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Real Time Bus Fare Collection Using Embedded and IoT

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Abstract

Challenges arise as the public transport fare collection process becomes complicated, inefficient, and prone to error by man due to mistakes such as a faulty human error prone fare evasive and also lengthy processing times. This work focuses on creating an RFID-Based Bus Ticketing and Stage Switching System based on NodeMCU to deal with these challenges. The proposed system automatically collects fares and tracks the stages by scanning RFID cards at the time of boarding and alighting, facilitating the computation of fares according to the number of stages traveled. The NodeMCU microcontroller processes RFID data, integrates stage-switching for updation of fares, and uses IoT to send real-time data to the central server for efficient management. Reduced human error, reduced fare evasion, efficiency, and scalability make it a cost-effective solution for modernizing public transportation ticketing systems.

Keywords: *RFID, Automation, Stage Tracking, Fare Calculation, Real-Time Data, Public Transit, Efficiency.*

1) INTRODUCTION

The RFID-Based Bus Ticketing and Stage Switching System, in turn, represents one important innovation that shall make bus transport systems become very modernized, hence avoiding old modes of fare collection methods in most bus routes today, where these have relied primarily on human processes for issuing the ticket, transacting with coins or work currencies. This system aims to eradicate the above disadvantages by using radio frequency identification with the help [1] of IoT, leading to a smarter ticketing service, increased efficient operation, and enhanced passenger convenience.

In conventional bus fare collection systems, passengers must rely on work tickets, tokens, or cash payments, which can lead to long boarding times, disputes over fare amounts, and the risk of losing or damaging tickets. Furthermore, manual fare collection is time-consuming for bus operators and increases the likelihood of fare evasion, affecting the revenue generated by public transportation services. A better and smarter system will be brought in because the real benefit of this RFID-based system would be upon passengers. The passenger could now board and alight from a bus without having to show their tickets; they simply need to scan their RFID cards.

Each passenger is given an RFID card that contains a unique identifier and is linked to his account in the system. Upon entering the bus, the RFID card is read by a reader installed on the bus, and the system records [2] the boarding stage. In this case, when the passenger gets off, the system scans the card, and automatically works out the fare using the number of stages covered. In this way, there is no manual work involved to find out the fare, hence they always pay the fare and no scope for an error.

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The NodeMCU microcontroller works as the central core in the system since it will collect all the data from the RFID reader and works for communication with the central server. It is the brain of the system [3], calculating the fare by the number of stages traveled and also keeping count of the stages covered as the bus transverses the pre-specified zones. The system is set to track passengers' journey correctly such that fares are computed just and in real-time. The integration of IoT allows the NodeMCU to send data to a central server, which enables transit authorities to monitor the bus's progress, track the number of passengers, and analyze transit data for better decision-making and operational optimization. The most important feature of the system is the stage-switching mechanism, which automatically updates the stage count as the bus moves through different predefined zones.

This mechanism allows the fare to be correctly computed, depending on the distance taken by the passenger. Also, there is reduced fare evasion risk since the system ensures that passengers are charged for traveling. There is no scope for passengers [4] to avoid the fare since the RFID card is scanned at both boarding and alighting. Additionally, the system improves the overall management of bus routes and schedules. Using real-time data transmission, transit authorities can track the location and status of each bus in the fleet. This allows for improved bus coordination, reduced passenger waiting times, and enhanced bus operations. The data collected by the system can also be analyzed to gain insights into passenger behavior, peak travel times, and route performance, which can inform future improvements to the public transportation infrastructure.

The RFID-Based Bus Ticketing and Stage Switching System using NodeMCU is a cost-effective and scalable solution for modernizing public transportation systems. The integration of RFID technology and IoT brings it much closer to traditional ticketing [5] methods, making fare collection more accurate and efficient, reducing operational costs, and improving passenger satisfaction. Its flexibility and ease of implementation make it an ideal solution for cities and transit authorities looking to modernize their fare collection systems and provide a more convenient and efficient service to their passengers. Through the use of advanced technology, this system promises to contribute to the growth and development of smart cities and sustainable transportation systems in the future.

This work is organized as Section II presenting a review of the literature survey. Section III describes the methodology, highlighting its key features and functionality. Section IV discusses the results, analysing the system's effectiveness. Lastly, Section V concludes with the main findings and explores future implications.

2) LITERATURE SURVEY

The System discussed existing research and technological advancements in the context of automated fare collection and management of public transport. It is evident that the traditional ticketing system suffers from several challenges like fare evasion, inefficiencies, and human error. Therefore, RFID-based technologies have gained significance in simplifying the fare collection process. With the use of IoT-based systems, real-time monitoring and data transmission are achieved. Previous researches have shown that the integration of these technologies can be effective in enhancing operational efficiency and passenger experience. This survey aims to analyze current solutions and identify gaps for further innovation in public transportation systems.

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The metro railway ticketing system has introduced a new way of travel with the focus on improving the travel experience by eradicating the problems [6] of ticketing. The biometric-based system, based on fingerprint recognition for registration, ticket purchase, and travel authentication, provides a hassle-free and secure journey. With the Arduino interface and fingerprint sensor, the system ensures safe and efficient travel with unique identification for every traveler. This innovative system will make commuting easy and convenient, reducing the hassle of traditional ticketing methods. The solution can revolutionize ticketing for metro systems, thus ensuring safety and ease of access.

A hybrid travel and parking ticket pass system has been developed for the UAE transport services with the aim of streamlining the user experience. The system, using RFID technology, offers an integrated solution for travel and parking, which increases automation and [7] convenience. The system also provides security in transactions using blockchain, addressing wallet sharing and international payment limitations. The system does away with the traditional work tickets, providing a digital and accessible solution to transportation challenges. It unifies multiple services at one platform and thus is helpful to manage the travel and parking facilities of the citizen conveniently. Blockchain technology is under study for solving security issues in e-ticketing systems. Due to the recent surge of ticket fraud and scalpers, this work reviews the application of blockchain as a secure alternative to the central system. Discussing the role of [8] blockchain in the improvement of ticket management, distribution, and payment through an analysis of various studies, the work emphasizes the use of platforms like Hyperledger and Ethereum, along with innovations such as RFID and NFTs, which promise the enhanced security and functionality of e-ticketing. Through this research, the challenges and opportunities of blockchain in transforming the e-ticketing landscape are well presented.

A passenger travel tracking system has been proposed using an IoT-based web application to improve the efficiency of public transportation. The system [9], integrating RFID, GPS, and IoT technologies, allows for automatic fare calculation and passenger identification. The solution replaces traditional work tickets with a reusable and more accurate method for fare collection. This approach reduces human errors and simplifies the process, providing a more streamlined experience for commuters. The system addresses not only the inefficiencies of work-based systems but also a more secure and ethical transport service.

A proposed IoT-based smart parking system with e-ticketing addresses the problem of traffic congestion and inefficiency in urban parking. By using RFID technology and Arduino, the system provides automated parking fee deductions and real-time display of available [10] parking slots. This eliminates the need for physical money transactions, reducing delays and improving traffic flow. The user-friendly system simplifies parking in multi-complex areas, offering a seamless experience for vehicle owners. The integration of RFID for identification and payment streamlines the process and enhances urban mobility in smart cities.

A cloud-based system has been developed to optimize passenger experiences in bus fare ticketing using machine learning algorithms. The system, using the Random Forest algorithm and cloud technologies, predicts [11] passenger demand and adjusts fares in real time, thereby making the ticketing process more efficient. The system analyzes historical data, weather, and events to provide dynamic pricing and route optimization. This solution improves both the passenger experience and the overall system performance, making public transportation more responsive. It offers scalable solutions for various city sizes, thus helping create more efficient, passenger-centric urban transport systems.

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The RFID-based Smart Public Transit System improves the efficiency of public bus transportation by addressing common issues like long waiting times, ticket collection, and seat availability. The research emphasizes the role of advanced technologies such as electronics [12], communication, and control systems to optimize transportation management. Through real-time monitoring and communication, the system alleviates traffic congestion, enhances safety, and provides accurate, up-to-date information for passengers and officials. The use of RFID technology with GPS and other sensors streamlines passenger tracking, improves the overall experience for users and drivers, and contributes to the sustainable development of the transportation system.

The IoT integration in fare payment systems for buses is presented as a solution to the common issues of fraud and ticket loss, especially in densely [13] populated areas. The system tracks the entry and exit of passengers by using RFID and GPS technology, ensuring secure and efficient fare collection. This will help in reducing the journey length of passengers, as it provides an easy card system, limits human error, and reduces evasion of fares. Furthermore, the system has increased monitoring for transport officers, hence allowing smooth operation. It has improved convenience and relieved the burden both on the passenger and driver sides.

Parking and traveling ticket automation are essential in urban areas in curbing congestion and increasing efficiency. Traditional systems mostly involve manual payment and ticketing, which takes [14] a lot of time and tends to make a lot of mistakes. This work describes recent advances in parking and public transportation automation, especially in terms of innovative solutions such as RFID and automation of fare collection. These technologies aim at simplifying the user experience by introducing less human dependency, ease of real-time update, hassle-free ticketing, and better management of both parking and transportation systems. It contributes to improving better service, reduction in congestion, and effective urban mobility.

The research aims at the performance of RFID tags implanted in electric safety tools by studying their communication characteristics and how the material properties, such as dielectric constants and implantation depth, affect the performance of the tag. It is done by software simulation and experimental [15] testing to analyze the effects on the RFID transmission range and signal strength. The results show that when RFID tags are implanted into safety tools, performance degradation due to the material surrounding them occurs. The obtained results are essential in enhancing the reliability and performance of RFID-based safety systems used in tools so as to perform efficiently in better safety and communication industrial applications.

The work looks into the difficulties encountered by passengers at train stations characterized by long queues and ticketing systems. It suggests a solution to automate passenger verification through face recognition technology, which allows for faster and more secure access to trains. Cameras are installed [16] at the entrance of the train, and the identity of the passengers is verified through face recognition algorithms, thus eliminating the need for physical tickets. This system not only speeds up the verification process but also reduces the potential for human errors and enhances security. It also helps improve the general passenger experience of travel while making sure the process is effective, on schedule, and even comfortable for everyone using the commute services.

This non-parking zones' automated penalized system attempts to curb unregulated parking. By employing the location sensors as well as number plate recognition for the vehicle, it detects any parked vehicle within restricted areas.

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This would identify that [17] the driver must have violated by his car without further action having been taken or with a violation in which action could be triggered with RFID technologies by deducting fines from cars automatically, sending an automatically-generated receipt to him. It erases the hands of man during intervention, instead promoting efficiency at parking regulations through their enforcement and reducing congestion hence smoothing out other traffics within nondenoting nonparking areas that enhance and orderliness.

The IoT-based solution for public transportation improvement in Sri Lanka addresses concerns such as bus delays, overcrowding, and the inefficiency of manual ticketing. The system [18] supports real-time updates of locations, time to estimated arrival, and seat availability via a mobile application, while an automated fare collection system with RFID technology replaces cash transactions and reduces delay time. The system will include a face recognition-based authentication process that ensures security of the passenger. This will, in return, improve quality and accessibility for the public transport service, therefore bettering the life of the commuter of Sri Lanka in daily life.

This research puts forward an automatic fare collection system specifically designed to facilitate visually impaired individuals to ease their experience using public transport services. The system calculates a fare based on the distance travelled during a passenger's journey [19] by using RFID tags, IR sensors, and GPS technology. It offers an accessible solution for passengers with visual impairments.

To assist users in boarding and deboarding the transport, audio feedback has been provided via speakers and eliminated visual input. This all-inclusive principle made public transport much easier to access, allowing even people with vision problems to travel with minimal dependency on conductors or other passengers to guide them while traveling, thereby making the travel experience less discriminatory.

The smart gravimetric system also supports security at access points for public transport by detecting abnormal behavior, such as two people using the same ticket to get into the bus or a person with special needs passing through access points. The system monitors and classifies events at entrances through load cells [20] and embedded microcontrollers. Real-time data are available for security personnel to respond appropriately. For event classification, the system utilizes the MobileNetV2 neural network to make it portable and energy efficient. Edge computing and neural networks make the system better in security and monitoring, but it has fewer installation costs and complexities. The approach can be implemented in various public places to enhance access control and safety.

3) METHODOLOGY

The methodology for the RFID-Based Bus Ticketing and Stage Switching System is to design the system architecture, which involves integration of RFID technology, NodeMCU microcontroller, and communication protocol for real-time data transmission. A block diagram is designed for mapping the connection between the various components to ensure smooth operation.

The design ensures minimal human error and fare evasion while optimizing the overall efficiency of the ticketing system. Proper integration of every part is critical for accurate fare calculation and stage tracking, thus offering a user-friendly experience to the passengers and effective management to the transit authorities.

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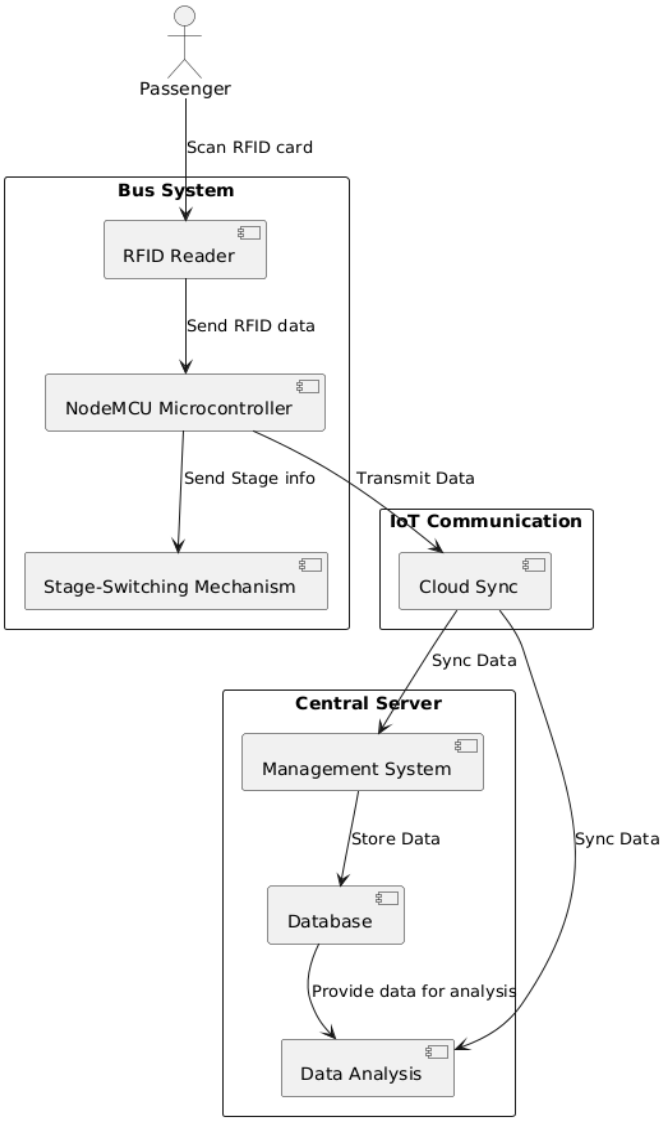

Fig 1: Architecture Diagram

A. RFID Technology Integration

The RFID technology is used to automate the fare collection process. Every passenger is given an RFID card that contains a unique identifier. The bus is provided with an RFID reader that scans the card when the passenger boards and alights. The system uses the scanned data to track the passenger's journey and determine the fare based on the number of stages traveled. This method eliminates the need for manual ticketing and reduces the chances of errors in fare collection. RFID technology also allows for a quick and convenient boarding process, improving overall efficiency and passenger satisfaction.

B. NodeMCU Configuration

NodeMCU is configured as the core controller for processing the RFID data. It is programmed to interface with the RFID reader to capture data as passengers board and exit the bus. The microcontroller calculates the fare by determining the stages traveled using the stage-switching mechanism. NodeMCU also facilitates communication between the bus system and the central server for real-time data transmission. Through this integration, it ensures smooth

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operation and timely updates to the fare and stage counts. It monitors every passenger's movement. It correctly computes the amount charged to them. The risk of fare evasions is further minimized.

C. Stage Change Mechanism

The number of stages the passengers have moved will be found through the mechanism for stage-changing. This will make the machine sense the different stages while moving between designated zones and count the exact stages changed. It sends real-time information to the NodeMCU on the bus's location so that the system is able to track the stages properly. The passenger's fare is computed based on the number of stages so that he or she is charged accordingly. This automatically removes the process of manual tracking and reduces errors. It also helps in charging the passengers justly, which enhances the efficiency and reliability of the system.

D. Real-Time Data Transmission

Real-time data transmission is a fundamental component of the RFID-Based Bus Ticketing and Stage Switching System. NodeMCU sends the processed fare and stage data to a central server through IoT communication. This server manages the collected data, providing real-time reports on passenger counts, fare collections, and stage transitions. This system will allow the transit authorities to check or monitor remote routes and passenger movement for effective operation or intervention in case an issue arises. The communication through IoT will facilitate the ticketing system management in a smooth way; even with continuous changes, it guarantees the better decision-making of service levels.

E. System Testing and Optimization

The system is tested for thorough optimization and reliability. Testing involves simulating passenger transactions, checking whether the fare is correctly calculated, and whether the stage-switching mechanism works properly. The following scenarios are tested: passengers board and alight at different stages. This way, proper tracking is ensured. The performance of NodeMCU is monitored for stability, and data is processed efficiently without any delay. Optimizing the system means removing bugs or inefficiencies that come up during testing. This phase is essential for ensuring that the system is reliable and ready for deployment in real-world conditions.

F. Deployment

After successful testing, the RFID-Based Bus Ticketing and Stage Switching System is deployed in the real world. RFID readers are installed on buses, and each passenger is provided with an RFID card for boarding and alighting. The NodeMCU microcontroller and the stage-switching mechanism are integrated into the buses, which enable automated fare collection and stage tracking. The central server receives real-time data from the buses, allowing transit authorities to monitor operations properly. As part of the deployment phase, the user is trained, and the system is set up to ensure smooth implementation. The system is monitored continuously for efficiency and to overcome any operational challenges encountered.

G. Maintenance and Upgrades

Post-deployment, the system is constantly maintained for peak performance. Firmware updates are carried out to add new features, improve security, and ensure future technological compatibility. Data from the central server is analyzed continually to look for patterns in the

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flow of traffic or peak hours that could be used to adjust bus schedules or fare structures. Additionally, maintenance checks are carried out on the RFID readers and NodeMCU microcontrollers to ensure proper functionality. Upgrades and improvements are made based on feedback from users and transit authorities, ensuring the system remains effective, scalable, and cost-efficient for future use.

4) RESULT AND DISCUSSION

The RFID-Based Bus Ticketing and Stage Switching System has demonstrated great potential towards improving the collection of fares in public transportation efficiency and accuracy. The system has successfully automated the process using RFID technology, thus reducing the chance of human error. With the RFID cards, passengers can quickly board and alight from the bus with a very smooth and fast ticketing process. This automation has allowed for a smoother flow of passengers, reduced waiting times, and general convenience. Besides, the fact that the number of stages passed is tracked enables the system to calculate the right fare, thereby making the entire process more transparent to the passengers.

The system has been streamlined further by using the NodeMCU microcontroller, which can transmit and process data in real time. The NodeMCU captures the RFID data very efficiently and calculates the fare based on the number of stages. It means that passengers will be charged for the right distance traveled. Also, with real-time sending of data to a central server, transit authorities can monitor the operations of the bus remotely. The real-time updates enable authorities to track the status of buses, identify operational issues, and optimize routes and schedules based on passenger demand.

Stage-switching has been effective for counting the actual number of stages traversed by the bus as it moves from one predefined zone to another, updating the count automatically. As a result, passengers are charged based on the actual distance traveled. This has done away with the need for manual stage tracking, which is prone to errors and inconsistencies. The integration of the stage-switching mechanism with the NodeMCU microcontroller has ensured that the fare calculation is precise, further enhancing the system's reliability.

The real-time data transmission of the system has also enabled better management of the public transportation system. The data collected by the central server, as well as the processing by various buses, provides various insights into fare collection, passenger flow, and more. It can be analyzed to optimize operations, routes, and fare structures through various passenger trends. Transit authorities can identify bottlenecks in the system, schedule adjustments, and optimize resource allocation toward better outcomes within the transportation network.

From a technical point of view, the system has proved to be reliable and scalable. In this regard, the NodeMCU microcontroller has been strong in handling more than one input from the RFID reader and the stage-switching mechanism. The capability of the system to send the data to the central server within no time is such that the ticketing process is not hampered at any moment. This increases the scalability of the system by making it applicable to different public transportation environments. As the system expands, it is easy to add more buses and RFID cards to the network, which makes the solution highly flexible and cost-effective.

However, there are challenges that need to be addressed. While the system is quite reliable, there can be issues sometimes with the RFID reader in the form of misreads or interference that causes a fault in the calculation of fares. More robust hardware or error-checking mechanisms in the software could overcome such problems. Also, because it depends

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on IoT connectivity, a problem with network communication can disrupt the system's transmission of data. Offline functionality or data buffering techniques can be integrated to ensure that the system will continue to work even when network connectivity is interrupted.

The RFID-Based Bus Ticketing and Stage Switching System has been proven to be a viable solution in modernizing public transportation. By automating fare collection and stage tracking, the system has enhanced both passenger experience and operational efficiency. The integration of RFID technology, NodeMCU, and IoT communication has created a scalable and flexible platform that can be adapted to different public transportation systems. The data-driven approach allows for better decision-making, helping transit authorities optimize routes and schedules. Despite some challenges, the system shows great promise for widespread adoption in public transportation networks, contributing to smarter, more efficient urban mobility solutions.

5) CONCLUSION

In conclusion, the RFID-Based Bus Ticketing and Stage Switching System can be considered the most effective and efficient solution that can modernize public transportation in the future. The system would automate fare collection and reduce human errors to a certain extent, because it uses the RFID technology and allows passengers to board the buses in a streamlined process, faster boarding, and even ensures accurate calculations of fares taken based on stages traveled. The NodeMCU microcontroller has helped in the process of real-time data processing and transmission without interference, thus increasing the management and operation of public transit authorities. Real-time monitoring and reporting capability helps authorities make proper decisions based on data, further optimizing routes and resource allocation. The stage switching mechanism has thus eliminated manual tracking, ensuring that fares are calculated to be accurate and consistent. The system can easily be scaled to suit any public transportation network through IoT-enabled communication. Furthermore, the central server can analyze data regarding passenger flow, operational efficiency, and fare collection to facilitate continuous improvements in service delivery. However, the occasional RFID misreads and network connectivity issues that occur are minimal and can be rectified through hardware improvement and additional software checks. Overall, it is a superb example of how all three technologies- RFID, IoT, and microcontroller-can collectively form an intelligent and efficient public transportation system. The advantages are obvious in the dimensions of convenience, accuracy, and operational efficiency. This position this technology as a scaled and cost-effective solution for modern urban mobility. The research proves RFID-based systems to be capable of improving public transport; the great perception has been given here for further development and deployment across cities.

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