International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 12 Issue: 04 | Apr 2025 www.irjet.net p-ISSN: 2395-0072

Smart Parking System

Vishakha Kakad[1], Mithilesh Kasar[1], Zakib Khan[1], Prof. Amit Hatekar[2]

[1]Undergraduate Students Department of Electronics and Telecommunication Engineering, Thadomal Shahani Engineering College, Bandra, Mumbai
[2]Assistant Professor Department of Electronics and Telecommunication Engineering, Thadomal Shahani Engineering College, Bandra, Mumbai

---

Abstract - *The increasing demand for urban parking spaces has led to congestion, inefficiencies, and unnecessary fuel consumption. This research presents a Smart Parking System that integrates IoT-based automation to streamline parking management. The proposed system utilizes an ESP32 microcontroller, IR sensors, and a servo motor to enable automated vehicle detection and gate control. A mobile application, developed using Android, allows users to book parking slots, make payments via Razorpay, and generate QR codes for verification. The system employs Firebase Realtime Database to handle real-time booking, slot availability, and gate control data. The admin module includes a QR code scanner to validate bookings and trigger the gate mechanism, ensuring secure and automated access control. Additionally, IR sensors detect slot occupancy and update the database dynamically, optimizing space utilization. This research demonstrates the efficiency of IoT and cloud-based parking solutions, reducing manual intervention, minimizing wait times, and enhancing user convenience. The implementation of this smart parking system provides a cost-effective, scalable, and real-time approach to urban parking challenges.*

***Key Words*: ESP32, Smart Parking, IoT, Firebase, Android App, IR Sensors, Automated Parking System.**

1. INTRODUCTION

Urbanization has led to a significant rise in the number of vehicles, creating challenges in parking management, traffic congestion, and fuel wastage. Traditional parking systems often rely on manual intervention, which results in inefficiencies, lack of real-time availability updates, and difficulty in space allocation. To address these issues, Smart Parking Systems utilizing Internet of Things (IoT) and cloud-based solutions have emerged as a promising alternative.

This project presents a Smart Parking System that integrates hardware and software components to enable an automated, real-time parking solution. The system comprises an ESP32 microcontroller, IR sensors for slot detection, a servo motor for gate automation, and an LED display for real-time status updates. The software component is an Android application that facilitates parking slot reservations, online payments via Razorpay, and generates QR codes for secure access verification.

The Firebase Realtime Database serves as the system's backend, managing real-time booking data, slot availability, and gate control. The admin module features a QR code scanner to authenticate bookings and trigger the gate mechanism, ensuring secure and automated parking access. Additionally, IR sensors continuously update slot occupancy status in the database, optimizing parking space utilization. The implementation of this IoT-based Smart Parking System provides a cost-effective, scalable, and automated solution to urban parking challenges. By reducing manual intervention, minimizing waiting times, and enhancing security, this system improves the overall efficiency of parking management while promoting smart city initiatives.

This research paper presents a Smart Parking System that integrates IoT-based hardware and a cloud-connected Android application to enable seamless and automated parking management. The system consists of three major components:

1. Hardware Module – An ESP32-based microcontroller interfaced with IR sensors for real-time slot occupancy detection and a servo motor for automated gate control.
2. Android Application – A user-friendly mobile app that allows users to view available parking slots, book a spot, make payments, and generate a QR code for verification.
3. Cloud-Based Database (Firebase) – Facilitates real-time synchronization between the hardware, application, and admin panel, ensuring accurate parking status updates and remote monitoring.

2. LITERATURE REVIEW

In recent years, the rapid growth of urban populations and increasing vehicle density have intensified parking challenges, necessitating the development of smart parking solutions. Traditional parking systems often suffer from inefficiencies such as manual slot allocation, lack of real-time availability updates, and security concerns. Researchers have explored IoT-based automated parking systems to optimize space utilization and enhance user convenience. This section reviews existing literature on smart parking technologies, IoT integration, and cloud-based management systems.

2.1 Evolution of Smart Parking Systems

2.1.1 Traditional Parking Systems and their limitations

Traditional parking systems rely on manual operations like ticket-based entries and human-operated gates, leading to inefficiencies, increased fuel consumption, and urban congestion. Studies show that drivers spend an average of 17 hours annually searching for parking, worsening traffic and emissions. Manual systems also incur high personnel costs and errors, making real-time monitoring challenging. [1]. These limitations have necessitated the development of more efficient, automated parking management solutions that leverage modern technologies. Traditional parking management systems are plagued by inefficiencies, including manual operations and lack of real-time information, leading to increased congestion and fuel consumption. The rise of IoT-based solutions aims to address these issues by providing real-time parking availability and optimizing space utilization [1][4]

2.1.2 Emergence of IoT and AI in Parking Solutions

IoT-based smart parking systems utilize sensor networks, such as ultrasonic and infrared sensors, to detect vehicle presence and communicate this information to central management systems. AI algorithms enhance these systems by predicting parking demand, optimizing allocation, and streamlining user experiences. For example, AI can analyze historical data to adjust pricing dynamically, improving revenue and space efficiency [2][4]

2.2 Implementation Architectures and Technologies

2.2.1 Hardware Components and Sensor Technologies

Smart parking systems typically employ microcontrollers like ESP32, which process sensor data and manage automated operations. IR sensors are commonly used for occupancy detection due to their reliability and cost-effectiveness. The integration of these sensors with mobile applications allows users to locate available spaces and reserve them in advance, reducing search times and congestion [3][7]

2.2.2 Communication Protocols and Integration Patterns

Effective communication between system components is crucial. Protocols like MQTT and REST APIs facilitate data exchange between sensors, microcontrollers, and cloud services, ensuring seamless integration and real-time updates [2][4]

2.3 Challenges and Limitations in Smart Parking Implementations

2.3.1 Technical Challenges

Technical challenges include sensor reliability in outdoor environments, network connectivity issues, and system interoperability. Power management and energy efficiency are also critical, particularly for remote installations [3][6]

2.3.2 Economic and Organizational Barriers

Economic barriers include high infrastructure costs and the need for clear revenue models. Organizational challenges involve stakeholder coordination and ensuring user adoption [4][6]

2.3.3 Privacy, Security, and Ethical Considerations

Privacy concerns arise from data collection, while security vulnerabilities can compromise system integrity. Ethical considerations require transparent data policies and user consent mechanisms [6]

2.4 Innovations and Future Directions

2.4.1 Integration with Smart City Initiatives

Smart parking systems are increasingly integrated into broader smart city frameworks, enhancing urban mobility by coordinating traffic management and public transportation. Emerging technologies like computer vision and blockchain are being explored for enhanced security and efficiency [2][6]

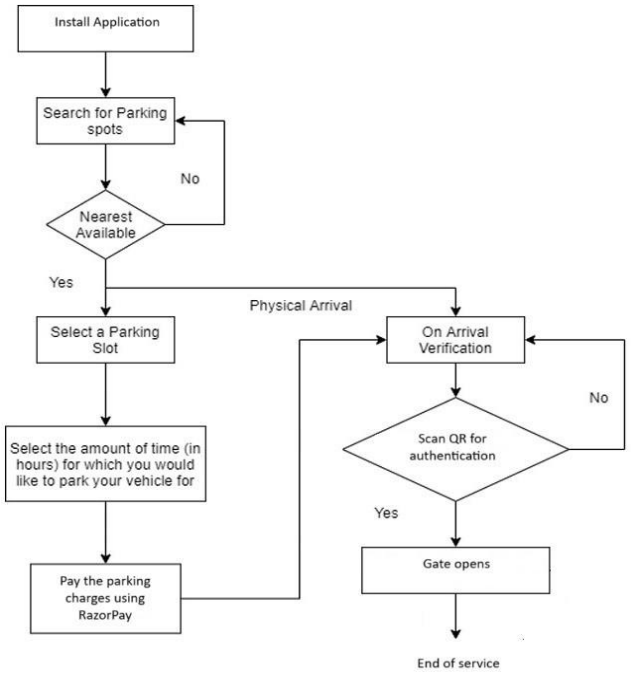
2.4.2 Emerging Technologies in Smart Parking

Technologies such as AI, computer vision, and machine learning are transforming smart parking by enabling predictive analytics, dynamic pricing, and personalized user experiences. Blockchain technology offers secure transaction records and reservation systems [5][6]

2.4.3 User Experience Enhancements

Improving user experience is a key focus area, with innovations like contactless entry systems, personalized recommendations, and real-time navigation guidance. Voice-controlled interfaces are also being developed for hands-free operation [3][7]

2.5 Block Diagram



The block diagram represents the workflow of an IoT-based smart parking system, designed to streamline the parking process for users.

The process begins with the user installing a mobile application, which serves as the primary interface for interacting with the system. Through the application, users can search for available parking spots in their vicinity. If no parking spots are found, the system loops back to continue searching until a nearby spot becomes available. Upon finding a parking space, users can select a specific parking slot and specify the duration (in hours) for which they wish to park their vehicle.

Once the parking slot is selected, users proceed to make payments for the parking charges using RazorPay, ensuring a seamless and cashless transaction. After payment confirmation, users physically arrive at the designated parking location. At this stage, an on-arrival verification process takes place where users are required to scan a QR code for authentication purposes.

If authentication is successful, the gate opens automatically, granting access to the parking space. This marks the end of the service, completing the parking process efficiently and securely.

The diagram highlights key features such as real-time availability checks, automated payment systems, and QR-based authentication mechanisms, which collectively enhance user experience and operational efficiency. By integrating IoT technologies and digital payment solutions, this system minimizes manual intervention while reducing congestion and optimizing parking space utilization

3. PROPOSED WORK

3.1. Component Integration (Hardware)

The proposed system centers around the ESP32 microcontroller for seamless connectivity between firebase and the android application via Wi-Fi. IR sensors will detect vehicle presence, while a GPS sensor aids real-time navigation. A servo motor will automate the barrier gate based on QR code authentication, and an OLED display at the entrance will show parking rates, availability, and user instructions. These components ensure an efficient, automated, and user-friendly parking experience.

3.1.1 ESP32 Microcontroller

The ESP32 is the core processing unit of the Smart Parking System, responsible for managing parking slot occupancy detection, controlling the servo motor for the parking gate, and enabling real-time data communication with Firebase. Unlike traditional microcontrollers such as Arduino, the ESP32 has built-in Wi-Fi and Bluetooth, making it an ideal choice for IoT applications. Its dual-core processor allows efficient handling of multiple tasks simultaneously, including reading sensor data, sending updates to the database, and controlling the gate mechanism. ESP32 continuously monitors the state of the parking slots by receiving signals from the infrared (IR) sensors.

When a user books a parking slot through the mobile application, the system updates the Firebase, and the ESP32 retrieves this data to verify slot availability. Additionally, upon scanning a valid QR code, the ESP32 triggers the servo motor to open the parking barrier, allowing vehicle entry. This microcontroller plays a crucial role in automating the entire process and ensuring real-time synchronization between hardware components and the mobile application.

3.1.2 Infrared (IR) Sensors for Slot Detection

The Smart Parking System integrates IR sensors to detect whether a parking slot is occupied or vacant. These sensors function based on infrared light emission and reflection principles. Each sensor emits infrared waves, which reflect off objects (such as a vehicle) and return to the sensor. If the reflection pattern changes, the system determines that a vehicle is present in the slot.

These IR sensors are strategically placed in each parking slot and are directly connected to the ESP32 microcontroller. When a car enters a slot, the corresponding IR sensor detects the presence of the vehicle and sends a signal to the ESP32, which then updates the Firebase Realtime Database. This real-time data is reflected in the mobile application, allowing users to view available slots dynamically. The IR sensors thus play a critical role in enhancing automation, reducing manual intervention, and providing users with accurate parking availability information.

3.1.3 Servo Motor for Automated Barrier Gate

A servo motor is used to control the movement of the parking barrier gate, allowing or restricting vehicle entry based on booking validation. Unlike DC motors, servo motors provide precise angular motion, making them ideal for applications where controlled movement is required.

In this project, the ESP32 microcontroller is programmed to operate the servo motor based on user authentication via QR code scanning. When a valid QR code is scanned by the admin, the system verifies the booking details against Firebase. Upon successful verification, the ESP32 sends a signal to the servo motor, prompting it to rotate and lift the barrier gate. Once the vehicle has entered, the motor returns the barrier to its original closed position. This automated mechanism eliminates the need for manual intervention, ensuring seamless and efficient parking access.

3.1.4 LED Display for Slot Availability

An LED display is integrated into the system to provide real-time parking slot availability updates to users. This display is positioned at the entrance of the parking facility and is directly connected to the ESP32 microcontroller. The display continuously receives data from Firebase, reflecting the number of vacant and occupied slots.

As users enter or exit the parking facility, the IR sensors detect slot status changes, and the ESP32 updates this information in real time. The LED display provides a user-friendly interface, ensuring that drivers can quickly locate available slots without manually checking each one. This enhances user convenience and ensures parking utilization.

3.1.5 GPS Sensor

A GPS sensor is integrated into one of the parking models to provide precise location tracking for the parking lot. This feature allows users to navigate to the selected parking area directly from the mobile application. The GPS data is also used for geofencing applications, ensuring that users check in within the designated parking zone. This enhances the accuracy of location-based services and prevents unauthorized parking.

3.2. Software / Application Development

The software component of the proposed system consists of a mobile application with separate admin and user dashboards, each accessible through secure login and signup functionalities. The admin dashboard will provide essential management capabilities, enabling administrators to add new parking locations with details such as *Price/hour, location coordinates, available slots, and landmarks*. It will also feature a comprehensive view of existing bookings and the ability to verify bookings upon user arrival by scanning the QR code generated during the reservation process.

The User dashboard will focus on providing a seamless parking experience for end-users. Users will be able to select their desired date, start and end times, and location. Based on these preferences, the application will display available parking slots for selection. Upon selecting a slot, users will be directed to RazorPay for secure payment processing, after which a unique QR code will be generated for their reservation.

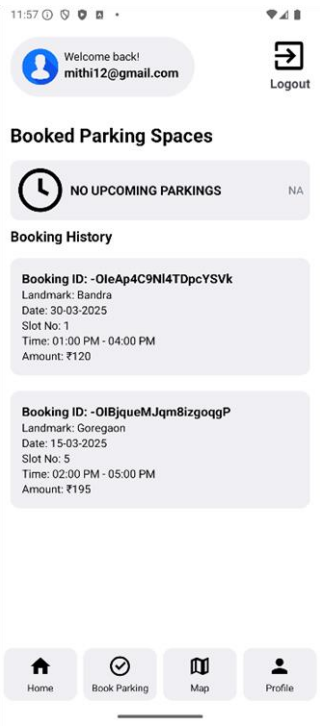
This modular design ensures that both administrators and users have access to the tools and information they need to efficiently manage and utilize the smart parking system.

3.3. Firebase Integration

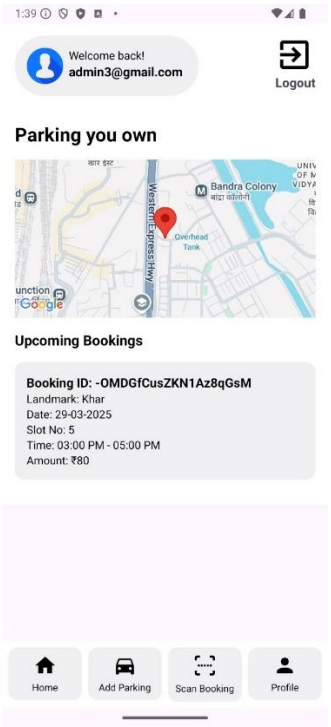
Firebase Authentication is implemented to manage user and administrator accounts securely. This includes features like email/password-based registration and login, password reset functionality, and potentially integration with third- party authentication providers, User data, including roles (admin/user), contact information, and parking history, are stored securely within Firebase Authentication.

Firebase Realtime Database is used to manage the real- time data related to parking space availability, pricing, and booking information. This allows for instant updates to the mobile application and admin dashboard whenever a parking slot is booked or becomes available. Additionally, location data for parking spaces is also stored, enabling the application to display available spots on a map and guide users to their selected parking space using GPS data. Firebase Cloud Functions are used to automate tasks such as generating unique QR codes for reservations, and handling payment confirmations from RazorPay. These functions run in a secure, serverless environment, ensuring reliability of the system

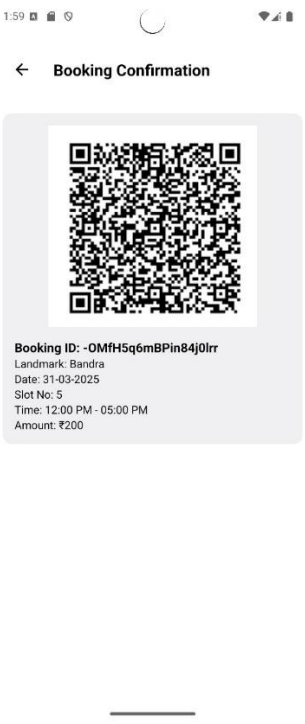
4. RESULTS



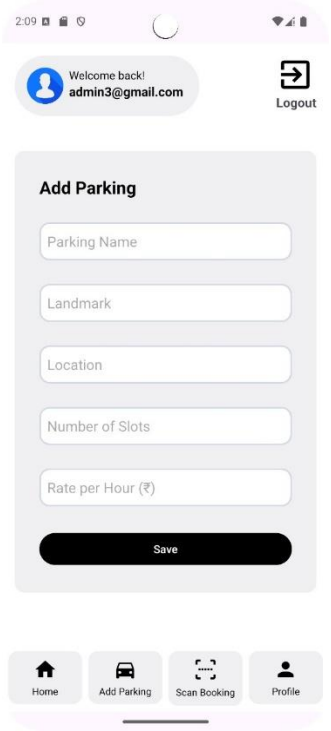
User Dashboard



Admin Dashboard



User Booking Confirmation



Admin Add Parking

5. CONCLUSIONS

This research successfully presents an IoT-based smart parking system designed to alleviate the challenges of urban parking. By integrating sensor technology, a user-friendly mobile application, and secure payment processing, the system provides a streamlined solution for locating, reserving, and paying for parking spaces. The implementation of QR code-based authentication further enhances security and automation, ensuring only authorized vehicles gain access.

The developed system effectively addresses the limitations of traditional parking methods by minimizing manual processes and maximizing user convenience. The mobile application empowers users with the ability to locate and reserve parking spaces remotely, reducing the time spent searching for available slots and contributing to lower fuel consumption and emissions.

The integration of RazorPay ensures secure and cashless transactions, further enhancing the overall user experience. The successful implementation of QR code authentication provides a reliable and automated access control mechanism, enhancing the security and efficiency of the parking process.

6. FUTURE SCOPE

Significant enhancement is possible by adding real-time data analytics in the parking search loop. By adding machine learning algorithms, the system could predict parking availability based on historical trends, time of day, and event calendars. This could allow the mobile app to not only display currently open parking but also to predict which parking is most likely to be open in the near future, allowing users to make more informed choices and spend less time driving around looking for parking. Furthermore, this predictive capability could be used to optimize pricing, encouraging users to park in less busy areas or at off-peak hours, leading to a more balanced use of parking resources.

Ongoing research and development of alternative sensor technologies and communication protocols is also warranted. Investigation into the use of computer vision and AI-based image recognition for parking space detection can offer higher accuracy and flexibility than traditional ultrasonic or infrared sensors. Investigation into the integration of the system with other smart city initiatives, such as traffic management systems and electric vehicle charging stations, can also offer a more cohesive and sustainable urban infrastructure. Development in these respects will result in a more comprehensive, intelligent, and future-proof smart parking system.

7. REFERENCES

[1] N. Cahyadi, P. Dorand, N. R. F. Rozi, L. A. Haq, and R. I. Maulana, “A Literature Review for Understanding the Development of Smart Parking Systems”, j_ict, vol. 5, no. 1, pp. 46–56, Dec. 2023.

[2] Sudheer Hanumanthakari, “Intelligent and real-time Parking System”, E3S Web Conf., Volume 472, 2024, ICREGCSD 2023

[3] Prof. J.Y. Hande, Pratik Sardar, Sagar Dhakate, Prajakta Nagbhidkar, Sejal Nagardhankar, Swabhav Marwadkar, “IOT BASED SMART CAR PARKING SYSTEM”, Volume:06/Issue:04/April-2024, IRJMETS

[4] Shashank Agnihotri, Ankit Kumar, Gopal Singh, Prateek Dixit, Shayan Ahmad, Shresth Chaurasia, “IOT Based Smart Parking System”, IJRASET, vol. 12, Issue V, pp May. 2024

[5] Rithik Krisna, “AI Based Smart Parking System using ESP32-CAM”, Published November 23, 2024

[6] Amber Soni, Aryan Atre, Harshita Raikwar, Palak Gupta, Sandeep Sahu, and Shalini Sahay, IoT Based Smart Car Parking System. International Journal of Transportation Engineering and Traffic System. 2024; 10(01): 21-28p.

[7] Mohd Alif Mohd Sofian, Lili Azwani Tiron, “ONLINE PARKING SYSTEM USING ESP32”, Journal of Engineering Technology Vol. 10(1): 136-142