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Next-Gen Authentication Public Transport System Using Smart QR Codes

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ABSTRACT

With the rapid evolution of urban mobility, traditional authentication methods for public transport are becoming inefficient and vulnerable to security risks. This paper proposes a Next-Generation Authentication System utilizing Smart QR Codes to enhance security, efficiency, and user convenience in public transportation networks. The system leverages dynamic QR codes, which change periodically to prevent fraudulent duplication, ensuring secure access for passengers. By integrating cryptographic encryption, cloud-based validation, and real-time monitoring, the proposed system enhances passenger authentication while reducing operational bottlenecks. Additionally, machine learning techniques can be incorporated for anomaly detection, identifying unauthorized access attempts and improving fraud prevention mechanisms. The smart QR-based system is cost-effective, easy to deploy, and provides seamless integration with existing transport infrastructure, making it a scalable solution for modern smart cities.

Keywords— Smart QR Codes, Next-Generation Authentication, Public Transport System, Dynamic QR Code, Secure Ticketing, Fraud Prevention, Cryptographic Encryption, Real-Time Monitoring, Machine Learning for Authentication, Urban Mobility Solutions, Passenger Flow Management, Smart Cities, IoT in Transportation.

INTRODUCTION

Public transport systems are crucial for urban mobility, but traditional methods like paper tickets, magnetic strip cards, and RFID-based cards are becoming outdated due to security concerns, ease of use, and environmental sustainability. The rise of digital technology necessitates smarter, adaptive, scalable, and efficient authentication solutions that safeguard passenger data and financial transactions.

As cities expand and public transport demand grows, ensuring secure, efficient, and scalable authentication systems is crucial. Traditional systems like magnetic stripe cards or paper tickets are vulnerable to counterfeiting and system vulnerabilities, causing

financial losses for operators and data integrity concerns. An efficient system that minimizes waiting times and optimizes operational throughput is also essential. Digital innovations like smart QR codes offer a transformative approach that streamlines user experience while enhancing security, making modernization of public transport authentication essential for today's urban environments.

Smart QR codes offer a dynamic solution to traditional authentication systems, providing enhanced security by changing with each scan or time interval. They prevent issues like code duplication or replay attacks, ensuring higher protection for users and transport authorities. By leveraging smartphones and mobile apps, passengers can authenticate themselves with a simple scan of their personal QR code, which can be linked to their travel account or payment system. Smart QR codes are cost-effective, adaptable, and easy to integrate into existing public transport infrastructures. They can store encrypted data, ensuring sensitive information is transmitted securely. Real-time monitoring allows transport authorities to track usage patterns, detect fraudulent activities or maintain system integrity.

The project "Next-Gen Authentication of Public Transport System Using Smart QR Codes" aims to harness the capabilities of smart QR codes and microcontroller technology to improve the overall public transport experience. By integrating modern technologies like smart QR codes, microcontrollers, and cloud computing, the system aims to make passenger authentication faster, enable real-time vehicle tracking, and improve communication between transport providers and passengers. This system is more efficient than the old paper-based method, benefiting both passengers and conductors, making the entire process faster and easier.

AIM AND PROBLEM STATEMENT

The main goal is to explore the advantages and difficulties of using smart QR codes in public transportation systems, and to make the system simpler and more cost-effective through the use of smart transportation technology.

The proposed Next-Gen Authentication Public Transport System uses Smart QR Codes to address ticketing fraud, long queues, and inefficient verification methods. This secure, contactless system integrates real-time validation, digital payments, and mobile app-based access, enhancing security and improving public transportation efficiency.

METHODOLOGY

3.1 Overview of the Proposed System -

The proposed system is a next-generation public transport authentication framework using smart QR codes. This system allows passengers to quickly and securely authenticate their access to transport services using their smartphones, enhancing security and preventing fraudulent use. The system integrates seamlessly with existing transport infrastructure, providing a scalable, user-friendly solution. The project involves defining project goals, conducting market analysis, creating a detailed project plan, selecting QR code and IR sensor technology, building the software, designing an intuitive user interface, integrating the technologies, testing the system, deploying it, and providing ongoing maintenance to ensure its continued functionality.

3.2 Components of the Smart QR Code System

QR Code Generation and Scanning -

The system generates dynamic QR codes for each journey, valid for specific time frames, allowing quick and secure authentication at transport entry points, minimizing risks like cloning and replay attacks.

3.3 Backend Infrastructure (Server,Database)-

The system's backend infrastructure manages data flow between passengers, transport authorities, and the authentication system, handling real-time user

authentication requests, validating QR codes, and storing encrypted user profiles, and travel history.

3.4 User Interaction -

The mobile connects users to the transport system, allowing QR code and send it to user mobile, fare collection, travel pass storage, and real-time schedule updates. It features user-friendly navigation for all ages.

3.5 Security Features -

The system prioritizes security through advanced encryption of QR codes, dynamic code design, multi-factor authentication, and real-time monitoring tools to prevent reuse or replication, and detect unusual patterns of use or fraudulent behaviour for quick intervention.

3.6 Integration with Existing Transport Systems -

The solution integrates seamlessly with existing transport infrastructure, ensuring smooth transition to a smart QR code system. It communicates with transport authorities for data analytics, improving route planning, capacity management, and resource allocation.

FRAMEWORK

4.1 Development of the QR Code Generation System

The proposed solution includes a QR code generation system that generates dynamic, periodically changing codes using encryption techniques. It can handle high user volumes and maintain minimal latency for a smooth user experience.

4.2 Backend System Setup

The backend infrastructure will consist of a centralized server that handles all the requests and all entry data. The server will manage user authentication, QR code validation, payment processing, and real-time monitoring. It will be responsible for checking the QR code against a secure database, ensuring that the data is correct and the code has not expired .

4.3 Data Management and Security Protocols

The system will handle sensitive user data, including personal identification, payment information, and travel history, using strict data management and security protocols. Encrypted databases will be stored in server or database, and QR codes will be verified using hashing algorithms. Secure communication protocols like HTTPS will protect data. Real-time monitoring tools will detect potential fraud or security breaches. Data privacy regulations will be followed.

FLOW CHART AND BLOCK DIAGRAM

Following figure shows the basic flow of system when its working. Flow shows that the starting and layer by layer execution of system in transportation system. It shows how the each component can work with the attached component with it.

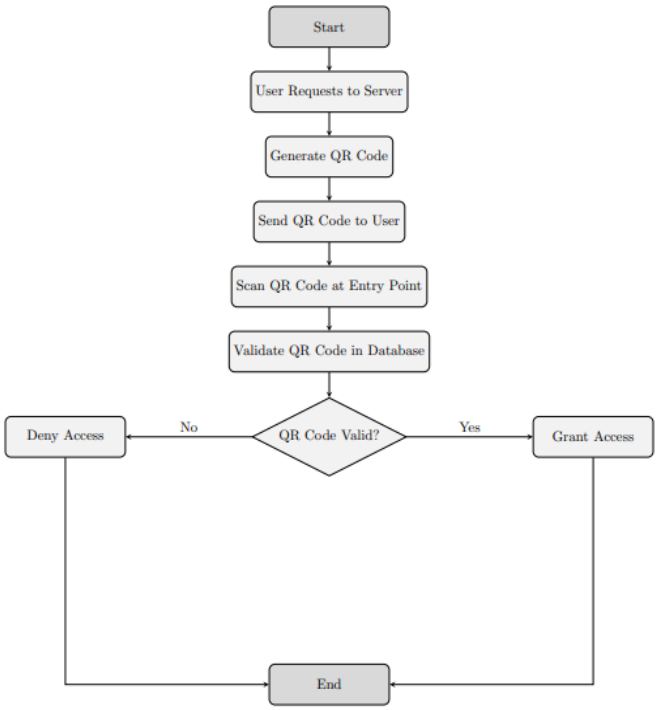

Figure 1.1: Flow of Work

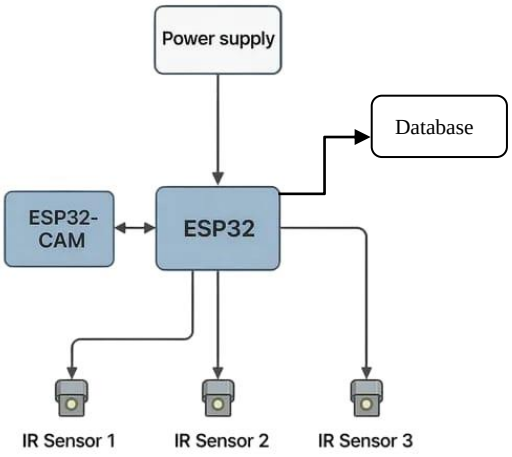

Figure1.2: Block Diagram

SYSTEM OVERVIEW

ESP32 processes the input data from the Camera Module (QR code image), authenticates it, and determines whether to give the permission for user or declined It. Also it ensures the seat availability in vehicle for the passengers journey using IR sensor feedback to the server. The Power Supply ensures that the entire system operates reliably by providing the necessary voltage to all components.

The Next-Gen Authentication Public Transport System uses Smart QR Codes to provide secure, efficient, and automated access to public transport systems. Passengers present a QR code with essential identification or ticket information, which is captured by a Camera Module at the entry point. The ESP32 microcontroller decodes the QR code and checks its validity and give permission for entry if the code is valid, allowing the passenger to pass through. If the code is invalid, the system cancel or declined the entry and requiring a valid QR code.The Power Supply is the system's backbone, ensuring consistent and reliable power for all components, including the ESP32, ESP32 webcam , and IR sensor.The power supply distributes voltage to the ESP32 microcontroller, motor driver, LEDs, and camera module, ensuring the system runs efficiently.

CIRCUIT DIAGRAM

The Circuit Diagram showa the basic connection of ESP 32, ESP 32 Cam, IR Sensors,etc. It shows the PIN configuration of diagram in detail.

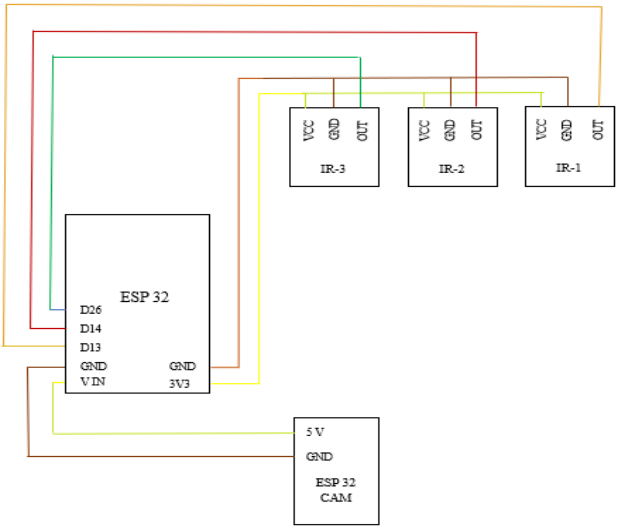

Figure1.3: Circuit Diagram

Camera Module

The Camera Module captures QR codes for validation, interacting with the ESP32 to authenticate passengers by processing the captured image and decoding it.

Use in the System:

The Camera Module captures the QR code presented by a passenger, sends the image to the ESP32, which processes it for authentication. The camera helps enable contactless entry to the transport system.

RESULT and ANALYSIS

Following image shows the working project result.

Analysis of Test Results

The results from testing the smart QR code authentication system was collected across several dimensions: speed, security, and usability. Key findings include:.

Usability: User satisfaction was high, with most participants able to navigate the app easily. The average task completion time for generating and displaying a QR code was 1.5 minutes, and users reported feeling confident in the system's reliability and security. However, some users suggested improvements in onboarding and navigation to make the app even more intuitive.

Speed and Efficiency: Traditional systems, such as RFID cards or magnetic strips, typically require users to tap or swipe, which can cause delays, especially during peak hours. In contrast, the smart QR code system allows for quicker and more streamlined access, with passengers simply showing their phone screens for scanning, reducing congestion and waiting times.

Security: While RFID-based and magnetic strip systems have been prone to cloning and fraud, the dynamic nature of smart QR codes, along with advanced encryption and time-sensitive features, offers superior protection.

Cost Efficiency: Traditional systems require the distribution and maintenance of physical cards, adding both cost and complexity for transport operators. The smart QR code system eliminates the need for physical infrastructure, reducing costs related to card production and distribution, while leveraging existing mobile devices.

CONCLUSION AND FUTURE SCOPE

While the system has proven to be a robust and forward-thinking solution, several areas offer exciting opportunities for future development and enhancement:

The dependency on smartphones is a notable limitation. To improve accessibility for all users, including older passengers or those without smartphones, future iterations could explore complementary solutions such as integrating the system with wearable devices (e.g., smartwatches or fitness bands) or offering physical smart cards that could still benefit from the system's dynamic QR technology.

Improved User Experience**:** Future versions of the mobile application could offer enhanced personalization features such as customizable fare options, smart route suggestions based on past travel behavior, and live notifications for real-time transport updates.

Advanced AI and Data Analytics**:** The integration of artificial intelligence and machine learning into the backend could significantly enhance the system's predictive capabilities.

Intermodal and Cross-Network Integration: Extending the system beyond individual transport networks into a seamless, intermodal platform would allow users to access multiple modes of transport with a single app or QR code.

Sustainability and Environmental Impact: As global awareness of environmental issues grows, integrating sustainability features into the system could drive eco-friendly travel behaviors. Future enhancements might include carbon footprint tracking for each journey, providing passengers with information about the environmental impact of their travel choices.

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