



6G Smart Networks and Services Industry Association

Smart city trials in Europe – Summary of activities in smart city vertical segments/use cases

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Executive Summary

This document concentrates on 5G and communication systems in concept of Smart City vertical, basic requirement and expectations of various stakeholders for future communication infrastructure. The report provides summary of the key 5G PPP Phase 3 projects related to smart city use case trials and validations. The more comprehensive information of project foci and results can be found from each project web page. The selected use cases for some of the projects are also presented in annual 5G PPP Trials and Pilots brochure, which is available at [5GPPP-T&P]. The part of the work on expectation and best practices for innovation and experimentation facilities and building the platforms was carried out with interviews for Digital Transition Partnership actions. Part of the summary on joint innovation and city partnership networks is also available in public within Urban Agenda for EU – Digital Transition Partnership progress report documents at EC and thus reflects the advances and requirements also outside 5G PPP and collaboration with European city networks.

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1 Introduction

The main phase of 5G commercial deployment was started in Europe and European Union member states during the 2019 and 2020 after the frequency allocations were completed in different member states. The commercial deployments have carried out mainly for enhanced mobile broadband (eMBB) services in 3,5GHz spectrum area and for example ultra reliable and low latency communication (URLLC) supporting use cases have been main non-commercial trials and demonstrations e.g. for local industrial use cases. The majority of 5G New Radio (NR) deployments have been carried out with non-standalone solutions, which are relying still the 4G/LTE RAN and core anchor. However, the standalone NR deployments are under way and those will enable the full potential of 5G NR capabilities. The deployments for 5G millimeter-wave new radios are expected to happen in earliest 2021/2022, and it will be still seen their relevance and usability in smart city use cases, although several potential use cases can be already seen including e.g. accurate positioning and high bandwidth hot-spot connectivity in urban areas.

In this document we address some of the aims and focus of 5G for European City Trials, smart city uses cases and activities in European innovation ecosystems and smart city networks. In addition the document will provide insight for the current 5G PPP projects related to Smart City trials and pilots and gives some insight of best practices related building and managing open innovation ecosystems to build smart city use cases and applications.

In the beginning of 5G development, large number of visions was thrown in the air about use cases and usability of new technology for different use cases. Several use cases were defined also for smart cities, urban city areas and citizens wellbeing. Today, the first deployments have started through which we have some understanding of technological readiness of 5G, so it is possible make evaluations, which kind use cases and application have been realized or has potential to be realized, and how 5G reflects to smart cities use case expectations. In overall, today for example the telecom operator deployments can enable large scale trials to demonstrate the 5G benefits for urban city, while before, the demonstrations have been only small scale trials or laboratory demonstrations of different technology features.

Already earlier several European cities announced their plans to become 5G Trials Cities, at the forefront of 5G experimentation and trials, where the different involved stakeholders come together to enable societal infrastructure benefits to the public. Several open innovation platforms and living labs have been defined in European cities to improve and enable the smart city use cases and citizen involvement. The 5G will be clearly the essential part of future cities, and to conduct relevant trials is a way to ensure the development of the best feasible 5G solutions further. It is essential that the technology development also for communication technologies and smart city requirements will match, and in addition, the maturity and availability of technology is also in reach of cities and citizens for the open innovation purposes. This document will illustrate and point out the main requirements for new technology from cities and civil engineering point of view in order to enable for example the wellbeing of citizens, development of services and sustainable growth of city.

2 Background and motivation

Successful digital transformation is in key role for European cities and municipalities to keep their essential services relevant and available to the public in a cost and resource efficient way. The key role of sustainable urban development and digitalization of public services in the transformation towards greener and more equal societies is highlighted also in many recent European agenda and policy documents [LeipzigCha, BerlinDec, LivingInEU], and the current COVID-19 pandemic has made the need for this change more evident than ever before. For smart cities, digital transformation is not enabled only by the various emerging technologies, but also by the new and innovative ways how these technologies are combined and utilized in parallel with the existing city infrastructures. A large variety of stakeholders is required to work towards a common goal in the ecosystems supporting and driving this change, and often, pilot implementations and experimental evaluations are the only way to verify the feasibility of new use cases and digital service concepts in scale. Open innovation platforms and living labs are an essential tool for the ecosystems to collaborate on such pilots and experiments utilizing digital services and emerging technologies.

Today and in future, cities are the places where also first experimentations and deployments of new communication technologies take place. This has been the case, e.g., with the fifth generation telecommunication system (5G) technology experimentations carried out by industry and academy. The rollout of 5G for example has started and proceeds in cities across Europe by telecom operators and technology vendors. However, how to involve citizens and different business ecosystem actors to benefit from new technology has been the challenge. Enabling new information and communication technology, such as 5G, facilitation in open innovation platforms and open public places, will pave way also for further development of new technologies and services. For this, city facilitated innovation platforms and living labs are important, not only, from citizen and city services, but also technology developers and business point of view.

In addition to the many national digital agendas and 5G deployment roadmaps published by the EU member states, different collaboration networks of European smart cities have published their views, roadmaps and requirements on the 5G deployment and use cases. One of the important networks in Europe is EUROCITIES, which is a network of about 190 cities in 39 European countries. Their main vision is to ensure good quality of life for all the citizens in Europe and achieve this by working together. The main goals for EUROCITIES include for example:

- **People taking part in inclusive cities;** tackling the problems of for example poverty and social exclusion, housing and homelessness, childcare, education, and migration.
- **Prosperous cities;** boosting the local innovation ecosystems, jobs and skills finance/investments, new business models, and circular economy.
- **Healthy and moving cities;** tackling the problems of pollution including air and water quality and noise pollution. Improving food security, farm-to-fork processes and sustainable food production, storage, distribution and consumption. Boosting the clean and active mobility, digital and automatic mobility and transportation.
- **Vibrant Cities;** enriching culture and creativity, inspiring people with design of attractive public spaces, finding innovative use of open and private public spaces and boosting cultural, art and community activities in those. Enriching green areas and taking in to consideration biodiversity in urban planning.

- **Localizing global challenges;** fighting to mitigate global warming and adapting to climate change in local city level, and targeting to the transition to climate-neutral society. Supporting the collaboration in different levels of city government, e.g., in key areas such as renewable energy, building, and transportation. Fostering the territorial and multi-level collaboration in digital transformation to boost the opportunities of data technology, and tackling the increasing concerns of privacy, security and accountability issues. In addition, managing the emergencies and crisis such as COVID-19 and their recovery actions have become essential also from collaboration point of view.
- **Innovative city governments;** Supporting and enhancing the citizen engagement in city governance, guaranteeing gender equality. Diminishing administrative borders in order to boost metropolitan area governance and increase urban-rural collaboration to enable sustainable and inclusive urban transformation. Improve collaboration between municipalities e.g. on local food supply and waste management, and circular economy.

These targets are also driving the smart city needs for telecommunication systems and data platforms, new technology trials, and application development in future. EUROCITIES as large collaboration network of European cities has also delivered a statement on 5G deployment, including the following requirements EU should ensure [EURO5G]:

- Balanced and fair 5G deployment – fostering equal distribution of 5G networks also in less densely populated areas, helping to reduce the digital divide and offering equal opportunities to all local ecosystem actors by safeguarding the EU network neutrality rules.
- Responsible and safe 5G deployment by coordinating and providing the information of impact of 5G on human health and environment with providing funding to support research on possible long term effects and implications.
- Sustainable 5G deployment in cities and common EU protocols on design of small cell devices to preserve visual identity of public spaces.
- Common and simplified regulatory framework on the use of public infrastructures to deploy 5G – telecom operators’ liability rules to guarantee safety and security, and cost coverage for management of these public infrastructures.
- Clear governance rules about 5G data sharing platform, responsibility and liability of data management.
- Strengthened collaboration with city governments for deployment and implementation of 5G, including the development and testing of future fit policies and use and impact of new technology.

This statement is well aligned with the need and development of open innovation platforms and experimentation facilities in EU.

The European Commission funded research on next generation mobile networks and future network technologies has been driven mainly by 5G Infrastructure Association (5G IA) and 5G Public Private Partnership (5G PPP). The different trials on 5G technology in variety of 5G PPP projects has been carried out still as private trials, however during the last years some of the trials has been extended also as public trials in cities [5GPPP-T&P]. These pilots and technology trials, especially conducted in partnership with city authorities and public organizations, e.g.,

universities and research and technology organizations (RTOs), are paving the way for development of larger experimentation and innovation platforms.

In the 5G IA Trials Working group view, it is important for the development that the different involved stakeholders will come together to enable societal infrastructure benefits to the public, as new technology provided by 5G is seen as an opportunity to enhance and enrich the public services, increase the cities attractiveness and streamline the cities functions. It is also seen that there is a clear need to modernize city governance and processes in the framework of constrained public expenditure, and a related demand for deploying disruptive technologies enabling further digitization in public service delivery. For this, the open innovation platforms are essential tools [5GRoadmap].

3 5G Use Cases and Technological Enablers for Smart Cities

The 5G is part of cities already now, and to conduct relevant trials is a way to ensure the development of the best feasible 5G solutions. The initial private trials, which were carried out by technology vendors and telecommunication operators, has laid the foundation also to city trials and pilot deployments, forming the basis of further commercial 5G deployment and use in city environment. In addition to private trials, the large scale publicly funded open test networks and trial environments, e.g., 5G Test Network (5GTN) [5GTN] in the city of Oulu, have been utilized as the first platforms to conduct also the city trials and public service pilots. These test network environments, funded by e.g. European Commission and EU member states, bring together both commercial technology vendors, operators and service providers as well as public authorities and academia, setting the initial ecosystem for further commercial deployment of 5G networks and services.

Within the 5G IA and 5G Trials Working Group, several smart city use cases have been reflected against the 5G functionalities. As example, the following Table 1 illustrates some of these technology requirements relevant for development of open innovation platforms for the smart city related use cases. The requirements are presented in the form of the required 5G services, i.e., ultra-reliable and low-latency communications (URLLC), massive machine type communications (mMTC) or enhanced mobile broadband (eMBB), and additional functionalities.

Table 1. Use case requirements for 5G related to smart cities.

Use case	URLLC	mMTC	eMBB	Additional 5G functionality requirements
Automotive/ connected cars	x		x	V2X communications, edge processing, network slicing
Traffic management		x	x	Edge processing, network slicing, broadcast/multicast (feMBMS)
eAdministration / eGovernment, services for city administration			x	Private networks/operator networks, slicing support, data management/policies, security, trusted communications
eHealth	(x)	x	x	Enhanced network and data security / privacy, network slicing capabilities, reliability, performance (e.g., URLLC for remote surgery)
e-Learning / education			x	Broadcast / multicast support, slicing support
Energy	x	x	(x)	Network slicing, trusted and secured communications, enhanced reliability
Factories of Future / Industry 4.0	x	x	x	Private local networks, vertical-local access network (LAN), slicing, positioning, cybersecurity, time synchronization, edge processing, time-sensitive networking
Financial technologies (e-commerce)	(x)		x	Cybersecurity, trustworthiness of communication platform and data platforms, reliability of communication
Media and entertainment			x	Load balancing for content, edge processing, feMBMS
Other public services for citizens (including culture, sports, services for public spaces etc.)	x	x	x	Support especially for IoT connectivity, efficient video and media communication, edge processing, network slicing, secure communications and privacy considerations
Public safety		x	x	Network slicing, edge processing
Public transportation / logistics		x	x	Network slicing, feMBMS, edge processing, local / private network operations
Smart buildings, construction / land use		x	x	Private local networks, network slicing, positioning, edge processing
Water management (incl. drinking water and sewage)		x		Long battery lifetime for sensors/energy efficiency, mobile broadband for video monitoring, edge processing

Even though 5G has been one of the most visible technologies deployed at the living labs and open innovation platforms during the past couple of years, the role of 5G in most smart city applications is to be only one of the key technology enablers. In addition to the connectivity, a variety of emerging technologies play a key role when new digital services are developed for urban environments and citizens. For example, artificial intelligence/machine learning, virtual/augmented reality, digital twins, blockchains and cybersecurity are all essential technological building blocks when data related to critical infrastructures and persons are collected, processed, analysed and visualised for smart city applications. From the point of view of cities and municipalities, the key challenge is to find the best ways to include all of these emerging technologies into their digital infrastructure and make them available for the smart city service developers through open innovation platforms and ecosystems.

3.1 5G PPP trials and use cases related to smart city vertical

During the execution of 5G PPP program, different projects have included smart city use cases in their pilots and demonstrations. Several platform projects (Phase 3 projects) have been also supporting the smart city use-case development and provide enablers to arrange the pilots and demonstrations. Within 5G PPP Phase 2 about 63 experiments were conducted in 38 cities, covering the use cases on automotive, industry, media and entertainment, public safety, energy, health, and transport & logistics. The work on 5G PPP projects have included also variety of smart city related use cases including e.g. public administration, tourism, assisted living, people mobility, smart buildings, and education. The summary of Phase 2 and Phase 3 projects with smart city related use cases are presented in the Table 2.

One of the 5G PPP smart city projects during Phase 2 was 5GCity, which focused especially on developing and deploying open multi-tenant cloud and virtualization platform for neutral host, third party operator business in smart cities. One of the key enablers for smart city application is efficient real-time media and video distribution for variety of use cases from safety and security to civil engineering application. The 5GCity project provided enablers for media and content distribution, real-time video acquisition and production for media industry and smart city use cases. For example, prevention of illegal waste dumping demonstrations at city of Lucca has utilised the edge processing of video streams from city's surveillance cameras.

Related to 5G network capabilities for media-related applications, for example 5G-Media project concentrated on demonstrating the immersive media and virtual reality as well as smart production and user-generated content over the 5G. In the smart city concept for example the immersive media and interactive augment and virtual reality applications benefit for example the tourism. One of the use case examples for 5G-Monarch included the “Touristic City”, where interactive augmented reality applications have been benefiting from resource optimized mobile broadband network.

In the 5G PPP Phase 3 Infrastructure project 5G-EVE, an edge cloud platform enabler was developed to support smart tourism applications, enabling services such as, location, image recognition, and augmented reality application to enhance visitor experience and providing additional information of historical sites and architectural landmarks.

Media-related use cases and application have been quite popular among the Phase 2 and Phase 3 projects and for example distribution of 360-video has been dealt with in different 5G PPP

projects. For tourism application 5G-EVE has been working on enabling the real-time 360-video distribution. In 5G-HEART the real-time, augmented video and 360-video distribution have been developed for educational surgery, and remote emergency operations. Also large stadium events supporting the broadcast / multicast operations have been demonstrated for example in DEDICAT 6G, 5G ESSENCE, and 5G-PICTURE -projects. The 5G ESSENCE demonstrated the local productions and edge processing as well as local broadcast / multicast distribution in stadium and the 5G-PICTURE demonstrated the media services in stadium at Bristol and gigabit communications to railways, which is important service enabler for both intracity and intercity railway infrastructure. The Phase 3 – 5G-PPP Smart connectivity beyond 5G project DEDICAT 6G validated the developed sustainability and security enablers for the smart connectivity platform using use cases such as public safety and security and network quality of service for enhanced experiences, which may extend the possibilities to arrange for example mass events in cities.

The other smart city related use cases and applications have included different transport and mobility related topics. In which for example the slicing concepts, edge processing, software defined networking, virtualization, and radio/network optimization methods have been developed. Projects have also demonstrated service provisioning and mobility for high speed railway use cases and transportation. The 5G enablers for other city services such as smart lighting, energy and water have been demonstrated and developed in various project. For example, projects like MATILDA and SLICENET have demonstrated the smart city lighting use cases and NRG-5 project focused on developing ICT enablers for smart energy; electricity and gas infrastructures. The enablers for public safety were considered and demonstrated especially ,e.g., in Metro-Haul project and One5G leveraged especially the massive machine type communications in smart cities. Also several other projects such as VITAL-5G and 5G-IANA developed and demonstrated the enablers on transport and logistics, public safety, and automotive use cases.

The Phase 3 projects especially the Advanced 5G validation trials across multiple vertical industries and 5G innovations for verticals with third party services have been further enhancing the smart city related use cases. In the Phase 3 vertical trials projects for example 5G SOLUTION project aimed for smart city vertical living lab trials especially in Ireland and Norway.

The 5G-TOURS trials concentrated specially to improve quality of life of citizens and tourist. The use case and vertical applications include transport in Athens, media and broadcast enablers for tourism in Turin and e-health in Rennes. The e-health and especially traffic safety related use cases are also developed and demonstrated in 5G-HEART project with human tachograph and health condition monitoring in addition to the real-time video delivery enablers for remote operations and educational surgery.

Related also to smart city use cases, the 5Growth project leverage from 5G-TRANSFORMERS and 5G-MONARCH project and arrange trials for example on transport and energy. The 5Growth project focused mainly on enabling the time critical telemetry and monitoring, connected workers, remote operations and augmented remote support in industrial use cases. Although the use cases were not directly under smart city concept, the covered use cases, such as, safety critical communication for traffic control and management can be related to smart cities. Similarly, the 5G-VICTORI -project use cases, for example, enhanced mobile broadband solution for transportation and railways are related to smart cities use cases for transportation. The work on trials in this use case included especially the URLLC and eMBB solution for multi-technology

infrastructure and seamless connectivity of services. In the same domains 5G-VICTORI aims especially to leverage the technologies from Phase 1 and 2 projects 5G-XHaul and 5G-PICTURE on transportation, high speed rails and media. The 5G!Drones project enhances further the smart city use cases with UAV (Unmanned Aerial Vehicle) use cases. The UAV/Drones can be seen suitable especially for arranging logistic and delivery cases in cities as well as, e.g., for ensuring public safety and acting as support for public protection and disaster relief (PPDR).

In the projects related innovations for verticals, several projects focus on arranging, developing and hosting experimentation platforms and network application (NetApps) for PPDR. These projects include for example 5GASP, 5G-EPICENTRE and 5G-ERA. The 5G-ERA project focuses especially on robot autonomy, which has also relevance in various smart city use cases including PPDR solutions as well as in transport and logistics. For example, for transport and logistics, the VITAL-5G aims to showcase the added value of 5G and to build specific network applications for it.

The innovation platforms and experimentation facilities are important from cities point of view, when they are looking for a) improve their own processes and services b) enable and support new growth and business in cities. The activities in 5G PPP projects to develop new 5G enablers and especially to develop experimentation platforms to enable 3rd party application and service development are definitely helping also the cities in their targets. For this it would be important to promote and find the ways in collaboration also with city administration to further utilise the trials, demonstrations and platforms developed in 5G research projects.

Table 2: Summary of smart city related use cases in 5G PPP projects

Project	5G PPP Phase	Use Cases	More information
5G-TOURS	3.3	Tourism, mobility and transport, quality of life for citizens	https://5gtours.eu/
5GCity	2	Security and surveillance, waste dumping prevention, mass events immersive services	https://www.5gcity.eu/
5G-Media	2	Immersive media, smart production and user-generated content at live mass events	https://5g-ppp.eu/5g-MEDIA/
5G-Monarch	2	Tourism	https://5g-monarch.eu/
5G-EVE	3.1	<u>End-to-end trial facility:</u> Smart transport and mobility/Italy, Smart tourism/Spain, Safety and environment/Greece&Italy	https://www.5g-eve.eu/
5G-HEART	3.3	Traffic control for emergency situations, safety, and transport.	https://5gheart.org/
DEDICAT 6G	3.6	Mass events, content production	https://dedicat6g.eu/
5G ESSENCE	2	Local video production / mass events, Critical applications, and communication for public safety	https://www.5g-essence-h2020.eu/
5G-PICTURE	2	Public safety and mass / stadium events in smart cities, virtual reality, smart city transport; gigabit communications for railways.	https://www.5g-picture-project.eu/
MATILDA	2	Public protection and disaster relief, intelligent lighting for smart cities, immersive service for retail and mass events	https://5g-ppp.eu/matilda

SLICENET	2	Smart lighting, remote monitoring of city infrastructure, public safety and traffic information/control	https://slicenet.eu/
NRG-5	2	Smart energy, efficient electricity and gas infrastructure service enablement	https://5g-ppp.eu/NRG-5/
Metro-Haul	2	Public safety	https://metro-haul.eu/
One5G	2	MTC applications, connecting and serving megacities with 5G	https://one5g.eu/
5G SOLUTION	3.3	Intelligent city lighting, smart parking, smart city co-creation, smart buildings, and safety and logistics at ports	https://5gsolutionsproject.eu/
5Growth	3.3	Transportation	https://5growth.eu
5G-VICTORI	3.3	Transportation, eMBB/URLLC for high speed transportation, critical services for railways, smart energy metering for public buildings and street lighting	https://www.5g-victori-project.eu/
5G!Drones	3.3	Public safety, crowded/mass events, traffic management	https://5gdrones.eu/
5GASP	3.6	5G Enablers to support public protection and disaster relief	https://www.5gasp.eu/
5G-EPICENTRE	3.6	Public protection and disaster relief	https://www.5gepicentre.eu/
5G-ERA	3.6	Public protection & disaster relief, semi-autonomous transport solutions	https://5g-era.eu/
VITAL-5G	3.6	Logistics and transport	https://www.vital5g.eu/
5G-IANA	3.6	Tourism: Immersive and virtual touristic services	https://www.5g-iana.eu/

5G-VINNI	3.1	<u>End-to-end trial facility</u> : Public safety&disaster relief / Norway, UK & Germany, Transportation/UK & Portugal, Tourism/Spain	https://www.5g-vinni.eu/
5Genesis	3.1	<u>End-to-end trial facility</u> : Smart City transport : Germany, Spain & UK, Public safety and disaster relief :Germany, Cyprus & UK, Smart buildings: Spain	https://5genesis.eu/

4 Joint innovation ecosystem efforts and city partnership networks

In addition to EUROCITIES and 5G PPP working groups, there are several other joint efforts on international, national and regional level defining the role of 5G and other new technologies in future urban environments and digital public services. Different groups are taking different approaches to the topic in their work, but all of them have the same long-term goal to enable more sustainable and equal living in the urban environments. At European level, Open & Agile Smart Cities [OASC] and Nordic Smart City Network [NSCN] are examples of networks of collaborating cities, whereas European Digital Innovation Hubs (EDIHs) [EDIH] and European Network of Living Labs [ENOLL] are networks of open innovation platforms and living labs serving companies in their experimentation and piloting needs. The living-in.eu web-portal gathers the latest news and events from multiple European smart city collaboration initiatives on to single platform [LivingInEU].

During 2019, a survey of innovation ecosystems was carried out for Urban Agenda for the EU and Digital Transition Partnership [Komorowski]. The survey outlines the number and types of ecosystem initiatives in all the regions of Europe. In survey, total of 247 innovation ecosystems were analysed from 35 different countries and 165 cities. The study was based on the interviews of ecosystem managers, cluster organizations and participants of ecosystems. Based on the survey Universities, SMEs and companies (including the large enterprises) form the majority of the actors involved existing innovation ecosystems. Only in about 50% of innovation ecosystems included regional authorities or municipalities. The study provided some information about focus areas collected from ecosystem stakeholders. Based on the survey the energy sector was represented in ecosystem initiatives in most of the cases. ICT and digital technologies sectors related to integrating ICT expertise such as communication technologies, artificial intelligence, sensor technologies and virtual/augmented reality solutions were represented second most. Healthcare, creative and cultural industries, construction, Internet of Things, and automotive sectors followed respectively. The study compared also the type of actors included in innovation ecosystems versus the size of city.

- Small cities – main actors included research organizations, public agencies, technology parks.
- Medium cities – main actors included large enterprises, municipalities, usually under 50 actors.
- Large cities – built around formal networks, freelancers and with even over 1000 actors.
- Very large cities – built around cluster organizations, banks, venture capitalists, universities, number of different actors usually between 100-1000.

Nordic Smart City Network is one example of inter-state city collaboration networks in Europe with common goals, values and vision. The city network includes currently 20 Nordic cities, including also all capital cities of Nordic countries. During the 2018 – 2020, the city network established and executed the Nordic Urban Living Labs project by combining the separate innovation and living labs and activities in Nordic countries. The project launched also several collaborative smart city application projects. In each of the project, communication and connectivity technologies had essential role. The projects included for example the following.

Wayfinding and smart furniture – concentrated on situated services and sharing of real-time data. The smart street furniture was used in city guidance and wayfinding services.

People and flows – goal of the project is to collect the people flow data to understand better e.g. effects of specific metro-lines on urban flows and by that to give feedback for city planning and traffic management. The project acted as technology testing and validation for city planning and maintenance purposes.

Mobility Hubs – project promotes environmental friendly travelling and solving e.g. the challenges on high land use caused by parking and transportation. Project aims solving the challenges by better combining various mobility offers and facilitating multi-modal transport, such as car-sharing, public transportation, cycle roads and pedestrian facilities. Real-time transport information and connectivity is essential to provide such services.

One successful example of the national collaboration in smart city domain has been Finnish 6Aika (Six City Strategy) joint strategy of the six largest cities in Finland; Helsinki, Espoo, Vantaa, Tampere, Turku, and Oulu [6Aika]. The 6Aika targets for city joint actions to tackle the common urbanization challenges. The Six City Strategy set up variety of projects especially for sustainable urban development, increase of employment, and competence development. The main target groups for the projects included especially the companies and research, development and innovation organizations as well as special target groups on e.g. unemployed youth, immigrants and jobseekers in general. The strategy included three large-scale spearhead projects:

- Open Data and Interfaces,
- Open Participation and Customership, and
- Open Innovation Platforms.

More than 60 development and innovations projects were started in different themes from e-learning, smart mobility, and health and well-being to circular economy and energy efficiency. The Six City Strategy enabled the project execution and companies' product development in real environment and with real users for example in schools, shopping centres, hospitals and different public spaces. These co-operation activities helped both companies to improve their products and city authorities to build and push forward the future smart city model, which enables new type of collaboration with cities, citizens and business through customer-centric co-creation and open innovation in real urban environment.

The Six City Strategy was implemented as a part for Finland's structural fund programme for sustainable growth and jobs 2014-2020. Different development projects received funding e.g. from European Regional Development Fund (ERDF) and European Social Fund (ESF).

Open and Agile Smart Cities (OASC) is an international network of over 150 smart cities and communities. Even though the majority of the member cities are from Europe, the network includes also several cities from Asia and Australia as well as from North and South America. The aim of the OASC cooperation is to create a global market for digital solutions, services, and data based on the needs of the cities and communities going through a digital transformation. The main tool to achieve this aim are the open specifications for Minimal Interoperability Mechanisms (MIMs) developed and governed by the network. In the OASC vision, MIMs provide the technical foundation for the procurement and scalable deployment of urban data platforms and end-to-end solutions in smart cities and communities worldwide. The MIMs currently under development are focusing on:

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- Context information management
 - Common data models
 - Marketplace enablers (ecosystem transaction management)
 - Personal data management
 - Fair artificial intelligent

The OASC project portfolio supports the technical work of the network. The projects apply key technologies, such as high-performance and cloud computing, digital twins, cyber security, data analytics and management, artificial intelligence and IoT, into a variety of smart city use cases and needs. As a dissemination tool, the network also maintains an online catalogue of showcase deployments and best practices that have resulted from the OASC activities so far.

European Network of Living Labs (ENoLL) is an international federation of benchmarked living labs in Europe and worldwide. Living labs are open innovation ecosystems integrating research and innovation processes in real life communities and settings. Living labs utilise a user-driven co-creation approach in their operation, facilitating experimental R&D and practical collaboration between public and private stakeholders in variety of vertical domains, such as energy, media, mobility, healthcare, agriculture and food. Currently, ENoLL comprises of more than 150 active living labs around the world. The current focus areas of ENoLL task forces are:

- Social innovation and digital rights
- Social impact and artificial intelligence
- Rural living labs
- Health and wellbeing
- Energy and environment

The ENoLL project portfolio contains a large variety of topics where the living labs' collaborative experimental research approach has been taken into use. These topics include smart cities, climate, education, design, future Internet, big data, creative industries and cross-border/cross-sector collaboration.

The city of Barcelona is determined to transcend the “smart city” concept and deploy a program that integrates and coordinates local initiatives related to a truly digital transformation of the services the city offers to its citizens. In particular, the main strategic objective of the city of Barcelona is to enhance the generation of new industrial activity and new companies in emerging technologies with high growth potential and the transformation of research and innovation outcomes into knowledge-intensive disruptive products and processes. This activity is expected to generate highly qualified jobs and to retain the local talent.

Among the many different initiatives highlighted above, one of the most important initiative is related to 5G trials. In particular, the city of Barcelona aims at offering an integrated metropolitan city-wide field and lab infrastructure environment for 5G validation and experimentation. The infrastructure features an integrated city-wide and lab environment spread over three sites across Barcelona metropolitan area, connected through a dark fiber infrastructure. These sites host equipment aiming at setting up an infrastructure capable to validate/test different type of

technologies like: MEC nodes, Small Cells, Massive MIMO antennas, massive MTC, mmWave transport, optical networks and Satellite stations.

This infrastructure enable the 5G ecosystem, including vendors, operators, service developers, SMEs, and academic institutions to experiment and validate 5G technology services. This initiative put together and offer a critical mass of 5G communication trial facilities, which will represent a key asset to increase competitiveness of the ICT and vertical industries in 5G. With this infrastructure environment the city of Barcelona targets to cover end-to-end solutions and expects play a key role in the trialing of 5G technologies by capitalizing the presence of the Mobile World Congress eco-system along with those of IoT Solutions World Congress and Smart City Expo World Congress.

City of Oulu is challenged to modernize the city governance and processes in the framework of constrained public expenditure and demand for deploying disruptive technologies enabling digitization, automation and robotisation in public service delivery. As strategic priorities are to enhance innovation led economic growth and competitiveness of the local economy and companies to create employment outcomes for the people, ensure sustainable and healthy living environment and wellbeing for the citizens, and provide economically viable and efficient governance. Digitalization of the public service delivery in close collaboration with the local ecosystem stakeholders, companies, research and innovation agencies as well as citizens is one of the selected key priorities to optimize the future development. This implies improving profoundly understanding, getting access to and facilitating state-of-the art novel methods, approaches and engineering paradigms through which the new smart technological solutions and rapidly increasing volumes of diverse data could best contribute to the digitalization of public services. As a key factor for efficiency, transparency and accountability of local governance is ensuring holistic integrated digital transformation of the city administration and public services and deployment of suitable technological solutions for the Future Networked Society.

There is a strong commitment to the deployment of disruptive technologies into the public service development to ensure smooth transfer to the citizen-centric digitalization of the city administration. The future digital city will reach its fully interconnected potential with the onset of 5G network connectivity, thus ensuring the seamless interworking of different network technologies in a common infrastructure, communication solution basis for many vertical applications, as well as new architectural concepts and value chains to efficiently support innovation and future needs. The city is already providing a fertile environment to test, develop and launch 5G services. This is thanks to the strong innovation ecosystem alliances and concrete innovation platforms and facilities already developed and piloted together with the local and international companies.

The aim is to become one of the forerunners in deploying and taking up the 5G enabled disruptive technological solutions providing cost-efficient, user-friendly, cyber-secure and seamless transfer to the digital governance and public services. The city is committed to provide innovation development environments and cross-sector hubs for experiments, trials as well as large scale pilot programs in 5G development.

City of Patras is aiming at organizing, transforming and finally extending its current digital infrastructure into an open platform that will interconnect 5G related technologies that will co-exist with established WiFi and IoT ones. This digital transformation is performed in order to address e-administration issues related to the City of Patras while enhancing the quality of life of its citizens.

During the past years smart city in Patras has only been sporadically addressed with small initiatives around the city, mainly driven by various technology providers. In order to facilitate the digitalization Smart City Patras Innovation Hub initiative that brought together the University of Patras Science Park, the City of Patras and the local industrial IoT and 5G ecosystems, was established. It has become clear that the way towards Smart Patras is paved through a digital transformation, facilitating the digitalization of the city administration together with establishment of new technologies (IoT, fibre etc). Moreover, the initiative unfolded the potential of establishing an openly accessible digital infrastructure in a holistic way. The infrastructure comprise orchestration of the communications (network) the IT resources (computational , storage etc), access technologies, data assets and the applications and will ultimately be operated by the Hub. The expected outcome of these collaborations is to build an ecosystem that actively involves local stakeholders from various sectors that will eventually shape a common digital infrastructure to be deployed across the city by projecting their requirements into it. It is also to be used by the city to offer various public e-services and interact with its citizens.

In order to achieve these targets the digital transformation is evolving along three axes:

1. open digital infrastructures (software, hardware, access)
2. scalable interoperable and expandable technologies and
3. public engagement and social impact maximization via governance and use.

City of Patras was selected by the *Greek Ministry of Digital Policy, Telecommunications and Media*, as one of the first two 5G pilot cities in Greece. Under this plan, 5G infrastructure is deployed across the city to facilitate 5G trials and validate the effectiveness of the proposed architecture. From the technology standpoint, the city plan is to efficiently integrate current network deployments e.g. IoT, optical network, as well as forthcoming deployments like 5G, aiming at creating an open smart city environment that will accelerate the city's transformation into a digital society and foster innovation through experimentation across all layers. Achieving this, an implementation agenda has been prepared that address challenges such as,

- Appropriate governance of the smart city environment that maintains openness while applying the necessary coordination among competing stakeholders originating from different verticals.
- Cost reduction of CAPEX and OPEX relying on open source and open hardware where possible.
- Establishing a Smart City Operations Centre that will manage and control the integrated environment and support experimentation.
- Citizen engagement in addressing local societal needs.
- Motivate members of the local ecosystem as well as outsiders by means of organizing 5G city challenges aiming at providing solutions in various city needs.

Expansion of the smart city digital infrastructure to the whole Western Greece region encompassing important economic and social sectors such as agriculture, tourism and shipping, to name but a few.

The aforementioned cities and activities are also involved in 5G PPP projects through the local stakeholder participation in variety of living lab and experimentation platform projects.

5 Recommendations for the implementation of experimentation activities

Based on the achieved results and lessons learned during the preparation and implementation of the European living lab activities, the following recommendations are given for future projects with similar aims in the form of best practises. These best practises aim also to aid when considering the technology transfer from 5G PPP trials to open city living labs and experimentation platforms. The 5G PPP trials can be seen as part of the city living lab development, bringing new use case ideas and implementations to smart city experimentation platforms. Thus, interaction between 5G PPP trials and cities are seen important.

As a general recommendation for the funding and organization of future partnerships, inclusion of some dedicated resources into the overall budget for the implementation of partnership actions and collaboration between different stakeholders, would help to maximize the impact of the collaborations. This would alleviate the issues related to the scheduling and execution of joint activities between two or more living lab sites. These activities usually suffer the most from the resource shortage and can be delayed due to the long time it takes to find the suitable timeslots for the key persons to perform the work related to joint tasks. This does not only impact the technical work related to the implementation and deployment of technologies and services, but also the administration and dissemination activities supporting the technical work. The funding for the implementation of partnership actions could be realized in the form of co-funding to boost certain types of efforts at the local living lab sites. The benefit of a co-funding approach is not only the additional resources available to implement the action, but also the stronger commitment from the partners. Another option could be a conditional budget share, which becomes available if certain prerequisites for the partnership action are met. The conditions could be related, e.g., to the number of collaborating partners or external users utilizing the results of the joint activity.

Another general recommendation related to the additional funding possibilities for the living lab activities is to carefully align the partnership actions with the new European programmes for digital transformation and research and innovation (R&I), i.e., Digital Europe and Horizon Europe, respectively. Within the Digital Europe programme, the option could be the utilization of the dedicated EDIH calls for additional funding. In this approach, the effort needed to prepare the infrastructure and services of the local living labs for the EDIH calls must be taken into consideration when planning the partnership activities. In Horizon Europe calls, the living lab infrastructures could be utilized as test facilities for a variety of R&I projects and extended with new functionalities in the process. The strong focus on ecosystem building and societal challenges through R&I missions in Horizon Europe will make it easier for the partnerships to align themselves with the objectives of the jointly funded R&I projects. Aligning the work with technology development planned e.g. in future Smart Networks and Services Public-Private Partnership program and current activities on 5G PPP project trials and pilots, would provide insight on the technological roadmaps and solutions to further develop the smart city use cases and enablers for living labs and experimentations.

Instead of individual contact persons and coordinators responsible for the partnership related activities at different living lab sites, set up larger management teams with representatives from the partnership, local living lab ecosystem and city or municipality. The approach to include committed and like-minded persons from different stakeholder groups facilitates information

sharing, keeps the ecosystem active and enables real cooperation in situations where the interests of an individual member of the management team would favour a single service provider approach. After all, the local test facilities participating to the living lab ecosystem can still be competing for the same customers as standalone platforms. In addition the following best practises for setting successful partnership between technology vendors, research, city administration and other stakeholders can be promoted.

Ensure flow of information between the local, national and international ecosystems related to the partnership topics.

The partnerships offer a great opportunity to enhance the pan-European visibility of the local living lab ecosystems as part of a larger network of collaborating innovation platforms. In addition to the enhanced local cooperation facilitated by the living lab administration teams and ecosystems, direct communication links towards central government officials participating to different EU policy and working groups related to the partnership topics are an invaluable asset while disseminating and collecting information. Efficient information exchange at multiple levels in the local and global networks can aid to maximize the impact of the running partnership activities and create new collaboration opportunities in the future.

Utilize the entire partnership network for information sharing and seek smaller groups of partners for the practical work related to joint experiments.

While a partnership is running, it is important to utilize it efficiently for multiple purposes. For the local living labs participating into the partnership, it is beneficial to first identify a smaller group of partners with similar interests and aims for continuous discussion around detailed technical topics and exchange of experiences during implementation of pilots. The continuous discussions keep the cooperation active and help to identify common problems suitable for further collaboration also outside the running partnership. In addition to the more intensive cooperation within a smaller group of partners, it is important to be active also at the whole partnership level in actions, which are not in the direct focus of the current pilots at the local living lab, but which have potential in the local ecosystem for future spearhead topics.

Combine and packetize the services offered by the local living labs and promote it as a joint pan-European service at the partnership level.

Real cooperation between living lab sites residing in different countries can be built around combined and integrated service offering targeted towards potential customers in a selected technology or vertical industry domain. With the support of the partnership, the third parties interested in deploying pilots on top of the existing living lab infrastructures can be served with international test facility assets if the local ecosystem cannot fulfil their needs. Smaller players interested in pilots usually do not have the resources to set up pilots in other countries without the contacts available through the partnership. Pilots in other countries can usually be operated either on location or remotely if the required support from the living labs is available.

Ensure that all the relevant stakeholders from the entire value chain related to the targeted use case are represented in the local ecosystem when preparing the living lab for service pilots.

When selecting target use cases and service pilots for the local living lab participating to a partnership, make sure that all relevant stakeholders from the local ecosystem are committed to contribute also to the partnership activities. For example, in case of service pilots related to smart

buildings or districts, involvement of the technology vendor, mobile network operator, property developer and city is needed to guarantee the required access to new equipment, existing communication infrastructure, buildings and public areas. Inclusion of all relevant actors prevents implementation roadblocks caused by unavailable resources or permits for the planned deployments. In order to increase the commitment, it is important to focus the use cases and pilots so that they have innovation and/or business potential for all involved partners.

Form the use cases and pilots around societal challenges to make them more approachable for the local ecosystem partners.

In order to include as many local ecosystem partners as possible, form use cases and pilots targeted in the partnership around societal challenges and megatrends. It is easier to find common interests for the local ecosystem when the problems to be solved are generic in nature and in line with the high-level national and international agendas, which are in their part guiding the R&D and business strategies of companies with international customers. From the point of view the visibility of the partnership results, piloting activities focusing on societal challenges are also easier to communicate towards the public.

Define the role of the partnership to be the coordinator of the generic technological building blocks and service offerings coming from the local living lab ecosystems.

Utilize the partnership for the coordination of contributions from the local ecosystem to the living lab infrastructure. By taking into consideration the needs of the partnership's combined pan-European service offering, the individual technology components and piloting capabilities offered by the local test facilities can be linked to the other living labs more easily. Seeing the big picture when planning development roadmaps for the local infrastructure facilitates active cooperation during and exploitation of the results after the partnership.

Ensure that each service pilot planned to be migrated between living lab sites is thoroughly analysed before committing resources to the technical work.

If existing service pilot implementations are planned to be exported or migrated from one living lab site to another as part of the partnership activities, adequate resources should be reserved for the analysis of technical compatibility of the utilized technology platforms. If the service migration fails due to unexpected inter-operability issues caused by differences in the infrastructure implementations and configurations, and the all cooperation activities are planned to be related to this specific service pilot, the whole partnership action can fail.

Prepare both funding and development roadmaps for the local living labs to make sure that the survival of the local infrastructures is not dependent only on the partnership activities.

For the local living lab infrastructures participating to the partnership activities, it is crucial to prepare a funding and development roadmap covering the entire duration of the partnership. As dedicated funding for infrastructure investments and maintenance is usually not available directly from the partnership, a plan for multi-annual partner investments or jointly funded project portfolio supporting the technology platform is needed. The plan can be used to guarantee that an up-to-date living lab is available at least in some form for the partnership activities throughout its lifetime.

Arrange flexible ad hoc funding possibilities towards the utilization of the living lab services for start-ups and SMEs operating in the local ecosystems.

For the specific needs of local start-ups and SMEs, extra support to utilize the services offered by the living labs is needed in the form of flexible funding opportunities. Traditional regional funding instruments usually fall short either in their flexibility to cover multiple kinds of expenses or in the time and effort needed to apply the funding. The possibility to locally link lightweight public funding instruments to ad hoc piloting needs on top of the living lab sites as well as other complementing funding sources, e.g., in the form of prizes related to innovation competitions and hackathons sponsored by local companies, should be investigated and set up already in the preparation phase of the partnerships.

6 Conclusions

This report summarizes the main project activities of 5G PPP Phase 2 and Phase 3 projects related to smart city vertical and its use cases. We also discuss shortly the digitalization aims of the modern European cities. How the digitalization also brings challenges for cities to understand the possibilities of new technology. One of the essential functions for cities is to improve the quality of life of their citizens and be able to provide the basic services citizens demand. In addition the modern cities needs to be attractive places also for business and thus be able to provide services also for new entrepreneurs and industry, starting from the land use and basic services to more advanced digital services and growth possibilities. It is seen that the innovation platforms and living labs are important tools for cities to develop their services both citizen and new business point of view.

In the document we also provided an insight of aims of several large European city collaboration and networks. How they see the 5G technology and what kind of statements they have for technology developers and policy makers on adopting the new technology at cities.

In addition to a summary of the 5G PPP projects with relation to the smart city use cases, we provided a brief introduction to European joint innovation ecosystem efforts. As an examples from European living labs and established innovation ecosystems we discussed two Digital Transition Partnership examples. One of big challenges in the smart city collaboration networks is the diversity of stakeholders and governance models and how to involve the right stakeholders for the common aims. In the large collaboration activity also the expectations and aims can be contradicting, but this can be reality also between the city stakeholders and company stakeholders, when building the common experimentation facility. One of the challenges is also how to maintain the new technology platforms and results from projects. In quite many cases, the development of platforms and services will end when the project funding ends. Thus, it is essential that the business model (including also the exit strategy), how the platform (or trial) is developed and maintained after the initial funding ends, is necessary.

In the sections of the document we give also some generic recommendations implementation of European wide living labs and experimentation platforms based on the various discussions. In overall we see that the 5G PPP trials and 5G enabler demonstrations can be seen as part of the city living lab development, and can bring new use case ideas and implementations to smart city experimentation platforms. This means that interaction between 5G PPP and cities, including the city administration and business development, are important.

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