5G-PICTURE

Ensuring Session Continuity for Railways Using a Stateful Programmable Data Plane

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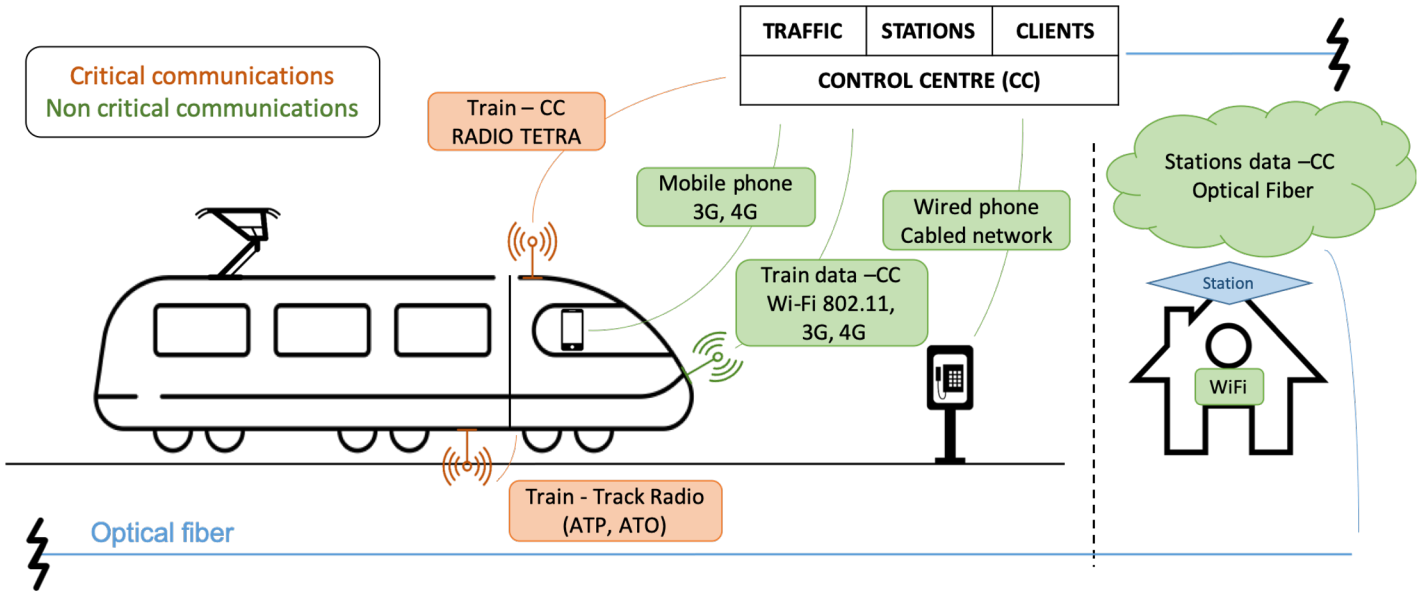
5G PPP

Scenario

Rail use case

- FRMCS defines three service categories: (i) critical, (ii) performance and (iii) business services
  - Critical services are expected to run over critical spectrum and dedicated railways 5G infrastructure
  - Performance and business services may run either over dedicated infrastructure or over a 5G slice leased from an MNO
- Legacy approach: different standards for each type of service



Railway use case - Evolution to 5G

- Desired approach
  - 1 multi-tenant Train Access Network
  - Different wireless access network technologies transparently aggregated
  - Network slicing
- Moreover, it is unclear that traditional cellular network models can efficiently support evolution to 5G along main railways paths
  - Low or no traffic from other demands
  - Traffic demand from train is instantly high but moves fast between sites
  - 5G at higher frequencies requires more sites
- Merging different services on the same network results in cost saving and development simplification

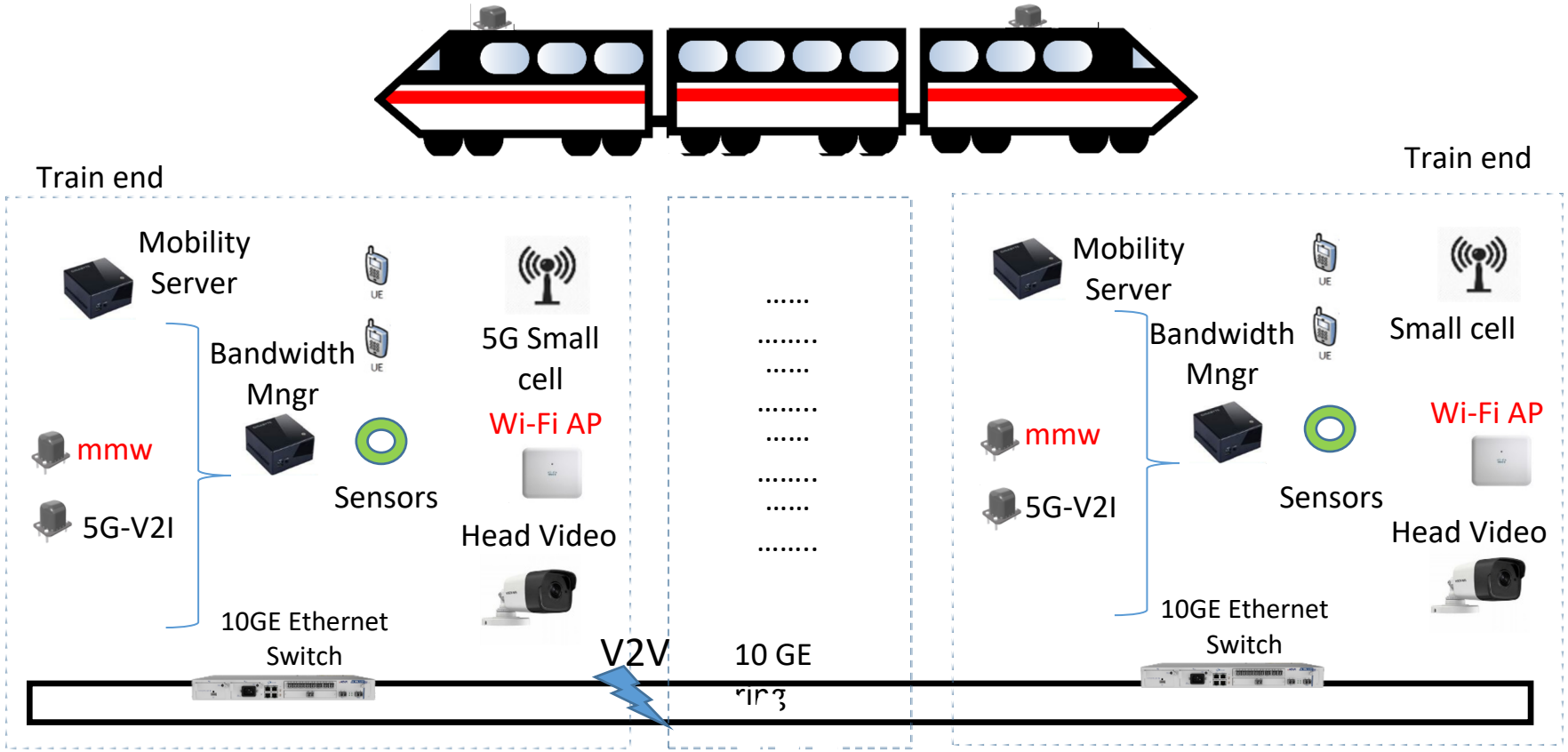
5G-PICTURE proposed a 5G network model
for performance and business services
under a multitenant approach in railway scenarios

High Performance Solution Architecture

High Performance Solution Architecture

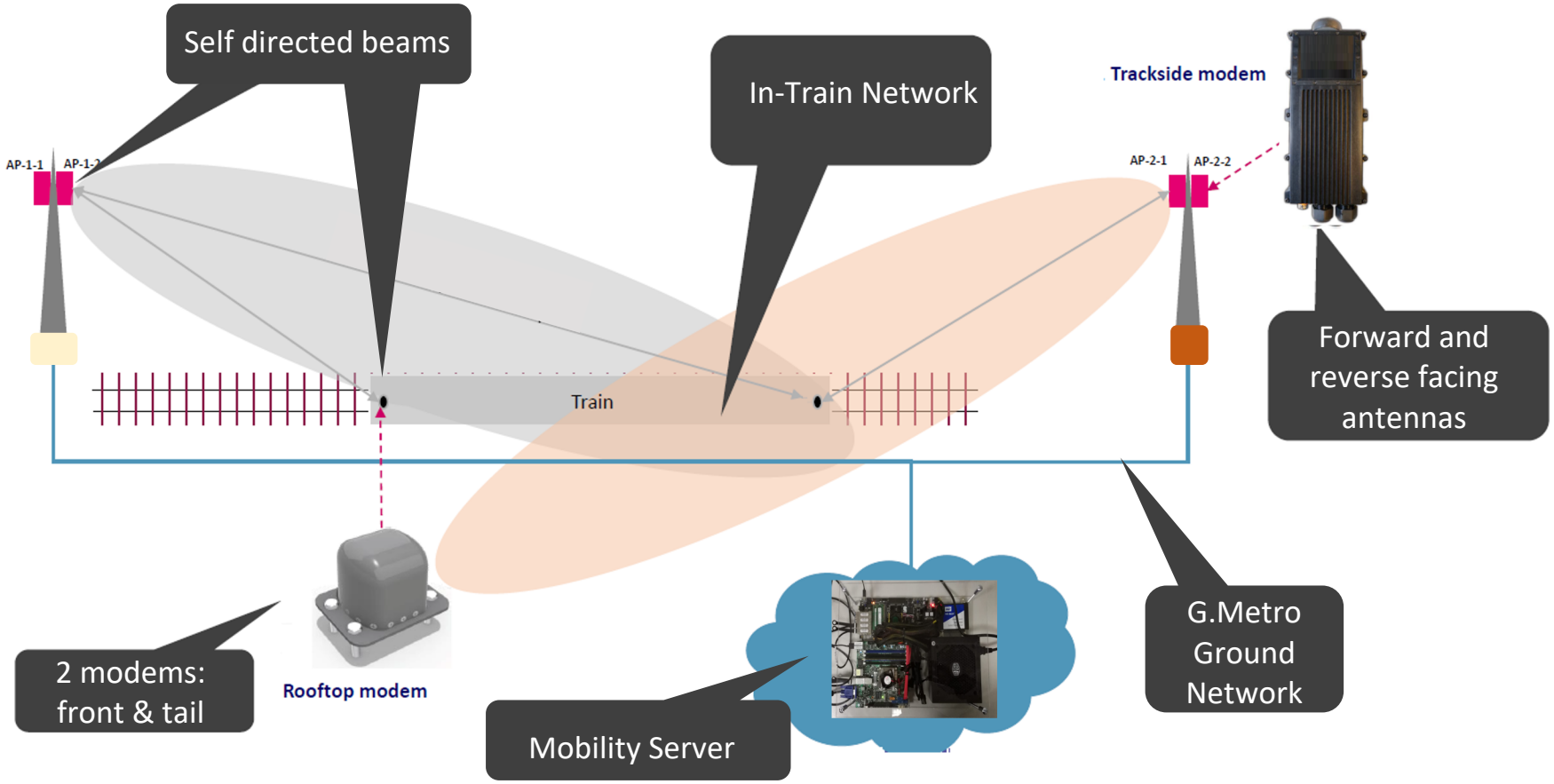
Moving wireless access inside train owned by train or telco operator

V2I networks owned by railways administrator or telco operator



Multitenant multi-technology approach to facilitate 5G deployment in railways

High Performance Solution Architecture mmwave RAN



- +1 Gbps throughput
- ~1ms e2e latency
- Precision time synchronization

Low TCO multi-service network to facilitate 5G deployment in railways

The mobility problem

- mmWave connections: high throughput V.S. limited range
  - extremely fast network handover solution is required
- Transport session continuity challenge
  - The network must dynamically track current active paths to the train
- Several solutions taken from other domains could be used
  - (e.g. mobility IP [5] or multi-path TCP [6]),
- The stringent requirements suggest to develop an ad-hoc solution for this problem

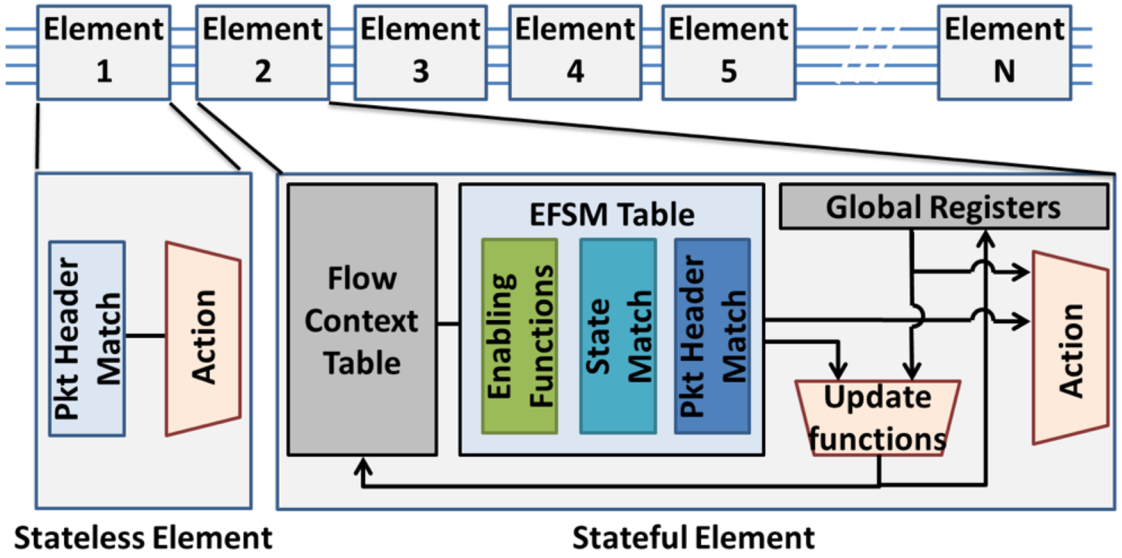
Design Challenges

- ***Location tracking***
  - which of the antenna nodes is able to forward traffic
- ***Flow redirection***
  - all active flows should be redirected to the new point of attachment
- ***Controlled flooding***
  - packet duplication improve performance

Data plane reverse path learning with FlowBlaze

Proposed solution: a layer-2 programmable data plane solution based on **FlowBlaze** (Pontarelli et al., Usenix NSDI '19):

- Stateful network processing
- EFSM executed in the fast path
- Programmed via XL DSL
- HW implementation (NetFPGA)



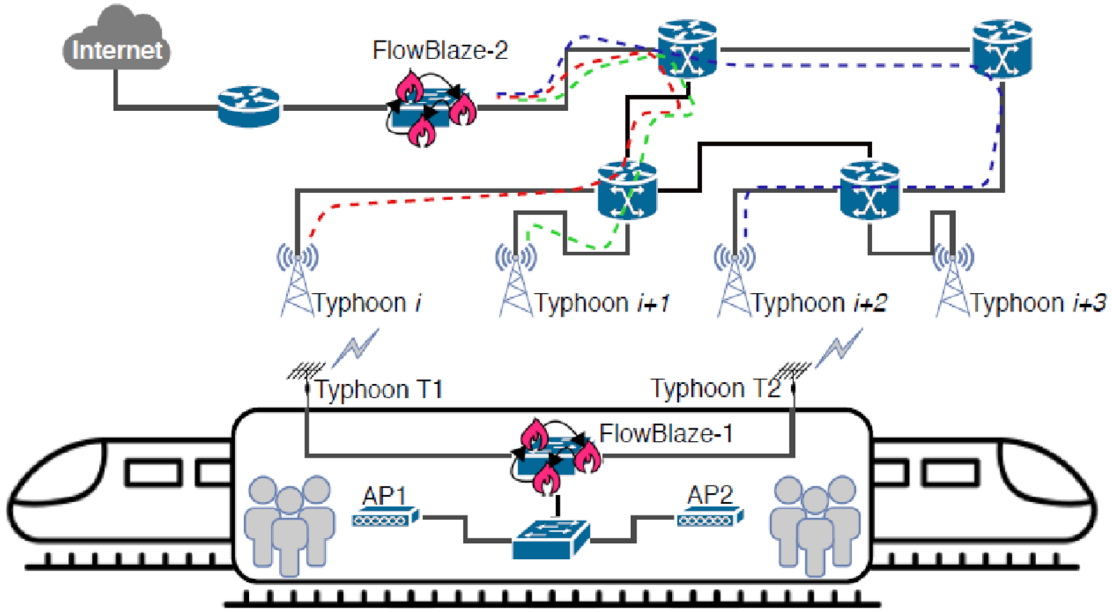
Data plane reverse path learning with FlowBlaze

2 FlowBlaze (FB) nodes:

- Node FB-1 (in-train): period probing
- Node FB-2 (CO): VLAN reverse path learning

Optimization: packet duplication to reduce handover time (both directions)

  - duplicates MUST be identified and discarded



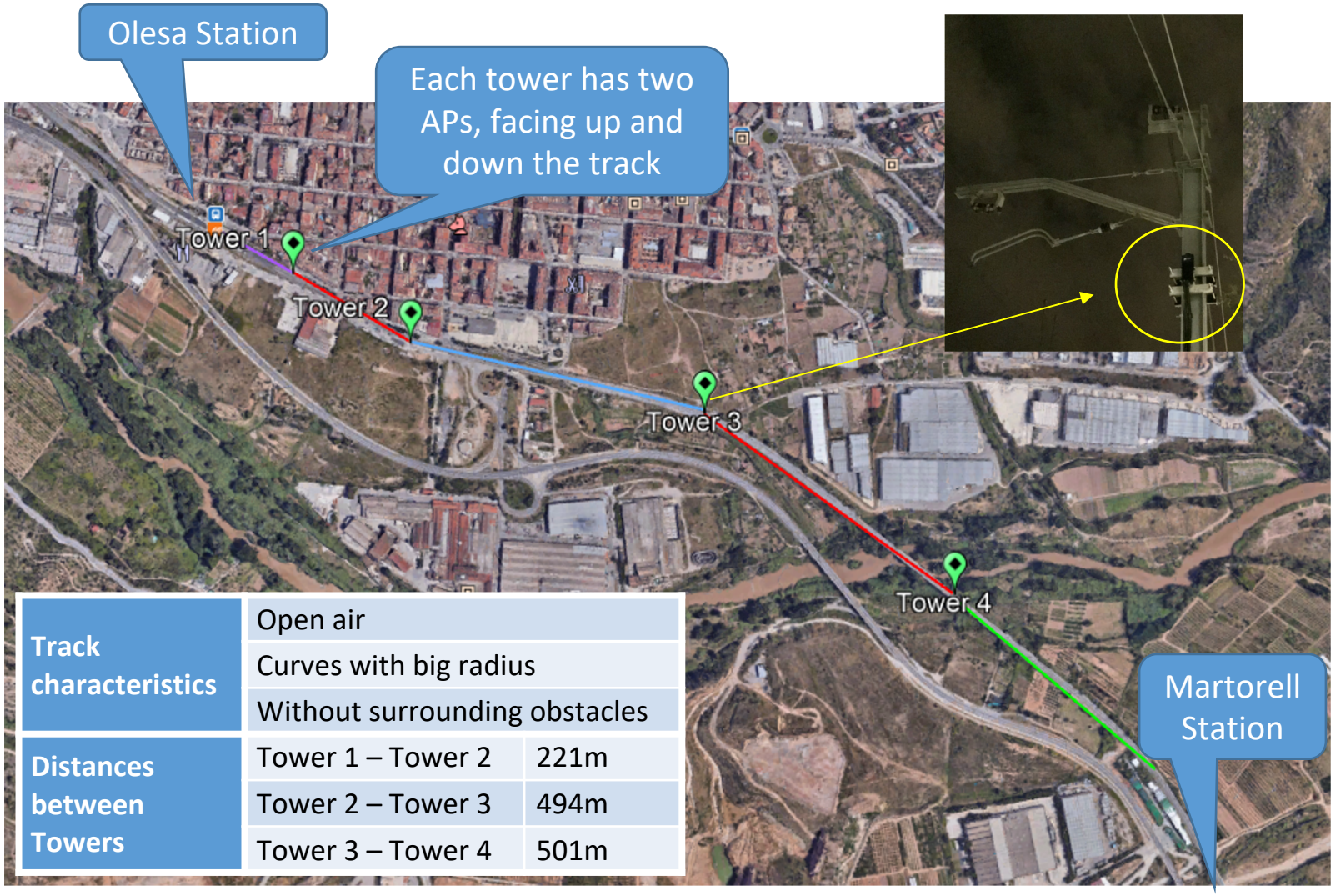
Trial Network Design

Trial Wireless Network Design

Radio planning guidelines:

- Range ~300m
- Access points on the <u>outside of curves</u>
- Train at mid-point between posts should have line of sight of each post

1,5km coverage
1 Gbps throughput target
to a train running at 90 km/h

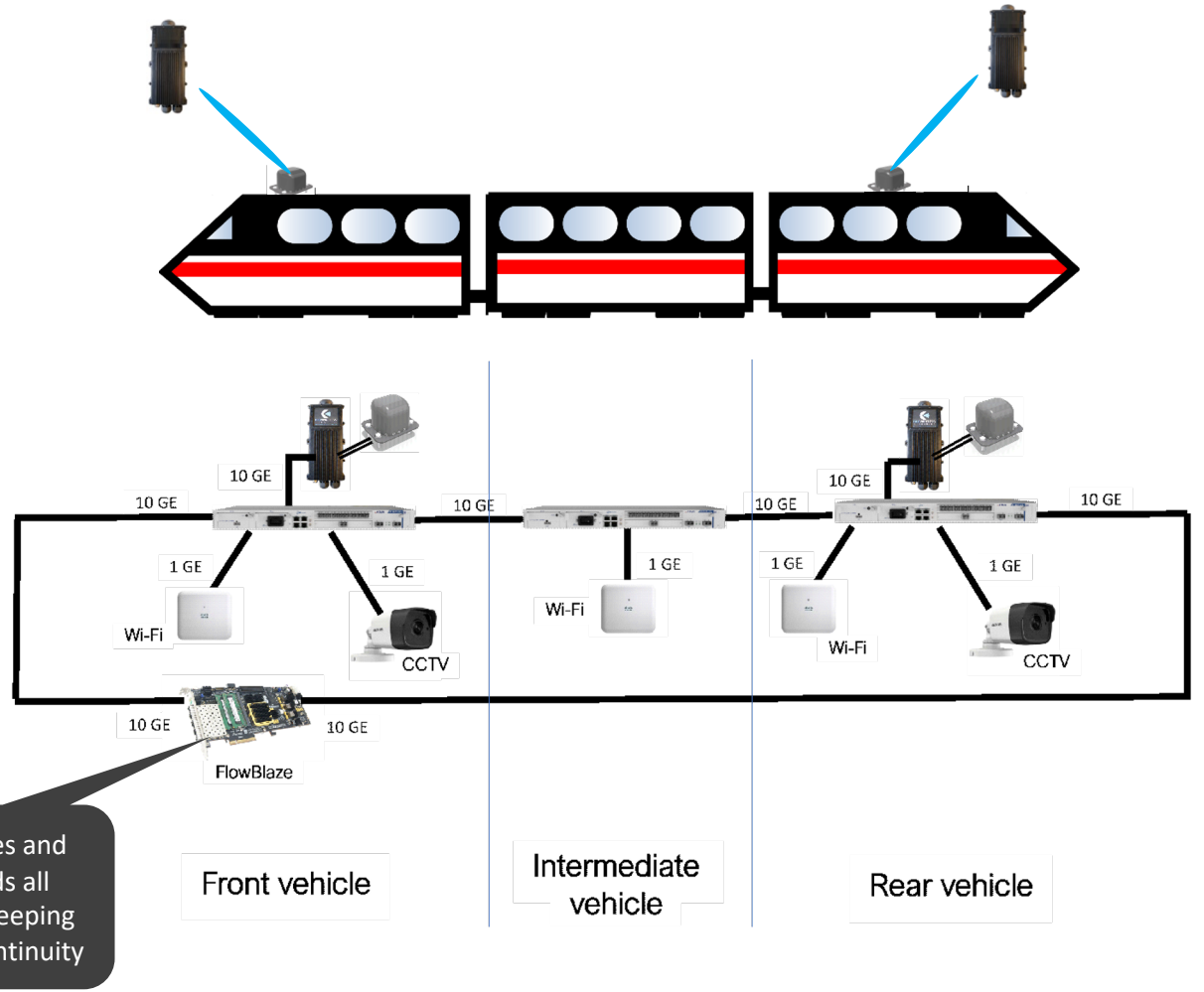


Track characteristics	Open air	
	Curves with big radius	
	Without surrounding obstacles	
Distances between Towers	Tower 1 – Tower 2	221m
	Tower 2 – Tower 3	494m
	Tower 3 – Tower 4	501m

Trial In-train Network

Trial services

- Forward looking critical video from train to control centre
- Passenger Information services: 4K video streaming
- Simulated high throughput, low latency & jitter data



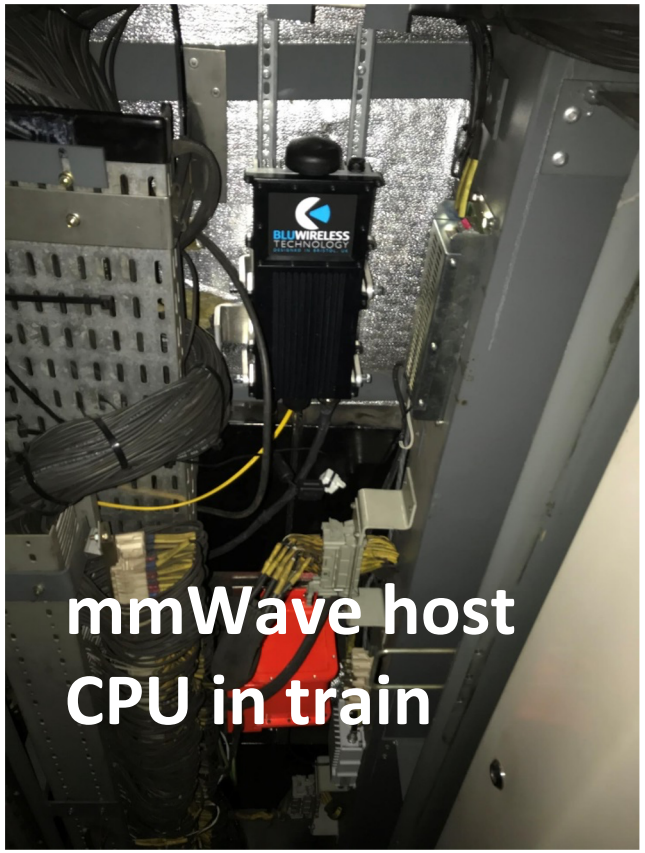
Ethernet services in a 10GbE network

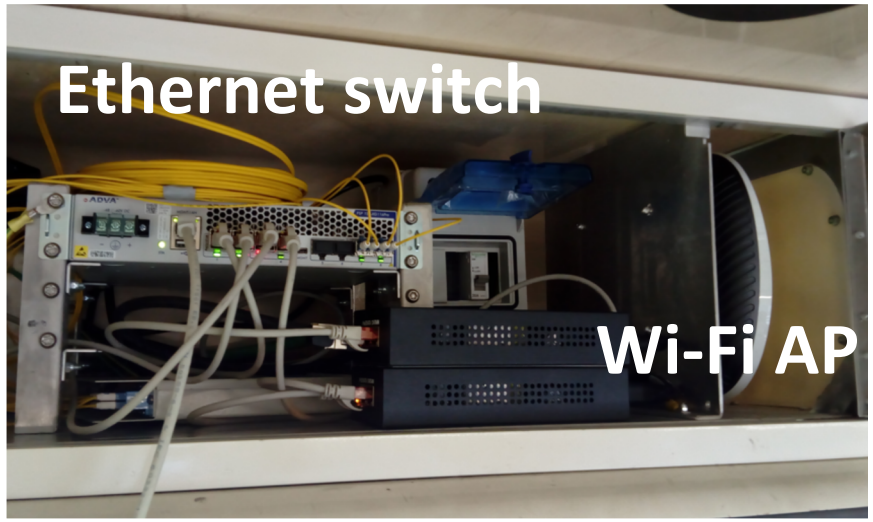
5G-PICTURE trial components on the Train

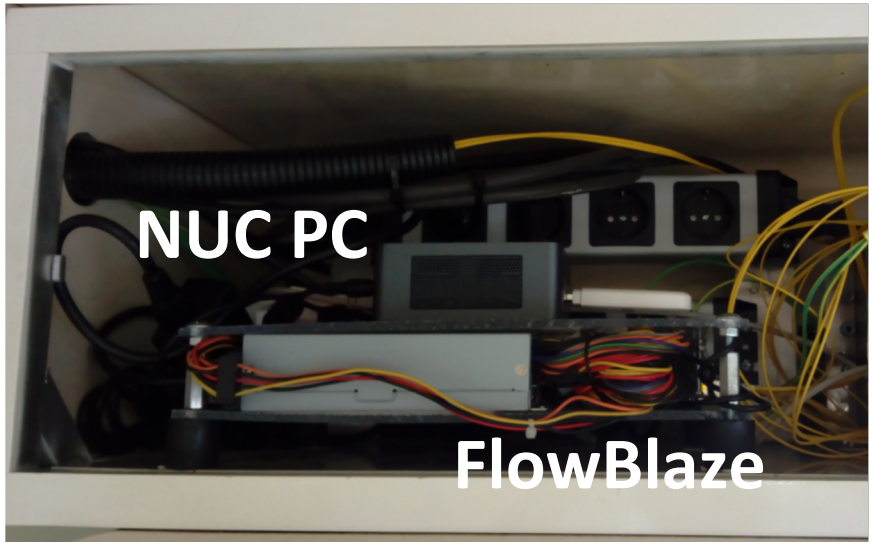
Prepared for any FRMCS service support and coexistence with 5GNR

Demo Sites

Demo Sites
Train Network

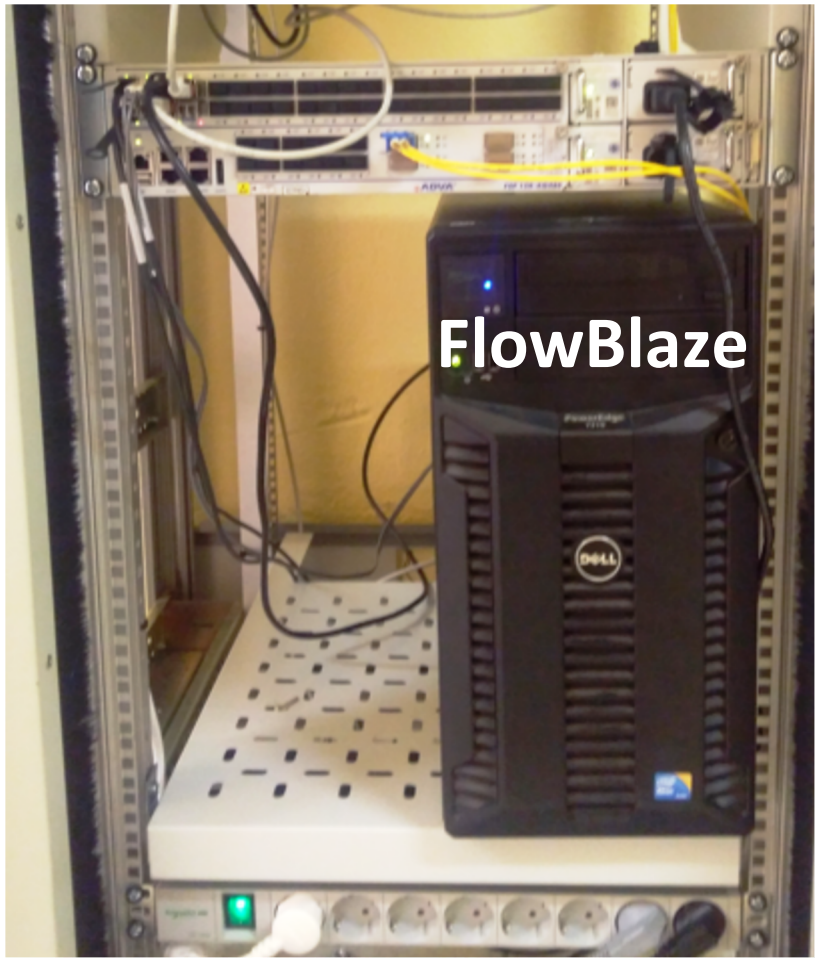


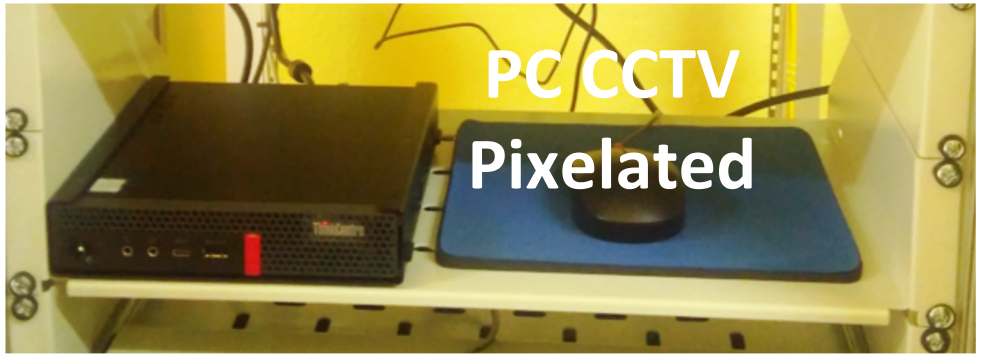


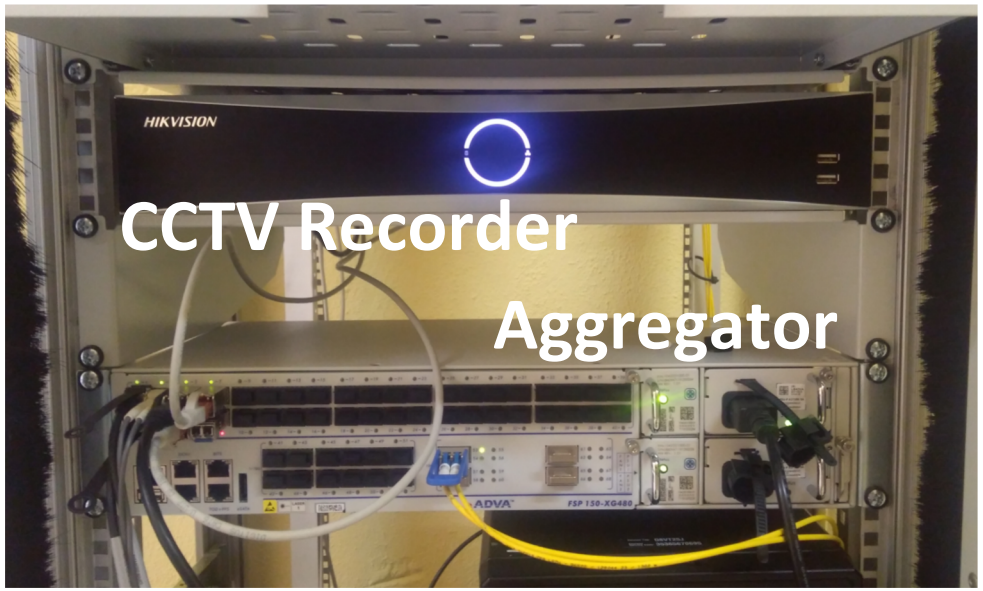


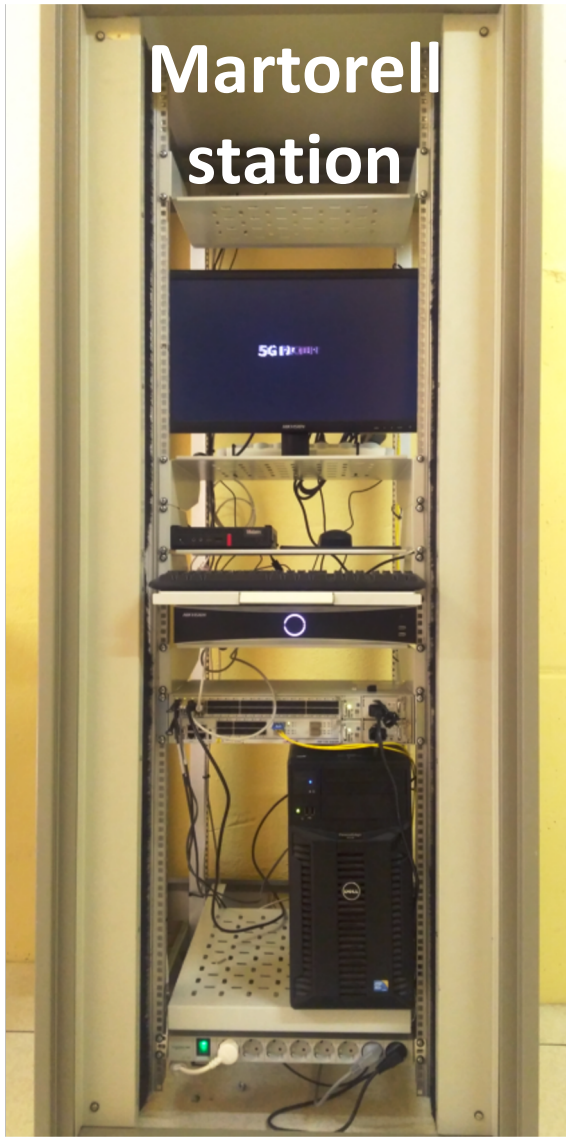
Demo sites
Track Network

Demo sites
Martorell Room









Test Results

Trial services Overview

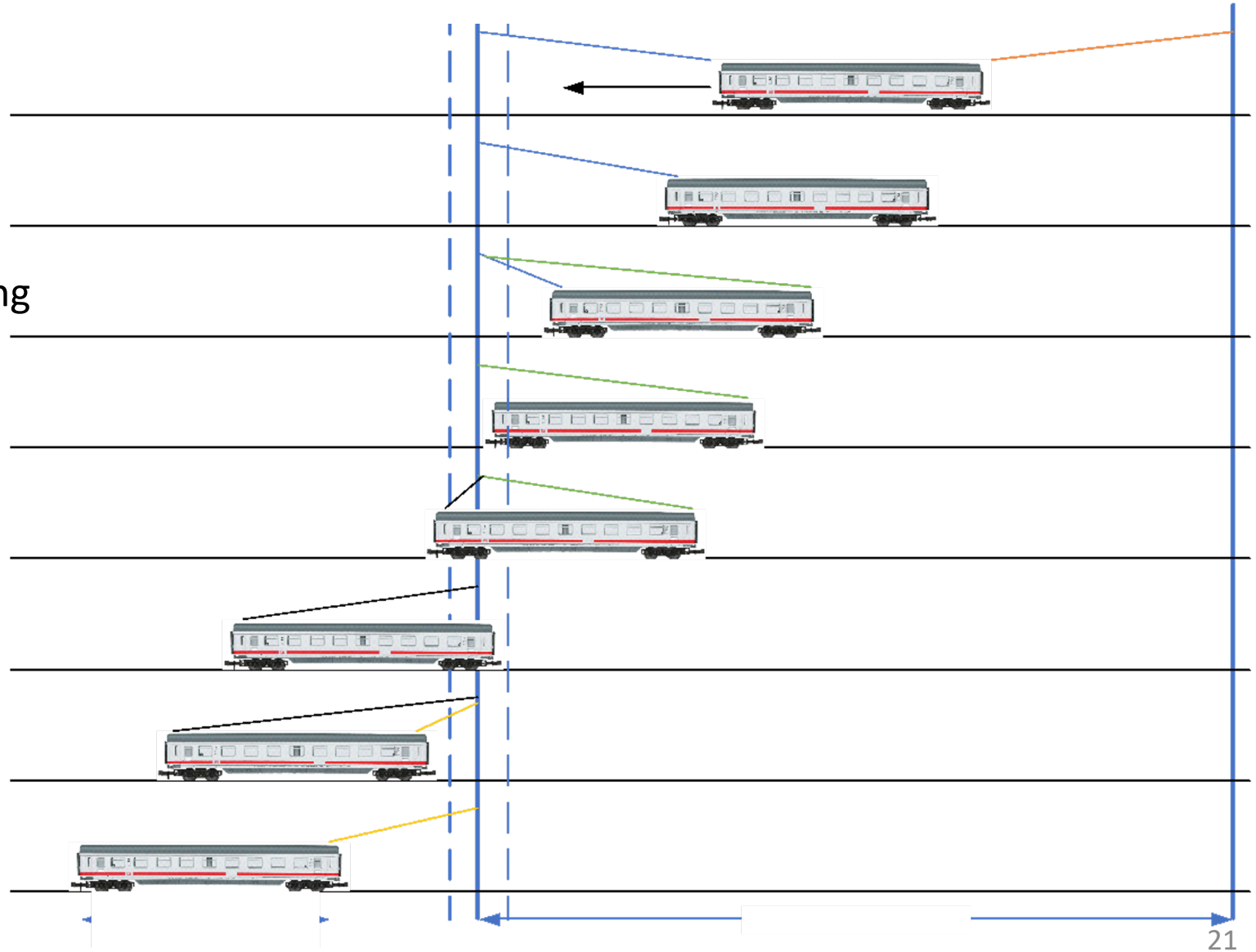
Forward looking critical video	High throughput sensitive to delay when best link is swopped (see next slide)
4K video streaming	High throughput sensitive to delay
Generated high-throughput, low-latency & low-jitter data	Iperf3 UDP/TCP analysis to stress load the network
Blu Wireless engineering mode	Iperf 3 packet generation in the AP, with reception at the STA – gives indication of maximum rate with no other constraints, including maximum aggregated rate

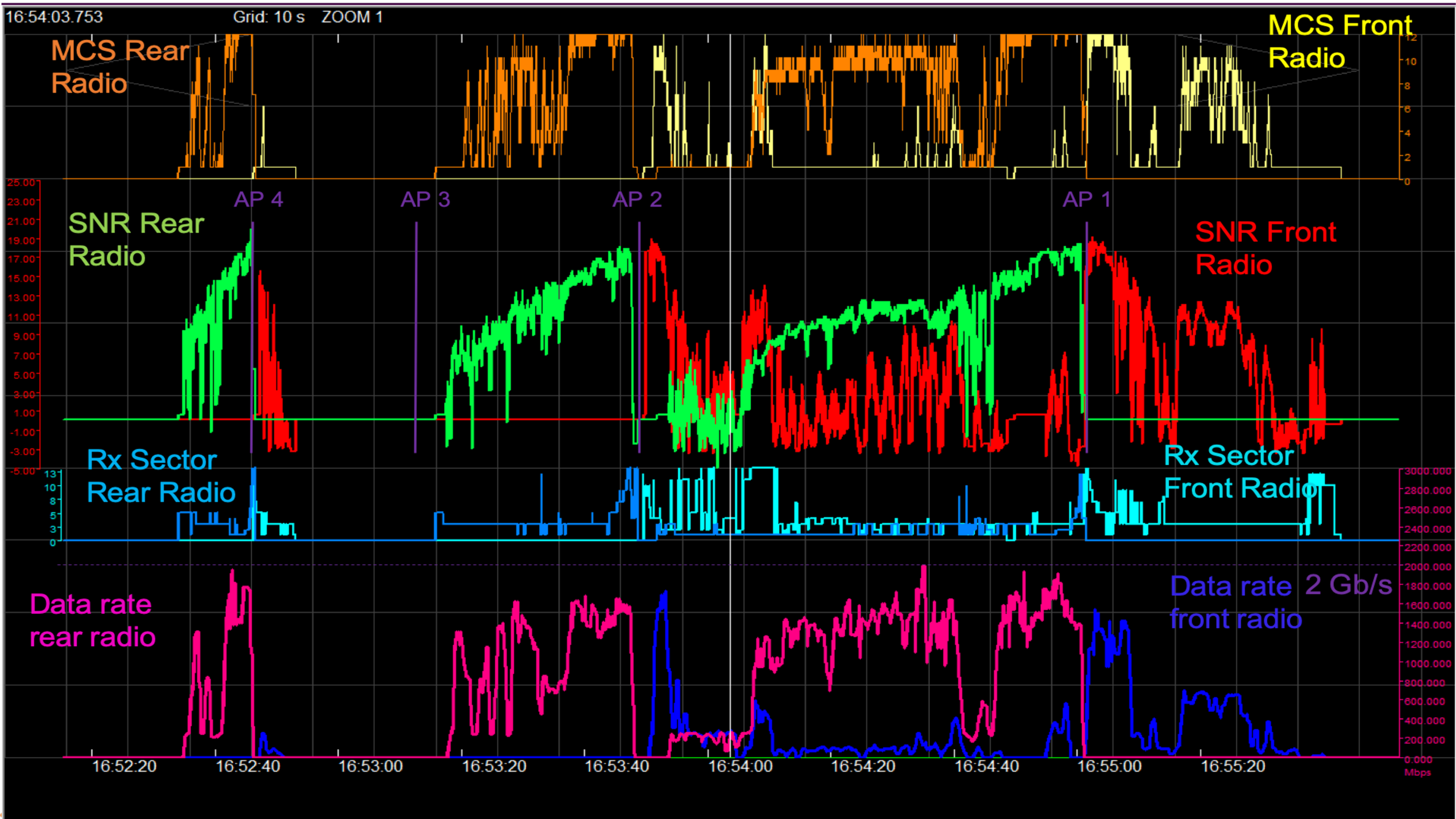
Millimetre-wave link orchestration

Train has 4 modems

- Head and Rear vehicles
- Forward and backward facing

At least one is connected at every point on the track

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Grid: 10 s
ZOOM 1
MCS Rear Radio
MCS Front Radio
AP 4
AP 3
AP 2
AP 1
SNR Rear Radio
SNR Front Radio
Rx Sector Rear Radio
Rx Sector Front Radio
Data rate rear radio
Data rate front radio
2 Gb/s
16:52:20
16:52:40
16:53:00
16:53:20
16:53:40
16:54:00
16:54:20
16:54:40
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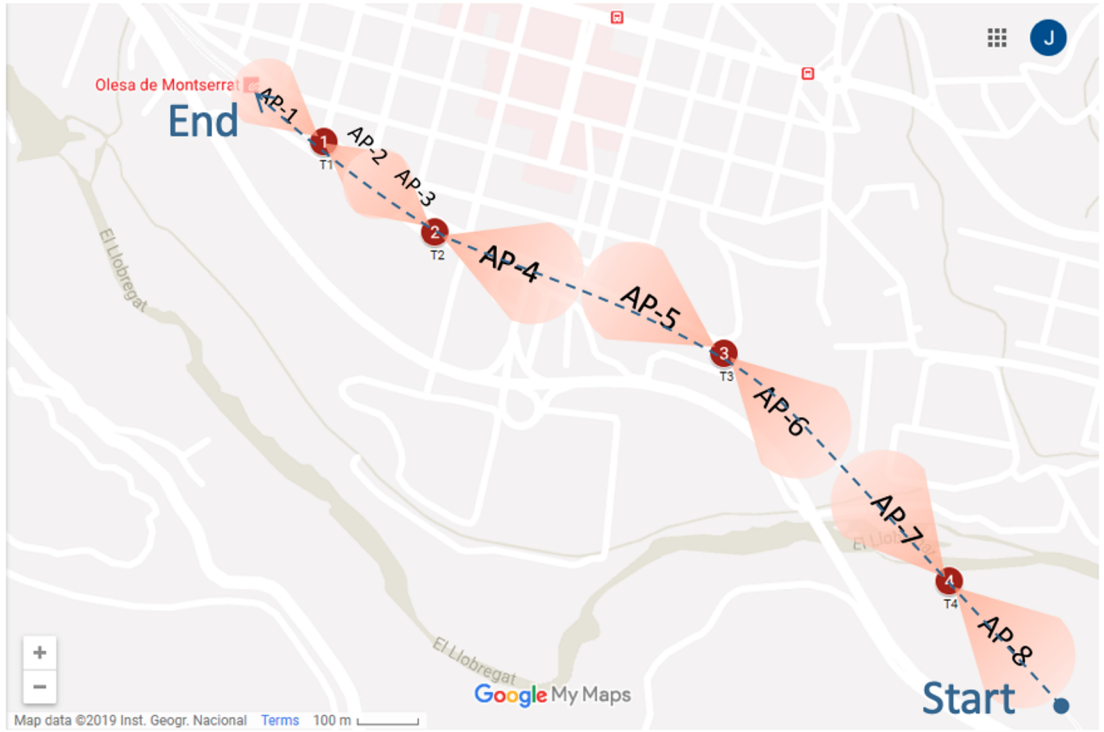
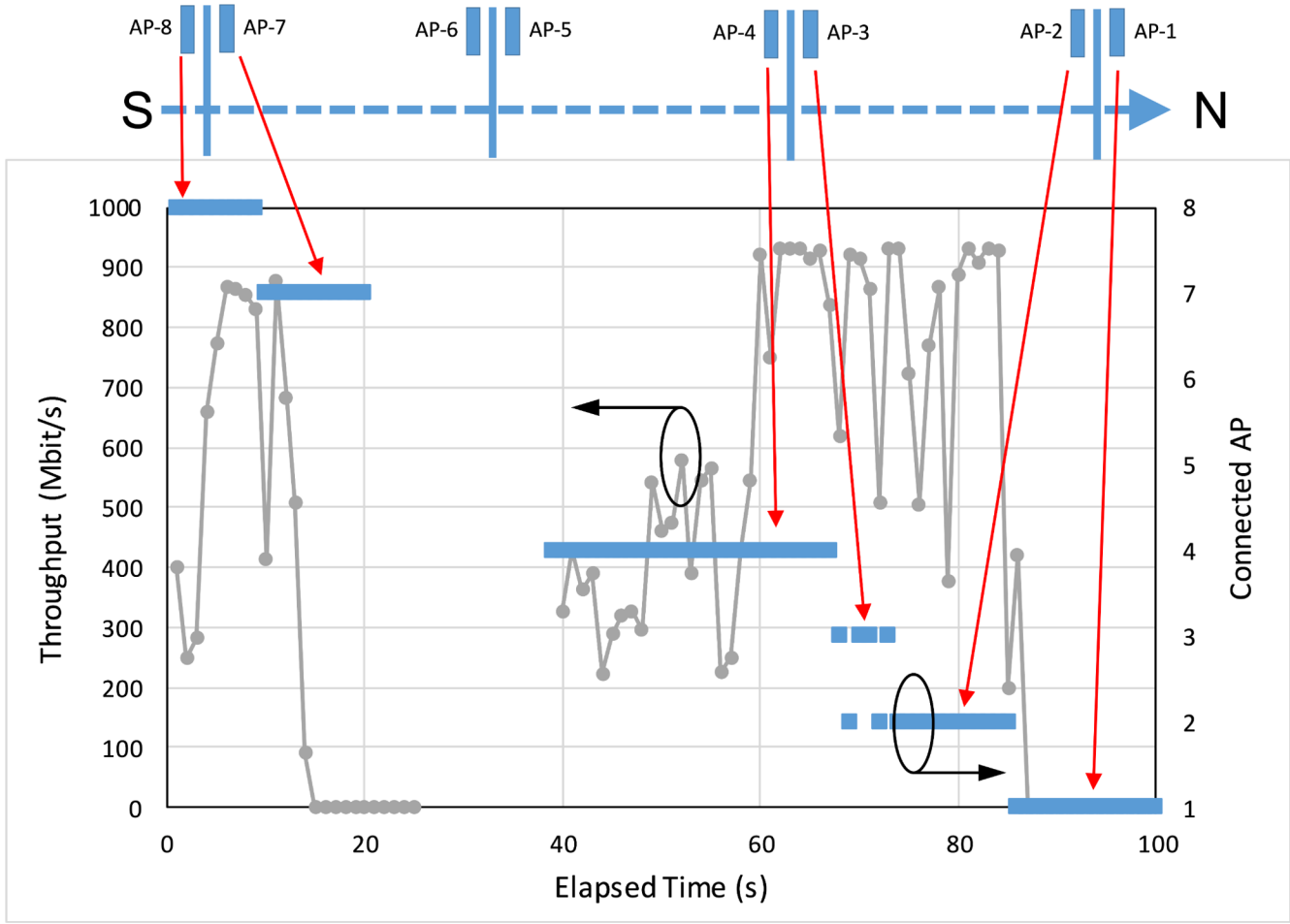
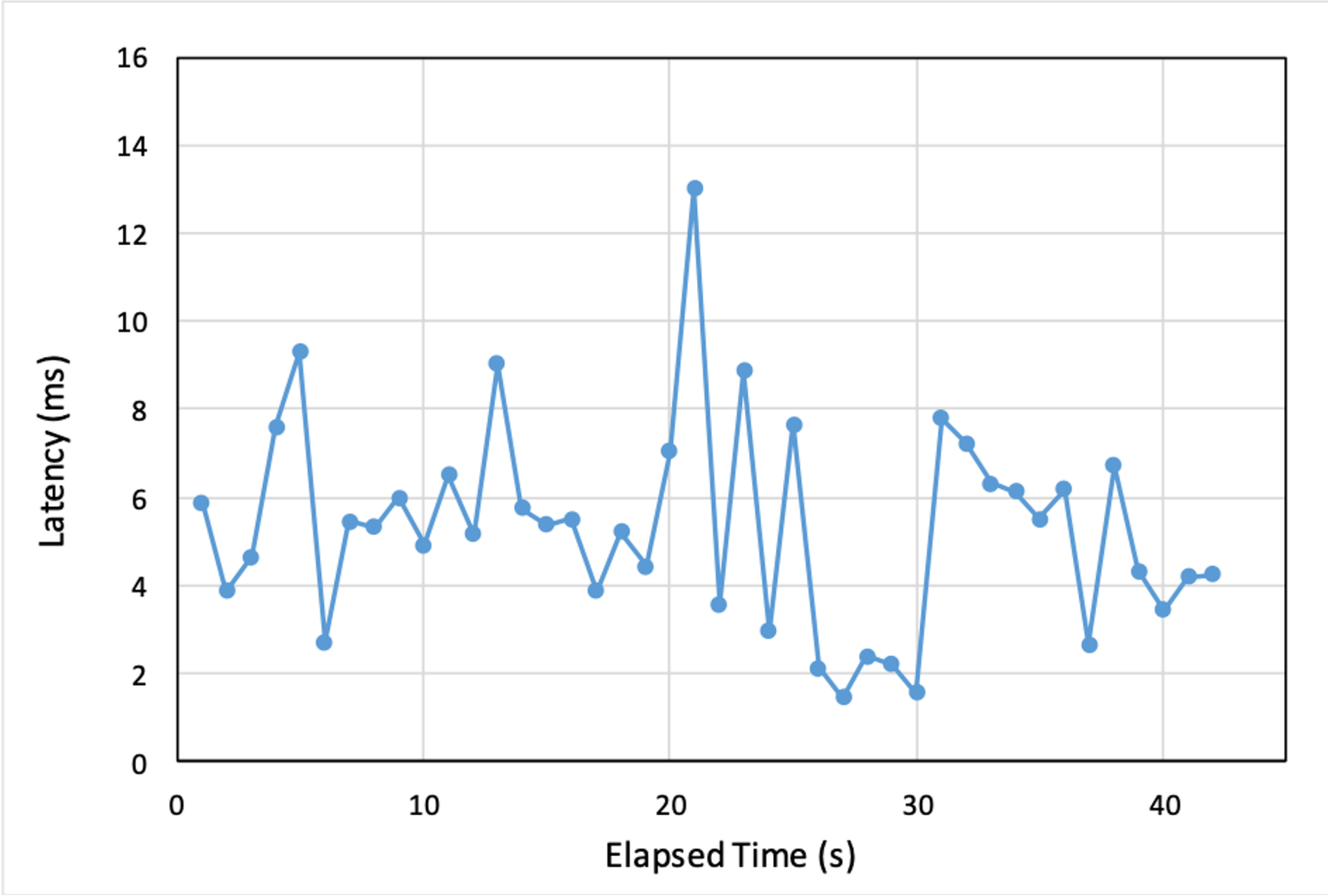
Mbps

Field Test Results





Stationary Latency test



Conclusions

Conclusions

- We proposed a L2 session continuity solution implemented on an FPGA-based programmable dataplane
- We implemented a VLAN reverse path NF with packet duplication
- The solution works entirely in the data plane, minimizing the binding update latency and reducing the control traffic
- Our solution was able to provide up to 1Gb/s to a moving train with less than 10ms end to end latency

Ongoing work

- The work done in 5G-Picture has been leveraged to design a multi radio access technology aggregator in 5GMed
- The 10gbps FlowBlaze technology has been improved to sustain 40-100 gbps and to support a wide range of network use cases
- Programmability further extended to support software based NF design (eBPF/XDP)