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# Ad Hoc IoT Approach for Monitoring Parking Control Process

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**Abstract.** The purpose of this research is to develop a collaborative approach to control the parking in a city using IoT (Internet of Things). This approach is based on Bluetooth Low Energy (BLE) beacons to control the parking process without having to investment in sensors. Parking violations can be easily detected through the proposed collaborative process among user's mobile devices. A reward mechanism incentives users' participation. This approach uses an ad hoc network of users who send information to a central system regarding georeferenced beacon information. Comparing with previous payments associated with a vehicle, the approach can identify parking violations, e.g. parking without associated payment.

**Keywords.** IoT, Beacons, BLE, Parking, Collaborative approach, Ad hoc Network

## 1. Introduction

Parking is one of the major issues in the cities due to reduced availability of space and the time consuming process for finding a place. Several studies show that in the majority of cities 20 to 30% of traffic is generated by the search for a parking space, which corresponds to average times of 10 minutes [1]. Drivers cover, on average, distance of 4.5 km to find a parking place [1], which corresponds to an average of 1.3 kg of $CO_2$ per month, or about 100 km per month, and to an additional estimated cost of about 10€ per month. The demand for parking places is responsible for one third of the traffic in the city [1]. In the Lisbon region (Portugal's capital), for example, the average number of vehicles per day is of 250 to 300 thousand[2]; if one considers that the demand for parking spaces affects part of this number of vehicles, an estimate of 100 thousand vehicles could be removed from the roads. In this scenario, it can also be estimated 1 M€ per month of additional expenses and additional production of 130 tons of $CO_2$ that could be avoided. Considering only the example of Lisbon, the annual distance traveled in search of parking place (4.5km-day x 230 days annual work x 100 000 cars) would allow to take about 2800 rounds to the planet and represents about 36 thousand hours of work lost. In the city inner zones the parking spots are difficult to find and often another driver (not involving logistics) has taken the parking spot. So there is a need of solutions to find if a parking spot is free and consequent guidance to these places. One such common system in closed environments (example of parking spaces at malls) has sensors at each parking spot with a light that indicates if it is available or not. The same approach can be applied to street parking and this data can be transferred to a driver's App, but the cost of this solution is prohibitive and involves high maintenance cost. For example Avenida

Liberdade, in Lisbon, has around 1,1 km and a solution with parking sensors was implemented for an investment value of 80K€ with associated annual maintenance cost of 10K€. The proposal in this research aims at avoiding these costs (investment and maintenance) and is based on a collaborative approach to detect if parking spaces are occupied.

## 2. State of the art in sensors

Many parking systems have been proposed in recent years. These work based on installed sensors that collect information about each individual parking spot. These sensors detect the presence of a vehicle or other objects. They can range from a simple ultrasonic sensor that detects a vehicle based on a threshold distance or RFID chips that are activated based on distance to complex optical sensors. These sensors can be divided into two main categories: namely, intrusive and non-intrusive sensors [3]. Intrusive sensors are sensors that are typically installed in holes on the road surface, including active infrared sensors, inductive loops, magnetometers, magneto-resistive sensors, pneumatic road tubes, piezoelectric cables and weigh-in-motion sensors. The main problem of these sensors are installation and maintenance cost. The non-intrusive sensors, by their nature, do not have the installation problem and encompasses microwave radar, passive acoustic array sensors, passive infrared sensor, RFID, ultrasonic, BLE beacons and video image processing. Non-intrusive sensors can be easily installed and maintained and do not affect the surface involved in the process.

Active infrared sensors detect vehicles based on infrared energy. These can detect the amount of energy reflected and most of the installation effort is based on multiple beams that can measure the vehicle position, speed and class [3, 4]. The main working problem is its sensitivity to weather conditions (example of fog or snow).

The Inductive Loop Detectors are used mainly for getting accurate occupancy measurements based on wire loops with frequencies ranging from 10 to 50 kHz. This frequency oscillation changes with vehicle presence and it is one of the most used sensors to detect the presence of a vehicle in a spot. The main issues are the installation and maintenance costs and the fact that these sensors are sensitive to water, especially if the pavement is cracked.

Fluxgate magnetometers work by detecting perturbation in magnetic field and have as main advantage being insensitive to weather condition such as snow, rain and fog. They are also more accurate and less susceptible to traffic stress than loop detectors. Among the disadvantages of using fluxgate magnetometers are the small detection zones in some models that require that multiple units are needed for full lane detection as well as the close proximity required for accurate detection [3,5].

Magnetometer Induction or search coil magnetometer identifies the presence of a vehicle in a spot by measuring the change in the magnetic flux lines caused by the moving vehicle according to Faraday's Law of induction [3, 6]. Some models can be installed without the need for pavement changes and have the advantage of being insensitive to weather conditions.

Magnetoresistive sensor are in general light and small, allowing versatile installation, low cost and are able to work in all temperature registers in earth surface [7]. They work by simply being energized with constant current [6].

Piezoelectric sensors are created from a material that is able to convert kinetic energy into electrical energy when subjected to vibration or mechanical impact, so it can detect when the vehicle is on and can detect speed and vehicle distance axle. For parking situations it has the disadvantage of the need to use multiple detectors to detect a vehicle presence in a parking spot.

There is also a diversity of others sensors like: Pneumatic road tube, Weight-in-Motion (WIM) sensors, Microwave radar, Passive infrared sensors, RFID and Ultrasonic sensors.

There is also the possibility of using CCTV with the drawback of some incident position of the working system. This approach works well in closed environments but on the streets there is the problem of the sun light at the beginning and end of the day. They are based on advanced digital signal processing (DSP) that transforms video cameras into intelligent counting sensors. Its stand-alone design enables it to detect and count vehicles utilizing video received from IP and/or analog video cameras The software even stabilizes the video image by removing camera and vibration effects. Advanced background algorithms then ignore any nuisance images, such as shadows or lighting changes uncertain limits. Once an object in detected, a filter is applied to avoid counting nonvehicle items, such as humans and luggage, or vehicles not moving in the desired direction.

Sensors implanted, in general, are expensive to deploy and maintain (e.g.,[8] cost USD$500 per system for each parking space, and [9] cost USD$400 per system for each car). These sensors may underperform in extreme weather conditions. Using mobile phones is cheaper, more convenient, and more flexible.

**BLE Sensors** - There is a new type of sensor devices that opens several business opportunities in healthcare, sports, beacons, security, monitor and home entertainment industries. This Bluetooth Low Energy (BLE) is a wireless personal area network technology that once compared to the Classic Bluetooth is intended to provide considerable reduced power consumption and cost while maintaining a similar communication range. Bluetooth is a low-cost, short-range wireless technology with small footprint, small power consumption, reasonable throughput and hence suitable for various small, battery driven devices like mobile phones, PDAs, cameras, laptops etc. Also in this context we have beacons with around 3-5 centimeters, a small hardware radio device that broadcasts data over Bluetooth Low Energy (BLE). BLE operates spectrum band (2402-2480 MHz), divided in 40x2MHz physical channels and uses GFSK variation, attaining a data rate up to 1 Mbps. Typical ranges of the radio signal is up to 20 or 100 meters (60-300 feet) and it is easy to fit it in many applications and contexts. Beacons offer the versatility of being placed anywhere - indoors or outdoors position. The challenge arises when beacons are deployed in environments that are disposed to weather conditions such as rain or humidity. Also beacons can be managed centrally without the need of going physically to where they are located.

Together with this, it is very easy to interact BLEs with mobile devices sensors, like GPS, Accelerometer and gyroscope creating a continuous monitoring process since users carry mobile devices all the time. This generates massive data (big data).

## 3. Crowdsensing

Mobile devices allow accurate tacking of world-related information and (physical) activities of citizens by taking advantage of people willing to collaborate toward a continuous data harvesting process called crowdsensing. According to [10]: “While crowdsourcing aims to leverage collective intelligence to solve complex problems by splitting them in smaller tasks executed by the crowd, crowdsensing splits the responsibility of harvesting information (typically urban monitoring) to the crowd". In other words, crowdsensing is the process where people or their mobile devices act as sensors and actuators to continuously harvest data and take actions upon the results [10]. It is a challenging task since several socio-technical issues may occur, such as the quantification of the sensing density. The users' participation and cooperation are essential in crowdsourcing [11], but users participation consume their resources such as battery and computing capacity [12]. This problem leads to an inevitable fact that many users might be reluctant to participate, which is a major obstacle to mobile crowdsourcing [13]. To avoid this incentive mechanism are needed to ensure users' participation.

Geo-referencing is available through GPS on mobile devices, and the mobile app only receives the beacon signal. Rinne et al. [14] presented the pros and cons of mobile crowdsensing.

## 4. Proposed Approach to Control Parking Process

Figure 1 shows the developed approach for mobile device application. It is possible to control parking spots based on the use of BLE beacons in vehicles. These beacons transmit an identification signal that can be captured by mobile devices, which can add GPS position and be transmitted to a central system.

To incentive users' participation a reward mechanisms based on free parking is introduced.

First time drivers should register and request for a beacon. Being part of this network allows them to have reduced parking fees.


**Figure 1.** Overview of proposed approach to create a parking monitoring facility without investment costs using an ad hoc network of user mobile device collaborative process.

In order to monitor parking activity our proposal is the installation of a beacon in each vehicle (it costs around 3€, with battery life time span of 2 years). These requirements should be reinforced by law and maintenance should be responsibility of the owner of the vehicle. This works like an electronic plate number that allows vehicle identification. To avoid the creation of infrastructure and networking, our approach is innovative by the usage of citizens and their mobile devices. In this, model users get rewards for each different beacon picked and transmitted to the central parking application. This reward could be free parking time (for instance, 5 minutes parking for each transmission) and the reward could be increased if an infraction is identified. This process is performed centrally, where the beacon ID is used to check if the vehicle-parking place was previously paid for or not. This is performed by an App (in the case of Lisbon the e-parking App from EMEL (epark.emel.pt)). This ad hoc transmission checks the beacon ID and verifies if it is paid for. Infraction data can be immediately sent to the nearest parking agent who can then issue an infraction ticket or the central system can send the invoice directly to the vehicle's owner. Figure 1 shows the main working idea for the main system with beacon signals captured by mobile devices and position is added and transmitted to a central server. This information is used to check if the parking spot was reserved or not. To avoid errors, because users can receive beacons from a moving vehicle in front of the parking place, the system waits for a second notification from a different user before proceeding with the identification of a violation.

In terms of communication, Figure 2 illustrates the process, with a local Bluetooth communication with a range of 20-30 meters between vehicle beacon and user mobile device and a http connection from mobile device to the central server.

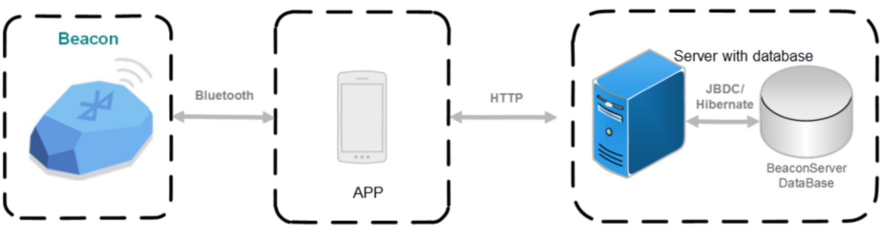


**Figure 2** – Communication process used.

## 5. Identification of free Parking Slots

We developed an interface to allow easy report on the number of free parking places in a street or to alert that the booked parking place will be free within x minutes. This collaborative process only requires power from users' mobile devices and consumes network communication but since we are transmitting data in usual communication packages this communication process does not have any impact in prices. This collaborative reporting can be performed by: 1) drivers in a car using NLP (Natural Language Processing), where the application asks about the number of identified places the driver saw. The application is calibrated to understand numbers in different languages (we tested in English and Portuguese); 2) Pedestrian, to give feedback about number of places available on the street. Geo-referencing is available through GPS on mobile devices. Under these conditions, the user needs only to introduce an estimation of the number of free places he remembers on that street.

These two crowdsensing approaches are complementary and users are incentivized to participate by the reward mechanisms introduced. Every input performed that match average performed in a pre-defined window time (this is to avoid spam inputs without any sense) gives free parking minutes in a city.

For drivers, it is possible to integrate mobile devices into vehicle's infotainment systems, it is possible to create an easy interface for drivers to give feedback about empty parking places while driving.

We tested several approaches regarding the reward. We tested using a population of 90 (60 drivers and 30 pedestrian) information providers in a three months test.

1) Every input gives 5 minutes of free parking in a green zone (low cost parking area). During the test period, we had an average of 43 notifications per day (monthly notification divided by the working days). This rewards gave around 3,6 hours of free parking in a green zone per day;
2) Every input gives 1 minute of free parking in a green zone. During the test period we had an average of 9 notifications per day. This reward gave around 9 minutes of free parking in a green zone. This meant we should increase the reward.
3) Every input gives 10 minutes of free parking in green zone. During the test period we had an average 58 notifications per day. Perhaps this is too much.

As a model, the system depends on the numbers of users versus the number of notifications performed. Lisbon has around half million person living, a surface of 100 thousands km2 and around 1500 streets [http://www.dgterritorio.pt/ficheiros/cadastro/caop/caop_download/caop_2014_0/areas fregmundistcaop2014_2].

To be able to work in peak times (9am to 6pm) the system needs notifications with a periodicity of 5 minutes; we need around 108 notifications per street. The rest of time: 1) 6pm to 12am and 6am to 9am, we need notifications with a periodicity of about 10 minutes, which gives 90 notifications per street; and 2) the remain time, from 12am to 6am, only hour to hour notifications are required. This gives the need for 200 notifications per day per street, so about 300 thousands per day. Estimating a goal of 50 notifications per user per day, the system needs 6000 users. Figure 3 illustrates this process.

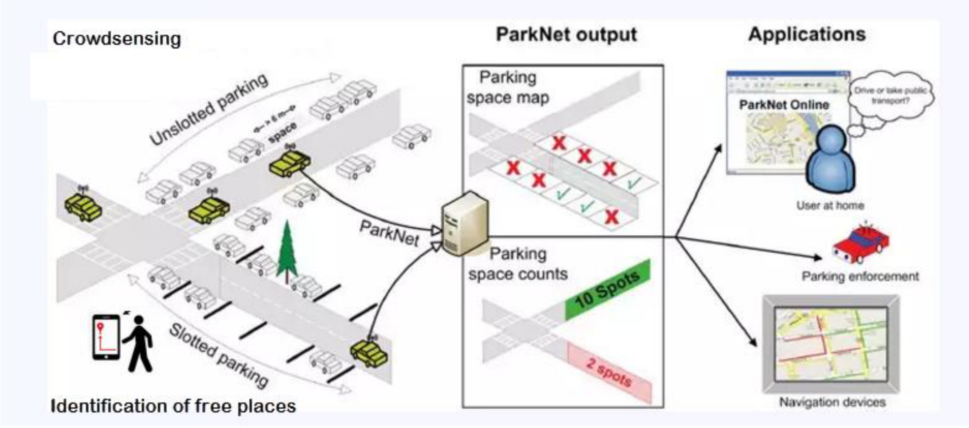


**Figure 3-** Users notification about free parking places, based on a crowdsourcing mechanism approach

**Spam -** To avoid spam we need more notifications to extract the average, deviations are treated as spam, and those users can be removed from the system. To avoid the creation of different logins, users are validated based on fiscal number.

## 6. Lisbon Pilot on Control Parking Process and Results Discussion

Lisbon has around 400 thousands vehicles entering in the city on a daily basis and 150 thousand parking places, according the information from Lisbon Municipality.

Current test is performed in collaboration with EMEL - Municipal Mobility and Parking Company of Lisbon and connected with their App - ePark application, which during its first year of operation has already raised more than 180 thousand users and processed more than 5 million parking spots. This App assumes mobile devices with users in the vehicle and gives georeferenced based on GPS information transmitted. From this users can pay the parking, set the exact time that drivers want to park, with a minimum of 15 minutes, and change parking time at any time. It is possible to view all active / inactive parking spots and ask for invoices from the App itself. From this, it is possible to handle the reservation process from where it is added the beacon information.

So testing is to avoid current control parking process performed by human agents, which goes to the street to check vehicle parking. These agents are distributed per street zones and for our testing purposes, we use one of these zones using as population students and teachers of our university who usually drive to this area and park the vehicle in a testing population of 25 drivers. To these vehicles, we associated a beacon. So, for the proposed test, we bought 25 beacons for 75€ (3€/each). The hardware chosen was the ARM NRF51822 from (Nordic Semiconductors, the SoC (System on Chip) with memory of 256KB Flash, 32KB RAM, serial interfaces I2C, UART. We added the core 51822, a microcontroller powered by the Nordid chipset nrf51822 (see Figure 4). The proposal works with others beacon solutions and a plastic box was also developed to put sensor and facilitate their colocation in the vehicle.

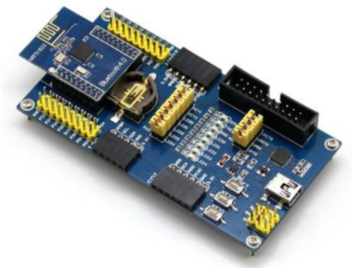

**Figure 4 –** BLE used from core 51822 with ble200 from waveshare. To this we add the battery and plastic box protection.

A population of 5000 users was invited to participate in the testing of the project. From here we collected data from 454 users. These users participated in a testing for a period of 3 months in 2017 and on average collected data from 17 beacons per day (only working days were considered). The testing was only based on the running in the mobile device a process that capture Bluetooth data and selects only beacon signal (to avoid the capture of others Bluetooth devices). To this beacon data the process adds mobile device GPS information and transmitted to a central server and counts the transmission performed.

This provided around 500 thousands beacon data transmitted. For each beacon data transmitted the users received 0,05€ as reward (this value should be checked in a future test to assess what is the best value to use). From the data received it was possible to identify 634 infractions (parking without the payment) and in these cases the user reward was 0,25€. These rewards are used only for parking purposes in the city. We noticed that drivers participated on this process to try to collect money for their parking process in the city. As they need to pay a daily fee of at least 2€ for a ful day of parking, most of then try to collect beacons until reaching that amount (around 40 beacons signal collection).

The proposed process system, is based on the principle that if the vehicle is parked the beacon signal can be captured by citizens with mobile device with Bluetooth on. Beacon ID, time and GPS coordinates were captured by mobile device and transmitted through a mobile device data network to a central server. This server collected this data and the identification of mobile device sender for the reward mechanisms. This data was compared (vehicle ID, time and place) with previous reserved information from the parking management system. Deviations were computed and penalties were automatically issued to the vehicle owner. In this initial phase external publicity is needed for citizens to be aware of this service and collect the parking slots data through their collaborative actions. Beacon transmission frequency was set to 30 seconds (pooling time takes effect on battery life time) and each beacon can be transmitted in time windows of 15 minutes to avoid spam (users that transmit data on the same beacon several times just to receive money).

We compared this collaborative control process with the work performed by control agents and we checked that this collaborative process catches more information and infractions but has the problem of beacon information collection distribution process over the day period (in general missing information on periods 15h-16h and 11h-12h) and also streets do not receive as many readings as desirable. There are time periods for which that are too many notifications and others when they are missing. This might be overcome by making the reward money dependent both on the time window and the zone to incentive a more uniform distribution. These problems could also be solved by increasing the population collecting this beacons information. Taking into account that this zone control testing was performed by 3 agents the reward should be based on these agents' salary and perhaps a better reward model can be studied.

## 7. Conclusions

We show a collaborative network of beacon collection to implement a parking control approach without the existing of dedicated solution. Users can participate in this process and collects free parking minutes for their own usage. This proposal needs a complete electronic solution for parking payment and needs beacons that are not implemented in every vehicle but the economics benefits are considerable because there is not the need of a dedicated infrastructure. Current payment solution can be adapted for the correlation among vehicle plat number to a beacon reference.

Identification of free parking places are important information to handle the problem of guidance of drivers to free parking places. Again, this system can work without big investments on sensors or other related equipment.

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