

# Powerline Communication for Freight Trains

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CC Intelligent Sensor Networks (ISN)

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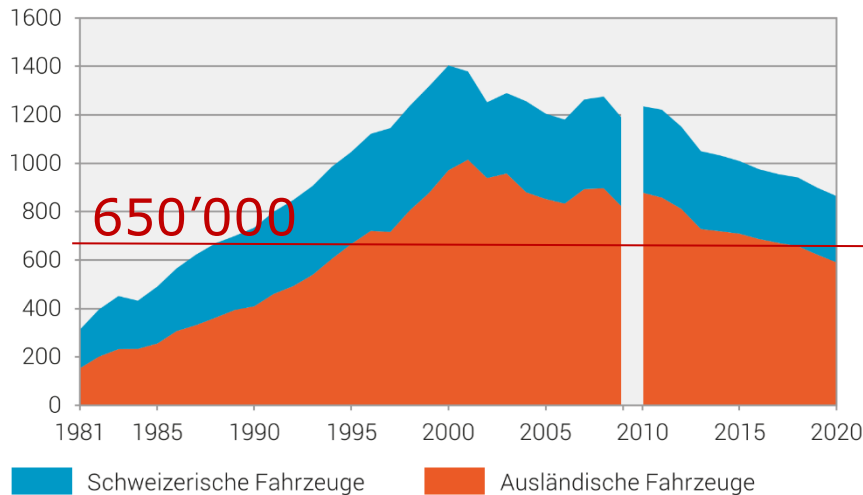
# The «Alpen-Initiative»

- 1994: Alpenschutz-Artikel in Constitution
- 1999: Verkehrsverlagerungs-Gesetz

## Alpenquerende Fahrten im Strassengüterverkehr

Anzahl Fahrten schwerer Strassengüterfahrzeuge in der Schweiz

Tausend Fahrzeuge



Methodenwechsel: Ab 2010 werden die Kontrollstationsdaten der Leistungsabhängigen Schwerverkehrsabgabe verwendet (bis 2009: Daten der Schweizerischen automatischen Strassenverkehrszählung).

Quelle: BAV, ASTRA – Alpenquerender Güterverkehr

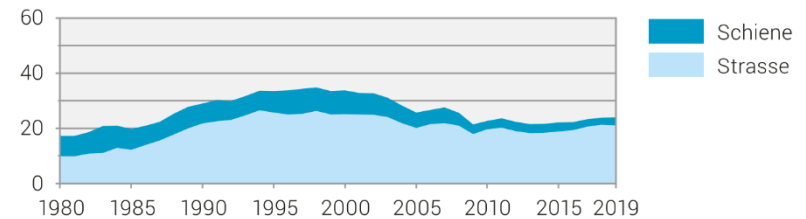
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## Beförderte Mengen im alpenquerenden Güterverkehr

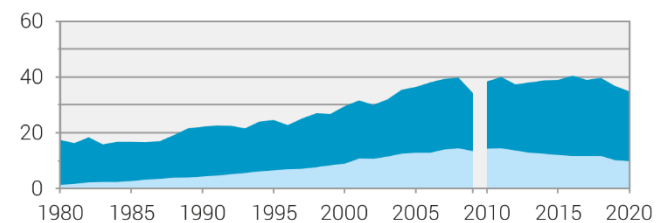
Alpensegment: Mt. Cenis/Fréjus bis Brenner

Millionen Nettotonnen

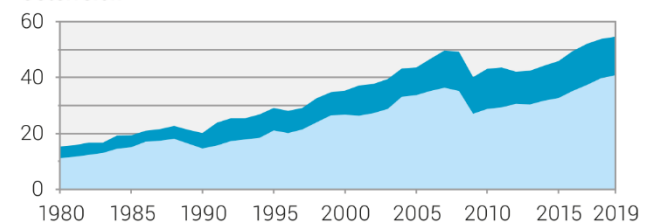
Frankreich



Schweiz<sup>1</sup>



Österreich

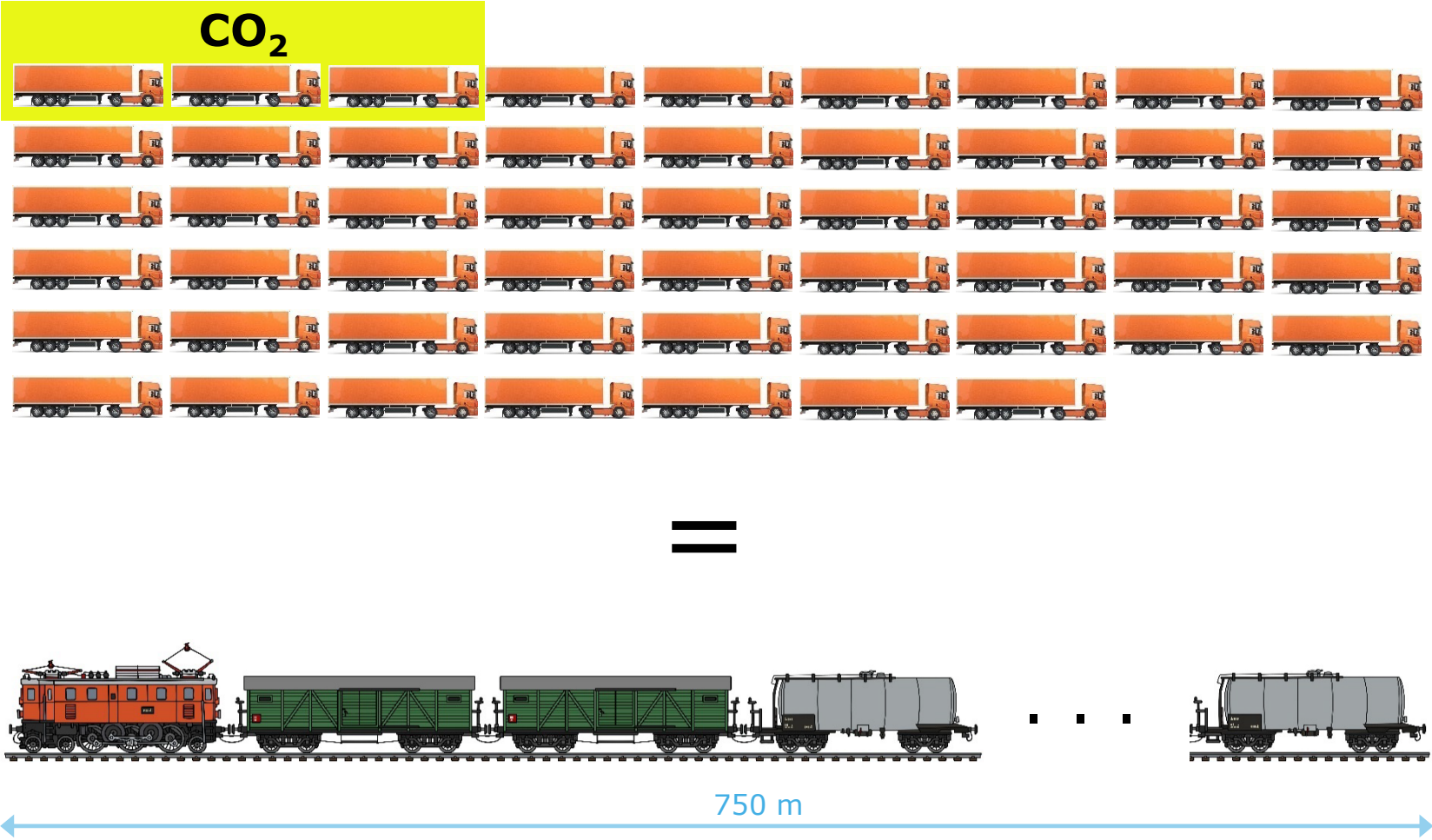


<sup>1</sup> Methodenbruch im Strassengüterverkehr: Ab 2010 werden die Kontrollstationsdaten der Leistungsabhängigen Schwerverkehrsabgabe verwendet (bis 2009: Daten der Schweizerischen automatischen Strassenverkehrszählung).

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# Truck vs. Freight Train



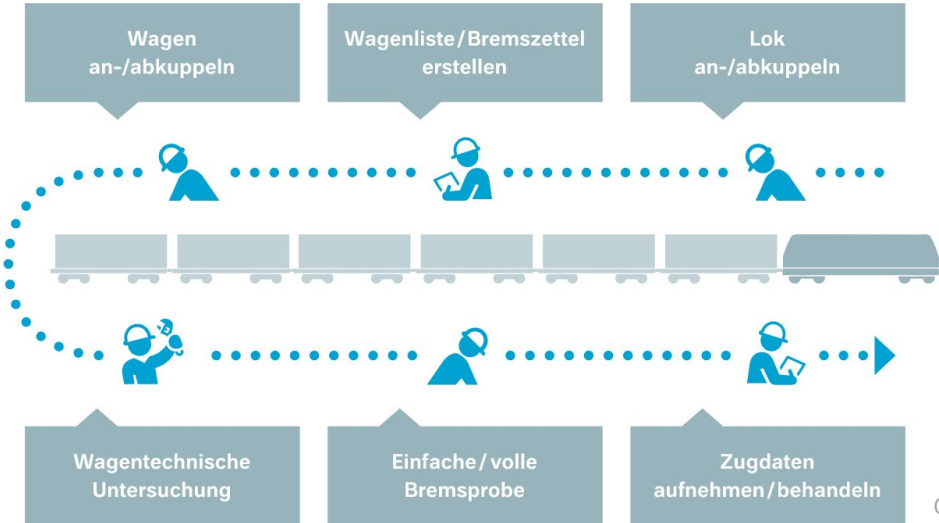
# So why not use more freihit trains?

Quelle: DAC4EU [3].

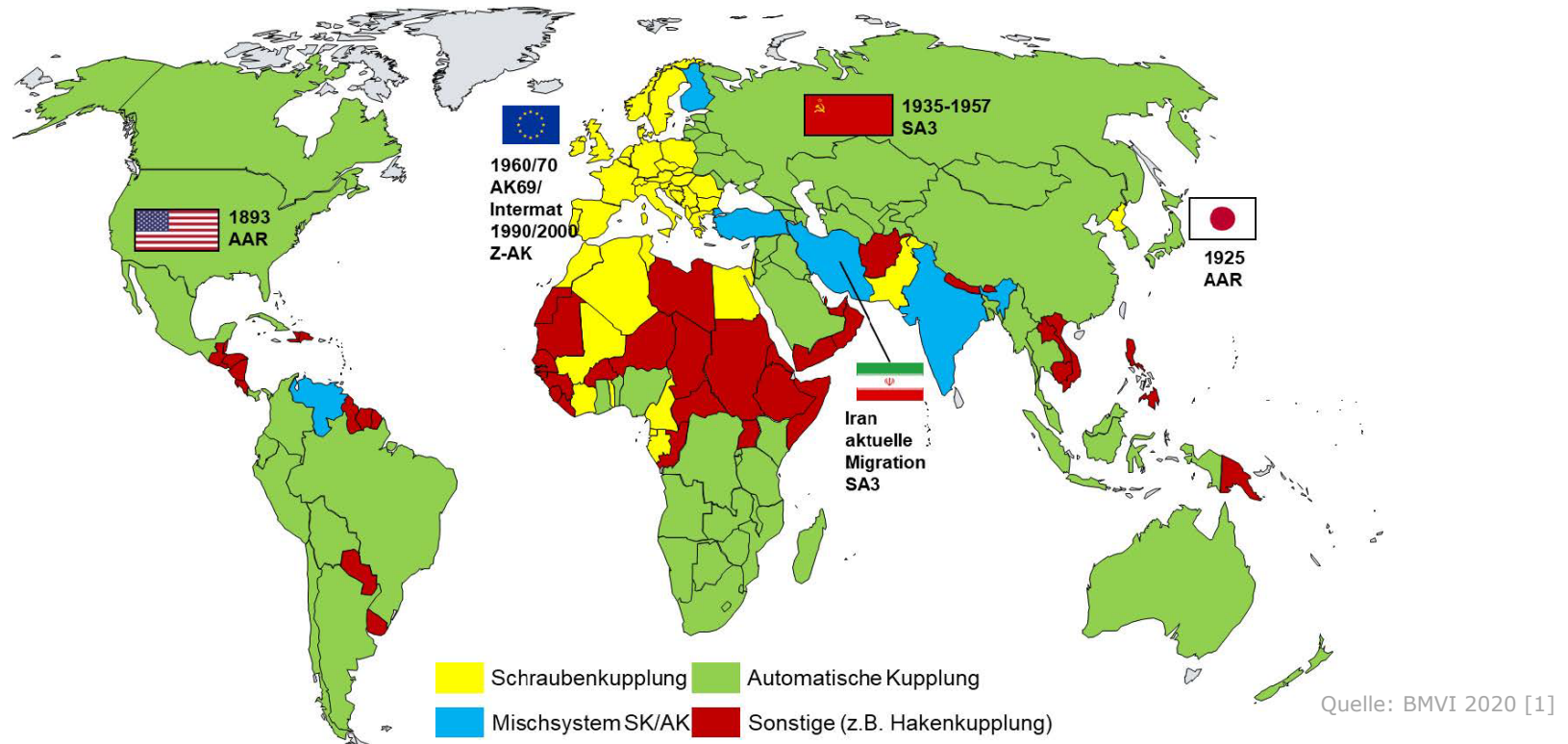


Early 20<sup>th</sup> Century

Early 21<sup>st</sup> Century

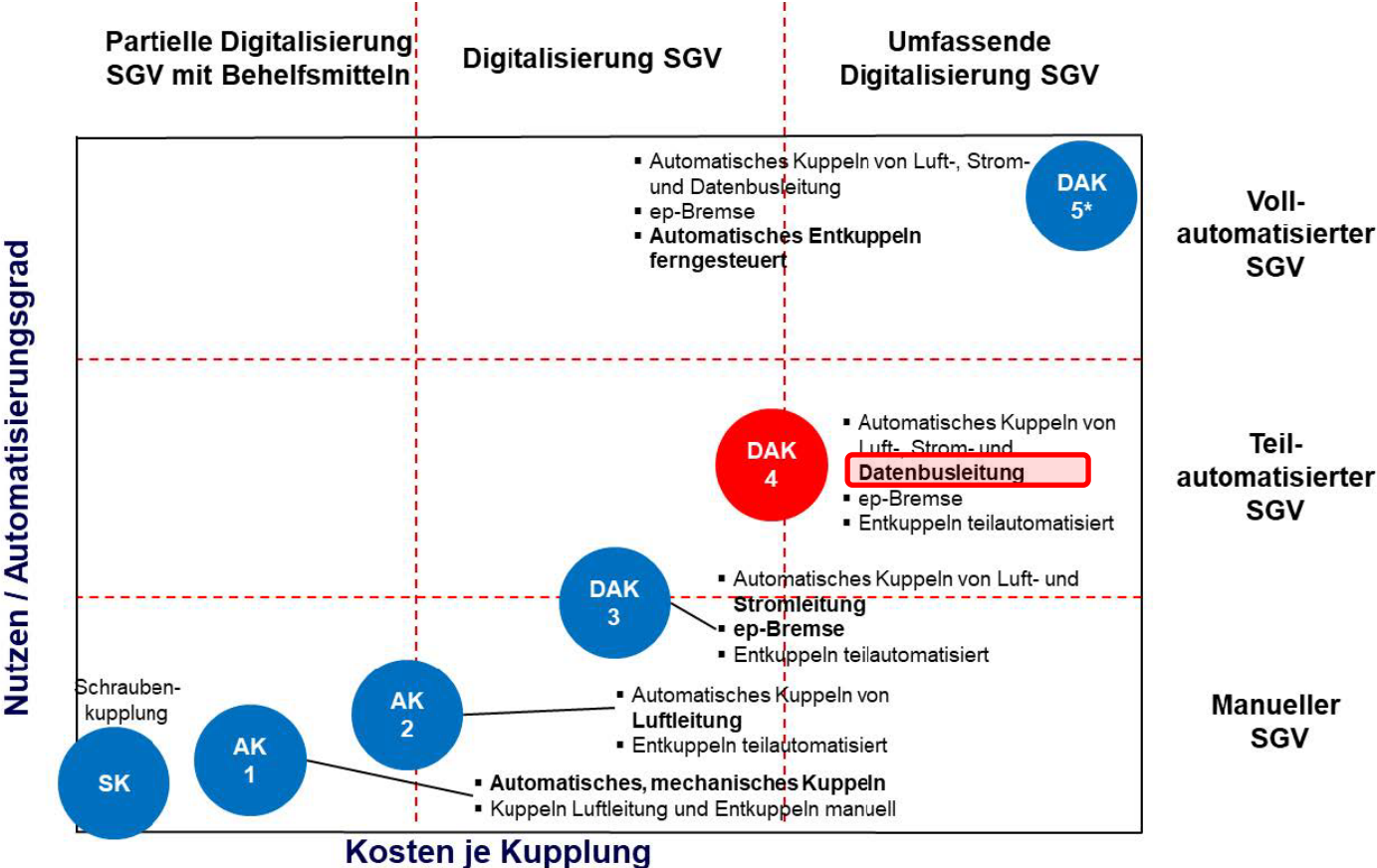


# The World-View



- Europe last continent without any form of automatic coupling for rail freight
- Chance: First continent with **Digital** Automatic Coupling (DAC)

# Automated Coupler Types



Quelle: BMVI 2020 [1].

# Benefits of DAC for Freight Trains



Quelle: S. Hagenlocher [2]

## Why not just re-using couplers from passenger trains?

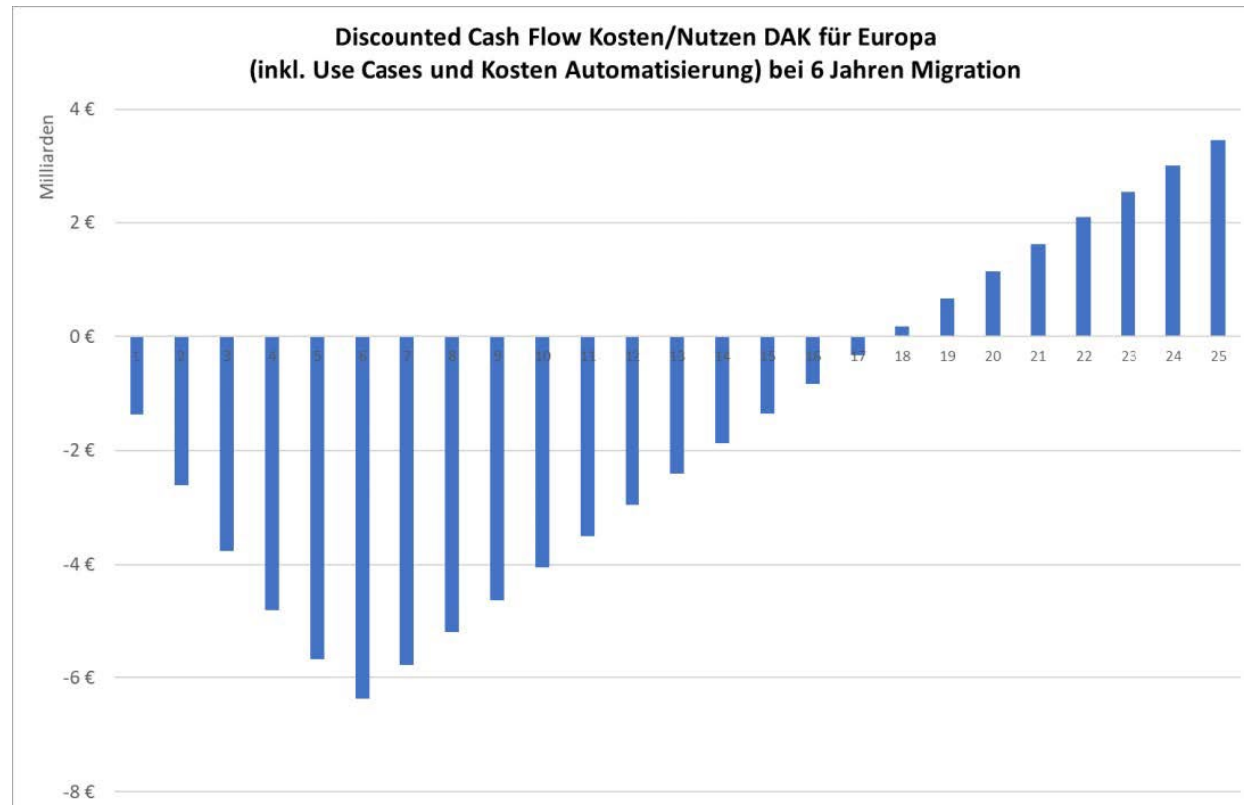


Main challenges:

- Reliability
- Price



## Cost/Benefit Analysis



Quelle: BMVI 2020 [1].

- Upgrade ca. 480'000 wagons over 6 years
- Build 8'000 new wagons each year
- Total Estimated Migration Cost: 8.5 Mrd. €

## Reliability

- Electrical Contacts in e-coupler considered most critical point
- Minimize # of systems that require electrical contacts
- Increase contact redundancy
- Re-use power distribution contacts for communication → PLC !?

Before

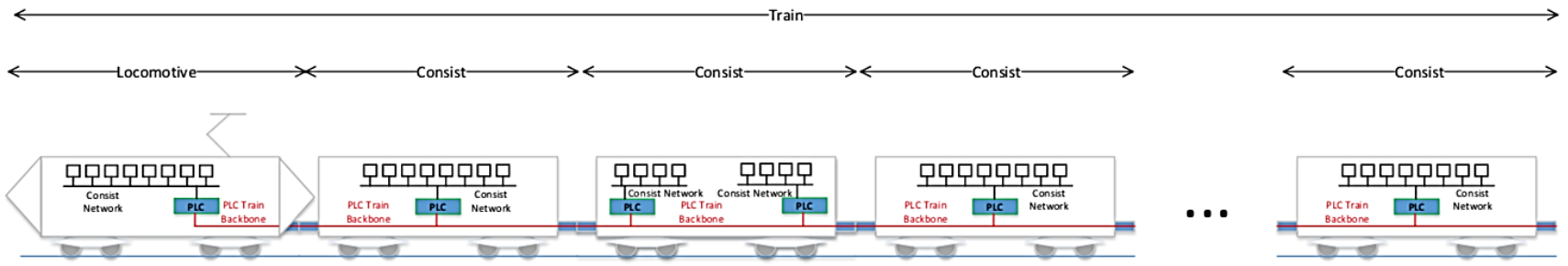


After

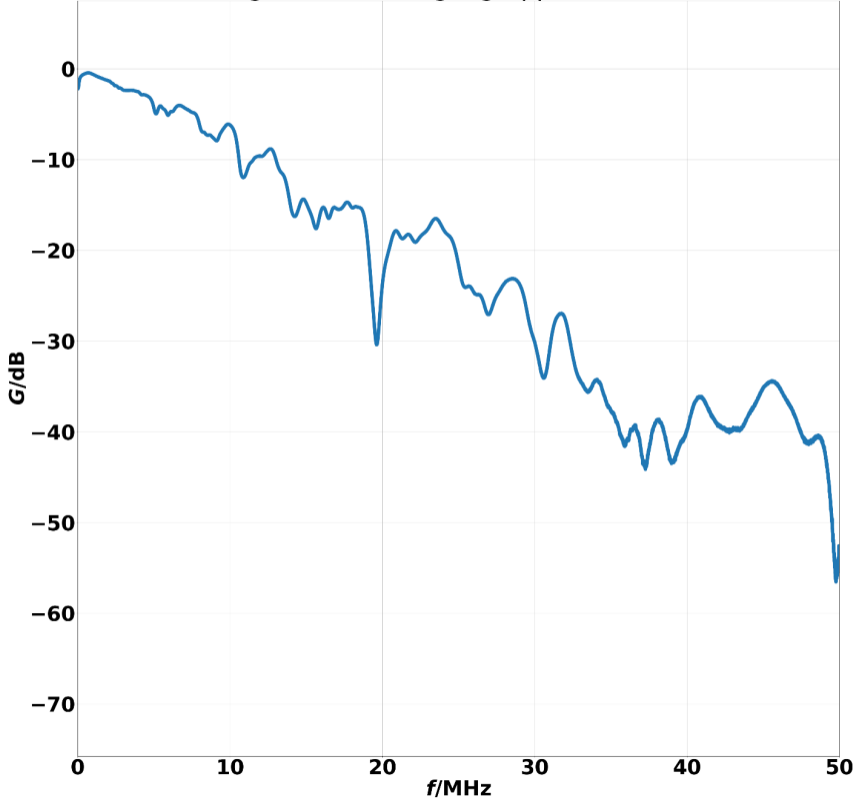
(a few sunny-day couplings)



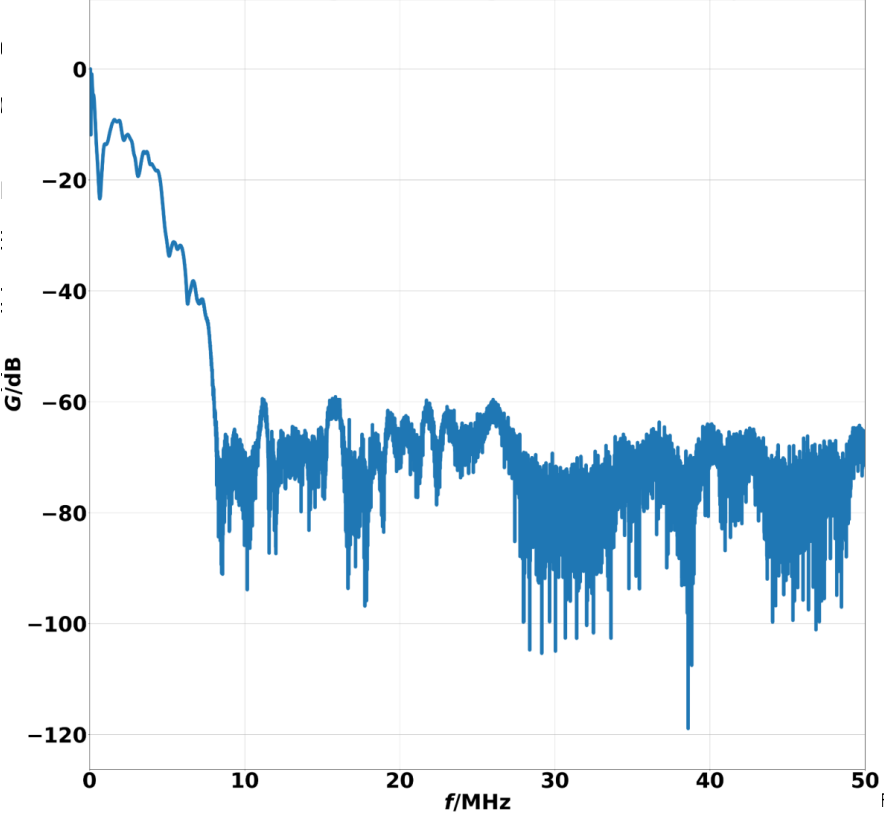
# PLC Train Backbone



02.Jul.2021.15.13, SITE B, S21, Dellner Zags--EANOS, Wagengruppe, Powerline

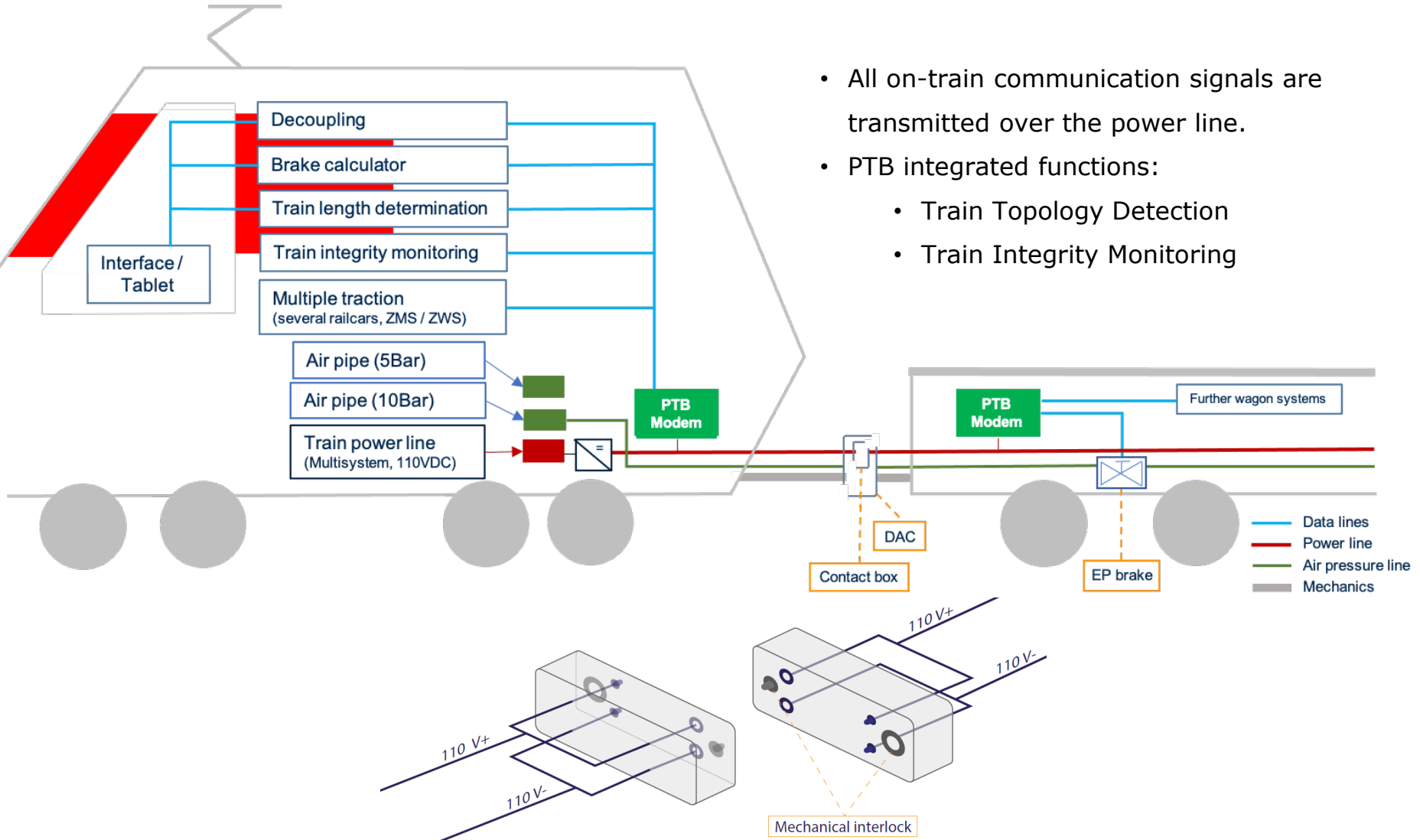


09.Jul.2021.11.05, SITE E, S21, Gesamtzug Gesamtzug, Gesamtzug, Powerline o. Komp.



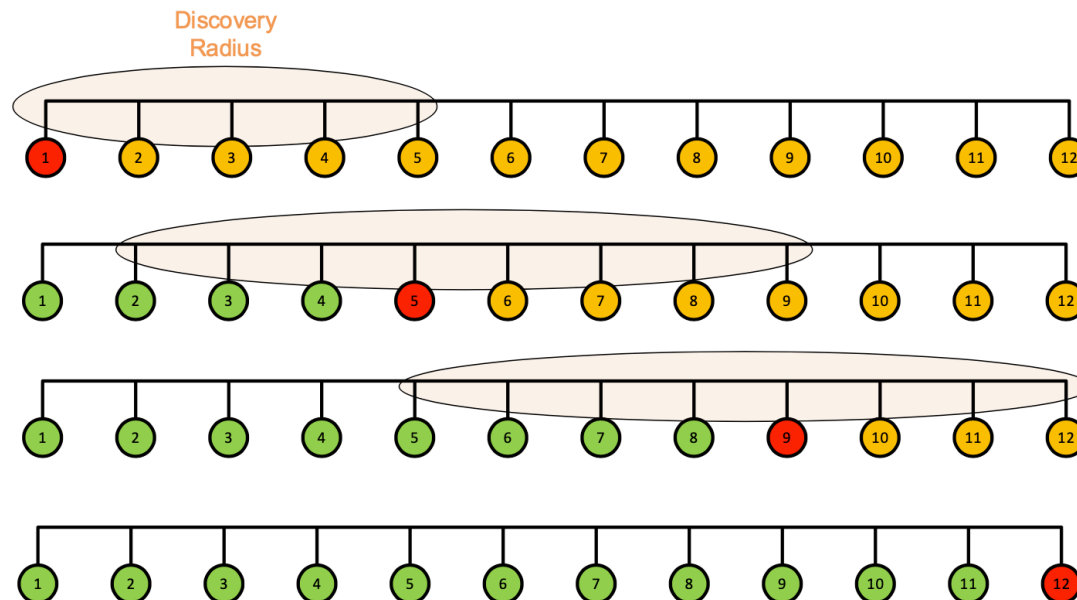
# PTB Use Cases

- All on-train communication signals are transmitted over the power line.
- PTB integrated functions:
  - Train Topology Detection
  - Train Integrity Monitoring

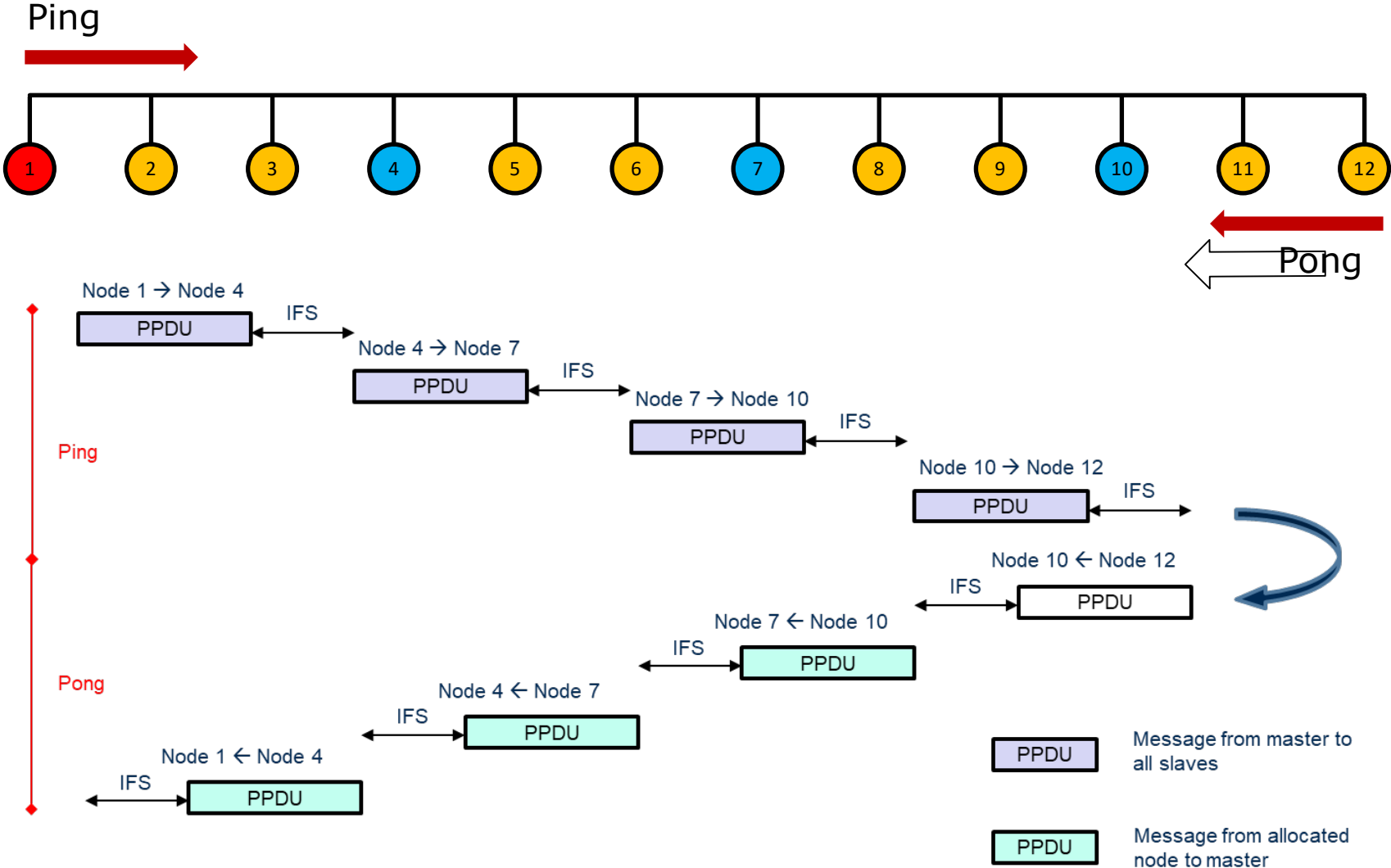


## Train Topology Detection

- Detect wagon order after train has been mechanically coupled
- Assign each wagon a logical address based on its position in the train
- Time-based method for Train Topology Detection (TTD)
  - Distance between wagons is estimated using time-of-flight of PLC signal
  - Currently a distance accuracy of ca. 5 m is achieved
  - Completes in less than 5 seconds for 50 wagons

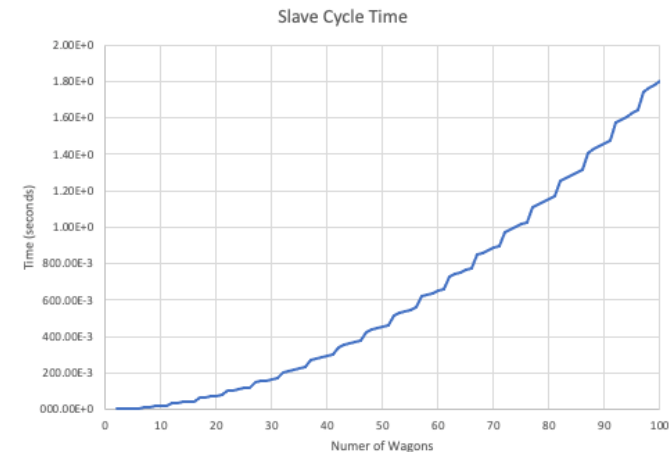
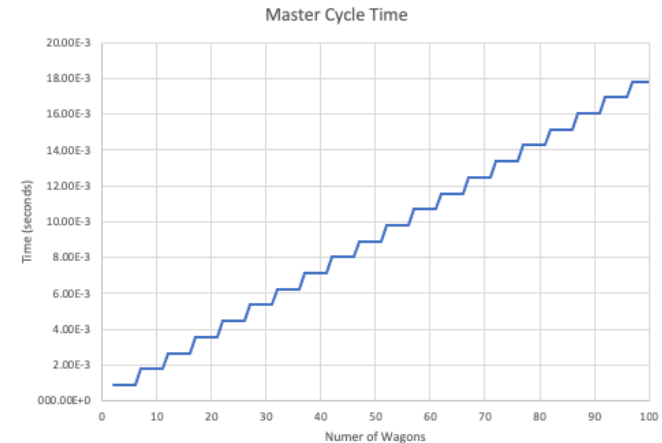


# PTB-TOKEN Protocol

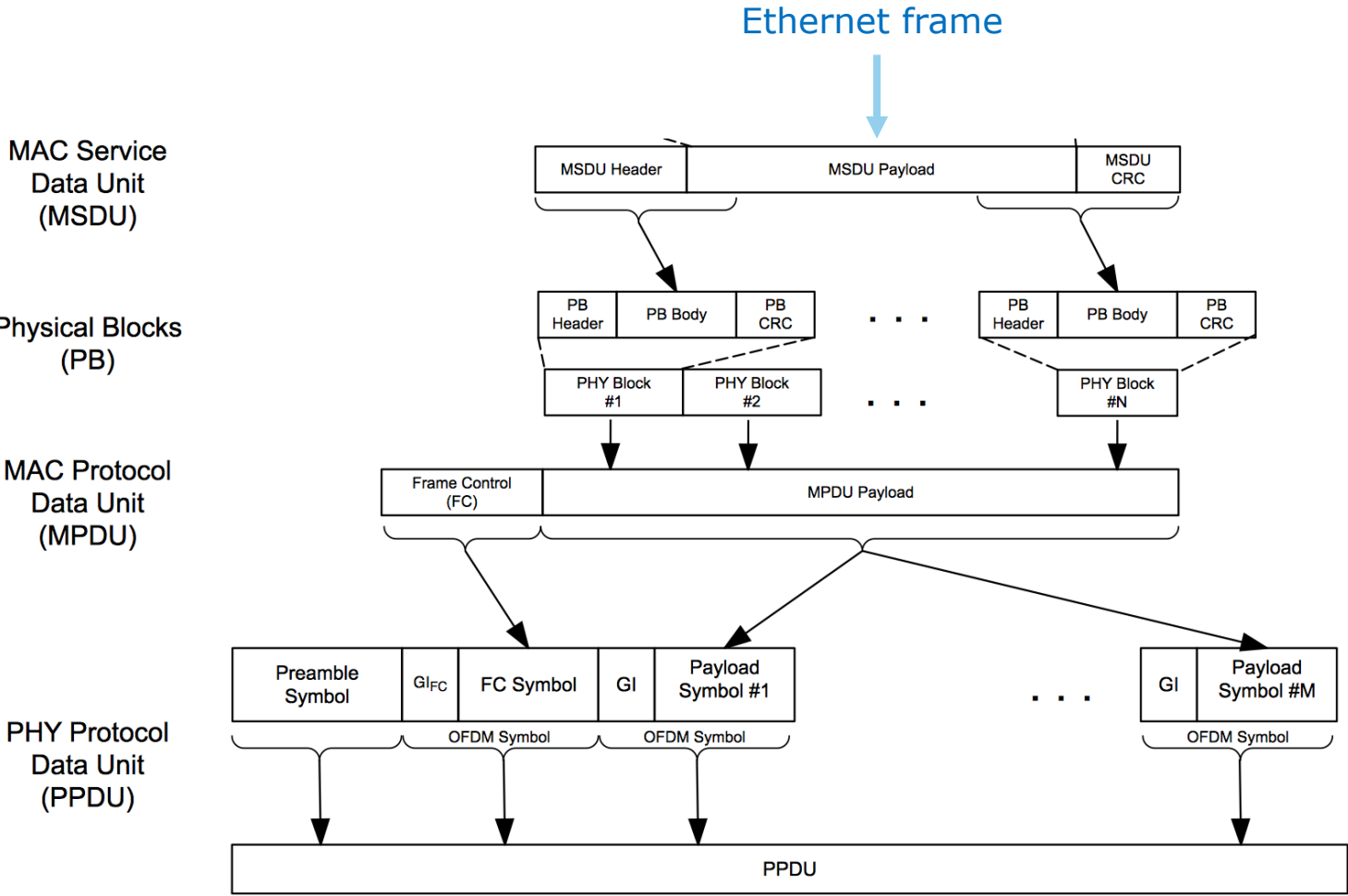


## PTB Performance

- PTB performance depends on many parameters
  - Distance between forwarding nodes
  - Duration of PLUS PHY Protocol Data Unit (PPDU)
    - size of the application payload data (e.g. Ethernet frame)
    - the transmission frequency band used by physical layer
- **Deterministic master and slave cycle times**
- Typical values for 50 wagons
  - Master cycle: 10 ms
  - Slave cycle: 500 ms
- Prioritized slave scheduling possible (e.g. last wagen)



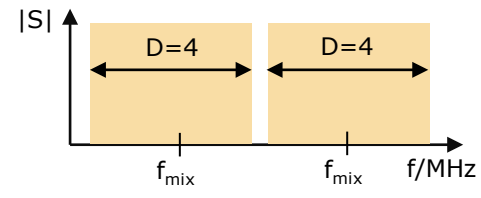
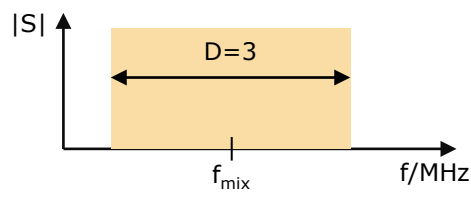
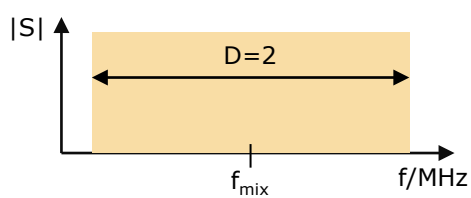
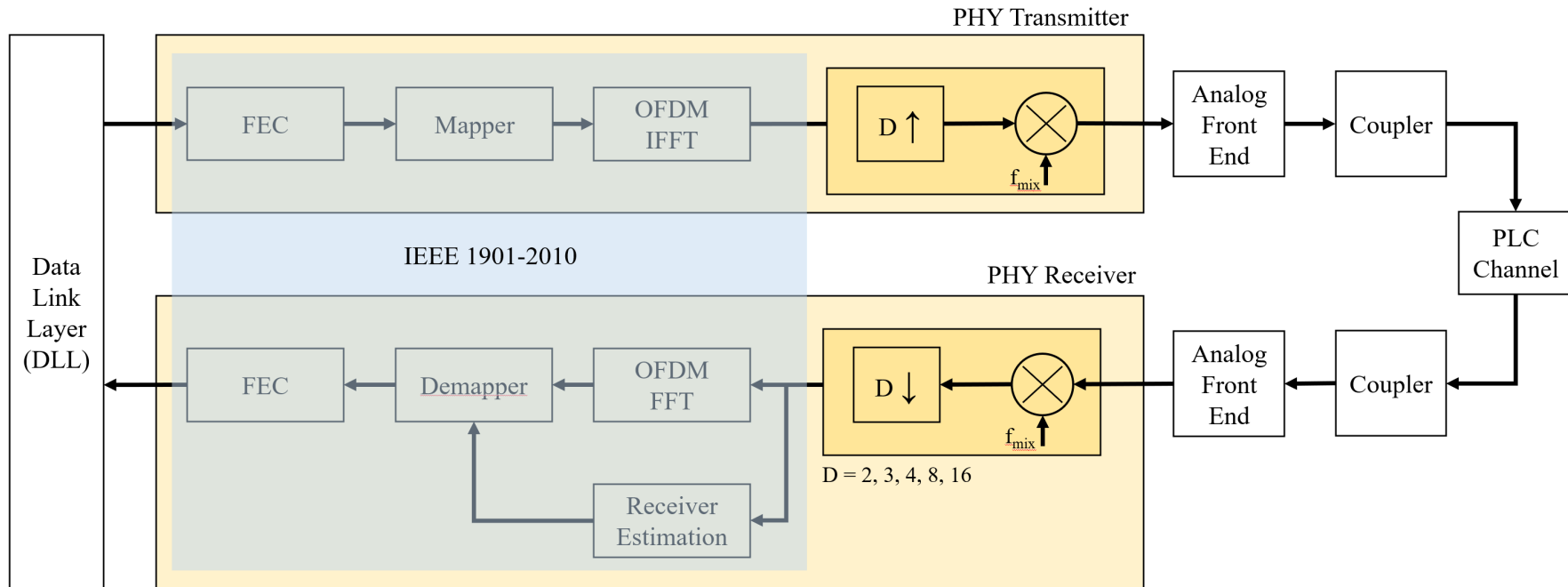
# PTB Layering





# Physical Layer

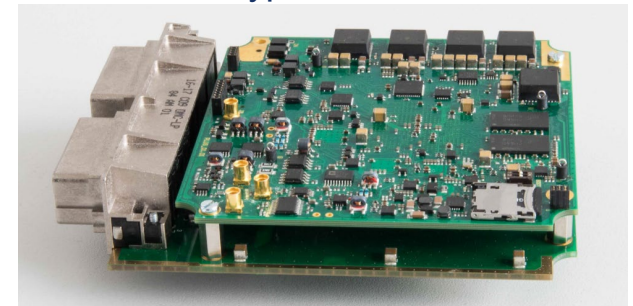
- OFDM physical layer according to IEEE1901 with configurable transmission frequency band



## PTB Modem Prototypes

- Evolutionary modem hardware platform
- Prototype Platform v1
  - separate modem- and baseboard
  - Xilinx Zynq SoC (VHDL + SW)
- Prototype Platform v2
  - Single rigid-flex PCB
  - Microsemi PolarFire FPGA (VHDL)
- Capacitive PLC coupler (up to 540 V)
- CAN and Ethernet data interfaces

Prototype Platform v1



Prototype Platform v2



## Status and next steps

- European DAC Delivery Program (EDDP)
  - 8 WP's on-going (use cases, technical specification, cost analysis, migration, ...)
- DAC4EU Testing (BMVI D)
  - Phase 1: Static wagon groups
    - PTB tested successfully over 12 wagons
  - Phase 2: Moving train with up to 24 wagons
    - Feb / Mar 2022: test drives in A / CH
- BAV Project: CH-Evaluation DAC
  - Dedicated Test train with SBB-C



Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra

## Sources

- [1] Erstellung eines Konzeptes für die EU-weite Migration eines Digitalen Automatischen Kupplungssystems (DAK) für den Schienengüterverkehr - Abschlussbericht. hwh Gesellschaft für Transport- und Unternehmensberatung mbH, 29.06.2020.
- [2] S. Hagenlocher. Erstellung eines Konzepts für die EU-weite Migration eines digitalen automatischen Kupplungssystems für den Schienengüterverkehr. 10. VPI-Symposium, Hamburg, 14.01.2020
- [3] Digitale Automatische Kupplung im Schienengüterverkehr. DAC4EU. <https://www.dac4.eu/>
- [4] Technischer Innovationskreis Schienengüterverkehr. <https://tis.ag/3-intelligenter-gueterzug/>