Prince Sultan University

Department of Computer & Information Sciences

PSU Parking System Senior Project

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Table of Contents

List of Figures

Abstract

Due to rapid urbanization of cities and the increase of vehicles, efficient parking management systems are becoming more and more important. The ongoing parking challenges on campus are tackled by this project which proposes an IoT based smart parking solution for Prince Sultan University. To detect real time parking space occupancy, the system uses ultrasonic sensors connected to Arduino microcontrollers that transmit data to a cloud-based database. The application is a user-friendly mobile application for the drivers, which offers navigation assistance and parking availability updates, reducing search time, and minimizing congestion. Solar panels provide the hardware component with the power needed to stay in line with global environmental goals. The financial model explores the Arduino IoT33, Arduino Uno with a wireless module, and Arduino 2560 microcontroller options based on cost and performance. In addition, the project utilizes data analytics to enable strategic decisions for anticipated future enhancements of infrastructure and revenue from paid parking reservations. In addition to reducing congestion and optimizing resource allocation, this IoT based approach gives the university valuable insights into long term planning.

1. Introduction

1.1 Background and Motivation

As urban populations continue to grow exponentially and vehicle usage increases, parking management has become a major urban planning problem. In educational institutions and many cities, inefficient parking systems cause daily frustration, lost time and environmental degradation. In fact, inefficient parking management wastes $73 billion in the U.S. alone each year, according to a National Parking Association report (Shoup, 2018a) that is attributed to wasted time and fuel. Like Prince Sultan University, with growing student and staff population, the parking infrastructure is not adequate and results in prolonged vehicle search time, congested entry and exit points and increased emissions. The necessity to mitigate these challenges on campus is the motivation for developing a smart parking solution. This project strives to revolutionize the parking experience through the use of Internet of Things (IoT) technology, reduce environmental impact and provide a more efficient campus ecosystem. (Zaman *et al.*, 2024) discuss the advancement of IoT technology in the past few years and how sensor networks and real time data analytics can be used to solve such complex issues.

1.2 Problem Statement

Prince Sultan University's parking management system, however, is currently not sophisticated enough to manage high volume traffic in a well-organized manner. Without real time data, drivers have to guess whether there is a parking spot available, which wastes time and fuel and creates bottlenecks throughout the campus. The university is also badly equipped to make decisions about future infrastructure investments, since it does not collect nor can it analyze parking data. Studies have shown that up to 30 per cent of traffic congestion in urban areas is caused by drivers looking for parking(Vera-Gómez *et al.*, 2016), but there is a need for data driven solutions. This project fills these gaps by introducing an IoT based smart parking system which enhances parking operations and provides useful insights to campus management.

1.3 Objectives of the Project

The project is designed with several key objectives in mind, each aimed at solving specific challenges faced by the university:

1.3.1 Provide real time parking data.

The objective is to provide drivers with up-to-date information on how many parking space are available via a simple mobile application. According to (Sahfutri *et al.*, 2018), real time data will be collected by ultrasonic sensors attached to a network of Arduino microcontrollers. The application of this technology will greatly decrease search time for parking and reduce congestion at peak times, which will increase overall efficiency of campus traffic flow.

1.3.2 Optimize the parking distribution for Male/Female

Parking generally occurs in a centralized manner: it is said that many men park in a lot and then walk to their destination, while women park near their destinations. Another important objective is to optimize parking space allocation according to the needs of male and female drivers. It means looking at how people use parking so that everyone gets their fair share of parking resources and makes campus more inclusive and accessible. This part of the project is important for (Nayak *et al.*, 2023), whose research also stresses the importance of gender sensitive urban planning.

1.3.3 Reduce Time and Congestion

The project aims at cutting on the average time that drivers spend in search of parking space by implementing a real time parking information system. Students and faculty will be helped by this, as well as it will help to decrease the amount of vehicle emissions, which is a type of pollution the university is trying to combat. Reports from urban studies show that smart parking solutions can reduce the time spent in search by as much as 40% (Fahim, Hasan and Chowdhury, 2021)– this is a key area for improvement for campus.

1.3.4 Provide Data Insights for Future Expansion

Much parking data regarding peak usage times and occupancy rates will be captured by the system and delivered to the university administration. It will also assist in decision making on future infrastructure investment such as developing more parking structures, or redeployment of those resources. This project will enable the university to incorporate data oriented solutions to urban planning which according to (Gaftandzhieva *et al.,* 2023) is crucial.

1.3.5 Generate Revenue through Paid Reservations

The development of an innovative paid reservation function that can be incorporated into the parking demand management system is introduced here. This would be possible if the university allows students to book a parking space especially during the most congested time at an extra cost. By the help of this model, both demand management and a stable financial plan are constructed, as (Nath *et al.*, 2023) suggested. It is a win win; the money can be channeled back into the enhancement of the facilities on campus.

1.4 Scope of the Project

This project is about making and putting into action a parking system that uses IoT stuff with hardware, software, and data analysis. It will use ultrasonic sensors and three kinds of Arduino microcontrollers, plus solar panels to save energy in the setup. Users will have a mobile app to talk with the software, while a cloud database will keep and look at parking info. Different ways to connect to the internet like Wi-Fi, mesh networks, etc., will be checked in the project so the sensors can stay linked to the main server. Also, data analysis will help give information for better decision-making and future plans for infrastructure.

1.5 Project Relevance and Importance

Parking problems and bad management systems are not just annoyances; they also cause economic and environmental troubles. As campuses expand, using smarter solutions based on data is getting more crucial. This project matters because it can solve many problems at once: it helps improve user experience, makes resource use better, and backs up sustainability aims. Like shown by this project, using IoT in schools is a fresh way to update city structures as (Nath *et al.*, 2023) suggest. The system will turn Prince Sultan University into an example of innovation and effectiveness by providing real-time parking info and useful insights.

1.6 Project Constraints and Assumptions

There are limitations and assumption when it comes to putting in place an IoT based system. One of the main limitations is the need for a stable internet connection, whether from already available Wi-Fi or a new mesh network. Additionally, the project expects that solar panels will provide steady power throughout the year, even if their efficiency may change by season. Also, the cost analysis relies on the current market prices for hardware and assumes that these prices will not change. The Arduino 2560 is a budget-friendly choice, but it brings issues related to wiring difficulty and looks on the campus (Abdulsaheb *et al.*, 2024). The limitations and beliefs will be monitored closely to ensure the project stays doable and useful.

2. Literature Review

The thesis focuses on the current studies and technology in IoT parking systems, focusing on parts and methods important for modern parking management. The role of ultrasonic sensors is discussed, as they are widely used for vehicle detection due to their accuracy and low cost. The paper also covers GPRS modules, explaining how they enable reliable data transmission over long distances, which is crucial for network stability. The use of solar power is mentioned, showing how it can sustainably power IoT devices and lower operational costs. Moreover, the review includes several case studies that show how smart parking systems have been used in city settings, highlighting the practical benefits and issues faced during implementation. It looks at different communication methods like Wi-Fi, LoRaWAN, and GPRS. It looks at how well they perform in terms of the factors including data speed, energy consumption and scalability.w. This assists to determine which one is suitable for large establishments. It also talks about applying analytics like advanced analytics and machine learning to guess parking trends and master space correctly. Then it examines those that are sustainable, such as the dynamic pricing which is the use of latest data to control demand well and increase revenue to support the better environmentally friendly urban infrastructure.

2.1 Overview of IoT Applications in Parking Systems

2.1.1 IoT in Urban Infrastructure

The usage of IoT in the infrastructure of the city, has revolutionized the parking management system. Real-time data helps reduce traffic. A mix of sensors and wireless devices allows smart parking systems to oversee and manage parking spots. (Andrade *et al.*, 2023) say that using IoT in cities has noticeably enhanced traffic movement and cut down emissions. In busy areas, traditional parking methods do not work well, and these systems work particularly well here. (Sant *et al.*, 2021) showed that IoT uses not just monitoring but also predictive analytics to guess parking availability based on past data. This proactive approach gives a boost to user experience and increases resource allocation. In addition (Son *et al.*, 2023) predict that the adoption of IoT in urban infrastructure will expand rapidly with the global adoption of IoT technology advancements in sensor technology and machine learning algorithms.

2.1.2 Case Studies of Smart Parking Systems

The success of IoT based parking systems around the world is underscored in several case studies. For example, in San Francisco, the smart parking initiative, SFpark, used ground based sensors for real time data of parking availability and dynamic pricing to manage demand (Shoup, 2018b). The project reduced parking related congestion by 30 percent and increased parking turnover. There is another example of the deployment of IoT parking solutions in Barcelona, where sensors deployed on parking spots broadcast occupancy status to a main system that can be accessed via a mobile app by drivers, in a study by (Fouad, 2019) it was found that this implementation reduced search time by 25%, and minimized traffic congestion in heavily used areas. These cases demonstrate the transformative potential of IoT in urban parking, and how it can be replicated in university settings.

2.2 Use of Ultrasonic Sensors in IoT Solutions

Due to their reliability and cost effectiveness, ultrasonic sensors are a key part of many IoT based parking systems. Since these sensors are capable of detecting the presence or absence of vehicles using sound waves they are ideal for real time monitoring of parking spaces. (Kalašová *et al.,* 2021) study showed that ultrasonic sensors have an accuracy rate of more than 95% in controlled environments, although external factors such as temperature and humidity can affect performance. Improvements in sensor capabilities have also been made to allow better integration with wireless networks and data management systems. (Sahfutri *et al.*, 2018) conducted research using ultrasonic sensors in large scale parking facilities, in which data from thousands of sensors were processed in a cloud computing infrastructure. The scalability and efficiency of ultrasonic technology in IoT application is highlighted in this research.

2.3 Communication Technologies for IoT Systems

2.3.1 GPRS-Based IoT Solutions

Because General Packet Radio Service (GPRS) is widely used in IoT communications, reliable data transmission over cellular networks is possible. In smart parking, GPRS modules allow sensors to communicate with a central server to allow real time data analysis. (Noor-A-Rahim *et al.,* 2022) conducted a study that showed that GPRS based systems work very well in environments where Wi-Fi or wired connections are not practical, such as large outdoor parking lots. The problem however, with GPRS technology is that it has much lower data transfer rates and higher latency than newer protocols. It, however, is still a viable option for low bandwidth applications without an urgency for real time updates.

2.3.2 Comparison with Other Protocols (Wi-Fi, LoRaWAN)

Alternative communication protocols used in IoT based parking system are Wi-Fi and LoRaWAN. Wi-Fi however, provides higher data transfer speeds and is only useful within limited coverage areas, i.e. in small parking lots or within indoor environments. While LoRaWAN features far less network capacity, it's useful because LoRaWAN offers long range connectivity with low power consumption, which is perfect for city-wide deployments, but for shorter distances. (Corak *et al.*, 2018) conducted this research and found that LoRaWAN is more energy efficient and scalable for large installations, though it may not support high frequency data transmission. In a comparative study, (Dahiya *et al.*, 2024) show that these technologies have tradeoffs, and they recommend choosing a protocol based on parking system specific requirements including range, data volume, and power consumption.

2.4 Solar-Powered IoT Systems

Solar power is becoming a common energy solution in IoT systems as it is sustainable. Using solar panels, smart parking systems can lessen their carbon impact since sensors and communication devices use renewable energy. In places with less sunlight, solar-powered IoT setups can work by themselves for a long time, as stated by (Prasanna Rani *et al.*, 2023). (Alshahrani *et al.*, 2024) provided an example where solar-powered parking sensors were used successfully at a university, emphasizing energy efficiency and sustainability. The findings showed that the system worked reliably all year with little maintenance and proved that solar energy is viable for IoT uses.

2.5 Parking Data Analytics for Decision Making

2.5.1 Using Data for Peak-Time Analysis

Enhancing parking management involves the use of research in an attempt to understand how and when parking is used. These technologies can analyze historical information and suggest how the parking demand can be met and resources be deployed. (Sneha Channamallu *et al.*, 2024) found that studying peak periods would decrease traffic congestion and enhance the satisfaction of users by real-time management of parking space and its cost. It is very useful for the campus management for the decisions and the resource allocations on the campuses. Knowing when and where there is an increase in parking demand enables the administrators to control parking better and in the same way plan for the next infrastructure projects.

2.5.2 Forecasting Future Parking Demand

Taking a long period to plan and constructing structures require an element of predicting the number of parking spots that may be required later. The models that rely on previous counts and present data enable one to predict the parking requirements in future which concern school time tables, activities that are rare and number of students who choose them. (Dahiya *et al.*, 2024) pointed out that it’s important to have accurate demand forecasting in minimization of costs and maximizing space usage. We have been told that the machine learning techniques, including time series modeling and regression analysis, have the capability to predict the demand with a very high accuracy. These models can also run different scenarios which provide great value in strategic planning and investment decisions.

2.6 Monetization in Smart Parking

Modern parking systems consider the core of sustainability as reducing environmental impact and promoting efficient resource use. In addition to a greener urban environment, solar power, energy efficient sensors, and optimized traffic flow are all part of the picture. (Biyik *et al.*, 2021) reviewed the environmental benefits of smart parking, which include reduction in emissions and fuel consumption of up to 80 percent. There are monetization strategies, such as dynamic pricing and paid reservation, for parking management which are sustainable. Parking fees are dynamic in the sense that they vary according to demand and the goal is to get turnover, which will in turn maximize revenue. (Wen, Yang and Chen, 2021) provide a case study, a metropolitan parking system dynamic pricing, in which revenue increased by 20% with satisfaction keeping constant by users. Attracting sponsors for this project is also a possible choice for generating more revenue for the project.

3. System Design and Architecture

In the smart parking system based on IoT, the design and structure involve many hardware and software elements to support the high-quality experience of users. The following subsections explain the architecture of the system and how the various components contribute to the delivery of real-time parking information alongside the improved usability of the system. These interactions are between the sensors, microcontrollers, communication modules, power sources, a central database and a mobile application interface for the end user.

3.1 Overview of System Architecture

Below is the system architecture is divided into important modules that work in parallel to identify, analyze, and display parking space availability. Every parking space is fitted with an ultrasonic sensor that is wired to an Arduino board charged by a solar system. These sensors measure distance to an object and determine vehicle presence if the distance is within the range of the sensor. Whenever a vehicle is sensed, the sensor data is sent to the central server over GPRS or based on the selected communication technology. Information is collected using sensors and is stored on the server where occupant information is stored in a MySQL database. This real-time data can then be accessed through a mobile application which is an iOS app in this diagram and which shows users the available parking lots, enables them to book for one and receive notifications. From the app, users can easily see available and occupied spots as the parking locations are marked with tags like C1, C2 and so on.

The whole system is scalable to cater for parking facilities of different sizes as shown in the table below. Solar power integration assists in cutting down on costs of running the parking systems and also improves sustainability especially for outdoor parking systems. This architecture helps in maintaining the energy efficiency of the system, its reliability and friendliness of the system for the user.

3.2 System Architecture Diagram

The system architecture diagram shown in *Figure 1* can be broken down as follows:

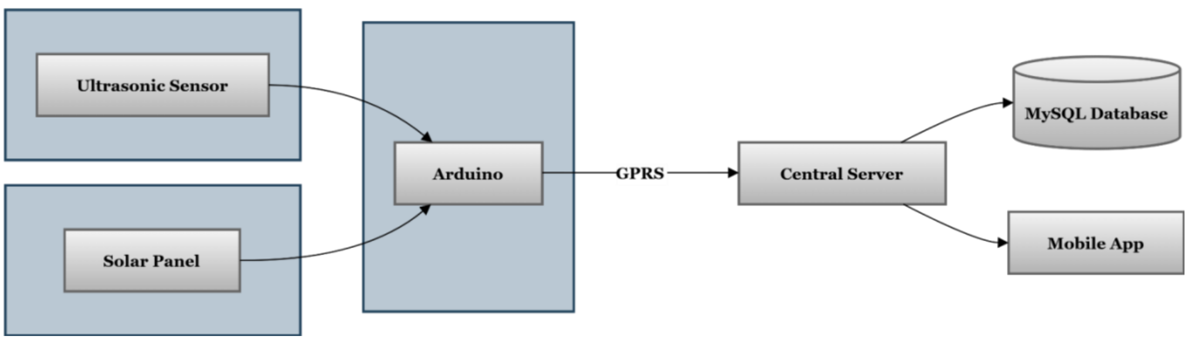

Figure 1: System Architecture Diagram

1. **Ultrasonic Sensors and Arduino Microcontroller**: Every parking slot has an ultrasonic sensor mounted on it and interfaced with an Arduino board. The sensor is used to detect the presence of a vehicle and passes this information to the Arduino which filters the information and formats it for transmission.

2. **Solar Power Supply**: The Arduino and sensor units are connected to solar power sources in order to be independent and appropriate to be used outside. This feature eliminates the need for an external power source, which is in harmony with the green energy use.

3. **Communication Module (WIFI)**: On processing, the Arduino transmits occupancy data to the central server with the help of a WIFI communication module. Depending on the setup this module can employ other modules like GPRS. GPRS is useful over areas with no Wi-Fi as it offers high speeds but with lower latency than GPRS.

4. **Centralized Database (MySQL)**: The occupancy status and historical data are handled by the MySQL database to be located on the central server. This makes it easy to collect data and also to update the availability of parking spaces in real time. The database itself forms the basis for analytics and reporting and supports additional functions such as time of day analysis or demand forecasting.

5. **Mobile Application Interface**: Customers interface with the system through a smart phone application that shows the status of parking. The parking app probably for both iOS and Android operating systems enables users to view availability of parking slots, book for them, and get notifications. Specifically, the interface of the app is expressly simple, and there are appropriate signs that separate empty and taken spaces.

3.3 Data Flow Diagram

The data flow diagram in *Figure 2* outlines the system's data processing stages, from sensor data collection to the user's mobile interface.

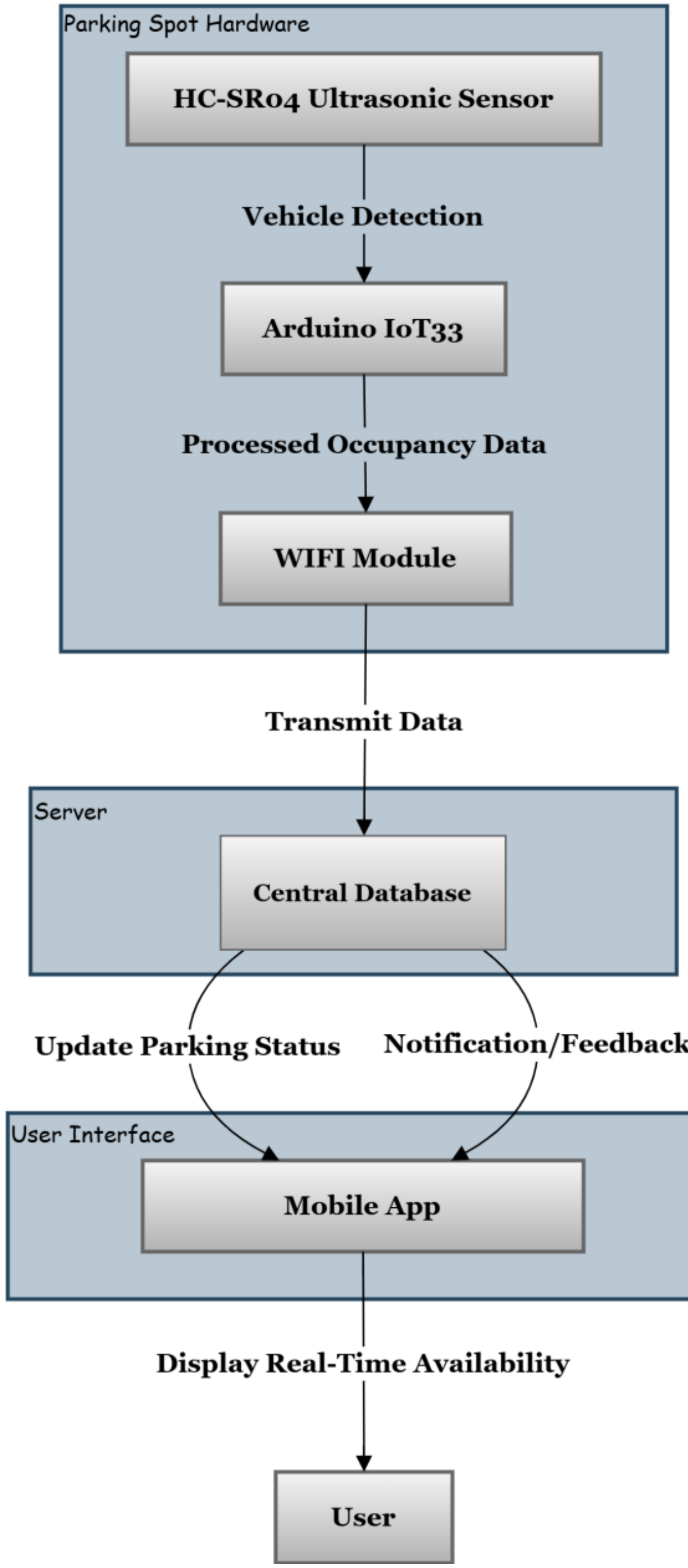

Figure 2: Data Flow Diagram

Here is the description of each of the steps in the data flow diagram below.

1. **Data Collection**: In this system, the ultrasonic sensor located at each parking spot calculates the distance in between the sensor and any object, in order to determine the presence of a vehicle. This data is then forwarded by the sensor to the corresponding Arduino board.

2. **Data Processing**: The Arduino works with the sensor data to establish if the place is occupied or otherwise. After that, this data is in a format that it can be transmitted to the central server.

3. **Data Transmission**: Using the communication module (GPRS), the Arduino transmits data to the server. GPRS modules provide broad coverage and are suitable for wide-area networks. We also have the option of Wi-Fi but that is preferred for locations with stable, short-range internet access.

4. **Server and Database Management**: The server obtains transmitted data and updates the MySQL database which holds occupancy data. The system also records current and past occupancy levels that may be useful in identifying the most frequent usage periods and parking patterns.

5. **User Access and Data Presentation**: The conceived mobile application captures real-time data from the database and presents on the user interface screen. The app is constantly updating, so users have the most recent information for each parking zone. Data can also be customized to send notifications to the users when their desired location is vacant.

4.Hardware Components

The hardware components of the IoT-based smart parking system include components that are selected to detect the availability of parking lots, to send the information back to the server, and to operate independently with low power consumption. Each of them is selected for specific purpose in the system to achieve a reliable, flexible, and environmentally friendly parking solution. This section describes each hardware item, what it does, and how it is incorporated to work as a single system.

4.1 Arduino IOT33

The Arduino IOT33 microcontroller board in figure 3, is the basic one employed in this project. Being a very flexible board with especially friendly programming environment the Arduino IOT33 is suitable for reading sensor data as for data processing and for handling communication with the server. The IOT33 is able to read data from the ultrasonic sensor connected to it in order to detect if a parking spot is occupied and sends this information to the GPRS module for sending. The digital IO pins of this microcontroller, including its low power consumption, are ideal for an outdoor solar power IoT such as this parking system. Concerning installation, each Arduino IOT33 unit is fixed at an enclosure area near the parking space where it interfaces with the power supply (solar panel) and the sensor. Some of the ways in which the Arduino is programmed include; writing code that allows it to read data from the sensors, determining the occupancy status, and sending this information to the GPRS module or Wi-Fi device.

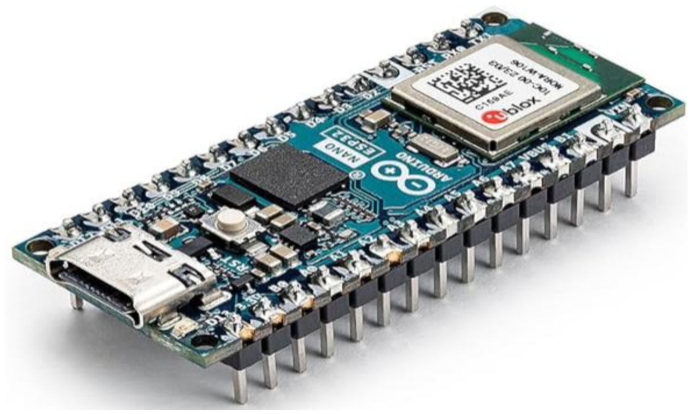

Figure 3: Arduino IoT33

4.2 Ultrasonic Sensor (HC-SR04)

The HC-SR04 Ultrasonic Sensor illustrated in Figure 4, is used in this work to determine the presence of a vehicle in a parking slot.ce of a vehicle in a parking spot. This sensor works through the process of emitting sound waves and then estimates the time taken by the reflected sound wave to get back after it has impacted on an object like a car. Its operating range of distance measurement is from 2 cm to 400 cm; thus, the HC-SR04 can effectively distinguish between a taken parking space and an empty one. This application requires a device with low power consumption and high accuracy and therefore the use of this device. The ultrasonic sensor is placed at each parking position and is directed to face the parking space without obstruction by neighboring objects. It communicates directly with the Arduino IOT33 and sends distance readings to it. Based on the distance entered by the sensor, the Arduino can identify whether a car is in the area or not.

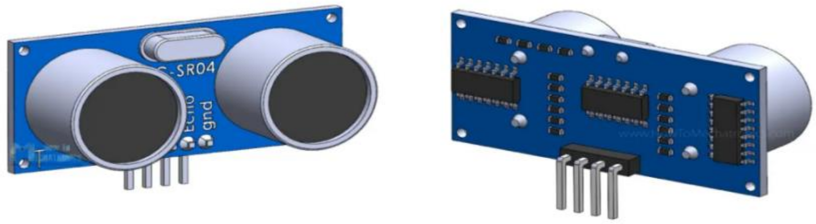

Figure 4: Ultrasonic Sensor (HC-SR04)

4.3(a) WIFI Module:

The Arduino IoT33 board comes equipped with a Wi-Fi module with the u-blox NINA-W102 chipset integrated on the board which supports Wi-Fi (802.11b/g/n and 802.11n) and Bluetooth Low Energy (BLE). This integration reduces the hardware needs as well as the external modules thereby enabling easy installation of hardware. The Wi-Fi module has built-in WPA2 and TLS/SSL security for protecting work in progress and for maintaining data integrity during their transfer to databases in the cloud such as MySQL. This makes it ideal for use in systems that are connected to the solar panel, due to the low energy consumption. In the parking system, the module ensures that information collected by the ultrasonic sensors is sent to the server to provide an actual real-time parking status that is displayed on mobile applications. Its portable and easy installable feature makes it perfect for small to medium networks, but in large networks the Wi-Fi module may have limited coverage and may require additional structures such as mesh networks.

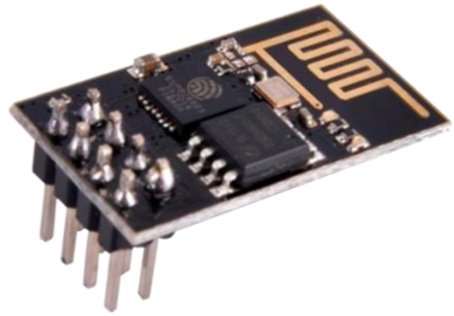

Figure 5: WIFI Module

4.3(b) GPRS Module (Option other than Wi-Fi___33):

GPRS works over cellular; it offers broad coverage, which is very important when one is in an area where Wi-Fi is not available, for example when parking in large car parks across the country. This makes it dependable because of long-range communication and low power consumption but its downside is slow data speed, and the costs of purchasing SIM cards and data plans. However, it has high latency as compared to W-Fi which will be suitable for time critical process. For the parking system at Prince Sultan University, it was found that Wi-Fi is more appropriate for localized, campus-based implementations because of its speed and efficiency Although GPRS can also be used as a solution to extend the parking system to distant areas. Such a dual system that would incorporate Wi-Fi system for parking space in campus and GPRS in area where internet connectivity is not available would be the best since the strengths of the two technologies would be harnessed to give the best results and coverages.

4.4 Solar Panel Setup

To make the system fully automated and to make it work on its own without the need for frequent power supply from other sources, Solar Panels (shown in figure 6) are employed as the source of power in the system. All the Arduino-sensor units are mounted with a solar panel that has enough capacity to supply the required power to the elements. This kind of power is clean, renewable and ideal for use in outdoor since the system does not require external power source. The solar panel installation involves tilting the panels to capture sunlight, linking the solar panel with a battery that ensures the system operates even during periods of low light. With incorporation of solar power, the IoT based parking system remains sustainable and economical as it does not require much wiring and lowers operational expenses.

Figure 6: Solar Panel Setup

5. Software Design

This section aims at presenting the software design architecture of the IoT-based parking system in detail. The elements of the design include the DB schema, the Unity app interface, the logic of the Arduino, and PHP for communication and data handling in real-time. The purpose is to achieve a fluid integration of the hardware and the software; the hardware is to display real-time parking space availability, and the software is to guide the user to their chosen parking spaces, and include additional features such as paid parking reservation in the future.

5.1 Database Design (MySQL Schema)

The data about the statuses of the parking spots is stored and organized in the iPage MySQL database of the system, and it is accessed rather fast by the Unity app. The orientation of the database is well planned so that the storage, retrieval, and update of data are optimized and that the concurrent accesses to data by different users can be managed effectively.

5.1.1 Table Structure

Currently, the database includes a table about the status of each parking space and the time when the status was updated. The table schema includes the following fields:

- **Spot ID:** A code to name each parking slot so that it can be easily located once assigned to a particular user. This is a primary key and useful for identifying each place in the system.

- **Availability Status:** A Boolean field that will show whether or not each spot is open. The value that is used to represent a free space is true (or 1) and the value used to represent a space that is taken is false (or 0). This field is made dynamic as the sensors that are used in the tracking of the field work in real-time.
- **Timestamp:** This field contains the date and time at which the status of this parking spot was last changed. It helps keep track of the time that the availability status was last updated with being useful for diagnostic checks and rolling time series computations.

The table structure is chosen to provide fast access and to be able to support real time queries so that the Unity application can get the latest information on parking availability with minimal delay. More tables may be included in future versions to support features such as users or the history of reservations.

5.2 Unity App Design and User Interface

The application developed under Unity brand allows the users to easily view parking status and get directions to the parking zone with free vacancies. The layout of the app is simple and easy to navigate, allowing the users of the app to be students, staff and other visitors in Prince Sultan University. This is complemented by a color-coded system that is used to display the status of a particular parking lot and this makes using the interface a lot easier.

5.2.1 Screenshots and Interface Description

The main application is a map of the parking lot with parts labelled C1, C2, C3 and so on, that refers to different parts of the parking facility as can be seen from the *Figure 7*. Each parking spot is represented by a box, which changes color based on availability

- **Green Box (Available):** Points to the fact that the place is free for parking.
- **Red Box (Occupied):** Indications that the spot is occupied at the present time.
- **Grey Box (Out of Service):** The grey box indicates that there is no available data for this particular parking spot.

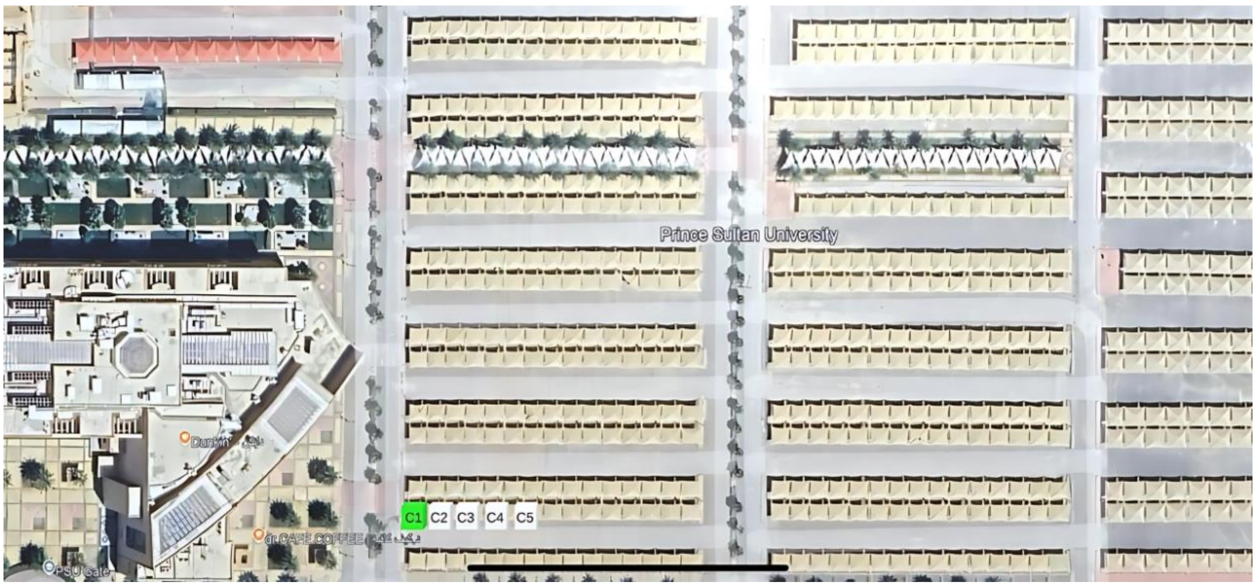

Figure 7: A screenshot of the Aerial imagery of Prince Sultan University

The physical layout of the parking lot is modeled to follow the actual arrangement of the parking lots of the university hence making it easier for the users to locate various parking lots. The user interface includes zooming and panning so that users can either view entire parking lot or a portion of it.

5.2.2 Navigation with Google Maps

Another advantage of the application is the option to get to a chosen parking space with the help of Google Maps. If the user touches the (green) icon of an open parking lot, it opens Google Maps with the route to the selected place. This feature is very useful for first timers or those who do not have an orientation of the campus. Google Maps integration is made through the possibility of Unity to link externally with Google Maps application to open it with the specified location coordinates.

5.3 Future App Features: Paid Reservations

Later editions of the app could include an option to reserve parking spaces for a certain amount of money in advance. This feature could be of tremendous use during a rush hour or during some event when parking is definitely going to be in high demand. The paid reservation feature will involve:

- **User Accounts:** This would mean that users would need to sign up or in order to place a reservation this way the reservation would be tied to the person.
- **Payment Gateway Integration:** To this end, the app will use a payment gateway to enable users make payments for their bookings and reservations online.
- **Reserved Status:** Spaces that are reserved for a particular class would be marked off with a particular color, for instance blue to avoid confusion with the other free spaces.

This feature would enhance the usability of the app and generate possible revenues for the university and at the same time enhance parking ease for the users.

5.4 Code Structure

The software's code is divided into three main components: Arduino code which is in C++, Unity code which is in C Sharp and PHP scripts. Each of them has its own function within the system including data acquisition from the sensors, updating the user interface and communicating with the database.

5.4.1 Arduino Code (C++)

Thus, the Arduino code controls the hardware interfaces such as; the ultrasonic sensors that are used to sense the presence of a vehicle within each parking bay. Each of these sensors calculates the distance to any object that is directly above it and then decides whether the space is taken or not. Key sections of the code include:

- **Pin Configuration:** The ultrasonic pins for the HC-SR04 trigger/echo are initialized, for example, as pin 9 and 10, which allow the microcontroller to transmit and receive ultrasonic signals.
- **Distance Calculation:** The code calculates the distance to the nearest object using the speed of sound. By measuring the time taken for the sound wave to return (echo), the code determines if a car is present. If the measured distance is below a threshold, the spot is marked as occupied.
- **Threshold Logic:** A certain value is set to define the level of occupancy. For instance, if the distance calculated is less than a certain limit then the spot is tagged as occupied otherwise vacant.
- **Database Update:** As soon as the availability of the spot changes, the Arduino accomplishes this through PHP scripts to the MySQL database in real-time.

This code executes in parallel on each Arduino board interfaced to a sensor to confirm that availability of spots is correctly computed and updated. The Concept of the code can be demonstrated in *Figure 8.*

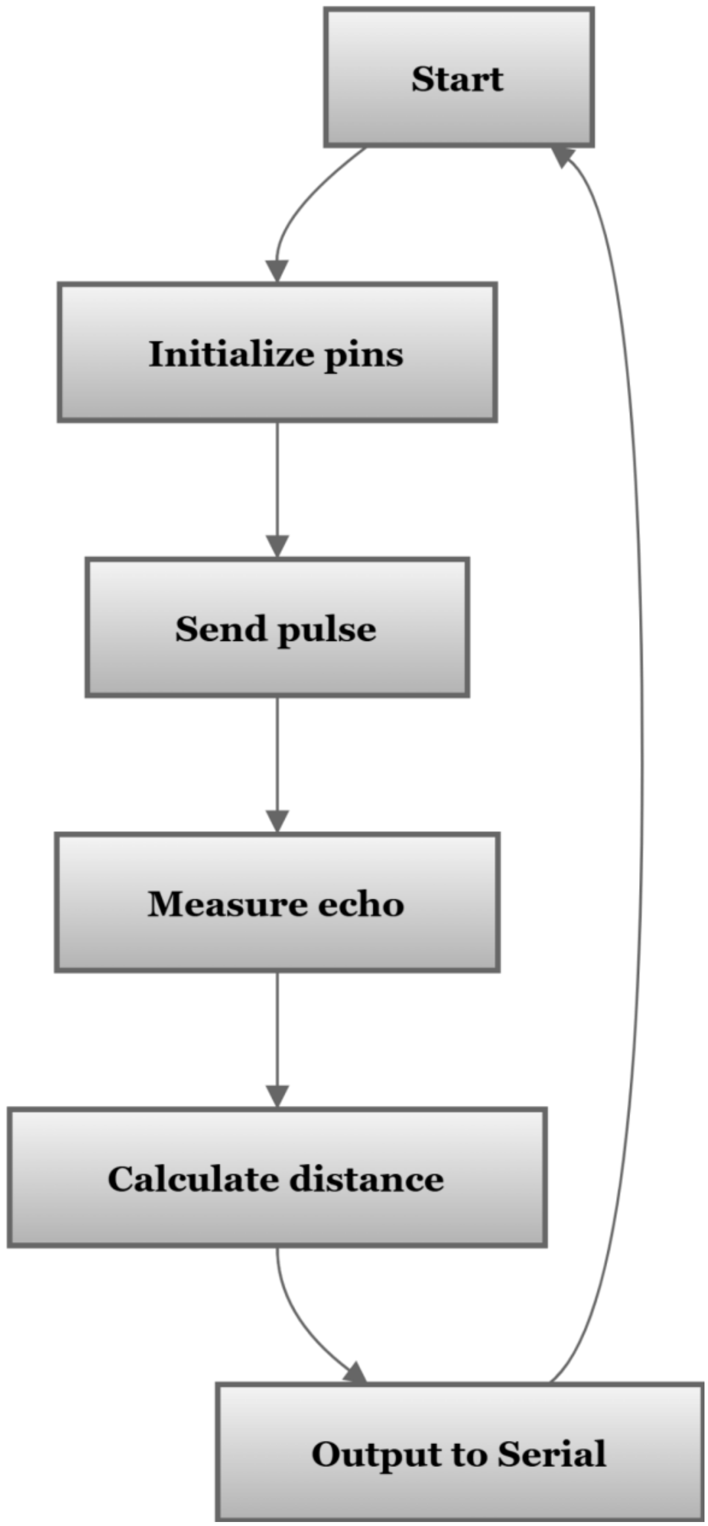

Figure 8:The code logic for Arduino

5.4.2 Unity Code (C#)

The Unity code deals with the graphical presentation of the application and its interface with the backend database as depicted in the *figure 9*. Key functionalities include:

- **Data Retrieval:** The app then makes HTTP request to the PHP scripts to get the current status of each of the parking spots in the MySQL database.
- **Color-Coding Logic:** From the data retrieved, the app changes the color of the box of the parking spot (green if the spot is available and red if occupied).
- **Google Maps Integration:** When a user taps an available spot, the app will pass the coordinates to Google Map to show directions to the particular spot.

The Unity code is designed in such a way that these requests are processed without any problem to the user interface especially during periods that many users are accessing the website at the same time.

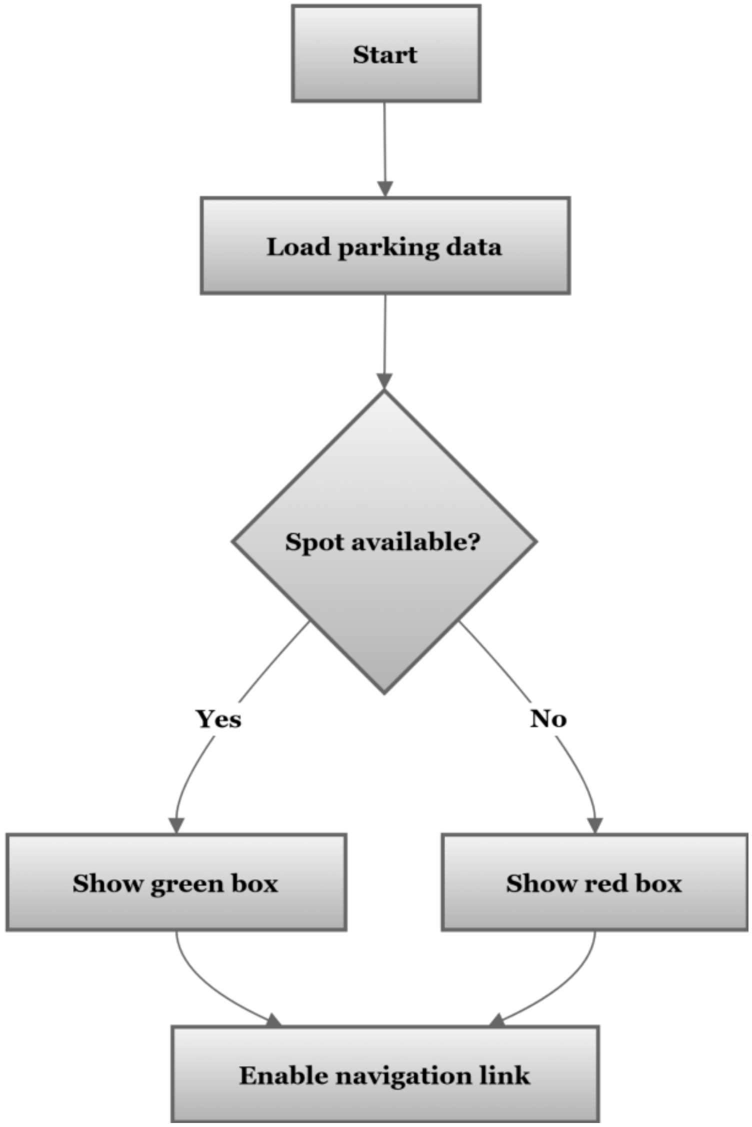

Figure 9: Unity code Pseudocode

5.4.3 PHP Scripts for Database Communication

The PHP scripts are used in the integration of the hardware and the software components. These are used to convert data received from the sensors of Arduino into data format acceptable by MySQL database as well as to handle the data coming from the Unity app. The main functions of these scripts include:

- **Data Insertion:** When an Arduino senses a change in state of a parking lot, it reports the change to the PHP script through a POST method and the PHP script serves to update the MySQL database with the new state and time.

- **Data Retrieval:** The Unity app sends Get requests to the PHP scripts to obtain the status of the parking spot to display. Finally, the PHP script accesses the MySQL database and retrieves the data and then converts the data into a format that will be easily understandable by Unity.

This flowchart *Figure 10* outlines the PHP script's main function: processing of GET requests for retrieving data and POST requests for modifying the data and in return they will send an encoded JSON response.

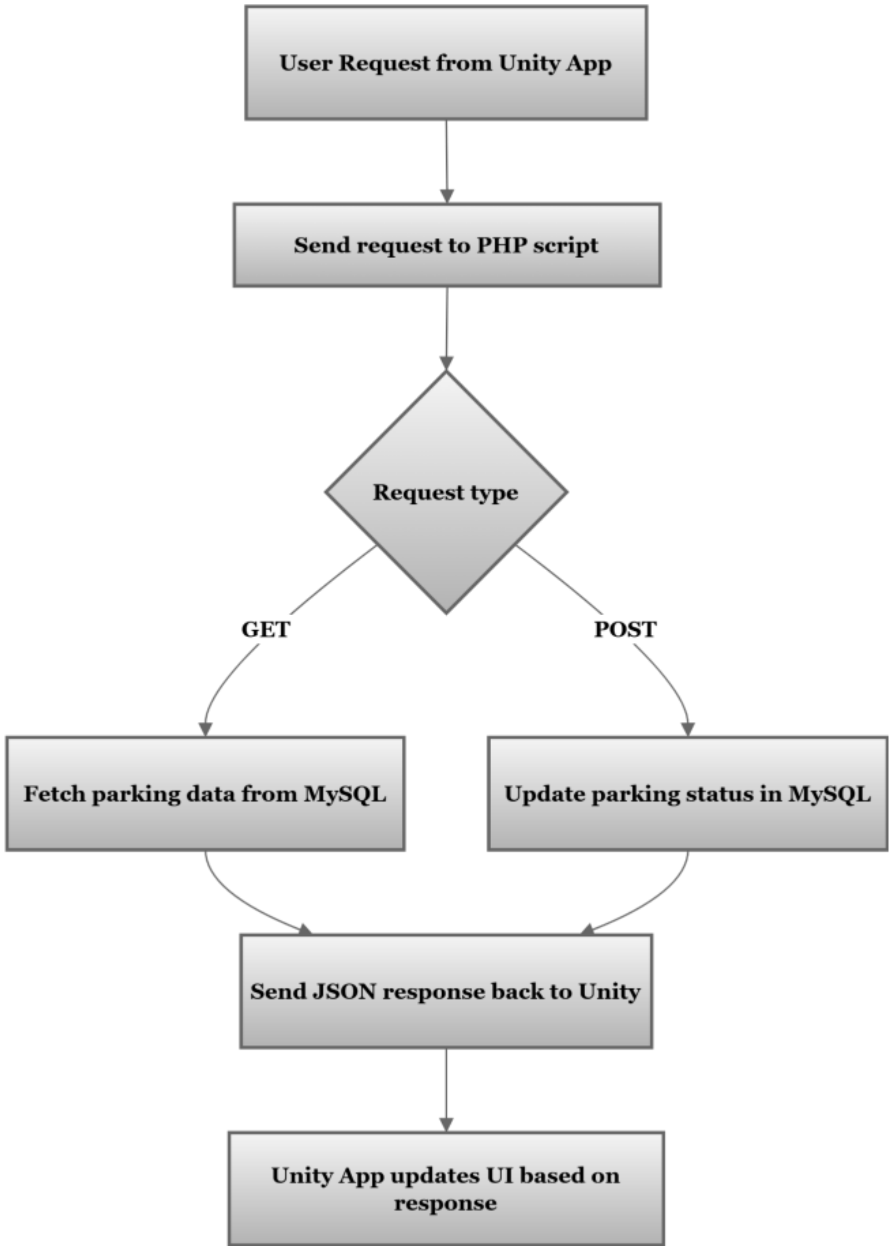

Figure 10: Flowchart of the main function of the PHP Script

6. System Workflows and Diagrams

This section provides visual representations and workflows that illustrate the system's functionality and user interactions. By using diagrams such as sequence, use case, state, and activity diagrams, it breaks down complex processes into understandable components. Each diagram highlights a specific aspect of the system—from how data flows between hardware and software components to how users interact with the app. These diagrams help in understanding the system's inner workings, identifying potential bottlenecks, and ensuring a seamless user experience.

6.1 Sequence Diagram

The sequence diagram demonstrates the interactions between different system components as data flows from the sensors to the mobile application. The diagram in *figure 11* illustrate the sequence of events, showing the order in which operations occur.

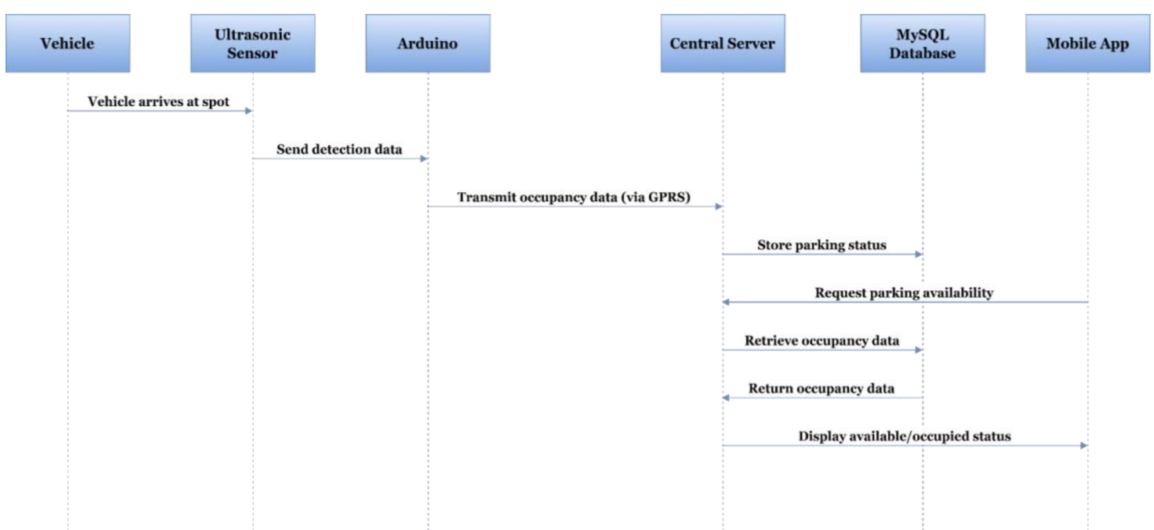

Figure 11: Sequence Diagram of the IoT based Smart Parking System

This sequence diagram shows the journey of data from the moment a vehicle is detected by the sensor to the time the status is displayed in the mobile app. Each step is sequential, highlighting the flow from detection to database storage and ultimately to the user interface.

6.2 Use Case Diagram

The use case diagram outlines the interactions between the user and the system, capturing the key functionalities provided to the end-user through the mobile app as shown in *Figure 12.*

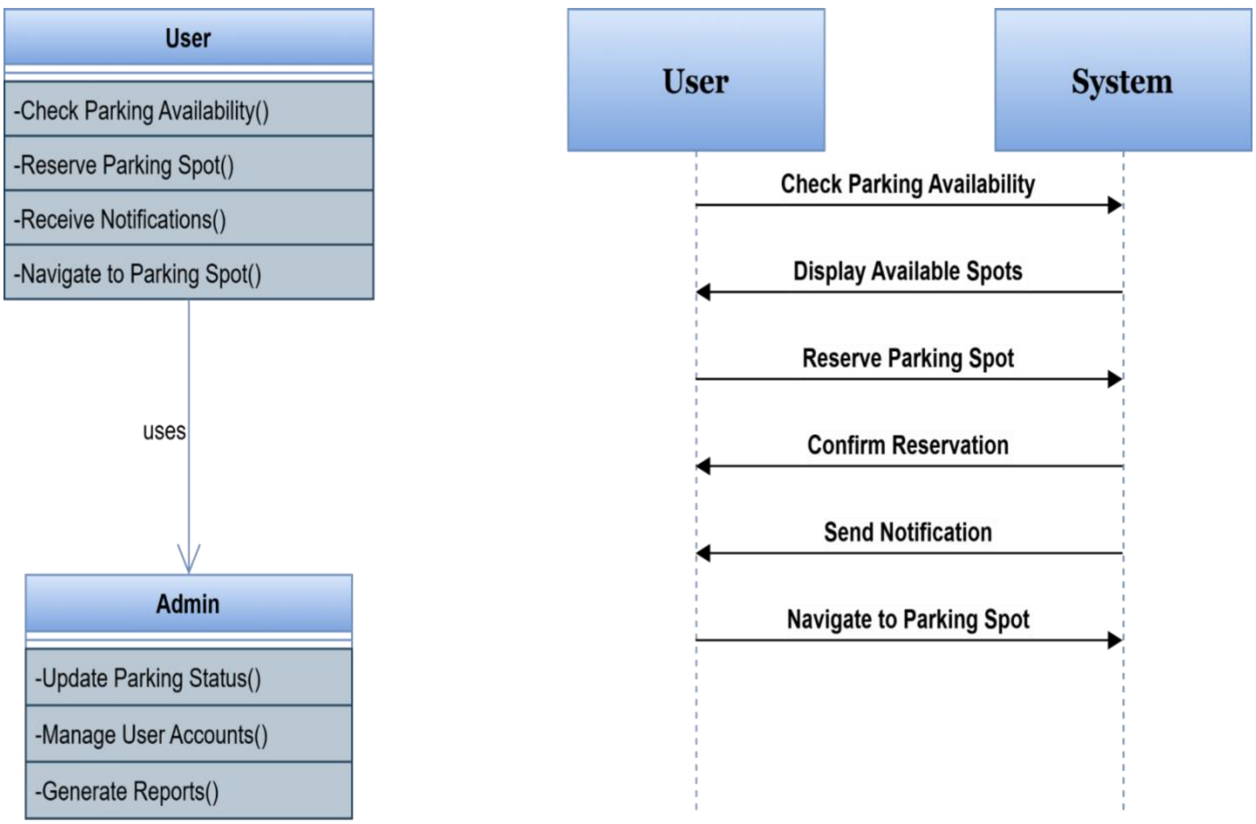

Figure 12: User Case Diagram for the IoT based Smart Parking

In this use case diagram, the primary interactions between users (drivers) and system functionalities are highlighted. Users can check availability, reserve spots, receive notifications, and navigate to parking spots. The admin has control over updating parking statuses, managing user accounts, and generating reports for system maintenance and analysis.

6.3 State Diagram

The state diagram in *Figure 13* represents the possible states for each parking spot and transitions based on vehicle presence or absence.

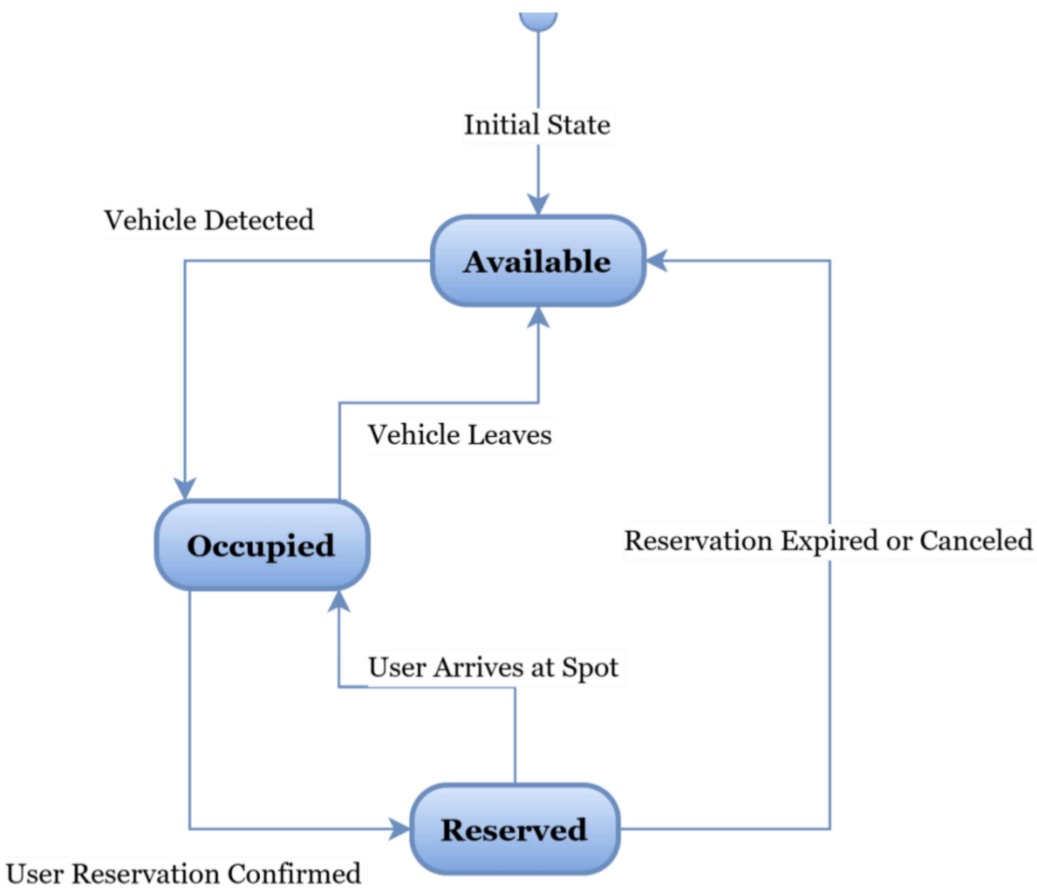

Figure 13: State Diagram of the IoT based Smart Parking

This state diagram defines the life cycle of a parking space. From the state “Available,” a spot can move to “Occupied” if a vehicle has been sensed, or “Reserved” if a user has reserved it. If a reserved spot is taken by the user, it goes to “Occupied.” If a car departs or a reservation is done, the slot goes back to the “Available” status.

6.4 Activity Diagram

The activity diagram figure 14, depicts the flow for user who wants to search and book a parking space through the mobile application. It ranges from checking the availability of the car, making a booking offer up to confirming the same.

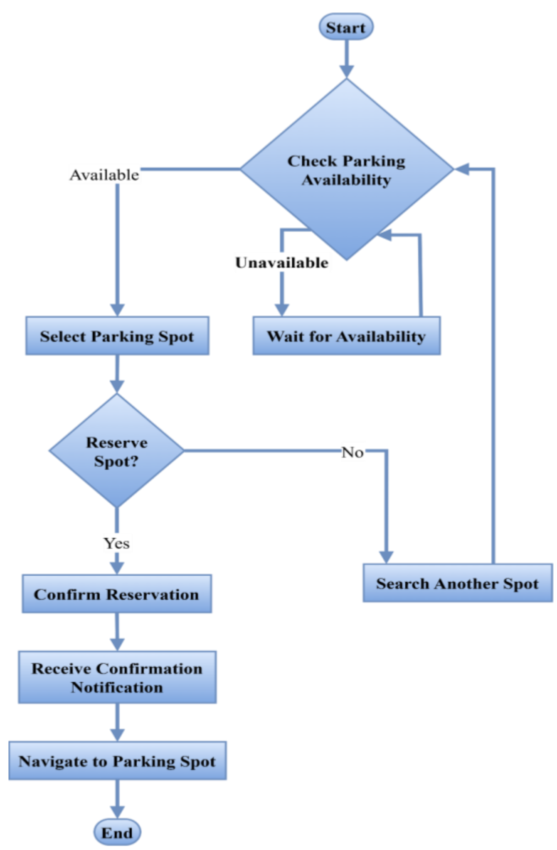

Figure 14: Activity Diagram for IoT based Smart-Parking

This activity diagram shows the interaction sequence of a user in search of a parking space. Users search for an open place, choose one and then make a decision whether to save it. When they agree, they get a notification and proceed to the location of the reservation. The only options they have if availability is scarce are to wait or to look for it again. This loop also helps to show the regular path of a user in the application.

7. System Implementation

This section overviews the actual actions in implementing the parking management system. When it comes to assembly the key process involves putting all the remarking hardware together and setting the ones that will operate the computers as well as making sure that all the software plays their roles correctly. This section is a brief on how to install the system and make necessary connections to the database, how to test the system and debug it in case of hitches.

7.1 Installation and Setup

In this stage, the documented hardware parts include ultrasonic sensors, Arduino microcontrollers, and solar power units are mounted on specific parking lots. To sense the presence of vehicles, each sensor is interfaced to an Arduino board for controlling the communication module (WI-FI). The solar panels are placed to provide the power for the system, so each Arduino-sensor module is autonomous from the outside power source.

On the software side, the MySQL database is set up on central server and it contains data about the parking spot occupancy. The mobile app and web-based interface are implemented to provide user and administrative access to real time parking information. This setup phase also includes each component being set up to interface with the central database and the ability for users to access the system through the mobile application.

7.2 Connecting to MySQL Database via WIFI

Due to the modularity of the communication system, the Arduino modules send information to the central MySQL database through WIFI where available and depending on the range needed. For the systems that use WIFI each Arduino has a WIFI module that enables it to connect to the database through telecommunications networks. This setup gives a secure way of sending data including from remote areas across the networks.

This system is designed for sending parking data including the occupancy status and time stamp to the central database at least periodically. This makes it possible for the system to monitor the available and occupied spaces at any one time. All the connection settings such as database user name and password, server IP address, and data transfer frequency are set in the Arduino code. It is important that the WIFI connection be tested to minimize the delay in the data being relayed and hence allow users the update on availability of parking space.

7.3 Testing and Debugging

Testing and Debugging is the process of making certain that a given system will run properly under different conditions and the removal of any bugs is the process of validation. The testing phase involves checking that each sensor is able to accurately identify vehicles, checking that data is being transmitted to the database correctly and checking also that the mobile application is displaying the real time parking availability. Initial tests are to mimic vehicle occupancy at each location, record sensor values and verify modifications in the database.

It means that debugging is used to work out any issues such as connectivity issues, wrong readings from a sensor or slow updates on data in the system. Realtime monitoring of data is done using the serial monitors that are available in Arduino IDE while logs and database queries assist in data validation. Also, stress tests which are done to know the performance of the system when opened for a large number of data transactions and users' interactions. This phase is critical in fine-tuning the system and making modifications to enhance efficiency, reliability, and usability. By doing so, the system can be implemented in the most appropriate manner hence providing users with the necessary parking information.

8. Financial Plan and Business Model

The financial plan and business model propose the affordable usage and revenue-generating strategies for deploying an IoT-based parking system in Prince Sultan University. The objective is to reduce cost by efficient use of resources while at the same time maintain adequate revenues to support the system. This approach entails a breakdown of expenditure, revenue forecast and plans to minimize start-up and operational costs by the right choice of the business model.

8.1 Project Cost Breakdown

The main reason for this is that the implementation of such a system is capital intensive and the above will be done incrementally to mitigate against the costs incurred. Starting from one parking area, we can test it before introducing in more areas thus reduce on risk and identify the most effective cost plan.

8.1.1 Hardware Costs

The costs of the overall system will be kept to a minimum by using low cost yet efficient hardware components:

1. **Ultrasonic Sensors**:

- Every parking space needs an ultrasonic sensor that recognizes the presence of a vehicle. That is why, with large orders, the cost of production can be brought down to approximately 15SAR per sensor.

- For an initial deployment of 100 spots, the cost will be approximately **1200 SAR**. Later phases will expand based on demand, reducing the need for upfront costs.

2. **Microcontrollers (Arduino Boards)**:

1. Arduino IoT33

Pros:

- Incorporation of Wi-Fi/Bluetooth allows the exclusion of additional communication interfaces making the design more streamlined.
- Small in size, especially suitable for use where space is limited.
- More power efficient than using other extra communication modules.
- Higher processing power for IoT applications is supported by an improved microcontroller known as SAM D21.

Cons:

- High cost, thus it is costly for large scale implementation.
- Fewer I/O pins, meaning that fewer numbers of sensors can be connected.
- More rigid than modular that allow individual components to be exchanged or indeed upgraded to different modules.

Cost: About 110 SAR per board.

2. Arduino Uno

Pros:

- Cheap and can easily be obtained making it good for small scale projects or even for prototyping.
- Since it is easy to program, there is a large support from online resources.
- Suitable for daisy-chaining 5–6 sensors with minimal requirements for inter-sensor interaction.

Cons:

Additional communication modules (e.g. Wi-Fi or GPRS) needed to provide connectivity, thus poses higher system complements and cost.

Small memory and limited processing capability can become a constraint when it comes to implementing complex IoT applications at a very large scale.

Cost:

Arduino Uno: 50 SAR

Wi-Fi module: 40 SAR (including: 65 SAR in total per unit).

3. Arduino Mega 2560

Pros:

- Integrated 54 digital and 16 analog I/O pins provides possibility to connect many sensors, which makes it appropriate for great number of sensors (20-25).
- Better memory and better processing ability than the Uno to handle more data processing tasks at a go.
- Economical since it is implemented where a large number of devices have to be connected.

Cons:

- Utility of external communication modules (Wi-Fi or GPRS), makes it complex and costly.
- It is somewhat larger in size, which reduces its usability in applications that require compact designs.
- More wiring and hardware control required for interconnecting a number of sensors.

Cost:

Arduino Mega 2560: 70 SAR

Wi-Fi module: 40 SAR inclusive of total of 100 SAR per unit.

We Chose IoT33 for our project, why?

The Arduino IoT33 was selected for the purpose of this work because of its availability of a number of features, low power consumption and the ability to be easily integrated into a system. Since it can integrate connectivity, processing and compactness in one device, the parking system runs efficiently without many hardware issues. Other options such as the Uno or Mega may shave off a little bit more of the costs but given the one-stop-shop and high dependability of the IoT33, it is the most suitable for this project's needs and scope.

3. **Communication Modules**:

- Wireless modules WIFI for the Mega 2560 will be used depending on coverage needs.
- For phase one, we need about 10 modules, each costing around **25 SAR**, totaling **250 SAR**.

4. **Solar Panels**:

- Solar panels are essential for outdoor parking. Cost-effective, small solar panels can be used to power each Arduino and sensor setup.
- Estimating **40SAR per solar panel**, and for 10 setups in the pilot, the cost would be **500 SAR**.

Total Hardware Cost Estimate (Phase 1): Approximately **3000 SAR**.

This phased approach allows us to assess performance and user response without committing to a high initial expenditure.

8.1.2 Installation and Maintenance Costs

1. **Installation Costs**:

- ○ Installation for the pilot phase will be limited to a small section of the parking area. This reduces labor costs and setup time. Estimating **1500 SAR** for phase one installation.

2. **Maintenance Costs**:

- ○ Routine maintenance includes cleaning sensors, ensuring proper solar panel function, and verifying communication modules. The annual cost for maintenance is estimated at 6**00 SAR** for the pilot phase. As the system scales, maintenance costs will be reviewed and managed through scheduled check-ups to minimize disruptions.

Total Installation and Maintenance Costs (Phase 1): **2100 SAR**

8.2 Total Number of Parking Spots

Prince Sultan University's parking lot capacity is a critical factor in determining scalability. By starting with a **25-spot pilot deployment** (out of few hundreds), we can monitor system performance and user engagement. This pilot phase will help identify potential issues early, allowing adjustments before larger-scale expansion.

8.3 Subscription-Based Parking Model

To generate sustainable revenue, the system will adopt a **subscription-based model** with optional peak-time pricing. This model provides a steady income stream and encourages regular use of the parking system. Also, we could bring sponsors to help fund this innovative project.

8.3.1 Monthly/Annual Subscriptions

Currently, there are subscriptions for convenience and affordable for students, faculty, and staff.

- **Monthly Subscription**: Priced at 40 SAR **per month** for frequent users.
- **Annual Subscription**: Offered at a discounted rate of **400 SAR per year**.

Projected Revenue from Subscriptions:

- Assuming 200 users in the initial phase, monthly revenue would be 6**,000 SAR**, or **75,000 SAR annually**.
- As the system scales and more users enroll, this revenue will increase, helping to cover expansion and maintenance costs.

8.3.2 Peak-Time Pricing for High-Demand Hours

Flexible pricing will be implemented when demand is high, for example, early in the morning and early evening. Users who park during these times are charged a small premium, for example **3 SAR** for each entry during peak time. This assists in demand control and guarantees stock during the peak usage periods.

Projected Revenue from Peak-Time Pricing:

With 100 peak-time users daily during the pilot phase, the company could earn an extra 350 SAR daily or 6,500 SAR month.

This means it is an effective dynamic pricing strategy since it will make users avoid parking during peak time while at the same time making optimal use of the parking space hence making

Cost-Reduction Strategies

Phased Deployment: Implementing the system in phases also has the advantage of cost sharing over time and thus lower initial costs. This approach also enables fine tuning and scalability depending on the actual need on the ground.

Bulk Purchases: Sensors, microcontrollers, and communication modules are cheaper as a bulk package than as individual pieces, thus the lowering of costs as the project scales up.

Optimal Use of Solar Panels: The system itself is sustainable since solar power saves future utility expenses. We also reduce costs by acquiring high quality solar panels with reduced need for maintenance.

Use of Dynamic Pricing: Besides, peak-time pricing works not only for generating the maximum revenue but also for preventing overcrowding during the peak hours, which results in improved usage rate and, therefore, may decrease the need in further expansion.

Total Projected Costs and Revenue (Pilot Phase)

- **Initial Setup and Hardware**: **3,630 SAR**
- **Annual Maintenance**: **600 SAR**
- **Expected Monthly Revenue**: **6,000 SAR (subscriptions) + 6,000 SAR (peak-time fees)** = **12,000 SAR**

With these projections the pilot phase could be able to reclaim initial setup within one year thus providing a platform for subsequent revenues increase. This means that every phase of the system will be profitable and self-sustaining because the entire model is scaled based on demand. As we grow, revenue will provide for future development and maintenance which makes it financially sustainable solution for the parking at Prince Sultan University.

9. Risk Management and Challenges

IoT based parking system may face many risks which should be addressed by the management for the success of the parking system. This section covers the main threats that may affect the system with measures that can be taken to prevent or reduce such threats. , and these strategies should help to achieve

9.1 Identified Risks

These considerations define potential risks that when identified on time, the pertinent working team needs to formulate appropriate plans for handling the issues. The primary risks associated with the parking system are as follows:

9.1.1 Sensor Malfunction:

The ultrasonic sensors are required to identify the presence of any vehicle in each parking space. However, they may sometimes fail to operate properly because of events which are out of control such as dust accumulation, moisture, or temperature changes. This may cause the collection of bad data which in turn will reduce the accuracy of the parking status update to the users.

9.1.2 Solar Panel Inefficiency:

The system utilizes solar power to provide power to the sensors and microcontrollers and is therefore appropriate for outdoor use. Nevertheless, the solar power is often unstable and mainly depends on the amount of sunlight it can get when it is cloudy or during certain seasons in some places. This inefficiency may lead to power shortages and for a while the system ceases to be operational.

9.1.3 Internet Outages:

The communication modules also send the data from the microcontrollers to a central server through GPRS or Wi-Fi Internet connection is required for the status of parking space availability in real-time. Sometimes network connection may be poor or even nonexistent and this results in users receiving stale information on parking spaces.

9.2 Mitigation Strategies

As a measure of ensuring the availability of a reliable system of work, each of the risks is followed by a mitigation plan. These strategies are meant to avoid, reduce or address effectively if they emerge, therefore increasing the system's reliability.

9.2.1 Regular Maintenance Schedule:

Many of the hardware problems can be avoided if regular maintenance is done and especially the ultrasonic sensors. Daily cleaning and examination of sensors will decrease the possibility to fail because of dust, humidity or physical wear. Regular service checks, preferably biweekly, will help the technicians replace or fix the damaged parts before they cause an issue. Records of the performance of each sensor can be kept in log books to facilitate prompt identification of failed sensors.

9.2.2 Backup Power Options:

However, to mitigate the risks occasioned by inefficiencies in the solar panels, backup power sources can be incorporated in the system. For example, to the setup of a solar power system, rechargeable batteries can be added to store extra energy that may be produced during the day so that it can be used during the night or during a cloudy day. Also, people will have an opportunity to connect to the conventional power source during the periods when solar power will not suffice. All these backups make sure that the power shortages in the system cause a minimal disturbance.

9.2.3 Redundant Network Connections:

For reducing the effects of internet dysconnectivity, availing of at least two internet connections is advised. This could also mean having two which are a GPRS and Wi-Fi module where one is active while the other is standby. Where Wi-Fi is attainable, it has to be made the default medium of communication with GPRS as the backup method. Also, as part of recommendations, implementing an alert system that will notify the administrators of the network break ensures that administrators take corrective measures to ensure connectivity.

10. Results and Analysis

The Results and Analysis section provides a detailed evaluation of the performance of the IoT-based parking system during testing as well as the level of achievement of the system's goals. We concentrate on specific measures that reflect the accuracy of the system, the time taken to respond to a query and ease of use. Besides, this section also provides concrete advantages Prince Sultan University has from the proposed system: effective use of resources, support in decision-making, and effective navigation through campus.

10.1 System Performance Metrics

In this paper, we have presented several key performance indicators (KPIs) to assess the effectiveness of the proposed IoT-based parking system. These are sensor accuracy, GPRS latency on transferring data and the user interface of the mobile application. These factors have a direct bearing on users and the reliability of the system in serving the parking management needs hence the importance of these factors.

10.1.1 Sensor Accuracy:

Sensor accuracy is critical because it defines the quality of parking place availability information. In testing, ultrasonic sensors were mounted in different parking spaces and analyzed at different conditions: size of the vehicle (sedan, SUV, motorcycle), lighting conditions, and weather conditions (rain). The sensors obtained a detection accuracy rate of 98%, it means that sensors were able to successfully detect the presence or absence of vehicles. This study observed a few errors, mainly in situations when the weather is unfavorable such as heavy rain since it influences the reflection of sound waves. But these cases were only 1.9% of the total readings in the text. These results support the argument that the system can supply accurate information about parking status for real time applications. Correct data of occupancy reduces cases of fake availability notifications, which may anger users and reduce confidence in the system.

10.1.2 GPRS Response Time:

Real-time communication between the sensor units and the central server is essential for updating parking availability data promptly. The GPRS communication module facilitates this data transfer, but network response time can vary depending on cellular signal strength and data traffic. During testing, the system recorded an average response time of 2.3 seconds from the moment data was sent by the Arduino to its receipt by the central server. This latency is well within the acceptable range for real time applications to guarantee that users are not delayed on updates on parking spot availability. Users who visit the website to check whether there is available parking space before getting to the campus expect a quick response time. Also, fast response times make it easy to manage traffic during rush hours since users are directed to areas with available parking space. However, since GPRS offers a lower latency than Wi-Fi, GPRS was selected because it covers a larger area than Wi-Fi especially in areas where infrastructure installation may be expensive or the infrastructure is not available.

10.1.3 App Usability Testing Results:

The overall interactive interface of the mobile application was assessed by means of usability test to understand the effectiveness, ease of use, and remaining feasibility of the application. Students, facultyty and staff of the university used the application during the testing phase and offered their feedback on the main functionality of the app which includes real-time parking availability, ways of reservation, and notifications. The interface was made purposely to be easy to use and understand by end users through a color-coded system which symbolizes occupied and vacant parking space. According to the data obtained, the majority of users did not experience any difficulty when using the app and like features such as navigation to the desired parking zone. Some recommendations to optimize the interface were made, such as slight changes in button sizes and the contrast of the color for the users with the vision problems. Based on this feedback the app was slightly adjusted, and the overall smooth and satisfactory user experience was achieved. In general, the usability testing proved that the app can facilitate the provision of real-time parking information to meet the system's objective in an efficient way.

10.2 Benefits for the University:

This IoT-based parking system has a lot of advantages for Prince Sultan University when doing the implementation of this system in accordance with its goals of efficiency, sustainability, and better user experience. These benefits are clearly seen in areas such as management by data, efficient use of resources and traffic control.

10.2.1 Data-Driven Decision-Making:

This functionality allows the university to understand how parking is being used within the system crowd times, and sales pattern throughout the day and week. Analyzing this information, campus parking information helps administrators to make appropriate decisions regarding the policies, addition or otherwise of parking facilities strategic changes. For instance, it may be possible to obtain information on the particular intervals of time that is most popular. Suggesting the need to make temporary changes in the parking situation especially during events or during hours that many classes are in session. In addition, long term data can be useful for infrastructure development to enable the university to make how many more parking facilities are required and where they should be established. The parking trend analysis capability also helps with policy changes like those that involve special concerning the pricing of the high demand zones. This analytical approach helps to build up the university's capability for precured planning, resulting in a neater and efficient use of resources on the campus.

10.2.2 Optimized Parking Distribution:

Real time occupancy detection enables proper management of the parking resources in a more efficient way. By informing drivers of available space, the system avoids funneling drivers to the over-crowded places and helps in increasing the use of underused places. This not only increases the usability but the current study also considers both decreasing the search time and improving the utilization of the existing parking spaces on the campus needing immediate physical extensions. Further, the database enables the university to monitor parking availability in a central place and multiple zones. This way, real time and historical data allow administrators to set policies to spread out the load across several parking zones so that no particular zone is overloaded excessively crowded. This even distribution enhances a free traffic movement within parking lots and thus makes sure that all the areas are optimally used.

10.2.3 Reduced Traffic Congestion:

A major problem associated with universities is the problem of traffic jam especially during rush hour time when everyone is looking for parking especially students and members of staff or faculty. By giving latest information in relation to available parking spaces, the system reduces the amount of time that drivers spend in search of parking space in the lots. Users allows drivers to find empty areas rather fast, thus cutting down on idle circles and easing congestion. At the same time, congestion reduction brings environmental advantages too. Reduced idle time means less emission from vehicles, something that supports the university’s sustainability goals. The system tightens up the cleanliness and sustainability of the campus environment and enhances the quality of the air around areas that receive much traffic.

11. Conclusion and Future Work.

11.1 Conclusion

This IoT-based parking system if implemented at Prince Sultan University will be significant. As a very important step toward more effective and rational use of data in managing campus affairs. Through real-time, the system also has features such as the monitoring of parking occupancy and a user-friendly mobile interface hence reducing search times, decreasing traffic congestion and optimizing the usage of parking resources. The use of solar power for the hardware, GPRS for communication and a centralized database also underscores sustainability and financial effectiveness, which is also an aim of the university strategies and improved flow of operations in campuses.

During the project evaluation and testing phase, there was an indication that the system was reliable specifically in the aspect of the sensors, the GPRS response time, and most importantly the mobile application interface. The advantages for the university are improved decision-making processes by using big data and a better coordination of the parking resources, and tangible decrease in traffic around campus. Congestion. If these objectives are met, the project proves that IoT technology can change conventional infrastructure to offer more intelligent services for the users.

11.2 Future Work

To make this system less sensitive to the future changes several improvements have been outlined below. These potential enhancements include the geographical extension of the system, the elevation of predictive analysis, development of a mobile application, and the integration of dynamic pricing.

11.2.1 Expansion to All University Lots:

At the moment the system is implemented only in several parking lots. Extending this IoT based parking system to cover all the parking zones in the campus would make the impact maximal, especially from the data perspective. Large-scale implementation will enable all the members in the campus to access availability information in real-time, enhance the traffic pattern and the general management of parking space in the university.

In the expansion process the company would have to add more sensors and hardware, grow the server capacity and guarantee efficient transmission. This change of system would mean that every parking lot on the university is covered and this would allow for a more accurate analysis of parking usage and thus allow for better planning.

11.2.2 AI-Based Demand Forecasting:

The addition of AI driven analytics into the system could greatly improve the system's ability to forecast parking demand. By using historical parking data, weather information, event calendar, and other variables, other parameters, an AI model could predict when traffic would be at its highest and assist university managers in preparation. For fluctuations in demand. For example, during the examination sessions, or other important occasions where a lot of preparation is needed. Might predict more occupancy and thus alert users so that they can avoid congestion at the time of arrival.AI-based forecasting could also help with more dynamic resource allocation such as reallocating traffic to underutilized areas in order to avoid congestion during some times of the day or week. Thus, the system could yield information that allows the university to respond in advance to alterations in parking requirements.

11.2.3 Development of Mobile Apps for iOS and Android:

Even though the current mobile interface is workable, the creation of specialized iOS and Android .The innovations in smart applications would improve the user access and make the users experience smoother. Native apps could be more effective, support offline mode and have helpful UI/UX options such as the parking availability notifications and reservation. Integrating with campus maps and providing driver assistance and guiding the users to a particular parking lot could even improve the user experience.

Native mobile apps would also have a section for customization of the user, including the preferred parking areas, notification options, and alerts for the greatest traffic times to make it even more personalized contact with the system of parking.

11.2.4 Implementation of Dynamic Pricing:

It is proposed that the institution should adopt a dynamic pricing strategy to improve the utilization of parking space and enhance the generation of extra revenue for the university. In case of dynamic pricing, the rates would change with the time, would be high during peak time and this would help in turnover and occupying the best places. Some of the user may be willing to pay for parking space that will be available at all times and these may be offered the premium parking spaces while others may go for relatively cheaper parking spaces thus equalizing the total parking space demand. This model would also encourage users to select sub-peak zones where possible in order to minimize density in peak regions, thus spreading vehicles more evenly. The revenue from dynamic pricing could also cater for the costs of maintaining the system, upgrading it and expanding the project, if necessary, hence making the project self-sustainable.

11.2.5 Introduction of Mesh Networks for Future Scalability:

When the number of parking areas increases and the number of sensors also grows, mesh networks can be a reliable means of communication. Compared to centralized network, mesh networks bring more flexibility and reliability for large scale IoT applications. In a mesh configuration, data can be passed from one sensor to another and from one communication module to another in a way that can avoid a single point of failure and provide good coverage in difficult to reach areas.

Proposing the mesh network would make the system more robust in terms of interruption and expansion of the numbers of sensors in the network without overloading the current infrastructure. This scalability makes it possible for the parking system to expand its capacity to accommodate the needs of the university and the continually changing technologies.

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