Smart City Applications TestBed

Towards a service based TestBed for smart cities applications

Danilo Silva, Felipe Ferraz
CESAR – Recife Center for Advanced Studies and Systems
Recife, Brazil
e-mail: {dls, fsf}@cesar.org.br

Felipe Ferraz, Carlos Ferraz
Informatics Center
Federal University of Pernambuco
Recife, Brazil
e-mail: {fsf3, cagf}@cin.ufpe.br

***Abstract*—Cities are facing a new challenge related to their population; it is the first time in history that most part of human population is now living in metropolis. Within this scenario, a city needs to deploy new solutions, presenting systems that answers to demands related to Security, Health, Resources, Government, Education and other urban daily systems to its citizens. In order to keep the creation of such solutions, it is vital to present developers with means to validate their projects. Focusing on this situation, this paper proposes the creation of a configurable testbed, where web services represent different systems of a smart city that could be consumed by applications in order to validate its implementation and features.**

Keywords - Smart City; TestBed; Solutions; Platform;

I. Introduction

With the fast increase of global urban population, cities now face risks in an unprecedented scale. Air pollution, lacking transportation infrastructure, uncertain economic landscapes, violence and unemployment – to name a few of the referred risks- are issues that nowadays can be addressed through the proper use of information and communication technology (ICT) 0

Batty et al. [2] reinforce the notion that technology applied to the concept of smart cities can help building a future in which a city will be interconnected, and relations between citizen and services and services to services will create an environment with innovative possibilities. Dirks et al. [3] stress the importance of software solutions that help society interact more efficiently with essential systems of a city. The "systems" of the city, in the context used by the referred authors, are: water and energy supply, transportation, security and healthcare [4][5].

Despite the fact that smart city applications can help society interact more efficiently with the available systems in the city, a great obstacle faced by developers, when creating new smart city solutions, stem from the difficulty of validating and testing their solutions [6][7]. This paper proposes a solution as an environment that could help on the construction of smart city solutions, with services and a data generator.

This paper is presented as follows: Introduction describes the problem. Section II depicts about smart cities and their concepts; Section III presents differences between TestBed and simulators, also describes related works; Section IV explains the proposed solution; Section V has details of the proposed TestBed platform architecture, and finally; section VI, presents conclusions and future works.

II. Smart Cities

Most concerns around the concept of smart cities arise because cities have become home of more than 50% of the population [3][4][6]. Even more, the cities being the home of the largest part of the population, they are the center of the modern economies [8].

Despite the many challenges that branch from the increase of urban population, the amount of people that now live in big urban centers is still rising [9][10]. In fact, since 2008, for the first time in human history, the bigger part of the global population is now living in big cities [11][13].

In a previous work [5], it was possible to represent a city as an operational center that has a set of main services, which are vital for the city maintenance. Those services are categorized in the following way: Education, Security, Transportation, Energy and Water Supply, Healthcare, Government.

Following the same line of development, a smart city is a representation of a system of systems. Such characteristic is due to the interoperability present in the systems that build the infrastructure and environment of the city. They tend to cooperate in a way that new solutions for the daily urban life are more possible and easier to follow.

III. TestBed

A TestBed is a platform for experimentation of large projects [14]. It allows testing applications with difficulty in accessing inaccessible domains – such as the case with many smart city applications [15]. Since smart city applications depend on city data to operate, this ends up hindering many efforts to create new solutions. Often city data is not readily available, or, when they are available, they are not in a format that is easily consumable by the applications [14]-[16]. The objective of this paper is to create a testbed, represented by different web services that represent city systems that will aid developers to create and test smart city applications in different urban landscapes [14][17].

A. Simulators vs. Testbeds

A simulator represents a special case of testbed. The main difference is that simulators generate data in real time while testbeds do not – in this case, data is pre-loaded in the storage of the solution [7][15].

When a simulator is used as a data generator for a smart city application, the simulator will generate city data during runtime, which has the downside of unpredictability since subsequent tests will yield different results. Using a testbed has the advantage of allowing consistent ability of repeating the tests since the data it provides for the smart city application is not prone to change.

B. Related works

By relating tests environment with smart cities solutions, it is possible to list some projects, such as: SmartGridLab [17], I3ASensorBed [12] and SmartSantander [18]-[22]. The following section presents a brief explanation about some of those solutions:

SmartSantander - is a project emerged after the identification requirement for an experimental Internet of Things (IOT) platform, which occurred during a Real World Internet congress, in 2009 [20]. Based on those requirements, a proposal to create a testbed in Europe emerged. The objective was to support research and experimentation of architectures, technologies, services and applications for IOTs in the context of SmartCities [19].

I3ASESORBED - The purpose of I3ASENSORBED is to create an experimentation testbed for different types of demographics -not only for universities but also for anyone who intends to create applications or to improve communication protocols for Smart Cities [12].

NetworkedCITY– An initiative derived from inside the IAAC –"*Institute for Advanced Architeture of Catalonia*" that combines physical computation, data visualization, and real time computing through interoperable devices, applications and models [23].

LOG-a-TEC – Conceived in JoJožef Stefan Institute in Slovenia, the initiative is an IOT testbed for small cities in Europe. Based on wireless sensor technology, its focus is in infrastructure of energy management and services [24].

Testbed for smart technologies in London – Intel, along with Imperial College London and London College, with the intent of promoting sustainable and connected cities, started an initiative that would turn London into a testbed for smart technologies [25].

IV. PROPOSED SOLUTION

The result of this work is a Smart City Testbed. A solution composed by two main components, an API set and a data generator.

The API set is composed of systems commonly found on the environment of the cities. On the following list, we detail the main objective of each of those systems [5].

Education: It is composed by services responsible for managing classes, grades and available courses [3][18] those services can help citizens and the government deploy or pay more attention to specific areas of expertise.

Healthcare: Is composed by units of treatment, Medical History of the patients with focus in providing a unique point of medical registers and hospitals specialties [4][10].

Transportation: Promotes improvements in mobility in the urban environment. This system receives great attention in vehicle traffic research [7], and proposes mechanisms related to Traffic Light control and Traffic management.

Government: Allows more transparency in the way the City is managed, for example, how tax money is spent by its politics [11].

Resources: Provides a way that enables to control the expenses of the city resources, such as water and energy [17].

Security: Related to public safety issues such as reporting crime and tracking violent areas [16].

To choose and define the mentioned types, we followed the approach proposed in a previous work [5], and back on this proposal, we summarized the most common types of solutions for smart cities. In addition, to determine the main goal of each system on this paper, we summarized some expectations and comments of related works.

Finally, Table I presents a compilation of the systems mentioned before along with different areas and testbed Services.

TABLE I. TYPES OF SYSTEMS AND LIST OF SERVICES

System Type	Area/Focus	Testbed Services
Education	Unified Grades	Register Grades
		View School Record
		Register Absent Days
	Courses	Register Courses
		View Courses
Healthcare	Medical Records	New Entry
		View Medical History of the Patient
		Assess Service
	Hospitals	Add Hospital
		Search for special treatment units
		Rate Hospital
Transportation	Control Traffic Lights	Open/Close Traffic Lights
		Detect malfunctioning of Traffic Lights
	Traffic control	Inform Traffic Jams
		View Traffic
Government	Taxes	Add Expenses
		View Expense History
	Registering of Occurrences	Report Occurrence
		Check Occurrence
Resources	Consumption	Register Consumption
		Consumption per Individual
		Consumption per Region
	Interruption of Service	Turn Service Off/On
Security	Register Occurrences of Crime	Report Crime Occurrence
		View History of Crime Occurrences
	Violence level per Area	Add new Area
		Areas by Crime Occurrence
		Assign Police to Area

The model created for the testbed respects three different levels, the first one, already presented, is represented by systems; each system is divided accordingly to sub areas or focus groups. The area represents level two, where one can find some specific solutions. For instance, Educational System presents unified Grades and Available courses. Lastly, layer three presents services built in each area, for example, Educational System, which has a unified grade solution, that offers services related to: Register Grades, View School records, and register absent days.

V. ARCHITECTURE

In this section, the testbed architecture will be described with more details. In addition, the components that were used as well as the reason for their adoption will be explained.

A. *Application server*

Jetty [26] is the application server chosen because it presents the advantage of being easy to set and integrate in Eclipse IDE. Another advantage is the fact that it is possible to embed Jetty inside of the application (inside of a main class, opposed as being packaged in a .war file). The main class is responsible for initializing the application server and exporting RESTful endpoints (created using JAX-RS of Apache CXF project).

B. *Persistence Layer*

On the persistence layer, the Java Persistence API (JPA) [27] implemented by Hibernate ORM [28] was used. HSQLSDB [29] is the database management system used for the solution, it is the selected option because it allows memory execution along with our solution, creating a fast and flexible solution. It presents downsides related to its simplest implementation, however, it is possible to change the persistence layer and DataBase by changing a specific layer.

However, the manual utilization of the persistence framework generates a repetition of the code, which is potentially dangerous due to the lack of appropriate persistence session management and JDBC transactions (Java's database connectivity API).

To overcome this code generation issue, we adopted the Spring framework [30] due to its dependency injection, persistence session management and JDBC transactions. By using Spring it was possible to minimize the code generation, speed up the development, reduce the amount of errors, and raise the overall quality of the solution.

C. *Architecture Overview*

The way each individual component communicates with one another is depicted in Figure 1. As it can be seen, the proposed solution follows the 4+1 architecture [31] of Philippe Kruchten.

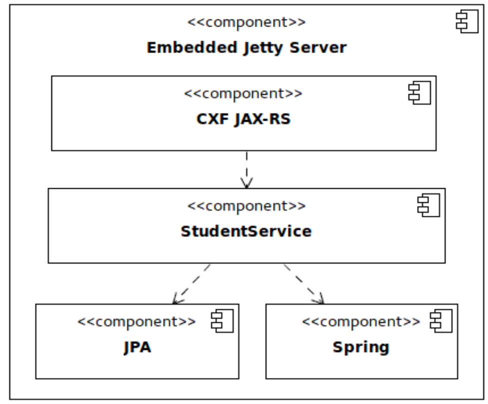

Figure 1. Architectural components

D. *Generation of Data*

As briefly discussed in this section, a mechanism to generate data was created. This mechanism allows the creation of various scenarios based on input parameters.

The parameters that the data generator accepts are the following:

- **City spot** - latitude and longitude: those values serve as a reference to geographical locations of the city.
- **City size:** values 1, 2, and 3 define, respectively, small, medium, and large cities. This parameter is used with the city spot to determine the size of the radius, which helps determining if a spot is part of the city.
- **Amount of inhabitants**: works as a parameter to determine how many inhabitants the city possesses.
- **Amount of accesses per inhabitant of urban systems:** a number that defines the amount of accesses that each system receives by the citizens of the city.
- **System rank index**: the system (Resources, Security, Education, Healthcare, etc.) receives values from 1 to 5 that ranks them from most to least accessed.

Table II serves as an example of input values, passed to the generator in order to create a base scenario.

TABLE II. VALUES USED TO CREATE A BASE SCENARIO

Latitude and Longitude	52,15 and 0,18
City size	1
Inhabitants	100
Amount of accesses	100
Resources, Security, Education, Healthcare, Transportation, and Government	1,2,3,1,2,3

In an early round of tests, Table II represents a city with a central point near Cambridge, and its inhabitants will perform 10.000 daily accesses to the services API.

To know how many accesses will be performed, one can sum up the "system rank" indexes of the systems. In the example previously presented, the result of the sum of indexes is 12. It means that, for instance, the Resources

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system will be responsible for 1/12 of the total amount of accesses, whereas Government will be responsible for 3/12.

Table III represents the total amount of accesses received by each service.

TABLE III. AMOUNT OF SIMULATED ACCESSES BY SYSTEM TYPE

Resources	834
Security	1.667
Education	2.500
Healthcare	834
Transportation	1.667
Government	2.500
Total	10.002

The creation of a data generator able to create realistic data was not the focus of this work. Because of that, it is likely to have a scenario where a student enrolls in two classes (courses) that happen at the same time. Likewise, it is possible to report crimes in the middle of the ocean.

VI. CONCLUSION

Based on research pertaining testbeds and smart cities, it is possible to notice that there is a great demand for testing smart city solutions, and that most of the existing testing strategies are based on the use of sensors and IOTs.

The advantage of the proposed solution is the possibility to create testing scenarios where validation of ideas and solutions for smart cities can be performed without having to rely on sensors and IOTs.

As future works from this research, it is intended to improve the data generator creating realistic scenarios and to develop a feature that enables the re-execution of previously created scenarios.

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