

RFID-Based Intelligent Car Parking System with Slot-Level Authentication and Unauthorized Vehicle Alert Mechanism

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doi.org/10.64643/ijirt.208798-459

Abstract—The exponential rise of vehicle density in urban areas has significantly increased the necessity for intelligent, secure, and automated parking management solutions. Although RFID, based parking systems have been broadly implemented for vehicle identification and entry automation, the majority of existing systems do not have intelligence at the parking, slot level, and thus they are prone to unauthorized occupation and inefficient space utilization. To address these issues, this work develops an RFID, based intelligent car parking system equipped with slot, level authentication and an unauthorized vehicle alert mechanism so as to elevate parking security and operational accountability. Firstly, RFID technology uniquely identifies each vehicle, and only its pre, assigned parking slot is allowed to be occupied. A violation, anytime and anywhere, results in an automatic image capture and instant notification to the parking owner via wireless communication. This paper proposes a system that combines embedded systems, IoT communication, and data, driven monitoring, thus it can be well integrated into smart infrastructure scenarios. Practical evaluation reveals that the system brings about considerable improvements in parking discipline, quicker violation detection, and better security compared to the traditional RFID, based parking solutions.

Index Terms—RFID, Smart Parking System, Unauthorized Parking Detection, Slot-Level Authentication

I. INTRODUCTION

The rise of urban living and the explosion of private vehicles have contributed to a parking nightmare in the areas of residential societies, corporate campuses,

educational institutions, and commercial complexes. Most of the conventional parking systems are continuous sources of trouble as they heavily depend on manual supervision which is inefficient, error, prone, and unable to provide security in slot utilization. The integration of the Internet of Things (IoT), data analytics, and intelligent automation to parking systems has removed many inefficiencies and made the smart parking experience more exciting for users. Short, range RFID communication technology is presently the most preferred method of vehicle identification and access control due to factors such as low cost, high reliability, and contactless operation [1][2]. Most of the existing RFID, based systems only perform the automation of entry and exit functions and do not prevent unauthorized parking in allocated slots, which is still a major problem of operation and security to a large extent [3][4]. In order to bypass this shortcoming, the present study introduces an intelligent RFID, based parking system with slot, level authorization having additionally integrated real, time violation detection, picture, based proof creation, and instant alert mechanisms. The system is in line with the prevalent trends of intelligent systems and the smart city framework.

II. RELATED WORK

Numerous research works have been presented in the domain of intelligent parking utilizing technologies like RFID, IoT platforms, wireless sensor networks, and cloud, based monitoring. Typically, RFID, based systems are employed for automated vehicle

identification, whereas sensor, based systems provide real, time parking availability [5]-[12]. IoT, enabled platforms have been instrumental in further enhancing monitoring through mobile and web applications [10],[11]. However, these systems still show some significant drawbacks, such as: No slot, wise vehicle authorization, Inability to recognize unauthorized use of parking spaces, Absence of visual evidence for parking violations, Limited or delayed notification mechanisms. The proposed system is conceived to overcome these issues by integrating RFID, slot mapping, real, time misuse detection, and automated alert generation, thereby enabling a more secure and intelligent parking environment.

III. PROPOSED SYSTEM ARCHITECTURE

3.1. System Overview

The proposed intelligent parking system comprises the following key components:

- RFID tags uniquely assigned to registered vehicles
- RFID readers installed at entry points and individual parking slots
- Microcontroller unit (Arduino / ESP32)
- Camera module for image capture
- GSM or Wi-Fi module for wireless communication
- Centralized database for RFID-slot mapping and monitoring

3.2. Working Principle

1. The vehicle approaches the entry gate, where the RFID reader scans the tag.
2. If the tag is authenticated, access is granted.
3. Each parking slot is pre-mapped to a specific RFID tag.
4. Slot-level RFID readers verify whether the parked vehicle matches the assigned slot.
5. In case of mismatch or unauthorized parking:
 - The camera captures the vehicle image.
 - An alert with evidential data is sent instantly to the parking owner or administrator.

This workflow ensures intelligent enforcement of parking rules with minimal human intervention.

IV. HARDWARE AND SOFTWARE IMPLEMENTATION

4.1 Hardware Components

Table1: Hardware used in the RFID-based parking system

Component	Function
RFID Reader	Vehicle identification
RFID Tag	Unique vehicle ID
Arduino / ESP32	System control and decision-making
Camera Module	Image-based evidence capture
GSM / Wi-Fi Module	Alert transmission
Power Supply	System operation

The hardware components mentioned in the table are the means through which the proposed RFID, based parking system operates efficiently [6],[8]. An RFID reader is a device that identifies vehicles by scanning attached RFID tags, while each RFID tag is an equipped with a unique identification number that differentiates one vehicle from another. The Arduino or ESP32 microcontroller acts as the system's main processing unit, managing the operations it controls, making authorization decisions, and enabling communication between various modules. The camera module is instrumental in security, capturing images of vehicles that have parked without permission, thus providing visual proof of violations. A GSM or Wi, Fi module facilitates wireless communication, making it possible for the system to send real, time alerts and notifications to the parking owner or administrator. Lastly, the power supply unit is the means by which the system can operate uninterruptedly as it provides the necessary and stable electrical power to all components of the system.

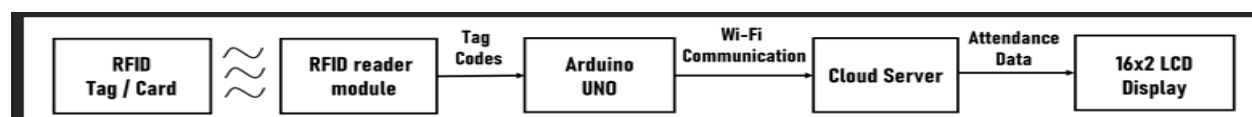


Fig.1 Block diagram of RFID-Based intelligent car parking System

The block diagram illustrates the overall architecture of the proposed parking system and explains the

interaction among its key components (Fig. 1). The Arduino UNO serves as the central control unit,

storage and further analysis. The LCD display provides real-time feedback by indicating parking slot availability and user status. Additionally, the power supply unit ensures stable and uninterrupted operation of all system components. The coordinated interaction between the Arduino UNO, RFID reader, LCD display, and data storage modules demonstrates an efficient and integrated approach for automated parking management.

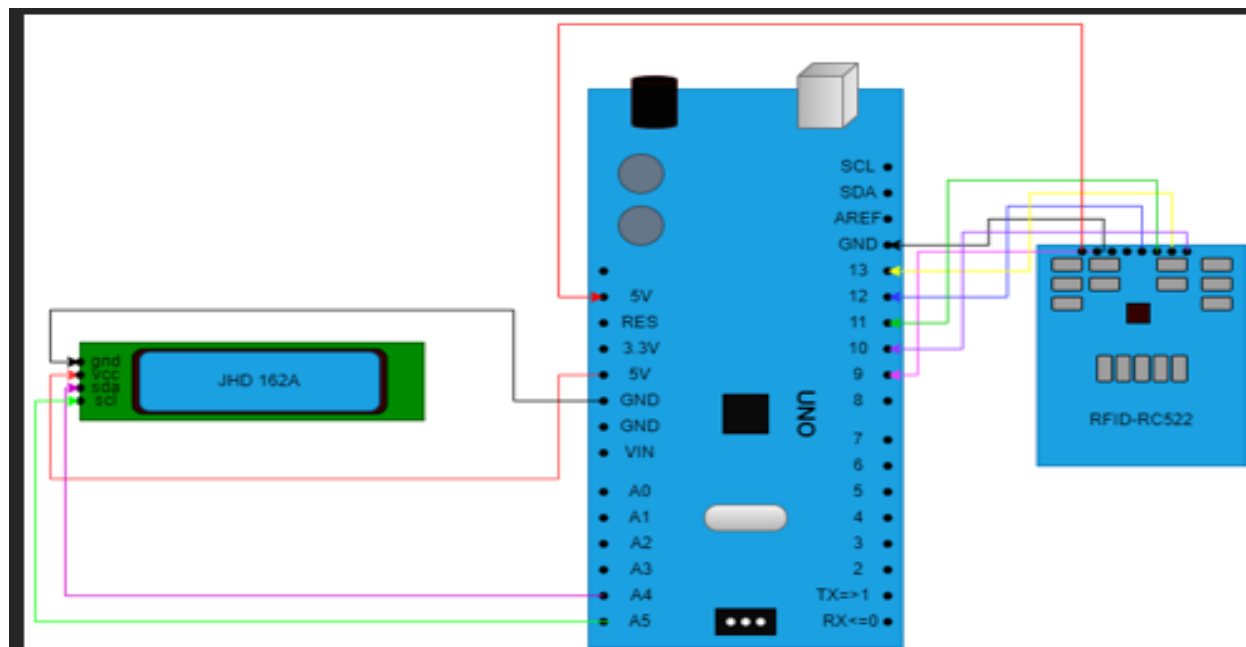


Fig.2 Circuit diagram of RFID-based parking system using Arduino-IoT

and efficient architecture for the automated parking system.

4.2. Software Modules

- RFID data acquisition and authentication
- RFID-slot association database
- Image capture and timestamping
- Alert generation via SMS or mobile notification
- Real-time display of system status

V. ALGORITHM

Step 1: Initialize system and load RFID-slot mapping database
Step 2: Scan RFID tag at entry gate
Step 3: If authorized, allow vehicle entry

Step 4: Scan RFID at assigned parking slot
 Step 5: If RFID matches slot ID, allow parking
 Step 6: Else
 a) Capture vehicle image
 b) Send alert with evidence to parking owner

VI. EXPERIMENTAL RESULTS AND DISCUSSION

Table 2: Comparison of Results of proposed system and existing system

Parameter	Existing RFID Systems	Proposed System
Entry Authentication	Yes	Yes
Slot-Level Authentication	No	Yes
Unauthorized Parking Detection	No	Yes
Image-Based Evidence	No	Yes
Real-Time Alert	Limited	Instant

The comparative results in the table 2 clearly highlight the benefits of the proposed system in comparison to traditional RFID, based parking solutions [2], [7]. Both systems are equipped with entry, level authentication, thus, only authorized vehicles are able to access the parking facility. Nevertheless, current RFID systems do not have slot, level authentication, which means that vehicles can use any empty space, thus, misuse is frequently caused. The proposed system, on the other hand, guarantees slot, level authentication so that each vehicle is parked in its designated slot only.

Moreover, traditional systems lack the provision of detecting unauthorized parking and also, they do not produce the visual evidence of the violations. The proposed system has removed these constraints by detecting unauthorized parking in real, time and capturing the image, based evidence for accountability. Similarly, while the alert operations in the existing systems are limited or delayed, the proposed system offers instant alerts, thus, allowing a quick response and drastically improving parking security and operational efficiency.

The findings reveal that the proposed system has a considerable impact on security enforcement, violation detection accuracy, and response time, thus, it is appropriate for intelligent parking applications.

VII. RESEARCH CONTRIBUTIONS

The major contributions of this research include:

- Introduction of slot-level RFID authentication
- Automated detection of unauthorized parking
- Image-based violation evidence generation
- Instant alert and notification mechanism
- Security-centric framework for intelligent parking management

These features distinguish the proposed system from conventional RFID-based parking solutions.

VIII. CONCLUSION

This article introduced a smart RFID, based automated car parking system that features slot, level authentication and unauthorized vehicle detection. The system, which combines RFID technology with image capture and real, time alert mechanisms, goes to great lengths to prevent the misuse of parking and also facilitates accountability. Implementation testing shows performance and reliability improvements over the most common systems. The suggested system is expandable and can be comfortably used in the development of smart cities, residential societies, corporate campuses, educational institutions, and high, security areas, which is consistent with the latest trends in intelligent infrastructure and data, driven automation.

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