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D2.4 –VERTICALS CARTOGRAPHY FINAL REPORT

Work Package	**WP2 - Market Watch**
Lead Author (Org)	AALTO
Contributing Author(s) (Org)	Trust-IT Services, INNO
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	PP: Restricted to other programme participants (including the Commission)
	RE: Restricted to a group specified by the consortium (including the Commission)
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Executive Summary

The purpose of this document is to report on the implementation and results of the verticals cartography action as part of the 5G Infrastructure Public Private Partnership (5G PPP) with the aim of classifying, illustrating and analysing the vertical use-case experiments implemented by 5G PPP Phase 3 projects (ICT-17, -18, -19).

A summary overview of the 5G PPP structure and programme-level objects, the 5G for Europe Action Plan and the envisioned impact of 5G on brief vertical industries is used as a starting point to provide an understanding of the context which inspired the verticals cartography action.

The document describes the verticals cartography use-case experiments of Phase 3 projects in terms of how it was structured, and the analysis carried out based on the information of the experiments provided by the different projects to the cartography. To that end, the perspectives considered in the analysis included:

- Vertical clusters covered with the clusters being Automotive, Industry, Broadcasting and Media, Health, Public Safety, Energy, Smart Cities, and Transport and Logistics.
- 5G ITU functionalities implemented out of enhanced mobile broadband (eMBB), ultra-reliable and low-latency communications (URLLC) and Massive machine type communications (mMTC).
- Maturity of the experiments considered in ascending order of maturity from proof-of-concept, prototype, demonstration, trial to pilot.
- Geographical distributions of the locations of the experiments across the different countries (both EU and non-EU).
- Participation of different vertical partners, namely: small and medium enterprises (SMEs), large enterprises, government and public sector, in different use-case experiments.

A number of observations are made from the analysis of the verticals cartography, particularly when contrasted with results obtained previously from Phase 2 projects.

- Over 120 use-case experiments planned or executed in 5G PPP Phase 3 projects were analysed (almost twice that in Phase 2), with the spread of use cases across vertical clusters being relatively larger (compared to Phase 2 use cases). A few exceptional clusters still requiring further attention are noted, including public safety, health and energy.
- The level of experimentation is generally more mature in Phase 3 projects, with trials and pilots being dominant in all vertical clusters, unlike the case of Phase 2 projects where PoCs, prototypes and demos were the prevailing activities.
- The 5G ITU functionalities (eMBB, mMTC and URLLC) are evenly addressed in the use-case experiments of Phase 3 projects (whereas eMBB was clearly dominant in Phase 2 projects).
- The geographical spread of the use-case experiments between Phase 3 projects correlates closely to the location of experimentation facilities under ICT-17. A significant increase in the number of use-case experiments in some countries, notably Finland, Norway and Portugal, is also noted. Furthermore, experimentation activities for Phase 3 projects are also happening in

some countries previously not hosting Phase 2 project experiments (e.g., Austria, Belgium, Sweden etc.); this also includes countries outside of Europe (China, South Korea and Turkey).

- The level of verticals participation in use-case experiments by Phase 3 projects is generally higher compared to Phase 2 projects. It is further noted that verticals participation is dominated by SMEs and large enterprises from the private sector, whereas government and public-sector verticals were more dominant in Phase 2 experiments.

Whilst most of the data gathering and analysis of the verticals cartography is carried out offline, there is also an online implementation of the verticals cartography available at http://global5g.org/cartography., where a content-rich approach is adopted as key to boosting impacts for the 5G PPP. This document briefly discusses the design approach and implementation of the web interface of the 5G PPP verticals cartography, and its sustainability within FULL5G through transfer of the website (https://global5g.5g-ppp.eu/).

Overall, the verticals cartography has proven to be a high-impact tool that provides a visual overview of a diverse set of use-case experiments in a way that can be conveniently consumed by stakeholders, both within and outside the 5G PPP programme. As such, it can inform strategies at programme level, and help in pinpointing possible synergies between experiment owners and other projects, vertical industry stakeholders, as well as 5G partners from other regions and so on.

1 Introduction

1.1 Purpose and Scope

D2.4 - Verticals Cartography, Final Version reports on the implementation and analysis of the Verticals Cartography as both an analytical and online tool for the 5G Infrastructure Public Private Partnership (5G PPP). Its development started with the definition of a Blueprint through collaboration with the Technology Board, and thereafter the Trials WG, with the focus on Phase 3 project use-case experiments. It also focuses on the design and rollout of the online tool, showing how it can easily be extended potentially beyond Horizon 2020 and to other 5G applications and services for a wide variety of vertical industries.

The main purpose of D2.4 is to:

- Present the main drivers for 5G across vertical industries, offering a general discussion on expected benefits and impacts.
- Define the development of the blueprint and methodological approach for data fields and collection, such as vertical clustering, use-case experiment types and 5G functionalities. This work has been coordinated with the chair of the Technology Board.
- Analyse the data to yield insights into the state of play for 5G use-case experiments in 5G PPP phase 3 projects, shedding light on, among others:
    - Level of coverage and intensity of 5G applications in specific verticals, e.g. smart cities with applications and scenarios that target multiple verticals.
    - Significant gaps in coverage of verticals, functionalities, locations and stakeholder engagement.
- Show the development of the online tool, its design, launch and maintenance.
- Plan future evolution of the online tool with updates from current Phase 3 projects and on-boarding of future projects.

1.2 Relationship to 5G PPP Work Programme and Project-Level Outputs

The Global5G.org[1] project is a Coordination and Support Action (CSA) within the 5G PPP. The specific role of Global5G.org is to help to strengthen the link between vertical industries, standardisation and research as diverse requirements emerge from different vertical industry use cases. This Global5G.org deliverable reports on the implementation and results of the verticals cartography action that was initiated within 5G PPP with the aim of classifying, illustrating and analysing the vertical use-case experiments implemented by different 5G PPP Phase 3 projects.

At the Global5G.org project-level, the work reported in this deliverable is within the scope of *WP2 Market Watch* which aims to analyse 5G potential across vertical industries. The deliverable is partially informed by insights from a previously published deliverable *D2.1 – Identify use cases from verticals* [Global5G2017]. The outcomes of this deliverable partially feed into deliverables *D2.3 and D2.5 – Vertical industries and rollout to markets,* as well as *WP3 Global 5G ecosystem: standards and support to consensus*

[1] http://global5g.org/.

building deliverables (most notably, *D3.3 – Report on 5G Standardization and Verticals*).

Specifically, D2.4 has close links to the following Global5G.org deliverables:

- *D2.2 – Verticals cartography 1st Report (June 2019)*.
- *D2.3 - Vertical industries and rollout to markets 1st Report (May 2019)*. It draws on some of the key findings of the two Global5G.org webinars on automotive and energy alongside selected IDC and external market analyses.
- *D2.5 – Vertical industries, market rollout, and emerging business models (December 2019)*. It updates D2.3 with consolidated analyses on selected verticals, information on partnerships between MNOs and vertical stakeholders, and indications on emerging business models.
- *D3.3 – Report on 5G Standardisation and Verticals (June 2019)*. The blueprint for the tracker draws on data regarding targeted standards group as a starting point to trigger further inputs from phase 2 projects within the 5G-IA Pre-Standardization WG.

1.3 List of Acronyms & Abbreviations

Acronym/Abbreviation	Description
3GPP	Third Generation Partnership Project
5G	Fifth Generation
5G-ACIA	5G Alliance for Connected Industries and Automation
5GC	5G Core Network
5G PPP	5G Infrastructure Public Private Partnership
5G PPP Phase 2	21 projects (including Global5G.org) on the research and validation of 5G technologies and convergent technologies funded under H2020 ICT-07-2017 and ICT-08-2017.
5G PPP phase 3	3 projects on implementing and testing advanced 5G infrastructures funded under ICT-17-2018; 3 projects on implementing and testing advanced cross-border 5G infrastructures; 8 projects (including FULL5G) on advanced 5G validation trails across multiple vertical industries
AR	Augmented Reality
CDN	Content Distribution Network
COCOM	Communications Commission
DER	Distributed Energy Resource
eMBB	Enhanced Mobile Broadband
ETP	European Technology Platform
ETSI	European Telecommunications Standardisation Institute
EV	Electric Vehicle
EU	European Union
GPS	Global Position System
IEC	International Electrotechnical Commission
IETF	Internet Engineering Task Force
IMT-2020	International Mobile Telecommunications 2020
IoT	Internet of Things
ITU	International Telecommunications Union
ITU-R	ITU Radiocommunication Sector
L4	Level 4 automation for vehicles

LV	Low Voltage
mMTC	Massive Machine Type Communications
MV	Medium Voltage
NGMN	Next Generation Mobile Networks
OEM	Original Equipment Manufacturer
PPDR	Public Protection & Disaster Recovery
PSCE	Public Safety Communications Europe
RAN	Radio Access Network
ToD	Tele-operated Driving
TSG	Technical Specification Group
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UHD	Ultra-high definition
URLLC	Ultra-Reliable and Low-Latency Communications
USD	United States Dollar
UTM	UAS Traffic Management
VR	Virtual Reality
V2X	Vehicle-to-Everything

1.4 Structure of the document

The rest of this document is organised as follows:

Section 2: Focuses on the background and impact. This includes a summary background on the 5G PPP verticals cartography action.

Section 3: Explains the development of the Verticals Cartography Blueprint. It briefly revisits the blueprint for the verticals cartography including description of its design, data fields and harmonisation. It also provides a brief description of data gathering methodology for the blueprint.

Section 4: Zooms in on the Portfolio Analysis for Phase 3 Projects. It outlines the approach, workflow and results from analysing the participation of diverse verticals in the use-case experiments compiled in the verticals cartography for Phase 3 projects. A summary comparison is then provided with corresponding results from analysis of verticals cartography of Phase 2 projects.

Section 5: Covers the impacts and sustainability of the Cartography. It summarises the impacts (5G PPP brochures, 5G PPP presentations, web stats for online tool, etc.) of the vertical cartography. Finally, the actions for sustainability of the cartography beyond Global5G.org are outlined.

Section 6: Contains the list of references

Section 7: Appendix.

2 Background and Impact

2.1 Context and motivation for the verticals cartography

The introduction of 5G technologies is underpinned by the need to address a **diverse range of use cases and business models for verticals with disparate requirements**. The 5G Infrastructure Public Private Partnership (5G PPP) whitepaper "5G empowering vertical industries" from February 2016 previously noted that "*…use-cases originating from verticals should be considered as drivers of 5G requirements from the onset with high priority and covered in the early phases of the standardisation process*" [5G PPP2016]. Similar observation was made in 5G Americas whitepaper titled "5G Services and Use Cases" from November 2017 which noted that "*…5G will create an ecosystem for technical and business innovation that will fundamentally alter entire vertical markets such as automotive, energy, food and agriculture, city management, government, healthcare, manufacturing, transportation, and many more*" [5GAmericas2017].

Furthermore, the EC SMART 2014/0008 study to forecast the qualitative and quantitative socio-economic benefits of 5G in Europe noted that verticals leveraging 5G capabilities will potentially derive the following benefits [EC016]:

- **Strategic benefits** arising from greater access to information (e.g. about supply chain, consumer utilisation of goods or services, etc.);
- **Operational benefits** through enhanced productivity;
- **Direct User benefits** through consumers access to goods or services with improvements in cost, quality, usability and so on.

In turn, these benefits for the verticals will lead to 'knock-on' impacts (in terms of societal benefits) from the use of new or improved goods and services. A conceptualisation of these 5G benefits from the SMART 2014/0008 study are illustrated in Figure 1.

Source: [EC2016]

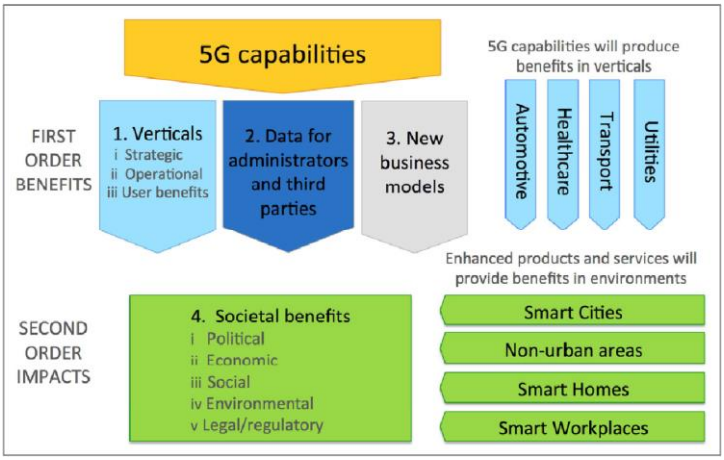


Figure 1 Conceptualisation of benefits and impacts of 5G capabilities

However, the realisation of 5G benefits for verticals is contingent on the tight collaboration of 5G system developers and vertical industries through joint innovation activities, such as co-development and piloting of 5G-enabled vertical use cases, defining of vertical-specific requirements and key performance indicators (KPIs), and involvement of vertical industry actors in specification of 5G-related technology standards. This synergy and its implications are also explicitly highlighted in the 5G for Europe Action Plan (5G AP), which notes "…*The launch of commercial 5G services will also require substantial investments, the availability of a suitable amount of spectrum, and close collaboration between telecom players and key user industries. Network operators will not invest in new infrastructures if they do not see clear prospects for a solid demand and regulatory conditions that make the investment worthwhile. Equally, industrial sectors interested in 5G for their digitisation process may want to wait until the 5G infrastructure is tested and ready*…" [EC2016b].

2.2 Rationale for the 5G PPP project verticals cartography

The 5G Infrastructure Public Private Partnership (5G PPP)[2] is the 5G collaborative research program that is represented by the 5G Infrastructure Association (5G-IA) on the private side and the European Commission (EC) on the public side. The 5G PPP promotes industry-driven 5G research underpinned by business-related considerations, technological performance and societal key performance indicators (KPIs). To that end, the 5G PPP research program is organised as part of the EC's Horizon 2020 (H2020) program, whereas the 5G-IA provides an advisory role by monitoring 5G PPP program and providing interventions via industry participants whenever case program falls short of its goals.
In the context of 5G for vertical industries, the 5G PPP program is aligned with the 5G Action Plan and among others addresses Action 1 below:

> *Action 1 — The **Commission** will work with **Member States** and **industry stakeholders** towards the voluntary establishment of a **common timetable** for the **launch of early 5G networks by the end of 2018, followed by the launch of fully commercial 5G services in Europe by the end of 2020**. The common timetable should be developed as quickly as possible. The EU timetable should be driven by the following key objectives:*
>
> *- Promoting **preliminary trials**, under the 5G PPP arrangement, to take place **from 2017 onwards**, and **pre-commercial trials** with a clear EU cross-border dimension **from 2018**(…)*

This emphasis on promotion of 5G trials is apparent in terms of the number of EU member states that are already engaged in 5G pre-commercial/commercial trials and pilots, as well as, 5G trials and pilots in both European and national research and innovation (R&I) projects. The trial activities are analysed in a recent report on "*5G Pan-European Trials Roadmap Version 4.0*" produced by the 5G PPP Trials WG in November 2018 [5G PPP2018]. The roadmap reports also include a high-level depiction of the Pan-EU trials roadmap as shown in Figure 2. To that end, it is noted that experimental trials and piloting activities by 5G PPP project constitute a critical part of the overall ecosystem of trial activities across the EU. The 5G PPP

[2] 5G PPP website https://5G PPP.eu/.

projects have been implemented in phases, whereby:

- Phase 1 including 19 projects (from year 2015 to 2017) focusing on development of baseline 5G technologies;
- Phase 2 included 21 projects (from mid-2017 to early 2020) focusing on prototyping and experimenting with different 5G technologies in collaboration with vertical stakeholders;
- Phase 3 includes 14 projects (from mid-2018 to 2022) implementing end-to-end 5G open platforms for joint trialling and piloting of different vertical use cases. Another 20-30 projects will be added to Phase 3 to develop the long-term evolution of 5G (8 of these projects have kicked off).

Source: [5GPPP2018]

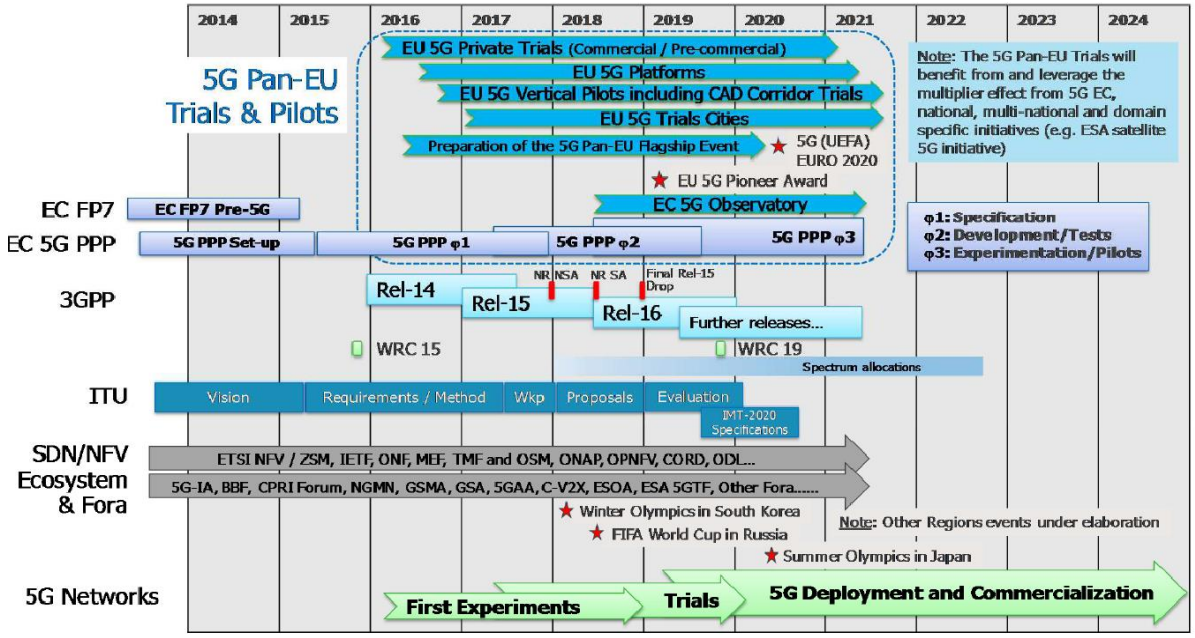


Figure 2 Pan-EU trials roadmap

The action on verticals cartography for 5G PPP Phase 2 and Phase 3 projects was initiated in the 5G PPP Technology Board (TB) as a way of providing a high-level view of vertical use-case experimentation undertaken by the different projects.

The 5G PPP verticals cartography aims to classify, illustrate and analyse the experimental vertical use cases implemented by different 5G PPP Phase 2 and Phase 3 projects. A number of factors motivate this verticals cartography:

(a) Need to provide a consolidated high-level visualisation of all experimental activities and impacts (e.g., standards) for different use cases across all Phase 2 and Phase 3 projects.
(b) Need to provide an overview of the participation of stakeholders from different vertical sectors in the Phase 2 project experiments.

(c) Need to highlight various trends in the experimental activities, such as highlighting vertical sectors with more active/mature experimentation activities, and vice versa.
(d) Use as a tool to further identify possible cross-project collaboration, define interventions (e.g., emphasis on certain verticals) and inform future research agendas.
(e) Need to provide analysis and insights on the 5G PPP project trial and piloting activities that could feed into program-level presentations and reports (e.g., the Pan-EU Trials Roadmap described previously in this Section).

From the time of inception to the time of this report, the verticals cartography activity has been driven by the Global5G.org project within the 5G PPP TB.

3 Development of the Blueprint

The 5G PPP Phase 2 and Phase 3 projects are use case driven, in the sense that the projects define a set of vertical use cases that will leverage the 5G technologies developed in those (or previous) projects. A typical 5G PPP project would have 2-5 use cases each, with corresponding experimentation activities, which results in a significant number of experimentation activities at 5G PPP program level (within and across Phase 2, Phase 3, etc.). As noted previously, the vertical cartography aims to capture information that allows observation of the vertical use-case experimentation across projects, providing useful insights in terms of the maturity of experiments, types of verticals addressed, stakeholder involvement and so on. The primary tool for gathering this information is the Excel-based verticals cartography blueprint. In the following section, the different fields of the Excel blueprint and their significance are described.

3.1 Verticals cartography data fields

3.1.1 Project name (acronym)

The projects are uniquely identified in the cartography using their official acronyms. The long names (full project names) are not utilised for sake of convenience.

3.1.2 Use case name and short description

Each use case addressed by a project is described both by a short phrase (as used within the respective project deliverables), and a brief (1-2 paragraphs) description of what is targeted.

3.1.3 Verticals clustering/categories

The classification or clustering of vertical industries has recently been harmonised at the 5G PPP program-level. Previously, there have been inconsistencies in the vertical clustering from differing 5G PPP projects, WGs and so on. The clustering adopted in the verticals cartography is based on this harmonised clustering, which is itself derived partially from the 5G PPP Phase 3 Pre-Structuring Model [5GIA2017]. The eight vertical clusters (and sub-clusters or examples in each) produced are shown in Table 1. Each use-case experiment in the verticals cartography is mapped to at least one vertical cluster. In addition to clusters listed below, supplementary cluster categories have been created to cater for use cases which do not have direct mapping to existing clusters. This includes satellite/non-terrestrial networks for verticals and use cases not tied to specific verticals (e.g., rural connectivity).

Vertical Cluster (Category)	What is included in each cluster?
1. Automotive	• Connected car – V2X • Autonomous driving • Remote assisted driving • Telematics
2. Industry	• Manufacturing & Automation • Factory & process automation (incl. remote controlling of digital factories) • In-factory tracking of goods and resources • Agriculture & farming technologies • Aquaculture / Aquafarming

Vertical Cluster (Category)	What is included in each cluster?
	• Financial Services
3. Broadcasting and entertainment	• Broadcast services (B2C, B2B2C, Home production) • Immersive & integrated Media and Gaming • (Mass) Media production, generation and consumption • Fixed (Home and SOHO) services • Education
4. Health	• Smart health • Smart pharmaceuticals • Medical emergency management • Hospital administration • Telemedicine
5. Public Safety	• Emergency communication • Daily first response • Rapid disaster response • Public event management • Critical assets protection and surveillance • Border protection and remote area coverage
6. Energy	• (Residential/industry) energy management and provisioning • Energy Distribution • Energy Management • Electric vehicles smart charging
7. Smart Cities	• Public administration • Tourism • Assisted living • People mobility • Smart Building • Infrastructure-to-everything connectivity (traffic lights, sensors etc.) • Education – Smart Campus
8. Transport and Logistics	• Rail, maritime and aviation • Efficient mobility of people and goods • Mobility as a Service • Smart Ports (including autonomous assets & Logistics and Safety) • Smart Roads • Smart Railways Tracks • Smart Airports

Table 1 5G PPP vertical clusters

3.1.4 Location of experiment (city, country)

This refers to the location in which the use-case experimentation activities are primarily located (in a lab environment, premises of a particular vertical, in public spaces, etc.). The location information in the verticals cartography is specified down to the city or town level.

3.1.5 Targeted date of experiment

The targeted date of the experiment refers to the time-period in which the experimental implementation of the use case will be available for demonstration. This date information is provided in the cartography to the nearest quarter of a particular year (e.g., Q1 2021 implies the experiment is carried out roughly within the months of January to March of year 2021).

3.1.6 5G ITU Functionality (IMT-2020 scenarios)

The International Telecommunications Union (ITU) set out the vision for 5G (in ITU-R Recommendation M.2083 [ITUR2015]) by defining requirements for International Mobile Telecommunications 2020 (IMT-2020) mobile systems, which support new capabilities beyond IMT-2000 and IMT-Advanced. These IMT-2020 systems provide improvements (in flexibility, security, reliability, etc.) for supporting diverse services in three functionality categories or usage scenarios, namely:

1. *Enhanced mobile broadband (eMBB)*: specified for use cases whose demands exceed existing Mobile Broadband applications in terms of improved performance and an increasingly seamless user experience.
2. *Ultra-reliable and low-latency communications (URLLC)*: specified for use cases with stringent requirements for capabilities such as throughput, latency and availability.
3. *Massive machine type communications (mMTC)*: for use cases characterised by a very large number of connected devices typically transmitting a relatively low volume of delay-tolerant data.

Figure 3 provides an illustration of the exemplary services or use cases and required capabilities across the three categories. In the verticals cartography, each use case is mapped to one or more of the aforementioned 5G ITU functionality categories.

(Source: [3GPP2015])

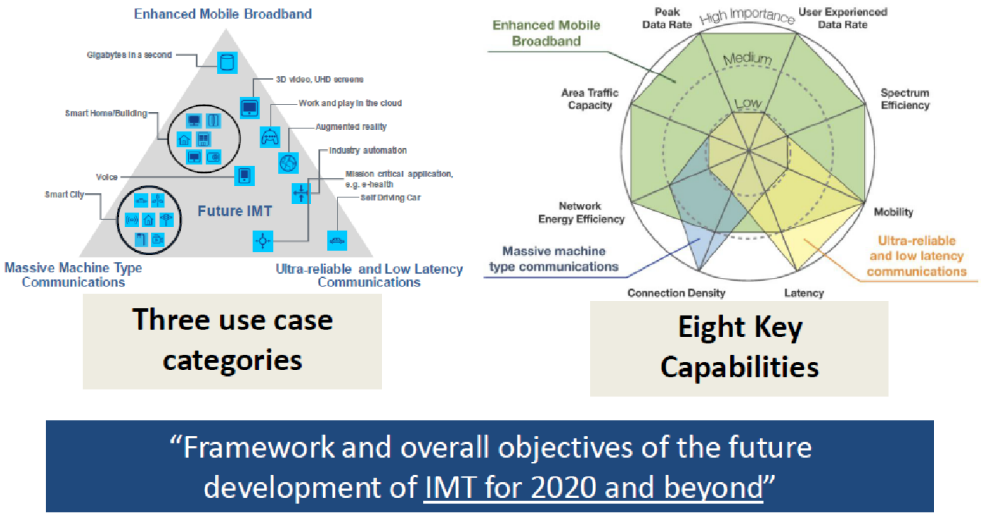


Figure 3 Three 5G ITU functionality categories and corresponding capability requirements

3.1.7 Type of experiment

The use-case experiments are classified in terms of maturity. To that end, the vertical cartography uses a classification specified within 5G PPP based on six levels of maturity from proof-of-concepts (least mature) to commercial products (most mature). These types of experiments are described briefly in **Errore. L'origine riferimento non è stata trovata.** (in ascending order of maturity). Each use case experiment in the verticals cartography is mapped to one type of experiment at any particular time. If maturity of the experiment evolves over time, it may be mapped to two or more types of experiments over the duration of the project. For example, a particular use-case experiment might be a prototype in Q3 2020, a demonstration in Q1 2021 and a trial in Q4 2021.

Type of Experiment	Description
1. Proof-of-Concept (PoC)	Lowest level of maturity where a "theoretical" concept is implemented to prove that a concept has merits
2. Prototype	Second level where the proved concept is embedded functionality in a component or system
3. Demonstration	Level where a system is complete from a certain perspective and is able to showcase a scenario or use case
4. Trial	Level where we conduct activities (outside the lab) that aim to verify the functionality of a system or parts of it; that is, when the correct functionality is still the primary interest
5. Pilot	The execution of a trial including business relationship assumptions, exemplifying a contemplated added value for the end-user of a product
6. Commercial Product	Commercial system or technology available for consumers

Table 2 Adopted classification of experiments (by maturity)

3.1.8 Verticals involved (in the experiments)

The use-case experimentation activities may preferably have some level of involvement from stakeholders from the vertical cluster to which the use case belongs. For instance, pilot activity for a use case in the health vertical cluster may be carried out together with a hospital. These stakeholders are typically vertical entities that may be involved as partners in the project consortium, Associate Partners or through other forms of external partnership that are agreed per project. Therefore, the use-case experiment appearing in the verticals cartography also includes names of the vertical partners involved in the experiment. Otherwise, the field is left blank in the case that no verticals are involved.

3.2 Data gathering approach

The information fed into the verticals cartography blueprint is directly provided by each individual Phase 2 and Phase 3 project. In practice this is done via interactions between Global5G.org project

representatives and the projects' Technical Managers or Technical Manager Deputies present in the 5G PPP TB. Historically, the information gathered was initially compiled in tables in a Word file, but a decision was later made to use Excel blueprints that provided more efficient handling of data collected as datasets grew in terms of both type and quantity.

The data gathering for the verticals cartography has been accompanied by an iterative process of data refinement and error checks before the data is utilised in the analysis of the cartography. Periodic update requests have also been triggered every 2-3 months to ensure that the cartography remains current with any changes in the plans of individual projects (e.g., change of time or location of use-case trials). The overall workflow for the gathering, correcting and updating of the data in the verticals cartography is shown in Figure 4.

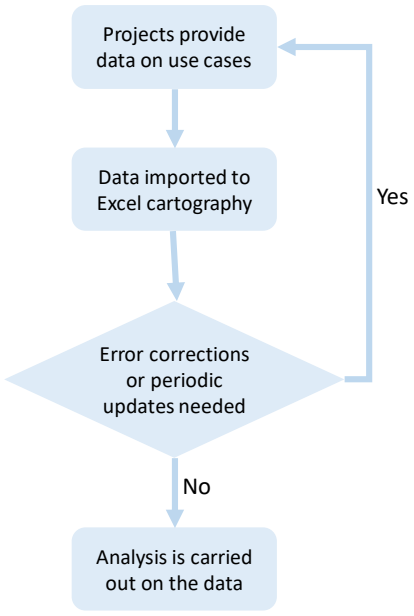


Figure 4 Workflow data gathering for the verticals cartography

4 Portfolio Analysis for Phase 3 Projects

4.1 Overview of Phase 3 Projects

As noted previously, the 5G PPP Phase 3 projects are implemented in a number of parts or instalments with some time overlap (unlike Phase 1 and Phase 2 projects, which had mostly synchronised start time). To that end, the Phase 3 projects fall roughly into these four main parts:

- **5G PPP Phase 3 Part 1 projects**: This includes 3 projects (5G-VINNI, 5G EVE and 5GENESIS) that were funded in response to the ICT-17-2018 call. These projects kicked off in 2018 and will run for 3 years to implement and test advanced 5G infrastructures (end-to-end 5G open test platforms) in multiple European countries.
- **5G PPP Phase 3 Part 2 projects**: This includes 3 projects (5G-MOBIX, 5GCroCo and 5GCARMEN) that were funded in response to the ICT-18-2018 call. These 3 projects kicked off in 2018 and will run for 3 years to implement and test 5G for connected and automated mobility (CAM) across different cross-border areas in Europe.
- **5G PPP Phase 3 Part 3 projects**: This includes 8 projects (5SOLUTIONS, 5G-TOURS, 5G!Drones, 5GHEART, 5GGROWTH, 5Gsmart, 5GVICTORI and Full5G) that were funded in response to the ICT-19-2018 call. These eight projects kicked off mid-2019 and will also run for about three years, contributing towards the European 5G Vision of "5G empowering vertical industries" by bringing this vision closer to deployment (mostly leveraging the platforms provided by Phase 3 Part 1 (ICT-17-2018) projects.
- **5G PPP Phase 3 Part 4 projects**: This includes six projects (ARIADNE, 5GCLARITY, 5G Complete, INSPIRE-5GPlus, MonB5G, 5GZORRO) that were recently funded in response to the ICT-20-2019- call. Further 25-30 projects will be added in future funding calls in this part. The projects in this category are working towards a longer-term evolution of 5G (beyond 5G).

As noted earlier the selection of projects and compilation of use cases is based on the verticals cartography for 5G PPP Phase 3 projects. Specifically, **the scope of this study is only on Phase 3 Part 1, 2 and 3 projects** (excluding Full5G, which is a Coordination and Support Action), whereas Part 4 projects will be onboarded in future versions of the cartography. A quantitative study is then done based on this cartography data to be able to visualise and highlight different experimentation coverage or gaps across different perspectives proposed above. The rest of this section outlines the approach and results for the portfolio analysis of the Phase 3 projects. Moreover, some comparisons are done between the analysis results in this report and those reported previously for Phase 2 projects (in deliverable D2.2). These findings will then form the basis of the summary observation or insights to be shared with stakeholders in and outside of the 5G PPP programme.

4.2 Main findings from portfolio analysis

Several definitions of *portfolio analysis* appear in strategic management depending on the area and

purpose. Portfolio analysis and management for research programmes is a mean for assessing the contributions and complementarities of projects within the programme, aiming at achieving a common goal [Landree2009]. This differs from assessment of individual projects typically conducted independently using each project's own unique set of goals.

In this section, we analyse the portfolio of over 120 unique use-case experiments carried out by different 5G PPP Phase 3 projects (these use cases are listed in the Appendix of Section 7). To that end, we opt for a custom methodology for portfolio analysis that takes into account:

- The specific nature of the 5G PPP programme and collaborations therein.
- The possible segmentation of use-case experimentation activities (e.g., by vertical cluster).
- The leveraging of the verticals cartography as a primary input to the analysis.

The overall workflow for the portfolio analysis is depicted in Figure 5.

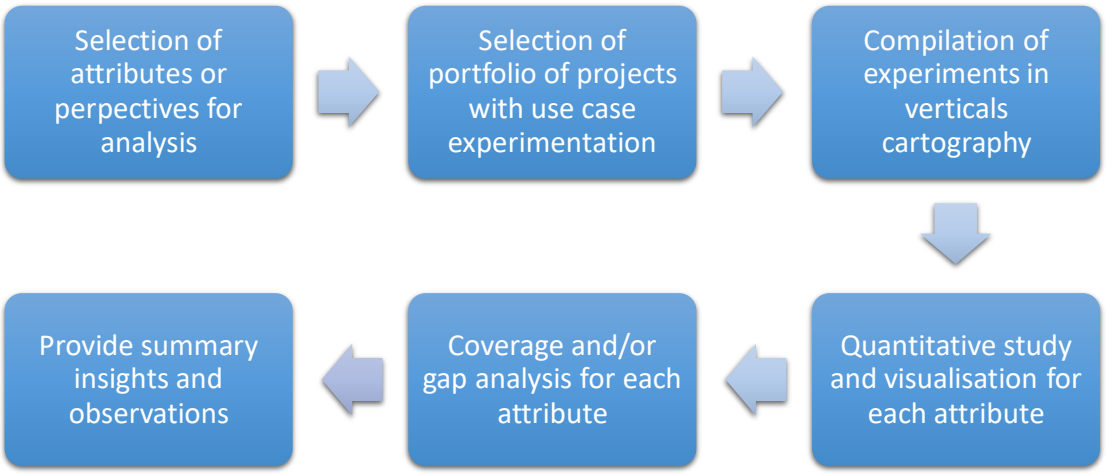


Figure 5 Overall workflow for portfolio analysis

This initial part of the workflow is the selection of the attributes or perspectives to be considered in the analysis. These include analyses from the perspectives of vertical clusters, 5G ITU functionality, the type (maturity) of the experiments and geography distribution or location of the experiments. Furthermore, in the analyses, each of these perspectives is further disaggregated by vertical clusters. In the case of maturity of the experiments, for simplicity, the experiment types are placed in two categories:

- Use-case experiments carried out in controlled or lab-based environments. This category includes experiments classified as prototype, PoC and demonstration (Levels 1 to 3) in the maturity classification of **Errore. L'origine riferimento non è stata trovata.**.
- Use-case experiments carried out outside the lab environment– whereby there is no more control over certain environmental conditions. This category includes experiments classified as trial and pilot (Levels 4 and 5) in maturity classification of **Errore. L'origine riferimento non è stata trovata.**. This category is of particular interest as it represents the early point of interaction with the intended customers and provides insights on the conditions the customer

is able and prepared to derive value from the developed solution. As the focus is on outputs of research and innovation activities of the project, the highest level of maturity (Level 6, commercial product) is not considered.

4.2.1 Vertical cluster perspective

As noted previously, the analysis considers 120 unique use-case experiments from 13 5G PPP Phase 3 projects. Each of these use-case experiments is associated with at least one vertical cluster (see Figure 6), with seven of them being linked to two vertical clusters. For instance, the 'urban mobility flow management' use case by the 5G-EVE[3] project has a profile that fits both *smart cities* and *transport and Logistics*.

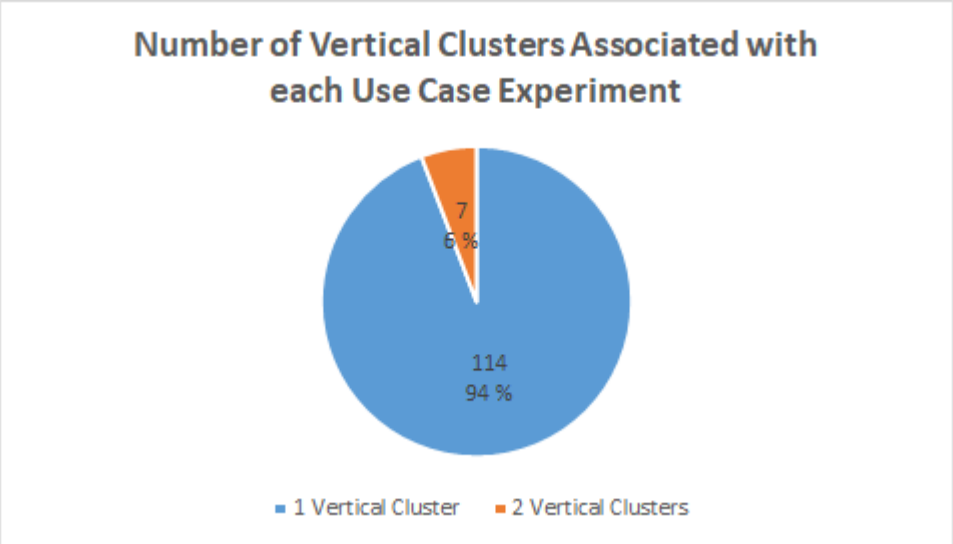


Figure 6 Vertical clusters associated with each use-case experiment (number or %)

A closer study of the mapping of the unique use-case experiments to different vertical clusters reveals that 80 out of 121 (i.e., 66%) of the experiments are targeting the following vertical clusters: *smart cities*, *transport and logistics*, *broadcasting, media and entertainment*, and *industry* (see Figure 7 and Figure 8). The new trend towards Industry 4.0 can be attributed to advancement in 3GPP specification of URLLC services. On the other hand, it is noted that the level of coverage for certain vertical clusters is still low, particularly for *energy*, *health*, and *public safety* vertical clusters, accounting for 8%, 20% and 10%, respectively, of all use-case experiments in the surveyed projects (see Figure 7 and Figure 8). The reasons behind lower coverage for these specific verticals can be attributed to several factors, such as domain criticality and stringent regulations that continue to slow down the interest in 5G in the respective industries.

[3] http://5g-eve.eu/.

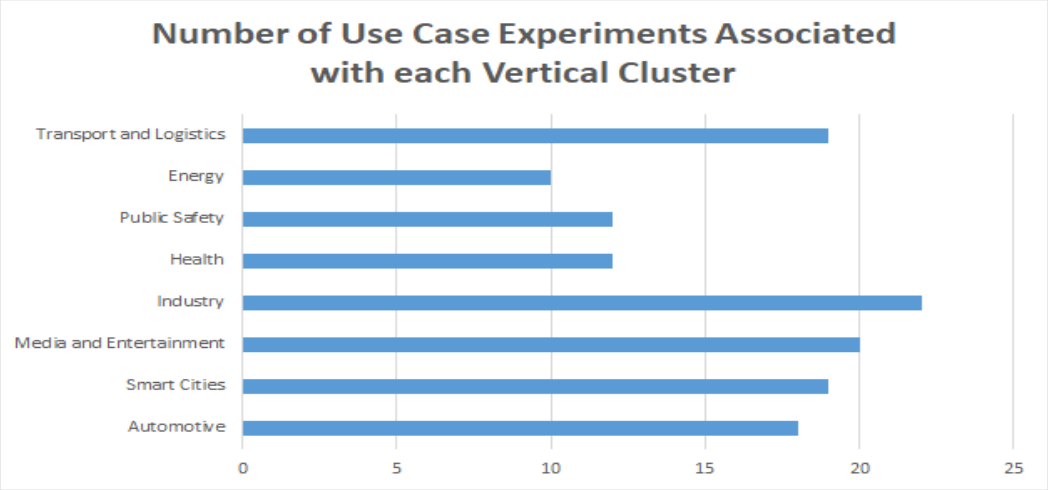


Figure 7 Number of use-case experiments associated with each vertical cluster

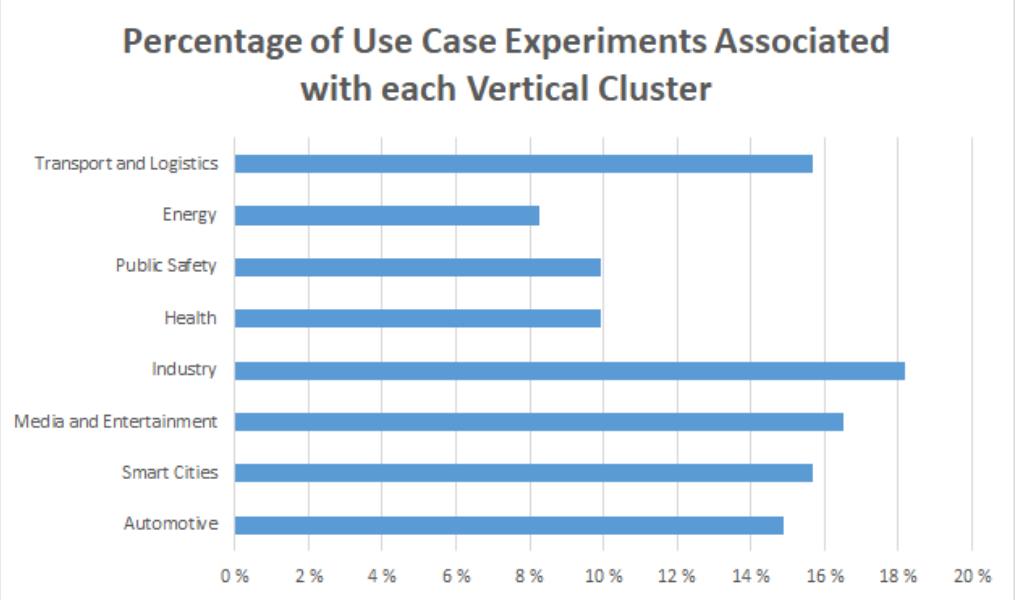


Figure 8 Fraction of use-case experiments associated with each vertical cluster

4.2.2 5G ITU functionality perspective

The analysis from the use-case experiments on 5G ITU functionality (see Figure 9) notes that 66% of the use cases involve two or three 5G ITU functionality categories (eMBB, mMTC, or URLLC). For instance, the *UAV-enhanced IoT data collection* use case of the 5G!Drones[4] project requires both mMTC and URLLC for reliable collection of IoT data using UAVs.

[4] https://5gdrones.eu/.

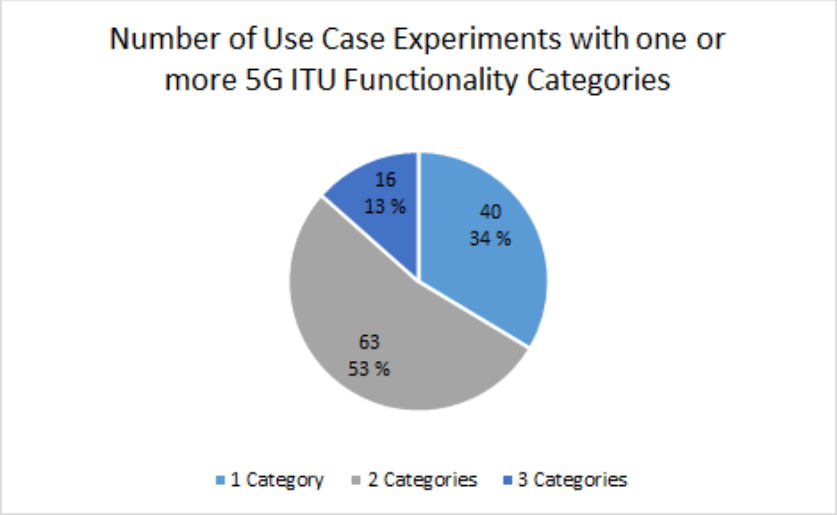


Figure 9 Number of use-case experiments with one or more 5G ITU Functionality

When the 5G ITU functionality categories are viewed separately (see Figure 10 and Figure 11), it is noted that eMBB is associated with most of the use-case experiments (73%) whilst URLLC capabilities are targeted in less than half of the use cases. This observation may be linked to the 3GPP standards timeline. The Phase 1 of 5G standards (Release 15) focused on rapid delivery to the market of networks with eMBB capability, initially through Non-Standalone (NSA) 5G NR mode and later with 5G NR Standalone (SA) mode [3GPP2017]. In the case of URLLC, the work on enhancements for URLLC in 5G Core Network (5GC) and 5G NR physical layer, as well as vertical-oriented enhanced V2X developments (which depend on URLLC) has been in 5G Phase 2 (3GPP Release 16) standards with the freeze date expected around mid-2020. Further work on standards enhancements (including URLLC, mMTC) for different vertical industries will continue in Release 17[5], which starts in early 2020. This release overlaps with the timelines of most of the 5G PPP Phase 3 projects, thus providing an opportunity for the projects to create some impacts in term of contributions to 3GPP within the Release 17 timeframe.

[5] https://www.3gpp.org/release-17.

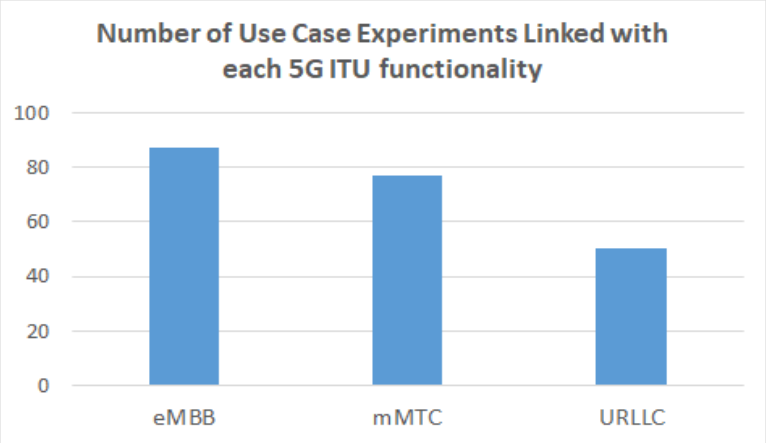


Figure 10 Number of use-case experiments linked with each 5G ITU functionality

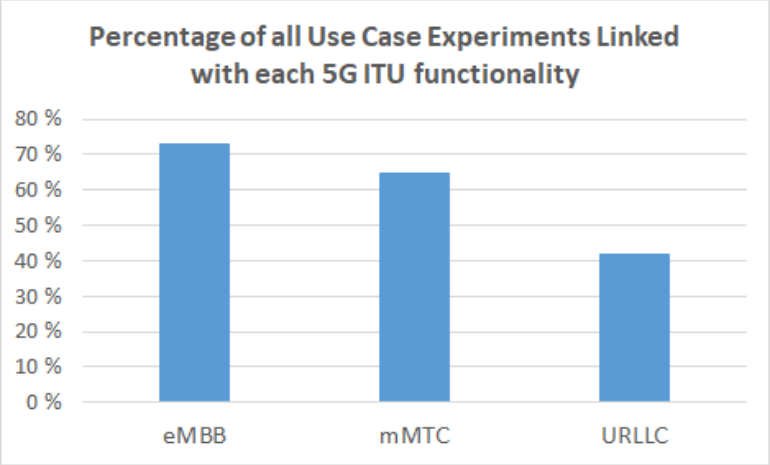


Figure 11 Percentage of all use-case experiments linked with each 5G ITU functionality

The 5G ITU functionality mapping to the use-case experiments when disaggregated by vertical cluster also presents some interesting observations as shown in Figure 12. Some of the more intuitive observations include the following:

- The three functionalities are almost equally considered in 5 vertical clusters, namely: *automotive*, *smart cities*, *industry*, *health*, and *transport and logistics*.
- eMBB features prominently in vertical clusters with use cases that are characterised by high user throughput requirements (e.g., broadcasting and *media*, and *public safety and digital divide*).
- With the same reasoning, URLLC capabilities are considered more in vertical clusters that are considering utilising 5G for mission- or business-critical automation services previously provided by wireline infrastructure (e.g., *energy*).

Figure 12 Share of all experiments in each vertical cluster targeting a specific 5G ITU functionality

4.2.3 Experiment type or maturity perspective

The analysis of use-case experiments from the maturity perspective is simplified by grouping them into only two categories (a 'less mature' category that includes experiments classified as prototypes, PoC and demonstrations; and a 'more mature' category that includes experiments classified as trials and pilots). Further simplification is obtained by displaying the experiments on a timescale with a yearly granularity. With these simplifications, the timeline of the use-case experiments for all vertical clusters is shown in Figure 13, whereby, the following is noted:

- The more mature trials and pilots are much higher in number than the less mature experiments. This is to be expected, as Phase 3 projects are leveraging experience gained and platforms developed in Phase I and Phase II projects. It could also be attributed to the availability of piloting partners.
- The total number of use-case experiments (226 experiments) in Figure 13 exceeds the number of unique use-case experiments (121 experiments) as listed in the Appendix of Section 7. This is due to the fact that some use-case experiments were carried out in multiple phases. For instance, the *Vehicles Platooning (see-what-i-see, L4 platooning)* use

case from the 5G-MOBIX[6] project has planned the use case implemented as demonstration and trial in two separate/progressive time periods.

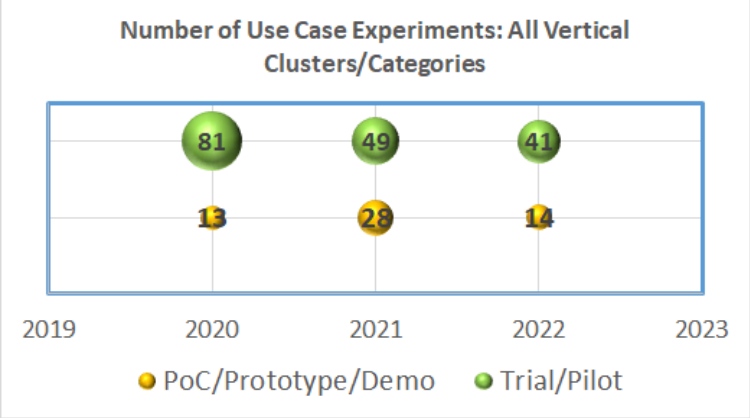


Figure 13 Aggregate number of use-case experiments for all vertical clusters 2020-2022

When the maturity perspective is disaggregated into different vertical clusters the differences in both number and maturity of the experiments is noted among the different clusters (see Figure 14). As noted previously, the number of *automotive*, *smart cities*, *media and entertainment*, *industry*, and *transport and logistics* vertical clusters account for the majority of experiments, whereas the *health*, *public safety* and *energy* clusters have the least coverage. Moreover, in all vertical clusters the number of mature trial and pilot experiments is higher than the less-mature type of experiments.

[6] http://www.5g-mobix.com/.

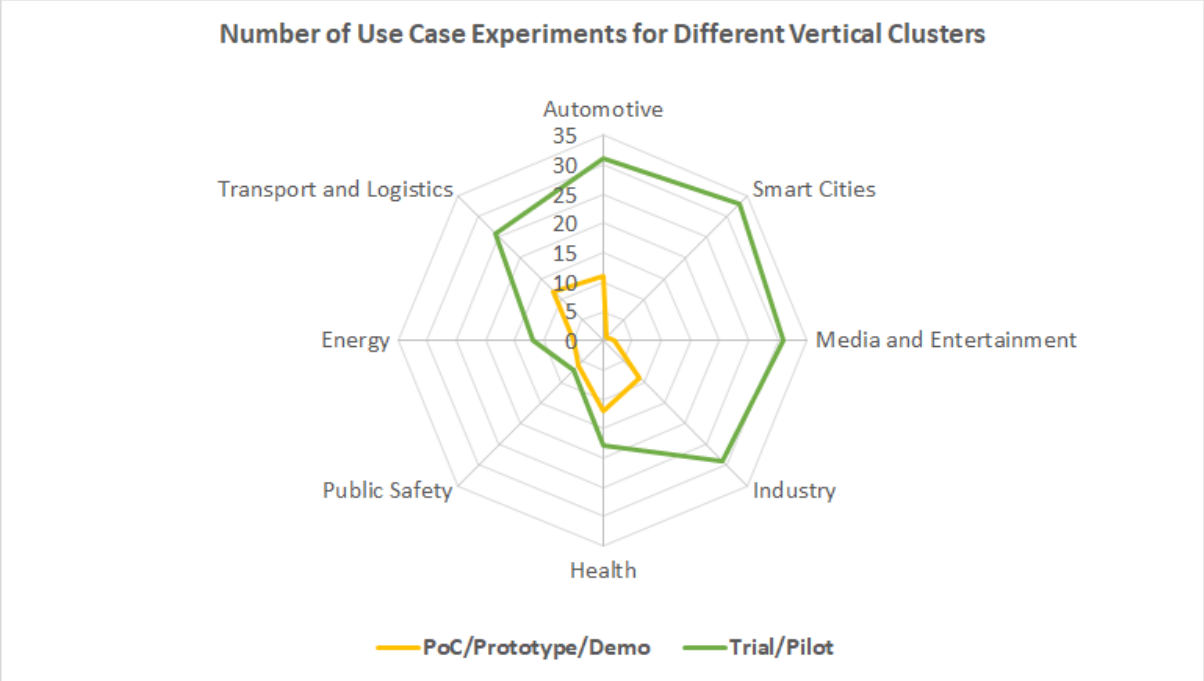


Figure 14 Number of use-case experiments disaggregated by vertical clusters

The timeline of the experimental maturity for different vertical clusters obtained by disaggregating Figure 13 further underlines the observations noted above (see Figure 15).

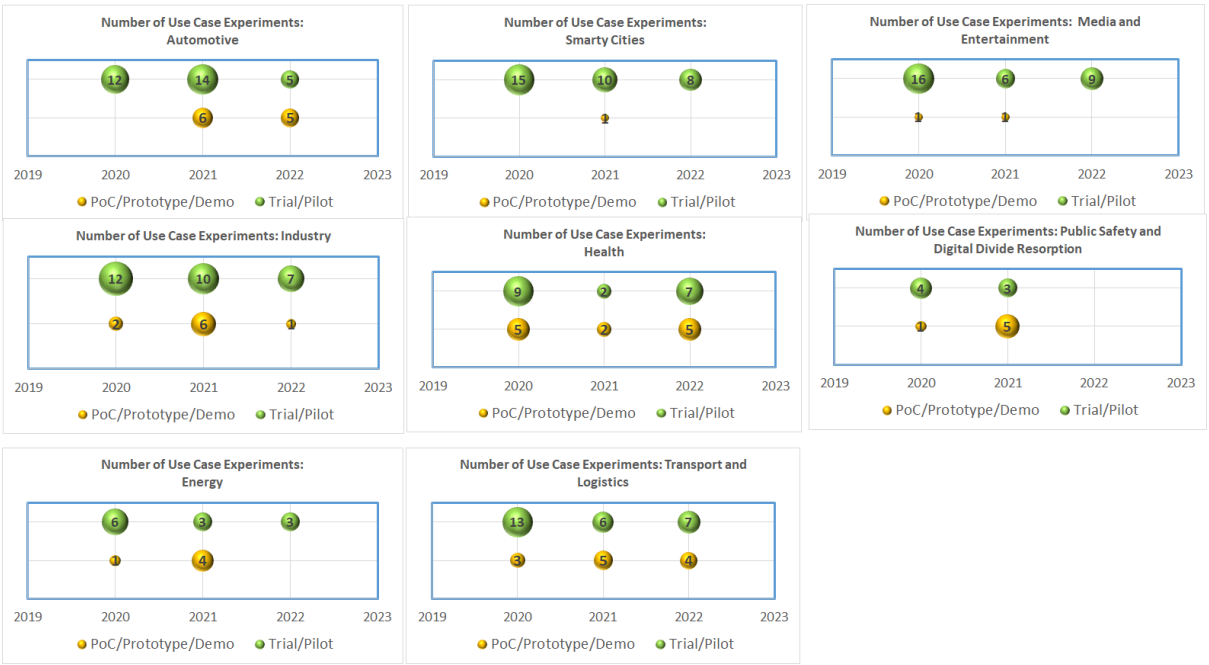


Figure 15 Number of use-case experiments disaggregated by vertical clusters 2020-2023

Alternatively, the maturity perspective can be observed by the 5G ITU functionality mapped to different

experiments (see Figure 16). It is interesting to note that while eMBB has (as expected) coverage in most mature use-case trial and pilot types of experiments, URLLC functionality also has over three quarters of use cases with more mature experimentation.

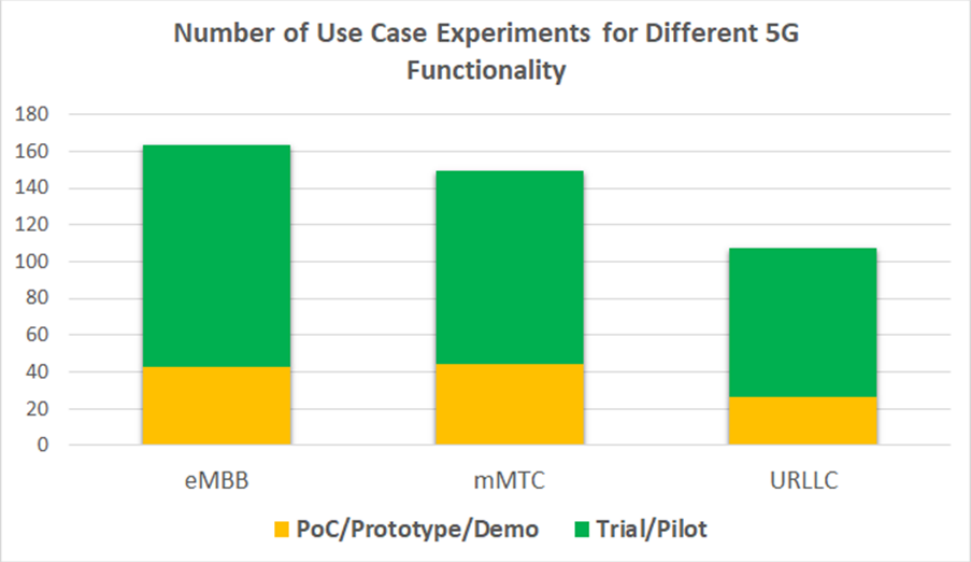


Figure 16 Number of use-case experiments targeting different 5G ITU functionalities

The above observation is even clearer when viewed on separate timelines for each 5G ITU functionality (see Figure 17), whereby it is noted that most use-case trials and pilots with URLLC functionality occur as early as in the year 2020.

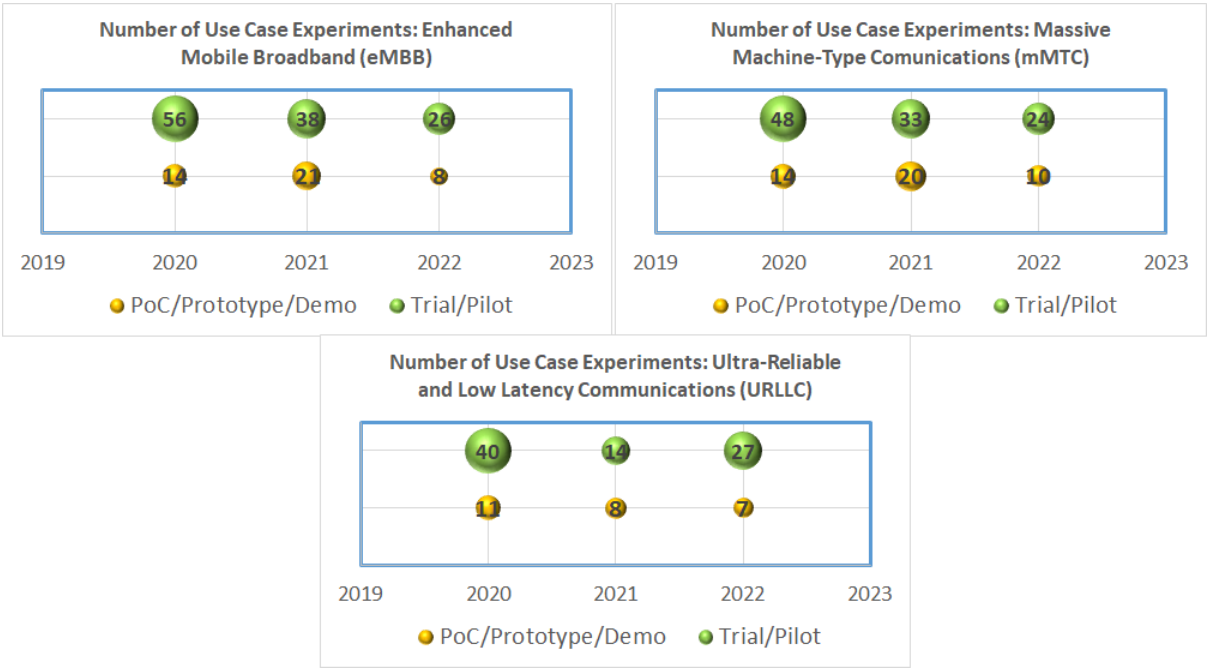


Figure 17 Number of use-case experiments disaggregated by 5G ITU functionality 2020-2023

4.2.4 Geographical perspective

The geographical perspective provides some insight on the distribution of the location of use-case experiments across the EU Member States or countries (see Figure 18). When viewed in terms of number of experiments, the majority (20 or more) of the use-case experiments are located in four countries: Greece, Italy, Spain and Norway. Another interesting note is the inclusion of non-European countries (China, South Korea and Turkey). These countries all happen to be part of the 5G-MOBIX project that is conducting experimentation on automotive use cases.

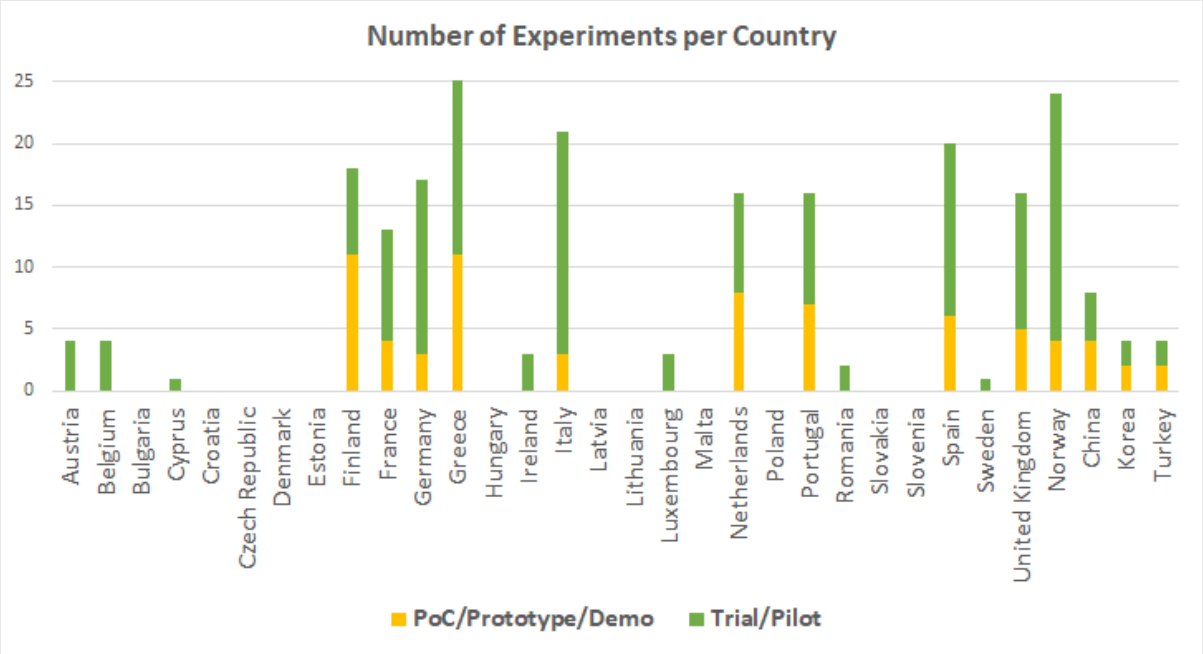


Figure 18 Number of use-case experiments per country

While there may be several reasons behind the geographical distribution observed in Figure 18, one key correlation is the location of experimentation facilities provided by the three ICT-17 projects 5G-EVE, 5G-VINNI and 5GENESIS (see **Errore. L'origine riferimento non è stata trovata.**). As noted previously in Section 4.1, these ICT-17 facilities provide platforms for experimentation by ICT-19 projects (some of these projects also contribute their own experimentation facilities in addition to those of ICT-17). From Figure 18, of the nine countries with the largest number of use-case experiments, seven of those countries (except for Finland and Netherlands) are hosting ICT-17 facilities.

Source: 5G PPP

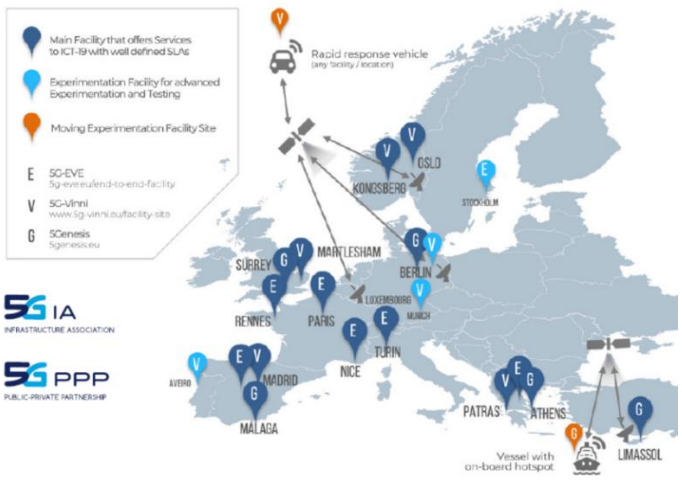


Figure 19 Location of ICT-17 experimentation facilities

4.2.5 Verticals participation perspective

4.2.5.1 Background and rationale

The development of 5G is use case-driven, whereby 5G provides flexible vertical-specific slice-based architectures over common physical infrastructure. To that end, the target is for a 5G platform that accommodates a multitude of use cases from different vertical clusters, each with unique contexts and requirements in terms of bandwidth, latency, reliability, security and so on. Therefore, the development of 5G solutions relies not only on traditional supply-side actors in the telecommunications ecosystem (e.g., network operators, system integrators, network software and equipment vendors, device vendors, chipmakers), but also on contributions from demand-side actors from various vertical industries [5GPPP2016]. This synergy facilitates the derivation of useful vertical-specific inputs in the processes of (but not limited to):

- Identification and development of use cases.
- Definition of requirements from both network and vertical domain perspectives.
- Specification of suitable KPIs.
- Further development of 5G technology standards to ensure 5G solutions better serve verticals.
- Co-innovation of new business models.

Use-case experimentation plays an essential role in all those aforementioned activities, as it provides the means for testing and validating 5G capabilities, jointly with the verticals (and preferably in their daily operational contexts). To that end, the analysis of verticals participation in use-case experiments in 5G PPP projects is a useful way to understand the extent to which these experimentation activities are shaped by inputs from verticals and hence able to provide tangible long-term impact (e.g. in terms of KPIs, standards etc.).

The overall workflow for analysing vertical participation also includes the level of vertical participation from multiple perspectives, vertical clusters targeted and type (maturity) of the experiments, as well as the *types* of vertical participation. This segmentation yields insights into the kind of vertical partners taking part in experiments of a particular vertical cluster or certain level of maturity. Moreover, it informs about the effectiveness of existing interventions (or highlights needs for new interventions) for encouraging vertical participation in use-case experimentation in 5G PPP projects. To that end, vertical participants are grouped into the three categories as in Table 3. The distinction between SMEs and large enterprises is based on EC Recommendation 2003/361 [EC2003], with thresholds based on staff headcount, turnover and/or balance total as parameters.

Type of Vertical Partner	Defining Characteristics
1. Small and Medium Enterprise	Private enterprise with staff headcount < 250 Turnover ≤ € 50 m or balance sheet total ≤ € 43 m
2. Large Enterprises (private sector)	Private enterprise with staff headcount ≥ 250 Turnover > € 50 m or balance sheet total > € 43 m
3. Government and Public Sector	Local government, government agencies, central government, public enterprises, public services etc.

Table 3 Classification of vertical participants in 5G PPP use-case experiments

The participation of SMEs from vertical industries has significant value in the development of 5G use cases, technologies and new business models due to the agility and flexibility of SMEs in this rapidly evolving technology and business landscape [5GPPP2016]. The importance of SMEs in this context has also been recognised in 5G PPP at the programme level, with a target of having SMEs constituting 20% of the participants in the 5G PPP projects [NetWorld2018].

On the other hand, participation of large enterprises from the private sector provides economies of scale and opportunities for large-scale adoption of 5G solutions in different vertical industries. Furthermore, trials and pilots conducted with these large enterprises are key in providing clarity of the 5G value proposition to those enterprises from non-telecom industries [5GPPP2018].

The use of 5G by government and public sector[7] verticals has the potential for creating many opportunities for delivery of public services at a lower cost. This is critical, as the public-sector accounts for over a quarter of total employment and significant portion of economic activity in EU Member States. Any efficiency and productivity gains would not only have impact on the public sector itself but also serve as a strong driver of private sector growth[8]. Furthermore, with Member States increasingly incorporating 5G targets into their national broadband plans (NBPs) in line with the 5G AP, there is an increased incentive for governments to lead by example in driving adoption of 5G in Europe. In any case, it is acknowledged that mature use-case experimentation is not feasible without involvement of the public sector in certain vertical clusters (e.g., *smart cities* and *public safety*) [5GPPP2018].

4.2.5.2 Overall level of participation

The analysis results of Figure 20 Number of verticals participating in each use-case experiment

show the level of participation of verticals in each use-case experiment. This is simply represented by the number of vertical partners involved in the use-case experiment. The intensity or impact of verticals participation is not necessarily proportional with the number of verticals participating in the use case; nonetheless, it is a useful indicator of the level of interest from diverse vertical actors. To that end, it is noted that over three quarters of use-case experiments have at least one vertical partner involved in their experimentation (see Figure 20 Number of verticals participating in each use-case experiment

). However, it should be noted that the current count of vertical participants is based on reports by projects in an early planning phase for the experiments. It is conceivable that the number of verticals participating may evolve, for instance with new verticals participating as piloting partners external to the project consortia.

[7] Public sector refers to those parts of the economy which are not controlled by individuals, voluntary organisations, or privately-owned companies. The public sector thus includes government at all levels, national and local; government-owned firms; and quasi-autonomous non-governmental organisations [Black2017].

[8] http://ec.europa.eu/growth/industry/innovation/policy/public-sector_en.

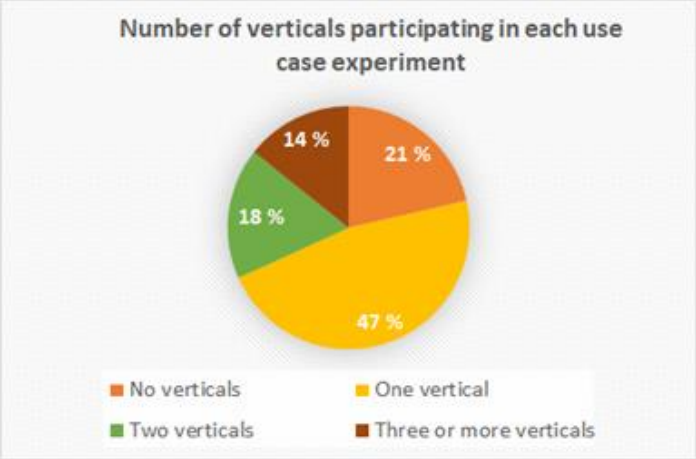


Figure 20 Number of verticals participating in each use-case experiment

Furthermore, it is noted that in use cases with verticals participation, the large enterprises from the private sector represent the greatest number of participants for the verticals types under consideration, followed by SMEs (see Figure 21 Number of use-case experiments with at least one vertical participant type

and Figure 22 Percentage of use-case experiments that involve at least one given vertical participant type

). This is indicative of the increased interest from the private sector to evaluate the potential value added to existing processes or entirely new opportunities enabled by 5G.

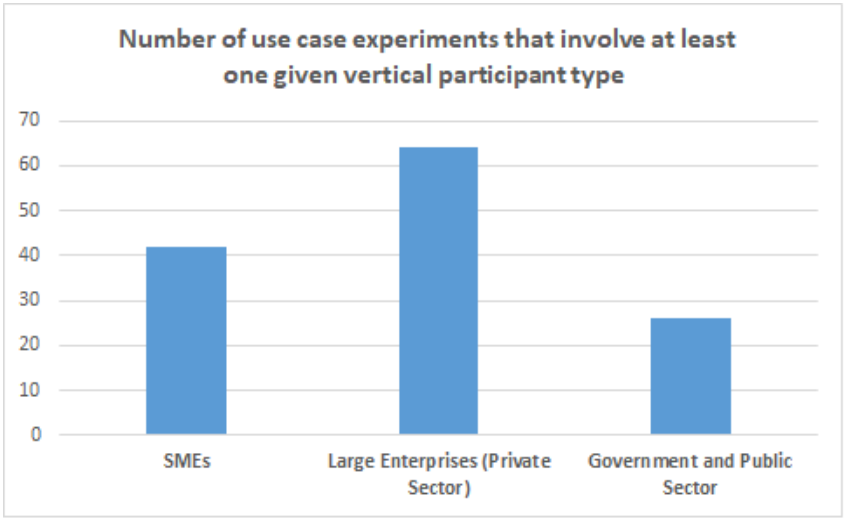


Figure 21 Number of use-case experiments with at least one vertical participant type

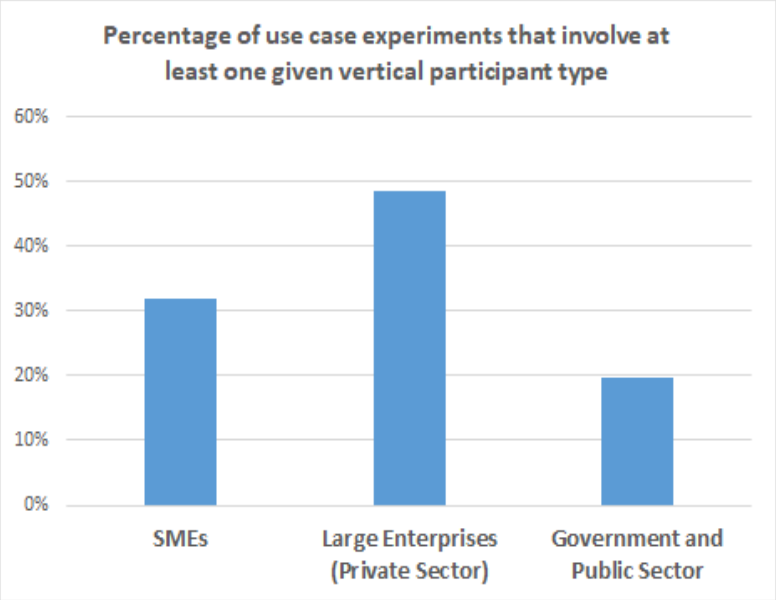


Figure 22 Percentage of use-case experiments that involve at least one given vertical participant type

4.2.5.3 Vertical cluster perspective

The participation of diverse verticals in use-case experiments provides further insights when disaggregated by vertical cluster (see Figure 23 Participation of diverse verticals in use-case experiments disaggregated by vertical cluster
). The following is noted:

- *Automotive cluster*: Majority of the participants are large enterprises, in this case automotive Original Equipment Manufacturers (OEMs), whereby the majority also figure prominently in the 5G Automotive Association (5GAA)[9]. The presence of government and public-sector verticals is notable, typically in the form of road network operators, traffic management agencies, and local governments, with their presence being essential in facilitating trials and pilots in real road environments.
- *Smart cities cluster*: Government and public-sector verticals provide the majority of the vertical participants in this cluster. This is to be expected since municipalities and local governments that manage towns, cities and other key urban infrastructure have been the most active drivers of smart cities initiatives.[10]
- *Broadcasting and Media cluster*: Private sector (SMEs and large enterprises) presence is dominant in this cluster, most likely driven by the new opportunities derived from 5G support of richer types of content (e.g., virtual reality).
- *Industry cluster*: Large enterprise verticals are the major participants, which is to be expected.

[9] http://5gaa.org/membership/our-members/.

[10] For instance, public authorities constitute a majority of the membership of the European innovation partnership on smart cities and communities https://ec.europa.eu/info/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en.

There are parallels with what is noted in the recently formed 5G Alliance for Connected Industries and Automation (5G-ACIA)[11], whose membership prominently features industrial automation players and industrial machine vendors.

- *Health cluster*: Government and public-sector verticals are the majority in this cluster, mostly attributed to public healthcare providers. The presence of SMEs is also noted, possibly driven by the transition to more decentralised patient-centric models which opens the field to smaller non-traditional healthcare solution providers [Global5G2017].
- *Public safety and digital divide resorption cluster*: the share of vertical types is more evenly distributed in this cluster. The verticals appearing here are mostly associated with 'public safety' rather than 'digital divide resorption' aspects. These include large enterprises and SMEs providing solutions for emergency responders and public-sector verticals who are responsible for providing emergency response services. This heterogeneous mix is more aligned with the views and outlook of industry alliances in this cluster. For instance, Public Safety Communications Europe (PSCE)[12] notes that *the process of Validation and Evaluation requires a co-creation process combining both technology developers and PPDR stakeholders* [Lund2018].
- *Energy cluster*: majority of the verticals in this cluster are large enterprises, which typically include the private utility companies, with noted absence of government and public-sector verticals. The observations are clearly linked to liberalisation trends[13] of the European energy sector that began with the first liberalisation directives in the mid-1990s.
- *Transport and logistics cluster*: this cluster has majority participation from large enterprise verticals and to some extent SMEs. This to be expected when considering the sectorial composition of transport operators, freight companies and operators of transport infrastructure (e.g., airports, ports, railways, etc.). The presence of SMEs is also noted for this cluster, likely inspired by the ongoing digital transformation and disruptions (e.g., autonomous driving) in the sector[14], which provide interesting opportunities for new smaller entrants to provide digital transport solutions (e.g., mobility-as-a-service).

[11] https://www.5g-acia.org/.
[12] https://www.psc-europe.eu/.
[13] https://ec.europa.eu/competition/sectors/energy/overview_en.html
[14] https://www.pwc.com/gx/en/industries/transportation-logistics/transport-tomorrow.html.

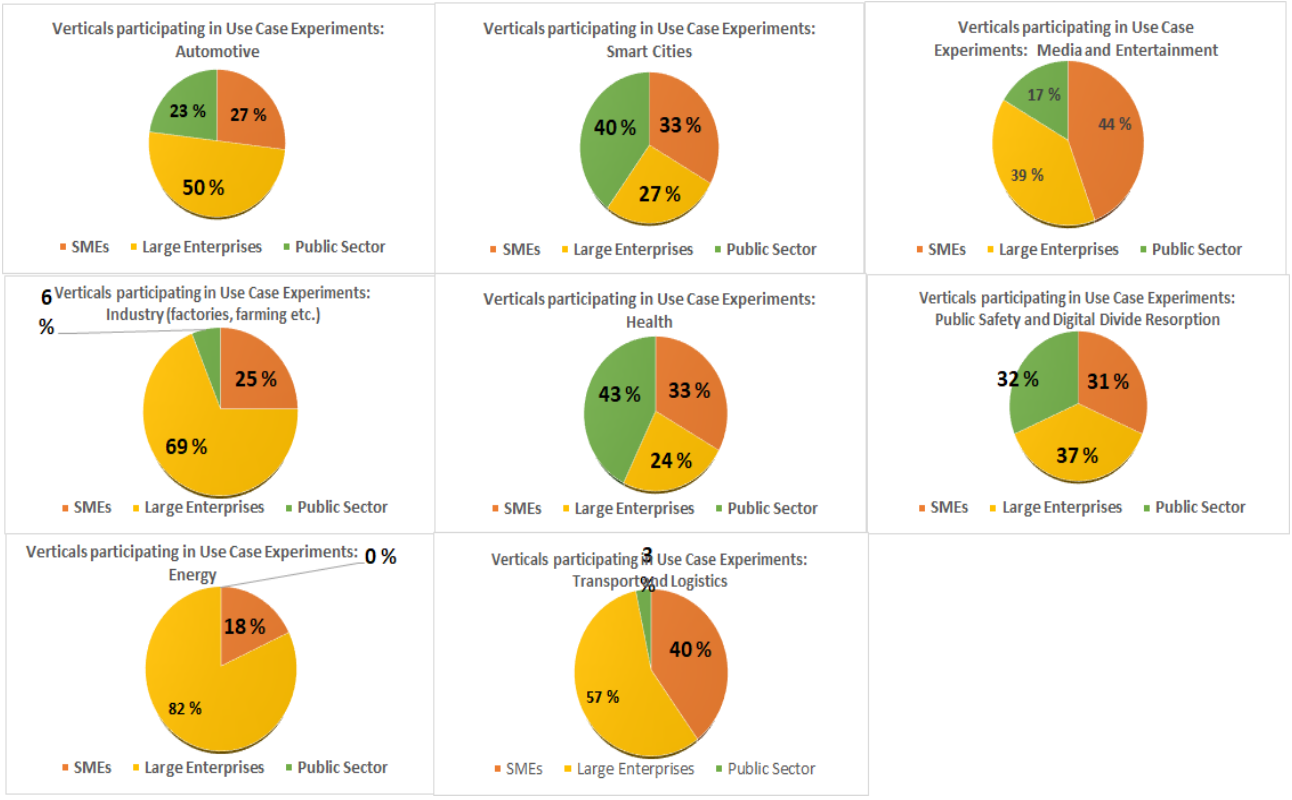


Figure 23 Participation of diverse verticals in use-case experiments disaggregated by vertical cluster

4.2.5.4 Experiment type or maturity perspective

The maturity perspective provides insights on the level of maturity of experiments conducted by different types of vertical participants in use-case experiments. To that end, it is noted in Figure 24 Type of verticals as a fraction of verticals with a PoC, prototype or demonstration

that SME verticals provide majority participation in less mature use case experiments (PoC, prototypes and demonstrations), which is more aligned with their traditional innovation processes. Typically, SMEs prefer to use R&I projects as opportunities for prototyping their solutions and market validation prior to any future scale-up activities[15].

[15] https://ec.europa.eu/programmes/horizon2020/en/h2020-section/sme-instrument.

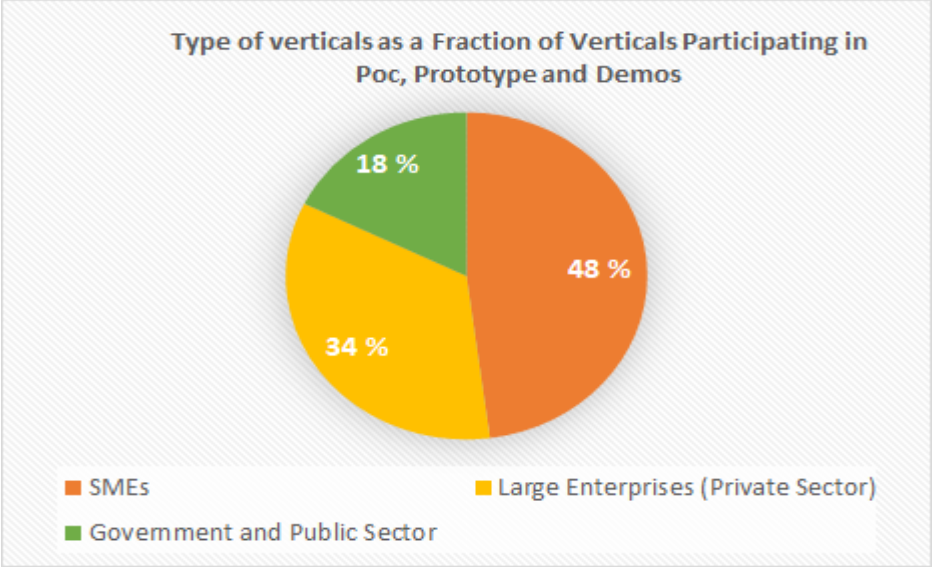


Figure 24 Type of verticals as a fraction of verticals with a PoC, prototype or demonstration

In contrast, more mature trial and pilot types of experiments are dominated by large enterprises (see Figure 25 Type of verticals as a fraction of verticals implementing a trial or pilot

). These enterprises are capable of providing facilities and operational expertise for conducting use case experiments in the real settings beyond the confines of the lab.

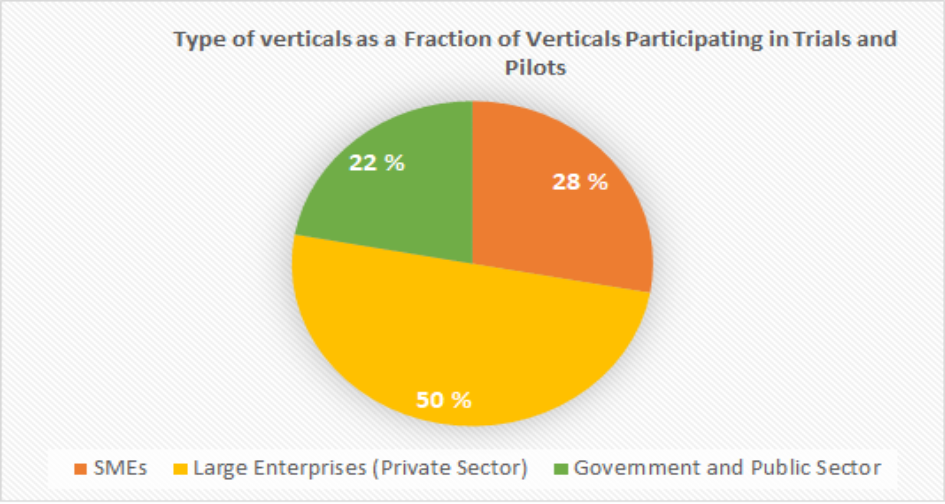


Figure 25 Type of verticals as a fraction of verticals implementing a trial or pilot

When use case experiments and their vertical participants are observed over project timelines (see Figure 26), it is noted that the participation of large enterprises and government and public-sector verticals occurs earlier in the project lifetimes (year 2020). This suggests presence of these entities from the early phases of experimentation, from transformation of use case specifications to initial experimental implementations.

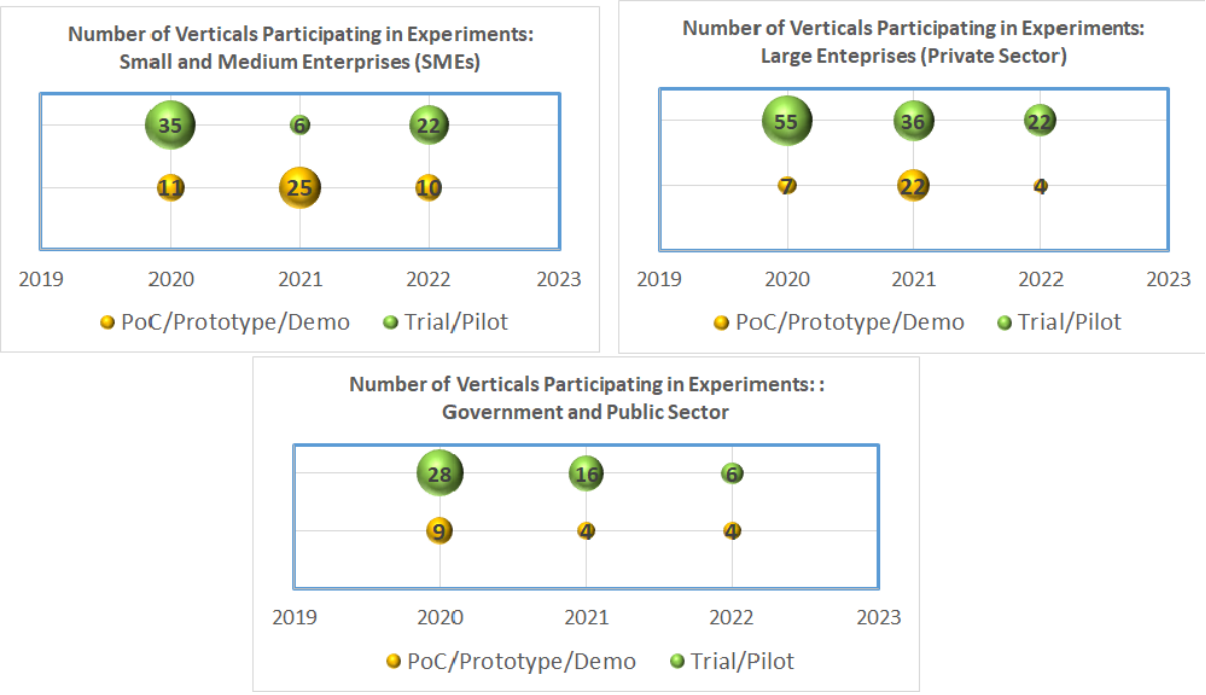


Figure 26 Number of verticals participating by type of participating vertical 2020-2022

4.3 Summary comparison of 5G PPP Phase 2 and Phase 3 projects

This subsection provides summary observations through comparisons and contrasts between results from portfolio analysis of Phase 2 projects (D2.2) and Phase 3 projects (in this report).

4.3.1 Vertical cluster perspective

An immediate contrast noted is that, on average, 5G PPP Phase 3 projects have more use case experiments compared to Phase 2 projects (almost twice as many use cases for a slightly lower number of projects). This is indeed consistent with the emphasis on verticals experimentation in Phase 3 project calls. In Figure 27, it is further noted that, whereas the *broadcasting, media and entertainment* cluster was clearly dominant in Phase 2 with much fewer use cases in other clusters, in Phase 3 the spread of use cases is relatively more even. A few exceptions involve clusters requiring further attention, including *public safety*, *health* and *energy*.

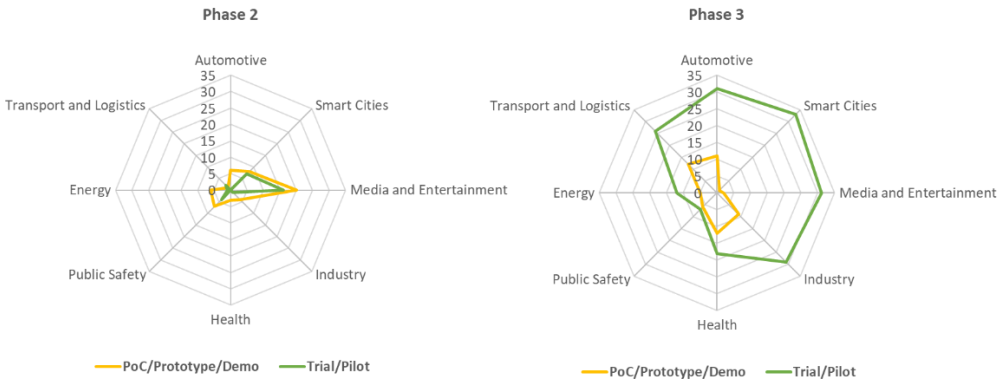


Figure 27 Number of use-case experiments disaggregated by vertical clusters (Phase 2 vs Phase 3)

Moreover, it may be noted in Figure 27 that the level of experimentation has generally matured from Phase 2 to Phase 3. For Phase 2 projects, less mature experimentation (PoC, prototype and demos) dominated in almost all clusters, whereas in Phase 3 projects the situation is reversed, with more mature trials and pilots being dominant in all vertical clusters.

4.3.2 5G ITU functionality perspective

The comparison according to the 5G ITU functionality perspective is provided in Figure 28. The main observation here is that eMBB functionality clearly dominated use cases for Phase 2 projects, whereas the distribution is more even in Phase 3 projects. When the distribution of functionalities is disaggregated by vertical clusters, it is interesting to note that mMTC is dominant for some clusters (*industry*, *energy* and *transport & logistics*). Some of this points to cluster-specific trends, for instance the prioritisation of Industrial IoT related use cases in the *industry* cluster.

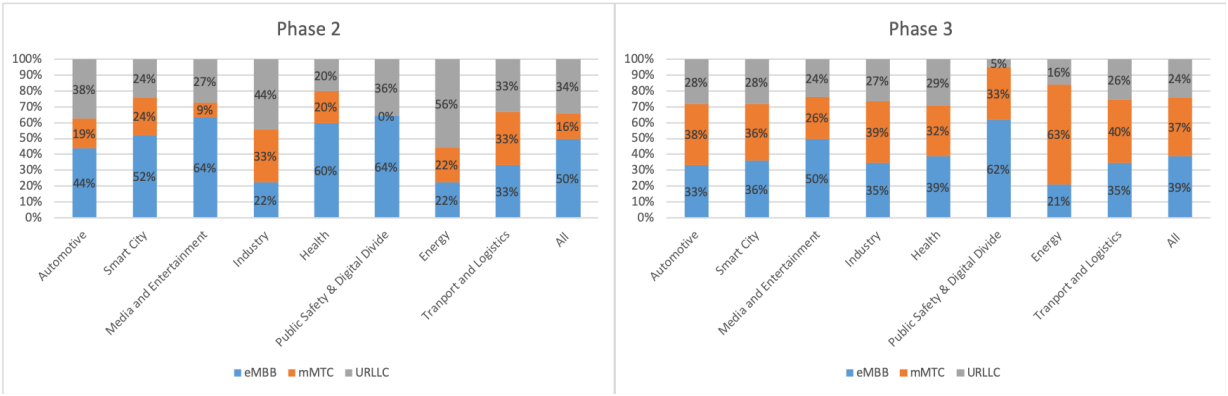


Figure 28 Share of all experiments in each vertical cluster targeting specific 5G ITU functionality (Phase 2 vs. Phase 3)

4.3.3 Geographical perspective

The comparison of the geographical spread of the use case experiments between Phase 2 and Phase 3 projects is provided in Figure 29. A number of contrast points are noted:

- As noted previously in Section 4.2.4, for Phase 3 projects there is the presence of ICT-17

experimentation facilities. However, it is also noted that some of the countries (e.g., Greece, Italy, Germany) were already providing experimental facilities for Phase 2 projects and likely contributed those facilities for ICT-17 projects.

- Significant increase in number of use case experiments is observed in some countries, notably, Finland, Norway and Portugal, the latter also being a country with some ICT-17 facilities.
- Experimentation activities for Phase 3 projects are also happening in some countries previously not hosting Phase 2 project experiments (e.g., Austria, Belgium, Sweden, etc.).
- In Phase 2 projects, use case experiments were conducted exclusively in Europe, whereas Phase 3 projects also include experiments outside Europe (China, South Korea and Turkey), as noted previously in Section 4.2.4.

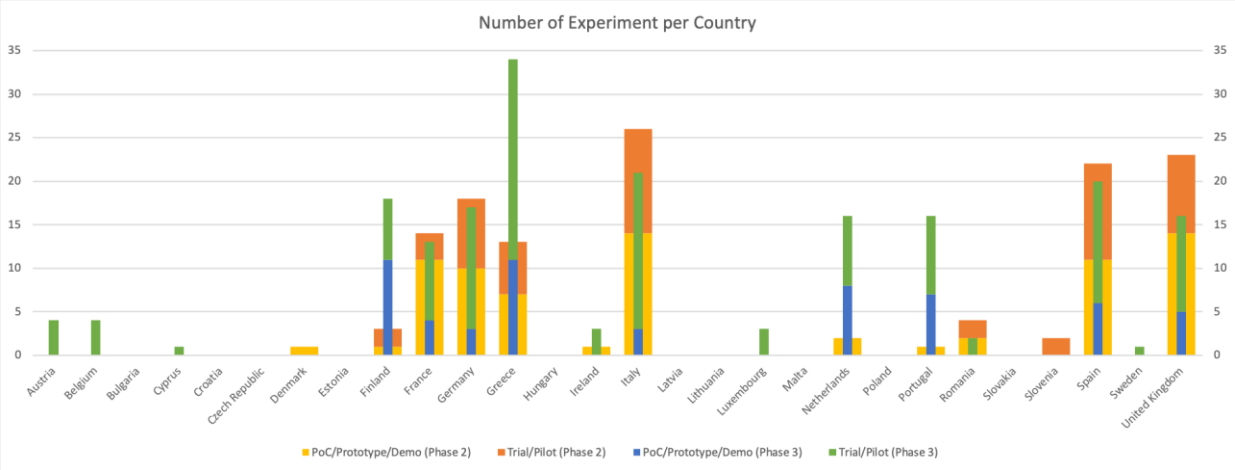


Figure 29 Number of use case experiments per EU country (Phase 2 vs. Phase 3)

4.3.4 Verticals participation perspective

The level of verticals participation in Phase 3 projects is generally higher compared to Phase 2 projects, whereby, 79% of use cases have at least one vertical participant in Phase 3 compared to 62% in Phase 2 projects (see Figure 30).

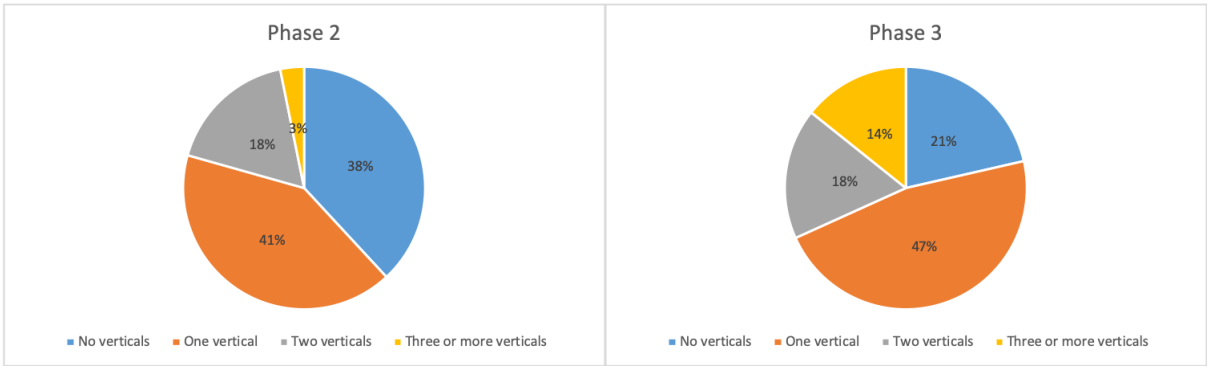


Figure 30 Verticals in each use case experiment (Phase 2 vs. Phase 3 projects)

When vertical participants are classified and vertical clusters disaggregated as in Figure 31, it is observed that government and public-sector partners were dominant in Phase 2 projects. In contrast, in Phase 3 projects they only constitute 19% of all vertical partners, pointing to increased participation of SMEs and large enterprises from the private sector. A similar trend is noted when observing contributions of different vertical partner types to more mature trial and pilot experiments (see Figure 32).

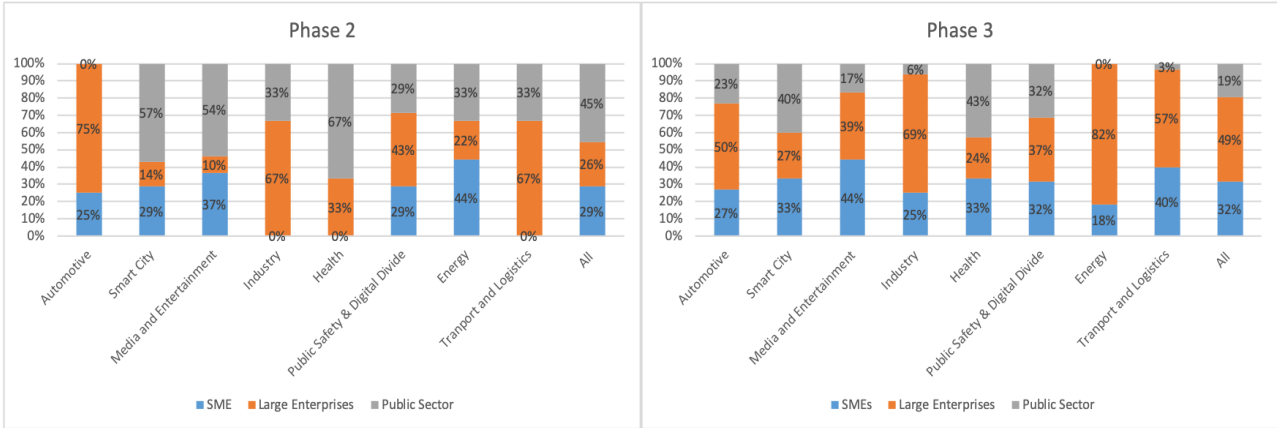


Figure 31 Vertical in use case experiments disaggregated by vertical cluster (Phase 2 vs Phase 3)

Figure 32 Type of verticals as a fraction of those implementing a trial or pilot (Phase 2 vs. Phase 3)

5 Impact and Sustainability

5.1 Online tool design

Work on Release V2.0 of the online tool started in mid-March 2019 with the aim of improving visualisation, the content and display of each use-case experiment. This work was completed in early April 2019. Here is a summary of the main activities on the further development and updates to the online tool between May and December 2019:

- **April-August 2019**: request to phase 2 projects for updates on results of use-case experiments. Creation of new icons and tags to capture examples of multiple verticals (e.g., smart cities – multiple verticals; smart cities – indoor spaces; satellite for verticals). Inclusion of all partner organisations in the consortium to help track the evolving ecosystem around vertical industries.
- **April-August 2019**: SMART campaigns on the main outcomes from the updates received, using a dedicated Twitter card and tracking impacts on Twitter and LinkedIn.
- **June-July 2019**: Participation in the Trials WG Competition Evaluation Committee to select the top ten trials and pilots in phase 2:
    - Definition of the criteria for selecting the top trials and pilots.
    - Creation of the evaluation template.
    - Creation of a brochure template (overview, architecture, deployment, result).
- **September 2019**: Participation in the Editorial Team for producing the 5G-PPP Brochure featuring the 10 selected use cases[16].
- **September-October 2019**: Adapting the brochure entries and updating the selected use cases.
- **October 2019**: Definition of a new blueprint and creation of new icons and taxonomies (verticals, countries) to capture the novelties of the ICT-17-18-19 projects.
- **November-December 2019 – Release V3.0**: Starting the integration of ICT-17-18-19 projects based on the inputs received through the Verticals Cartography Blueprint and with the aim of continuing the content-rich approach with each new update.

Figure 33 below shows examples of the new icons created to better capture specific use cases in phase 2 and phase 3 projects, such as smart cities – multiple verticals, satellite integration, smart cities – indoor spaces, rail, cross-border automotive, drones and public safety, smart tourism in cities, smart mobility in cities, as well as broadcasting and media better aligned with 3GPP standardisation work and mapping of common requirements (see D1.3 and D4.5 for more information).

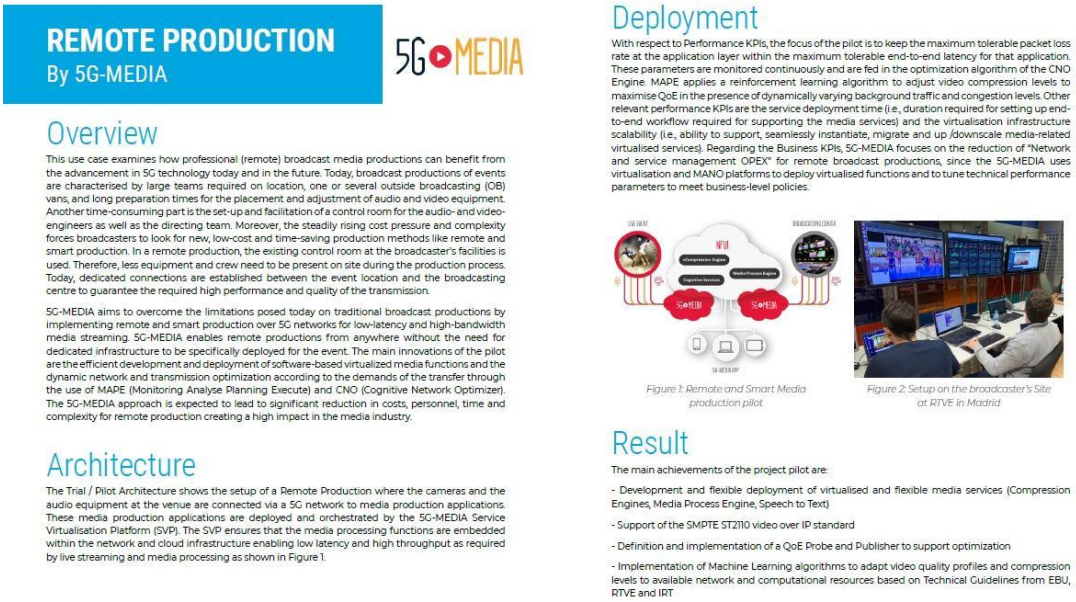
[16] https://5G PPP.eu/the-5G PPP-infrastructure-trials-and-pilots-brochure-is-out/.

Figure 33 Creation of new Icons for the Online Cartography

Figure 34 shows the brochure cover, contents and introduction, where the online tool is cited.

Figure 34 5G PPP Trial & Pilots Brochure

Figure 35 shows the example of 5G-MEDIA pilot on remote production using the Trials WG brochure template.



REMOTE PRODUCTION
By 5G-MEDIA

5G MEDIA

Overview

This use case examines how professional (remote) broadcast media productions can benefit from the advancement in 5G technology today and in the future. Today, broadcast productions of events are characterised by large teams required on location, one or several outside broadcasting (OB) vans, and long preparation times for the placement and adjustment of audio and video equipment. Another time-consuming part is the set-up and facilitation of a control room for the audio- and video-engineers as well as the directing team. Moreover, the steadily rising cost pressure and complexity forces broadcasters to look for new, low-cost and time-saving production methods like remote and smart production. In a remote production, the existing control room at the broadcaster's facilities is used. Therefore, less equipment and crew need to be present on site during the production process. Today, dedicated connections are established between the event location and the broadcasting centre to guarantee the required high performance and quality of the transmission.

5G-MEDIA aims to overcome the limitations posed today on traditional broadcast productions by implementing remote and smart production over 5G networks for low-latency and high-bandwidth media streaming. 5G-MEDIA enables remote productions from anywhere without the need for dedicated infrastructure to be specifically deployed for the event. The main innovations of the pilot are the efficient development and deployment of software-based virtualized media functions and the dynamic network and transmission optimization according to the demands of the transfer through the use of MAPE (Monitoring Analyse Planning Execute) and CNO (Cognitive Network Optimizer). The 5G-MEDIA approach is expected to lead to significant reduction in costs, personnel, time and complexity for remote production creating a high impact in the media industry.

Architecture

The Trial / Pilot Architecture shows the setup of a Remote Production where the cameras and the audio equipment at the venue are connected via a 5G network to media production applications. These media production applications are deployed and orchestrated by the 5G-MEDIA Service Virtualisation Platform (SVP). The SVP ensures that the media processing functions are embedded within the network and cloud infrastructure enabling low latency and high throughput as required by live streaming and media processing as shown in Figure 1.

Deployment

With respect to Performance KPIs, the focus of the pilot is to keep the maximum tolerable packet loss rate at the application layer within the maximum tolerable end-to-end latency for that application. These parameters are monitored continuously and are fed in the optimization algorithm of the CNO Engine. MAPE applies a reinforcement learning algorithm to adjust video compression levels to maximise QoE in the presence of dynamically varying background traffic and congestion levels. Other relevant performance KPIs are the service deployment time (i.e., duration required for setting up end-to-end workflow required for supporting the media services) and the virtualisation infrastructure scalability (i.e., ability to support, seamlessly instantiate, migrate and up /downscale media-related virtualised services). Regarding the Business KPIs, 5G-MEDIA focuses on the reduction of "Network and service management OPEX" for remote broadcast productions, since the 5G-MEDIA uses virtualisation and MANO platforms to deploy virtualised functions and to tune technical performance parameters to meet business-level policies.

Figure 1: Remote and Smart Media production pilot

Figure 2: Setup on the broadcaster's Site at RTVE in Madrid

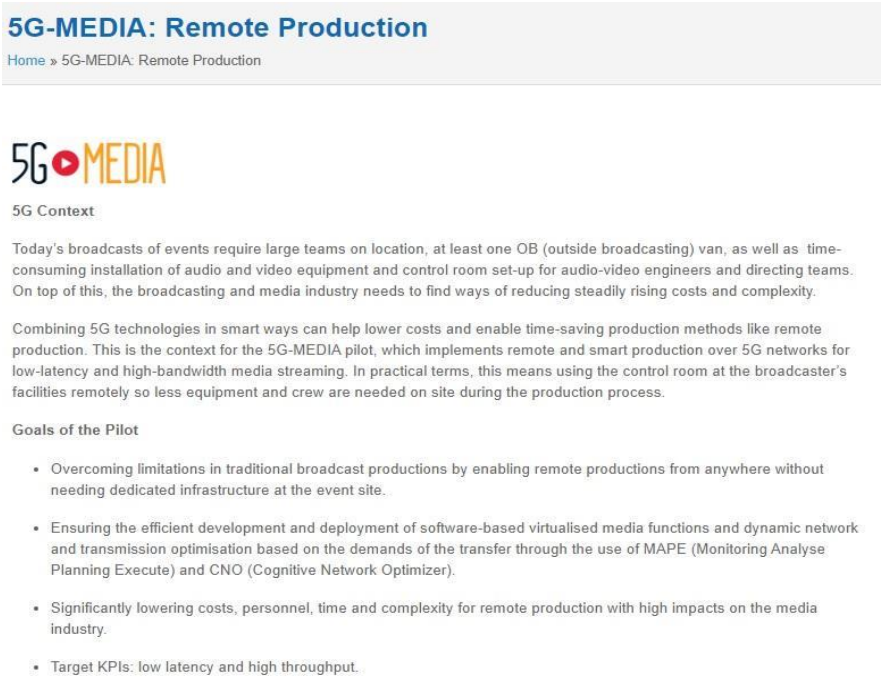
Result

The main achievements of the project pilot are:

- Development and flexible deployment of virtualised and flexible media services (Compression Engines, Media Process Engine, Speech to Text)
- Support of the SMPTE ST2110 video over IP standard
- Definition and implementation of a QoE Probe and Publisher to support optimization
- Implementation of Machine Learning algorithms to adapt video quality profiles and compression levels to available network and computational resources based on Technical Guidelines from EBU, RTVE and IRT

Figure 35 Brochure Section on 5G-MEDIA Pilot

This next figure is an example of how the brochure entries have been implemented online, with an introduction on the 5G context.



5G-MEDIA: Remote Production

Home » 5G-MEDIA: Remote Production

5G MEDIA

5G Context

Today's broadcasts of events require large teams on location, at least one OB (outside broadcasting) van, as well as time-consuming installation of audio and video equipment and control room set-up for audio-video engineers and directing teams. On top of this, the broadcasting and media industry needs to find ways of reducing steadily rising costs and complexity.

Combining 5G technologies in smart ways can help lower costs and enable time-saving production methods like remote production. This is the context for the 5G-MEDIA pilot, which implements remote and smart production over 5G networks for low-latency and high-bandwidth media streaming. In practical terms, this means using the control room at the broadcaster's facilities remotely so less equipment and crew are needed on site during the production process.

Goals of the Pilot

- Overcoming limitations in traditional broadcast productions by enabling remote productions from anywhere without needing dedicated infrastructure at the event site.
- Ensuring the efficient development and deployment of software-based virtualised media functions and dynamic network and transmission optimisation based on the demands of the transfer through the use of MAPE (Monitoring Analyse Planning Execute) and CNO (Cognitive Network Optimizer).
- Significantly lowering costs, personnel, time and complexity for remote production with high impacts on the media industry.
- Target KPIs: low latency and high throughput.

Figure 36 5G-MEDIA Remote Production

5.2 Impacts of the verticals cartography

Global5g.org has tracked the impacts of the online tool, with updates in April 2019 at the launch of Release v2.0, then at the end of June and monthly in Q4-2020 in view of the high numbers achieved. The graph below shows the impacts in terms of the views of the cartography entries over a period of nine months.

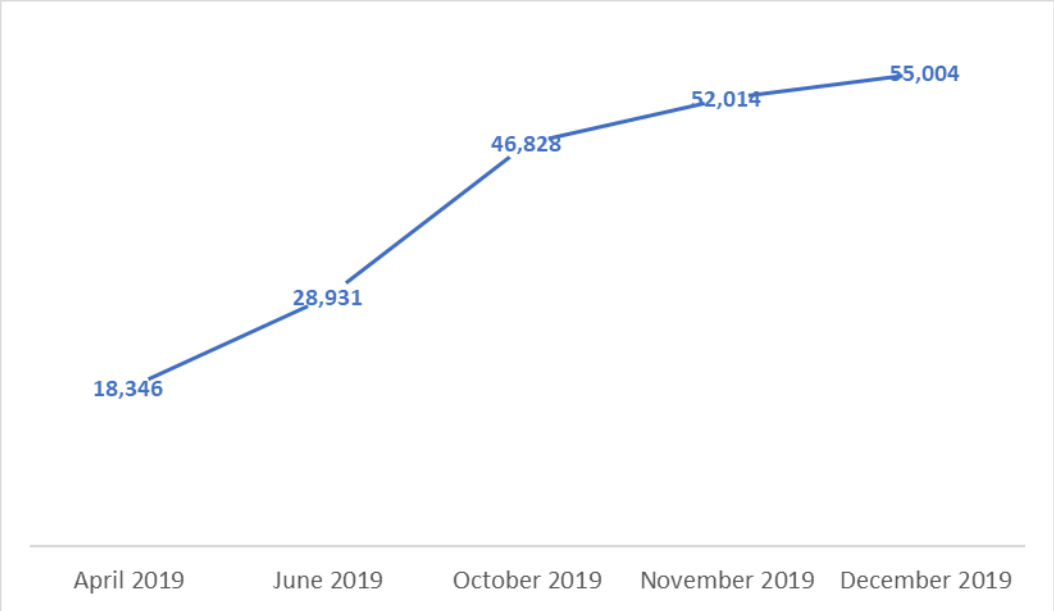


Figure 37 Impacts of the Online Tool Rel-V2.0

By April 2019, the tool had been viewed 18,346 times since its launch. By June 2019, this figure had jumped to 28,913, reflecting the importance of the improvements.

The period from July to December 2019 saw even bigger increases, due to continuous updates and especially the more detailed entries adapted from the 5G PPP Brochure, leaping to 46,828 in October and 55,006 in December.

Figure 38 below gives several examples of the impacts of the SMART campaigns where updates have been published beforehand. The impacts are from LinkedIn posts, showing the importance of this network for broadening reach to stakeholders. The top two posts are based on detailed updates received from the projects in Q2-2019. The bottom posts are examples of updates based on the Brochure entries.

Figure 38 Sample of Visibility on LinkedIn

5.3 Sustainability of verticals cartography beyond Global5G.org

5.3.1 FULL5G Work Plan

The sustainability of the online tool, analyses and impact assessments is ensured through FULL5G, where work will be taken forward by Trust-IT. These will be reported in contractual deliverables in August 2020 and August 2021. To this end, a schedule has already been fixed to collect updates from active Phase 2 and Phase 3 projects at specific points in their lifecycles. Explicit references are made in the work plan in pursuing a content-rich approach.

5.3.2 Proposed enhancements

Throughout this document, we describe a web-application platform that will help to insert and store the

needed details of ongoing and future projects, as well as to present the details of the stored project via different statistical methods and graphs.

5.3.2.1 The global architecture

As shown in the Figure 39, we suggest a client-server application with two types of interface-user profile. While the administrator would use one interface, the second interface would be used by the project-owner. In addition, the application would have one data-base that serves for storing different data.

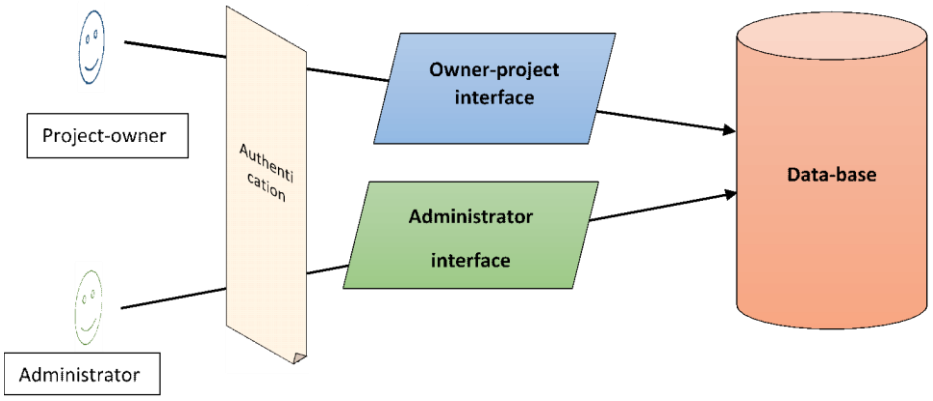


Figure 39 Web-application architecture

5.3.2.2 The partner profile interface

First, the project owner has to authenticate to the web-application using, for example, his email address. Then, as depicted in Figure 40, the project owner fills in all use case details and saves them in the database.

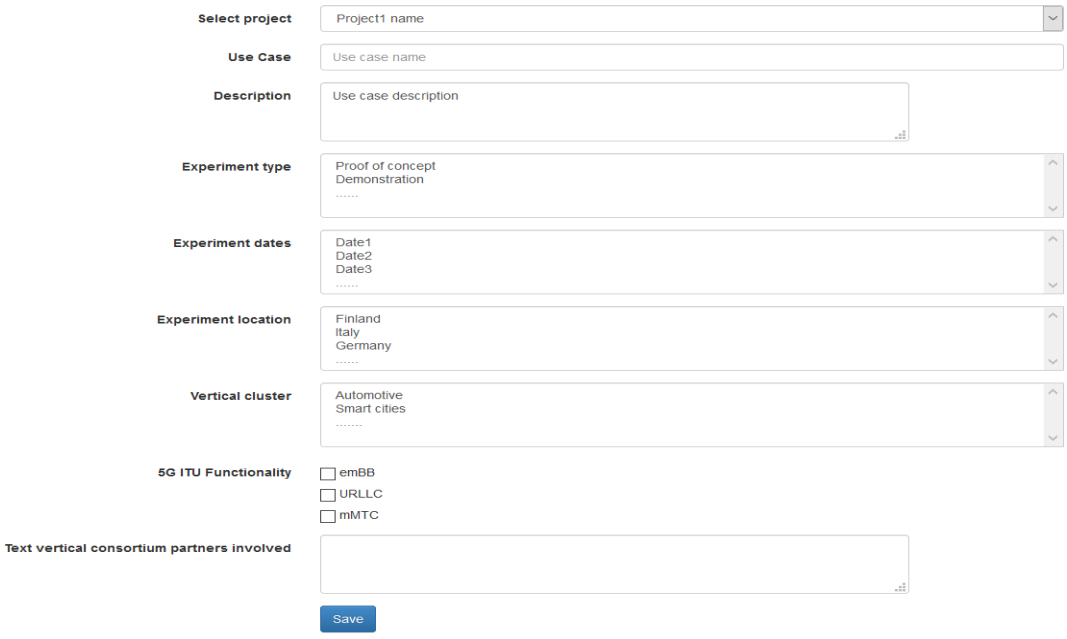


Figure 40 Interface for use case data providers (projects)

5.3.2.3 The administrator profile

The administrator interface should give to the user the ability to explore the stored data by providing:

- A list of statistic graphs to analyse data with a two-dimensional view.
- A three-dimensional data analysis based on the data warehouse cube.

5.3.3 Sustainability actions with Full5G project

The online tool is being sustained, extended and updated by Trust-IT through FULL5G. For this purpose, Global5G.org was migrated to FULL5G in early February 2020 ahead of the planned transfer in March (FULL5G, M7): https://global5g.5G PPP.eu/.

The full transfer means that all Global5G.org assets will live on in 5G PPP phase 3, and potentially beyond.

To ensure inputs and updates from projects happen in a timely manner, a schedule has been prepared (*See D4.5*) with clear timelines, for both active phase 2 and phase 3 projects. This schedule is shared with both the Technology Board and the Steering Board to alert technical managers and coordinators to the deadlines. Reminders are also part of the TB and SB calls and face-to-face meetings through liaison with the respective chairs.

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7 Appendix: 5G PPP Phase 3 Projects and their Use Cases

5G PPP Phase 3 Project	Use cases recorded in the verticals cartography
5G EVE	Media content in high-speed trains
	Urban mobility flow management
	Smart Turin: safety and environment
	Augmented reality for smart tourism
	Media, On-site Live Event Experience and Immersive and Integrated Media
	Autonomous vehicles in manufacturing environments
	Video 360° 5G - Virtual Tickets (On-demand)
	Video 360° 5G Immersive Experience (Live)
	Video 360° 5G virtual visit
	Fault management for distributed energy generation in Smart Grids
	Smart electricity management for power grid control
	5G-Connected AGVs
	Connected Ambulance
	Remote eHealth monitoring and forecast
5G-VINNI	Dedicated slice for Norwegian defense
	Autonomous edge
	Satellite backup for backhauling
	eHealth
	Aqua culture
	Media Production and distribution use cases
	Energy Metering for HV and LV
	Enhanced mobile broadband under high speed mobility in rail environments

5G PPP Phase 3 Project	Use cases recorded in the verticals cartography
	Digital Utilities
	360° immersive experience
	Sensor network for use in healthcare
	QoS Management for Media Broadcast
	360º immersive experience
	Safety critical communications for railway signalling systems
	Critical signal and data exchange for smart grids
	UAV multiuser remote control and operation (indoor i.e., factory)
	UAV multiuser remote control and operation (Outdoor)
	Efficient edge content delivery via satellite multicast/broadcast
	eMBB and IoT use cases using satellite backhauling (Smart Villages & Rural Areas)
	PPDR use cases using resilient satellite backhauling
	Autonomous Edge on-board Satellite connected vehicle
5Genesis	3GPP MCS & Video for surveillance
	Festival of Lights
	Large-scale public event
	“5G hotspots” on passenger and cargo ships
	Sport event
5G CARMEN	Cooperative Manoeuvring
	Situation Awareness
	Video Streaming
	Green Driving
5GCroCo	Tele-operated Driving (ToD)
	HD maps for enabling autonomous driving

5G PPP Phase 3 Project	Use cases recorded in the verticals cartography
	Anticipated Cooperative Collision Avoidance
5GMOBIX	Advanced Driving (lane merge, overtaking, collision avoidance
	Vehicles Platooning (see-what-i-see, L4 platooning)
	Extended sensors (assisted border crossing, cooperative perception / HD maps)
	Remote Driving (automated shuttle, tele-operation, remote manoeuvre)
	Vehicle QoS support (public transport scenarios, tethering via vehicle)
5G!Drones	UAS Traffic Management (UTM) command and control application
	3D Map and supporting visualisation/analysis software for UTM
	UAV logistics
	Secure UTM communications
	Monitoring a wildfire
	Disaster recovery
	Police (incl. counter-UAS)
	Network extension in disaster situations
	Infrastructure inspection
	UAV-enhanced IoT data collection
	Location of UE in non-GPS environments
	Autonomous Drone-based delivery system
	Connectivity extension
5G HEART	Remote interventional support
	Pillcam
	Vital-sign patches with advanced geo-localisation
	Platooning
	Autonomous/assisted driving

5G PPP Phase 3 Project	Use cases recorded in the verticals cartography
	Remote driving
	Remote diagnosis
	Remote monitoring of water and fish quality
	Concurrent testing
5GROWTH	Connected Worker Remote Operation of Quality Equipment
	Connected Worker Augmented Zero Defect Manufacturing (ZDM) Decision Support System (DSS)
	Digital Twin Apps
	Telemetry/Monitoring Apps
	Digital tutorials and remote support
	Safety Critical Communications
	Non-safety Critical Communications
	Advanced monitoring and maintenance support of secondary substation - Medium Voltage/Low Voltage (MV/LV) distribution substation
	Advanced critical signal and data exchange across wide smart metering and measurement infrastructures
5G smart	5G-Enhanced Industrial Robots
	5G for Enhanced Industrial Manufacturing Processes
	5G in Semiconductor Factory
5G SOLUTIONS	Time-critical process optimisation inside digital factories
	Non-time-critical communication inside the factory
	Remotely controlling digital factories
	Connected goods
	Rapid deployment, auto/re-configuration, testing of new robots
	Industrial Demand Side Management
	Electrical Vehicle (EV) Smart Charging

5G PPP Phase 3 Project	Use cases recorded in the verticals cartography
	Electricity network frequency stability
	Intelligent Street Lighting
	Smart Parking
	Smart city co-creation
	Smart buildings / Smart campus
	Autonomous assets and logistics for smart harbour/port
	Port Safety: monitor & detect irregular sounds
	Ultra High-Fidelity Media
	Multi CDN selection
	On-site Live Event Experience
	User & Machine Generated Content
	Immersive and Integrated Media and Gaming
	Cooperative Media Production
	Multi-vertical concurrent usage of eMBB, mMTC & URLLC
5G-TOURS	Augmented tourism experience
	Telepresence
	Robot-assisted museum guide and monitoring
	High quality video services distribution
	Remote and distributed video production
	Remote health monitoring and emergency situation notification
	Teleguidance for diagnostics and intervention support
	Wireless operating room
	Optimal ambulance routing
	Smart Airport parking management
	Video-enhanced ground-based moving vehicles

5G PPP Phase 3 Project	Use cases recorded in the verticals cartography
	Emergency airport evacuation
	Excursion on an AR/VR-enhanced bus
5G VICTORI	eMBB under high speed mobility in rail environments
	Digital Mobility
	Critical services for railway systems
	Factories of the Future: Digital Utilities
	CDN services in dense static and mobile environments
	Energy metering for HV and LV

Table 4 List of 5G PPP Phase 3 projects and their respective use cases