

## BUS TRACKING AND MONITORING SYSTEM USING RFID

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**Abstract:** The increasing demand for efficient and reliable public transportation has necessitated the development of advanced tracking and monitoring systems. This research presents an IoT-based Bus Tracking and Monitoring System using RFID technology, aimed at improving operational efficiency, reducing waiting times, and enhancing commuter safety. The proposed system employs RFID tags placed at bus stops and RFID readers installed on buses to enable real-time tracking. When a bus reaches a stop, the RFID reader detects the tag's unique ID, allowing the system to determine the bus's location accurately. The collected data is processed using a microcontroller and transmitted to a web server via the ESP8266 Wi-Fi module. Commuters can access real-time bus location updates through a dedicated website, enabling them to make informed travel decisions. By addressing key challenges such as unpredictable bus schedules, overcrowding, and mismanagement, this system significantly improves the reliability of public transportation. The integration of RFID technology with IoT ensures a cost-effective and low-power solution suitable for large-scale implementation in urban and suburban areas. This research highlights the potential of RFID-based solutions in optimizing public transit systems and contributing to the development of smart cities.

## INTRODUCTION

Public transportation plays a crucial role in urban mobility, providing an affordable and efficient means of travel for millions of people. However, many cities face significant challenges in managing public bus systems, leading to inefficiencies that affect both passengers and transportation authorities. Irregular bus schedules, long waiting times, and overcrowding at bus stops are among the most pressing issues that commuters encounter daily. The lack of real-time bus tracking systems often results in uncertainty, making it difficult for passengers to plan their journeys effectively. Without accurate information about bus locations, commuters are forced to wait for extended periods, sometimes leading to overcrowding at bus stops, increased frustration, and safety risks such as accidents and theft. Additionally, inefficient fleet management leads to poor resource allocation, resulting in buses operating with uneven passenger loads, unnecessary fuel consumption, and avoidable delays. These problems not only reduce the reliability of public transportation but also discourage people from using buses, leading to an increased dependence on private vehicles, further contributing to traffic congestion and environmental pollution.[8]

To address these growing concerns, this research presents an IoT-based Bus Tracking and Monitoring System that leverages RFID technology to provide real-time bus location updates, enhancing both passenger convenience and operational efficiency. The proposed system integrates RFID tags at bus stops and RFID readers on buses, enabling automated and accurate tracking of bus movements[6]. When a bus arrives at a stop, the RFID reader detects the tag's unique identification number and processes the data using a microcontroller. This information is then transmitted to a web server through the ESP8266 Wi-Fi module, allowing real-time updates to be displayed on a dedicated website. Passengers can access this website to check the live location of buses, enabling them to make informed decisions about when and where to board, ultimately reducing waiting times and minimizing overcrowding. By automating the tracking process, this system eliminates the errors associated with manual data collection and ensures reliable transportation for commuters. [4] Unlike GPS-based tracking solutions, which may suffer from inaccuracies in densely populated urban environments due to signal interference, RFID technology provides a more precise and cost-effective alternative for bus tracking. [1] The use of RFID and IoT integration makes the system scalable, energy-efficient, and suitable for deployment across a wide range of public transportation networks. Moreover, the system provides valuable insights for transportation authorities, allowing them to monitor fleet movements, optimize bus routes, and improve overall service reliability. With access to real-time data, administrators can identify patterns in passenger demand, adjust schedules accordingly, and allocate resources more efficiently.

## LITERATURE SURVEY

Author(s)	Method	Advantages	Disadvantages
Mona Kumar; Ajitesh; Arbaz	Uses GPS based tracking	Reduces passenger waiting time with real-time location updates	Relies on stable GSM/GPS connectivity; disruptions can occur
Ahmad Hanis, Mawarny Md. Reja	Uses LoRa Technology	Long range tracking, and passenger count, reducing wait times.	Latency issues due to LoRa
Shraddha Shah; Bharti Singh	Zigbee based school bus tracking and security system	The system provides real-time tracking, and features like alcohol detection	Low Throughput and interference
Muhammad Wasim Raad, Mohamed Deriche	A GUI Application of School Bus Tracker Based on RFID	Provides real-time updates, reduces human error	GUIs are platform-dependent and have limited accessibility

### GPS-Based Tracking (Mona Kumar, Ajitesh, Arbaz)

- **Advantages:** The use of GPS-based tracking systems significantly enhances the efficiency of bus transportation by providing real-time location updates, which helps in minimizing passenger waiting times. With continuous tracking, passengers and authorities can access accurate arrival times, reducing uncertainty and improving the overall transit experience.
- **Disadvantages:** Despite its advantages, GPS-based tracking systems heavily depend on stable GSM or GPS connectivity, which can be disrupted in areas with weak network signals, such as tunnels, remote locations, or densely populated urban regions with high interference. These disruptions may result in inaccurate location updates, causing inconvenience to passengers and affecting the reliability of the system.

### LoRa Technology (Ahmad Hanis, Mawarny Md. Reja)

- **Advantages:** The implementation of LoRa (Long Range) technology in bus tracking systems allows for extensive coverage, making it an ideal choice for monitoring buses over long distances. Additionally, this method enables the counting of passengers in real time, helping in better fleet management and reducing unnecessary wait times for commuters. The long-range capabilities ensure that tracking remains functional even in areas with limited traditional network infrastructure.
- **Disadvantages:** One of the significant drawbacks of using LoRa technology for bus tracking is the presence of latency issues, which can affect the accuracy and timeliness of real-time data updates. Delays in tracking information can lead to inefficient route

planning and passenger dissatisfaction, especially during peak hours when timely updates are crucial for managing travel schedules.

#### **Zigbee-Based Tracking and Security System (Shraddha Shah, Bharti Singh)**

- **Advantages:** The integration of Zigbee technology in bus tracking not only ensures real-time location monitoring but also enhances security by incorporating additional features such as alcohol detection. This dual functionality makes it a valuable system for improving passenger safety, particularly in school bus transportation, where ensuring driver sobriety is critical. The low power consumption of Zigbee-based systems further contributes to their cost-effectiveness and sustainability.
- **Disadvantages:** While Zigbee-based tracking systems offer multiple advantages, they suffer from low data throughput, which limits the amount of information that can be transmitted efficiently. Additionally, these systems are prone to interference from other wireless devices operating in the same frequency range, potentially leading to inaccurate or delayed data transmission, affecting the reliability of the system in high-traffic areas.

#### **RFID-Based Bus Tracking with GUI Application (Muhammad Wasim Raad, Mohamed Deriche)**

- **Advantages:** The use of an RFID-based tracking system combined with a graphical user interface (GUI) application offers the advantage of real-time updates, allowing for efficient monitoring of buses and passengers. By reducing human intervention and automating data collection, this method minimizes the chances of human error, leading to better accuracy in tracking and improved decision-making for route optimization. The integration of a user-friendly GUI makes it easier for administrators to manage and analyze bus movement efficiently.
- **Disadvantages:** Despite its benefits, GUI-based applications for bus tracking face limitations related to platform dependency, meaning that their functionality may vary across different operating systems and devices. Additionally, accessibility challenges can arise if the application is not designed to be compatible with multiple platforms, restricting its usability for certain users. These limitations can hinder the widespread adoption of the system and require additional development efforts to ensure cross-platform compatibility.

### **PROPOSED SYSTEM**

Radio Frequency Identification (RFID) is a widely adopted technology that enables the wireless identification and tracking of objects using radio waves. Unlike traditional barcode systems that require direct line-of-sight scanning, RFID offers the advantage of remote and contactless data transmission, significantly improving efficiency and automation in various applications. The core components of an RFID system include RFID tags, RFID readers, and a backend system that processes and manages the collected data. The primary working principle of RFID technology is based on electromagnetic coupling between a tag and a reader, where the tag transmits stored information upon activation by the reader's radio signals. This capability has led to the widespread integration of RFID into diverse domains such as transportation, inventory management, security access control, healthcare, and public transit systems. The success of an RFID-based tracking system depends on factors such as the frequency of operation, the communication protocol between tags and readers, the security mechanisms implemented, and the system's ability to integrate seamlessly with existing digital infrastructure.[9] RFID tags serve as the fundamental building blocks of RFID-based identification and tracking systems. Each RFID tag consists of an embedded microchip that stores unique data, which can include a simple identifier, sensor-based readings, or encrypted authentication details. These tags are broadly categorized based on their power source into passive, active, and semi-passive (also known as battery-assisted) tags. Passive RFID tags do not have an internal power supply and rely entirely on the electromagnetic energy transmitted by the RFID reader to power their response. This makes them cost-effective and suitable for applications where short-range communication is sufficient, such as retail inventory tracking or access control. Active RFID tags, in contrast, contain an internal battery that enables them to continuously transmit signals over long distances, making them ideal for large-scale monitoring operations, including vehicle tracking, logistics management, and high-speed toll collection. Semi-passive RFID tags function as a hybrid between the two, where the internal battery is used to power the tag's microchip but still requires an external reader signal to initiate communication. The selection of the appropriate type of RFID tag for a given application

depends on multiple factors, including cost, range, durability, and environmental constraints.[7]

The RFID reader plays a crucial role in an RFID system, acting as the bridge between RFID tags and the backend processing system. These readers function by emitting radio frequency signals that activate RFID tags within their range, capturing the data stored on the tags, and transmitting this information to the backend system for further processing. RFID readers can be classified as fixed or handheld based on their deployment. Fixed RFID readers are strategically installed at key locations, such as entrances, exits, or checkpoints, where they can automatically scan passing RFID tags, making them ideal for applications such as automated bus tracking, warehouse management, and electronic toll collection. Handheld RFID readers, on the other hand, provide mobility and flexibility, allowing users to manually scan RFID tags in environments where fixed installations may not be feasible. The performance and effectiveness of RFID readers depend on various factors, including antenna design, power output, communication range, and interference handling capabilities.[9]

RFID systems operate across different frequency ranges, with each range offering unique advantages and limitations that determine their suitability for specific applications. Low-Frequency (LF) RFID, which operates within the 125–134 kHz range, is characterized by short read distances (typically within a few centimeters) and slower data transfer rates. These attributes make LF RFID ideal for applications that require close-range scanning, such as access control systems, animal identification, and keyless entry solutions. High-Frequency (HF) RFID, which operates at 13.56 MHz, provides moderate read distances (up to one meter) and is widely used in applications such as electronic passports, library management, and public transportation ticketing systems. Ultra-High Frequency (UHF) RFID, ranging between 860–960 MHz, offers significantly longer read ranges (several meters) and higher data transfer speeds, making it well-suited for large-scale tracking applications such as supply chain management, industrial automation, and public transit monitoring. The choice of RFID frequency depends on application-specific requirements, where factors such as communication range, speed, power consumption, and susceptibility to environmental interference must be carefully considered.[2]

A critical component of any RFID system is the backend infrastructure, which is responsible for collecting, processing, and managing the vast amounts of data generated by RFID readers. This infrastructure typically includes middleware software that filters and aggregates RFID data before integrating it with existing enterprise systems, such as cloud-based monitoring platforms or database management systems. In the context of public transit management, RFID readers deployed at bus stops detect RFID tags attached to buses, triggering real-time updates in the backend system. This enables accurate arrival and departure tracking, ensuring that both commuters and transit authorities receive timely and reliable information. The automation provided by RFID technology eliminates the need for manual tracking, reducing human errors and enhancing overall operational efficiency. Additionally, the integration of RFID systems with web-based platforms allows users to access real-time data through mobile applications or websites, improving convenience and accessibility for passengers.[4]

Despite its numerous advantages, RFID technology is not without its challenges. Security and privacy concerns remain among the primary issues associated with RFID-based tracking systems. Unauthorized access to RFID data, commonly known as RFID skimming, poses a significant risk, particularly in applications involving sensitive information such as financial transactions and personal identification. Implementing encryption, authentication, and access control mechanisms can mitigate such risks by ensuring that only authorized RFID readers can access and process data from RFID tags. Furthermore, environmental factors such as interference from metal surfaces, water absorption, and signal obstruction can impact the performance of RFID communication. These challenges necessitate careful planning in RFID system design to optimize reliability and minimize errors in real-world deployments.

In the context of public transportation, RFID technology offers an effective and scalable solution for enhancing transit management, improving passenger experience, and optimizing resource utilization. By deploying RFID readers at bus stops and embedding RFID tags in buses, real-time tracking of bus movements can be achieved without requiring complex or expensive infrastructure. This enables commuters to make informed travel decisions based on accurate arrival and departure updates, reducing waiting times and improving overall transit efficiency. Additionally, transit authorities can leverage RFID-generated data to analyze travel patterns, optimize bus schedules, and allocate resources more effectively, leading to better operational planning and service improvements. The automation facilitated by RFID technology not only streamlines fleet management but also enhances passenger safety by

providing reliable tracking and monitoring capabilities. As urbanization continues to increase, the demand for intelligent public transportation solutions is growing. RFID-based bus tracking and monitoring systems present a viable approach to addressing the challenges of congestion, scheduling inefficiencies, and passenger uncertainty. The ability to provide real-time, automated updates on bus movements contributes to a more seamless and reliable commuting experience, ensuring that public transit remains an attractive and efficient mode of transportation. By overcoming challenges related to security, interference, and system integration, RFID technology can play a transformative role in modernizing transportation infrastructure and paving the way for smarter, data-driven transit management solutions.

## **RESEARCH METHODOLOGY**

The research methodology for the RFID-based Bus Tracking and Monitoring System is designed to ensure real-time, efficient, and reliable tracking of buses using RFID technology. The methodology follows a structured approach, covering various phases, including hardware selection, system architecture design, data transmission, integration with a web-based platform, and system evaluation. The primary objective of this methodology is to create a cost-effective and scalable solution for tracking buses, reducing passenger wait times, minimizing overcrowding, and enhancing public transportation efficiency.[5]

### **System Design and Hardware Implementation**

The proposed system is built around RFID technology, which is used to track bus arrivals at different stops. RFID readers are installed at designated bus stops, while each bus is equipped with an RFID tag containing a unique identification code. When a bus reaches a stop, the RFID reader detects the tag, reads the data, and transmits it to a microcontroller for further processing. This approach ensures that each bus's arrival is accurately recorded in real-time, eliminating the need for GPS-based location tracking, which can sometimes be inaccurate due to signal interference in urban environments. [8]

The microcontroller used in the system is NodeMCU, which has built-in Wi-Fi capabilities, allowing seamless communication between the RFID reader and the web server. The microcontroller processes the RFID data, formats it for transmission, and ensures that only valid data is sent to avoid errors. Additionally, an LCD display is integrated into the system at bus stops to provide immediate feedback, confirming the successful detection of a bus. This ensures that both passengers and bus stop administrators can verify in real-time whether a bus has been accurately detected and recorded in the system.[6]

### **Data Processing and Transmission**

Once the RFID reader detects a bus, the extracted data, including the bus's unique identification number and the timestamp of detection, is processed by the NodeMCU microcontroller. The microcontroller then transmits this data to a central web server using a Wi-Fi connection. This process follows a client-server model, where each RFID-enabled bus stop acts as a client, continuously communicating with the central server. The server receives and processes the incoming data, updating its database and ensuring that real-time bus arrival information is stored efficiently for further use.[5]

Unlike GPS-based tracking systems that require continuous monitoring of the bus's location, this RFID-based approach updates the bus location only when it reaches a stop. This reduces unnecessary data transmission, optimizes bandwidth usage, and ensures that network congestion is minimized. By focusing on stop-to-stop tracking, the system provides highly reliable location updates without requiring a constant stream of GPS signals, which can sometimes be inaccurate in dense urban environments.[2]

### **Web-Based Passenger Information System**

To make the real-time bus tracking information accessible to passengers, a web-based platform is developed. This platform is designed to provide live updates regarding bus locations, helping commuters make informed decisions about when to board a bus. The web server processes requests from users,

retrieves the latest bus tracking data, and presents it in a structured, user- friendly format. The website ensures accessibility on various devices, including smartphones, tablets, and desktop computers, making it convenient for passengers to check bus arrival times on the go.[4]

The system is also beneficial for transportation administrators, who can use the web platform to monitor bus movements, detect delays, and optimize scheduling. The interface is designed to be simple yet efficient, ensuring that even users with limited technical knowledge can access and interpret the data without difficulty. The ability to track buses in real time improves overall transportation efficiency, reduces waiting times, and enhances the commuter experience by providing accurate, up-to-date information about bus arrivals

## **Theory and Calculation**

The RFID-based Bus Tracking and Monitoring System operates based on the principles of radio frequency identification (RFID), embedded system communication, and real-time data processing. The system utilizes RFID technology to detect and track buses as they arrive at designated stops, with a microcontroller (NodeMCU) handling data processing and transmission, while an LCD display provides real-time feedback. This section explores the theoretical foundation behind RFID technology, the system's architecture, and the necessary calculations that ensure optimal performance in terms of detection, communication, and power efficiency Encryption.

### **1 RFID Technology and Working Principle**

RFID technology enables contactless identification through radio waves. It comprises two key components: RFID tags and RFID readers. RFID tags, which are placed on buses, contain unique identification numbers (UIDs) stored in an electronic chip. These tags are typically passive, meaning they do not have an internal power source but instead rely on energy from the RFID reader's emitted signal. When a bus equipped with an RFID tag comes within range of an RFID reader installed at a bus stop, the reader generates an electromagnetic field that powers the tag. The tag then modulates and transmits its unique identifier back to the reader through backscatter communication.

The RFID reader, upon receiving the UID, sends it to the NodeMCU microcontroller for processing. The microcontroller verifies the UID against a pre-defined list of authorized buses and then relays the bus arrival information to an LCD display for passengers. Additionally, the NodeMCU transmits this data to a web-based platform for live tracking of bus locations, ensuring real-time updates for users.

## **RESULT & DISCUSSIONS**

### **User cases and sequences**

The RFID-based Bus Tracking and Monitoring System operates through a structured sequence of events, ensuring seamless interaction between buses, RFID readers, and the web server to provide real-time location updates. The system is designed to serve multiple user groups, including commuters, transportation administrators, and maintenance personnel, each benefiting from the system's ability to track bus movement efficiently. The use cases involve various real-world scenarios where the system enhances the overall commuting experience by minimizing uncertainty regarding bus arrivals, reducing waiting times, and improving fleet management operations.

#### User Case: Commuter Checking Bus Arrival Information

One of the most critical user interactions occurs when a commuter wants to check the real-time location of a bus to decide whether to board it or wait for another. The sequence begins when a bus approaches a stop, and its RFID tag is detected by the RFID reader installed at the bus stop. The reader captures the tag's unique identification number and forwards it to the NodeMCU microcontroller, which processes the data and transmits it to the web server. The updated bus arrival information is then displayed on the web application, allowing passengers to view the bus's last detected location. Since the system works in real-time, commuters can accurately assess whether the bus is on schedule or delayed. This eliminates the uncertainty and frustration often associated with unpredictable bus arrival times, ensuring that passengers can plan their journeys efficiently.

The system also improves accessibility for users who rely on public transportation for daily commuting. By providing accurate location tracking, it prevents commuters from having to wait for prolonged periods at bus stops, particularly in extreme weather conditions or unsafe environments. Additionally, the web-based interface allows users to access this information from anywhere, further enhancing convenience and user experience.

#### User Case: Bus Approaching a Stop and Updating System

Another essential process occurs when a bus arrives at a designated stop, requiring the system to update its location in real-time. As the bus moves toward a stop, the RFID reader installed at the bus stop detects the approaching bus's RFID tag. The NodeMCU processes the data, recognizing the bus ID and associating it with the corresponding route. The information is then transmitted to the web server, which updates the database and makes the latest bus arrival details available to passengers through the web application.

## CONCLUSION

This seamless exchange of data ensures that the system accurately reflects the latest movement of buses without requiring manual intervention. Unlike traditional systems where bus drivers or station operators manually update arrival times, this automated RFID-based approach significantly reduces errors and delays in reporting bus location updates. Additionally, since RFID detection occurs instantaneously, the update process remains efficient and scalable, even when deployed across large fleets of buses. From a transportation management perspective, the RFID-based system offers significant advantages in fleet supervision, route optimization, and operational efficiency. Administrators can use the system to track the movement of multiple buses in real-time, allowing them to identify delays, bottlenecks, or deviations from planned routes. The web application provides an interface where administrators can view bus arrival logs and assess whether buses are operating according to schedule. If a particular bus experiences an unusual delay or repeated inconsistencies in its arrival pattern, corrective measures such as rerouting or adjusting schedules can be implemented to optimize the overall efficiency of the fleet. In cases where buses experience technical issues or require maintenance, the system allows administrators to pinpoint their last known location, ensuring that assistance is dispatched efficiently. Furthermore, the historical data generated by the system can be analyzed to gain insights into traffic patterns, peak travel times, and areas with high passenger demand, helping transportation authorities make informed decisions regarding service improvements.

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