WHITE PAPER from 5G-MOBIX, 5G-CARMEN, and 5GCroCo

May 31st, 2023

5G technologies for connected automated mobility in cross-border contexts

Abstract

This White Paper describes valuable insights the three ICT-18 projects 5G-MOBIX, 5G-CARMEN, and 5GCroCo provided into the potential of 5G technology for supporting Connected and Automated Mobility (CAM) services, particularly in cross-border contexts and also compared to 4G. Seamless service continuity in cross-border corridor areas is feasible and can be guaranteed, and the projects trialled different solutions involving the network side and the end-device.

Overall, the projects trialled five different solutions which were evaluated to assess the cross-border service continuity. Further, edge computing capabilities (MEC) and their implications towards service continuity were evaluated. This research highlights the potential for 5G technology to enhance cross-border connectivity, and the importance of prioritizing inter-PLMN handover in this context. With further development and implementation, 5G technology has the potential to revolutionize cross-border communication and connectivity and enable advanced, real-time CAM services.

Inside the whitepaper

1 Introduction

The first wave of H2020 5G PPP projects working on 5G-enabled connected, automated mobility (CAM) in cross-border scenarios were 5G-MOBIX [1], 5G-CARMEN [2], and 5GCroCo [3]. They are collectively referred to as the ICT-18 projects as they were funded under the ICT-18-2018 topic of the 5G PPP call from the European Union's Horizon 2020 research and innovation program. The three projects shared the objective to build a sustainable future for connected and automated vehicles. To do so, all three aimed at qualifying 5G as a core connectivity infrastructure to address advanced CAM services focusing on cross-border areas.

The provision of CAM services across different countries when vehicles traverse various national borders has a promising business potential. However, the seamless provision of connectivity and the uninterrupted delivery of real-time services across borders also pose technical challenges that were addressed in the ICT-18 projects. The situation is challenging given the multi-country, multi-mobile network operator (MNO), multi-telco-vendor, multi-car-manufacturer (OEM), multi-road operator, and cross-generation scenario of any cross-border layout. In that setting, 5G-MOBIX, 5G-CARMEN, and 5GCroCo trialled a wide variety of use cases, that were selected to validate 5G features that can contribute to a successful deployment of CAM services. The most relevant trialling activities conducted by the three projects took place at large-scale corridor areas, which are part of the Trans-European Transport Network (TEN-T) [4] and which are listed below:

- 5G-MOBIX: ES-PT (Vigo, Spain – Porto, Portugal)
- 5G-MOBIX: GR-TR (Thessaloniki, Greece – Turkey)
- 5G-CARMEN: DE-AT-IT (Munich, Germany – Innsbruck, Austria – Bologna, Italy)
- 5GCroCo: FR-DE-LU (Metz, France – Merzig, Germany – Luxembourg)

In these cross-border settings, different approaches to address service continuity were analysed together with an assessment of the performance obtained with 5G (especially compared to 4G). In addition, during the execution of the three projects, it became apparent that all service continuity approaches have different business and organizational requirements that strongly depend on new cooperation models between MNOs. Thus, besides presenting the main results related to cross-border service continuity and 5G performance, this whitepaper also discusses recommendations related to network deployment and its associated roadmap to contribute to an overall industry consensus on mechanisms implemented to ensure CAM service continuity over 5G.

For the sake of completeness, the three ICT-18 projects are briefly summarized in the following.

5G-MOBIX: In order to enable innovative and advanced automated driving applications 5G-MOBIX had the objective to align the benefits of both 5G technology and CAM use cases. By using 5G key technological innovations, 5G-MOBIX developed and tested vehicular functionalities along two cross-border corridors (Spain-Portugal and Greece-Turkey, a non-EU hard border) and urban pilot sites. Besides economic, legal, and social aspects different from region to region, further conditions of automotive traffic, network coverage and service demand were considered throughout the test phase.

5G-CARMEN: The project 5G-CARMEN focused on the 600 km Bologna-Munich corridor which crosses Italy, Austria and Germany. 5G-CARMEN implemented a multi-tenant platform that can assist the automotive sector in delivering more eco-friendly, intelligent, and secure transportation with the support of 5G technology.

5GCroCo: 5GCroCo tested and trialled 5G technologies for CAM use cases along the borders of France, Luxembourg, and Germany with the main focus on the technical validation of cross-border and inter-Public Land Mobile Network (PLMN) handovers to ensure service continuity. Furthermore, 5GCroCo identified new business models which can be established based on 5G's exceptional connectivity and service provisioning capacity. Relevant standardization committees were impacted by the automotive and telecommunications industry partners in this project.

The remainder of this whitepaper is organized as follows: Section 2 presents the different trialed solutions related to cross-border service continuity and its related results. Section 3 focuses on the measured performance of 5G Non-Stand Alone (NSA) and achieved improvements compared to 4G. The focus is on 5G NSA only as this was the technology deployed at the corridor areas by the three projects. The aim of Section 4 is to discuss aspects related to the presence of Multi-access Edge Computing (MEC) in cross-border settings. Finally, Sections 5 and 6 provide the recommendations related to network deployment and overall roadmap, respectively.

2 Cross-border service continuity

The combination of the results obtained by the three ICT-18 projects has yielded valuable insights into the capabilities and potential of 5G technology. As the most significant outcome from trials in cross-border contexts, the three projects have independently shown that seamless service continuity in cross-border corridor areas is feasible and can be guaranteed provided there is overlapping RAN coverage.

The three projects implemented and trialed different solutions, which can be categorized in two main groups: (i) those involving implementations and re-configurations on the network side and (ii) those involving implementations and re-configurations on the end-device. Besides the different solutions, a baseline configuration was also trialed. Thus, the projects trialed five different options to assess the cross-border service continuity (one baseline, three different network side solutions and one group of end-device based solutions), which can be summarized as:

1. Network reselection[1]
2. Release-with-redirect (no S10 interface present)
3. Release-with-redirect (S10 interface present)
4. Inter-PLMN handover
5. End-device based solutions

Regarding 1, network reselection refers to the case where the end-device (modem or router) remains connected to the last base station of the MNO in the previous country while already driving through the new one. This situation will continue until the connection is lost due to too-weak radio signal. At this point, an MNO search and eventually selection and connection to a new MNO is triggered. This can overall result in many seconds or even minutes of service interruption.

Regarding the network side solutions 2, 3, and 4, a detailed technical description of the underlying 3GPP specifications for these solutions improving network reselection can be found in Section 4.1.1.2

[1] The name "network reselection" was chosen as the baseline solution as the other solutions 2, 3, and 4 are often referred to be "network reselection improvements", so it makes sense to refer to the baseline, which is being improved, as "network reselection."

in [5], Section 3.3.6 in [6], as well as Section 3 in [7]. Nonetheless, a short, high-level summary is provided below for convenience:

2. and 3. Release-with-redirect (RwR): A UE not having active data connections or calls is in "idle" mode. It is still "camping" on a certain eNB[2] which would page it if there is incoming data and which would be used to establish a connection when going from "idle" to "connected". When moving, the eNB can change, which is called "idle mode mobility" and it is a much simpler procedure than the handover used in connected mode. Release-with-redirect is a procedure where the UE is actively sent to idle mode and then executes the described idle-mode mobility procedure. Knowing the frequency of the target eNB is a prerequisite for that, in order to determine if there is an eNB with better quality available. Once the UE synchronizes to the target eNB, it will immediately initiate transition to "connected" mode, as there are ongoing data sessions. Once connected, it will also issue a Tracking Area Update (TAU) towards the Core. For solution 3 (S10 interface present), this will trigger a transfer of Core context information over the S10 interface. In case the S10 interface is not present, as for solution 2, the context cannot be transferred and the TAU fails. The UE detaches from the network. Usually, the modem or router manager software issues a reconnection which results in successfully attaching to the same network and cell which previously detached the UE as the TAU failed. Compared to the network reselection baseline, solutions 2 and 3 remove the interruption time until the UE connection is completely lost and, also, the UE network searching time. For solution 3, the interruption time necessary to create a new PLMN context is also removed.

4. Inter-PLMN handover: For an inter-PLMN handover, the frequency of the target eNB must also be known and provided to the UE to scan for it. Once it is decided to execute an inter-PLMN handover, as the target eNB has sufficiently better radio quality than the current source eNB, the UE remains in connected mode throughout the inter-PLMN handover. The source eNB contacts the target eNB to request if a handover is possible, and upon positive response transfers the RAN context information of the UE. In a last step, it tells the UE to detach from it and attach to the target eNB. When scanning, the UE only obtains a Physical Cell ID (PCI) from the target eNB. The source eNB must have a mapping of this PCI to the identifiers of the target eNB. It will then realize it cannot reach the target eNB directly over the X2 interface, as those are typically not present across different PLMNs, so instead all inter-PLMN handover related communication is done over the S1 interface between eNB and MME. The MME, based on the target eNB identifiers, realizes that another MME is connected to the target eNB and uses the S10 interface towards that MME to relay the inter-PLMN handover-related communication.

Finally, regarding 5 (end-device based solutions), the results provided in Section 4.5.1 in [8] show that the measured service interruption times strongly depend on the modem settings and configurations and involve many different types of solutions: from multi-SIM implementations to re-configuring the received power thresholds to trigger the connection to the new MNO.

The following Table 1 and corresponding plot in Figure 1 summarize the results obtained in the trials carried out in the different corridor areas by the three projects, and show the average service interruption times achieved by the different solutions listed above. Observe that end-device solutions are not shown in the table because they were not evaluated in corridor areas. Also, note that the network deployment and configurations used in the different corridor areas are not fully comparable on a one-to-one basis and, accordingly, the presented results provide only an indication on the achieved service interruption times:

[2] With 5G NSA, all control plane procedures are conducted on the 4G LTE eNB. Once completed, the 5G NR gNB is added as secondary cell handling user plane communication.

Project: corridor area	Network reselection (baseline today)	RwR (no S10)	RwR (S10)	Inter-PLMN HO
5G-MOBIX: ES-PT	Highly dependent on end-device configuration, but typically resulting in tens of seconds and even a few minutes of interruption time	-	-	245 ms
5G-MOBIX: GR-TR		-	-	194 ms
5G-CARMEN: DE-AT-IT		1950 ms	-	-
5GCroCo: FR-DE-LU		6246 ms	727 ms	121 ms

Table 1: Service interruption times achieved by the 4 network side solutions trialled in the corridor areas by the three ICT-18 projects

The inter-PLMN handover service continuity solution evaluated in 5GCroCo and in 5G-MOBIX results in an almost imperceptible service interruption time between 120 ms to 245 ms. This low interruption time is to be compared to the service interruption times that are achieved with other solutions, like Release with Redirect (RwR), which comes in two flavors depending on whether or not an S10 interface is available between the two national mobile networks. When an S10 interface is available, RwR achieves interruption times around 730 ms, which go up to few seconds if the S10 interface is not available. In the latter case, the connection breaks and needs to be reestablished, which took between around 2 and 6 s with the devices used in the conducted trials. However, even the 6 s are better than the current situation at the border with network reselection where the connection is dropped and a connection to the visited network occurs only after tens of seconds or even minutes when being away enough from the home network.

It should furthermore be noted, that once RwR with S10 is enabled, evolving it to inter-PLMN handover requires only refining information on neighbor cell IDs between MNOs. Information about frequencies are already part of the RwR configuration. In this case, it is a matter of the contractual agreements that should be put in place among the operators involved.

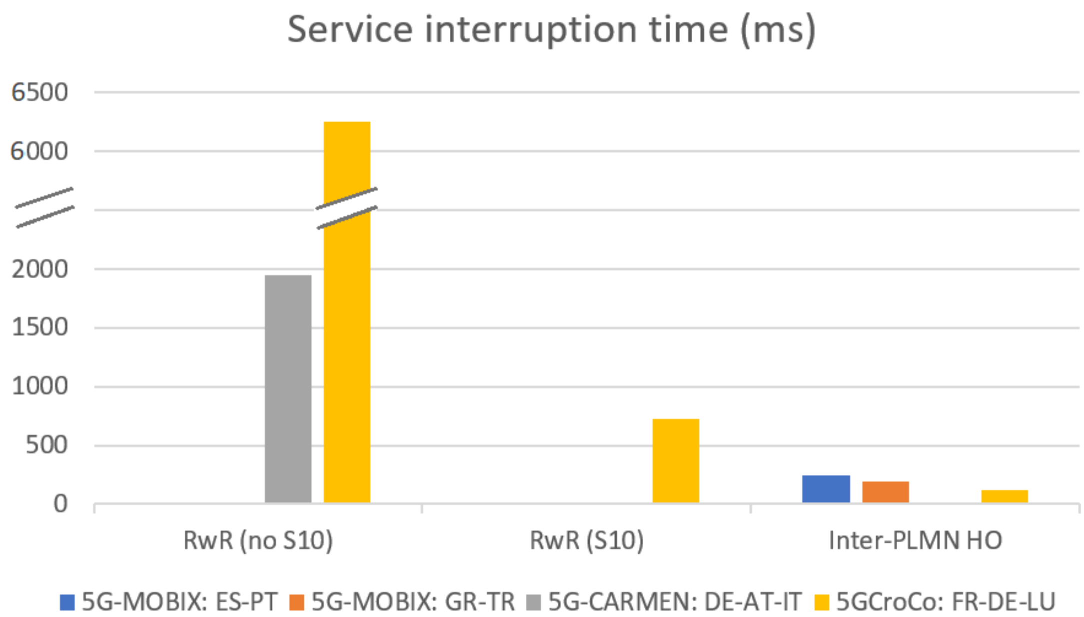

Figure 1: Bar diagram of the service interruption times achieved by the 3 network side solutions trialled in the corridor areas by the three ICT-18 projects (the network reselection baseline is not plotted)

3 5G performance and improvement compared to 4G

During the trials carried out by the three projects, it was confirmed that 5G will bring a lot of benefits relative to 4G. In particular, the ICT-18 projects focused their measurements related to the performance of 5G in three main categories:

1. Throughput (user experienced data rate) both in the UL and DL
2. Delay and round-trip-times
3. Reliability

Table 2 and the corresponding plot in Figure 2 summarize the main results obtained in the different corridor areas. Similarly as in the previous section, note that the network deployment and configurations used in the different corridor areas are not fully comparable on a one-to-one basis and, accordingly, the presented results provide only an indication on the achieved 5G performance.

Project: corridor area	Throughput (UL+DL)	Delay (UL+DL) / RTT	Reliability (UL+DL) / Total
5G-MOBIX: ES-PT	(75 + 399) Mbps	20 ms	98-100 %
5G-MOBIX: GR-TR	(N/A + 525) Mbps	16.3 ms	99.9%
5G-CARMEN: DE-AT-IT	(57 + 349) Mbps	32 ms	98 %
5GCroCo: FR-DE-LU	(30 + 900) Mbps	8.7 ms	97-100 %

Table 2: Performance obtained by the 5G NSA networks deployed in the corridor areas

Figure 2 below provides a graphical representation of the numerical results presented above.

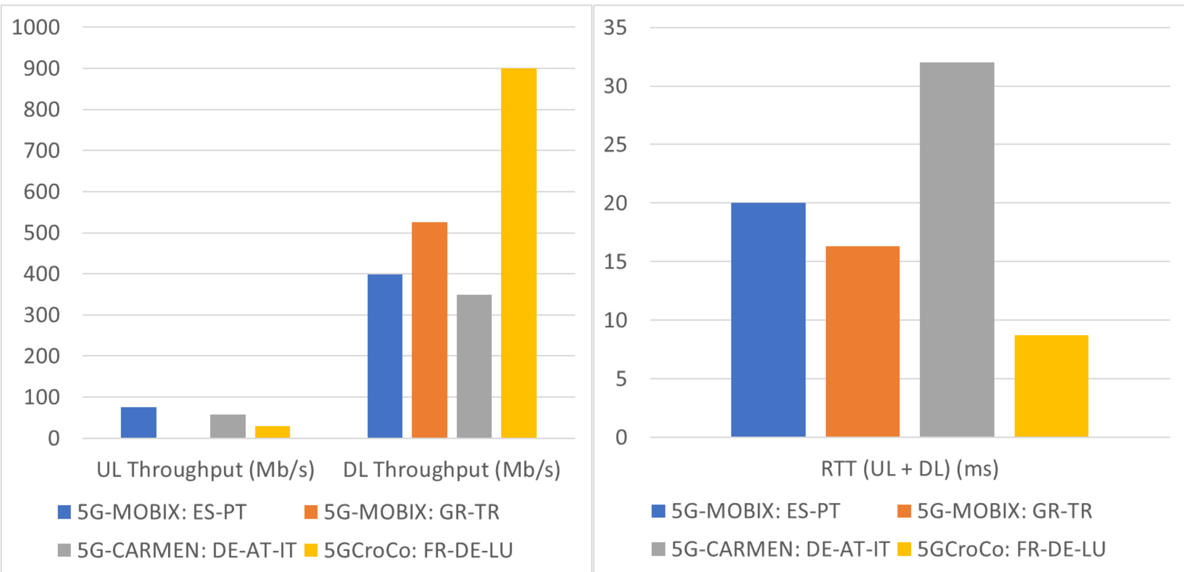

Figure 2: Bar diagram of the performance obtained by the 5G NSA networks deployed in the corridor areas by the three ICT-18 projects (excluding the Reliability figures as they are not informative)

In addition to conducting trials to assess the performance of 5G, the projects 5G-CARMEN and 5GCroCo also trialled some results using 4G, which serve as a baseline. In particular, 5G-CARMEN obtained a throughput of (30 + 68) Mbps – compared to (57 + 349) Mbps in 5G and a reliability of 99 % (very similar to the one obtained in 5G). In the case of latency, 5GCroCo obtained a RTT of 19.6 ms with 4G – compared to 8.7 ms reached in 5G.

From the results presented above, it is clear that 5G brings, first of all, down the overall network latency compared to 4G. It also enhances the throughput. This is especially important for the UL part of many use cases as e.g. 5GCroCo tele-operated driving use case. A local breakout of the user plane allowing Mobile Edge Computing (MEC) is bringing down further the latency. Especially 5GCroCo's use case Anticipated Cooperative Collision Avoidance showed the improvements of this low latency where an application layer RTT latency is about 25 ms for server hosted locally (MEC) compared to about 50 ms for a cloud server. 5G-MOBIX's trials yielded similar results, where the stability of these low latency values was also shown, against the higher fluctuations observed on Internet paths towards central cloud locations. But edge computing may allow as well higher average throughput for smaller file sizes as e.g. for a TCP connection the peak throughput is achieved faster thanks to a lower latency; this was observed by 5GCroCo HD Mapping trials.

While a fair comparison between 5G and 4G for the delays and reliability can easily be achieved as shown in the previous two paragraphs, a fair throughput comparison typically requires identical radio spectrum bandwidths, which was not the case for any of the projects. In case of peak throughput evaluation, results can be normalized to spectrum bandwidths to achieve spectral efficiency results. Unfortunately, with the live (i.e., commercial) networks used in 5G-CARMEN and 5G-MOBIX, computing the equivalent bandwidths used for the trials is not possible. In the case of 5GCroCo, since the deployed network was used for testing and trialing purposes only, a fair comparison among peak spectral efficiencies comparing 5G and 4G was possible and the achieved conclusions were:

- Downlink spectral efficiently is more than doubled from 4.4 bit/s/Hz in 4G to 9.2 bit/s/Hz in 5G.
- The increase of uplink spectral efficiency is 45 % from 2.2 bit/s/Hz in 4G to 3.2 bit/s/Hz in 5G.

The complete trial results describing the 5G performance can be found in: [8] for 5G-MOBIX, [9] for 5G-CARMEN, and [10] for 5GCroCo.

4 MEC in cross-border

Within the scope of this whitepaper, the term MEC describes application server hosting capabilities within the domain controlled by the MNO, e.g., in its data centres or cabinets. Further details also considering shared data centres and controlled backbone connectivity links can be found in Section 4.3.2.5 in [5], Section 3.2 in [6], and Section 3.5 in [7].

Some MNOs already today host application servers to provide services to their customers. Furthermore, Content Delivery Networks (CDNs) exist bringing services close to the peering points of MNOs, but remain within the public Internet domain. A study conducted in Q1 2020 [11] revealed that 9 out of 30 interviewed MNOs started MEC service deployment (first movers) and 17 were planning it (followers).

MEC enables controlled end-to-end QoS as the service provider, typically an MNO, has control over the whole data path. Even when multiple MNOs are involved, solutions exist through collocation in shared data centres and/or controlled wide area network lines. This was demonstrated for the latter case in 5G-MOBIX, where highly provisioned inter-MEC node links was shown to keep end-to-end latencies within use case requirements, even in the presence of inter-PLMN/inter-MEC node communications (see Section 4.5.4 in [8]). Besides the performance aspect, MEC also simplifies contracting relations as the same entity, usually the MNO, provides connectivity and computation/hosting. Inter-PLMN handover for cross-border/cross-MNO service continuity in conjunction with MEC needs further effort to result in an integrated and seamless solution with limited-service interruption time. The data path from the vehicle to the MEC usually becomes very long, exhibiting high delays after the Inter-PLMN handover, as the gateway (P-GW / UPF) is not changed, not even when Local Breakout Routed Roaming is enabled. The inefficiency of the Home Routing (HR) configuration, against Local Break-Out (LBO) is shown in Figure 3 below: HR traffic always traverses the home PLMN gateway suffering the corresponding delays e.g., 60-100 ms against 40 ms of LBO as quantified in several scenarios during 5G-MOBIX trials. To benefit from a short and low latency path to MEC hosts in the target network, it is required to re-establish the packet data network connection in the target network. Only SSC mode 3, available with standalone 5G New Radio, offers the means to conduct an uninterrupted transition from Home Routed to Local Breakout Routed Roaming. SSC mode 3 only covers the portion within 3GPP specification domain spanning the RAN and especially Core. End-to-end solutions from service providers must cover the service layer edge-to-edge on top.

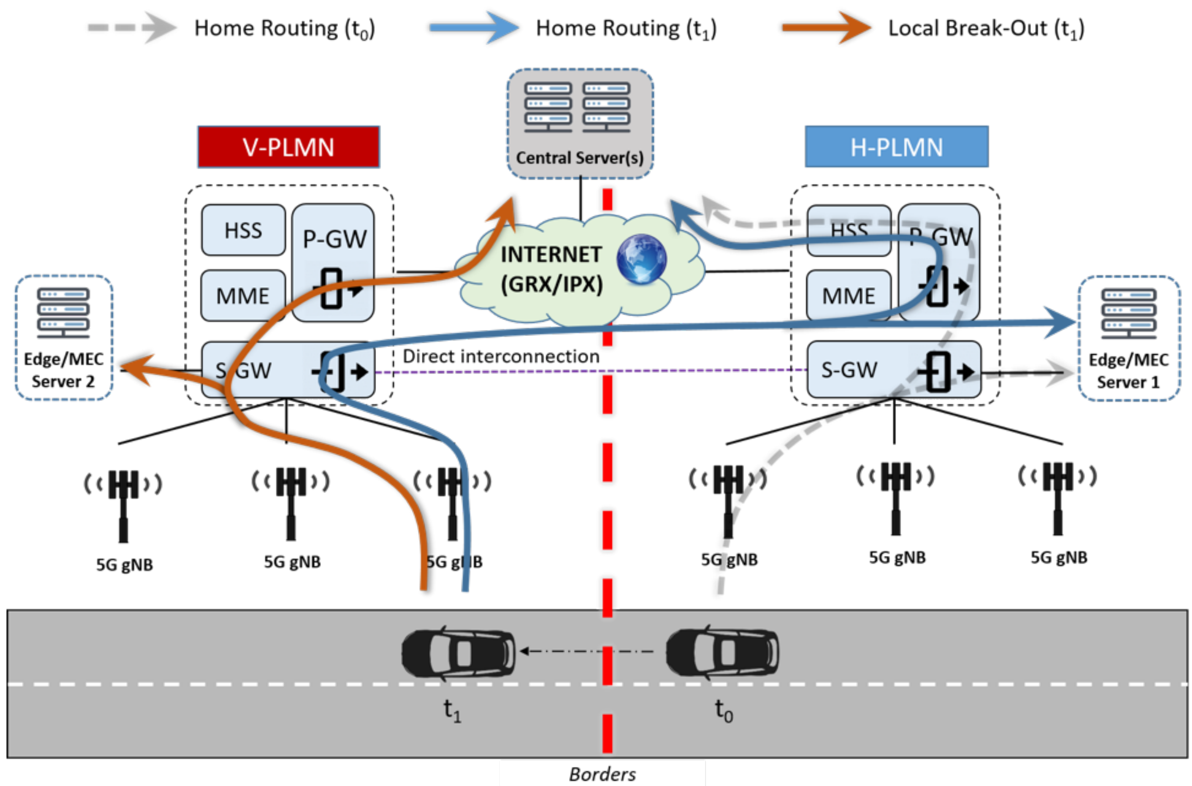

Figure 3: Graphical representation of the path followed by data in the Home Routing configuration (blue path) compared to Local Break-Out (brown path)

5 Deployment recommendations

During their execution, the three ICT-18 projects provided individual deployment studies of 5G for CAM on their respective corridor areas, which could be used as a starting point for CEF2 projects and private investments [12], [13], and [14].

Then, a joint deployment workshop was held among all ICT-18 projects, 5G-MOBIX, 5G-CARMEN and 5GCroCo, in order to present and discuss the results of each individual project deployment study. It was decided to integrate study outputs in a meta-study [15]. The overall purpose was to evaluate and contrast the three original individual studies, aiming to consolidate them, identify methodological and analytical open issues, while reflecting the diversity of the three different approaches, to provide a perspective on 5G deployment and related investment estimations.

The outcome showed that the individual project studies had analyzed a broad scope of corridors, with different geographical and topologic settings. The applied methodologies substantially differed among the studies. On the other hand, investment delta results from the three independent studies were comparable when the methodological differences were considered. Key cost drivers were concluded to depend on geographic location and topology, the existing RAN infrastructure and planned 5G roll-out of the mobile operators along the corridors. The studies identified and listed many open issues for further investigation that may impact the deployment with extra investment, with the most relevant one being the fact that an actual defined set of CAM services and its collective requirements to 5G infrastructures remain unclear for the time being.

Nonetheless, some deployment recommendations could be extracted from the work carried out by the three ICT-18 projects, which concluded that the most suitable 5G network deployment to provide CAM services along corridors sections would be to start with low-band spectrum (e.g., 700 MHz band) for quickly achieving wide-area coverage, by leveraging primarily existing tower and roof-top sites. These sites can be upgraded to include a capacity layer based on the mid-band spectrum such as, e.g., the 3.x GHz band or other legacy bands. Extrapolating for areas around the corridors, a significant number of new sites will be required to deploy such a capacity layer – as 5G for CAM and non-related eMBB traffic will grow.

While 5G communication infrastructures are the first and foremost foundation of enabling 5G for CAM, the low-latency computing element must not be neglected, especially for more advanced 5G for CAM services. Here, the deployment of regional MEC data centres in reasonable (no more than a few hundred kilometers, same country) proximity to the 5G RAN "network edge" will become pivotal for completing the enabler infrastructure elements required for 5G for CAM services. As a start, regional MEC deployments like one per region within the respective corridor sections of the involved countries have been suggested. These can scale by deploying more computing power per MEC site or by deploying more distributed MEC infrastructures in subregions – and the combination of both.

6 Conclusions and roadmap recommendations

The combination of the results obtained by the three ICT-18 projects has yielded valuable insights into the capabilities and potential of 5G technology. As the most significant outcome from trials in cross-border contexts, the three projects have shown that seamless service continuity in cross-border areas is feasible and can be guaranteed. The solutions proposed in the three projects improve, with respect to service interruption times, from tens of seconds (even up to minutes) that are endured today, down to a few seconds or, even, in the order of a hundred milliseconds, should the necessary interfaces among the operators in both sides of the border be in place. 5G was shown to be a capable solution that can significantly improve performance compared to previous technologies, mainly 4G, especially in terms of quantitative terms like reduced latency, higher capacity and spectral efficiency, but also very importantly in other qualitative terms like, e.g., exposure of APIs like QoS prediction, which are not available in 4G. As a result, 5G can support, already today, about 80 % of connected/automated driving services (including all day-1 services) as their requirements are in line with commercially available performance.

However, within the mobility ecosystem of persons and goods, the value of 5G for CAM, although recognized, has not yet been transformed into valorized services and solutions. Obviously, service providers and (personal and professional) OEMs need to know when, what, and where 5G for CAM connectivity will be available before they can offer it. Vice-versa, MNOs need to know when, what, and where services will be available. Overcoming this market challenge is being addressed within CEF2 Digital 5G Corridor by funding the deployment of coverage and capabilities.

Taking these circumstances into account and following a similar approach as in Section 3 for the service continuity solutions, there are two main related approaches for the deployment of 5G for CAM and the services that use it: the network approach and the end-device approach. Depending on the requirements for a use-case and its related service and on the underlying business case, it is logical to follow only the first, or amend it with the second. The timelines and priorities depend on the use-case.

For use-cases that (i) can wait, (ii) are unrelated to mission-critical issues, or (iii) have unclarity in the valorization of the offering, it is logical to piggyback on the developments within the network-only approach. Service coverage will increase gradually with more deployments of cross-border connectivity realized in the CEF2 Digital projects. However, the actual specifics of the connectivity of these projects are left to the organizations proposing the work. From the ICT-18 projects experience, the following approach to provide clarity to potential users of the connectivity would be recommended:

- If there is at least a 5G-NSA deployment, deployment projects should implement inter-PLMN handovers. If this is not possible, as a minimum Release with Redirect using the S10 interface should be implemented. These features are available within 5G-NSA deployments.
- If coverage is key for a specific corridor, the focus should be on creating seamless connectivity.
- If capacity is key for a specific corridor, the focus should be on QoS mechanisms for service differentiation.

For use-cases where the business case is clear, that require international travel, and have requirements fitting the 5G service offerings, the deployment will likely need end-device specific implementations anyway, and the implementation can be *expedited*, providing early benefits and a valorization for further 5G deployment. The network recommendations provided above remain valid, but the recommendation from the ICT-18 projects would be to include the following amendments:

- For 'local' cross-border[3] use-cases and very specific deployment scenarios, targeted deployments together with the MNOs should have the focus.
- Link aggregation and/or multi-sim/multi-modem solutions provide both the needed use-case specific QoS and seamless cross-border service handover needed earlier than through waiting for full deployment, to expedite service deployment. Trials in 5G-MOBIX demonstrated the clear advantage of link aggregation solutions, over link selection ones, in the presence of dual connectivity i.e., dual-modem. On the other hand, NTN solutions proved unable to support CAM use case specific QoS in limited trials conducted in 5G-MOBIX.

For demanding use-cases like tele-operation or remote supervision, being able to have a short path between vehicle(s) and Edge/Cloud is critical. For this, the ICT-18 projects recommend using 5G SA with SSC mode 3 to prevent very long paths due to home routed roaming. This can be either a bespoke specific deployment or within a commercial deployment.

Agreements should be made on service centres where vehicles in need can be operated/driven. These service centres should have controlled, enterprise, connectivity to the MNOs. Furthermore, Local Breakout Routed Roaming should be enabled to assure vehicles actually communicate through these controlled links and not their home networks, that could be very far away.

[3] Meaning a use-case in a confined area, either using a fully local network or a specific set of features deployed by an MNO for that confined area

However, it is also important to note that CAM services with higher requirements can be adapted to network status to ensure smooth automated driving. This requires close collaboration between telecom operators and service providers / OEMs to tailor their needs and solve technical challenges, e.g. related to configuration provisioning and service discovery. This cooperation is particularly needed to cover the period until general offerings are available and can be implemented, e.g. through joint living labs and field operational tests (FOTs), as natural next steps for commercialization after TRL 6 is achieved in EC funded Innovation Actions. By working together, telecom operators and service providers can ensure a smooth and reliable experience for users.

In addition to the immediate benefits that 5G will bring, the potential for 5G to further evolve is also a significant lesson learned from the work carried out in the three ICT-18 projects, with 5G SA being the relevant basis upon which performance will be built upon. By using a 5G Core instead of an Evolved Packet Core and discarding the need for control signaling over 4G LTE radios, 5G SA simplifies network planning, which now focuses only on the 5G New Radio layer, not the 4G one. Furthermore, 5G SA supports Session and Service Continuity (SSC) mode 3, which enables seamless Local Breakout Routed Roaming necessary for re-anchoring: once a seamless Inter-PLMN handover has been executed, all traffic is efficiently routed through the visited network. This is expected to overcome the limitations of home routing, which, as shown in the trials, increases latency, due to the default traversal of the home network, even in the presence of a local edge server. Finally, 5G SA adds Network Slicing as another option to achieve QoS service differentiation. As validated by the ICT-18 projects, this feature, like other QoS differentiation features, can be effectively used for the support of guaranteed end-to-end QoS, especially when it comes to loaded cells. Indeed, without a dedicated protected and prioritized slice, high load in cells can impact on the performance.

In this general context, it is clear that solutions for universal support of CAM services already exist, and incentivizing their deployment will greatly contribute to increase their penetration rate. Joint development between telecom network and service providers can also boost performance by using the actual capabilities within the services and contribute to solving the differences in technical knowledge of cooperating partners. Moreover, detailing how the 'value' is co-created will help define organizations' roles, find synergies, allow for investments, and increase the significance of national regulators to help create clarity. By continuing to innovate and collaborate, 5G can help to create a safer, more efficient, and more sustainable transportation system for all achieving thus societal and commercial benefit.

References

[1] https://5g-ppp.eu/5g-mobix/

[2] https://5g-ppp.eu/5g-carmen/

[3] https://5g-ppp.eu/5gcroco/

[4] https://transport.ec.europa.eu/transport-themes/infrastructure-and-investment/trans-european-transport-network-ten-t_en

[5] 5GCroCo consortium, D3.3 “Final E2E, MEC & Positioning Architecture”, July 2022. Available on-line: https://cordis.europa.eu/project/id/825050/results

[6] 5G-CARMEN consortium, D3.4 “5G-CARMEN Final report on 5G Technological Enablers for CCAM”, August 2022. Available on-line: https://cordis.europa.eu/project/id/825012/results

[7] 5G-MOBIX consortium, D3.7 “Final report about development, integration, and roll out”, June 2022. Available on-line: https://cordis.europa.eu/project/id/825496/results

[8] 5G-MOBIX consortium, D5.2 “Report on technical evaluation”, August 2022. Available on-line: https://cordis.europa.eu/project/id/825496/results

[9] 5G-CARMEN consortium, D5.3 “5G-CARMEN Final pilot report”, October 2022. Available on-line: https://cordis.europa.eu/project/id/825012/results

[10] 5GcroCo consortium, D4.3 “Final Trials Execution Report and Analysis of 5GCroCo KPIs”, July 2022. Available on-line: https://cordis.europa.eu/project/id/825050/results

[11] Analysys Mason, “Edge computing: operator strategies, use cases and implementation,” 2020.

[12] W. Knospe, R. Saakel and A. Sorokin, 5G-MOBIX: CAM Deployment

[13] G. Avdikos, A. Chiha, F. Vannieuwenborg, J. Hillebrand, F. Poli, B. Denis, D. G. Roger, A. M. Handzel, J. F. Monserrat and W. Aigner, "5G-CARMEN Strategic Deployment Agenda (SDA) Study Report v1," 2021.

[14] E. Fischer, D. Hetzer, O. Laaroussi, F. Coulet, M. Bouillon, D. Rouma, A. E. Fernandez, A. Schimpe and C. Everingham, "5GCroCo: Detailed deployment planning in view of CEF2 Digital (5G Corridors for Connected and Automated Mobility)," 2022.

[15] R. A. Saakel, T. Scheich, W. Alhallak and A. Nambiar, “5G for CAM: A Deployment Metastudy- A synthesis of three Pan-European studies on 5G deployment for connected, automated mobility in border regions,” Detecon, 2022.

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