# Smart ITS Sensor for the transportation Planning using the IoT and Bigdata approaches to produce ITS cloud services

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*Abstract*— **Currently, there exist a lot of challenges in the transportation scope that researcher are trying to resolve and one of them can be focused on transportation planning. The main contribution of this paper was the design and implementation of an ITS smart sensor prototype that incorporates and combine the Internet of Things (IoT) and Bigdata approaches in order to produce ITS cloud services for helping transportation planning for Bus Rapid Transit (BRT) systems. The ITS smart sensor prototype is capable of detecting several Bluetooth signals belonging to several devices (for instance from mobile phones) that people uses into the BRT (for instance, in Bogota city) system. As from that information, the ITS smart sensor prototype can create the O/D (origin/Destiny) Matrix for several BRT routes and this information can be used by the Administrator Authorities (AA) in order to produce a suitable transportation planning for the BRT systems. In addition, that information can be used by AA as from cloud services.**

***Keywords-, Traffic sensor, IoT, BigData, SOA, Web Services, NoSQL.***

## I. INTRODUCTION

Intelligent Transportation Systems (ITS) based solutions influence strongly the traffic and transportation in cities or countries. For this reason, the governments and public authorities invest resources in several initiatives, for promoting and organizing the ITS infrastructure [2]. As a result, public policy makers, transport planners, traffic engineers, research institutes and the private sector, tends to develop or use new technology approaches that support several ITS services in order to lessen the energy consumption, congestion, and money required to build new transportation infrastructure, among others [9].

A significant area in transportation sector is the mobility for instance, the urban areas are facing important challenges in terms of diagnose, planning and control. In light of this, the availability of traffic information plays a key role in different processes such as preventing or handling traffic jams or calculating: average travel time, fuel consumption and air pollution, among others. As regard of this, there are several kinds of hardware devices for traffic monitoring, such as inductive loops, video cameras, ultrasonic sensors, etc. However, most existing devices are expensive and sometimes bigger in terms of hardware, therefore its installation and maintenance tends to be limited [3]. In light of this, technology evolution from last years has driven to introduce innovating solutions such as embedded technologies, which are producing a revolution in the computing systems [2]. Embedded technologies provide benefits, including reduction in: cost, power consumption and size, along with that, flexibility and ease of install increases. These benefits contribute to place devices and deploy systems on a large scale, throughout the traffic system, thus, provide ubiquitous coverage.

These technologies are increasingly being joined together into an Internet of Things (IoT). IoT approach regards to an infrastructure of interconnected objects, people, systems and information resources together with intelligent services to allow them to process information of the physical and the virtual world and react [22]. The IoT creates an intelligent and invisible network that have several facilities, for instance, monitor several phenomena, control several devices and program tasks, all of this, through IoT-enabled products based on embedded technology approaches. The IoT-enable products allow generate a scenario where can communicate, directly or indirectly, among them or with Internet [23]

ITS and the technology are evolving constantly, in recent times. Conventional technology-driven ITS have been morphing into data-driven ITS [12], which taking advantage of the availability of vast amounts of data can offer new kind of services [10],[13],[14],[15]. Furthermore, there are a global ITS working group belong to ISO TC 204 (International technical committee for ITS) which regulates and specifies the use of different applications and databases for exchanging data among different systems [6] [11].

On the other hand, in a previous research [1], we design and implemented a system that produced the automatic-construction of Origin/Destination matrix, however to achieve that, we use several ITS sensors from several brands to gather the information. These ITS sensors were not based on IoT platforms, BigData approaches and neither in cloud ITS services. After this research, we focused our efforts in the

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development a system that takes advantage of BigData approach [6], however, this in not focused on IoT platforms and neither cloud ITS services. It is worth noting that, the main problem that this paper want to resolve is focused on the transportation planning for BRT (Bus Rapid Transit) systems as from the automatic-construction of O/D matrix using Bluetooth signals presents in the BRT stations. The novelty of this new paper is focused on the design and implementation of an ITS smart sensor prototype that involves an IoT platform, BigData approaches to produce ITS cloud services that can be used for the administration authorities to the planning transportation of the cities that uses BRT systems.

The remaining of this paper is organized as follows. Section II Illustrates the context which the proposed device is involved in. Section III proposes the new IoT device and cloud based platform design and their architecture; here the paper describes each development level of the sensor and the platform architecture. Section IV and V focuses respectively on the applications, deployments, related implementations, and a case study alongside several tests based on automatic generation of O/D matrix. Finally, Section VI describes conclusions and Section VII acknowledgements.

## II. CONTEXTUALIZATION AND RELATED WORK

Currently, big cities as Bogota in Colombia, face major challenges in the field of transportation and mobility, those include, traffic planning and management, which is very important for sustainable development of public transport in a country. In this area, ITS comes into play, offering several technological approaches.

There are a variety of solutions focused on public transportation; however, this research focuses on traffic planning for bus rapid transit systems (BRT). In Colombia, have been implemented several BRT, such as MIO in Cali city, Metrolínea in Bucaramanga, or Transmilenio in the capital city. Each BRT implementation should be developed as an integrated system with certain key attributes [20], these attributes highlight the importance of good transportation planning.

Currently, there are several developments that focus on transportation planning; in fact, the Origin/Destination matrix tool is a widely used procedure for traffic planning, in this way there are a solution for its automatic generation [20], this one is based on Bluetooth technology, and follow the Service Oriented Architecture (SOA) paradigm implementing a web service platform. Based on this solution, then, this implementation [6], purposes the NoSQL approach in regard to handle vast amounts of data produced by Bluetooth sensors.

In the other hand, the last few years have seen the emergence of new approaches and technologies and approaches that potentially have great impacts on ITS. One of these approaches is IoT, in fact in accordance with ISO/JTC the IoT deployment and its capabilities is focused on several sectors such as: healthcare, Information and Communications Technologies (ICT), Manufacturing and heavy industry, Finance and banking, Food and Farming, Transportation, Domestic, Water, Education, Energy, Entertainment and sports, Public Safety and Military, Retail and Hospitality, and Government [22]. In fact, actually, several projects which aim to solve transportation affairs using the IoT approach, such as monitoring highways [23].

As regard of this, there are a lot of new technologies, advanced approaches that can be used on the delivery of ITS services and these can produce solutions for the planning transportation focused on BRT systems

## III. PROPOSAL

### A. *Description.*

In light of this, our proposal step on the approaches used to generate the O/D matrix in previous researches and puts them together to be deployed, based on a new Cloud and IoT architecture. Our system, takes advantage of its versatility, low cost and fast deployment, it means that a single cheap device, can fulfill four main tasks: Gather Bluetooth signals, filter and store gathered data, and make it accessible throughout standard interfaces to other devices and components, in order to the construction of O/D matrix. With our purpose, we can give, a reduced cost, high scalable, reliable and fast-deployment platform, which is a great solution for supporting the traffic organization and planning in massive transportation systems.

In our proposal, we make use of IoT devices, for designing and implementing a new novelty ITS sensor that is focused on gathering and processing data in order to the generation of O/D matrix, using Bluetooth technology. As said before, this proposal builds on previous study [20], moreover, this paper use the same business logic (see figure 3), but replace almost all components to use IoT enabled devices, and put the system in a cloud platform. Following system operation is detailed.

The system has several devices that capture Bluetooth signals, use algorithms for filtering these signals, then, store this data in an embedded database, at a customizable interval, this data is submitted to a NoSQL database located on a Cloud Platform provider, (see figure 1), to then be processed and become accessible to the clients, application servers, and external components through standard interfaces such as web services. As a Cloud Platform Provider, we decided to use Firebase[24] which provides real-time features and can be connected to different clients, applications, mobile, and web. After that, processing applications which run over a cloud infrastructure use the data provided by the sensors to generate the O/D matrix automatically.

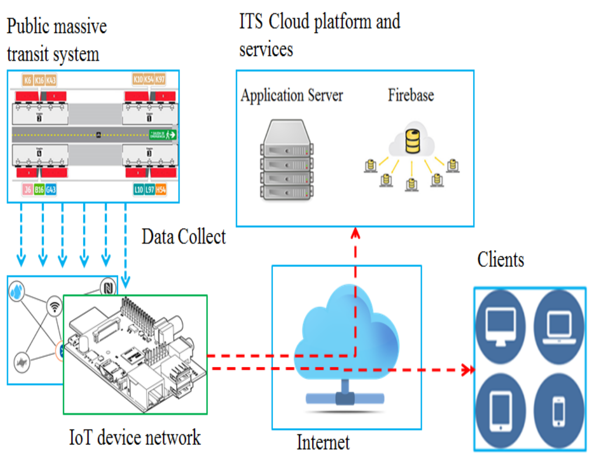


**Figure 1.** IoT System integration

### B. System Architecture

The systems design is component based, which gives loose coupling between each other, and high consistency. The system we improve is made up of four as described in [20]: uptake signal, device classification and acceptance, device comparison and O/D matrix construction. (See Figure 2).

As mentioned above, the system designed previously has four subsystems. The first subsystem is focused in capturing Bluetooth signals. The second subsystem analyzes filter data captured and decides which ones will be accepted to be processed. The third eliminates duplicate records in a time range, and the last subsystem gives the results of an O/D matrix from a specific date and time. This system implements a web services platform, and is component based.

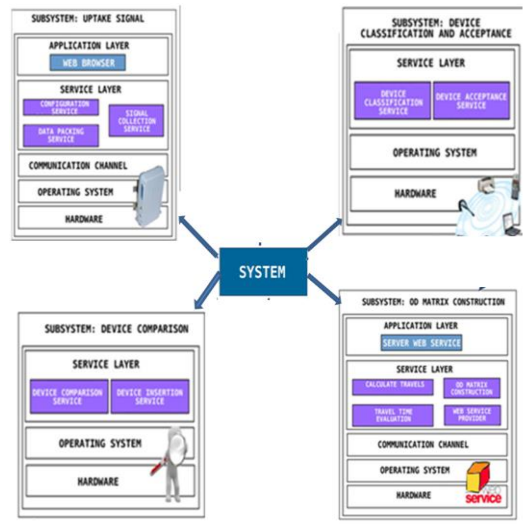


**Figure 2.** Previous architecture

Thus, this paper redesigns this architecture, merging capture, classification and acceptance, subsystems into a unique subsystem running over an IoT enabled device, even providing local storage. It means, now the platform is composed of two subsystems, plus the systems clients (See Figure 3). The first one, denominated sensor subsystem, responsible of capturing, analyze, filter and store Bluetooth signals and records, additionally this subsystems provides interfaces of configuration and administration. Second subsystem, is composed by several components described as follows:

1. *Firebase:* Collects and stores the information prevenient from the first system.
2. *Backend Apps:* Runs analysis and generation tasks for O/D Matrix. Also provide standard application interfaces, to allow the system clients to connect and retrieve data.
3. *Device Management Tools:* Set of tools used to admin, and monitoring deployed devices.

We selected the Google Cloud Platform, including Firebase [24], moreover, it's important to highlight, this architecture is easily replicable at least in the major cloud providers such Amazon Web Services[25] and Microsoft Azure [26] or even step on their IoT solution suites.[27][28].
As we mentioned before, our proposal follows the SOA paradigm, therefore the system platform uses Web services technology to integrate subsystems, in this way we follow the REST (Representational State Transfer) architectural principles to provide simple and intuitive interfaces to access to the resources located in the sensor and also for connecting with systems clients. We used the IoT ready device Raspberry Pi [21] for implementing the sensor device, this product provides enough performance and characteristics for carrying our implementation in

addition it's cheap and small.

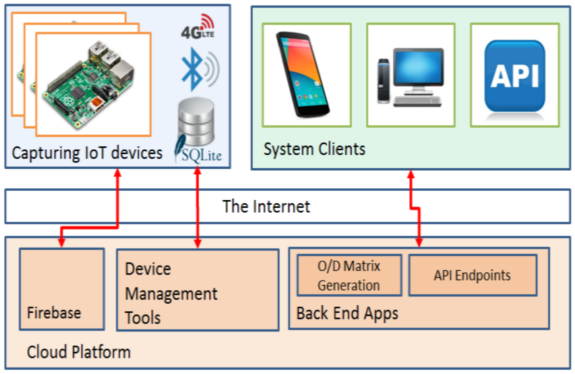


**Figure 3.** Proposed architecture

## C. *Capture Device.*

The development of an IoT capture device is the major novelty in our proposal; it is composed by several technologic bricks which supports the functionalities of sensor subsystem mentioned above. This device integrates an embedded web server, database and Bluetooth signal sniffer.

### 1. *Hardware.*

The hardware mainly consists in two components: A single board IoT device and a Bluetooth signals sniffer. We used the embedded computer Raspberry Pi [21] for implementing the sensor device, this product provides enough performance and characteristics for carrying our implementation in addition it's cheap and small.

| Characteristic | Value |
|---|---|
| CPU | 700 MHz ARM |
| GPU | Dual core VC. IV |
| Memory | 512 MB SDRAM |
| USB | 2.0 |
| OS | Linux, Android, Firefox |
| Dimensions | 86.0mmx54.0 mm |
| Ethernet | 10/100 RJ45 |
| Cost ($USD) | 35 |

**Table 2.**Raspberry Pi specs

Previous table describes the main specifications for the first generation of the raspberry pi, (currently on 3rd generation) which was used in our project.

**Figure 4.** Raspberry Pi aspect

There are several IoT enabled devices available in the market, for this reason we realized a comparison before selecting Raspberry Pi. In this case we measured and compared characteristics: performance, amount of memory, community support and cost, among others. As a result we synthesize those values in the following table.

| Device | Price (USD) | CPU (Mhz) | RAM (MB) | Max Storage (GB) |
|---|---|---|---|---|
| Raspberry Pi | 35 | 700 | 512 | 64 |
| Beagle Board | 55 | 1024 | 512 | 4 |
| PandaBoard | 174 | 1024 | 2014 | 32 |
| Intel Galileo | 70 | 400 | 256 | 32 |

**Table 3.** IoT devices comparison

### 2. *Device architecture*

We designed and implemented architecture to achieve the functionalities proposed for the capture IoT devices (see Figure 3), the IoT device architecture has different layers, described as follow (See Figure 5): In the top layer are web services interface to facilitate the access to the sensor functionalities, this interfaces also provide management options, in order to set up the sensor. Lower, we developed different scripts which interact with the interfaces provided by the operative system to access Bluetooth resources, that interfaces allow manage Bluetooth adapter, perform Bluetooth inquiry and retrieve signals captured, among others (hcid). These scripts are event driven; it means once the data is captured by the Bluetooth interface, the scripts perform the actions to automatically store that data in the local (Sqlite) database. Then, every 5 minutes, the same set of scripts, collect the data stored previously, and perform the routine to submit it to Firebase, located in the ITS Cloud Platform.

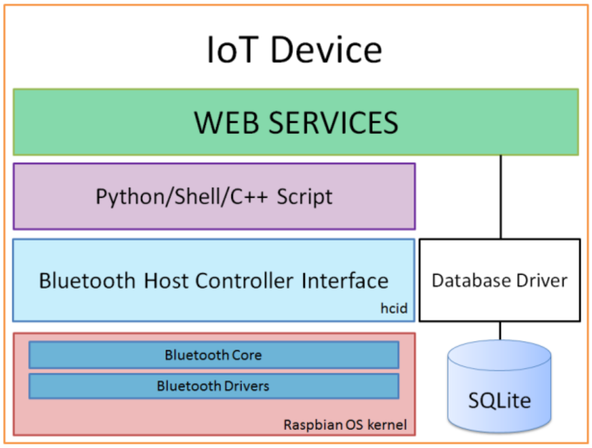


**Figure 5.** Capture device architecture

## IV. APPLICATIONS.

In order to achieve our goal, two applications where developed. The first one is a web based application (Figure 6) that offers a user interface for the traffic center or administrators, it allows to retrieve the current configuration of each sensor device and edit them as well; it allows saving its characteristics, even its location in the map.

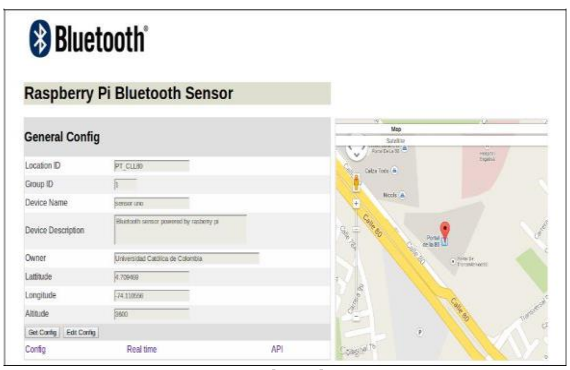


**Figure 6.** Web application sensor set up

Another functionality of this web application, allows scan for Bluetooth devices in the range of the device, given a set of parameters such as inquiry time or decide if save on database. (Figure 7)


**Figure 7.** Web application Bluetooth scan

The second one is a mobile application for the Android platform; this application allows the users from the transit authority consulting the O/D matrix for two points in a range of time. It also proves the correctness of the Backend Apps and its API end points (See Figure 3)

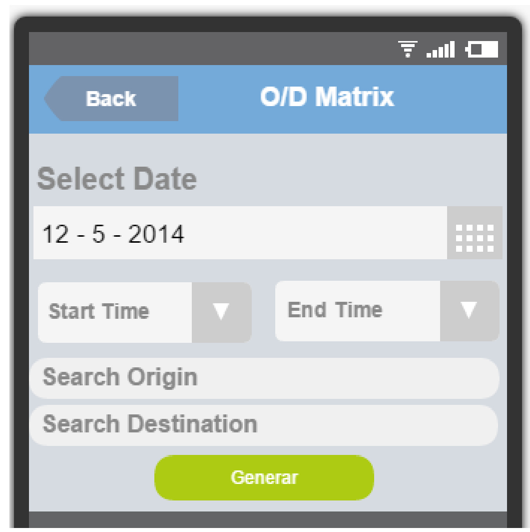


**Figure 8.** Mobile application

## V. CASE STUDY.

To our case study, we used the capture device developed, and several devices equipped with Bluetooth technology (Table 3). We put the sensor device to scan several times, in order to filter and store records multiple times.

| Device class | Local name | MAC Address |
|---|---|---|
| Laptop | User-hp | E0:2A:82:97:44:85 |
| Smartphone | Nokia Lumia 800 | 0C:C6:6A:54:C4:D7 |
| PC/PDA | My iPad | 84:29:99:63:08:5E |
| Smartphone | HTC evo | 18:87:96:C2:D5:5A |
| Smartphone | GT-S5830 | D4:87:D8:38:5F:00 |
| Wearable headset | 222 Plantronics | 00:19:7F:CB:AD:07 |
| PC | Julian-PC | 00:02:72:DA:2C:AD |

**Table 4.**Devices equipped with Bluetooth

After all devices captured were stored, we made a test to evaluate the response time of web services implemented in the Raspberry Pi (figure 10). The Webservice consulted, retrieve all records stored in the local database of embedded system. With this test we observed that our proposed capturing device can handle over thousand requests, with hundred level of concurrency without drop of performance. Furthermore in this test, the proposed device, handled 100% of requests.

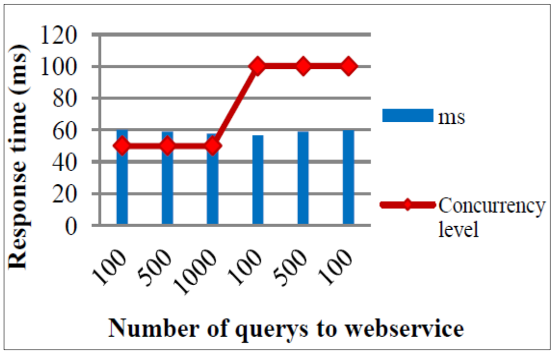


**Figure 9.** Query test

In this case study we also tested the cloud schema proposed, and how it would respond to hundreds of IoT devices sending their data to the cloud concurrently. To achieve this, we used the Apache JMeter Tool [29], to perform many HTTP requests to the API endpoints from the NoSQL database.

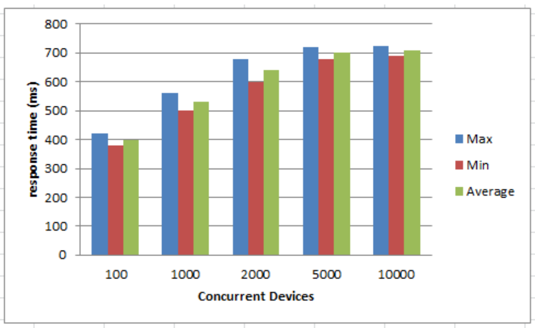


**Figure 10.** Cloud schema load test

In previous figure we can notice how response time tends to grow until stabilize, its due to cloud self-scaling response to high demand or resources. It's important to highlight that this request performs write operations that are substantively slower.

## VI. CONCLUSIONS

This paper proposed a new Internet of Things implementation for capturing data for an ITS solution. The proposed model follows SOA, which is successful paradigm for integrating systems, implements, and the NoSQL approach, which helps to handle vast amounts of data; and integrates them into IoT enabled devices that are a revolutionary trend in the intelligent transportation field.

The proposed devices offer benefits, to the previous innovating system proposed, because one single and cheap device can accomplish tasks were meant to be performed by several devices, as computers, servers and sensors.

Moreover the proposed device helps in the fast deploy of ITS solutions, reduce cost, and increase reliability, due to versatility, flexibility and easy access of the internet of things approach.


## VII. ACKNOWLEDGEMENTS.

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