Towards Unified Smart City Communication Platforms

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***Abstract*—Smart City solutions are gaining more momentum recently, motivated by the increase of population moving towards living in urban environments. The need to create a unified Smart Platform in order to overcome challenges in various domains has become an important research topic. In this paper we highlight our efforts in addressing requirements and challenges associated with building Smart City Communication platforms.**

I. Introduction

During the last decades, we have witnessed new technological evolutions on the Internet, wireless networks and sensors fields. We are currently able to build Smart Systems that improve the quality of life and enhance environment management. However, most available Smart Systems are implemented based on proprietary hardware/software solutions, which restricts the interoperation feature required for large-scale deployment of Smart City solutions. According to the United Nations (UN) more than half of the worlds population lives in urban areas, and it is suggested that thousands of new cities need to be built worldwide by 2050. Furthermore, humans keep demanding technologies to improve their lives and support them in daily activities. Experts point at Smart Cities as an emerging market with enormous commercial potential, which are expected to drive the digital economy forward in the coming years. Globally, the current consensus value of the IT market for Smart Cities is approximately $35bn [1].

The connection between the physical and the IT infrastructures forms the new Machine-to-machine (M2M) communication trend, which is one of the key enabler technologies for Smart Cities. This trend, coupled with the emergence of new features from network operators and IT infrastructure suppliers, is the driving force behind Smart City platforms. These are needed to fulfill the communication requirements between heterogeneous access technologies and applications suppliers. This paper features the effort to address design, requirements and challenges of the implemented unified Smart City Communication platforms. These platforms leverage the convergence of real world sensors and communication networks forming the Internet of Things (IoT).

The remainder of the paper is organized as follows: Section II provides a brief literature review of the definition of Smart Cities and their main aspects; Section III and IV discuss the requirements of Smart City architecture and applications; Section V presents our work on developing Smart Cities prototypes at Fraunhofer InnoCity and the University of Chile. Finally, in Section VI the conclusions are presented.

II. Aspects of Smart Cities

A Smart City is widely considered as a hot topic; however, there is no clear definition of Smart City concept among practitioners and academia. The authors in [2] define the idea of a smart city as a system of systems; i.e. integrated systems form a closed loop and are characterized by functions such as, sensing, information management, analysis and modelling, and influencing outcomes. Each system produces its own information and consumes others information in a well-defined urban planning environment.

A holistic definition of the term from [3] embraces six characteristics that need to act smartly to achieve a Smart City, these being, *well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens*. Experts from various fields provide more concrete definitions, which emphasize the role of their own approach and activities. From the Information Technology (IT) perspective, a Smart City can be defined as *a city connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city* [4].

Many initiatives address the creation of Smart Cities worldwide. Some examples are: the Barcelona Smart City model [5] that aims to generate smart ideas in an open environment through raising clusters or developing proper living labs while directly involving citizens in the co-creation process of products or services. The main assets of the Barcelona Smart City Model are: Smart Governance, Smart Economy, Smart Living and Smart People. The Helsinki Smart City Region [6] forms a strong innovation-oriented cluster around mobile technology, supported by local and regional government and driven by the Living Labs approach and the mobile application cluster. Various Living Labs have been established in and around the Helsinki region. Their functions are diverse, but they all base their activities on the principles of User-Driven Innovation (UDI). The aim of the Living Labs is to promote the Smart City concept and drive the development of the Future Internet by providing knowledgeable, experienced and idea-rich users together with the developers of new services and products. This should increase the quality and usability of the services and products created. Some large cities in China, Beijing, Shanghai, GuangZhou, and ChongQing, have launched Smart City strategies, in order to strengthen city management and improve services dealing with traffic jams and overcrowding [7].

III. The Requirements of Smart City Infrastructure

Increasingly more devices are being connected to the Internet every day. In the past 5 years, the numbers of connected M2M devices have increased by 300% [8]. In the near future, almost any kind of object will be allowed to seamlessly integrate into a large-scale M2M environment. M2M setups provide the opportunity to deploy a new category of services. However, they have traffic patterns very different from the human-centred services, which mainly involves multimedia sessions, web browsing, and remote control.

On the one hand, Smart Devices are connected through the networks to novel service platforms in a self-controlled system. On the other hand, the current communication networks are designed to support human-centered communication, optimized for devices under direct human control. Generally, the common research challenges faced by the previously mentioned initiatives towards a Smart City infrastructure, can be summarized as follows:

A. Scalability

Existing technologies make the IoT concept feasible but these do not fit well with the scalability and efficiency requirements at different levels including: naming and addressing, communication and networking, data management, and service provisioning. Therefore, scaling issues are urgently needed to be addressed.

B. Governance

Smart City services involve many different stakeholders, such as distinct application providers, device vendors, and radio and core network providers. In order to be able to manage the overall system consistently, flexible horizontal solutions are needed for sharing skills, network infrastructures, and devices between stakeholders.

C. Testbeds

To perform precise experimentations of Smart City services, a city scale testbed is needed. Many existing testbeds [9], [10] provide a good proof-of-concept. However, they merely offer experimentation and testing that is limited to specific environments or application specific deployments and do not allow conclusive experimentation at the level required for commercial developments. Moreover, Smart City deployment involves different non-technical stakeholders. Hence, many non-technical constraints must be considered such as users, public administrations, government, etc.

IV. The Requirements of Smart City Applications

As we evolve from the static web to social networking (Web 2.0) to a ubiquitous computing web (Web 3.0) the Internet is stepping toward as a fully integrated Future Internet, which significantly increases the need for sophisticated Smart applications. The M2M communication aims to enable connecting everyday existing objects, and allows more non-human content providers to feed the Internet with data in various formats. Smart City services should have the capability to analyses data and provide instant real time solutions for many applications in order to promote positive outcomes. There are many domains and environments in which new Smart Services are likely to improve the quality of our lives, such as: transportation, logistics, healthcare, and Smart environment (home, office, plant) domains.

Smart Communication middleware aims to enable a seamless combination of services by providing a single point of access that supports various application layer technologies for communication services and networks. The main requirements of deploying M2M applications in large-scale systems can be summarized as follows:

- Supporting services deployed and hosted by 3rd party developers.
- Rapidly delivering services to the market.
- Co-existing and collaborating with current core networks and new deployment.
- Delivering and handling different kinds of content and supporting variable bit rates.
- Being compliant with standard-based services.

The process of designing Service Enablers and Application Programming Interfaces (APIs) is critical because it is intended to be written once and used many times over for various cases that can influence the design. Latter changes or updates may impact users due to compatibility issues. We suggest a taxonomy for centric enablers that will aid in defining the requirements for both, Smart Communication and Future Internet.

A. Human-to-Human (H2H) communication

In H2H both participants of the session are humans using Smart Devices (e.g. mobile, PC), who wish to exchange voice, video or data during the session. Applications targeting this kind if communications will require service enablers such as: Address book, presence and file transfer.

B. Machine-to-Machine (M2M) communication

M2M refers to the paradigm of communication that enables machines to interact autonomously with no human intervention. Service enablers for M2M should be designed keeping in mind the fact that devices are not under direct human control.

C. Overarching Services

This category include all types of management and control services that are required in association with H2H and M2M communications, such as security and Quality of Service (QoS) controlling.

V. FOKUS InnoCity and University of Chile Reference Platform

A joined effort between Fraunhofer FOKUS in Germany, Fraunhofer Chile Research FOKUS InnoCity and the University of Chile, is building the Reference Architecture for Smart City Communicational Platforms developed by FOKUS. So far, the partnership has implemented this platform in Chile as a combination of technology between vendor Labs and innovative platforms from FOKUS. The OpenMTC platform [11] for M2M communications is implementing a prototype of the latest standards from ETSI SmartM2M specifications [12], [13] and oneM2M [14]. The OpenMTC platform aims to provide a standard compliant middleware platform for M2M oriented applications and services enabling Smart City implementation, through supporting application domain driven scenarios [15].

Let's consider the Smart City applications that require low latency and broadband wireless access based services; for example, in Mobile Cloud Computing based applications, the University of Chile has added E-UTRAN and EPC Labs from technology vendors since 2009, as the diagram in Fig 1 shows. This LTE Lab complements the (Open)IMS and 3G Labs for test bedding and prototyping purposes. The existence of distributed and seamless architectures for communicational platforms that support Smart Cities prototypes at Fraunhofer InnoCity and UdeChile, is the natural extension of the UniFI project. This is depicted in Fig 2. The objective of the UniFI project is to build sustainable teaching and research infrastructures in the areas of Future Internet and Smart Cities through global collaboration among academic institutions. This project also includes the creation of Competence Centers for a sustainable development and bundling of local expertise in Chile, Vietnam, South Africa and Thailand with a strong collaboration and technology transfer from Technische Universitt Berlin (TUB) in Germany. The federation of seamless Labs that support Smart City prototyping is another important goal of UniFI [16]. Fraunhofer Innocity plays an important role in Chile, developing M2M competence and also facilitating the Smart City technology transfer, especially in the Communicational Platforms for distributed prototyping and interoperability testing purposes. A Smart City Center based on Fraunhofer InnoCity that coordinates the Chilean universities is under preparation and considers various domains, including Smart Building, Smart(er) Campus as part of Smart Education, Smart Energy, Smart Health and Smart Transport. The international networks established by Fraunhofer will allow the assimilation of knowledge developed in other environments to be rapidly integrated and prepared for scaling required for applications in a City such as Santiago.

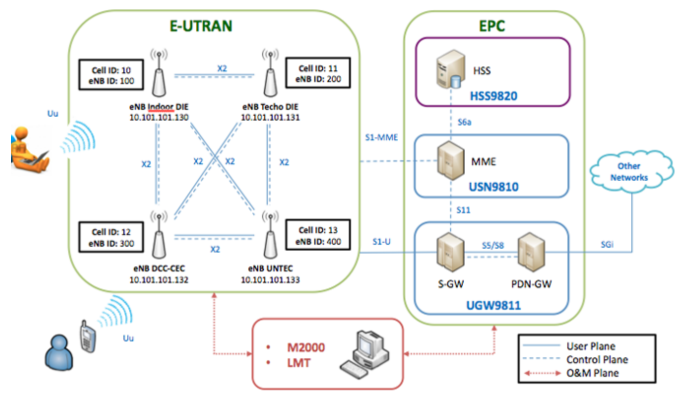

Fig. 1. LTE Lab Architecture at Universidad de Chile.

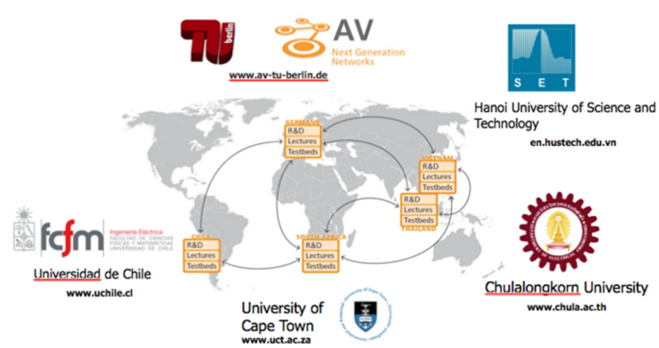

Fig. 2. UnifI Project Testbed.

VI. TRESCIMO Federated Testbeds

Aiming for large-scale testbeds for Smart City deployment, the Testbeds for Reliable Smart City Machine to Machine Communication (TRESCIMO) project is building a federation of testbeds [17]. This federation allows for experimentation with enabling technologies, standardized platforms and Smart Cities applications with different configurations. As part of this project, two testbeds are deployed at TUB and University of Cape Town (UCT) [18]. Fig. 3 shows the current high level architecture of the federated testbeds. The two testbeds shared a common control stack that consists of a Virtual Private Network (VPN) Server, Monitoring Server and an Orchestrator. The VPN Server provides secure interconnectivity for servers and devices located at both testbeds. In order to ensure the reliability of the federated testbeds, the Monitoring Server checks and reports on the status of the virtual Smart Infrastructure Services, physical devices and servers. The orchestrator is used to provision and reserve the resources required by an experiment.

Smart infrastructure services such as emulated devices, OpenMTC Servers and gateways are provided as virtual services running in an OpenStack cloud. Providing the infrastructure as virtual services allows for the facility to provide experimenters with complete configuration capabilities within the assigned resources, while at the same time optimizing the use of the physical infrastructure. Critically, this provides the experimenters to generate more complex that involve multiple servers, gateways and devices. The use of physical devices, provides opportunities for experimenters to develop, test and evaluate services for real world deployments. Energy measuring, home automation and health care devices are deployed within the federation of testbeds. Access to these real devices is controlled as part of the orchestration process. To complement the physical devices, emulated devices are provided as a service. Using emulated devices allows for the testbeds to provide a means for scalability experiments. Scalability experiments typically involve a large number of similar devices interacting with a single service.

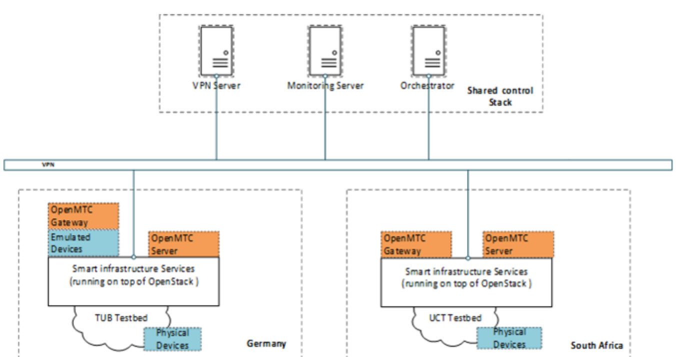

Fig. 3. TRESCIMO Federated Testbeds.

VII. Conclusion

At a recent workshop in Berlin in April this year an active transfer of know-how and experience to FOKUS InnoCity and the University of Chile took place. This will bring the OpenMTC platform to Santiago. As OpenMTC is a Standard Based Platform it will allow Interoperability testing in Santiago with both commercial as well as government partners. The experience which the University of Chile has gained in providing access and training of more than 600 engineers and technicians in the FOKUS OPEN X and LTE Vendors laboratories, as telecommunications operators will be an invaluable stepping stone for the Interoperability development in Chile. This will allow FCR FOKUS InnoCity and University of Chile to develop into a reference laboratory for prototyping Smart City communication requirements.

The international networks established by Fraunhofer will allow the assimilation of knowledge developed in other environments to be rapidly integrated and prepared for scaling required for applications in a City such as Santiago.

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