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AUTOMATED IOT-BASED ROADSIDE SMART PARKING SYSTEM

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INTRODUCTION & AIM

Introduction

Rapid growth in vehicle usage has created significant parking challenges in urban and institutional environments. Traditional parking systems are inefficient, unorganized, and lack real-time monitoring, leading to traffic congestion, fuel wastage, delays in finding parking spaces, and poor space utilization. In many areas, the absence of secure monitoring, automated access control, and structured parking management creates inconvenience for users and reduces operational efficiency. To overcome these limitations, an IoT-based automated roadside smart parking system is proposed using ESP32, ultrasonic sensors, ESP32-CAM, Firebase cloud integration, OTP-based authentication, and automated billing. The system provides real-time slot monitoring, secure entry and exit, online booking, and automated parking management to improve efficiency, security, and user convenience.

Aim

To design and implement a secure, automated, and cloud-integrated IoT-based smart parking system that enables real-time parking slot monitoring, online booking, OTP-based secure access, and automated billing for efficient and organized parking management.

METHOD

The smart parking system follows an automated workflow controlled by the ESP32 microcontroller and integrated with the Firebase cloud database for real-time parking management. The complete workflow is divided into four major stages: vehicle entry, user exit without vehicle, user re-entry, and final vehicle exit.

1. Vehicle Entry

The process begins when the user starts a parking session through the application. An Entry OTP is generated and sent to the user. At the parking gate, the user enters the OTP using the keypad module. The ESP32 verifies the OTP with the Firebase database, and if the authentication is successful, the servo motor opens the gate for the first time, allowing the vehicle to enter the parking area. After entry, the user parks the vehicle in the allocated slot. Ultrasonic sensors detect vehicle occupancy and update the slot status in real time to the cloud database.

2. User Exit Without Vehicle

After parking the vehicle, the user may temporarily leave the parking area without taking the vehicle. In this stage, the user selects the “Open Gate” option in the application. The ESP32 processes the request and activates the servo motor to open the gate for the second time, allowing the user to exit while the parking session remains active.

3. User Re-Entry Without Vehicle

When the user returns to the parking area, the “Leave Spot & Pay” option is selected in the application. The system calculates the parking duration and generates the parking bill automatically. After successful payment, an Exit OTP is generated. The user enters this OTP through the keypad at the gate. The ESP32 verifies the OTP from Firebase and opens the gate for the third time, allowing the user to re-enter the parking area securely.

4. Vehicle Exit

Finally, when the user decides to leave with the vehicle, the “Leave Spot With Vehicle – Open Gate” option is selected in the application. The servo motor opens the gate for the fourth time, allowing the vehicle to exit the parking area. At the end of the session, the system updates the parking slot status as AVAILABLE in the Firebase cloud database and stores all parking details, including timestamps, OTP records, billing information, and captured vehicle images for monitoring and future analysis.

The entire workflow enables secure access control, automated parking management, real-time slot monitoring, cloud synchronization, and efficient parking operation with minimal manual intervention.

RESULTS & DISCUSSION

The developed IoT-based smart parking system was successfully implemented and tested under real-time operating conditions. The system demonstrated reliable performance in monitoring parking slots, managing secure access, and automating parking operations. Ultrasonic sensors accurately detected vehicle occupancy and continuously updated slot availability in the Firebase cloud database with minimal delay. This enabled users to monitor parking availability in real time through the web/application interface.

The ESP32 microcontroller established stable communication with the Firebase cloud platform and efficiently coordinated all hardware components, including the keypad module, servo motor, ultrasonic sensors, LCD display, and ESP32-CAM module. The OTP-based authentication mechanism functioned effectively for both entry and exit operations, preventing unauthorized access and improving parking security. The servo motor responded accurately to valid OTP verification and automated the opening and closing of the parking gate without manual intervention.

The ESP32-CAM module successfully captured vehicle images during entry and exit, enhancing monitoring and maintaining secure parking records. The automated billing system correctly calculated parking duration and generated parking charges based on the predefined rate. The booking-to-payment workflow operated smoothly and provided a convenient user experience through cloud-based synchronization and automated processing.

The system significantly reduced the time required to search for parking spaces and improved overall parking organization and slot utilization. Real-time monitoring minimized congestion inside the parking area and improved vehicle movement efficiency. The structured parking mechanism also reduced confusion among users and improved parking discipline within the premises.

Experimental observations showed that the system performed efficiently under normal internet conditions with fast cloud synchronization and reliable hardware response. However, minor delays were observed during weak Wi-Fi connectivity, affecting real-time cloud updates. Slight inaccuracies in ultrasonic sensor readings occurred occasionally due to environmental interference and object positioning. Despite these minor limitations, the system maintained stable overall performance and demonstrated the feasibility of implementing a cost-effective, scalable, secure, and user-friendly IoT-based smart parking solution for modern urban and institutional environments.

CONCLUSION

The IoT-based smart parking system successfully implemented real-time parking monitoring, secure access control, and automated parking management using ESP32, ultrasonic sensors, ESP32-CAM, Firebase cloud integration, and OTP-based authentication. The system accurately detected vehicle occupancy, updated slot availability in real time, and automated gate operations through OTP verification. Automated billing, cloud synchronization, and image capture improved parking efficiency, security, and user convenience..

FUTURE WORK

Integration of AI and Machine Learning for parking prediction and smart slot allocation Automatic License
Plate Recognition (ALPR) for fully automated entry and exit