A Mobile Application for IoT-based Car Parking

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***Abstract*—This paper presents an innovative IoT-based car parking system aimed at solving parking issues. Our proposed application aims to develop a user-friendly mobile application that integrates with IoT technology to provide real-time updates on parking availability. With the growing number of users, it is necessary to implement a more efficient and data-driven parking management system. The key issue this project aims to address is the challenge of finding available parking spaces for users. This problem causes inconvenience, congestion, and wasted time. This paper proposes a design methodology that incorporates Infrared (IR) sensors into each parking slot to accurately detect the presence of cars. The data is sent to a cloud server and seamlessly integrated into a mobile app for the user to access. The project's major results include the successful development of a mobile application using the Flutter framework, which provides a cross-platform solution for users. Firebase was utilized as the database and user authentication system for efficient data management. The evaluation results show that the IoT-based car parking system has greatly enhanced the users' parking experience by enabling them to easily locate and reserve parking spaces.**

***Index Terms*—IoT, Parking System, Functional Requirements, Mobile Application**

I. Introduction

In recent years, with the growth of cities and the increase in car ownership, parking has become a major problem. City planners are currently assessing potential solutions for the issue. The Internet of Things (IoT) plays a significant role in this context. It's a new technological idea that could potentially solve the issue of parking. Finding a parking spot in big cities can be extremely difficult [1].

IoT technology involves connecting everyday objects, such as parking sensors, to the Internet, allowing them to communicate and share data. In our Car Parking System, we will use IoT devices with infrared (IR) sensors and a cloud-based infrastructure. These sensors will be strategically placed in parking spaces to continuously monitor the occupancy status of each slot. The advantages of this IoT-based Car Parking System are good. The system will offer up-to-date information on parking availability, allowing users to easily find and reserve parking spots through a mobile app. This eliminates the need for time consuming searches and reduces frustration. Additionally, the system will collect valuable data on parking patterns, allowing parking administrators to make informed decisions about optimizing their parking facilities [2], [3].

Our IoT-based car parking system is designed to improve and simplify the parking experience on our campus. We will evaluate the effectiveness of our proposed system on the parking area of Al Ain university at Abu Dhabi campus (Henceforth, AD campus parking).The system utilizes IoT technology to deliver real-time updates on parking space availability to students, teachers, and administrative staff. The system utilizes strategically placed IoT sensors in each parking space to detect the presence or absence of vehicles, providing accurate and real-time information. Users can easily check parking availability, reserve spots in advance, and navigate to their reserved parking spaces through a user-friendly mobile app. This eliminates the inconvenience of searching for parking. This system enhances parking efficiency and offers valuable insights into parking usage patterns, allowing administrators to optimize parking infrastructure.

This paper is organized as follows: Section two presents the scope and the expected deliverables of our proposed application. Section three highlights several related studies available in the literature. Section four presents the application design and its implementation. The evaluation is presented in Section five, and the paper is concluded in the last section.

II. Scope and Expected Deliverables

In this paper, we will develop an iOS app integrated with IoT hardware using infrared (IR) sensors to enhance the parking management system. The goal is to utilize technology to streamline the parking process, reduce time spent searching for spots, and improve overall efficiency and user experience. The scope of our proposed application can be summarized as follows:

- The project will cover the development of the iOS app and integration with the IoT hardware;
- Deployment will be limited to the parking area of Abu Dhabi campus at Al Ain Univeristy with potential for future expansion;
- The system will manage a specific number of parking spaces, including a reserved female parking area;
- The scope includes the conversion of the female parking area into a paid parking zone to ensure proper usage.

The expected deliverables can be summarized as follows:

1) IOS Car Parking App:
   - Real-time parking availability information.
   - Reservation system for parking spots.
   - Secure payment gateway for paid parking areas. User authentication to access reserved areas.
2) IoT Hardware Setup:
   - IR sensors in parking spots for vehicle detection.
   - ESP32 microcontroller for data processing. Wi-Fi module for internet connectivity.
   - Real-time data transmission to cloud server.

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3) Backend Infrastructure:
   - Cloud-based server setup for data storage and processing.
   - Database management for parking occupancy and user accounts.
   - Admin panel for monitoring and managing the parking system.

III. Related Work

The study of [4] effectively monitors parking lot vacancies by combining ZigBee technology with PIC (Peripheral Interface Controller). The proposal stands out for its emphasis on heightened security. Before exiting the parking area, users must enter an exit password. The barrier gate remains closed to prevent unauthorized vehicles or those without proper clearance from leaving the premises. This feature highlights the model's focus on security and regulation. A notable concern arises from integrating the GSM (Global System for Mobile Communications) and SMS (Short Message Service) modules. Though these elements enhance functionality by sending users entry and exit passwords via text messages, they also significantly increase the system's cost. Additionally, there is a reliability issue. During periods of high network traffic or congestion, users may not receive the required SMS. This could potentially cause inconveniences, as individuals would be unable to access or exit the parking area without the necessary password [4].

A new method has emerged in the field of parking solutions that utilizes Bluetooth technology, which is commonly found in modern devices. Within this system, an individual's Bluetooth feature serves as a means of identification, enabling effortless registration upon entering the parking facility. The ability to quickly identify a vehicle based on its Bluetooth signature streamlines the parking process. This system incorporates a mechanical component called the "rack and pinion mechanism" to simplify the parking process. This mechanism efficiently guides vehicles into parking slots in a linear motion, maximizing space utilization [5].

A surveillance system has been implemented with a camera to monitor the parking lot. This camera captures images of the ground markings in parking lots. The system can analyze images to identify available parking spaces. One camera can detect multiple cars at the same time. A single camera can replace the need for multiple sensors and gadgets, simplifying tasks. However, there are some traffic accidents. The camera's visibility can be affected by unfavorable weather conditions like fog or rain. Sometimes, visibility can be challenging on a cloudy day. The camera requires an unobstructed view. The security camera needs to be positioned at a high location to ensure an unobstructed view of the parking spaces [6].

In [7], a car parking app automatically sends a signal to the university's computer system, like a digital greeting. By sending an HTTP request through the gate's internet connection. The university system responds with a JSON-formatted message. Think of it as a quick text message conversation between your phone and the university's computer system. However, this is where the discussion becomes more specific. The conversation management system consists of three layers: Application (the mobile app), Session (chat management), and Communication (ensuring chat delivery). These three layers can add complexity to parking management, although they are an effective approach.

The mobile application presented by [8] enables users to access open parking areas, view parking charges, locate their vehicles, and conveniently pay parking fees. Despite the promising results of the system in preliminary tests, there are potential challenges that need to be addressed. These challenges include maintaining the project timeline, ensuring smooth wireless communication, and safeguarding user data and payments within the app.

A recent study presented a smart parking app created specifically for university campuses [9]. The app aims to streamline parking reservations for staff, students, and visitors. Each parking slot is uniquely identified and equipped with an infrared (IR) sensor that is connected to an Arduino device. This allows for the determination of the slot's availability. The software, developed in Android Studio and integrated with an SQL Database, efficiently manages parking spaces and has potential for wider use.

The system presented by [10] comprises two essential modules, a monitoring module and a reservation and security module. The monitoring module uses wireless sensors to detect parking spaces. Each sensor is installed at a specific parking location. The monitoring module uses wireless sensors to detect parking spaces at individual locations. These sensors create a network that gathers data on parking space availability and transmits it to the central car park management center. The reservation and security module utilizes the Global System for Mobile Communication (GSM) system. The parking system of [11] utilizes wireless sensors, specifically infrared sensors, to detect the presence of vehicles in parking spaces. The system consists of two modules: a monitoring module and a master module. The monitoring module consists of a ZigBee transmission and reception unit, an LCD display, and a PIC microcontroller. Infrared sensors detect the presence of cars and send this information to the microcontroller. The microcontroller then displays the status of the parking spaces on the LCD screen. Data is transmitted to the master module through ZigBee technology. ZigBee technology is selected for its energy efficiency and cost-effectiveness in wireless data transmission.

IV. Application Design and Implementation

To design and implement our proposed IoT-Based Car Parking System, we need to highlight the key requirements. These requirements cover a wide range of functional and non-functional aspects, from how it works to what users can expect. By establishing these requirements, we have a clear roadmap for the proposed system. Figure 1 presents a high-level system architecture of our proposed framework.

The elements of our proposed framework can be summarized as follows:

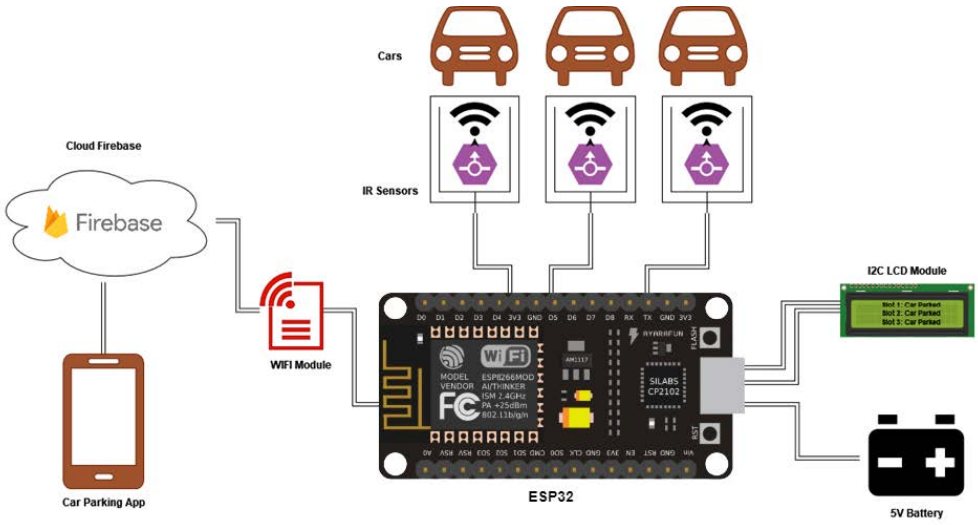

Fig. 1. A general framework of our proposed IoT-based parking system

- We have the Cloud Firebase, which is a cloud-based database and backend service. It's where all the data related to the parking system is stored and managed. This data can include user accounts, parking spot availability, payment processing, and more.
- Next is the mobile phone with the Car Parking App installed on it. This app communicates with the Cloud Firebase, allowing users to interact with the parking system. Through this app, users can find available parking spots, make reservations, and process payments.
- The WiFi Module represents the hardware component that provides internet connectivity. In this case, it appears to be connected to an ESP32 microcontroller a powerful and versatile module popular in IoT projects for its WiFi and Bluetooth capabilities.
- The ESP32 is the central controller for the hardware side of the system. It receives sensor data, processes it, and communicates with other components. In this system, it's likely responsible for collecting information from the IR Sensors and sending it to the cloud.
- The IR Sensors are used to detect the presence of cars in parking slots. They are likely set up to communicate their status to the ESP32, which then updates the parking status in real-time.
- There's an I2C LCD Module connected to the ESP32, which is used to display information such as parking slot statuses directly on the site.
- Finally, there's a 5V Battery providing power to the hardware components, ensuring that the system can operate independently of a wired power source.

The hardware design for our car parking application focuses on efficient and reliable detection of the presence of vehicles in parking slots. With the use of ESP32 and IR sensors, we have built a real-time parking monitoring system that provides instant feedback regarding the availability of parking slots. The key hardware components of our proposed IoT-based parking system can be summarized as follows:

- ESP32: This is the microcontroller that acts as the brain of the system. It is responsible for processing the input from the IR sensors and driving the LEDs accordingly.
- IR Sensors: These sensors detect the presence or absence of vehicles in each parking slot. When a car is parked over them, the IR signal is reflected back, which the sensor detects.
- Breadboard and Wires: Used to make the necessary connections between the components without the need for soldering.
- I2C LCD: Used to LCD to show the live car slots booking on the screen.

The hardware design for the car parking application provides a simple yet effective solution for parking management. With real-time accurate vehicle detection using IR sensors, it ensures an enhanced user experience while optimizing parking space utilization. This design is not only efficient and reliable but also easy to implement and scale based on the requirements.

The hardware implementation of our proposed system is presented in Figure 2.

The programming environment of our proposed system encompasses the essential tools and technologies required to develop, test, and deploy the parking application, incorporating both iOS app development and IoT integration aspects. The following environments and frameworks have been used and applied to implement our parking system:

- Xcode: Xcode is the primary IDE for developing the iOS-based Parking Finder Application. It offers a comprehen-

Fig. 2. The hardware implementation of our proposed IoT-based parking system

sive set of tools for Swift programming, interface design, debugging, and app deployment on iOS devices. Xcode streamlines the entire app development process within a single environment.

- Swift: Swift is the core programming language used to develop the iOS application. It's known for its speed, efficiency, and robustness. Swift's syntax is concise and user-friendly, making it ideal for iOS app development.
- Firebase: Firebase serves as the cloud-based database for the application. It provides real-time data synchronization, user authentication, and secure storage. Firebase's scalability ensures smooth handling of user data, reservations, and parking spot information.
- ESP32: The IoT component is integrated using ESP32, a versatile microcontroller. It facilitates communication between the app and IR sensors placed in parking spots.
- Arduino IDE: Arduino IDE is employed for programming ESP32 boards. It simplifies the process of uploading code to the microcontroller.
- C Programming Language: C is the programming language used for writing code that runs on ESP32. It enables efficient management of IoT functionalities.

V. Evaluation

The development of our parking system is centered around Apple's ecosystem using Swift as the primary programming language and Xcode as the integrated development environment (IDE). Swift is the heart of the iOS application development for this project. Additionally, Swift's strong typing and error handling capabilities prevent crashes and ensure code safety. Figure 3 presents a screenshot of create account, select payment, login, and add parking functionalities of the implemented mobile application. To evaluate our proposed mobile IoT parking application, the implementation has been done at the AD campus parking area of Al Ain University. We tested all the key functionalities of our mobile application. To achieve this aim, we created testing artifacts such as test cases and test plans, which outline the specific conditions under which a test is performed, the steps taken to execute the test, the expected result, and the actual result. Table 1 presents the test cases related to reserve parking slot functionality. Table 2 presents test cases to check if the app correctly displays available parking slots without knowing how the app fetches and displays this data.

TABLE I
Test cases related to reserve parking slot functionality

Test Case ID	Description	Steps	Expected Outcome	Actual Outcome	Status
TC_RP_01	Reserve a parking slot via the app	Select Find Parking, choose a parking slot and confirm reservation.	A parking slot is reserved	Shows parking slot is reserved	Done
TC_RP_02	Reservation without internet connection	Disable internet Attempt to reserve a slot	An error message is displayed	Shows error messages	Done

Conclusion

This paper presented an IoT-based car parking system that successfully addressed several key objectives with the aim of improving the parking experience. The primary goals of the project were to develop a user-friendly mobile application that empowers students and staff to conveniently reserve parking slots in real time and to integrate IoT technology for accurate

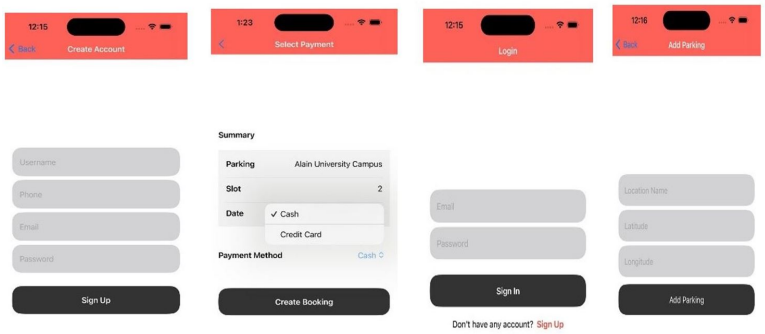

Fig. 3. A screenshot of create account, select payment, login, and add parking functionalities

parking slot availability updates. The project also aimed to provide valuable insights to the administration regarding parking patterns to optimize infrastructure in the future. To achieve these objectives, we followed a comprehensive design methodology that involved developing both the mobile application and the IoT infrastructure. As the evaluation test cases suggest, our proposed mobile application provided users with real-time parking slot information, making it easy for them to find and reserve a parking space. Furthermore, the administration gained valuable insights into parking patterns, enabling them to make informed decisions about parking infrastructure optimization. It's important to acknowledge certain limitations that emerged during the project. The IR sensor-based system, while effective, may require maintenance and occasional sensor calibration. Additionally, the real-time availability updates are dependent on the sensors' accuracy and connectivity.

TABLE II
TEST CASES TO CHECK IF THE APP CORRECTLY DISPLAYS THE AVAILABLE PARKING SLOTS

Test Case ID	Description	Input	Expected Output	Actual Output	Pass/Fail
TC01	Login Test	Valid email and password	Successful login, redirection to the home screen	As Expected	Pass
TC02	Login Test	Invalid email	Error message for invalid email	As Expected	Pass
TC03	Reserve Parking Slot	Choose a specific date, time, and slot	Confirmation of reservation	As Expected	Pass
TC04	Payment Process	Valid payment information	Successful payment processing	As Expected	Pass
TC05	Update Profile	Change phone number	Updated phone number in profile	As Expected	Pass
TC06	Parking Availability	Query for current parking slot availability	Display of available parking slots	As Expected	Pass
TC07	Logout Test	User initiates logout	Successful logout, return to login screen	As Expected	Pass
TC08	Navigation to Slot	User selects 'Navigate'	App provides directions to reserved slot	As Expected	Pass
TC09	Submit Complaint	User submits a valid complaint	Confirmation message of received complaint	As Expected	Pass
TC10	Parking History View	User navigates to parking history	Display of past parking reservations	As Expected	Pass

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