# RFID framework for intelligent traffic monitoring.

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## ABSTRACT

Nowadays the transportation systems show new challenges in management and supervision issues due to amount of vehicles and the variability and extension of the roads . New technologies have been developed to get information about traffic in cities. Nevertheless, new frameworks with different technologies applied to traffic monitoring have not been well defined.

In this paper, a new framework with Radio Frequency Identification technology (RFID) applied to road traffic monitoring is exposed. In order to validate the designed framework, an experiment in a university campus was carried out, concluding the effectiveness of the RFID technology for traffic monitoring.

## Keywords

Intelligent Transportation Systems, RFID, Radio Frequency Identification.

## 1. INTRODUCTION

One of the main problems in cities around the world is road traffic. There are differents techniques to monitor and control traffic based on differents technologies such as image processing [1, 2], magnetic detectors [3], infrared detectors [4], global positioning system (GPS) [5], and Radio Frequency IDentification [6, 7]. The radio frequency identification system (RFID) technology is a low cost and efficient alternative to monitor inventory and other mobile things. For these reasons, RFID technology is an option to consider in the intelligent monitoring traffic systems design. RFID technology can be applied to monitor road network traffic by sensing the presence and speed of tags attached to vehicles. This information is stored and can be processed in order to determine the way the traffic should be managed and take decisions in real time. Nevertheless, there is a problem regarding the definition of requirements and hardware architecture of a platform or framework that can be used for road traffic monitoring.

This paper shows the design of a framework applied to the traffic monitoring that integrates RFID technology and guarantees the accomplishment of requirements such as data exchange support, data interpretation support, scalability, data filtering, reliability, and easy configuration. In the same way, technology validation issues are shown, in order to perform an effective solution to the problem. The proposed framework was validated by an experiment to monitor traffic at entries and exits of the university using RFID. Results showed that the proposed framework is effective to integrate technologies applied to the road traffic monitoring platforms.

## 2. ITS AND RFID FRAMEWORKS.

Intelligent Transportation Systems (ITS) are primary systems in the implementation of smart cities; in turn they are for the social and economical progress in cities around the world [8]. ITS provide tools based on technology in order to solve some problems, such as traffic congestion.

An ITS architecture can be divided in three parts: convergence and traffic measurement, application supports, and transport management. The convergence and traffic measurement is related to the way some variables can be measured and collected in order to get an idea about traffic in any moment in any city. The application supports are related to the processing and visualization of information, and the transport management is a set of applications for making of decisions to manage traffic in the cities.

In recent years, many authors such as Zongwei [9], Zhiyang



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[10], Bhaska [3] have experimented with different technologies in order to improve the sensing and collecting process of information concering the traffic in cities. These technologies involve RFID, mobile network location, and Bluetooth and loops respectively. Authors as Jian [11] and Jing [12] proposes frameworks to define the design and implementation of systems applied to the traffic monitoring with any of these technologies; nevertheless, the definition about RFID systems in this area is limited. In the last years, the definition of RFID platforms applied to solve some industrial problems has been an interest topic. In pharmaceutical industry, for example, related works include investigating the complete manufacturing process of drugs to involve the RFID technology to increase the security and performance [13]. Other authors propose frameworks to apply RFID in other processes such as e-health and hospitals to determine its viability. In general, it can be identified that any RFID framework.

These frameworks can be divided in three parts [14]:

- Data acquisition: This is done through of set of tag-reader, readers placed on road's sides capture the Electronic Product Code (EPC) or data that is in tag memory.
- Data management: Data management can be done with an embedded system, that filters, organizes, and sends the information to services and applications that require those information.
- Organizational management: It corresponds to services that develop a specific aplication (Transportation, Education, Health, etc). These services generally are on the cloud or a server, which has communication with the readers to send and receive information of the tags.

Other works are focused on defining frameworks to apply faster and efficiently RFID systems in different areas [15], on analyzing its security [16], or on improving other manufacturing processes [17, 18]. Amaral defines a framework proposing some conditions that a RFID platform should accomplish [19, 20] in order to be applied to transportation, education, health care, and logistics areas. Those restrictions involve interoperability, security, scalability, extensibility, data processing, and others, applied to different areas.

Chattara et al. [21] presents RFID as an alternative to traffic monitoring in road intersections, increasing security and preventing possible traffic accidents. Although the authors in [21] do not go deeply in the framework description, they present the technical and operating conditions to perform this kind of applications.

Kim et al. [22] presents the network requirements to use RFID in traffic monitoring. This work shows some network and RFID recommendations, such as active tags operating at 2.45GHz. In the same way, Kim et al. differentiate three main subsystems in traffic monitoring applications: a hardware-software subsystem for reading and pre-processing tags, a transmitting and storing subsystem in a remote server, and an application subsystem to make decisions. These subsystems are close to the architecture proposed by Fosso [14].

It is clear that the presented platforms are applied to different areas, such as health, manufacturing processes, traffic monitoring or logistics, but they do not present real experiments neither define the main requirements for using RFID technology in each application.

In the next sections we present a *framework* and its requirements based on RFID technology applied to traffic monitoring in Intelligent Transportation Systems (ITS).

## 3. PROPOSED FRAMEWORK

The main purpose of a RFID framework in ITS is the measuring the traffic variables in order to know its state in a city. Those variables involve flow and density, speed, Headway and others. In order to define the framework, it is proposed a simple tag attached to the vehicle reading that sense the car passing by a specific spot. After that, the reader validates that the tags belong to the system, the tag information is sent to a remote platform to be stored and processed.

Some of the requirements for the framework include [20]:

- Data sharing support. It is relevant to define interfaces to perform data sharing with other systems. These interfaces should be included in the reader and the final applications in a remote server.
- Tag filtering. It is possible to sense some external tags, causing bad results to the system. Hence, the sensed tags should be validated.
- Reading and writing tags support. The system should be able to read tags, but, those tags have to be written with some information related to the car on the system.
- Conditioned reading. In some cases, the reading process should be made under some circumstances, such as specific hours, or authorized days.
- Extensibility. The platform should be extended in any situation to sense, for example, more vehicles, more lanes or more roads.
- Runtime configurability. The design platform configuration can be changed in any moment. Number of reader antennas, leasing time for tags, and other parameters can be changed.

Figure 1 depicts the structure of the proposed framework. Two main parts can be observed: a RFID subsystem and a software subsystem. The first one includes the tag reading process with antennas, RFID readers, an embedded system for validation and data preparing, interfaces and data security support. The second one defines the cloud-software behavior and the user interface.

### 3.1 RFID subsystem.

The proposed framework must define the RFID related subsystem that includes the tag sensing hardware, an embedded system to validate, encrypt, and prepare the data to the software subsystem, and a 3G/4G-based communications device.

One of the most relevant tasks of the RFID subsystem is to prepare the information to be sent to the remote server (software subsystem). This task includes the data structure preparation and its encoding to accomplish with security standards and its transfer to the remote server. Figure 2 shows the tasks included in this subsystem. Also, it can be

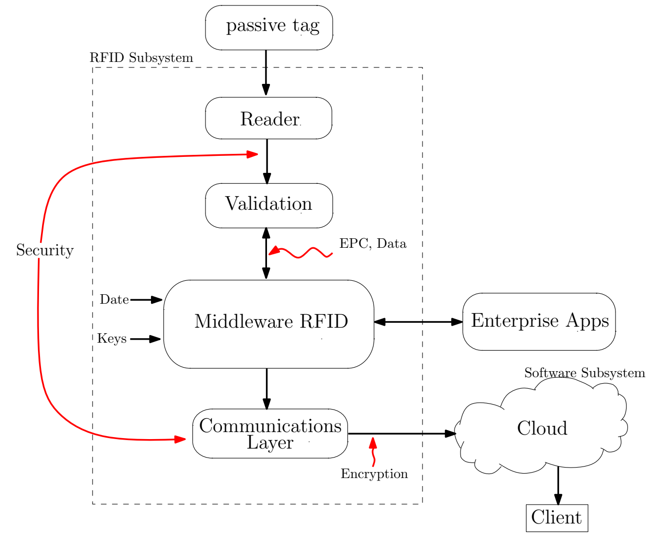


Figure 1: Proposed framework.

observed the data structure for a single RFID reading: EPC (electronic product code), reading timestamp, reader geo-localization, and the type of the tag. Finally, the communication device creates the communication with the platform for that information be sent by embedded system when a reading is present.

## 3.2 Software subsystem

A prototype of the information system has been developed as a web application that uses the client-server architecture pattern and takes advantage of the scalability and reliability offered by the cloud platforms, in order to support large load increases and maintain high availability at the same time. It allows easy integration with other systems and services (e.g., Google Maps), extension and maintenance.

This subsystem has three main modules:

- **Statistics module:** Calculates and displays Vehicle Volumes, Matrices Origin-Destination, Vehicle Permanence Histograms, Occupation in a zone charts. This aggregated information supports the analysis and decision making related with mobility.
- **Admin module:** Control the number of readers, and configures zones, user permissions, keys access. Additionally, this module monitors the readers status in real time, calculates the up-time of each reader authentication to administrators and also can reset a reader remotely.
- **REST API:** Receives, validates and saves all readings and status reports from readers. Furthermore, it provides a web service to query readings with custom parameters (Tag Id, Reader Id, Timestamp, Geographic Coordinates, among others). This functionality allows the development of new Intelligent Transport Systems with validated data from the software subsystem and another sources, which will be independents and non-coupled with the software subsystem.

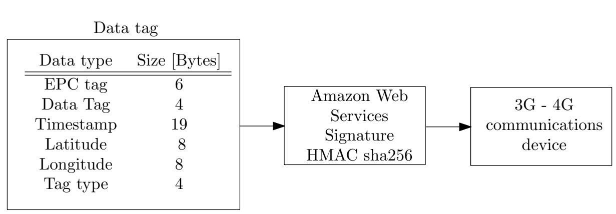


Figure 2: Tag data, encryption, and communication to server structure.

### 3.2.1 *Security*

In order to protect the data transfer and avoid replay type attacks, the software subsystem uses the HTTPS protocol in all communication with readers and external systems.

To guarantee the integrity during the exchange of information, all readers are authenticated by the API using a protocol based on the Amazon Web Services Signature specification (version 4). This protocol ensures that the system only accepts readings of known readers (i.e., properly registered in the database), and that the readings are not from an impostor.

# 4. FRAMEWORK VALIDATION.

The framework was validated by implementing a sensing system to monitor traffic on the campus of the National University of Colombia. The main objective was to monitor vehicular behavior inside the National University of Colombia campus using a RFID platform based on the proposed framework, so determine the origin-destination matrix within of university. Figure 3 shows the entrances and exits of the campus and geographical position where the RFID subsistems where installed.

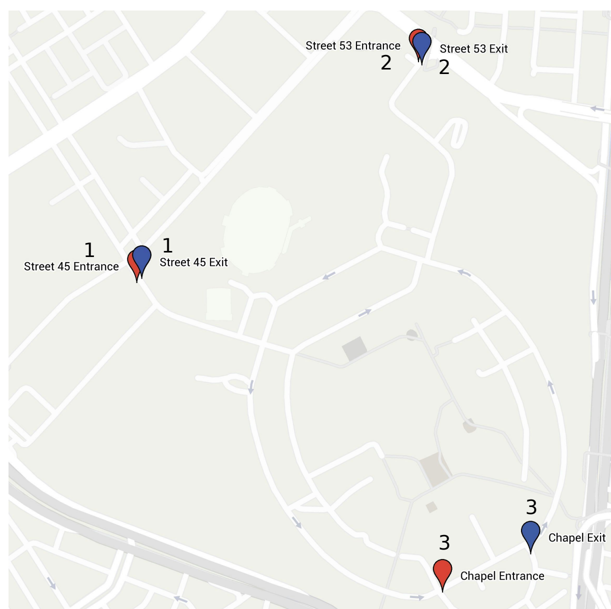


Figure 3: RFID sensing points in National University of Colombia- Bogotá. The blues points represent the exits, and reds points the entrances of the campus.

## 4.1 Experiment Description

In each entrance and exit of the campus was installed a RFID reader. Each reader has two antennas to increase the reading probability by spatial diversity, the first antenna is integrated in the reader and the second antenna is external as we see in figure 4. The distance of measuring is between 6 and 8 meters, transmitting a power of 1 Watt. The experiment was performed by using 724 vehicles of the university community. This sample was chosen since in a working day is approximately 5000 vehicles enter and leave the campus. To guarantee the system validation a manual count was performed.


Figure 4: RFID reader installed in one of entrances of the campus. The external antenna and the RFID reader with an integrated antena are shown.

# 5. RESULTS.

The implemented platform was tested by measuring the amount of vehicles at entrances and exits in working days. Figures 5, 6 and 7, show an example of the results during four days.

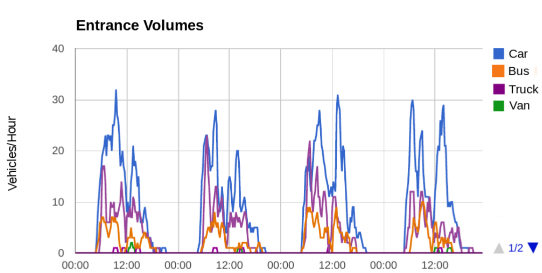


Figure 5: Entrance activity

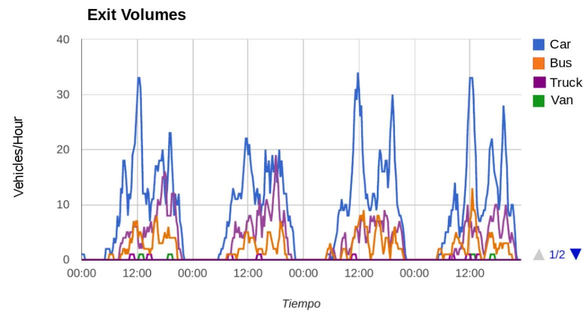


Figure 6: Exits activity

Figures 5 and 6 depict the amount of vehicles during the days at entrances and exits according with vehicle type. Coherence can be observed in both cases, that is, the number for entrances and exits are similar. In the same way, figure 7 shows a comparison between entrances and exits during the day and its proportion in any hour. These numbers determine an effectiveness of the system around 95% for several scenarios during the experiment. The information was obtained since the readers located in the university campus (figure 3).

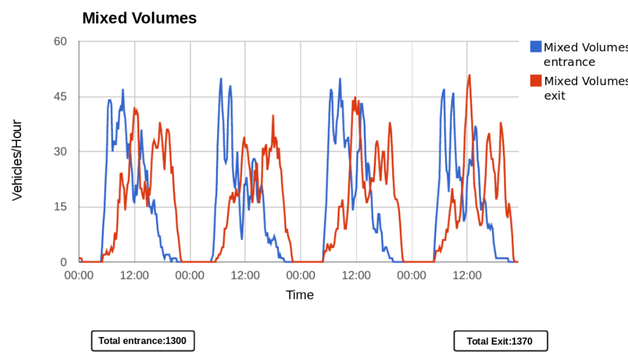


Figure 7: Entrances and exits activity

Table 1 shows the origin-destination matrix for a single business day for each university entrance. This is an interesting information because it determines the activity for each entrance and a corresponding exit. With this information for future work, we can do predictions on travel routes, which will let us determine the possible behavior of the travelers, and so performing the process of roads management. It can be observed an important amount of cars in the entrance and exit 2.

Table 1: Origin-destination matrix for a single business day.

| | **Exit 1** | **Exit 2** | **Exit 3** | **Total** |
|---|---|---|---|---|
| Entrance 1 | 62 | 32 | 50 | 144 |
| Entrance 2 | 123 | 328 | 193 | 644 |
| Entrance 3 | 40 | 68 | 168 | 276 |
| Total | 225 | 428 | 411 | 1064 |

For the framework validation we did a manual count for compare it with our system as we see in the figure 8.

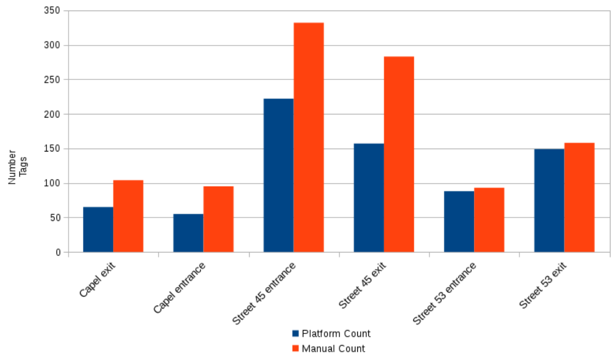


Figure 8: Comparison between the manual counter and platform counter.

As we can see in the figure 8 it presents more manual count than platform count. This is due to factors as location of antennas, distance of measuring, location of tags in the vehicles, and fall in mobile networks that can affect the tags readings. In table 2 we show the reading error.

Table 2: Errors presented at the readings of the tags by the system developed.

| Location | Error |
|---|---|
| Capel exit | 37.5 % |
| Capel entrance | 42.1 % |
| Street 45 entrance | 33.1 % |
| Street 45 exit | 44.5 % |
| Street 53 entrance | 5.3 % |
| Street 53 exit | 5.6 % |

According the test, it was determined that the factors that most degrade the reading process are antennas locations, tags locations in vehicle, and readings distances. For example, in Street 45 entrance and exit, the road is wider than in street 53 therefore the distance in readings of tags increases, increasing at the same time the error at the readings of the system due to that distances of readings no should exceed the recommended distance of readings. For this reason there are readings that are lost and are not recognized by the system.

One advantage of our system is that it presents the information in real time, allowing simple monitoring to any application (Transportation, health care, education, etc).

# 6. CONCLUSIONS.

The proposed framework demostrated the use of emergent technologies such as the RFID technology to monitor traffic car in cities. The above was performed, identifying some conditions to perform based in RFID platforms in Intelligent Transportation Systems, especially in traffic monitoring.

The pilot experiment, which include 724 vehicles showed, that it is possible to implement RFID systems in cities with a low cost and an adequate reading effectively. .

# 7. ACKNOWLEDGMENT

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