DAC4EU Data Communication Tests

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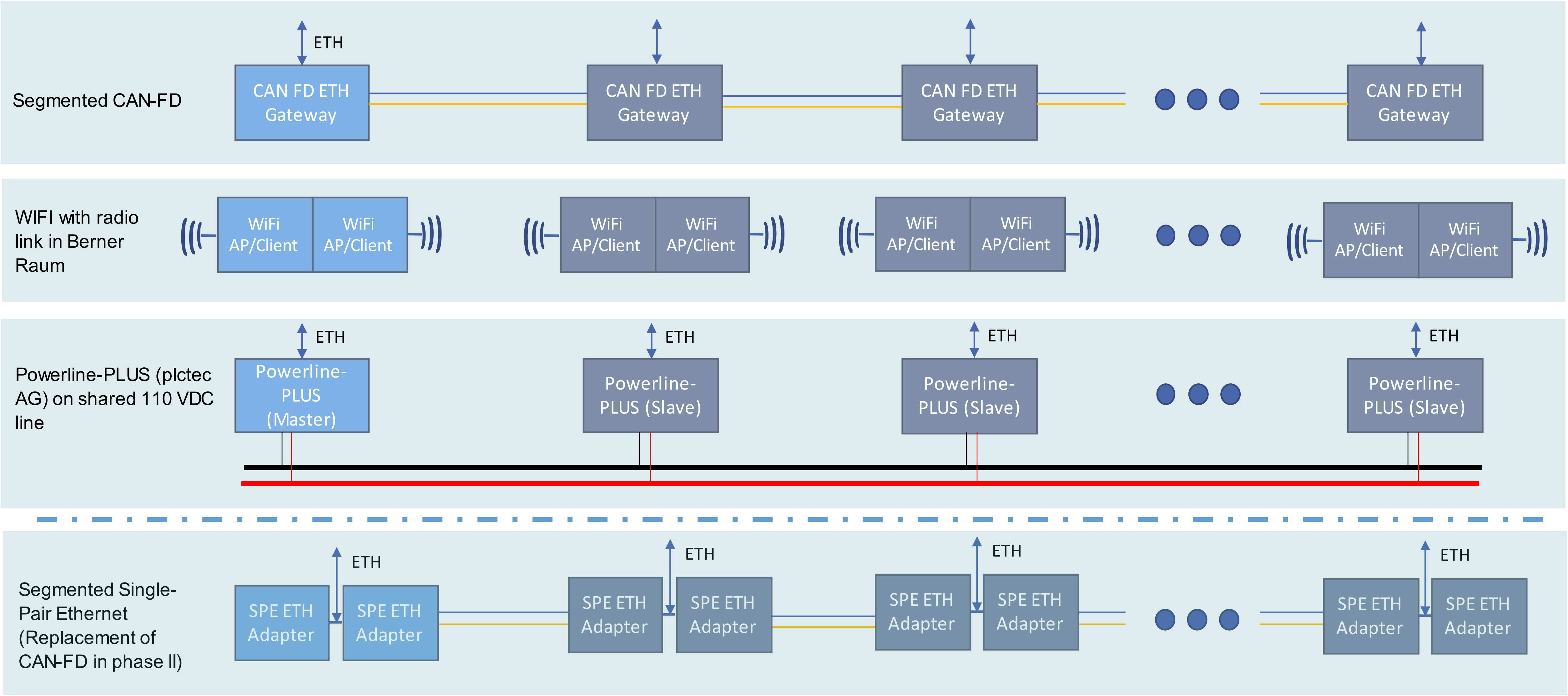
Phase I – Brief Look at Phase I

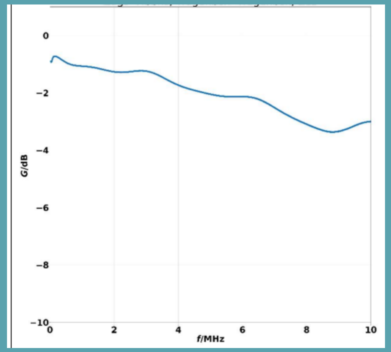
Tested Communication Concepts

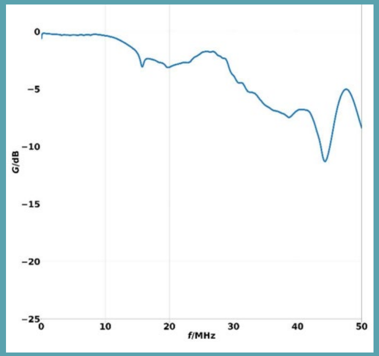


Phase I – Brief Look at Phase I

Communication Tests in Standstill of Wagons

Measurements of physical communication channels (wired, radio)





Result of the channel measurements

- Communication with modern communication systems possible (2-wire bus, powerline, radio)
- Slight differences between couplers regarding channel quality identified

Performance measurements with communication systems:

- WiFi,
- CAN-FD,
- Powerline-PLUS

Datarates: 1 – 6 Mbit/s

Packetrates: 330 – 2600 Packets/Second

Latency (RTT): 6 – 200 ms

(Train with 12 wagons)

Results of the performance Measurements:

- Requirements for the transferred information rate could be reached by tested systems (WiFi, CAN-FD Powerline-PLUS)
- Differences of latency, datarate and packetrate depending on communication system (no dependency of coupler type)

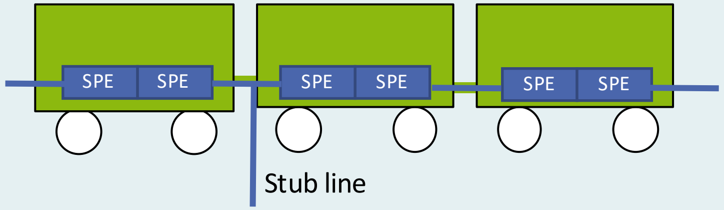
Official report: Phase I: https://bmdv.bund.de/SharedDocs/DE/Artikel/E/dak-demonstrator.html

Stress Tests (Standstill)

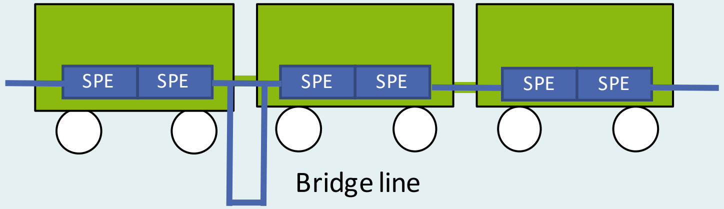
SPE

➔ **Evaluation of the max./sufficient segment length:** Communication established in available train segment of 5 wagons

➔ **Test with stub lines (up to 30m):** Insertion of a stub line caused a short link down -> link up event (may cause integrity fail)
Reason: The change of the physical communication channel leads to a new channel estimation procedure (0.5 – 1s)



➔ **Test with bridge lines (up to 30m):** Insertion of a bridge line caused a short link down -> link up event
Reason: The change of the physical communication channel leads to a new channel estimation procedure

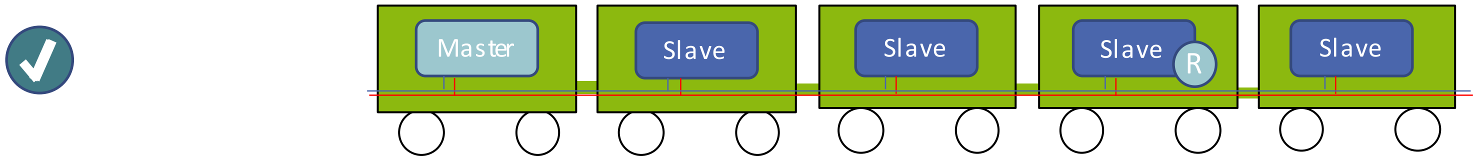


Stress Tests (Standstill)

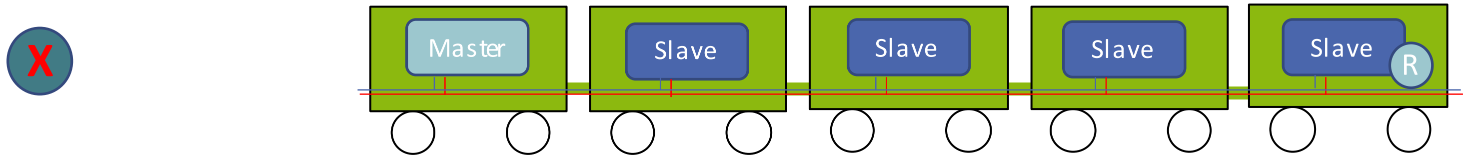
Powerline

➔ **Evaluation of the max. segment length without repeater slave**

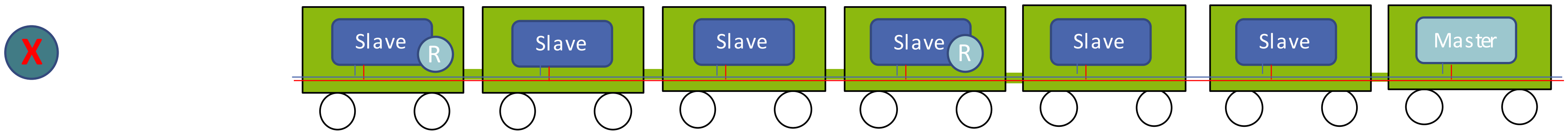
Forward Distance 3:



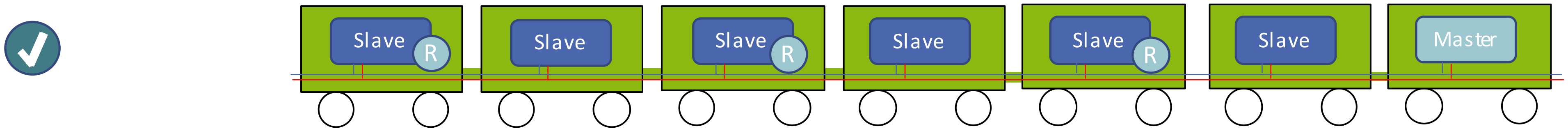
Forward Distance 4:



Forward Distance 3:



Forward Distance 2:

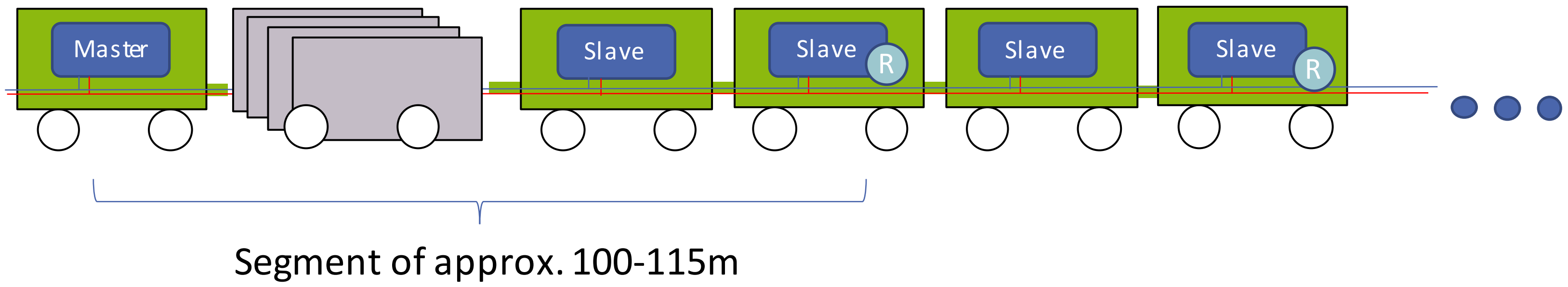


Stress Tests (Standstill)

Powerline

➔ **Long segment length in train composition with ballast wagons**

Forward Distance 2: ✓



- **All devices could be identified**
- **No communication problems found with insertion of a long segment**
- **Segment with ballast wagons equipped with 2x10mm² cable (EDDP proposed cable with twisted pair wires)**

Phase II – Communication Tests on Train Operation

Tests on Tracks

Demonstration of operational functions:

1. Train initialisation process to identify:
    - Count of wagons
    - Sequence of wagons (UIC wagon numbers)
    - Direction of wagons
2. Train integrity during train operation
    - Communication availabilty to the last wagon

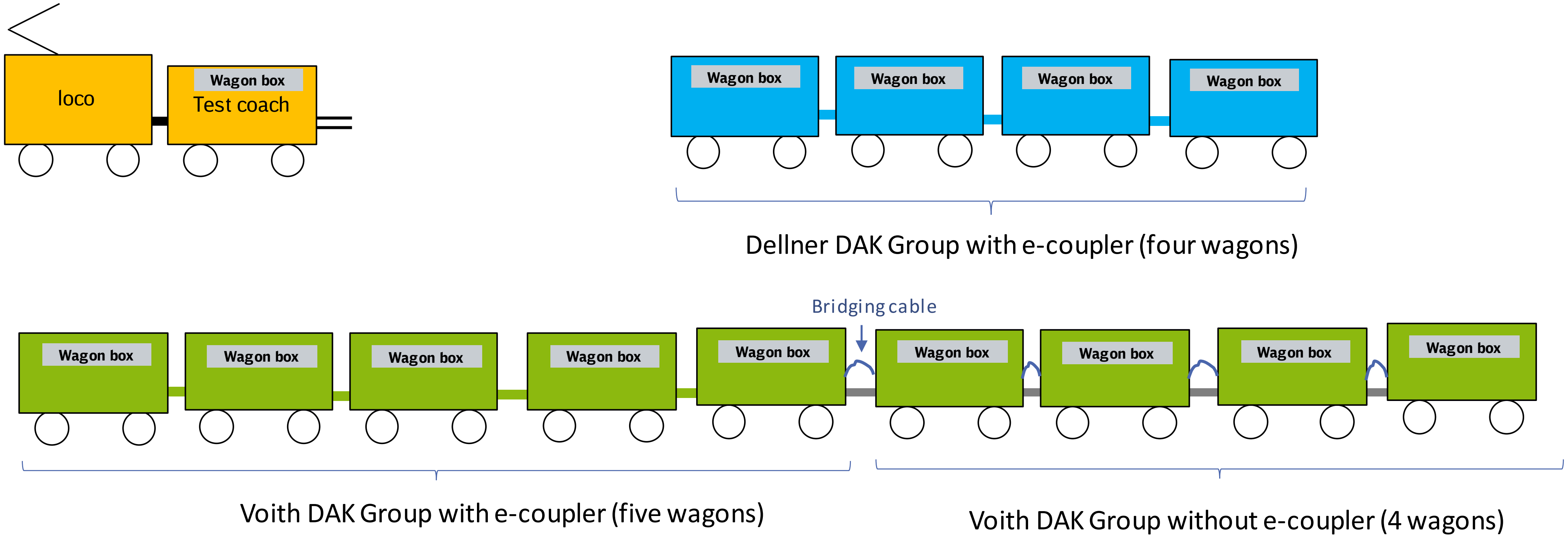
Availability of the communication systems

- Monitoring of packet error rates and temporary failures of the communication systems

Phase II – Communication Tests on Train Operation

Test Setup in Phase IIa with 13 Wagons

- ➔ Only changes of the position of the wagon groups between tests
- ➔ No changes inside wagon groups possible => Couplers always connected to the same opposite coupler partner



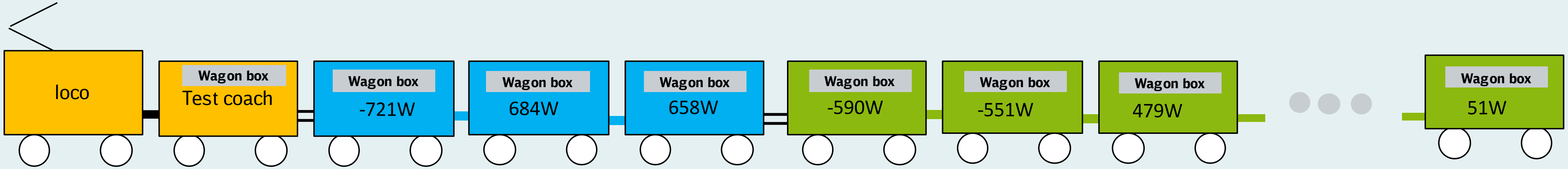
Operational Function

Train Initialisation

Detection of wagon count and sequence (SPE and WiFi):

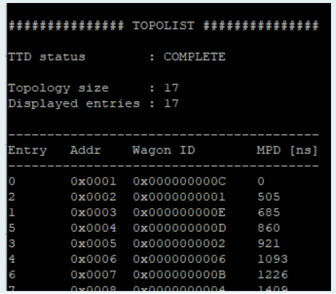
- Scan of the train via ICMP (Internet Control Message Protocol) to detect the count of the wagons
- Sorted wagon list derived from power values of the 110 V_{DC} powerline

Alternative solution:
Topology detection using TRDP (Train Redundancy Data Protocol)



Detection of wagon count and sequence in Powerline-PLUS:

- The Powerline-Plus generates a list of the wagons from internal detection function
- Sequence is derived from the signal runtime (with a minimum distance of 5 meters in the DAC4EU test setup between modems)



```
################ TOPOLIST ################

TTD status        : COMPLETE

Topology size     : 17
Displayed entries : 17

----------------------------------------
Entry   Addr    Wagon ID        MPD [ns]
----------------------------------------
0       0x0001  0x000000000C    0
2       0x0002  0x0000000001    505
1       0x0003  0x000000000E    685
5       0x0004  0x000000000D    860
3       0x0005  0x0000000002    921
4       0x0006  0x0000000006    1093
6       0x0007  0x000000000B    1226
```

Operational Function

Train Initialisation Test Result

<u>Detection of wagon count and sequence (used in SPE and WiFi):</u>

- Detection of wagon count (by ICMP) always functional as long as communication connection to the last wagon could be established

- Detection of the sequence based on power measurement in 40% of the initialisations wrong, reasons:
  => Inaccurate power sensors,
  => No synchronized power measurement with changing power over time
  ➔ *For SPE and WiFi the method defined in ETB (TRDP, IEC61375-2-5) should be considered*

- Detection of the wagon orientation (based on current flow direction) was working successfully.

<u>Detection of wagon count and sequence in Powerline-PLUS:</u>

- Generated list with **amount and sequence of wagons** was **correct** in all initialisation processes

WIFI Communication

WiFi Results – Tests on Communication Faults

Note: Tested **WIFI** system **different to** the EDDP WIFI on **short list**

Table of the WiFi communication results:

Test run	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Integrity fails	1	3	0	broken after 30 minutes	27	129	213	135	111	268
PER (%)	8,40	14,24	0	63,94	6,67	13,05	7,84	34,04	6,86	38,88

* Integrity fails are incremented on communication interruption for more than 900 ms

Two different fault scenarios could be seen for WiFi:

➔ Communication **interruption of few packets** (several 100 ms) up to **several seconds**

➔ Communication **interruption** for a **long period** (> 2 minutes)

➔ Later examinations showed that location of fault connections were changing between a few wagon connections. Some connections had a stable link without fails.

WIFI Communication

WiFi Results – Conclusions

- **Long** communication **interruptions** caused by special device mode (ACC) and **can be avoided** by using other smart technologies

- **Shorter** communication **interruptions** caused probably by **interferences** and partly by **instable devices**

⇒ **Radio communication** outside the coupler should not be considered due to the following aspects:

  - Interferences can cause burst packet fails,
  - Unsafe initialisation process: Links may jump over one or two wagons, especially in reflective environments. Detection of correct sequence and wagon count could not be guaranteed.

Removed from EDDP short list
=> **Testing of WiFi discontinued!**

Powerline PLUS Communication

Powerline Communication Tests

Table of the Powerline-PLUS communication results:

Test run	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
Integrity fails	0	0	0	0	0	0	0	0	0	no measures	0
PER	0%	0%	0%	0%	0%	0%	0.03%	0.02%	0.01%	no measures	0.02%

➔ **Stable** communication over **all tests**

➔ Tests after T6 showed occurence of single packet fails (no burst errors). The latency increased as well. This happened in timeslots where packet errors appeared

➔ PLC Integrated **integrity check** and additional integrity check (ICMP) **without malfunction**

➔ Monitoring of the 110V_{DC} supply voltage of the powerline showed few interruptions. This can lead depending on the interruption to a single packet fail on the powerline system

Single Pair Ethernet Communication

SPE – Communication Tests Phase II

Table of the SPE communication results:

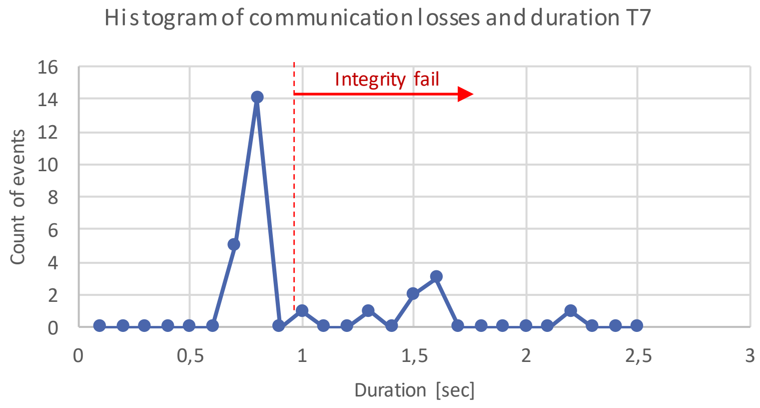
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
Integrity fails*	0	0	0	0	0	1	83	16	86	19	1
PER (%)	0.008	0.107	0.027	0.033	0.015	0.411	2.762	1.267	2.341	0.624	0.042

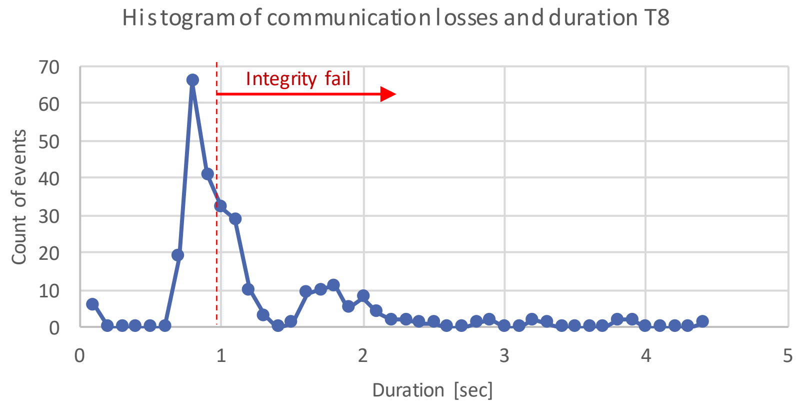
* Integrity fails are incremented on communication interruption for more than 900 ms

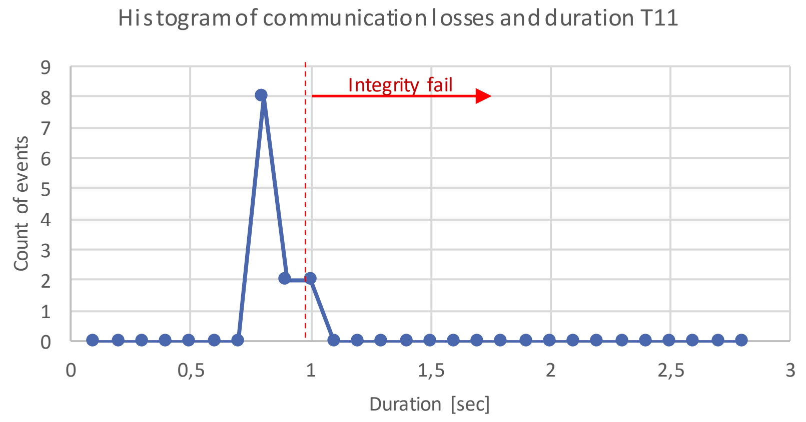
➔ **Massive communication** problems **started** at tests with **T7**

➔ Assumption, that one or several wagon connections caused the problems

➔ With test T8 a new function was integrated to detect the point of failures







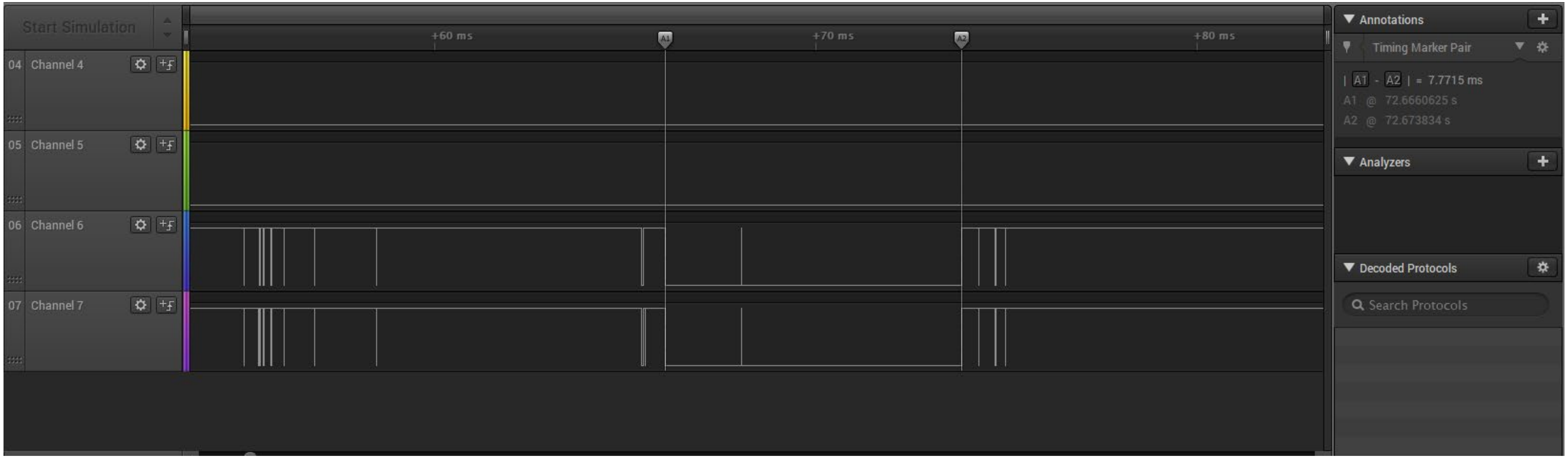
Contact Monitoring

Monitoring with Logic Analyzer

➔ Tests with logic analyzer at four couplers

➔ Massive measurement errors (very short peak interruptions with a duration of 1 µs and below)

➔ Nevertheless, few interruptions on one coupler could be seen with intervals from 3 ms to 19 ms



Contact Monitoring

Monitoring with Current Loop Through all Wagons

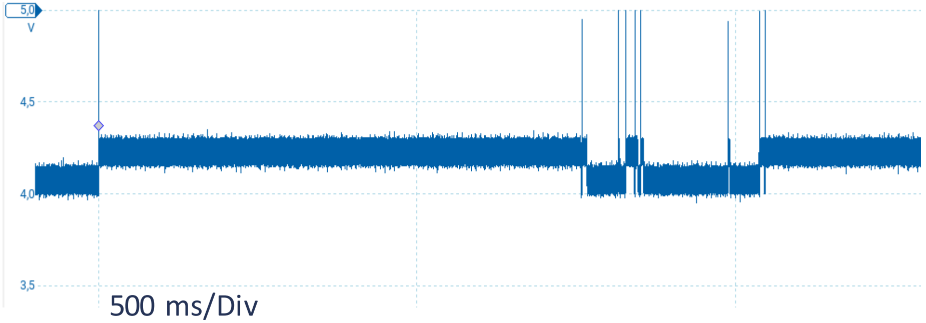
<u>Measurement idea:</u> Monitoring of all coupler connections on communication line (with location tracking of the interruption)

➔ Second two wire line connected in the wagon boxes to get connected line through the train

➔ Resistor installed in each wagon between the two wires

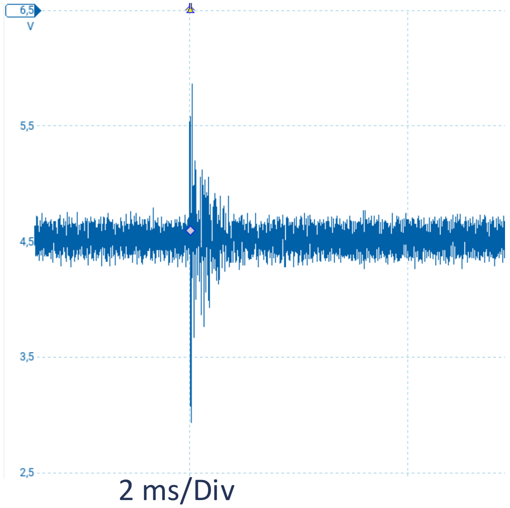
➔ Measurement of the current with an oscilloscope (by shunt resistor) should show the length and location of interruptions

<u>Expected result:</u>



<u>Result:</u>

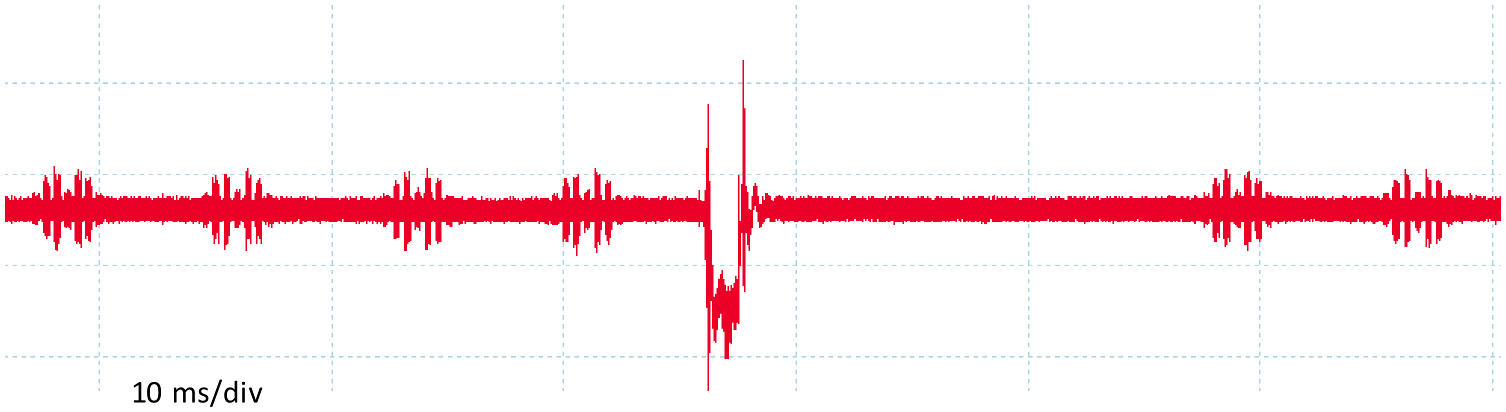
- **No** (long) **interruption** on communication pins could be seen
- Sporadic **distorsions** on the line, but very **short pulses**
- Distorsions can often be seen after **train vibrations**, but also in standstill
- <u>Assumption:</u> Crosstalk from the powerline to the data bus line at specific wagons



Contact Monitoring

Monitoring on a Specific Wagon

<u>Measurement:</u> Scope monitoring of the 110 V_{DC} powerline contacts



Result:

- In a few cases a contact failure on the powerline pins could be seen (2 ms)

Data Communication Tests

Conclusions

➔ The Powerline-PLUS system works in the DAC4EU train composition well:

- ➔ The **detection** of the **position worked well**
- ➔ Robustness: **Stable** communication **to the last wagon**
- ➔ Using the Repeater **Forward Distance of 2** always **worked**. A **higher forward distance of** repeater slave **caused problems** and may be **reached** on using **EDDP proposed cabling** (integrated cables with constant wave resistance)

➔ SPE-Communication is less reliable:

- ➔ **Problems** regarding the **stability** of the communication must be investigated. In some testcases the **contact problems** at the couplers seems to be the **problem**, in latest tests distorsions on the communication line may lead to packet losses
- ➔ Robustness (distorsions): Adaption to filters inside the single pair ethernet device may lead to better resilience
- ➔ If **contact failures** in the couplers appear for **more** than **several 100 µs**, SPE loses the synchronisation and needs to **reinitialize** the link for **500 ms -3 seconds**. This is an **issue** for **safety** relevant **functions**!

DAC4EU

Bundesministerium
für Digitales
und Verkehr

Thank You!

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