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Intelligent Bus Monitoring and Alert System Based on IoT

K. Amarender[1], K Raju[2], M Manoj[3], S. Manoj Kumar[4], S. Manu[5]

Asst. Professor, Dept. of Electronics& Communication Engineering,

Christu Jyothi Institute of Technology & Science, Jangaon, Telangana, India[1]

UG Student, Dept. of Electronics & Communication Engineering,

Christu Jyothi Institute of Technology & Science, Jangaon, Telangana, India[2-5]

Abstract: In the era of smart transportation, ensuring the safety, efficiency, and accountability of public transit systems has become a critical challenge. This project introduces an Intelligent Bus Monitoring and Alert System that leverages advanced Internet of Things (IoT) technologies to provide real-time surveillance, a anomaly detection, and automated alerting for public buses. The system is designed to address key issues such as unauthorized access, route deviations, overcrowding, and emergency response delays— common problems in conventional bus operations. The proposed solution integrates multiple sensors including GPS modules for location tracking, infrared (IR)sensors for passenger movement detection, and vibration sensors for accident or tampering detection. These sensors are interfaced with a Raspberry Pi microcontroller, which performs edge-level data processing and communicates with a cloud-based dashboard for centralized monitoring. In case of any irregular activity—such as a sudden stop, excessive vibration, or deviation from the assigned route.

The architecture supports scalability, low power consumption, and modular integration with existing fleet management systems. It also enables remote diagnostics, data logging, and predictive analytics for maintenance and operational optimization. Experimental Simulations demonstrate the system's ability to detect anomalies with high accuracy, minimize false positives, and maintain robust performance under varied environmental and traffic conditions.

I. INTRODUCTION

In recent years, public transportation has passengers can view live information and receive real-time alerts.
This project not only enhances safety and reliability but also provides transparency in bus operations, ensuring timely communication between the bus, control room, and passengers.

II. PROPOSEDSYSTEM

The proposed system aims to design and implement an **Intelligent Bus Monitoring and Alert System using Internet of Things (IoT)**technology to enhance passenger safety, improve transport management, and provide real-time monitoring of bus operations. Unlike traditional systems that rely on manual supervision, this system enables automated monitoring and instant alerts through connected smart devices.

In the proposed system, each bus is equipped with a **GPS module, IoT communication module (such as Wi-Fi or GSM), sensors, and a microcontroller unit**. These components work together to continuously monitor the bus location, speed, and internal conditions. The microcontroller acts as the central processing unit that collects data from different sensors and transmits it to a cloud-based platform.

The GPS module tracks the **real-time location of the bus**, while sensors such as temperature sensors, passenger counting sensors, and emergency buttons monitor internal bus conditions and passenger safety. The collected data is processed by the microcontroller and transmitted to the IoT cloud server through the communication module.

become a fundamental part of modern life, playing a vital role in connecting people and communities. However, with the increasing demand for safe and efficient transport, monitoring the movement, security, and condition of buses has become a major concern. Traditional bus tracking and management systems rely on manual operations or outdated technologies, which are often inefficient and fail to provide real-time data.

With the emergence of the Internet of Things (IoT), it is now possible to interconnect physical devices such as sensors, GPS modules, and cameras with cloud- based systems. IoT technology enables real-time monitoring, automation, and intelligent decision-making in transportation systems.

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The "Intelligent Bus Monitoring and Alert System based on IoT using Raspberry Pi" is designed to modernize public bus transportation by integrating multiple IoT components into a single intelligent framework. The system continuously tracks the bus using GPS, authenticates passengers through RFID, detects abnormal vibrations or accidents using sensors, and captures security footage using a Raspberry Pi camera. The data is processed and transmitted to the IoT cloud platform, where authorities and

III. LITERATUREREVIEW

Road transportation systems face several challenges such as passenger safety, inefficient monitoring, and lack of real-time information about vehicle status and location. To overcome these issues, researchers have proposed **Intelligent Bus Monitoring and Alert Systems using Internet of Things (IoT)**technologies. These systems use sensors, GPS modules, wireless communication, and cloud platforms to monitor bus operations and provide real-time alerts to administrators and passengers.

IoT-based monitoring systems have gained significant attention because they enable **real-time tracking, data collection, and remote monitoring** of vehicles. By integrating technologies such as GPS, GSM, Wi-Fi, and cloud computing, researchers aim to improve the safety and efficiency of public transportation systems. These smart transportation solutions allow authorities to monitor bus routes, detect abnormal situations, and respond quickly to emergencies.

Several project-level implementations and research studies demonstrate the feasibility of **IoT-based intelligent bus monitoring systems** using microcontrollers such as Arduino, Raspberry Pi, and NodeMCU, along with GPS modules, various sensors, and cloud communication platforms. These studies highlight advantages such as real-time location tracking, improved passenger safety, and better fleet management, although they also identify challenges such as network dependency, data status, and transmits the data to a cloud platform for analysis. The authors report that IoT-based monitoring systems help improve passenger comfort and operational efficiency.

Various conference papers and open-access reports (IRJET, IJRASET, IJSRD,2018–2025)
Describe similar architectures consisting of:

Microcontroller units (Arduino, NodeMCU, Raspberry Pi)

GPS modules for real-time bus location tracking

IoT communication modules(Wi-Fi, GSM, or LTE)

Sensors such as temperature sensors, passenger counting sensors, and emergency buttons

Cloud platforms and mobile applications for remote monitoring and alert notifications

These studies consistently report benefits such as **real-time monitoring, improved safety, reduced waiting time for passengers, and efficient transportation management**. However, challenges such as **network dependency, data security concerns, and system scalability** still exist, indicating the need for more reliable and optimized IoT-based bus monitoring solutions.

IV. EMBEDDED SYSTEMS

An embedded system is a specialized computing system designed to perform dedicated functions or tasks within a larger system. Unlike general-purpose computers, embedded systems are optimized for specific applications and often have constraints in terms of processing power, memory, and storage. They are typically integrated with hardware and run software (often called firmware) that directly interacts with that hardware.

Embedded systems are used in a wide range of applications, from household appliances like washing machines and microwaves to critical systems in automobiles, healthcare devices, industrial machines, and consumer electronics. These systems are designed to be reliable, efficient, and real-time, often operating continuously with minimal human intervention. Embedded systems are integral parts of modern life, from controlling household appliances to ensuring safety in automobiles. These systems are usually designed with a focus on efficiency, reliability, and specific functionality. As technology evolves, the role of embedded systems is growing, especially in the realm of the Internet of Things (IoT), where many devices are becoming interconnected and smarter.

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V. ANALYSIS AND DESING

The **Intelligent Bus Monitoring and Alert System using IoT** is designed to provide real- time monitoring of buses, improve passenger safety, and enhance transportation management. The system integrates hardware components such as sensors, GPS modules, microcontrollers, and IoT communication modules with cloud platforms to collect, process, and transmit data efficiently. The analysis and design phase focuses on identifying system requirements, defining system architecture, and designing the operational workflow.

A. System Analysis

The primary objective of the system is to **monitor bus operations in real time and provide alerts in case of abnormal situations**. The system continuously collects data such as bus location, speed, passenger count, and emergency signals using various sensors and monitoring devices. This information is processed by the microcontroller and transmitted to a central server through IoT communication networks.

The system must meet several key requirements:

- **Real-Time Bus Tracking:** The GPS module continuously determines the bus location and sends updates to the monitoring system.
- **Passenger Safety Monitoring:** Emergency buttons or sensors allow passengers or drivers to trigger alerts during emergency situations.
- **Data Communication:** IoT modules such as Wi-Fi or GSM transmit collected data to a cloud platform for remote monitoring.
- **Alert Notification:** In case of abnormal conditions such as route deviation, over speeding, or emergency activation, alerts are automatically sent to the control center.
- **User Interface:** Administrators and Transport authorities can monitor bus status through a web or mobile application.

Through this analysis, the system ensures that transportation authorities can monitor buses efficiently and respond quickly to safety issues

B. System Design

The system design focuses on integrating hardware and software components to achieve efficient monitoring and communication.

The **hardware design** consists of components such as a micro controller (Arduino or NodeMCU), GPS module for location tracking, IoT communication module (Wi-Fi or GSM), sensors for monitoring bus conditions, and an emergency alert button. The microcontroller collects sensor data and processes it before transmitting it to the IoT cloud platform.

The **software design** involves cloud-based data storage, data processing, and user interface development. The IoT platform receives the transmitted data, stores it in a database, and displays it through a dashboard or mobile application for monitoring.

C. System Architecture

The system architecture consists of three main layers:

1. **Data Collection Layer:**

Sensors, GPS modules, and emergency buttons collect real-time data from the bus.
Processing Layer:
The microcontroller processes the collected data and determines whether any abnormal conditions occur.

2. **Communication and Monitoring Layer:**

The IoT module sends data to the cloud server, where it can be accessed through web or mobile applications by administrators or transport authorities.

D. Working Process

1. Sensors and GPS modules continuously collect data related to bus location and status.
2. The microcontroller processes the collected information.
3. The IoT communication module transmits the processed data to a cloud server. The monitoring system displays real- time bus information on a web or mobile dashboard.
4. If an abnormal situation occurs, the system automatically generates alerts and notifications.
5. Overall, the analysis and design of the Intelligent Bus Monitoring and Alert System using IoT ensure reliable

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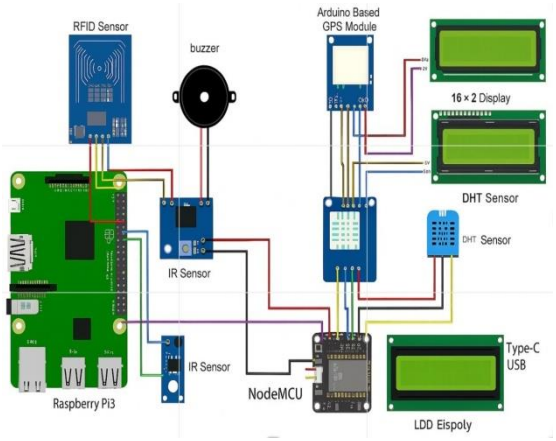
data collection, real-time communication, and efficient monitoring, which significantly improves passenger safety and transportation management



Circuit Diagram

The **circuit diagram of the Intelligent Bus Monitoring and Alert System using IoT** shows how all the hardware components are connected to work together. The main component in the circuit is the **microcontroller (Arduino or NodeMCU)**, which controls the entire system. The **GPS module** is connected to the microcontroller using TX and RX pins. It continuously sends the **bus location information** to the microcontroller.

The **IoT communication module (GSM or Wi- Fi)** is also connected to the microcontroller. This module sends the bus data such as **location and status** to the cloud server or monitoring system. An **emergency push button** is connected to a digital pin of the microcontroller. When the button is pressed, it sends an **emergency alert message** to the monitoring center bus and send alerts in real time.
Fig. Intelligent Bus Monitoring and Alert System Based on

VI. SOFTWAREUSED

Arduino is a prototype platform based on an easy-to-use hardware and software. It consists of a circuit board, which can be programmed and a ready-made software called Arduino IDE, which issued to write and upload the computer code to the physical board.

Key Features:

a. Arduino boards are able to read analog or digital input signals from different Sensors and turn it into an output such as activating a motor, turning LED on/off, connect to the cloud and many other actions.

- It can control the board functions by sending a set of instructions to the microcontroller on the board via Arduino IDE.
- Most previous programmable circuit boards, Arduino does not need an extra piece of hardware (called a programmer) in order to load a new code onto the board. You can simply use a USB cable.
- Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program.
- Finally, Arduino provides a standard form factor that breaks the functions of the microcontroller into a more accessible package. After learning about the main parts of the Arduino UNO board, we are ready to learn how to set up the Arduino IDE. Once we learn this, we will be ready to upload our program on the Arduino board.

Figure: Arduino IDE

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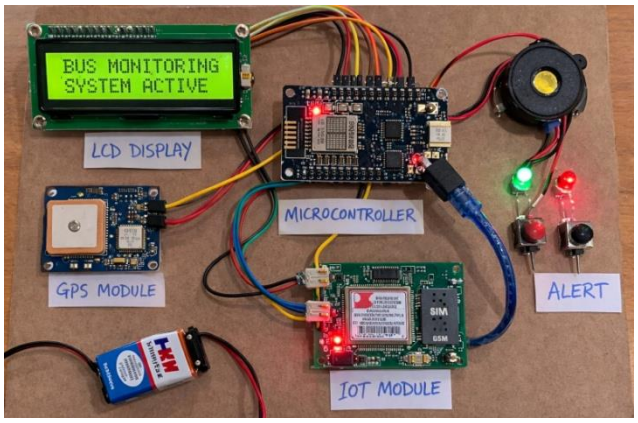
VII. RESULT



VIII. CONCLUSION

The Intelligent Bus Monitoring and Alert System based on IoT successfully demonstrates how modern technology can enhance the efficiency, safety, and reliability of public transportation. By integrating sensors, GPS, GSM, and cloud platforms, the system provides real-time tracking, accident detection, and instant notifications to both passengers and authorities.

The implementation of Raspberry Pi as the central controller ensures seamless data processing and communication with allconnected modules. Through the IoT platform, users can access live data such as bus location, speed, and route status from anywhere, enabling better decision-making and improved service management.

Overall, the system offers a smart, cost-effective, and scalable solution to reduce waiting times, enhance safety, and promote the development of intelligent public transport infrastructure.

IX. FUTURE SCOPE

The Intelligent Bus Monitoring and Alert System using IoT has significant potential for further development and real-world implementation. With the advancement of smart transportation technologies, the system can be enhanced in several ways to improve efficiency, safety, and reliability.

1. **Integration with GPS and Advanced Communication Networks:**
   The system can be integrated with GPS modules and advanced communication technologies such as GSM, 4G, or 5G networks to provide accurate real-time location tracking of buses. This will allow transport authorities and passengers to monitor bus movement and estimated arrival time through mobile or web applications.
2. **Cloud-Based Monitoring and Data Storage:** Bus monitoring data can be stored and processed on cloud Platforms for centralized monitoring and long-term data storage. Cloud-based systems can help administrators monitor multiple buses simultaneously and analyze operational data more effectively.
3. **Real-Time Data Analytics and Smart Fleet Management:**
   The collected data can be analyzed to study travel patterns, traffic conditions, and passenger usage. This analysis can help transportation authorities optimize routes, improve scheduling, and manage fleets more efficiently.
4. **AI-Based Safety and Alert Mechanisms:** Artificial intelligence and machine learning techniques can be integrated in to the system to analyze sensor data and identify abnormal conditions such as over speeding, route deviation, or emergency situations. This will improve the accuracy of alerts and reduce false warnings.
5. **Integration with Smart Transportation and Smart City Systems:**
   The system can be integrated with intelligent transportation systems used in smart cities. This will allow buses to communicate with traffic management systems and other vehicles to large scale in public transportation, school buses, and private transport services, making transportation

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