PROJECT "LOCUS": LOCalization and analytics on-demand embedded in the 5G ecosystem, for Ubiquitous vertical applicationS

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Short Abstract:	The goal of this deliverable is to report on innovation and exploitation results, on the progress achieved and performance against plans, as well as on the awareness on achieved innovation and exploitation results.
Keyword List:	Innovation, Exploitation

Content of the Deliverable

This deliverable is a continuation of actions taken in Task T7.3 on innovation and exploitation of the LOCUS project after the initial plan which was presented earlier in D7.5. The document describes the following main areas:

- main areas of exploitation considered by the LOCUS consortium;
- list of LOCUS innovations together with their descriptions and protection plans;
- actions taken on further steps in exploitation including preliminary business plans.

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2.0	Second draft	CNIT, Stefania Bartoletti Samsung, Tomasz Mach NXW, Giacomo Bernini NXW, Elian Kraja	29/09/2021
2.1		Revision by Nicola Blefari Melazzi and Andrea Conti Additions by CNIT Stefania Bartoletti, Domenico Garlisi, Danilo Orlando and Samsung, Mythri Hunukumbure	06/10/2021
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5	Final version	Final revision by Nicola Blefari Melazzi	11/10/2021

Contents

1. Executive Summary

At the time of this deliverable, LOCUS has already reached its mid-life and the consortium has a good record of collaborations and networking activities within different partners of the project, and with external stakeholders. Therefore, we have a solid backbone structure to advance our innovation and exploitation plans, already defined in D7.5.

Since the submission of D7.5, the project has successfully set a record of outcomes in respect to IPR, standardization contributions, key publications and enhancement on products, features and services harnessing localization. During the latest months, the partners have selected a subset of innovations jointly conceived within LOCUS which can have a potential of commercialization and exploitation. This deliverable summarizes such main innovation and exploitation outcomes within LOCUS.

The LOCUS value proposition lies on the wide telecom ecosystem coverage of its industrial and academic partners covering all is needed for complete, secure, accurate and reliable end-to-end location-based analytics services. In this deliverable, we are not simply listing and summarizing the exploitation plans of each partner, but we first categorize the exploitation characteristic work of each partner and try to list the exploitation plans within a common LOCUS frame and then define each partner acting role within this frame. By properly linking different partners' relations with each other, we obtained a LOCUS preliminary business model, which will progress till the end of the project, with a link to suppliers and customers within the localization industry and possible creation of spinoffs from the project.

This document provides an analysis of the potential industrial impact of LOCUS, structured around the identification of roles and stakeholders, and the main technology trends. The general framework for industrial contributions has been highlighted including market situation and trends, opportunities for formal standardization, contributions to relevant open-source communities, and other industrial collaborative initiatives. An advanced and detailed business analysis with a preliminary high level business model is provided in this deliverable, including a SWOT analysis. We expect to provide a more complete business model by the end of the project in D7.7.

Finally, this document sets the ground for further exploitation and dissemination efforts and will facilitate the industrial impact of LOCUS during the lifetime of the project and beyond. Work on consolidation and further expansion of exploitation plans, both for individual partners and jointly within the Consortium, will continue in the project, to capture and quantify emerging business opportunities for LOCUS solutions.

1.1. List of Abbreviations

ABBREVIATION	FULL NAME
3GPP	3rd Generation Partnership Project
BMB	Business and Marketing Board
CA	Consortium Agreement
CAPEX	Capital Expenditures
CFS	Certificate on Financial Statement
CT	Core network and Terminals
DOA	Description of the Action
E4P	Europe for Privacy-Preserving Pandemic Protection
EB	Executive Board
ETSI	European Telecommunication Standards Institute
EU	European Union
GA	Grant Agreement
GB	General Board
GDPR	General Data Protection Regulation
INEA	Innovation and Networks Executive Agency
IPR	Intellectual Property Rights
IvD	Invention Disclosure
KOM	Kick off Meeting
LBS	Location-Based Services
NDA	Non-Disclosure Agreement
OAI	Open Air Interface
OPEX	Operating expenses
O-RAN	Open- Radio Access Network
PC	Project Coordinator
PO	Project Office
PoC	Proof of Concept
PII	Personally Identifiable Information
RAN	Radio Access Network
RB	Review Board
RTLS	Real-Time Location Systems

SA	Service and System Aspects
SB	Scientific Board
UE	User Equipment
URLLC	Ultra-Reliable Low Latency Communication
WPL	Work Package Leader
WPT	Work Package Team

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2. General LOCUS Analysis Framework

LOCUS is exploiting localization and analytics on-demand embedded in the 5G ecosystem for ubiquitous vertical applications. 5G is one of the key enablers in this project, while some localization techniques have been around even since 4G time. Despite the uncertainty caused by COVID-19, service providers continue to switch on 5G and more than 160 have launched commercial 5G services according to Ericsson Mobility Report [1]. This means that 3.5 billion 5G subscriptions are forecasted for 2026 (see Figure 1).

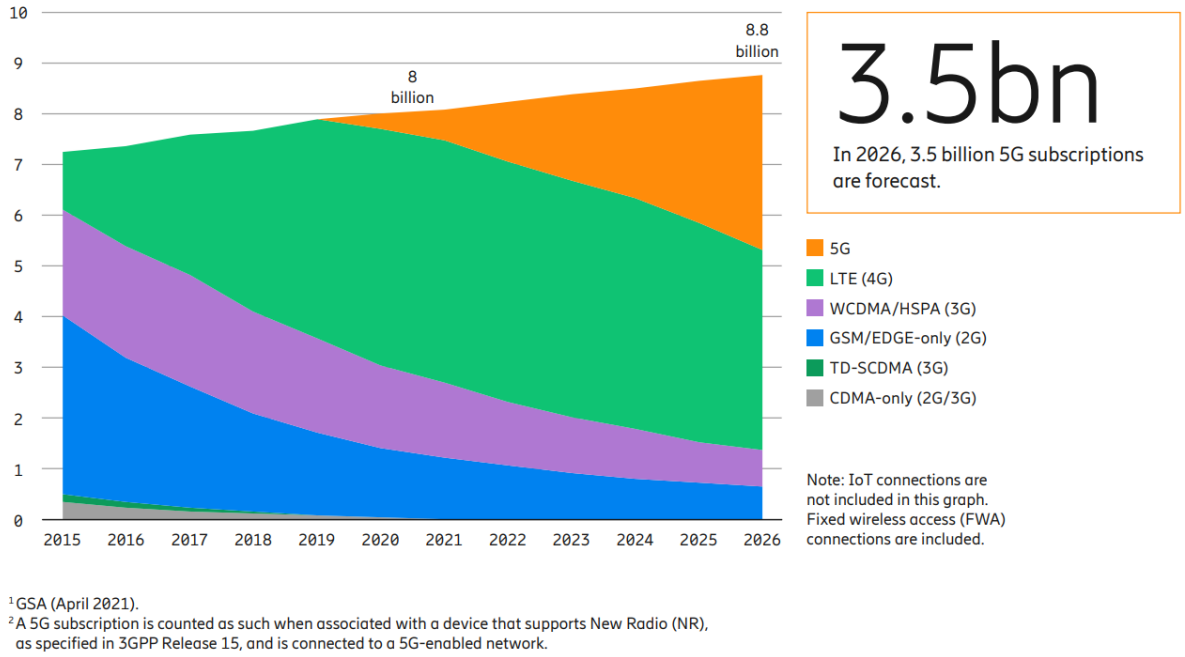

Figure 1: Mobile subscription by technology (billion) [1]

According to the same report [1], the network transition towards 5G is happening in almost all part of the globe looking into 2020 to 2026 horizon, while the change is much more drastic for Northern East Asia, Western Europe, Gulf Cooperation Council and North America (Figure 2). This shows the timely program and importance of LOCUS project in terms of the chosen technology enablers.

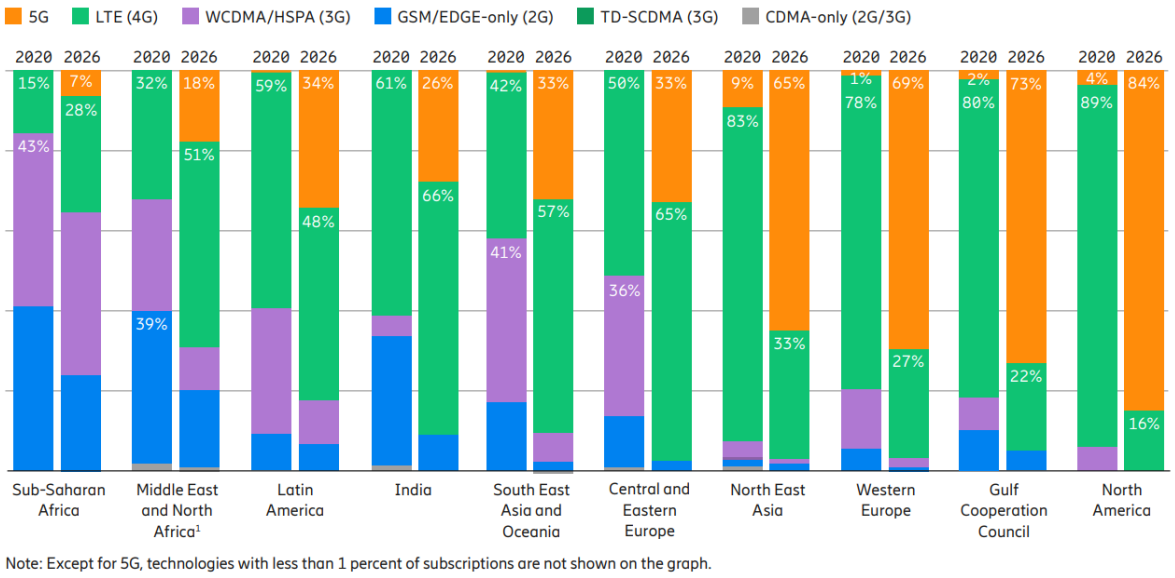

Figure 2: Mobile subscriptions by region and technology (percent) [1]

On the other hand, the location-based analytics industry is driven by the increasing use of spatial data and analytics tools. Moreover, the rising need of predictive analytics for businesses and the growing use of location-based applications further contributes to the growth of the location-based analytics market. The location-based analytics market is segmented into:

- risk management,
- emergency response management,
- customer experience management,
- remote monitoring,
- supply chain planning and optimization,
- sales and marketing optimization,
- location selection and optimization, and
- others (including predictive asset management and inventory management) [3].

The Location-Based Services (LBS) and Real-Time Location Systems (RTLS) market is expected to grow from USD 17.8 billion in 2020 to USD 39.2 billion by 2025, at a Compound Annual Growth Rate (CAGR) of 17.1% during the forecast period. Major factors expected to drive the growth of the LBS and RTLS market include various applications of geospatial data; growing demand for LBS and RTLS for industry applications; proliferation of social media, smartphones, and location-based apps among consumers; and growing demand for geo-marketing [3]. Figure 3 presents the attractive opportunities in the LBS and RTLS markets.

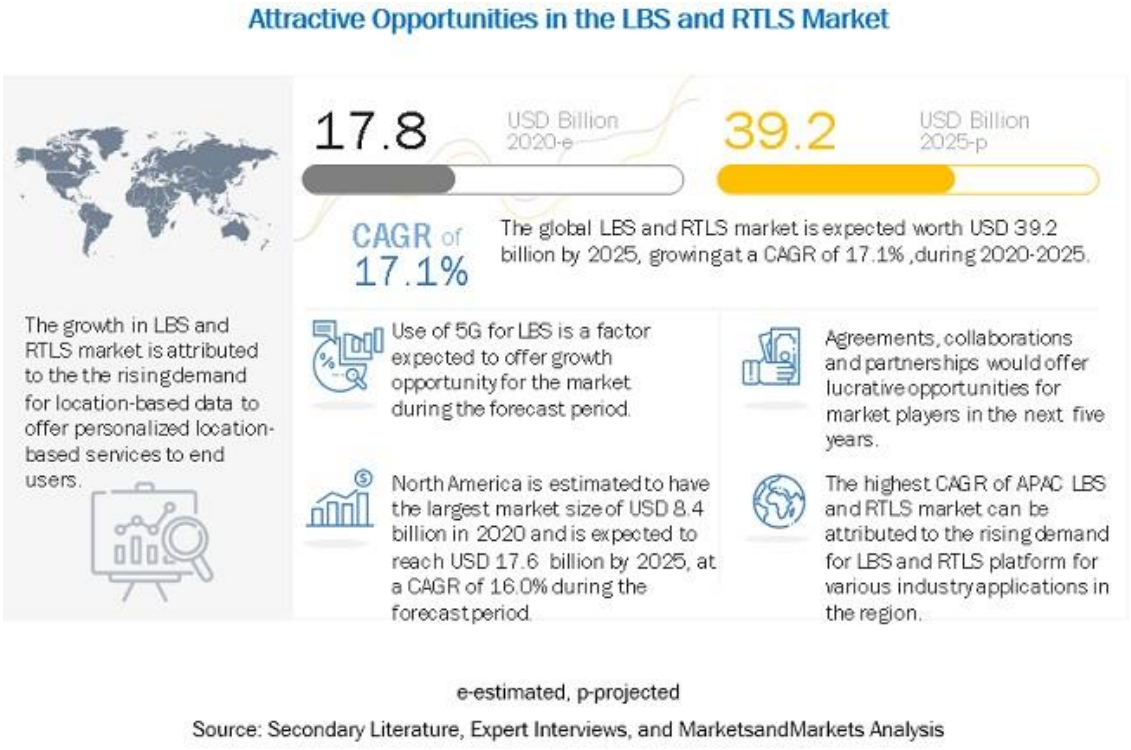

Figure 3 Opportunity analysis in the LBS and RTLS market.

The increasing availability of location information offers innovative applications and services to users, and such easy availability of location-based information leads to different kinds of privacy concerns. Misuse of location data intentionally or unintentionally can lead to serious legal consequences for both organizations and customers. Though LBS and RTLS applications have the benefit of offering location-specific information to users, it still comes at the cost of the user's privacy. As and when the user accesses LBS, they also reveal location details and personal information, such as where they live and details about their lifestyle whether visiting a hospital, restaurant, or going on vacation for a long time. When the user position is publicized, it raises the possibility for misuse of the user's location. Thieves and stalkers can take advantage of tracked information from user movements. The risk of identity theft grows whenever entities begin to collect data profiles, especially if the information is not maintained securely [3].

One of the biggest challenges to the growth of the LBS and RTLS markets are stringent rules and regulations. Government rules and regulations are restricting the data collection process, location sharing, use of location-based information, and storage of information. Any country's regulations place a country's security on priority and limit the use of location-based information. The European Union (EU) General Data Protection Regulation (GDPR) is the first unified attempt by the EU that focuses on safeguarding the Personally Identifiable Information (PII) of citizens.

There are many ways to categorize the LBS and RTLS markets, one is in respect to the verticals they are applied to. For example the need for localization is highly important in Transportation and Logistics, Retail, Government, Tourism and Hospitality, Manufacturing, Healthcare and Life Sciences, Media and Entertainment, Energy and Utilities, Banking, Financial Services and Insurance, Telecom, and Education [3].

The COVID-19 pandemic has also led to a decline in the growth rate of the RTLS market for healthcare, especially in 2020 and 2021. This is mainly because COVID-19 has led healthcare organizations to dedicate a major part of their funds toward the procurement of medical equipment and other resources required to combat COVID-19. As RTLS solutions do not fall under the essential resources category required for COVID-19 treatment, this factor is expected to hinder the penetration rate of RTLS technology in the short run. Additionally, COVID-19 has also disrupted the supply chain of the RTLS market for healthcare, which is hindering the manufacturing, distribution, and installation of RTLS solutions [3]. However, based on LOCUS insights, we believe that the pandemic itself has shown an important new use-case in terms of the need for tracking and localization in pandemic-like scenarios.

3. Target Stakeholders

The large focus of LOCUS on a wide set of use-cases provides the project with a proper study on the requirements and demands of the users and stakeholders. Specifically, there are a number of stakeholders that are relevant to LOCUS for exploiting the project findings, i.e.:

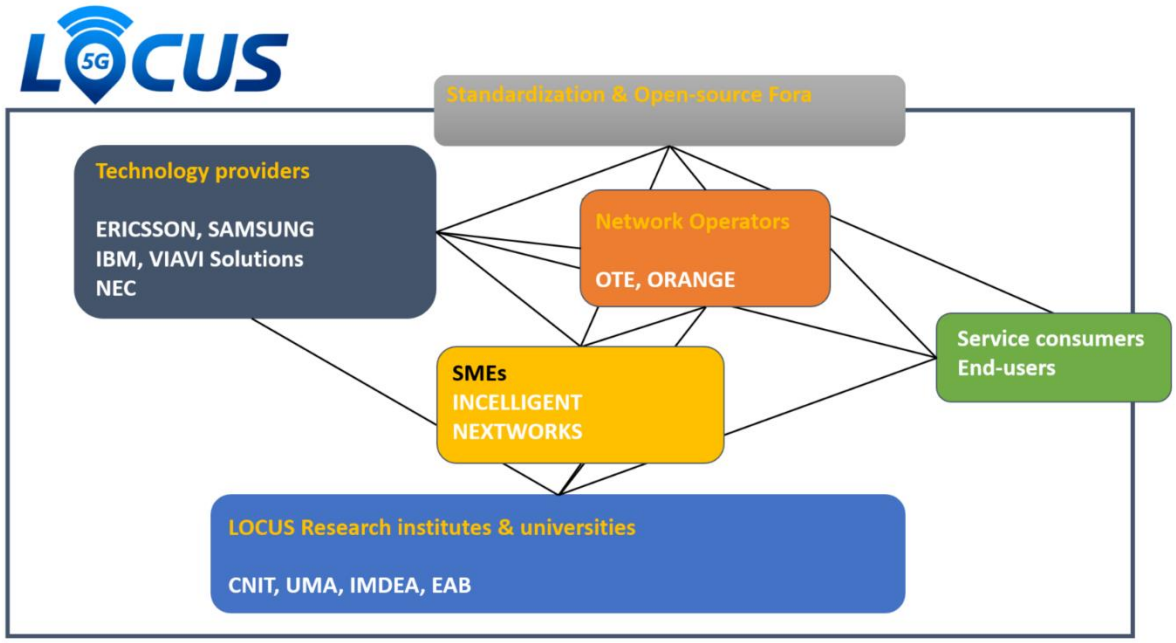

Figure 4 LOCUS partners and target stakeholders

- Technology providers, including vendors, large industry and SMEs, will be the first to position their products in the new segments that LOCUS will define, and additionally they can benefit from the additional knowledge and insight on the relevant technologies to increase their competitive advantage, incorporating LOCUS concepts and software into their product roadmaps.

- Network operators will be in the position of applying LOCUS concepts to enhance network planning and operations, maximize network utilization, reduce operational expense and enhance their service portfolio.

- Research institutes and universities, for which LOCUS can create a competitive advantage in terms of research themes and background, with potentials to generate consultancies, as well as spin-off business initiatives.

- Standardization fora, where the involvement of LOCUS allows the project findings to be considered for standardization, and in case of agreements within these fora, the solutions of LOCUS would be exploited and adopted in all standard-based devices and networks globally.

- Open-Source fora, where the involvement and contribution of LOCUS provides easy and free access to the software and the edge computing society to explore and exploit the code and algorithms development within the project.

- Service consumers/end-users of the localization and analytics that LOCUS expose. A large list of use-cases has been already identified within LOCUS including smart retail, autonomous vehicles, smart manufacturing, logistics, etc.

4. SWOT Analysis

LOCUS will generate a significant impact on the business of all its partners and is expected to also impact the business of companies that will use the project's outcomes. Results produced in LOCUS in the form of reference architecture and specifications, simulations and proof of concept developments can validate project concepts, but also and more importantly act as key enablers for the long-term (post-project) impact, e.g., for the subsequent phases of the 5G PPP strategy, and in parallel, the 5G market product definition by the LOCUS partners. To maximize the exploitation of LOCUS results beyond the lifetime of the project, the following SWOT analysis has been carried out within the project as the first step to deliver a business model for the finalization of the project. The SWOT analysis is a structured strategy planning method used to evaluate strengths, weaknesses, opportunities and threats involved in a project or in a product. It is carried out to identify the internal and external factors that are favourable and unfavourable to achieve the planned objectives. The following SWOT analysis is based on the overall framework of LOCUS and not specific to one specific WP or platform within the project.

4.1. Strengths

1. Having at least one partner for each localization product and service delivery solution is one of the main strengths of LOCUS.
2. The wide investigation and exploration of use-cases within LOCUS provides a better knowledge of the end-users demands and requirements in terms of positioning accuracy, availability and privacy matters.
3. The timeliness with respect to the 3GPP standardization work for 5G localization, together with the participation of partners directly involved in such standardization process, eases the exploitation of LOCUS results within the 3GPP.
4. Automated deployment of localization and analytics services which makes easier the management of exposure of high level and easy to consume localization and analytics services and data outputs, which hides to the service consumer the complexity of data management, processing and pipelines

4.2. Weaknesses

1. Lack of extensive and comprehensive testing and validation of the LOCUS technologies in full blown 5G network deployments, including 5G New Radio and 5G Core.
2. Lack of deployment and validation in large scale infrastructures/testbeds and distributed edge/core environments.
3. Covid19 had a serious impact on experimental activities and partially on R&D work.

4.3. Opportunities

1. Different vertical sectors and industries can benefit from the localization and analytics services offered by the LOCUS platform, e.g. smart manufacturing, automotive and V2X, logistics, smart retail, etc. This opens several heterogeneous market opportunities for the LOCUS outcomes.
2. The LOCUS platform can offer service providers and telco operators innovative, complementary and added-value localization and analytics services that are ready-to-be integrated add-ons of legacy 5G network service management and orchestration tools.
3. Readiness to integrate with 5G network infrastructures and service management and orchestration tools, as the LOCUS platform leverages on the same 5G architecture, 3GPP RAN and ETSI NFV and cloud-native principles.

4.4. Threats

1. More stringent rules and regulations in respect to localization data.
2. Early involvement of policy makers, societal and environmental stakeholders to the project results and the early adoption of results based on a value proposition that can be understood by the public at large are both required; their lack would be a threat to the project exploitation.
3. Service consumers and end-users may be concerned about data and location privacy

5. LOCUS Exploitation Main Areas and Business Plans

The LOCUS consortium includes both academic and industry partners and is contributing to a variety of aspects in respect to exploiting localization solutions. In this deliverable and in our mid-review report, we decided to divide the LOCUS exploitation plans into three different categories and instead of reporting the plans and contributions of each partner separately, we considered reporting the exploitation plans within this categorization and exemplify the work of each partner within these three main areas:

1- LOCUS exploitation within standardization
2- LOCUS exploitation in industry
3- LOCUS exploitation through collaboration links

In the following subsections, we provide a list of LOCUS impacts and the contributions from different partners.

5.1. LOCUS Exploitation within Standardization

In today's fast-paced telecom industry, it is very important to have access to the up-to-date research questions, concerns and problems timely. Standardization fora are the platforms in which these problems are tackled and while not always the solutions are the best and the most optimum ones, they are basically the result of consensus among many different sectors and players in this field. LOCUS has the capacity in terms of engaged partners to monitor, identify and impact on the problems and solutions brought up in the positioning field of these standardization fora [2].

5.1.1. 3GPP Standardization

The 3rd Generation Partnership Project (3GPP) unites telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), known as "Organizational Partners" and provides their members with a stable environment to produce the Reports and Specifications that define 3GPP technologies. The 3GPP covers cellular telecommunications technologies, including radio access, core network and service capabilities, which provide a complete system description for mobile telecommunications currently also shaping 5G ecosystem. The 3GPP specifications also provide hooks for non-radio access to the core network, and for interworking with non-3GPP networks. 3GPP specifications and studies are contribution-driven, by member companies, in Working Groups and at the Technical Specification Group level [4]. Figure 5 presents the three technical specification groups (TSG), which are Radio Access Networks (RAN), Service & Systems Aspects (SA) and Core Network & Terminals (CT) within 3GPP. In LOCUS we are mainly focused on RAN and SA WGs.

Some basic positioning support based on LTE reference signals became supported in New Radio (NR) Rel-15, however the main 5G positioning was introduced in Rel-16 and enhanced in Rel-17. The 5G RAN standardization time plan is presented in Figure 6.

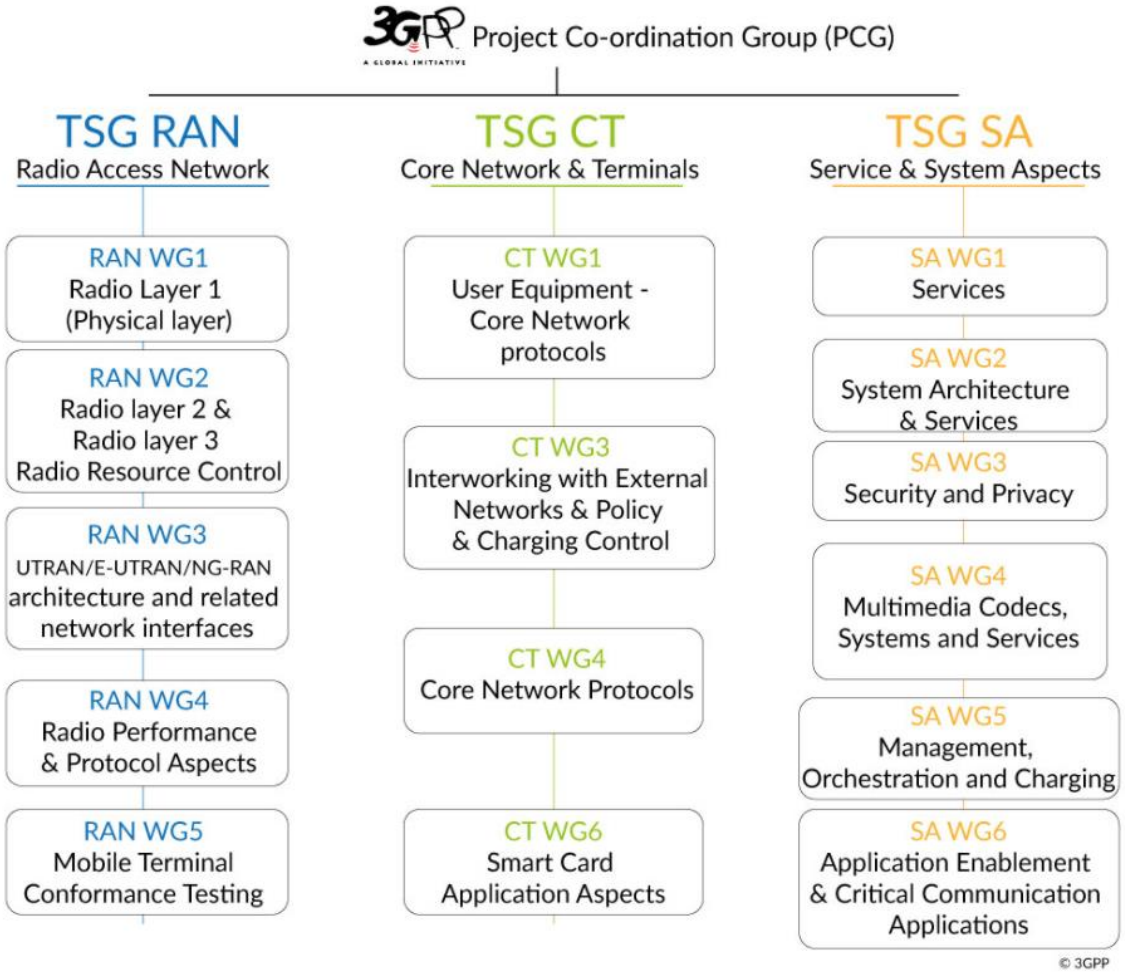

Figure 5 The 3GPP Technical Specification Groups [4]

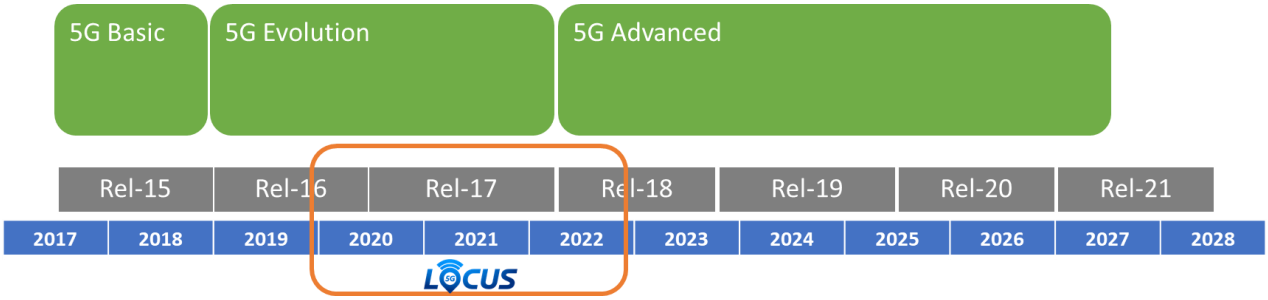

Figure 6 The 5G RAN standardization time plan in 3GPP

As regards the activity of LOCUS in this framework, **Ericsson** brings the most recent information from the 3GPP standardization work, and feedbacks insights from LOCUS into 3GPP. Since the start of LOCUS, **Ericsson** was fully engaged in finalizing the Rel-16 work item (WI) on positioning and the Rel-17 study item (SI) and WI which were relevant to study the enhancements of 5G positioning beyond what was possible in Rel-16. Currently, companies including

Ericsson and **Samsung** are involved in Rel-18, that is the start of 5G-Advanced. Positioning is again part of Rel-18 5G Advanced discussions and naturally the 3GPP work and LOCUS collaboration will continue in Rel-18 work.

Ericsson and **Samsung** within LOCUS have been continuously monitoring the 3GPP work for positioning and localization in Rel-16 and Rel-17 in both RAN and SA WGs. They are contributing to 3GPP in RAN1, RAN2 and SA2 on the outcomes and enhancements obtained within LOCUS. **Samsung** and **Ericsson** have already initiated two co-sourced SA2 contributions in Rel-17 thanks to their connections via LOCUS.

Moreover, **CNIT,** by studying 5G standardized compliant models and simulations, and by working with companies inside the project, has been providing concepts such as a new localization approach based on soft information (SI) extracted from intra- and inter-node measurements, as well as from contextual data, which are potentially good candidates to be further presented in 3GPP. If LOCUS succeeds in this direction this can be a unique exploitation opportunity within the consortium.

The complete and latest list of 3GPP contributions on behalf of LOCUS partners can be found in D7.3.

5.1.2. ETSI Standardization

ETSI is a European Standards Organization (ESO) recognized a standard body dealing with telecommunications, broadcasting and other electronic communications networks and services. This includes supporting European regulations and legislation through the creation of Harmonised European Standards. Only standards developed by the three ESOs (CEN, CENELEC and ETSI) are recognized as European Standards (ENs) [5].

ETSI, which has not been oblivious to the consequences of the pandemic, has not wanted to be involved, either, to its mitigation. For this reason, last May it approved the constitution of an Industry Specification Group (ISG), called "Europe for Privacy-Preserving Pandemic Protection" (E4P), which was commissioned to study current digital contact tracing methods and solutions, and the analysis and standardization of its future interoperability, the latter being the greatest lack of the numerous solutions proposed up to that moment [6].

The work in E4P is very much related to the COVID-19 use-case work in LOCUS WP5. **SAMSUNG** was the rapporteur of the ‘Device-based mechanisms for pandemic contact tracing systems’ in E4P. Hence, insights into E4P work progress, status and roadmap were presented to LOCUS partners and potential LOCUS contributions to E4P were identified. However, in May 2021, after publishing 1 Group Report (GR) and 4 Group Specifications (GS) where LOCUS industry partners (SAMSUNG, ORANGE, NEC and IBM) contributed, ETSI decided to close the E4P group and transfer its work and deliverables to the ETSI EP eHEALTH group.

SAMSUNG has been also monitoring and updating the LOCUS partners on the progress of recently completed Vulnerable Road Users (VRU) specifications developed in the ETSI Intelligent transport Systems Technical Committee. The objective is to keep the ongoing work on the VRU use case and related research work in LOCUS aligned with the new standard.

NEC also contributes through ETSI ISG (particularly ETSI ISG CIM). The complete and latest list of ETSI contributions on behalf of LOCUS partners will be updated in D7.3.

5.1.3. Telecom Community

LOCUS is leveraging functionalities of 5G infrastructures, in conformity with 3GPP releases of specifications, for providing accurate and ubiquitous location information as a network-native service, as well as for deriving complex features and behavioural patterns.

Exposition and provision of location-based analytics to applications via simple interfaces in a virtualization platform for network control and management is also underway.

Aside from direct LOCUS support in certain standardization fora, there are some general contributions and exploitations from LOCUS which will impact the telecom community in general. For example, the description of LOCUS is included in the 5G PPP Projects – Phase 3 brochure.

LOCUS has been also involved in drafting the 5G PPP white paper on Delivery of 5G Services to Indoors (5g-ppp.eu), as localization is being considered as one of the main indoor services that 5G can deliver.

Another example is a LOCUS paper "Spectrum Occupancy and Interference Model Based on Network Experimentation in Hospital", which has been appeared in the reference list [i.18] and its results are used in pp. 69-74 of ETSI TR 103 395 V1.1.2 (2020-12).

Another activity of LOCUS is disseminating results to the broad research and development community via publications, co-authorship in 5G-PPP white papers, invited talks, keynotes and tutorials at flagship conferences. **CNIT** is one of the main contributors in this regard and is also participating to several working groups, including the Automotive WG.

VIAVI also exploits collaborative research to build industry consensus that can lead towards standardization, in particular within 3GPP and the O-RAN Alliance.

Furthermore, **SAMSUNG** has been monitoring the progress of pre-standardization work in the 5G Automotive Association, in the context of VRU use case work and its relevance to LOCUS.

The complete and latest list of 5G-PPP white papers, keynotes and tutorials and other contributions on behalf of LOCUS partners will be updated in D7.3.

5.2. LOCUS Exploitation in Industry and Business Plans

Technology providers, including vendors, large industry and SMEs, will be the first to position their products in the new segments that LOCUS defines, and additionally they can benefit from the additional knowledge and insight on the relevant technologies to increase their competitive advantage, incorporating LOCUS concepts and software into their product roadmaps. The

solutions derived within LOCUS can be an added feature within a network, or in respect to a new or an improved service to the end user, or in the nature of additions in components or enhanced products. In the following subsections, we provide plans within industry in which LOCUS impact can become exploited and appreciated.

5.2.1. IPRs generated within LOCUS

LOCUS partners are generating IPRs starting from the findings from the individual research activities. Below we list the four already protected ideas within LOCUS in Table 1, more detailed explanation is provided in the submitted Innovation Radar forms prior to LOCUS review meeting in July 2021. As this deliverable is public, we decided not to elaborate further on these IPRs within this document.

While we have exceeded our own expectations in terms of number of IPRs to be generated within LOCUS from the target we had in D7.5, we see still a great potential to have at least a couple of more IPRs to be generated within LOCUS in the remaining time of the project.

Table 1 Submitted LOCUS IPRs

No.	IPR Title	Owner
1	Mapping of scatterer locations in a radio environment for device free localization	Ericsson AB
2	3D Isosceles Triangle Based Positioning	Ericsson AB
3	System for monitoring physical environment's proneness to infectious disease transmission	NEC Laboratories Europe GmbH
4	A method for efficient Memory sharing between Virtual machines executing AI Inference workloads on Specialized Operating System	NEC Laboratories Europe GmbH

5.2.2. Selected Innovations generated in LOCUS

In addition to individual research activities, there are several innovations that have arisen in LOCUS from the collaboration between the partners. These innovations not only find an output in potential IPRs, but they also have a clear potential for commercialization and the generation of an emerging market. Among the several concepts conceived in LOCUS, five of them have been selected as among the most promising for exploitation purposes and reported in Table 2. Note that while a main investigator has been indicated, the innovation is intended with a shared ownership within the consortium. The selected innovations are intended as work-in-progress, and their definition will be updated until the end of the project.

Table 2 Selected innovations generated in LOCUS

No.	Title	Main Investigator
1	Localization analytics exposed as virtualized services on top of hybrid edge/core virtualization platform integrated with 5G network infrastructures	Nextworks, Incelligent, VIAVI
2	People (individual and group) mobility analytics as virtualized network functions	IBM, NEC, VIAVI
3	5G localization enhancement by pencil beamforming	CNIT
4	Threat detection algorithms fed by high-level data	CNIT
5	Testbed for location security and privacy in 5G networks	CNIT

5.2.2.1. Localization analytics exposed as virtualized services on top of hybrid edge/core virtualization platform integrated with 5G network infrastructures

5G Localization and analytics functions are virtualized following the ETSI NFV principles and dynamically deployed as services on top of a hybrid virtualization platform supporting cloud native edge/core distributed infrastructures (based on opensource and de-facto standard technologies like Kubernetes) seamlessly integrated with the 5G network. This allows to expose 5G localization and analytics as services to fulfil smart network management and 3rd party vertical applications needs, leveraging on an innovative API layer embedding Machine Learning pipeline orchestration.

Target Stakeholders: Telecom Vendors and Operators, 3rd party vertical application owners

5.2.2.2. People (individual and group) mobility analytics as virtualized network functions

This innovation consists of analytics functions using Machine and Deep Learning to address the challenge of individual/crowd flow monitoring/management in an indoor/ outdoor environment. Crowd mobility are detected from spatio-temporal data collected from UEs. Algorithms are developed leveraging localization and traces from UEs to detect and classify groups of individuals. The functions are virtualized functions for smart network management or applications built on top of network functions.

Target Stakeholders: Telecom Vendors and Operators

5.2.2.3. 5G localization enhancement by pencil beamforming

5G-Pencil is a framework for evaluation of localization-enhanced pencil beamforming implementing a simple yet effective pencil beamforming policy that synthesizes the traffic beams by leveraging the 5G localization uncertainty level of each served user. When the UE location is precisely estimated, very narrow and almost non overlapping pencil beams are synthesized by 5G gNBs, yielding to a general exposure reduction, which is also coupled by a substantial throughput increase.

Target Stakeholders: Telecom Vendors and Operators

5.2.2.4. Threat detection algorithms fed by high-level data

Nowadays, attackers can leverage practical concerns that force operators to slowly and incrementally deploy next-generation cellular technologies (in fact, as we write, 2G systems are still active) and convince the UE to believe that the only base station available in a coverage area is a fake one implementing a past generation standard, thereby circumventing the new protections. More importantly, air interface attacks can be thwarted only by developing compelling techniques and systems which detect the early-warning signs of their appearance, namely (possibly smart) jamming and rogue base station activities, etc. Thus, we developed algorithms that adaptively monitor, within a preassigned temporal sliding window, a number of physically observable quantities, gathered from commodity receivers, and, exploiting change detection theory, can identify abrupt variations in data triggered by an attack. Remarkably, the proposed architectures have been assessed in a real-world experimental playground setup by using Software-Defined Radios.

Target Stakeholders: Telecom Operators, Cybersecurity Agencies, Experts from Academia

5.2.2.5. Framework for location security and privacy in 5G networks

A framework for location security and privacy in 5G networks is in under development and will be available to target stakeholders for remote access. The framework, which will be open source and based upon SDR devices such as USRPs, can be exploited to test new algorithms in terms of robustness to location security and privacy attacks.

Target Stakeholders: Telecom Operators, Cybersecurity Agencies, Experts from Academia

5.2.3. Additional Features for Cellular Networks

OTE is the dominant telecommunications operator in Greece, and along with its subsidiaries one of the largest telecom groups in South-eastern Europe. **OTE** has long ago identified the growing need for investing in 5G technology since this has been proven one of the fields which is very promising for OPEX and CAPEX reduction while, at the same time, offering demanding and advanced services to the end users. Based upon technical and market-led priorities, **OTE**

is expected to gain several advantages by the project results, to further increase its market profile. **OTE** aims to exploit the expected LOCUS concept by initially verifying the proposed platform and then coming with a plan of "how to promote it" into its existing and/or future solutions, thus strengthening customers' confidence and enhancing its competence in the field of telecommunication networks. The innovative features of the expected LOCUS findings will also help to design and promote new business models. By active participation within LOCUS project, **OTE** uses the relevant results in order to initiate customer trials that represent the baseline for future commercial products and services based on location analytics. In addition, **OTE**'s plans to use the innovation and the technologies developed in LOCUS project for enhancing and optimizing location-aware service management and operation and by using 5G localization and analytics functions aims to improve customer experience

NEC is active in industrial research projects in Europe and overseas related to location data and/or location-based analytics. **NEC** Laboratories Europe has on-going collaborations with NEC internal units in countries such as Japan, Spain, and India as well as other industrial/academic partners. **NEC** plans to exploit the outcomes of the LOCUS projects in some of these collaborations where applicable.
Further, **NEC** has a new project with the local municipality of Heidelberg in Germany where the focus is on human mobility and location-based analytics. **NEC** plans to work with humanitarian institutes, such as ICRC (International Committee of the Red Cross) for projects related to refugee camps and tracking of Covid-19 spread.

The Japan side of **NEC** is exploring the LOCUS use cases and the situation awareness research behind it. **NEC** explored a Covid-19 tracking use cases in a Japanese hospital environment and on a smart district environment using context-based brokering and linked data features.

Samsung is the contracted device provider for the developing Emergency Services Network (ESN), which will replace the current TETRA based emergency network in the UK with the LTE based ESN. The Samsung business unit (BU) involved in the ESN is keen to showcase the 5G capabilities that can enhance the emergency communications and one of the key questions they have faced is that with the limited initial 5G deployments, how can the 5G service can be guaranteed within the wide service areas of the emergency crew. In the LOCUS T3.1 work by Samsung, a drone-based 3D indoor localization solution is developed which can overcome this limitation. The initial results from this solution have been provided to the BU and with their support, the UK Home office and emergency communications services delegates have also been updated. The response from these external entities have been very positive and they recognize this as an effective solution to the limitations within the early 5G deployments.

5.2.4. Improved services and platforms

Nextworks, as a technology provider and software SME active in the ICT and telecommunication sectors, participates to LOCUS aiming at identifying and developing innovative solutions and application scenarios in the area of location-aware service management and operation, to be then turned into company assets and knowledge services for its ICT market. Nextworks has indeed a wide portfolio of consultancy services [7], which includes training courses, technology support, and third-party software development offers that are planned to be enhanced and

augmented with new knowledge derived from the LOCUS outcomes. In LOCUS, Nextworks develops the localization analytics as a service as a virtualization platform for flexible operation and exposure of localization services. This substantially contribute to the consolidation and improvement of the existing company research-oriented network and service management portfolio, which already includes a network slice manager, an NFV Orchestrator, a multi-NFVO catalogue and a Service Development Kit for designing services. Even if Nextworks does not have direct plans for commercialization for these outcomes from LOCUS, the target is to build a comprehensive inventory of integrated software tools bound with specific 5G use cases to validate innovative concepts such as those related to the location-based services. This aims at attracting interest from telco industry and vertical sector players (e.g., through public demonstrations at relevant events) and foster the creation of new research and innovation collaborations, as well as new opportunities for consultancies.

On a more commercial and product-oriented side, **Nextworks** develops and markets an IoT platform called Symphony [8], a service-oriented generalized platform capable of integrating thousands of interconnected devices in support of multiple vertical needs and services. It integrates several functional subsystems into a unified fully decomposed, virtualized, and distributed IP-based platform. Nextworks is currently evolving Symphony towards an Industrial IoT (IIoT) platform called Symphony Factory Edition (FE), aiming at positioning it in the smart manufacturing market. Symphony FE is going to provide interfacing with more industry field bus protocols, as well as data acquisition and actuators control, data storage and processing, rule-based engines, application logic and GUIs. Here, the localization technologies developed in LOCUS, including the various analytics services, ML models and data movement interfaces, can be integrated with the Symphony FE to enhance and improve the support of localization-enabled manufacturing services and assets. In this regard, Nextworks has also recently identified the 5G Non-Public-Networks (NPN)s as a key topic to look at to exploit the company assets and knowledge in both the 5G network management and IIoT areas. Here, the use of Symphony FE platform augmented with LOCUS localization and analytics capabilities would help Nextworks to be more competitive in providing a comprehensive technology solution for enterprise and IIoT services private networks through 5G in several scenarios, including smart building and events, holiday resorts, residential parks, industry 4.0, hospitals.

Incelligent is a software SME with specialization in the area of big data and analytics for telecommunication providers and other enterprise and public sectors. **Incelligent**'s core IP is a platform that has been developed out of years of R&D in the areas of Big Data and Advanced Machine Learning. On top of this platform, Incelligent has packaged and commercialized RAN.ai, a suite of analytics-based use-cases covering traffic predictions, mobile network/spectrum/capacity planning & optimization, but also improved customer experience and analytics-based marketing/retail optimization. The localization technologies and location-based enablers and APIs designed and validated through LOCUS, have been already exploited by Incelligent, particularly towards extending its RAN.ai suite with an advanced location and mobility analytics component that will support further use cases and thus, will enhance the company's offering towards their collaborating operators (including the LOCUS partner OTE).

As a matter of fact, **Incelligent** has been already engaged in contractual agreement with one of its telecom operator customers in Europe. This involves the development, deployment and operation support of a geo-location-based tool, that will exploit the data pre and post-processing and analytics functions designed as part of LOCUS architecture/platform and will offer a set of analytics for serving geo-location-based network monitoring and management use cases on top

of predefined, highly-important and properly geo-localized areas (highways, national roads, touristic prefectures, big cities hotels etc).

Moreover, **Incelligent** is already exploiting concepts and know-how gained through LOCUS in one of its ongoing engagements with a telecom operator in North Africa. This mainly involves various mechanisms for ingestion and appropriate geo-tagging and enrichment of data, cell classification through geospatial correlations, mobility patterns and trajectories identification, transporters' classification etc., all of them to be used for supporting subscriber mobility, customer- and marketing-oriented use cases.

As a leading provider of geolocation technology, **VIAVI** will exploit the improvements in geolocation estimation technology achieved by LOCUS to open up new use cases for mobile networks. In particular, the vision for 5G is that it must be able to address use cases that have a wide variety of QoS characteristics for what constitutes a good service. VIAVI sees accurate estimation of geolocation, trajectories, UE densities and other location-related quantities as key to managing network resources. For mobile network operators to have the confidence to address the market for these services, they must have solutions that allow the services to be delivered reliably, and in some cases for strict SLAs to be met. Research activities and trials for future development of geolocation solutions, network optimization and orchestration.

5.2.5. Additions of components and enhanced products

For more than 20-years, **Ericsson** has provided market leading positioning solutions to operators throughout the world. Built on this experience and technology leadership, Ericsson Network Location (ENL) is the new modern location platform built to answer the needs of 5G and IoT location use cases.

For **Ericsson** it is highly important to be part of research and industry cooperation in understanding the requirements on 5G positioning components and 5G positioning solutions for massive IoT use-cases, critical machine type use-cases as well as regularity, manufacturing, automotive, logistics, construction, and mining use-cases. LOCUS has made a great effort in exploring many positioning use-cases and requirements. Moreover, LOCUS positioning platform and algorithms are part of the input to the ENL. This would be particularly the case when LOCUS solutions can be agreed in standardization fora.

Incelligent's core product is an analytics platform that has been developed out of years of R&D in the areas of Big Data and Advanced Machine Learning. The platform already exposes a set of APIs and services for implementing variant analytics-based use cases in various sectors. Incelligent is exploiting the localization-centric principles, concepts and technologies developed within LOCUS for extending its platform's set of APIs/services and eventually supported vertical applications, to enrich the company's offerings and sales towards its customers. Apart from the service APIs, the platform will be enhanced with a standard connector for ingesting geo-located data from well-established geo-location tools in the market. Business wise, this is important as it highly contributes to the product readiness and eventually to supporting a more repeatable revenue model.

Samsung's flagship 5G Smartphones (and many other leading brands) now contain the UWB positioning capability. Within the LOCUS project T3.2, Samsung Research UK studied a

potential limitation in the UWB positioning, i.e. the device congestion when a high number of devices have to be supported in parallel. A potential solution, through the integrated use of UWB and 5G positioning to this problem was also developed and reported in D3.4. These solutions were also conveyed to Samsung standardisation and product teams in South Korea. This has created much interest in the benefits of integrating 5G and UWB localization capabilities. The support for UWB localization is likely to be a study topic in 3GPP RAN and SA working groups in near future.

As a leading provider of network assurance products, **VIAVI** will exploit the enhanced geolocation technology developed in LOCUS to enhance the assurance portfolio and build on the network optimization capability. The adoption of technologies such as massive MIMO and mmWave will present aggressive targets for accuracies and latencies of location estimates. The improved capabilities will open the door to more powerful network monitoring, enhanced diagnostics and improved optimisation.

5.3. LOCUS Exploitation through Collaboration Links

5.3.1. Links to SME

The project results will be disseminated to the local companies by the links that the **UMA** research group has with SME and international companies in the Andalusian Technology Park (PTA). New national and international industrial research projects related to 5G and localization will be pursued to continue research in the area after the project lifetime, possibly in collaboration with these companies. Based on the project results in WP6, **UMA** will consider offering its testbed as a research infrastructure to external parties.

5.3.2. Links to international companies

The participation to a Project such as LOCUS enables a strong collaboration with companies and other institutions that will go beyond the scope of the project and that permit to carry out a top-level application-driven research based on requirements form companies and verticals. **CNIT** for example focuses on exploiting the developed techniques for location awareness inside the project (in collaboration with companies internal to the project) and outside the project.

Use cases of LOCUS gave inputs for the internal research on situation awareness in **NEC**, in particular, the Covid-19 use cases and indoor tracing of the infections using multi-modal data from sensors. The Wi-Fi dataset of the Emilia-Romagna region of Italy available in the LOCUS COVID-19 use case opened a research path towards predicting COVID-19 spreads. Crowd mobility data analytics is considered useful in the smart cities, where activities in Heidelberg and other cities in Europe has been already initiated. Moreover, there are smart city related activities by **NEC** in Japan where **NEC** technologies are deployed in various cities.

Ericsson has recently become involved in a European Space Agency (ESA) project called HOP-5G with Airbus as the prime company. This project aims to provide proof of concept of hybrid GNSS positioning together with 5G local overlay testbed for enhanced user positioning. The field test would happen in an airport in Germany and there will be both drone as a UE and

drone as a BS considered in the work setup. The project aims to implement in both FR1 and FR2 and to consider all potential positioning solutions including time difference of arrival, angular measurements and even sensor data. Ericsson is responsible in providing benchmark analysis and validation of field test measurement and positioning results. The fundamental learnings and outcomes we have in WP3 of LOCUS would be definitely exploited in the HOP-5G project.

5.3.3. Potential spin-offs

Partners such as **IMDEA, CNIT** and **UMA** will exploit the results of the LOCUS project by exposing the Ph.D. students that work at the institute to a solid and multi-faceted knowledge in localization technology and 5G network architecture, creating the foundations for spin-offs from innovation generated in LOCUS. For example, the **UMA** incubator program is a good platform for the generation of a spin-off company from LOCUS. This may become clearer by the end of the project.

Also, the 5TONIC open research and innovation laboratory for 5G hosted by **IMDEA** represents a unique opportunity to create a global open environment to perform research and innovation, boost technology and business innovative ventures and promote joint project development and entrepreneurial venture together with major players steering the evolution of future 5G and beyond networks.

Incelligent is continuously looking for further exploitation through funding opportunities for its products, new business plans and/or spin-off schemes. One such opportunity is now offered by a Greek-based Fund that was recently created in order to fund and support companies which exploit 5G networks and technology advancements to offer vertical services. This will be closely followed by **Incelligent** for promoting and exploiting its LOCUS technology enabled solutions.

Another important aspect for the younger researchers at **CNIT** and other partners is that the project represents an essential component for the growth of next-generation workforce.

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