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A QR CODE BASED SOLUTION FOR ENHANCING LUGGAGE SECURITY IN INDIAN RAILWAYS

Computer Science

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ABSTRACT

With Indian Railways catering to millions of passengers on a daily basis, it's a challenge to provide them with the security of their belongings during long journeys. In a bid to work around the problem, the concept of Secure Rail Lockers-a digital locker solution embedded within sleeper coaches has been designed. It was an attempt to bring increased security to passenger luggage by providing a dedicated space under the passenger seat and being opened by QR code identification linked to them. The Secure Rail Locker system utilizes a QR code-based access mechanism. The passengers can process the required steps through a user-friendly interface designed to produce a QR code based on their ticket information. The QR codes for each locking mechanism are unique to the passenger and their respective locker; access is thus exclusively granted to the assigned individual. Access to the locker is granted after verification of Passenger Name Record (PNR) and QR Code. The QR code's validity lasts till the end of the journey, once again preventing the user from using any more than they are entitled to. In case of any discrepancy in access, there will be a complaint system to settle disputes. This system has been demonstrated by replacing physical QR scanning with a software-based QR engine, and the lockers are controlled with an LED circuit as a way to simulate the locking and unlocking of the locker module.

KEYWORDS

Digital Lockers, ESP32-based access control, Luggage Security, QR code authentication, Smart Railway Infrastructure.

INTRODUCTION

Indian Railways, catering to millions of passengers every day, has so far struggled with the problem of securing one's luggage during long journeys, particularly within sleeper coaches. The traditional means of luggage storage, open luggage racks and beneath-the-seat compartments, are highly prone to theft, unauthorized access, and misplacement. The lack of any substantial security for these compartments often forces passengers to be perpetually on guard, which hinders their comfort and tranquility while traveling. To combat this problem, we- propose Secure Rail Lockers, a QR-based digital locker system that empowers passengers to store their belongings securely in train compartments.

This research paper deals with the internal working of this system with an emphasis on the QR-code-based authentication system and ESP32 controlled access. Rather than using a hardware-based QR scanner, a software-based QR scanner using the ZXing library that recognizes QR codes and validates them using a camera-based interface has been employed. The physical solenoid lock system has been replaced with an LED-based circuit, which imitates the locking mechanism of a locker functioning to demonstrate a case scenario where a QR code generation, validation, and communication with the ESP32 microcontroller join hands into a single functional module.

The working principle is simple: passengers generate a QR code using an interface with details of their tickets, which is thereafter scanned for verification. Once the ticket information and Passenger Name Record (PNR) are verified, the ESP32 microcontroller controls the simulation of the locker operation using LED indicators, which enables to demonstrate how the system authenticates access, recognizes the QR codes, and communicates with the ESP32 module on a wireless network. Furthermore, since a QR code is generated on a one-to-one basis for every passenger and expires once the journey session is complete, any re-use by an unauthorized person will not be efficacious, thus ensuring increased security with enhanced accountability.

By shifting the focus to the software and communication aspects of the system, this research paper serves as a functional prototype to demonstrate the feasibility of digitally controlled smart lockers. The implementation of such a system in Indian Railways aligns with the Digital India and Smart Railways initiatives, offering a modern, efficient, and contactless security solution for railway passengers. This research lays the foundation for future hardware integration, providing a scalable and secure alternative to traditional luggage storage systems in public transportation.

Literature Study

Lucian Cucu et al. [1] present a modular storage system for optimized space utility proposes physical lockers secured by traditional means such as keys or PIN-based systems. On the one hand, it lacks QR-based authentication, thereby opening itself up for eventualities such as misplacement of keys and any unregulated duplication. Also, the paper does not seem to indicate digital integration with the railway ticketing system, which means locker management would remain separate from passenger verification.

One of the, however, more recent studies is by Alícia F. S. Luís et al. [2], which concerns smart lockers in public spaces concentrating more on biometric and NFC-based authentication. While such solutions are indeed valid, they are nonetheless expensive for wholesale railway implementation. Moreover, there is no reference in the study to temporary access control; therefore, lockers are left vulnerable to misuse once the passenger journey is completed.

Usman K et al. [3] advocated for a QR code-based railway ticketing system for lesser paper utilization and amelioration of ticketing done in booking and validation procedure. The methodology behind this relies mainly on the use of static QR codes for booking and validating tickets, with a view to minimize paper wastage and make ticketing much easier for passengers. The system deploys a digital interface through which unique QR codes relative to tickets for passengers are generated and could be scanned at checkpoints. While their approach magically addresses ticketing efficiency, it does not incorporate physical security systems. There is, however, no attempt made to show a method of ensuring the safety of passengers' luggage through the entire journey. Moreover, the various means by which these QR codes may be used in locker access to luggage storage are not explored. This makes the ambit of the study limited to ticketing, thus overlooking the larger picture of passengers' baggage security while traveling.

Anjali Devi et al. [4] have researched GPS tracking and QR code integration in metro ticketing. This design is based on QR code ticketing and location tracking whereby passengers receive conditions such as location-based notifications. QR codes are very efficient for ticket verification, and meanwhile, GPS enhances the experience of the passenger experience through location-sensitive services. Unfortunately, the study does not augment the facet of stored luggage protection, a fundamental issue in long-haul train travel. The methodology is overly zealous to merely consider ticketing efficiencies and makes the task of marketing ticketing and service systems but is severely blemished in light of their neglect of the authorities to lock away personal belongings belonging to passengers.

Prasad R. Deshpande et al. [5]. The methodology of the paper is chiefly a scanning process to validate online tickets via QR codes, providing a more streamlined way to verify ticket information compared to traditional paper-based methods. Reduce the manual effort of ticket validation to make the ticketing process much faster and more efficient. However, while still providing a convenient way to verify or validate a ticket, such a system makes no provision for security in physical means. Physical access to Luggage really is unaddressed. It defines itself solely as validating ticket details, leaving holes in regard to management of physical accesses to luggage storages. The mention of hooking it into systems, such as digital lockers for the storage of luggage is missing, leaving a gap concerning the safety of passenger belongings.

The Institute of Transport [6], however, establishes the integration of smart technologies into railway infrastructure and desires that digitization and automation transform public transport systems. The study suggests follow-ups by other research, work in functionalities applying smart technologies like the Internet of Things, real-time monitoring, and automation-intended to improve the passenger experience and performance of infrastructure. The paper's discussion of all technological advances adds little, in the way of practical solutions, to resolve specific concerns around luggage-safety issues pertaining to travelers. More of a spread on infrastructure and the introduction of solutions toward guaranteeing safety of passengers' belongings is downplayed-a serious concern in regards to contemporary railway systems.

The Institute of Infrastructure Security [7] studies recent innovations in security for public infrastructure and includes some technologies targeted for access control and identity verification, such as biometric scanners and near-field communication. Each of these security enhancements offers safety at public transport hubs focused on identity verification and access control. Although these technologies sound promising, often they target high-cost systems, making them not practically accessible for low-budget railway infrastructure on a massive scale. Furthermore, the study fails in addressing the integration of security systems with ticketing for eco-friendly consumer and luggage management. The void of useful solutions for temporary access control-such as an expiring credential for lockers-and results in the possession of these systems that can be violated once a passenger's journey has been completed.

According to the World Transport Forum [8], smart locker systems can enhance the customer experience in public transport hubs by providing secure luggage and personal belongings storage. The research discusses some of the advantages of smart lockers available for public use, such as the ease of self-service access, but it does not go into detail on how these lockers look in use with each current transport ticketing system. There is no QR-based authentication approved with a passenger's ticket, and there is no method of locking lockers at the end of the journey. Thus, this establishes an opportunity for abuse of luggage lockers. In public transport hubs deemed to be very busy, the issue of having luggage secured is becoming ever more crucial, and the gap identified in the study demands ticketing and locker access to be integrated better.

A. D. James, M. A. Anderson, and S. L. Wang [9] present a Secure Digital Locker for Public Use, a system providing cut-out public lockers in an intelligently authenticated manner. Digital authentication is part of their proposed system, focusing not on a public transport service, but rather on providing a general-purpose locker solution. While the use of digital lockers is promising, the system would not likely interact with existing transport ticketing systems to ensure that access to a locker is limited only to verified passengers. This lack of integration potentially limits their effectiveness with securing luggage by allowing unauthorized individuals access to lockers.

The security risks of public transport ticketing systems, mainly due to vulnerabilities that may be exploited for frauds, have been examined by M. N. D. Gubiana and R. J. L. Santos [10]. While exploring multiple security concerns on ticketing systems, this work does not address issues of physical storage or lockers in transit. The study is on secure ticketing systems yet does not combine that in addressing passenger belongings with secured storage systems. The failure to take a more integrated approach results in a deficiency in the verification of passengers with secured luggage.

There are different aspects that have been reviewed regarding public transport security and their technologies. Serious disadvantages in protecting passengers' luggage and its integration with the ticketing systems have, however, come to light. While there are traditional sensing methods such as PINs, biometrics, and NFC technologies, they are costly and impractical due to poor integration with transport ticketing. Many of the researches focus on ticket verification or improving infrastructure in general, leaving luggage security in the oblivion. Even when digital locker systems are suggested, they do not adopt any feature to ensure verified passengers have access or provide solutions for locker access expired at the end of a trip, which is necessary to avoid potential abuse. Moreover, while advanced technology is cited by some works, practical applications suitable economically and scalable for mass implementations remain ignored.

In conclusion, whereas other existing systems address one aspect of ticketing and security, they seldom offer a seamless solution for both efficient ticketing and secure luggage management. This research paper will bridge these gaps by creating a unified solution merging the benefits of digital ticketing with an access lock and real-time validation, hence providing a viable, scalable, and well-applicable solution in real railway conditions. The ESP32 microcontroller enhances the functionality of the system by making communication and control possible in a seamless manner, and consequently providing a state-of-the-art and effective solution to securing passengers and their belongings during travel.

METHODOLOGY/EXPERIMENTAL STUDY

Materials/Components

The system includes an ESP32-WROOM-32 development board with a dual-core Xtensa LX6 processor (240 MHz), Wi-Fi support, operating at 3.3V, with ~30 GPIO pins. The LEDs used are 5mm Red and Green LEDs with a forward voltage of 1.8V–2.5V and an operating current of 10–20mA. Resistors include 150Ω for Red LED and 120Ω for Green LED, with a tolerance of ±5% and a power rating of 0.25W. A MB-102 solderless breadboard with 830 tie-points is used for circuit assembly. 22 AWG jumper wires with a length of 10cm–20cm provide connections.

SYSTEM ARCHITECTURE / WORKING

The secure locker access system automates the process of issuing lockers with a QR code verification process and an interface controlled by an ESP32. It comprises a web-based platform to generate QR codes and validate them, a backend for user data management, and the locker control by an ESP32 microcontroller. The system provides a combination of all hardware and software components to control and manage the access while securing the same by means of session-based authentication. The following are the architecture diagrams that will give an overview of the system layout and workflow.

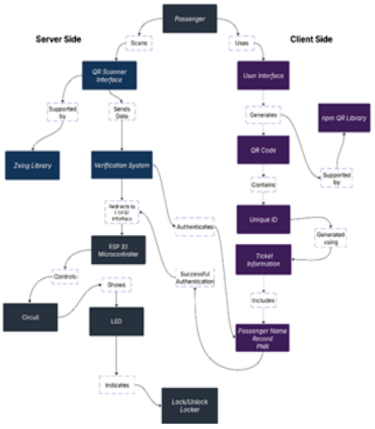

Fig. 1. System Architecture

This proposed system secures and automates locker access through QR code authentication and an ESP32-controlled interface, combining an interface of both software and hardware for maximum efficiency. The process starts when the passenger enters ticket information such including name, PNR (Passenger Name Record), phone number, and seat number via a graphical frontend interface (HTML, CSS, and JavaScript) and requests generation of a QR code for this information. The backend, developed in Node.js and Express.js, then accepts input, processes it, and creates a unique object consisting of this information in a MongoDB database by means of Mongoose once the input is received. This is then assigned a unique ID, upon which a QR code generated based on this ID acts as a digital authentication token, permitting the passenger access to the locker system.

The QR code scanning and verification process, first inputting Passenger Name Record (PNR) manually and allowing the QR code scanner to access the camera, retrieves the PNR from the scanned QR code and cross-verifies it with the one manually inputted. A successful match authenticates the passenger, and the system grants access to the ESP32 interface developed in HTML, CSS, and programmed in the Arduino IDE. Otherwise, it shows the message "Access Denied," halting any attempt at further entry into the locker system.

After successful authentication, the passenger interfaces with the ESP32, wherein he can control the locker using on-screen buttons to lock/unlock. The microcontroller in this system is of the ESP MCU-Node32S family and is able to control hardware components like LEDs, jumper wires, breadboards, and resistors. Then, the ESP32 is wired to control two different colored LEDs, suitably current-limited by resistors for the red and green LEDs, with values 150Ω and 120Ω, respectively. The locker mechanism is controlled through GPIO pins, such that a HIGH signal unlocks and a LOW signal locks it. The locker status is visually conveyed using the green and red LEDs. The green LED is on when it is open for business, and the red one burns when it is locked. Timeliness is paramount since the QR code and the information related to it are erased at the end of any given session or journey, thereby securing against any replays of a transaction. The status is indicated visually by the green or red LEDs; if the locker is open, the green LED lights and if it is locked, the red LED lights up. The entire process is time-sensitive in that, at the end of any defined session or journey, the QR code and associated information are erased for improved security and to avoid a replay of the same transaction. This consequently guarantees that data integrity will not be compromised and authentication secured, providing secure overhead for proper locker operation and a smooth user experience with unmatched security.

RESULT & DISCUSSIONS

QR code generation and validation were done fairly fast and with utmost security, thus ensuring access to lockers exclusively for passengers with valid credentials. User data were efficiently harnessed by MongoDB, while authentication requests were effectively handled with node.js and express.js. The scanned details from the QR code were verified against the manually entered PNR, and that prevented unauthorized access from non-privileged users. Operations for the locker devices could be executed through the ESP32 Microcontroller; it provided easy and rapid interface at the hardware level. An LED indication was put in place so that the user could know whether the locker is locked or opened, thus ensuring smooth operation. Circuit design itself would keep the currents controlled by resistors, ensuring they remain stable at all times and do not risk component destruction. Session-based regeneration of QR codes provides, from the security perspective, an extra layer of defense against the unauthorized use of obsolete credentials. Future improvements can further advance the initiative such as the support of the users with better-scanning software that works fine at low light, and Biometric methods assuring even greater security.

FUTURE SCOPE

The potential and the scope for QR code-based digital lockers in Indian Railways is very wide, inasmuch as security, scalability, and smart integration are combined with a few advancements in the future. These may be succeeded by AI predictive maintenance and integration with smart city programs of intermodal transport. Green energy solutions, like solar-powered locks, would make things easier for the environment, while data analytics would ensure extreme passenger convenience through value-added services. Emergency remote access would provide authorized users or passengers remote control of lockers to enable speedy troubleshooting and locking mechanisms bolstering security. This might effectively augment the revenue-generation, dynamic pricing and other traffic-generating partnerships, adding value to the overall system, making it an economical and a secure upgrade for railway infrastructure.

CONCLUSIONS

The Secure Rail Lockers research paper offers Indian Railways a modern, secure, and efficient means of luggage management with the advantage of QR-based digital access to be used as passenger safety and convenience enablers. Addressing notions of theft, misuse, and inefficiency of old traditional locker systems, this will allow for seamless ticket-linked access, reduce security vulnerabilities, and promote a worry-free travel experience. Its importance is that it will revolutionize the luggage security regime within public transport and enhance operational efficiency in line with digital transformation imperatives and sustainability goals set up for India. The system may also be extended to old international metro stations, airports, bus terminals, hotels, e-commerce parcel lockers, workplaces, and healthcare facilities: it offers scalable and flexible smart storage solutions. The research paper doesn't just build on the railways but also opens up to the other potential of secure storage solutions where contact has to remain contactless to foster safety and efficiency in public spots.

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