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Automation and Control of Vehicle Flow using Raspberry Pi

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ABSTRACT

The number of vehicles in the world's cities increases exponentially, this is the case of Latin American cities, and particularly in the city of Portoviejo, province of Manabí in Ecuador, has been growing considerably in recent years, the city has been expanding towards its surroundings. Due to this big number of vehicles, which also adds little planning to improve the use of public transport, little planning to improve urban vehicular flow, the centralization of administrative area and main shops in the city, are the main reasons why in certain times of the day the traffic can become a little slow.

Universidad Técnica de Manabí, has the objective of modernizing the improvement of vehicular flow in its surroundings and in addition to automating the vehicular entrance to its facilities through the automation of the respective permit for visiting drivers and staff.

In this paper we show the methodology and tools necessary to create a system to control vehicles entry and exit using a Raspberry Pi, an analysis of the different technologies that can be used to improve vehicular flow is also included, approaching the Internet of Things.

KEYWORDS: Internet Of Things, Opportunistic Network, OppNets, Ad-hoc Networks, MANETs, VANETs, Raspberry Pi, Image Recognition, QR code.

1. Introduction

The cities of the world have been growing on themselves since the date they were founded. With the beginning of the industrial age, human life has become simpler, and with the digital age we have begun to automate many processes that previously required more energy, time and money. Currently in the era of *Internet of Things* we can say that we always carry a mobile device in our pocket, which connects wirelessly either using cellular connection, wifi or bluetooth, these connections can be used to transmit either an encrypted key, or even an image for a reader that could be a QR code [1], or transmitted by RFID [2]. By other way, the performance and availability of technology of communications mobile like WiFi or 4G, can be seriously affected by congestion issues in crowded spaces.

Opportunistic Networks [3, 4] can be use in these scenarios, commonly as a solution to the lack of fixed infrastructure. The OppNets (for short) performance relies mainly on users mobility. It is in fact mobility that creates the opportunities for contacts and therefore for data forwarding. The evaluation of these networks is usually based on either synthetic mobility models or real mobility traces generally characterized by a fixed number of users.

Evaluating realistic scenarios is a challenging problem due to the current methodologies used for evaluating OppNets [5]. Evaluating Opportunistic Networks combines the use of a network simulation tool

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with realistic mobility traces where available simulators allow to evaluate various standard protocols. Although there is the availability of a large collection of traces obtained from the observation of nodes mobility in real scenarios, the results are specific to those scenarios. The utilization of these mobility simulators was originally proposed in [6], for statistically studying the mobility along a street. Combining the pedestrian simulator with an Opportunistic Networks simulator was recently used in [7]. Following this idea, in [8] has created external traces that has used PEDSIM [9] pedestrian simulator with the ONE simulator.

In this paper, we will proceed to create the bases to create a vehicle network, with a unique identifier for vehicles and user services. With the help of the raspbery pi, QR codes and connection wifi, we focus on characterizing scenarios in which there is a lot of vehicular or pedestrian flow at certain times of the day at the Universidad Técnica de Manabí (UTM), i.e., with users that can either enter or leave the evaluated scenario. So that, we creating a QR code recognition system to carry vehicular flow control at the entrances and exits of UTM.

The rest of this paper is organized as follows: Section 2 presents some related work indicating the relations with our proposal whereas, section 3 is focused on full description of opportunistic information-dissemination, section 4 describes mobile ad-hoc networks from manets to vanets. Section 5 describes the scenarios and tools used to perform the experiments. Section 6 presents the initial tests. Finally, section 7 presents some conclusions and future research directions.

2. Related Work

Opportunistic Networks [3, 10] are based on the opportunity of exchanging messages between nearby devices establishing some type of direct and local communication (Bluetooth or WiFi). OppNets (for short), have been used in different fields, such as sensor networks, monitoring of wild animals, and for the diffusion of information between mobile devices. The performance of OppNet depends also on two important aspects: how messages are forwarded and how they are locally managed (in the buffer nodes). The first aspect depends on the different routing algorithms and will be see in the next section. Regarding the buffer management, it has been recently shown [11], that it is important to implement certain mechanisms to improve the efficiency management of the buffer, prioritizing the forwarding and discarding of messages. Generally these traces mobility have a fixed set of nodes and the renewal is very reduced. In order to avoid this restriction, synthetic mobility models can be used. The utilisation of these mobility simulators was originally proposed in [6], for statistically studying the mobility along a street. This model is compared with simulation results using the commercial pedestrian simulator LEGION. Using this pedestrian simulator, the authors in [12] study the impact of mobility and the scenario on opportunistic communication. Finally, [7] proposes a model for crowd-counting based on an application that receives messages from AP (access point) and also by contact between nodes. They propose a model based on SDE (Stochastic Differential Equations) and evaluate them using some mobility traces generated with Legion and other mobility models.

There are several studies where mobile devices have been used to send some type of information, in [13] a fairly detailed study has been made of how to count people through two access points conveniently located at the entrances of a metro station in the city of Valencia, Spain. In [14] the authors has created an opportunistic network, where they send information between access points and taxis, this study uses real traces of the vehicular flow of the cities of Rome and San Francisco.

3. Opportunistic Networks

Opportunistic Networks are based on the opportunity of contact between pairs of nodes as a way to propagate messages. The effectiveness of OppNets depends mainly on the number and duration of these contacts, which finally rely on the mobility of the nodes. We can say that mobility is the main enabler of opportunistic data dissemination [15].

The mobility and its impact on the performance of OppNets has been studied extensively, see [16], [17],[12], which evaluates the message dissemination behaviour of different protocols by focusing on the mobility patterns of the nodes. In these works, the authors explain the relationship between factors such as speed, mobility model, node density, and places.

Two main approaches can be considered for the diffusion of this information between the mobile devices. The *direct delivery* protocol [17] can be considered the simplest way to spread a message. The fixed nodes deliver the message only to the contacted mobile nodes. On the other hand, *flooding* protocols spread a message over the network. Mainly known as *Epidemic* diffusion or protocol [18], it makes a copy of the message for all contacted nodes so that these nodes can also transmit the message to other nodes, improving the message diffusion.

Since mobility is a key factor for evaluating OppNets, several models were devised in order to capture this mobility behaviour. From the basic models, such as *Random Walk* and *Random Way-Point* [19] more realistic models were proposed that considered some social aspects of human movements, such as working days, meals, like SWIM [20], SLAW [21], and the Working Day movement model [22]. Nevertheless, in order to have more realistic simulations, the best approach is to use real mobile traces [23],[24], combined with an OppNet simulator.

3.1. Link Technologies Models

The most well known link technology which can be used freely, i.e., without being bound to any operator, is the WiFi technology, which is based on the IEEE 802.11 standard [25], [26] defined by the Institute of Electrical and Electronics Engineers (IEEE).

The most widely known being the 802.11n and the 802.11ac, which are currently available in most of the modern handheld devices. But several other specifications exist which are relevant for opportunistic networks. Related to WiFi and relevant to opportunistic networks is WiFi-Direct, a technology that enables WiFi devices to connect directly, allowing an easy pairing of devices for short-term data transmission without the need of an infrastructure. It basically uses the ability of modern handheld devices to become an access point.

Bluetooth (standardized as IEEE 802.15.1) in all its variants [27] are another widely used technology. Version 4, known as Bluetooth Low Energy and with the features introduced with Bluetooth 5.0, offers energy efficient functionalities for wireless communication in restricted environments and opportunistic networks. The main advantage of Bluetooth and WiFi is their wide availability on a variety of end-user devices ranging from smartphones to a large number of IoT (Internet of Things) oriented devices. However, there are other specialized technologies that should also be considered for opportunistic networks, as they may become relevant to some specific application scenarios and environments, such as national park monitoring.

4. Mobile Ad-hoc Network from MANETs to VANETs

Vehicular OppNets are also based on the opportunity of contact between vehicle pairs for message propagation. Some recent works are devoted to evaluating the information dissemination on Vehicular Networks in urban scenarios, using real traces. The authors of [28] [29] [4] offer a wide application of Vehicular Networks, establishing some key differences between *MANETs (Mobile Ad-hoc Network)* and *VANETs (Vehicular Ad-Hoc Network).*

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In [30], the authors performed an analysis over VANETs using three vehicular traces of Chinese cities: a trace of the taxis of the city of Shenzhen, and two traces of the city of Shanghai (buses and taxis). In [31], [32], [33] the authors examine the performance of routing protocols in OppNets based on real traces of big cities such as Beijing, Rome, Berlin and others.

The message delivery ratio of mobile opportunistic networks is highly dependent on the available transmission time, which is closely related to the mobility of users and the communication properties of mobile devices. Furthermore, user mobility is a crucial factor to consider, especially when mobile nodes are in vehicles, due to their limited freedom of movement and faster.

Table 1: Timetable of staff entry / exit

Section	Hours
Morning	07h00 to 13h00
Afternoon	15h00 to 17h00
Night	17h00 t0 21h30

5. Description of the Experiments

This section describes the experimental infrastructure and the procedure used to create a device with image recognition. We present the hardware and networking scheme based on WiFi technology, and we describe some details of a system based on image recognition with a raspberry pi by vehicular nodes.

In figure 1 we can see the main areas of the campus. The University Technical of Manabí is located in the city of Portoviejo, in the province that gives its its name, in Ecuador. We present a possible design for an opportunistic message transmission device for vehicular networks using our device raspberry pi like as qr code reader.

Figure 2 shows the components and their interactions to implement an opportunistic communication system. This figure depicts the hardware elements: 1) a Raspberry Pi device, 2) internet connection, and 3) sticker or card with a Qr-code, which will serve as a unique identifier for the vehicle or staff. Moreover, shows the scheme of the system to be implemented, on the one hand we can see the university

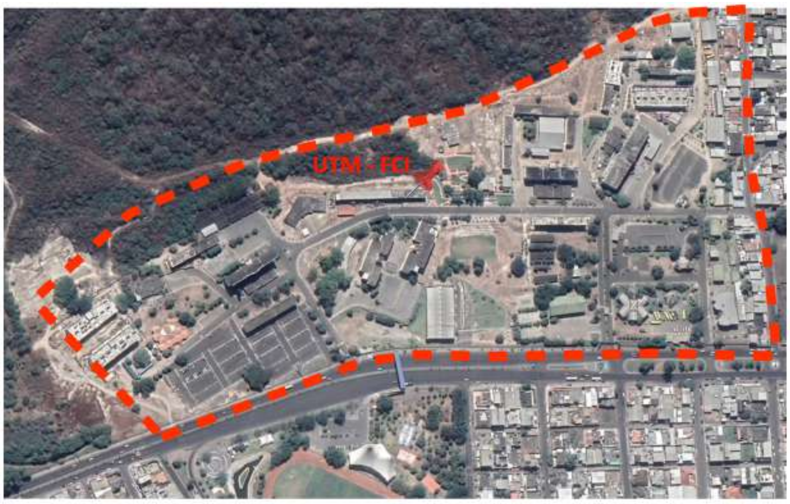


Figure 1: Universidad Técnica de Manabí Main Area.

entrances, and show the device created for image recognition, which will verify that the data of the person entering is correct, later the data will be saved for analysis.

Table 1 show timetable of the university staff, where some 30,000 people work, must go to the university campus to work or study, which would mean that about ten thousand people pass through its doors in each hour range at least once.

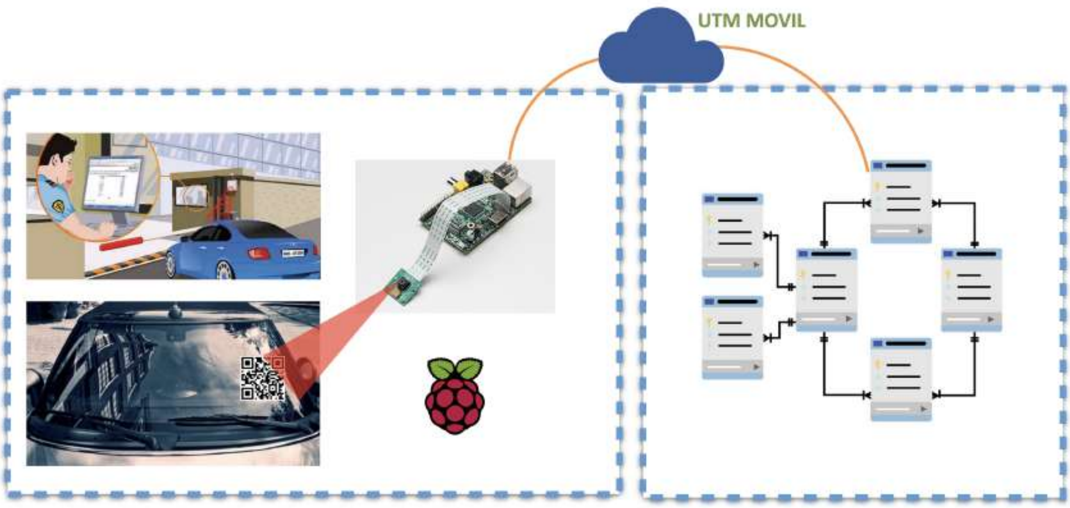
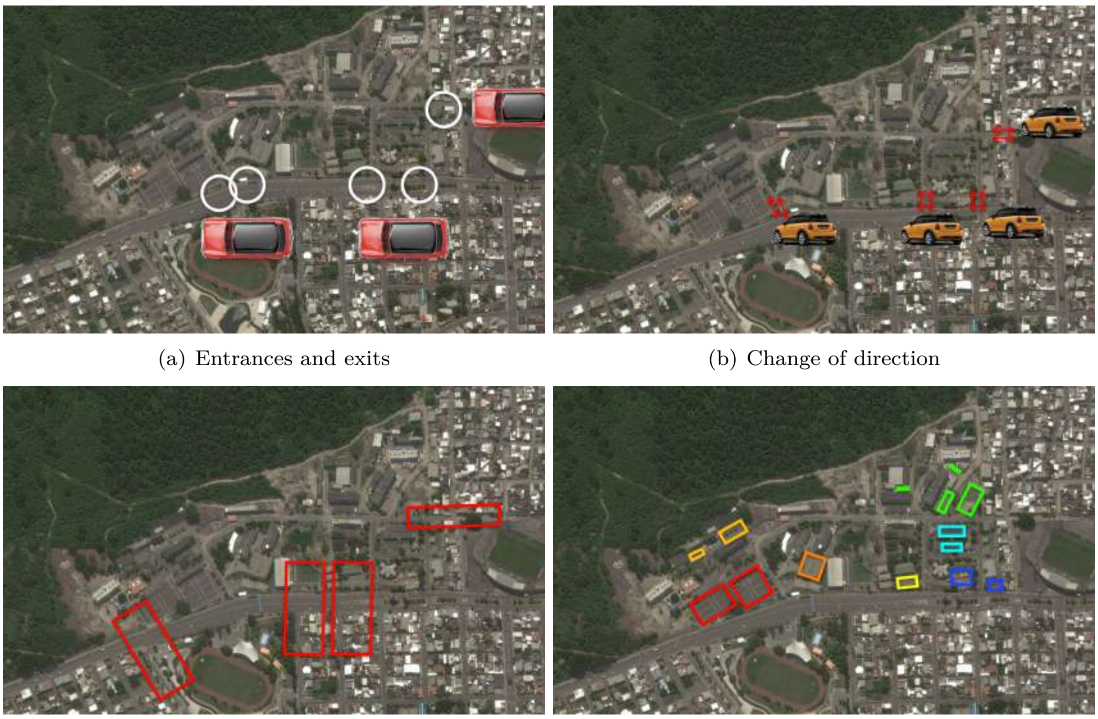


Figure 2: Scheme for the image recognition system



(a) Entrances and exits

(b) Change of direction

(c) Section increase on the road

(d) Main parking areas

Figure 3: Main areas to take into account for the automation of vehicular flow at the UTM

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Figure 4: Personnel card with identifying QR code

(a) Recognition with a smartphone (b) First field test

Figure 5: First tests

Figure 3 shows the described scenarios and the improvements to be made. Now we will describe the different improvements:

- Figure 3(a) shows which are the main entrances or exits found on campus
- In the figure 3(b) possible changes of ways in the entrances are described
- As we can see in the figure 3(c) the general plan of the university campus, we realize that a certain expansion could be made on certain streets that can directly enter the campus.
- An additional point in the improvement that is intended to take into account is the sectorization of certain parking lots, as can be seen in the 3(d) where most departments have small parking lots with organized sectorization.

Among the possible solutions, it can be suggested that all students who have a vehicle do so in the largest parking lot, in addition to certain safeguards that will arise in subsequent works.

In figure 5(a) we can see the first valid test capturing the data that is displayed from a smartphone. While figure 5(b) shows the data capture from the university grounds prior to returning to work due to the problems of the pandemic caused by SARS-CoV-2.

6. Prototype and Future works

After having analyzed the previous points, we will proceed to assemble the system and we will show the first results. Figure 4 shows the hardware used and the digital card that can be downloaded from the *https://app.utm.edu.ec/movil/*, where you can read the data from the embedded qr code, and check its veracity. For this reason it would not be necessary to print the qr code, but it would always be available from the comfort of your pocket.

7. Conclusions

In this article, we have created a system with qr code recognition, with a methodology to automate vehicle flow. This methodology is based on the use of qr codes to later be able to recreate realistic mobility scenarios, through unique identifiers of users and their vehicles.

To sum up, the contributions of this paper are the following:

1. We have created a device with real time qr code recognition.
2. We have made a study of the vehicular flow of the main entrances of the university campus.
3. We have created a system to save the input and output data of users' vehicles

As future work, we plan to improve and automate the flow of entry and exit at the University, in addition to transmitting opportunistic information from the hot spots where vehicles and users pass more often.

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