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SmartSantander – a smart city experimental platform

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Abstract. SmartSantander is a large-scale experimental framework primarily focused on enabling experimentation in the context of smart cities and Internet of Things. In this paper, an overview of the SmartSantander project and the experimental framework the project has designed and deployed areprovided. The main architecture components are described, a few of the main deployed services are presented and an outline is given of how experiments are run using the framework.

Keywords: Smart city, IoT, experimental platform

1 INTRODUCTION

The smart city concept has recently become one of the major topics, both in the research and business communities. The number of people living in the cities is continuously increasing, year after year. Today, more than 50% of the World population lives in the cities and it is estimated that by 2050 this will rise to more than 70% [1]. Such a dramatic expansion of the cities has given rise to the need of developing the cities in a sustainable manner while making the quality of life in the cities as high as possible.

Complex systems like cities require careful management to ensure uninterrupted performance of all the relevant activities and thus uninterrupted living conditions for all stakeholders. Creating and maintaining an efficient public transport system, provision of electric energy, water and gas distribution systems as well as waste management and maintenance of the city infrastructure like roads and public parks are some of the activities important for any city.

The responsibility for different services mentioned above is usually delegated to appropriate utility companies. Coordination of the activities between these companies is expected and planned, but due to various reasons, technical, administrative and political, this coordination is more than often inefficient. This results in each public service being run as a standalone activity with (administrative) walls built between the domains preventing an efficient exchange of information and sharing of the available infrastructure.

Contrary to this approach, the automatic sharing data, interacting and combining services as required, will be done by an embedded feature of the smart cities. ICT will play a crucial role in development of such infrastructure and Internet of Things (IoT) will represent one of the core components. By just using such approach it will be possible to efficiently connect, integrate and utilize information generated by an ever increasing number of city actors, items and events: passengers travelling, public transportation system vehicles, roads, traffic lights, waste bins (and the amount of waste to be collected), water distribution pipes (and the amount of water to be distributed), as well as the number of various administrative requests and answers processed, etc.

Having the above in mind, it is clear that cities serve as an excellent catalyst for the IoT research, as they represent a very dense techno-social eco-system that can act as an invaluable source of challenging the functional and non-functional requirements from a variety of problem and application domains.

Aiming at leveraging such an environment for advancement of the Future Internet research in the domains of IoT and smart cities, the SmartSantander project [5] is creating a large-scale experimental facility across 4 European countries (Spain, Germany, the UK and Serbia) with an additional installation in Australia. The project started in September 2010 with plans to deploy close to 20 thousand sensors. The main deployment site is the city of Santander (Spain). Today, there are around 5 thousand sensors deployed across the sites which integrated with a set of back-end components comprise the SmartSantander platform. The deployed devices combine a range of hardware platforms, communication technologies and sensor types to implement a number of city services.

The three main groups of the platform users are the following:

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- Researchers: experimenting with different protocols, data processing algorithms, data mining, visualization etc. They can re-program the selected IoT devices (one IoT device supports one or more different sensors), follow execution of their programs, collect traces, etc.
- Service developers: evaluating their services in a real environment before full commercial deployments. They can re-program the IoT devices or deploy services that are using data generated by the deployed IoT devices and run user trials or evaluate performance of their applications.
- Citizens and city administrations availing of and benefiting from the deployed services: a number of services, ranging from the on-street parking to environment monitoring and participatory sensing are deployed on the platform and are available to be used by the end users.

The rest of the paper is organized as follows. Section II, provides an overview of the SmartSantander architecture. In Section III details of several implemented services are given. Section IV explains the steps to be taken to run an experiment in the framework. Section V concludes the paper.

2 Architecture

The SmartSantander framework is built as a 3-tiered system comprising the following layers: IoT device, IoT gateway and server tier.

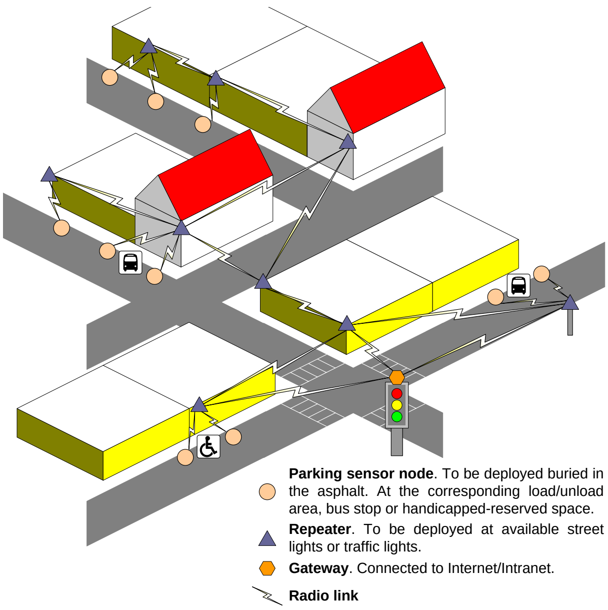

Figure 1. Deployment of the irrigation IoT devices

The deployed IoT devices, physical or virtual, create the *IoT node tier*. This layer accounts for the majority of devices used in the system and typically comprises resource-constrained devices (in terms of power, memory and energy availability). To provide heterogeneity, a variety of the IoT device types is used: diverse remote platforms, RFID readers and tags as well as more powerful platforms. Some nodes are deployed at fixed locations (Figure 1), while the others are mobile (Figure 2).

As already highlighted, the SmartSantander is an experimental framework and the goal of deploying the IoT devices is to make them available for use in various experiments. However, due to the constraints coming from the fact that deployment is done in the cities and is not used only for experimentation, but also for provision of various city services, this is not always possible. Therefore, from the experimentation perspective, two main groups of the IoT devices can be identified in the framework:

- fully available for experimentation: these are the devices that can be completely re-programmed according to the experimenter requirements, including switching them off/on, breaking functionality to test performance, etc.
- with a limited availability for experimentation: these devices are involved in providing a city service and cannot be re-programmed, altered or impacted in some other way (for example overloading), as it could negatively affect the provided service. Such IoT devices can be used for experimentation on higher layers like service evaluation, societal impact, data processing (of the data generated by the devices), etc.

The *gateway node tier (GW)* links the IoT devices at the edges of the network to a core network infrastructure. The nodes of the GW tier are also part of the programmable experimentation substrate in order to allow for experimentation for different inter-working and integration solutions of the IoT devices with the network elements of the current or Future Internet. The GW tier devices are typically more powerful than the IoT nodes but at the same can still be based on embedded device architectures – and are thus more resource-constrained than the devices of the server tier. Examples of the GW node devices are embedded servers, e.g. Plugcomputers, mobile phones or netbooks.

The *server tier provides* more powerful server devices with a high availability and directly connectable to the core network infrastructure. The servers can be used to host the IoT data repositories and the application servers that can be configured to realise a variety of different IoT services and applications or to investigate approaches for real world data mining and knowledge engineering.

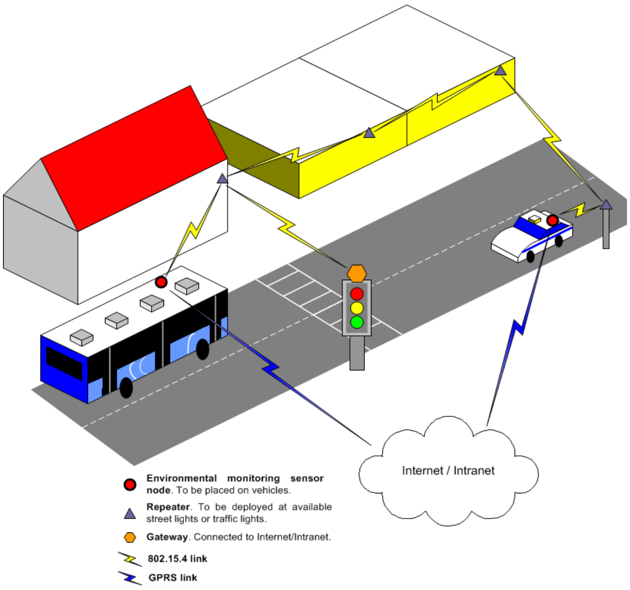

Figure 2. Environmental monitoring and public transport management

3 SERVICES

Several services have been deployed on the SmartSantander platform. In this section, a summary of the selected services is given.

3.1 Outdoor parking management

The Outdoor Parking Management use-case implies provision of a Limited Parking Space Management service in the city of Santander. To achieve this, several hundred parking places in the city centre of Santander are equipped with ferromagnetic wireless sensors (buried in the asphalt). These sensors detect when a car is parked and transmit this information wirelessly to the closest repeater installed on a nearby lamp post. The repeater then forwards the information about the occupancy status to the backend server, often using multihop routes. The collected information is pushed to public displays installed on the main city junctions informing drivers about the number of free parking places in different areas including standard parking spaces as well as parking spaces for the disabled persons.

3.2 Environment monitoring

The current solutions for environmental monitoring in urban settings are based on a handful of measurements stations at fixed locations. Although the rate of accuracy of the measurement equipment in these stations is high, the cost makes large-scale deployments to obtain measurements at finer granularity not feasible. On the other hand, by leveraging the IoT technology it is now possible to deploy a large number of low-cost sensors for a fraction of the current cost. These IoT sensors do not provide the same degree of accuracy as modern environmental measurement stations. However, by using a large number of measurement points and intelligent processing of the measurement results, it is possible to obtain sufficiently accurate observations that can be used as initial indicators of the status of the environmental pollution.

A large number of the environmental monitoring devices has been installed on lamp posts in different parts of Santander. The deployed devices contain air pollution sensors as well as noise sensors. To further increase the coverage of the environmental monitoring network, a number of devices is being deployed on the public transport buses, police cars and municipality vehicles. A similar deployment of 65 buses is in use in Pancevo (Serbia). All measurements are available via web and mobile applications.

This deployment serves multiple application domains. For instance, provides additional services like smart public transportation management and traffic conditions assessment.

3.3 Participatory sensing

In this scenario, users utilise their mobile phones to send physical sensing information, e.g. GPS coordinates, compass, environmental data such as noise, temperature, etc., depending on the sensors embedded in a particular phone. This information is fed to the SmartSantander platform. Users can subscribe to services such as “the pace of the city”, where they can get alerts for specific types of events currently taking place in the city. Users can themselves also report the occurrence of such events, which will subsequently be propagated to other users that are subscribed to the respective type of events, etc.

Users receive notifications about the occurred events via a smartphone application, phone calls, SMS and e-mails in the preferred language.

All the users interested in receiving the notifications have to subscribe the service, defining their personal profile (including the preferred language) and selecting the information they are interested in. This subscription can be done via a web interface; if the city Council wants to provide the service also to users with no web access, it can provide a phone number of a help desk to be called in order to subscribe the service with the operator support.

3.4 Precision irrigation and garden monitoring

The Precision Irrigation service offers a wide data set acquired in a distributed way from multiple locations in a selected region. It complements the automated irrigation systems currently in use in parks and gardens. Such systems use a set of programs executing defined activities based on preconfigured timetables and hence without taking into account the real-time parameters specific for each region.

The precision irrigation and garden monitoring service provides relevant real-time information to the gardening authorities and parks technicians, allowing them to assess the concrete situation before and after a program has been executed, thus faciliating better and more informed management (Figure 3. It is being deployed in two parks in the city of Santander, the Las Llamas Atlantic park and the Magdalena Palace gardens. Apart from providing tools for the gardening authorities, there is also an alert module to notify users when irregular conditions are detected and a function to remotely monitor water consumption and to measure and/or estimate important performance indicators like water absorbed, water waste, energy and labor cost.

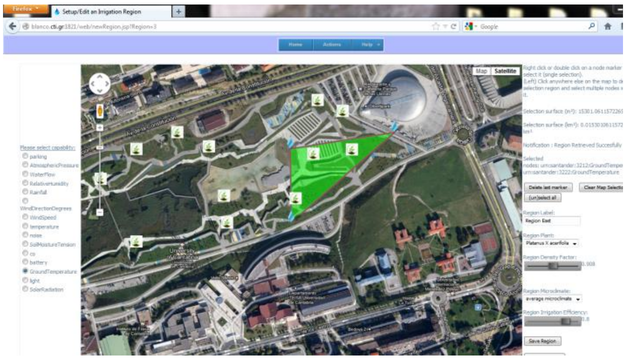

Figure 3. Park Region Management

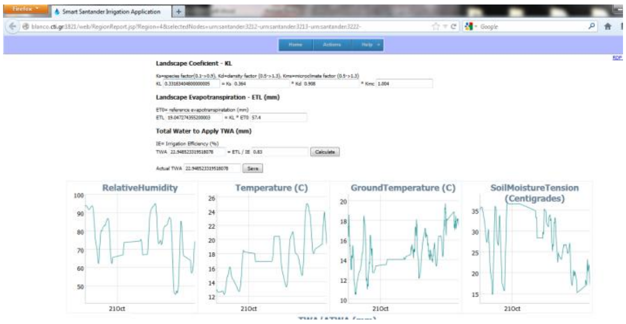

Figure 4. Region Report

3.5 Augmented reality

This service provides the possibility of "tagging" the points of interest in the city, for instance a touristic point of interest, shops and public places such as parks, squares, etc. Today there are 112 tags installed on a metal surface identifying different points of interest for tourism, 406 tags at the bus stops and 2000 Window stickers (double side printing) on shops in Santander. Using the mobile application, users can get additional information about the tagged locations as well as provide a feedback to the city administration (Figure 5).

On a smaller scale, the service provides an opportunity to distribute information in the urban environment as a location based information. On a larger scale, the tags can be coupled with more advanced services such as "feedback" from the citizens to the city council.

Figure 5. SmartSantanderAR application view

Besides providing information based on the scanned tag, the mobile application developed for this purpose can also record the user movement patterns in an anonymous way to support experimentation. Such information can be used by application developers to enrich their applications based on the user experience within the city. For the municipality, the observations collected will provide more information about the number of people visiting certain points in the city over a period of time, thus enabling them to better organize and improve supporting the city infrastructure as well as to receive a feedback from the visitors.

3.6 Smart metering

The ultimate goal of this scenario and of its related use cases is to explore the use of the IoT based solutions to manage the user side power demand in an office environment. This scenario builds upon an instance of the SmartSantander testbed currently deployed throughout the office space of the Centre for Communication System Research (CCSR) at the University of Surrey, Guildford. It consists of 200 SmartMeters and 100 reprogrammable gateways. On top of this testbed instance, a system collects power consumption information of all the devices associated with a particular work desk and relate this information with a particular user. Apart from collecting metrics concerning the power consumption of the used devices, the system also recognizes the corresponding context such as the employees presence at his or her work desk, occupancy of the meeting rooms, etc.

4 CONCLUSIONS

As the cities are becoming home for more and more people around the globe, efficient methods for the management of the cities that will ensure sustainable development while providing high quality of living are becoming one of the core challenges in front of us. The SmartSantander framework represents a significant enabler facilitating better understanding of the issues involved, technical, societal and economic, in creating smart and sustainable cities.

In the last year of the project, development of the framework will be continued with deployment of more IoT devices and new services. The main focus of experimentation is expected to be on the service, application and user level, although research on the lower layers will be supported as well.

The goal of the project's last year will also be to increase the number of users as well as to create mechanisms for keeping the platform running after the project ends.

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