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Smart Car Parking Fee Collection System

1. Abstract

The proposed work focuses on the development of a smart car parking fee collection system that utilizes a combination of Arduino Uno, ESP32, RFID sensors, servo motor, and LDR sensors to provide an efficient and automated solution for parking management. The proposed system aims to enhance the user experience, streamline the payment process, and offer real-time analytics for parking administrators. The system's key features include user authentication, automated barrier control, timer-based fee calculation, email notification, and smart lighting control. This paper presents the detailed design, implementation, and evaluation of the proposed system, showcasing its effectiveness in addressing the challenges associated with traditional parking management systems.

2. Introduction

The continuous growth in the number of vehicles on the roads has led to an increasing demand for efficient and user-friendly parking management solutions. Traditional parking systems often face a multitude of challenges, including manual fee collection, long queues, and a lack of real-time data for effective decision-making by parking administrators. These issues not only hinder the overall user experience but also impede the optimal utilization of parking resources.As the trend of vehicle ownership continues to rise, particularly in urban areas, the need for innovative and technologically-advanced parking management systems has become paramount. The shortcomings of traditional approaches, such as manual fee collection and limited monitoring capabilities, have led to increased congestion, wasted time, and inefficient resource allocation within parking facilities.

To address these pressing challenges, this system proposes the development of a smart car parking fee collection system. This system leverages the integration of cutting-edge technologies, including Arduino Uno, ESP32, RFID sensors, servo motors, and LDR sensors, to provide a comprehensive and automated solution for parking management.The primary objective of this system is to design and implement a smart parking system that enhances the user experience, streamlines the payment process, and offers real-time analytics for parking administrators. By seamlessly integrating various components, the proposed system aims to revolutionize the traditional approach to parking management, addressing the key pain points faced by both users and parking authorities.

The key features of the developed system include user authentication, automated barrier control, timer-based fee calculation, email notification, and smart lighting control. These innovative functionalities are expected to contribute to a more efficient, secure, and user-friendly parking experience, while also enabling data-driven decision-making for improved resource allocation and optimization. This

system represents a significant step towards addressing the growing challenges in parking management, particularly in urban centers with high vehicle density. The integration of advanced technologies and the development of a comprehensive solution have the potential to transform the parking industry and pave the way for the implementation of smart city infrastructure.

3. Literature Survey

Existing research efforts have focused on developing efficient and automated parking management systems to address the challenges posed by the growing number of vehicles in urban areas. These studies have explored the integration of various technologies, such as RFID, IoT, sensors, and computer vision, to streamline the parking experience and enhance administrative control.

One such project is the "Smart Car Parking System" [1], which aims to create an efficient and automated solution for complex multi-story parking structures. This system utilizes IR sensors to detect vehicles, manage the number of vehicles entering and exiting, and provide real-time feedback. The system simplifies the process of finding empty parking spaces, guides drivers to available spots using visual indicators, and reduces the time spent searching for parking. The "Smart Car Parking Management System" [2] introduces a smart parking system designed to address the challenges of managing increasing vehicle numbers in densely populated urban areas of Bangladesh. This system utilizes RFID technology to track vehicle entry and exit times, automate fare calculation, and provide a user-friendly interface for system maintenance and reporting. The inclusion of an LED display to indicate parking slot availability helps to streamline parking management and alleviate congestion within public buildings. The "A Research On Smart Vehicle Parking System" [3] project presents an IoT-based solution to address the challenges posed by the increasing number of vehicles on the roads. By leveraging RFID technology and IoT, the system aims to automate parking management and alleviate traffic issues. It enables custodians to easily identify vacant parking slots and ensures accurate tracking of parking duration and fees, while also focusing on reducing fuel consumption and pollution in urban areas.

The "Smart Parking System using IoT" [4] introduces an efficient and smart parking management solution that utilizes IoT technology to allocate parking spaces effectively. By providing wireless access to the system, users can monitor parking availability, addressing the challenge of road congestion in metropolitan cities. The system aims to minimize the time and effort spent by users in searching for available parking spaces by sending parking information via notifications. Additionally, RFID technology is incorporated to enhance security and prevent car theft. The "Smart Car Parking System using Arduino UNO" [5] presents a parking system based on IoT technology, aiming to provide an efficient and convenient approach to parking vehicles by monitoring parking slot availability. It outlines the deployment of an IoT module to monitor and indicate the status of single parking spaces, and discusses the system's operation through a usage case, demonstrating the effectiveness of the

proposed model. The "Automatic Parking Management System and Parking Fee Collection Based on Number Plate Recognition" [6] aims to enhance the convenience and security of public parking lots while simplifying the process of collecting parking fees. This system utilizes number plate recognition technology to automate parking operations and billing, reducing the need for human intervention and eliminating the use of magnetic cards. Additionally, it incorporates a parking guidance system to assist users in locating available parking spaces.

The "Automated car parking system commanded by Android application" [7] introduces an automated car parking system that not only manages the number of parked cars based on available spots but also automates the process of parking and exiting vehicles using sensing devices. This system is controlled through an Android-based application, reducing the need for human intervention. The "Smart Car Parking System using Arduino" [8] outlines a simple smart vehicle parking system utilizing basic components such as the Arduino Atmega328p (microcontroller), IR sensors, servo motor, and LCD. The system aims to address the time-consuming nature of parking management in locations such as malls and shopping areas by automating the process. The "Integrated Approach in the Design of Car Park Occupancy Information System (COINS)" [9] introduces the Car-Park Occupancy Information System (COINS), which aims to address the challenge of finding vacant parking lots in large parking areas. The system utilises an integrated approach of image processing algorithms to acquire car-park occupancy information, leveraging security surveillance cameras commonly found in most car parks.

These research efforts have contributed to the advancement of smart parking systems, addressing various aspects such as user authentication, automated barrier control, fee calculation, and real-time data analytics. However, the integration of comprehensive solutions that encompass features like email notification, smart lighting control, and dynamic pricing models remains an area of active research, which the present work aims to address.

4. Proposed System

The proposed smart car parking fee collection system aims to provide a seamless and efficient parking experience for users, while also offering valuable insights for parking administrators.

4.1 Identification of Gaps

- Lack of focus on efficient and automated parking systems for complex multi-storied parking structures.

- Absence of emphasis on integrating RFID technology for vehicle tracking and automated fare calculation.

- Limited discussion on leveraging IoT technology for effective parking space allocation and congestion management.

• Scarcity of detail on minimizing human intervention and automating parking operations efficiently.

• Insufficient attention to real-time monitoring of parking availability and user notifications.

4.2 Contributions

• Integration of RFID technology for automated fare calculation and user-friendly interface.

• Utilization of IoT technology for dynamic parking space allocation and congestion alleviation.

• Implementation of wireless access for real-time monitoring of parking availability.

• Email notification and thingspeak visualisation.

4.3 Designed System

The key features of the system include:

1. User Authentication: The system utilizes RFID sensors to identify authorized users, allowing for automated access control. This feature ensures that only legitimate users can access the parking lot, enhancing security and preventing unauthorized entry.

2. Automated Barrier Control: The servo motor-based barrier system is integrated with the RFID sensor to provide smooth entry and exit for authorized users. This automated barrier control eliminates the need for manual intervention, streamlining the parking process and reducing wait times.

3. Timer-based Fee Calculation: The system tracks the duration of each user's stay and calculates the parking fee accordingly, which is then communicated to the user via email. This feature ensures a transparent and fair payment process, as users are charged based on the actual time spent in the parking lot.

4. Email Notification: The ESP32 module is responsible for sending the parking fee details to the user's email address, providing a convenient and transparent payment process. Users can easily access the fee information and make the necessary payment without any hassle.

5. Smart Lighting Control: The LDR sensor is used to automatically turn on the parking lot lights when it's dark, enhancing the user experience and improving energy efficiency. This feature ensures optimal lighting conditions throughout the parking lot, contributing to a safer and more comfortable environment.

6. Real-time Analytics: The system integrates with ThingSpeak, an IoT analytics platform, to provide parking administrators with comprehensive data on total money collected, total time stayed, total cars visited, and other relevant metrics. This feature enables data-driven decision-making, allowing administrators to optimize resource allocation, identify usage patterns, and implement strategic improvements to the parking system.

4.4 Novelty

1. The proposed system employs SMTP to generate automated emails that contain the parking details like cost and time spent.

2. The system forwards all the real time data to ThingSpeak platform, therefore adding an analytics view for the administrator for data collection and future planning.

3. An LDR-sensor based smart lighting system has been integrated to ensure safety when the parking space gets dark.

5. Architecture

The proposed smart car parking fee collection system follows a modular architecture, where each component plays a specific role in the overall functionality of the system. The architecture of the proposed system is illustrated in figure 1. The key elements of the architecture are:

1. Arduino Uno: The central microcontroller that handles the overall system operation, including sensor data processing and communication with other modules. The Arduino Uno serves as the brain of the system, coordinating the various components and ensuring their seamless integration.

2. ESP32: The Wi-Fi module responsible for sending parking fee details to the user's email and uploading data to the ThingSpeak platform. The ESP32 enables the system's connectivity, allowing for remote access and communication with external services.

3. RFID Sensor: Used for user authentication, the RFID sensor detects the presence of authorized users and triggers the appropriate actions, such as opening the parking barrier or activating the buzzer for unauthorized access.

4. Servo Motor: Controlled by the Arduino Uno, the servo motor opens and closes the parking barrier, enabling smooth entry and exit for authorized users. This automated barrier control enhances the overall user experience and streamlines the parking process.

5. LDR Sensor: The LDR (Light Dependent Resistor) sensor detects the ambient light level and triggers the parking lot lights accordingly, ensuring optimal lighting conditions and energy efficiency.

6. ThingSpeak: The IoT analytics platform used to visualize and analyze the parking data, providing real-time insights for parking administrators. The integration with ThingSpeak allows for comprehensive data monitoring and decision-making support.

The modular architecture of the proposed system ensures flexibility, scalability, and ease of maintenance, enabling future expansions and adaptations to meet evolving parking management requirements.

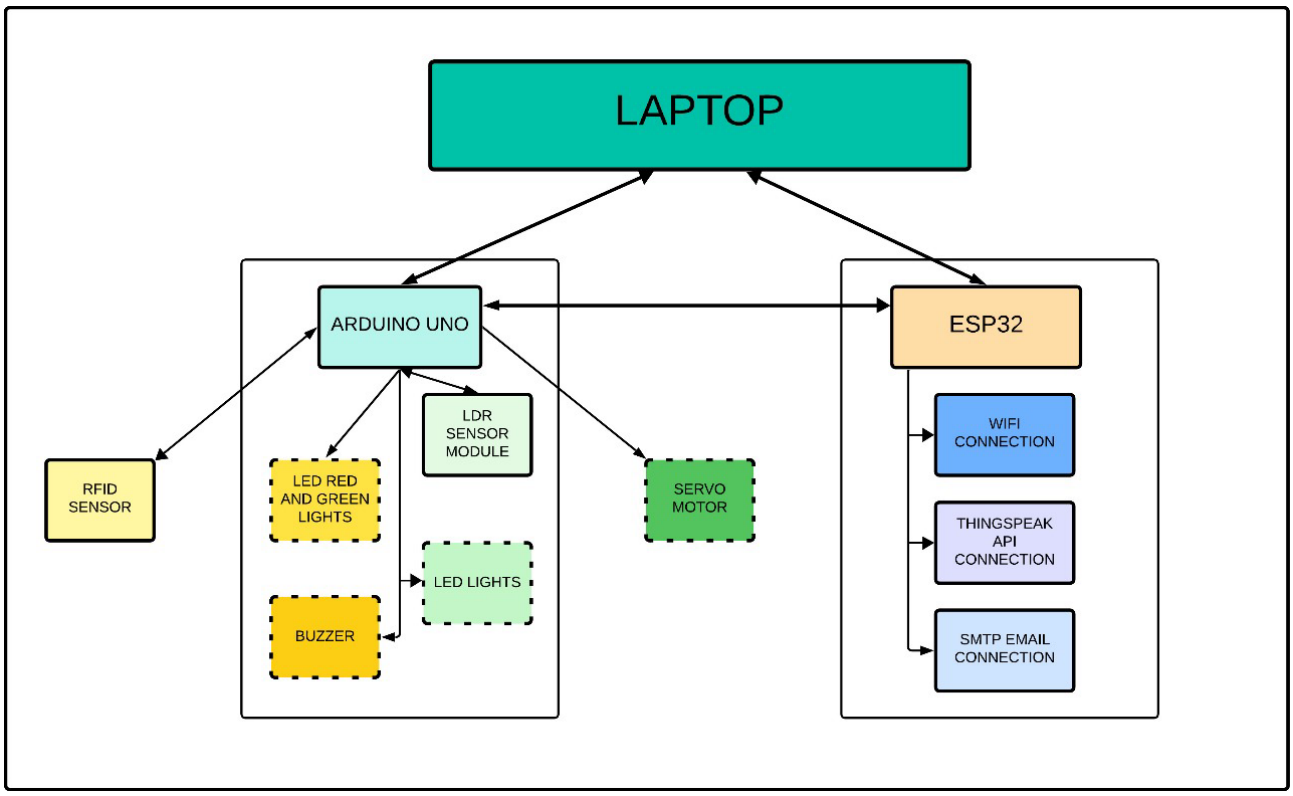

Figure 1. Schematic of the proposed system

6. Hardware Components

The following hardware components were used to design the proposed system:

1. Arduino Uno: The core microcontroller that coordinates the system's operations.

2. ESP32: The Wi-Fi module responsible for email notifications and data uploads to ThingSpeak.

3. RFID sensor: Used for user authentication and access control.

4. Servo motor: Controlled by the Arduino Uno to open and close the parking barrier.

5. LDR sensor: Detects the ambient light level to control the parking lot lights.

6. Buzzer: Provides audio feedback for unauthorized user access.

7. LED indicators (green and red): Visual indicators for the system's status and user access as well as for smart lights.

7. Software Modules
The following software modules were used for designing the system:

1. Arduino IDE: The integrated development environment used for programming the Arduino Uno and ESP32 modules.

2. ThingSpeak: The IoT analytics platform that receives and visualizes the parking data for real-time insights and decision-making.

3. SMTP (Simple Mail Transfer Protocol): The email communication protocol utilized by the ESP32 module to send parking fee details to the user's email address.

8. Algorithm and Flowchart
The working of the proposed smart car parking fee collection system can be visualised using the flowchart in figure 2. The proposed system can be summarized through the following algorithm:

1. Initialize the system components (Arduino Uno, ESP32, RFID sensor, servo motor, LDR sensor, buzzer, and LED indicators).

2. Load the authorized RFID tag IDs into the system.

3. Wait for a vehicle to enter the parking lot.

4. When a vehicle enters, the RFID sensor checks if the user is authorized.
   a. If the user is authorized, start the timer and open the parking barrier using the servo motor.
   b. If the user is not authorized, turn on the buzzer and the red LED indicator.

5. When the user exits the parking lot, the RFID sensor detects the user's tag and stops the timer.

6. Calculate the parking fee based on the time spent in the parking lot.

7. Send the parking fee details to the user's email address using the ESP32 module and SMTP.

8. Upload the parking data (total money collected, total time stayed, total cars visited, and other relevant metrics) to the ThingSpeak platform for real-time analytics.

9. Use the LDR sensor to automatically turn on the parking lot lights when it's dark, and turn them off when it's bright.

10. Repeat the process for the next vehicle.

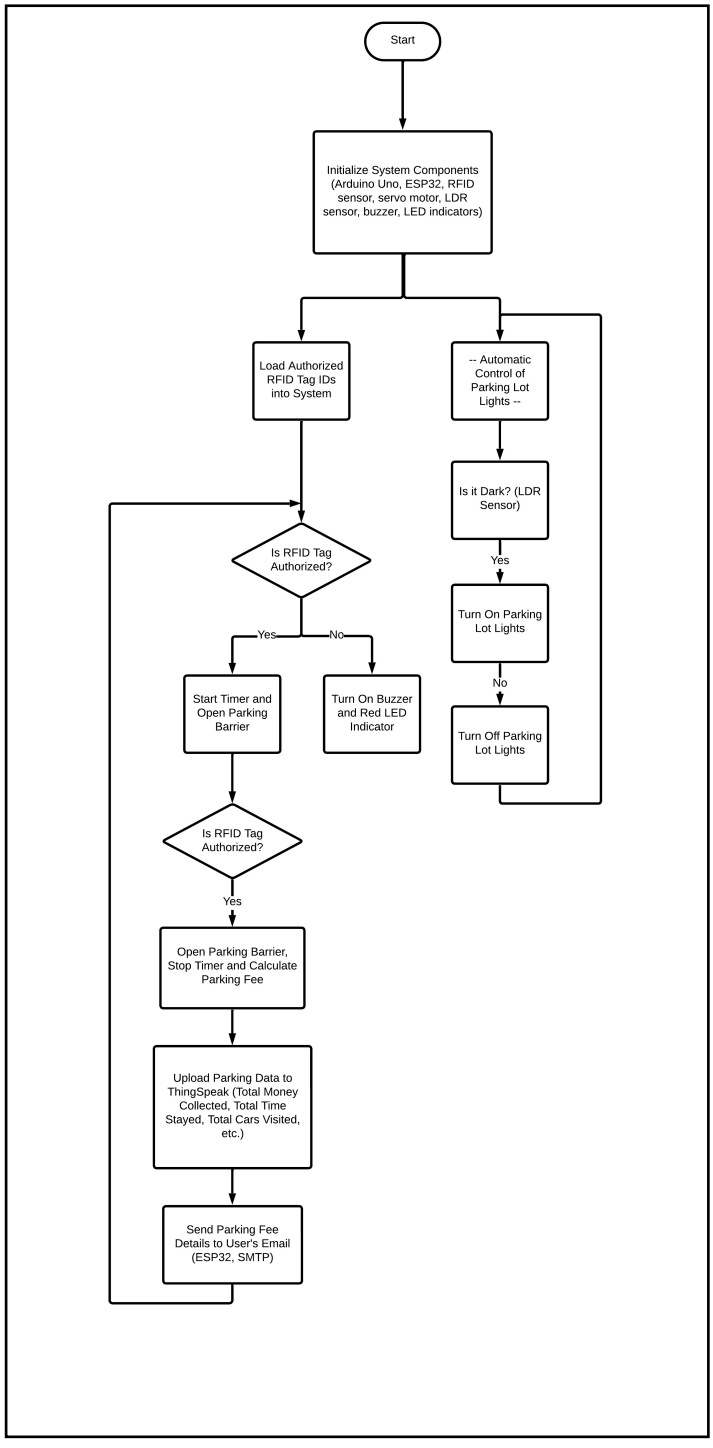

Figure 2. Flowchart

9. Results and Discussion

The proposed smart car parking fee collection system has been implemented and tested, and the results are presented below. The system has demonstrated its effectiveness in streamlining the parking experience, automating the fee collection

process, and providing valuable insights for parking administrators. The serial monitor for Arduino and ESP-32 are illustrated in figure 3 and 4 respectively.

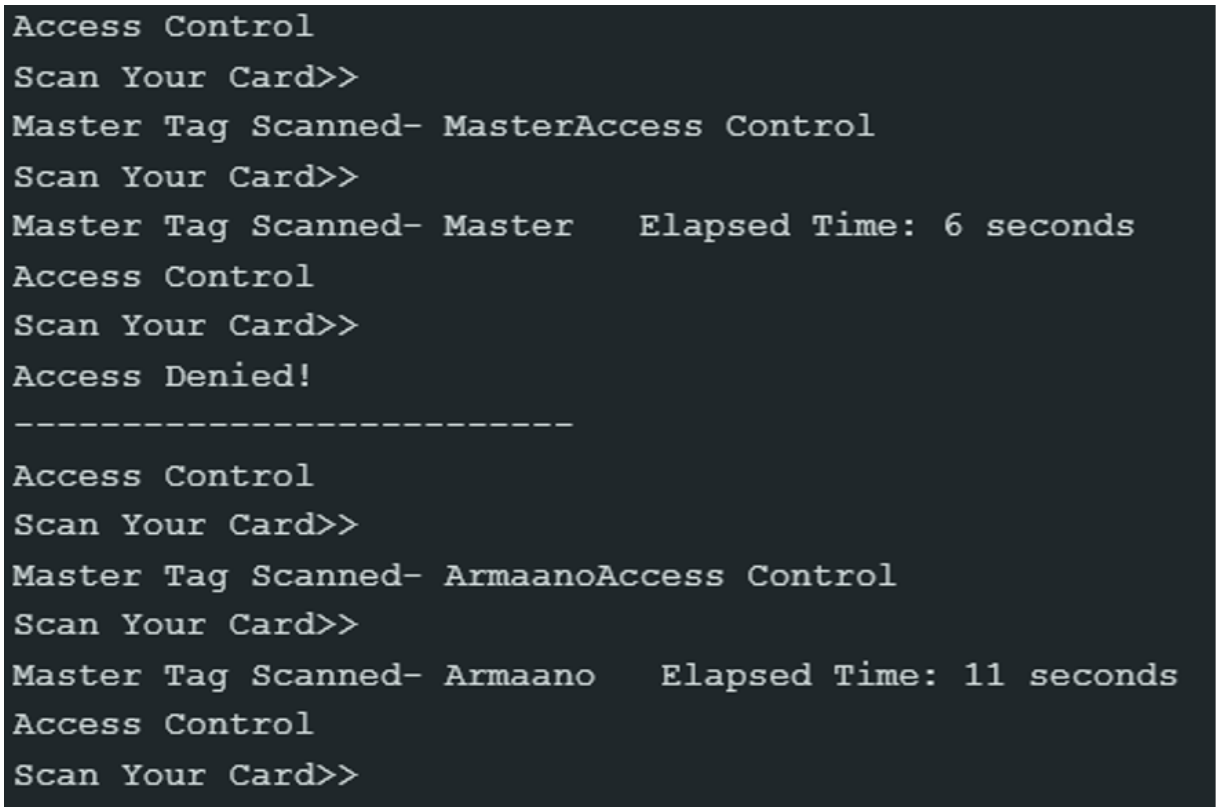

Figure 3. Authorised and Unauthorised scans on Arduino

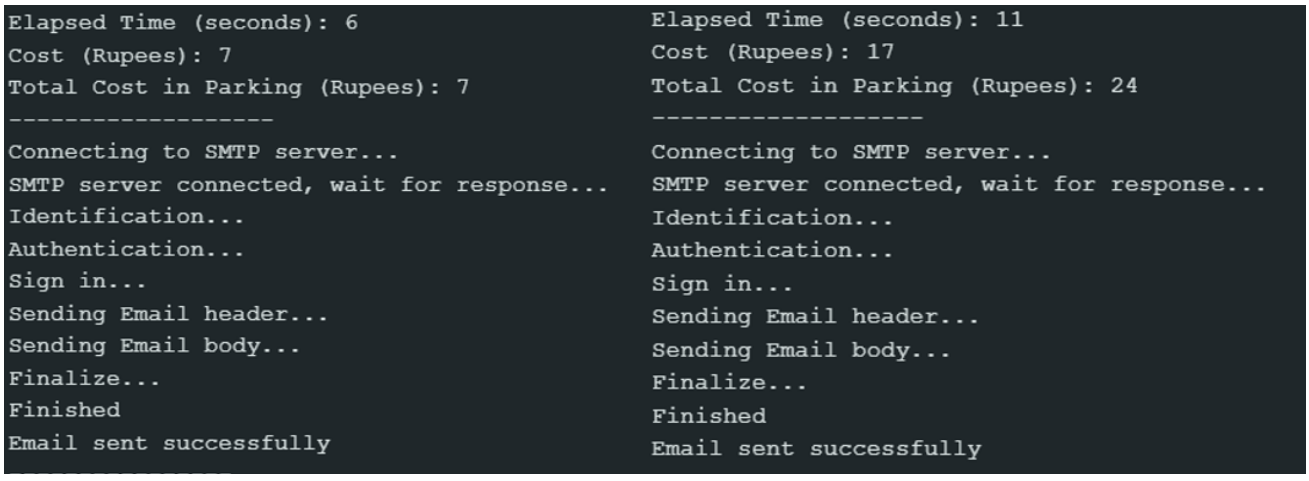

Figure 4. E-mail and ThingSpeak handling by ESP32

The data is visualised in two separate views (figure 5) in ThingSpeak, one for the admin (figure 6) and one for the user (figure 7). The email generated contains the fee details for the latest parking (figure 8).

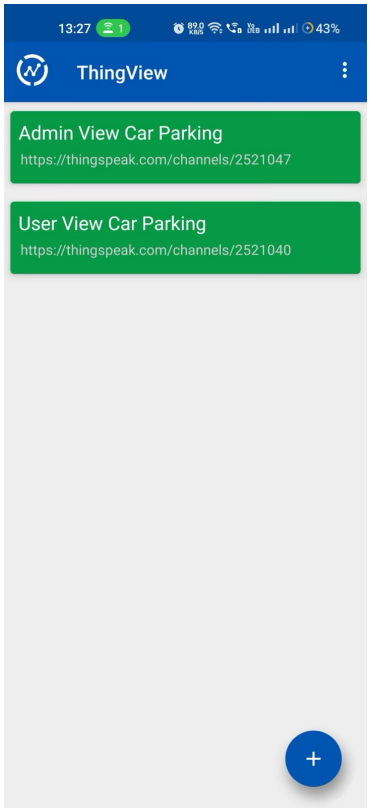

Figure 5. ThingSpeak Mobile App

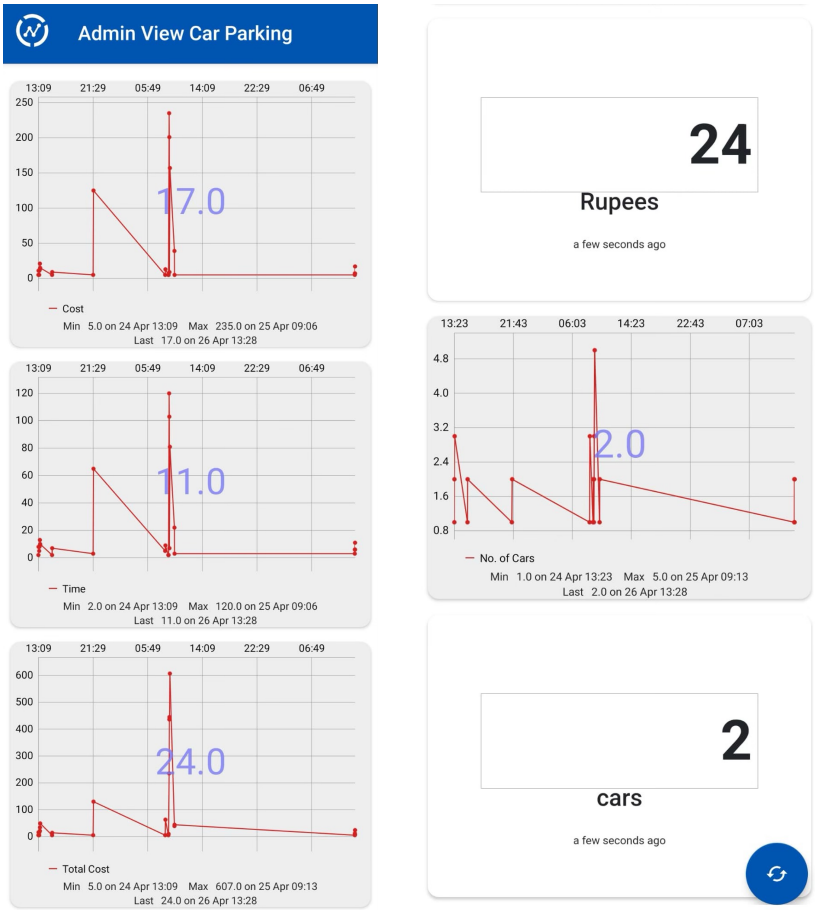

Figure 6. Admin View

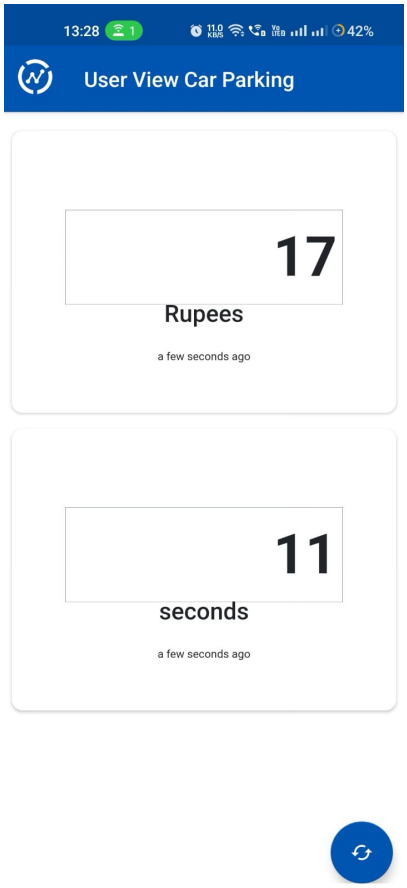

Figure 7. User View

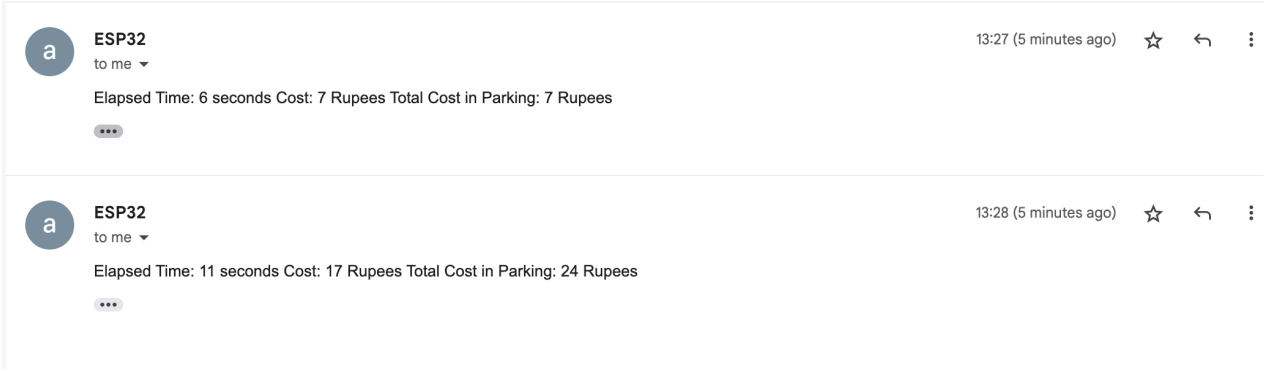

Figure 8. E-mail notification using SMTP

10. Future Work

While the current implementation of the smart car parking fee collection system addresses many of the challenges associated with traditional parking management, there are opportunities for further improvements and expansions. Some potential future work includes:

1. Integrating advanced computer vision and deep learning techniques for automated vehicle recognition and license plate detection, enhancing the system's capability to identify authorized users.

2. Developing a mobile application or web-based interface to provide users with real-time parking availability information and the ability to reserve parking spots.

3. Incorporating dynamic pricing models based on factors such as peak hours, special events, or seasonal variations to optimize revenue generation and resource utilization.

4. Exploring the integration of renewable energy sources, such as solar panels, to power the parking lot's infrastructure and reduce the system's carbon footprint.

11. Conclusion

The proposed smart car parking fee collection system presents a comprehensive solution to the challenges faced by traditional parking management systems. By leveraging the integration of Arduino Uno, ESP32, RFID sensors, servo motors, and LDR sensors, the system offers an efficient and user-friendly parking experience. The key features, including user authentication, automated barrier control, timer-based fee calculation, email notification, and smart lighting control, contribute to a seamless parking process for users. Additionally, the system's integration with the ThingSpeak platform provides parking administrators with valuable real-time analytics, enabling data-driven decision-making and optimization of parking resources. The successful implementation and evaluation of the proposed system demonstrate its potential to revolutionize the parking industry and pave the way for further advancements in smart city infrastructure.

12. References

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