ParkingSpot - Parking Management and Information System

Miguel Matos de Almeida
Instituto Superior Tcnico
Av. Prof. Dr. Cavaco Silva
miguel.d.almeida@tecnico.ulisboa.pt

***Abstract*— This document intends to give an overview on a system that automatically detects the movement of cars using ultrasonic sensors and reads and stores their license plates while entering a parking lot. The developed system manages free parking spots and zone occupation with a low cost equipment, RaspberryPi 3, using wireless mesh networks for diverse system nodes communication, and storing all the information in a central database. This system also offers a web application to inform users about the park availability.**

I. INTRODUCTION

In large cities and urban centers, it is increasingly difficult to find free parking spots, which often leads drivers to spend a lot of time searching for free parking spaces in order to park their vehicle. This may cause traffic jams, have a negative influence on people and cause the emission of gaseous pollutants unnecessarily harming the environment [2] [10].

It is possible to determine the parking lots occupation by installing sensors in specific places of the park. The developed system has the ability of identifying cars movements by using ultrasonic sensors, and their license plates by using a low cost camera and processor in the parking lot/zones entrance. The system processes the collected data and the information is sent through a wireless mesh network with a proactive routing (layer 2 protocol), B.A.T.M.A.N.-advanced, to a main server over where it is treated and presented both to the final customer and to the park management team.

II. RELATED WORK

In this section an overview about useful related work and technologies for this implementation will be given. This section was divided into several subsections: location techniques, sensor technologies, networks concepts and protocols, and lastly intelligent parking systems overview.

A. Location techniques

There are several localization techniques than can be divided into two types: outdoor location and indoor location. The following ones are the most relevant location techniques in the context of the car parking: GPS, assisted GPS, dead reckoning and fingerprint.

Outdoor location:

a) GPS: stands for Global Positioning System. It uses a set of 24 geostationary satellites in order to give the user information so that he can compute is own position on earth. It doesn't require the user to transmit any data and has a precision of about 5 meters [12]. It was originally designed for military purposes, and was released for general public in 1980.

Assisted GPS: This technique uses information provided by the cellular network in order to aid the GPS receiver in the calculation of an accurate position more quickly. Assisted GPS reduces the time required for signal acquisition by eliminating sections of the signal search space [12].

Indoor location:

Dead reckoning: This technique consists in using previous information about vehicle's location and movements to predict future locations. It is only useful when the vehicle location at a starting point is known and when the dynamics of the vehicle movement is fairly constant. However, the estimation error can be very large when the technique is being used for a long period of time. In case of GPS outage, as dead reckoning estimates the location of the vehicle merely based on prediction and previous estimates, it only guarantees an aproximate location for a certain amount of time [7].

Fingerprint: This technique makes use of Wi-Fi or Bluetooth radio signal strengths to compute a location. It is a two stage process: offline stage and online stage. During the offline stage, the physical space is characterized in terms of the received signal strength indication (RSSI) and a map - radio map - is built. The radio map divides the test area into small cells, whose center is defined as the reference point. After the reference points are set, a mobile device can collect the RSSI values in each designated point from surrounding access points(APs). During the online stage, an unknown location can be computed by comparing the measured RSSI of all APs with those stored in the database. The RSSI pattern is then compared with the pattern of each fingerprint stored in the radio map and the highest similar neighbor is determined [11] [4].

B. Sensor technologies

Several kinds of sensors exist. The following ones are the most relevant for detect cars in a parking spot.

1) Passive infrared: This kind of sensors receive infrared waves emitted by objects. All the objects radiate when they are above absolute zero temperature. It is passive because the sensor itself doesn't use any energy. It can make correct detections up to 10m [4].

2) Magnetic sensor: This kind of sensor uses the variation of earths magnetic field in order to detect an object. They are low range sensors and they are used mostly in open environments [8].

3) Ultrasonic sensor: This kind of sensor emits a wave and waits for its feedback in order to calculate the distance to the object, just like a radar. Since the speed of sound is constant in the air, the distance to the object may be calculated just by knowing the time between emission and detection of the reflected wave. This may be affected by the type of materials of the detected objects [8].

4) RFID: RFID stands for radio-frequency identification and this technology is used to detect and trace objects with tags in them. The tags in the objects are powered by the waves emitted by the reader itself. RFID system strongly provide the security for the purpose of authentication of valid user to park the car, fast and easy checking out of the vehicles in secure conditions [1] [8].

5) Image Recognition: In image recognition technique, the image data is scanned for a specific condition. One or several specified, or learned objects or object classes can be recognized, with their 2D positions in the image. It can be applied for parking lot detection, vehicle detection, license plate detection and also for security. This detection solution does not require sensor installation at every parking spot: instead it uses an overhead video camera system to detect and identify empty spots. This solution is cost effective when applied in very large car parks. However, it needs the deployment of closed-circuit television cameras and image processing techniques to compare consecutive frames and identify the differences between empty and occupied spots.

C. Networking

In this section an overall description of some network technologies and protocols will be given.

1) Computing platforms: RaspberryPi3 is a single-board computer that was designed for all intents and purposes. It runs a specially designed version of the Linux operating system, Raspian, that makes it easy to install most Linux software. Raspberry Pi 3 has various network communication interfaces, such as 2.4 GHz Wi-Fi 802.11n, Bluetooth 4.1, Ethernet, USB, GPIO and CSI ports.

2) Technologies: Several communication technologies may be used for wireless signal transfers. A quick description about the most relevant ones will be made in the present section.

a) ZigBee: It is a low consumption wireless technology. It is based on IEEE 802.15.4 specification. They are usually low bandwidth devices designed for close proximity communications. Its range is about 100m for line of sight communication and it uses non-registered frequencies. This technology is a standard for mesh networking.

b) Bluetooth Low Energy: This is similar to "classic" bluetooth, but with lower consumption. It is also called smart bluetooth and it is not backward-compatible with previous blutetooth systems. This technology may use up to 8 nodes for transmissions and its range can go up to 60m.The main advantage of this technology is its low power consumption.

c) Wi-Fi IEEE802.11: This technology is widely used in all kinds of electronic devices including computers, smartphones and all kinds of sensors. It was first released in 1997 and evolved to 3 different protocols IEEE802.11b, IEEE802.11g and IEEE802.11n. Each of this protocols have different speed rates: 11Mbit/s, 54Mbit/s and 150Mbit/s respectively. Raspberry Pi includes one WiFi board in its standard equipment which uses IEEE802.11n protocol, released in 2009. With IEEE802.11n the data rate is increased by adding MIMO (multiple-input multiple-output antennas). 802.11n uses both 2,4 GHz and 5GHz bands to operate.

d) GSM & GPRS: GSM is the most widely used communication protocol. It is used by cellphones and other devices. It is based in a set of antennas that communicate among themselves to transmit voice information between the emitter and the receiver. GPRS is a protocol that is used over GSM to transmit data using GSM network system. It is divided in several classes, and was firstly presented in 1993. It supports up to 384Kbps for downlink with EDGE evolution (Enhanced Data GSM Evolution)

3) MANET - Mobile Ad-Hoc Network: It is type of wireless network represented by a set of wireless network devices that connect to each other and auto-configure in order to form a independent network. In this type of network there is no central entity to control or synchronize all the devices.

4) WMN-Wireless Mesh Networks: Wireless mesh networks are a subtype of MANET networks. These are non structured mesh radio networks. They have the ability to auto connect and auto configure with the remaining network nodes. They can use different types of technologies (Wi-Fi, bluetooth, etc). In this kind of mesh there are two different node types: routers and clients. Routers have specific functions in order to support network routing and support the clients. Routing mechanisms are of extreme importance because they define the paths for the information to flow. When a node disconnects the remaining network must have the ability to reconnect.

a) Protocols: Protocols for this type of networks may be divided in three different families: proactive, reactive and hybrid.

In proactive routing, the paths are established to all the end nodes even though not all routes are needed. For each node, a routing table is mantained, representing the full network. This table is often updated in order to keep the correct information about the network topology. In reactive routing, the routes are established on-demand meaning that the nodes don't store information about paths and the network topology. The route discovering process is started when the source node floods the network with path requests for a destination node. This discovering process finishes when a path or no path is discovered. Hybrid routing intends to join the advantages of both active and reactive routing [16].

b) B.A.T.M.A.N.-advanced: This is a multi-hop proactive routing protocol was designed specifically to handle wireless mesh networks. It is a layer 2 routing protocol that uses the MAC addresses of the computing platforms. Routing is harder to handle in ad-hoc networks because the topology may dynamically change. Its objective is to detect other B.A.T.M.A.N. nodes and find the best route to them. The approach of this algorithm is to spread the information

about the best paths to all the nodes [15] [14].

All the nodes broadcast a signal informing of their own existence. Their neighbors receive this information and retransmit this message, according to specific rules, in order to inform their own neighbors about the first one's existence. This messages include at least: address of the source, the address of the node transmitting the packet, a Time To Live (TTL) and a sequence number do distinguish the messages.

After all the nodes broadcast the messages, all the nodes chose the best neighbors to use for each final destination according to the computed times.

D. IPS systems

Intelligent parking systems(IPS) are systems that intend to minimize the problems associated with the lack of parking spots in big cities such as: driver stress, time spending, pollution and traffic jams. The main goal of an IPS is to monitor the availability of parking spaces and make that information available to the drivers and parking administrators. Drivers may use it to select the parking space and, inside a park, to be guided to an empty spot. Administrators may use it for management and capacity planning purposes.

1) Solutions Available: There are several type of solutions available nowadays. We can divide parking lots in diverse properties: on-street or off-street parking areas, public or private, gate to enter or not, type of sensors, allowing or not reservation, parking information availability and guidance to the drivers.

The most relevant design aspects of a parking solution are: payment policy, and availability of occupancy measurement, booking service and and park guidance and information services.

2) Components: The main components to build an IPS are: parking sensors, servers and information systems.

Parking Sensors: Parking sensors are used to detect parking spots occupancy. The detection system is normally composed of a wireless or wired sensor network that provides the occupation state of every parking spot, or alternatively composed of counter sensors at the entrance and exit of parking lots that are only capable of providing total utilization value. The last method can only work in controlled environments, where all the entrances and exits of a parking have sensors to control the entrances and the exits respectively.

Servers: Parking servers should maintain multiple databases with data of the parking spaces utilization, users bookings and payments, searches and real-time context information. They must also keep all the parking data securely stored and accessible, and process all the information relative to parking areas, users, and payments.

3) Main offered services:

Occupancy Management: The occupancy management is possible through data retrieval from these sensors and transmission to a central server which stores it, making it available for managers and users.

Booking: In some paid IPS, users are allowed to book a spot in a parking space. In this systems, each parking space should have a reservation authority deployed, for managing booking request, authenticate the drivers and communicate with specific individually users. Once the reservation order is confirmed, the reservation authority updates reservation information to hold the related space for the user [8] [2].

Park Guidance and Information System: The IPS services should provide users with parking space availability before the driver enters the park. The services should also provide automated navigation for users until the entrance of a park, through smartphone or GPS navigation to specific area or parking spot. The system should be able to automatically detect changes in the parking areas across the network, and transmit the information with the maximum detail [5] [2].

Price Politics: E-parking employs advanced technologies to combine parking reservation and payment systems. With this systems, a driver could inquire about the availability, book a parking space at a given destination, and pay when leaving. This system can be accessed via mobile phone or web application [3]. Smart payment systems employ advanced technologies to implement payment systems in place with conventional parking meters. These systems allow fast and convenience payment. The employed technologies include contact methods (debit, credit cards), contact-less methods (smart cards, RFID cards), and mobile communication devices (mobile phone services). These systems are also good for the parking managers, because the information provided gives them a more accurate perception about the usage profile, such as the time each car spent parked, the date and so on [2].

III. SYSTEM ARCHITECTURE

This chapter begins with the presentation of the necessary requirements for the construction of the IST-Taguspark outdoor parking management system. The general view of the system is described below and it was developed on the basis of requirements analysis.

A. Requirements Analysis

1) Functional Requirements: The main requirements identified are: inexistence of physical barriers, availability of parking information, facilitating the search for parking, parking management and lastly authorization of access and privacy.

2) Architectural Requirements: The main requirements identified are: modularity of the code, integral coverage, dynamic routing, data redundancy and information consistency.

B. Main Architecture & Description

In this article a low cost network and car detection infrastructure system is purposed. The cars are detected by using a low cost camera with dedicated software to detect and interpret a car plate. The used camera is the Raspberry Pi Camera V2 model and and the designed software is supported by OpenALPR library. It can also be used to detect the amount of cars that go through each of the zones of the parking lot, depending on the amount of installed cameras. It was decided that it would be better to use a independent ad-hoc network using only the Raspberry Pi that supports the

cameras to build it. B.A.T.M.A.N. protocol was chosen for information transmission because of its easy implementation and high efficiency. The processing nodes are Raspberry Pi model 3 platforms, because of its low cost and high level of integration with all kinds of sensors, giving the system more possibilities to evolve. The system also makes use of ultrasonic sensors in order to detect movement in more than one lane. In order to fully cover all the parking area where the system is to be installed, and also to provide information about the occupation of each distinct area, the parking lot should be divided in several small areas. The transmission of information should be assisted by the all the areas of the park. For this information to flow different types of nodes should exist: collectors, relay and a manager node. All this nodes are to be part of a wireless mesh that will allow the communication between them. It is also required that the network allows the communication between the more distant nodes, hence the installation of relay nodes. Collector nodes acquire information about the entries and exits of vehicles by using the installed sensors in each area of the parking. Afterwards, the occupation of the zone is controlled by the node through the analysis and data processing of the sensors information. This information is then transmitted along all the nodes until it reaches the manager node. The manager node is responsible for the counting and computing the total occupancy for the parking lot. It is also responsible for storing information that comes from different areas of the parking in a dedicated database and provides information for the parking users. Relay nodes help collector nodes to transmit information to the manager node when the communication between source and destination is not direct. All the collectors in the design system can also make the relay action. All the information that the collector nodes send to the manager nodes are transmitted along a wireless mesh supported by all the nodes, making usage of a proactive multi-hop routing protocol. The designed network will use IEEE 802.11n (2.4 GHz frequency) and will be a wireless mesh network. This was the chosen protocol because of it is highly scalable, allowing the system to grow without restrictions, permitting communication with bigger distances by making usage of the multi-hop protocol.

At Taguspark campus, vehicles can park along the road or in three open outdoor parks: one in students dorm, the second one in front of the main building and the last one near the northern entrance. The geography of the area leads us to divide the on-street&open parking area in different parking zones and to build an automatic occupancy detection system. In order to efficiently inform drivers about parking utilization allowing them to save time, fuel, and another negative aspects inherent of this problem, the objective is to divide the parking area in eight zones. With this zone division, any driver will know the exact zones where they can find vacant spots, reducing the searching time and increasing their own commodity.

The designed system is supposed to be installed in the park entrance and specific spots that delimit different zones of the park. When a car approaches the entrance the system photographs, and detects the license plate. Afterwards the information is sent to the local node in order to compute the information of the plate. If it is a valid plate it computes if it is a entry or an exit action. The driver may then proceed to its parking spot destination, that can be chosen by giving use to the information given by the system. The parking spot where the vehicle stopped it then stored in a local database amongst a series of other different data: time, zone, etc. The computed data is then formated and sent to the manager node that stores it in the global database. This database controls the usage of the different parking zones and provides the information for a node to recover after failure. A CRM or another management system may be developed on top of this database information.

IV. IMPLEMENTATION

The system was developed using low cost equipment for all the sensors, servers, etc. All the used software is free source or developed for this works purpose by the author.

1) Computing platforms: For the computing platforms Raspberry Pi 3 was used for both client and server. It is a powerful and widely tested system. It offers several different communication platforms which avoids costs. This type of hardware uses a Unix based operating system making it easier to develop software for this platform. By default it brings a Wi-Fi network card. It is a low power system that can be powered by cheap low power photo voltaic panels or batteries.

2) Sensors: Two types of sensors were used in this system. One to detect vehicle movement along the park and another on to identify vehicles through their license plates.

a) Ultrasonic: This type of sensor is connected to the Raspberry Pi GPIO interface. They may be powered by 5V and 15mA using the Raspberry Pi ports to do it. Its range is between 2cm and 4m and they are very low cost. They are used to detect the position of the vehicle in a certain part of the park.

b) Image recognition camera: A Raspberry Pi camera model v2 was used in this system. It is highly integrated with raspberry pi, has the ability to capture 1080p videos, and has the resolution of 8Mpx for photographs. It uses a dedicated Raspberry Pi port for connection. This camera is used to make photographs of the car plates in order to identify the cars.

3) B.A.T.M.A.N.- operation principle: In the purposed system B.A.T.M.A.N. protocol is the chosen protocol for the wireless mesh network communication. The easy implementation and high efficiency determined the choice.

4) Database: For this system a MySQL database was used. MySQL was chosen because it is free, widely used, being one of the most safe and reliable existing databases. They are also light weight and of easy implementation.

5) Frontend: For the sake of demonstration a simple web page of developed for showing some informations of the developed system. There is a different page for the park clients and the park manager. This frontend can be improved in order to show more stats.

TABLE I

LATENCY VS DISTANCE

Number of nodes	Distance (m)	Latency (ms)
1	80	9.32
1	110	3013
4	225	66.34

V. TESTS

Several tests were made to prove the correct functioning of all the parts of this system: routing, range, license plate reader. These tests were conducted in open environments with line of sight between nodes.

1) Routing: Multi hop communication tests were made. They were successful: if a node disappears the network rearranges to try and use the remaining nodes. The information flows through a series of 4 nodes to reach the final destination. The transmitted package reaches the final destination even if it has to cross all the 4 nodes.

2) Range: The maximum distance between nodes is about 110m without loosing quality, i.e. the latency is acceptable. This test was conducted in an open air environment, with line of sight, in order to present the maximum allowed distance. The table I has the information about the distance between nodes and the average latency for communication using the chosen routing algorithm.

3) Web application: The developed web application is supported by an html interface. It reads directly from the database and computes some statistics regarding the parking lot. The combination of html and php allows several interactions between the user and the system.

4) License plate reader: OpenALPR library was used to compute the license plates. A python program was developed to make use of this library. The produced program is able to detect the numbers and letters impressed in the license plates. Different portuguese license plates were tested both in laboratory and real environment to produce the present test results. The success rate for the license plate reader is above 80% and may be improved by using a more powerful camera, or the combination of several cameras.

A set of 5 (non genuine) license plates was used to test the software and camera. The table (II) represents the test results. The average test success rate was 81%. Although it is acceptable as proof of concept, it can be improved using a camera with greater resolution.

TABLE II

READING PLATE SUCCESS RATES

Plate	Success (%)
20-QU-30	85
57-DI-20	81
89-TE-54	78
52-80-LX	92
18-CZ-29	67

VI. CONCLUSION

A lightweight and low-cost intelligent parking system can be implemented using RaspberryPi platforms to support the infrastructure. RaspberryPi is a low cost board with high processing power and low energy consumption. When equipped with RaspberryPi model v2 cameras and using specific libraries and software, a automatic license plate reader may be implemented. This identification system is highly reliable. It is also possible to design a mesh of sensors to detect the rate of occupation of a parking lot, that are connected between themselves by using B.A.T.M.A.N. protocol producing a self managed ad-hoc network (when a node fails, the system still recovers). This type of networks does not require any type of routing hardware making them less expensive. To store data, a MySQL database may also be implemented. This work intends to be the base of a highly scalable system for parking management.

REFERENCES

[1] Patil, Manjusha, and Vasant N. Bhonge. "Wireless sensor network and RFID for smart parking system." International Journal of Emerging Technology and Advanced Engineering 3.4 (2013): 188-192.

[2] Mahmud, S. A., et al. "A survey of intelligent car parking system." Journal of applied research and technology 11.5 (2013): 714-726.

[3] Kotb, Amir O., et al. "iParkerA New Smart Car-Parking System Based on Dynamic Resource Allocation and Pricing."

[4] Wilfinger, Roman, et al. "Indoor position determination using location fingerprinting and vehicle sensor data." Navigation Conference (ENC), 2016 European. IEEE, 2016.

[5] Amini, Arghavan, et al. "Improving GPS-based vehicle positioning for intelligent transportation systems." 2014 IEEE Intelligent Vehicles Symposium Proceedings. IEEE, 2014.

[6] Khanna, Abhirup, and Rishi Anand. "IoT based smart parking system." Internet of Things and Applications (IOTA), International Conference on. IEEE, 2016.

[7] Mariakakis, Alex T., et al. "SAIL: single access point-based indoor localization." Proceedings of the 12th annual international conference on Mobile systems, applications, and services. ACM, 2014.

[8] Polycarpou, Elena, Lambros Lambrinos, and Eftychios Protopapadakis. "Smart parking solutions for urban areas." World of Wireless, Mobile and Multimedia Networks (WoWMoM), 2013 IEEE 14th International Symposium and Workshops on a. IEEE, 2013.

[9] Wang, Hongwei, and Wenbo He. "A reservation-based smart parking system." Computer Communications Workshops (INFOCOM WKSHPS), 2011 IEEE Conference on. IEEE, 2011.

[10] Rico, Juan, et al. "Parking easier by using context information of a smart city: Enabling fast search and management of parking resources." Advanced Information Networking and Applications Workshops (WAINA), 2013 27th International Conference on. IEEE, 2013.

[11] Baniukevic, Artur, Christian S. Jensen, and Hua Lu. "Hybrid indoor positioning with wi-fi and bluetooth: Architecture and performance." 2013 IEEE 14th International Conference on Mobile Data Management. Vol. 1. IEEE, 2013.

[12] Zandbergen, Paul A., and Sean J. Barbeau. "Positional accuracy of assisted gps data from high-sensitivity gps-enabled mobile phones." Journal of Navigation 64.03 (2011): 381-399.

[13] Anas, Nuzli Mohamad, et al. "Performance analysis of outdoor wireless mesh network using BATMAN advanced." Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing (SNPD), 2015 16th IEEE/ACIS International Conference on. IEEE, 2015.

[14] Herrmann, Patrick, and Ulrike Meyer. "BATMAN Handover Extension for Routing Nodes in Infrastructure WMNs." Local Computer Networks (LCN), 2016 IEEE 41st Conference on. IEEE, 2016.

[15] Vijayakumar, K. P., P. Ganeshkumar, and M. Anandaraj. "Review on routing algorithms in wireless mesh networks." International Journal of Computer Science and Telecommunications 3.5 (2012): 87-92.

[16] Singh, Moirangthem Sailash, and Viswanath Talasila. ”A practical evaluation for routing performance of BATMAN-ADV and HWMN in a Wireless Mesh Network test-bed.” Smart Sensors and Systems (IC-SSS), International Conference on. IEEE, 2015.