Estimating Smart City Sensors Data Generation

Current and Future Data in the City of Barcelona

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***Abstract*— Nowadays, Smart Cities are positioned as one of the most challenging and important research topics, highlighting major changes in people's lifestyle. Technologies such as smart energy, smart transportation or smart health are being designed to improve citizen's quality of life. Smart Cities leverage the deployment of a network of devices – sensors and mobile devices–, all connected through different means and/or technologies, according to their network availability and capacities, setting a novel framework feeding end-users with an innovative set of smart services. Aligned to this objective, a typical Smart City architecture is organized into layers, including a sensing layer (generates data), a network layer (moves the data), a middleware layer (manages all collected data and makes it ready for usage) and an application layer (provides the smart services benefiting from this data). In this paper a real Smart City is analyzed, corresponding to the city of Barcelona, with special emphasis on the layers responsible for collecting the data generated by the deployed sensors. The amount of daily sensors data transmitted through the network has been estimated and a rough projection has been made assuming an exhaustive deployment that fully covers all city. Finally, we discuss some solutions to both reduce the data transmission and improve the data management.**

Keywords—Smart City; Sensor Data; Data Managment; Data Collection; Data Aggregation; Internet of Things

I. Introduction

The world human population is estimated to increase from 7,336 million in mid-2015 to 9,804 million in mid-2050 [1]. This human population evolution is and will be demanding more and much better services aiming at city resources optimization. Smart Cities provide new solutions and opportunities for efficient management through the use of the most advanced Information Technology. In fact, it is widely accepted that Smart Cities have the potential to improve its citizens' quality of life through the economy development, the social and political progress, the availability of new services and solutions, the protection of the environment, the hyper connectivity among citizens, and so on [2]. In addition, the Smart City concept can be applied in several domains, such as smart environment, smart energy, smart transport, smart health, or smart security, just to name a few.

The Smart City technological architecture is typically organized into layers, including the sensing layer, the network layer, the middleware layer and the application layer [3]. The sensing layer consists of a broad network of sensors spread across the whole city, responsible for collecting as much data as possible through either different types of sensors, other smart devices, such as smart phones or smart vehicles, or also through web services, surveillance cameras, or GPS devices. The network layer connects the sensors layer to the middleware layer through a diverse set of communication technologies, such as cellular networks, satellite networks, WiFi, Ethernet, or any other ad hoc technology enabling non easy to reach location connection. The middleware layer contains the main framework aimed at both organizing and centralizing the data collected as well as providing a platform for an easy and usually open access to the information. And eventually, the application layer provides the set of appropriate services for citizens or third party consumers [4].

Research on Smart Cities is an open challenge and continuous contributions are being brought about Smart City concepts and architectures in different scenarios. The technological progress in chronological order points out that Smart City architectures do not provide yet any comprehensive model integrating all expected Smart Cities functionalities, such as standardization or data collection globalization. Moreover continuous advances in technology and innovation are bringing in new challenges for Smart Cities deployment, even exacerbated by the unstoppably demands citizens have regarding immediate service delivery.

Smart Cities become an open and active research topic. Indeed, cities compete and invest many efforts and budget to endow their citizenships with innovative services. Several reports classify cities around the world ranking smarter cities according to different factors, such as energy efficiency, transport effectiveness, public management, and so on. Recently, IESE Cities in Motion Index (CIMI) 2015 reported that Barcelona is ranked first in Spain and thirty-fourth in the world [5, 6]. The report has analyzed some values, such as human capital, social cohesion, public management, the environment, mobility and transport, technology, or the international outreach of the cities.

In this paper, the Smart City of Barcelona has been analyzed in detail, with special focus on the two lower layers, namely the sensing layer and the network layer. Our interest is to estimate the amount of data generated by the sensors network, later collected and managed through its central platform, named Sentilo [2, 7], aiming to perform a data volume projection considering an exhaustive sensors development. We analyze the scalability of this eventual deployment and discuss different solutions to deal with this complexity.

This paper is organized as follows. Section 2 introduces some main insights related to Smart City architecture and data collection. Section 3 describes the particular Smart City architecture of Barcelona, paying special attention to the data collection process. In Section 4 the current state of the city sensors' network is listed and described, also providing an estimation of the volume of data to be generated. Then, Section 5 extends these measures assuming an exhaustive development of the sensing capabilities and proposes a set of improvements. Finally, Section 6 concludes the paper.

II. Smart City Architecture

There are many different Smart City designs and architectures, most of them following similar patterns though. This section revisits main architectural strategies for smart cities, as categorized in [2], also presenting a deeper description of the data collection technology..

A. *The Smart City General Architecture*

Providing appropriate architectures for Smart Cities assuming different scenarios and environments has recently become an active research topic,. There is no unique solution, rather several exist following similar patterns. In [2], Kyriazopoulou identifies six different architectural approaches to design a Smart City, such as Architectural Layers, Service Oriented Architecture, Event Driven Architecture, Internet of Things, Combined Architectures, or Internet of Everything.

Smart cities design through Architectural Layers (AL) defines a framework organized by some specific hierarchical layers. Each layer has a different responsibility and defines an interface to interact with higher and lower layers. The main aim of an AL framework is to offer an efficient solution for developing modular services and applications at each layer. Main AL architecture advantages are both its simplicity and its modular design facilitating extensions for future development.

The Service Oriented Architecture (SOA) approach defines a platform for interaction between service stakeholders and services. Three roles are usually defined in SOA: the service provider, the service agent and the service consumer, to make the interaction between end-users, services and service provider through data collection, data filtering, and so on [8]. The benefit of the SOA architecture is its capability for adaption between service stakeholders and services.

The Event Driven Architecture (EDA) approach defines an architecture for managing asynchronous events under uncertain conditions. This architecture proposes a model to manage events in terms of creation, identification, utilization and response, which can for instance detect emergency cases through sensors data registering. An advantage of an EDA model is its capacity to provide sustainability and security in Smart City environments through events management.

The Internet of Things (IoT) approach defines a framework enabling heterogeneous devices management, including sensors, smart devices, web services, and so on. Each kind of heterogeneous devices can connect and communicate with other through Internet, or any other local networks. In addition, Cloud Computing can also be used to help share computational resources also offering services to devices through Internet. Therefore, the IoT architecture creates an appropriate unified scenario to overcome all possible requirements for IoT stakeholders. The main profit of an IoT architecture is to provide connectivity with many different type of sources and provide variety of services for end-users.

The Combined Architecture is a new trend in current Smart City design that properly combines different aspects of the previous proposals, hence taking the most out of any individual architecture. Some popular architectures are IoT-SOA, IoT-SOA-AL, IoT-EDA, or IoT-SOA-AL-EDA.

The Internet of Everything (IoE) is a new generation paradigm to extend the IoT. Although no much difference is reported among both concepts, IoE could be understood as an IoT extension guaranteeing "everthing" connectivity. The IoE proposes a new and broader paradigm for smart objects that can connect to each other easily and quickly, anytime and anywhere around the city. The highly increasing interest of the IoE architecture is to manage a wider variety of information, from any device, for creating smarter applications and services through faster Internet infrastructure and network connection.

B. *Data Collection in Smart Cities*

There is a large number of distinct devices with different sensing capabilities that generate raw data in the context of a Smart City. These devices are usually spread along the city hence enabling real time monitoring thus setting a wide and complete snapshot of the city state. However, it is usually difficult to guarantee good quality from sensors, since current technology trades off quality and cost, and a massive deployment of high quality sensors would be unfeasible. But the raw data quality generated is acceptable. In addition, different sensors installed in different places, require frequently complex and sophisticated ad hoc solutions to connect them into a power supply source or to a connection network. These difficulties turn the data collection into a highly complex process.

Some of the main sources for data generation are sensors, smart devices, and web services:

- The sensor is a physical device that is able to sense and get a specific type of input, such as light, heat, motion, pressure, or noise, from the physical layer. The input can be converted to human-readable display at the sensor location, or transmitted electronically through the network for future use. There are many different types of sensors, for instance, acoustic and sound sensors (e.g. microphone), automotive sensors (e.g. speedometer), chemical sensors (e.g. pH sensor), electric and magnetic sensors (e.g. metal detector), environmental sensors (e.g. rain gauge), optical sensors (e.g. wave front sensor), mechanical sensors (e.g. strain gauge), thermal and temperature sensors (e.g. calorimeter), proximity or presences sensor (e.g. Doppler radar), and so on [9]. There are some important challenges for selecting and installing the appropriate sensors in a given context, such as accuracy, environmental condition, range, calibration, resolution, cost and repeatability [10].

- Smartphones are common devices spread all over the city that may behave as a great physical and mobile source for data gathering, everywhere and every time. It provides great opportunities to invest efforts for collecting data from anywhere at a very low cost. In fact, many smartphone apps are already sensing and saving large amount of data together with the user's location. In fact, some mobile applications are collecting such data even without Internet connection and, therefore, this information is stored offline and can be retrieved later.

- Web services generate huge amounts of data that may be of interest in a Smart City environment. However, the veracity and quality of this information should be carefully considered before being used. Some efforts have been made to filter this data for a proper utilization in the context of a Smart City. Techniques such as Semantic Web, Linked Data, and so on [11], are used to obtain information from websites to the Smart City's stakeholders.

III. The Barcelona Smat City Architecture

Barcelona is a metropolitan city in the northeast of Spain on the Mediterranean coast. Barcelona started to develop its Smart City scenario in the period 2007 to 2012 leveraging its telecommunications network. The initial idea was to set up a ubiquitous network and a set of services for citizens and companies. In addition, several sensors were deployed and tested around the city in order to provide higher quality of services to the city [12]. Recently, Barcelona has become an interesting location for Cisco to open a global innovation center for the IoE paradigm and architecture [2].

A. General Architecture

In the period 2011 to 2012, the Barcelona City Council and Municipal Institute of Informatics (IMI) jointly cooperated to set the basics of an architecture defining the strategies and policies allowing Barcelona to become a Smart City (see Figure 1).

The Barcelona Smart City IT architecture has been designed with three main layers, namely the Information Sources layer, the Middleware layer, and the Smart City Applications layer.

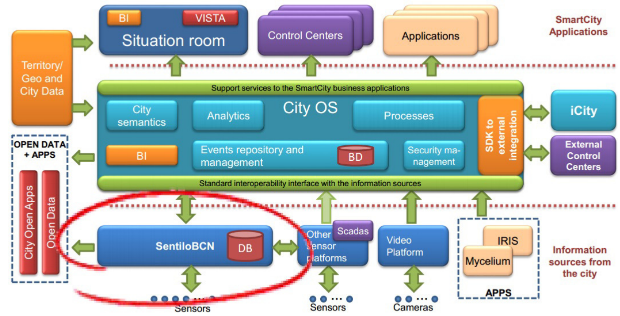

Fig. 1. Barcelona Smart City IT architecture.

The Information Sources (IS) layer aims to collect raw data from the Smart City's different sources, such as sensors, video, apps, and so on. The Middleware layer is in the middle of this architecture and collects raw data from the IS layer. This layer also provides some processing, filtering, and analytics procedures to obtain the meaningful information as feeds for abundant applications. Finally, the information will be made available to the upper layer. The Smart City Application layer is the set of applications that use the required meaningful information from low level layers and provides services for the city.

Some main design goals considered during the Smart City design are: *i*) cost reduction in sensors' deployment and maintenance; *ii*) cost reduction in applications development; and *iii*) cost reduction in platform evolution.

B. Data Collection

The Barcelona Smart City component collecting all data from sensors and actuators is named Sentilo, which refers to the word sensor in Esperanto. Sentilo is the piece of architecture that will isolate the applications that are developed to exploit the information "generated by the city", and the layer of sensors deployed across the city to collect and broadcast this information, and provides openness and interoperability. It is a key component in the Smart City framework, as can be seen in Figure 1 inside a red circle. The Sentilo platform collects data from more than 1800 sensors spread in the city of Barcelona, registering far beyond 1,300,000 daily records in its data bases.

As shown in Figure 2, the platform is organized into two main layers. The first layer is the Data Acquisition layer that collects raw data from several Direct data providers, such as devices, hubs and third party apps, or other W/Protocol data providers that include Scada (ModBus/RTU/MTU/OPC), Smart Metering (DLMS IEC62056) and third party systems. The second layer is the Data Transmission. This layer is responsible for transferring raw data from the Data Acquisition layer to the Middleware, as shown in Figure 2, through different communication methods, such as Ethernet, 3G/4G, and so on [13].

The Sentilo infrastructure brings several advantages, such as: i) simple and flexible platform for any kind of future development, be it software or hardware; and ii) open and shared platform for anyone.

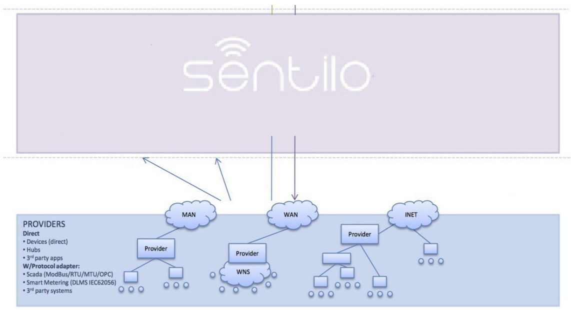

Fig. 2. Sentilo Data Collection platform

IV. Estimating Data Collection in Sentilo

The area of Barcelona has an approximate area of 100 Km^2 and has a population of 1.62 million habitants [14]. The city manages the urban furniture and city equipment, such as 150.000 lampposts, 40.000 garbage containers, and 80.000 public parking spots in the street [15]. These large geographical distances and residency demands should be managed in the city according to a smart city concept and project. The Sentilo platform supports the City Council in Barcelona to collect the city data provided by the network of sensors for an effective management of such demands. As shown in Figure 3, the city sensored data can be categorized in Energy monitoring, Noise monitoring, Urban Lab monitoring (includes air, temperature and humidity monitoring), Garbage Collection monitoring, and Parking Spots monitoring.

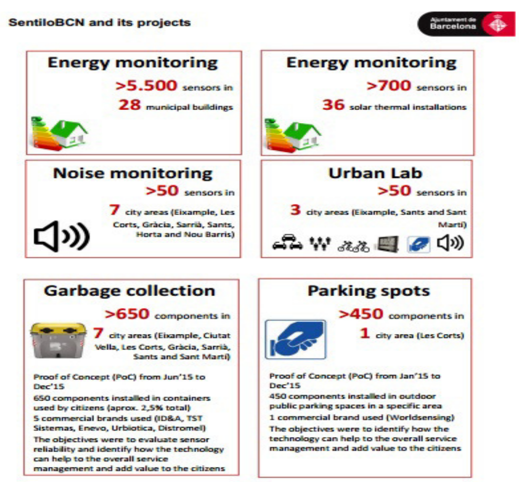

Fig. 3. City Data provides by Sentilo

In this section we will estimate the amount of data generated in current Sentilo's platform as part of the Barcelona Smart City implementation. To that end, we will account the number and types of sensors currently installed in Barcelona, and we will analyze the amount, type, and frequency of the generated data to be sent to the main framework. With all this information, an approximate measure of the daily sensor traffic can be obtained.

A. *Sensors Data Description*

There are almost 1,800 sensors installed as part of the Sentilo platform in Barcelona, monitoring data about energy, noise, urban lab, garbage collection, and parking spots.

Energy monitoring management includes two main categories installed in municipal buildings and solar thermal installations. The sensors installed in municipal building obtain sensing information about energy consumption, such as electricity meter, electricity ambient conditions, gas meter, internal ambient conditions, and temperature. The solar thermal installation helps the city understand the solar thermal energy produced and consumed. The current number of components, frequency of measure, frequency of sending and updating information, and some other information details can be seen in Table I (a).

Noise monitoring management detects any kind of noise and acoustic pollution in the city. Currently, about 50 sensors are deployed in the city to collect this information. They have been installed in seven different city areas. The current number of components, frequency of measure, frequency of sending and updating information, and some other information details can be seen in Table I (b).

Urban Lab monitoring management provides a variety of services related to the air, temperature, humidity, and other transportation issues (including people and bicycle flow). There are about 50 active sensors in the city, as shown in Table 4, to take the relative and appropriate information for the services. The sensors are spread in different zones of Barcelona for obtaining the accurate data for services, as shown in Table I (c).

Garbage Collection management aims to obtain precise information about garbage and containers in the city, organized by glass, organic, paper, plastic and refuse. The associated information can help the city in terms of better health and cleaning services. There are approximately 660 components for this area, shown in Table 5, which hang to the containers in the distinct zones of the city, as shown in Table I (d).

Parking Spots monitoring management comes with the specific idea to give some advantages and added values to the citizens for a traffic management service, such as finding free parking spaces. Currently there are almost 500 components installed in a single area of Barcelona. The current number of components, frequency of measure, frequency of sending and updating information, and some other details about the Parking Spots management is shown in Table I (e).

B. *Estimating Data Transfer Volume by Service*

Each previously analyzed service transfers and updates several data packet regularly. In this section we estimate the amounts of data transferred from each sensor, according to the data types to be sent, its sending frequency, and the number of sensors. Note that each sensor generates and manages different set of data types and, usually, includes the timestamp of the measure. All estimations have been made assuming a per day basis, this is, we have estimated the data transfer volume during one day of measurements. The total amount of data per day, for each type of service, can be seen in Table II (a, b, c, d and e).

Table II shows the total number of generated data in a day in Energy monitoring management (>3MB), Noise monitoring management (578KB), Urban Lab monitoring management (153KB), Garbage Collection management (480KB), and Parking Spots management (615KB). To sum up, the total data currently generated in a single day is about 5GB that is transferred through the Smart City network in Barcelona.

V. Data Volume Estimation in a whole deployed Sensors Network

According to the statistical department in the Barcelona's City Hall, there were 70,000 buildings, 40,000 containers and 80,000 parking slots in 2014 [14, 15]. In addition, we have estimated that there are around 40,000 street corners in Barcelona. Thus, in this section, we present a projection of the number of sensors, and the corresponding expected generated data, assuming a complete sensors network deployment fully covering the Barcelona area.

A. *Data Volume Estimation*

As we shown in Figure 3, there are several types of data currently sensed, transmitted and managed by sensors as sensored data in Barcelona. We have estimated the amount sensors and data to deploy a ubiquitous Smart City in Barcelona, as shown in Table III (a, b, c, d and e). Consequently, we have measured the total number of data to be about 8 GB (8,583,503,168) per day from all sensors in the city. Moreover, we must consider 320,925,019 sensors for a whole coverage in the city. It is worth noticing that this volume only measures data obtained from sensors, and does not consider other data obtained from other eventual sources. In short, the huge amount of data to be managed requires a clear and stable management plan to be defined, aiming at efficiently handling the existing data, thus taking the most of it, ending up in novel benefits for citizens and city managers.

B. *Proposals for Improvement*

The total amount of data estimated is not that extremely high to require a vast investment in technology, rather it can be easily managed by a specialized data center. However, generating this amount of daily data, year after year, may become a technological problem. Even worse, in our study we have only considered the data generated through sensors, and it is unquestionably that other sources of data exist, such as mobile devices, surveillance cameras, information generated through web services, and some others, which may aggravate the magnitude of this problem.

In this section we enumerate some alternatives that may help improve the cost and efficiency of the data collection in a Smart City platform.

- Data Aggregation: The type and frequency of data from each sensor can be adjusted to reduce its traffic. However, in a complete sensors deployment the number of sensor devices will be very high.. Data aggregation consists in combining the information generated in different but close devices, so that the amounts of data to be transferred can be reduced substantially.
- Distributed data organization: The data collected from sensors is generated by sensors installed at a certain location. Usually, this data will be consumed by services executed in some close ubieties. Instead of centralizing the data storage and management, a smart solution may be to distribute different management subsystems across key city areas so that the global traffic will be drastically reduced and, in addition, higher quality of service can be offered, for example in terms of shorter latency. In addition, distributed data organization will improve the robustness of the system, in case of network failure. In this case, there could still be a centralized platform, but with some kind of simplified data collection strategy.
- Fog computing: In a modern city there are multiple computing devices spread all over it, such as citizen's mobile devices (either personnel or inside vehicles), or even municipal distributed computing devices (for instance, one small computer inside traffic lights). These devices provide a sophisticated computing environment that, if used efficiently, may become a dynamic, yet powerful, data mobile center. The possibilities of an efficient management of such resources are unlimited and, of course, they will have an effect on the sensors data management.

VI. Conclusions

In this paper we have studied the Smart City architecture deployed in Barcelona, with a special focus on Sentilo, that is the framework for sensors data collection and management. In our study we have estimated the per sensor volume of daily data transmission, from sensors to Sentilo. With this information, we performed a rough projection of the global data amount that would be transmitted throughout the network in the case of an eventual sensors deployment completely covering the Barcelona area, according to the statistical information available for the city. And finally, in order to reduce this data volume while also optimizing the data collection and management, different strategies have been discussed.

We conclude that the amount of information to be generated in a Smart City is very high, but it will be even much higher in a near future. Moreover, non-negligible data coming from other data sources was not considered in our study, (such as mobile devices, surveillance cameras, or web services), all exacerbating the data figures. For this reason, we propose several alternatives for improving data management. For instance, we propose distributing the data collection framework in order to provide different data access points that simplify data transmission and, additionally, supply a closer data repository for real-time applications; or implementing fog computing technologies in order to partially process the generated data close to the source sensor and transfer only valuable information. Furthermore, fog computing could provide a sophisticated distributed computing environment in the city that, if used efficiently, may become a dynamic, yet powerful, mobile data center.

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TABLE I. DATA MONITORING MANAGEMENT IN BARCELONA SMART CITY

Type	Number of devices	Frequency of sending and updating information
Electricity meter	28	Every 1 minute (instantaneous data) and every 15 minutes (average data)
External ambient conditions	7	Every 1 minute (instantaneous data) and every 15 minutes (average data)
Gas meter	1	Every 1 minute (instantaneous data) and every 15 minutes (average data)
Internal ambient conditions	41	Every 1 minute (instantaneous data) and every 15 minutes (average data)
Network analyzer	421	Every 1 minute (instantaneous data) and every 15 minutes (average data)
Solar thermal installation	36	Every 15 minutes
Temperature	7	Every 15 minutes
Total	541	

(a) Energy monitoring management

Type	Number of devices	Frequency of sending and updating information
Noise	3	Every 15 minutes
	40	Every 1 minutes
	10	Every 1 minutes
Total	53	

(b) Noise monitoring management

Type	Number of devices	Frequency of sending and updating information
Container glass	57	Every 20 minutes or Every 60 minutes
Container organic	71	Every 20 minutes or Every 60 minutes
Container paper	57	Every 20 minutes or Every 60 minutes

Type	Number of devices	Frequency of sending and updating information
Air quality	4	Every 15 minutes
Bicycle flow	2	Every 10 minutes
People flow	4	Every 10 minutes
Traffic	4	Every 1 minute
Weather	7	Every 30 minute
Total	21	

(c) Urban Lab monitoring management

Container plastic	205	Every 20 minutes or Every 60 minutes
Container refuse	277	Every 20 minutes or Every 60 minutes
Total	667	

(d) Garbage Collection management

Type	Number of devices	Frequency of sending and updating information
Parking	513	Every change of status and (always) every 7 hours
Total	513	

(e) Parking Spots management

TABLE II. ESTIMATING DATA TRANSFER VOLUME BY SERVICE IN BARCELONA SMART CITY

Type	Number of devices	Sending data (byte)		
		by each sensor at each transaction	by each sensor per day	Total amount of data per day
Electricity meter	28	22	2,112	59,136
External ambient conditions	7	22	2,112	14,784
Gas meter	1	22	2,112	2,112
Internal ambient conditions	41	22	2,112	86,592
Network analyzer	421	242	23,232	9,780,672
Solar thermal installation	36	22	2,112	76,032
Temperature	7	22	2,112	14,784
Total	541	374	35,904	10,034,112

(a) Energy monitoring management

Type	Number of devices	Sending data (byte)		
		by each sensor at each transaction	by each sensor per day	Total amount of data per day
Air quality	4	144	13,824	55296
Bicycle flow	2	22	3,168	6,336
People flow	4	22	3,168	12,672
Traffic	4	44	63,360	253,440
Weather	7	120	34,560	241,920
Total	21	352	118,080	569664

(c) Urban Lab monitoring management

Type	Number of devices	Sending data (byte)		
		by each sensor at each transaction	by each sensor per day	Total amount of data per day
Noise	3	22	2112	6336
	40	22	31,680	1,267,200
	10	22	31680	316800
Total	53	66	65,472	1,590,336

(b) Noise monitoring management

Type	Number of devices	Sending data (byte)		
		by each sensor at each transaction	by each sensor per day	Total amount of data per day
Container glass	57	50	1,800	102,600
Container organic	71	50	1,800	127,800
Container paper	57	50	1,800	102,600
Container plastic	205	50	1,800	369,000
Container refuse	277	50	1,800	498,600
Total	667	250	9,000	1200600

(d) Garbage Collection management

Type	Number of devices	Sending data (byte)		
		by each sensor at each transaction	by each sensor per day	Total amount of data per day
Parking	513	40	4,000	2,052,000
Total	513	40	4,000	2,052,000

(e) Parking Spots management

TABLE III. DATA VOLUME ESTIMATION IN BARCELONA SMART CITY

Type	Number of devices	Sending data (byte)		
		by each sensor at each transaction	by each sensor per day	Total amount of data per day
Electricity meter	70,717	22	2,112	149,354,304
External ambient conditions	70,717	22	2,112	149,354,304
Gas meter	70,717	22	2,112	149,354,304
Internal ambient conditions	70,717	22	2,112	149,354,304
Network analyzer	70,717	242	23,232	1,642,897,344
Solar thermal installation	70,717	22	2,112	149,354,304
Temperature	70,717	22	2,112	149,354,304
Total	495,019	374	35,904	2,539,023,168

(a) Energy monitoring management

Type	Number of devices	Sending data (byte)		
		by each sensor at each transaction	by each sensor per day	Total amount of data per day
Air quality	40,000	144	13,824	552,960,000
Bicycle flow	40,000	22	3,168	126,720,000
People flow	40,000	22	3,168	126,720,000
Traffic	40,000	44	63,360	2,534,400,000
Weather	40,000	120	34,560	1,382,400,000
Total	200,000	352	118,080	4,723,200,000

(c) Urban Lab monitoring management

Type	Number of devices	Sending data (byte)		
		by each sensor at each transaction	by each sensor per day	Total amount of data per day
Noise	10,000	22	768	7680000
	10,000	22	31,680	316,800,000
	10,000	22	31680	316800000
Total	30,000	66	64,128	641,280,000

(b) Noise monitoring management

Type	Number of devices	Sending data (byte)		
		by each sensor at each transaction	by each sensor per day	Total amount of data per day
Container glass	40,000	50	1,800	72,000,000
Container organic	40,000	50	1,800	72,000,000
Container paper	40,000	50	1,800	72,000,000
Container plastic	40,000	50	1,800	72,000,000
Container refuse	40,000	50	1,800	72,000,000
Total	200,000	250	9,000	360,000,000

(d) Garbage Collection management

Type	Number of devices	Sending data (byte)		
		by each sensor at each transaction	by each sensor per day	Total amount of data per day
Parking	80,000	40	4,000	320,000,000
Total	80,000	40	4,000	320,000,000

(e) Parking Spots management