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

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Short Abstract:	This is the final deliverable on all the innovation and exploitation activities happened during the project and the ones which would be continued even after the finalization of LOCUS.
Keyword List:	Innovation, Exploitation

Content of the Deliverable

This deliverable presents all the activities and targets accomplished during the LOCUS project on innovation and exploitation within Task T7.3. Within this deliverable we merge the two previous deliverables D7.5 and D7.6, which were separate documents and finalize all the achievements starting from those deliverables [1][2]. One can consider this report as the summary of the whole Innovation and exploitations activities within the LOCUS life cycle. Moreover, the document aims to describe all the potentials and continuous exploitation of the LOCUS findings even after the project finalization. The document describes the following main areas:

- main areas of exploitation and analysis framework considered by LOCUS
- list of all LOCUS innovations and IPRs together with their descriptions and outcomes
- list of all LOCUS exploitation activities including standardization, open source, Wiley book, knowledge transfer and PoCs.

VERSION CONTROL TABLE			
VERSION N.	PURPOSE/CHANGES	AUTHOR (S)	DATE
1.0	First draft	EAB, Sara Modarres Razavi	27/06/2022
2.0	Second draft, after the LOCUS focus meeting for this deliverable	EAB, Sara Modarres Razavi	07/09/2022
3.0	Third draft including updates from partners after the focus meeting inputs.	IMDEA, Domenico Giustiniano, Giuseppe Santaromita INCE, Athina Ropodi, Kostas Tsagkaris, VIA, Takai Eddine Kennouche SAMS, Mythri Hunukumbure NEC, Gurkan Solmaz	26/09/2022
4.0	Fourth draft including updates from 3 PoCs and other inputs from the LOCUS review meeting	INCE, Athina Ropodi TEI, Stefano Stracca VIA, Takai Eddine Kennouche	20/10/2022
4.1	Internal Revision	CNIT, Andrea Conti	30/10/2022
4.2	Final Revision	CNIT, Stefania Bartoletti and Nicola Blefari Melazzi	31/10/2022

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1. Executive Summary

Innovation and Exploitation of project results are among the key factors in the success of any European Horizon 2020 project. LOCUS indicated a strong preference and motivation in terms of these two goals from the beginning. One indication was the consideration of having a separate deliverable and task in respect to Innovation and Exploitation and that these factors were dealt in a separate path compared to the general disseminations and publication of the project from the beginning of the project.

LOCUS has finalized its work with a great track record on collaborations and networking activities by different partners of the project and external stakeholders. Moreover, an impressive outcome in terms of IPR, standardization contributions, key publications and enhancement on products, features and services harnessing localization.

To build up a consortium that can generate high level of innovation and exploitation, there is a strong need of team development, trust and motivation within all the partners in the project. Despite the very challenging time in which LOCUS started its work with the pandemic covering most of the life cycle of the project, and the fact that COVID-19 situation limited the project by not having any face-to-face meetings and normal team development platforms, LOCUS was very successful in still filling this gap and making a good connection between all partners and members, which was the main successive building block on the journey of innovation and exploitation. The motivated and dedicated partners were the main reasons for this success.

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 would be 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 had the muscles in terms of engaged partners to monitor, identify and impact on the problems and solutions brought up in the positioning and localization field of these standardization fora. These fora are the sources of standard related IPRs as well as platforms which initiate global solutions that would be adopted in all devices, networks in future releases in a wide aspect. For example, LOCUS partners, in particular Ericsson and Samsung, were continuously monitoring and contributing to the 3GPP Positioning works while regularly debriefing the main achievements within 3GPP with LOCUS colleagues and received their feedback and contributions to be presented to 3GPP.

One of the main characteristics of the team in LOCUS was the flexibility and the dynamic attitude towards change. For example, while COVID-19 has stroked all projects, and LOCUS hasn't been an exception, the discussion on how LOCUS can use its platform to find solutions in terms of virus tracking or any other support needed for such pandemics in short- and long-term horizons have been discussed and then included as an additional use-case and a separate task work to evolve within the project life cycle. One solid example in this respect is the engagement of LOCUS representative in the work of ISG group in ETSI called E4P ("Europe for Privacy-Preserving Pandemic Protection), which its standardization scope was partially related to COVID-19 work in LOCUS. LOCUS has been updated with the status and roadmap of E4P

and the ongoing COVID-19 use-case has been directed towards the roadmap of this standardization group to make the LOCUS contribution possible.

Aside from the potential of protecting novel ideas and presenting them to standardization fora, one main contribution of LOCUS to software, analytics, algorithms and edge computing societies is the fact that in this domain it would be very beneficial to share the knowledge in an Open-Source fashion. Of course, LOCUS also received benefits from such communities, and hence it is a straightforward return of the access to the publicly available platform which is being used. One example in this respect was the use of Open-Air Interface (OAI) in WP3 where the 5G link channel model between the UE and the base station are fully defined and are being used to build a localization platform for localization. LOCUS has also provided support to Open-Source platforms with proper documentation and explanation which makes it easily reusable by anyone any time.

The LOCUS value proposition lied 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.

2. Introduction

This document presents the innovation and exploitation strategies and activities performed and addressed during LOCUS project. The results and the awareness of the achieved outcomes on driving the innovation and commercial potential of the technical work and technical goals of LOCUS are also summarized. The main goals of the LOCUS innovation and exploitation activities were to:

- offer the LOCUS localization and analytics service within the consortium, for extensive testing by partners developing advanced location/context-based services;

- extend access beyond the project to other projects and external players, including SMEs; and

- build a community of users.

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
GA	Grant Agreement
GB	General Board
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
RAN	Radio Access Network
RB	Review Board
RTLS	Real-Time Location Systems
SA	Service and System Aspects
SB	Scientific Board
SME	Small and Medium-sized Enterprises

UE	User Equipment
URLLC	Ultra-Reliable Low Latency Communication
WPL	Work Package Leader
WPT	Work Package Team

Table 1: Abbreviation List

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WP7 and T7.3 setup

Figure 1 presents the whole structure of LOCUS project. It can be observed that the work in WP7 was linked and related to all other WPs within LOCUS while it was also the platform in which the project was being presented externally.

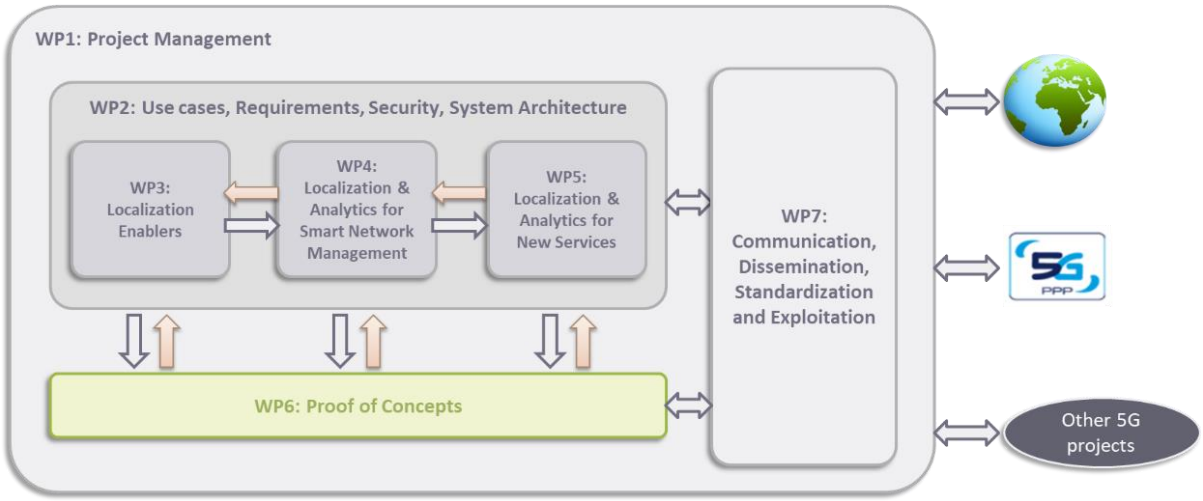


Figure 1 LOCUS structure overview

Figure 2 shows how the ideas and documents needed to be set and followed within WP7. It was highly important that before communicating and disseminating the ideas and results externally, we made sure that we follow the checking process for innovation and standardization boxes.

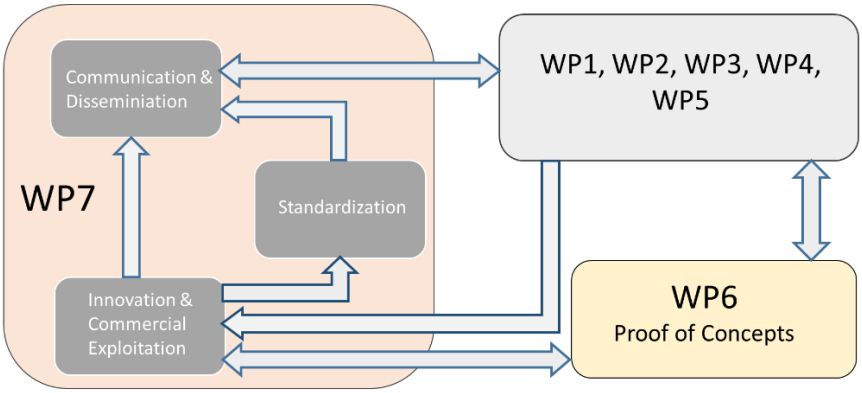
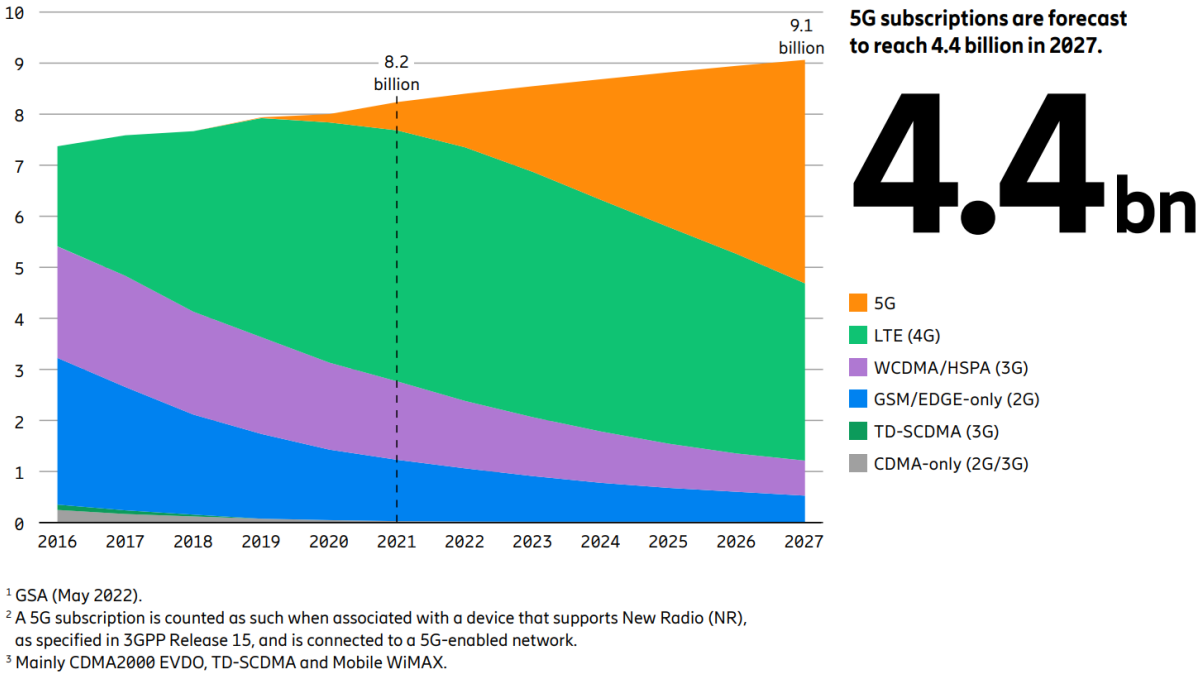


Figure 2 WP7 structure

3. General LOCUS Analysis Framework

LOCUS exploits 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. By the end of 2027, Ericsson forecasts 4.4 billion 5G subscriptions globally, accounting for 48 percent of all mobile subscriptions. *5G subscription uptake is faster than that of 4G following its launch in 2009, reaching 1 billion subscriptions 2 years sooner than 4G did* (Figure 3).



[1] GSA (May 2022).
[2] A 5G subscription is counted as such when associated with a device that supports New Radio (NR), as specified in 3GPP Release 15, and is connected to a 5G-enabled network.
[3] Mainly CDMA2000 EVDO, TD-SCDMA and Mobile WiMAX.

Figure 3 Mobile subscription by technology (billion) [3]

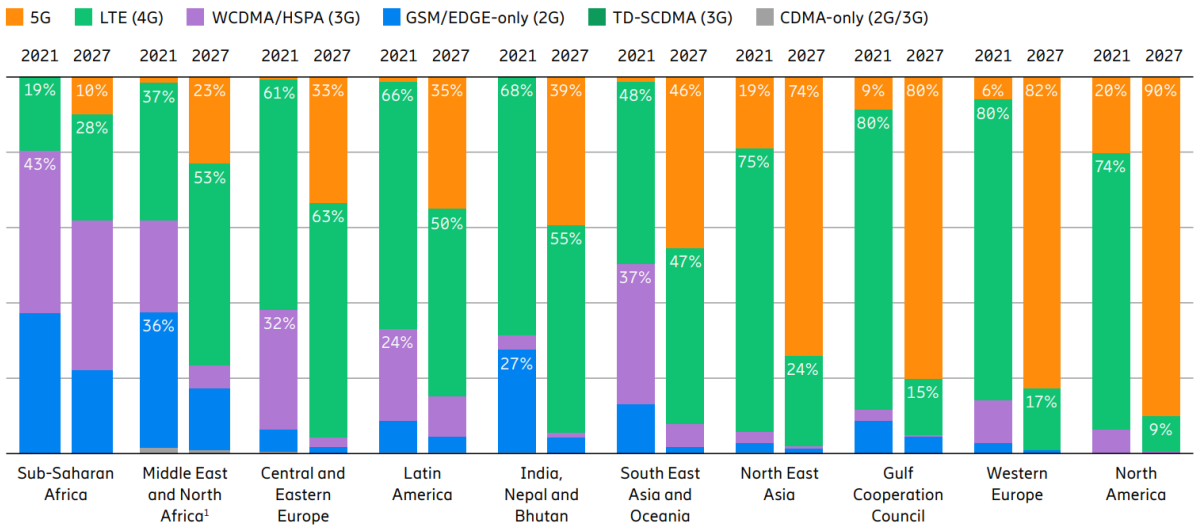


Figure 4 Mobile subscriptions by region and technology (percent) [3]

According to the same report [3], the network transition towards 5G is happening in almost all part of the globe looking into 2020 to 2027 horizon, while the change is much more drastic for Northern East Asia, Western Europe, Gulf Cooperation Council and North America (Figure 4). This shows the timely program and importance of LOCUS project in terms of the chosen technology enablers.

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 services (LBS) 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).

The 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 [4]. Figure 5 presents the attractive opportunities in the LBS and RTLS markets.

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 [4].

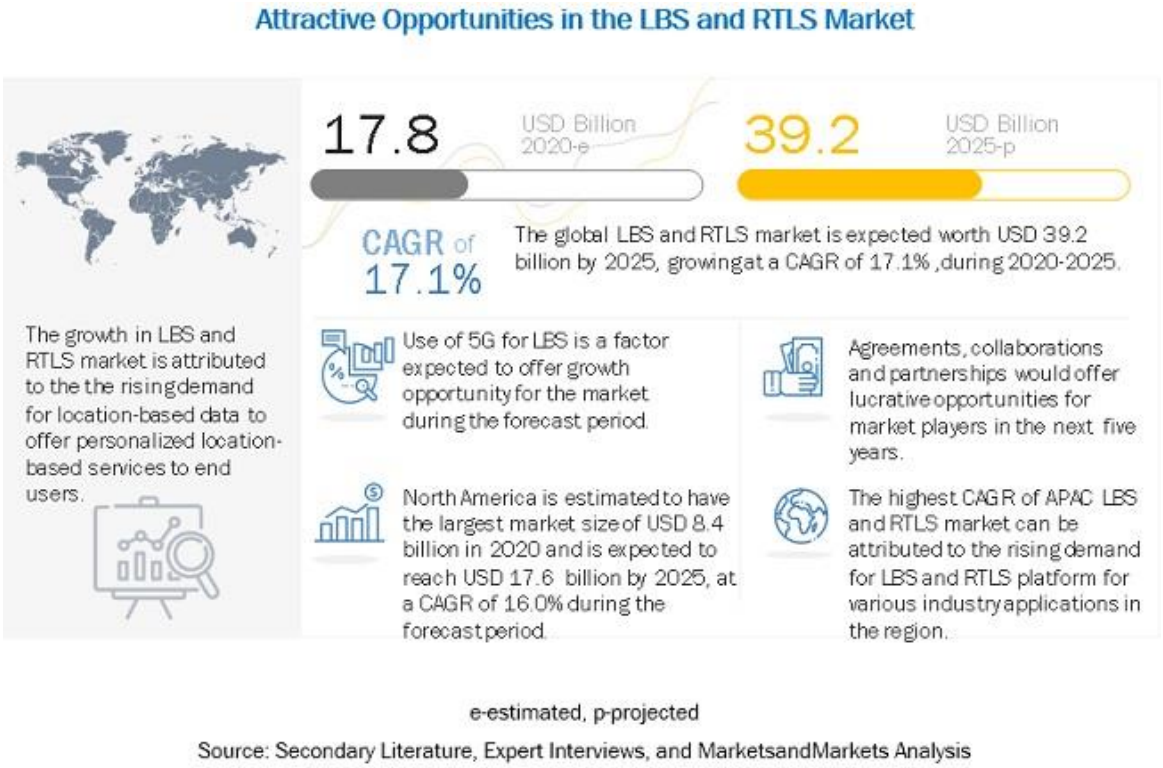


Figure 5 Opportunity analysis in the LBS and RTLS market [4].

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 [4]. 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.

4. Target Stakeholders

The large focus of LOCUS on a wide set of use-cases provided 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.:

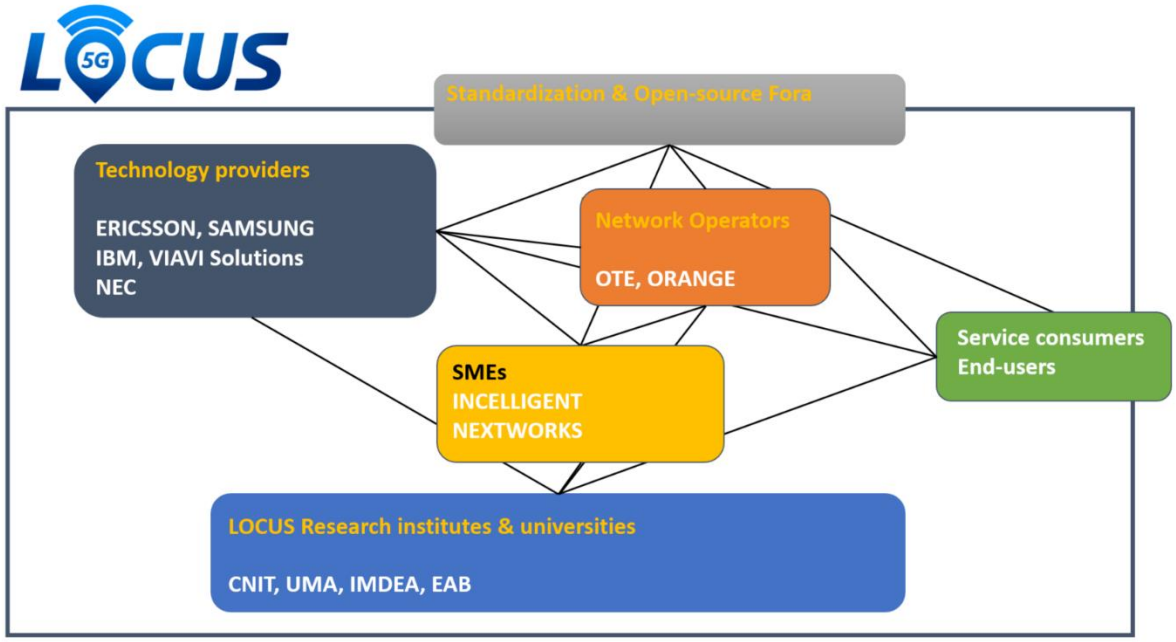


Figure 6 LOCUS partners and target stakeholders

Technology providers, including vendors, large industry and SMEs, are the first to position their products in the new segments that LOCUS defined, 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 are in the position of applying LOCUS concepts to enhance network planning and operations, maximize network utilization, reduce Opex and enhance their service portfolio.

Research institutes and universities, for which LOCUS created 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 allowed 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 provided 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 exposed. A large list of use cases was identified within LOCUS including smart retail, autonomous vehicles, smart manufacturing, logistics, etc.

5. SWOT Analysis

LOCUS generated a meaningful impact on the business of all its partners and is expected to impact also 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 to our view validated project concepts, but also and more importantly acted 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 was carried out within the project as the first step to deliver a business model for 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. Moreover, the PoCs developed in WP6 which are also further explained in this document were other assets in defining LOCUS potential future business plans.

Strengths

Having at least two partners for each localization product and service delivery solution was one of the main strengths of LOCUS.

The wide investigation and exploration of use-cases within LOCUS provided a better knowledge of the end-users demands and requirements in terms of positioning accuracy, availability, and privacy.

The timeliness with respect to the 3GPP standardization work for 5G localization, together with the participation of partners directly involved in such standardization process, eased the exploitation of LOCUS results within the 3GPP.

Automated deployment of localization and analytics services which made 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

Weaknesses

Impossibility of extensive and comprehensive testing and validation of the LOCUS technologies in full blown 5G network deployments, including 5G New Radio and 5G Core.

Lack of deployment and validation in large-scale infrastructures/testbeds and distributed edge/core environments.

Covid19 had a serious impact on experimental activities, shortage and delay in delivery of hardware (still ongoing), and partially on R&D work.

Opportunities

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.
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.
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.

Threats

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.
Service consumers and end-users may be concerned about data and location privacy.

6. LOCUS IPR and Innovation

Intellectual property rights (IPR) are legal rights aimed at protecting the creations of the intellect, such as inventions, the appearance of products, literary, artistic and scientific works and signs, among others. IPRs include copyrights, related rights and neighbouring rights, patents and utility models, designs and trademarks.

IPR potentials were being checked prior to any dissemination by each partner. The strategy for translation of the foreground knowledge into technical inventions could include the possible filing of patents by the partner(s). These actions are assessed to be the adequate form of protection for information and will include specific statements indicating Community support for the achieved results where commercially viable.

The consortium was aware of the services of the Commission's IPR Helpdesk. There has been already Innovations reported via Innovation Radar form for LOCUS and responses have been received and the ideas were secured, and other EU projects and organizations worldwide are aware of these new innovative ideas.

LOCUS delivered a wide range of results in terms of prototypes, test-bed facilities, services/procedures/processes, and data. The appropriate handling of intellectual properties on all these areas was one of the keys for the success of the project and assurance of each partner.

The consortium handled IPR in line with the applicable IPR directives and regulations for H2020 (“Rules for Participation and Dissemination” (http://www.iprhelpdesk.eu/). IPR were managed in line with a principle of equality of all the partners towards the foreground knowledge and in full compliance with the general Commission policies regarding ownership, exploitation rights and confidentiality.

LOCUS innovation activities

A focus group was created within LOCUS in which the standardization and innovation tasks were being followed regularly. This group meets based on demand. All partners involved in the T7.3 have at least one representative in this focus group, and there is also at least one which may need to be evaluated within the focus group. Table 2 provides a list of representatives at this LOCUS focus group.

Table 2 LOCUS representatives in the focus group

Partner	Name
EAB	Sara Modarres Razavi
EAB	Fredrik Gunnarsson
EAB	Gustav Lindmark
EAB	Satyam Dwivedi
UMA	Sergio Fortes Rodríguez

SAMS	Mythri Hunukumbure
VIAVI	Takai Eddine Kennouche
NXW	Giacomo Bernini
NEC	Gurkan Solmaz
CNIT	Andrea Conti
INCE	Kostas Tsagkaris
Orange	Sana Benjemaa
IMDEA	Domenico Giustiniano
IMDEA	Giuseppe Santaromita

LOCUS innovation strategy

LOCUS partners regularly checked and protected the innovative knowledge produced by means of IPRs. The LOCUS strategy is to provide a suitable platform for all partners to not only protect their innovative solutions in their own company or institute, but to also have a shared platform for benefiting from innovative ideas within the project and a joint invention co-sourcing between partners. In WP7, we were responsible for identifying and driving the innovation for LOCUS technical work and goals.

The ownership, protection and sharing of the foreground knowledge, for those cases where multiple partners contribute to a result, and ways of sharing will be considered, such as co-ownership, royalties, licensing, etc.

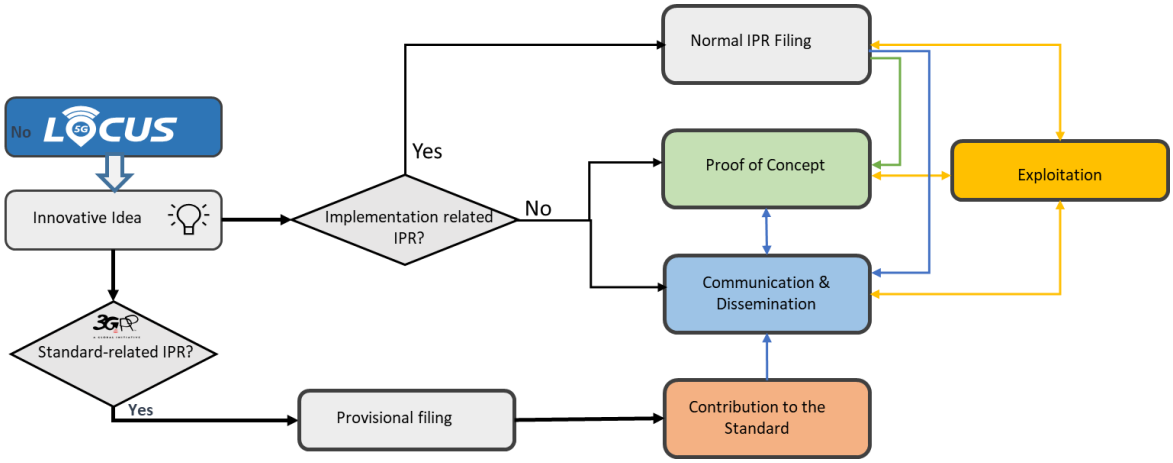


Figure 7 LOCUS Innovation and Exploitation setup

Figure 7 provides a flow chart of how an innovative idea would be evaluated and considered as an IPR filing until it is time to disseminate and exploit it. It is very important to identify within the project whether the idea is standard-related and needs to be shared as a contribution or it is mainly for implementation purposes. In case of standard-related ideas, as it is important to have a timely filing and it is also important to see if the idea would be agreed in the standard, provisional filing can be considered in this respect. In the occasion that after the novelty check of the idea, it is proven that there is no state of the art on the idea, the project will consider filing the idea as a patent. After the patent filing is complete, it is safe to

communicate the idea in the different conference or journal papers, present it as a contribution to the standard or exploit it as a proof of concept or early product exploitation.

IPRs generated within LOCUS

LOCUS partners have generated IPRs and protected ideas within LOCUS in Table 3, more detailed explanation is provided in the submitted Innovation Radar forms prior to LOCUS review meeting in July 2021. We have also provided a new column in this table mentioning the current status of each IPR. As these deliverables are public, we decided not to elaborate further on these IPRs within this document.

Table 3 Submitted LOCUS IPRs

No	IPR Title	Owner	Status
1	Mapping of scatterer locations in a radio environment for device free localization	Ericsson AB	PCT application filed;
2	3D Isosceles Triangle Based Positioning	Ericsson AB	Pending PCT filing after provisional filing
3	Method and System for Supporting Memory Deduplication for Unikernel Images	NEC Laboratories Europe GmbH	PCT application filed
4	Method and System for Monitoring of a Physical Environment's Proneness to Infectious Disease Transmission	NEC Laboratories Europe GmbH	International Search Report received
5	Active Learning System using Generative Weak Supervision for Knowledge Extraction	NEC Laboratories Europe GmbH	PCT application filed
6	System and Method of Energy Management through Building Digital Twins	NEC Laboratories Europe GmbH	Pending PCT filing after provisional filing
7	Long-Term Accurate Crowd Estimation in Smart Cities	NEC Laboratories Europe GmbH	International Search Report received
8	Using Machine Learning to Estimate User Device Spatiotemporal Behaviour	VIAVI Solutions Inc	Application filed

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 ideas for exploitation purposes and reported in Table 4. Note that while a main investigator has been indicated, the innovation is intended with a shared ownership within the consortium. While the selected innovations would remain as work in progress within the owners

community after the lifecycle of LOCUS, here we present the updated status of them by the end of the project.

Table 4 Selected innovations generated in LOCUS

No.	Title	Main Investigator	Status
1	Localization analytics exposed as virtualized services on top of hybrid edge/core virtualization platform integrated with 5G network infrastructures	Incelligent Idiotiki Kefalaiouchiki Etaireia, Viavi Solutions France Sas, Nextworks	**Selected as a technology-ready innovation of high-impact by the European Commission's Innovation Radar**. Currently exploring exploitation potential within the consortium, starting with determining ownership/ IP rights related to this innovation.
2	People (individual and group) mobility analytics as virtualized network functions	IBM, NEC Laboratories Europe GmbH, Viavi Solutions France Sas	This innovation has been analysed by the European Commission's Innovation Radar. It has been estimated that it falls in the Exploring category (more details on this categorization are provided here).
3	5G localization enhancement by pencil beamforming	CNIT	This innovation has been analysed by the European Commission's Innovation Radar. The scientific innovation was then published as “Pencil Beamforming Increases Human Exposure to ElectroMagnetic Fields”: True or False?” in the IEEE Access.
4	Threat detection algorithms fed by high-level data	CNIT	This innovation has been analysed by the European Commission's Innovation Radar. The scientific innovation was then published as “Innovative Attack Detection Solutions for Wireless Networks with Application to Location Security” in the IEEE Transactions on Wireless Communications and two more conference proceedings.
5	Testbed for location security and privacy in 5G networks	CNIT	This innovation has been analysed by the European Commission's Innovation Radar. The testbed has been completed for the positioning activity through open-air interface and the positioning part is presented as LOCUS demo. In the future, beyond the project LOCUS, the testbed will be used to test security attacks to the 5G positioning.

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

Market Maturity of the Innovation: Tech Ready
Market Creation Potential of the Innovation: High

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

Market Maturity of the Innovation: Exploring
Market Creation Potential of the Innovation: Addresses needs of existing markets

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

Market Maturity of the Innovation: Exploring
Market Creation Potential of the Innovation: Addresses needs of existing markets

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

Market Maturity of the Innovation: Exploring
Market Creation Potential of the Innovation: Addresses needs of existing markets

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

Market Maturity of the Innovation: Exploring
Market Creation Potential of the Innovation: Addresses needs of existing markets

7. LOCUS Exploitation Activities

According to Horizon 2020 program the term ”exploitation” refers to “*the utilization of results in further research activities other than those covered by the action concerned, or in developing, creating and marketing a product or process, or in creating and providing a service, or in standardization activities*”.

LOCUS had the potential to generate a significant impact on the business of all its partners. Results produced in LOCUS in the form of reference architecture and specifications, simulations and proof of concept developments validated project concepts, but also and more importantly acted 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.

LOCUS partners were well-aware of the need to early involve policy makers, social and environmental stakeholders aware of project results and discuss the early adoption of results based on a value proposition that can be understood by the public at large, therefore LOCUS organized and participated in several workshops, keynotes, tutorials, and panel discussions. Indeed, communication activities and related efforts are concentrated on selected conferences, workshops, social media (LinkedIn, Twitter), website, press releases, consortium partners’ internal communications, consortium meetings, public events, etc. in order to ensure effective dissemination of LOCUS achievements. More details on this can be found in D7.4.

In the following sections we go through the main areas which we believe LOCUS had an impactful exploitation outcome.

And finally in the last section, every LOCUS partner summarizes the impact of LOCUS within their company/institute.

8. 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 had 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 for a [1][2].

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 [5].

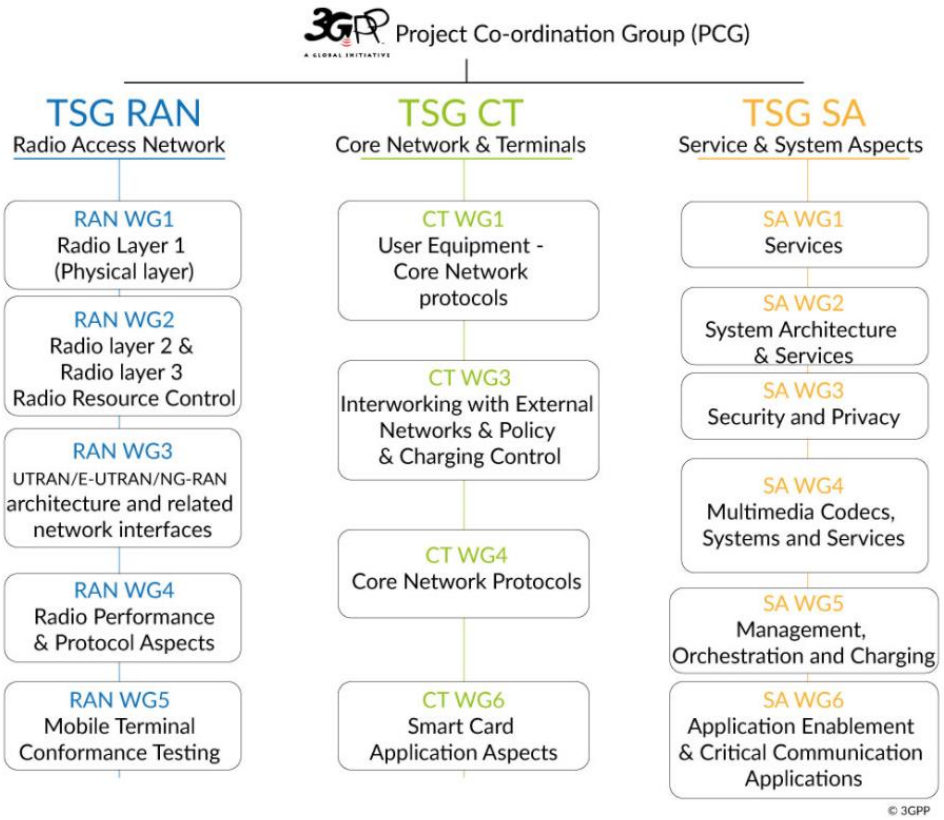


Figure 8 The 3GPP Technical Specification Groups [5]

Figure 8 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 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. Rel-18 also has one of the largest SI/WI on the positioning topic among any other topic in the Rel-18 package. The 5G RAN standardization time plan is presented in Figure 9.

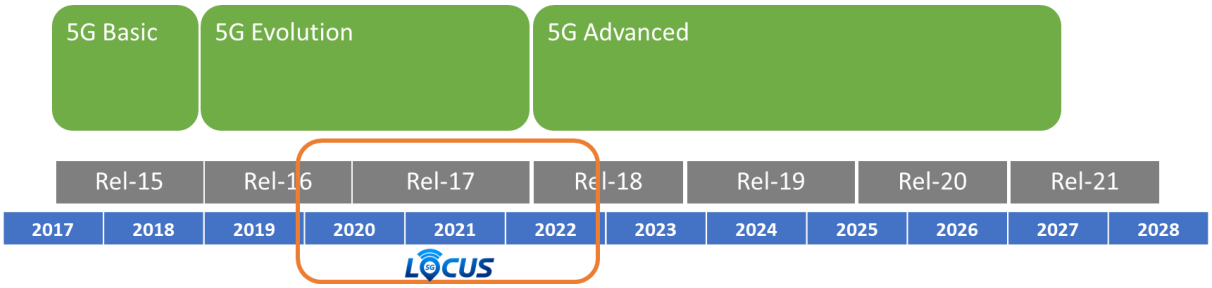


Figure 9 The 5G RAN standardization time plan in 3GPP

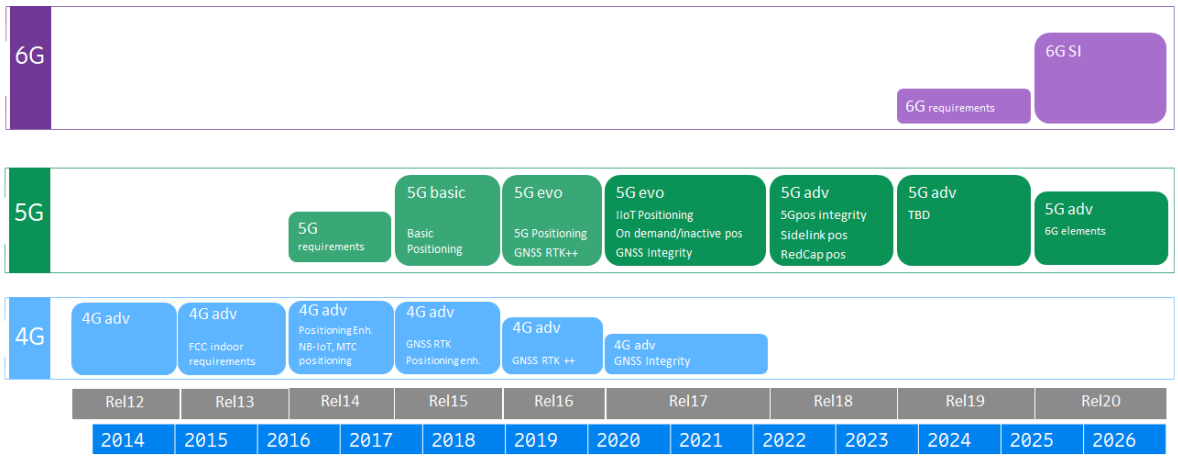


Figure 10 3GPP LTE and NR positioning timeline

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 was extended to Rel-18 work. Figure 10 summarizes the 3GPP positioning timeline from LTE support until 5G and beyond.

The 3GPP related activity within LOCUS is co-ordinated by the 3GPP focus group, which meets every 3-4 months and is led by **Samsung** (as the Standardisation task lead). 3GPP delegates from **Ericsson**

and **Samsung** regularly take part in these meetings and update the participants on the 5G localization and positioning related activity in RAN 1, 2 and SA2 working groups. These meetings have been well attended and have provided a platform to discuss and formulate the collaborations and actions as noted below.

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 3GPP focus group. In Release 18, **Ericsson** continued to provide technical contributions to RAN1 and 2 NR-pos-enh studies, which has relevance to LOCUS. **Samsung** also continued to submit technical contributions to eLCS-phase 3 study in SA2 with LOCUS relevance, with some Tdocs (i.e. Technical contribution documents), directly mentioning the LOCUS project. Most of these Tdocs have been approved in the current study phases.

The time to collision analytics concept (initially developed for the V2X domain but also applicable to other 5G verticals e.g. Industry 4.0) partly developed within LOCUS research by **Samsung** was an extension of the related to the ETSI standardisation work on Cooperative Intelligent transport Systems (C-ITS). Then in 3GPP, a new study item on Ranging was approved for SA2 release 18 agenda. **Samsung** succeeded in taking some of the ideas in the time to collision analytics concept to this study item. Some of the Tdocs directly mentioned the LOCUS project and have been approved in the study.

A full list of 3GPP Tdocs that has relevance to LOCUS or has mentioned the LOCUS project directly will be contained in the Standardisation section of the final deliverable D7.4.

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.

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) [6].

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 made a decision 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.

Telecom Community

LOCUS leveraged 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 was also studied.

Aside from direct LOCUS support in certain standardization fora, there are some general contributions and exploitations from LOCUS which impacted 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 the 5G PPP white papers, including the one 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 the dissemination 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 also participated 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.

Standardization contributions

The complete and latest list of 5G-PPP white papers, keynotes and tutorials and other contributions on behalf of LOCUS partners are provided in D7.4. In some of those contributions the name of LOCUS has been mentioned and acknowledged, while in others the work that has been presented in the contributions were the results of the works happening in LOCUS and have been before or after reported in LOCUS corresponding deliverables.

9. LOCUS Exploitation within Open Source

Open source is source code that is made freely available for possible modification and redistribution. Products include permission to use the source code, design documents, or content of the product. The open-source model is a decentralized software development model that encourages open collaboration. A main principle of open-source software development is peer production, with products such as source code, blueprints, and documentation freely available to the public.

PyTorch

PyTorch is an open-source machine learning framework that accelerates the path from research prototyping to production deployment. **NEC** within the LOCUS work has been contributing to PyTorch with three accepted contributions below. The context of the contribution is the work on the SOL platform (described in D5.3 and D5.4). Code contributions goes from bug-fixes to configuration support for a new hardware platform.

PyTorch (contributors: 2k, stars: 57k)
https://github.com/pytorch/pytorch/pull/59620
https://github.com/pytorch/pytorch/pull/61274
https://github.com/pytorch/pytorch/pull/61275

TensorFlow

TensorFlow is an end-to-end open-source platform for machine learning. TensorFlow provides a collection of workflows to develop and train models using Python or JavaScript, and to easily deploy in the cloud, on-prem, in the browser, or on-device no matter what language you use. **NEC** within the LOCUS work has been contributing to TensorFlow with one pending contributions below. The context of the contribution is the work on the SOL platform (described in D5.3 and D5.4). Code contributions goes from bug-fixes to configuration support for a new hardware platform.

TensorFlow (contributors: 3k, stars: 166k)
https://github.com/tensorflow/tensorflow/issues/55497

OpenAirInterface

OpenAirInterface (OAI) is an open-source initiative that provides a 3GPP compliant reference implementations of key elements of 4G LTE and 5G NR Radio Access Network (RAN) and Core Network (CN). It allows users to set up a 4G/5G network and inter-operate Commercial Off-The-Shelf Software Defined Radio (COTS SDR) cards like the USRP.

On the Core Network side, 5G CN (5GC) architecture is designed to be natively deployed and operated on top of virtualized infrastructures using Network Functions (NF). The main components of CN are implemented by OAI developing each NF in separate docker composes. The message bus between the NF is a service-based interface (SBI). The SBI employs RESTful API principles over HTTP/2, and it is implemented over the C++ pistache framework.

IMDEA, within the LOCUS work, has developed a prototype of NF, relevant for the project and for localization, namely Localization Management Function (LMF), a function currently missing in OAI. The connection between 5GC and LMF occurs via the Access and Mobility Management Function (AMF) module via an SBI called Nlmf. **IMDEA** has developed this last part, then fully integrating this LMF module implementation into the 5GC OAI dockerized environment, ensuring full compliance with 3GPP and OAI standards.

The LMF implementation could be used to determine the position of UEs through 3GPP standard compliant procedures, to coordinate and schedule resources, or to calculate or verify a final location, estimate velocity, and compute the achieved location accuracy. LMF efficiency was fully characterized in terms of CPU utilization, throughput and latency varying the number of users and the volume of requests for the location service. The result of the work was accepted in two papers, an ACM MOBICOM demo (in the main track) and an IEEE NFV-SDN'22 paper, and the source code has been released and is available online in [8].

10. LOCUS Wiley Book

The book “Positioning and Location-based Analytics in 5G and Beyond” have been approved to be published by Wiley. The authors of this book are mainly from LOCUS and few from other relative projects and companies.

The content and chapters of this book include Positioning Enablers (i.e. Positioning Methods, Standardization in 5G and 5G Advanced Positioning, Enablers towards 6G Positioning and Sensing, Security, Integrity and Privacy Aspects), Location-based analytics and New Services (i.e. Location and Analytics in Verticals and Location-aware Network Management) and Architectural Aspects for Localization and Analytics (i.e. Location-based Analytics (platform) principles, Location-based analytics as a Service Platform basis and Reference Standard Architecture).

The reader will benefit from understanding how the 5G localization technology and requirements will evolve in the future and how context-awareness, which relies on accurate location information of people and things, is essential for a variety of existing and emerging applications. On the other hand, the location-based analytics industry is driven by the increasing use of spatial data and analytics tools. The rising need of predictive analytics for businesses and the increasing use of location-based applications further contributes to the grow risk of the location-based analytics market. The location-based analytics market is segmented into:

- 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) the of the location-based analytics market

Since fundamentals of localization, analytics, and architectural principles are also covered in the book, it is not intended for specialists, although an understanding of network communication, inference, machine learning, and cloud computing is recommended to fully appreciate the more advanced chapters. Potential target readers are:

- Students and researchers from institutes and universities
- Telecom specialists not necessarily experts .
- Technology providers and vendors
- Network and service operators
- Standardization fora
- Open-Source fora
- Service consumers/end-users

11. LOCUS Knowledge Transfer

Localization is a rapidly evolving field both in the research and standardisation domains. Hence there is a notable need and a demand from the wireless research and student communities to gain the latest knowledge from projects like LOCUS. The LOCUS project has identified this knowledge transfer as a priority, so that the wider community can also benefit from our beyond SoTA research and contributions to the standardisation. The following planned activity is one of the key examples of this knowledge transfer. Deliverable 7.4 provides a complete list of similar knowledge transfer activities from all partners during the whole life cycle of the project.

- *An industry panel session titled 'Localization and Sensing in 5G-Advanced and Beyond - Research and Standardisation Outlook' at the IEEE GLOBECOM conference, 04-08 Dec. 2022, Rio de Janeiro, Brazil. This panel will be moderated by Mythri Hunukumbure (SAMS) and will include the following experts connected to the LOCUS project: Andrea Conti (CNIT), David Estevez Gutierrez (SAMS), Sara Modarres Razavi (ERI), Joerg Widmer (IMDEA).*

12. LOCUS Proof of Concepts

LOCUS targeted three PoCs in WP6 exploiting the concepts and platforms developed in other WPs. The following section presents an elevator pitch on each of these PoCs while they have been extensively discussed in WP6 deliverable.

PoC1:

Elevator Pitch: PoC1 demonstrates the LOCUS Platform Capabilities, in delivering real-time positioning and actionable analytics for network management. PoC1 leverages 1) OSM MANO to deploy Containerized Network Functions, on a cloud infrastructure, 2) RabbitMQ as the message broker, allowing the composition of end-to-end storylines, 3) A persistency service to store actionable data and enable scenarios where pre-existing data can be exploited to boost online processes, 4) An anonymization service allows hiding the actual estimated user location with different methods, this can be used in real-time in situations where anonymization is required, and when the additional positioning error incurred by such anonymization can be tolerated by a network management service. Two storylines where implemented, both relying on an integration with a physical testbed where RAN measurements are initially captured, and a cloud cluster, where OSM-managed CNFs are deployed, implementing data provisioning, processing for location estimations, anonymization, network management, etc. The first storyline serves contextualized indicators, that enrich network data with location information, this empowers network troubleshooting and diagnosis use-cases. The second storyline serves radio coverage maps based on dispersed and positioned UE traces, using data-driven interpolation, this empowers coverage hole detection and network parameters correction uses-cases.

PoC2:

Elevator Pitch: PoC2 goal is to simulate operation of logistics in a seaport terminal where Automated Guided Vehicles (AGV) are used to shuttle general cargo freights between the reception and the warehouse area at goods arrival in the seaport and between the warehouse area and the crane during the loading operations. The general cargo freights are goods characterized by variable size and shape (e.g., crates, pipes, vehicles). The PoC addresses the aspects related to the verification of the performances of the 5G positioning system in this operative scenario. The activities of a real seaport terminal are simulated using a realistic digital twin of a seaport terminal. The inputs from a simulated 5G positioning system feeds the AGV navigation system to drive it during its shuttling operations. The PoC can show how localization accuracy and latency can impact the successful pick, transport, and placement of freights in the planned positions.

PoC3:

Elevator Pitch: The purpose of PoC3 is to demonstrate the delivery of Location-based analytics as a Service to 3rd parties on two different levels. On the first level, it presents the analytics provided that focus on people flow monitoring and crowd mobility aspects, including detecting Points/areas of interest (POIs), popular path/trajectories, predicting the future trajectories of UEs, monitoring/detecting crowds/groups of people, etc. The applicability of these analytics for 3rd party applications is highlighted by the various contexts they are presented within the PoC, i.e. flow tracking in a commercial environment, transportation optimization, crowd monitoring applications, as well as APIs exposed for trajectory prediction and collision detection. On the second level, it illustrates the use of the LOCUS Platform various internal components that allow through an API Gateway the exposure of those advanced analytics.

13. LOCUS Exploitation Impact for each partner

All LOCUS partners consider the studies and research in this project to be beneficial and have significant impact in their company or institute on so many different levels including economic, market and business aspects. Table 4 summarizes the impacts of LOCUS project on the business and missions for each partner.

Table 5 LOCUS impacts on each partner

Partner	Exploitation Impacts
EAB	*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 is part of the input to the Ericsson Network Localization (ENL) product. Moreover, Ericson has been actively involved in Rel-16, 17 and 18 3GPP standardization work and being part of LOCUS together with other standardization partners provided the opportunity for exploring LOCUS solutions within 3GPP and vice versa.* *EAB works on concepts, research, standardization and evaluations in general, including positioning. Ericsson always brought the most recent information from the 3GPP standardization work, and feedbacks insights from LOCUS into standardization work. During 2020, Ericsson was fully engaged in finalizing the Rel-16 work item (WI) on positioning and the Rel-17 study item (SI) which was also in respect to study the enhancements of 5G positioning beyond what was possible in Rel-16. In 2021, Ericsson was again involved in Rel-17 WI, which its finalization was postponed until the end of 2021 due to COVID-19 situation. Ericsson attended all the E-meetings and finalized the Rel-17 SI and WI and updated LOCUS in this regard. The new Rel-18 3GPP work, which is the beginning of 5G-Advanced era, is being covered by EAB with full engagement in both e-meetings and F2F ones. EAB contributed to all agenda items within both positioning SI and also AI/ML SI that has positioning as one of its use-cases. Moreover, EAB is involved in the scoping of Rel-19 in which Sensing is already agreed to be part of it. The work in LOCUS has been a great support for EAB's engagement within 3GPP.*
SAMSUNG	*As the market leading Smartphone vendor, research on localization technologies that impact the mobile device are of huge significance to Samsung. Recently there has been a lot of interest in UWB (Ultra Wide Band) based localization, due to the very high precision achievable with*

	UWB. Many Smartphones, including Samsung models now contain this UWB positioning capability. In the LOCUS project, the Samsung Research UK (SRUK) team studied some of the limitations of UWB localization and proposed a novel concept of combining UWB with 5G-NR positioning, as contained in D3.4. SRUK was able to draw the attention of Samsung HQ teams on this concept, with the simulation results on the net gains that were achieved through research in LOCUS. This work has been highly noted in Samsung research and standards teams in the HQ, including teams that contribute to the FiRa standardisation. *Since Jun 2020, SAMSUNG has been directly involved in the work of new ISG group in ETSI called E4P ("Europe for Privacy-Preserving Pandemic Protection"). Its standardization scope is partially related to COVID-19 work in LOCUS. SAMSUNG is currently a rapporteur of the 'Device-based mechanisms for pandemic contact tracing systems' Group Specification and as part of this role organized drafting sessions, attended plenary meetings and drafting sessions of complementary specs. On the technical side, SAMSUNG contributions include updating the device-based mechanisms Group Specification draft and others, substantial input to E4P reference pandemic contact tracing systems architecture work, Back-End Task Force and high level and interoperability requirements definition. To allow LOCUS insight into E4P work progress so far, E4P status and roadmap presentations have been provided to WP5 and also draft E4P specifications were shared. In addition, suggested directions for its ongoing COVID-19 use cases work, and the potential LOCUS contributions to E4P in the future have been identified. This work has been supported by Samsung to make sure interoperable international implementation of the future digital contact tracing systems is enabled.*
OTE	*The evolution of location-dependent services and applications in mobile networks continues to require the development of more accurate and reliable mobile positioning technologies. LOCUS results in the field of improved positioning using 5G networks are expected to have an impact in the development of future OTE's services portfolio. Precise location data will contribute to the identification of new market opportunities in the proximity of their assets creating thus new sources of revenue and growth and will assist in the future network planning and /or expansion in a cost-effective manner.* *OTE is the dominant telecommunications operator in Greece, and along with its subsidiaries one of the largest telecom groups in South-eastern Europe. As of that, 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, so that 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. *OTE, as the key market player and the incumbent telecommunications provider in Greece, is always seeking for new business opportunities, aiming to the growth and competitiveness of its portfolio. OTE Group of Companies recognizes the necessity to have a clear view of the trends, standards and roadmaps that shape the 5G sector and which will allow its services to better position and align with the market needs. For this, OTE encourages innovation and development actions related to ICT domain. LOCUS platform can assist in redefining new business processes and location-based analytics use cases can enable the design and the deployment of future business models. Finally yet importantly, OTE is always exploring new exploitation opportunities with partnerships with other consortium members, raising the level of business relationship and developing a partner ecosystem.*
UMA	*UMA obtained important benefits from LOCUS. The participation in a European project in collaboration with the main companies of the mobile communications sector is a significant advantage increasing the opportunities to obtain future national and international projects. Results obtained in LOCUS were published in high impact journals increasing the prestige of the research group in the scope of the project. In addition, several PhD theses were supervised in the project improving the training capacity of the research group involved in LOCUS.* *UMA focuses its exploitation plan on the collaboration with companies within the project and external to the project. The project results were disseminated to the local companies by the links 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, possibly in collaboration with these companies. Based on the project results in WP6, UMA considers offering its testbed as a research infrastructure to external parties. Finally, an analysis will be carried out on the opportunities of creating a spin-off company based on the project results by means of the UMA incubator programme.*

NEC	*Use cases of LOCUS gave inputs for the internal research on situation awareness. In particular, Covid-19 use cases and indoor tracing of the infections using multi-modal data from sensors. 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.* *NEC Laboratories Europe considers exploitation through standardization in bodies such as ETSI ISG (particularly ETSI ISG CIM). 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 partners. NEC plans to exploit the outcomes of the LOCUS projects in some of these collaborations where applicable. Further, NEC research groups aimed for IPR filings for 5 patent applications based on the outputs of the LOCUS project. NEC collaborates with iICRC for a project related to humanitarian aid application… Lastly, NEC applied an algorithm developed in the LOCUS for the building occupancy in the University of Murcia campus in Spain as part of the Distributed Computing Intelligence (DCI) project.* *Japan side of NEC 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.*
VIAVI	*LOCUS provided an opportunity for VIAVI to explore 5G localization methodologies with the objective of making localization 5G native as a service. This will support VIAVI to build the global R&D relationships in 5G systems by cooperating with key vendors, operators, and leading research centres and universities across Europe. VIAVI exploits output results of LOCUS research activities and trials for future development of geolocation solutions, network optimization and orchestration. We also seek collaborative research to build industry consensus that can lead towards standardization, in particular within 3GPP and O-RAN.*
NXW	*Nextworks is a technology provider and software SME active in the ICT and telecommunication sectors. The participation to LOCUS substantially contributed to identify and develop innovative solutions in the area of location-aware service management and operation. There is a concrete path and opportunity for turning these results (at conceptual, architectural and software prototype levels) into company assets and knowledge services for the Nextworks ICT market. Nextworks has indeed a wide portfolio of consultancy services [7], which include training courses, technology support, and third-party software development offers that are highly impacted by the new knowledge derived from the LOCUS outcomes. In LOCUS, Nextworks has*

	substantially contributed to the design, development, integration, validation and demonstration of the localization analytics as a service platform, with main focus on the aspects related to analytics service management, orchestration and exposure on top of the hybrid edge/cloud virtualization platform. The developed and validated LOCUS solution is perfectly aligned with the company strategy and interest of looking towards beyond 5G and 6G service orchestration frameworks with native integration of in-network analytics, AI and ML capabilities and services. In practice, the software prototypes developed by Nextworks for the LOCUS localization analytics as a service platform provide concrete innovation and contribution to the existing company research-oriented network and service management portfolio, which already include several tools and solutions for 5G network slice and service management. On top of these heterogeneous results and assets, Nextworks lays the foundation of its R&D group knowledge and technical background, which is fundamental to be competitive in the telco consultancy market with cutting-edge beyond 5G and 6G ideas and solutions. This highly contributes to position the company as an ideal partner for carrying out third party software development activities, as well as pilots targeting 5G Non-Public-Networks (NPN)s in industrial scenarios involving vertical players and small-medium scale telco operators. *Beyond these pure research and innovation exploitation opportunities, Nextworks actively develops and markets an IoT platform called Symphony [7]. Nextworks is actively working on evolving the Symphony platform towards a generalized industrial IoT (IIoT) solution, with the aim of entering the smart manufacturing market. As detailed in the dedicated section on Improved services and platforms, Nextworks plans to integrate part of the LOCUS outcomes in this Symphony transition to offer a comprehensive IIoT solution with embedded (localization) analytics and AI/ML capabilities.*
CNIT	*CNIT is obtaining important benefits from the Project LOCUS. First of all, the participation to a Project such as LOCUS enabled 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. Second, but not less important especially for the younger researchers at CNIT, the project represents an essential component for the growth of next-generation workforce. CNIT focuses on exploiting the developed techniques for location awareness inside the project (in collaboration with companies internal to the project) and outside the project. By working with companies inside the project, the aim is to impact 3GPP TRs in preparation offering new solutions for high-accuracy localization, especially for harsh wireless environments, that are fully compliant with the ongoing standardization process for 5G and beyond. CNIT also disseminates his 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.
IMDEA	*The research conducted in the project is strengthening the scientific excellence of IMDEA in 5G localization, and it is perfectly aligned with IMDEA mission to perform first-class research, publish at top-tier conferences and journals in the area of computer networking, ensure successful technology transfer to the industrial sector and the creation of spin-offs.* *IMDEA exploits the results of the LOCUS project by exposing the PhD 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. The 5TONIC open research and innovation laboratory for 5G technologies, hosted by IMDEA and of which IMDEA is a founding partner, will represent 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.*
INCE	Incelligent is a software SME with specialization in the area of big data and analytics for telecommunication sector and other verticals including private 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 as well as various vertical applications. The localization technologies and location-based enablers and APIs designed and validated through LOCUS, will highly impact Incelligent, particularly by 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). *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 will exploit the localization-centric principles, concepts and technologies developed within LOCUS for extending its platform's set of APIs/services and eventually supported vertical applications, in order to enrich the company's product portfolio and offering towards its customers. The same stands for service-based*

	projects. As a matter of fact, Incelligent is already exploiting concepts and know-how gained through LOCUS involvement for implementing location-based analytics use cases in one of its customer telco operators. 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 and marketing oriented use cases. Last but not least, Incelligent is continuously looking for further exploitation through funding opportunities for its products, new business plans and/or spin-off schemes. Such an opportunity has arisen through the European Commission's Innovation Radar, where work by Incelligent and others within the consortium related to the LOCUS Platform has been selected as a technology-ready innovation of high-impact. In this context, Incelligent is currently exploring the potential for exploitation along with other innovators within the consortium, initiating a decision for the determination of ownership/IP rights related to this innovation and possible avenues for exploitation.

14. LOCUS Exploitation in Industry and Business Plans

Technology providers, including vendors, large industry and SMEs, are 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 LOCUS impacts that has been exploited and appreciated within the industry and academic communities.

New & 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 from the project results, to increase its market profile further. **OTE** aims to exploit the expected LOCUS concept by initially verifying the proposed platform and then coming up with a plan of "how to promote it" into its existing and 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 actively participating in LOCUS project, **OTE** could exploit the services and the features developed in its commercial network and through trials will investigate the opportunity 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 will exploit 5G localization and analytics functions in new services that will improve customers' experience.

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.

Improved services and platforms

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 evolving Symphony towards an Industrial IoT (IIoT) platform called Symphony Factory Edition (FE), aiming at positioning it in the smart manufacturing market. Symphony FE aims at 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. In very complex, dynamic and heterogeneous industry 4.0 contexts (in terms of deployed technologies, tools, services, etc.) the integration with (localization) analytics and AI/ML services is becoming a key requirement to make IIoT platform effectives in their control, monitoring and actuation capabilities. Moreover, accurate localization information (especially considering device-free and non-3GPP solutions) can highly impact production processes optimization in those scenarios with high mobility of shopfloor assets and systems. In this context, Nextworks believes that the technologies developed in LOCUS, including the various analytics services, ML models and data movement interfaces, can be of highly benefit for the Symphony FE to enhance and improve the support of localization-enabled manufacturing services and assets. In particular, the localization analytics as a service solution developed in LOCUS represents a valuable asset for the Symphony FE, which can leverage on the in-network analytics information exposure and AI/ML pipeline virtualization and management solutions for optimizing its control and actuation logics in small scale private and industrial networks. Specifically, 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) analytics capabilities will help Nextworks to be more competitive in providing a comprehensive technology solution for enterprise and IIoT 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 involvement 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.

NEC has new and on-going work with humanitarian institute ICRC (International Committee of the Red Cross) for a project related to humanitarian demining. NEC plans to leverage the machine learning algorithms developed in the LOCUS for humanitarian data space. Further, NEC currently applies a machine learning algorithm developed in LOCUS for the building occupancy prediction in the University of Murcia smart campus project in Spain. NEC plans to leverage the machine learning outcomes for the smart campus.

VIAVI will exploit the output results of LOCUS research activities and trials for future development of geolocation solutions, network optimization and orchestration.

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 high volume 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.

Shaping 6G & beyond 5G

The timing of LOCUS has been very vital for the fact that this project becomes a significant source for shaping the positioning and localization paradigms in beyond 5G and 6G. LOCUS was started when 5G networks was initially starting to grow worldwide, and the positioning standardization work was fully considered in the agenda of 3GPP during the whole LOCUS lifecycle. The extension of the project due to COVID 19 pandemic, allowed us to continue our work in the 3GPP Rel-18 time frame as well. This means that we were able to impact the 5G-Advanced technology and solutions as well. Moreover, the topics such as sensing which was called device-free-localization within LOCUS is now part of the scope of Rel-19 3GPP work. Many of the concepts studied within LOCUS are very likely to be part of the solutions in 6G and this is extensively covered in the LOCUS Wiley book.

15. LOCUS Exploitation through Collaboration Links

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.

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. 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 is 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 is currently exploited in the HOP-5G project.

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.

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 continuously looks 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 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 represented an essential component for the growth of next-generation workforce.

16. LOCUS KPIs Assessment

Key exploitable results are assessed in terms of development status, facts and figures that facilitate the assessment of the potential impact, differences from existing competing products/services, etc. In order to enable a project evaluation and assessment both internally and externally, we set the following project exploitation targets for LOCUS shown in Table 6. Fulfilling these targets required full engagement from all partners. The values are set for the whole life cycle of the project and each year we tried to see how much we have approached these targets and in case we were exceeding these goals in any way. These numbers have been set in a way to be reasonable in terms of the early commitment of every partner to fulfil the target goals and then with some extra effort we shall be able to exceed the expectation and feel satisfied and accomplished from the project output. Now in the finalization of the project, we see that LOCUS has successfully managed to exceed all our early targets with large margin in most areas. We are internally very proud of this outcome and assessment. This is indeed an outstanding result despite the fact that we were completely challenged with the COVID 19 pandemic for 2 years and not being able to meet each other for all this period.

Table 6 List of project targets and assessments

Goals	Target	Exceeding Target	Actual Outcome	Assessment
LOCUS Open-Source contributions	1	> 1	5	Exceeded
LOCUS Standardization contributions	4	> 4	32	Exceeded
LOCUS IPR filing	2	>2	8	Exceeded
LOCUS involvement in exploitation external activities	3	>3	8	Exceeded

17. References

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