Communication and Sensor Solutions for Smart Cities and Communities

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ABSTRACT: *Rapid urbanization affects both, increased environmental pollution of cities and communities as well as the need to ensure sufficient resources and adequate services for the living and well-being in cities. This requires the development and introduction of innovative solutions to cities and communities, that will preserve/ensure the high quality of life and will enable the development of new, user-oriented public services. The concept of smart cities is largely based on information, communication and sensor technologies and infrastructure for capturing and monitoring various phenomena. The purpose of this article is to present the research and development activities of the Department of Communication Systems at Jozef Stefan Institute in the fields of wireless communications, embedded and sensor systems with which it has been successfully participating in several EU and national projects. The research activities resulted, among others in the development of two own technologies, (i) modular sensor platform VESNA, whose flexible design allows its adaptation and use in different application areas, and (ii) a lightweight infrastructure management and message broker framework VIDEK, as well as functional prototype of personal ECG and other body signals measurement device PCARD. VESNA also represents the basis for several sensor network pilot deployments and LOG-a-TEC experimental testbed, which plays an important role in research and development of functional building blocks for new smart cities services.*

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1. Introduction

In modern conceptions, cities are perceived as complex systems of essential infrastructures built to facilitate interaction between people and businesses. Traditionally, the term infrastructure refers to utility, transport and energy infrastructure. Besides these, the information and communication infrastructures as well as sensorial infrastructure have gained in importance in the last decade or so, especially in line with the Smart Cities paradigm. Due to the growing environmental challenges and fast pace of

urbanization, cities and communities are compelled to develop integrated, cheaper and environmentally friendly solutions. In order to ensure the high quality of life for its citizens and attractive environment for the business, cities and communities started to implement *smart city* solutions. That is to say, they try to capitalize on new, particularly the ICT and sensor technologies, to transform their infrastructures and service delivery. To facilitate the transformation of modern cities towards smart cities, further research and development is needed in the fields of next-generation telecommunication networks, wireless communication, embedded and sensor systems **Error! Reference source not found.**, **Error! Reference source not found.** .

The mentioned are being the core activities of the Department of Communication Systems at Jo•ef Stefan Institute. The Departments' research activities are carried out by approximately 30 researchers in three laboratories, the *Communication Technology Laboratory,* the *Parallel and Distributed Systems Laboratory* and the *Networked Embedded Systems Laboratory.* The work of the laboratories is complementary, which is reflected in several joint projects.

The Department has successfully participated in more than 20 EU research projects since FP4, acted as a research partner in several large national projects including the Centre of Excellence in ICT (2004-6), OPCOMM and CLASS Competence Centres (both 2010-13), carried out many technology development projects for/with industrial partners, and has developed extensive international cooperation with partners from research organizations and industry.

2. Competences in the Area of Smart Cities

2.1 Projects and Programs

Smart cities and communities are described as places where information and communication technologies are used to make traditional infrastructure and services more efficient. Underlining technologies and services address areas such as utilities management, transportation, energy efficiency, smart buildings, public safety as well as responsive public administration **Error! Reference source not found.**.

Researchers from the Department of Communication Systems have developed expertise in many of the before mentioned areas by successfully participating in various projects and two basic research programs. The projects and research results most applicable to Smart City solutions development are briefly outlined in the following.

ABSOLUTE project (FP7) researched into requirements for designing a rapidly deployable mobile communications and sensor networks to provide broadband services in the aftermath of an emergency, disaster or related unexpected events. Department participated in the development of modular sensor nodes for emergency situations, their integration and validation as well as in activities aiming at system requirements definitions, study and implementation of advanced cognitive radio and networking techniques. Among others it developed and demonstrated a geolocation database approach for determining exclusion zones for the operation of ad hoc emergency communication systems. The project is directly relevant to smart city initiative Secure Society.

The main aim of the **APRICOT** national basic research project was to annotate, discover and reason upon sensor and associated communication resources and compose those resources into dynamic global sensor infrastructure. By allowing supporting searching, discovering and sharing of sensor resources the results of this project are directly relevant to smart cities supporting infrastructure.

CITI-SENSE project (FP7) aimed to develop "citizens' observatory" to empower citizens to contribute to and participate in environmental governance and enable them to influence the societal priorities and associated decision-making. It developed, tested and validated community based environmental monitoring and information system. The case studies focused on a range of services related to environmental issues and were based on distributed and/or participatory data collection using innovative static, portable and personal air quality monitoring devices. The Department mainly contributed in the area of sensor and communication technologies by developing a portable/personal air quality monitoring unit (see Fig.1) and a related mobile app for collecting, visualizing and forwarding measurements to remote data center for further processing and provision of advanced services. Air quality monitoring and participatory data collection are directly relevant to the concept of smart cities, where they can empower citizens and support policy and decision makers.

SUNSEED, another FP7 project, proposed an evolutionary approach to converged exploitation of communication infrastructures

Figure 1. A mobile portable sensor pact developed for the CITI-SENSE project

provided by telecom operators for future smart energy grids offering open services. By doing this, the project will lower the investments and total cost of ownership for future smart energy grids that will cover large, dense distributed energy generation and e-car charging infrastructures. The Department contributed with the design of wide-area measurement units and power metering and control units, both based on the VESNA platform, and their deployment in a large scale real-world smart grid pilot in Slovenia, as well as with a platform for distribution system state estimation and prediction. The experience and results from the project are directly applicable to improving energy efficiency in smart cities.

The **CREW** project (FP7) established an open federated testbed platform, which facilitates experimentally-driven research on advanced spectrum sensing, cognitive radio and cognitive networking strategies in view of horizontal and vertical spectrum sharing. The Department developed a cognitive radio networking component to its wireless sensor network testbed LOG-a-TEC and is in the phase of extend it to support experimentation with low power long range wireless technologies, particularly well-suited to utility metering, infrastructure monitoring and similar applications. As an open testbed LOG-a-TEC is also suitable for testing and validation of functional building blocks for new smart cities services.

The Department also participates in the **Fed4FIRE** project (FP7) with the target to fully integrate the existing wireless sensor network testbed LOG-a-TEC into the Fed4FIRE federation. In doing so it is adapting the existing interfaces and components, creating the adapters between LOG-a-TEC and the Fed4FIRE federation platform and validating the newly federated testbed. It is an experimentally driven project, aiming to promote virtual experimentation in realistic set-ups and will make the LOG-a-TEC testbed even more accessible to external experimenters.

PROASENSE project (FP) enhances business processes through integration of sensing capabilities. The main aim of the project is to develop methodologies and tools that support proactivity in digital enterprises, making them able to anticipateproblems and opportunities. It showcases its results in manufacturing domain and in oil and gas sector. The Department is involved in the development of smart sensing services, feeding into probabilistic data stream processing and goal-driven complex event processing, particularly in the indoor manufacturing environment, but the approach taken is adaptable either to various indoor public spaces in the city or to outdoor environments.

Additionally to the mentioned EU projects, the Department carries out research in radio propagation, wireless access architectures for heterogeneous wireless networks (from low power long range to mobile, stratospheric and satellite), mesh and ad hoc wireless networks, management of radio and network resources, cognitive communications, parallel and distributed computing, complex system modeling and simulation, computer simulations supporting biomedical procedures and specialised equipment and procedures for advanced bio-signal processing and interpretation.

Research activities in the area of wireless sensor networks have materialized in two own technologies, both suited to support the development and deployment of various solutions for Smart Cities, namely:

• **VESNA -** Custom developed, fully flexible, modular, networked embedded system platform. It is used as a baseline for sensing natural phenomena, channel propagation in difficult environments and radio spectrum occupancy as well as for testing and validating new communication protocols and cognitive radio networking solutions. VESNA consists of the VESNA core module and a set of special feature modules (sensor node radio, sensor node expansion and sensor node power), which are used in accordance with the needs of particular application. More information about VESNA can be found at SensorLab website[1].

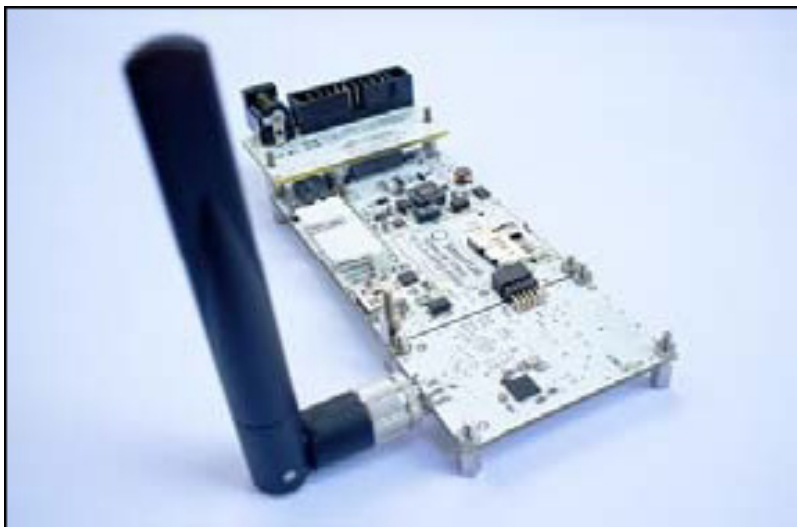

Figure 2. VESNA platform

• **VIDEK -** Data handling and device management FI-WARE compatible enabler, supporting a variety of APIs and protocols for integration with other software components.

VESNA and VIDEK represent the main building blocks of the deployed wireless sensor network testbeds for experimentally driven research and piloting.

Furthermore, we developed a personal wearable device for monitoring ECG, vital signs, and activity of patients, older persons in home care or other settings, etc., that is particularly well suited for monitoring user's everyday activities regardless of its current location. As such and in combination with other location-based services in smart city it may benefit user's wellbeing and if necessary healthcare support.

2.2 Experimentally driven Research - testbeds and Pilots

In order to successfully implement the Smart Cities paradigm, a need for testing and validating the newly developed technologies has been widely recognized in the research community. It is emphasized that only real-life, large scale test beds can offer the appropriate environment to design robust, heterogeneous systems that will meet the growing needs of the future Smart Cities **Error! Reference source not found.**.

Supporting this conclusions, the Department of Communication Systems has set up a LOG-a-TEC testbed. The testbed was set up in close cooperation between Jozef Stefan Institute, the Municipality of Logatec and utility company Komunalno podjetje Logatec. It primarily consisted of two clusters, one cluster of nodes located in the industrial zone and another cluster of nodes in the city center of Logatec. Most of the sensors were installed on street lighting poles while others were mounted on buildings or roofs and the user interface to the physical experiments was provided by a web application.

[1] http://sensorlab.ijs.si/hardware.html

However through various projects, the LOG-a-TEC testbed has been enhanced and extended to other locations, operating environments (including indoor) and has, through CREW and Fed4FIRE projects become one of the FIRE/FIRE+ facilities, thus made open to all researchers and available for different experimental investigations.

One of the extensions of the LOG-a-TEC is the semantic sensor network testbed at Jozef Stefan Institute campus. This testbed consists of VESNA platforms equipped with Contiki OS and is used for experimentation with cognitive networking on MAC and higher layers. It uses the ProtoStack2 tool for remote composition, reconfiguration and reprogramming of Crime protocol stack.

The LOG-a-TEC experimental infrastructure was also used for testing and validation of the air quality monitoring within the CITI-SENSE project, where the VESNA platform was chosen as one of the sensor platforms for air quality monitoring.

Additionally, a pilot developed in collaboration with Telekom Slovenije and Elektro Primorska also forms a distinctive part of the LOG-a-TEC experimental infrastructure. Using the VESNA platform, a sensor network was developed for detailed real time monitoring of operating parameters in a photovoltaic systems.

3. Future Research and Collaboration in the Area of Smart Cities and Communities

Smart Cities and Communities paradigm builds on developing value added through the development of new, users-oriented services, especially in the areas of integrated public infrastructure, sustainable urban mobility and reduced energy consumption. Thus the Department of Communication Systems will, in line with the business and research initiative for Smart Cities and Communities, focus its future research and development activities to support the following areas:

- Open wireless communication networks;
- Networked sensor and actuator devices and embedded communication modules;
- Modules for data acquisition;
- Open web applications and mobile apps;
- Micro smart-grids for energy self-sufficient communities;
- Power quality monitoring in sustainable smart-cities distribution energy systems
- Integral energy and utility provision;
- Smart public lighting systems;
- Support for electric vehicles;
- Set up of open demonstration and experimental testbeds;
- Support to participatory sensing;
- Environmental monitoring.

For successful implementation of smart city solutions, the Department will strive to strengthen its collaborations with public infrastructure providers, utility operators and public administrations as well as private service providers in order to develop tailor-made Smart City solutions. It will, through national and international projects, look into possibilities to endorse the partner cities from Slovenia as demonstration centers for newly developed Smart City solutions hence opening new opportunities for sustainable development and inclusive economic growth.

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