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Sahaj Yatra: A Digital Approach to Transportation

Aayush Shrestha [a], Dikshyanta Aryal [b], Pramis Gurung [c], Santosh Kumar Rajbhandari [d]

[a, b, c, d] *Department of Electronics and Computer Engineering, Paschimanchal Campus, IOE, Tribhuvan University, Nepal*

[a] aayushstha54321@gmail.com, [b] adikshyanta456@gmail.com, [c] gurungpramis361@gmail.com, [d] newasantosh2001@gmail.com

Abstract

This is a digital bus fare management system, which address the problems faced by both passengers and bus owners in fare collection. This system utilizes RFID-based scanning and the NodeMCU for hardware integration. The system aims to enhance the passengers experience and improve operational efficiency by offering seamless fare validation and convenient payment options. This project aims to provide a fair fare management system providing consumers with a easy and hassle free experience. The passengers will be issued RFID cards, which will be scanned by onboard RFID scanners installed on buses to deduct the fare amount in real-time. The Node server will handle user registration, fare deduction, recharge history, and transaction logs, all of which will be saved in a database, ensuring secure storage and efficient data management. Moreover, the passengers will be able to track the bus in real-time, helping them manage their schedule accordingly. Additionally, they will be provided with the facility to recharge their cards using local payment methods, enabling a hassle-free experience. The bus operators will be provided with the facility to get an overview of the details of buses owned by them. The proposed Digital Bus Fare Management System brings efficiency and convenience to the existing transportation system, improving the daily lives of millions of passengers and introducing a hassle-free service for both passengers and bus operators.

Keywords

Database, GPS, Nodejs, NodeMCU, RFID, Transaction logs

1. Introduction

As the population is increasing rapidly, especially in city area, one of the many issues is transportation management. Anyone who had travelled in public buses can only understand the difficulty and headache of travelling in our public buses. Public buses are always crowded and if not are waiting for passengers. Reason of the crowded buses is not only due to insufficient number of vehicles but also poor management system. Infrequent service intervals can lead to overcrowding, as passengers tend to accumulate while waiting for the limited number of vehicles. Another reason is certain routes or lines may experience heavier passenger loads due to population distribution or specific destinations, causing congestion.

AFC system aims to revolutionize the public transportation system. This system involves IC card, mobile app, server. Passenger scan IC card once they get into the bus and scan again while getting off the bus. The server calculates the fare according to the distance he/she has travelled. Whole system is autonomous, passenger just has to load money to the account using mobile application. Passenger can also track different buses available in area using the app. Owner of the bus also has dashboard that shows revenue collected. Buses can be sent to the area, where there are large number of passengers during pick hour.

Thus, implementing solutions that reduce overcrowding helps enhance passenger safety and reduces the risk of accidents or incidents. Passengers experience shorter wait times and reduced travel durations, making their journeys more convenient and time-efficient. Also reduces stress and anxiety among passengers and driver. Overall, implementing solutions to address crowded public transportation improves the overall quality of public transportation services, enhances the passenger experience, and promotes sustainable and efficient urban mobility.

1.1 Problem Statement

The existing system relies on paper tickets or cash transactions, leading to inefficiencies such as time-consuming ticketing processes, potential errors, and delays for passengers and bus operators. Cash transactions onboard buses also create challenges in terms of handling change, accounting, and security risks.

The current lack of a reliable real-time tracking system poses several issues. Firstly, without accurate real-time tracking data, it becomes difficult to provide passengers with timely and accurate information regarding bus arrival times, leading to inconvenience and frustration. Secondly, ineffective resource allocation due to the absence of real-time tracking can result in inefficient bus deployment, overcrowding on certain routes, and underutilization of buses on others[1]. Furthermore, the lack of a robust tracking system makes it challenging to track the maintenance needs, fuel consumption, and overall performance of the bus fleet, resulting in increased costs and reduced reliability. These limitations underscore the importance of implementing a reliable bus tracking system to enhance passenger information, optimize resource allocation, improve route planning, and ensure effective fleet management in the transportation system.

1.2 Objectives

The objectives of this system is to:
• Integrate the digital payment system with existing bus infrastructure to create a modern and data-driven transportation network.

2. Literature Review

The use of RFID and gps module for bus tracking and digital fare management has been the subject of numerous studies in the literature.

The study on potential of public transport smart card data by Bagchi, M., White, P. R. (2005) explores the potential of smart card data analysis in understanding passenger behavior, planning services, for improved decision-making.[2]

The research by Bonneau, W. and editors (2002) on the role of smart cards in mass transit systems examines the benefits and applications of smart cards in mass transit systems, including their impact on fare collection efficiency.[3]

Another research conducted by Clarke, R. (2001) on Person location and person tracking: Technologies, risks, and policy implications discusses person location and tracking technologies, including smart cards, and explores associated risks and policy implications.[4]

Smart card evolution by Shelfer, M., Procaccino, J. D. (2002) discusses the evolution and applications of smart card technology, including its relevance in transportation systems.[5]

Origin and Destination Estimation in New York City with Automated Fare System Data done by Barry, J. J., Newhouser, R., Rahbee, A., Sayeda, S. (2002) explores the use of automated fare system data for estimating origin and destination patterns in New York City.[6]

Design and development of GSM and GPS (Global Positioning System) tracking module by U. Bharavi and R. M. Sukesh (2017) discusses the design and development of a GSM and GPS tracking module, highlighting its potential applications in tracking and monitoring systems for fleet management, and location-based services.[7]

Automatic bus fare collection system by using GPS and RFID technology by Karthika J, Varshanapriyaa S, Sai Haran S, SuriyaPrakash C (2020) discusses the effectiveness of automatic fare collection system compare to ticket based system. They discuss the paper based ticket system being one of the reason for financial loss in transportation in India.[8]

The Use of Smart Cards in Transportation Systems: A European Perspective by C.M. Shield, P.T. Blythe (2017) discusses the use of smart card technology in the field of transport applications. They review some major areas of application and cites some of the more innovative implementations of the technology in Europe. The paper covers both contact and contactless (proximity) smart cards for transport applications, used on their own as a payment and information carrier device, or with a reader to provide contactless communications.[9]

RFID networks: hardware, software, and services explains the methods and technologies of large-scale mobile computing systems enabled by RFID by George Roussos (2008), placing them within the framework of particular case examples. The basic concepts of RFID technology are covered in the work, along with the essential system elements, operational principles, and performance trade-offs related to the choice of particular RFID platforms.[10]

Bus fare collection system using RFID and GPS bus fare collection system using RFID and GPS by Shazid Bin Zaman, Richard Victor Biswas and Eftakharul Islam Emon (20023) eliminates the need for paper tickets, offers onboard ticket inspection, and possibility of introducing spatial validation elements to enhance its usefulness.[11]

3. Methodology

The methodology for integrating the digital payment system with existing bus infrastructure involves several key steps, including hardware integration, software development and system assembly. These steps are essential to ensure the successful development and implementation of our purposed system.

3.1 Sytem Requirement

The system requires the following hardware components: RFID cards and scanners for passenger identification and fare processing, GPS modules for real-time bus tracking, a central microcontroller to manage data from sensors and communicate with other components, a Wi-Fi module for connection to the backend server, and a reliable power source. The system utilized a Neo-6M module for GPS functionality, an MFRC-522 module for RFID scanning, and a NodeMCU board as the microcontroller and Wi-Fi module.

For the software side, Node.js was chosen for the backend server due to its efficiency with multiple requests. This server manages user accounts, calculate fares, store bus location data, and communicate with the user interface. React.js, was used to create user application. Passengers will interact with this app to view bus locations and potentially manage accounts. Finally, MongoDB was used to store user information, bus real time location , transaction,etc.

3.2 Haversine Formula

Haversine formula is an accurate way to compute distance between two points on the surface of sphere using latitude and longitude. The system records the boarding and alighting locations (latitude and longitude) when the passenger scans their RFID card. System employs the Haversine formula to measure the distance between these positions. The bus fare is determined by the distance traveled, and it is then deducted from the user's account.
Haversine formula is given as:

$$a = \sin^2\left(\frac{\Delta\Phi}{2}\right) + \cos\Phi_1 \cos\Phi_2 \sin^2\left(\frac{\Delta\lambda}{2}\right)$$

$$c = 2\arctan 2\left(\sqrt{a}, \sqrt{1-a}\right)$$

$$d = R \cdot c$$

where,
Φ (Phi): Latitude (in radians)
λ (Lambda): Longitude (in radians)
R: Radius of the Earth (6,371 km)

3.3 System Diagram

The basic block diagram of the system "Digital Fare Management System" shows connection between components. In the circuit diagram, there are mainly seven

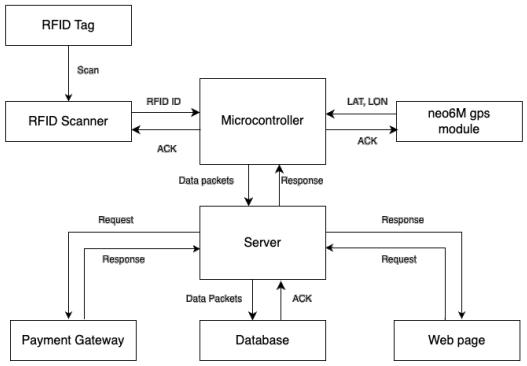

Figure 1: Block diagram

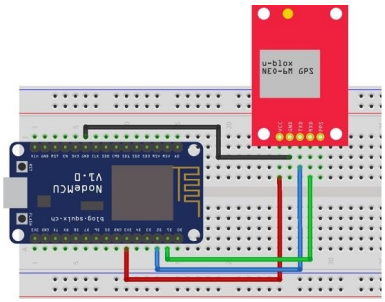

Figure 2: Connection between nodemcu and neo-6m gps module

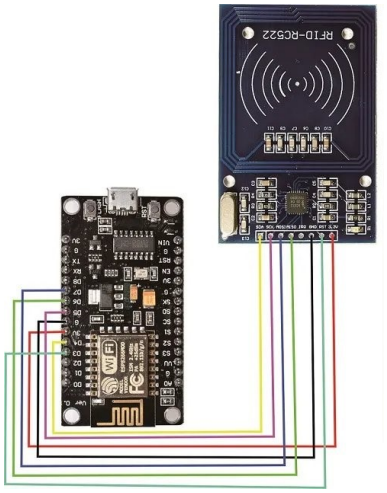

Figure 3: Connection between node mcu and RFID reader

components they are: buzzer , led, resistor, nodemcu, rfid scanner, power supply, neo-6m gps module. In nodemcu, 11 pins D0, D1, D2, D3, D4, D5, D6, D7, D8, 3V, GND pin and micro usb type A port were used. In rfid scanner 7 pins SDA,

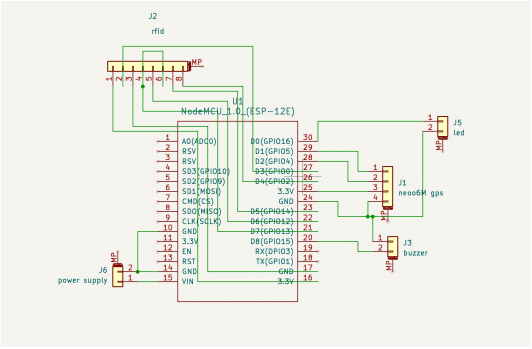

Figure 4: Circuit Diagram

SCK, MOSI, MISO, RST, 3.3V, GND pin were used.In neo-6m gps module, 4 pins Rx, Tx, Vcc, GND pin were used.

Following circuit connection were made between RFID Scanner and NodeMCU. 3.3V of RFID to 3V, RST to D3 pin, SDA to D4, SCK to D5, MOSI to D6, MISO to D7, GND to GND. These connection set up communication between the RFID scanner and the NodeMCU utilizing the serial peripheral interface (SPI) convention. NodeMCU to Neo6m GPS Module.D1 to TX, D2 to RX, VCC to 3V, GND to GND. The positive terminal of buzzer is connected to D8 pin. Positive terminal of LED connected with Resistor to D0 and negative terminal to GND. Power is supplied through micro usb a port.

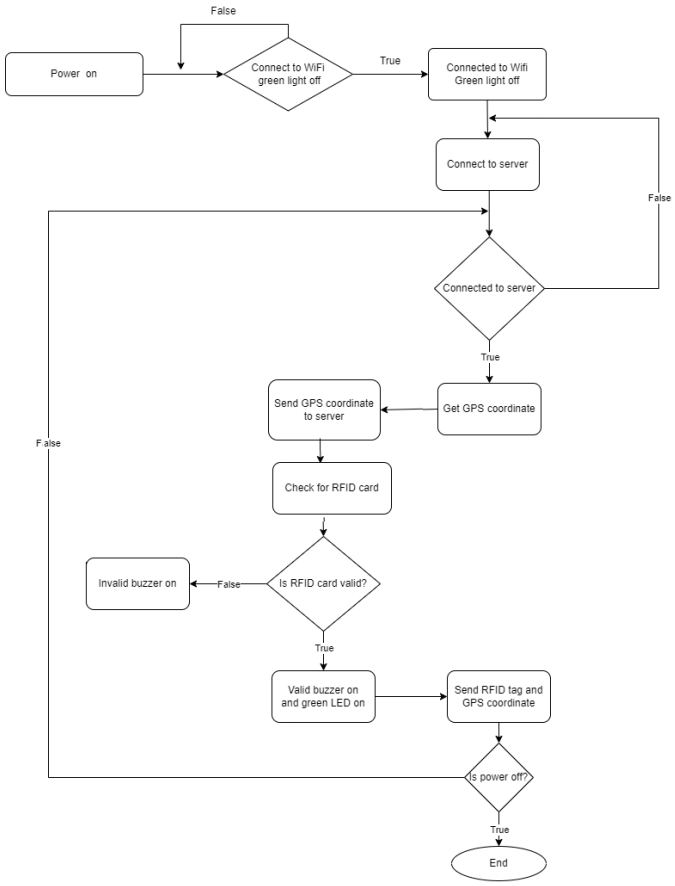

Figure 5: General Work Flow of System

The flowchart explains how the system work in real time. The scanning device attempts to connect to wifi when its green LED is lit up or power is on. After the device has connected to the

wifi, the green light will turn off and it will attempt to connect to the server. Once connected, it will retrieve the bus's current GPS coordinate and send it to the server. The device is now prepared to read RFID cards. The RFID reader will read the card and perform a validation check if it is positioned less than five centimeters away from it. The buzzer will sound invalid sound if the card is invalid; otherwise, it will sound valid beep if the card is legitimate. The RFID tag log with the current GPS coordinate is provided to the server after the RFID card has been confirmed. Until the power is turned off, this cycle will continue.

3.4 Software Flowchart

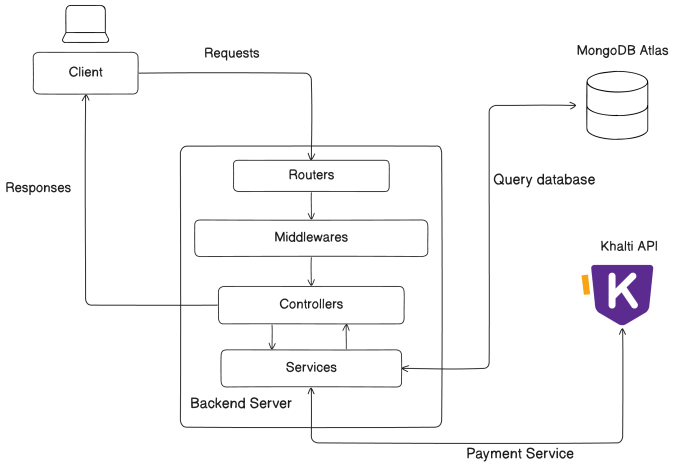

Figure 6: Software Flowchart

A backend server has components like routers, middleware, controllers, and services to manage incoming requests and data flow. Requests from clients are first routed through the server's routers, which direct them to the appropriate endpoints. Middleware layers intercept these requests, providing essential functionalities such as authentication, logging, and request preprocessing. Following middleware processing, requests are handed over to controllers, responsible for executing business logic and coordinating interactions with databases or external services. Controllers delegate tasks to services, encapsulating application logic, data manipulation, and service integrations, such as interacting with a MongoDB database for data storage and retrieval. Additionally, if the request involves payment processing, the services interact with payment gateway Khalti to facilitate transactions securely. Once operations are completed, responses are crafted and returned to clients, completing the server's workflow. This structured approach ensures efficient request handling, modular development, and scalable architecture within backend systems.

4. Features and Functionalities

Features and functionalities of Digital Fare Management System:

4.1 User Authentication and Access Control

- Secure login for admin, owners and passengers.
- Role based access control to ensure appropriate access to system functionalities and data.

4.2 Passenger Management

- A new general user or passenger can be registered and then login.
- User can view available balance and can load balance using khalti payment gateway.
- User can view buses locations and know the exact time of arrival of bus.

4.3 Owner Management

- A bus owner can be registered and login.
- Bus owner can request to add new bus and remove registered bus.
- User can view daily revenue collected.
- Owners can view their buses live location.
- Owners can analyse their revenue in different (daily, weekly, monthly etc) time frame.

4.4 Admin Access and Control

- Admin can login.
- The administrator can verify the general user and the bus owner, and give the general user a unique RFID tag.
- Admin can view all registered general user and bus owner.
- The admin can delete user data account.
- The administrator has the ability to add new buses to or delete buses from the owner's registered bus registry.

4.5 Result and Discussion

The implementation of the digital fare management system provided efficient operation by offering seamless fare validation and convenient payment options. Bus owners can easily compare their daily and weekly revenue by logging into the owner dashboard. Because RFID cards are reusable, they are far more useful than the ticketing system that uses paper. Digital fare management systems, as opposed to traditional ones, address a number of issues, including dishonest employees, excessive operating expenses, and fare invasion. That being said, there are also some limitations and challenges in this system:

- The first challenge of this system is that people might not like to carry an extra card to travel by bus. Therefore, it will take time for people to get used to this system.
- RFID card can be easily cloned by copying unique identification number. Smart card can be better options than RFID.
- Scanner can only be able to read RFID card, if it is placed at a distance less than 5cm from scanner.

5. Future Enhancements

There are several rooms for further development and enhancements to maximize the potential of the digital fare management system. Some of the possible future enhancements are as follows:

- After collecting enough data, we can use the data to visualize the movement patterns of passengers. And train a model that assigns the required number of buses to a particular area and time, which overall minimizes the under-utilization and overcrowding of buses.
- RFID cards can be integrated into student ID cards, which helps track the movement of students if needed.
- By keeping record of the capacity of a particular bus, the number of passengers on the bus at a particular time can be monitored, and a warning can be sent to the bus driver.
- RFID can be replaced with a smart card, which has higher security, can store encrypted data, and supports secure authentication mechanisms. Further, this smart card can be used to store personnel details like bank account details and citizenship details and is compatible with existing contactless payments, which will make it a multipurpose card.
- Instead of nodeMCU, raspberry pi can be used which has few more benefits, it has more powerful processor, has larger storage, can be integrated with other hardware components easily like using keypad, display,etc.

6. Conclusions

There are numerous problems with the conventional bus fare collection system, including high operating costs, dishonest employees, bus fare gouging, fare evasion, etc. This method can help solve the issue since it uses an RFID-based payment mechanism, which lowers the amount of labor needed, in the digital fare collection system. With this system the problems such as under utilization and over crowded of buses can be minimized which will benefit the passengers, bus owner and transportation administration. Currently there is no existing automatic fare collection system in our country. But we believe developing of this system creates convenience to passenger and bus conductor to collect fare and provide travel service more efficiently. This system can also be used as data(latitude, longitude) collection system to create maps.

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