Comparing Wireless Traffic Tracking with Regular Traffic Control Systems for the Detection of Congestions in Streets

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Abstract. Detecting congestions on streets is one of the main issues in the area of smart cities. Regular monitoring methods can supply information about the number of vehicles in transit and thus the saturation of the streets, but they are usually expensive and intrusive with respect to the road. In recent years a new trend in traffic detection has arisen, considering the Wireless signals emitted by 'smart' on-board devices for counting and tracking vehicles. In this paper, two traffic monitoring methods are compared: detections using a regular Inductive Loop Detector on the road and an own Wireless Tracking System based on Bluetooth detection called *Mobywit*. The correlation between the day of the week and the hour with the traffic flow in a metropolitan busy street has been analysed. Assuming that our system is not able to defect all the vehicles, but just only subset of them, it is expected a causality between the results obtained using the two methods. This means, that the Bluetooth-based system can detect the same variations in the traffic flow that the regular loop detector, but having two main advantages: the tracking possibilities and a much lower cost.

Keywords: smart cities, traffic monitoring, traffic tracking, bluetooth detection

1 Introduction

The detection of traffic congestions in streets is an essential issue inside the philosophy of a Smart City. In it, a *smart traffic system* should be able of detect, predict and, ideally, manage, these traffic troubles. An optimal management system can provide a better performance in citizens' displacement time, the energy consumed by vehicles, and the resources or costs employed [1, 13, 15].

Regular Traffic Control Systems are based in several kinds of devices, such as pneumatic tubes, loop detectors, floating vehicles or automatic Optical Character Recognition [14]. Usually, those technologies are very expensive to be placed in every street and are quite intrusive. Thus, traffic monitoring technologies can be classified as *intrusive*, when they are installed over or under the pavement, and *non-intrusive*, if they are not in contact with the road, so they cause a minimal effect on the traffic flow [8].

These regular technologies are normally expensive (above a thousand euros), they require altering the road, and they have a high cost of maintenance (several thousand of euros per year) [9, 16]. However, they are the most precise way of measure the traffic density. That justifies their use used in important highways and roads with heavy traffic, where just deploying a few devices it can be possible to, virtually, monitor all the traffic.

In urban scenarios the problem is that the traffic flows move through several different points (streets), connected between them, so it is needed to gather a lot of information about most of these streets in order to study and model the traffic [12]. Major cities can afford installing traffic control systems only in main streets, but reaching most of the streets are normally beyond their possibilities.

Thus, it would be recommended to find a cheaper alternative, also less intrusive, to gather (and provide) information about the traffic. This could be implanted in every street, giving a fair level of accuracy, or at least, able to detect or 'recognise' the traffic fluctuations as a regular system does, i.e. being reliable.

In this line, this work applies a monitoring system called *Mobywit* [4] able to collect vehicle mobility data by means of a grid of low-cost devices (or nodes) connected to a central server. The nodes capture Bluetooth (BT) signals emitted by other devices, mainly hands-free systems and *smartphones* on board of vehicles. This type of traffic monitoring technology is becoming widely used in the private sector [5, 18, 17, 3], as it is quite cheap (about a few hundred euros), it is non-intrusive with the road, it is easy to implement, and requires minimal maintenance. It has also become a very profiting research area [11, 7, 10].

Thus, this paper presents a study comparing a Regular Traffic Control System based in an Inductive Loop Detector and the *Mobywit* System. Specifically, it is analysed if a system based in Wireless Traffic Tracking (focused on Bluetooth) can provide the same information about the traffic flows and traffic congestion than a regular method. For each system, the influence of the weekday and the hour of the day in the congestion is studied. The goal is to determine if the same variations in the data collected by the regular method are reproduced in the data obtained using the Wireless Tracking System. And therefore a Wireless Tracking System can be used as an economic alternative to regular traffic measure methods.

In order to study the relationship between both systems, the Granger Causality Test[6] is used. The Granger test is a statistical hypothesis test for determining whether one time series X is useful to forecast another series Y. That means, it exists a causality between both time series.

The rest of the work is structured as follows: Section 2 presents the Wireless Tracking functioning applied to the traffic control and why it can be approximated the number of vehicles with the number of Bluetooth devices. Then, the problem studied is introduced in Section 3 that presents information about the data compared for each system. Section 4 shows the results of the studies of correlation of the information about the traffic flow and about indicatives of traffic saturation. Finally, Section 5 presents the conclusions reached in the work.

2 Wireless Tracking of Vehicles with Bluetooth

In this work the Wireless Tracking System is compared with a regular Inductive Loop Detector working as shown in Figure 1. And Inductive Loop essentially is a square-form wire embedded into the road with an electric current. When a metal surface with certain minimum area passed or is stopped above the loop, a pulse is triggered and detected by a sensor. Two records are saved for a time interval, number of times that turns on flow field and how much time in total has been activated the field in that interval. With that information, it is estimated the number of vehicles that have passed by the road and their average speed.

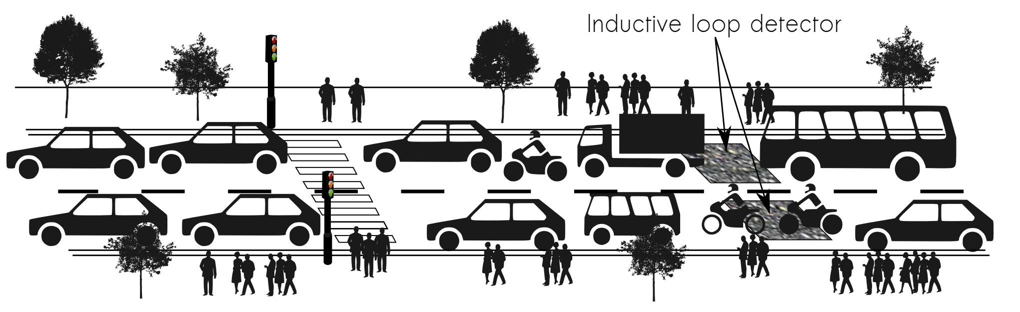

Fig. 1. Inductive loop detector for Traffic Control

In Wireless Tracking, a number of devices or nodes are placed near of the road as Figure 3 shows. These devices are provided with antennas that are able to search for *Bluetooth beacons*. A Bluetooth beacon is a type of frame that Bluetooth devices drop for announcing a *"I am here"* message proclaiming their *MAC Address* and other information about his nature.

The *MAC Address*, also called physical address, is a unique identifier assigned to network interfaces for most IEEE 802 network technologies. *MAC Addresses* are most often assigned by the manufacturer of the network interface controller (NIC) and are stored in its hardware, such as the NIC's read-only memory or

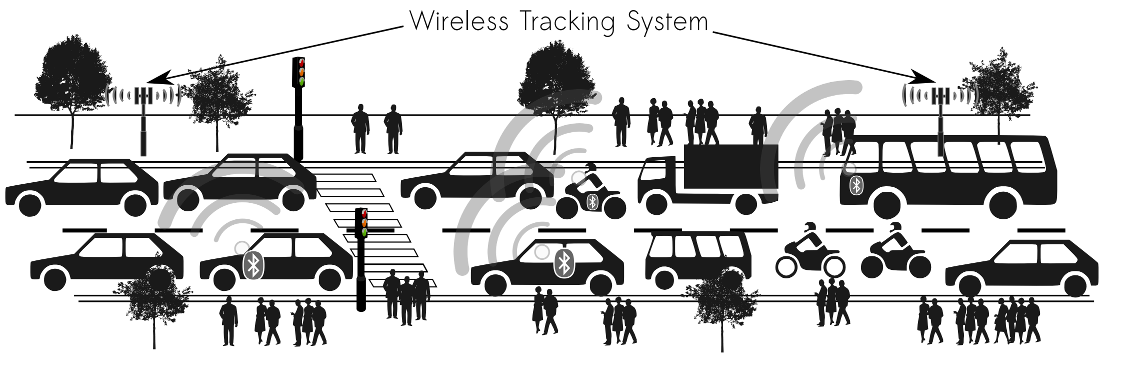

Fig. 2. Wireless Tracking of Vehicles

some other firmware mechanisms. Hence as it is assigned by the manufacturer, a *MAC Address* usually encodes the manufacturer's registered identification.

Obviously exists a huge variety of devices that use Bluetooth for their communications. So in can not be considered a priori that any detected Bluetooth device corresponds to a vehicle. In addiction, even with the energy management enhances of Bluetooth 4.0 LE, the devices that have some type of user interfaces (buttons, screens or dials) can disable the auto-sending of beacons for saving battery. This means that not all th devices are sending beacons all the time.

However a Bluetooth beacon contents information about the nature of the device, in a bit-code named Major and Minor Device Class[1]. This class and the manufacturer extracted from the *MAC Address* can provide information about the type of detected device.

So on the one hand, most advanced devices are not sending beacons all time, just those that do not have a friendly user interface. Furthermore disable the auto-sending of beacons correspond with the necessity of save battery, so most of the devices that not need save battery do not disable auto-sending of beacons.

Other hand, a Wireless Tracking system for traffic have some points of interest in vehicles. The vast majority of new cars on the road include a Bluetooth connection used as hands-free with a smartphone, to synchronise music player, in GPS, cellulars for emergency calls or even because they are smartcars. Fortunately a car is complex system, with a non-friendly user interface, in that not worth it give an option to disable auto-sending of Bluetooth beacons. Moreover a car have a huge and inexhaustible auto rechargeable battery when the engine it is in movement. So there are not a real necessity of save battery evading the auto-sending of beacons.

But all this is just a guess. It is needed to study in a functional Wireless Tracking System the nature of the detected devices. Figure 3 shows the manu-

[1] www.bluetooth.com/specifications/assigned-numbers/baseband

facturer, major and minor class of the devices detected in the interval of time that was used in this paper by the *Mobywit* System.

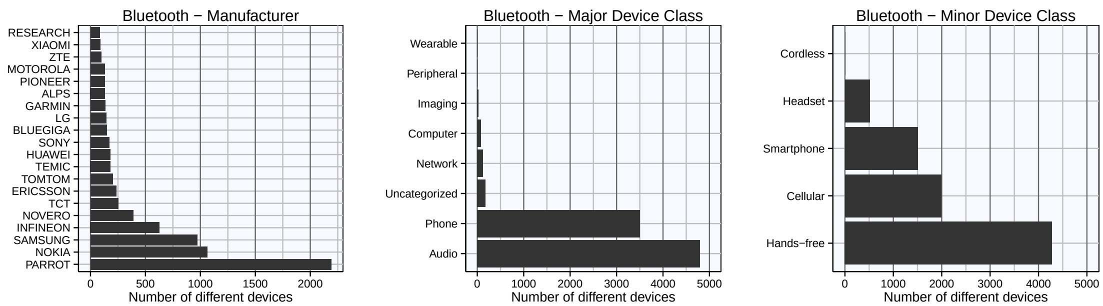

Fig. 3. Manufacturer, Major Device class and Minor device class of every different Bluetooth Device tracked.

The principal type of device detected by the System belong to hands-free devices. A similar number of cellulars and smartphones are detected. However, a surveys about the habits of the use of Bluetooth in smartphones made with more than 500 people showed that the 84.6% of users only turn on Bluetooth when will be used, turning off it the rest of the time.

Loocking the manufacturer of the tracking devices can be seen that most of them are tracking devices that belong to hands-free manufacturer (PARROT, NOKIA, SAMSUNG, ERICSSON, HUAWEI, MOTOROLA, LG, ZTE and XIAOMI), GPS manufacturer (TOMTOM,GARMIN), music players manufacturer (PIONER, SAMSUNG, SONY), manufacturers of NICs inside cars (NOVERO, TCT, TEMIC, BLUEGIGA, ALPS, RESEARCH) and smartphones (again NOKIA, SAMSUNG, ERICSSON, HUAWEI, MOTOROLA, LG, ZTE and XIAOMI).

It cannot be generalized, but a that the significant amount of device detected by a Bluetooth Tracking System belong to vehicles or devices travelling inside a vehicle.

Considered that Bluetooth devices inside vehicles or vehicles are the principal devices sending beacon, because need to save battery (the vehicle is providing it) and they usually do not have an easy way to disable the auto-sending of beacons.

3 Analysis of traffic flow in a busy street

Thanks to the collaboration with the Mobility Area of the Local Council of Granada City, it had the opportunity to compare the two systems in one of the most busy and conflicting streets of the city.

Figure 4 shows a map of the street. It is a main street that collects much of the traffic of the north area of city and allows the driving to move to other areas.

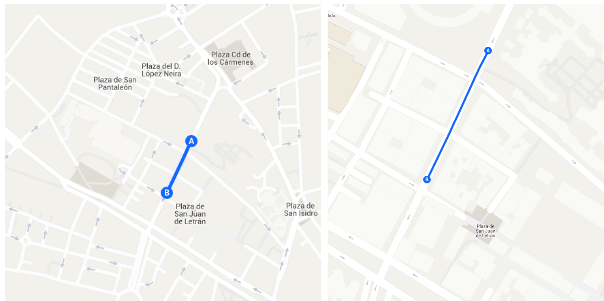

Fig. 4. Location and detailed location of the busy street Doctor Oloriz in Granada.

3.1 Data sources

Historical Inductive Loop Detector Unfortunately the council cannot yield recent data about the traffic because the Inductive Loop is not always working.Thus, historical data are provided from January to April 2015. Figure 5 plots the number of vehicles per hour detected for two Inductive loops placed near Point B of Figure 4.

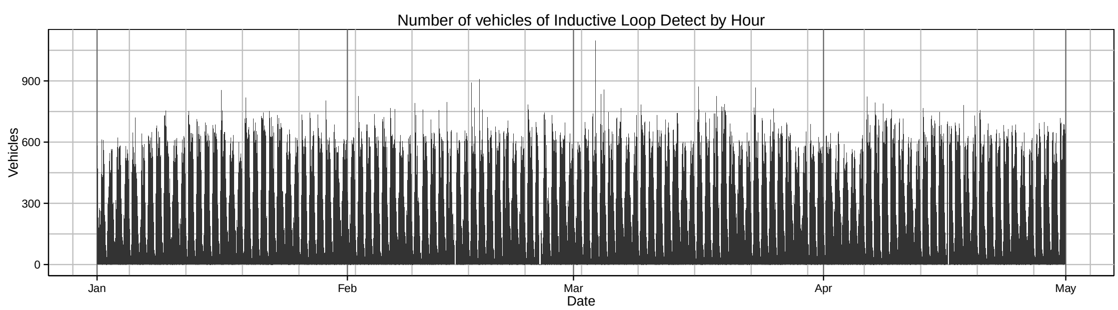

Fig. 5. Vehicles detected by Inductive Loop by hour in point B.

Bluetooth The collaboration with the council allow to install two Mobywit device both A and B that have been tracking Bluetooth devices from 11 January 2016 to 29 February 2016. Figure 6 plots the number of devices detected by hour in that period.

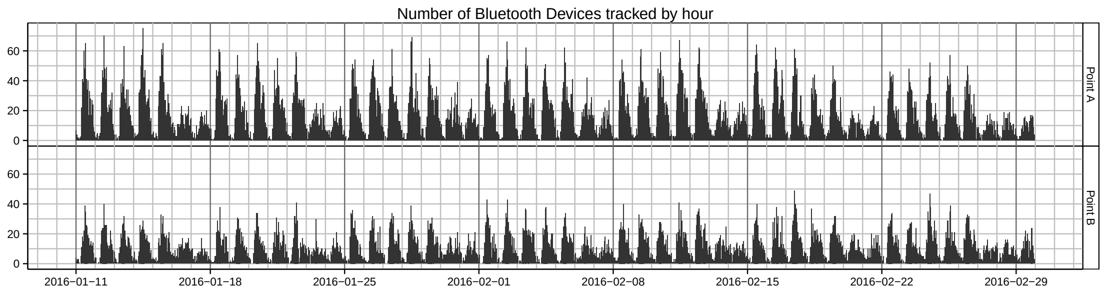

Fig. 6. Bluetooth devices tracked by Mobywit System per hour in points A & B.

4 Experiments & Results

Figures 5-6 show that Wireless Tracking System detects less devices (or vehicles) that the regular Inductive Loop Detector. It is necessary to study if there is a correlation between both system in the variation of traffic flow and in the indicators of a traffic congestion.

4.1 Traffic Flow

For a smart city, it is more important to know if there is a high or less utilization of the road than expected in the same period, than the real number of vehicles moving on that street.[2].

There are not equal periods of data for the systems, so a correlation of the weekday and hour it is approximated. Figure 7 plots the variation and influence of the weekday and hour of the day in the number of vehicles detected for each system. Apparently the two systems behave similarly, but there are some statistical evidences reflecting they are related.

Despite the similarity between the two measures, it is need some statistical evidence of the causality. A simple linear regression analysis yields a $R^2 = 0.6389$ that results insufficient to attain any conclusion. It is needed other test that uses the data as time series. Granger Causality introduced in on Section 1 is an optimal test to infer whether both series behave similarly.

The result of the Granger test yields a p-value equal to 0.0002355 that is less than the confidence threshold. This means a big statistical evidence which

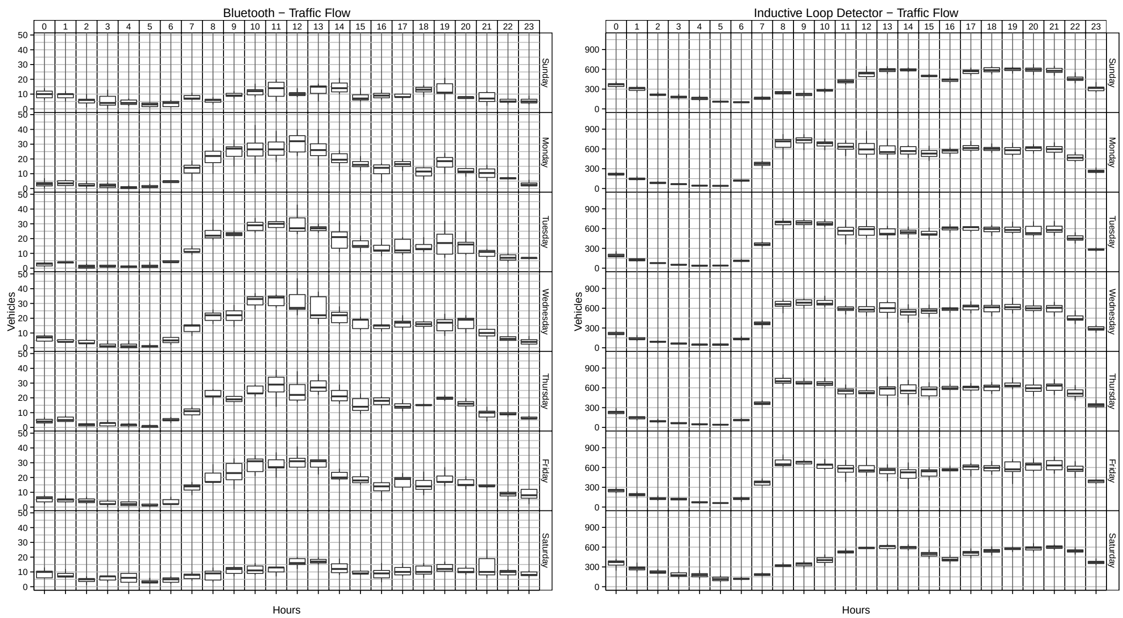

Fig. 7. Traffic Flow of Bluetooth and Inductive Loop Detector by weekday and hour.

means that the variation of number of Bluetooth devices tracked by a Wireless Tracking System can be considered for measure the variation of the real traffic flow.

4.2 Indicatives of saturation of the street

Time of use of the Inductive Loop Detector With the use of Induction Loops Systems can be approximated the average speed of vehicles, using the total time the loop has been actived divided by the total number of vehicles and the length of the loop. This information is used for detecting congestion in traffic. If traffic is moving slower than usual, means that there are something hinder to the traffic go faster. However this speed is a punctual speed in the loop, not the cruising speed.

Time to cross the street In a Wireless Tracking System with at least two nodes or devices. It can be calculated the real time needed for every single device to go from A to B. This time can be useful to compute the average time needed for example to cross a street or another.

As it has been done previously, a correlation between the weekday and the hour of the day has been calculated for both measures. Figure 8 plots the usual time needed to cross the street obtained with *Mobywit* system, and the time of

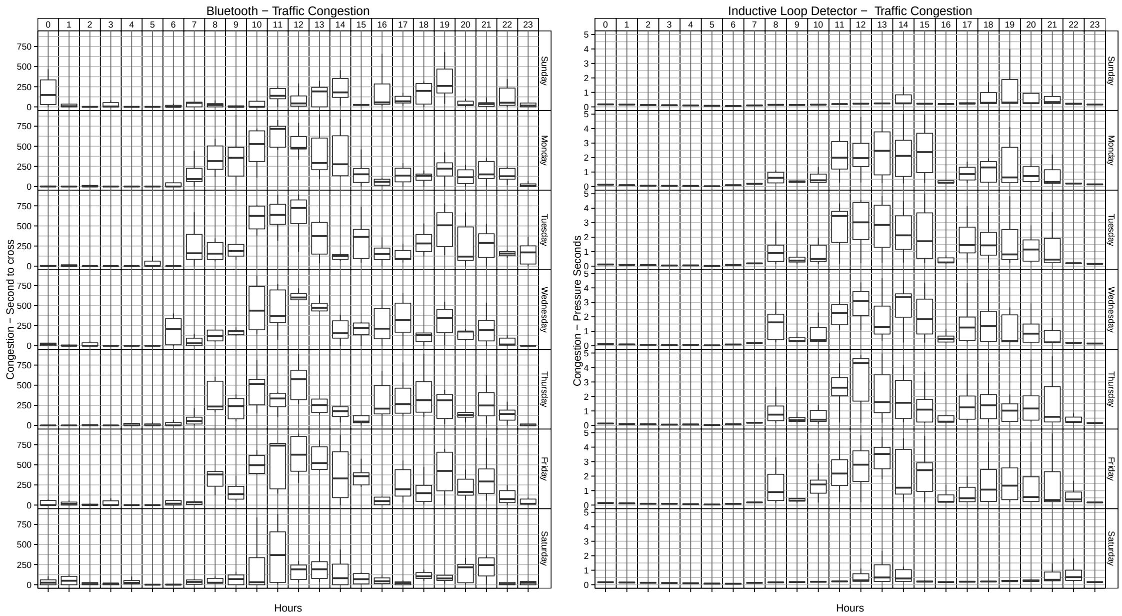

Fig. 8. Congestion indicative for Bluetooth and Inductive Loop Detector per weekday and hour.

activation of the loop for each vehicle (together with the length of the loop can be calculated the instant speed).

Again a linear regression drops $R^2 = 0.4662$ results poorly statistically significant. Granger Test of the two time series obtains a p-value of $0.5844 \cdot 10^-11$ that is almost zero. This means that there is a strong correlation between both time series measures.

5 Conclusions

This paper presents has been presented theoretical and empirical evidences of the tracking of Bluetooth devices mainly will detect vehicles (devices inside vehicles). The detection of other type of devices detected is insignificant, because they are handy devices that have to save battery, and for that, usually auto-sending of beacons was disabled. Furthermore, if any device belongs to some other major and minor class, can be easily discounted by the node.

Has been statistically proved using the Granger Test, that there is a strong correlation between the number of tracking Bluetooth devices and the number of real vehicles (according to loop detections). The indicators of congestion in the streets, in both methods, are also strongly statistically correlated according to the Granger Test. This enables detecting the fluctuation and congestion of the real traffic using the Bluetooth devices tracked. But using a cheaper and less intrusive with the road system.

So finally, it can be concluded that using a Wireless Tracking System is a valid alternative for the control of the traffic flow and the detection of congestion on the street. That will be useful in smart cities, since it provide an economic system to control the traffic. With advantage of vehicle tracking so, that a system with more nodes can provide also information about the origin and destination of the traffic or the paths they follow. This topic will be explored as a future work in this line.

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