Design and Development of Smart Parking Management System

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Abstract—The parking systems in the modern age are under tremendous stress as the number of vehicles on the roads are increasing every year. Due to this increase, the current parking lots do not suffice which leads to people driving for parking spaces thus wasting valuable time and adding to the greenhouse emissions. Therefore, new efficient and innovative solutions need to be developed which meets the ever-increasing demand for parking spaces and be as environmentally friendly as possible. The solution devised in this project is an enhancement of the current parking system with an integrated mobile application which allow drivers to remotely monitor parking lots, make reservation for a spot prior to visiting the parking lot and make in app payments for the parking services. This reduces the time spent in looking for parking spots as well as reduces the unnecessary carbon emissions while offering a practical and seamless parking experience to the users.

Keywords—Remote Monitoring, parking systems, eco-friendly, mobile application.

I. INTRODUCTION

As ubiquitous technology can get, it has yet to be used in countless sectors to unlock its full potential and advantages. One such sector where use of IOT would be quite beneficial is the parking sector. Parking lots have existed ever since the invention of the great automobile and have grown in size and demand since then. As countries are growing both in population and economic activity, the demand for mass transit is at an all-time high. According to [9] the number of cars on the roads increased by 4.6% in the year 2016 alone and has been growing exponentially since. The growth in the number of cars can be visualized in Figure 1.

The greatest increase can be witnessed in the Asia pacific countries and since these countries are densely populated and rapidly developing, the increase in the number of cars has put a strain on the already fragile parking system infrastructure. In addition, due to limited number of parking spaces and increased number of cars, drivers often spend a considerable amount of time in looking for a parking spot. This in turn has disastrous impact on the environmental and ecological balance. According to a study conducted in India [2], due to insufficient parking spaces the amount of traffic on the roads has increased by 30% and the exhaust fumes released from cars looking for a parking space contributes to 10% of the overall carbon dioxide, a greenhouse gas, emissions of cars. Moreover, increasing number of parking lots charge for parking spaces, drivers tend to spend time in looking for parking spots closest to entrance, in case of mall and business centers, in order to get their money’s worth, thus spending valuable time cruising and adding to the greenhouse emissions. Cruising is the act of driving around to find the best parking spot and in many cases looking for free parking spots.

Figure 1. Graph of number of cars on the road (regionally divided)

Any effective parking system focuses on 3 vital parts; quantity, quality, and management. Due to immense construction activities being carried out around the globe, land as we know it is becoming a scare and a priced resource. This in turn has pushed up the demand to optimize land usage. According to [1], parking lots are the least environmentally friendly usage of land. In respect to the demand of land and environmental concerns, optimization of the ‘quantity’ component, which deals with the number of parking lots and spaces available to the public, of parking systems is inapplicable. In addition, the quality component of the parking system deals with the aspects such as how spacious a parking spot is, how easy is to access the parking lots and how user friendly the parking lots are in general. However, the quality component is highly correlated to the quantity component thus optimization efforts of this component would be insignificant unless a completely revamped parking lot is devised. On the other hand, management component is the one where policies and
techniques that make efficient use of parking resources to provide significant social, economic and environmental benefits are used. Positive and resourceful changes and developments made in this component can result in better parking systems and offer seamless parking experiences without much negative impact on the environment.

To thoroughly get the public’s view on the current parking solution, limited to malls and business centers, a survey was devised which took into account the number of times people visited a mall, the average amount of time spent in looking for a parking space and is the public satisfied with the current parking solution. The complete result of the survey is presented on the following page.

1. Around 2/3 of the people visit the mall more than once a month and usually spend more than 5 minutes in looking for a parking spot. This indicates that on average, a driver spends 10 to 15 minutes a month in looking for a parking spot consuming valuable time and cars emitting unwanted greenhouse gases through their exhausts.

2. When it comes to the current parking systems, 5/4 of the people are not satisfied with the current systems and would want an innovative and efficient system to be developed.

3. More than 70% of the people believe that a mobile application-based solution is a viable option over the traditional methods.

4. 3/4 of the people surveyed believed in the idea of booking a parking spot prior to visiting a mall as a practical solution to the problem of valuable time lost in looking for a parking spot.

5. In addition, when asked about the method of payment, a mere 7% of the people opted for payment at pay station. A great percent of the public opted for either in app payments or RFID based payment system.

A. Problem Statement:

Going through the result of the survey and the background study a list of problems is identified:

1. Due to an increase in the number of cars in general, parking lots are more crowded due to which people waste a considerable amount of time in looking for a parking spot.

2. As parking lots get more crowded, drivers must drive extra distance to look for a parking spot which leads to an unnecessary increase in greenhouse gas emissions.

3. Since people usually have to pay for the parking services through pay stations, additional valuable time is lost.

B. Objective:

To develop an internet of things based smart parking management solution.

C. Scope:

This project is aimed to provide a solution to the problems faced by the current parking system.

1. To address the problem of time wastage, a system which allows drivers to book a parking spot in advance and make payments through their preferred method will be developed. This would in turn help curb the unnecessary carbon emissions from cars driven around in search of parking spots.

2. A RFID system will be used which will uniquely identify each registered user and allow them to enter the parking lot and make use of the services offered. Moreover, many parking lots need to be physically manned to oversee whether people adhere to the parking disciplines and use traditional gated entry and exit points. This method will be optimized by the help of the RFID system implemented.
3. The prototype of the proposed solution will be developed using Raspberry pi, Firebase cloud storage and android studio. Each of these components are discussed in detail in the later sections of the report.
4. Since the application is developed using android studio, it is limited to android users only.

II. LITERATURE REVIEW

To combat the problems faced by the current parking system some ingenious solutions have been developed and deployed to the market. One such system is the ParkIt. A solution initially deployed in 7 locations and now being expanded to 13 different locations in the city of Kuala Lumpur. The system tackles the problems in a different way whereby a mobile application allows its users to put up their personal parking spaces for the use of general public and charge a fee based on the location and the length of time the parking is used. In addition, the system also allows users to book these private spaces in advance thus saving time. However, albeit the system does offer a helpful solution by providing more parking spaces, these spaces are not exactly located at the users desired place and the solution does not address the inefficiency and inconvenience of the parking lots in malls and business sector.

The system developed in [3] makes use of two modules: a monitoring module and a booking module which is also a security module. The monitoring module makes use of wireless sensors to identify vacant or occupied parking spaces. The sensors are installed over each parking spot and connected to a gateway which is equipped with a car park management system. The system is an efficient network used to indicate the status of the parking spaces and display the results to the customers through LCD displays or LED lights. The reservation module allows the drivers to book a parking space through the global system for mobile communication (GSM) system. The drivers send an SMS to book a spot in the parking lot and in return receives a pass code and the ID of the reserved parking spot. This helps the drivers to use the parking spaces conveniently and with all security. However, due to increasing demand for parking spaces, the number of people reserving a parking spot at any particular time can be high blocking the GSM system and thus not allowing drivers to make a reservation. Moreover, only drivers who have a priori reservation are allowed to enter the parking lot leaving the parking lots empty at times.

The system proposed in [4] also makes use of 2 modules which are a monitoring module and a master module. The monitoring module comprises of infrared sensors which detect the presence of cars in the respective parking spaces and a PIC microcontroller which is connected to a master module and displays the status of the parking spaces through a liquid crystal display (LCD) placed at the entrance of the parking lots. The proposed system is a flexible and an inexpensive solution but limited to the parking lot itself. The system does not allow the drivers to remotely monitor the parking lots and make reservation for the parking spots.

The authors of [5] developed a smart parking system which is a combination of sensors to detect the presence of cars in the parking spaces and a radio frequency identification system for uniquely identifying each driver, authorized entry and prevention against thefts. The sensors placed at each parking spot are treated as nodes which communicate to a master node. When a driver enters a parking lot, they are handed a RFID card which assigns them a parking space. After the assignment a variable message screen guides the drivers to their respective with the help of RFID tags. The authors also discussed about the potential scalability of the system to allow for reserving of parking lot, payment services, remote monitoring and gate management services. However, according to [8] the master/slave model of communication is expensive to implement thus limiting the system for future extension.

In [6] the authors made use of wireless sensors network connected to a server. The sensors read the status of the parking spaces and transmit it to the server which is further connected a central server to which many different servers from different parking lots are connected. The system incorporates a mobile application which gives real time information about the status of the parking spaces in different parking lot to the users. However, the system makes use of light sensors which are prone to errors depending upon the state of the ambient lighting in the parking lots and sensitive to pollution thus effecting the accuracy of the system. In addition, even though users can monitor the parking lots remotely through a mobile application, they are not provided with an option to reserve a parking spot or make payment for the parking services.

The solution proposed in [7] comprises of three technologies: RFID, automatic license plate recognition (ALPR) and wireless sensor network (WSN). A mass algorithm is executed by the WSN which consists of sensor nodes divided into three different types. A SN node implemented over each parking spot to detect the status of the parking spot. A GN node, to which a cluster of SN nodes is connected to, collect the occupancy from the SN nodes and forward them to the CN node. The CN node gathers all the information from the different GN nodes and communicates it to a database server which is used by a mobile application to allow users to remotely monitor the parking spaces. In addition, NFC (near field communication) is used to for reservation of parking spots and online payment. Moreover, RFID tags and ALPR are used for prevention against theft and help in the management and supervision of the parking lots through detection of illegal or wrongly parking cars.

III. METHODOLOGY

The idea behind the project is to make use of the current parking system and enhance it in order to provide the drivers an end-to-end parking solution. The system comprises of sensors which record the status of the parking spaces, whether vacant or occupied, send it to a gateway which updates a cloud database in real time. The database is integrated with a mobile application to display the status of the parking spaces within a and reserve a parking spot. The users will be required to enter their vehicle license plate number and a unique identification
number to make use of the mobile application and have access to the parking lots. The prototype to be developed will showcase the proposed solutions capability when employed in a single parking lot. particular parking lot thus allowing users to remotely monitor. The overview of the proposed solution can be visualized below:

For better understanding the proposed solution can be broadly divided into 3 essential components: Parking end, backend and mobile application. To understand the relevance of these components, they will be individually discussed along with the hardware and software tools used in each component. A fundamental part of the solution is the integration of hardware elements to the required software elements. In the following sections, the different components are discussed.

1. Parking end:
2. Cloud backend:
3. User end:
4. Tools and Components:
For fast prototyping of the project the following tools and software elements are selected based on previous studies and availability in the market.

| Tools                  | Units | Description                        |
|------------------------|-------|------------------------------------|
| Raspberry Pi 3, Model B| 1     | Controller and gateway for sensors |
| HC-SR04 Ultrasonic sensor | 2   | To identify vacant and occupied parking spaces |
| RGB LED                | 2     | To indicate the status of the parking spot |
| MFRGC-522 RFID         | 2     | To identify the user               |
| Software Development Kit |      | Cloud storage                      |
| Firebase               |       | Development of cross platform mobile application |
| Android Studio         |       |                                    |

Ultrasonic Sensor: Ultrasonic sensors are used to identify whether a parking spot is vacant or occupied. These sensors work on the principle of reflected waves. A trigger sends an ultrasonic pulse which is reflected and received by a receiver. The time taken for the module to receive back the sent pulse is then used to compute distances or lengths using a simple formula i.e. distance = speed x time.

These low powered sensors are widely used in parking lots to indicate the availability of a parking spot. Therefore, to avoid additional costs on new sensors and infrastructure, these ultrasonic sensors will be used in this project to detect the presence of an automobile in the parking spot.

RFID: Radio-frequency identification use electromagnetic fields to automatically identify and track tags attached to objects. The tags contain electronically stored information. The reader broadcasts a signal which energizes the RFID tags within its proximity which in turn send back an identifying response which is used for data collection, logging and processing.

RFID cards are low powered and relatively cheaper identification system. They are used in multiple applications such as key card locks, point of sale data, toll gates etc. Due to their widespread usage, these tags are chosen to register and identify a user when he/she uses the mobile app for booking a parking spot.

RGB LED: LEDs have revolutionized the technology industry and are being use in countless applications. These are low power, cheap and extremely efficient sources of lighting and displays used in the modern age. There are many different types of LEDs, however, RGB LEDs will be used for this project. This is because these LEDs offer a range of colors to be displayed on a single platform. Since multiple colors, red, green and yellow to be specific, are required to indicate the status of the parking space whether its vacant, occupied or reserved, RGB LEDs would be a cheaper and a viable option.

Raspberry Pi: This is a powerful microcontroller packed with ample number of general-purpose input/output pins (GPIO)
and processing power. In addition, RPI comes with its own WIFI Lan and Bluetooth making it ideal for IOT prototyping, integration with other components of the system, and allows for scaling of the systems to a larger deployable system. In this project the raspberry pi is essentially a gateway between the hardware and the software components of the system. All the ultrasonic sensors, RFID system and LEDs are connected to the RPI which in turn is connected to a mobile application through a cloud database.

![Raspberry Pi 3 Model B+](image)

**Figure 6. Raspberry Pi 3 Model B+**

**Firebase:** Firebase is an opensource platform which provides a real-time database and backend as a service. The service provides application developers an API that allows application data to be synchronized across clients and stored on Firebase's cloud. This platform effectively removes the dependency of building and managing servers; however, the service is available on a pay to scale basis.

IV. RESULTS AND DISCUSSION

The prototype developed consists of a single RFID reader, an ultrasonic sensor and LED lights to display the status of the different parking spots. The developed mobile application allows for registering users, selection of desired parking lots, reserving a parking spot, get details of the reserved parking spot and online payment for the parking services.

![Front view of the sensing component](image)

**Figure 7 - Front view of the sensing component**

The database holds information about individual parking spots. The data captured gives the status of the spot whether it is vacant, occupied, or booked. Furthermore, it records the RFID tag the parking spot is booked against, the scanned user’s RFID and the time the parking spot is occupied for.

![Snippet of the Firebase database](image)

**Figure 8. Snippet of the Firebase database**

To reserve a parking spot the user must register themselves along with the RFID numbers of their respective automobiles. Upon successful registration, users are directed to a page which allows them to select their destination.

![Activity that allows users to select their parking destination which is represented by lot numbers](image)

**Figure 9. Activity that allows users to select their parking destination which is represented by lot numbers**

Once a user selects their desired location, the application displays the number of empty parking spaces available in that location and allows the user to select their car and make a reservation. Upon reserving a spot, the database is updated accordingly and the LED changes from green to yellow at the parking end.

When a successful reservation is made, a buffer time is set within which the driver is supposed to be at the spot or else the booking is nullified. However, if the driver is in the parking spot within the stipulated time, the occupied field is updated to 1 and a timer is started to record the duration the driver uses the parking spot for. Additionally, the application offers an optional feature to navigate to the chosen destination.
After the car is parked, the RFID scanner scans the UID of the driver and if it matches the UID against which the booking was made, a timer is started. However, if it does not match, a buzzer is sound. Once the driver has used the parking services, the database is updated accordingly, and the application directs the user to a payment page which offers different payment options.

V. CONCLUSION

In this study the problems faced by the current parking systems were identified and a smart internet of things-based solution was developed. The developed solution aims to offer the public a seamless parking experience with reduced time in looking for empty parking spots and making payments for the parking services. In addition, since drivers will no longer have to drive around looking for parking spots, unnecessary greenhouse gas emissions can be reduced. Use of existing infrastructure i.e. ultrasonic sensors and LED lights make it easier to implement the proposed solution. Furthermore, the use of RFID system allows to uniquely identify users and to assist in the proper management of the parking lots. Moreover, the use of Raspberry Pi allows for other robust and cheaper alternate sensors to be tested and used with the developed solution. Due to the flexibility of the proposed system, many services beyond the above mentioned can be enabled such as additional security, car retrieval services etc. Comparing to the existing solutions, the proposed solution offers many advantages which can help shift the focus of urban authorities from traffic and parking issues to other serious and budget crunching matters.

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