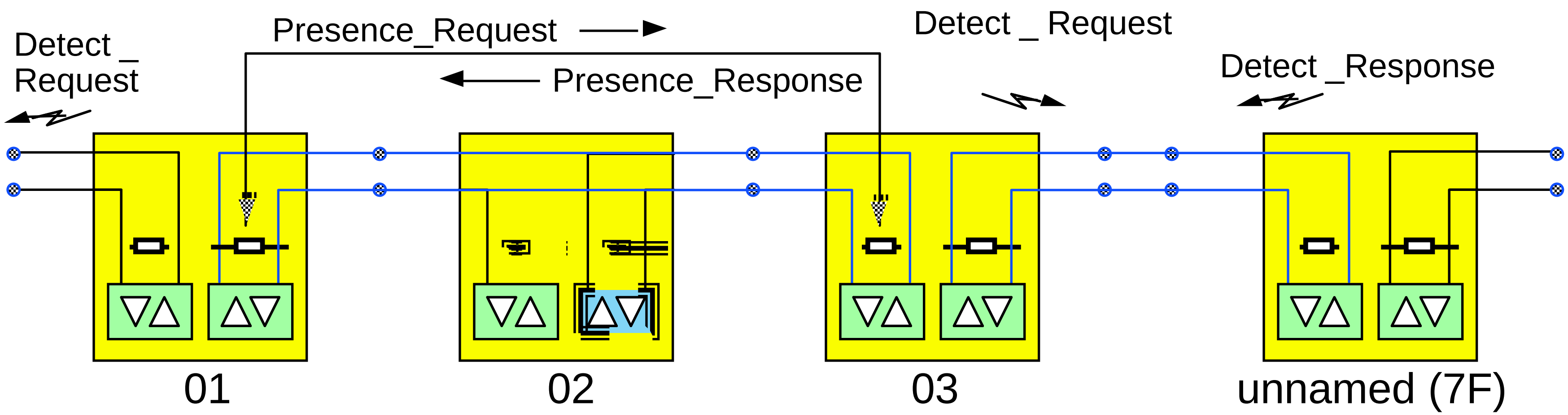


A node may be:

- EN: end node: one channel operating, the other detecting
- IN: intermediate node: one channel operating, the other idle.

Detection channels are active on each end node to find additional nodes.
They periodically send "Detect Request" frames, expecting a response.

Bus Lengthening



An unnamed node does not send "Detect_Request" frames.

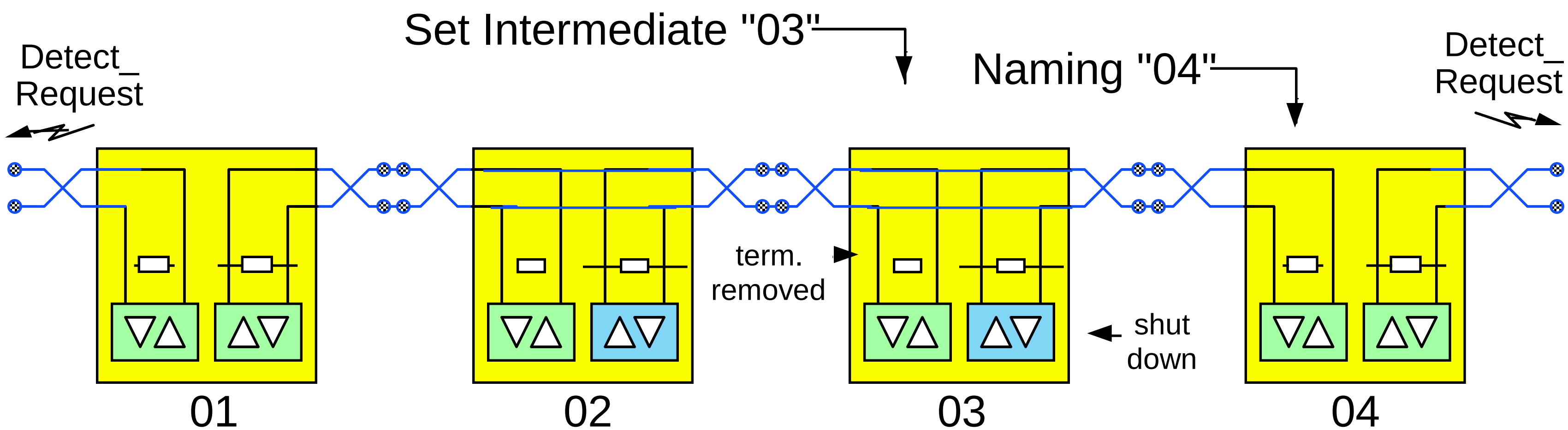
An unnamed node responds to "Detect_Request" with a "Detect_Response"

The master polls an end node with a Presence_Request every other basic period.

End node 03 reports a composition change to the master next time it is polled.

Including An Unnamed Node

The master sends a "SetInt_Request" to switch node 03 to intermediate.



The master then gives address 04 to the unnamed node by a Naming_Request.

The new node 04 responds by a Naming_Response with its Node_Descriptor.

The new node 04 starts sending Detect_Requests to find further nodes.

Naming a Node

Naming a node requires 4 telegrams:

1 - Read the status of the end node (SR)

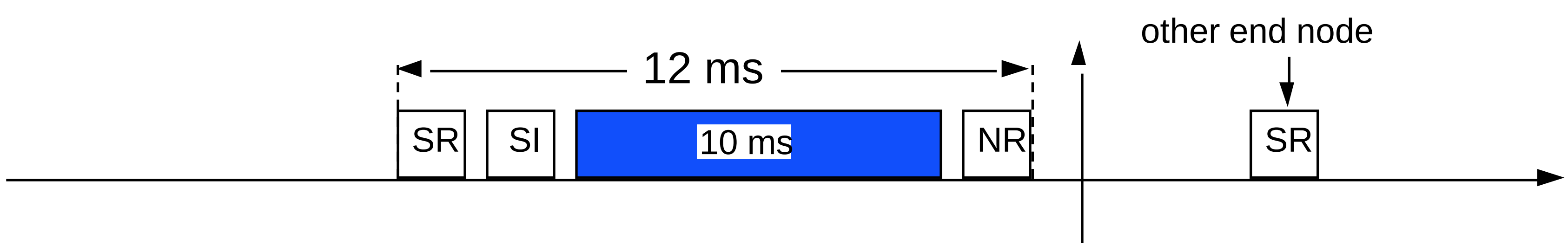
2 - Set the end node to intermediate setting (SI)

wait 10 ms to allow relay position change (no traffic !)

3 - Name the new node (NR)

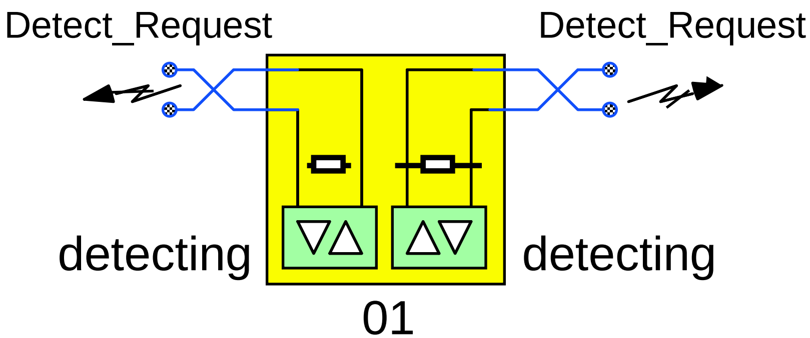
4 - Inform the opposite direction about the new strength

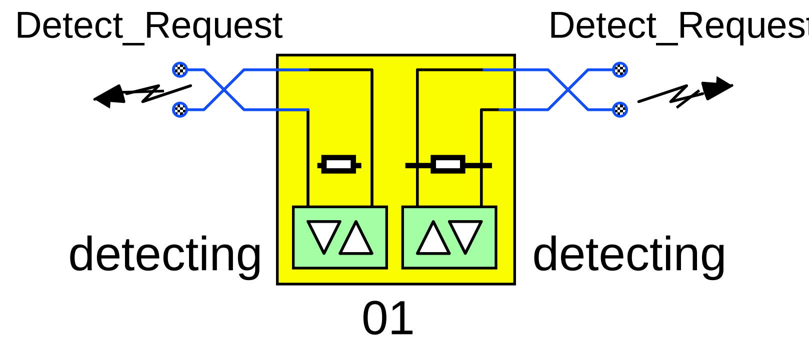
This last step is done by a status reading in the next period (naming in alternate direction).



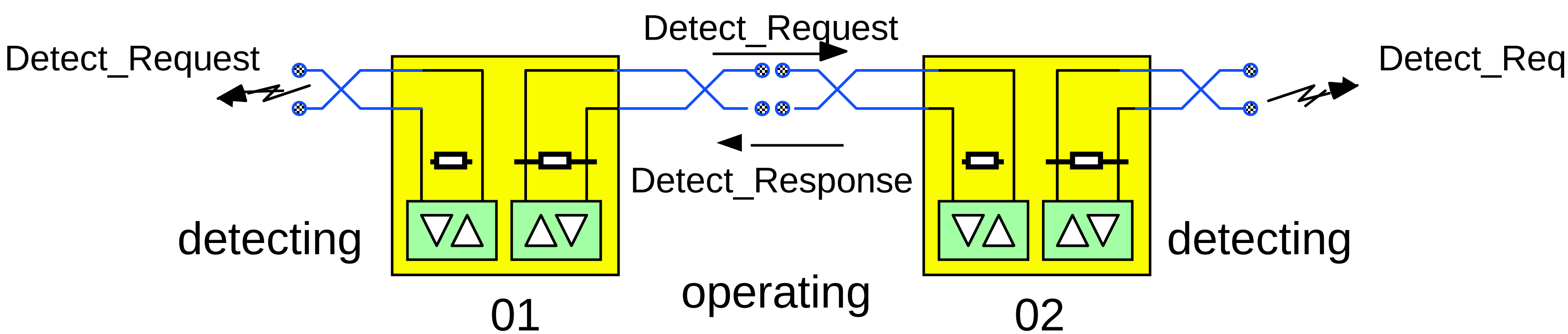
First Two Nodes

At power-up, a weak node which detects no bus traffic becomes bus master.
It takes address "01" and sends "Detect_Requests" to find further nodes.



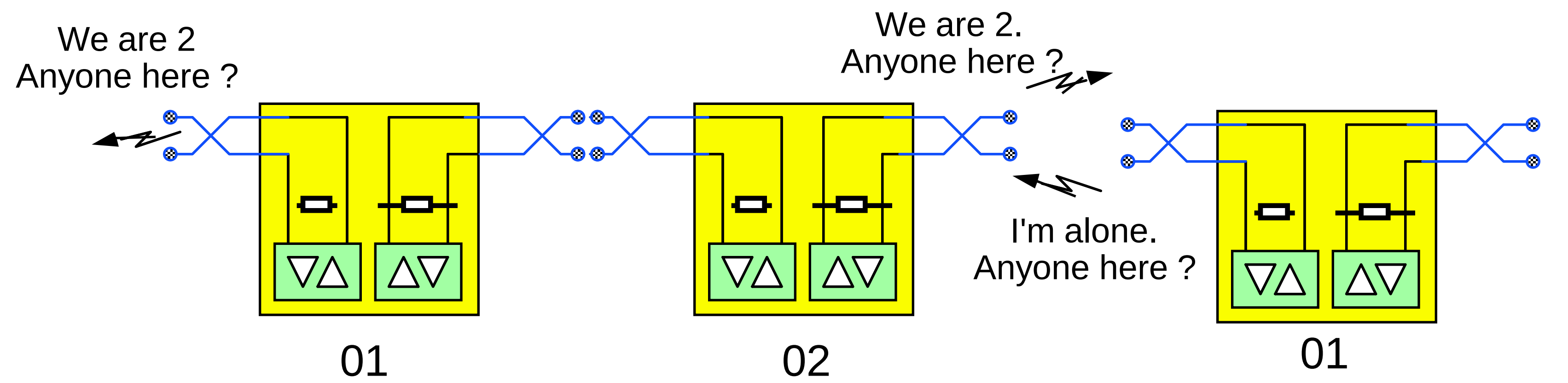


A node which receives a "Detect_Request" telegram replies with a "Detect_Response" telegram, signalling that it would accept naming.

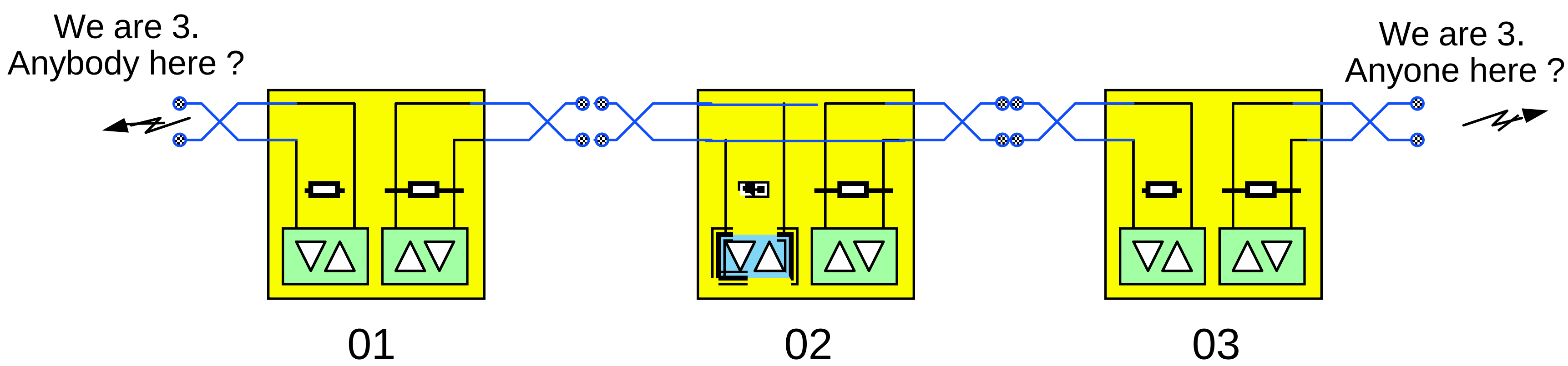


The bus master send a naming telegram to that node and gives it the address 02. The two nodes can now operate as train bus.

More Nodes



Node 02 detects a third node, which agrees to be named (yields).
Node 02 reports the detection of an additional node to the bus master 01
Node 01 switches node 02 to the intermediate node setting.
Node 01 names node 03



Colliding Segments

When two named segments approach each other, each one includes in its"Detect_Request" the strength (number of nodes) of its composition.

This ensures that the segment with the largest number of nodes will rename the smallest segment, and ensures that the inauguration terminates deterministically.

In case of equal strength, the first extremity node to place its "Detect_Request" wins (this is the only random element in the inauguration).

A segment (through its en node) can refuse naming.

For instance, two trains with two drivers can be coupled.

Although both segments detect each other, a train inauguration can only take place if both drivers agrees to it.

Since the decision to inaugurate or not is taken by the master, the application must tell the master when to accept inauguration. Until then, the strength of the segment is considered infinite.

Master Types

The application distinguishes:

➤ Strong Nodes

- Strong Nodes are appointed by the application to become the master.
- If more than one node is appointed as strong, the bus divides into several segments, each controlled by a strong node.
- The application on a strong node is tied to the master function. It may send process data in the poll frames.

➤ Weak Nodes

- Weak nodes may become master if no other node takes over this function.
- A weak node automatically takes over in case of failure of the master, without need for authorization of its application
- The application on a weak node does not care if the node is master.
- Therefore, weak nodes may not send process data in their poll frames.

➤ Slave Nodes

Slaves nodes may not become master (for test purposes).

Node Descriptor

	◄—— Node_Key ——	——►
Node_Poll	Node_Type	Node_Version
8 bits	8 bits	8 bits

The node descriptors of all nodes are collected by the master during inauguration and distributed to all other nodes as teh topography.

- The **Node_Poll** indicates the desired individual period in multiples of the basic period - this information is not communicated to other nodes.
- The **Node_Type** indicates to the destinations how to marshal the process variables.

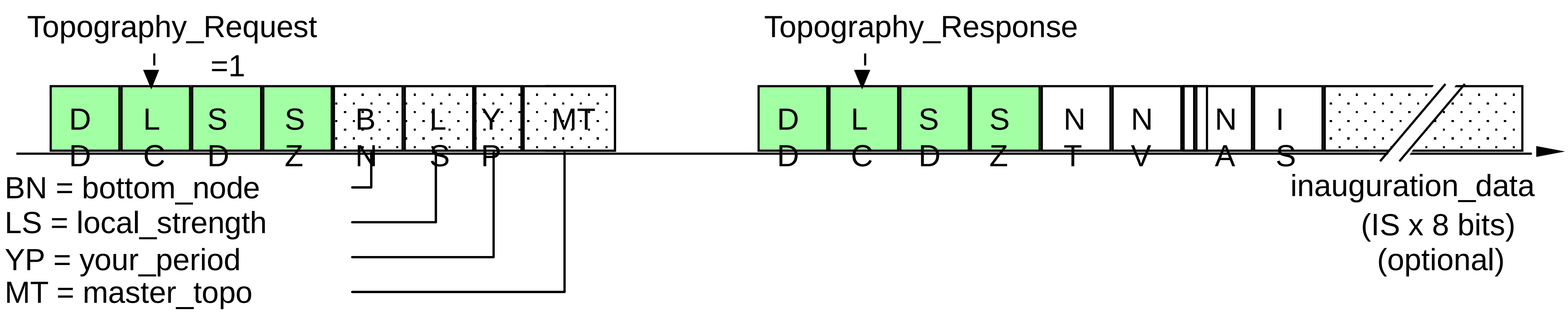
  It selects for instance a cluster list for a given application
- The **Node_Version** indicates the version of the format.

  all nodes can communicate over the lowest version number.

  node type and node version are included in each WTB Process Data frame as a safety against configuration errors.

Topography Distribution

When the train inauguration is completed (no more nodes detected), the master asks each node three times in sequence to broadcast its Topography:

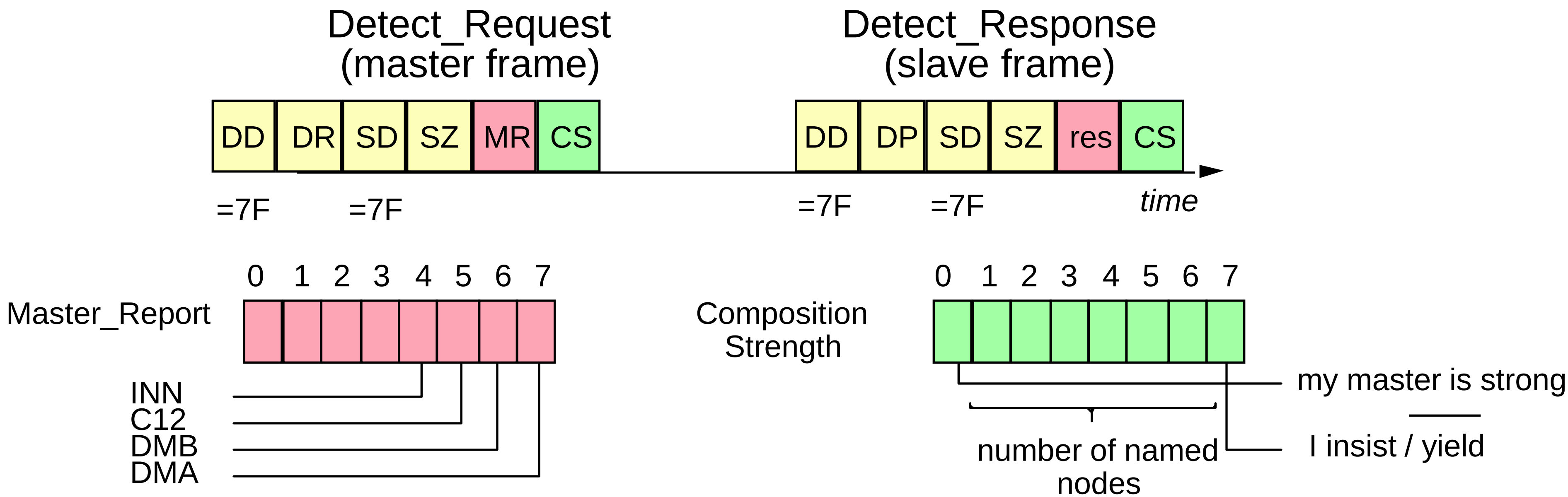


Each Topography contains the Node_Key issued by the node during naming.

When all nodes sent the Topography, the master proceeds to regular operation.

If a node did not receive the Topography when regular operation starts, it unnames itself, causing a new inauguration.

Detection Telegram

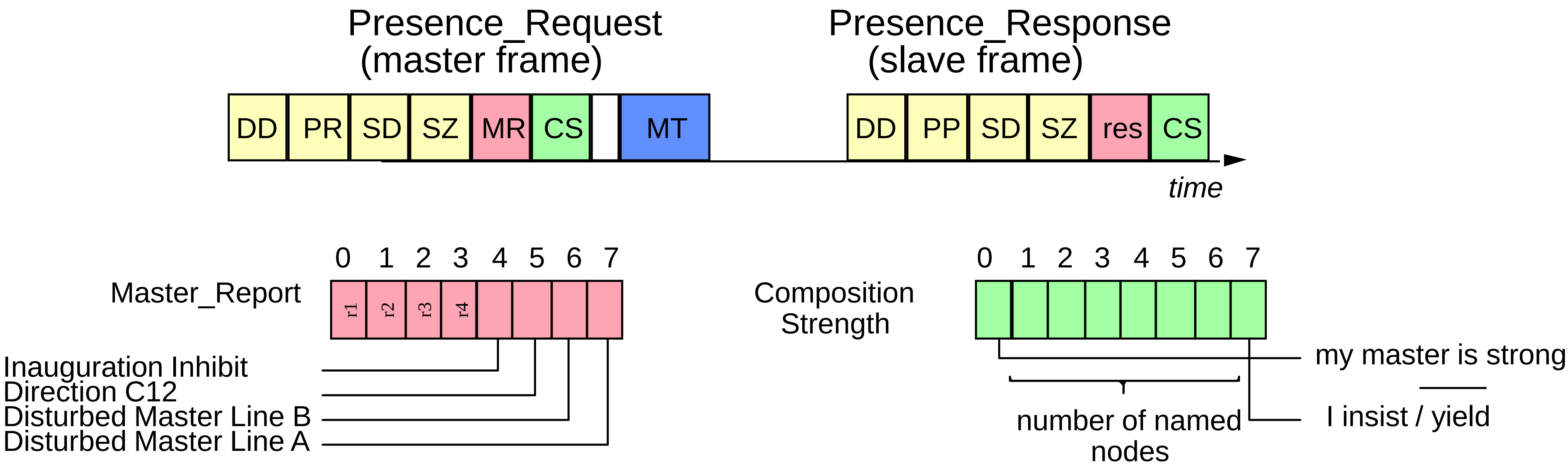


The Detect_Request and Detect_Response indicate to the other party the strength of the composition (CS) represented by the end node.

When the two compositions are of equal strength, the first one to place its request wins.

When both compositions are under control of a strong master, the inauguration closes with a "master conflict".

Presence Telegrams



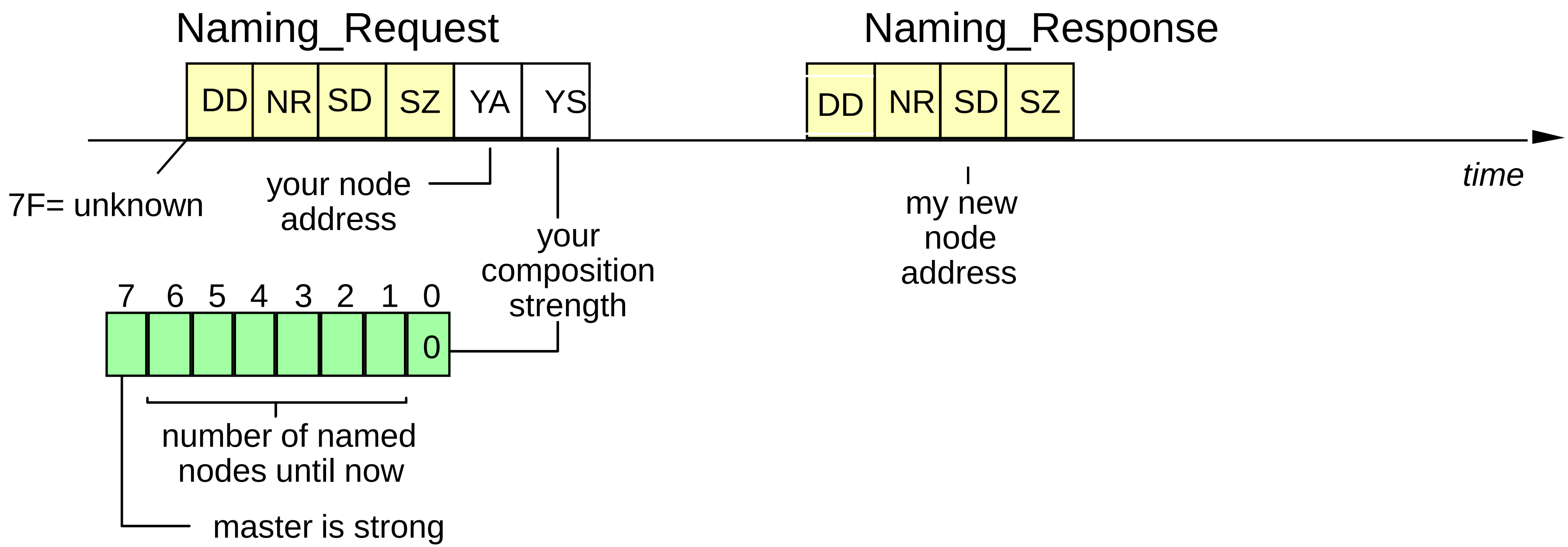
The master sends a Presence_Request to each end node alternatively, indicating

- its composition strenght and if inauguration is enabled
- the redundancy status of the lines

The end node responds with a Presence_Response indicating:

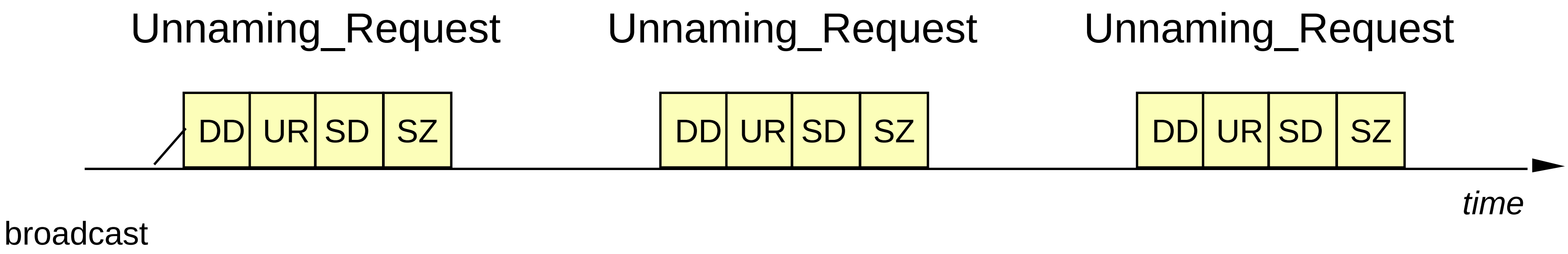
- that it is still present and that the bus is correctly terminated
- that another composition has or has not been detected.

Naming Telegram



The master tells the slave its name and composition strength
The slave responds with its new address if it accepts naming.

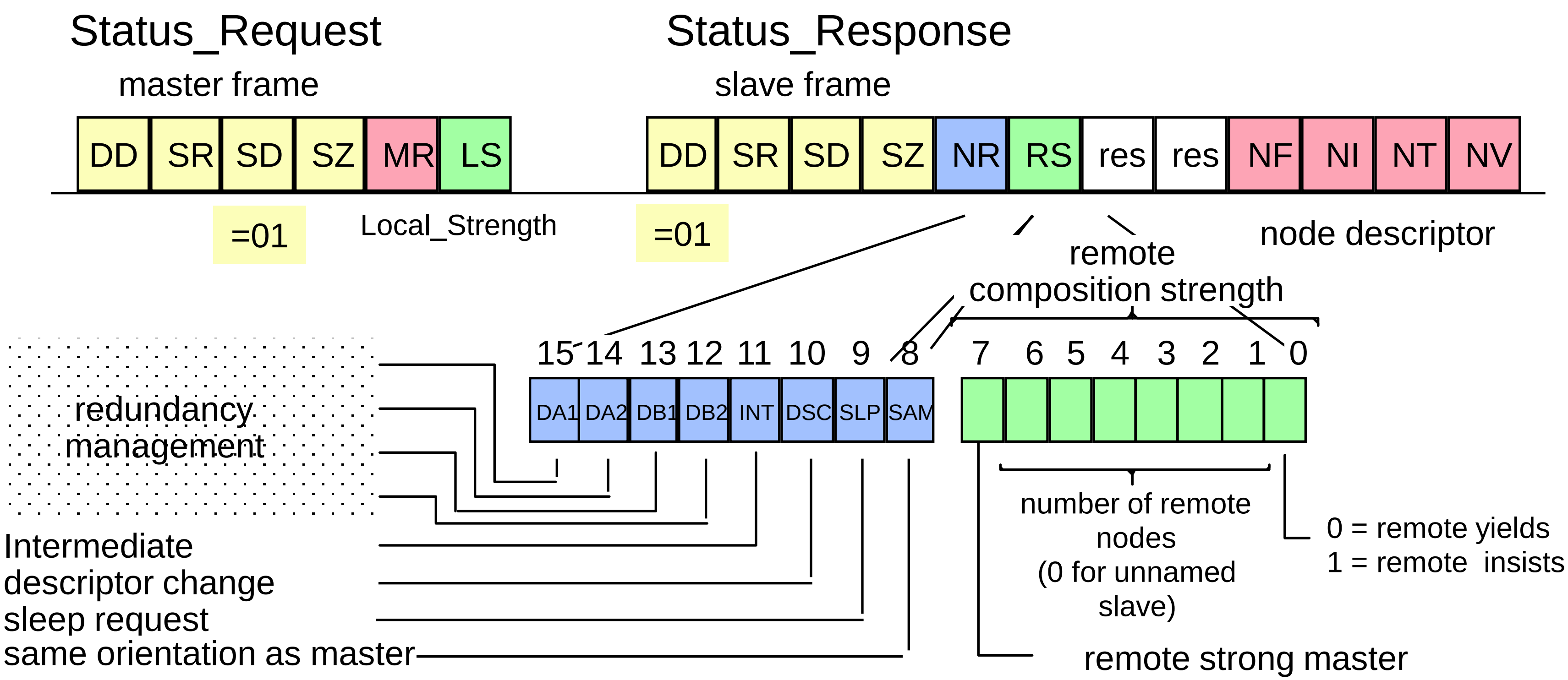
Unnaming Telegram



The master unnames all nodes by sending an Unname_Request three times in sequence.

The slaves do not respond, but return to the unnamed slave state after a time-out.

Node Status Report



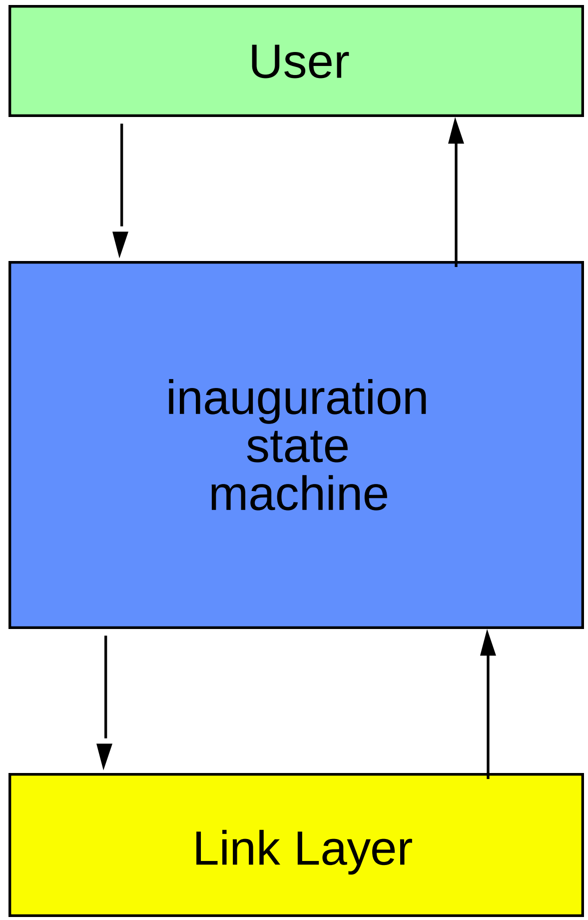
When a node requests attention (C_bit in response frame), the master requests its status

The reasons can be:
- -inauguration
- -change of descriptor
- -sleep wish

Inauguration States In Each Node

Requests
reset
configure
set_mode
promote
demote
remove
start_naming
get_topography
get_node_status

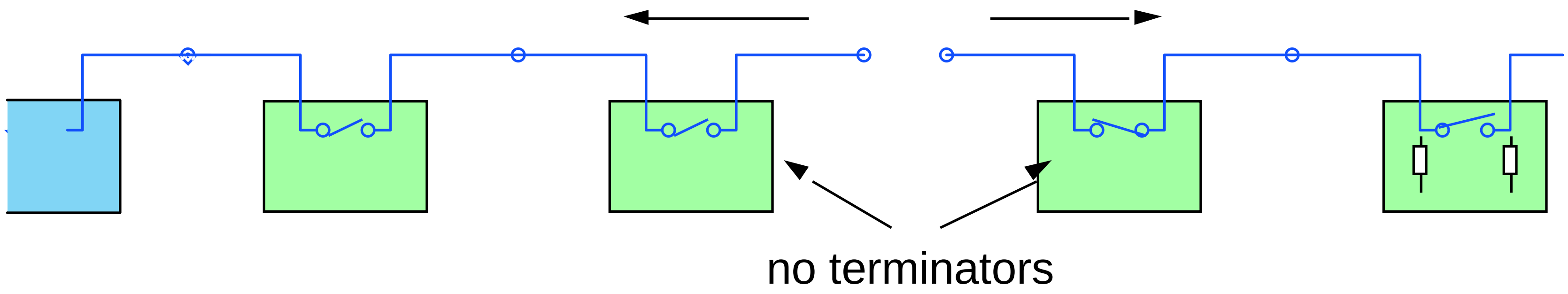
Commands
detect
get_status(N)
set_end(N)
set_intermediate(N)
naming(N)
unname(N)
take_topo(N)
test(N)



Indications
configuration_change
status_change

Reports
bus_shortening(N)
node_change(N)
node_attention (N)
more_nodes(dir)

Bus Shortening



Bus shortening occurs when vehicles are separated or when an end node fails.

It has the effect that the bus is not any more terminated.

Some nodes may continue to receive the data, others not.

A node which detects that an extremity node ceases to respond for three consecutive polls goes to the unnamed state.

The former master is first to recover and inaugurates the bus again.

This goes fast since all nodes are unnamed.

Regular operation is resumed after a new topography is distributed.

Master Redundancy & Bus Shortening

A slave node cannot distinguish if the bus has been shortened or if the master has failed: in both cases it receives no more data.

A node which ceases to sense the end nodes for three consecutive basic periods goes to the “UNNAMED_SLAVE” state.

If the master succeeds in recovering the bus, this node will be renamed and reintegrated.

Otherwise, if the node is a weak node, it shall assume after a while the master role, providing master redundancy.

If several weak nodes are in this case, the collision resolution will elect exactly one master.

However, to avoid collision, the nodes become weak master after a time-out depending on their former address
(distance to the master, multiplied by the time that it takes to name a node)

Therefore, it is advantageous to name alternatively in both directions.

Exception Handling & Sleep Mode

The WTB allows to switch all nodes to a low-power state (sleep mode), during which a node ceases to receive frames and only monitors line activity.

A node is woken up by a local application signal (WakeUp signal) or by detecting the presence of a valid bus activity (HDLC frame).

Since bus activity wakes up the nodes, a concerted procedure ensures that all nodes enter the sleep state at the same time.

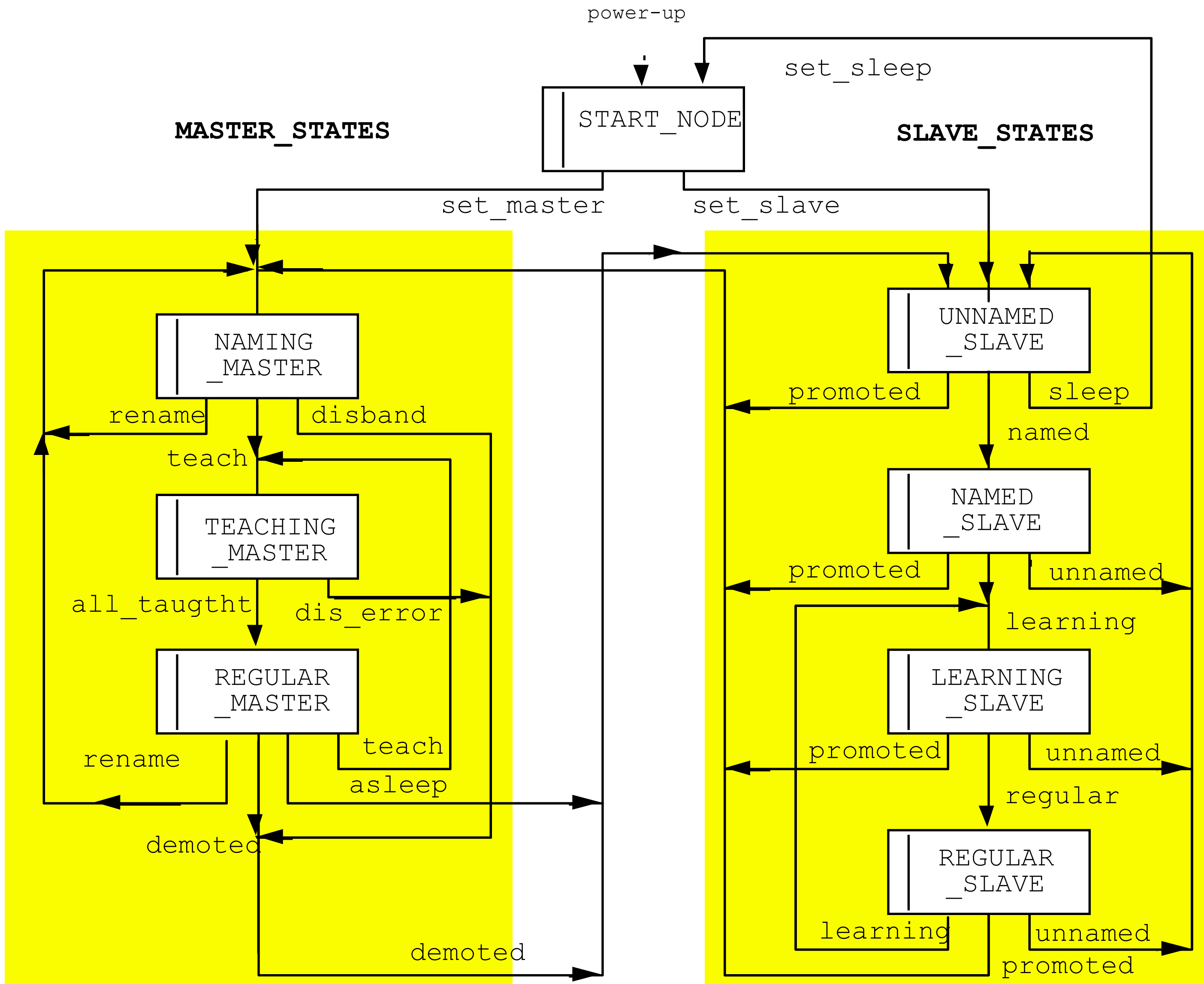
When the master detects that all attached nodes wish to go to low-power mode, it ceases transmission. All nodes then enter the sleep mode.

A node with a sleep request cannot become weak master.

To draw as little as possible from the train's batteries, the detection logic can be pulsed, e.g. be active every 10 s.

The UIC 556 paper describes the conditions which lead to sleep mode, the TCN executes the procedure.

States of a Node

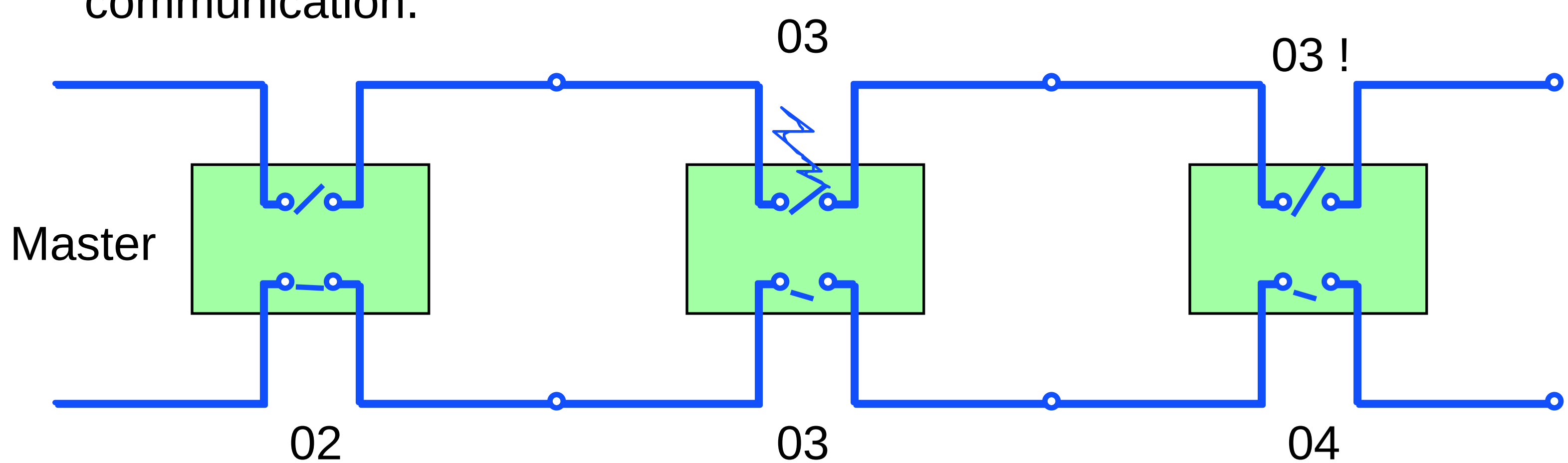


Line Redundancy

The inauguration takes place simultaneously over lines A and B.
If one line is damaged, the node receives its name over the healthy line.

If the bus switch is stuck closed on one line, two nodes could respond simultaneously, defeating physical redundancy.

To avoid this, a node which detects that one of its bus switches is stuck goes to the passive state (intermediate node) and does not participate in bus communication.



There exist no link layer redundancy, i.e. an error in a communication processor can put down the whole bus. Only a full duplication of the WTB (with two nodes per vehicle) can remedy.

Special Redundancy Conditions

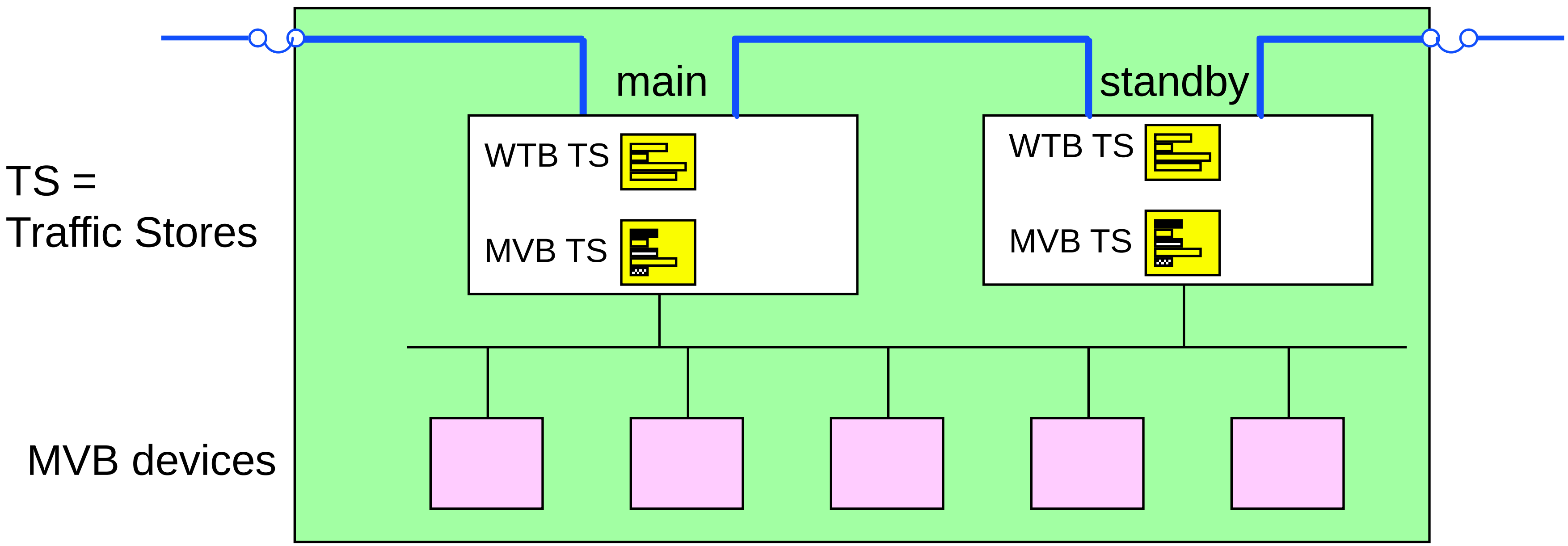
The inauguration has to succeed also under difficult conditions:

- disturbances (as in any transmission)
- one redundant line not connected or damaged
- redundant lines connected one after the other (as normal)
- stuck relay in a node
- power-up or power-down of a node during inauguration

All efforts have been made to avoid that a single failure defeats redundancy.

The largest part of the WTB specification is devoted to the specification of these exceptional conditions.

WTB Redundancy Concept



Gateways operate in warm redundancy (loosely synchronized over the MVB)

Both gateways execute the same cyclic tasks (e.g. for each boogie)

Switchover is not bumpless (some data can be lost during switchover)

Redundant gateways have different WTB addresses (differing by 1)

WTB and gateway failures are independently treated

WTB redundancy for messages

MVB devices send message data alternatively to each gateway.

Other WTB nodes transmit the data alternately to each gateway (increases throughput)

The failure of a gateway is not distinguished from the failure of its MAU

The network layer cares for the correct selection of the gateway

An error counter associated with each gateway indicates which one is operating (if not both)

Reinsertion of a gateway takes place when a correct message is received from that gateway (individually for each device or node).

WTB redundancy for process variables

Both gateways listen simultaneously for the data traffic.

Only one gateway is source for the WTB or for the MVB

The other gateway can detect failure of the on-line gateway because sink time supervision fails.

After a while, the standby gateway takes over and changes the status of its ports from sink to source.

WTB redundancy actualisation

Synchronous operation requires synchronisation of operation

There is no link between the gateways except the MVB (WTB is not used)

If is necessary to transmit parts of the context to avoid too large an effort in synchronisation

To this effect, a synchronisation once every 1,0 s should be sufficient.

Beyond inauguration

Once inauguration established a data connection between devices,
further information is exchanged between the vehicles for the purpose of train operation.
Each vehicle indicates its capabilities, such as length, weight, braking capabilities, etc..
This information is defined in companions documents.