SmartSantander: A joint service provision facility and experimentation-oriented testbed, within a smart city environment

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Abstract: In order to foster user support, involvement and engagement in ICT-based innovation areas, Smart Cities position as important areas of application being considered as excellent playgrounds for Future Internet (FI) research and experimentation. For this purpose, SmartSantander project aims at the design and implementation of a novel architecture, covering a twofold approach: experimentation support and service provision. In the city of Santander, and within the project framework, it has been carried out a dense network deployment associated to a set of use cases, oriented to provide a service and support experimentation over them. In addition to this, different applications running on main mobile operating systems (Android and IOS) are developed in order to foster the citizens' involvement.

Keywords: IoT; smart city, use case.

1. Introduction

The SmartSantander project aims at the creation of an experimental test facility for the research and experimentation of architectures, key enabling technologies, services and applications for the Internet of Things in the context of a city (the city of Santander located in the north of Spain). The envisioned facility is conceived as an essential instrument to achieve the European leadership on key enabling technologies for IoT, and to provide the European research community with a one-and-only platform of its characteristics, suitable for large scale experimentation and evaluation of IoT concepts under real-life conditions.

SmartSantander project provides a twofold exploitation opportunity [1]. On the one hand, the research community gets benefit from deploying such a unique infrastructure which allows true field experiments. Researcher will be allowed to reserve the required resources within the whole network and for a determined time period in order to run their experiments. On the other hand, different services fitting citizens' requirements will be deployed. Different from the experiment applications, it will be either the authorities or the service manager/responsible, the ones in charge of determining the cluster of nodes running each service, as well as, the time duration of the aforementioned service.

In order to fulfill all the project requirements, SmartSantander architecture relies on existing components from other platforms, complemented with the corresponding additional building blocks to address the specific singularities of the SmartSantander project. Among the aforementioned platforms, it can be indicated: FP7 Integrated Project SENSEI [2], FP7 STREP WISEBED [3], Telco 2.0 Open Platform [4].

In terms of deployment size, and stepping forward to the current existing deployments, the SmartSantander facility will consist of more than 20,000 IoT devices, 12,000 of them deployed in the city of Santander and its surroundings, while the remaining 8,000 devices are expected to come from the deployments in Belgrade, Guildford and Lübeck.

The remaining paper is structured as follows: Section II shows the architecture implemented for joint experimentation support and service provision. Section III focuses on the main deployment carried out during the project in the city of Santander, describing the different use cases implemented. Finally, section IV indicates the main conclusions derived from the designed architecture, as well as the deployment carried out.

2. SmartSantander Architecture: Service/Experimentation duality

As previously commented, the main objective of the SmartSantander project is the provision of a framework to provide service provision and experimentation support over a determined novel architecture based on a three-tiered network approach: IoT node tier, gateway tier and testbed server tier.

- The IoT node tier embraces the majority of the devices deployed in the testbed infrastructure. These devices are typically resource-constrained and host a range of sensors and in some cases actuators. Other devices such as mobile phones and devices with reasonable computing power (e.g. mobile devices in vehicles) and communication capabilities, behave as IoT nodes in terms of sensing capabilities and as GW nodes regarding processing and communication capabilities.
- The GW tier links the IoT devices on the edges of the capillary network to the core network infrastructure, being IoT nodes grouped in clusters depending on a GW, which locally gathers and processes the information retrieved by IoT devices. The GW tier devices are typically more powerful than IoT nodes in terms of memory and processing capabilities, also providing faster and more robust communication interfaces.
- The server tier provides more powerful computing platforms with high availability and directly connected to the core network. The servers are used to host IoT data repositories and application servers, receiving data from all GW tier nodes.

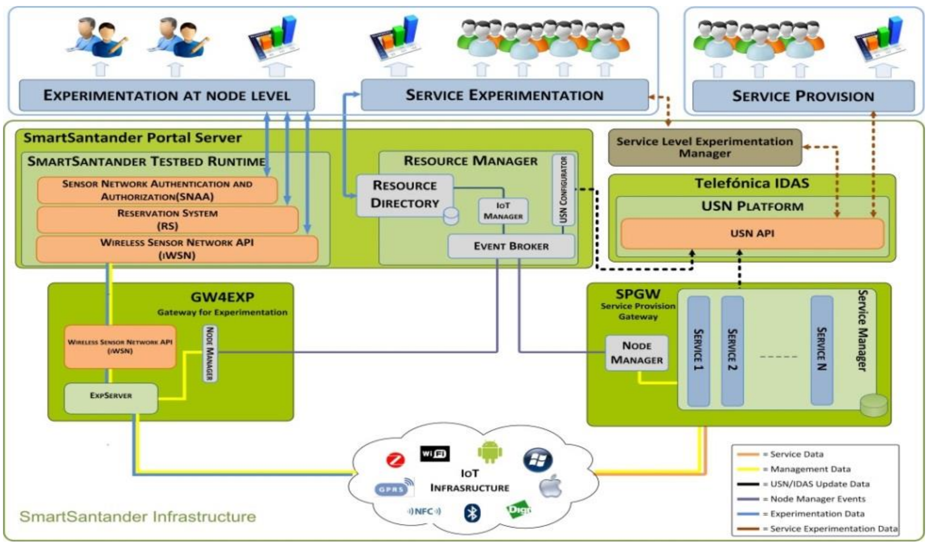

Figure 1. SmartSantander architecture and building blocks

The three-tiered network approach previously described bases on the architecture shown in Figure 1. From the user perspective, three main blocks can be identified: service provision, service experimentation and experimentation at node level. Service provision includes the use cases developed within the SmartSantander project, taking information from the IoT infrastructure and processing it accordingly to offer the corresponding services. Service experimentation refers to the different experiments/services that can be implemented by external users, utilizing the information provided by the deployed IoT infrastructure. Experimentation at node level implies node reservation, scheduling, management and flashing in order to execute different experiments over a group of nodes, i.e., routing protocol, network coding or data-mining.

Service Provision GW receives the data retrieved by the deployed devices, storing them in the USN platform. Node Manager is also fed with this information in order to monitor the available resources, reporting and keeping update the Resource Manager accordingly.

Service-Level Experiment Manager (SLEM) allows the service-level experimenters (i.e. those running experiments using data provided by deployed nodes) to access data collected from the services, stored at the USN component. For service providers (i.e. those providing a service with data retrieved by the deployed nodes), data generated by nodes within the network is directly accessed through the USN.

The Portal Server represents the access point to the SmartSantander facility for node-level experimenters, through SmartSantander Testbed Runtime module, providing access (SNAA) to the platform, reserve (RS) set of nodes to be running the experiment and act (iWSN) over them, both remotely flashing them with the corresponding code image [5], as well as receiving data associated to the experiment carried out over them. Finally, the GW4EXP allows the access to the nodes in terms of both network management and experimentation at node level.

3. SmartSantander deployment: Use cases

The Santander testbed is currently composed of around 3000 IEEE 802.15.4 devices, 200 devices including GPS/GPRS capabilities and 2000 joint RFID tag/QR code labels deployed both at static locations (streetlamps, facades, bus stops) as well as on-board of public vehicles (buses, taxis).

Deployment shown in Figure 2, associates to the development of different use cases :

- **Static Environmental Monitoring**: Around 2000 IoT devices installed (mainly at the city centre), at streetlamps and facades, are provided with different sensors which offer measurements on different environmental parameters, such as temperature, CO, noise and luminosity. All these devices are provided with two independent IEEE 802.15.4 modules, one running the Digimesh protocol (proprietary routing protocol) intended for service provision (environmental measurements) as well as network management data transmission, whilst the other one (that implements a native 802.15.4 interface) associated to data retrieved from experimentation issues.
- **Mobile Environmental Monitoring**: In order to extend the aforementioned static environmental monitoring use case, apart from measuring parameters at static points, 150 devices located at public vehicles (buses, taxis) retrieve environmental parameters associated to determined parts of the city. Modules installed in the vehicles are composed of a local processing unit in charge of sending (through a GPRS interface) the values (geolocated) retrieved by both sensor board and CAN-Bus module. Sensor board measures different environmental parameters, such as, CO, NO2, O3, particulate matters, temperature and humidity, whilst CAN-Bus module takes main parameters associated to the vehicle, retrieved by the CAN-Bus, such as position, altitude, speed, course and odometer. Furthermore, an additional 802.15.4 interface is also included in order to carry out experimentation, interacting with aforementioned static devices, the so called vehicle to infrastructure (V2I) communication.
- **Parks and gardens irrigation**: Around 50 devices have been deployed in two green zones of the city, to monitor irrigation-related parameters, such as moisture temperature and humidity, pluviometer, anemometer, solar radiation, pressure and humidity, in order

to make irrigation as efficient as possible. In terms of processing and communication issues, these nodes are same to those deployed for static environmental monitoring, implementing two independent IEEE802.15.4 communication interfaces.

- **Outdoor parking area management**. Almost 400 parking sensors (based on ferromagnetic technology), buried under the asphalt have been installed at main parking areas of the city centre, in order to detect parking sites availability in these zones.
- **Guidance to free parking lots**: Taking information retrieved by the deployed parking sensors, 10 panels located at the main streets' intersections have been installed in order to guide drivers towards the available parking lots.
- **Traffic Intensity Monitoring**: Around 60 devices located at the main entrances of the city of Santander have been deployed to measure main traffic parameters, such as traffic volumes, road occupancy, vehicle speed or queue length.

As it can be derived from the described use cases, all of them are intended to provide a different service, as well as offering the retrieved data for other users, the so called experimentation at service level. On the other hand, static and mobile environmental monitoring and parks and gardens irrigation, also offer the possibility of carrying out experimentation at node level, offering an additional communication interface.

Apart from the aforementioned use cases, two citizens-oriented services have been deployed, thus including corresponding applications for Android and IOS operating systems, in order to foster the citizens' involvement.

Figure 2. Use cases deployment

Figure 3. Developed applications: Augmented Reality (left) and Participatory Sensing (right)

- **Augmented Reality:** As shown in left side of Figure 3, this service includes information about more than 2700 places in the city of Santander, classified in different categories: beaches, parks and gardens, monuments, shops. In order to complement and enrich this service, 2000 RFID tags/QR code labels have been deployed, offering the possibility of “tagging” points of interest (POI) in the city such as touristic POI, shops and public places (parks, squares). In a small scale, the service provides the opportunity to distribute information in the urban environment as location based information.
- **Participatory Sensing**: As it can be derived from right side of Figure 3, in this scenario users utilize their mobile phones to send to the SmartSantander platform and in an anonymous way, physical sensing information, e.g. GPS coordinates, compass, environmental data such as noise, temperature. Users can also subscribe to services such as “the pace of the city”, where they can get alerts for specific types of events currently occurring 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 corresponding types of events.

It is important to highlight that, in the same way as aforementioned use cases, information retrieved by these two services is made available to the SmartSantander platform, in order other users to experiment with it (experimentation at service level).

4. Conclusions

The smart city scenario stands at the meeting point between the provision of a facility for offering different type of services as well as the deployment of a massive testbed for running a great variety of experiments over it. This translates in a wide portfolio of stakeholders, ranging from citizens to experimenters, including public administration and service providers, all of them under the supervision of the network managers.

In order to cover this twofold approach, experimentation and service provision, SmartSantander project aims at deploying a unique in the world city-scale experimental research facility in support of typical applications and services for a Smart City. This unique experimental facility is sufficiently large, open and flexible to enable horizontal and vertical federation with other experimental facilities, and stimulates development of new applications by users of various types, including experimental advanced research on IoT technologies as well as realistic assessment of users’ acceptability tests.

Within SmartSantander framework, a massive deployment has been carried out in the city of Santander, developing different use cases: static and mobile environmental monitoring, parks and gardens irrigation, outdoor parking management with the corresponding guidance to free parking lots, and traffic intensity monitoring. Apart from these use cases, two applications for Android and IoS operating systems have been also developed offering augmented reality and participatory sensing services.

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