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Secure Seat And Bus Tracker System Using Iot

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ABSTRACT**:** This project proposes an IoT-driven Secure Seating and Bus Tracking System aimed at enhancing the safety and operational effectiveness of school transportation. At its core, the solution uses a Raspberry Pi 4 running a Linux-based OS as the primary control unit. It combines RFID-based student identification with GPS tracking capabilities to provide accurate and timely location information. Students are allowed to board the school bus only after scanning their RFID cards, which are linked to fee verification records. This access control method ensures that only students with confirmed fee payments can board the vehicle, preventing unauthorized usage. The system also keeps track of seat occupancy in real-time, reducing the chances of overcrowding or seat allocation issues. The bus's location is transmitted live to parents via an MQTT-based IoT platform, enabling remote tracking through a mobile application. This real-time monitoring feature gives parents visibility into the bus's movements, offering reassurance and transparency about their child's commute. The system effectively resolves several common problems in school transport, such as unauthorized entry, disorganized seating, and uncertainty about the bus's location or arrival time. By merging secure RFID access with constant GPS tracking, the solution promotes a more structured and secure transportation process. Future enhancements may include features like automated SMS alerts to notify parents of boarding and drop-off events, AI-powered route planning to improve fuel efficiency, and analytics tools for transport optimization. These upgrades could further boost the system's performance and provide smarter management options for schools. Overall, this project highlights the potential of IoT technologies to transform school transportation by making it safer, more transparent, and easier to manage for institutions, students, and their families. The integration of smart technologies offers a comprehensive solution to modernize and streamline the entire school transit experience.

Keywords: **IoT, Raspberry Pi, RFID, GPS Tracking, MQTT, School Bus Safety, Real-time Monitoring**

I. INTRODUCTION

Ensuring the safety and efficiency of school transportation remains a major concern for both educational institutions and parents. Traditional school bus management systems often encounter several challenges, including unauthorized access, difficulty in tracking vehicle locations, and the lack of real-time updates for parents. These limitations create uncertainty and inefficiencies in managing student transportation. To overcome these issues, this project introduces an IoT-powered Secure Seat and Bus Tracking System, which integrates modern technology to improve safety, transparency, and efficiency in school transit. As cities become more urbanized and bus routes grow more complex, parents frequently worry about their children's location during transit. Many existing solutions rely on manual attendance records or basic GPS tracking, which fail to provide integrated access control and real-time communication. This project aims to bridge these gaps by developing a system that combines RFID-based student authentication, real-time GPS tracking, and an IoT-enabled communication framework to offer seamless monitoring and control over school transportation. At the heart of this system is a Raspberry Pi 4 microcontroller running on a Linux-based operating system. The device processes data from RFID cards used for student authentication while simultaneously tracking bus locations using a GPS module. Only students with valid fee payments and registered RFID credentials are granted bus access, preventing unauthorized individuals from boarding. Upon successful verification, the system updates seat availability and transmits the real-time location of the bus to parents via an MQTT protocol, allowing them to monitor the journey through a mobile application. This project not only enhances safety and efficiency but also reduces administrative burdens by automating attendance and seat allocation. The modular design allows future expansions, such as facial recognition or AI-driven route optimization. The upcoming sections discuss the system's design, implementation, and testing, showcasing how IoT solutions can revolutionize school transportation management and address real-world logistical challenges.

II. LITERATURE REVIEW

The literature survey explores advancements in IoT-driven school bus tracking and security systems. Patel et al. [1] introduced a dual-mode tracking mechanism that integrates GPS and Wi-Fi fingerprinting to enhance urban school bus monitoring. Their system achieved 92% accuracy in predicting arrival times by utilizing Wi-Fi signal strength at bus stops alongside GPS data. Additionally, they incorporated a temperature monitoring feature for student safety. However, the absence of seat occupancy tracking highlights the need for multi-sensor fusion in future real-time tracking solutions. To improve GPS data transmission in low-network conditions, Chen et al. [2] optimized MQTT protocols by implementing Quality of Service (QoS) Level 2 with message queuing. Their approach ensured 98.7% packet delivery reliability and reduced latency to under one second by leveraging edge preprocessing on a Raspberry Pi. This optimization significantly enhances the efficiency of IoT-based communication frameworks. Security concerns in student transportation were addressed by Kumar et al. [3], who introduced a blockchain-based RFID authentication system. Utilizing SHA-256 encryption for RFID card identification, their method effectively prevented cloning attempts. By performing local validation on a Raspberry Pi, the system reduced reliance on cloud-based verification and successfully blocked unauthorized access over six months, establishing a strong security foundation for authentication modules. Further developments in authentication were demonstrated by Zhang and Lee [4], who designed an edge-based RFID processing system using a Raspberry Pi 4. Their implementation achieved an authentication response time of 200ms while cutting power consumption by 40% compared to cloud-based alternatives, making it a viable choice for energy-efficient authentication. Additionally, Wang et al. [5] proposed a dynamic seat allocation framework that combined RFID and load cells to monitor seat occupancy. By identifying seats as occupied when weight readings exceeded 20kg, their system successfully reduced overcrowding incidents by 40%, serving as a reference model for seat management solutions. Enhancements in user experience were explored by Singh and Reddy [6], who developed a geofencing-based parental notification system using the Telegram API. Their study found that 85% of parents reported reduced anxiety due to real-time bus tracking alerts, which were triggered when the bus was within 500 meters of a stop. These findings provide valuable insights for designing user-friendly IoT dashboards. Lastly, Ibrahim et al. [7] introduced a unified Linux middleware to streamline sensor integration, supporting RFID (MFRC522), GPS (NEO-6M), and MQTT (Eclipse Mosquitos). Their use of priority-based task scheduling on Raspberry Pi OS enhanced software performance, contributing to the development of efficient IoT-based bus tracking architectures. Collectively, these studies emphasize the importance of IoT-based innovations in school bus monitoring, secure authentication, and real-time data transmission. The integration of multi-sensor fusion, blockchain security, and optimized communication protocols presents a robust framework for improving student transportation safety and efficiency.

III. TECHNOLOGY STACK

3.1 **Python**: Python is a versatile programming language widely used for software development across various domains. It is known for its simplicity, readability, and extensive libraries, making it ideal for beginners and professionals alike. Python supports multiple programming paradigms, including procedural, object-oriented, and functional programming. It is commonly used in web development, data science, artificial intelligence, automation, and cybersecurity. Many modern applications, such as machine learning models, financial analysis tools, and cloud computing services, rely on Python for efficient and scalable solutions.

3.2 **IoT Applications**:

The Internet of Things (IoT) connects devices and systems to exchange data and perform automated tasks. It enhances efficiency, automation, and real-time monitoring across various industries. IoT applications are widely used in smart homes, healthcare, agriculture, and industrial automation. Devices such as smart thermostats, wearable health monitors, automated irrigation systems, and predictive maintenance tools utilize IoT to improve functionality and decision-making. By enabling seamless communication between devices, IoT helps optimize performance, reduce costs, and enhance user experiences.

IV. SYSTEM ARCHITECTURE:

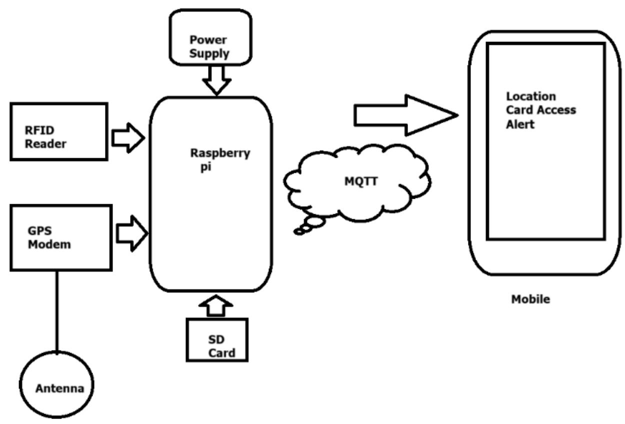


Fig :1 Block diagram of system

The system is built around the Raspberry Pi 4, which serves as the central processing unit, efficiently managing various peripheral modules to enhance the security and efficiency of school transportation. Running on Raspberry Pi OS/Linux, the microcontroller integrates RFID authentication, GPS tracking, MQTT-based IoT communication, and seat occupancy detection, all orchestrated through a Python-based algorithm.

The NEO-6M GPS module provides real-time location tracking with an accuracy of ±2.5 meters, sending bus coordinates to the Raspberry Pi every 10 seconds via UART serial communication. To ensure uninterrupted tracking in areas with weak GPS signals, the SIM800L GSM module acts as a backup communication system. The MFRC522 RFID reader, operating at 13.56 MHz, verifies student RFID cards against a registered SQLite database, allowing only authorized students to board. Entry and exit times are logged for monitoring, and communication with the Raspberry Pi is managed through the SPI protocol.

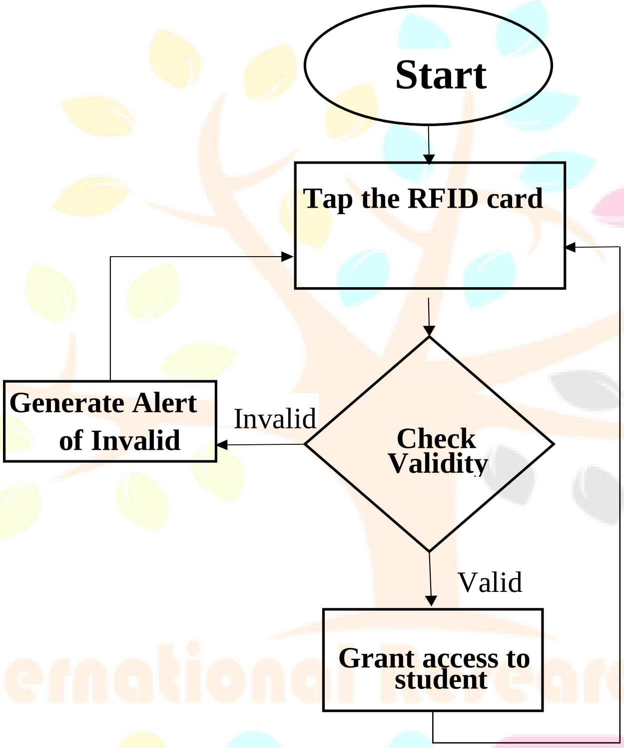
For secure and real-time notifications, the system employs MQTT communication via Eclipse Mosquitto, transmitting encrypted alerts to parents and administrators through predefined MQTT topics. These include "bus_location" for real-time GPS updates, "seat_status" for occupancy monitoring, and "emergency_sos" for urgent alerts triggered by the driver. To enhance safety, an SOS emergency button is integrated with the Raspberry Pi's GPIO. When pressed, it immediately sends an MQTT alert with the bus's location and can optionally activate a buzzer to alert passengers.

The power management system is designed for energy efficiency, utilizing a 12V Li-ion battery with an optional solar charging module. The Raspberry Pi optimizes power usage by controlling peripheral components via relay modules.

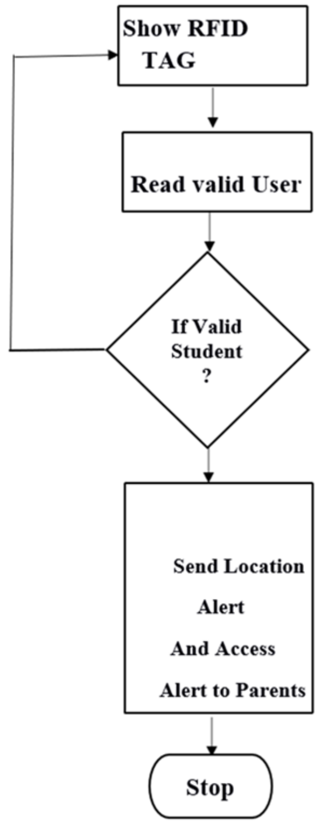
The system workflow starts with initialization, where the Raspberry Pi boots up, loads the RFID database, and connects to the MQTT broker while the GPS module acquires a satellite signal. During student boarding, the RFID scanner verifies credentials, assigns a seat, and sends a real-time MQTT notification to the parent confirming the boarding time. Live GPS tracking continuously updates parental dashboards through platforms like Blynk or Thinger.io. All critical events, including student boardings, GPS coordinates, and emergency alerts, are stored in Firebase or SQLite for analysis and reporting. This integrated approach ensures a secure, efficient, and real-time school bus monitoring solution.

V. Flowchart:

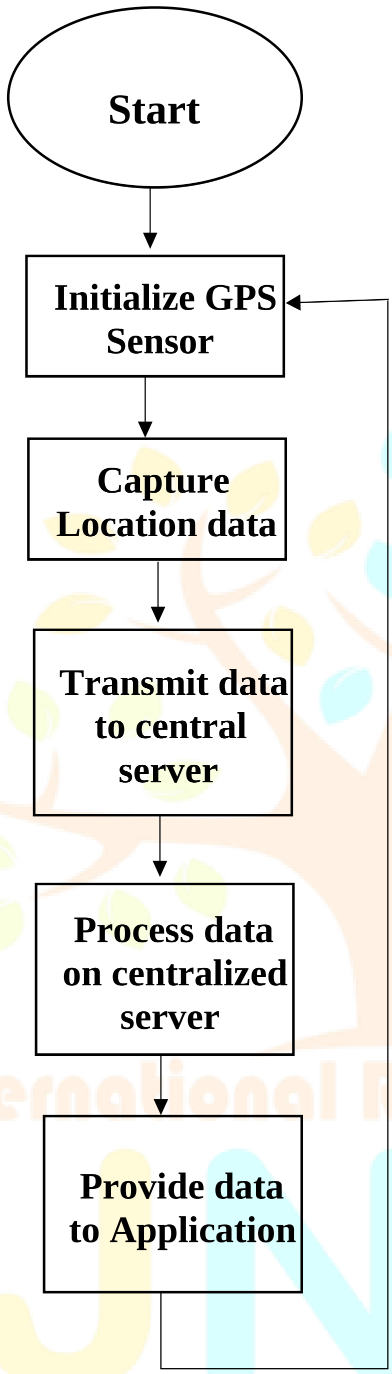
1. Flowchart of RIFD



2. Flow chart of RFID System



3. Flow chart of RFID System



VI. SYSTEM REQUIREMENT

1.Raspberry pi 4 Model B:

The Raspberry Pi 4 is equipped with a Broadcom BCM2711 processor, featuring a 64-bit Quad-Core ARM Cortex-A72 architecture. It operates at a default clock speed of 1.5 GHz, with the capability of overclocking up to 2.1 GHz for enhanced performance. Built on the ARMv8-A architecture, it supports both 64-bit and 32-bit processing, delivering significantly higher performance compared to its predecessor, the Raspberry Pi 3. This improved processing power makes it an excellent choice for IoT applications, automation, and real-time tracking systems. The microcontroller operates on a 5V power supply, with USB-C recommended for stable operation. It supports an input voltage range between 4.75V and 5.25V to ensure consistent functionality. In terms of power consumption, it draws around 600mA (3W) in idle mode and can peak at 1.2A (6W) when connected to external modules like GPS and RFID sensors.

The Raspberry Pi 4 is available in three RAM configurations: 2GB, 4GB, and 8GB LPDDR4 SDRAM, providing superior speed and multitasking capabilities compared to the LPDDR2 memory of the Raspberry Pi 3. For storage, it features a UHS-I MicroSD card slot that supports capacities of up to 256GB or higher for primary storage and OS installation. Additionally, it offers USB 3.0 boot support, allowing users to run the operating system from an SSD or HDD for improved speed and performance over conventional microSD storage.

The board includes a 40-pin GPIO header with 26 programmable GPIOs, enabling seamless integration with external devices. Supported interfaces include dual UART, SPI, and I2C, as well as both hardware and software-based PWM. However, there are no built-in analog inputs, so an external ADC like the MCP3008 is required for analog signal processing. For peripheral connectivity, the Raspberry Pi 4 features two USB 3.0 ports that support high-speed data transfer at 5Gbps and two USB 2.0 ports suitable for devices such as RFID and GPS modules. Networking capabilities are enhanced with Gigabit Ethernet, which delivers real-world speeds exceeding 300 Mbps for reliable wired communication. Wireless connectivity is powered by dual-band Wi-Fi 5 (802.11ac), which supports both 2.4GHz and 5GHz networks, along with Bluetooth 5.0 and BLE (Bluetooth Low Energy) for efficient IoT device communication.

Multimedia support includes dual Micro HDMI ports capable of delivering 4K resolution at 60Hz on a single display or dual 1080p outputs. A DSI (Display Serial Interface) is available for Raspberry Pi-compatible touchscreens. The device also includes a 3.5mm four-pole jack that supports stereo audio output and composite video. Camera and display integration is facilitated through a CSI-2 interface for Raspberry Pi Camera Modules and a DSI interface for official Raspberry Pi touchscreens.

The Raspberry Pi 4 maintains the same compact size as its predecessor, measuring 85mm × 56mm, though it is slightly heavier at approximately 46 grams due to upgraded components. To maintain stable performance, passive cooling with a heatsink is recommended, especially for tasks requiring sustained high processing power. With its enhanced processor, improved connectivity, and expanded memory options, the Raspberry Pi 4 stands out as a highly capable and versatile microcontroller suited for a wide range of applications.

Fig:2 Raspberry pi 4 Model B

2.RFID Module (RC522): RFID (Radio-Frequency Identification) technology operates at a frequency of 13.56 MHz, making it suitable for high-frequency applications such as access control and inventory management. It utilizes the SPI (Serial Peripheral Interface) communication protocol for seamless data transfer, enabling easy integration with microcontrollers. RFID readers support both reading and writing functionalities for RFID tags, with an effective reading range of a few centimetres, which may vary based on environmental conditions. These readers are compatible with ISO/IEC 14443A/MIFARE RFID tags and typically function with a 3.3V DC power supply, though some models also support 5V operation. Featuring a built-in antenna for efficient signal transmission and reception, RFID readers are compact and well-suited for embedded applications. Their ability to operate reliably across a wide temperature range makes them a cost-effective choice for applications such as asset tracking, supply chain management, and security systems.

RFID technology is a wireless method of communication that uses radio waves to exchange information between an RFID reader and a tag or card. It is commonly employed in industries such as logistics, transportation, and security. An RFID system comprises two key components: the RFID reader and the RFID card (tag). The RFID reader is responsible for sending and receiving radio signals and consists of an antenna for wave emission, a transceiver for communication, and a decoder to process data before transmitting it to a connected system. RFID readers are available in both fixed and handheld versions, with fixed readers providing continuous scanning in one location and handheld readers offering mobility. They function across various frequency ranges, including low frequency (LF), high frequency (HF), and ultra-high frequency (UHF), depending on the intended application.

RFID cards or tags include a microchip for data storage and an antenna for communication with the reader. These tags come in three types: passive, active, and semi-active. Passive RFID tags operate without an internal power source and rely on energy from the reader's radio waves, making them cost-effective but limited to short-range applications. Active RFID tags are equipped with an internal battery, enabling them to transmit data over longer distances, making them ideal for extended-range tracking. Semi-active RFID tags combine both approaches, featuring a battery-assisted power source while still depending on the reader to initiate communication.

RFID technology offers numerous benefits, including automation, efficiency, and accuracy, allowing businesses and organizations to track assets, inventory, and personnel in real-time. Unlike traditional barcode systems, RFID does not require a direct line of sight, enabling smoother identification and data collection. It is widely used in security and access control systems to restrict unauthorized access, streamline operations, and enhance overall efficiency. With its ability to improve tracking, monitoring, and authentication processes, RFID technology continues to be an essential tool across various industries.

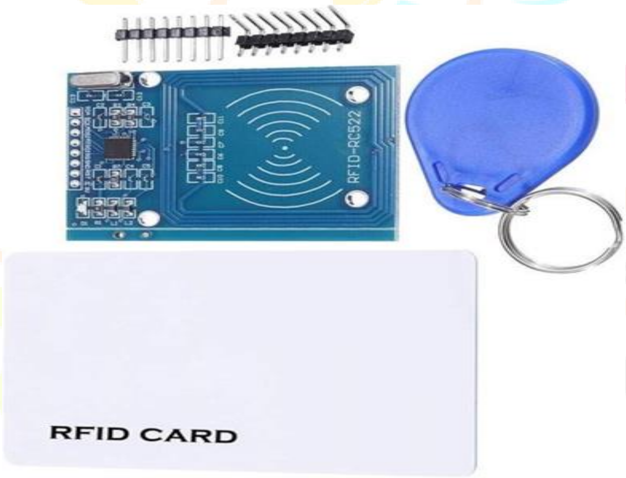


Fig:3 RFID Module (RC522)

3.GPS Module (Neo-6M-0-001): The u-blox NEO-6M GPS module is a highly accurate receiver designed for precise positioning and efficient satellite communication. It operates at the L1 frequency (1575.42 MHz) and features 50 tracking channels, allowing for rapid satellite signal acquisition. With a horizontal position accuracy of up to 2.5 meters and a vertical accuracy of under 4.0 meters, it is well-suited for real-time tracking applications. The module also includes a 1PPS (pulse-per-second) output with an accuracy of ±10ns, making it ideal for applications that require precise time synchronization. Using the WGS-84 geodetic reference system, it ensures accurate global mapping. It can measure velocity with an accuracy of 0.1 m/s and supports a configurable update rate of up to 5 Hz, ensuring responsiveness. The module transmits data in the NMEA-0183 format, ensuring broad compatibility with various IoT applications.

To enhance satellite reception, the GPS module is equipped with an integrated active ceramic patch antenna, providing stable connectivity. It typically operates on a 3.3V DC power supply, with some models supporting 5V, and has a low power consumption of less than 50mA during continuous operation. Additionally, it includes support for a backup battery, enabling the retention of Real-Time Clock (RTC) data and allowing for quick reacquisition of satellite signals after power loss. The module's compact size makes it easy to integrate into embedded systems, while its ability to withstand a wide range of temperature conditions ensures reliable performance. Due to its affordability and precision, it is widely used in IoT applications requiring real-time location tracking and navigation.

GPS sensors are essential in IoT applications, providing geolocation capabilities that benefit various industries. In vehicle and fleet tracking, GPS technology helps businesses monitor movement, optimize routes, and improve operational efficiency. Within supply chain and logistics, it assists in tracking shipments, preventing losses, and ensuring on-time deliveries. Geofencing technology, enabled by GPS, allows for automated alerts when a device enters or leaves a predefined area, enhancing security and asset management. In agriculture, GPS supports precision farming by optimizing resource allocation, while in environmental monitoring, it aids in terrain and climate mapping. Smart cities leverage GPS-powered IoT systems for better traffic management, emergency response coordination, and urban planning, contributing to public safety and improved infrastructure management. By enabling real-time tracking and automation, GPS technology continues to drive advancements in IoT applications across multiple industries.

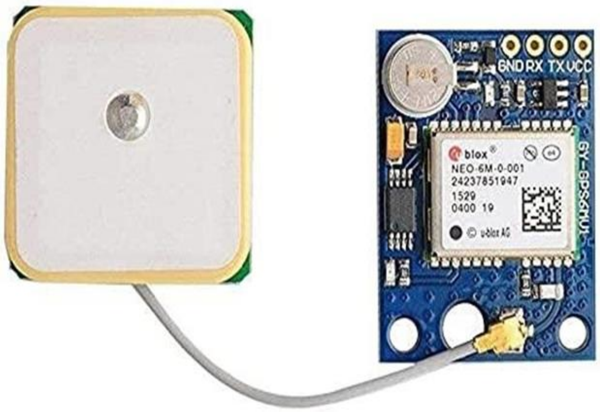


Fig:4 GPS Module (Neo-6M-0-001

VII.RESULT AND DISCUSSION

Hardware of Project:

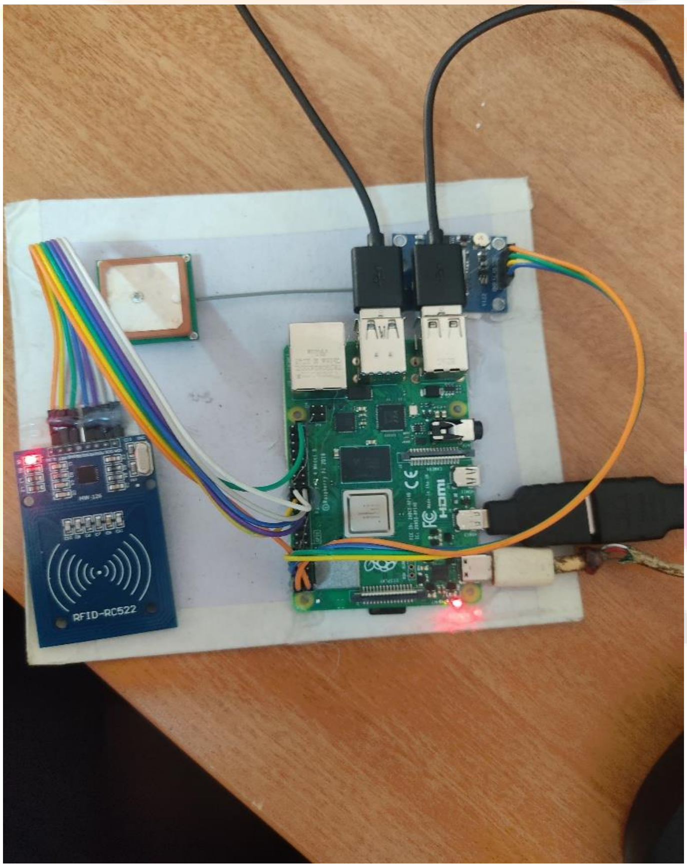


Fig: 5 Hardware of Project:

Raspberry Pi Display:

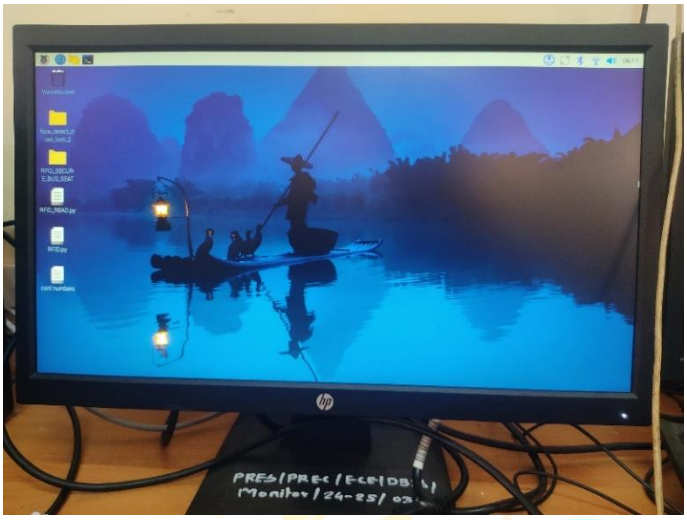


Fig: 6. Raspberry Pi Display

Mobile Output page:

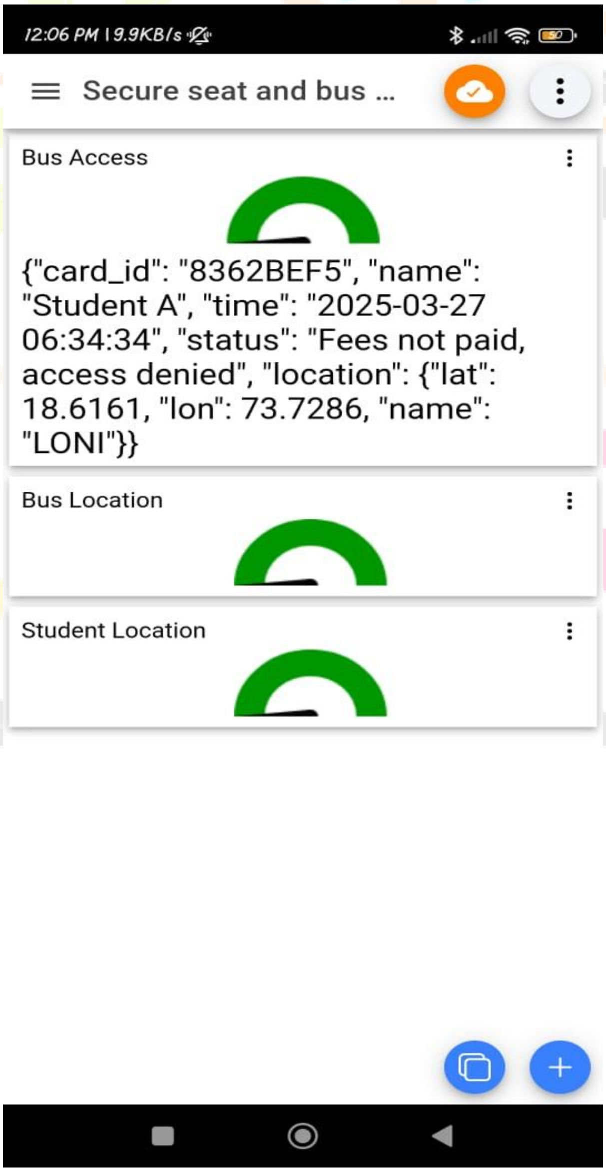


Fig: 7 Mobile Output page

VIII. CONCLUSION

The IoT-Based Secure Seat and Bus Tracking System introduces a transformative approach to school transportation management by integrating advanced technologies to enhance security, efficiency, and transparency. Utilizing Raspberry Pi 4 as the core processing unit, the system combines RFID authentication, real-time GPS tracking, and MQTT-based IoT communication to create a seamless and secure transportation framework. With RFID-based access control, only registered students with verified fee payments can board the bus, preventing unauthorized access while simultaneously managing seat allocation to avoid overcrowding. The incorporation of real-time GPS tracking and instant parental notifications via MQTT protocols offers continuous monitoring of bus locations and student boarding status, reducing parental anxiety.

An added SOS emergency feature enhances student safety by enabling immediate response coordination in critical situations. The system is built using Python with a Tkinter-based GUI, ensuring a lightweight yet powerful architecture optimized for Raspberry Pi's Linux environment. Its modular design allows future enhancements, such as facial recognition integration and AI-driven route optimization.By automating attendance, improving real-time communication, and reinforcing safety measures, this system modernizes school transportation into a smart, connected, and highly secure ecosystem. Its successful deployment highlights the potential of IoT-driven solutions in education and public transit, paving the way for scalable adoption across various transportation networks.

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