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IoT-Based School Bus and Student Monitoring System Using RFID and GSRM Technologies

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Abstract: Parent's primary concern is children's safety during school bus travel. It is difficult for parents to keep track of their children due to their busy schedules and hectic working lives. Thus, this paper presents the design and development of a prototype for children's safety. The authors implemented a tracker tool that checks the school children in vehicles and sends SMS alerts to priority contacts in case of emergency/dangerous situations. The proposed design includes global positioning system (GPS) tracking as a way to track school vehicles. At the same time, passive radio frequency identification (RFID) technology is used to record the children's presence inside/outside the vehicle. The data extracted by the hardware is fed to the cloud in real-time through Internet of Things (IoT) technology. Parents could monitor the school vehicle's movement while their children are on board. From the safety concern, when the child is in danger, a small button-like arrangement is made so that when pressed/triggered, the system will send an SOS message through the Global System for Mobile (GSM) communications module to the previously saved contacts. The results ensure the completeness of the vehicle monitoring system.

Keywords: *IoT, Children's safety, GPS tracking, GSM, RFID, ThingSpeak*

1. Introduction

As per a recent survey, nearly one-third of the children travel by school bus, followed by school van (12%), and another 11% of children commute to school by walking. Parents are genuinely concerned for their children's safety when it comes to school transportation. They expect the transportation to be safe, reliable, and on time. Overall, they want to be assured that the school transportation is providing the highest level of safety, comfort and efficiency for their children, and that any concerns they may have are being addressed promptly and satisfactorily. Schools are responsible for keeping parents updated about the transportation services provided for their children. This includes providing information about the transportation schedule, routes, and any changes or disruptions to the schedule. Additionally, schools should have clear and effective communication channels for parents to raise concerns or questions about transportation. This could include email, phone, or a dedicated section on the school's website. Advancements in intelligent systems technology have led to the development new transportation management systems that can improve school transportation's safety, efficiency, and convenience. GPS based tracking and real-time monitoring is one example of intelligent transport system [1]. These systems allow school officials to track the location and movement of school buses in real-time and provide parents with real-time updates on the status and estimated arrival time of their child's bus. These systems use data on student pick-up and drop-off locations, traffic patterns, and other factors to optimize the routes and schedules of school buses [2]. This can help reduce travel time and improve the transportation system's efficiency. Smart systems can analyze data from various sources such as weather, traffic, and student data, and use this data to predict potential problems and adjust the transportation plan accordingly [3]. In summary, smart systems technology can improve school transportation safety, efficiency, and convenience by providing real-time tracking and monitoring, optimizing routes and schedules, and providing other features to improve the overall transportation experience for students, parents and school officials. The development of IoT technology

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has dramatically improved the ability to monitor and track school buses, allowing for enhanced safety and efficiency for students and school administrators. IoT devices such as GPS, GSM, and RFID, enable real-time location tracking, route optimization, and attendance tracking for school buses [4],[5]. One of the key advantages of IoT in school bus monitoring is the ability to provide real-time location tracking of the bus [6]. This allows parents and school administrators to have up-to-date information about the location of the bus, including the estimated arrival time at bus stops. This can provide parents peace of mind and help school administrators better plan their routes to improve efficiency [7]. Another advantage of IoT in school bus monitoring is the ability to track students' attendance on the bus. This can be done using RFID technology, where each student is assigned a unique RFID tag [8]. This can help to ensure that all students have safely boarded the bus, and also aid in identifying any missing students. IoT technology can also provide emergency alerts in case of any issues, such as a bus deviates from its regular route or a student being left behind on the bus [9]. This can help to ensure the safety of students and can also aid in the quick resolution of any issues.

There are several alternative solutions for school bus tracking, depending on the specific needs and requirements of the application [10]. Another alternative solution is to use cellular-based tracking, which uses GSM or cellular networks to communicate the location data of the bus to a central server[11]. Bluetooth-based tracking uses Bluetooth low energy (BLE) technology to track the location of school buses [12]. This can be done using BLE beacons, which are placed on the bus, and BLE-enabled devices, such as smartphones, which can detect the beacons and provide the location data of the bus. Wi-Fi-based tracking uses Wi-Fi technology to track the location of school buses. This can be done using Wi-Fi enabled devices, such as smartphones, which can detect the Wi-Fi signal from the bus and provide the location data.

2 Background and Literature Review

Safety of school-going children are proposed in [13] while they are on the bus and also keeping track of their attendance. But, it's essential to consider the scalability and cost-effectiveness of the system in a real-world scenario before implementation and ensure the data privacy and security regulations are respected. The work presented by [14] proposed an approach that aims to improve the efficiency and safety of public transportation in urban areas by providing real-time location tracking and route optimization for buses [15]. The system uses GPS, GSM, and general packet radio service (GPRS) technologies to track the location of buses in real-time, and a greedy forwarding algorithm to optimize the routes of buses based on real-time traffic data [16]. RFID technology-based intelligent transportation system is proposed to improve the safety and efficiency of school bus transportation system[17]. Additionally, using RFID technology can provide a cost-effective solution for tracking student's attendance on the bus [18]. IoT technology enables real-time communication between various devices, allowing for collecting and analyzing data from various sources, including GPS, traffic sensors, and passenger demand [19]. Machine learning algorithms can then be used to analyze this data and make predictions about the best routing options for the bus . Authors presented a method for simultaneous localization and speed measurement of mobile vehicles using radio frequency-electronic license plate (RF-ELP) [20]. The authors propose a system that uses RF-ELP to determine the location and speed of vehicles in real-time accurately. The system consists of RF-ELP reader and GPS receiver, which work together to provide the location and speed of a vehicle. Speed monitoring in vehicles is critical to road safety, traffic management, and efficient driving [21]. In addition, monitoring speed can improve fuel efficiency and reduce emissions, promoting environmentally friendly driving [22]. Furthermore, speed monitoring can positively impact driver behaviour by providing real-time feedback on speed, encouraging safe and responsible driving [23]. RFID technology has been widely adopted in intelligent transportation due to its versatility and numerous benefits [24]. Research has shown that information fusion is a crucial study area across various applications, as it allows for better decision-making and improved performance. Passive RFID tag is powered by the energy of the RF signal sent by the reader, and it responds by sending back its unique identification number [25]. In school bus tracking systems, passive RFID tags can be embedded in student's ID cards, and RFID readers can be installed on buses.

Several cloud platforms can be used for school bus monitoring, providing easy access to location and attendance data from anywhere with an internet connection. Amazon web services (AWS) IoT, Azure IoT, and Google cloud are cloud platforms that provide services for connecting, monitoring, and managing devices, including school buses [26], [27]. These technologies can collect data from GPS devices, RFID readers, and other sensors, store processes, and analyse the data to provide real-time location tracking and attendance tracking [28]. ThingSpeak is an open-source IoT platform for real-time collecting, storing, and analysing data from connected devices [29]. It provides cloud-based data storage, analysis, and visualization and supports various devices and protocols. The wireless sensor network (WSN)-based Intelligent Transportation Systems is presented in [30]. This work is targeted primarily to road transport in military areas due to their stringent requirements in terms of security and reliability while collecting the data from the deployed sensor nodes. Finally, since vehicle tracking is a localization problem, there exist some studies about localization in WSNs. Table 1 compares GPRS, RFID, and WSNs-based tracking, concerning various parameters such as cost, power consumption, accuracy, network connectivity, storage and safety. GPRS-based tracking utilizes mobile networks to track devices and provides high accuracy, real-time tracking, and large storage capacity [31]. However, it also has high cost, power consumption, and requires regular maintenance. RFID-based tracking uses radio frequency identification to track objects and is cost-effective, with low power consumption, and requires minimal maintenance[21]. However, it has limited range and real-time tracking capabilities. WSN-based tracking involves using sensors to track devices wirelessly, provides real-time tracking, low power consumption, and is scalable [32]. Though, it has limited range and storage capacity, and can be expensive to set up. The comparison between these tracking systems will depend on the specific requirements of a particular application and the trade-off between the different parameters.

The proposed work presents a school bus monitoring system that balances cost-effectiveness, easy integration, real-time vehicle tracking, and improved safety and security:

- The system employs passive RFID technology and GPRS communication to achieve real-time vehicle tracking and monitoring.
- The advantage of GPRS as a communication protocol is that it provides a WAN connection, making it easier to track and monitor vehicles in areas without Wi-Fi connectivity.
- On the other hand, passive RFID provides real-time identification and tracking without consuming power, making it energy-efficient and cost-effective.
- The system's alert system provides enhanced security by sending alerts to the owner or administrator in case of any irregular activity such as theft.
- The real-time data generated by the system can be used for efficient fleet management, streamlined communication, better record-keeping, and increased safety and security.
- This system can help schools and bus operators comply with regulatory requirements and provide children a safer and secure environment.

Table 1 Comparison of various tracking techniques

Parameters	**GPRS Based tracking**	**RFID Based tracking**	**Wireless sensor based tracking**
Cost	Costly	Cost-Effective	Costly
Power Consumption	High	No Power Consumption	Low
Accuracy	High	Less Accurate Than GPS	Less Accurate Than GPS
Installation Location	On Vehicle	On Vehicle	Infrastructure
Network Connectivity	Needed	Not Needed	Needed
Safety/Security	Low	High	High

The rest of the paper is organized as follows. The system model, architecture, and hardware details are presented in Section 3. Section 4 presents results and discussions. Finally, the paper is concluded with the conclusions presented in Section 5.

3. Methodology

3.1. System Architecture

The architecture of the proposed system consists of four main components, as shown in Figure 3.1. The first component is the GPS device, which tracks the movement of the school vehicle by sending signals to the GPS satellite. The second component is the RFID system, which is a passive system that contains the reader and the tag. The RFID system identifies the children who are boarding the vehicle. The third component is the microprocessor (that is the Arduino UNO), which handles the backend processing. The fourth component is the GSM module, which will be activated when triggered; the child presses a button in danger. Once the GSM module is triggered, the alert SMS is sent to the previously saved contacts. Thus, calling for help as early as possible. This is our approach to ensuring children's safety on school buses. The GSM module also uses GPRS to send the RFID and GPS data to the ThingSpeak cloud for analysis and visualization. Our proposed model can be clarified using two systems based on their functionality.

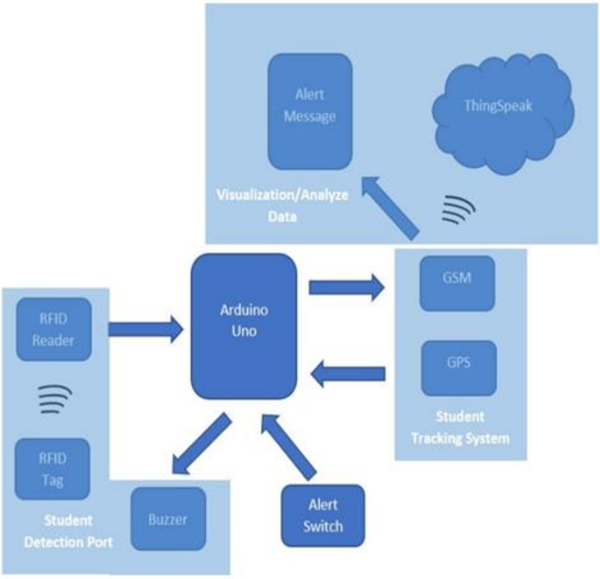


Fig. 3.1. Block diagram of the proposed model

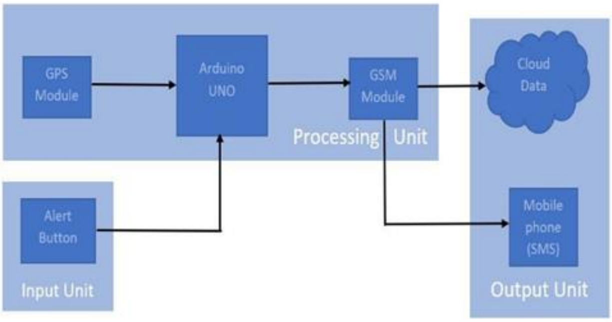


Fig. 3.2. Block diagram of System-1

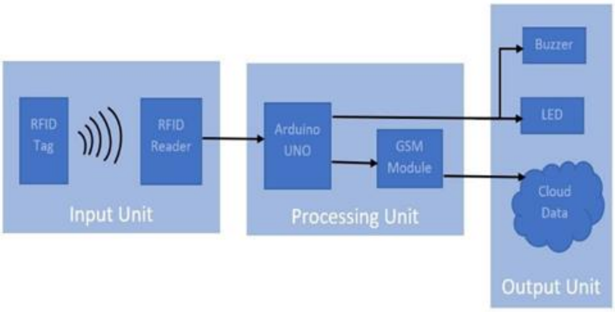


Fig. 3.3. Block diagram of system-2

System–1 is used to manage the GPS data as depicted in Figure 3. 2. The GPS device transmits the sensor data to the Arduino Uno once enabled. The processor then processes the data (latitude and longitude data) extracted from the GPS and uses GSRM to send it to the cloud to access the vehicle's location by the parent. The student's current location will be sent to the registered phone number whenever the safety button given to the student is pressed. A visualisation of the same with markers for tracked locations is also available on the ThingSpeak cloud based on GPS data.

System–2 tracks individual students using RFID technology, as illustrated in Figure 3.3. An RFID reader and tag make up the input unit. An Arduino Uno and a GSM module constitute the processing unit, and a led buzzer and a cloud contribute to making up the output sector. The RFID data is read when the RFID tag is brought close to the reader. The buzzer and led are connected to Arduino Uno to serve as a visual cue that the student has entered or exited the vehicle. Additionally, data is sent to the cloud through the general packet radio service (GPRS) when the RFID is activated. The same visualization is displayed on the ThingSpeak cloud platform.

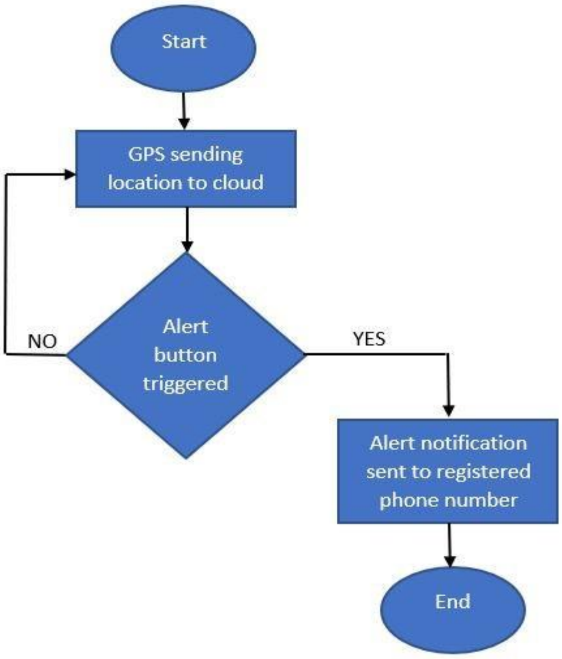


Fig. 3 4. Flowchart of the System-1

The System–1's security functionality is described in Figure 3.4. The GPS sends the location information to the cloud first. If the alert switch's precondition is met, the device will send an SOS message to the user's registered phone number; otherwise, it will wait for the alert button to be re-pressed. The flow diagram of System–2 is shown in Figure 3.5, which describes how RFID is used to track specific individuals. The flow begins with the tag being identified by the reader, which causes the led and buzzer to be activated. If the if condition is true, the RFID tag's unique identifier (UID) is sent to the cloud so that the parent can have real-time mobile access.

GPRS is a cellular network technology that allows data to be transmitted over a mobile network. At the same time, transmission control protocol (TCP) is a transport layer protocol that provides reliable data transmission between applications. By connecting GPRS to TCP, users can take advantage of the reliable data transmission provided by TCP and the wide network coverage and cost-effectiveness of GPRS to build mobile and remote applications. Before sending or receiving data, TCP protocol must establish a connection. To use the GPRS module, the user must configure related AT commands. This includes setting the connection mode, baud rate, domain name, and port. Once these settings are successful, the GPRS module and server will form a TCP connection.

The GSM module has ten states it goes through while setting up GPRS connectivity, as shown in Figure 3.6, which change with each AT command sent. The first state is the GPRS Initial Status, where the module is in its initial status and ready to establish data connectivity. In the second state, the access point name (APN), username, and password must be set to establish a connection with the service provider. The third state starts a wireless connection with the GPRS, and the module connects with the service provider, obtaining an IP address. In the fourth state, the GPRS context becomes active.

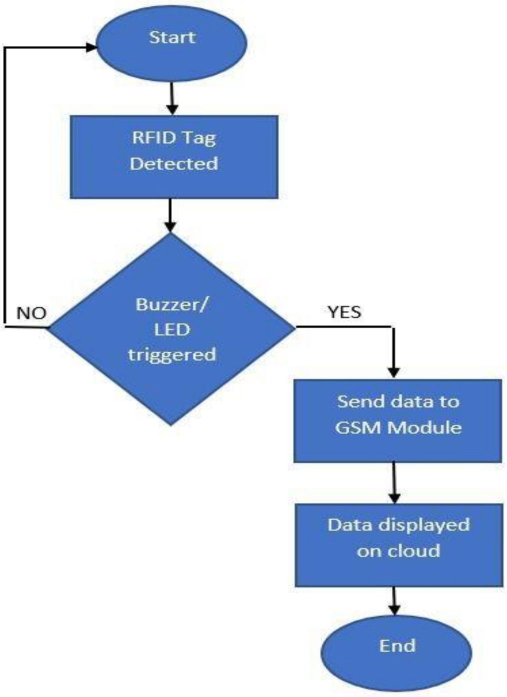


Fig. 3.5. Flowchart of the System-2

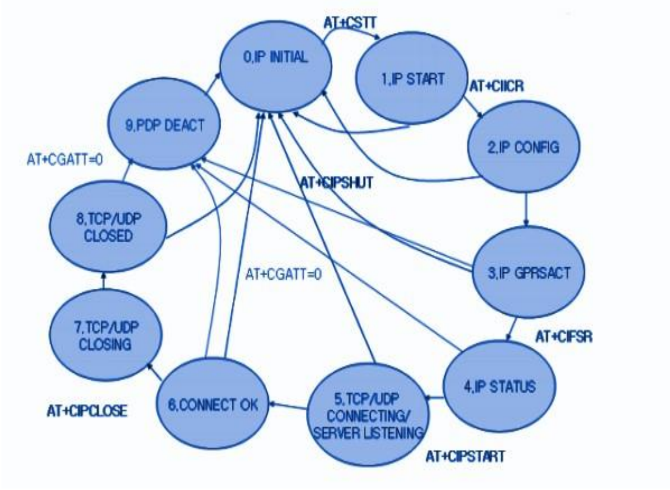


Fig. 3.6. Flow diagram of setting up GPRS for TCP protocol messaging

The fifth state is reached when the module is successfully connected to the GPRS and has been assigned an IP address. In the sixth state, a TCP connection is made with a website on port 80. The first ‘OK’ received in the seventh state is a response to the command being accepted, and the second ‘OK’ indicates a successful connection. The eighth state is reached when the TCP/UDP connection is closed. The module is in the ninth state if the connection is closed successfully. In the tenth state, the context is deactivated.

3.1 Hardware

The hardware setup of the proposed system is shown in Figure 3.7. It consists of the Arduino Uno processor, which is powered by a computer's 5V supply and is programmed using the Arduino IDE. Since the sim800L GSM module needs 4.1V 2A of power, which Arduino is unable to provide, it is powered by an XL4015 dc step down converter. At the heart of the module is a SIM800L GSM cellular chip from Simcom. There is a SIM socket on the back. Any 2G Micro SIM card will work perfectly. We have used an Airtel sim in our case. We are utilizing its TCP protocol and AT commands to send data to cloud. On the top right of the SIM800L module is an LED that indicates the status of your cellular network. It blinks at different rates depending on which state it is in. For GSM communication it blinks every 3 seconds and for GSRM it blinks every 2 seconds. This GPS module, designated NEO-6m, operates at 3.3 volts and is 5 volts tolerant. It can update its location five times in a second with a 2.5m horizontal position precision, which is faster than conventional GPS units. Additionally, the Time-To-First-Fix (TTFF) of the U-blox 6 positioning engine is less than one second. Power save mode (PSM) is one of the chip's best features. This enables a decrease in system power usage by selectively turning on and off specific receiver components. The NEO-6M GPS module has an LED that displays the Position Fix state. A patch antenna with a sensitivity of -161 dBm is included with the module to enable radio reception of GPS satellite signals. To increase signal strength, we used a UFL antenna. Serial communication is the method of communication used by the GSM and GPS. As a result, we used soft serial for SIM00L connections and hard serial for GPS data. For input trigger, a small push button is connected to the Arduino's digital pin. The usage of the GSM module resolves the connectivity issue faced while interfacing WIFI modules. Thus, proposed model can be used not only in smart cities but also areas with common 2G connectivity.

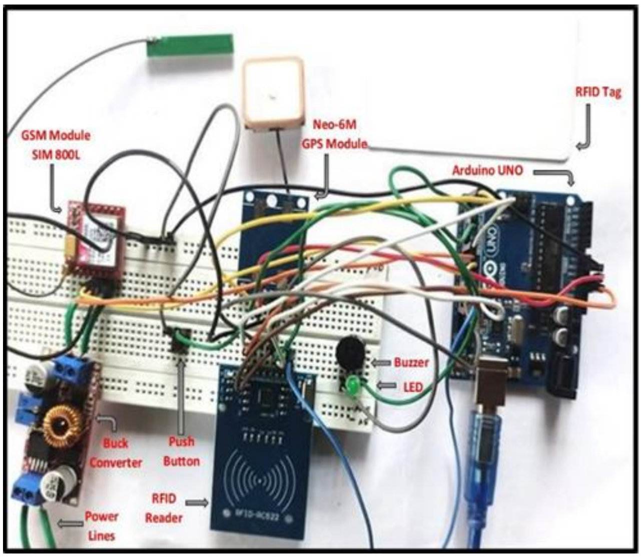


Fig. 3.7. Hardware model of proposed system

The RFID system consists of two main parts: a tag attached to the identified item and a reader that reads the tag. The reader has a radio frequency module and an antenna that produces a high-frequency electromagnetic field. On the other hand, the tag is usually passive and doesn't require a battery. It has a microchip for storing and processing information and an antenna for receiving and transmitting signals. When the tag is brought close to the reader, the reader's electromagnetic field activates the tag's antenna, powering its microchip. The chip then sends its stored information back to the reader through a radio signal, which the reader interprets and transfers to a computer or microcontroller. The paper mentions using the RC522 RFID module, a low-cost option based on the MFRC522 IC from NXP. This module operates at 13.56MHz and can communicate with standard RFID tags, and its operating voltage ranges from 2.5 to 3.3V. The logic pins are 5-volt tolerant, making it easy to connect to an Arduino, which will be used for individual student tracking. The data obtained by the Arduino, the UID, will be sent to the cloud using GPRS communication.

4. Results and Discussions

The hardware execution is depicted in Figure. 4.1. This figure shows how the LED and buzzer are activated when the reader reads the RFID tag. The GSM and GPS, module indicator LEDs are also lit, indicating they are in on the state. The Arduino IDE is used to compile the code before uploading it to the Arduino UNO for execution. Figure 4.2. depicts the alert message the parent or user sees when the alert switches are activated in dangerous circumstances. Figure 4.3. demonstrates that the modules and Arduino UNO are successfully communicating serially.

4.1. AT commands and instructions

AT commands are instructions used to control a modem. AT is the abbreviation of ATtention. Every command line starts with "AT" or "at". That's why modem commands are called AT commands. We use AT commands to communicate with the sim800L module. As shown in Fig. 10, the RFID data such as latitude and longitude are extracted from the modules and displayed on the serial monitor.

The 'AT' command checks if the module is correctly interfaced with Arduino Uno, the expected response from the module is 'OK'.

- The 'AT+CPIN' command checks if the sim card is inserted correctly. If yes, then it responds with a 'READY' message.
- The 'AT+CREG' command gives information about the serving cell's registration status and access technology.

Possible values of registration status are:

0 – not registered, MT is not currently searching for a new operator to register,

1 – registered, home network 2 not registered, but MT is currently searching for a new operator to register,

3 – registration denied,

4 – unknown (e.g. out of GERAN/UTRAN/E-UTRAN coverage,

5 – registered, roaming.

- The AT+CSTT AT command sets up the APN, user name, and password for the packet data protocol (PDP) context. Here we are using the Airtel network, whose APN is airtelgprs.com.
- The AT+CIICR command brings up the GPRS or CSD call depending on the configuration previously set by the AT+CSTT command.
- The ‘AT+CIFSR’ command returns the local IP address. The PDP context must have been activated before getting the IP address. So, PDP context is activated using the command 'AT+CGACT=1'.
- The 'AT+CIPSTART' command starts a TCP or UDP connection. We are using TCP for the proposed model functioning. Once the connection is established to the ThingSpeak server, we send the respective field data. After the data is sent, the communication is closed using AT+CIPSHUT.
- The AT+CIPSHUT will close the GPRS PDP context. When the trigger button is pressed.
- The AT+CMGF and AT+CNMI commands start massage services from the SIM800L module.

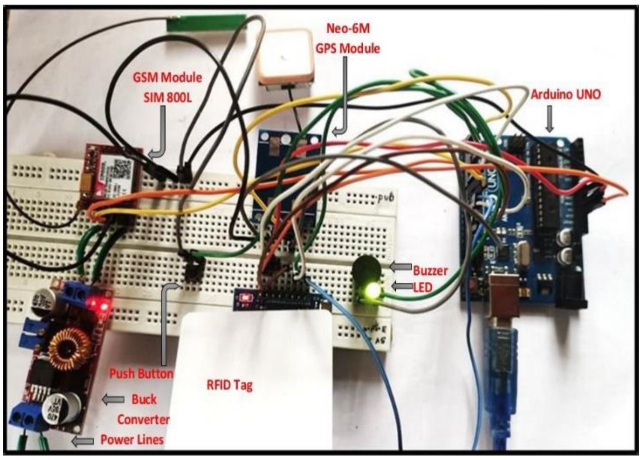
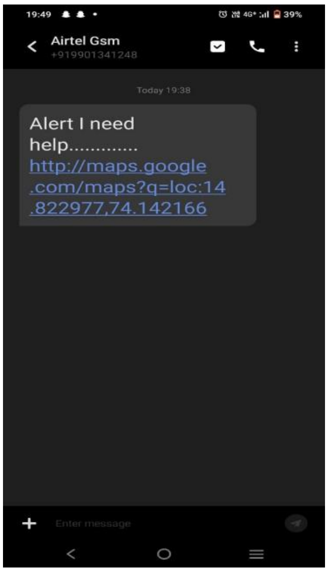


Fig. 4.1. Execution of hardware



Alert I need help............
http://maps.google.com/maps?q=loc:14.822977,74.142166

Fig. 4.2. Received alert message

```
Starting the RFID Reader...
243 204 37 172
Latitude = 14.823019
Longitude = 74.142097
AT
OK
AT+CPIN?
+CPIN: READY

OK
AT+CREG?
+CREG: 0,1
AT+CSTT="airtelgprs.com"
OK
AT+CIICR
OK
AT+CIFSR
100.84.175.187
AT+CIPSPRT=0
OK
AT+CIPSTART="TCP","api.thingspeak.com","80"
OK

CONNECT OKAT+CIPSENDGET https://api.thingspeak.com/update?api_key=YFALKBUT41G2739U&field1=14.823019&field2=74.142097&field3=50
GET https://api.thingspeak.com/update?api_key=YFALKBUT41G2739U&□

SEND OK
110
CLOSED
AT+CIPSHUT
SHUT OK
AT+CMGF=1AT+CNMI=2,2,0,0,0Sending SMS
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Fig. 4.3. Message flow of hardware setup

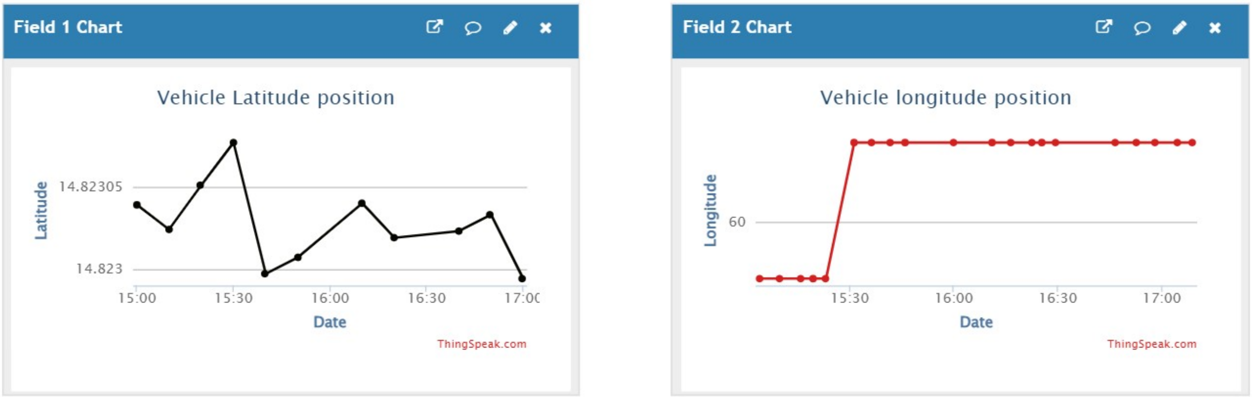

Fig. 4.4 Received latitude and longitude data of the vehicle

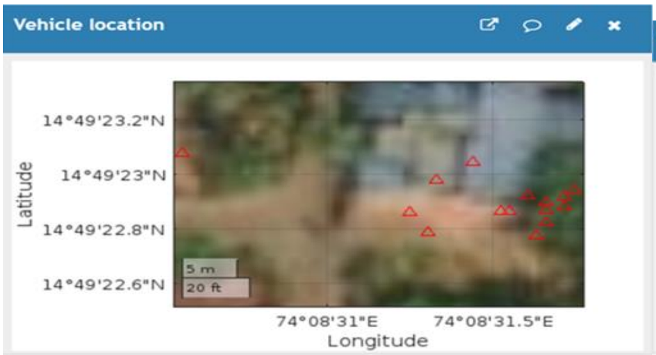

Fig. 4.5 Visualization of vehicle's location in cloud

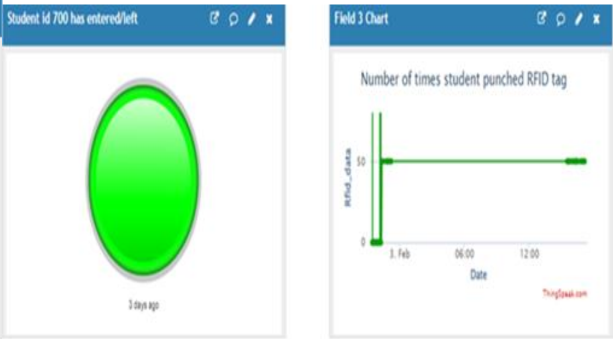

Fig. 4.6 A virtual LED widget

The cloud platform's visual representation is presented in Figure 4.4, Figure 4.5, and Figure 4.6. The visualization consists of three fields representing the latitude, longitude, and RFID data. As seen in Figure 4.4, the latitude and longitude positions of the vehicle are plotted in relation to time. A Matlab visualisation of the map is also made for easier comprehension as shown in Figure 4.5. A virtual LED widget is also utilised in Figure 4.6. to demonstrate that the RFID data is being received. Users can now access the data from any location at any time.

5. Conclusion

We have presented an IoT-based vehicle tracking system model by combining RFID, GSM, GPRS and GPS technologies. The proposed model provides a comprehensive and effective solution for enhancing the safety and security of students during transportation. By incorporating RFID technology in students' ID cards and integrating it with GSRM technology. The proposed

system effectively tracks the location of the school bus and the students on board in real-time, thereby providing peace of mind to parents and school authorities. The system also ensures that students are accounted for and alerts the concerned authorities in case of any emergency. This system has the potential to revolutionize the school transportation industry and promote safer and more secure transportation for students.

The problem of vehicle tracking can further improved by using on personal vehicles with the extra drowsiness monitoring attribute utilizing image recognition/machine learning algorithms [33]. Additionally, an approach to determine the estimated time of arrival of the vehicle could also be done using neural networks. This data could likewise be made available through the cloud. Since the prototype is bulky, further advancements on this project can be accomplished by creating an IC equipped for carrying out all tasks of the model.

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