Smart QR Vehicle Access System with User-Defined Time Selection and ID Verification

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***Abstract*—This work signifies a Vehicle access control is a critical aspect of security in shared vehicle services, rental systems, and restricted areas. Traditional methods like manual verification, RFID cards, and biometric systems lack flexibility and real-time monitoring. To address these challenges, this project introduces a Smart QR Vehicle Access System with User-Defined Time Selection and ID Verification. Registered users can scan a QR code displayed on the vehicle's screen, select their usage time, and request approval from the owner. The owner receives a real-time notification and can accept or deny the request. If the time expires, the user must reselect the duration and send a new request. This system enhances security, prevents unauthorized access, and ensures full control over vehicle usage.**

Various vehicle access systems exist, including RFID-based access, biometric authentication, and Automatic Number Plate Recognition (ANPR). RFID systems are prone to cloning, while biometric authentication introduces delays and privacy concerns. ANPR relies on cameras but can be affected by poor lighting and dirty plates. QR-based authentication is a cost-effective, scalable, and reliable alternative. However, existing QR-based systems lack real-time authorization and time selection features. This project enhances QR-based access by integrating user-defined time selection and owner approval, ensuring secure and flexible vehicle access control.

The main challenge in vehicle access management is balancing security and user convenience. This project employs a touchscreen display, QR scanner, and microcontroller unit (Raspberry Pi or Arduino) for authentication. Users select their usage time, scan a QR code, and send an access request via a cloud-based system (Firebase). The software stack includes Python for backend processing and OpenCV for QR scanning. If the approved time expires, the user must request an extension. By integrating real-time notifications and secure access control, this system provides a scalable, user-friendly, and efficient vehicle access solution, reducing reliance on manual intervention and preventing unauthorized access.

Key words- Authentication, Data Privacy, Time Based access, ID Verification.

I INTRODUCTION

The Smart QR-Based Vehicle Access System is an innovative solution designed to enhance security and streamline vehicle entry management through automation. In an era where security concerns are paramount, this system leverages QR code technology to provide a seamless and efficient method for user authentication[1]. By utilizing a mobile application, users can scan a unique QR code that is linked to their identity, which is then verified through Firebase, a robust cloud-based platform that ensures secure data handling and real-time processing [2].

At the core of this system is the ESP32 microcontroller, which processes verification requests in real-time[3]. The ESP32 is a powerful device equipped with built-in Wi-Fi and Bluetooth capabilities, making it ideal for IoT applications[[4] . When a user scans their QR code at a vehicle entry point, the mobile application communicates with Firebase to authenticate the user's credentials[5]. This interaction is crucial, as it allows for immediate verification of the user's identity against the stored data in the Firebase database[6]. If the credentials are valid, the ESP32 grants access, allowing the vehicle to enter. This automated process eliminates the need for manual verification, significantly reducing wait times and enhancing the overall user experience [7].

A key feature of the Smart QR-Based Vehicle Access System is its ability to allow users to define custom time slots for access[8]. This functionality is particularly beneficial in environments where access needs to be controlled based on specific schedules[9]. For example, a

user may set access permissions for certain hours of the day, ensuring that only authorized individuals can enter during those times[10]. This feature not only enhances security but also provides users with greater control over their access rights[11], allowing for tailored access management that meets the specific needs of different users or groups[12][13].

The system architecture is designed for seamless communication between the mobile app, Firebase, and the ESP32 module[14][15]. Firebase serves as the backbone for real-time database management, storing user data, access logs, and time slot configurations[16][17]. This ensures that all access attempts are logged, providing a comprehensive audit trail for security monitoring and compliance purposes[18]. The ability to track access attempts in real-time allows administrators to quickly identify any unauthorized access attempts and take appropriate action [19].

The Smart QR-Based Vehicle Access System is applicable in various real-world scenarios[20], including smart parking systems, gated entries for offices and residential complexes, and automated toll booths[21]. In smart parking systems, for instance, users can reserve parking spots in advance and gain access through QR code scanning, streamlining the parking process[22]. In gated communities, the system enhances security by ensuring that only authorized personnel can enter, thereby reducing the risk of unauthorized access[23].

II PROPOSED SYSTEM

The Smart QR-Based Vehicle Access System is designed to enhance security and streamline vehicle entry management through the integration of advanced technologies, including QR code authentication, mobile applications, and real-time data processing. This innovative system allows users to register their vehicles and generate unique QR codes linked to their identities, ensuring a secure and personalized access experience.When users approach a vehicle entry point, they can easily scan their QR code using a dedicated mobile application. This application communicates with Firebase, a robust cloud-based platform, to authenticate the user's credentials in real-time. The ESP32 microcontroller, which serves as the system's core, processes these verification requests efficiently. Upon successful authentication, the ESP32 grants access, allowing the vehicle to enter without the need for manual verification. This automated process significantly reduces wait times and enhances the overall user experience.A key feature of the Smart QR Vehicle Access System with User-Defined Time Selection and ID Verification is its ability to allow users to define custom access time slots. This functionality is particularly beneficial in environments where access needs to be controlled based on specific schedules, such as gated communities, corporate offices, and parking facilities. Users can set permissions for certain hours of the day, ensuring that only authorized individuals can enter during those times.The system architecture is designed for seamless communication between the mobile app, Firebase, and the ESP32 module. This integration not only provides real-time data processing but also ensures that all access attempts are logged, creating a comprehensive audit trail for security monitoring and compliance purposes. Overall, the proposed Smart QR-Based Vehicle Access System offers a secure, efficient, and user-friendly solution for modern vehicle access management, addressing the evolving demands of security and convenience in various environments.

Design Methodology

A. Requirement Analysis

The first phase involves gathering and analyzing the requirements of the system. This is crucial for understanding the needs of potential users, including residents of gated communities, employees of corporate offices, and users of smart parking facilities. The requirements analysis includes:

- Stakeholder Interviews: Engaging with users and administrators to gather insights on their needs and expectations.
- Surveys: Distributing questionnaires to potential users to collect data on desired features and functionalities.
- Market Research: Analyzing existing solutions to identify gaps and opportunities for improvement.

B. Sensor Selection and Integration

In this phase, appropriate sensors are selected and integrated into the system to facilitate effective vehicle access management. Key activities include:

- Sensor Identification: Determining necessary sensors, such as QR code scanners, proximity sensors, and cameras for license plate recognition.
- Specification Evaluation: Assessing sensor specifications, compatibility, and performance to ensure they meet system requirements.
- Integration: Connecting selected sensors with the ESP32 microcontroller for data processing and communication.

C. Data Acquisition and Transmission

This phase focuses on establishing a reliable method for data acquisition and transmission between system components. Key activities include:

- Data Collection Protocols: Developing protocols for collecting data from sensors, including QR code data and vehicle identification information.
- Communication Protocols: Implementing protocols (e.g., MQTT, HTTP) for transmitting data between the ESP32, Firebase, and the mobile application.
- Security Measures: Ensuring data security during transmission through encryption and secure communication channels.

D. Smart QR Vehicle Access Mechanism

This phase involves implementing the core functionality of the vehicle access system using QR code technology. Key activities include:

- Mobile Application Development: Creating an application that allows users to generate unique QR codes linked to their identities and vehicles.
- QR Code Scanning: Programming the ESP32 to scan QR codes and communicate with Firebase for user authentication.
- Access Control Mechanism: Developing a mechanism for granting or denying access based on authentication results.

E. Alert System Integration

In this phase, an alert system is implemented to notify users and administrators of access events and security breaches. Key activities include:

- Notification Features: Developing features within the mobile application to inform users of successful or failed access attempts.
- Administrator Alerts: Integrating alerts for administrators regarding unauthorized access attempts or system malfunctions.
- Communication Channels: Utilizing push notifications, SMS, or email alerts to ensure timely communication.

F. Dashboard and Remote Management

This phase focuses on creating a user-friendly dashboard for monitoring and managing the vehicle access system. Key activities include:

- Dashboard Design: Designing a web-based dashboard for administrators to view access logs, manage user permissions, and configure system settings.
- Data Visualization: Implementing real-time data visualization tools to display access statistics and alerts.

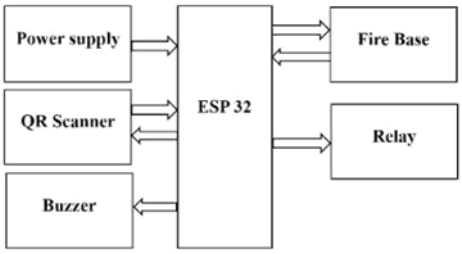

Figure 1:block diagram

III RESULT and DISCUSSION

Figure 2: Design model for hardware implementation

The work proposes a Smart QR-Based Vehicle Access System, enhancing security and convenience in vehicle management. Users register vehicles and generate unique QR codes for access. Scanning these codes with a mobile

app triggers real-time authentication via Firebase and an ESP32 microcontroller. The system features user-defined time slots, allowing for scheduled access control, crucial in gated communities and corporate settings. Real-time logging and alerts ensure robust security and monitoring. The system integrates a dashboard for remote management, offering administrators control over permissions and access logs, addressing modern security and convenience demands.

Figure 3: QR Code for Car 2

This figure 3 shows a digital screen showing information for "Car2". It includes the vehicle's license plate number "AP-24-2312" and a prominent QR code. This suggests a system where scanning the QR code might provide access to the car, verify its details, or initiate a transaction. The clear display and prominent QR code indicate a user-friendly interface designed for quick and easy interaction, likely related to vehicle access or management.

Figure 4: User Interface

This figure 4 shows the interface displays "User Home," indicating a personalized user experience. At the center is a prominent button labeled "Scan QR Code," which enables users to quickly access QR code scanning capabilities, enhancing interaction and facilitating efficient actions. The background features a minimalistic design with a soft, light tone, contributing to a clean and user-friendly layout; this simplicity aids usability, making navigation intuitive. Overall, the design effectively combines functionality with aesthetic appeal, prioritizing ease of use and accessibility.

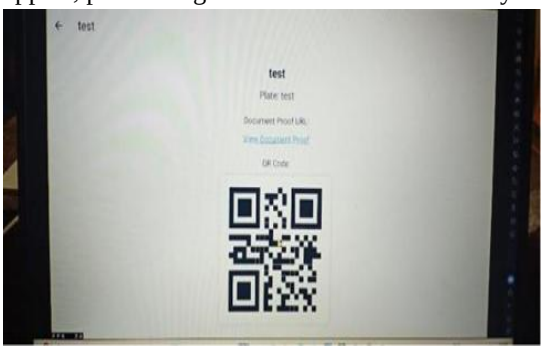

Figure 5:QR code for test car 1

The QR code depicted in Figure 5 is an essential feature designed to enhance user interaction with the vehicle. By simply scanning the QR code using the integrated scanner available in the vehicle, users can conveniently connect and control various functions of their car. This innovative technology allows drivers to efficiently turn the vehicle ON or OFF, offering a seamless and modern approach to vehicle management. The integration of QR code functionality not only elevates the user experience but also ensures enhanced accessibility and security, making it easier for individuals to engage with their vehicles using just their smartphones. This advancement reflects the growing trend of smart technology.

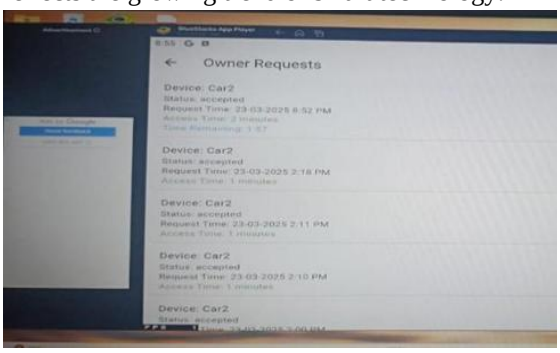

Figure 6: Requests shown in email

The interface depicted in Figure 6 illustrates the user home screen for a vehicle access application. Central to this interface is the "Scan QR Code" button, suggesting that clients utilize QR codes to request access to vehicles. This method enhances user experience by allowing quick and seamless interaction. Users likely input specific vehicle details or permissions after scanning, streamlining the process. The simplicity of the interface indicates a focus on accessibility, ensuring varied users can navigate the system effortlessly. This QR-based access request mechanism likely simplifies vehicle management and enhances security in accessing vehicles.

IV CONCLUSION

In conclusion, the Smart QR-Based Vehicle Access System is a transformative solution that enhances vehicle entry management through the integration of advanced technologies. By utilizing QR code authentication, real-time data processing, and a user-friendly mobile application, the system effectively addresses the security and convenience needs of various users, including residents of gated communities and employees in corporate settings. The structured design methodology encompasses thorough requirements analysis, careful sensor selection, and rigorous testing, ensuring a reliable and efficient system. Additionally, the incorporation of an alert system and a comprehensive dashboard for remote management further enhances user experience and administrative oversight. With a focus on scalability and adaptability, the system is well-prepared to meet the evolving demands of vehicle access management. Ongoing maintenance and support will ensure its long-term effectiveness, making it a valuable asset for enhancing security and streamlining access in diverse environments.

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