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Wireless monitoring and tracking system for vehicles: A study case in an urban scenario

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ABSTRACT

This paper describes the application of a Wireless Traffic Monitoring and Tracking system in the Spanish city of Granada, as an approach for addressing important tasks in the field of *Smart Traffic*. To this end, several nodes of the so-called *MOBYWIT* system have been deployed at important urban points. They collect real-time vehicles' movement information based on *Bluetooth signals detection*. The gathered data have been processed in several ways, showing some of the applications that the system has, such as the composition of Origin/Destination matrices, the computation of accurate displacement times, or the estimation of real traffic in short terms by means of Time Series Forecast. The obtained results validate the system and proves its value as a tool for the urban traffic flow monitoring, analysis and prediction, which could be used as a part of an *intelligent transportation system*.

1. Introduction

An *Intelligent Transportation System* (or Smart Traffic System) able to monitor, predict and, ideally, manage traffic flows, is an essential component inside the philosophy of a smart city. An optimal traffic management system would shorten the users' displacement times (both in particular vehicles or in public transport). Therefore, this system would lead to a save in energy consumption and also in generated emissions [1,2].

Nowadays, this kind of system strongly depends on information, and more specifically, on data about the traffic or the mobility of vehicles.

However, usual Regular Traffic Control Systems (RTC) [3], such as loop detectors or pneumatic tubes are just able to provide very limited information (a count or estimation of the amount of vehicles). Optical Character Recognition (OCR) systems can also yield more interesting data, such as the vehicles' plate numbers which could be used for performing a kind of tracking (hard to be automatised). Their main disadvantage is their high cost, both in installation (more than a thousand dollars on average per unit) and also in maintenance (several thousands of dollars per year) [4,5]. In addition, most of them are *intrusive*, in the sense that they must be installed under the pavement [6].

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In urban scenarios, the problem is that the traffic flows move through several interconnected streets, so it is necessary to deploy a lot of these devices if one wants to monitor and model the traffic [7]. The cost this would imply cannot be afforded by most of the cities.

Thus, the current tendency is to propose low-cost and *non-intrusive* traffic monitoring tools [8–11]. In this line, *MOBYWIT* (Mobility by Wireless Tracking), which is described in this paper, is a novel system presented by the authors in [12]. Every node of the system is, essentially, a single-board computer with WiFi and Bluetooth (BT) cards, monitoring the radioelectric space on its range. The node is then able to capture BT and WiFi signals emitted by other devices. Thus, it normally detects personal devices, such as smartphones, or devices on board of vehicles, for instance hands-free systems. The collected data is filtered and the MAC (Median Access Control) address, which is unique per device, is extracted, processed[1] and stored in the system with a time stamp. So it is identified as a traffic/mobility ‘event’.

Hence, this monitoring system is able to collect people’s and vehicles mobility data, and also able to track them by means of a grid of *nodes*, connected to a central server. This allows the easy construction of traffic flow models or mobility graphs. The proposed system is formed by low-cost elements, around 100$ each node, which is another advantage over the usual monitoring systems.

RTC systems are still the most precise way to measure the traffic density (given that there is a good infrastructure). That justifies their use in important streets in the city, and key roads with heavy traffic. However, we demonstrated in a previous study [14] that the Wireless Traffic Monitoring is equally useful for the objective of detecting and/or predicting jams or congestion in the streets. To this end, the data gathered by this system were compared with those obtained using an Inductive Loop Detector (ILD) by means of the Granger Causality Test [15].

In this work, MOBYWIT system has been validated in a real scenario, i.e. some of the main streets in the city of Granada (Spain). Several studies have been conducted, in order to predict the direction and magnitude of the real traffic flow in these streets. Thus, considering the tracking ability of the system, the gathered data have been processed using statistical techniques, and also Origin/Destination (O/D) matrices have been computed for a set of nodes in an crossroad. Finally, the value of the data for traffic forecasting has also been tested. So, the collected data have been converted into several Time Series with different frequency, and short-term predictions have been performed, obtaining very good results. According to the obtained results, we conclude that our Wireless Tracking System could be considered as a reliable (and fairly accurate) alternative to address several different issues in a Smart Traffic System.

This work is also a complete analysis of real traffic flows that goes beyond usual researches in the scope of urban traffic, which, to our knowledge, are normally focused on one type of problem and methodology, e.g. traffic forecasting, origin/destination matrices, traffic modelling, pollution estimation, etc.

The presented study could be used to create accurate traffic simulation models or to plan a better synchronisation of the traffic lights, in order to anticipate and prevent congestion or jams on the streets, for instance. Furthermore, due to the architecture of MOBYWIT system, in which the nodes are interconnected through a network – and also to Internet – it is possible to monitor (in a central control office, for instance) traffic flows in almost real time.

The rest of the paper is structured as follows: Section 2 presents the background and state of the art on the main topics of the work. The used wireless monitoring and tracking system is described in Section 3. Section 4 presents the real test scenario and the data gathered to be considered in the studies. The experiments conducted in order to predict the traffic flows (direction and magnitude) are described in Section 5, where the obtained results are discussed. Finally, Section 6 plots the conclusions that we have reached in the work and propose future lines of work.

2. Background and related work

A *smart city* is a city that works in an intelligent and sustainable way, integrating all their services and infrastructures and services as a whole, using intelligent devices to control and monitoring to ensure sustainability and efficiency [16].

Smart Cities are key to a sustainable urban development. Different elements in a city, such as vehicles and people, could be detected by a number of sensors to obtain a wide quantity of data. These data can be the base to extract knowledge. Understanding those patterns that guide the inhabitants of an intelligent city is a compelling research area. There are different applications to help a city getting smarter by means of data mining methods, such as the intelligent urban planning, public health, public security, and commerce (geomarketing). But it is the field of intelligent transport, which is the most important one for this work. Besides that different models exist, the human mobility prediction is still a challenge [17].

As previously described in the Introduction, the inductive loop detectors and pneumatic tubes are the main technologies used in current RTC systems. However, the inability to identify the vehicle detected (tracking is not possible), and their high cost are some important drawbacks of these sensors.

Besides, they do not produce the quality data required by real-time applications [18]. That is, they just measure the number of vehicles, and their type taking into account the length between wheels. This number, although valuable, does not allow us to know many traffic flow characteristics like, for example, repetitive passes of the same vehicle across the same road.

[1] In order to respect the person’s privacy as well as data protection laws, the MAC is encrypted just in one-direction using the SHA1 algorithm [13] before storing it, so, it is not possible to associate a captured MAC with any person.