FROM THE INTERNET OF THINGS TO THE SOCIAL INNOVATION AND THE ECONOMY OF DATA

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Abstract

Historically, cities and their citizens have led the largest changes that have been taking place continuously, especially since the transition from an agricultural economy to an industrial one. This phenomenon is especially significant from the mid-eighteenth century and it will become more intense if the predictions that establish that, around the year 2050, approximately 70% of the world population will concentrate in some type of city finally come true. With these boundary conditions, it is evident that the achievement of more efficient and sustainable cities is an unavoidable objective for which politicians, managers and technicians must work in order to guarantee the quality of life of their citizens. Although this paradigm of sustainability and efficiency has always been present in the managers of cities, it has not been until very recently that technology has made available to the responsible parties a plethora of possibilities that, when properly employed, translate into significant savings. At the same time, the day-to-day improvement of the citizens is consolidating a new urban concept in which the different processes and systems that occur in it are continuously monitored in both time and space. This paper reviews the evolution of one of the pioneering examples of such cities, Santander, where an Internet of the Things infrastructure was deployed a decade ago. In this time, multiple technologies and services have been developed and deployed in smart city pilots. The paper discusses the key lessons learnt from the digitalization of the city and the new challenges that have arisen as we were paving the way for a smarter and more liveable city.

Keywords

Smart City, Internet of Things, Economy of Data, Open Ecosystem.

1. Introduction

The smart city market is still largely fragmented, with vertical solutions dominating and horizontal solutions more mirroring experimental petri dishes rather than solutions to real problems. This results in below-critical mass efforts in standardisation and commodity solutions. Vendor lock-in thus dictates the landscape, resulting in lowering cities' confidence that smart city strategies can achieve a major change. Conversely, the fragmentation of emerging IoT-enabled city platforms makes it difficult for entrepreneurs and SMEs to achieve economies of scale by replicating innovative solutions from one city to another. In this sense, planning to effectively meet the conditions and realities of a post-carbon, climate responsible world will require a shift in our current understanding of what constitutes good urban design and planning. Many of the practices that we now take for granted, such as planning cities around automobile transportation and zoning for single uses, will no longer be economically, environmentally, or culturally viable.

Smart cities hold the potential to be a key driver and catalyst in creating a large-scale global IoT market of services and hardware [1]. However, the emerging smart city market faces specific challenges that act as barriers to growth, impeding rapid innovation and inhibiting widespread market adoption. In this paper we are reviewing the key lessons learnt gathered from the experience of a decade of developing and deploying smart city services in the city of Santander, Spain. Based on this, we are proposing some of the key challenges that should be addressed in order to bring the smart city paradigm a step forward. In this sense, we are foreseeing four key objectives that should be pursued: (i) Scaling city platforms without vendor and/or city lock-in; (ii) Developing services that really meet citizens' needs; (iii) Guaranteeing resilient wireless connectivity in massive 5G scenarios; (iv) Encouraging new high-value data sources beyond open data.

The remaining of the paper is organized as follows. Section 2 summarizes the history of the SmartSantander ecosystem consolidation by briefly sketching the projects that have been carried out and presenting how they have contributed to the evolution of the city. In the path that these projects have opened some fundamental lessons have been learnt, which are also summarized. In Section 3, the way forward is outlined by identifying the crucial challenges that have to be addressed in order to fulfil the aforementioned key objectives. The high-level framework for addressing these challenges is also presented. Existing related work and initiatives already developing innovative solutions for these challenges is reviewed in Section 4. Finally, some concluding remarks are highlighted in Section 5.

2. SmartSantander Lessons Learnt

This section presents the three key pillars of the SmartSantander evolution and the three key lessons learnt that we have concluded. These lessons learnt are based on our developments around the SmartSantander concept evolution as a successful case of the implementation of the smart city paradigm.

2.1. SmartSantander Evolution

The objectives of SmartSantander's developments 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.

In the following subsections, a brief summary of three key factors that have structured the evolution of the SmartSantander approach is presented.

2.1.1. Massive deployment of IoT devices

The deployment, influenced by Santander Municipality's strategic smart-city service requirements, intentionally provided a concentration of IoT devices in the city centre (a 1 Km2 area) in order to achieve the maximum possible impact on the citizens. Nonetheless, other city areas are also covered.

Figure 1 shows an excerpt view of the deployment. The different markers represent the deployed nodes (e.g. illuminance, sound pressure level, ambient temperature, mobile nodes or car presence detection sensors).

Figure 1. Santander IoT infrastructure deployment excerpt view

The SmartSantander testbed is composed of around 3000 IEEE 802.15.4 devices, 200 GPRS modules and 2000 joint NFC tag/QR code labels deployed both at static locations (streetlights, facades, bus stops) as well as on-board mobile vehicles (buses, taxis). Moreover, smartphones belonging to citizens who have downloaded the Pulso de la Ciudad App [2] are also part of the testbed infrastructure.

To attract the widest interest and demonstrate its usefulness, the deployment of the IoT experimentation infrastructure has been undertaken to create interesting use-cases that will generate an impact. In this respect, application areas have been selected based on their high potential impact on the citizens. Diversity, dynamics and scale of the IoT environment are also taken into consideration in the selection of application use cases:

- Environmental Monitoring: Around 2000 IoT devices installed (mainly in the city centre), on lampposts and facades provide measurements of different environmental parameters, such as temperature, CO, noise or light).
- Mobile Environmental Monitoring: In order to extend the aforementioned environmental monitoring use case, apart from measuring at static points, devices

located in vehicles retrieve environmental parameters (related to air pollution). Sensors are installed in 150 public vehicles, including buses, taxis and police cars.

- Outdoor Parking: Almost 400 parking sensors (based on ferromagnetic technology), buried under the asphalt, have been installed in the main parking areas of the city centre in order to detect parking site availability in these zones.
- Traffic Intensity Monitoring: Around 60 devices have been deployed at the main entrances to the city of Santander to measure the main traffic condition parameters, such as traffic volumes, road occupancy, and vehicle speed or queue length.
- Parks and gardens irrigation: In order to make irrigation as efficient as possible, around 50 devices have been deployed in two green zones of the city to monitor irrigation-related parameters such as moisture temperature and humidity, rain precipitation or wind conditions.
- NFC/QR tags: More than 2000 tags have been deployed and distributed throughout different strategic locations. These tags are mainly at transportation points (bus stops, taxi ranks, etc…), points of interest (monuments, etc…) and shops. All the information provided is online and can be updated at any time. Every time one of these tags is read, an observation is generated including information relating to the reader.
- Participatory sensing: In this scenario, mobile phones are used as sensing devices automatically feeding information from the device's built-in sensors such as GPS, compass, noise or temperature into the SmartSantander platform. Users can also participate by manually reporting events or incidences occurring in the city, which will subsequently be propagated to other users who are subscribed to the respective type of events.

The deployment of IoT devices to compose the SmartSantander infrastructure has been motivated both by requirements for 'in-situ' experimentation and by the aforementioned smart city services. The details of the SmartSantander's IoT devices regarding hardware specifications, deployment locations and network organization have been thoroughly described in [3] and [4].

2.1.2. Service provision

One of the instruments of the strategy of Santander for sustainable development has been starting and performing a progressive enhancement of its Smart City dimension. The SmartSantander project [5] has been a clear milestone that has opened a wide variety of research lines converting the city in a kind of urban laboratory. Within the objectives of this initiative, the improvement of the quality of municipality services is paramount but also the contribution to the reactivation of the regional economic fabric is a heavyweight aim.

The facility was 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. To build such facility, the project analysed, designed and developed several services that were ranked as a priority by the local authorities, regional government and end users, which are described next.

- Environmental Monitoring: Due to global warming, governments around the world are devoting significant effort and resources to the management of the environment. The city of Santander, likewise, is involved in this activity and it is trying to carry out an effective policy for environmental management.
- Parking Management: With the aim of reducing CO emissions and other pollutants, as well as petrol consumption, ICT are becoming a transversal enabler. Drivers looking for

available parking places within the city may use both smartphone applications as well as panels installed in the city.

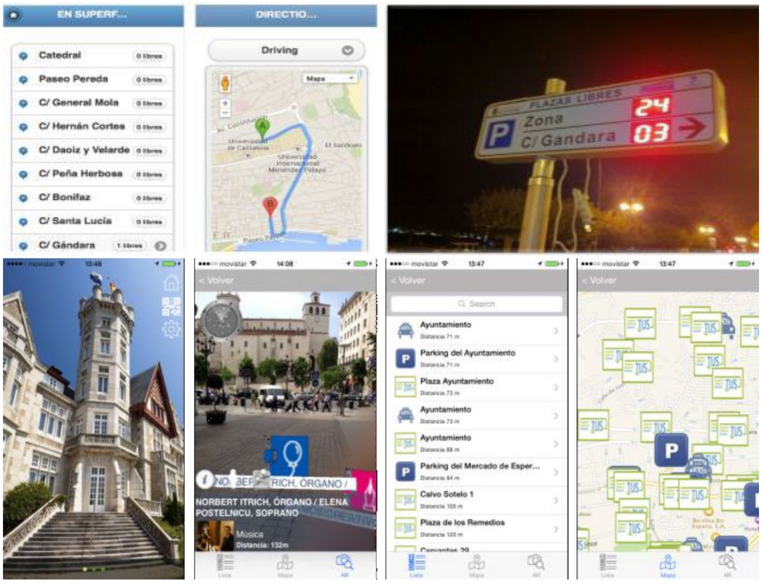

Figure 2. Smart City services examples at Santander

- Traffic intensity: The assessment and classification of vehicles in road traffic is mainly accomplished by inductive loops placed under the pavement. These inductive loops allow monitoring vehicle passing and provide us information on several parameters of the traffic (vehicle speed, traffic congestion and traffic accidents, among others). The information is sent to the SmartSantander platform.
- Parks and gardens irrigation: The service is aimed at complementing the automated irrigation systems currently deployed at parks and gardens within the city of Santander. It offers a wide data set acquired in a distributed way, gathering the information of interest from multiple locations within each area. Agricultural IoT devices and weather stations have been deployed in three major parks of Santander. All the information captured by the sensors is sent to the SmartSantander platform and merged on an application that provides parks management technicians with accurate information on the green areas status.
- Tourist and Cultural information: In the majority of cities, there is a huge amount of information that may be of interest for tourists and citizens, but it is not readily accessible because it is so disperse. To avoid that, a service has been implemented to unify the way to access all data sources and presenting them in a context-sensitive, location-aware manner to the end users using Augmented Reality (AR) technology. The service includes information about more than 2700 places in the city of Santander, classified in different categories: beaches, parks and gardens, monuments, buildings, tourist offices, shops, art galleries, libraries, bus stops, taxi ranks, bicycle hire points, parking lots and sports centres. Furthermore, it allows real-time access to traffic and beach cameras, weather reports and forecasts, public bus information and bike hire service, generating a unique ecosystem for end users when moving around the city.
- Participatory Sensing: The service aims at exploiting the use of citizens' smartphones to make people to take an active role in the generation of data for the SmartSantander Platform. Citizens, Santander City Council and the local newspaper are connected through the SmartSantander platform so that they can report, share and be notified of events happening in the city. Users also utilise 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. Municipal services were reorganized to adopt this application as the main way to report incidences. This has permitted to improve the response time to the citizen claims reducing the time to find out a solution for an incidence from 40.76 to 13.2 days.

2.1.3. Co-creation

Co-creation as a strategy where diverse stakeholders collaborate and produce a mutually beneficial product/service together was a crucial element of SmartSantander development. The SmartSantander facility provides the possibility that different stakeholders within the smart cities can co-create new services and innovative applications that can be tested and validated under real conditions in the urban landscape.

SmartSantander has accomplished the concept of co-creation by opening its infrastructure and platform to third-party developers, entrepreneurs and companies for them to try their novel ideas over a real-world environment where not only a real infrastructure is available but also a complete living lab has been created (i.e. real users, real policies, real impairments, etc.).

The SmartSantander experimentation tier consists of various components (deployed services and applications, template applications or libraries) that facilitate the building of applications and services for experimentation with them. At this level, any experimenter might develop and deploy its own services (e.g., a website, a web service, a desktop application or a smartphone application) that interact with the platform through the Experimentation as a Service (EaaS) Application Programming Interfaces (API). All applications at this tier have to be authorized and users utilizing them (either experimenters or services' users) can be authenticated and authorized to interact with the various services/assets exposed by the platform.

On this level, SmartSantander's facility provides a set of user interfaces that aims to facilitate the experimentation and co-creation activities: (i) a User Interface (UI) for discovering assets and the corresponding metadata associated to them like ranking and comments; (ii) a portal for defining, managing and monitoring experiments during their life cycle; (iii) Web and Smartphone Applications or Services for gathering annotations or any other data provided by the users; and (iv) another UI for interacting with the different communities participating in each experiment.

2.2. Lessons Learnt

From the experience that have been gathered throughout the years of evolution of the SmartSantander ecosystem, we discuss in the following sub-sections three aspects that are crucial for the development of smart cities.

2.2.1. Necessary infrastructure deployment

The baseline fabric of a smart city is surely the infrastructure that it has deployed. In this respect, what is meant with a smart city is the creation of a system of systems that is conscious about itself and that can adapt to the situation dynamically. Basically, we want the city to behave as a smart living entity. For this to happen, it is necessary to have sensors that makes the system aware of what is going on in the city. Also actuators that receives the commands and modify its behaviour to optimize their performance. It is likewise necessary to have the networks that bring the information back and forward in a secure and reliable way and respecting the quality and grade of service required.

Without this sensing, actuating and communicating infrastructure deployed, developing a smart city is simply not possible. However, as we have learnt from the experience gathered in Santander, two important aspects have to be observed during the necessary infrastructure deployment. Firstly, there is already a lot of infrastructure deployed in the city. It is possible that some of it could already be useful as the aforementioned smart city fabric. Other, might only need some adaptations to be part of it. In other words, most of the times it is not a clean-slate start when a city embarks itself into its smart transformation, thus, it is sensible to create a portfolio of "sensors", "actuators" and "networks" that the city has. Secondly, it is not necessary that all the systems that encompass the city are equally smart (or even smart at all). Making all the city services smart at the same time is plainly non-sense. Gradual and cyclical infrastructure deployment is much more sensible. The infrastructure should be deployed according to the city priorities. Indeed, the procurement and physical deployment processes have a learning curve that is not negligible.

2.2.2. Multi-stakeholder ecosystem creation

Cities are complex ecosystems participated by many actors with heterogeneous backgrounds, interests and/or expertise. Thus, while the main responsible and policy regulator is the city administration, the deployment of a smart city has to observe this multi-stakeholder nature of the city. Moreover, in general, cities' challenges are analogous globally. Thus, the ecosystem created for one city should be reproducible in another widening even more the scope and multilateralism of potential stakeholders.

In the creation of this multi-stakeholder ecosystem, the adoption of a Smart City Platform (cf. Figure 3) is fundamental. It should leverage interoperability technologies to aggregate the underlying heterogeneous infrastructure and enable service and application development independently of the information providers and the technologies that they use.

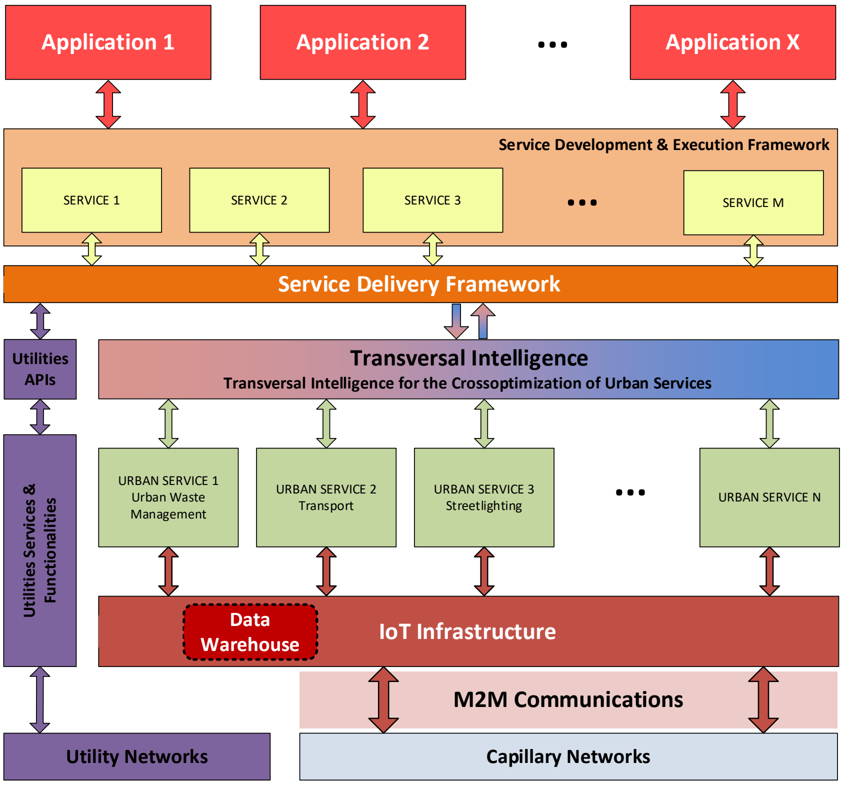

Figure 3. Smart City multi-stakeholder platform deployed at Santander

The existing utilities and municipality infrastructures provide a first abstraction level in terms of resource management and data handling. Making use of IoT technologies [6], advantage is taken from the pervasive presence around the city of information sources and actuators belonging to the utilities. These elements interact with each other and cooperate with their neighbours to reach common goals. In this sense, by generating virtual instances of real physical objects, it is possible to deploy services and applications, characterized by a high degree of autonomous data capture, event transfer, network connectivity and interoperability [7].

However, they are mainly vertical systems that are exclusively tailored to the city service they are supporting. Hence, it is necessary to provide adequate mechanisms for added-value services creation and execution. In the city utilities application domain, this should enable new business opportunities for 3rd parties that can reuse available city assets and existing services to create new ones with added value and thus generate new forms of revenue. The later requires changing data sharing policies and making data generated seamlessly available to 3rd parties. To facilitate such development and deployment, an open API [8] framework is included in the envisioned ecosystem as one of its integral parts of our architecture.

On top of this abstraction level, a service information model (described through a service catalogue) is provided to allow extending the traditional utility use cases towards new business scenarios. Different services can be combined through the service federation concept either by service re-use (by sticking to modular service development practices) or through creation of service mash-up resulting in relevant savings in terms of the Capital Expenditure (CAPEX) and Operation Expenditure (OPEX). Further on, the service framework can be supported over cloud-enabled technologies thus allowing assignment of resources in an elastic way, driven by demand, meeting Service Level Agreements (SLAs) and providing flexibility in the business requirements (e.g. the end user only pays for actual use or ICT resources).

2.2.3. Open ecosystem

Openness have been addressed on two main axes that are critical for the success of the deployment of smart city solutions with a global scope in mind.

Firstly, standardization is crucial in the sense of breaking vendor lock-in as well as city lock-in. The first lock-in situation avoidance refers to the need for usable standards and an interoperable vendor ecosystem for IoT-enabled smart city solutions so that cities do not have to commit to a specific solution so there are no dependencies on a single vendor. The latter one refers to the necessity of APIs for accessing streamed data from IoT infrastructures that homogenize the availability of data sources and underlying data formats. This way developers and providers of IoT-based smart city services can deploy and operate a service, which has been initially developed for one city, to another, thus getting benefit from the opportunities that come from economies of scale.

Secondly, open APIs are equally important to guarantee that no lock-in situation is produced. FIWARE [9] is a large ecosystem providing standardized APIs used in open-source implementations of generic enablers based on open specifications. FIWARE is now at the centre of the Open and Agile Smart Cities (OASC) initiative [10]. oneM2M [11], on the other hand, provides a global standard for IoT common service functionalities that are used by the emerging IoT services and products. oneM2M and FIWARE are two powerful existing ecosystems that are worth the effort to make them interoperable [12]. Indeed, in Santander this interoperability has been granted and it is possible, nowadays, to develop applications [13] that can transparently consume data from platforms that use any of this technologies as baseline.

3. Future Challenges

Despite the advances in the implementation and deployment of novel technologies towards the realization of the smart city paradigm, globally, and in the city of Santander in particular, this is not a completed endeavour. Surely, the current scenario has addressed some of the original objectives, but it has become evident that there are large possibilities of enhancement for creating smarter cities.

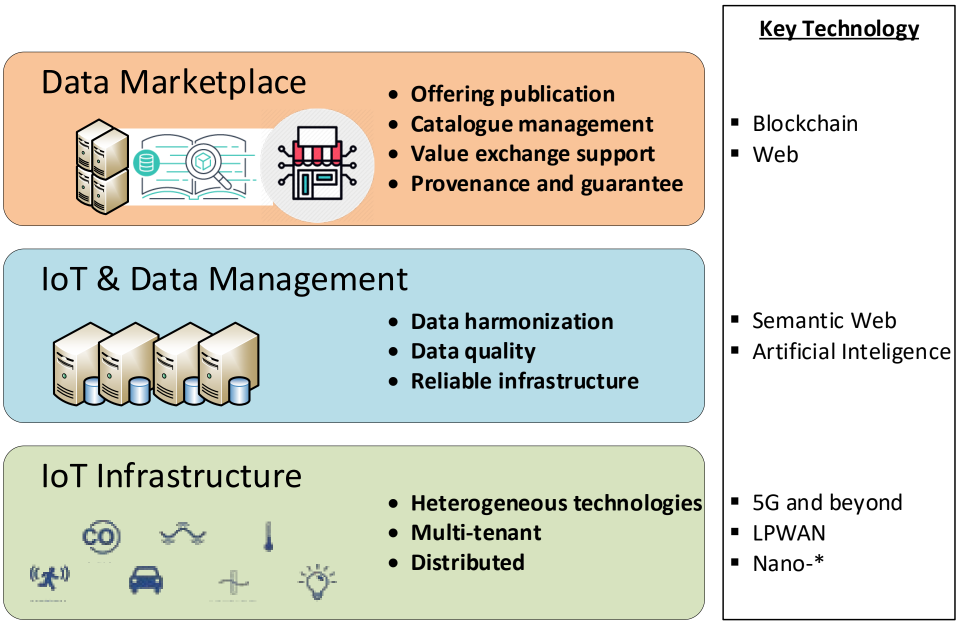

Figure 4. Smart City challenges high-level framework

Figure 4 summarizes the high-level framework to address the foreseen challenges and the establishment of novel business models based on the valuable data-streams that emanate from a full-blown smart city. The framework identifies the main tiers in which IoT-based smart city platforms are typically structured, namely IoT Infrastructure, IoT & Data Management and Data Marketplace. For each of these levels, key challenges and enabling technologies have been highlighted.

At the bottom layer, the IoT Infrastructure will be characterized by the heterogeneous communication technologies that will be available for best fitting the plethora of application domains. Additionally, muti-tenancy must be supported as the IoT deployments will come from both public and private domains and they should be handled under a common framework. Finally, distribution of infrastructure and intelligence is the only option to manage the complexity at this bottom layer.

The second tier deals with the infrastructure management and more importantly with the data organization. On the one hand, it is of utmost importance that the underlying infrastructure is kept in good working order and guaranteeing this is not trivial considering its dimension and composition. On the other, the data produced has to be homogenized and its quality also guaranteed in order to make it easy and valuable to consume.

Finally, the top layer handles the interaction with the services and applications that are based on the context information retrieved. The creation and maintenance of a data marketplace where data is organized in straightforwardly accessible offerings whose provenance and quality are systematically registered and guaranteed. Additionally, it has to provide the mechanisms to enable value exchanges among data providers and data consumers. These mechanisms have to be flexible enough to facilitate the adoption of different business models.

Some of the challenges and development paths to implement this framework are depicted in the following sub-sections.

3.1. Adoption of common APIs and common data models

Worldwide cities are involved in a digital revolution that will transform the way in which existing and new city systems are operated. However, optimizing the behaviour of any specific urban service has to be carried out taking into consideration the service itself as well as its interaction with adjacent services. This means that any solution aiming at achieving the autonomous city management paradigm is tightly coupled with the adoption of common frameworks, among in-city systems, which are able to guarantee systems interoperability.

Furthermore, cities themselves are not isolated systems. They will interact one to the each other depending on different attributes. This implies that, eventually, optimizing some processes in one city without having in mind the adjacency to the others might result in inefficiencies [14]. Hence, interoperability among inter-city systems will become necessary. Not just in terms of pure optimization but also in terms of replicability.

Moreover, it is necessary to highlight the multitude of actors that participate in the smart city services provision. This leads to heterogeneous service models and underlying infrastructure.

In order to maximize the efficiency, exportability and horizontality of the cities digitalization, it is of utmost importance that the access to the data supporting the city services is homogenized, not only from a procedural viewpoint, but also from a syntactic and even semantic perspective. Standardization initiatives [15] as well as front-runner actors in the smart city ecosystem [9] .are working on setting common APIs and data models that shall enable the necessary grounds for seamless data exchanges among data producers and data consumers.

3.2. Data, Network and Communications Reliability

The next generation of communication networks and services, so-called 5G, will not only be an evolution of mobile broadband networks but it will also bring new unique network and service capabilities. Specifically, 5G will be a key enabler for the Internet of Things by providing a platform to connect a massive number of sensors, rendering devices and actuators with stringent energy and transmission constraints. However, it is still open how to model these scenarios (mainly at the access network level), and which technologies (or combination of them) will be part of the future communication systems.

3.3. Data Marketplace

In order to exploit data, the platform is required to provide data providers with means to decide and enforce how and with whom data is shared. In this sense, the data market place has to let data providers to define access policies based on both the particular data assets and the data consumer. In addition, considering the growing importance of data, such marketplace needs also to provide charging mechanisms, so that the data assets can be monetized. In this respect, pricing models are needed to assign cost to data assets. An appealing starting point can be the Black-Sholes model [16] used for options pricing modelling.

Along with the different possibilities of sharing data, it is also necessary to provide different licensing levels and means for the data provider to ensure that a particular data asset is exploited under the negotiated conditions. Finally, it would be also desirable that the platform brings mechanisms to provide feedback concerning data quality, in order to implement reputation raking that can be afterwards exploited to better define the data sharing policies.

3.4. Opportunities Creation

The vision of smart cities has been shaped, for long, by sales pitches of larger technology vendor and system integrators. Early "smart city 1.0" examples such as Masdar or Songdo have been technology- or marketing- driven rather than addressing typical operational and citizen needs. Other services often take the perspective of the city authorities, which is in many cases different from the one of the citizen. While there are significant cultural differences globally, from a European perspective, there is a lack of citizen voice in the current debate about IoT instrumentation. If smart city services are to make a real difference to citizens, and be accepted by the public, then citizens must play a strong role in their creation and design.

Moreover, the smart city has to be promoted as a scenario where new business models are created around the exchange of data and the services that arise from this sharing. For example, cities are becoming the playground for the sharing economy [17]. The concentration of economic activity and ubiquity of technology in cities facilitate the rapid, location-based exchange of services and products among citizens (P2P), among businesses (B2B), and businesses to the crowd. Novel business concepts like the Commons Collaborative Economy [18] characterized by using data as the new key good for trading in the newly created digital marketplaces shall be able to:

1) Favour peer-to-peer relations -in contrast to the traditionally hierarchical command and contractual relationships.

2) Settle new value distribution and governance among the community of peers where profitability is not its main/unique driving force.

3) Leverage privacy-aware public infrastructure that results in the (generally) open access provision of commons resources that favour access, reproducibility and derivativeness.

3.5. Blockchain technologies and its impact on the smart city paradigm

The first wave of smart city services have been predominantly developed around open data. Such data is in most cases shared if not considered sensitive, and the success of services developed on top is often only modest. Proprietary data sets such as IoT-generated data, closed organisational data or personal data have the potential to offer higher value for richer smart city services, but are not released for exploitation or not readily available. There is a lack of incentives, market confidence and trust for organisations and individuals to share new data sets as licensing models are not yet properly understood and developed, and key ecosystem foundation for such a market place are still missing.

It is necessary to develop a security-by-design approach increasing the transparency of all the IoT asset governance flow shifting from the current paradigm of discrete centralized trusted authorities to a paradigm of liquid and decentralized trust of the network as a whole.

In this shift, the creation of Blockchain platforms that can be employed following the "as a Service" paradigm will enable fully decentralised solutions delivering certified mechanisms to support the management of IoT devices, during their whole lifecycle. Blockchain-based distributed ledger concept offers provenance and quality of data guarantee, as well as reputation mechanisms for qualification of assets shared in a participatory fashion. The shifting from the current paradigm of discrete centralized trusted authorities to a paradigm of decentralized trust of the web as a whole responds to the consumers' needs and to the providers' demands. The first because they require reassurance of the data's quality. The latter because they are reluctant to share some datasets due to uncertainty of how and for what purposes the data is used.

4. Conclusions

Worldwide cities are involved in a digital transformation focused on sustainability and improving citizen's quality of life. This digital transformation will make a reality the paradigm of an autonomous city meaning that relying on the massive amount of data as well as the appropriate machinery the city management platform will be able to run it near to the optimal operating point predicting any unexpected event making daily citizen's life easier. While this paradigm of sustainability and efficiency has been always present for city administrators, digital transformation is opening new opportunities besides the optimization of the urban services that have been traditionally offer to its citizens (mobility, lighting, water distribution, waste management, etc.). Among these new opportunities, there is one, co-creation, with a large transformative potential from the economic and social viewpoint.

Co-creation paradigm stands for the participatory creation of solutions and services among multiple stakeholders. In order to enable this scenario, cities have to set up a platform equipped with a set of highly intuitive tools and enablers that allow the design and implementation of novel services and, why not, so-called killer applications. For the platform to be valuable, it has to be fed by as many city assets, and the information that they generate, as possible. Moreover, it is of utmost importance to scale up the concept and federate such platform with other cities so that the creative process can be enriched and its impact enlarged. Another crucial aspect that has been highlighted is the need to include enablers associated to the incentives and rewards of participating, not only during the trial phases but also considering the long-term sustainability of the whole platform and smart city ecosystem.

In this paper, we have reviewed the status of the SmartSantander ecosystem and the key features and lessons learnt through its evolution from a testbed for IoT experimentation to an open platform for co-creative innovation that is federated with other front-runner cities towards unleashing the potential of smart cities as social innovation hubs. Additionally, the challenges that have to be addressed in the short and medium term have been sketched. The path defined by these challenges is meant to establish a new economic model around the cities, bound to innovative exploitation of data exposed in a digital single market.

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