UParking: Developing a Smart Parking Management System Using the Internet of Things

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***Abstract*— Smart cities employ modern technology to manage and enhance resources effectively. Urban parking facilities are one of the critical assets that need to be managed. Management of parking and congestion is insufficient and requires further investigation. A smart parking management system has developed to solve parking issues efficiently and apply technical solutions to improve different aspects of smart cities. The overall system architecture and environment are specified to provide the framework for a complete design. The proposed system provides multiple facilities, including searching for parking slots, reservation, payment, receiving notifications, showing statistics and monitoring parking states. It applies concepts of the Internet of Things (IoT) by using supportable hardware and sensors to detect parking availability and recognition to control access processes. This approach is expected to reduce costs and efforts in the long term and improve the standard of living of a city's citizens.**

Keywords—Smart Cities, Smart Parking, IoT, Management System, Parking System.

I. INTRODUCTION

Searching for parking wastes significant amounts of time and effort and leads to substantial financial costs. This is particularly the case for people who are always pressured to be on time. Smart cities employ all kinds of modern technologies to manage and enhance resources effectively. Urban parking facilities are one of the essential assets that must be managed.

We developed a smart parking management system (SPMS) as a modern solution to manage parking and save users time, effort and cost. In the context of today's modern life, it has become necessary to improve search methods for available parking and minimize the congestion that occurs at the parking entrance. Searching or booking available parking online earlier is a better substitute than searching at a parking lot where there is a possibility of not being able to find parking. Our smart parking management system was developed to:

- Manage parking and solve problems efficiently using technology
- Apply technical solutions to improve the smart cities concept

The proposed system uses a variety of technologies that help manage parking. It provides essential services for users, including searching for parking, reservations and payment. It is extended to cover more advanced services such as receiving notifications, statistics and monitoring the parking state. The system is connected to sensors to detect occupancy and an automatic number plate recognition (ANPR) camera to control access.

The remainder of the paper is organized as follows. Section 2 describes the related work, and Section 3 explains the analysis stage of the developed system and its design. Section 4 focuses on the practical part, showing implementation and testing processes. Section 5 provides a conclusion and discusses future work.

II. RELATED WORK

The most popular applications and recent research covering smart parking systems are described in this section. Some well-known existing applications and their features are shown in Table 1.

TABLE I. SOME EXISTING MOBILE PARKING APPLICATIONS

Features	Parker	Parkwhiz	Best Parking	Spot Hero	Parking Panda	Mawgif	Mawqifi
Uses maps	√	√	√	√	√	√	
Searches for specific parking		√	√	√	√	√	√
Shows available parking	√	√	√	√	√	√	√
Provides a close-by location	√	√	√		√	√	
Sends notifications	√	√			√		√
Extends reservation time		√	√		√	√	
Monitors car location	√	√				√	
Views prices for parking	√	√	√	√	√	√	√
Multiple reservations		√	√				

Most applications provide the basic features that allow users to browse available parking and prices. Some applications in [1–6] offer additional similar services that include using maps and showing the shortest path to parking; they all search for a specific location except for *Parker* [1]. The *Parker* and *Parkwhiz* [1, 2] applications monitor the car location, as does Mawgif [6].

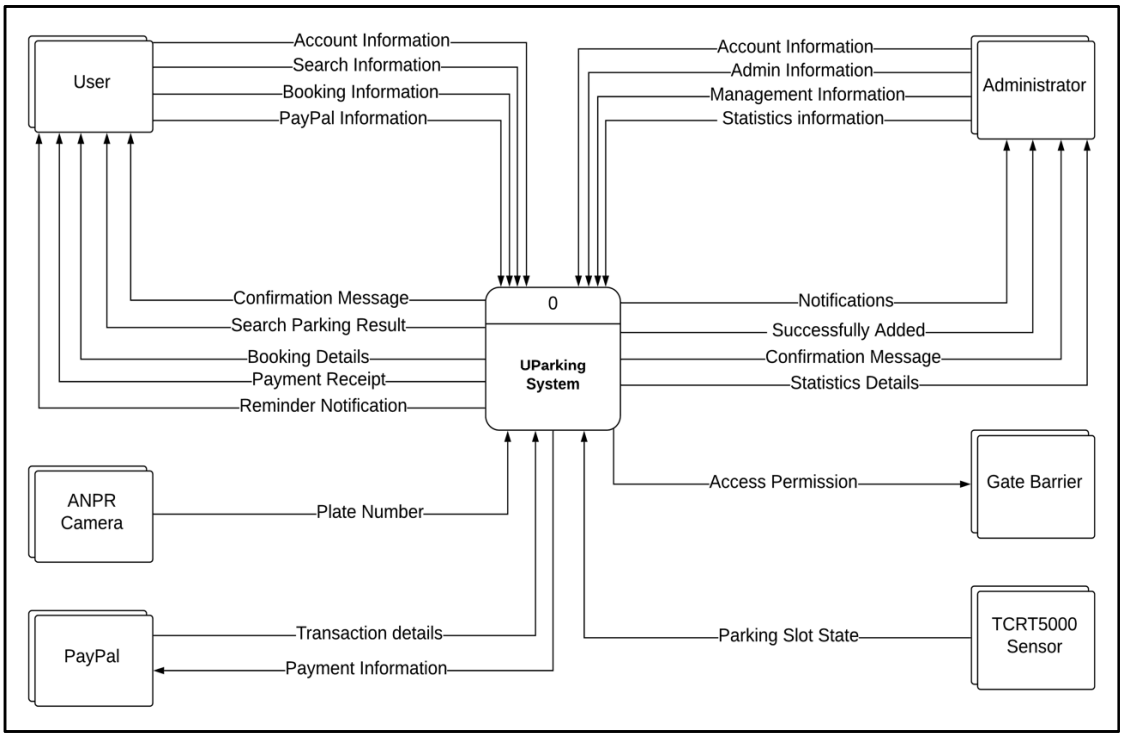

Fig. 1. UParking DFD level 0 (context-level diagram)

Also, some applications, such as *Parking Panda* and *Mawqifi*, send out dynamic notifications [5, 7]. *Parkwhiz* and *Best Parking* both have a multiple reservations option [2, 3]. *Parking Panda* and *Mawgif* share similarities with the two previous applications because they allow extending reservation time [5, 6]. All the applications mentioned previously provide a close-by location except for Spot Hero and Mawqifi [4, 7].

Many studies have considered parking management and proposed a variety of solutions. Some researchers used different sensors to build a smart parking system that detects the occupancy of parking [8–13].

Radio-frequency identification (RFID) technology has been used to enable access to a parking lot [8, 14]. One study [9] applied optical character recognition (OCR) to identify cars by converting plate number images into text. The proposed system in [15] mixed both RFID and OCR technologies for driver identification and subsequent authorization to enter a parking lot.

Some of the related work developed either applications or were web-based to support their system [8, 10–15]. Both [10, 11] implemented mobile applications run on iOS and Android. The Java language is also used in [8, 12, 15] to develop different mobile applications on the Android platform. In contrast, the application developed in [14] supports the Windows platform. In [13], the application is still at the prototype stage. The study in [9] focuses on writing an algorithm for smart parking without applying application.

Most existing applications suffer from various limitations because their platforms cover some features but ignore others. Theoretical methods for some of the above-mentioned studies focused on technologies and algorithms that assist with the parking management process. This approach led to developing the proposed system that combines all the features supported with additional technologies, including a license plate recognition camera, motion detector sensors and generating reports that help in decision-making.

This system offers a smart alternative for the applications used locally and efficiently. It enables searching for parking, reservations and payment. It also sends notifications and monitors the parking state by using a motion detector sensor for parking occupancy and a camera at the gate barrier that uses ANPR technology to control parking access.

III. UPARKING SYSTEM

This section covers both analyses and design stages. The UParking system will manage parking by handling searching, booking and payment procedures. Users will use the application to book a parking slot. the ANPR camera captures the vehicle plate number when a user arrives at the parking lot. The gate barrier will be triggered to open only if the plate number has a registered booking in the database. The TCRT5000 sensor detects motion, leading to modification of the slot state. Users can extend the booking time and view the parking location. Also, users can cancel bookings, edit personal information and display statistical reports, as can the administrator who also has authorization to manage the entire system.

A. System Analysis

1) Data flow diagrams

The context level diagram in Figure 1 shows a high-level view of the UParking system that illustrates the data flow.

2) System use case

The following use case diagram describes the actions and use-cases that the UParking application can perform with one or more actors in the scope of the system shown in Figure 2.

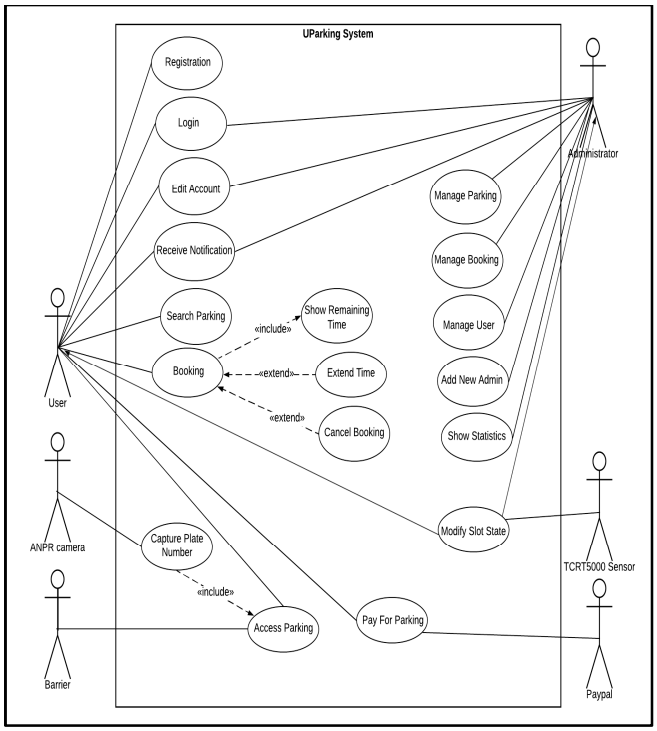

Fig. 2. UML use case diagram of UParking system

3) *Activity Diagram*

The UML Activity diagram shown in Figure 3 illustrates how the ANPR Camera and TCRT5000 sensors work in the system starting from a car's arrival at the parking entrance.

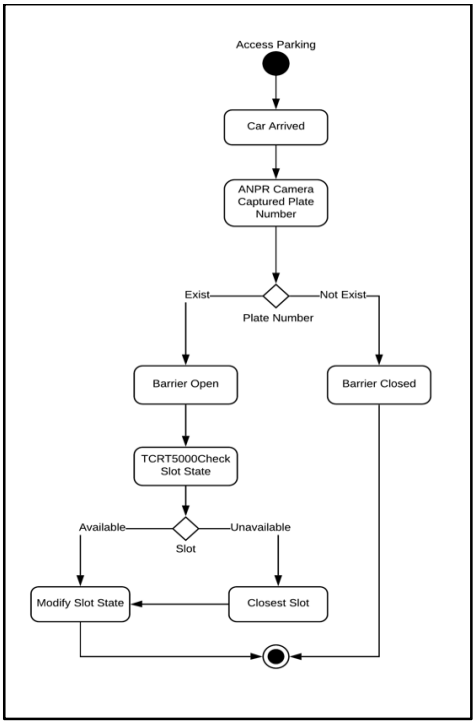

Fig. 3. UML activity diagram for ANPR camera and TCRT5000 sensor

4) *Functional Requirements*

The system will provide the functionality of searching, listing available parking slots, booking, payment, statistics and controlling parking access. The user will receive notifications from the app. The administrator will be able to manage the parking, booking and users through the website.

5) *Non-Functional Requirements*

The system is available, familiar, clear and easy to use for all users from different categories and ages. The availability, integrity and confidentiality of the data will be maintained to comport with information security requirements.

B. *System Design*

1) *System Architecture and modules*

This system consists of many parts, including the two actors (user and admin), user interface, database, ANPR camera and TCRT5000 sensor (Fig. 4).

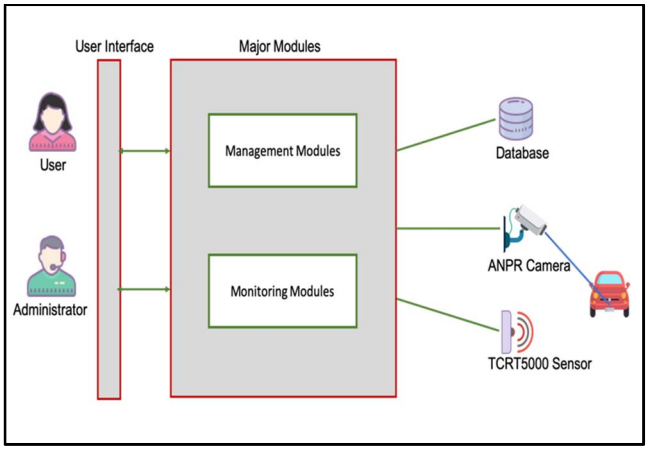

Fig. 4. UParking architecture

There are two sub-modules in this system: a management module and a monitoring module. The management module handles booking, managing users and parking information, and storing their information in the UParking system database. The mobile application enables users to interact with the system through the user interfaces. This system has two actors that benefit from this application—user and administrator; this approach helps users save both time and effort. The monitoring module includes using the ANPR camera that monitors the entrance of the parking and controls access by capturing a plate number image; the system then checks the UParking database to determine whether the car plate number exists in the database. Also, TCRT5000 sensors that are distributed in each parking slot monitor the slot state by detecting a car's presence in the parking space.

2) *Database Design*

A UParking entity relationship diagram (ERD) in Figure 5 illustrates the structure and design of the system database.

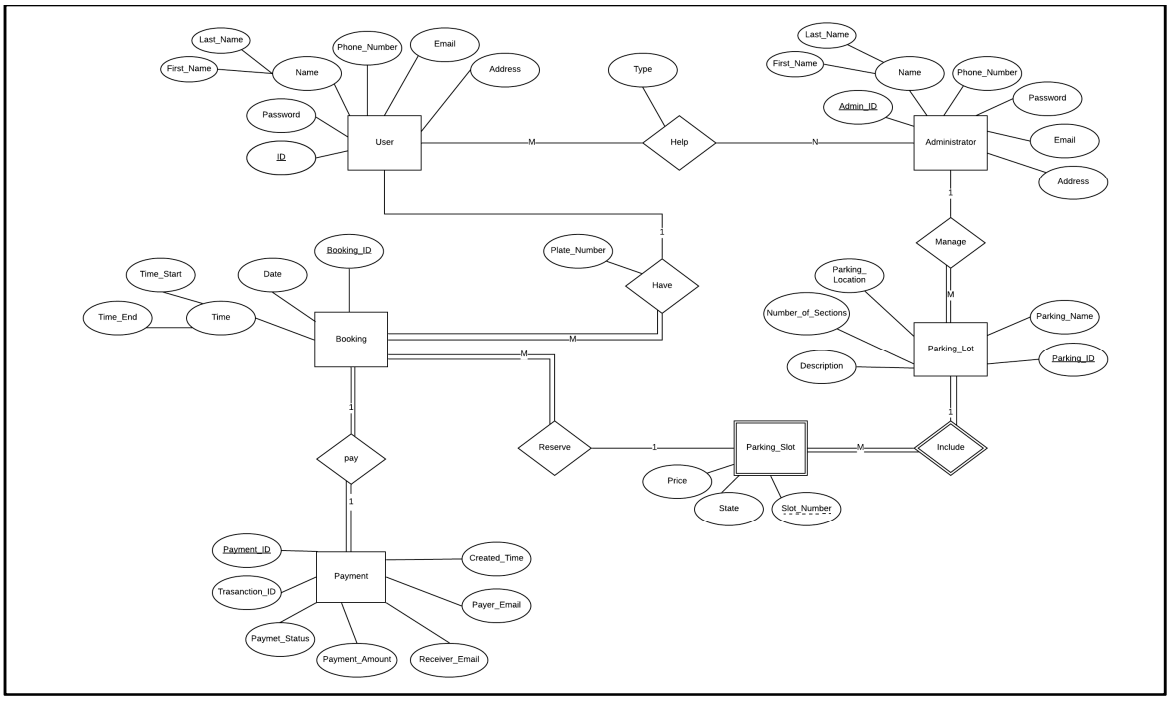

Fig. 5. UParking entity relationship diagram

IV. System Implementation

1) *Operating Environment*

For the hardware environment, the devices used are an Android smartphone, ANPR Camera, TCRT5000 sensor, servo motor, and an ESP8266/NodeMCU microchip. Regarding the software environment, the application will run on the Android operating system. The software platforms that are used for development are Android Studio, MySQL, Arduino, XAMPP (as the local web server) and Notepad++ (as the source-code editor). The programming languages are Java, PHP, JSON, HTML5, CSS and JavaScript. UParking reuses existing software components and integrates their services into the system, such as Google Maps API, PayPal API and the ANPR Camera system.

2) *UParking Website*

The website is developed for the administrator side. It allows the administrator to manage parking, booking and users. It also generates statistics and facilitates viewing of records and exporting them as PDF files. The administrator also can monitor the state of the parking lot. The libraries used to implement the administration side are PHPMailer, fpdf and chart.js.

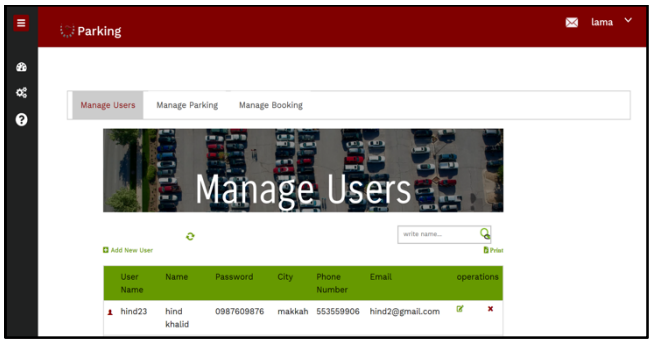

Fig. 6. UParking website (Manage Users page).

3) *UParking Mobile Application*

The user side is implemented as an Android mobile application to handle searching, booking and payment procedures. Libraries used include Volley, PayPal SDK, Google Maps SDK and MPAndroidchart.

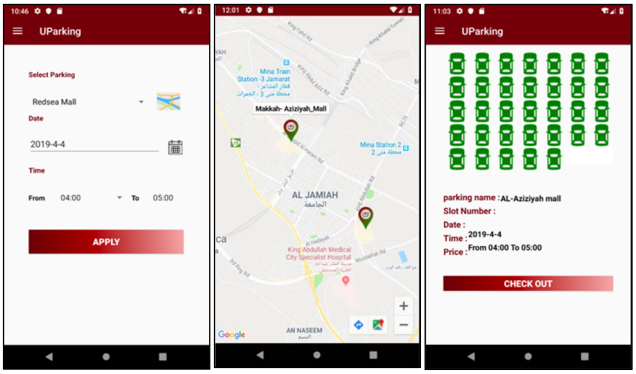

Fig. 7. UParking mobile application (select parking and booking available parking slot).

4) *Connect with ANPR Camera*

The ANPR camera system is connected to the UParking server to capture the plate number and permit users to access the parking lot by creating a socket. The camera will read the plate number using OCR technology and register additional information, such as the date and time.

5) *Connecting with Arduino*

The UParking system provides a monitoring service that shows the state of each slot in the parking lot by using TCRT5000 sensors, an Arduino mega board and Nodemcu chip. Both the Arduino mega board and Nodemcu are programmed separately and then run sequentially.

6) Testing and verification

We performed tests to verify the system against functional requirements. Each functionality was tested individually, and results were compared with predictions. For each subsystem, functions were described, and expected and actual results were specified. For the administration side, the tested functions involved the detailed processes of signing in, generating statistics, and controlling the parking, users and reservations. Meanwhile, the user-side functions were tested in detail including registration, searching, booking and payment. Tests were extended to check more functions and specify further actions to consider for the results. The TCRT5000 sensor was tested to determine whether it modified the occupancy state or not. Also, the camera was tested to see if it sensed the car's presence and allowed registered users to access it.

Non-functional aspects of the system were also executed to check performance, usability and security. The system was evaluated by users through testing scenarios that included verifying the main functions of the system, checking usability in navigation processes and error handling. The scenarios were set to evaluate the integration of units where three users were selected to follow different scenarios. For example, the first user would register and book a slot then go to the entrance of the parking lot and park his or her car inside. The second user would try the same without confirming the reservation. A third user would manage and modify the parking records as an administrator. The users also evaluated the non-functional requirements and provided feedback about their experiences. Moreover, the system modules were integrated and tested as an entire system to verify that the interfaces of the software and hardware modules worked with the database accurately. The system sufficiently passed functional, non-functional and integration tests.

V. CONCLUSION

This paper presented a developed smart parking management system based on IoT technology. The UParking system combines a mobile application that offers a variety of features and services to serve users and a website to manage parking. The system is supported by interrelated IoT devices such as ANPR Camera and the TCRT5000 sensor to provide automated control technology with minimal human intervention. It will control access to parking and continuously monitor the location of the cars and parking lot. This system proposes an integrated solution to enhance parking management processes effectively based on defined requirements and analyses. The system will also be extended to cover additional new features. It will be tested practically in various situations and can be integrated with other systems.

VI. REFERENCE

[1] Streetline. (2017). Parker (Version 5.0.5.5) [Mobile application software]. Retrieved Sep. 2018 from https://www.theparkerapp.com/

[2] ParkWhiz. (2017). ParkWhiz (Version 7.5.4) [Mobile application software]. Retrieved Aug. 2018 from https://www.parkwhiz.com/

[3] BestParking.com. (2017). BestParking (Version 7.5.4) [Mobile application software]. Retrieved Aug. 2018 from https://www.bestparking.com/

[4] Spot Hero Inc. (2017). SpotHero (Version 4.11.0) [Mobile application software]. Retrieved Sep. 2018 from https://spothero.com/

[5] Parking Panda. (2013). ParkingPanda (Version 4.4.0) [Mobile application software]. Retrieved Sep. 2018 from https://www.parkingpanda.com/

[6] mawgif. (2018). mawgif (Version 1.5.1) [Mobile application software]. Retrieved Aug. 2018 from https://www.mawgif.com/

[7] Ajman Municipality. (2017). Mawqifi (Version 2.6) [Mobile application software]. Retrieved Aug. 2019 from https://play.google.com/store/apps/details?id=ae.gov.am.mawqifi.smartapp

[8] L. Mainetti, L. Patrono, M. L. Stefanizzi and R. Vergallo, "A Smart Parking System based on IoT protocols and emerging enabling technologies," *2015 IEEE 2nd World Forum on Internet of Things (WF-IoT)*, Milan, 2015, pp. 764-769.

[9] D. Kanteti, D. V. S. Srikar and T. K. Ramesh, "Intelligent smart parking algorithm," *2017 International Conference on Smart Technologies for Smart Nation (SmartTechCon)*, Bangalore, 2017, pp. 1018-1022.

[10] A. Khanna and R. Anand, "IoT based smart parking system," *2016 International Conference on Internet of Things and Applications (IOTA)*, Pune, 2016, pp. 266-270.

[11] J. Shi, L. Jin, J. Li and Z. Fang, "A smart parking system based on NB-IoT and third-party payment platform," *2017 17th International Symposium on Communications and Information Technologies (ISCIT)*, Cairns, QLD, 2017, pp. 1-5.

[12] B. M. Mahendra, S. Sonoli, N. Bhat, Raju and T. Raghu, "IoT based sensor enabled smart car parking for advanced driver assistance system," *2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT)*, Bangalore, 2017, pp. 2188-2193

[13] S. Hamid, E. Nuraihan Mior Ibrahim, M. Bin Abdul Rahman and S. Mohamed Shuhidan, "Industry 4.0 urban mobility: goNpark smart parking tracking module", in ICCIP '17 Proceedings of the 3rd International Conference on Communication and Information Processing, Tokyo, Japan, 2017, pp. 503-507.

[14] L. Kumar, M. H. Khan and M. S. Umar, "Smart parking system using RFID and GSM technology," *2017 International Conference on Multimedia, Signal Processing and Communication Technologies (IMPACT)*, Aligarh, 2017, pp. 180-184.

[15] Y. Joshi, P. Gharate, C. Ahire, N. Alai and S. Sonavane, "Smart parking management system using RFID and OCR," *2015 International Conference on Energy Systems and Applications*, Pune, 2015, pp. 729-734.