Towards a rational use of loading and unloading areas in urban environments

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ABSTRACT

Despite the efforts of the authorities, that promote the use of alternative transportation systems, the traffic still increases in European cities, leading not only to traffic jams but also to pollution episodes. Delivery vehicles are part of both problems, because of their intensive use, the advent of e-commerce, the limited number and sizes of loading and unloading areas in many ancient European cities, and the difficulties associated to keep track of the correct use of these spaces.

In this work we propose an holistic solution to the management of delivery vehicles in urban environments. Our solution, called RYDER, is based on the use of BLE (Bluetooth Low Energy) devices that should be provided by the local authority to delivery vehicles, as part of their authorization to use the loading and unloading areas. With the help of low-cost, low-power antennas with Bluetooth and 4G capabilities installed next to each loading/unloading area, the authorities are able to know in real time (a) the use of these areas by delivery vehicles, (b) the paths of the vehicles while they travel across the city, (c) the time spent in each area by each one of them, and (d) with the help of a mobile/tablet App, the local Police can check in seconds the permissions of each vehicle using these public spaces. Moreover, the use of a GIS-based platform allows the Traffic Department to track online each particular vehicle, based on the loading/unloading spaces being used, and to infer the most representative paths they follow, an information that may guide the decision about where these spaces are really necessary and whether each particular vehicle follows their associated usage rules.

The deployment of RYDER low-cost antennas can also serve for other purposes, such as to track the routes followed by public loan bicycles, or by other fleets of public vehicles. With the help of low-cost sensors, antennas can also return an estimation of pollution values, such as levels of ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrous oxide, among others. This information may in turn drive the installation of certified pollution detectors.

Keywords: delivery vehicles, loading/unloading areas, low-cost sensoring, sensor deployment, Bluetooth Low Energy, beacons, pollution, smart cities, transportation, vehicles

1. INTRODUCTION

Pollution episodes and traffic jams in many European city centers are considered normal nowadays. Although the use of bicycles is common in many Central Europe cities and towns, and their popularity is increasing in other regions, the gases generated by internal combustion vehicles forces the authorities to keep a close look to pollution levels. In turn, this leads to the installation of complex and expensive pollution measurement stations, devices that also need a noticeable space and that do not fit well in the city centers of many ancient European cities.

There are four main groups of internal combustion vehicles in our streets: private-owned cars, public transport vehicles, such as buses and taxis, service vehicles, such as those dedicated to waste collections, and delivery vehicles. Private users may be encouraged to use public transport systems, that are gradually switching to non-polluting engines; waste collection trucks usually belongs to local administrations or subcontracting companies,

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so it is also possible to gradually replace them with trucks that incorporate cleaner engines. However, it is very little what the local authorities can do with respect to delivery vehicles, apart from obligate them to undergo periodic inspections. In fact, local authorities do not usually know much about them. Very little is know about their routes inside the city. Classic systems used to measure traffic, such as metal detectors used to measure the amount of traffic, can not distinguish between private and delivery vehicles. The use of surveillance cameras may help to discriminate between them, but it is still difficult to track a particular vehicle during its delivery itinerary. The advent of e-commerce and the limited number and sizes of loading and unloading areas in many ancient European cities, together with the difficulties associated to keep track of the correct use of these spaces, makes the daily movement of delivery vehicles a source of both pollution and traffic jams.

Having more information on the routes followed by delivery vehicles can help the local authorities in several ways. First of all, the number and size of loading and unloading areas may be properly adjusted to their effective use. Nowadays, these areas are designed based on guess, but there are not figures that support these decisions. A second advantage of knowing the main routes followed by delivery vehicles is that it can help the authorities to better schedule traffic cuts for repairing works, since they will have the historic information needed to disturb traffic as little as possible. This is not a minor advantage: While private drivers may reach their destination to certain areas of the city center by feet or using public transportation, many goods should be delivered on time to supermarkets, pharmacies and shops. The commercial and social implications of disturbing delivery traffic is a major concern to local authorities.

There exists many systems to keep track of fleets of vehicles based on GPS, such as Tookan,[1] Orbcomm,[2] or Amac.[3] By installing a GPS receiver with GPRS/3G/4G capabilities, the fleet manager can keep track all the company vehicles online, representing their movements on an interactive map, usually web-based, and accessing to their movement statistics. While being an excellent solution to manage fleets, GPS-based systems are of little use for the authorities to keep track of delivery vehicles, due to several reasons. First, the cost of the devices that should be installed in each particular vehicle are in the range of several hundred euros. Second, these devices need a communication link to transmit their particular position, and these communications impose additional costs. Third, the GPS coverage in many European cities are far from optimal, due to the existence of many narrow streets surrounded by buildings, making GPS-based solutions to greatly reduce their accuracy during potentially long time intervals.

In this work we propose an holistic solution to tracing the behavior of delivery vehicles in urban environments. Our solution, called RYDER, is composed of four main elements:

- Low-cost, low-energy Bluetooth[4] beacons, that are provided by the authorities as part of their authorization granted to delivery vehicles to use the city loading and unloading areas, authorization that the drivers should expose in their vehicles' dashboard.
- Low-cost Bluetooth receivers, based on Raspberry Pi 3.[5] These receivers are installed in each loading and unloading area to be monitorized. Additional receivers can be installed in strategic junctions of the city, to better track the delivery vehicles in their daily route. These receivers transmit all the gathered information to a cloud-based service.
- A cloud-based service receives the information collected by the antennas, processes it and delivers all types of statistical information to the local authorities, both in text and web-based form, including GIS-based positioning in real time.
- An *app* for smartphones and tablets, called Fisher, that allows the Police agents to check whether the vehicles in a 30-meters range effectively owns the authorization cards and beacons they show in their dashboard.

With our solution, the authorities are able to know both in real time and from an historical perspective a vast amount of information regarding delivery vehicles, such as their use of loading and unloading areas, the paths of the vehicles while they travel across the city, the time spent in each area by each one of them, and, since the local authorities know the model and age of each vehicle being authorized, an estimation of the accumulated weight supported by each street, an information that can be used to make preventive maintenance. Moreover, with the help of our smartphone/tablet *app*, the local Police can check in seconds the permissions of each vehicle using these public spaces.

One of the main advantages of this solution is that the technology involved is relatively inexpensive: BLE emitters cost are falling, and many DIY platforms such as Raspberry Pi 3 comes with Bluetooth and WiFi connectivity.

In this paper we will examine in detail the solution design space to the problem of vehicle detection, discussing the main advantages and drawbacks for each alternative. We will then describe our proposed solution in detail, enumerating its functionalities. We will also discuss the possibility of using these antennas to also measure pollution, thanks to the use of ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrous oxide solid-state sensors. Other sensors to measure light and noise pollution are also simple to add, making these antennas the all-in-one solution for smart cities sensing.

The rest of the paper is organized as follows. Section 2 discusses the technological alternatives to GPS that may be applied to solve this problem. Section 3 describes in detail the hardware and software involved in the development of the RYDER project. Section 4 examines the possibilities for local authorities that the deployment of the RYDER project offers. Finally, Sect. 5 concludes our work.

2. TRACKING VEHICLES: TECHNOLOGICAL ALTERNATIVES

As we stated in the previous section, GPS-based solutions are not applicable to the problem we aim to solve: GPS receivers are expensive; they need additional hardware for communicating the information outside the vehicle; someone should pay for the communication costs associated to each vehicle; and GPS coverage is far from optimal in the center of many ancient European cities.

Designed as an alternative to GPS, Local Positioning System (LPS)[6] do not offer a global coverage. Instead, they cover a relatively small area, delimited by the range of the receivers being used. These receivers are installed in known positions, and, with the help of appropriate algorithms, they allow to locate an object or a person in a local coordinates system.

During the last years, different LPS techniques have been proposed, such as Infrared, Ultrasounds, WIFI, RFID, or Bluetooth. Recently, some new alternatives have appeared, such as the use of the Ultra-Wideband (UWB) technology. Each one of these alternatives offers a solution with unique characteristics in terms of range covered, precision, sensibility to obstacles, and cost, making them suitable for specific use cases. A general solution, that allows positioning in real time, with good precision, fast response to movements, good range of operation and inexpensive has not appeared in the market yet.

There exist different works describing the state of the art in the field of LPS and Indoor Positioning, such as.[7,8] These works center the discussion in four main alternatives: RFID, Ultra-Wideband, Bluetooth, and Ultrasound, analyzing how they work and they advantages and drawbacks of they deployment in real scenarios. The literature in this field is abundant, and some of these technologies have been used in the field of LPS for years. In this section we will examine the subset of solutions that may give an answer to the particular restrictions of our problem, that can be summarized as:

- Real-time positioning, with a precision in the range of a few meters.
- Deployment in uncontrolled environments, with movement of people and objects.
- Positioning with minimal participation of the person or object being tracked.
- Low-cost solutions, to allow their economical viability.

2.1 RFID: Radio Frequency Identification

RFID technology[9,10] has a long history that can be traced to World War II, when the Allies started using radar systems. To let the radar system distinguish between friends and enemies, Allied pilots rolled their planes when returned to base, thus changing the radio signal reflected back. Nowadays, passive RFID technologies are based on the use of small tags, composed by a chip and an antenna. Their most well-known use is to read the information stored in them. RFID systems come in two flavors:

- Passive RFID: Uses simpler tags, that are activated thanks to the energy transferred by the RFID receiver using radio frequency. For this reason, they operational range is severely limited (about three meters).
- Active RFID: Tags have their own batteries, increasing their operational range (up to 100 meters).

Although RFID tags are very cheap (particularly passive RFID tags), this technology present several disadvantages. First of all, RFID readers are expensive. Second. RFID reads have a strong directional component, making necessary to install more readers for an acceptable coverage. For these reasons, the positioning systems based on this technology are better suited to detect their transit under a RFID reader than to use them for real-time positioning.

With respect to our problem, RFID systems have the advantage of the low cost associated to their tags. However, the need of expensive, directional receivers makes this solution unfeasible for the problem of local positioning of vehicles in the streets.

2.2 UWB: Ultra-Wideband

Ultra-Wideband (UWB) technology[11,12] is relatively new. It consists in sending wide-band pulses. A UWB-based positioning system consists on the use of a set of fixed stations and a number of UWB emitters. The system works as follows:

1. The emitter sends a first message.
2. The receiver gets this message and sends an answer.
3. The emitter receives the answer and sends a second message.
4. The receiver gets the second message and calculates the distance by using the time difference between both messages received.

UWB is a promising technology for LPS, showing several advantages, such as a relatively low energy consumption, relative insensitivity to obstacles, high data rate transfer thanks to the use of a wide band, and an error margin in the order of centimeters. However, this technology has also some drawbacks. The first one is its cost, still high to allow large-scale deployment. A second problem is that UWB signals interfere with GPS systems, as well as with systems that works in the frequency ranges of 250-750MHz, 3.2-4.7GHz, and 5.9-10.2GHz. A third drawback is that it needs the use of specialized receivers: Low-cost computers and smartphones are not directly capable to interact with them.

For cases when the interferences with GPS systems were acceptable, and if deployment costs continue to fall, and if smartphones were able to act as receivers, this solution would allow an economically feasible solution with an excellent precision. However, this is not still the case for the problem described in this paper.

2.3 Ultrasounds

Ultrasound-based solutions[13,14] can be used to local positioning and tracking of persons and goods. This technology is sometimes complemented with the use of RFID technologies for synchronization tasks. Its main advantage is that is a low-cost technology.

There are three different ultrasound-based LPS. The first one is known as *bat*. The people or goods that are wanted to be localized carry an emitter that is activated by receiving an external signal. A network of receivers get the answer, thus allowing to determine the position of the emitter. The second alternative, called *cricket*, uses emitters in fixed locations that send ultrasounds to receptors carried by the people and goods to be tracked. Finally, the *dolphin* system is a symmetric solution, where all devices are equal, and some of them are fixed in known positions. The exchange of ultrasounds allow the system to estimate the position of the mobile devices.

The main disadvantages of this technology are that signals can not overcome obstacles such as walls; refractions severely affects the measurements; and the identification of the particular object being tracked is problematic. These limitations make ultrasounds a non-acceptable solution for our problem.

2.4 Infrared

Infrared-based technologies have been extensively used for indoor positioning.[15,16] These systems need direct vision between an infrared emitter and its corresponding detector. The positioning is calculated using triangulation algorithms, so both the angle of incidence and the position of the fixed elements should be known.

As with other technologies, this system can be indistinctly used by emitters and receptors. In any case, the need of direct vision from them limits its use to situations where this visual line can be maintained to carry out the triangulation process. For the identification of the particular object being tracked, each object should send an identifier. The relatively low bandwidth is related to how frequent is the data being sent, and it needs adequate synchronization mechanisms.

Infrared devices can reach a very high precision, in the range of centimeters. However, their use in LPS poses challenges that are difficult to overcome: The need of visual contact between devices, the deployment difficulties associated to this fact, and the limited bandwidth for identification purposes.

2.5 Computer Vision

Computer vision systems can be used to develop a LPS system.[17] The system is composed by a set of cameras that captures images of the area to be covered. Images are sent to a remote server for processing, identifying the position of the person or element to be tracked. To do so, the server should detect some identification marks.

The advantage of computer vision systems is that they are completely non-intrusive: They only need a set of fixed cameras in known locations. However, it present some disadvantages, such as the need of computing power to perform tracking at real time, the need of training to detect and identify certain objects, and the high cost of the hardware and software involved.

With respect to our problem, the use of computer vision systems are widely use to recognize licence plates in roads around the world. To use this technology for our purposes is somewhat problematic, because in narrow streets we do not always have a clear view of the delivery vehicle in order to read their license plate. Second, such a read would allow us to know that the vehicle was in that position at a certain time, but, unless we combine the lecture of the license plate with sophisticated vision algorithms, it is hard to tell how long the vehicle was parked in a loading/unloading area, where the licence plate is not longer visible. Third, the processing of the captured images can be done either locally or remotely. Local processing requires expensive hardware. Remote processing, on the other hand, requires high bandwidth to send the images to the central server, increasing the communication costs. These reasons make computer vision solutions not optimal to track the behavior of vehicles in urban environments.

2.6 Bluetooth Low Energy

Bluetooth Low Energy (BLE) devices are a type of WPAN (Wireless Personal Area Network) device, although their operational range could reach 30 or 40 meters, at the expense of a reduction in the bidirectional capabilities of information transference. For LPS systems this does not represent a problem. These devices operate in the band of 2.4GHz and their energy consumption is particularly low, allowing long autonomies (in the order of years) with a single coin-cell battery.

LPS based on BLE[18, 19] consist of a set of BLE emitters, called beacons, and a set of BLE receivers. These systems allow two different usage strategies. The most common one is to deploy a set of beacons in fixed places. These beacons sends data packets at fixed intervals between 0.1 to 5 seconds, usually using the *iBeacon*[20] protocol. A receiving device is in charge of reading these packets. Based on the perceived intensity of the signal received, the latter can calculate the distance with respect to each beacon, allowing the calculation of its position.

This approach has several advantages:

- The computing needs are transferred to the receiving devices, who just need to take care of their own position with respect to the beacons that send the incoming packets.
- The deployment complexity is greatly reduced.
- The receiving devices can be either low-cost, general-purpose computers, such as the Raspberry Pi platform, or smartphones running an Android or iOS application.

However, this approach shows also some drawbacks:

- The precision is in the order of 3..5 meters, so this technology is not useful when the precision required is greater.
- Its use require the elements to be located to carry a computer or a smartphone.
- The duty of calculate and communicate the localization is transferred to the user, a situation that can be a problem in certain circumstances.
- This solution needs a computer or smartphone for each element to be localized. In scenarios where there are more elements to be positioned than places to be covered, this is an issue in economic terms.
- While the autonomy of a beacon is measured in years, the autonomy of the receiver is just a few hours, making this solution unfeasible when the element to be positioned does not have an energy source.

The second approach is the opposite one: Beacons are carried by the people or elements that should be positioned, and the receiving computers are installed at fixed locations. This solution offer a solution to the problems described above:

- The user or element to be positioned does not need to make any effort to keep the system running: They just need to carry the beacon.
- Beacons are relatively inexpensive (less than 20 euros at the time of writing) so it is a feasible solution when the number of elements to localize is greater than the places being covered.
- Beacons run during years with a single coin-cell battery, allowing the tracking of elements during long periods of time.
- Fixed receiving systems, that need an external source power, can be connected to the electricity grid or be fed with the help of small solar panels.

Figure 1. XtremeLoc (XLoc) beacons and receiving antenna. Beacons have a diameter of around 45mm.

Figure 1 shows some beacons and a Raspberry-Pi receiving antenna developed by RDNest, a spin-off of the University of Valladolid, Spain. These elements are part of the XtremeLoc (XLoc) solution developed by the company, intended to offer LPS localization services for situations where GPS is not a feasible solution. As indicated in the figure, beacons can be easily carried by the element to be tracked, while the receiving antennas, build with IP protection, can be installed in either indoor or outdoor facilities. RDNest has also more discreet antennas to be seamlessly installed in offices. The RYDER project consist of using XtremeLoc antennas and beacons, together with specialized software, to monitorize the traffic of delivery vehicles in urban environments.

2.7 Why the use of LBE is the best solution to our problem

The latter solution described, with mobile elements carrying beacons and fixed receiving antennas, is particularly well suited for the problem of tracking vehicles in urban environments, for the following reasons:

- The associated costs (less than 20 euros for beacons and a few hundred euros for antennas) makes the solution economically feasible at different deployment scales.
- The precision of this solution is adequate for this problem, consisting in detecting vehicles within the areas to be monitorized;
- The range of 30..40 meters is adequate for our needs, covering many loading/unloading areas with a single antenna (more antennas can be installed on demand).
- Although precise positioning can be calculated by setting up at least three receiving antennas, it may not even be necessary, since a single receiver per loading/unloading area suffices to detect the presence of vehicles within range and their distance to the antenna.
- Since beacons emit a packet at intervals in the range of seconds, it is straightforward to know how much time has the delivery vehicle spent in the loading/unloading area.
- The autonomy of beacons, that last 2..4 years with a single coin-cell battery, is adequate for tracking delivery vehicles. When the beacons run out of battery, it can be easily replaced without losing the beacons' configuration. Moreover, the beacons continuously emit their percentage of battery left.
- Communication costs are modest: each receiving antenna incorporates a SIM card and transmit all the gathered information to a central server at regular intervals.
- Identification of the particular vehicle is straightforward, since each beacon emits an unique identifier.
- Additional antennas may be located in important streets and junctions, to better keep track of the movements of vehicles in the city.

All these reasons make LBE technology the best choice for tracking vehicles in urban environments. Moreover, the same technology and the same antennas deployment can be used to track other vehicles as well, such as bicycles that are part of a public loan system, or public service vehicles.

3. HARDWARE AND SOFTWARE INVOLVED

The solution developed by RDNest consists of four main elements:

1. A set of general-purpose beacons, incorporating the iBeacon protocol, adequately configured for this problem (with unique identifiers and transmitting power and frequency).
2. A set of low-cost receiving antennas to be installed in the areas to be covered, that send the collected information to a cloud-based service.
3. A cloud-based service that keeps track of the elements and show the results in an online map, offering also historical and statistical information.
4. A smartphone/tablet *app*, called Fisher, to help the Police agents to check whether all beacons in range effectively belongs to the delivery vehicles they are installed into.

3.1 Receiving antennas

Antennas are based on the Raspberry Pi 3 platform,[5] with some additional hardware. This platform is a complete, inexpensive computer system capable of running Linux and with extended connectivity, including not only Bluetooth but WiFi and Ethernet. 3D/4D connectivity is possible by adding a SIM800L GPRS module using the Raspberry Pi GPIO pins. The system incorporates a MicroSD card to store the operating system and the dedicated software.

The antennas developed by RDNest run a tailored version of GNU/Linux, compiled entirely from scratch, that consumes just 100MB. An exclusive, proprietary software solution minimizes the number of accesses to the MicroSD card, performing an initial read at bootup and not accessing again except in very special circumstances. This behavior greatly augments the lifetime of MicroSD cards, that are known to start degrading after a certain number of read and write cycles. This behavior also makes the antennas extremely robust to unexpected energy interruptions, since no data is stored locally, except when a momentary connectivity problem arises.

Software updates are also handled automatically. At bootup, the antennas register themselves in the system. As part of the response, the cloud-based server checks if there is any software update to deploy to them, and transmit it to the new antenna. The system guarantees that the new update is not installed in the antenna until it has fully downloaded and its integrity has been checked. Time-based synchronization is also carried out at bootup. All communications are carried out with SSL encryption.

At regular intervals, the antenna scans the Bluetooth spectrum, chooses the incoming packets that belong to XtremeLoc beacons, and sends this information to the cloud-based server in JSON[21] messages. Information sent includes the identifier fields of each beacon, the measured intensity of its signal, a timestamp, and additional information such as its percentage of battery left, a very useful data when several thousand beacons have been deployed and many of them can stop working unexpectedly.

3.2 Cloud-based service

The cloud-based service is responsible of receiving and storing the information sent by the antennas, handling their software upgrades, and return the information to the end user. The most simple information returned is the real-time situation of the different loading/unloading areas (see Fig. 2), including the number of vehicles detected in each one and their current capacity (with respect of the total number of vehicles that can use each area). The color of each loading/unloading area (green, yellow, red) changes not only because of the number of vehicles, but also taking into account their length with respect to the total space available in the loading/unloading area: When authorizing a new delivery vehicle, the local authorities gathers the model of the vehicle being authorized, so all its data (length, maximum authorized weight) is known by the system.

Besides the occupancy information, the system is also able to represent (pale blue boxes in Fig. 2) the number of delivery vehicles detected in important junctions of the city center, thanks to the use of additional antennas. These antennas have several purposes: to estimate the traffic of the corresponding junction due to these vehicles, and to capture additional information on the routes followed by each vehicle.

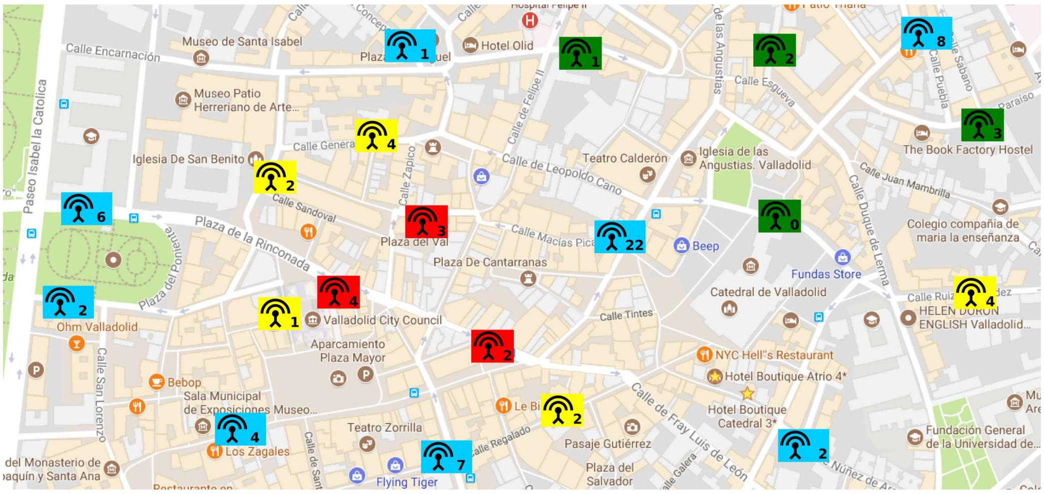

Figure 2. Screenshot of basic GIS-based information on loading/unloading area current occupancy.

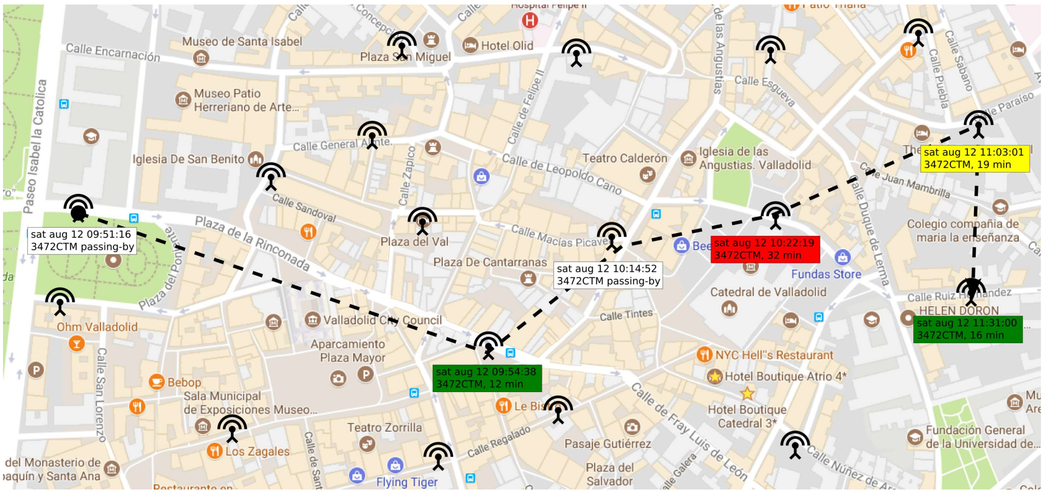

Figure 3. Screenshot of the behavior of a particular delivery vehicle during its delivery activities.

The system is not only intended to show the occupancy of loading/unloading areas. It also serves to study the behavior, both individually and aggregated, of all the delivery vehicles that works in the area monitorized. Figure 3) represents the route followed by a particular delivery vehicle during one morning, based on the packets received by the antennas and their corresponding timestamps. Note that, although we may infer the particular route followed by the vehicle using timestamps and the underlying cartography, we only can guarantee that the vehicle was indeed present in the areas covered by our antennas. This is why we do not draw an inferred route across the city. Colors indicate the amount of time spent in each area. As long as the maximum time the areas can be used in our city is 20 minutes, we can color each visit according to the behavior of the vehicle with respect to the local regulations.

The cloud-based server does not only return real-time information. It can be configured to obtain all kinds of reports about the fleet of the authorized delivery vehicles in the city, and to infer the amount of delivery traffic supported by each street in any time interval according to different parameters, such as the number of vehicles, their size, and their estimated weight. We will return on this topic in Sect. 4.

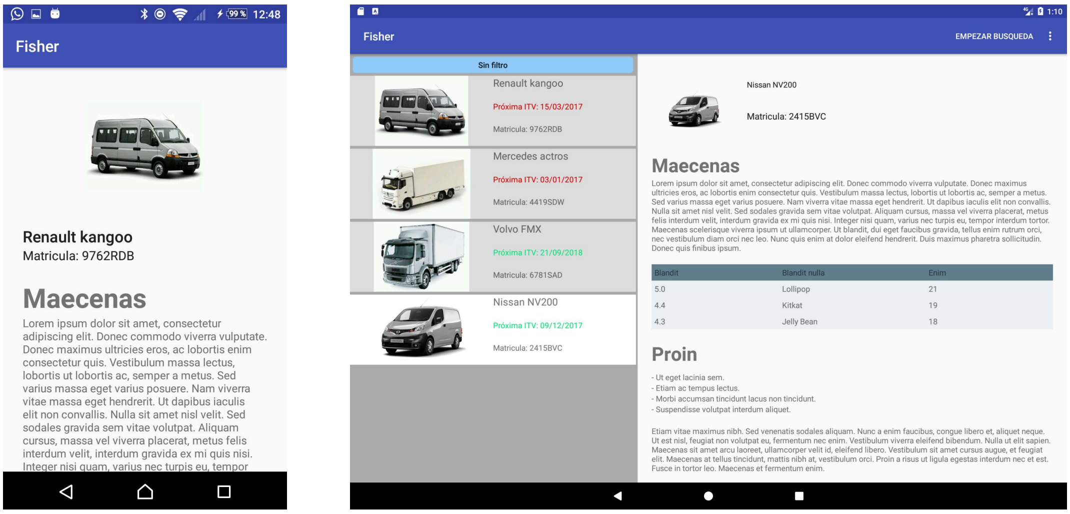

Figure 4. The Fischer app quickly returns information about the vehicles associated with the beacons within range.

3.3 Inferring and measuring pollution

To measure pollution at the city center is not an easy task. Pollution counters are big, complex and expensive systems that can not be seamlessly installed in the narrow streets of many ancient European cities.

The RYDER project can be also used to both infer and measure the pollution in the city center. Pollution may be inferred by combining all the information regarding the delivery vehicles being tracked by the system. The system knows the model of each vehicle, their age, and the time each one of them spent in different points of the city. This information, adequately combined, may give an idea of the pollution that can be expected to be suffered at particular times in different parts of the city.

However, it is always better to measure than to infer. The receiving antennas can be equipped with different low-cost sensors. Magnitudes subject to measure include ozone, carbon dioxide, sulfur dioxide, nitrous oxide, and suspended particles, together with temperature and humidity. All these measurements are transmitted by the antennas in JSON messages, together with the information regarding the Bluetooth beacons within range.

The measures obtained, although unofficial (because the measurement instruments are not certified for this purpose) can give additional insights about the pollution of the city, both at real time and in historic terms, and can in turn guide the installation of certified pollution counters where they are really necessary.

4. APPLICATIONS

The deployment of RYDER to monitorize vehicular activity in a city has a myriad of applications, including:

- To know the real use of all loading/unloading areas of the city.
- To detect at real time vehicles that have exceeded their authorized usage time for a particular loading/unloading area, indicating this fact to Police agents surrounding the area.
- To offer to local authorities all kind of information about the delivery activities in the city, both at real time and aggregated.
- To offer the owners of delivery vehicles an estimation, both at real time and historically, of the usage of the loading/unloading areas, to better schedule their activity.
- With additional processing, the system can answer many interesting questions, including:

  - The approximate path followed by each delivery vehicle, and by all the vehicles that belongs to the same delivery company.
  - The type of vehicles that use each loading/unloading area.
  - The time intervals with bigger amount of delivery traffic for each city zone.
  - Which loading and unloading areas requires more space, and which ones can be safely reduced or removed.
  - How much time spends the vehicles in each area on average.
  - How much weight due to delivery vehicles suffers each area.
  - With the help of other sources of information and Big Data techniques, a complete model of the traffic of the city can be built, including the contribution of all types of vehicles.

- Optionally, the deployment of RYDER can also give the local authorities an estimation of the pollution in different parts of the city, by measuring ozone, carbon dioxide, sulfur dioxide, nitrous oxide, and suspended particles, together with temperature and humidity. This information, although unofficial, can guide the local authorities to examine the need of setting up certified pollution measurement equipments at certain places.

The use of beacons in each vehicle can also allow the authorities to detect improper use of the authorization cards issued by the city. We have developed a smartphone/tablet *app*, called Fischer, that helps the local Police to quickly check whether the beacon shown by a particular vehicle indeed belong to it. The Fischer *app* shows the Police agents the characteristics of the vehicles associated to all the beacons within range (see Fig. 4).

5. CONCLUSIONS AND FUTURE WORK

The RYDER project is a complete sensoring solution for smart cities, that can be used for multiple purposes, including the use of loading/unloading areas, the estimation of pollution, not only due to exhaust gases, but also due to light or noise, and the tracking of all kind of vehicles and people that carries a Bluetooth emitter. Additional use cases are easy to imagine, from tracking valuable goods to mascots, among a myriad of other uses.

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