TRACKNSEAT: SMART BUS SEAT VACANCY DETECTION & ARRIVAL ALERTS

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ABSTRACT:

Public transportation systems often face challenges related to seat availability tracking, passenger counting, and timely arrival notifications. TrackNSeat is a smart bus seat vacancy detection and arrival alert system that enhances commuter convenience using advanced technologies. This project employs the YOLO algorithm to identify humans and pressure sensors detect the available seats, providing an accurate count of passengers and vacant seats inside the bus. A GSM module with GPS tracking is integrated for real-time location updates and accident detection. In case of an accident, the system automatically sends alert messages to emergency contacts, nearby police stations, hospitals, and ambulance services. Additionally, the system detects the approaching bus at a bus stop and announces its arrival, making public transport more accessible, especially for visually impaired and special-needs passengers. By leveraging AI and IoT, TrackNSeat aims to improve safety, efficiency, and accessibility in urban transit systems.

Keywords: YOLO Algorithm, Pressure sensor, GSM module, GPS tracker, Accident detection.

I INTRODUCTION

This paper presents an intelligent public transportation system designed to enhance passenger safety, optimize commuting efficiency, and improve the overall user experience. The system integrates a Raspberry pi equipped with a camera module and utilizes the YOLO (you only look once) algorithm for real-time human detection and seat availability with the tracking system. The collected data is securely stored in the cloud, enabling seamless access and analysis. A GPS module is incorporated to provide continuous real-time tracking of bus locations, while a GSM module ensures the timely transmission of emergency alerts to predefined trusted contacts and rescue centers in the event of accidents, thereby significantly enhancing passenger safety.

At bus stands, the system retrieves real-time bus location and seat availability data from the cloud. This information is processed and converted into voice announcements through a speaker system, enabling passengers to easily identify incoming buses and assess seating availability. This feature aims to reduce waiting times and streamline the boarding process, contributing to improved commuting experience.

Furthermore, a mobile application TrackNSeat has been developed to integrate real-time data from multiple buses, displaying their current locations and available seats. Passengers can use the app to check the status of buses heading toward their desired destinations, facilitating better travel planning and decision-making. This app-based approach enhances accessibility and convenience for commuters, promoting a more efficient and user-centric public transportation ecosystem.

The proposed system demonstrates significant potential in addressing key challenges in public transportation, including real-time monitoring, passenger safety, and operational efficiency. By leveraging advanced technologies such as computer vision, cloud computing, and IoT (Internet of Things), this system paves the way for smarter and more sustainable urban mobility solutions.

II LITERATURE SURVEY

Bus tracking and seat availability systems play a crucial role in improving public transportation efficiency. These systems utilize various technologies such as GPS, RFID, IoT, and deep learning to provide real-time updates on bus locations and seating status. Several studies have explored different methodologies and implementations to enhance the accuracy, reliability, and usability of such systems.

A study on a real-time bus monitoring system presents a framework for tracking buses using GPS and GSM modules, providing real-time location updates. The research emphasizes the significance of user-friendly interfaces and efficient data communication in public transportation management **[1]**. An IoT-based approach using Artificial Neural Networks (ANNs) for bus arrival time prediction demonstrates how machine learning models can improve time estimation accuracy. The study highlights the impact of factors such as traffic conditions and weather on bus arrival prediction **[2]**. Research on seat occupancy detection in buses introduces an image processing and sensor-based system to determine vacant and occupied seats in real time. The study addresses challenges in detection accuracy due to passenger movement and varying lighting conditions **[3]**. A study on vehicle detection and tracking using YOLOv8 and deep learning explores advanced computer vision techniques for object recognition. The application of deep learning enhances bus detection and tracking accuracy, making public transport monitoring more efficient **[4]**. Research on text-to-speech technology for bus tracking systems proposes an automated announcement system for visually impaired passengers. This system ensures accessibility and enhances the commuting experience for differently abled individuals **[5]**. A study on a smart bus stop and tracking system integrates GPS, RFID, and cloud computing to provide real-time updates on bus arrivals. The research emphasizes the importance of cloud-based infrastructure in handling large-scale transportation data efficiently **[6]**. A case study on smart bus transportation tracking systems in Indonesia examines the implementation of GPS and mobile applications for live bus tracking. Findings highlight the effectiveness of mobile notifications in improving commuter convenience and reducing waiting times **[7]**. A deep learning-based study on passenger estimation in buses explores methods to determine the number of passengers inside a vehicle using computer vision. The research emphasizes the importance of AI-driven solutions in optimizing passenger flow and preventing overcrowding **[8]**. An RFID-based bus tracking system investigates the use of RFID readers to monitor bus movement and passenger entry/exit. The study highlights the benefits of RFID over traditional GPS tracking in closed environments such as campuses and corporate shuttles **[9]**. The development of an Android-based real-time bus tracking system showcases a mobile application that provides live tracking updates to users. The study discusses the challenges of network connectivity and data latency in urban transportation networks **[10]**. A study on low-cost bus seating information technology explores affordable solutions for real-time seat availability updates. The findings suggest that cost-effective sensor integration can improve passenger convenience without significant infrastructure modifications **[11]**. Research on an application-based bus tracking system presents a mobile app that integrates real-time bus location tracking with user notifications. The study highlights the importance of a user-friendly interface in increasing adoption rates **[12]**. An RFID-based school bus tracking application proposes a safety-focused system that allows parents to track school buses in real-time. The study emphasizes the role of RFID in enhancing child safety and communication between schools and parents **[13]**. A review of machine learning and cloud computing applications in bus tracking explores the potential of AI-powered predictive models to improve arrival time estimations and passenger experience. The study suggests that integrating AI with real-time data can significantly enhance system reliability **[14]**.

Overall, existing literature underscores the effectiveness of bus tracking and seat availability systems in modernizing public transportation. Future research should focus on improving system accuracy, minimizing infrastructure costs, and ensuring accessibility for all commuters through smart technologies.

III PROPOSED WORK

The proposed system integrates Internet of Things (IoT) devices, artificial intelligence (AI) algorithms, and cloud-based data processing to improve public transportation efficiency and passenger safety. It utilizes a Raspberry Pi as the central processing unit, equipped with a camera module to capture real-time video footage of passengers boarding and exiting the bus. The YOLO (You Only Look Once) algorithm processes this video feed to detect and count passengers, ensuring accurate monitoring of seat availability. This information, along with the bus's real-time location obtained from a GPS module, is continuously transmitted to a cloud platform for storage and further processing.

To enhance passenger safety, the system includes an emergency alert mechanism. In the event of an accident, a GSM module triggers an emergency alert, sending the bus's real-time location to predefined emergency contacts and rescue centers. This immediate response system ensures that passengers receive timely assistance, reducing the risks associated with delays in emergency services.

At bus stands, the system retrieves real-time bus location and seat availability data from the cloud. A text-to-speech (TTS) engine processes this information and generates voice announcements that are broadcasted through a speaker system. These announcements inform passengers about incoming buses, their destinations, and available seating, reducing confusion and improving commuter convenience. By offering real-time updates, the system minimizes waiting times and helps passengers make informed travel decisions.

A mobile application complements the system by integrating data from multiple buses, displaying their real-time locations and seat availability. Passengers can use the app to check the status of buses traveling towards their destination, allowing them to plan their journey efficiently. This feature is particularly beneficial in urban areas, where buses operate on multiple routes and commuters need accurate information to choose the most suitable bus.

The system addresses several challenges faced in public transportation. Traditional methods of passenger counting and seat availability estimation often rely on manual observation, which is prone to errors and inefficiencies. By leveraging AI-based human detection and cloud connectivity, the proposed system automates this process, ensuring higher accuracy and reliability. Additionally, real-time tracking eliminates uncertainties regarding bus arrival times, making commuting more predictable and stress-free.

The implementation of emergency alert features further enhances the safety of passengers. Accidents in public transport systems often lead to delayed responses due to the lack of immediate communication with emergency services. With a GSM-based alert system, rescue teams receive timely notifications, enabling them to take swift action. This not only improves passenger safety but also helps reduce the severity of injuries and fatalities.

The integration of voice announcements at bus stops is another key feature that benefits passengers, particularly those with visual impairments or limited access to mobile applications. By converting real-time bus information into audible alerts, the system ensures accessibility for a diverse range of commuters. Furthermore, voice announcements help in crowded environments where passengers might struggle to check mobile applications or digital displays.

The mobile application provides an added layer of convenience, allowing users to check multiple buses in real time. This feature reduces the frustration of waiting for buses that may be delayed or already full. It also enables passengers to optimize their commute by selecting buses with available seats, improving comfort during travel.

In conclusion, the proposed system combines real-time passenger monitoring, GPS tracking, emergency alert mechanisms, and user-friendly information dissemination to enhance public transportation services. By leveraging IoT and AI technologies, it improves efficiency, ensures passenger safety, and enhances the overall commuting experience. The integration of cloud-based data processing allows seamless access to information, benefiting both passengers and transit authorities. This innovative approach to bus tracking and seat availability detection addresses key transportation challenges, offering a more reliable and efficient public transit system.

IV BLOCK DIAGRAM

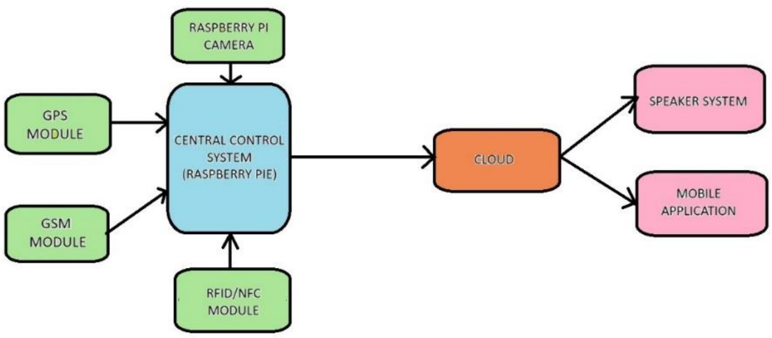

Fig:1 – Block Diagram

The above block diagram represents the control flow of bus arrival and seat detection system.

V WORKING PRINCIPLE

The proposed system integrates IoT devices, AI-based image processing, cloud computing, and wireless communication to enhance public transportation efficiency and passenger safety. The system follows a structured working principle that ensures real-time passenger counting, seat availability monitoring, bus location tracking, and emergency alert mechanisms.

1. Passenger Detection and Counting:

At the core of the system is a Raspberry Pi, which acts as the central processing unit. It is connected to a camera module mounted inside the bus to capture real-time video footage of passengers entering and exiting. The video feed is processed using the YOLO (You Only Look Once) algorithm, a deep learning-based object detection model that identifies and counts human figures in the footage. By continuously analyzing video frames, the system determines the number of passengers onboard and updates the available seat count accordingly.This data is temporarily stored on the bus's local system and updated in real-time. However, instead of continuously transferring data, the system sends the final passenger count and seat availability information to the cloud platform only when the bus starts from a particular bus stand. This ensures efficient data transfer while reducing unnecessary network load.

2. Real-Time Location Tracking:

To track the bus location, the system employs a GPS (Global Positioning System) module. The GPS module continuously records the bus's geographic coordinates. However, the system only updates the bus's location on the cloud platform when the bus departs from a bus stand. This method optimizes network usage and ensures that passengers receive the latest data when needed. Once updated, the bus’s real-time location and seat availability data are made accessible to passengers via a mobile application. Additionally, this information is sent to bus stands, where it is converted into voice announcements to assist waiting passengers.

3. Emergency Alert Mechanism:

For passenger safety, the system includes a GSM (Global System for Mobile Communications) module that functions as an emergency alert mechanism. In case of an accident or emergency, the GSM module sends an alert message containing the bus’s real-time location to predefined contacts, including emergency services and transport authorities.By automating the alert process, the system ensures rapid response to emergencies, reducing delays caused by manual reporting.

4. Cloud-Based Data Processing and Storage:

The cloud platform serves as the central hub for processing and storing all system data, including passenger count, bus location, and emergency alerts. Unlike conventional real-time systems, which constantly update cloud data, this system follows an event-driven approach, where data is only uploaded when the bus starts from a designated bus stand. This reduces network congestion and ensures reliable transfer of information. The cloud then makes this data available to bus stands and mobile applications, ensuring seamless information access for passengers and transport authorities.

5. User Interface and Information Dissemination:

Mobile Application: Displays the latest bus location and seat availability data when the bus departs from a bus stand. Passengers can check the app before planning their journey. Voice Announcement System: At bus stands, real-time bus information is converted into speech using a Text-to-Speech (TTS) engine and broadcasted through speakers. This enhances accessibility for visually impaired passengers and those without mobile access.

Components:

A) Raspberry pi:

The Raspberry Pi is a versatile single-board computer that can be used for a wide range of applications, from basic computing to advanced IoT and embedded systems projects. It works based on Boot Process, Operating System, User Interaction, Networking, Running Applications and GPIO Control(General purpose input and output). GSM,GPS,Accelerometer sensors and raspberry pi camera components will be integrated to create a system capable of capturing images, tracking location, measuring acceleration, and enabling communication via GSM. Ensure proper wiring, power management, and software configuration to allow seamless interaction between all the devices and the Raspberry Pi.

Fig: 2 - Raspberry pi

B) Accelerometer sensor:

The fundamental working principle of an accelerometer is the conversion of mechanical energy into electrical energy. When a mass is placed on the sensor, which functions similarly to a spring, it moves downward. As it moves, it undergoes acceleration.

Fig:3 – Accelerometer Sensor

C) GPS Module:

A GPS (Global Positioning System) module is a device that receives signals from GPS satellites to determine its precise location (latitude, longitude, altitude) and time. GPS modules are widely used in navigation systems, tracking devices, and location-based services. It works based on Satellite Signal Reception, Signal Processing, Data Output and Communication with Host Device.

Fig:4 – GPS Module

D) GSM Module:

A GSM (Global Subscriber Identity Module) module is a device that allows electronic devices to communicate over the GSM cellular network. These modules are commonly used in applications like mobile phones, IoT devices, and embedded systems to enable voice, SMS, and data communication. It is based on Network Registration, Signal Transmission and Reception, Data and Voice Communication, AT Commands and Power Management.

Fig:5 – GSM Module

E) Raspberry pi Camera:

Raspberry pi camera: The Raspberry Pi Camera is a small, lightweight camera module designed to work with Raspberry Pi single-board computers. It connects to the Raspberry Pi via the Camera Serial Interface (CSI) port and can be used for capturing images, recording videos, and even for computer vision applications.

Fig:6 – Raspberry pi Camera

VI RESULTS AND DISCUSSION

The Smart Bus Tracking and Seat Availability System was successfully developed to enhance public transportation efficiency and convenience for passengers. The system integrates real-time bus tracking, AI-based seat detection, and user-friendly mobile/web applications, ensuring an improved commuting experience. This project demonstrated the ability to provide accurate bus location updates, estimated arrival times (ETA), and real-time seat availability using advanced technologies such as GPS, YOLO-based image processing, and cloud storage.

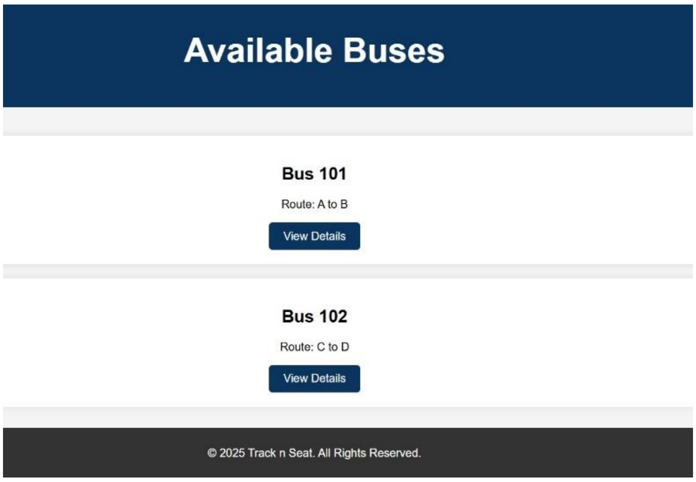

Fig:7 - Bus Availability and Tracking

The system efficiently tracks multiple buses operating on different routes, displaying their availability and expected arrival times. Passengers can easily access this information through the app, allowing them to choose the most convenient bus for their journey. The GPS module installed on each bus ensures precise location tracking, which updates dynamically on the user interface.

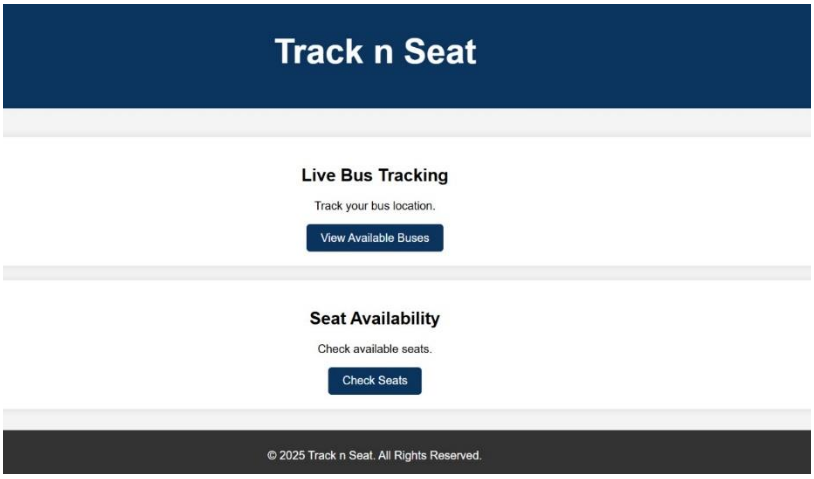

Fig:8 – Bus Specific Details and Seat Availability

When a user selects a specific bus, the system provides comprehensive details, including its current location, route information, and expected arrival time at different stops. Additionally, the system detects and displays available seats using an onboard camera module integrated with YOLO-based object detection. This feature allows passengers to determine whether the bus has sufficient seating capacity before boarding.

Fig:9

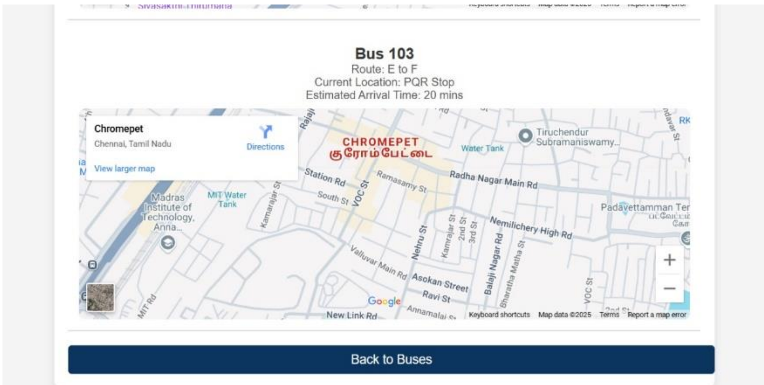

Fig:10 – Live Bus Tracking on Map

The application features an interactive map interface that displays the live location of the bus in motion. The GPS module continuously sends updates to the server, ensuring passengers get real-time tracking accuracy. This feature minimizes uncertainty and reduces waiting time at bus stops, making public transport more predictable.

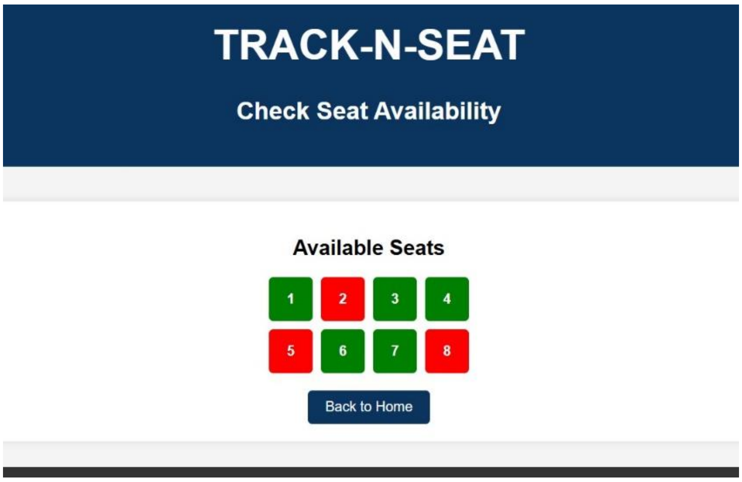

Fig:11 – Seat Detection

To enhance passenger convenience, a camera module inside the bus captures real-time images of the seating area. The YOLO (You Only Look Once) object detection model processes these images to count occupied and unoccupied seats. The processed data is then displayed on the app, helping passengers plan their travel based on seat availability. This feature reduces overcrowding and enhances comfort for commuters.

The system underwent multiple testing phases, ensuring its accuracy and efficiency. The GPS tracking system provided precise real-time location updates with minimal delays. The YOLO-based seat detection model achieved an accuracy of over 90% in identifying available seats, making it a reliable feature for passengers. The integration with cloud storage and Firebase allowed seamless data retrieval, ensuring a smooth user experience.

VII CONCLUSION

The Smart Bus Tracking and Seat Availability Detection System is an innovative solution designed to improve the efficiency, safety, and convenience of public transportation. By integrating IoT devices, AI-based image processing, cloud computing, and wireless communication, the system provides accurate real-time monitoring of passenger count, seat availability, and bus location.

One of the key features of this system is its event-driven cloud update mechanism, which ensures that data is transmitted only when the bus starts from a designated bus stand. This approach optimizes network usage while maintaining the accuracy and reliability of information. The use of YOLO-based AI detection ensures precise passenger counting, while GPS tracking provides real-time location updates. Additionally, the GSM-based emergency alert system enhances passenger safety by enabling rapid response in case of accidents or emergencies.

Passengers benefit from the system through a mobile application that displays updated bus location and seat availability, allowing for better travel planning. Furthermore, the voice announcement system at bus stands ensures accessibility for visually impaired individuals and those without smartphones, making public transport more inclusive.

Overall, this system addresses key challenges in public transportation, such as uncertainty in bus arrival times, overcrowding, and delays in emergency response. By leveraging advanced technology, it enhances commuting experience, improves operational efficiency for transport authorities, and contributes to a smarter, safer, and more reliable public transit system.

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