
PREPAID CAR PARKING SYSTEM

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ABSTRACT

The rapid growth of vehicular traffic in urban environments has significantly increased the demand for efficient parking management systems. Conventional parking systems, which rely on manual ticketing or postpaid billing methods, often result in long queues, inefficient space utilization, billing inaccuracies, and lack of transparency. These challenges lead to congestion, time wastage, and reduced operational efficiency, especially in high-density areas such as shopping malls, educational institutions, and residential complexes.

This paper presents the design and implementation of a **Prepaid RFID-Based Smart Car Parking System** developed using embedded systems technology. The proposed system aims to automate the entire parking process, including vehicle entry, slot allocation, billing, and exit, while minimizing human intervention. The system utilizes an Arduino Mega 2560 microcontroller as the central processing unit, along with dual RC522 RFID readers for contactless user authentication and prepaid transactions. Ultrasonic sensors (HC-SR04) are employed to detect real-time parking slot availability, and servo motors are used to automate entry and exit gate operations. A DS3231 Real-Time Clock (RTC) module ensures accurate tracking of parking duration, while a Micro SD card module is used for secure transaction logging.

The prepaid balance is stored in the microcontroller's EEPROM, ensuring data persistence even during power failures. At the entry gate, the system verifies the RFID card, deducts the base parking fee, assigns an available slot, and opens the gate automatically. At the exit, the

system calculates the total parking duration and deducts any additional charges if applicable. All transactions are recorded with timestamps for transparency and auditing purposes.

The proposed system operates entirely in offline mode, eliminating dependency on internet connectivity and reducing implementation costs. The developed prototype demonstrates high reliability, efficiency, and accuracy, making it suitable for deployment in small to medium-scale parking environments.

KEYWORDS: RFID, Smart Parking System, Arduino Mega 2560, Ultrasonic Sensor, Embedded Systems, Prepaid Billing, Automation, Offline System.

INTRODUCTION

The increasing number of vehicles in urban areas has created significant challenges in parking management. Traditional parking systems rely heavily on manual processes, including ticket generation, human supervision, and postpaid billing mechanisms. These methods often result in long waiting times at entry and exit points, inefficient utilization of parking spaces, and frequent billing errors. Moreover, the absence of real-time information about slot availability leads to unnecessary congestion and wastage of time and fuel.

With advancements in embedded systems and automation technologies, there has been a shift towards smart parking solutions. These systems aim to reduce human intervention, improve operational efficiency, and enhance user experience. However, many existing solutions are based on IoT platforms, which require continuous internet connectivity and involve higher costs and maintenance complexities.

To address these challenges, this paper proposes a Prepaid RFID-Based Smart Car Parking System that operates entirely offline. The system integrates RFID technology for user authentication, ultrasonic sensors for real-time slot detection, and servo motors for automated gate control. By adopting a prepaid billing model, the system ensures faster processing at entry points and eliminates congestion at exit gates.

The proposed solution is designed to be cost-effective, reliable, and scalable, making it suitable for deployment in various environments such as educational institutions, shopping complexes, and residential areas.

LITERATURE SURVEY

Various research studies have explored different approaches to improve parking management systems using modern technologies. RFID-based parking systems are widely used for vehicle identification and access control. These systems help reduce human errors and improve

operational efficiency. However, most of these systems follow a postpaid billing mechanism, which results in congestion at exit gates due to payment processing delays.

Sensor-based parking systems utilize technologies such as ultrasonic sensors to detect parking slot availability in real time. These systems enhance space utilization and reduce the time required for drivers to locate vacant slots. Despite these advantages, they do not incorporate user authentication or automated billing, limiting their functionality.

IoT-based smart parking systems provide advanced features such as remote monitoring, mobile application integration, and cloud-based data storage. These systems offer real-time updates and improved user convenience. However, their reliance on internet connectivity increases implementation cost and reduces reliability in areas with unstable networks.

Some researchers have proposed prepaid parking systems to reduce congestion at exit points by deducting charges in advance. While these systems improve traffic flow, they often lack real-time slot detection and complete automation.

The analysis of existing systems indicates that there is a need for an integrated solution that combines prepaid billing, real-time slot monitoring, automation, and offline functionality. The proposed system addresses these gaps effectively.

PROPOSED SYSTEM

The proposed system is a fully automated prepaid parking management solution designed using embedded systems technology. It integrates multiple hardware components to provide efficient vehicle entry, slot allocation, billing, and exit processes. The system is centered around the Arduino Mega 2560 microcontroller, which acts as the main control unit and coordinates all operations.

At the entry gate, an RFID reader scans the user's card and retrieves the unique identification number. The system then verifies the prepaid balance stored in the EEPROM. If sufficient balance is available, the base parking fee is deducted automatically. Simultaneously, ultrasonic sensors installed in each parking slot detect availability and help in assigning a vacant slot to the incoming vehicle. Once the conditions are satisfied, a servo motor is activated to open the entry gate, allowing the vehicle to enter.

Each parking slot is equipped with an ultrasonic sensor and LED indicator to display its status. The LED turns green when the slot is free and red when it is occupied. This real-time monitoring system helps drivers easily identify available spaces and reduces internal congestion.

At the exit gate, the RFID card is scanned again, and the system calculates the total parking

duration using the RTC module. If the vehicle has exceeded the predefined parking time, additional charges are calculated and deducted from the remaining balance. After successful transaction processing, the exit gate is opened automatically using a servo motor.

All transactions, including entry, exit, and recharge operations, are recorded on an SD card in CSV format with accurate timestamps. The system also includes a keypad interface that allows users to recharge their prepaid balance conveniently.

METHODOLOGY

The methodology of the proposed prepaid parking system is based on a structured and sequential approach that ensures efficient system operation. The entire process is divided into multiple stages, each responsible for a specific function within the system.

The first stage involves data acquisition, where RFID readers and ultrasonic sensors collect input data. The RFID reader captures the unique identification number of the user, while ultrasonic sensors detect the presence or absence of vehicles in parking slots.

In the second stage, the collected data is processed by the Arduino Mega 2560 microcontroller. The system verifies the RFID card and checks the prepaid balance stored in EEPROM. If the balance is sufficient, the process moves to the next stage; otherwise, access is denied.

The third stage involves decision-making, where the system determines whether to allow vehicle entry or exit. It also identifies available parking slots based on sensor data and assigns a slot accordingly.

The fourth stage includes control actions, where servo motors are used to operate entry and exit gates. The gates open automatically when all conditions are satisfied and close after a predefined time interval.

The fifth stage focuses on time tracking, where the RTC module records entry and exit timestamps. This data is used to calculate the total parking duration and determine any additional charges.

The sixth stage involves billing and deduction, where parking charges are calculated and deducted automatically from the user's prepaid balance.

Finally, the system logs all transaction details in an SD card for future reference. This structured methodology ensures smooth operation, reliability, and accuracy of the parking system.



Fig 1: Block Diagram.

Hardware Components

Item Description	Qty Req.
ARDUNIO MEGA 2560	1
SERVO MOTOR	2
RFID READER	2
ULTRASONIC SENSOR	4
RTC MODULE	1
SD CARD MODULE WITH SD CARD	1
KEYPAD	1
LCD DISPLAY	1
POWER SUPPLY	1
LED INDICATORS	6
JUMPER WIRES	1

Fig 1 : Block Diagram



The Arduino Mega 2560 is used as the main microcontroller board in the Prepaid Car Parking System, acting as the central processing unit of the entire setup. It is chosen over simpler boards like the Arduino UNO due to its higher number of input/output pins and larger memory capacity, which make it more suitable for complex embedded applications.

2.SERVO MOTOR:



Servo motors are used in the Prepaid Car Parking System for automatic control of the entry and exit gates (barriers). They provide precise angular movement and are ideal for applications where accurate position control is required.

3.RFID READER:



The RFID (Radio Frequency Identification) Reader is one of the most critical components of the Prepaid Car Parking System. It is responsible for contactless user identification and prepaid payment processing.

4. ULTRASONIC SENSOR:



The Ultrasonic Sensor is a key component used for real-time parking slot detection in the Prepaid Car Parking System. It helps determine whether a parking slot is occupied or vacant by measuring the distance between the sensor and the vehicle.

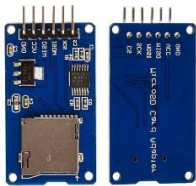
5: RTC MODULE:



The Real-Time Clock (RTC) module is an essential component in the Prepaid Car Parking System. It is used to accurately track the entry and exit time of vehicles, calculate the total parking duration, and

6. SD CARD MODULE

WITH SD CARD:



The Micro SD Card Module is used in the Prepaid Car Parking System for permanent and reliable storage of all parking transactions. It plays a vital role in maintaining transparency, accountability, and proper record-keeping.

8. LCD DISPLAY



The 16x2 LCD Display is used in the Prepaid Car Parking System to provide real-time visual feedback and status information to users and operators. It enhances the user experience by displaying important messages during entry, exit, balance checking, and recharge operations.

9. POWER SUPPLY:



A stable and reliable power supply is crucial for the smooth and uninterrupted operation of the Prepaid Car Parking System. Since the system consists of multiple components with different voltage and current requirements, a well-designed power supply unit is essential.

10. LED



LED indicators are used in the Prepaid Car Parking System to provide **real-time visual feedback** about the status of each parking slot. They help drivers quickly identify vacant and occupied slots without any confusion.

BENEFITS OF PROPOSED SOLUTION

The proposed prepaid RFID-based parking system offers several advantages over traditional parking methods. One of the primary benefits is the reduction in waiting time at entry and exit gates due to automated processing and prepaid billing. This helps in minimizing congestion and improving traffic flow within the parking area.

The system provides real-time information about parking slot availability using ultrasonic sensors and LED indicators. This allows drivers to quickly identify vacant slots, reducing the time spent searching for parking spaces.

Another significant advantage is accurate billing, as all calculations are performed automatically using the RTC module. This eliminates human errors and ensures transparency in transactions. The system also maintains detailed records of all activities using an SD card, which can be used for auditing and analysis.

Since the system operates completely offline, it does not depend on internet connectivity, making it reliable and cost-effective. Additionally, the modular design allows for easy scalability and future upgrades, making it suitable for various applications.

WORKING PRINCIPLE

The working principle of the prepaid RFID-based parking system is based on the integration of sensing, processing, and control mechanisms. When a vehicle arrives at the entry gate, the driver taps the RFID card on the reader. The system reads the card's unique identification number and verifies the prepaid balance stored in the EEPROM. If sufficient balance is available, the system deducts the base parking fee and proceeds to allocate a parking slot.

Ultrasonic sensors installed in each slot continuously monitor occupancy by measuring the distance between the sensor and the vehicle. Based on this data, the system identifies an available slot and indicates its status using LED indicators. Once a slot is assigned, the entry gate opens automatically using a servo motor.

During the parking period, the RTC module keeps track of time. When the vehicle exits, the

RFID card is scanned again, and the system calculates the total parking duration. If the parking time exceeds the predefined limit, additional charges are calculated and deducted from the user's balance.

After successful transaction processing, the exit gate opens automatically. The system updates the slot status and records all transaction details in the SD card. This integrated process ensures efficient, accurate, and automated parking management.

RESULT



CONCLUSION

The Prepaid RFID-Based Smart Car Parking System presented in this paper offers an efficient and reliable solution to modern parking challenges. By integrating embedded systems, RFID technology, ultrasonic sensors, and automated control mechanisms, the system eliminates the limitations associated with traditional parking methods. The prepaid billing approach significantly reduces congestion at exit points and ensures smooth vehicle movement within the parking area.

The system provides real-time slot detection, accurate billing, and secure transaction logging, enhancing overall transparency and operational efficiency. Its ability to function completely offline makes it cost-effective and suitable for deployment in areas with limited or no internet connectivity.

The modular design of the system allows for easy scalability and future enhancements.

Overall, the proposed solution demonstrates improved performance, reduced human intervention, and better resource utilization, making it a practical choice for smart parking applications.

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