5G Standalone Seamless Roaming for Cross-Border Automotive Use Cases

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***Abstract*—5G and beyond 5G networks are designed to enable a set of novel applications and industry verticals with very different requirements, such as agriculture, transport, or healthcare. For example, to support automotive and teleoperated transport, 5G systems are expected to guarantee URLLC (Ultra Reliable Low Latency Communications) requirements with minimal interruption times. The 5G-Blueprint project aims to provide technical solutions for 5G-enabled uninterrupted (i.e., seamless) communications in cross-border teleoperated automotive use cases. To support these services, this poster presents, to the best of our knowledge, the first practical implementation of seamless 5G Standalone Roaming using off-the-shelf UEs and gNBs. Preliminary results of our experiments show an interruption time in the range of 100-150 milliseconds, thereby meeting the requirements of teleoperated automotive services.**

I. Introduction

Vehicular teleoperation is a step towards autonomous driving and other advanced Cooperative, connected and automated mobility (CCAM) use cases. It is an exciting alternative for road transport and logistics in the context of the current labor shortage affecting multiple industry sectors. However, to enable such mission-critical use cases, 5G connectivity should satisfy stringent latency requirements and remain uninterrupted. This task is more challenging in a cross-border roaming scenario where the vehicle has to be handed over to the network of a different operator in a different country. Currently, the 3GPP standards for 5G provide support for roaming, but under the assumption that the PDU session is terminated at the home PLMN, and a new one is established at the visited PLMN. This results in long interruption times that are unacceptable for vehicular teleoperation. Therefore, new mechanisms are required to enable Seamless 5G-enabled roaming.

The 5G-Blueprint [1] project ambitions to design and demonstrate technical solutions and business and governance models to support 5G-enabled uninterrupted cross-border teleoperated transport. The developed solutions will be validated in-lab and tested during trials on a Dutch and Belgian cross-border corridor.

II. Seamless Roaming in 5G

Current 3GPP 5G specifications support two types of roaming implementations in standalone (SA): Local breakout (LBO), where data traffic is directly routed from the UPF of the Visited PLMN to the Data Network, and Home-Routed (HR), where traffic is sent back to the UPF of the Home PLMN to be classified and routed. In previous trials, cross-border roaming has been enabled in a non-standalone (NSA) setting (i.e., 5G RAN with a 4G core)[2]. Furthermore, this project's precursor 5G-MOBIX[3] has implemented a standalone (i.e., two 5G cores) roaming solution based on local-breakout (LBO), where the observed interruption times were in the range of tens of seconds [4]. This is not sufficient for the teleoperation use-cases, which tolerate an interruption time in the range of hundreds of milliseconds only.

To further minimize interruption time, the proposed solution builds on the results and findings of 5G-MOBIX. Further, as shown in Figures 1 and 2, it combines two procedures from the 16th Release of the 3GPP specifications[5], namely:

- Home-Routed roaming, where the UE's traffic is redirected to the home PLMN core network by establishing a tunnel between the UPFs on the N9 interface, where tunnel info is exchanged between the SMFs of both networks through the N16 interface.
- N14-based handover, where the UE context is transferred between two gNBs through the N14 interface connecting their AMFs in two phases: a preparation phase where the context is proactively transferred to the gNB of the Visited PLMN, and an execution phase where the UE leaves the Home PLMN and connects to the Visited PLMN.

The combination of those procedures allows the user context to be transferred across PLMNs so that the Visited PLMN can reuse it. Moreover, since this is done in the N14 preparation phase, the PDU session can be set up in advance (i.e., before the N14 execution phase). This way, the downtime can be minimized, enabling the URLLC services.

III. Test Setup, Trials

A. Lab setup

Our lab setup consists of two Intel NUCs, each running a 5G SA core, two off-the-shelf gNBs (e.g., Ericsson), and a Quectel 5G modem (acting as a UE) that is placed in a Faraday cage (see Fig. 3). Two attenuators are used to attenuate the signals from the gNBs. This way, we are able to mimic cross-border scenarios (e.g., a car moving away from the coverage

[1] https://www.5gblueprint.eu/

[2] https://www.ericsson.com/en/blog/2019/5/connected-vehicle-cross-border-service-coverage

[3] https://www.5g-mobix.com/

[4] https://www.5g-mobix.com/assets/files/5G-MOBIX-D5.2-Report-on-technical-evaluation-v1.0_final.pdf

[5] 3GPP, "Technical Specification Group Services and System Aspects; Procedures for the 5G System (5GS); Stage 2" 3rd Generation Partnership Project (3GPP), Technical Specification (TS) 23.502, 12 2022, version 16.15.0.

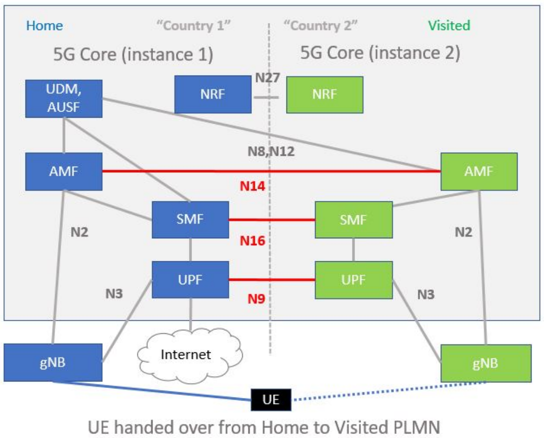

Fig. 1. Architecture for Seamless 5G SA Roaming

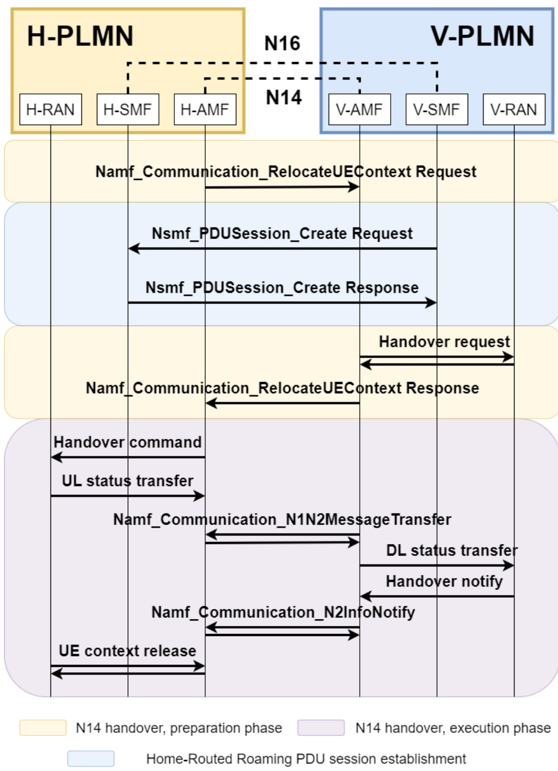

Fig. 2. Simplified call-flow for Seamless 5G Roaming

area of MNO1 to the coverage area of MNO2). Moreover, due to the controlled environment that the Faraday cage provides, the described setup allows for reproducible experiments.

B. Results

We compared our roaming implementation to the results achieved in the 5G-MOBIX project. To do so, we generated UDP traffic from the UE (using iperf) and measured the time needed for the UE to switch the UE data traffic between the MNOs. All experiments were run 10 times. Our preliminary results show that, due to the N14 handover and the reuse of the already established session in the HPLMN, the downtime can be significantly reduced from 14s (which was the minimum

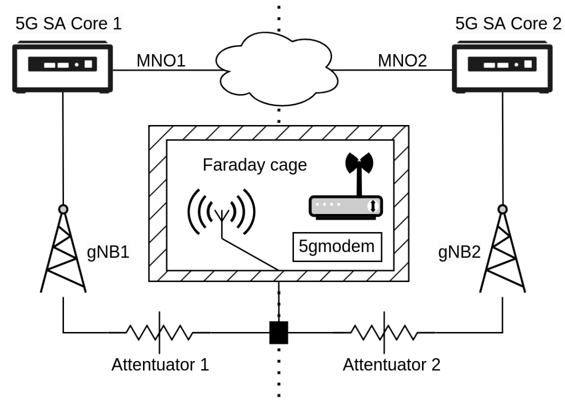

Fig. 3. Inter-Lab setup

achieved in 5G-MOBIX) to 135ms (on average).

C. Trials

After the lab setups are complete, the roaming implementation will be evaluated in the field at the border between the Netherlands and Belgium. To do that, the same 5G SA cores and configuration of the gNBs from the lab will be reused.

IV. Conclusion

To enable cross-border teleoperated services, the 5GS architecture needs to be enhanced to support a Seamless roaming process between network operators. The 5G-Blueprint project proposes a solution that enables this by combining the Home-routed roaming and N14-handover, which preserves the vehicle's session and context and minimizes service interruption time to the range of hundreds of milliseconds.

Acknowledgment

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Appendix: About 5G-Blueprint

Project Name:	Next generation connectivity for enhanced, safe and efficient transport and logistics
Call:	H2020-ICT-2018-2020
Topic:	ICT-53-2020: 5G PPP – 5G for Connected and Automated Mobility
Type of action:	Research and Innovation
Total Budget:	13.91 Million euros
Duration:	36 months
Starting Date:	01/09/2020
End date:	31/12/2023
Description:	The 5G-Blueprint project aims to design and validate the technical architecture and business and governance models for uninterrupted cross-border teleoperated transport based on 5G connectivity.