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In This Issue

Engaging Individuals in the Smart City Paradigm: Participatory Sensing and Augmented Reality

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Abstract

Smart City concept relates to improving efficiency of city services and facilitating a more sustainable development of cities. However, it is important to highlight that in order to effectively progress towards such smart urban environments, the people living in these cities must be tightly engaged in this endeavor. This paper presents two novel services that bring the Smart City closer to the citizen. The Participatory Sensing service we are proposing exploits the advanced features of nowadays smartphones to make the user part of the ubiquitous sensing infrastructure over which Smart City concept is built. The Augmented Reality service is connected to the smart city platform in order to create an advanced visualization tool where the plethora of available information is presented to citizen embedded on her/his natural surroundings. These services have been developed and deployed together with a real-world smart city deployment that will be also described. Finally, a brief description of the smart city platform on top of which these services are built will also be presented.

Keywords

smart city; participatory sensing; augmented reality

Introduction

Smart cities exploit synergies between the ubiquitous sensing technology and their social components to enhance the quality of life of citizens, while improving the efficiency of the city services. In this sense, the Smart City concept (Schaffers et al., 2011a; Nam & Pardo, 2011) has been typically associated to an eco-system where technology is embedded everywhere so that the different city services (e.g. traffic, water, sewage, energy, commerce, etc.) are highly improved by exploiting the interconnected information and actuation capabilities that this technology provides. However, sometimes this advanced technological environment leads to disregard the fact that the ultimate aim of the Smart City concept must be the citizens living in urban areas focusing too much on the technology and missing the engagement of the society with this paradigm. Smart cities are not simply those that deploy ICT. They combine new technology with smart new ways of thinking about technologies' role in organization, design and planning. As smart city initiatives are planned, ways that technology can create new urban user experiences must be envisioned. Thinking about the

Smart City as a holistic system and considering ways that new systems can result in positive behavioral change needs from citizens' engagement from the very first moment of the city smartening transition.

This paper presents an architecture that, following Internet of Things (IoT) precepts (Atzori, Iera, & Morabito, 2010; Vermesan et al., 2011), enables the creation of a ubiquitous sensing infrastructure within the scope of a Smart City aiming at improving city services efficiency. This architecture does not only tackle the main challenges pertaining to the infrastructure management and data handling but also defines the necessary middleware that enables seamless access to such infrastructure for the development of value-added services. This latter aspect is what mainly motivates this article as two novel services have been developed on top of an urban deployment (in the city of Santander, Spain) of a large-scale IoT infrastructure which supports the provision of impact-generating smart city services directly perceivable by all the Smart City stakeholders (Galache et al., 2012).

Augmented reality (AR) systems have recently emerged as a powerful visualization tool which augments real world elements with digital information. The proliferation of powerful smartphones has accelerated the adoption of AR also in mobile environments. Additionally, the wide deployment of Wireless Sensors Networks (WSNs) will give the possibility to integrate AR systems with sensor data and create sophisticated visualization systems. Moreover, a particularly important aspect from the AR is its ability to make the user to feel naturally surrounded by the technology thus providing a perfect eco-system for the user to engage with the Smart City concept. In this paper the Augmented Reality service that has been developed for bringing the information generated on the aforementioned Smart City infrastructure will be described. In this sense, main insights of the service architecture as well as details of the developed mobile App will be given.

Mobile phones have evolved from devices that are just used for voice and text communication to platforms that are able to capture and transmit a range of data types (image, audio, and location). The adoption of these increasingly capable devices by society has enabled a potentially pervasive sensing paradigm. A coordinated participatory sensing system engages individuals carrying mobile phones to explore phenomena and events of interest using in situ data collection and reporting. The Participatory Sensing service that will be described in this paper exploits the ubiquitous sensing enabling infrastructure developed. Users can 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. Finally, 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.

The paper is structured as follows. Section 2 presents a thorough description of the smart city IoT infrastructure deployed in Santander. This infrastructure is the baseline on top of which different smart city services are being provided, specifically the two services described in this paper are supported by it. In Section 3 the architecture and platform on top of which these services have been developed will be briefly sketched. Particular emphasis will be put on the part of the architecture which deals with the service development framework. In Section 4 the Smart City Augmented Reality service that has been implemented will be described in detail. The service architecture as well as the implementation insights will be thoroughly presented. The Smart City Participatory Sensing service will be described in Section 5. As previously mentioned, this service engages citizens on reporting events which are treated as rich pieces of sensed information. Finally, conclusions will be derived in Section 6.

Santander Smart City IoT Infrastructure

The objectives of the IoT infrastructure deployed in Santander are two-fold as well as concurrent. As a testbed, it enables experimental assessment of cutting-edge scientific research. However, this testbed goes beyond the experimental validation of novel IoT technologies. It also aims at supporting the assessment of the socio-economical acceptance of new IoT solutions and the quantification of service usability and performance with end users in the loop. For instance, it simultaneously supports the trial and subsequent provisioning of smart city services. To attract the widest interest and demonstrate the usefulness of the SmartSantander platform, the deployment of the IoT experimentation infrastructure has been undertaken to realise the most interesting and impact-generation use cases (Sanchez et al., 2013). In this respect, application areas have been selected based on their high potential impact on the citizens, thus enabling the execution of extensive experiments to obtain insights into the uptake of IoT-based services deployed in a live environment. Also taken into consideration in the selection of application use cases are the diversity, dynamics and scale of the IoT environment. All these aspects increase the potential of the testbed for the evaluation of advanced protocol solutions.

The IoT experimentation facility deployed in Santander has been settled on a cyclic approach with the three planned phases already undertaken. The objective of the first cycle of deployment was to create a meshed WSN on fixed locations that would serve as a testing environment for the experimental validation of advanced WSN-related mechanisms. The deployment also influenced by the city of Santander smart-city service requirements and strategy, focused on three geographical areas of significance to the smart-city services. To achieve the maximum possible impact to the citizens, the deployment process intentionally accomplishes a concentration of IoT devices in the city center (a 1 Km2 area). This area has the highest IoT node density in Santander and frequent usage provides insights into the acceptance of IoT-based services running in live environments.

Figure 1. Santander city center development excerpt view

Figure 1 shows an excerpt view of the Santander city center deployment. The different icons represent the deployed nodes (i.e. Carbon Monoxide – CO –, light intensity, noise, temperature, and car presence detection sensors). The deployment includes clusters of wireless sensors and gateway devices acting as cluster heads.

Once the areas for the deployment were decided, the next step in the deployment process was to specify where to physically install the devices. In this sense, the key factor influencing the decision was ensuring a viable power supply to all the devices. Although, WSNs are typically considered autonomous in terms of power needs, this assumption does not reconcile with the envisaged high-frequency multi-user usage model of our platform. Energy autonomy is achieved through the use of long-lasting batteries and most importantly, energy efficient mechanisms. However, testbed experimentation requires frequent node-software updates, which impose a stiffer power consumption penalty on IoT nodes than can be realistically met by batteries alone.

A hybrid solution to IoT node power requirements was adopted to minimize the infrastructure's energy consumption signature on the power grid, but ensure the survivability of its experimentation nodes. To fulfil the need for proximity to a power source, sensor devices were attached to public lampposts (as illustrated by the picture in Figure 2). The sensor devices are also endowed with rechargeable batteries and a charging circuit. Thus, daylight operation of the nodes (lampposts turned off) draws power from the batteries which are charged at night when the lampposts are turned on. Nightly operation of the nodes relies on the power from the lamppost. This solution guarantees power supply even under energy-hungry experimentation scenarios. Corresponding electrical adaptation and protections (transformer, fuse and differential protection) were added in order to obey municipal regulation.

Although this solution was feasible for sensor nodes supporting the environmental monitoring service, proximity to permanent power supplies for parking sensor nodes is impossible due their deployment location (buried under the asphalt, see Figure 2). Thus, due to their exclusive reliance of batteries, power consumption on these nodes is kept minimal using energy efficient mechanisms similar to those presented in commercial products (http://www.nedapavi.com/products/sensit/sensit.html, http://www.tst-sistemas.es/en/solutions/parking/, http://www.streetline.com/parksight/). This guarantees a device lifetime of over 3 years. Experimentation over these nodes is restricted only to accessing car-presence detection information.

Gateway devices have other deployment peculiarities in that they require a constant power supply and connectivity to the Internet. The solution was to install most of these devices at municipality premises located along the area to be covered. These premises are connected through a fiber-optic ring which allows GWs to be connected to a high-capacity backbone network. Where no such municipality premises were available, access to the Internet is achieved through WAN connectivity via a 3G telecoms network interface.

The first cycle of IoT deployment yielded 740 points of presence in the city. Each point of presence is equipped with several sensors making a total of more than 50 noise sensors, 600 temperature sensors, 500 light intensity sensors and 30 CO sensors. Additionally, 390 nodes with car presence detection modules have been installed in parking bays and 23 GWs have been installed to ensure connectivity between the IoT node tier and the server tier.

In the second cycle, three additional fixed-node clusters totaling approximately 50 IoT nodes were added to the infrastructure. These clusters support the smart irrigation use case and offer sensing capabilities via 45 temperature and relative humidity sensors, 25 soil moisture and soil temperature sensors, 4 weather stations with solar radiation, atmospheric pressure, anemometer and rainfall sensors, and 2 water flow sensors.

The second cycle also improved node heterogeneity with the deployment of 150 mobile devices on top of public transport buses, municipality fleet vehicles and taxis. These nodes provide useful mobility patterns for experimentation as well as support environmental monitoring service. These devices are equipped with sensors for detecting air pollutants such as Nitrogen Dioxide (NO_2), CO, Ozone (O_3) as well as detection of particles in suspension, temperature and air humidity. Most importantly, they are also equipped with GPS so that all their observations come geo-localized and they also report speed and course of the vehicle. Besides the enhanced experimentation possibilities, we envisage these nodes to serve multiple application domains such as smart public transportation management and traffic conditions assessment.

Further, to support experimentation based on alternative technologies and facets of the IoT paradigm, 2,000 Quick Response (QR) and Near Field Communication (NFC) tags (cf. Figure 2) have been deployed over the city (at touristic Points of Interest (POI), bus stops and municipality's premises). These collectively support the operation of the augmented reality smart-city service.

Figure 2: Details of sensor nodes installed in Santander

Finally, citizens' smartphones are also part of the testbed. A Participatory Sensing mobile app has been developed within the SmartSantander project to enable these devices to send sensed physical measurements as well as mobile phone users' observations (text, images and video).

Last but not least, during the third and last cycle deployment was dedicated to extend two of the already existing deployments. In this sense, although the deployment of mobile sensors of the previous phases was very representative as it covered the majority of the city with special emphasis at the Santander city center, for this third phase it were necessary and appropriate to extend the Environmental Monitoring service to other areas beyond Santander area. Hence, the nodes were deployed on public buses covering lines that interconnect main cities in Cantabria with Santander. Additionally, another 330 car presence detection modules have been deployed at parking lots on the city center streets. Interestingly, 30 of these nodes support authentication of the parked vehicle so they have been used for controlling restricted access lots such as handicapped-reserved areas.

Smart City Platform

This section, first, elaborates on the requirements for providing a rich IoT based smart city environment and addressing many open research challenges in the area of IoT platforms. Based on these requirements, it provides an overview of the architecture of the SmartSantander smart city platform with particular attention to the platform subsystem addressing the service provision aspects.

Design considerations

Heterogeneity: Future Internets of Things will consist of a wide variety of devices integrated with other Future Internet (FI) infrastructure and service provisioning platforms. For reasons of applicability, it is expected that the development and evaluation of protocols and other IoT technologies be undertaken under conditions that is representative of the degree of heterogeneity inherent in the Internet of Things. In this respect, the SmartSantander provides a multi-tier architecture that encompasses the most relevant device tiers of IoT systems. The IoT device tier, in particular, offers a diverse set of heterogeneous IoT nodes (sensors, actuators, QR and NFC tags and mobile-phone-based sensing-platforms) connected via different network technologies, with different mobility (fixed or mobile), and with different sensing/actuation modalities.

Mobility: The IoT is composed of fixed and mobile devices which can also interact with each other in real life scenarios. While some indoor testbeds offer robot-controlled mobility, it is often difficult to reproduce real life mobility patterns in such testbeds. SmartSantander therefore provides support for realistic mobility by deploying a part of the infrastructure on moving real world entities, such as buses, public service vehicles or taxis. Furthermore the mobility of users is opportunistically leveraged by allowing the smartphone of a citizen to report information captured in a participatory manner (Burke et al., 2009).

User support and end user involvement: The deployment of an IoT facility in the heart of a city and the considerable costs involved motivate the exploitation of the facility for the development and evaluation of IoT enabled Smart City services and applications targeting developers of commercial Smart City services and applications. The involvement of concrete end users adds another dimension to the evaluation capabilities of the platform by allowing not only the assessment of technical performance of IoT solutions, but also their user adoption and social impact.

Reliability: Having in mind the purpose of the infrastructure, in particular that it is intended to be used for service provision, reliability of the complete system represents an important requirement to ensure smooth and uninterrupted operation.

High level architecture

This section presents the architecture that forms the basis for the deployment of services on top of a Smart City IoT platform. In this sense, it certainly exceeds the requirements imposed by the two Smart City services to be presented in the following sections. However, for the sake of completeness, it is important to make a brief sketch of the main architecture blocks for allowing a better understanding of the services' architecture, design and implementation.

The proposed Smart City IoT platform is realized by a three tiered network node architecture, which consists of an IoT device tier, a gateway (GW) tier and server tier.

The IoT node tier provides the necessary sensing substrate consisting of IoT devices. These devices are extremely heterogeneous, from diverse mote platforms (typically resource-constrained in terms of power, memory and energy availability), RFID readers and tags as well as more powerful platforms such as mobile phones with short range communication capabilities.

The gateway node tier links the IoT devices at the edges of the network to a core network infrastructure. The GW tier devices are typically more powerful than IoT nodes but at the same can still be based on embedded device architectures.

The server tier provides more powerful server devices, with high availability, which are directly connected to the core network infrastructure. The servers can be used to host IoT data repositories and application servers that can be configured to realize a variety of different IoT services and applications.

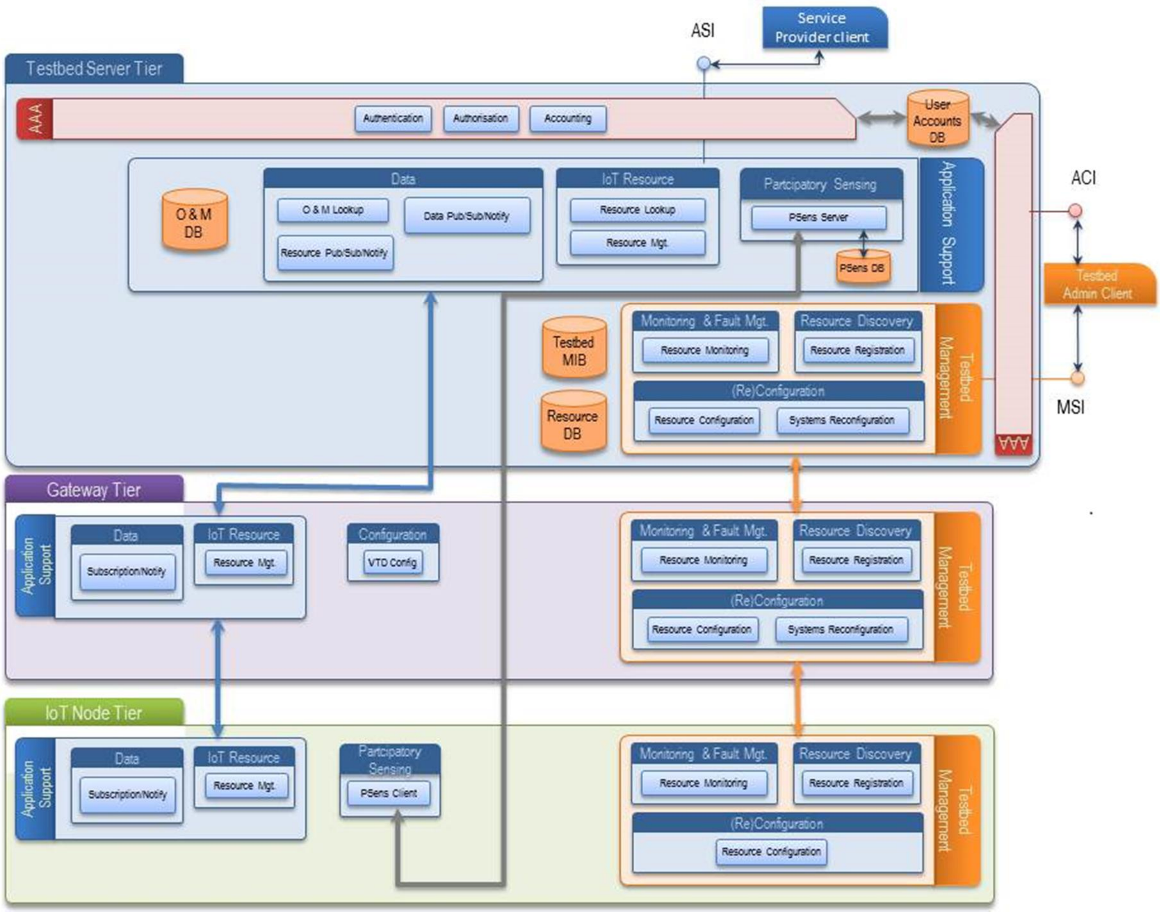

Figure 3. Smart City IoT platform

Figure 3 provides an overview of the software architecture, showing the different subsystems and service functions of the testbed observation and management plane. The architecture distinguished between three subsystems: 1) Authentication, Authorization and Accounting (AAA) 2) Testbed Management and 3) Application Support.

The AAA subsystem is common for all user groups and controls the access to the testbed functions. Its services are exposed via the Access Control Interface (ACI). Depending on user privileges the other subsystem functions can be invoked.

The management support interface (MSI) exposes the service functions of the management subsystem and is typically used by the system administrators. It provides access to functions such as user accounts, testbed resource discovery and configuration as well monitoring and fault management.

The application support interface (ASI) offers a wide range of data management functions that can operate on information retrieved from the deployed sensors of the IoT node tier including citizen provided information through participatory sensing on mobile phones.

The Application Support System (ASS) is intended to provide the functionalities that can facilitate the development of services either for experimentation or final service provisioning.

First of all, through the IoT Management component blocks, users are notified when either changes to the resource descriptions occurs or when resources matching certain criteria appear or disappear. This component, at the server tier, will be receiving notifications from GW nodes, and also checking the Resource DB in order to keep track of infrastructure dynamicity. At the GW nodes and IoT nodes, it is expected that the Resource Management modules update the descriptions and register resources respectively when needed.

The Data Publish/Subscribe/Notify components will provide the mechanism for applications based on the observations and measurements provided by the resources to get such observations as soon as they come. The way of working is the following:

1. The application will subscribe to the Data Pub/Sub/Not component provided by the testbed server expressing filter criteria. This filter can contain simple or complex conditions involving several resources and current or historical measurements.
2. The resources in the IoT nodes or IoT Gateways will generate the information that will be stored in the O&M DB and also sent to the Data Pub/Sub/Not module.
3. Every time an observation is provided, it is checked against the filter criteria and if required a notification is sent to the subscribed applications.

The O&M Lookup allows application to ask for information stored in the O&M DB. This might refer to the current value of an observation or to historical data.

Finally, the Resource Lookup function enables applications to search for resources stored in the Resource DB. This allows users to find resources matching certain criteria like location, type of information provided, available functions, IoT node hardware and software capabilities, etc.

Santander's Augmented Reality Service

In Santander, as in many other cities, there is a glut of information that may be of interest for citizens and tourists but, which may not be readily accessible. The reason for this include the heterogeneous mix of data sources producing data in different formats and the lack of a uniform data access specification/layer that would make data access easier. Information about transport, shopping, leisure activities, cultural agenda and so on is available in many different sites and is unknown to end users. To unify all these data sources and present them in a context-sensitive, location-aware manner to end users, the SmartSantanderRA app was developed.

With an AR application users can define their own preferences (language, touristic places to visit, monuments, etc.) and have an interactive context-sensitive experience visiting the city rather than using traditional standalone applications. The video stream produced by the smartphone camera is presented to the user of the AR mobile application which augments the live feed of the camera with virtual objects (mainly digital content, video, texts, and photos) of the POI, based on the current position of the device thereby creating an augmented view of the reality.

For each POI, the app provides a description of the place or reference image to be used in the AR view and the type of content to be superimposed. The content itself (3D model, image, videos, audio, etc.) is stored in the AR Server. Moreover, this server is in charged off getting all the real-time data from the Santander city Council legacy System (transport Services, city agenda, etc.). Pre-recorded multimedia content and a Multilanguage portal accessible from any terminal could be created to categorize the contents and make it easy the access to them.

As an illustration of the type of service the Augmented Reality application supports, the service provides a touristic experience through its "stroll in the city" mode. With the application in this mode, the tourist will receive information on specific monuments in his preferred language as he/she strolls around the city. This, in general, enhances the serendipity effect of the tourist visit.

Furthermore, placing NFC tags on certain shops in the city provides new opportunities for shops to build or strengthen customer relationships. The shops can explore the relationship between physical presence and the web. The users can get specific information about the shop, for instance, opening hours, contact, special offers, accessibility in the shop, etc.

From the City Council perspective, the placement of NFC tags in strategic places in urban facilities will provide location-sensitive information to the citizens. Also the use of location-aware applications using Augmented Reality technology allows the municipality to provide better touristic services to visitors. For the municipality, observations sent to the smart city platform by the AR applications will allow the collection of information about how many people visit the different POI, or at least is in the nearby areas, origin from that people, seasonality, etc. Based on this information, they can improve the touristic offer of the city, adapting the cultural events and activities during each season.

The SmartSantander platform offers to the augmented reality scenario the possibility of generating observations with relevant data to generate new services. These observations include:

- Position information: based on smartphone sensors such as GPS, digital compass and accelerometer (location based tracking) or tags reading or with a combination of the two techniques. In this sense, the AR application will support both QR codes as well as NFC tags.
- Users Preferences: the language, the kind of POI searched the individuals POI visited.
- Devices: device capabilities and OS.

Figure 4 shows the functionalities or services the user can interact with.

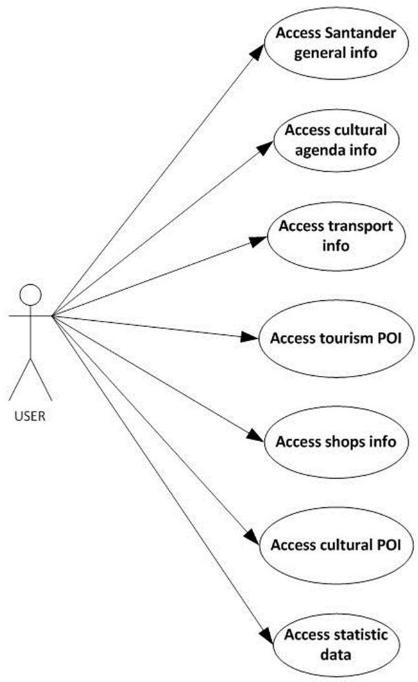

Figure 4. Augmented Reality – Citizen Use Case diagram

To realize this use case, two software components were developed: a mobile application (SmartSantanderRA) for the users and a server component (Augmented Reality Server, AR Server in short) which runs the service business logic and bridges the application with the SmartSantander platform.

The AR Server is responsible for collecting all the information needed from other external organizations servers that collaborate with the city council. For this purpose, it stores a database with all the POI's static data. Moreover, this server accesses the legacy system (services previously developed by the Santander City Council) to get the real time data from the public transport services, city agenda, city news, traffic webcams, etc. The communication between the Augmented Reality Server and the Legacy System is based on XML Web Services (using SOAP as transport) and XML for parsing data.

The SmartSantanderRA application (https://play.google.com/store/apps/details?id=es.unican.tlmat.smartsantanderra, http://itunes.apple.com/us/app/smartsantanderra/id541890402?l=es&mt=8) provides information on all areas of interest in the city. The data is structured in two groups:

- Augmented Reality data: The data showed is based on the current position of the device. The app gets the data of a configurable number of POIs closer to the current position.
- City General data: The data showed is independent of the position of the device.

Figure 5 shows some screenshots from the application.

Figure 5. SmartSantaderRA application screenshots

The application currently offer information on five different topics, namely tourism, shops, cultural agenda, transportation and museums, numbered 2 to 6 in Figure 5. Additionally Santander's general information (independent from user location) is also accessible. Here the user can find info about the city news, beaches info (with real-time webcams), parks and gardens info, weather info (data from Spanish weather agency), traffic webcams, tourist offices info, museums and exhibition info, libraries info, number of interest info and sport facilities info.

Information related to the aforementioned five topics is shown to the user on a location aware manner. Information can be overlaid over the image captured by user's smartphone camera or presented over a Google Maps view. The application presents on one of these formats the POI which are closer to the user. Besides displaying information, it is also possible to request from the application to inform the user on the best route to reach them.

Santander's Participatory Sensing Service

Participatory Sensing service aims at exploiting the use of citizens' smartphones to make people to become active in contribution and generation data for the SmartSantander Platform. Citizens, Santander City Council and the local newspaper "El Diario Montañes" are connected into a common platform where they can report, share and be notified of events happening in the city. Users also utilize their mobile phones to send physical sensing information, e.g. GPS coordinates, compass, environmental data such as noise, temperature, etc., feeding this information into the same platform.

The Pace of the City application is the tool provided to citizens in order to generate the Pace of the City.

Available for both Android and iOS platforms since November 2012, it has reached more than 3500 downloads. The application allows the citizens to report the occurrence of events, which will subsequently be propagated to the SmartSantander platform and shared with the rest of the Pace of the City applications users. Furthermore, users with smart phones can receive the notifications on the occurred events via a smartphone application, by subscribing to the Pace of the City service. In this sense, all users interested in receiving the notifications have to register with the service, thereby their personal profile (including e.g. the preferred language) and selecting the information on which they are interested. A web interface has been also arranged to make this subscription.

Apart from the Pace of the City application, a web interface has been created both for Santander City Council and Local newspaper El Diario Montañes in order to allow them to report their own geo-positioned events.

Pace of the City Service is linked to their Citizens' Inbox service at Santander City Council, reporting those events that need to be solved by the municipality. Once they receive an event, they analyze and assign it to the corresponding team. In some cases, depending on the event type, some of them are automatically assigned (the most common ones).

As an example, a user is walking in the city center and finds a hole in the pavement; he can take a picture, write a text and finally share this incidence with the other users of the application. The Santander City Council will therefore be notified of the occurrence of the event and proceed accordingly by sending an employee to the location in order to fix this problem. Another example can be that a user reports on a road accident, all the other users (drivers) that are subscribed to this type of event will get notified and try to avoid this area. By being also connected to the Participatory Sensing service, the local newspaper "El Diario Montañes" also enriches this body of knowledge by sharing the daily news information with all the other users of the service, The newspaper has created an online information channel called "ElPulsodelaCiudad", which provides an interface to the citizens to access the Participatory Sensing events as well as public transport information, cultural agenda and sensors values retrieved from the SmartSantander IoT infrastructure from the same website.

Figure 6 shows the functionalities or services the user can interact with.

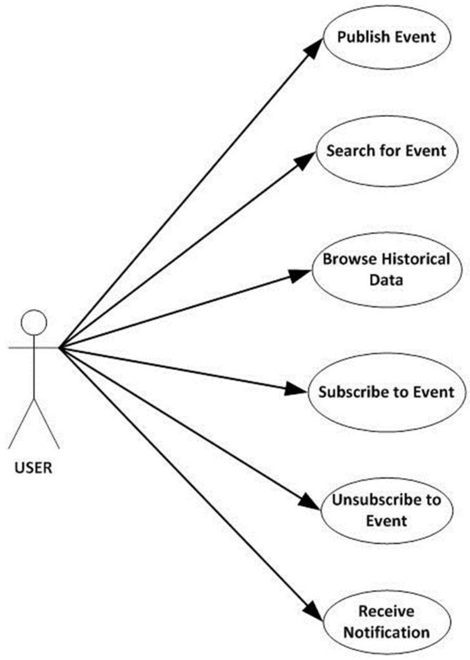

Figure 6. Participatory Sensing – Citizen Use Case diagram

For this scenario three software components were developed: 1) a mobile client application for the users; 2) a server that runs the service business logic and bridges the application with the SmartSantander platform which we call Pace Of The City Server; and 3) a server component that allows the mobile devices to register themselves to the SmartSantander platform called PSens Server.

The PulsodelaCiudad App (https://play.google.com/store/apps/details?id=com.eu.smartsantander.participatorysensing&hl=en, https://itunes.apple.com/es/app/pulsodelaciudad/id570422605?mt=8) enables the citizens to:

- Access to Historical information in a map or in a list (physical sensing information and previous events);
- Subscribe/Unsubscribe to specific types of events occurring in the city;
- Getting Notified of the occurrence of an event of a type the users are subscribed to;
- Search for Events filtering by date, type or location;
- Publish Events;

Figure 7 shows some screenshots from the application.

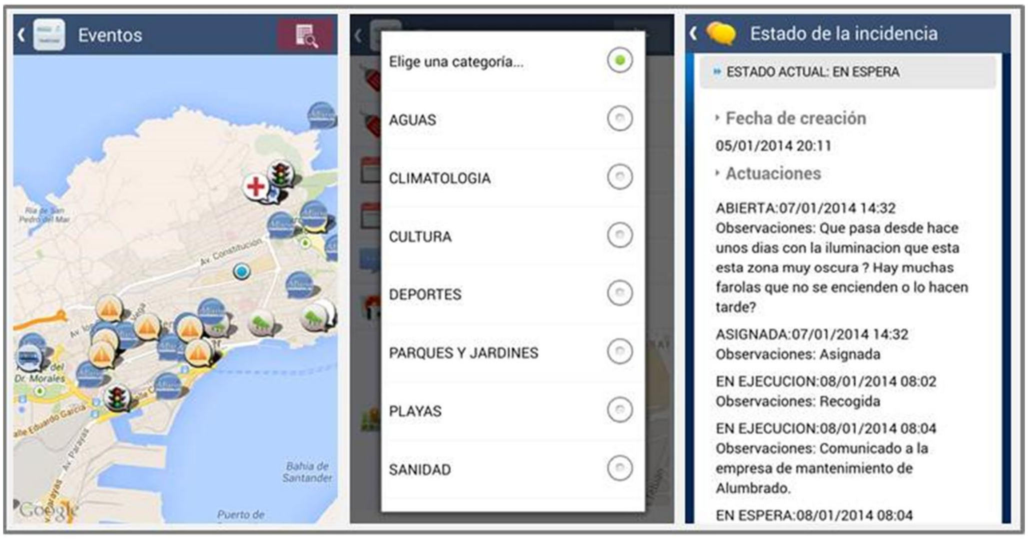

Figure 7. PulsodelaCiudad application screenshots

In order to tackle internally the incidences sent by the users through the Participatory Sensing scenario (for instance hole in the street events), the Santander City Council implemented two Web services developed using the Microsoft .NET 4.0fplatform which integrates the Participatory Sensing Scenario with the pre-existing system in the municipality to manage incidences (INCISYS). These web services collect the information from SmartSantander Participatory Sensing Scenario, then format, adapt and resend that data to the different departments responsible for resolving the incidence provided by the final user.

For this development all the standards proposed by the W3C were honored to ensure compatibility with any other platform interacting with the Santander Municipality's systems thus ensuring the interoperability with any other system. The standard adopted for this development has been "SOAP WS-I Basic Profile" (http://www.ws-i.org/Profiles/BasicProfile-1.1.html).

Conclusions

Smart cities are perfect ecosystems for cross-fertilizing ideas and actions in response to the crucial needs we all might be facing in the coming years to improve the quality of life and efficiency at the city level. Societal innovation paradigm can be leveraged by immersing urban society in a technologically advanced scenario thus fostering crowd-sourced creativity potential.

The deployment of the research-oriented IoT infrastructure described in this paper in the heart of a city, and the considerable investments required to create and amplify it to the necessary scale, motivates the exploitation of the facility beyond the experimental research community. The facility has therefore been conceived not only to act as a testbed for research with IoT technologies, but also for the development and evaluation of IoT enabled smart city services and applications targeting developers of commercial solutions.

Furthermore, it also caters for the actual end users by providing IoT enabled services to the city and their citizens. The involvement of end users adds another dimension to the evaluation capabilities of the platform by allowing not only the assessment of technical performance of IoT solutions, but also their societal implications and user acceptance (Schaffers et al., 2011b). This aspect is the one that promotes what the authors categorizes as societal innovation, being the engagement of communities towards the development of new concepts and solutions tackling societal needs (more effectively than alternatives) and creating new social relationships or collaborations.

From the different services already running on the Santander platform, this paper has presented the two services that best exemplifies our notion of societal innovation, namely the Augmented Reality Service and the Participatory Sensing Service.

SmartSantanderRA is a free Augmented Reality technology app that has been downloaded massively by more than 13500 people in less than one year, providing an interactive experience for both citizens and visitors when walking along the city. It provides a unified access to all city data sources, presents them in a context-sensitive and location aware manner to the end users using augmented reality technology. Additionally, the information implicitly generated by the user when using the application is processed by the system with the aim of acquiring knowledge about citizen preferences, mobility patterns and other statistics. The further analysis of this data will allow the creation of new services and experiments within the smart city context.

Thanks to the "Pace of the city" App developed, quantitative KPIs collected show evidence of improvements gained after the introduction of IoT, Specific examples we have are "City council time to resolve incidents" has decreased from 38 days (before IoT) to 5.71 (after), "Incidents reported to the municipality services", Before launching the Pace of the City service, 122 incidents were reported to the municipality services through the citizens' inbox during 10 months period in 2012 year. Since November 11th 2012 to the end of the year, 251 incidents were received by the municipality services. During the first six months of 2013 449 incidences have been reported. From a qualitative point of view it is important to highlight the interest from the population with more than 5000 people downloaded the application in the first 8 months.

Future work to be carried out will involve the deployment of new use cases, some of them oriented to strengthen the participation of the citizenship in the definition of new end-user services and their involvement in the validation of the proposed technological approaches. Furthermore, it is of utmost importance to add to the already existing smart city platform the tools allowing the assessment of the social engagement produced by the smart city services tested on top of Santander's IoT infrastructure.

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the volume of data maintained and managed within the database expands, thus growing synergies across sectors and departments, as well.

- Although the volunteer module has proven the most attractive to Red Cross Red Crescent National Societies, the RMS is now also being displayed as a technical and sectorial resource. For instance, in the Africa zone, the RMS is utilized to disseminate deployment messages to regional disaster response team members, alerting members of disaster operations seeking sectorial expertise and support, and offering a method for members to apply for deployment. The RMS can thus serve wider purposes, such as the Pakistan Red Crescent Society's anticipated plans to use the RMS to manage and map its domestic disaster response-trained staff, assets and volunteers. In addition, the Asia-Pacific zone's water and sanitation unit will begin in January 2014 to map its technical resources across the zone, including trained staff, volunteers and assets, through the RMS. Given that one of the main goals of the RMS has been to build the capability to share and disseminate information across IFRC, National Societies and partners, the promotion of modules beyond just the volunteer module will help to demonstrate and utilize the full capacity and value of the RMS.

An evaluation of the RMS implementation with the Philippines Red Cross and Timor-Leste Red Cross will take place in early 2014. Already, one lesson learned from the RMS experience concerns the scale of rollout within a National Society. For instance, the Philippines Red Cross Society chose to utilize the RMS as its volunteer management system. It was deemed that if all information on volunteer trainings, skills, experience and contact information was entered into the RMS volunteer module, the system would offer great value to the Philippines Red Cross and partners. However, due to the scale of the implementation, the size of the National Society and other on-going disaster operations, this proved to be a challenging goal to achieve. In actuality, a portion of the volunteers and their information has been uploaded onto the system thus far, and it is still an on-going task, in addition to ensuring appropriate data quality of the more than 200,000 records in the system. The recent disaster in the Philippines, Typhoon Haiyan, affected provinces that had yet to implement the RMS, which therefore, were not in a position to benefit from the comprehensive volunteer information that the RMS could provide.

Results and lessons learned from the new vulnerability module are still to be determined and compiled, based on the outcomes of piloting the module in various contexts. Discussions are underway to determine the indicators to be tested as part of the UDRR programme, potentially adopting several 'global' indicators tracked at a national level, along with another few indicators more specific to the particular urban context. For the urban community level indicators, it is anticipated that Red Cross Red Crescent National Societies will select from a list of indicators that are most appropriate to address the risks and priorities identified as part of the VCA exercises in their specific targeted urban communities.

Conclusion

The benefits of the overall RMS are manifold, including offering contributions to organizational development, and programme development and management. The system allows for information to be more easily shared and organized across National Society's headquarters and branch offices, as well as IFRC. Given the multi-sectoral nature of the system, the RMS allows for integrated operations and programme planning and oversight, as well as greater preparedness for and response to disasters. Data is backed up on a daily basis, thus reducing the threat of losing information. The online system does not present additional costs to National Societies utilizing the RMS, thus a financial advantage. Additionally, the development of new modules and features is guided by the needs and requests of Red Cross and Red Crescent National Societies themselves, further ensuring the relevancy and utility of the system.

As auxiliaries to their national governments and often with comprehensive coverage and access to communities through their wide networks of volunteers, Red Cross Red Crescent National Societies are well placed for collecting information on vulnerabilities, capacities and resilience. This extends also to urban communities, where the Red Cross Red Crescent is further expanding its work and efforts. In order to make a real impact on the lives of the most vulnerable, accurate and more extensive information should be shared openly amongst key stakeholders involved in urban disaster risk reduction efforts. Accessible and easy to use systems should be developed, such as the RMS, in order to facilitate information sharing and utilization. Additionally, the importance of urban disaster risk reduction and the benefits that GIS data offers to risk reduction efforts should be more widely advocated. Through the use of the RMS's vulnerability module, IFRC aims to offer an innovative approach to humanitarian initiatives focused on urban disaster risk reduction through the compilation of community-driven results from the VCA processes that contribute to relevant indicators in the system. In addition, the module allows for the ability to geospatially map these results, so as to improve interventions in targeted communities, ultimately improving communities' resilience.

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