5G PAN-EUROPEAN TRIALS ROADMAP VERSION 4.0

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The 5G Pan-European Trials Roadmap Version 4.0 has been elaborated and is supported by the Trials Working Group (WG) Members organizations listed on Page 19. It is coordinated by the 5G Infrastructure Association (5G-IA), expanding the work initiated by the Industry and the European Commission (EC) in the context of the 5G Manifesto[1] and of the 5G Action Plan (5GAP)[2].

1. Introduction

This document addresses the 5G Pan-European Trials Roadmap Version 4.0 and its implementation. It is produced for public release at the 6th Global 5G Event[3] and extends the Roadmap Version 3.0[4] made public at the 5th Global 5G Event[5] and highlighted during MWC 2018[6].

The main objectives of the Roadmap are to:

- Support global European leadership in 5G technology, networks deployment and profitable business.
- Validate benefits of 5G to vertical sectors including public sector, businesses and consumers.
- Stimulate a clear path to successful and timely 5G deployment in Europe.

To that end, it expands commercial trials and demonstrations as well as national initiatives, with a clear focus on activities revolving around EU cities. It is expected that 5G activities centred on major EU cities will contribute to meeting the challenge of making 5G a reality for all citizens and businesses in Europe.

Most of the Roadmap implementation is driven by the Industry on a private basis. Through the 5GAP, the EC supports the setting up of framework conditions for 5G deployment in Europe, notably the identification of the relevant harmonized spectrum and of the regulatory conditions, whilst additional financial support for trials and pilots is made available from the EC H2020 programme in support of the 5G Infrastructure PPP implementation[7], specific National programmes of Member States (MSs) as well as from specific programmes such as the European Space Agency (ESA) Satellite for 5G Initiative[8].

[1] http://ec.europa.eu/newsroom/dae/document.cfm?action=display&doc_id=16579
[2] http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=17131
[3] 5th G5GE on 28-30.11.18 in Rio – http://5gbrasil.telebrasil.org.br/ecossistema/eventos/82-6th-global-5g-event-brasil-2018
[4] https://5g-ppp.eu/wp-content/uploads/2018/05/5GInfraPPP_TrialsWG_Roadmap_Version3.0.pdf
[5] 5th G5GE on 16-17.05.18 in Austin - http://5gnewhorizons.com/home/
[6] https://5g-ppp.eu/wp-content/uploads/2018/02/flyer-trials-roadmap-MWC18_v0.1.pdf
[7] www.5g-ppp.eu
[8] https://artes.esa.int/satellite-5g

This Roadmap Version 4.0 highlights the key EU cities that are targeted for 5G early deployments, already engaged in 5G pre-commercial/commercial trials and pilots, engaged in 5G R&I trials and pilots and also making available 5G R&I platforms. A description of the major EU cities engaged in the 5G UEFA EURO 2020 Flagship event is also provided.

2. 5G Pan-EU Trials Strategy and Roadmap

5G has been strongly boosted in EU in 2018. As specified in the EU 5GAP in 2016, the initial targets to have (1) the early 5G launch in selected areas in 2018, (2) the commercial launch of 5G services in at least one major city in all MSs in 2020 and (3) the uninterrupted coverage in all urban areas and along main transport paths in 2025 are clearly on the right tracks. Many EU cities are already strongly engaged in 5G development, trials and pilots and first commercial deployment will already start in specific EU cities in 2019. As detailed in the GSMA Mobile Economy Europe 2018 report[9], "*We expect Europe to reach 203 million 5G connections by the end of 2025, accounting for 29% of total connections in the region. The largest advanced mobile markets, such as the EU5, will drive much of the take-up*". In addition, as also highlighted in this GSMA report "*more coordinated rollouts of 5G services, compared to the staggered approaches of 4G, will result in coverage and adoption levels increasing at a faster pace in Europe in the first few years after launch than with the previous technology generation*".

The EC EU 5G Observatory website/online platform[10] has been officially launched on 27.09.18, in the context of the 5G Techritory event[11,12]. The first quarterly report is available on the corresponding Observatory webpage[13]. The EU 5G Observatory provides independent monitoring information regarding the main actual and likely market developments, 5G trials and other actions taken by MSs, as well as industry stakeholders regarding 5G market introduction in EU and in a global context. This allows assessing the progress of the EU 5GAP and to take actions to fully implement it. The Observatory focuses primarily on developments in EU, along with major international developments that could impact the EU market.

As detailed in the previous versions of the 5G Pan-EU Trials Roadmap, the core part of the 5G trials and pilots is and will be achieved through private trials (commercial and pre-commercial) between network operators and manufacturers/vendors and is increasingly involving vertical stakeholders. As reported in the EC EU 5G Observatory, EU mobile operators have been working for two years with equipment manufacturers/vendors and vertical players on various trials in order to validate 5G capabilities. They are now preparing the deployment phase and will be able to perform tests in "real" conditions as the first 5G smartphones are expected to be available by early 2019. As a first example of forthcoming commercial deployment, the Finnish network operator Elisa announced the expected 5G launch in 2019[14]. At mid-November 2018, EU operators are heavily involved in 5G testing with more than 105 trials and pilots reported in EU countries. In parallel, twelve EU MSs/countries have published national 5G roadmaps or global strategy documents (Austria, Denmark, France, Germany, Italy, Luxembourg, Malta, Poland, Spain, Sweden, Netherlands and UK).

[9] hhttps://www.gsmaintelligence.com/research/?file=884c77f3bc0a405b2d5fd356689be340&download
[10] http://5gobservatory.eu/
[11] https://ec.europa.eu/digital-single-market/en/news/eye-future-european-5g-observatory
[12] 5G Techritory Event organized on 27-28.09.18 in Riga - https://www.5gtechritory.com/
[13] http://5gobservatory.eu/PDF/80082-5G-Observatory-Quarterly-report_1.pdf
[14] https://www.telegeography.com/products/commsupdate/articles/2018/10/10/elisa-close-to-concluding-pre-5g-upgrade-work-in-jyvaskyla/

As stressed in the EC 5GAP, spectrum is a fundamental building block for launching 5G for both testing and commercial launch. The bands 700 MHz, 3.4-3.6 GHz (band 42), 3.6-3.8 GHz (band 43) and 26 GHz (the upper part of the 26 GHz band) were identified for the first deployments of 5G in EU. Focusing on the bands 42 and 43, designated as pioneers and mainly supported by network and mobile equipment at the 5G launch, several significant allocations have been awarded in 2018 in Italy (700 MHz, 3.6-3.8 GHz and 26 GHz in October 2018), Finland (3.4-3.6 GHz, 3.6-3.8 GHz in October 2018), Spain (3.6-3.8 GHz in July 2018) and in UK (3.4-3.6 GHz in March 2018). With Ireland, Czechia and Latvia in 2017, 7 EU countries have now seen part of the band 42 and 43 allocated for 5G deployment. In addition to the recent awards of bands 42 and 43, 10 EU countries have already forecast auctions between the end of 2018 and 2020 for 5G spectrum.

As detailed in the 5G Pan-EU Trials Roadmap Version 3.0, the acceleration of 5G in EU is also happening thanks to a specific joint strategy between Industry (hand in hand with Research Centres, Academics and local communities), EC and MSs and Domains specific initiatives. The EU 5G strategy is clearly targeting large scale adoption of 5G by vertical sectors[15]. Expanding bilateral and multilateral private trials, the EU strategy hence relies on the development of initiatives addressing 5G vertical pilots, 5G corridors, 5G platforms, 5G trials cities and 5G UEFA EURO 2020 as the major 5G Pan-EU Flagship event. Verticals engagement in 5G deployment is strongly supported by the 5G Infrastructure PPP though a specific Board Task Force providing guidance to relevant activities in terms of vertical industries education and partnerships, Memorandums of Understanding (MoUs) with relevant verticals fora such as 5GAA (Automotive), 5G ACIA (Smart Manufacturing), ECSO and PSCE (Public Safety), ESA (Satellites) are envisaged as partnerships models in order to foster adoption and clear roadblocks in vertical sectors.

The running 21 5G Infrastructure PPP Phase 2 projects[16] (2017-2019) contribute to the prototyping, experimentation and trialling of 5G technologies and components for specific use-cases including vertical use-cases developed with vertical stakeholders. The 3 PPP Phase 3 pan-EU 5G end-to-end facilities / platforms (ICT-17) projects[17] started in July 2018 cover 20 platforms/nodes in EU and the 3 PPP Phase 3 corridors (ICT-18) projects started in November 2018 address multiple EU test corridors. In June 2019, 6-9 PPP Phase 3 Vertical Pilots (ICT-19) projects will target large scale trials and pilots including complete end-to-end 5G systems and leveraging the existing platforms projects. It is expected that additional 5G test corridors projects will be launched in the context of the PPP Phase 3. In addition, the current definition of the EC Connecting Europe Facility (CEF2) programme (2021-2027) includes a specific focus on 5G corridors deployment[18].

The overall 5G Pan-EU Trials Roadmap time plan and relevant standardization, regulatory and ecosystems time plan are summarized in Figure 1. The categorization of 5G trials and pilots in EU, from test to pre-commercial/deployment, is detailed in Section 3 of this Roadmap. The major EU cities engaged in 5G R&I trials and pilots (including PPP Phase 2 projects and Phase 3 corridors projects), providing 5G R&I platforms (including PPP Phase 3 platforms projects) and currently engaged in the definition of the 5G UEFA EURO 2020 Flagship event are detailed respectively in Sections 4, 5 and 6.

[15] https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf
[16] https://5g-ppp.eu/5g-ppp-phase-2-projects/
[17] https://5g-ppp.eu/5g-ppp-phase-3-projects/
[18] https://ec.europa.eu/commission/sites/beta-political/files/budget-may2018-cef-regulation-annex_en.pdf

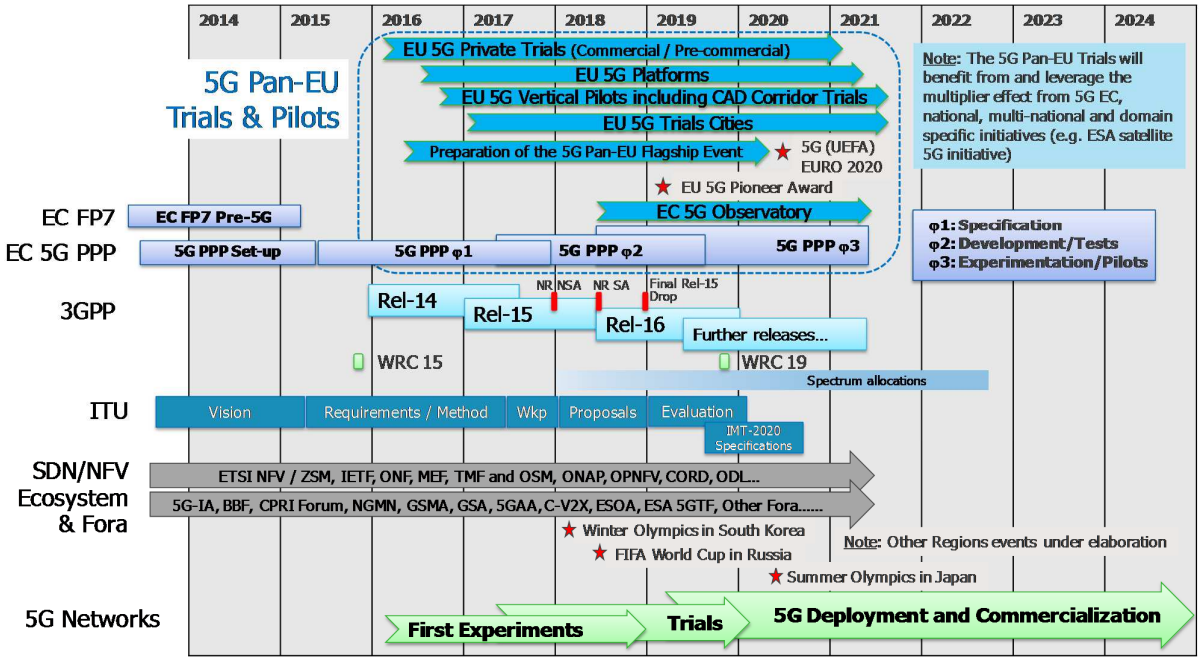


Figure 1: 5G Pan-EU Trials Roadmap – Time Plan

Considering all the very promising 5G developments in EU, the EU 5G Pioneer Award initiative[19], in partnership between EC and GSMA, aims to single out the front runners in EU adopting 5G, whether they are key partnerships with vertical sectors, innovative 5G cities, regions, or any other initiative enabling to identify 5G deployment best practices to stimulate 5G ecosystems. The first award will be granted during MWC 2019.

Beyond the 5G EU-focused developments, 5G Pan-EU trials are implemented within a global context where trials, pre-commercial and even commercial deployment initiatives are already taking place in other countries and regions outside the EU. By 1Q18, more than 70 network operators worldwide reported[20] to be testing 5G either in lab or field trials and, since then, the list of operators active on 5G trialling is increasing. Moreover, during 2018 there have been announcements of, at least, three commercial launches of 5G services in 2019 by Elisa in EU (as already pointed out above) and Etisalat[21] and Ooredoo[22] in the Middle East. All these activities provide a clear indication that operators all around the world are speeding up their 5G readiness, e.g. with Verizon, AT&T, T-Mobile US and Sprint in the US [23] and, in Asia, with SK Telecom, KT and LG Uplus in South Korea, China Mobile and China Unicom in China, and NTT Docomo in Japan[24].

Now that the 3GPP 5G initial standardization effort has been completed, the risks related to potential fragmentation among different countries, which may have hurt both industry and consumers, have been mostly avoided achieving thus a major milestone towards global 5G

[19] https://www.mobileworldcongress.com/conference-programmes/global-mobile-awards/categories/outstanding-achievement/european-5g-pioneer-award/
[20] https://www.viavisolutions.com/en-us/literature/state-5g-trials-2018-poster-chart-en.pdf
[21] https://etisalat.ae/en/about-us/media_center/press_releases/etisalat_launches_first_commercial_5g_network_in_the_mena.jsp
[22] https://www.ooredoo.qa/portal/OoredooQatar/supernet-5g
[23] https://www.fiercewireless.com/wireless/at-t-sprint-t-mobile-verizon-ctos-give-their-takes-5g
[24] https://www.mobileworldlive.com/asia/asia-news/asia-accounts-for-nearly-half-of-global-5g-trials/

adoption. Within this new standard stability context, several network equipment manufacturers have announced their involvement in standard compliant 5G trials, with EU players occupying the forefront with an aggregated presence in 51% in the 5G trials conducted over the world. Outside EU, 5G trials with presence of EU stakeholders (mostly equipment vendors) have been announced and/or conducted in many different counties like Australia, Brazil, Canada, China, India, Japan, Russia, South Africa, South Korea, Taiwan, UAE and US, and these are covering a wide range of frequency bands (from 800 MHz up to 90 GHz) and 5G trialled functionalities (interoperability, DU/CU splits via Cloud-RAN, application to verticals like mining, health, manufacturing…). For example, in China, three operators agreed with the government to carry out 5G trials in at least 16 cities across the Asian nation. The first two phases of these trials were finished by mid-2018 with presence of the two EU manufacturers/vendors Nokia and Ericsson, and the third phase has just recently started.

In addition to these activities which are promoted by stakeholders outside the EU, 5G trial actions implemented through EU research collaboration with EU third countries are also foreseen in the near future. In particular, two initiatives of collaboration with Taiwan are forecasting to conduct trials end of 2018 and also in 2019 in the 3.4-3.8 GHz band with focus on Media/Entertainment and Industry 4.0 applications and another one of collaboration with Brazil is focusing on the provision of 5G high speed access in low density areas. Moreover, 5 additional initiatives (2 with South Korea, 2 with Japan and 1 with China) have been recently launched with special emphasis on spectrum and interoperability at different bands, mmWave and integration of 5G vertical testbeds in heterogeneous environment, Vehicular-to-Everything (V2X) communications and enhanced Mobile Broadband (eMBB) applications.

3. 5G Pre-commercial Trials and Pilots in Key EU Cities

When approaching the first 5G cities, it is important to classify the different types of trials and pilots in terms of maturity and impact on the ecosystem, such as for instance:

1. Proof-of-Concept (PoC): Demonstrating the merits of a "theoretical" concept.
2. Prototype: Embedding the proven concept as functionality in a component or system.
3. Demonstration: Showcasing a scenario within a complete system from a certain perspective.
4. Trial and Pilot: Verifying the functionality of a system or parts of it to test the correct functionality outside a lab environment.

Further relevant elements include:

- Contractual nature of the trials or pilots.
- Involvement of a large number of partners.
- Number of deployed radio sites (as the number of sites grows significantly, the closer it gets to a commercial deployment).
- Presence (or not) of real customers (a full-scale test to real customers shows a technological maturity and the confidence in the solution).

Table 1 aims at describing and classifying the different steps leading to the 5G Cities.

Classification	Description	Size of the Trial (in nb of sites)	End-user Type	Timeline estimate
Technological Trial	Usually aims at assessing technological building blocks, functionality, management and performance	1 (2 sites maximum)	Without customers	**early 2017**
Friendly User Trial (FUT) level	A full system technology testing with real customers to qualify user experience. A multi-vendors approach could be proposed	1 or 2 sites	Real customers	**2017-mid 2018**: Pre-standard solution or mono-vendor E2E one
FUT level Cities	Mature pre-commercial equipment and with real customers for a given period of time (in general no longer than 3 months). The customers could be engineers or existing selected customers. In general the test is made in an isolated network	Between 2 and 15 sites	Real customers	**mid 2018- mid 2019:** Standardized solution expected with first devices
The "5G Cities": Pre-deployment Cities	Pre-commercial deployment with real customers and with commercial devices, usually the deployed network equipments are supposed to stay on site for the commercial launch after the "5G Cities" period	Above 15 sites	Real customers	**mid 2019-2020:** Commercial solution with multiple commercial devices

Table 1: 5G Trials, Pilots, Pre-Commercial and Commercial Deployment

5G Cities and Deployment Cities

In practice, the frontier between FUT level cities and pre-deployment 5G Cities could be thin, nevertheless, for 5G Cities the presence of real customers equipped with commercial devices can be expected and is a key differentiator. Even if 5G Cities are to be considered as pre-deployment and not as the official start of deployment, it can be expected that the first 5G deployments may be built on and around the initial 5G Cities. In Section 4, a list of 5G Cities, their plans as well as potential services being deployed are presented. This does not appear in the table above as a dissociation parameter, however on top of the involvement of 5G Cities, involving verticals demonstrates, even in the absence of a certain technological maturity, an important ecosystem maturity. Subsequently, in case of vertical trials or pilots, with advanced services, a low number of deployed sites could be mitigated by a mature ecosystem, which can be either qualified as "FUT level cities" or as "5G Cities".

Timeline: Spectrum and Device Availability

The agenda in EU of the major technological trials and 5G Cities is conditioned by two interdependent aspects:

- Spectrum availability, at least on a temporary basis for the duration of the trials and 5G Cities, in particular in bands 42 (3.4-3.6 GHz) and 43 (3.6-3.8 GHz) in the different EU countries.
- Equipment availability and in particular commercial devices supporting the proposed band configuration (band, aggregation capabilities and supported bandwidth).

Therefore, the first 5G cities should start in 2H19, with the release of devices that will support the EU configuration in bands 42 and 43.

4. 5G Trials and Pilots in Key EU Cities

As it has already been pointed out in previous sections, 5G trials and pilots are executed and planned in various cities across EU. Before elaborating on exemplary showcases in some countries and cities, a high-level perspective is provided. Extracted from the EC EU 5G Observatory trials announcements, more than 105 concrete 5G private trials and pilots have been already executed in EU as illustrated in Figure 2 that includes the EU countries / MSs in which 5G trials and pilots have been publicly achieved or announced (note that the EC EU 5G Observatory is including the publicly achieved and announced trials and pilots and the specific announced 5G MoUs, which are not included in this Roadmap). The number of different trials is increasing constantly and up-to-date information can be acquired from EC EU 5G Observatory as it is updated frequently.

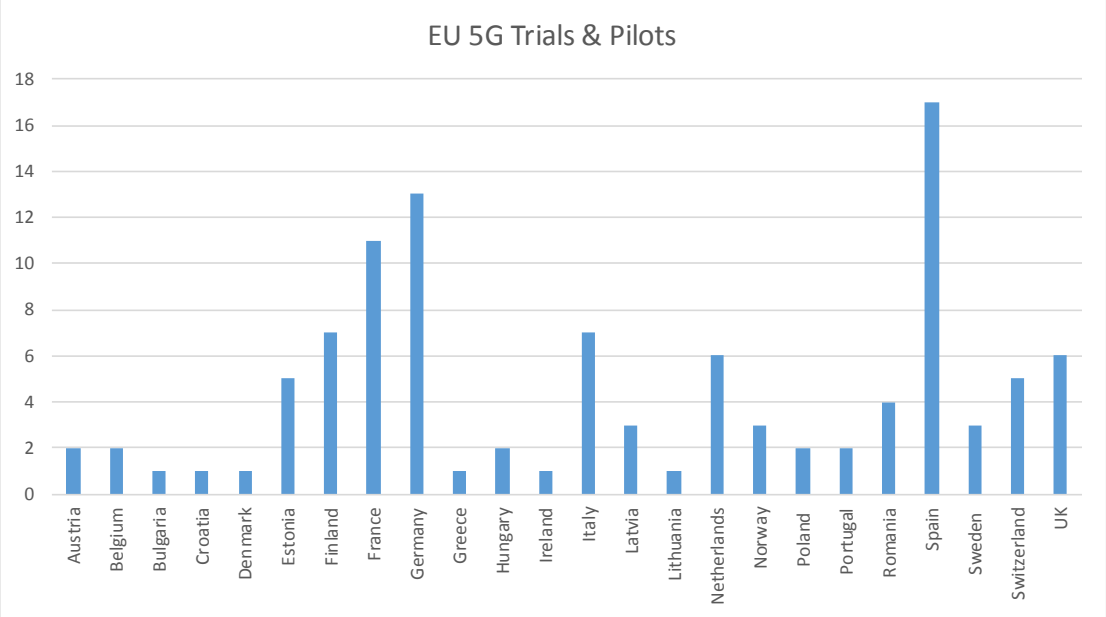


Figure 2: 5G Trials & Pilots in EU MSs

In addition to the 5G private trials and pilots reported in the EC EU 5G Observatory, the 5G Infrastructure PPP Verticals Cartography, launched in September 2018, tracks city-based 5G trials and pilots from 5G Infrastructure PPP Phase 2 projects across eight vertical clusters: Automotive, Energy, Health, Industry, Media and Entertainment, Public Safety, Smart Cities, Transport and Logistics planned in 2018-2020[25]. Figure 3.a shows that the peak of trials and pilots targeting verticals occurs with Media and Entertainment. One reason for this is that eMBB is among the first services supported in 5G. Cities are as well an important axis in the Cartography, with many trials and pilots directly or indirectly contributing to the 5G smart city ecosystem. Figure 3.b shows the distribution of projects in terms of eMBB, mMTC (massive Machine Type Communication) and URLLC (Ultra-Reliable Low-Latency Communication). Focussing on Smart Cities, plans for trials are scheduled in the timeframe 2019 and 2020 as shown in Figure 3.c. Obviously, this timing is congruent with the availability of technologies that support the 5G New Radio, core network functions and the user equipment. Another important aspect in this context is the provision of radio spectrum for 5G, which varies across EU[26]. As expected, trials and pilots on Smart Cities do not work without the involvement of the Public sector, i.e. the cities. Figure 3.d thus proves this assumption.

[25] http://global5g.org/cartography.
[26] http://5gobservatory.eu/5g-spectrum/national-5g-spectrum-assignment/

On-going analyses of 5G functionalities (eMBB, mMTC and URLLC)[27] and Performance KPIs will provide further insights in pinpointing market maturity levels and 5G coverage levels mapped across the trials and pilots.

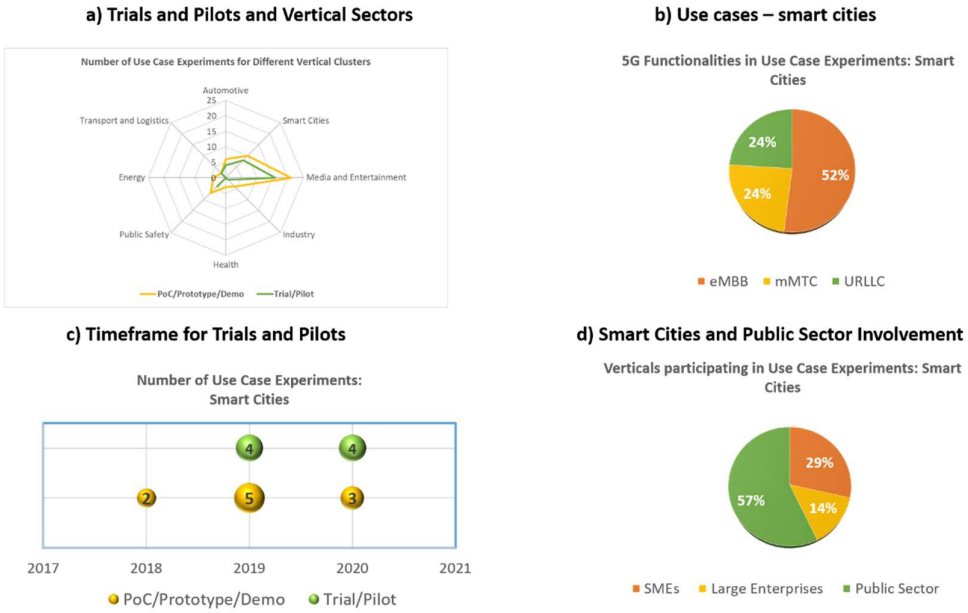


Figure 3: Verticals Cartography on 5G PPP Phase 2 Trials – Statistical Analysis

The Verticals Cartography currently counts 63 trials and pilots in 38 cities across 13 EU countries. Figure 4 illustrates the city locations for the trials and pilots featured in the Cartography across the 8 vertical clusters.

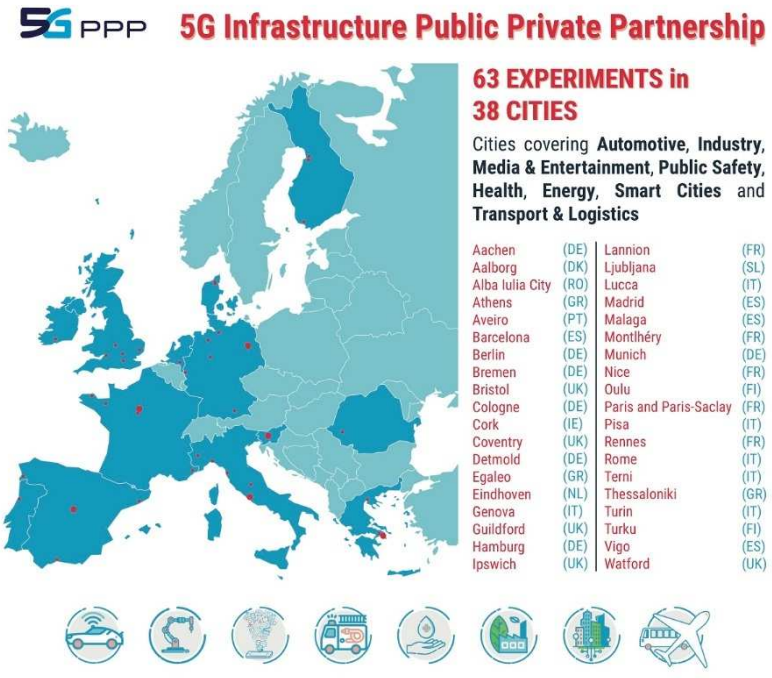
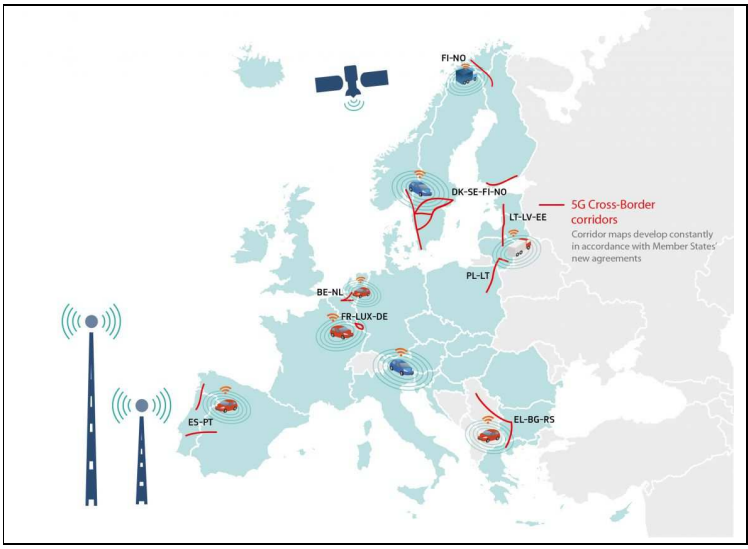


Figure 4: A Cityscape of the Verticals Cartography

[27] http://global5g.org/cartography-analysis.

As already highlighted in the Roadmap Version 3.0, Connected and Automated Driving (CAD) is clearly considered as a 5G flagship use-case in EU. The Pan-EU Corridors[28] between MSs, are made available to industry and stakeholders to test and validate 5G and are further boosted in the current and future EU plans. Corridors will support 5G CAD projects engaging stakeholders at large, notably network operators, manufacturers/vendors, chipset providers, car makers and road administration. The 5G Infrastructure PPP Phase 3 provide opportunities to support such early test projects. The key countries and cities involved in these first test corridors are summarized in Figure 5[29]. It has to be noted that specific discussions currently occur in EU concerning the technology roadmap and options/orientations for Connected and Automated Mobility (CAM) development and deployment (e.g. 5G and ITS G5[30]). Beyond the technical and technological development related to 5G automotive and corridors, attention is also paid to the overall security, legal and regulatory issues as currently being addressed in the EC CAM Consultation[31].



EU Corridors

- Metz-Merzig-Luxembourg (FR-DE-LU).
- Rotterdam-Antwerpen-Eindhoven (NL-BE-NL).
- Porto-Vigo and Evora-Merida (PT-ES).
- Tromso-Kolari - E8 "Aurora Borealis": (NO-FI)
- Helsinki-Turku-Stockholm-Gothenburg-Oslo-Copenhagen Nordic Way2 (FI-SE-NO-DK).
- Munich-Bologna - Brenner Corridor (DE-AT-IT).
- Thessaloniki-Sofia-Belgrade (EL-BG-RS)
- Tallinn-Riga-Kaunas - Via Baltica (E67)– Lithuanian/Polish border (EE-LV-LT).
- Kaunas-Warsaw - Via Baltica (LT-PL).

Figure 5: EU 5G Test Corridors

In addition to the 5G Infrastructure PPP Phase 2 and 3 trials in EU cities and the 5G test corridors between EU cities, the next paragraphs illustrate the national 5G deployment and trial activities in few selected EU MSs / countries and related cities, most of the private trials and pilots being reported in the EC EU 5G Observatory (details on trials and pilots including involved stakeholders are available from the Observatory website). In some MSs / countries, the activities have already moved from use-case and network design to deployment phase and the major operators as well as other 5G test network providers, such as national test beds for research, development and education, have launched and deployed 5G systems in several cities. The deployment and demonstration activities are now gradually moving to commercial use through public trials and demonstrations with different national test network initiatives.

[28] https://ec.europa.eu/digital-single-market/en/news/new-5g-cross-border-corridors-connected-and-automated-driving-announced-digital-day-2018

[29] https://ec.europa.eu/digital-single-market/en/news/new-5g-cross-border-corridors-connected-and-automated-mobility-baltics-will-allow-testing

[30] https://www.reuters.com/article/eu-autos-technology/volkswagen-a-winner-as-eu-set-to-favour-wifi-over-5g-draft-idUSKCN1MT1IT

[31] https://ec.europa.eu/digital-single-market/en/news/open-public-consultation-connected-and-automated-mobility-cam

In Finland, the main piloting and trialing cities include Espoo/Helsinki, Tampere and Oulu, where the key telecom operators have already launched 5G activities, such as the Telia Company 5G Finland[32]. The 5G Test Network Finland[33] (5GTNF) ecosystem, supported by Finnish Government through national technology development funding, has enlarged the open 5G test network for research and development, testing and education. It provides the network and service infrastructure for both public and private trialling of vertical use cases in mentioned cities. The current use-cases include public safety, energy and eHealth as well as autonomous/self-driving vehicles for personal and mass-transportation. After closing the auction for 5G band, the Ministry of Transport and Communications has set a proposal of easement for operators in the spectrum use in three 5GTNF cities. The proposal would guarantee the possibility to use part of the band for research and development, testing and educational purposes. The reserved band also benefits further public 5G city trials in these cities.

In France, the spectrum auctions are expected mid-2019. Orange will be piloting 5G full scale technological tests from 2018, in the cities of Lille, Douai, Marseille, Châtillon at Orange Gardens site and at the Linas-Monthléry circuit. Orange is also planning further tests in 2019, in the district of Paris Opéra (megastore Orange Opéra). Bouygues, which has conducted tests in Bordeaux by deploying two sites in 2018, is targeting more extensive tests (around a dozen different sites) in Bordeaux and Lyon. SFR has announced experimentations in Nantes and Toulouse in 2019. The first full scale technological trials ("FUT level test" of about 10 sites) are scheduled to happen in France at late 2018 for Orange and Bouygues, and in 2019 for SFR in several major cities. The first deployments in 2020, as announced by Orange, Bouygues and SFR previously this year, are following these trials.

In Germany, 5G BERLIN is an innovation cluster for testing technologies and driving new 5G applications[34]. The initiative started in early 2018 with the opening of a 5G-Testfield and 5G Centre serving as a networking platform for start-ups, SMEs, research institutes, large companies and public authorities. The 5G-Testfield includes the sustainable establishment and operation of a high-performance test infrastructure and testing technologies under real conditions. To fully realize innovation potential, the infrastructure will expand incrementally on a need-driven basis: Installation of 5G technology at existing macro-cell sites, equipping streetlights with 5G and networked millimetre wave technologies to achieve very high data rates, with high potential for future 5G applications.

In Greece, Trikala has been selected as the country first 5G city. The agreement was signed in March 2018 by the city council, e-trikala SA and the General Secretariat of Telecommunications and Post[35]. The project prioritizes sustainable urban development solutions aimed at benefitting citizens and businesses. It develops a free 5G pilot network that integrates existing smart services with 5G technologies and measures performance: IoT sensors for waste meter measurement, smart lighting and smart environment. Under the programme, the smart farming for cultivating medicinal plants using sensors and computers will also be tested. Athens.5Glink[36] is a large-scale end-to-end 5G testbed, involving a number of stakeholders from research institutes, SMEs and large companies, aiming at demonstrating and validating 5G technologies at NCSR Demokritos and municipality of

[32] https://www.telia.fi/yrityksille/english/telia-partners/5g-finland
[33] http://5gtnf.fi/
[34] https://www.5g-berlin.org/?lang=en.
[35] https://www.digitallytransformyourregion.eu/trikala-become-first-greek-city-5g-technology.
[36] http://www.athens5glink.eu/.

Egaleo test sites. The Athens.5Glink provides both indoor and outdoor test environments such as the Egaleo stadium for mass event field tests related e.g. to mMTC and flash-crowd events on cloud system.

In Italy, Turin has been selected as the country first 5G city, with an MoU signed by the city council and Telecom Italia (TIM) for a 5G mobile network[37]. Under the programme, metropolitan trials will start in 2018, with the aim of covering the entire city by 2020. TIM will install over 100 small cells in key areas around the city, two universities, and with 3 000 users taking part in the trial process. In October 2018, TIM presented demonstrations of a 5G-controlled driverless car, an environmental monitoring use case using drones, a 5G-connected robot for manufacturing and smart city applications powered by Narrowband IoT (NB-IoT)[38]. The Ministry for Economic Development (MISE) is investing in 5G experimental trials through a series of government bids. Several such trials started in early 2018 in the cities of Bari and Matera, Prato[39], L'Aquila and Milan involving the operators TIM and Vodafone. The 5G Matera-Bari project will receive €60 million over four years with the involvement of 52 partners[40]. Started in September 2018, the trials use 5G New Radios alongside a TIM LTE network, targeting to further upgrade from mid-2019 to full 5G coverage using the allocated 5G band. The trials focus on smart cities, public safety, environmental monitoring, Industry 4.0, smart port, media and VR, transportation and road safety, smart agriculture, health 5.0, tourism and cultural heritage. The ROMA5G programme focuses on a touristic city with virtual reality (VR) and augmented reality (AR) applications, traffic mobility and public safety in Rome[41].

In the Netherlands, 5G trials are mostly focused on vertical applications rather than providing 5G coverage for consumers. In Amsterdam, City of Amsterdam, the Johan Cruijff Arena together with the government and private partners are collaborating on 5G trials related to media applications, transport, and public safety especially in South-East Amsterdam. The Arena has obtained test licenses for 3.5 GHz band covering the football stadium and its surrounding area, especially targeting for the trials during the UEFA EURO 2020 football championships. In the province of Groningen, the Economic Board Groningen has launched 5Groningen initiative for trials. The 5Groningen, supported by the operators KPN and Vodafone, telecom vendors, research organizations and Dutch Radio Communications Agency, focuses on 5G applications in areas of agriculture, healthcare, energy, traffic and logistics, environment, and smart industry instead of testing the 5G technology itself. 5Groningen has established also a collaboration with ESA to test the use of space applications (e.g. earth observation, navigation, or satellite communication) in the context of 5G applications (ESA Satellite for 5G Initiative). In Rotterdam, Dutch operator KPN is testing 5G together with Shell on their Pernis refinery. Application partners like ABB, Accenture and SPIE provide industrial maintenance applications with e.g. AR, machine learning, robot control and remote sensing. KPN is also performing 5G trials on a farm in the province of Drenthe (drones in agriculture), and in the Helmond - Eindhoven region with a focus on trials related to automotive applications (self-driving cars, platooning, and intelligent transport systems).

In Spain, several 5G activities are emerging across the country together with the recently created 5G National Observatory (ON5G), aimed at positioning and strengthening the impact of 5G. Among

[37] https://www.iottechexpo.com/2017/03/smart-cities/turin-become-italys-first-5g-city-aims-total-deployment-2020/.
[38] https://www.ericsson.com/en/news/2018/10/5g-and-the-city-of-turin.
[39] http://www.cittadiprato.it/IT/Sezioni/336/Sperimentazione-5G-a-Prato/.
[40] http://www.barimatera5g.it/.
[41] http://www.roma5g.eu/.

the Spanish national 5G initiatives, 5GBarcelona[42] has emerged as a pubic and neutral initiative. The aim is to create a 5G Digital Hub and transform the metropolitan area of Barcelona into an open and neutral city-wide lab for the validation and adoption of 5G technologies and applications in a real-life environment. Telefonica has contributed with the creation of an IoT/5G Open Lab for validating solutions in a lab environment. 5GBarcelona will take advantage of the annual celebration of Mobile World Congress (MWC) in Barcelona to strengthen 5G European visibility with different city pilots presented there in its 2019 edition. Currently deployed pilots at MWC 2019 are: A pilot between Vodafone and Hospital Clinic to demonstrate the first operation with 5G support for remote surgeons, a pilot led by Telefonica and SEAT to demonstrate V2X and Intersection Collision Avoidance (ICA) between cars and bikes, and a pilot led by Orange and Nissan to validate impact of 5G in logistics and Industry 4.0. Moreover needs-driven pilots are emerging within public administrations. One example is the Spanish Regional Catalan Government with its Advanced Digital Technologies Research and Innovation programme[43] that responds according to a "mission-driven"[44] model to the Government's strategic objectives. The first 5G challenge[45] consists in adapting a mountain road and an autonomous bus for a 4.5 km journey through a natural park with real time services and autonomous control. The second challenge deals with the impact of 5G in non-dense areas. The government requests a set of indicators that analyse 5G technical and commercial viability, together with a new set of political policies in remote areas. It specifically targets industrial estate areas and small remote towns.

In the UK, funding is allocated for a 5G Testbeds and Trials Programme, Urban Connected Communities Project and for testing the security of 5G networks to build and test capabilities in collaboration with the National Cyber Security Centre (NCSC)[46]. The Trials and Testbeds scheme includes 5G RuralFirst: Rural Coverage and Dynamic Spectrum Access Testbed and Trial (Orkney, Shropshire and Somerset), 5G Smart Tourism (Bath and Bristol), Worcestershire 5G Consortium Testbed and Trials (e.g. Worcester, Kidderminster), Liverpool 5G Testbed, AutoAir: 5G Testbed for Connected and Autonomous Vehicles (Millbrook), 5G Rural Integrated Testbed (Cumbria, Northumberland, North Yorkshire, Inverness-shire, Perthshire and Monmouthshire). Funding has also been awarded to the West Midlands Combined Authority (government bid winner announcement in September 2018) to create the UK first multi-city 5G testbed with trials of new high-speed connectivity with hubs in Birmingham, Coventry and Wolverhampton. Funding from the National Productivity Investment Fund (NPIF) will be used to upgrade the Network Rail test track in Melton Mowbray and for the installation of trackside infrastructure along part of the Trans Pennine route with the rollout of full-fibre and 5G networks. In terms of verticals, the UK 5G Programme includes automotive, industry (factories and process automation; construction; farming and agriculture), health, public safety, tourism, transport and logistics.

5. 5G R&I Platforms over EU

Experimental platforms for 5G developments and trials in EU are the results of private and public efforts at national and EU level. Accelerating trial capabilities and other pilots, the platforms remain subject to continuous efforts targeting the full 5G picture and future evolutions. As such, the future

[42] https://5gbarcelona.org/
[43] http://smartcatalonia.gencat.cat/en/projectes/tecnologies/detalls/article/Programa-de-recerca-i-innovacio-en-Tecnologies-Digitals-Avancades
[44] http://europa.eu/rapid/press-release_SPEECH-17-1881_en.htm
[45] http://smartcatalonia.gencat.cat/ca/projectes/tecnologies/tecnologies-digitals-avancades/reptes/
[46] https://www.gov.uk/government/collections/5g-testbeds-and-trials-programme.

roadmap of actual 5G infrastructure deployment is highly dependent on the capability to up-date existing or deliver a new relevant and comprehensive set of platforms addressing the remaining gaps and challenges. One should also consider platforms as valuable and demonstrated set of 5G enablers, beyond trial objectives. In order to increase the complementarity of the available platforms and the forthcoming developments, tight coordination is need, including first in the documentation of the platforms. It is of tremendous importance to describe the matching elements of each platform compared to the complete 5G landscape. This documented orientation helps 3rd parties to assign their interests to the respective platform purpose. To boost access to 5G platforms, it is necessary to help different stakeholders on their knowledge level to identify the right platform targeting their interests Therefore a common classification and documentation for 5G platforms addressing different target groups is mandatory. Consistent data structures and unified meta information like name of the platform, countries where the platform is deployed and additional information on features and capabilities is fundamental. The data collections provided by platforms have to support questions from diverse stakeholders including research, public sector or industry.

5G Infrastructure PPP Phase 3 platforms projects (2018-2021) started in July 2018 and provide a pan-EU large-scale end-to-end 5G validation network infrastructure, covering about 20 EU sites and nodes on a pan-EU basis. This infrastructure will provide the adequate level of openness to make it possible for vertical industries to test their innovative 5G business cases using ad-hoc network resource control in an end-to-end interoperability framework.

The key platforms and cities of the PPP Phase 3 platforms projects are summarized in the geographic cartography presented in Figure 6.

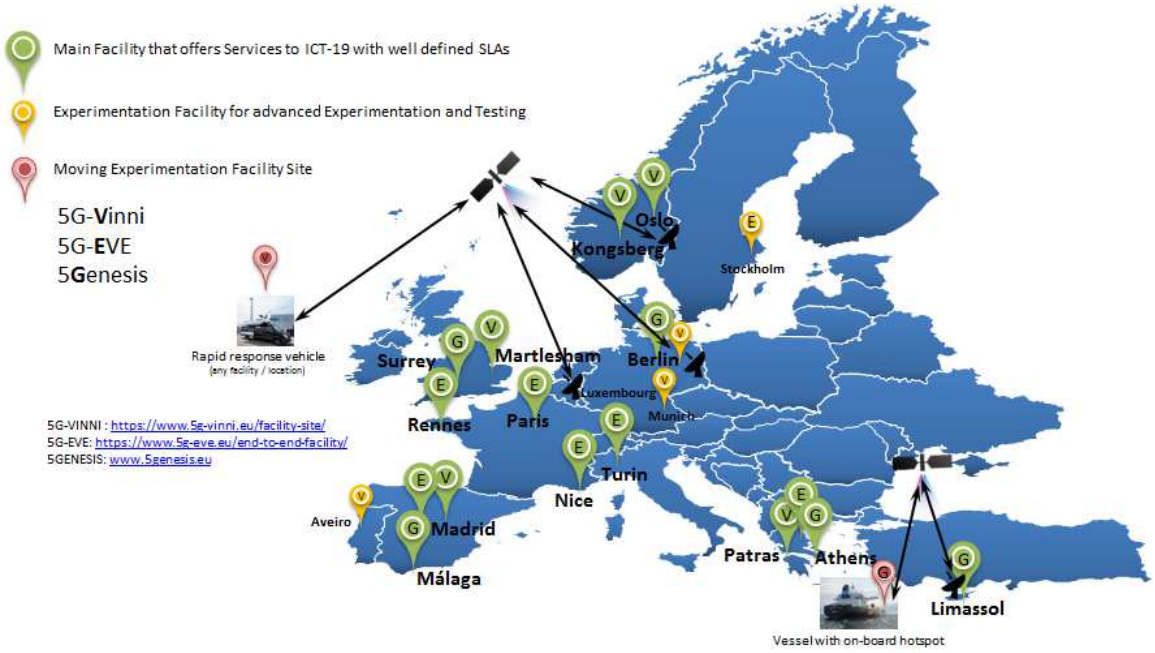


Figure 6: 5G Infrastructure PPP Phase 3 Platforms Projects – Geographic Cartography

The key capabilities and features of the PPP Phase 3 platforms projects are summarized in the Table 2. It should be noted that (1) capabilities will be incrementally added until the end of the projects, (2) interworking refers to interconnection of two or more sites to provide unified service(s) in the 5G E2E facility and interconnection does not assure interworking, (3) integration will be

developed/funded by ICT-19 Vertical Pilots projects and (4) exact time line will be communicated after evaluating ICT-19 needs. The notes (2), (3) and (4) apply as reported in specific corresponding capabilities rows.

Platforms Capabilities	5G-EVE	5G-VINNI	5GENESIS
Rel15-5GNR in Non Standalone Alone (NSA) mode	Turin, Madrid, Paris, Athens *January 2020*	Oslo, Kongsberg, Martlesham, Patras, Madrid, Aveiro	Athens, Berlin, Limassol, Malaga, Surrey
Rel15-5GNR with Rel15-5GCore in Standalone Alone (SA) mode(4)	Turin, Madrid, Paris, Athens *June 2021*	Oslo, Kongsberg, Martlesham, Patras, Madrid, Aveiro. *After Jan2020*	Athens, Malaga, Berlin, Surrey
Rel16-5GNR and 5GCore (NSA or SA)(4)	Turin, Madrid, Paris, Athens *June 2021*	Oslo, Kongsberg, Martlesham, Madrid, Patras *After Jan2020*	Surrey
Network Slicing as a service(3)	-	Oslo, Kongsberg, Martlesham, Patras, Madrid, Aveiro	Athens, Malaga, Surrey
Customized network slice (e.g. SFC, security, enhanced Cloud access) (3)	Turin, Madrid, Paris, Athens *June 2021*	Oslo, Kongsberg, Martlesham, Patras, Madrid, Aveiro	Athens, Berlin, Limassol, Malaga, Surrey
Hosting of 3rd party VNFs(3)	Turin, Madrid, Paris, Athens. *January 2020*	Oslo, Kongsberg, Martlesham, Patras, Madrid, Aveiro	Athens, Berlin, Limassol, Malaga, Surrey
Interworking(2) with other ICT17 facilities(3)	Turin, Madrid, Paris, Athens *June 2021*	Oslo, Kongsberg, Martlesham, Patras, Madrid	Athens, Malaga, Surrey
Integration of additional gNB to ICT-17 facility(3)	Turin, Madrid, Paris, Athens *January 2020*	Oslo, Kongsberg, Martlesham, Patras, Madrid, Aveiro *After Jan2020*	Athens, Berlin, Limassol, Malaga, Surrey
Edge Computing	Turin, Madrid, Paris, Athens *January 2020*	Madrid, Aveiro, Oslo, Kongsberg, Patras, Martlesham (TBD). *After Jan2020*	Athens, Malaga, Surrey
Distributed Data fabric service for analytics	-	Oslo, Kongsberg, Patras (TBD), Madrid. *After Jan2020*	Athens
3.5 GHz 5G Radio	Turin, Madrid, Paris, Athens *January 2020*	Oslo, Kongsberg, Martlesham, Patras, Madrid, Munich, Aveiro	Athens, Malaga, Surrey
26 GHz 5G Radio	-	Oslo, Kongsberg, Martlesham	Surrey
Millimeter wave for Backhaul	-	Patras	Surrey

End UserTesting	Turin, Madrid, Paris, Athens *January 2020*	Oslo, Kongsberg, Martlesham, Patras, Madrid	Athens, Berlin, Limassol, Malaga, Surrey
Automatic testing framework	Turin, Madrid, Paris, Athens	Oslo, Kongsberg, Martlesham, Patras, Madrid	Athens, Malaga, Surrey

Table 2: 5G Infrastructure PPP Phase 3 Platforms Projects – Capabilities/Features Cartography

Beyond the 5G Infrastructure PPP Phase 3 platforms projects cartography, an inventory of available 5G platforms in EU and their functionalities is currently under development [47], as illustrated in Figure 7. It describes the supported technologies and functions of platforms compared to the complete 5G target landscape. This inventory boosts the access to 5G platforms, by helping the different stakeholders (research, public sector, industry…) identifying the right platform (common classification and documentation) for their interests.

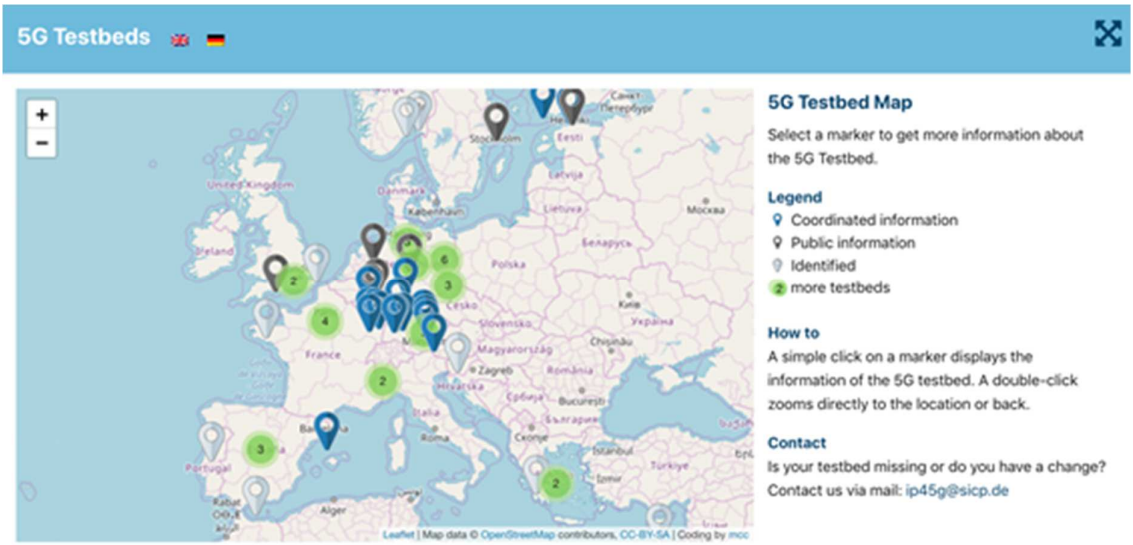


Figure 7: 5G EU Platforms Inventory– Geographic and Features Cartography

6. 5G Pan-EU Flagship Event – 5G UEFA EURO 2020

In order for 5G to be truly successful, beside the different activities described in the previous Sections, high profile trials and pilots, accessible to large public audiences are planned. The target flagship event has to get widespread media attention and serve as a milestone for industry, governments and the general public showing that 5G is coming now and is beneficial for individuals and society.

The UEFA EURO 2020 football championships will be played in 12 different cities in EU (Amsterdam, Baku, Bilbao, Bucharest, Budapest, Copenhagen, Dublin, Glasgow, London, Munich, Rome, Saint Petersburg). This makes the EURO 2020 an excellent opportunity for a 5G Pan-EU trial, also because of the media attention it will get. The timing of UEFA EURO 2020, summer 2020, just before the 2020 Olympics in Japan, fits well with the EC 5GAP.

[47] https://www.ip45g.de/en/testbeds/ was built and is maintained by the German accompany research project for the research imitative "5G: Industrial Internet" lead by Paderborn University's SICP – Software Innovation Campus Paderborn and funded by German Federal Ministry for Education and Research (BMBF).

The intention is that the UEFA EURO 2020 acts as the "launching event" for 5G in EU with a number of 5G services that will be trialed around the UEFA EURO 2020 football cup. In each of the cities a consortium of local governments, stadium facility managers, infrastructure vendors and application providers is needed. In some cities additional stakeholders may need to be involved. Private or local funding through private trials or/and national or/and regional initiatives will be used to develop the trials. The City of Amsterdam, with the Johan Cruijff ArenA as UEFA EURO 2020 host stadium publicly announced at the MWC 2017 in Barcelona that they are committed to participate in 5G trials and to get as many playing cities on board. For each playing city, an agreement with (at least one) operator is targeted to ensure there will be a 5G coverage on which the intended 5G services can be trialed. There will be a trade-off between what coverage specific trials need and what local operators and manufacturers/vendors can deliver. Sufficient spectrum (across the 3.4-3.8 GHz band and in the 26 GHz band) needs to be available in order to allow demonstrating the full performance capabilities of 5G. Cities that are not a playing city can participate with 5G AR/VR applications at local fan zones with restricted requirements regarding coverage and spectrum. The trial services will be developed together with the local partners, e.g. public safety trials will need collaboration with local governments. Though, the different local governments and local initiatives may lead to differences in the trials, however replication of common 5G trial services across multiple cities is aimed for as far as possible. A Pan-EU steering committee, including representatives of the cities, the playing stadiums and telco partners, will ensure a consistent coordination of trial objectives and implementation. It will also address the marketing and communications aspects of this profile event.

A Vanguard Group, which consist of hosting cities is now being formed. The aim of this Group is to further define the initiative that describes the use-cases and launch of 5G in 2020 during UEFA EURO 2020. The following cities are now included in the discussions: Amsterdam, Dublin, London, Bilbao, Munich and Rome. Each city consists of a stadium partner and a city lead organization. The stadium partners which have confirmed are Johan Cruijff ArenA, Estadio San Mames, Aviva Stadium and Stadio Olimpico. Hosting cities currently describe the 5G use-cases as discussed during the first 5G UEFA EURO 2020 Trial meeting organized in February 2018 in Amsterdam, collocated with the Innovation Summit 2020[48] organized at Johan Cruijff ArenA, and attended by governmental and non-governmental organizations, from different cities. The initiative is further developing and will be signed and communicated to EC for further development. The description and focus of the hosting cities will formulate a focus to launch 5G as a Pan-EU Service. A relation with UEFA will be established in order to investigate the rights and constraints associated with using EURO 2020 as a flagship event and to ensure the trials add to the success of UEFA as well. A win-win-win perspective between 5G Infrastructure PPP, EC and MSs (and related Cities) and other stakeholders is sought.

7. 5G in EU – Key Cities – Summary Perspectives and Next Steps

Following the goals for 5G implementation put forth in EC 5GAP, including (1) early 5G launch in selected areas in 2018, (2) commercial launch of 5G services in at least one major city in all MSs in 2020 and (3) uninterrupted coverage in all urban areas and along main transport paths in 2025, 5G has been strongly boosted in EU in 2018, as it has been detailed in the preceding sections of this Roadmap. In particular, in its different sections, this roadmap has described how many key EU cities are already strongly engaged in 5G development, trials and pilots. Section 3 provided a summary of the framework to move from technological trials to (pre-)deployment in cities, Section 4 detailed

[48] http://amsterdaminnovationarena.com/summit/ .

the heterogeneity of verticals, use-cases, considered traffic types (eMBB, mMTC, URLLC), maturity (from PoC to pilot) in all the 5G-related activities taking place in key EU cities, Section 5 highlighted the distributed, relevant and comprehensive set of 5G platforms different cities within the EU territory and MSs and finally Section 6 highlighted the targeted Pan-EU Flagship event and the 12 related cities involved.

The following Table 3 summarizes the key cities in EU involved in 5G activities related to 5G private trials and pilots, 5G National Programmes (incl. platforms), 5G test corridors, 5G Infrastructure PPP (vertical trials and pilots and platforms) and to the 5G Pan-EU Flagship event UEFA EURO 2020. All the content in Table 3 is based on publicly available information and does not pretend to be exhaustive. For up-to-date information, the reader is referred to EC EU 5G Observatory, 5G Infrastructure PPP and EC 5G websites.

EU Countries / MSs	**5G Activities** (5G Private Trials and Pilots, 5G National Programmes (incl. Platforms), 5G test Corridors, 5G Infrastructure PPP (Vertical Trials and Pilots and Platforms) and 5G Pan-EU Flagship event UEFA EURO 2020.	**Key Cities**
Austria	5G Private Trials & Pilots, 5G test Corridors	Innsbruck
Belgium	5G Private Trials & Pilots, 5G test Corridors	Antwerpen, Leuven
Bulgaria	5G Private Trials & Pilots, 5G test Corridors	Sofia
Croatia	5G Private Trials & Pilots	Jastrebarsko
Cyprus	5G Infrastructure PPP	Limassol
Denmark	5G Private Trials & Pilots, 5G test Corridors, 5G Infrastructure PPP	Aalborg
Estonia	5G Private Trials & Pilots, 5G test Corridors,	Tallinn
Finland	5G Private Trials & Pilots, 5GTNF, 5G Finland, 5G test Corridors, 5G Infrastructure PPP	Espoo, Helsinki, Muonio, Oulu, Sodankylä, Tampere, Turku, Ylivieska
France	5G Private Trials & Pilots, 5G test Corridors, 5G Infrastructure PPP	Bordeaux, Chatillon, Douai, Lannion, Lille, Lyon, Marseille, Metz, Montlhery, Nantes, Paris, Paris-Saclay, Nice, Rennes, Toulouse
Germany	5G Private Trials & Pilots, 5GBerlin, 5G test Corridors, 5G Infrastructure PPP	Aachen, Berlin, Bremen, Cologne, Detmold, Hamburg, Merzig, Munich
Greece	5G Private Trials & Pilots, Athens5Glink, 5G test Corridors, 5G Infrastructure PPP	Athens, Egaleo, Patras, Thessaloniki, Trikala
Hungary	5G Private Trials & Pilots	Zalaegerszeg
Ireland	5G Private Trials & Pilots, 5G Infrastructure PPP	Cork, Dublin
Italy	5G Private Trials & Pilots, 5G MiSE, ROMA5G, 5G test Corridors, 5G Infrastructure PPP	Bari, Bologna, Genova, L'Aquila, Lucca, Matera, Milan, Pisa, Prato, Rome, Terni, Turin
Latvia	5G Private Trials & Pilots	Riga, Talsi
Lithuania	5G Private Trials & Pilots, 5G test Corridors,	Kaunas, Riga, Vilnius
Luxembourg	National Program (1Q19), 5G test Corridors	Luxembourg-City
Netherlands	5G Private Trials & Pilots, 5G Amsterdam, 5Groningen, 5G test Corridors, 5G Infrastructure PPP	Amsterdam, Eindhoven, Groningen, Rotterdam
Norway	5G Private Trials & Pilots, 5G test Corridors, 5G Infrastructure PPP	Kongsberg, Olso, Tromso
Poland	5G Private Trials & Pilots, 5G test Corridors,	Gliwice, Warsaw

Portugal	5G Private Trials & Pilots, Aveiro5GCity, 5G test Corridors, 5G Infrastructure PPP	Aveiro, Evora, Porto
Romania	5G Private Trials & Pilots, 5G Infrastructure PPP	Alba Iulia City, Cluij-Napoca, Bucharest
Serbia	5G test Corridors,	Belgrade
Slovenia	5G Infrastructure PPP	Ljubljana
Spain	5G Private Trials & Pilots, 5GBarcelona, 5GTonic, 5G test Corridors, 5G Infrastructure PPP	Barcelona, Bilbao, Castelldefels, Madrid, Málaga, Merida, Talavera de la Reina, Segovia, Valencia, Vigo
Sweden	5G Private Trials & Pilots, 5G test Corridors, 5G Infrastructure PPP	Gothenburg, Stockholm
Switzerland	5G Private Trials & Pilots	Burgdorf, Renens, Zurich
United Kingdom	5G Private Trials & Pilots, UK5G, 5G Infrastructure PPP	Bristol, Coventry, Ipswich, Guildford/Surrey, Martlesham, Watford

Table 3: 5G EU Countries / MSs Initiatives and Related Cities

The release of the Roadmap Version 5.0 is planned for June 2019 in conjunction with the 7th Global 5G Event to be organized on 17-18.06.19 in Valencia. It will provide up-dates on the overall Roadmap implementation, including (among others) on the interworking of 5G end-to-end facilities / platforms with the initiatives of vertical sectors.

Trials WG Members organizations contributing to the Trials Roadmap Strategy

ABB, ADVA Optical Networking, Ahlers, Airbus, Altice Labs, Atos, Avanti Communications Group plc, BMW, Bosch, BT, COMSA, Deutsche Telekom, DOCOMO Communications Laboratories Europe, Engineering, Ericsson, Eurescom, Eutelsat, Fastweb, Fiat, Huawei Technologies, IBM Research, IDATE, Indra Sistemas, Inmarsat, Intel Mobile Communications, KPN, Leonardo, LiveU, Mitsubishi Electric R&D Centre Europe, NEC Laboratories Europe, Netaş Telecommunication, Nokia, OpenFiber, Orange, Philips, Proximus, QinetiQ, Samsung Electronics Research Institute, SES, Siemens, SIGOS, Telecom Italia, Telefónica I+D, Telenor, Tele2, Telespazio, Telia Company, Thales Alenia Space, Thales Communications & Security, Trenitalia, Trust-IT, Turkcell, Turk Telekomünikasyon, Vodafone, Zodiac Aerospace, ZTE Wistron Telecom, EBU, ECTA, ETNO, ESA, GSMA, T-REGS, AICO Software, AMBEENT WiRELESS YAZILIM, CityPassenger, Ingeniería y Soluciones Informáticas, Integrasys, InterInnov, M.B.I., Nextworks, Quobis, Sequans Communications, WINGS ICT Solutions, CEA-LETI, Centre Tecnologic de Telecomunicacions de Catalunya (CTTC), Consorzio Nazionale Interuniversitario per le Telecomunicazioni (CNIT), Cork Institute of Technology (CIT), DLR (German Aerospace Center), Fraunhofer Gesellschaft zur Foerderung der angewandten Forschung e. V., Fundació Privada i2CAT, Internet i Innovació Digital a Catalunya, Fundacion IMDEA Networks, IMEC, Institut Mines-Télécom, Instituto de Telecomunicações, IHP, IRT, TNO, TUE, Universidad de Málaga, Universidad Politecnica de Madrid, Universitat Politècnica de Catalunya, University of Bologna, University of Bristol, Universität Paderborn, University of Patras, University of Sussex, University of Oulu/CWC, University of Patras, VTT Technical Research Centre of Finland, Universidad Carlos III de Madrid (UC3M), Amsterdam CTO.

Note: Specific comments / questions can be communicated to the 5G-IA Trials WG @ TrialsRoadmap@5g-ppp.eu.