Develop of Mobility Services based on Intelligent Transport System (ITS) Architecture for an Intermediate City using Internet of Things (IoT)

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Abstract

Intermediate cities in most developing countries have problems with traffic and vial security. Mayors' offices of these cities developed technological services in mobility to try to solve these problems, within the framework of the ITS. However, these services have not developed using an adequate ITS architecture, therefore, there are major drawbacks in the integration of services, due to the technical complexity and high associated costs. To improve proper development of mobility services, we developed a process based on ITS architecture. To formulate process, we developed a methodology with which the entities in charge in the city will be able to design an ITS architecture suitable for their city. We also identify the appropriate steps for the design and development of ITS services from architecture designed using enabling technologies such as the Internet of Things (IoT), for which we use a case study with a Colombian city. This article presents a summary of proposed process. The main result obtained was a process that serves as a tool for the development of these services. Next work will be evaluate if the process is adequate, through implementation of the services developed and evaluation of results.

Keywords: Intelligent Transport System, Internet of Things, mobility services.

1. Introduction

Colombia has great problems in the number of traffic accidents and people deceased in this type of accidents, identifying an incremental trend in last 10 years. Analysis of data shows that death rate (for this cause) is the highest in the last decade, reaching 14.28 per 100,000 inhabitants in 2015 [Var15].

The average rate of death by traffic accidents in Colombian intermediate cities is almost 50% higher than in large cities. In four of the main cities: *Bogotá*, *Medellín*, *Cali* and *Bucaramanga*, the average death rates are 18.65 in men and 4.58 in women. While in eight intermediate cities: *Pasto*, *Popayán*, *Ibagué*, *Cúcuta*, *Armenia*, *Pereira*, *Santa Marta and Neiva*, the averages are 26.86 in men and 6.87 in women [Var15].

In addition to loss of human lives caused by traffic accidents, there are other problems related to mobility in cities such as traffic congestion. The traffic congestion in cities around the world is measured by institutions as Tom Tom Traffic Index [Tom17] (which does not present information of Colombian cities) and Inrix Global Traffic Score Card [Inr18].

Inrix [Inr18] has a ranking that depends on the number of hours that travelers spend on congestion. *Bogotá*, capital of Colombia, is located in sixth position with 75 annual hours. Intermediate Colombian cities included in report have values between 45 and 27 hours.

Looking for a solution to these problems, the mayor's offices have developed mobility services within the ITS framework. An ITS uses technologies such as computers, telecommunications, positioning, and automation to improve the safety, management, and efficiency of transportation systems [ITU11].

These mobility developed services, in very few cases have been developed based on ITS architectures. When mobility services in a city are developing without an ITS architecture, it is very possible that its infrastructure and/or functionality is not properly integrated.

To improve development of mobility services, we formulated a process to develop mobility services based on an appropriate ITS architecture. Initially we developed a design methodology of ITS architecture for intermediate cities in developing countries. Then, we applied the methodology to design ITS architecture for a particular city (*Popayán*, Colombian intermediate city). Subsequently, we evaluated the appropriate enabling technologies to implement ITS architecture

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services, determining that IoT was the most appropriate technology. Next, using an IoT platform design methodology, we developed a mobility service for "Public transport vehicle tracking". Finally, collecting the steps taken and identifying best practices, we determined service development process.

This article presents a summary of process to develop these mobility services. The following sections present the related works, methods, results obtained and finally, conclusions and future work. This document does not present details on development of the service performed. Nor does it present information on the implementation of the service, which is outside of the scope.

2. Related Works

Works over development of mobility services related to ITS and implemented with IoT were reviewed, focusing in developments with use of a ITS architecture.

FOTsis project objective was test the capacity of road infrastructure to incorporate latest technology of cooperative system in nine test sites in four countries, providing a set of seven services focused on traffic safety and improvement of the efficiency [Kur13].

Although in FOTsis project [Kur13] an ITS architecture is presented focused on seven services that are evaluated in the project, a general ITS architecture is not presented. In addition, the context of this project is very different from the context in this paper.

Theme of other proposed project is to develop a prototype for ITS, which is useful to track a public service vehicle through GPS, receive payment of tickets, analyze crowds within said bus and finally, measure the environment inside the bus [Boj14].

Another ITS development is presented in an intelligent parking system, based on IoT [Raj17].

INTEL proposes the construction of an ITS, with the use of IoT [Int14], Proposed architecture has three main layers: sensing, communication and service.

In last three presented works some ITS proposals based on enabling technology are presented, however, none of them is based on an ITS architecture. In addition, proposals (except [Int14]) are focused on solving a specific mobility problem, these do not present a proposal that can be applied to any mobility domain.

3. Methods

We built a process to develop mobility services in intermediate cities, making the next five tasks.

In the initial task, design methodology of ITS architecture, we did some activities such as: study of the most representative reference ITS architectures (American [Nat18], European [Eur18] and Colombian [Con10]), analyze environment of the city through the PESTLE tool [Bus16] and study of methodologies for development of a regional ITS architecture.

Once the aforementioned methodology was developed, we applied it (as a second task) to design of ITS architecture for the city of *Popayán*, following the four stages that were determined in methodology.

For design of mobility services based on ITS architecture developed, we proceeded (in the third task) to identify the most appropriate enabling technologies for the implementation of ITS. We determined that IoT was the best option, because, in a large number of ITS services it is required to collect information from devices (located on roads or in vehicles that transit them) and send them to a centralized storage using some type of communication (normally Internet), in which IoT technology is currently ideal. In addition, recent ITS implementation projects use it with very good results.

Once IoT was selected, we proceeded to validate whether IoT architecture that we proposed fit well for the ITS architecture, obtaining good results.

In the four task, we selected two services for develop, considering limitations of time and resources of research. The services were selected from 35 services identified for ITS designed architecture for the city, taking into account the next aspects: relationship with traffic, utility of the service, and complexity.

The first service selected “public transport vehicle tracking” will allow control of speed of these vehicles, in an attempt to minimize the number of accidents of these vehicles. The second service “traffic measuring" will allow provide users and drivers with valuable information so that they can make efficient travels and they avoid increasing traffic at a certain crossroad.

Once two services were selected, we developed the first one. To develop service, we searched a designed methodology for the development of services in IoT platforms. We determined that proposal presented by Bahga and Madisseti [Bah14] was a good option.

Finally, in the last task (task 5), we did the service development process, collecting the steps taken and identifying best practices.

4. Results

The results of research were: methodology that we formulated for the design of ITS architecture, ITS

architecture that we designed applying methodology for the city, detailed description of ITS mobility services selected to develop, and the development of one service using an enabling technology for ITS as it is IoT.

The first partial result of research was our methodology for the design of ITS architecture for an intermediate city. Methodology that we proposed considers the following four stages: review of the reference ITS architecture, analysis of the city context, determination of architecture components, and designing of ITS architecture views.

The general ITS architecture that we designed for the city was the second result. ITS reference architecture that we selected for ITS architecture of the city was the American architecture, called ARC-IT. For determination of the reference ITS architecture, a comparison was made between ARC-IT, FRAME, and others. Sixteen services areas were considered with respect to five ITS architectures. The architecture with largest number of covered areas was the American. After reviewing documentation of the architectures and the context of the city, it was confirmed that the more suitable architecture was ARC-IT, adding two services taken from other international architectures as a complement. Based on the reference ITS architecture, we designed the basic views of ITS architecture (physical and logical). In addition to these views, we defined stakeholders, needs and selected services.

Specific ITS architecture of each of selected services developed was another result. This architectures allow development of services in a better way.

The last relevant result was the development of one of services selected, using the IoT implementation methodology proposed by Bahga and Madisseti [Bah14]. We developed the "Public transport vehicle tracking" service, doing each of the steps recommended.

5. Conclusions and future work in research

ARC-IT was the reference architecture selected in the design of the ITS architecture for the city of *Popayán*. We considered this reference architecture is quite complete and adapts better (than the rest of the reference architectures evaluated) to the context of *Popayán.*

When a city has an ITS architecture designed particularly for its case, selection of mobility services for its development is much simpler, identifying services with great possibilities for improvement.

Future work for next research projects will be implement in the city the operation of the service developed (through small and controlled pilot) and other similar services that are developed, in order to measure if these effectively improve the mobility of the city.

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