Teleoperation and automation are complementary approaches

Driven in autonomous mode:
98.2 % of the trajectory*

27 years of R&D later …

2% issue

Edge & corner cases

5G-Blueprint approach

5G seamless roaming for teleoperated driving

5G-Blueprint approach

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Outline

- Quick overview of 5G-Blueprint project
- Automotive use cases and teleoperation
- 5G seamless roaming
- Summary & Lessons learned

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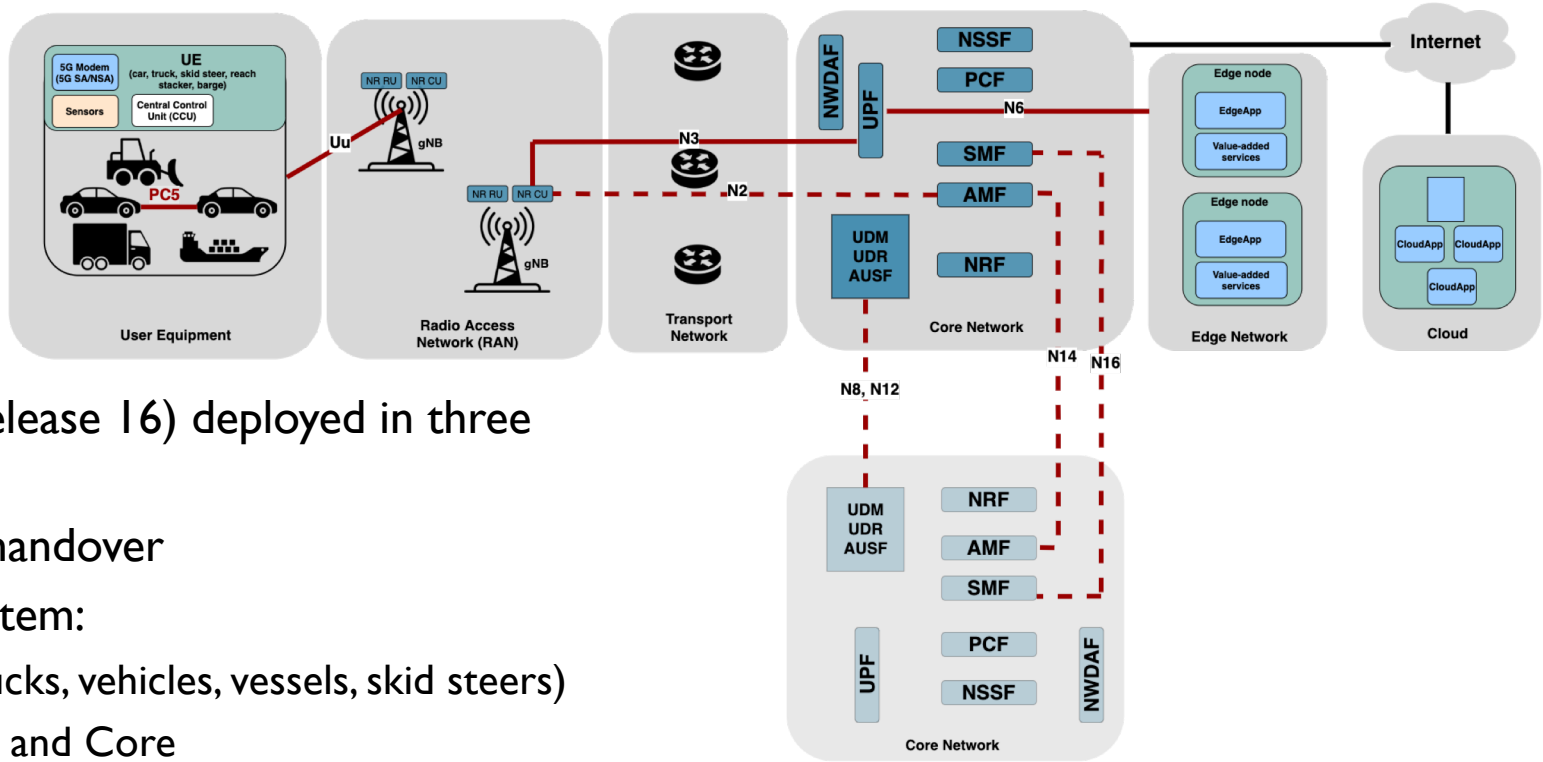
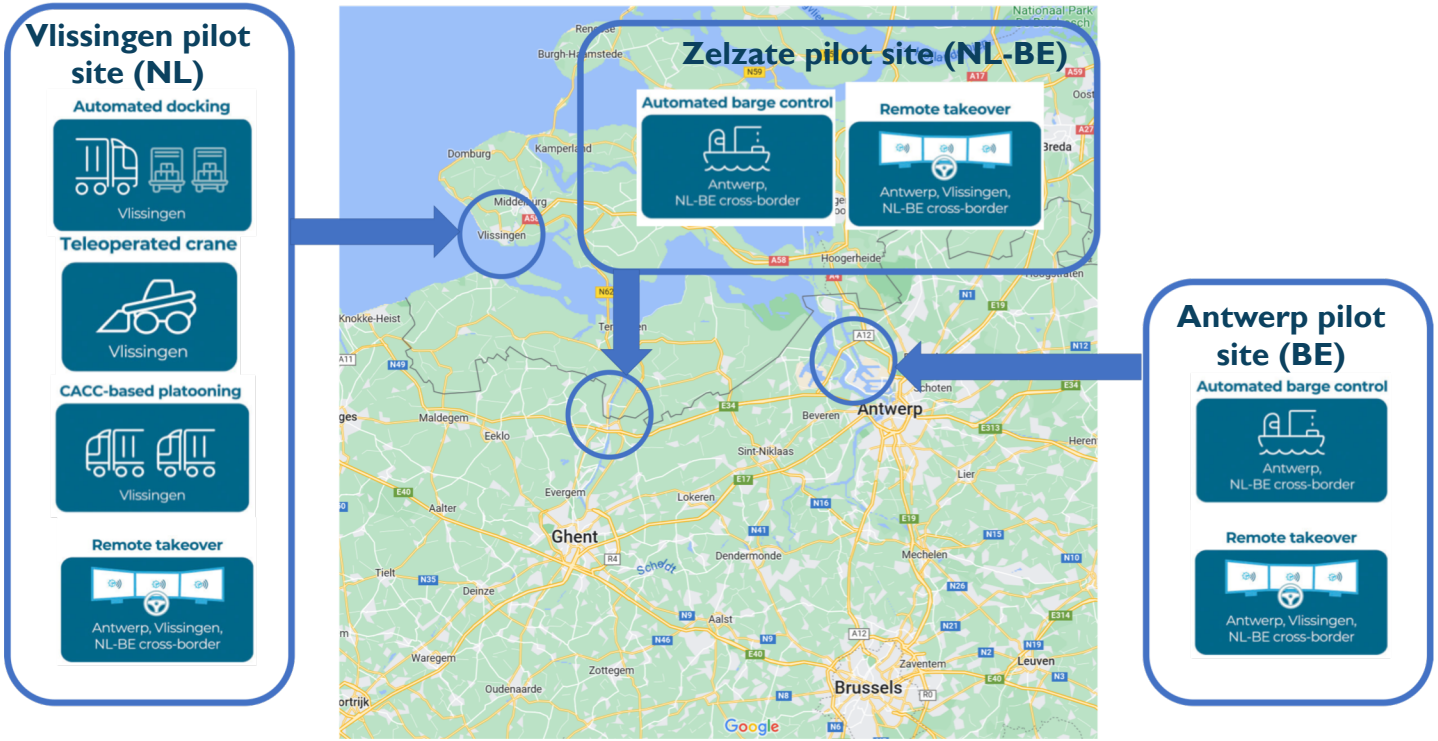
5G-Blueprint combines (cross-border) 5G SA with teleoperated driving and sailing



- 5G SA (Release 16) deployed in three pilot sites
- Seamless handover
- 5G ecosystem:
  - UE (trucks, vehicles, vessels, skid steers)
  - 5G NR and Core
  - Data network (Enabling functions and Use case components)

Use cases and Pilot sites



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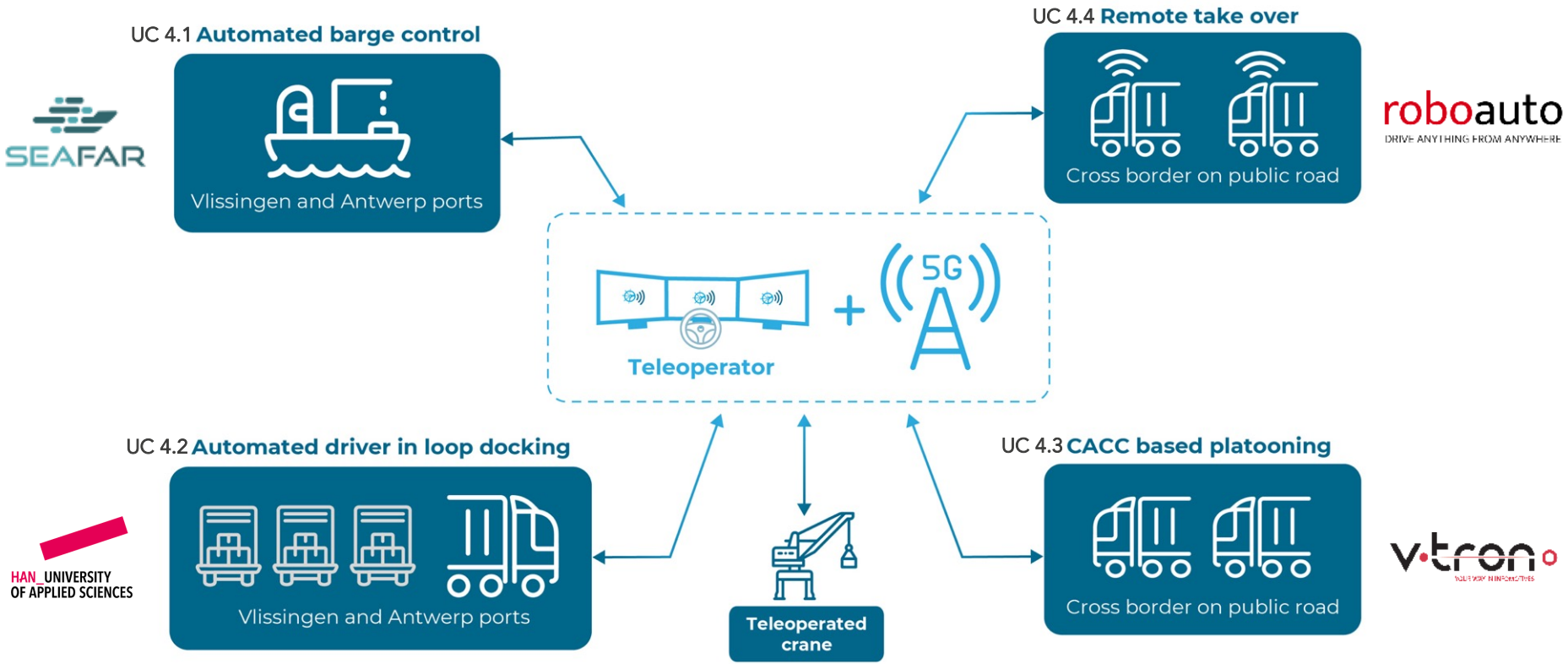
Use cases are tested in real-life environments such as busy ports and public roads



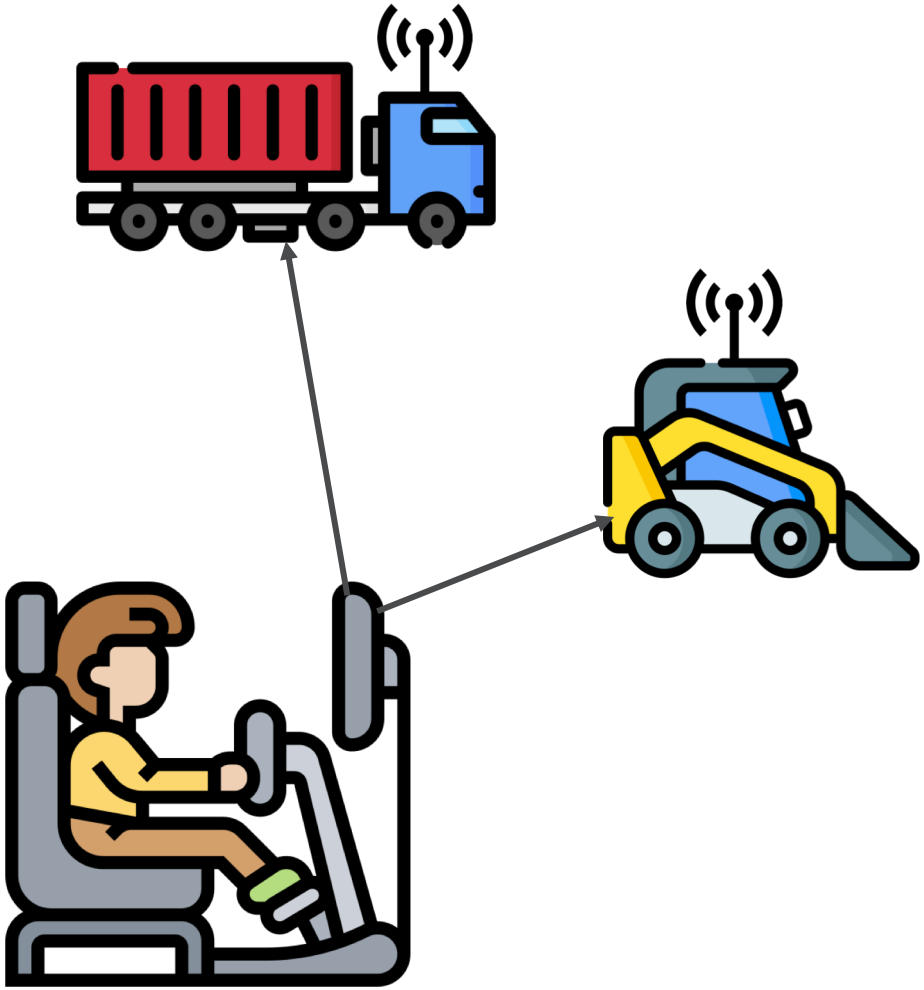
Challenges

Trucks

- Increasing driver shortage
- Increase in online shopping
- Waiting times at depos
- Bounded to one vehicle
- Long away from home

Material handling

- Unsafe operating conditions
- Bounded to one vehicle



Solution

TELEOPERATION USING 5G

EXPECTED BENEFITS:

- Higher efficiency
- Switch between vehicles
- Less waiting
- Attract new type of driver/operator
- Safer work environment
- Bridge to fully autonomous
- Drivers can work from other time zones during the day, while the truck drives at night.
- One operator can manage a platoon of multiple trucks by automating the following trucks
- ‘Gamification’ of the traditional professions using teleoperation could potentially interest the younger generation.

Teleoperated Docking scaled from simulations to pilot with trucks

Digital twin / Simulations → Scaled prototype testing → Full scale pilots

Teleoperated Docking scaled from simulations to pilot with trucks

MSP Onions test site in the Netherlands

Teleoperated Docking scaled from simulations to pilot with trucks

Teleoperator view

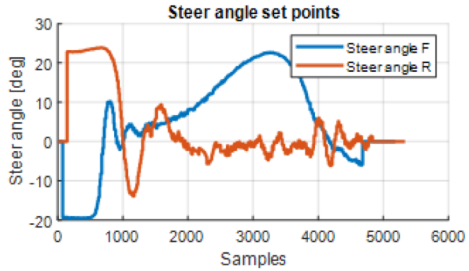
Cabin

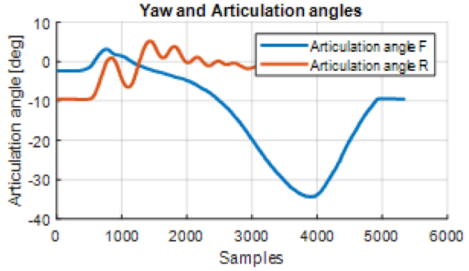
Average tracking error 0.16m, target values less than 0.5m

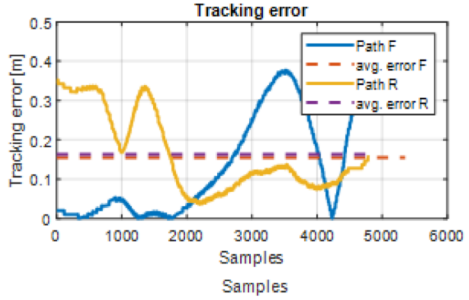
An example test run at MSP Onions

Final docking state error:

- A = 3.6cm, required < 10cm
- B = 8.4cm, required < 10cm
- C = 0.4deg, required < 2deg







Overall robustness of the teleoperation system improved, full takeover of DAF truck achieved

Steering accuracy: Mean absolute error 4.83deg (<6deg)

Braking accuracy: Mean absolute error 0.72% (<4%)

Steering accuracy: Mean absolute error 2.41deg (<3deg)

Braking accuracy: Mean absolute error 0.51% (<4%)

Overall robustness of the teleoperation system improved

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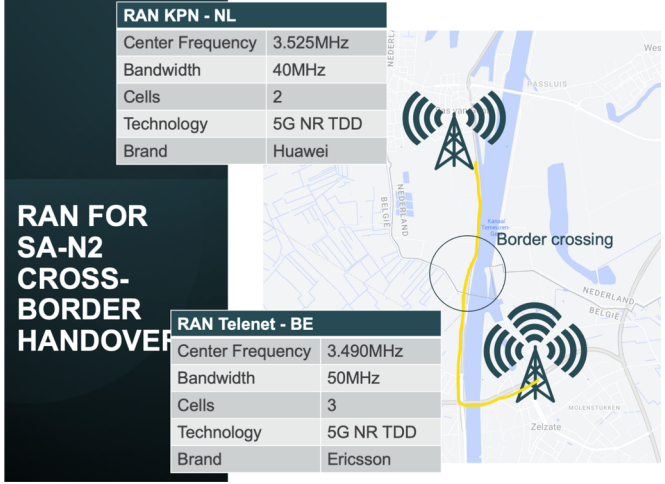
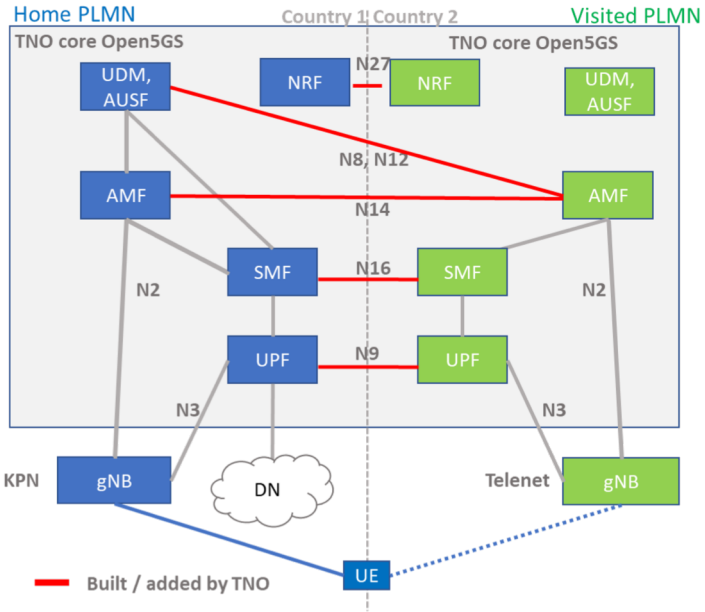
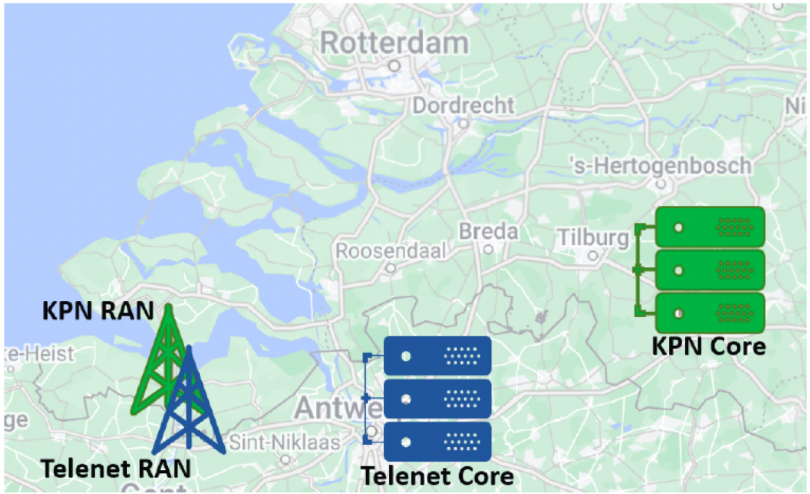
Seamless roaming

- 5G SA seamless roaming working and deployed at cross-border site
- Network evaluation done at BE and NL sites
- Successful seamless roaming demos







Roaming procedures can be optimized by combining Home routed SA principles with N14-based roaming

N14 vs N2

Seamless cross-border N14 handover performs similar to the N2 handover, the main difference is that it depends on the latency between the cores

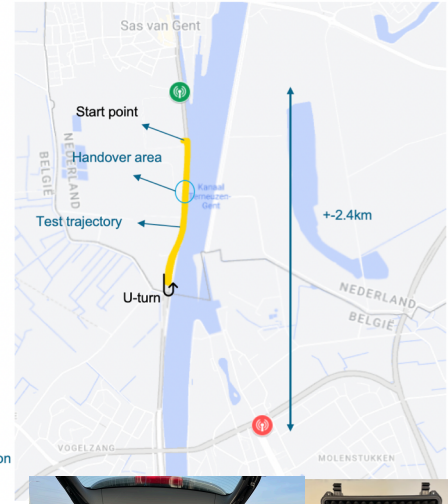
Lab results

- N2 handover: 100-120ms
- N14 handover: 100-150ms

Field results

- N14 handover: ~100ms
- Latency between the two cores: ~7ms → small impact compared to the other latency components

- Uplink throughput: 32.4 Mbps
- Downlink throughput: 145 Mbps



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Summary

Teleoperation of vehicles

- Autodocking successfully tested with the full-scale trucks over 5G SA
- Teleoperation of vehicles (Toyota vehicles and DAF trucks) successfully tested over 5G SA in the national sites (BE, NL)
- Network testing demonstrated that its performance enables **safe teleoperation across borders**
- Testing campaigns with teleoperation of vehicles ongoing in the cross-border setup

Seamless roaming

- 5G-Blueprint solution one of the first practical implementations for seamless roaming in 5G SA
- Solution combines Home routed SA roaming with the N14 interface
- Service interruption time significantly reduced → sufficient for teleoperation (<150ms)

Lessons learned

Teleoperation of vehicles

- Human factors need to be considered for teleoperation: varying driver experiences, resolutions and frame rate effects, fatigue
- Handover-caused interruption times sufficient for cross-border teleoperation

Seamless roaming

- Standardization potential:
  - New procedure to enable Home-Routed Seamless roaming in 5G SA → **merges** N14 handover with Home-Routed Roaming
  - Seamless roaming with inter-PLMN handover in **both** directions → procedure for V-PLMN to H-PLMN direction is also missing in standards.

- Handover decisions currently based on signal strength, exploring other criteria (allowed IMSI, service availability, contractual relations)
- Vast amount of configuration parameters → to be automated

Join us at the final event

Date: November 21st 2023

Location: Industrial Museum Zeeland, Sas van Gent, The Netherlands

The event is free of charge, but registration is mandatory, due to limited seats