International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Smart Train Ticket Verification System

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Abstract

Train ticket checking is still done manually in many places, which takes more time and may lead to mistakes. This paper presents a **Smart Train Ticket Verification System** that makes the ticket verification process faster, easier, and more secure. The proposed system uses **IR sensors** to detect passenger movement, **NFC technology** to verify train tickets, and an **ESP32-CAM AI Thinker module** to capture images whenever any unauthorized entry or suspicious activity is detected. The collected data and images are stored in **Firebase**, which allows real-time access and secure data management. An **ESP32** is used to connect and control all the hardware components efficiently. By combining sensor-based detection, contactless ticket verification, and cloud storage, the system reduces manual work and minimizes human errors. It also helps railway authorities monitor passenger activities more effectively and improves the overall ticket-checking process. The proposed solution is designed to be simple, scalable, and cost-effective, making it suitable for future smart railway systems. It provides a better travel experience for passengers while helping railway staff perform ticket verification more efficiently.

Keywords: NFC Technology, IR Sensors, ESP32-CAM AI Thinker, ESP32 DEV-MODULE, Firebase, Real-Time Monitoring, Passenger Authentication, Image Recognition.

1. Introduction

- Railway transportation is one of the most widely used modes of travel because it is affordable, reliable, and convenient. Every day, thousands of passengers travel by train, making ticket verification an important part of railway operations. At present, ticket checking is mostly done manually by ticket examiners. This process requires more time, increases the workload of railway staff, and may sometimes lead to human errors. It also becomes difficult to identify passengers who travel without valid tickets, especially during peak hours.
- With the growth of smart technologies and the Internet of Things (IoT), many traditional railway operations can be automated to improve efficiency and security. Technologies such as **NFC**, **IR sensors**, cloud databases, and AI-based image recognition provide an opportunity to develop a faster and more reliable ticket verification system. These technologies help reduce manual effort while improving the accuracy of passenger verification.
- This research proposes a **Smart Train Ticket Verification System** that combines **IR sensors**, **NFC readers**, an **ESP32-CAM AI Thinker**, **ESP32**, and **Firebase** to automate the ticket-checking process. The IR sensors detect passenger movement, while the NFC reader verifies the passenger's ticket. If any unauthorized entry or suspicious activity is detected, the ESP32-CAM captures an image and

stores it in Firebase for future verification. The ESP32 acts as the main controller to coordinate communication between all hardware components and the cloud database.

- The proposed system aims to reduce ticket fraud, minimize human errors, improve railway security, and decrease the workload of ticket examiners. It also provides real-time monitoring and secure data storage, making the system more efficient and suitable for future smart railway transportation. By integrating IoT and AI technologies, this research contributes to building a modern, automated, and reliable railway ticket verification system.

2. Literature Survey

- Railway ticket verification has improved over the years with the help of digital technologies. Many researchers have developed systems to reduce manual work and improve passenger verification. However, each existing method has certain limitations that affect its efficiency in real-world railway environments.
- Traditional train ticket verification is completely manual, where ticket examiners check passengers' tickets during the journey. Although this method is simple, it consumes more time, increases the workload of railway staff, and may result in human errors. During crowded travel periods, it becomes difficult to verify every passenger efficiently.
- Several researchers introduced **QR code-based ticket verification** systems to reduce paperwork and speed up the verification process. These systems allow passengers to display digital tickets on their mobile phones. While QR codes are easy to use, they can be shared, copied, or misused, making them less secure against ticket fraud.
- Another approach is the **RFID-based ticket verification** system. RFID technology enables automatic ticket detection without manual checking and reduces waiting time. However, RFID tags have limited storage capacity, require dedicated readers, and may experience interference, affecting the overall reliability of the system.
- Recent studies have also focused on **face recognition and AI-based passenger verification**. These systems improve security by identifying passengers through facial recognition techniques. Although they provide better authentication, they require high-quality cameras, powerful computing resources, and stable network connectivity, making them expensive for large-scale railway deployment.
- Cloud-based ticket management systems have also been developed to store passenger information and provide real-time access to ticket records. These systems improve data availability and simplify management, but many of them do not include automatic passenger detection or image-based monitoring for unauthorized activities.
- To overcome these limitations, this research proposes a **Smart Train Ticket Verification System** that combines **IR sensors**, **NFC technology**, **ESP32-CAM AI Thinker**, **ESP32**, and **Firebase**. The proposed system provides contactless ticket verification, real-time image capture during suspicious activities, secure cloud storage, and automated passenger monitoring. This combination improves security, reduces manual effort, minimizes ticket fraud, and offers a more efficient solution for modern railway transportation.

Table 1: Comparison of Existing Methods

Existing Method	Advantages	Limitations
QR Code Ticketing	Fast and paperless	QR codes can be copied or shared
RFID-Based System	Automatic verification	Tag interference and additional hardware
Face Recognition	High security	High cost and complex implementation
Cloud Ticketing	Centralized data storage	No automatic passenger monitoring
Proposed System	Contactless verification, AI-based image capture, cloud storage, real-time monitoring	Requires IoT hardware and internet connectivity

3. Proposed Methodology

- The proposed **Smart Train Ticket Verification System** is designed to automate the train ticket verification process by combining IoT devices, cloud technology, and AI-based monitoring. The system aims to reduce manual ticket checking, improve passenger verification, and increase railway security through real-time monitoring.
- The system consists of **IR sensors**, an **NFC reader**, an **ESP32-CAM AI Thinker**, an **ESP32** , and **Firebase** as the cloud database. Each component performs a specific task and works together to complete the ticket verification process efficiently.
- Initially, **IR sensors** are placed at the entry and exit points of the train compartment to detect passenger movement. When a passenger enters the compartment, the entry IR sensor detects the movement and activates the verification process. The passenger is then required to tap their NFC-enabled ticket or smart card on the **NFC reader**. The reader checks whether the ticket information is valid by comparing it with the data stored in the Firebase cloud database.
- If the ticket is valid, the passenger is allowed to continue the journey without any interruption. If the ticket is invalid or if a passenger enters without performing ticket verification, the **ESP32-CAM AI Thinker** automatically captures an image of the passenger. This image is uploaded to **Firebase**, where it is securely stored for future verification and monitoring by railway authorities.
- The **ESP32** acts as the central controller of the system. It receives data from the IR sensors and NFC reader, processes the verification logic, and controls the communication between all hardware components. It also sends commands to the ESP32-CAM whenever capturing images is required.
- Firebase provides secure cloud storage for ticket details, passenger verification status, and captured images. It enables real-time synchronization of data, allowing authorized railway officials to monitor passenger information from anywhere through a connected application. This centralized storage improves data accessibility, reduces the chances of data loss, and simplifies record management.
- The complete verification process is automatic and requires very little manual intervention. By combining **IoT devices**, **cloud computing**, and **AI-based image monitoring**, the proposed system provides a reliable, scalable, and cost-effective solution for modern railway transportation. It helps reduce ticket fraud, minimizes human errors, improves operational efficiency, and enhances passenger security.

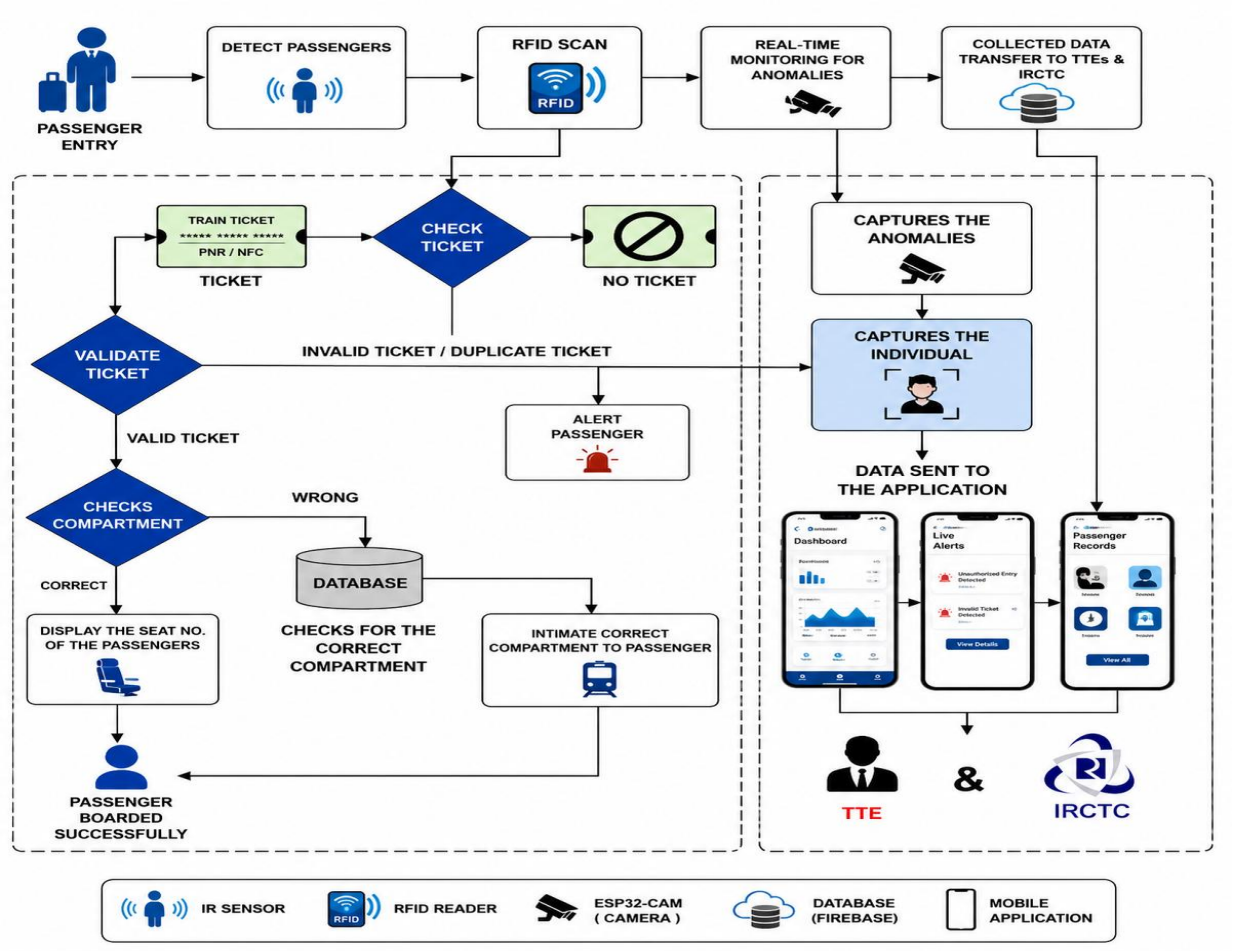
Methodology Workflow

1. Passenger enters the train compartment.
2. Entry IR sensor detects passenger movement.

3. ESP32 activates the ticket verification process.
4. Passenger taps the NFC ticket on the NFC reader.
5. Ticket details are verified using Firebase.
6. If the ticket is valid, passenger verification is completed successfully.
7. If the ticket is invalid or verification is skipped, ESP32-CAM captures the passenger's image.
8. The captured image and verification details are uploaded to Firebase.
9. Railway authorities can monitor the records through the connected application.
10. Exit IR sensor detects passenger movement while leaving the compartment.

4. System Architecture

Figure 4.1: System Architecture



- The proposed Smart Train Ticket Verification System consists of several interconnected hardware and software modules that work together to automate the ticket verification process. The architecture is designed to provide real-time passenger verification, secure cloud storage, and efficient monitoring while reducing manual intervention.
- The system begins with the **entry IR sensor**, which detects the movement of a passenger entering the train compartment. Once a passenger is detected, the **ESP32** activates the ticket verification process and coordinates communication between all connected components.

- The passenger verifies the ticket by tapping an **NFC-enabled ticket or smart card** on the NFC reader. The ticket information is processed and verified using the data stored in the **Firebase cloud database**. If the ticket is valid, the verification process is completed successfully.
- If the ticket is invalid or if a passenger enters without proper verification, the **ESP32-CAM AI Thinker** captures an image of the passenger. The captured image is uploaded to Firebase for secure storage and future verification by railway authorities.
- The **exit IR sensor** detects when passengers leave the compartment, allowing the system to maintain accurate passenger movement records.
- Firebase serves as the centralized cloud database for storing ticket information, passenger verification status, and captured images. Authorized railway officials can access this information through the monitoring application in real time.
- The modular architecture allows each component to perform its dedicated function while communicating efficiently with other modules. This design improves reliability, simplifies maintenance, and enables future enhancements without significant changes to the overall system.

4.1 IR Sensor Module

The IR sensors detect passenger movement at the entry and exit points of the train compartment. They automatically trigger the verification process without requiring manual intervention.

4.2 NFC Verification Module

The NFC reader verifies the passenger's ticket by reading the NFC card or mobile ticket. The ticket details are compared with the information stored in Firebase.

4.3 ESP32 DEV Control Module

ESP32 acts as the central controller of the system. It receives signals from the IR sensors, controls the NFC reader, communicates with the ESP32-CAM, and manages the overall verification process.

4.4 ESP32-CAM Module

The ESP32-CAM captures passenger images whenever unauthorized entry or invalid ticket usage is detected. The images are uploaded to Firebase for monitoring and record keeping.

4.5 Firebase Cloud Module

Firebase stores ticket details, verification records, and captured images. It provides secure, centralized, and real-time data access for authorized railway personnel.

4.6 Monitoring Application

The monitoring application allows railway authorities to view passenger verification status, monitor captured images, and access stored records in real time.

5. Hardware and Software Requirements

The proposed Smart Train Ticket Verification System uses both hardware and software components to automate the ticket verification process. The hardware is responsible for passenger detection, ticket validation, and capturing images, while the software manages data processing, cloud storage, and system monitoring. The combination of these components provides an efficient and reliable solution for smart railway transportation.

5.1 Hardware Requirements

Table 2: Hardware Components

Hardware Component	Purpose
ESP32	Acts as the main controller and coordinates all hardware components.
ESP32-CAM AI Thinker	Captures passenger images when unauthorized entry or invalid ticket usage is detected.
NFC Reader	Reads and verifies the passenger's NFC-enabled train ticket or smart card.
IR Sensors	Detect passenger movement at the entry and exit points of the train compartment.
Buzzer	Produces an alert sound whenever an invalid ticket or unauthorized passenger is detected.
LED Indicators	Display the verification status of the passenger.
Jumper Wires	Connect different hardware components together.
Breadboard	Used for circuit connections during prototype development.

The hardware components are connected to create an automated ticket verification system. The IR sensors detect passenger movement and activate the verification process. The NFC reader verifies the passenger's ticket by reading the NFC card. The ESP32 controls the overall operation and processes the received data. If an invalid ticket or unauthorized entry is detected, the ESP32-CAM captures the passenger's image and stores it in Firebase. The buzzer and LED indicators provide immediate feedback about the verification status.

5.2 Software Requirements

Table 3: Software Components

Software	Purpose
ESP32 IDE	Used to develop and upload programs to the ESP32 and ESP32-CAM.
Firebase	Stores ticket information, passenger details, verification records, and captured images in real time.
Embedded C / ESP32 Programming Language	Used to program the ESP32 DEV controller and hardware modules.
ESP32 Board Package	Enables programming and configuration of the ESP32-CAM module in the ESP32 IDE.
Firebase Libraries	Allow communication between the hardware devices and the Firebase cloud database.

The software controls the communication between all hardware components and the cloud database. Programs are developed using the ESP32 IDE and uploaded to the ESP32 and ESP32-CAM. Firebase is used for secure cloud storage of ticket details, captured images, and passenger records. The software enables real-time data synchronization, making it easier for railway authorities to monitor passenger information through the connected application.

6. Working of the Proposed System

- The proposed Smart Train Ticket Verification System works by integrating IoT devices, cloud storage, and AI-based monitoring to automate the train ticket verification process. The complete system operates in a sequence of steps, ensuring secure and efficient passenger verification with minimum manual intervention.
- When a passenger enters the train compartment, the **entry IR sensor** detects the movement and sends a signal to the **ESP32** . The ESP32 acts as the central controller and initiates the ticket verification process.
- The passenger is then required to tap the **NFC-enabled ticket** on the NFC reader. The NFC reader reads the unique ticket information and forwards it to the ESP32. The ESP32 communicates with **Firebase** to verify whether the ticket is valid and belongs to the correct passenger.
- If the ticket is valid, the verification process is completed successfully. The system indicates a successful verification through LED indicators, and the passenger is allowed to continue the journey without any interruption. The passenger information and verification status are also updated in the Firebase database for future reference.
- If the ticket is invalid, duplicated, or the passenger attempts to enter without performing ticket verification, the system immediately identifies the irregularity. The **ESP32-CAM AI Thinker** is then activated to capture an image of the passenger. The captured image, along with the ticket verification status and timestamp, is uploaded to Firebase. A buzzer alert is also activated to notify the railway staff about the unauthorized activity.
- All verification records, captured images, and passenger details are securely stored in the cloud database. Railway authorities can access this information through the monitoring application in real time, allowing them to verify passenger details, review alerts, and monitor suspicious activities whenever required.
- When the passenger leaves the train compartment, the **exit IR sensor** detects the movement and updates the passenger movement status in the system. This helps maintain accurate records of passenger entry and exit throughout the journey.
- By automating passenger detection, ticket validation, anomaly detection, capturing images, and cloud-based monitoring, the proposed system significantly reduces manual effort, minimizes human errors, improves railway security, and provides a faster and more reliable ticket verification process.

Working Flow

1. Passenger enters the train compartment.
2. Entry IR sensor detects passenger movement.
3. ESP32 starts the ticket verification process.
4. Passenger taps the NFC ticket on the NFC reader.

5. Ticket information is verified using Firebase.
6. If the ticket is valid, the passenger is verified successfully.
7. If the ticket is invalid or verification is skipped, the ESP32-CAM captures the passenger's image.
8. The image and verification details are uploaded to Firebase.
9. A buzzer alert is generated for unauthorized activities.
10. Railway authorities monitor records through the application.
11. Exit IR sensor detects passenger exit and updates the system.

7. Results and Discussion

- The proposed **Smart Train Ticket Verification System** was successfully developed and tested using **ESP32** , **IR sensors**, **NFC technology**, **ESP32-CAM AI Thinker**, and **Firebase**. The prototype demonstrated that the integration of IoT devices and cloud technology can automate the train ticket verification process while reducing manual intervention.
- During testing, the IR sensors accurately detected passenger movement at the entry and exit points of the train compartment. Once a passenger entered, the ESP32 initiated the verification process and successfully communicated with the NFC reader to validate the ticket information. Valid tickets were verified quickly, allowing passengers to proceed without delay.
- The ESP32-CAM AI Thinker successfully captured images whenever an invalid ticket or unauthorized entry was detected. These images, along with the ticket verification details, were uploaded to Firebase in real time. The cloud database stored all passenger records securely and enabled authorized railway personnel to access the information through the monitoring application whenever required.
- The monitoring application displayed passenger verification status, captured images, and ticket information in an organized manner. This allowed railway authorities to identify suspicious activities more efficiently and maintain a centralized record of all verification events.
- The developed prototype showed that the proposed system can reduce the workload of ticket examiners by automating repetitive verification tasks. It also minimized human errors, improved passenger verification accuracy, and reduced the possibility of ticket fraud. The use of Firebase provided reliable data storage and real-time synchronization between the hardware modules and the monitoring application.
- Although the prototype performed successfully, the system depends on stable internet connectivity for cloud synchronization. Future improvements can focus on enhancing offline support, increasing processing speed, and integrating additional AI features for more advanced passenger verification.
- Overall, the experimental results indicate that the proposed Smart Train Ticket Verification System is an effective, reliable, and scalable solution for modern railway transportation. The integration of IoT devices, cloud computing, and AI-based image monitoring provides a secure and efficient approach to automated ticket verification.

Table 4: Experimental Results

Test Scenario	Expected Result	Obtained Result
Passenger detected by IR sensor	Passenger movement should be detected	Successfully detected
Valid NFC ticket scanned	Ticket should be verified	Successfully verified
Invalid NFC ticket scanned	Verification should fail and alert generated	Successfully detected
Unauthorized passenger entry	ESP32-CAM should capture image	Image captured successfully
Image upload	Image stored in Firebase	Successfully uploaded
Passenger data storage	Ticket details stored securely	Successfully stored
Monitoring application	Display passenger records and alerts	Successfully displayed

Discussion

The proposed system combines **IoT**, **cloud computing**, and **AI-based monitoring** to improve railway ticket verification. Compared to conventional manual checking, the developed prototype performs verification more efficiently and provides additional security through automatic capturing images and cloud-based record management. The modular design also allows future enhancements, making the system suitable for deployment in smart railway environments.

Figure 7.1: Hardware Prototype

Figure 7.2: Monitoring Application Dashboard

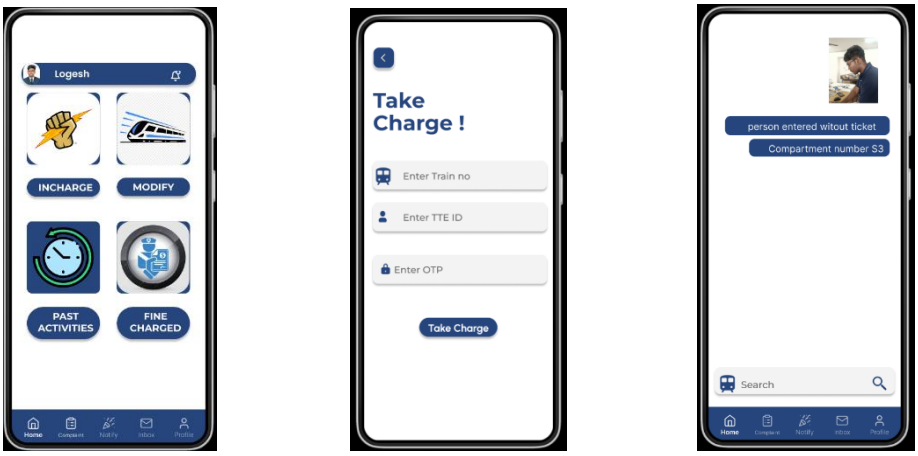
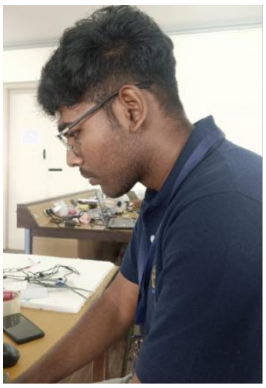


Figure 7.3: Captured Image of Unauthorized Passenger



8. Advantages

- The proposed **Smart Train Ticket Verification System** offers several advantages over the traditional manual ticket-checking process. By integrating IoT devices, cloud technology, and AI-based monitoring, the system improves the overall efficiency, security, and reliability of railway ticket verification.
- One of the major advantages of the proposed system is the **automation of ticket verification**. Passengers can verify their tickets using NFC technology, reducing the need for manual checking by ticket examiners. This saves time and speeds up the verification process.
- The system provides **real-time passenger monitoring** through IR sensors and the ESP32-CAM AI Thinker. Any unauthorized entry or invalid ticket usage is immediately detected, allowing railway authorities to respond quickly.
- Another important advantage is the **reduction of ticket fraud**. Since every ticket is verified against the Firebase database and suspicious activities are recorded with captured images, the chances of duplicate or invalid ticket usage are significantly reduced.
- The use of **Firebase cloud storage** enables secure and centralized management of passenger records, ticket details, and captured images. Authorized railway officials can access this information in real time through the monitoring application, improving transparency and record management.

- The proposed system also **reduces human errors** that may occur during manual ticket checking. Automated verification ensures consistent and accurate results, improving the reliability of the entire process.
- The modular design of the system makes it **easy to maintain and upgrade**. Additional features, such as facial recognition, QR code verification, or AI-based analytics, can be integrated in the future without major modifications to the existing system.
- Overall, the proposed Smart Train Ticket Verification System provides a **cost-effective, scalable, secure, and efficient solution** for modern railway transportation while improving passenger convenience and reducing the workload of railway staff.

Key Advantages

- Automated ticket verification with minimal manual intervention.
- Faster passenger verification using NFC technology.
- Real-time passenger detection using IR sensors.
- AI-based capturing images for unauthorized passengers.
- Secure cloud storage using Firebase.
- Reduces ticket fraud and duplicate ticket usage.
- Minimizes human errors during verification.
- Improves railway security and passenger safety.
- Provides real-time monitoring through the application.
- Easy to maintain, scalable, and suitable for future smart railway systems.

9. Limitations

- Although the proposed **Smart Train Ticket Verification System** provides an efficient and secure solution for automated ticket verification, it has a few limitations that can be addressed in future developments.
- The system depends on a **stable internet connection** to communicate with the Firebase cloud database. If the internet connection is unavailable or unstable, real-time ticket verification and data synchronization may be delayed.
- The current prototype is designed for **small-scale implementation** and has been tested with limited hardware components. Deploying the system across multiple train coaches and railway stations would require additional hardware, network infrastructure, and proper system integration.
- The **ESP32-CAM** captures images only when unauthorized entry or invalid ticket usage is detected. The quality of the captured images may be affected by poor lighting conditions, camera angle, or environmental factors, which can reduce the effectiveness of passenger identification.
- The system currently supports **NFC-based ticket verification** only. Passengers without NFC-enabled tickets or compatible devices cannot use the automated verification process and may require an alternative verification method.
- Since passenger information and captured images are stored in the cloud, **data privacy and security** must be carefully managed. Proper authentication, encryption, and access control mechanisms are necessary to protect sensitive passenger data from unauthorized access.

- Finally, the proposed system is a prototype and has not yet been tested under **real-time railway operating conditions** with a large number of passengers. Therefore, its performance in highly crowded environments requires further evaluation before large-scale deployment.

Key Limitations

- Requires a stable internet connection for Firebase synchronization.
- Prototype tested on a limited scale only.
- Image quality depends on lighting and camera position.
- Supports only NFC-based ticket verification.
- Requires proper data security and privacy measures.
- Large-scale deployment requires additional infrastructure.
- Performance in crowded railway environments needs further testing.

10. Future Scope

- The proposed **Smart Train Ticket Verification System** provides an efficient solution for automating the ticket verification process. However, there are several opportunities to further improve the system and expand its capabilities in the future.
- One possible improvement is the integration of **facial recognition technology** to verify passenger identity along with NFC ticket verification. This would provide an additional layer of security and reduce the possibility of ticket misuse or unauthorized travel.
- The system can also be enhanced by supporting **multiple ticket verification methods**, such as QR codes, digital wallets, and mobile ticketing applications. This would make the system more flexible and convenient for passengers using different types of electronic tickets.
- Future versions of the system can use **artificial intelligence and machine learning** to analyze passenger movement, detect unusual travel patterns, and identify suspicious activities automatically. These technologies can improve decision-making and strengthen railway security.
- To improve scalability, the system can be deployed across **multiple train coaches and railway stations** using a centralized cloud platform. This would enable real-time monitoring of passenger verification records throughout the railway network.
- The monitoring application can be upgraded to provide **live notifications**, passenger statistics, system health monitoring, and detailed analytical reports for railway authorities. These features would support better operational planning and faster response to security incidents.
- Future work can also focus on improving **data security and privacy** by implementing advanced encryption techniques, secure authentication, and role-based access control to protect passenger information stored in the cloud.
- Overall, the proposed system has significant potential for further development and can become a fully automated, intelligent, and secure railway ticket verification solution that supports the growing needs of modern smart transportation systems.

Future Enhancements

- Integrate facial recognition for passenger authentication.
- Support QR code and mobile ticket verification.

- Apply AI and machine learning for intelligent monitoring.
- Deploy the system across multiple coaches and railway stations.
- Improve cloud security using encryption and secure authentication.
- Develop a more advanced monitoring dashboard with live analytics.
- Integrate with the IRCTC ticketing system for real-time ticket validation.
- Optimize the system for faster processing and large-scale deployment.

11. Conclusion

- The **Smart Train Ticket Verification System** presented in this research provides an efficient and secure approach to automating the railway ticket verification process. The proposed system integrates **IR sensors**, **NFC technology**, **ESP32-CAM AI Thinker**, **ESP32** , and **Firebase** to reduce manual ticket checking and improve the overall efficiency of railway operations.
- The developed prototype successfully performs passenger detection, ticket verification, capturing images, and cloud-based data storage in real time. By automating these processes, the system minimizes human errors, reduces ticket fraud, and decreases the workload of railway staff. The use of Firebase ensures secure and centralized storage of passenger records, while the ESP32-CAM enhances railway security by capturing images whenever unauthorized activities are detected.
- The modular design of the proposed system makes it reliable, scalable, and suitable for future enhancements. Features such as AI-based analytics, facial recognition, and integration with existing railway ticketing platforms can be incorporated to further improve system performance and security.
- Overall, the proposed Smart Train Ticket Verification System demonstrates the effective use of **IoT**, **cloud computing**, and **AI-based monitoring** in modern railway transportation. The system provides a practical, cost-effective, and user-friendly solution that can contribute to the development of smarter, safer, and more efficient railway services in the future.

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