BPM: Bluetooth Parking Manager

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ABSTRACT

The goal of our Bluetooth Parking Manager, parking lot gate opening system, is providing seamless authentication without additional user effort and additional devices. We propose to use Bluetooth technology as a communication channel with a smartphone as a control device. Given that most smartphones have embedded Bluetooth module, and most users bring their device in everyday life, even when driving, the combination of Bluetooth with smartphone is a strong candidate for our solution. In this paper, we demonstrate that parking lot gate can be easily controlled by a smartphone using Bluetooth technology with a reasonable waiting time. We will also show that through thoroughly analyzing the signal strength of Bluetooth module, the system can verify the location of the user and eliminate possibilities of granting access to unauthorized users.

Keywords

Android, Arduino, Bluetooth, Parking lot, Garage

1. INTRODUCTION

According to [4], the United States parking industry is an $18 billion dollar industry, and there are more than 40,000 parking facilities in the United States. [5] also reported that the revenue of the parking lots and garages industry has reached $9 billion dollars, and over 136,000 employments and 8,000 businesses are involved with the industry. Although the industry has been decreasing for the past five years mostly due to the recession and under capacity of airport parking lots, [5] had reported that the demand will pick up in the next five years as employment improves and demand from airports and other businesses revives.

The access of these parking lots and garages are managed through different types of gate openers, and they are mostly operated with access card using RFID or dispensing paper tickets to customers. Although the gated parking lots and garages provide more security and guaranteed parking spaces, there are few problems to both users and the parking service providers in current systems. The most cumbersome task users have to bear with is physically swiping the access card to the reader or inserting the paper ticket to the machine to open the gate. As the result, it creates extra user actions such as finding the access card or the paper ticket, opening the window, and finally swiping the access card or inserting the paper ticket to the machine. From the service provider's perspective, it is inconvenient to issue a new access card or a paper ticket for each new client. For the access card, it is hard to retrieve or revoke expired access cards.

Through our BPM (Bluetooth Parking Manager) system, we demonstrate that users can easily use parking lots and garages with minimum user action using Bluetooth technology embedded in their smartphones. In our approach, we allow users to easily purchase parking permits through our client Android application, and seamlessly control the gates of desired parking lots and garages using Bluetooth communication channel between the user's smartphone and the Bluetooth module which controls the gate. Additionally, our approach only requires attaching a Bluetooth module to the current parking lot system, which is a low cost solution. It allows most parking lot service providers to implement the solution and improve their parking lot and garage services.

2. RELATED WORK

There has been active and extensive researches focusing on improving the parking lot and garage user experience. Motorola has been actively researching Automatic License Plate Recognition system [2], which reads

the vehicle's license plates and checks them against the database to quickly identify the verification of vehicles (as shown in Figure 1). This system has been widely used not only the parking ticketing systems, but also locating stolen or wanted vehicles, tolling, boarder control, etc. As the name of the system indicates, this system uses illumination, such as infra-red, and a camera to take the image of the license plate of vehicles, then analyzes the image with an image-processing software to extract the license plate information. Once the license plate information has been extracted, it is checked against the database to identify the vehicle, and the parking lot gates opens automatically if the vehicle is authorized to use the parking lot [3]. This system has an advantage of not requiring any installation on the vehicle.

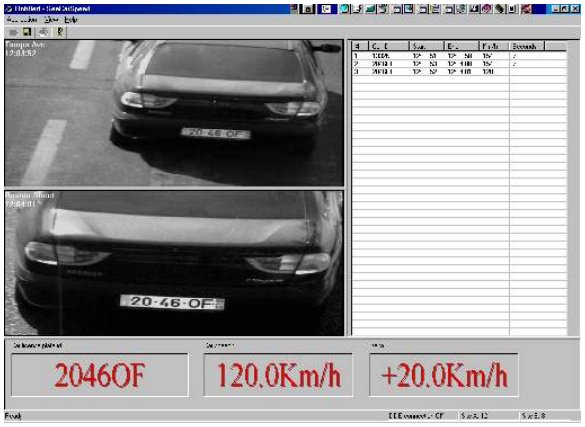


Figure 1: Automatic License Plate Recognition system takes an image of the vehicle and extracts the license plate information

However, such system requires a major upgrade in the parking lot, because it requires a completely different set of components, such as cameras, illumination, frame grabber, computer, and image-processing software. These equipments can be very expensive, in order to achieve a certain level of accuracy. This high cost of the system is not very appealing to the parking lot service providers. Additionally, the external effects, such as sun and headlights, and bad license plates, can severely affect the performance of the system.

The rest of this paper will explain the system overview of our low-cost parking lot system, followed by the details of the system, evaluation, and conclusion.

3. SYSTEM OVERVIEW

The BPM system can be broadly divided into three components (as shown in Figure 2). The first component is the client Android application. It is the core component of the BPM system, which provides an interface allowing users to register with our system. In addition, the application also allows users to easily look up available parking lots and buy permits for desired parking lots. Another main task of the Android application is scanning available Bluetooth devices around the user. It periodically scans a discoverable Bluetooth device which is attached to the gate of parking lot or garage.

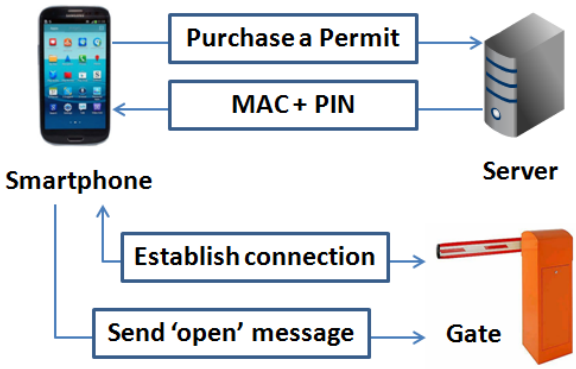


Figure 2: The BPM system consists of three components: client Android application, server, and Bluetooth enabled parking lot gate

The second component is the application server, which provides RESTful end-points for useful functions that are used by the client Android application. These functions include registration, parking lot searching, buying parking lot permits, etc. When a user registers with our system, he/she may search for parking lots simply buy providing a ZIP code, which then the server retrieves available parking lots and garages for the user. Oncec the user purchases the permit, the server returns the MAC address of the particular parking lot's Bluetooth device and the PIN associated with the Bluetooth device for pairing to establish a communication channel between the user's smartphone and the Bluetooth device.

The last component is the Bluetooth device which is attached to the gate of parking lot. It is essentially a combination of an Arduino board and a Bluetooth module. Once the user purchases the permit, the user's smartphone maintains the MAC address and the PIN. Once the client Android application finds the correct Bluetooth device by matching with the MAC address, it automatically initiates pairing process and establishes a communication channel. Once the communication channel is successfully established, the client Android application sends a message to the parking lot Bluetooth device to open the gate. The parking lot Bluetooth receives the message and command the gate to open via the Arduino board attached to the gate.

4. SYSTEM DETAILS

As already mentioned in Section 3, the BPM system consists of three components. Of the three components, the client Android application plays the most important role in our system. This section of the paper will elaborate on the client Android application component in more detail. First of all, we will discuss the interaction between the client Android application and the application server focusing on retrieving the MAC address and PIN of the parking lot Bluetooth device. Then we will discuss how the client Android application uses the MAC address and PIN to scan the correct device and initiating a connection establishment between the client smartphone and the parking lot Bluetooth device.

4.1 Purchasing Parking Permit

In order to use BPM system, the user must register with our system and purchase the parking permit through the client Android application. Parking permit purchasing process starts with searching for a parking lot. As shown in Figure 3, parking lots can be easily searched by ZIP code, which shows a list of available parking lots in the region.

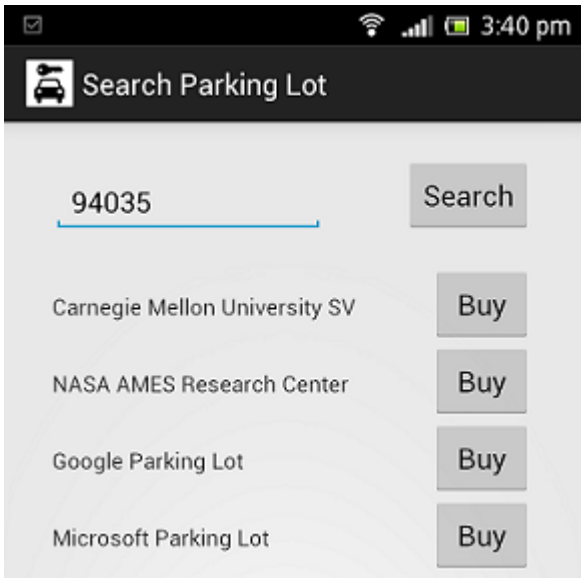


Figure 3: The client Android application allows users to easily search parking lots by ZIP code

When the user purchases the parking permit, the application makes an HTTP POST request to the server requesting that the user wants to purchase a permit of a parking lot with the specific parking lot ID. Then the server replies back to the client with the MAC address of the Bluetooth device and the PIN associated with the Bluetooth device (as shown in Figure 4).

Once the client application receives the MAC and

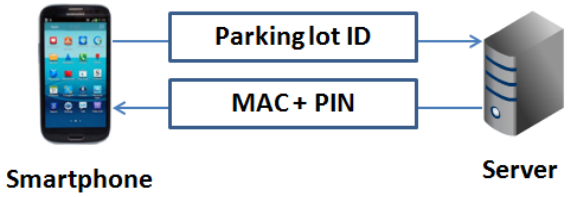


Figure 4: The application requests a permit with a parking lot ID, and the server responses with MAC address and PIN

PIN, it starts scanning for available Bluetooth devices, and establishes a communication channel if the found Bluetooth device's MAC address matches with the MAC address of the permit the user has purchased. Once the connection is established, the client is ready to control the parking lot gate.

4.2 Controlling Parking Lot Gate

Using Bluetooth technology allows users to control the parking lot gate with minimum user effort compared to the current system of using RFID access card or paper tickets. However, this approach is not a perfect solution, and therefore has some drawbacks as well. The range of Bluetooth signal is quite long that it may trigger the connection establishment and open the gate while the authorized vehicle is not even close to the gate. It enables unauthorized vehicles to piggy back the parking lot access, if they are in front of authorized vehicle users.

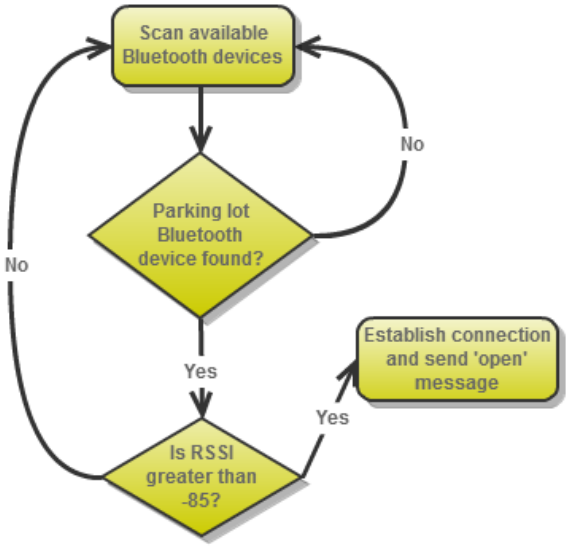


Figure 5: RSSI of the Bluetooth device is checked during the parking lot gate control process to ensure that the authorized user is in front of the gate

In order to address this particular issue, we have conducted a number of experiments to determine the po-

sition of the authorized user's vehicle. We have collected the Radio Signal Strengthh Indicator (RSSI) of the Bluetooth device at various location. The experiment has shown that various location of the user's vehicle results in different range of the RSSIs of Bluetooth device. By setting appropriate threshold of RSSI and only initiating the connection establishment above the threshold, we could mostly eliminate the problem of granting unauthorized users access to the parking lot. Figure 5 shows the flow of parking lot gate control process.

5. EVALUATION

5.1 Signal Strength Threshold

Once we build a basic service flow, we needed to set up the threshold of Bluetooth signal strength to determine when the system will open up the gate depending on how far the user is. Since we presumed that the distance to user from the parking lot gate attached to Bluetooth module is correspond the signal strength, we needed empirical data of signal strength to evaluate the system efficiency and stability.

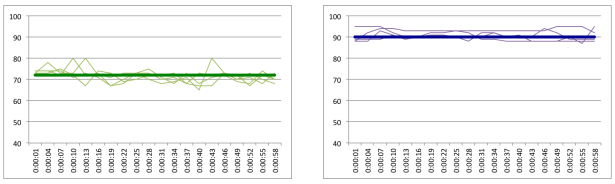
Thus, we performed experiments to collect signal strength of Bluetooth with the android device after setting up a practical environment outside. We put the two cars in a row and collected signal strength inside of each car, first car in front and second car behind.

Figure 6 shows the comparison between the collected data for 60 seconds in the first car and the second car. As a result of plentiful of experiment, 10 minutes * 3 times in a day * 3 days, we observed that the range of signal strength in the first car was -67 to -80 and -88 to -96 (or less) and the median was -72 and -90 (Bold lines).

Based on the analysis, we set the threshold at -85 and it returned desirable result to an extend that it prevents perfectly for even a corner case problem that unregistered user in front gets in to the gate piggybacking the grant of user behind. What it means is the system only opens the gate for the user who is within a range of about a car length.

5.2 Discovery Latency

In addition, to evaluate the performance of our system regarding latency, we also measured waiting time to open the gate, while the vehicle is in motion and in stillness. Through this experiment, we observed that the waiting time is truly random whether the vehicle is moving or not. This is because the Bluetooth discovery process in Android usually takes 12 seconds of inquiry scan cycle [1]. In order words, at any moment during 12 seconds, the Bluetooth module can be found and the user might have no waiting time to 12 seconds of waiting time, at most.



(a) The first car in front (b) The second car behind

Figure 6: RSSI Comparison between two cars

This limitation made the system cannot use average value of multiple samples to set up the threshold. Since, suppose, the system wants to collect 5 samples for averaging them out, then the user has to wait 60 seconds in worst-case scenario.

6. CONCLUSION

In this paper, we proposed the Bluetooth Parking Manager system that overcomes current parking lot gating system's problems. With using Bluetooth technology and Android smartphone, our system minimizes user's extra effort and lowers administrative demanding. Also it would be easily deployed on top of current parking lot system since it only needs one additional Bluetooth module, adaptation would be possible with low cost. Throughout our work, we demonstrated the seamless system works reliably and it could effectively cope with corner case problem. However, we found that currently developed system has a minor issue in user waiting time and one time pairing requirement because of Android device's limitation. Thus, we leave those topics as our future work to improve in next stage of BPM system.

7. REFERENCES

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