5G FOR CONNECTED AND AUTOMATED MOBILITY (CAM) IN EUROPE: TARGETING CROSS-BORDER CORRIDORS

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ABSTRACT

Confronted with the patchy, slow deployment of 4G in Europe, the European Commission (EC) President Jean-Claude Juncker recognized that, in spite of being strong in research, Europe "needs a more aggressive infrastructure roll-out". He called for coordinated action "to make 5G a reality for all citizens and businesses", to reap the benefits that would accrue and achieve the European Digital Single Market. However, coverage of sparsely populated areas, in particular rural ones and those near the borders, remains a challenge. Similarly, Connected and Automated Mobility (CAM) adds taxing real-time requirements. By focusing on these exacting scenarios, aiming at continuity of service across the continent, and addressing the broad scope of issues involved, which go well beyond technology, we are aiming for large-scale deployment across Europe as early as 2025.

INDUSTRIAL POLICY, DE FACTO

Europe certainly played a driving and leading role in the development of 4G, but its deployment in Europe sputtered, suffered considerable delays and ended up putting Europe at a disadvantage relative to its competitors in the world scene. In his 2016 State of the Union address [1], the European Commission (EC) President Jean-Claude Juncker (2014-19), set as an objective "to fully deploy 5G, the fifth generation of mobile communication systems, across the European Union (EU) by 2025."

One of the main benefits of 5G is the "mutualization" of costs between various services and sectors using the same basic infrastructure, improving the overall economic case. A preparatory socio-economic study [2] had identified millions of jobs and billions of euros of benefits arising from 5G deployment. Concretely, investments of approximately 57B€ are likely to create 2.3 million jobs in Europe, and benefits from the introduction of 5G capabilities could reach 113B€ per year in four key sectors (automotive, healthcare, transport and utilities) alone.

This has been recently confirmed by an Ericsson study on 5G for business [3]. Namely, 5G-enabled 1.5 trillion USD in revenue are forecast to be captured by 5G in 2030, including 700 billion USD of new, additional revenue streams beyond enhanced-mobile broadband (eMBB).

In the context of the 2016 Telecom Package, the EC set two important, closely related goals: the Gigabit Society [4] and 5G for Europe [5]. In fact, 5G requires broadband, namely pervasive fiber availability, but can also competitively provide broadband.

The 5G Action Plan aimed at full deployment by 2025, in particular everywhere people live and pass by: all urban areas as well as all major transport paths should have uninterrupted 5G coverage. The objective is to accelerate deployment in those areas where the market would be too slow to act, but not in urban areas where the market is expected to deliver full coverage through strong competition. Focusing on Cross-border sections of Trans-European Transport Network (TEN-T) corridors, mostly in rural, less populated areas, does make sense. In fact, in the context of the 2018 Mobility Package, while setting the EU Connected and Automated Mobility (CAM) vision, the CAM Communication [6] called for working with Member States and stakeholders toward large-scale testing and pre-deployment of 5G cross-border corridors[1], addressing these challenging deployment scenarios while fully taking into consideration 5G licensing coverage conditions and local deployment constraints.

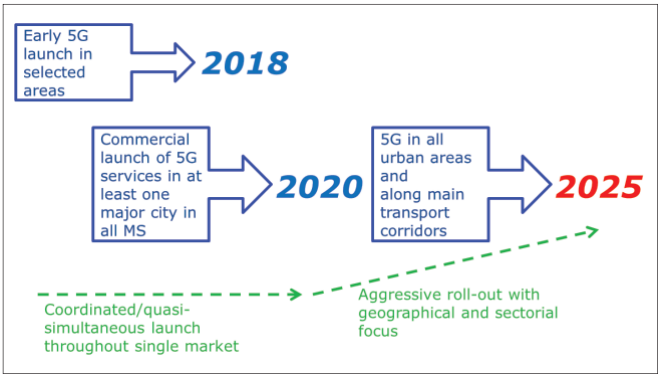

FIGURE 1. Committing to coordinated EU-wide deployment.

The communication sets out the requirement for seamless roaming of CAM services, on top of other data services, including eMBB and IoT. Some critical CAM services require real-time connectivity, so best-effort is not enough! Unfortunately, the majority of current deployments was not designed with that in mind. Furthermore, uninterrupted coverage of sparsely populated areas to deliver high data rate (in the order of Mbit/s per vehicle) and Ultra Reliable, Low Latency (URLLC)-type services (sub-1ms delay) will require dense deployment of cells with the supporting fiber infrastructure along at least the major highways, not to mention close proximity to Multi-access Edge Computing (MEC) resources.

This fiber deployment will be extremely expensive[2], and it is difficult to see return on investment. On the funding side, co-investment by relevant stakeholders seems essential to share the burden. On the connectivity side, solutions like (various degrees of) infrastructure sharing, potentially extending to the MEC, as well as national roaming[3], are being considered.

R&D WITH A TRIAL FOCUS

The European Horizon 2020 (H2020) program was the framework for R&D in the period 2014-20[4], with 80B€ of EU-funding for a broad scope of activities. To address 5G, the EC established a 5G Public-Private Partnership (5G PPP) [7], with 700M€ EU-funding, with the 5G Industry Association (5GIA). The 5G PPP brings together a broad range of stakeholders from the communications technology sector and from its extended value chain including the user communities and actors from the microelectronics and IT sectors. 5G PPP is open to international participation, and was structured in three phases, from core technologies to proof-of-concept to trials involving verticals, and namely CAM. It includes as well research on long-term evolution beyond-5G.

In Europe, there is a long-standing tradition of experimentation for testing and validation of technologies, services and applications [8]. The realization that end-to-end systems are now too complex, too heterogeneous, too "connected" to be analyzed or even simulated, and that therefore they need to be "prototyped" to be tested and validated, led to the launch

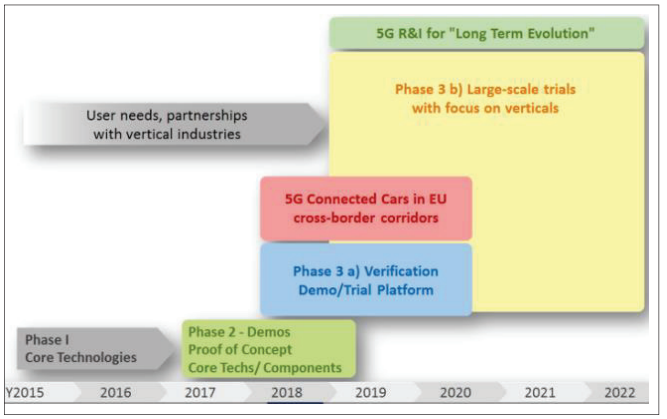

FIGURE 2. 5G PPP three-phase structure.

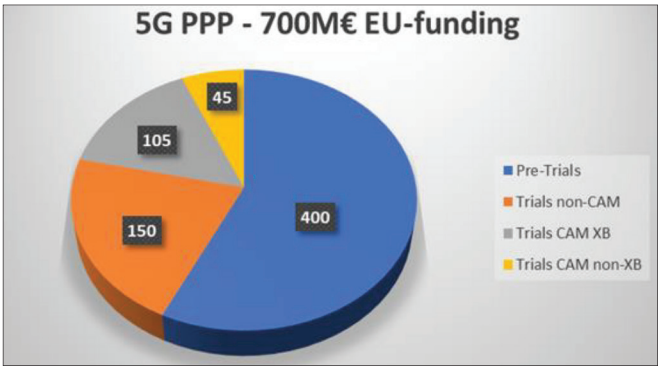

FIGURE 3. Funding allocation in 5G PPP.

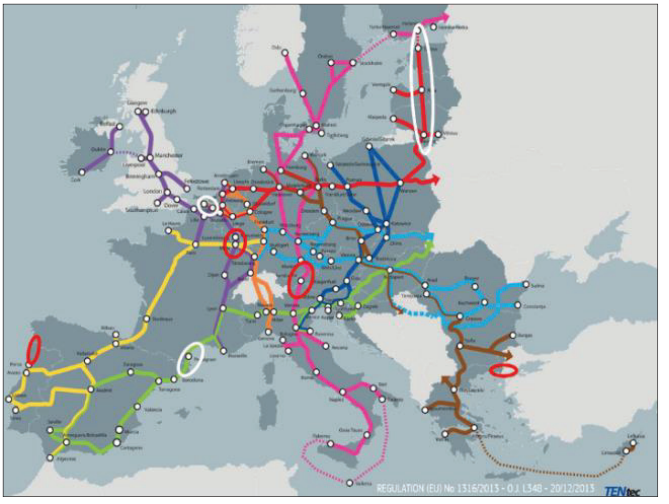

FIGURE 4. Cross-border Corridors in the TEN-T network (first CAM call in red, second CAM call in white)

of experimentally-driven research with over 200M€ funding under Future Internet Research and Experimentation (FIRE) [9,10], moving from experimental platforms and facilities to open experimentation, even remote, on top of them.

End-to-end, and even individual (sub-), systems need to be experimented with in the real world, under real conditions, with real traffic/loads and real users [11]. Also quite pragmatically, no one, not even the largest corporations, can afford to assemble, much less operate, the "entire" system to be able to test/assess their solutions, developments, and improvements.

5G PPP built upon this approach, calling first for demonstration and trial platforms, and then for trials on top. For CAM, the approach was slightly different, as the "platform" is actual infrastructure in specific sections of a corridor, with unique characteristics. It is important to understand the amounts engaged, reflecting the political importance of the different areas. From the 700M€ envelope of the 5G PPP, the Commission reserved 300M€ for trials (43 percent), with around 150M€ of these for CAM (50 percent), of which 105M€ is specifically for cross-border corridors.

5G FOR CAM CROSS-BORDER CORRIDOR PROJECTS

In support of the 5G for CAM political priorities, the EC launched two calls targeting cross-border corridors, with 105M€ EU-funding. The aim was concretely to engage the constituency, identify gaps, create consensus, propose solutions, and, most importantly, test and validate in the field. By addressing stringent "boundary" conditions, they will identify and resolve problems, both technological and institutional, offering solutions with repercussions on 5G at large, empowering and accelerating novel advanced services and applications [12].

A first 5G for CAM call was launched end-2017; the objective was to "identify the problems and barriers and provide a blueprint toward accelerating the deployment of 5G for CAM in cross-border scenarios, and in general in areas where there would be no business case and therefore deployment would not happen, or where there are identified mild market failures and therefore deployments risk being substantially delayed."

Three cross-border corridor projects with 63M€ EU-funding were selected and launched in November 2018:

- 5GCroCo: Metz (FR) - Luxembourg (LU) - Saarbrücken (DE) triangle [13]
- 5G-CARMEN: Brenner corridor: Munich-Innsbruck-Bologna (DE-AT-IT) [14]
- 5G-MoBiX: Porto (PT) - Vigo (ES) and Thessaloniki (EL) - Istanbul (TR) corridors [15]

The involved corridor segments are quite distinct, stretching over 1000km of highways, and crossing eight borders.

A second 5G for CAM call was launched in 2020, aiming both at automotive and rail cross-border corridors. Three projects, mainly with a road transport focus, were selected and launched in September 2020:

- 5G-Blueprint - North Sea corridor (BE-NL) [16]
- 5G-ROUTES - Baltic corridor (FI-EE-LV-LT) [17]
- 5GMED - Mediterranean corridor (ES-FR) [18]

A fourth one, focusing on rail, was launched in November 2020: 5GRAIL [19]. Their total EU-funding was 42M€. The seven projects above aim at demonstrating 5G-enabled advanced CAM use cases in the field, in actual cross-border segments. They also illustrate well the variety of corridor scenarios across Europe.

OTHER RELEVANT PROJECTS

Besides the above projects focusing specifically on cross-border corridors, a number of 5G PPP phase-3 projects address, at least to some extent, CAM-relevant issues, some of them covering rail aspects. The EU-funding associated with the focus on Mobility in general (persons and goods), on Logistics, and also on Ports, is approximately 45M€. The projects cover mainly technological aspects and a few address application aspects and platforms for service provision. Non-exhaustive examples [20] are: 5GCAR, 5G-DRIVE, 5G-HEART and 5G-IANA (CAM); 5G-PICTURE and 5G-VICTORI (Rail); VITAL-5G and 5G-Logginnov (logistics); 5G-MoNArch and 5G Solutions (ports).

ACHIEVEMENTS AND CONTRIBUTIONS

Even if affected by COVID-19 confinement measures across Europe, the identification and characterization of currently deployed infrastructure and connectivity, the solutions implemented and their assessment, the lessons learned, and the sys-

Technological	Telecom/Network issues - 5G Radio, Core and MEC; 3GPP releases and equipment
	Road Infrastructure/ Road Operator - instrumentation and ITS functionalities
	Automotive issues - Equipped and legacy vehicles; Various levels of automation
Business Models	from Competing to Cooperating
Legal and Regulatory	from GDPR to access to data across borders
Security and Privacy	
Reliability and Availability	
Liability	

TABLE 1. Challenges toward deployment of CAM.

Development	Flexible, adaptable and evolutionary
	with very high level of cybersecurity
Must provide	Boundless connectivity
	Continuity of service across borders, across MNOs, across vendors/OEMs, across service providers, as well as across traffic managers and road operators
Relies upon	Cooperative planning
	Coordination with public authorities and relevant private actors
	Multi-service/multi-application platform using standardized specifications and/or data interfaces

TABLE 2. Shared vision for 5G CAM infrastructure.

tematic testing in the field of various CAM use cases, constitute unique contributions to the advancement of 5G for CAM. The 5G PPP white paper on 5G CAM Trials [21] provides a detailed analysis of the achievements thus far of the first CAM call projects. They started by identifying challenges toward deployment, which go beyond technology, telecommunications, and even equipment.

Driven by the objective of delivering cross-border demonstrations, the first priority was to investigate continuity of service across borders. Understanding the constraints of current and planned network implementations was just the first step. Aspects like cross-border connectivity breakouts, inter-operator agreements and the need for close-by MECs become critical. Equally critical is conjuring the necessary investments in infrastructure extension and upgrade. It is a difficult, complex challenge, and certainly specific of the border scenario under consideration. Funding agencies will need to be involved.

The projects addressed cooperative business models to enable and even drive the necessary investment. By identifying market failures and technical requirements, specifically in cross-border regions, their work informed a recent 5GAA white paper [22]. They have also addressed the need for institutional support from National and Regional authorities, to facilitate deployment: coordinating with authorities across the border, reducing bureaucracy and, where applicable, providing access to public infrastructure and right-of-way.

Finally, keeping in mind that the end game is large-scale deployment, the projects contributed decisively to the 5G PPP 5G for CAM Strategic Deployment Agenda (SDA) [23]. The work was done in the context of the 5G PPP automotive working group, involving also other relevant projects, namely those dealing with V2X, and in cooperation with key stakeholders such as the GSM Association (GSMA) and the 5G Automotive Association (5GAA).

The SDA aims at accelerating and maximizing investment, both public and private, by:

- Defining deployment priorities and roadmaps,
- Identifying appropriate cooperation models and investment strategies
- Advising on most suitable regulatory incentives

with a view toward maximizing societal benefits[5], and concretely toward accelerating the digital transformation of upstream and downstream industries.

Key Drivers for accelerating infrastructure rollout were identified as: Standards; Spectrum; Network slicing; Regulatory innovation; Access and data sharing; and Cybersecurity. On the other hand, in order to retain economic competitiveness at a global scale, the political driver behind the decision to deploy 5G for CAM across Europe, we need to shape a complex CAM ecosystem involving all relevant stakeholder communities, reflecting the need for a system's approach on an EU level. Here is where the need for synergies with other EU policies and mechanisms becomes important.

ARTICULATION WITH OTHER POLICIES

A specific element of the Gigabit Society is the provision of extremely high data rate connectivity to all "main socio-economic drivers (SED)", such as schools, universities, research centers, transport hubs, hospitals, public administrations, libraries, museums, business parks, and enterprises relying on digital technologies. The idea is now to provide wireless broadband connectivity to SEDs and surrounding areas under the 5G Communities initiative.

This initiative will expand upon WiFi4EU [24], a 130M€ initiative (2018-20) to promote access to wireless connectivity for citizens and visitors in public places via free public Wi-Fi. The funding came mainly from the Connecting Europe Facility (CEF) Telecom program. It operates via a system of 15.000€ vouchers per qualifying municipality.

Obviously, the broadband infrastructure needed to provide service to SEDs in remote/rural, low population density areas will be of good use to provide CAM to the crossing transport paths (roads, railways and waterways). To render more economical, and ultimately feasible, the coverage enhancements to deliver both CAM and connectivity to SEDs, exploiting this synergy is critical [25].

Another important focus, arising already under the Ursula von der Leyen Commission, spearheaded by Commissioner Thierry Breton, has to do with European data spaces [26,27]. Here again, the synergies with the investments to bring MEC closer to the borders to enable CAM service continuity is of paramount importance; in fact, many such facilities could in principle be shared with, or made available to, operators, and, conversely, operators could open their MECs to other uses and players, with all necessary security and isolation caveats.

NEXT STEPS

From large-scale testing and pre-deployment in H2020, we now need to move toward large-scale deployment, in the context of CEF2-Digital. In March 2019, the Council and Parliament provisionally agreed on a Regulation to extend the Connecting Europe Facility (CEF becoming CEF2) and adapt it to the needs of the Gigabit Society, namely supporting Member States in addressing existing funding gaps with strategic projects.

The main objective in the new digital focus, CEF2–Digital, is "to contribute to the development of projects of common interest relating to the deployment of safe and secure very high capacity digital networks and 5G systems, to the increased resilience and capacity of digital backbone networks on EU territories by linking them to neighboring territories, as well to the digitalization of transport and energy networks."

The European Commission proposed, in this context, a major public financing support action for accelerating private investments in 5G infrastructure along sections of TEN-T corridors known as "5G Corridors", to enable 5G for CAM solutions. The focus will be put on cross-border and "challenge" areas, in sup-

port of growth and cohesion and for a better integration of the Digital Single Market.

It is expected that EU-funding for the 5G corridors will amount to 0.9B€, a significant part of the 2B€ proposed by the Commission for CEF2-Digital. This represents an almost one order of magnitude increase relative to the preparatory work in H2020, even more if one considers other sources of funding, at regional, national and EU levels.

In what concerns R&D, a Smart Networks and Services (SNS) partnership [28] has been agreed in the context of the Digital, Industry and Space cluster, of the Global Challenges and European Industrial Competitiveness pillar of Horizon Europe [29], with 0.9B€ EU-funding to continue work on 5G evolution, with a longer-term focus on 6G. 5G Corridors will be implemented in coordination with SNS, which will also articulate with the Digital Europe Program [30] (in areas like Artificial Intelligence and Cybersecurity), structural funds and InvestEU [31].

Conclusions

Challenges as well as gaps, technological and otherwise, have been identified and are being addressed by a number of 5G for CAM cross-border projects with substantive funding. A broad constituency has been engaged, spanning Telecom MNOs; Automotive OEMs; Rail, Ferry, and Road operators; as well as as Local, Regional and National authorities. A number of solutions have been proposed and are being tested and validated in the field, in spite of COVID-19 pandemic restrictions, with a view toward delivering cross-border demonstrations from the second half of 2021.

We are now at a critical juncture, where we need to start planning for large-scale deployments of 5G for CAM in pan-EU corridors. In order to address the variety of challenges involved, including the critical one of syndicating the necessary investments, we need to engage a broad ecosystem. Only so will we be able to deliver on the promise of CAM for all.

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Biography

JORGE M. PEREIRA has been with the European Commission since September 1996, becoming Principal Scientific Officer in 2005, dealing with ICT Research and Policy, covering a broad variety of areas, with a focus on networking, devices, applications and services, testing and validation, as well as deployment. Since 2016, he has been in the Future Connectivity Systems unit, focusing on 5G and beyond. He is responsible for the areas of Advanced Spectrum Management; Optical/Wireless Convergence; Connected and Automated Mobility (CAM); and Public Protection and Disaster Relief (PPDR). Prior to that, he was responsible for re-structuring the area of Future Internet Research and Experimentation (FIRE). He is a Member of the IEEE, where he is an associate editor for Mobile Radio, including Vehicular Communications, for the *IEEE VTS Magazine*, and a member of the IEEE 5G Summit Steering Committee of the IEEE Communications Society. He also served as an associate editor for *ACM Transactions on Sensor Networks*. He has been involved in the organization of major IEEE conferences, namely PIMRC, WPMC, VTC, ICC, ICT, GLOBECOM and 5G Summits in various positions, including TPC, Panel and Special Session co-Chair. He obtained the Engineering and Master degrees in electrical and computer engineering from Instituto Superior Técnico, Lisbon Technical University, Portugal, in 1983 and 1987, respectively. He received the Ph.D. in electrical engineering-systems from the University of Southern California, Los Angeles, in 1993. He received the Industry Achievement Award of the Software-Defined Radio (SDR) Forum in 2003, in recognition of his "outstanding contributions, research and development in the field of SDR", and was inducted as a life-member of the Wireless Innovation Forum. He was inducted in the IPv6 Hall of Fame at the IPv6 Forum Summit in Nanjing, China, in October 2019.

Footnotes

[1] A set of cross-border corridors have been identified to foster large-scale testing and deployment of 5G for CAM, following the letter of intent of 23 March 2017 signed by 26 Member States, plus the UK, Switzerland and Norway.

[2] A 250B€ funding gap has been identified to provide Broadband in rural areas.

[3] National roaming is already enshrined in the 5G licencing conditions of a number of EU Member States, e.g., Germany, at least for new operators, e.g., Portugal.

[4] Many projects will extend into the next framework program.

[5] Namely, Safe ride (zero deaths in road accidents); Efficient ride (reduced travel times; automated driving; no traffic jams; zero pollution); and Connected ride (HD infotainment).