Cross-border/-MNO Handover Architecture and Trial Results

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5G PPP

5G Cross Border Control

Innovation Action H2020-ICT-18-2018
Contract 825050

Cooperative, Connected and Autonomous Mobility (CCAM)

a 5G-PPP Phase III Project

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Before we Start…

- This presentation is being recorded and recording will be shared with registered participants (password-protected link)
- Slides will be shared

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Outline

- About Me
- Background: 5GCroCo Deliverables D3.2 & D4.2
- Cross-border / -MNO Handover Architecture
- Trial Site Architecture and Deployment
- Initial Trial Results
- Selected Open Questions
- Summary, Conclusion, and Next Steps

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About Me

Key research interest: Modelling, design, evaluation, and certification of highly reliable / safety critical communication systems

- 2008 – 2012 ComNets - RWTH Aachen University
  - Open Wireless Network Simulator developer
  - PhD research on "VoIP Performance of LTE Networks: VoLTE versus OTT" (2015)
- 2012 – 2016 ComNets - Hamburg University of Technology (TUHH)
  - Group leader "Mobile & Vehicular Communication" (**focus on aviation, maritime**)
  - Sometimes acting group leader for "Sensor Networks and IoT" & "Future Internet and Network Planning"
- Since 2017 Ericsson Research Germany
  - Research Area "Networks" – Master Researcher - Industry Verticals Coordination (focus on automotive)
  - Coordination of tech. work in external associations (5GAA, AECC, ETSI-ITS) and projects (5GCroCo, 5GMOBIX, 5G-ROUTES, ART-04 SHOW)
  - Deputy Technical Coordinator 5GCroCo & leader of WP3 "Architecture"
- **Living in Belgium, working in Germany**
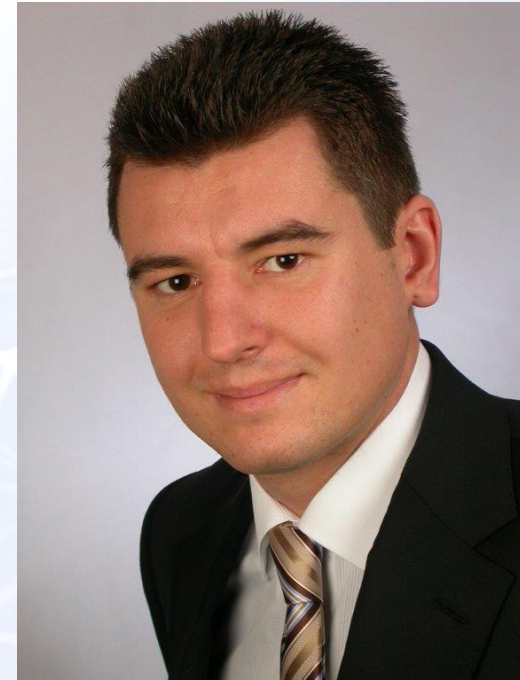
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Background: 5GCroCo Deliverable D3.2 & D4.2

- Architecture in Deliverable D3.2 Section 4.1.1: **"Network Service Continuity at Country Borders"**
- Deliverable D4.2 cross-border trial results:
  - Section 3.3.3: HD Mapping
  - Section 3.4.3: Anticipated Cooperative Collision Avoidance
- Not yet done for Tele-operated Driving
- German network not up yet
  - ➔Two networks in Luxembourg instead
- D4.2 and use case presentations in June provide more result details than today's presentation

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Fifth Generation Cross-Border Control

Deliverable D3.2
Intermediate E2E, MEC & Positioning Architecture

Version: v1.0

2021-01-31

DISCLAIMER: This 5GCroCo D3.2 deliverable is not yet approved by the European Commission.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825050. Any 5GCroCo results reflects only the authors' view and the Commission is thereby not responsible for any use that may be made of the information it contains.

European Commission   5G PPP

http://www.5g-ppp.eu

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Fifth Generation Cross-Border Control

Deliverable D4.2
First Phase Trial Execution Report and Analysis of 5GCroCo KPIs

Version: v2.0

2021-04-14

DISCLAIMER: This 5GCroCo D4.2 deliverable is not yet approved by the European Commission.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825050. Any 5GCroCo results reflects only the authors' view and the Commission is thereby not responsible for any use that may be made of the information it contains.

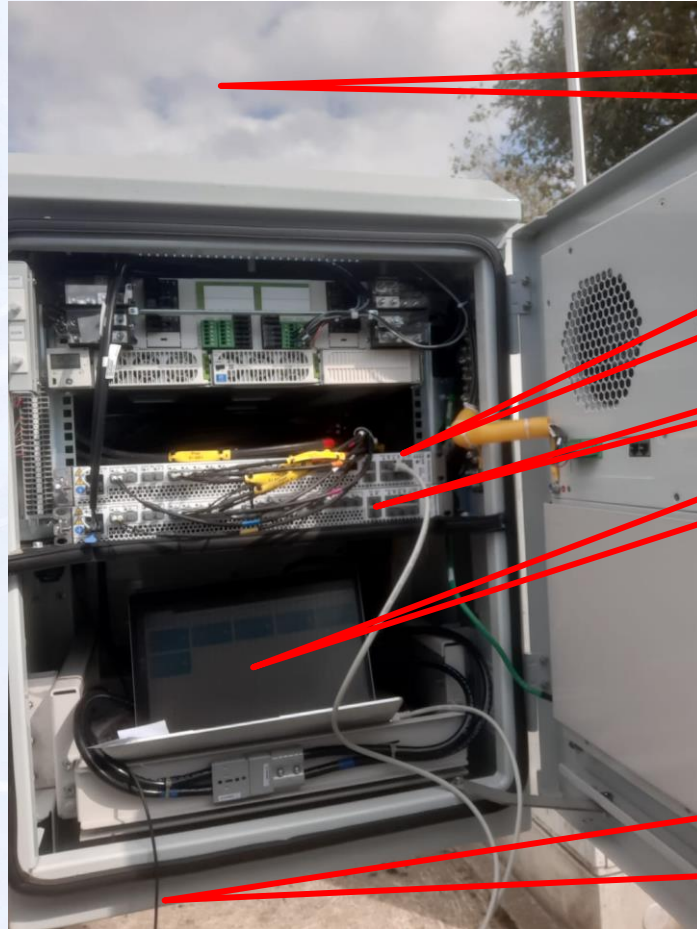European Commission   5G PPP
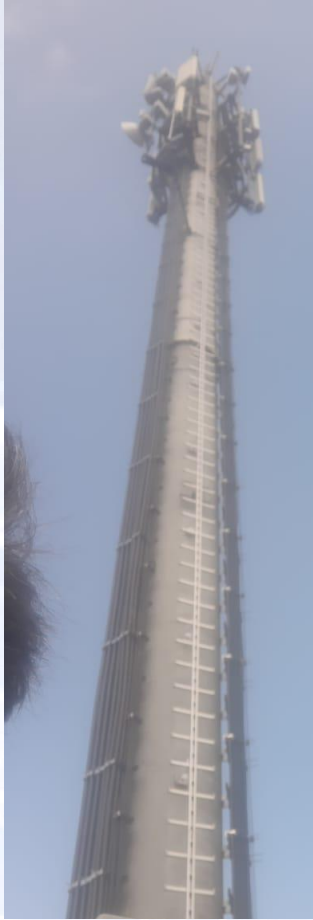
http://www.5g-ppp.eu

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Thank You!

Hochschule für Technik und Wirtschaft des Saarlandes (htw saar) were eventually the only ones allowed to travel and conduct experiments

Many thanks also to everyone else who made the network rollout and trials possible

Fabien Coulet

Daniel Giemsa

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Thank You!

Rain

4G BBU

5G BBU

Laptop

Headset (MS Teams remote support)

BBU: Baseband Unit

Hochschule für Technik und Wirtschaft des Saarlandes (htw saar) were eventually the only ones allowed to travel and conduct experiments
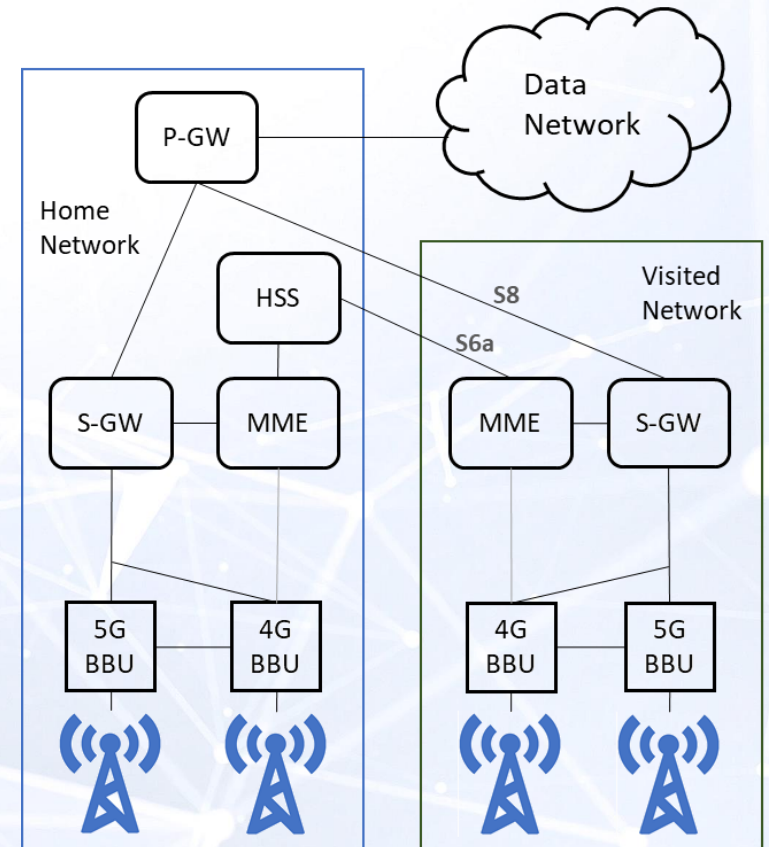
Many thanks also to everyone else who made the **network rollout** and trials possible

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Cross-border / -MNO Handover Architecture

"It shall be possible to support Inter-PLMN handover with seamless service continuity within a 3GPP specified access system"

3GPP TS 22.278 "Service requirements for the Evolved Packet System – **Release 8", 2006**
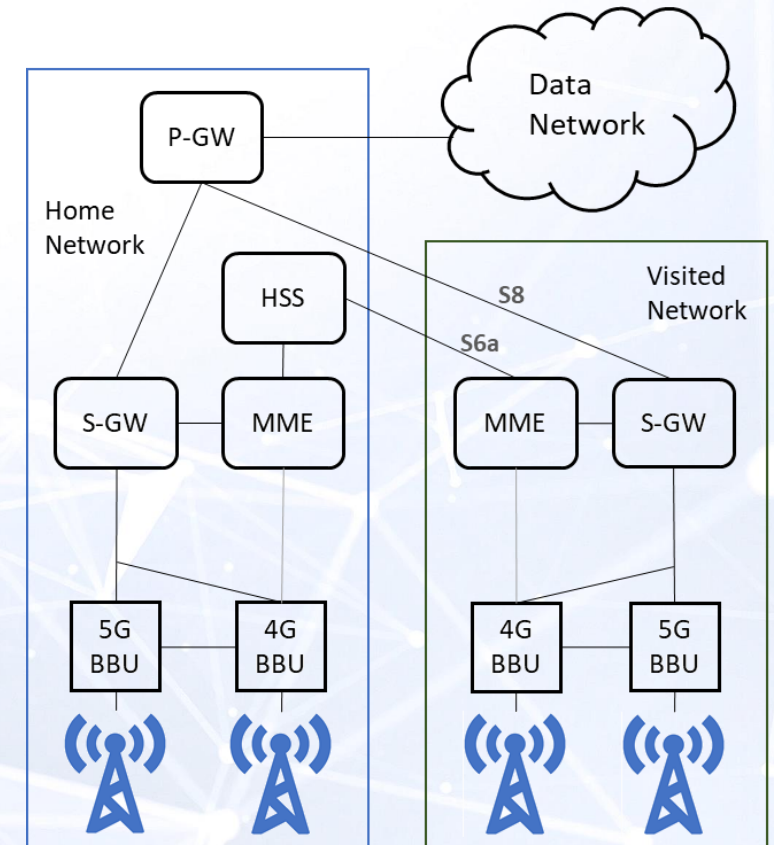

HSS: Home Subscriber Service
MME: Mobility Management Entity
S-GW: Serving Gateway
P-GW: Packet Data Network Gateway
BBU: Baseband Unit

Cross-border / -MNO Handover Architecture

Non-standalone 5G with 4G Evolved Packet
Core (EPC)

• Baseline: Normal roaming interfaces S6a & S8

HSS: Home Subscriber Service
MME: Mobility Management Entity
S-GW: Serving Gateway
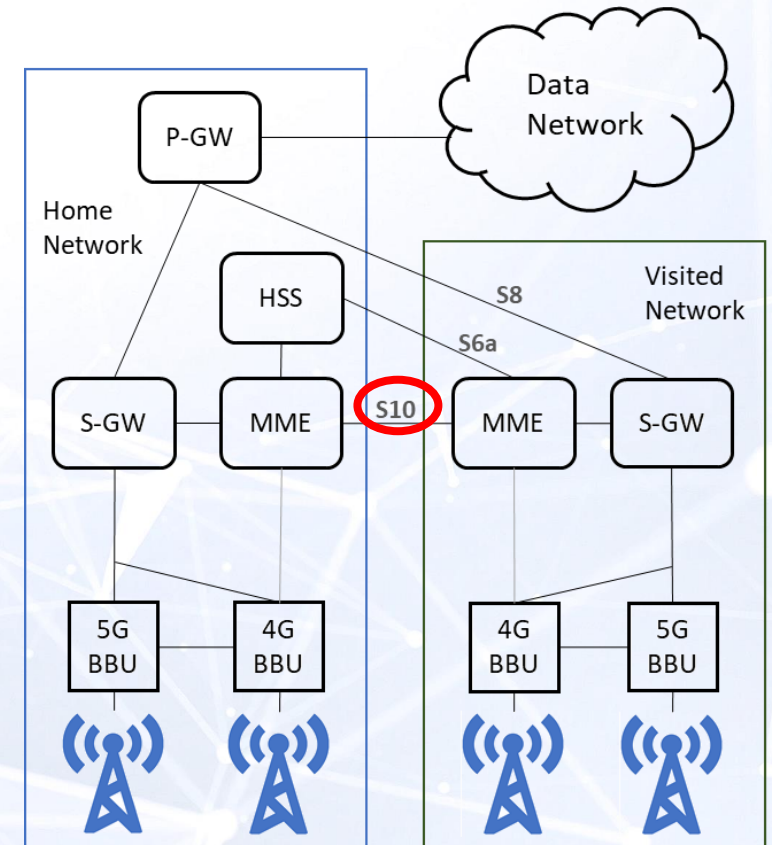P-GW: Packet Data Network Gateway
BBU: Baseband Unit

Cross-border / -MNO Handover Architecture

Non-standalone 5G with 4G Evolved Packet Core (EPC)

- Baseline: Normal roaming interfaces S6a & S8

- Add S10 interface to enable cross-border/-MNO handover

  - Allows BBUs in different MNO networks to exchange information for handover

  - Identical to intra-MNO handover with S-GW and MME change

 - S8 ≠ S5 interface
    ➔ no data forwarding during handover

HSS: Home Subscriber Service
MME: Mobility Management Entity
S-GW: Serving Gateway
P-GW: Packet Data Network Gateway
BBU: Baseband Unit

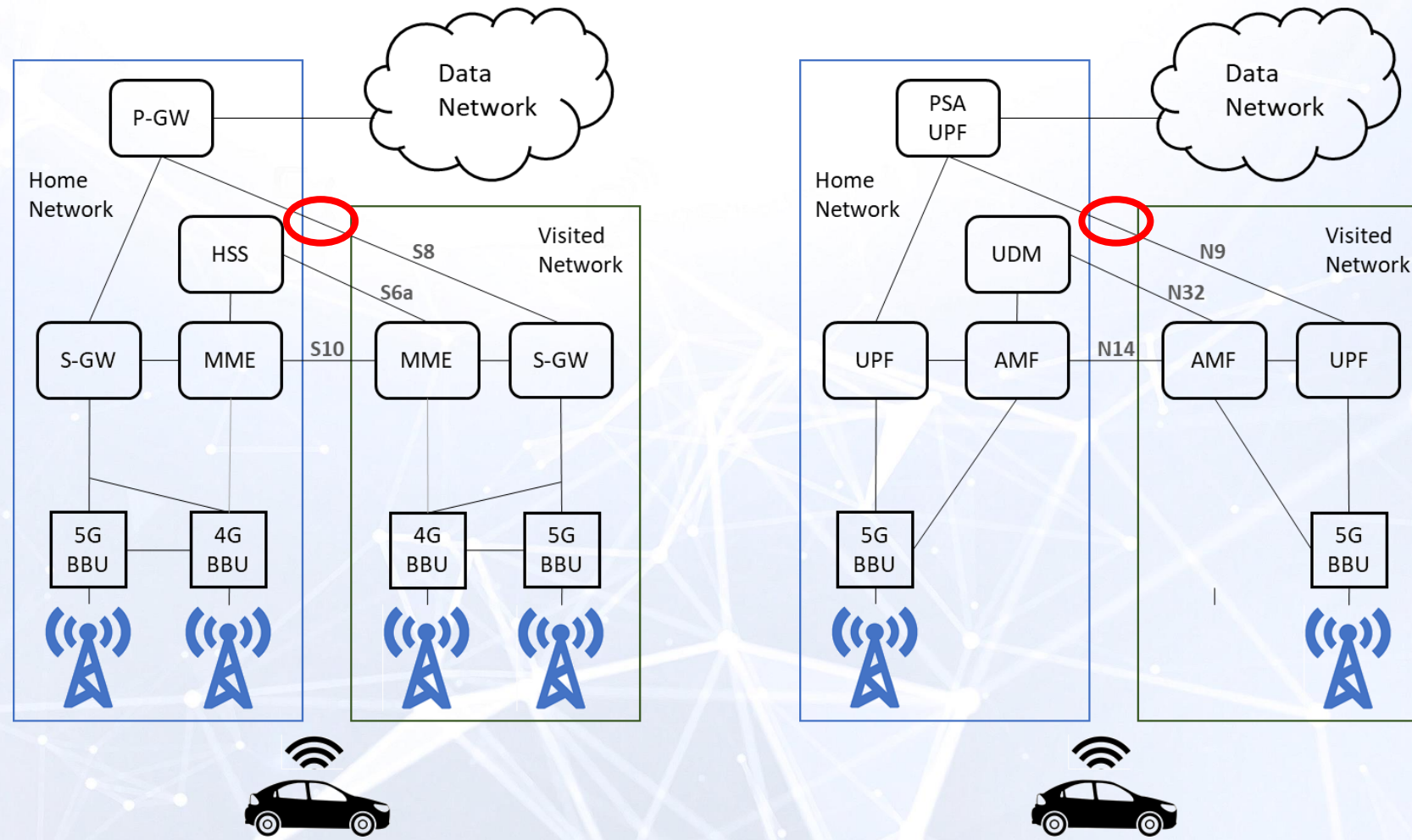# Cross-border / -MNO Handover Architecture

Standalone 5G with 5G Core

- Baseline: Normal roaming interfaces N9 & N32

- Add N14 (as part of N32) interface to enable cross-border/-MNO handover

  - Allows BBUs in different MNO networks to exchange information for handover

  - Identical to intra-MNO handover with AMF change
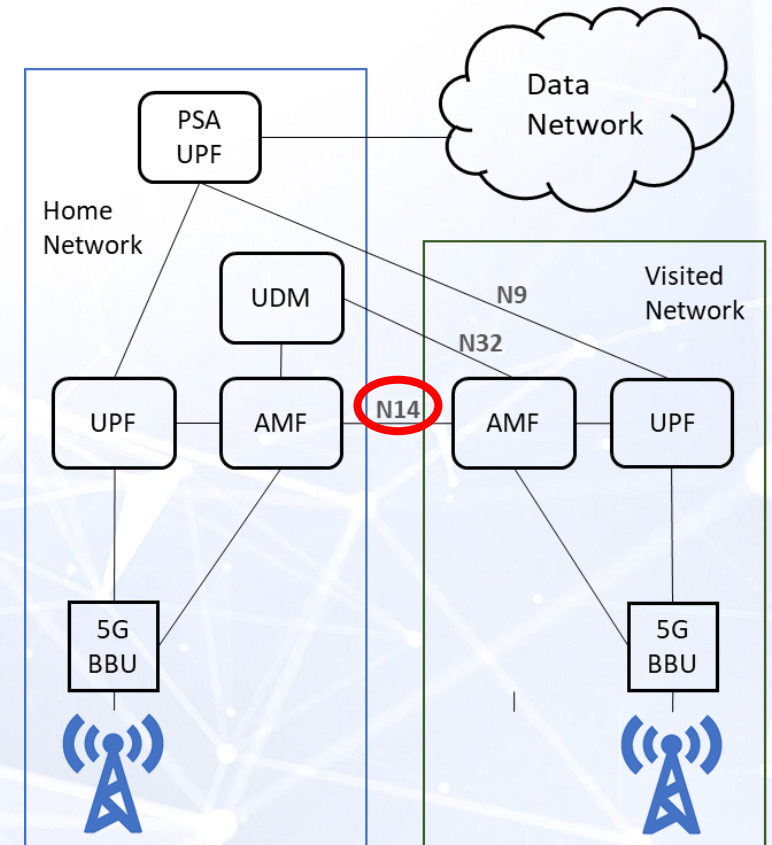
UDM: Unified Data Management
AMF: Access and Mobility Management Function
UPF: User Plane Function
PDU: Protocol Data Unit (aka „packet")
PSA: PDU Session Anchor
BBU: Baseband Unit

Cross-border / -MNO Handover Architecture

- Today only Home Routed Roaming will be presented

- Local Breakout Routed Roaming will be discussed under Mobile Edge Computing/Cloud 24./31.05.

Cross-border / -MNO Handover Architecture

- BBUs must have neighbor information from other network:
  - Frequency
  - Cell ID

- Easy for trial setup but **large organizational challenge for commercial operation**
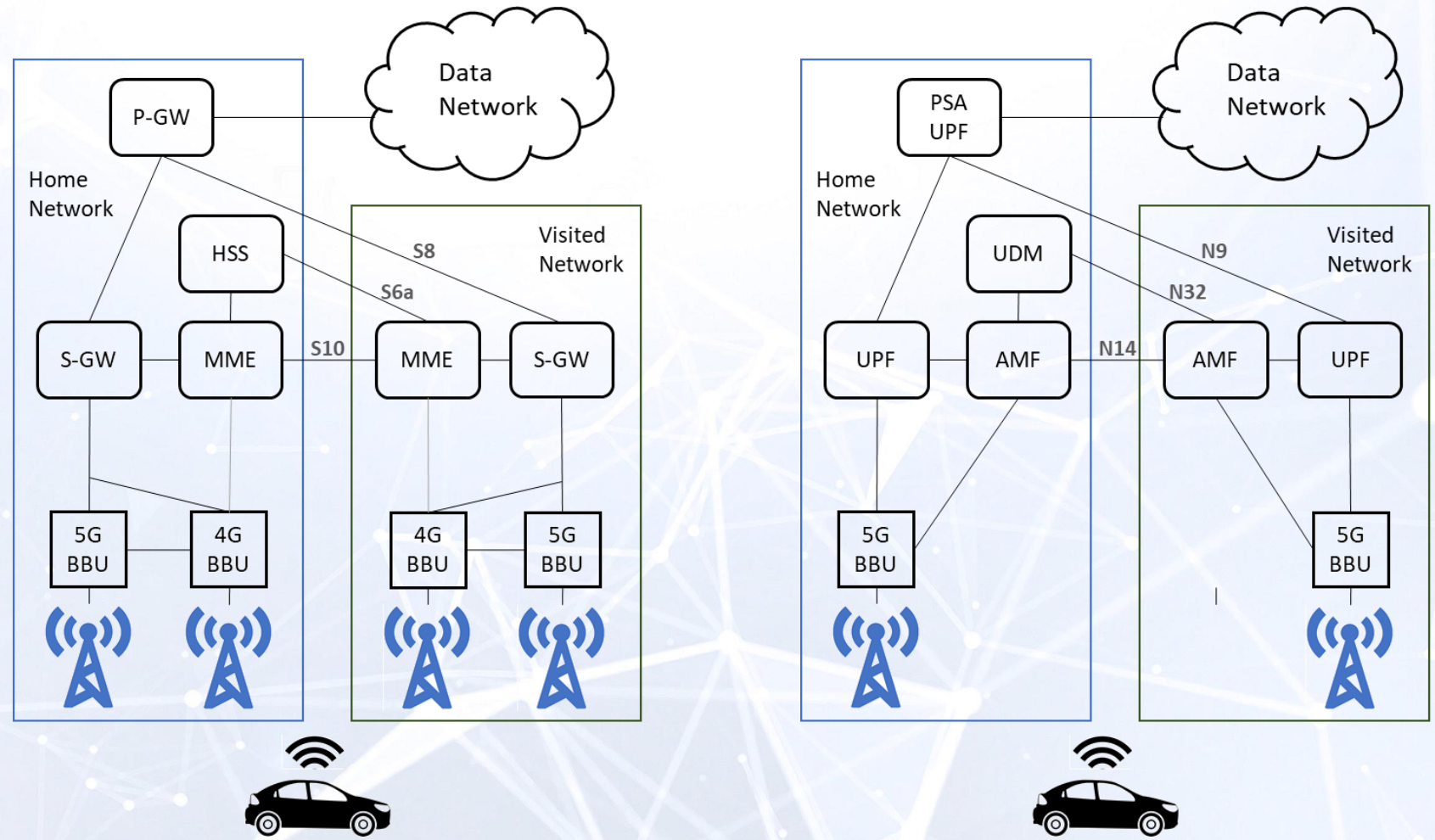
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Trial Site Architecture and Deployment

- 5 cell sites in Luxembourg

- 4 non-standalone 5G equipped (5th site could not carry more load)

- 3.7 GHz Band n78

- 40 MHz, 4:1 downlink-uplink TDD ratio
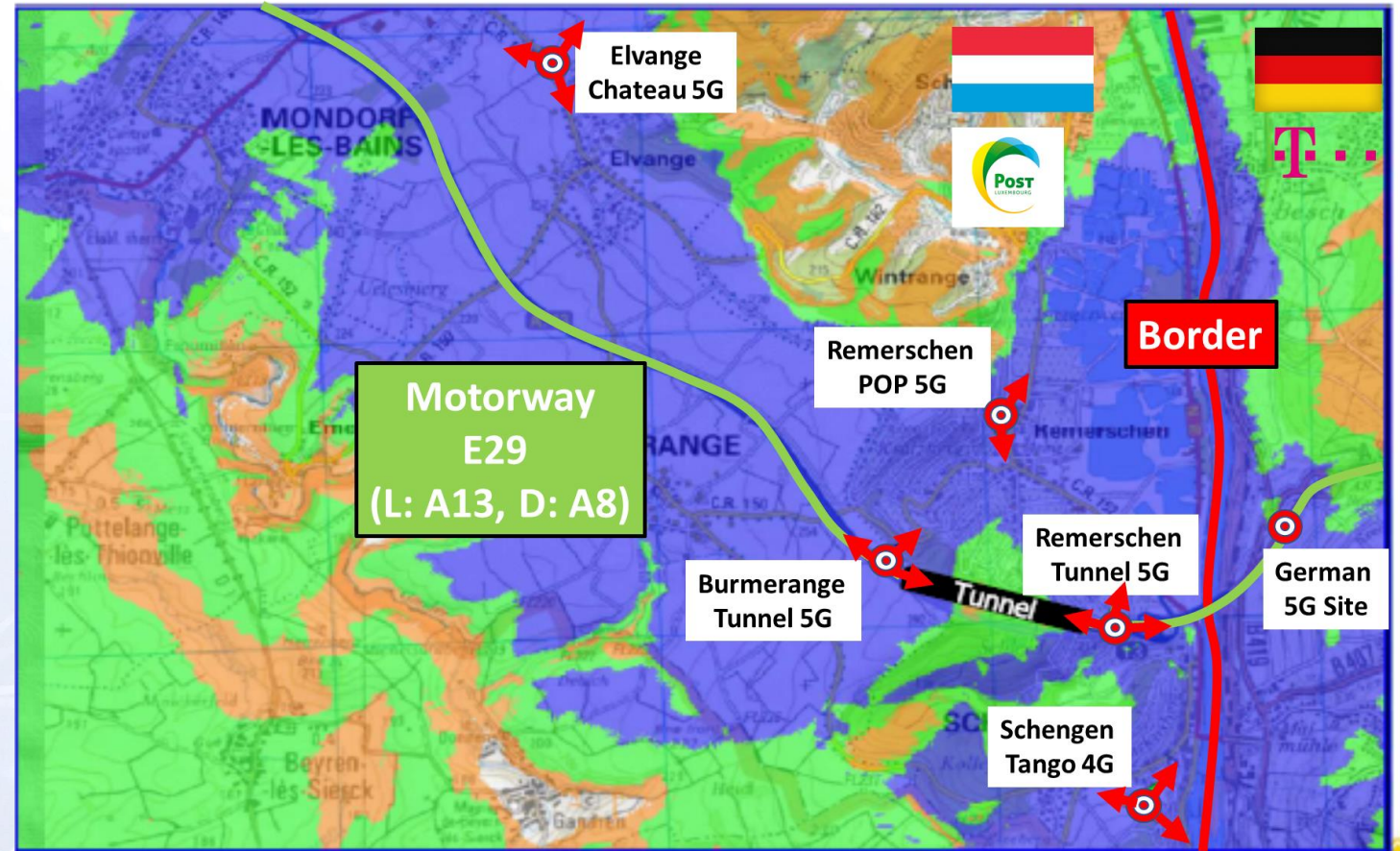
TDD: Time Division Duplex
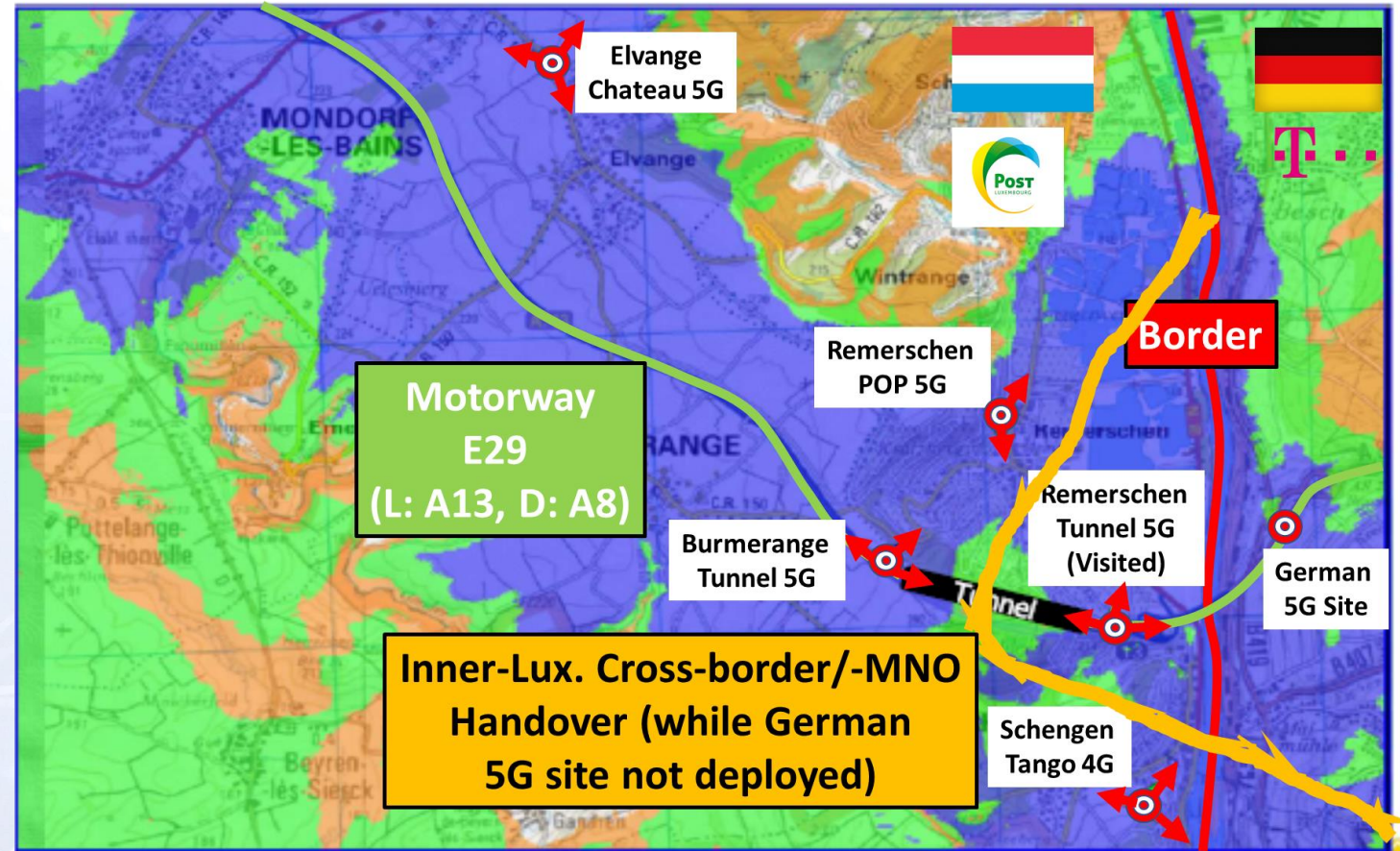
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- Rollout in Germany delayed, expected for Summer 2021

- Cell site "Remerschen Tunnel" moved to different MNO network

- It also serves Germany but next German exit too far away for 5G trials

TDD: Time Division Duplex

Elvange Chateau 5G

Remerschen POP 5G

Border

Motorway E29 (L: A13, D: A8)

Remerschen Tunnel 5G (Visited)

German 5G Site

Burmerange Tunnel 5G

Inner-Lux. Cross-border/-MNO Handover (while German 5G site not deployed)

Schengen Tango 4G

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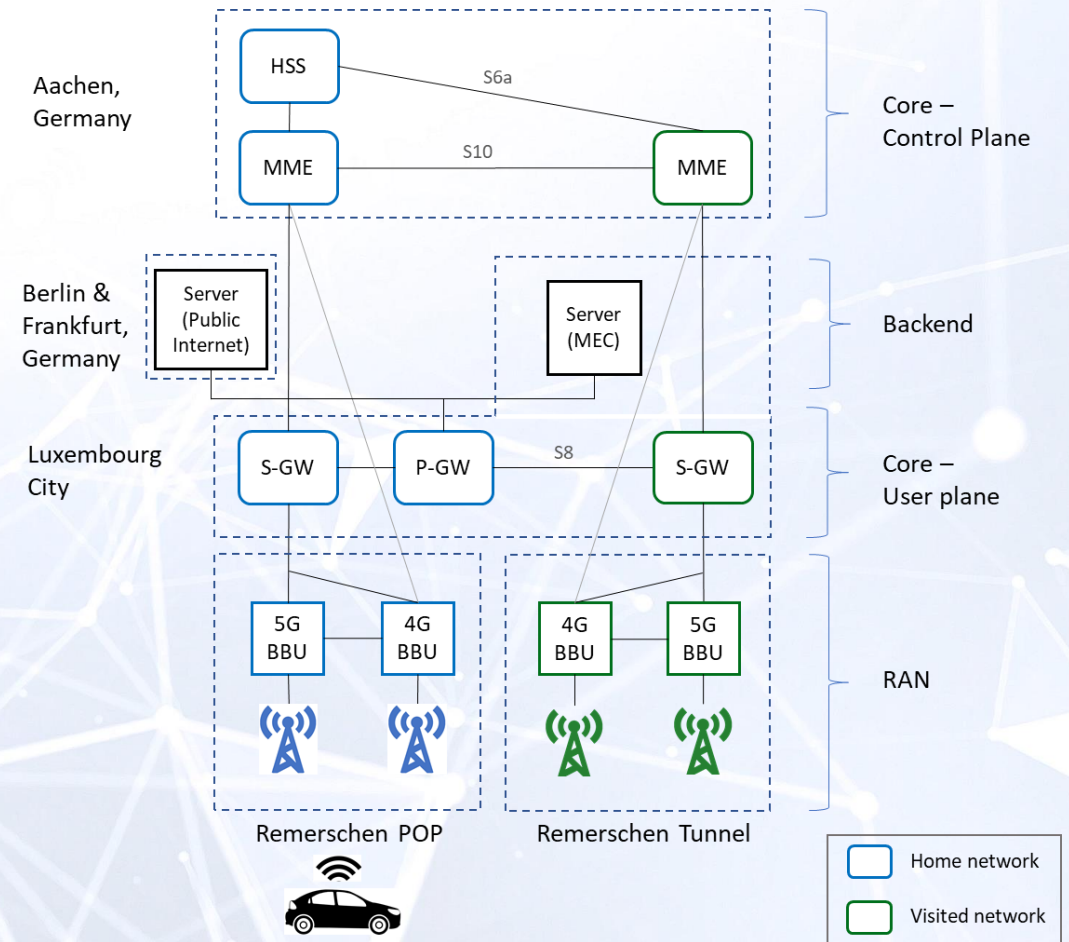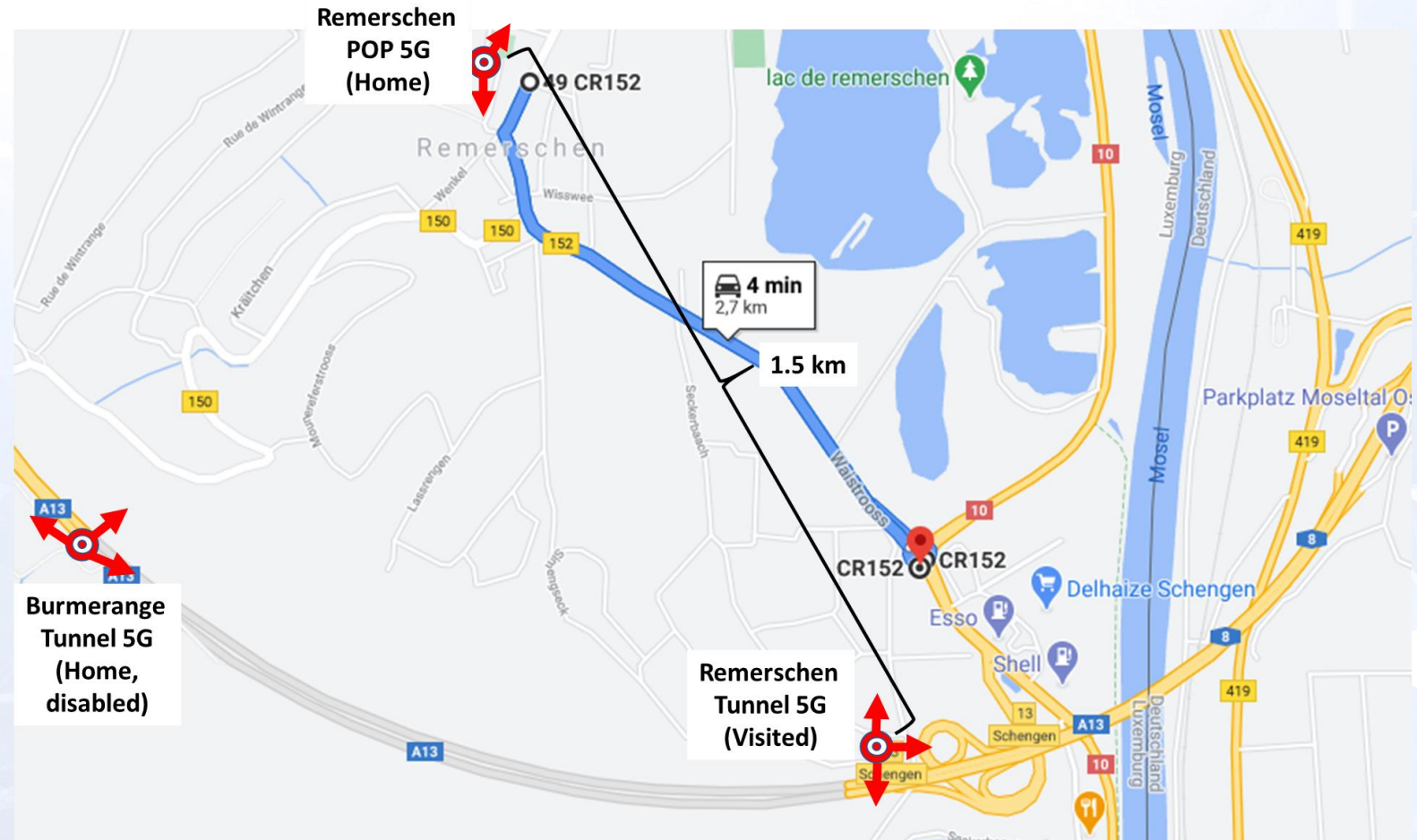# Trial Site Architecture and Deployment

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- It also serves Germany but next German exit too far away for 5G trials

- User- and Control Plane of both networks terminate in same location
 - ➔ Result slightly better than in reality

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Trial Site Architecture and Deployment

- Trials in 2020 were done on motorway between the countries
  - 5G signal to weak at first exit in Germany
- Now using ~1.5 km rural road
- Motorway tunnel has 5G coverage but no GNSS signal for use cases

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Trial Site Architecture and Deployment

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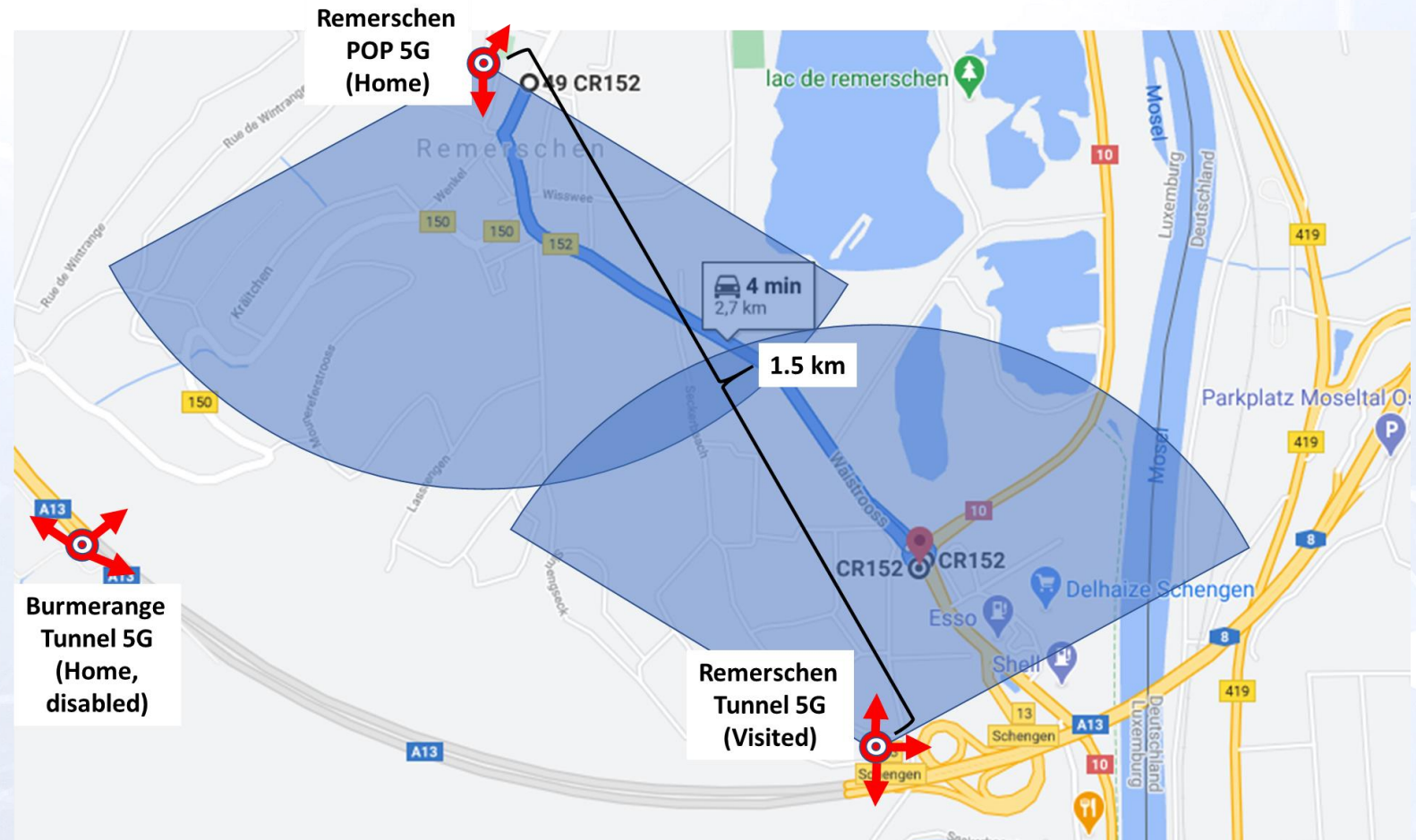
Use Case: HD Mapping

- Lane-accurate maps support assisted- and automated driving (AD) decision algorithms, e.g.:
  - Assist: Lane keeping
  - AD: Where can I (not) drive?
- Gets quickly outdated (construction, repainting)
  ➜ **Download on-the-fly**
- Crowd-sourced detection and upload of changes
- QoS prediction (for Round 2 trials second half of 2021)

https://www.youtube.com/watch?v=1v1i2vp8cEQ&t=2s
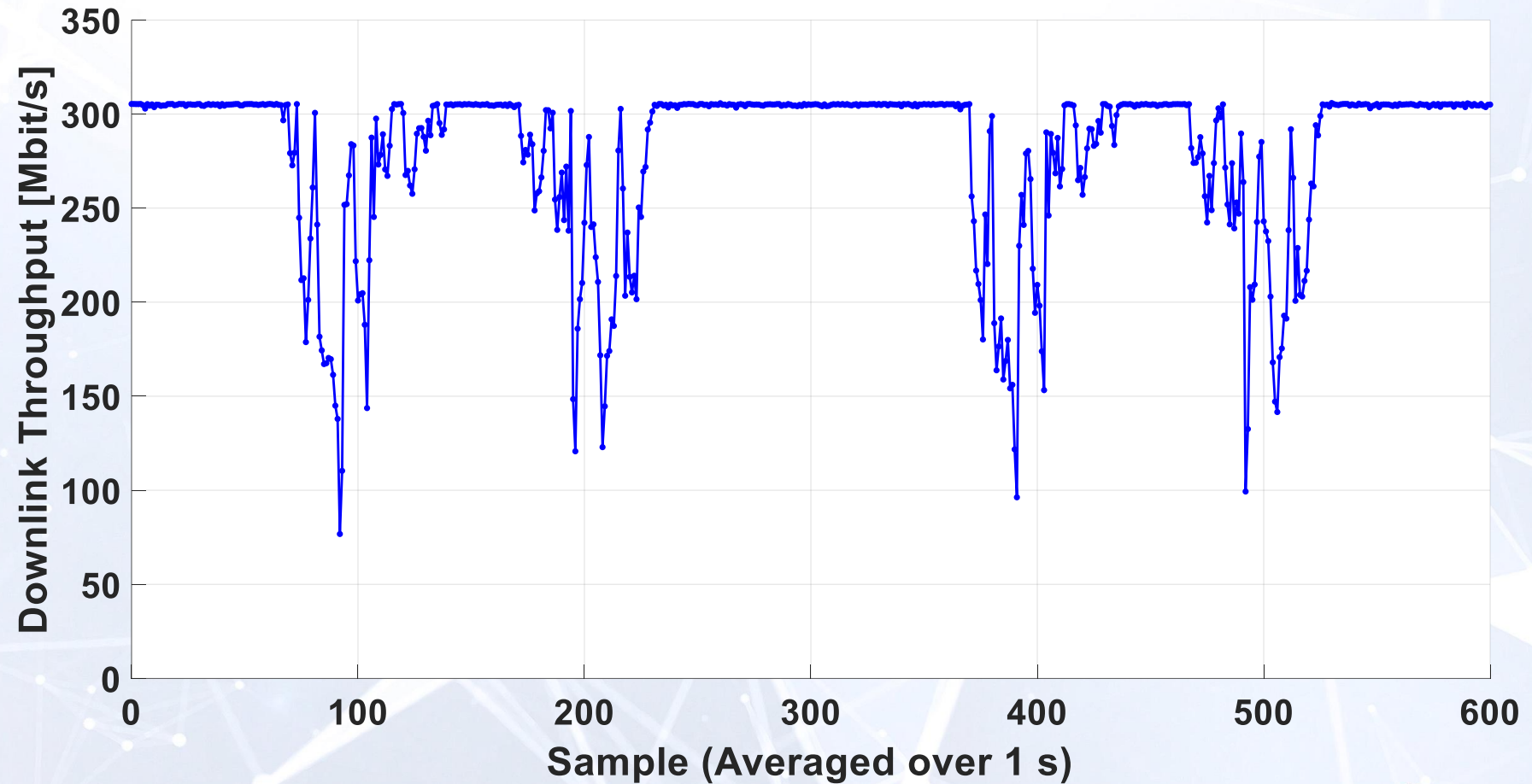
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Initial Trial Results: HD Mapping
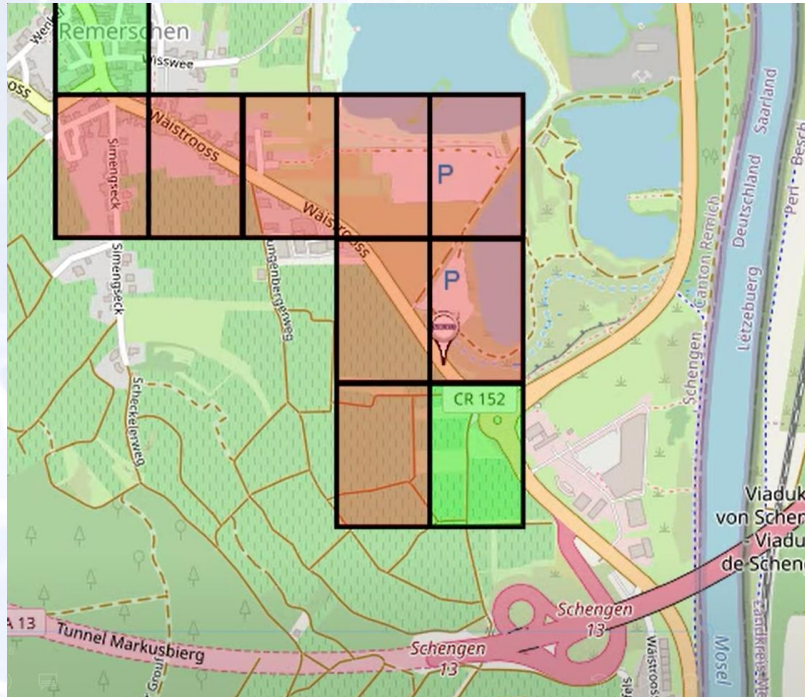
Handover disabled

Handover enabled

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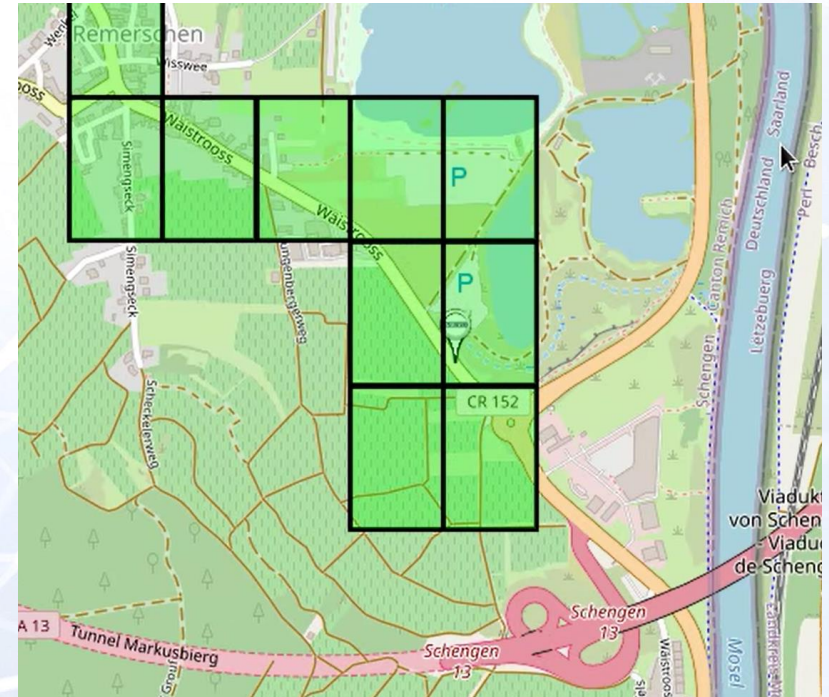
Initial Trial Results: HD Mapping

- Driving back and forward two times (4 cross-border/-MNO handovers)

- As usual: radio channel quality decrease at cell edge causes lower throughput

- Throughput increases again after handover

Initial Trial Results: HD Mapping

- 6.7 MByte large tiles are downloaded before max. throughput (305 Mbit/s) is reached

- Impact of cross-border/-MNO handover causes variance like other effects:

  - # of concurring tile downloads

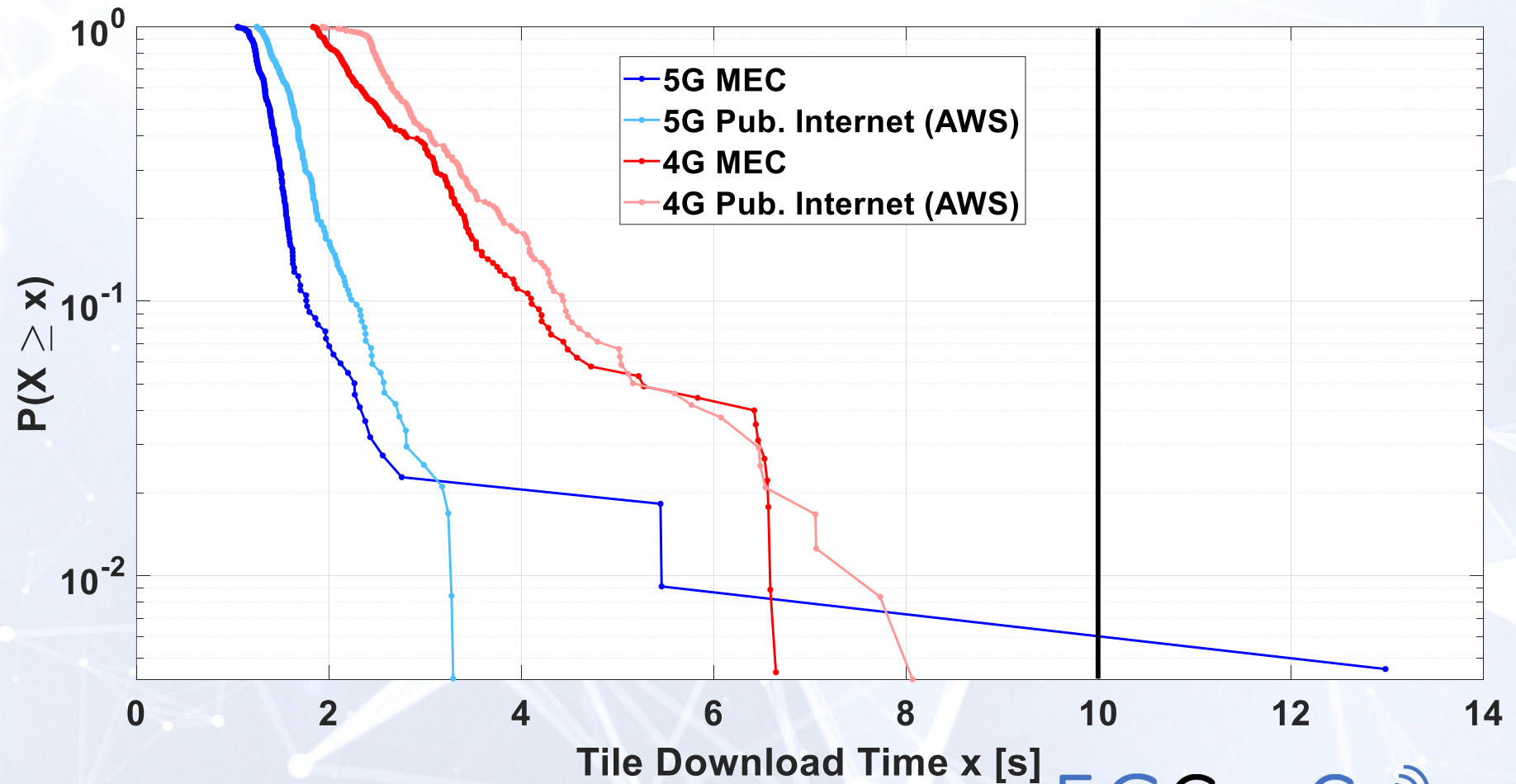 - TCP protocol sensitivity to small delay changes (Link)

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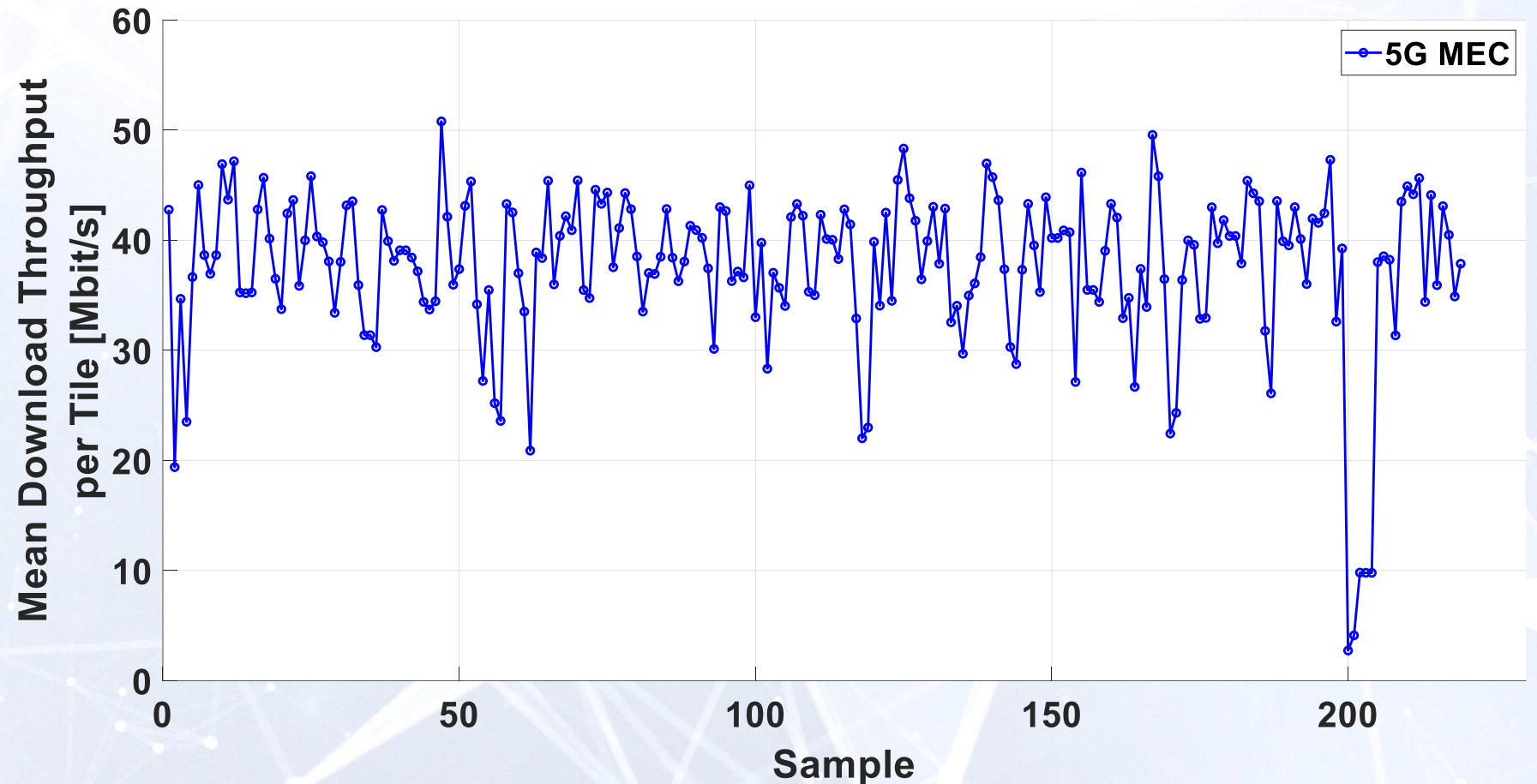
Initial Trial Results: HD Mapping

Some "problem" during
5G MEC experiment
caused outliers

**<10 s tile download
time requirement
fulfilled**

Scenario	Mean Download Time [s]
5G MEC	1.6
4G MEC	2.9
5G Pub. Inet.	1.7
4G Pub. Inet.	3.2

Legend:
- 5G MEC
- 5G Pub. Internet (AWS)
- 4G MEC
- 4G Pub. Internet (AWS)

Y-axis: $P(X \geq x)$

X-axis: Tile Download Time x [s]

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Use Case: Anticipated Coordinated Collision Avoidance (ACCA)

- More than just "Hazard Warning"
- User stories:

Hazard:

- Stationary vehicle
- Traffic jam

Reported/detected by:

- Vehicle(s) "in the hazard" and/or
- Other vehicles sensing it and/or
- Derived in cloud from other data like Cooperative Awareness Messages (CAMs)

https://www.youtube.com/watch?v=1v1i2vp8cEQ&t=2s

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Initial Trial Results: ACCA

- Hazard Reports were sent every 5 s

- Some Hazard Reports (uplink) and/or Hazard Notifications (downlink) experience larger delay
    - Could be caused by handover

- Impact is higher than other effect causing variance

- **1 s requirement (to allow much time for in-cloud processing) not violated**
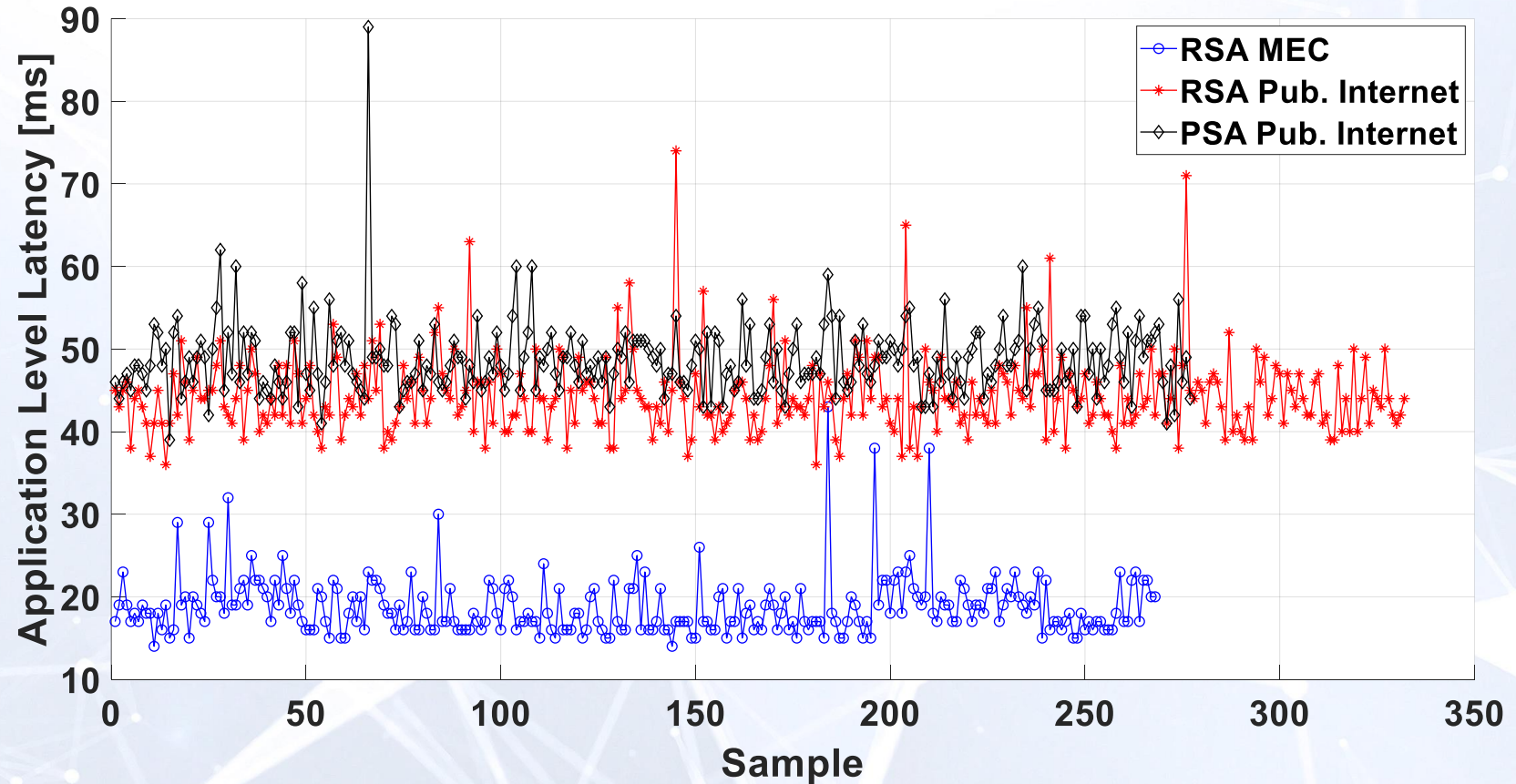
Initial Trial Results: ACCA

Scenario	Mean App. Level Delay [ms]
RSA MEC	18.8
PSA MEC	Experiment failed[1]
RSA Pub. Inet.	44.4
PSA Pub. Inet.	48.7
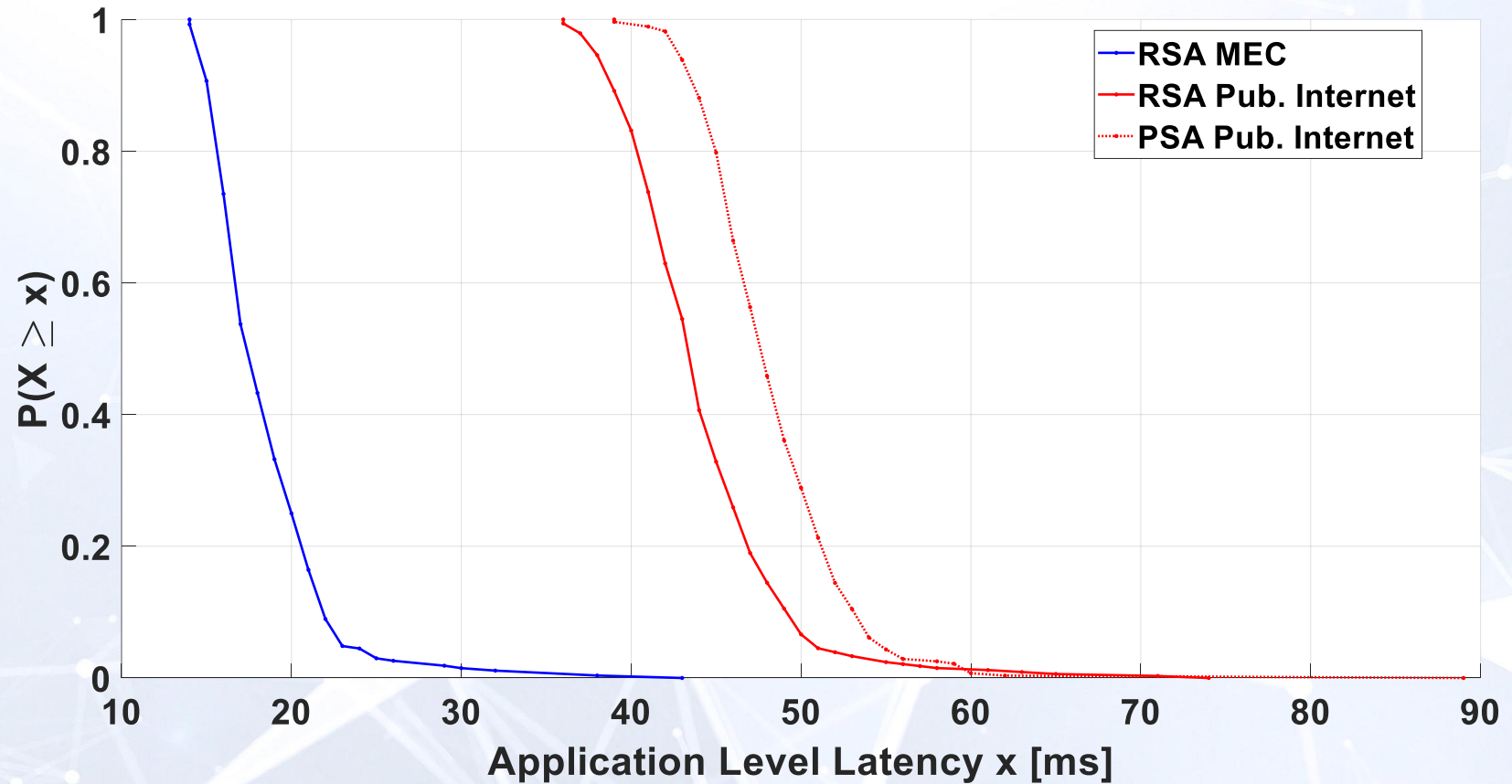
1) Experiment was done but something went wrong, and we got no results.
No time to repeat before D4.2 deadline

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Selected Open Questions

- Can S10 / N14 interfaces become as common as the other roaming interfaces?

- Can services and infrastructure for roaming be evolved to support S10 / N14?

- What are the performance requirements for S10 / N14 interfaces?

- How can frequency and Cell ID information be shared and kept up to date across MNOs?

- How to deal with different TDD-patterns, e.g. Germany-France?

From audience:

- Scalability

- It is not just between two PLMNs/MNOs but a many-to-many (incl. different freq. allocations)

- Inter-telco-vendor equipment testing of S10 / N14

Country 2

Country 1

Spectrum 1

Spectrum 2

Spectrum 3

Summary, Conclusion, and Next Steps

- Cross-border/-MNO handover was successfully demonstrated at the German-Luxembourgish border

- Results were documented and published in Deliverable D4.2

- Cross-border/-MNO handover allows seamless mobility across country borders and MNOs

- **It prevents many seconds or even minutes of service interruption**

- **For the HD Mapping and ACCA use cases no (substantial) performance degradation was experienced**

- Soon trials for Tele-operated driving and with Germany network (incl. French-German border) will be done

Thanks!!

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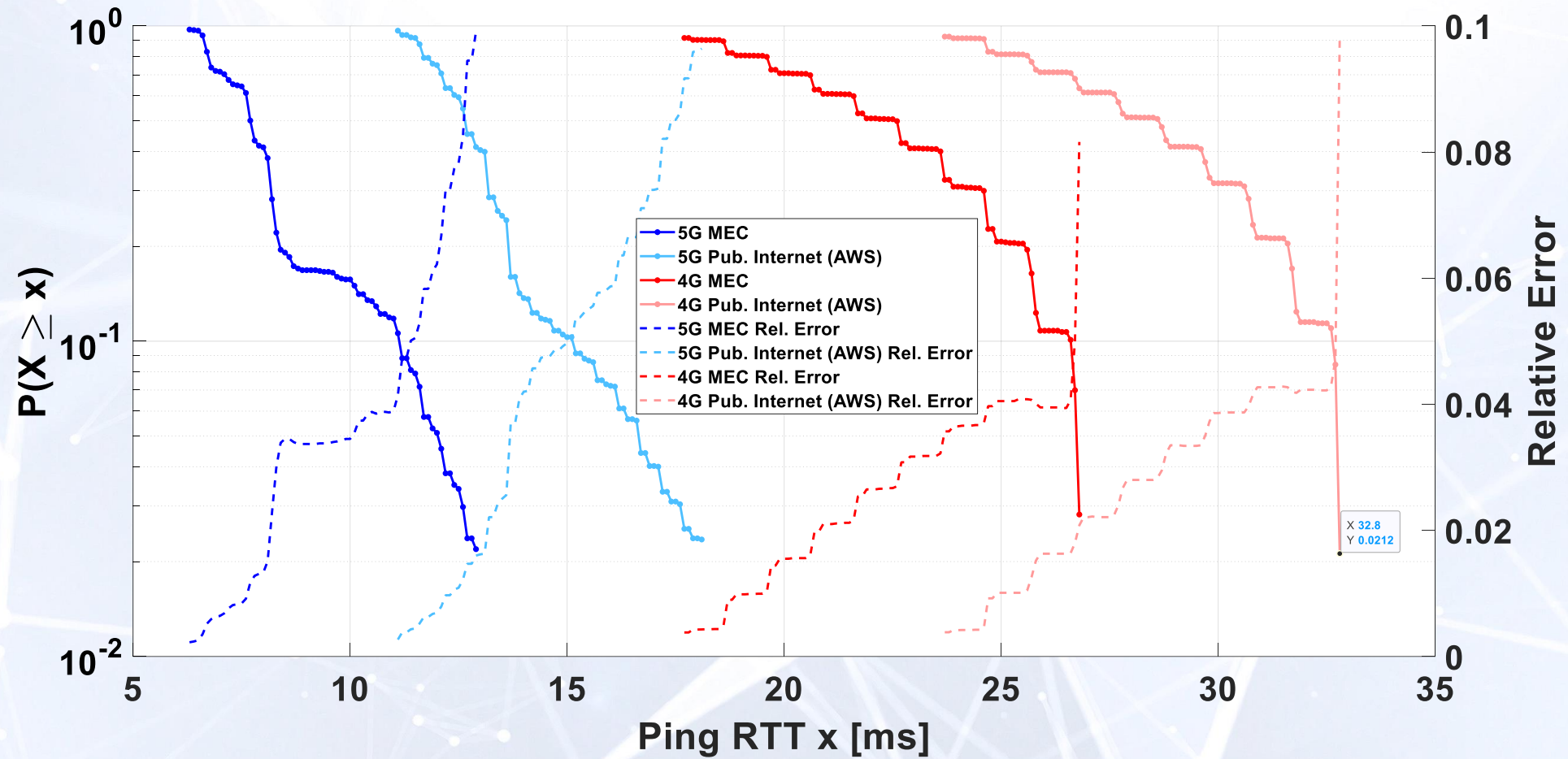Connect in LinkedIn
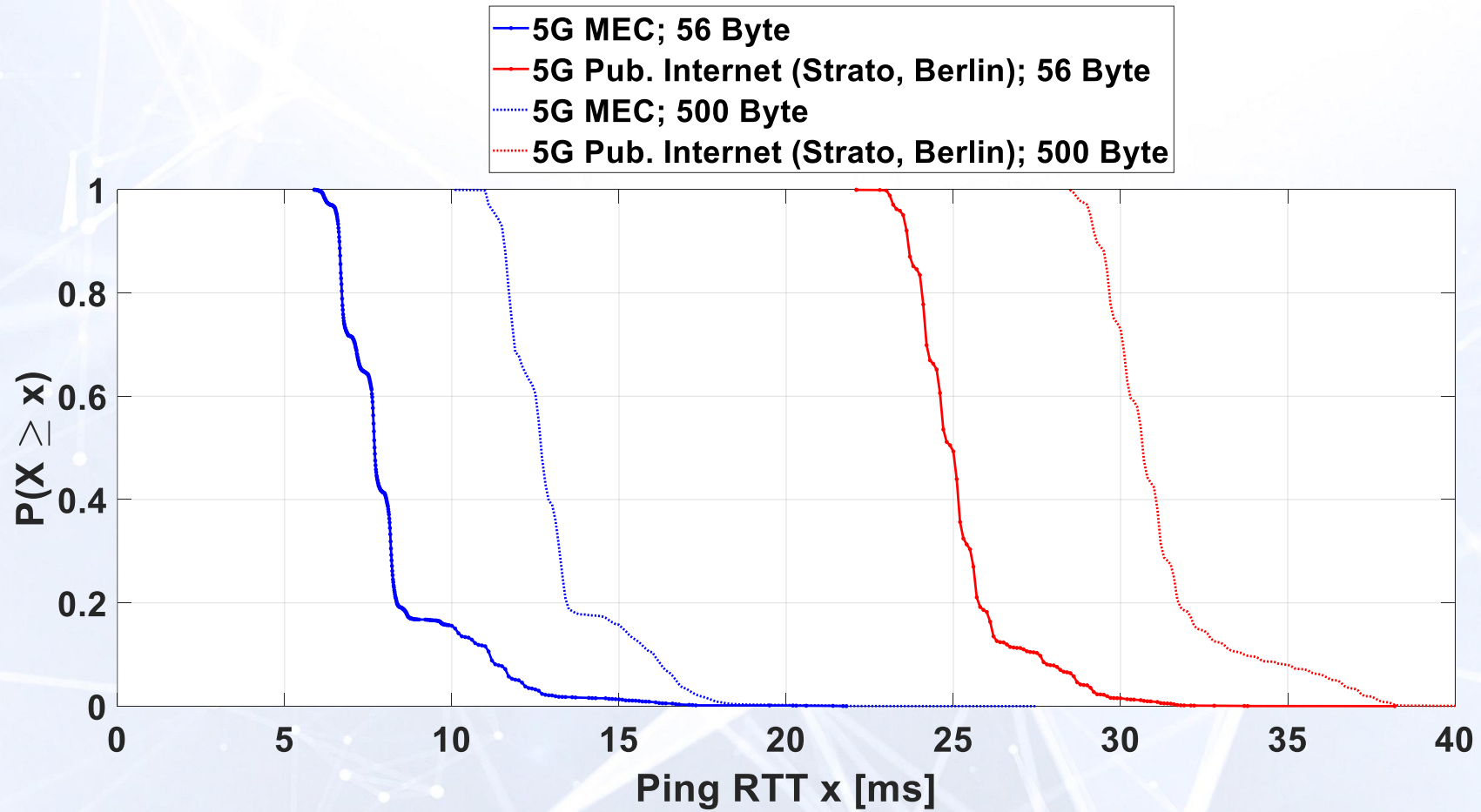Subscribe to our Newsletter

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