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D4.1: Outline of the Pilot Concept and Identification of Ongoing IoT and 5G Large Scale Pilots between Europe and China

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Abstract	In this deliverable, our studies of Task 4.1 are presented. The primary goal of WP4 and the two phases methodology are introduced at the beginning of this deliverable. Then LSP and testbeds of IoT from both Europe and China are listed in Chapter 2. Moreover, an analysis of IPv6 potential for Europe and China is also provided to help for further understanding and identifying the ongoing LSP between two parties. In Chapter 3, we studied several ongoing pre-pilot or large scale testbed of 5G. The achievements of Task 4.1 in this deliverable will be used as input for Task 4.2, which targets on a set of practices and recommendation to be considered in future cooperation opportunities of LSP for IoT or 5G.
Keywords	IoT, 5G, Large Scale Pilots, Europe, China.

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** R: Document, report (excluding the periodic and final reports)*

Project co-funded by the European Commission in the H2020 Programme		
Nature of the deliverable:	R	
Dissemination Level		
PU	Public, fully open, e.g. web	√
CI	Classified, information as referred to in Commission Decision 2001/844/EC	
CO	Confidential to EXCITING project and Commission Services	

DEM: Demonstrator, pilot, prototype, plan designs

DEC: Websites, patents filing, press & media actions, videos, etc.

OTHER: Software, technical diagram, etc.

EXECUTIVE SUMMARY

The aim of this deliverable is to present our studies of Task 4.1 outline of the pilot concept and identification of ongoing Internet of things (IoT) and 5G large scale pilots (LSP) between Europe and China. First, the main goal of WP4 and our two phases methodology are introduced at the beginning of this deliverable. Then LSP and testbeds of IoT from both Europe and China are listed in Chapter 2. Moreover, an analysis of IPv6 potential for Europe and China is also provided to help for further understanding and identifying the ongoing LSP between two parties. In Chapter 3, we studied several ongoing pre-pilot or large scale testbed of 5G. The achievements of Task 4.1 in this deliverable will be used as input for Task 4.2, which targets on a set of practices and recommendation to be considered in future cooperation opportunities of LSP for IoT or 5G.

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ABBREVIATIONS

5G PPP	5G Public-Private-Partnership
AHA	Active and Healthy Ageing
API	Application Programming Interfaces
CMRI	China Mobile Communications Research Institute
EC	European Commission
ERC	European Research Center
ETE	End-to-end
EU	European Union
HD	High Definition
ICT	Information and Communications Technology
IERC	Internet of Things European Research Cluster
IoT	Internet of Things
ITU	International Telecommunication Union
KPI	Key Performance indicator
LSP	Large Scale Pilots
SME	Small and Medium-sized Enterprises

1. INTRODUCTION

In this chapter, the main context of our study in WP4—Large Scale Pilots (LSP) Cooperation Actions, will be introduced here. First, the objective of WP4 and the methodology used are reviewed at the beginning of this chapter. Then the definition of LSP, Internet of Things (IoT) and the latest vision of 5G are also given and discussed.

1.1. Objectives

WP4 in EXCITING is designed to investigate practical opportunities for future cooperation on LSP for IoT and 5G on a reciprocal basis. In WP4, cooperation opportunities are taking into consideration existing LSP cooperation actions between Europe and China. To approach this goal, two tasks are planned in WP4, i.e. Task 4.1 and Task 4.2. In Task 4.1, our aim is to identify some major ongoing LSP between the two parties and the detailed discussions are given in the following chapters of this deliverable. Then Task 4.2 will identify the best practices for optimized cooperation opportunities between them, and report the results in the final deliverable in WP4, i.e. D4.2.

1.2. Methodology

The scope of our study is on how Europe and China can best support the deployment of IoT and 5G, in order to enhance the acceptability and adoption by users, citizens and foster possible new market opportunities for both Europe and China suppliers. Therefore, our study is conducting through a methodology consisting of two phases and delivered by two tasks, i.e. Task 4.1 and Task 4.2, as shown in Figure 1.1. The focus of Phase 1 is to outline of the pilot concept and identification of ongoing IoT and 5G LSP in Europe and China. The achieved results of Task 4.1 reported in D4.1 produces a candidates list of the ongoing LSP. This list will be used for analysis in Phase 2, which aims on developing a set of best practices and recommendation for LSP between Europe and China. Then final achievement of WP4 will be delivered in our D4.2 at the end of EXCITING.

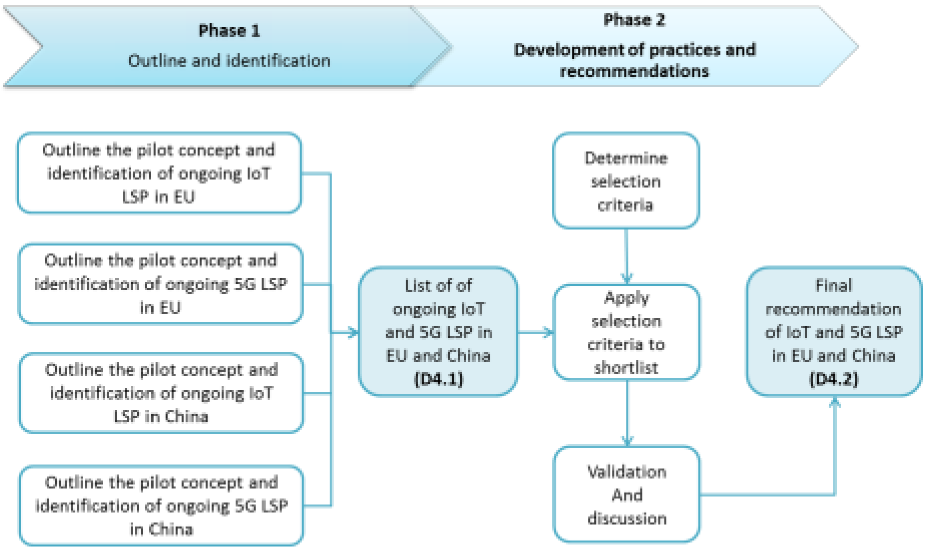

Figure 1.1 Overview of the study methodology in WP4

To help to understand the vision and discussion of our study, we also briefly introduce the definition of LSP, IoT and the latest version of 5G (reported in 5G Public-Private-Partnership (5G PPP)) in the following of this chapter.

1.3. Large Scale Pilots (LSP)

While the interest in topic is growing in business world and users are getting more and more involved in IoT and 5G applications, it is in great needs to make sure that innovation and results is focusing on the right objectives and generates real value for the market and citizens. It is also one of our focuses to study how IoT and 5G can enable Ecosystems of smart solutions, applications and services in many areas, e.g., Smart homes, Smart Grid etc. LSP can play a very important role in tracking specific challenges for IoT and 5G, relating to deployment, technological and business model validation and acceptability.

The concept of LSP is not new already, however, many of the pilots have been typically designed with a reduced scope or been used to showcase solutions with less strong emphasis on replications [1]. LSP should provide the opportunities to demonstrate actual IoT or 5G solutions in real-life setting and should make it possible for providers to validate business models and integration modalities through direct experimentation with users. This could also help clarify the need for complementary actions around notably standardization, interoperability and other policies concerning trust and security, as well as provide an environment where to test data analytics tools at scale. Therefore, in terms of the design of LSP, the following non-exhaustive list indicates elements are expected to be covered all or some by IoT and 5G LSP:

- need to cover the full value chain and to demonstrate integration capabilities;
- requirement to deliver open Application Programming Interfaces (APIs) / interoperability;
- requirement to duplicate the pilot (several locations, re-use of components);
- requirement to deliver a certain scale for the pilot to be considered large enough;
- involvement of European Small and Medium-sized Enterprises (SMEs) capable of working together to deploy the LSP;
- physical display of the solution proposed;
- capability in changing the perception of the actors involved (lighthouse effect);
- clear and auditable rules for privacy management and handling of personal data; and
- involvement of social scientists and multiple user groups, in order to design systems that are useful and acceptable for people.

1.4. Internet of things (IoT)

As it is known, the IoT has been defined by ITU (International Telecommunication Union) and IERC (Internet of Things European Research Cluster) as a *dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols, where physical and virtual "things" has identities, physical attributed and virtual personalities and use intelligent interfaces and are seamlessly integrated into the information network.* In Figure 1.2., elements that comprise the IoT in relationship to the definition:

- Network infrastructure: "A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols,"
- Things, sensors, and actuators: "…where physical and virtual 'things'…"

- Data: "… have identities and physical attributes (sensors and actuators) and virtual personalities…"
- Service platform: "… and use intelligent interfaces and are seamlessly integrated into the information network."

Figure 1.2 Elements that comprise the IoT [1]

Recently, IoT has moved from being a futuristic vision to an increasing market reality, or sometimes a hybrid. The aspects such as a large number of competing technology standards, lack of understanding of new business models, and social questions and inhibitors to the "cognitive wave" of the IoT, expected to "facilitate object and data reuse across application domains, leveraging on hyper-connectivity, interoperability solutions and semantic enriched information distribution, incorporating intelligence at different levels, in the objects, devices, network(s), systems and in the applications for evidence-based decision making and priority setting [2]."

1.5. 5G

5G is the terminology used to describe the fifth generation of wireless systems. In the recently released 5G vision of European information and communications technology (ICT) sector by 5G PPP, 5G will not only bring new unique service capabilities for consumers but also for new industrial stakeholders (e.g. vertical industries, novel forms of service providers or infrastructure owners and provides). It targets on ensuring user experience continuity in challenging situation. High definition (HD) video or teleworking will be commonplace and available anywhere, regardless of if the user is in a dense area like a stadium or a city centre, or in a high speed train or an airplane. 5G systems will provide user access anywhere and will select transparently for the user the best performing 5G access among heterogeneous technologies like WiFi, 4G and new radio interfaces. The choice of the best performing access will not only be based on throughput but on the most relevant metrics depending on the nature of the service, e.g. latency may be more important than throughput for an online application. Moreover, 5G will be a key enabler for the IoT through providing the platform to connect a massive number of objects to the Internet. Sensors and actuators will spread everywhere.

1.6. Summary

In this chapter, the objectives and methodology used in WP4 are introduced. To help to harmonize the study, we also briefly review the definition of IoT given by ITU and IERC, the latest version of 5G provided by 5G PPP. In the following chapters, the list of studied IoT and 5G LSP or large scale testbed in both Europe and China will be discussed with the factors of objectives, applications, etc.

2. IOT TEST-BED AND LSP DEPLOYMENT

2.1. Introduction

In this chapter, we will study the pilot concept of IoT and some ongoing IoT LSP and testbeds. The scope of IoT LSP is to encourage the deployment of IoT solutions through the integration of advanced IoT technologies across the value chain, demonstration of multiple IoT applications at Scale and in a usage context, and as close as possible to operational conditions. These operational conditions may include [1]:

- Mapping of pilot architecture approaches with validated ioT reference architectures such as IoT-A enabling interoperability across use cases
- Contribution to strategic activity groups that were defined during the LSP kick-off meeting to foster coherent implementation of the different IoT LSP
- Contribution to clustering their results of horizontal nature (interoperability approach, standards, security and privacy approaches, business validation and sustainability, methodologies, metrics, etc.)

The IoT LSP introduced here includes projects addressing the IoT applications based on European relevance, technology readiness and socio-economic interest in both Europe and China.

Research and innovation effort in specific IoT topics ensure the longer-term evolution of IoT and the IoT European LSP projects are addressing [3]:

- The integration and further research and development, where needed, of the most advanced technologies across the value chain (components, devices, networks, middleware, service platforms, application functions) and their operation at large scale to respond to real needs of end-users (public authorities, citizens and business), based on underlying open technologies and architectures that may be reused across multiple use cases and enable interoperability across those.
- The validation of user acceptability by addressing, in particular, issues of trust, attention, security and privacy through pre-defined privacy and security impact assessments, liability and coverage of user needs in the specific real-life scenarios of the pilot.
- The validation of the related business models to guarantee the sustainability of the approach beyond the project.

The IoT LSP make use of the rich portfolio of technologies and tools so far developed and demonstrated in reduced and controlled environments and extend them to real-life use case scenarios with the goal of validating advanced IoT solutions across complete value chains with actual users and proving its socio-economic potential.

2.2. Ongoing IoT Europe LSP

In this section, we list some ongoing IoT LSP which addresses the IoT applications based on European relevance, technology readiness and socio-economic interests in Europe. 7 LSP are listed in the umbrella of EC H2020 IoT Coordination Support Action as shown in Figure 2.1.

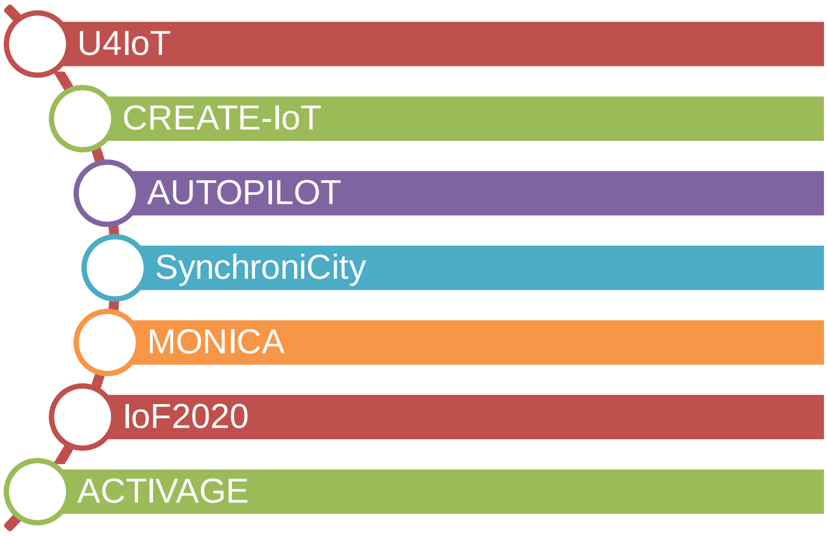

Figure 2.1 IoT Europe LSP overview

- U4IoT (User Engagement for LSP in the Internet of Things)

U4IoT will support the LSP funded by the European Commission in the context of the Horizon 2020 research programme. It will enable a citizen-driven process by combining multidisciplinary expertise and complementary mechanisms from state-of-the-art European organizations. It will also analyse societal, ethical, and ecological issues related to the pilots in order to develop recommendations for tackling IoT adoption barriers including educational needs and skill-building.

U4IoT combines a wide range of knowledge and experience from a number of leading European partners in end-user engagement through crowdsourcing, Living Labs, co-creative workshops, and meetups designed to support end-user engagement in the Large Scale Pilots. Its strategy is built on four main sets of activities. It will:

- Develop a toolkit to facilitate the LSP's end-user engagement and adoption activities including: online resources and tools for end-user engagement; privacy-compliant crowd sourcing and crowd sensing tools and surveys to assess end-users' acceptance of the pilots; online resources and an innovative game that will promote awareness of privacy and personal data protection risks with guidelines on personal data protection;
- Support and mobilize: end-user engagement through the training and supporting of the LSP teams so that they may organize their own workshops; meetups; training on the use of crowdsourcing and crowd sensing tools in an efficient and privacy-friendly way in line with IoT Lab12 tools; the presentation and facilitation of Living Labs support; an online pool of experts for end-user engagement; online training modules.
- Analyse societal, ethical, and ecological issues related to the pilots' end-users and make recommendations based on the analysis of IoT adoption barriers and how to tackle them including education and skill building. It will leverage on end-user interactions to design participatory sustainability models that can be replicated across LSP and future IoT pilots.
- Support communication, knowledge-sharing, and dissemination including: the development of an interactive website with an online toolkit as well as online knowledge database on lessons learned, FAQs, solutions, and end-user feedback. It will support the end-user communication and outreach strategies for LSPs and will enable information-sharing and retro-feed towards LSPs and their end-users.

- CREATE-IoT (Cross Fertilisation through Alignment, Synchronisation and Exchanges for IoT)

CREATE-IoT is the coordination and support action involving all IoT European LSP innovation actions projects, articulating altogether the IoT European LSP Programme that is built around eight activity groups. Through an active participation of these activity groups, IoT LSP projects are able to contribute to the consolidation and coherence work that is implemented by the CREATE-IoT and U4IOT. This is done by supporting the clustering activities defined by the Programme and addressing issues of common interest such as interoperability approach, standards, security and privacy approaches, business validation and sustainability, methodologies, metrics, etc. The ultimate goal of the IoT European LSP Programme and the coordination/collaboration activities is to increase the impact of the activities and development in the IoT LSP on citizens, public and private spheres, industry, businesses and public services. The activity groups are key enablers for the identification of key performance indicators to measure progress on citizen benefits, economic growth, jobs creation, environment protection, productivity gains, etc. The coordination mechanisms implemented through the activity groups will help to ensure a sound coherence and exchange between the various activities of the IoT Focus Area, and cross fertilisation of the various pilots for technological and validation issues of common interest across the various use cases. The issues of horizontal nature and topics of common interest, for all IoT LSP projects, such as privacy, security, user acceptance, standardization, creativity, societal and ethical aspects, legal issues and international cooperation, etc., are coordinated by the activity groups and consolidated across the pilots to maximize the output and to prepare the ground for the next stages of deployment including pre-commercial or joint public procurement.

- AUTOPILOT (Automated Driving Progressed by Internet of Things)

"Automated driving Progressed by Internet Of Things" (AUTOPILOT) is a three-year project that started in January 2017, receiving funding from the European Union's Horizon 2020 research and innovation programme. The AUTOPILOT consortium, consisting of 45 partners, represents all relevant areas of the Internet of Things (IoT) eco-system. Its overall objective to enable safer highly automated driving through smart and connected objects – the IoT.

During the last decade, numerous IoT technologies have been developed by the research community, including IoT software engineering tools and techniques, schemes for safeguarding security/privacy as well as infrastructures. Built upon these recently finished or ongoing research and innovation activities, AUTOPILOT focuses on utilizing the IoT potential for automated driving and on making data from autonomous cars available to the IoT. In particular, AUTOPILOT aims to bring together relevant knowledge and technology from automotive and IoT value chains in order to develop IoT-architectures and platforms to explore the growing market for mobility services. IoT enabled autonomous cars are tested, in real conditions, at six large scale sites, whose test results will allow multi-criteria evaluations (technical, user, business, legal) of the IoT impact on pushing the level of autonomous driving.

Connectivity and the ability to collect data from thousands of objects surrounding vehicles are key enablers for highly automated driving. The IoT provides the mechanisms and tools to create virtual objects in the Cloud from real connected objects, thereby allowing these objects to become more automated in the not-so-distant future. Overall, AUTOPILOT pursues five main objectives. First, it seeks to enhance the vehicle's understanding of its environment, utilizing IoT sensors. Second, the project sets out to foster innovation in automotive IoT and mobility services. Third, it wants to use and evaluate advanced vehicle-to-everything connectivity technologies. Fourth, AUTOPILOT is designed to involve users, public services and businesses to assess the IoT's socioeconomic benefits. Last, the project aims to contribute to the standardization of IoT eco-systems worldwide.

- SynchroniCity (Delivering an IoT enabled Digital Single Market for Europe and Beyond)

Smart cities hold the potential to be a key driver and catalyst in creating a large scale global IoT market of services and hardware. However, the emerging smart city market faces specific challenges that act as barriers to growth, impeding rapid innovation and inhibiting widespread market adoption. SynchroniCity is an ambitious initiative to deliver a digital single market for Europe and beyond for IoT-enabled urban services by piloting its foundations at scale in reference zones across eight European cities and involving other cities globally. It addresses how to incentivize and build trust for companies and citizens to actively participate and find common co-created IoT solutions for cities that meet citizen needs, and to create an environment of evidence-based solutions that can easily be replicated in other regions. These reference zones are based on cities at the forefront of smart city development covering different geographies, cultures and sizes and include Antwerp (BE), Carouge (CH), Eindhoven (NL), Helsinki (FI), Manchester (UK), Milano (IT), Porto (PT) and Santander (ES). Globally, SynchroniCity adds committed replicating reference zones in Mexico, Korea, USA and Brazil.

Digital technologies offer an opportunity to profoundly change how our existing society works. They can enable a transformation of different industry sectors improving existing business activities, processes, and competencies within organizations and across their boundaries. Data infrastructures and the IoT form a critical part of the digital transformation of cities and communities by creating adequate awareness of real-world processes in order to drive more efficient, partially autonomous, decision making, while still maintaining a high level of data protection, inclusivity and general support for local priorities such as economic development and cultural heritage. In terms of data infrastructures, cities have been at the forefront of embracing the open data movement. The release of data sets to the public has increased transparency and provided early innovation potential for third party stakeholders. Services such as Citymapper3 show how open data can add great benefits to the journey experiences of citizens. Many cities have invested in the setup of open data portals and proactively encourage stakeholders across public departments and the private sector to contribute data sets. At the same time, cities are trying to engage entrepreneurs and communities to innovate around these data stores. Early results are promising, but static or sporadically changing data sets have their limitations.

IoT infrastructures are increasingly becoming an important element in providing the underpinning digital layer of smart city services. They augment the open data sets with rich real-time information about public infrastructure conditions and city processes that can be exploited for a more responsive delivery of public services. Examples range from an improved mobility experience through adaptive traffic management and multi-modal transportation to resource savings achieved by smart street light control, waste collection and irrigation management. Various demonstrations of such systems are emerging globally showing the benefits of data-driven services based on IoT and data infrastructures. However, many of these systems currently operate in silos both in terms of the technology employed and the operating environments of the city. Interoperability issues and lack of economies of scale make many potential business cases still hard to justify and result in a lack of confidence in the market.

SynchroniCity aims to overcome the existing barriers in the market by fostering the emergence of a digital single market for smart city services. It brings eight European cities together to work on a common blueprint for IoT and data infrastructures with standardized interfaces and information models, creating an environment that allows vendors and solution providers to more openly compete.

Their vision is to move from disparate data stores and city platforms to vibrant marketplaces for urban data and services providing adequate incentives for a variety of stakeholders to participate. For providers of IoT infrastructure and other urban data sources, this should provide a trusted environment to generate reliable revenue flows. For application and service developers, it should allow frictionless access to reliable and trusted urban data streams to be used as assets underpinning the innovation no matter what city is involved. We call this aspect "avoiding city lock-in". Cities and infrastructure providers can benefit from an aligned environment with standardized interfaces to access a diverse pool of vendor solutions able to compete fairly on price and performance. We call this aspect "avoiding vendor lock-in". Together, they form the robust underpinnings of a global market for IoT-enabled urban services.

- MONICA (Management Of Networked IoT Wearables – Very Large Scale Demonstration of Cultural Societal)

The LSP MONICA demonstrates how cities can use the Internet of Things to deal with sound, noise and security challenges at big, cultural, open-air events. A range of applications will be demonstrated in six major European cities involving more than 100,000 users in total. The project brings together 29 partners from 9 European countries with the objectives to provide a very large scale demonstration of multiple existing and new IoT technologies for Smarter Living.

Imagine sound zones at outdoor concerts in the city where the sound experience is enhanced for those who enjoy the music and the noise mitigated for those who don't. Visualize intelligent cameras deployed at city festivals which, while preserving privacy, estimate crowd size and density in real time, notifying security staff of any unusual crowd behaviour. Or imagine smart wristbands and mobile apps, allowing people to interact with each other and the performers, informing people of the best way out of the venue or guiding them to the nearest exit in case of an emergency.

These are some of the several applications which MONICA will demonstrate at minimum 16 cultural events, taking place all over Europe in Copenhagen, Bonn, Hamburg, Leeds, Lyon and Torino. The broad list of events includes concerts, festivals, city and sport events and involve the use of multiple, wearable, mobile and fixed devices with sensors, such as wristbands, smart glasses, video cameras, loudspeakers, drones and mobile phones, etc.

- IoF2020 (Internet of Food and Farm 2020)

IoT is expected to be a real game changer that will drastically improve productivity and sustainability in food and farming. However, current IoT applications in this domain are still fragmentary and mainly used by a small group of early adopters. The IoF2020 addresses the organizational and technological challenges to overcome this situation by fostering a large scale uptake of IoT in the European food and farming domain. The heart of the project is formed by a balanced set of multi-actor trials that reflect the diversity of the food and farming domain. Each trial is composed of well-delineated use cases developing IoT solutions for the most relevant challenges of the concerned subsector. The project conducts 5 trials with a total of 19 use cases in arable, dairy, fruits, vegetables and meat production. IoF2020 embraces a lean multi-actor approach that combines the development of minimal viable products in short iterations with the active involvement of various stakeholders. The architectural approach supports interoperability of multiple use case systems and reuse of IoT components across them. Use cases are also supported in developing business and solving governance issues. The IoF2020 ecosystem and collaboration space is established to boost the uptake of IoT in Food and Farming and pave the way for new innovations.

IoF2020 is a European LSP on IoT for Smart Farming and Food Security. Its main objective is to foster a large scale uptake of IoT in the European farming and food domain. This will contribute to a next huge innovation boost and consequently to a drastically improved productivity and sustainability in the agri-food domain. More specifically, IoF2020 aims to:

- Demonstrate the business case of IoT for a large number of application areas in farming and food;
- Integrate and reuse available IoT technologies by exploiting open architectures and standards;
- Ensure user acceptability of IoT solutions in farming and food by addressing user needs, including security, privacy and trust;
- Ensure the sustainability of IoT solutions beyond the project by validating the related business models and setting up an IoT Ecosystem for large scale uptake.

The IoF2020 consortium consists of 71 public and private partners from 16 different countries and has a total budget of 35 M€. The project started in January 2017 and will last for 4 years.

- ACTIVAGE (ACTivating InnoVative IoT smart living environments for AGEing well)

ACTIVAGE is a European Multi LSP on Smart Living Environments. The main objective is to build the first European IoT ecosystem across 9 deployment sites in seven European countries, reusing and scaling up underlying open and proprietary IoT platforms, technologies and standards, and integrating new interfaces needed to provide interoperability across these heterogeneous platforms. This ecosystem will enable the deployment and operation at large scale of Active and Healthy Ageing (AHA) IoT based solutions and services, supporting and extending the independent living of older adults in their environments, and responding to real needs of caregivers, service providers and public authorities.

Deployment sites will deploy reference use cases that address specific end-user needs, to improve their quality of life and autonomy. A single common interoperable ACTIVAGE IoT ecosystem suite will be built up that provides every deployment sites with the capacity to develop standard and interoperable IoT ecosystems on top of legacy IoT platforms, or communication and data management infrastructures. GLOCAL Evaluation Framework (local key performance indicator (KPI)s and global KPIs) will be designed and implemented to demonstrate and evaluate health & social outcomes and socio-economic impact from local up to a European scale, enabling effective exchange of experiences and cooperation among peers (e.g. users, providers, policy makers). 9 development sites rolled out in 7 countries to constitute a major breakthrough to sustain open innovation in AHA field.

2.3. IoT Europe Testbed

In this section, a table is provided with our study of IoT Europe testbeds which target to address IoT challenges and offers tools to support IoT innovations based on European relevance, technology readiness and socio-economic interests. First, twelve testbeds are listed in the umbrella of EC H2020 IoT Coordination Support Action as shown in Figure 2.2.

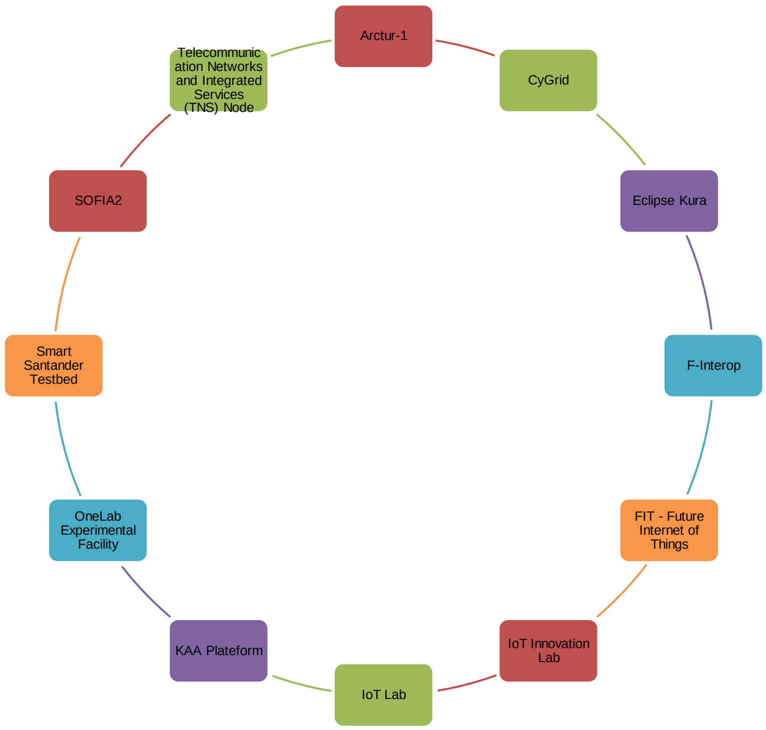

Figure 2.2 IoT Europe testbed overview

There are twelve dedicated IoT testbeds in Europe. They are, in alphabetical order,

Arctur-1	Slovenia	Arctur-1 is a Living Lab open to the general public offering HPC services to industries that require high-end technology ranging from astrophysics to 3D animation.
CyGrid	Cyprus	CyGrid is a local testbed aimed at students and researchers initiated by the Laboratory for Internet Computing (LiNC) - a research group located in the Department of Computer Science of the University of Cyprus. CyGrid includes a Grid Computing facility in Cyprus, the Cypriot node of the European Grid Infrastructure (EGI), the Cyprus Certification Authority (CyCA), e-Mammoth, a Cloud storage facility and Nephelae, a Cloud computing facility. It has a range of environmental and mobility sensors as well as satellite communication infrastructure in three Cypriot hospitals including the main referral hospital of Cyprus in Nicosia.

Eclipse Kura		Eclipse Kura is an Eclipse IoT project that provides a platform for building IoT gateways. It is a smart application container that enables remote management of such gateways and provides a wide range of APIs for allowing writing and deploying IoT applications. These applications leverage OSGi, a dynamic component system for Java, and Kura API to facilitate access to the underlying hardware (serial port, GPIOs, etc.), to communicate with an IoT server backend, to manage the runtime settings, etc. Eclipse Kura is a product which can be considered in the creation of gateways within the interoperability framework.
F-Interop	France	F-Interop is a Europe-wide federation of over 32 testbeds and Living Labs and 4755 nodes. It combines the testbeds registered in the three testbed federations: Fed4FIRE, OneLab, and IoT Lab (see separate entry). It's primarily aimed at improving interoperability and scalability between developing technologies with consideration for business, ethical, and environmental concerns.
FIT - Future Internet of Things	France	FIT is a large scale testbed for testing performance, interoperability, and security using nine sites across France including in Paris, Grenoble, Lille, Strasbourg, and Lyon. It is part of the OneLab federation (see separate entry). FIT IoT LAB offers a very large scale IoT testbed to address IoT challenges and offers to IoT designers, engineers, and researchers an large scale open access multi user scientific tool to support design, tuning, benchmarking, experimentation and accelerate the development of protocols, applications, IoT services and IoT technologies ranging from low level protocols to advanced services integrated with the Internet and cloud services. IoT-LAB testbeds are located in seven different locations across France (Grenoble, Lille, Paris, Rennes, Paris, Strasbourg, Saclay) offering access to 2728 wireless IoT fixed and mobile nodes equipped with various sensors: ambient sensor light, temperature, atmospheric pressure and temperature, tri-axis accelerometer, tri-axis magnetometer, tri-axis gyrometer.
IoT Innovation Lab	Sweden	IoT Innovation Lab positions itself as a simple cloud-based backend system for sensor network applications. It specialises in testing sensors in extreme and diverse conditions including those related to elevation (high and low) and temperature.
IoT Lab	Switzerland	IoT Lab forms one part of F-Interop (see separate entry) and concentrates predominantly on crowdsourcing and crowdsensing technologies.
KAA plateform		KAA (http://www.kaaproject.org/) is an open source multipurpose middleware IoT platform (Apache License 2.0) for building smart, connected and end-to-end IoT solutions.

		It facilitates data exchange among the attached devices, data analytics, visualization, and IoT cloud services. Capturing of device specifications, performing device provisioning, configuration, enabling cross device communication, and allowing distributed firmware update are the core activities done by KAA. It provides back end functionality to operate large scale IoT solutions comprising data security, consistency, interoperability, and data management with help of SDK that gets embedded into developer's chip or device.
OneLab Experimental Facility	France	OneLab is designed to be able to test in a variety of diverse networked communication environments including IoT networks with mobility and sensing capabilities, ad-hoc wireless and wireless broadband access networks, a global, public, fixed-line Internet, and Cloud and SDN networks. Both wireless and fixed-line emulated environments are available.
SmartSantander Testbed	Spain	SmartSantander is modelled as a highly localised Smart City in Northern Spain. It is large and flexible and available for use by researchers.
SOFIA2		SOFIA2 is a middleware that allows the interoperability of multiple systems and devices, offering a semantic platform to make real world information available to smart applications (Internet of Things). It is multi-language and multi-protocol, enabling the interconnection of heterogeneous devices. It provides publishing and subscription mechanisms, facilitating the orchestration of sensors and actuators in order to monitor and act on the environment. SOFIA2 is one of the several IoT platforms which have the potential to be considered for the interoperability of heterogeneous IoT platforms in this project.
Telecommunication Networks and Integrated Services (TNS) Node	Greece	TNS's network architecture consists of a Distribution Network and Servers; a 4G/B4G Wireless Network, an IoT-ready Wireless Sensor and Actuator Network. It is limited to selected users.

Table 2.1 IoT testbeds in Europe

2.4. Ongoing IoT LSP and testbeds in China

In this section, we list some ongoing IoT LSP and testbed in China which address the IoT applications based on China relevance, technology readiness and socio-economic interests in China. First, CNGI project is studied with the details as shown in Figure 2.3 and Table 2.2. Then a few other IoT LSP and testbed are also studied and introduced in this section.

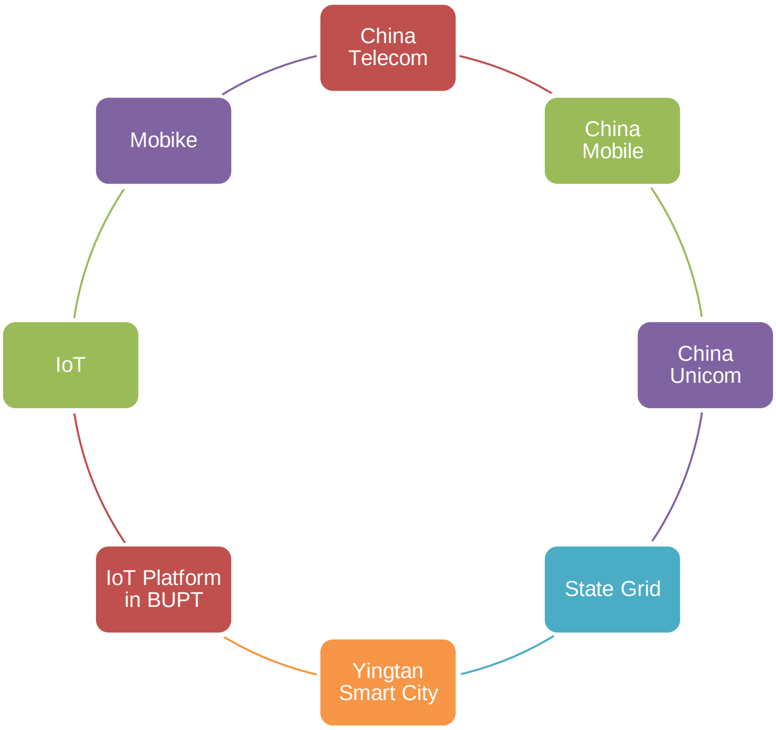

Figure 2.3 IoT China LSP project overview

In 2007, China set up the China Next Generation Internet (CNGI) with the intention of capitalising on technological advances in Internet infrastructure and, currently, the advances in IPv6 technology. All of the following information in Table 2.2 is derived from the CNGI project.[1]

China Telecom	China Telecom is a core network of the CNGI project with heavy investment in IoT infrastructure in China. It aims to have nationwide narrow-band IoT (NB-IoT) coverage and has already released the enterprise standard "NB-IoT equipment v1.0". This standard includes ITS, logistics, security monitoring, public utilities, intelligent manufacturing, modern agriculture, smart street lighting, video monitoring, intelligent financial POS information, waste management, smart manhole covers, and auto-parking. Over 400 NB-IoT base-stations have already been installed covering the entire city of Yingtan in Jiangxi province.

[1] Although CNGI has been launched with the target on the world's largest pure next-generation Internet, one of the primary goal is to provide the platform for IoT [4] or even making the IoT the very core of the future Internet [5]. Therefore we provide Table 2.2 here.

China Mobile	China Mobile is a core network of the CNGI project and runs the OneNET open cloud platform which offers PaaS and SaaS. It offers a variety of network access protocols and access to networked devices, smart homes, smart cars, and wearable devices. China Mobile offers intelligent parking including parking online queries, online booking, reverse searches, and online payments. They have conducted NB-IoT and eMTC trials in Hangzhou, Shanghai, Guangzhou, and Fuzhou and now have 5000 stations. As of 2015, they have over 65 million IoT terminals registered with China Mobile.
China Unicom	China Unicom is a core network of the CNGI project and will launch NB-IoT LSP in at least six cities for testing purposes. Their IoT-service platform and NB-IoT private network is supporting smart city construction, smart meters, smart parking, environmental monitoring, and intelligent manufacturing in Shanghai. Over 3000 base stations are being built in 2017.
State Grid	The State Grid will experience IPv6-sensor deployment with a minimum transmission speed of 250kbps. It will permit power transmission monitoring and, with the help of Mobile IP technology, power line monitoring and mobile meter reading.
Yingtan Smart City	Yingtan Smart City has built a global coverage of NB-IoT business network, with 135 NB-IoT base stations. Several IoT businesses have been deployed, including smart city management, smart street light, smart parking, smart logistics and smart agriculture.
IoT Platform in BUPT	The IoT platform in BUPT includes both an Android-based gateway and Cloud service. It is an open platform - easy to extend to new scenarios - supports restful architecture and heterogeneous devices (IP and non-IP), and represents data in XML/JSON. An example of its use is the smart classroom where it is possible to control the lights and environmental controls as well as to monitor the number of students and what devices they have with them. New functions can easily be added while old functions can easily be updated. Cloud-computing allows for the possibility of Big Data Analysis too.
IoT Testing Platform in Southeast University	The IoT testing platform includes 200 sensor nodes. Users are able to control the nodes for testing, including base station, nodes, relay and malice node remotely. The protocols to be tested can be downloaded remotely as well. The performance metric include throughput, loss rate, delay, average path, average energy consumption and scalability of network, etc.
Mobike	Mobike is created by Beijing Mobike Technology Co., Ltd., which is a fully station-less bicycle-sharing system currently deployed in Beijing, Shanghai, Guangzhou, Shenzhen, Chengdu, Ningbo, Xiamen, Foshan, Zhuhai and Wuhan. It is the world's largest bicycle operator, and recently made Shanghai the world's largest bike-share city. Mobike works with China mobile, Vodafone, Ericsson, Qualcomm, and Huawei to create a seamless mobile networking system. It is also the first one to use NB-IoT in the real case.

Table 2.2 IoT testbeds in China

In addition to these networks, CNGI includes three more core networks: CERNET2 featuring IPv6 technology, an IX6 international exchange centre linking to GEANT2/Internet2/TIEN3, and more than 700 organizations connecting over 6 million users; China Netcom/CAS; and China Railcom.

Apart from the CNGI project listed in Table 2.2. There are several other IoT LSP are ongoing in China. We also listed them here for our study in WP4.

- GreenOrbs: an IoT platform for forest surveillance

GreenOrbs project is a long-term LSP, which the missions of it are twofold: on the one hand, GreenOrbs realizes all-year-round ecological surveillance in the forest, collecting various sensory data, such as temperature, humidity, illumination, and carbon dioxide titer. The collected information can be utilized to support various forestry applications. On the other hand, GreenOrbs is one of the latest efforts in the research community to build practical IoT. Through the real-world experience in GreenOrbs, research expects to explore the potential design space and scientific solutions of it.

This large scale deployment of GreenOrbs system is carried out in the Tianmu Mountain, Zhejiang, China. Researchers adopt TeloB motes with MSP430 processor and CC2420 radio. The sensor node software is developed based on TinyOs 2.1, using a globally synchronized duty-cycling mechanism for all the nodes. In each power-on period of the nodes' radios, researchers adopt the CTP protocol to collect the data, whereas the beacon frequency is modified to save communication cost. Data disseminations from the sink are enabled to control the nodes' operational parameters, i.e. the transmission power, sampling frequency, duty radio, and the length of a duty cycle. By April 2020, GreenOrbs has expanded to include 1,000+ nodes. The nodes using battery power will be kept in continuous operation for over 1 year. Currently, GreenOrbs supports three typical applications: canopy closure estimate, fire risk evaluation, and forest microclimate observation.

- NB-IoT: Demonstration of IoT in smart-city scenario

Developed by China Telecom in Xiong'an, Hebei. Since 2017. Xiong'an is a new metropolitan zone that will share parts of the capitals functionalities. NB-IoT is developed by China Telecom since May 2017, aiming at showing the potential of IoT in building smart cities. Currently, it supports the demonstration for smart parking, manhole cover monitoring, as well as smart road lamps. It also has full support from the government and three telecom operators. An open IoT Lab has been put in place, notably by the Chinese Academy of Sciences.

- The Internet+ Mega Project

It will be a demonstration network for IPv6-oriented education and will feature a backbone network with speeds of up to 100Gbps, more than 40 network Giga pops, and more than 100 million IPv6 users. This project is a NGI Innovation Project organised by CERNET.

Concerning the IoT use cases, some of them are also deployed and evaluated in the first testbed for 5G in China. This testbed is composed by 27 partners.

In addition to the IoT network, development of an operating system for IoT is underway covering things such as smart homes and MEMS sensors. The former includes examples such as Qingke Mico and Ali YunOS that cooperate with hardware suppliers and home appliance manufacturers, and

LiteOS which was developed by Huawei. The latter has been developed by multiple Chinese sensor manufacturers and includes improvements to accelerometers and thermal detection.

Since 2010, the National Development and Reform Commission and the National Standards Commission have been jointly working on defining unifying standards across the IoT industry in China. This includes the following unique sectors: public security, transportation, healthcare, agriculture, forestry, and environmental protection. Their work includes unifying terminology, technical requirements, and performance evaluation.

2.5. IPv6 potential for European Union (EU)-China testbed integration

The deployment of IPv6 is highly advanced in China, in particular, the core networks managed by organizations across China. The natural need for scalability within China necessitates a lot of entry points to the Chinese IPv6 network. Every end point and, eventually, every base station for wireless communication protocols will be able to be connected harmoniously. In Europe, this is a little different as the deployment of IPv6 is variable across the European continent. This deployment depends on several factors like the size of the country, the budget allocated to or by the national telecom operators, and the will of each of the national governments. In Europe, the European Union and different private or non-governmental organizations like the IPv6 Forum and the IoT Forum actively encourage the deployment of IPv6.

The advantages of IPv6 for connecting the European Union (EU)-China testbeds are obvious. First, the routing is more efficient for ISPs: this could be important for long transactions between Europe and China. The configuration of the network is facilitated by IPv6 and less work is needed on the testbeds' side. Of course, security is improved with IPSec, which didn't exist in IPv4. Through IPv6, an end-to-end connectivity is possible, for instance, an IoT device connected in Europe can be easily accessed by a Chinese testbed. The benefits of the end-to-end connectivity are huge and permit the creation of new services on the Internet. The usage of IPv6 to interconnect the EU-China testbeds means that there are fewer problems than the older IPv4 protocol.

The connections between the different testbeds spread across China and Europe can be established directly with the help of IPv6. Indeed, the end-to-end connectivity brought by IPv6 doesn't require the installation of specific network infrastructure on both sides of the world. In case of eventual problems, a strong collaboration between big network managers (GEANT in Europe for example) is necessary. This has already been put in place through the IX6 international exchange centre.

2.6. Summary

In this chapter, our studies of IoT LSP and testbed in both Europe and china are discussed here. First we listed the ongoing IoT LSP and testbed in Europe. Then a list of China LSP and testbed is also introduced in this chapter. Moreover, a discussion about of IPv6 potential for EU-China testbed integration is also provided in this chapter.

3. 5G TEST-BED AND LSP DEPLOYMENT

3.1. Introduction

In this chapter, the pilot concept of 5G and some ongoing 5G large scale testbeds will be studied. The scope of 5G large scale testbed is to support the development of 5G ecosystems in both Europe and China and contribute towards the delivery of the objectives in the 5G strategy. The aim is to foster technology and deployment, large scale testbeds and trials to stimulate the development of 5G use cased and business models.

As it is known, 5G will not only be an evolution of mobile broadband networks, it will bring new unique network and service capabilities. It will ensure user experience continuity in challenging situations such as high mobility (e.g., trains), very dense or sparsely populated areas, and journeys covered by heterogeneous technologies.

In addition, 5G will be a key enabler for the IoT by providing a platform to connect a massive number of sensors, rendering devices and actuators with stringent energy and transmission constraints. In addition, 5G will be a key enabler for the IoT by providing a platform to connect a massive number of sensors, rendering devices and actuators with stringent energy and transmission constraints. Furthermore, mission critical services requiring very high reliability, global coverage and/or very low latency, which are up to now handled by specific networks, typically public safety, will become natively supported by the 5G infrastructure. Leveraging on the characteristic of current cloud computing, 5G will push the single digital market further, paving the way for virtual pan European operators relying on nationwide infrastructures.

5G will be designed to be a sustainable and scalable technology. Firstly, the telecom industry will compensate tremendous usage growth by drastic energy consumption reduction and energy harvesting. In addition, cost reduction through human task automation and hardware optimization will enable sustainable business models for all ICT stakeholders.

Last but not least, 5G will create an ecosystem for technical and business innovation. Since network services will rely more and more on software, the creation and growth of start-ups in the sector will be encouraged. In addition, the 5G infrastructures will provide network solutions and involve vertical markets such as automotive, energy, food and agriculture, city management, government, healthcare, manufacturing, public transportation, and so forth.

It is essential that large-scale, multi-layered collaboration projects are available to achieve the goals of 5G development. The ICT sector in Europe is leading the way to drive this process, which is supported by the 5G PPP in Horizon 2020 of the EU. The initiative can remove obstacles that may hamper the 5G development by achieving an early consensus among key global stakeholders, e.g. on a common 5G vision (as we introduced in Chapter 1), architecture, spectrum utilization, pre-standardization and international collaboration between Europe and the relevant bodies in China, Japan, Korea and USA, to start from. In addition to the private continuous effort, it is of vital importance that public authorities and the private sector develop effective policies with regard to spectrum, pre-standardization and international collaboration. What we need is an evolving regulatory framework that provides a true level playing field for current and new players coming into the picture, thanks to the novel sustainable business models that 5G will enable.

3.2. 5G Europe large scale testbed

In this section, we list several ongoing 5G Europe large scale tested based on European relevance, technology readiness and socio-economic interests in Europe. As shown in Figure 3.1, four testbeds are introduced here.

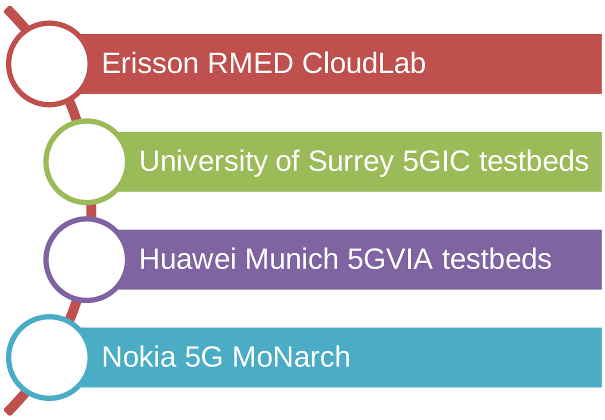

Figure 3.1 5G Europe testbeds overview

- Ericsson RMED CloudLab

Ericsson SoftFIRE testbed is part of the Ericsson RMED CloudLab. Located in Rome, CloudLab's scope is to provide hands-on competence build-up, and to show specific and concrete "proof" points for cloud computing. The lab is also designed to house demonstrations to customers on specific products, which helps to show the customers how issues can be addressed and hence mitigates potential risks.

Main activities performed in CloudLab are:

- Experimenter demos,
- Deep dive on customer-specific requests,
- Fully customized Proof-of-Concept (PoC) demonstrations on customer premises,
- Validation and certification on customer specific stack / solutions.

Cloudlab in SoftFIRE provides an Infrastructure as a Service (IaaS), creating and managing large groups of virtual private servers in a single data centre. It runs OpenStack Liberty as its infrastructure controller.

- University of Surrey 5GIC testbed

The UoS SoftFIRE testbed segment is part of the overall UoS 5GIC testbed. Located in the UK, the scope of the testbed is to provide hands-on access to a 3GPP based campus RAN with indoor and outdoor coverage that is able to be interconnected with a variety of virtualized core slices, in order to develop Core Network 5G evolutions and demonstrate 5G use cases running over the resultant end-to-end (ETE) cellular network. In this manner, the testbed can be used to build industry core competence in 5G.

The network was initially built as a fixed ETE cellular system, but has now been evolved to provide a set of virtualised network capabilities that can be configured to connect with IP stubs towards the RAN to enable various network slices to be connected in circuit under the control of the federated SoftFIRE core.

It is envisaged that experimenters using the facilities of the UoS SoftFIRE testbed will be able to show specific and concrete "proof" points related to the 5G RAN and Core evolutions and demonstrate applications running over this infrastructure. These use case proof points can be used to support many types of use cases to highlight their benefits, explain to customers and industry partners how they work and demonstrate how 5G targets may be met, and what the pros and cons are for each demonstration.

- Huawei Munich 5GVIA testbed

Huawei, a leading global ICT solutions provider, is accomplishing a crucial step in making the 5G a reality for Europe. In cooperation with the Bavarian State Government, City of Munich, Technische Universität München, and M-Net, Huawei is building the 5G Vertical Industry Accelerator, a large experimental system for testing promising 5G communication concepts.

Huawei has recently revealed plans to invest US$600M in research and innovation into 5G technologies by 2018. The Munich 5G VIA testbed will be an important part of this process. Namely, most of the research work on 5G throughout the world has focused so far on developing generic concepts for 5G communication. The 5G VIA experimental system will enable researchers to test the developed algorithms in real-world environments and specific scenarios envisaged for the vertical markets of the digital society beyond 2020. The testbed will be built with the crucial support from the Bavarian State Government, City of Munich, TUM and M-Net for the setup of trial sites in the city and the conduct of experiments.

The first trials were performed in December 2014 on Huawei European Research Center (ERC) campus in Munich. The focus was put on demonstrating some of the key features of the new waveforms for the 5G air interface such as flexible fragmented spectrum usage and latency reduction, which can support versatile 5G application scenarios and ultimately render a 5G Service-Oriented Radio Network. As a prominent example we highlight E-health, where 5G technologies will play a crucial role in the progressive virtualization of health care and the strengthening of the self-management capabilities of patients and carers. In response to the latest German legislative activity on E-health, and the booming (medical) Internet of Things, Huawei and TUM are planning to set up joint activities at Klinikum rechts der Isar to continue the so far successful work at the forefront of digital health.

The Munich 5GVIA testbed is part of Huawei's broader 5G research and innovation activities in Europe. Huawei ERC in Munich participates as a member of the European research consortium METIS in the development of the key technology components for the new 5G air interface. The ERC is also one of the principal contributors in the Horizon 2020 and the advanced 5G PPP funded by the European Commission, where it collaborates with major companies from various industry verticals. Ultimately, the Munich 5GVIA testbed will become an innovation platform for global collaboration among the ecosystem partners, such as large private sector companies, SMEs, universities, and governments, in order to drive 5G technologies.

5G heralds the next generation of wireless networks that will power the technology of tomorrow. Huawei expects 5G to be deployed commercially by 2020. Compared with the 4G systems which are currently being deployed, 5G will, besides a significant capacity increase, enable lower latency of less than 1ms, yielding reaction times indiscernible to humans, ultra-reliable links, and 1000-fold improvement in data transmission energy efficiency, and support for massive numbers of versatile devices including the estimated 50-100 billion internet-of-things connections by 2020. Correspondingly, 5G wireless communication will foster a significantly broader set of applications in areas such as internet-of-vehicles, factory automation, smart grid, healthcare, etc., unimaginable with the wireless technology of today, and it will revolutionise the corresponding industry verticals.

- Nokia 5G MoNarch

5G MoNArch involves 14 key mobile network players from six European countries, bringing together the complementary background and technical know-how required to turn the project's vision into reality. In continuation of 5G-NORMA, 5G-MoNArch enriches the original architectural concepts of the first phase with innovations such as cloud-enabled network protocols, and showcases the new technology in two testbeds. The flexible and programmable architecture will support the vast variety of services, use cases, and applications that 5G will bring in the next years.

The main objectives of 5G MoNArch are:

- Detailed specification and extension of 5G architecture
- Enhancement of architectural designs with key enabling innovations such as inter-slice control and cross-domain management, experiment-driven modelling and optimization, and native cloud-enabled protocol stack
- Functional innovations around the key technologies required for dedicated 5G use cases: resilience, security, and resource elasticity
- Deployment and experimental implementation of the architecture for two use cases in real-world testbeds - heavy communications usage in a tourist-heavy city, and secure and reliable communication in a seaport environment
- Evaluation, validation, and verification of the architecture performance

3.3. 5G China Large Scale testbeds

Here, we provided a couple of 5G testbeds developing in China.

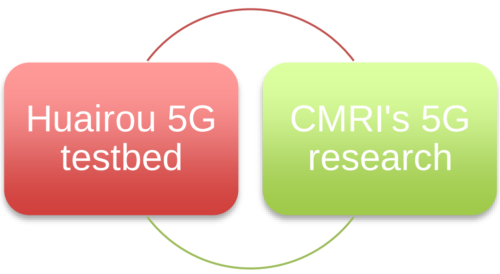

Figure 3.2 5G China testbeds overview

- Huairou 5G testbed

Developed by CNIC and Datang Telecom. Since 2017. This testbed was first announced on March 29,

2017. It was initialized by MIIT (Ministry of Industry and Information Technology) to build the world's largest 5G experimental network in Huairou, Beijing. The testbed has been then developed by CNIC (Computer Network Information Center, CAS) and Datang Telecom. At present, the central site of the testbed has been established. A small-scale network testbed is expected to be ready at the end of this year. Then, some experiments will be carried on, including high capacity, low latency-high reliability and low-power consumption connectivity of 5G network.

- China Mobile Communications Research Institute (CMRI)'s 5G research

Lots of companies are partnering up to figure out what 5G is and how it will be deployed. One of the newest collaborations is between test-and-measurement vendor Agilent Technologies and China Mobile Communications Research Institute (CMRI), the R&D arm of the world's largest mobile operator.

Agilent was tapped to provide wireless testing solutions for CMRI's 5G research, which will also leverage Agilent's expertise software-defined radios.

CMRI's research topics include large scale antenna systems, full-duplex radio, energy efficiency and spectral efficiency co-design, and new signalling/control mechanisms "to achieve the main theme of green and soft," the companies said. They explained that "green and soft" refers to 5G research areas related to energy and spectral efficiency co-design, signalling and control, invisible base stations and full duplex radio.

3.4. Summary

In this chapter, our studies of 5G pilot concept and large scale testbed in both Europe. A list of Europe 5G testbeds is provided in this chapter based in our study in WP4. Then a couple of China 5G testbeds are also introduced in this chapter.

4. CONCLUSIONS

In this deliverable, the studied results of Task 4.1 are presented here. The primary goal of WP4 and the motivation of designed two tasks are reviewed at the beginning of this deliverable. To approach the targets, two phases methodology is used in this work package. Then LSP and testbeds of IoT from both Europe and China are studied and listed here. Moreover, an analysis of IPv6 potential for EU-China bestbed integration is also provided to help for further understanding and identifying the ongoing LSP between two parties. 5G as one of the fastest growing area in technology sector, several pre-pilot or large scale testbed are under developing. We studied several of them from both side, and listed them in Chapter 3. The results of this deliverable will be used as the input for the phase 2 in WP4, which will target on a set of good practices and recommendation to be considered in future cooperation opportunities for LSP.

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