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GPS-GSM Based Bus Monitoring System and Providing Necessary Information Using IoT

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ABSTRACT
GPS-GSM based vehicle tracking systems are widely used in various countries for precise location tracking and providing necessary information. However, there is no appreciable vehicle management framework for Rajshahi University of Engineering & Technology (RUET), that provides a complete vehicle monitoring system, bus route optimization, and real-time tracking. This paper proposes a trustworthy, low-cost and IoT-based vehicle monitoring system for RUET's Teachers' Bus. The developed prototype device will improve both efficiency and safety of the operation. The GPS-GPRS based module and open-source controller provide real-time position tracking of the test vehicle. The combination of IoT technology with geolocation APIs guarantees real-time information provision while enhancing the system's capabilities. In addition to addressing privacy and security concerns, this paper will open up new avenues for research and future system development opportunities.

Keywords: Vehicle tracking system, IoT-based monitoring, GPS-GPRS, Bus route optimization.

1. Introduction

A Vehicle Tracking system is comprised of an electronic device that is installed in a vehicle, allowing it to be monitored for its location either by the vehicle owner or a third part. Moreover, it represents a comprehensive solution not only for security but also an administrative approach to vehicle management. The system incorporates modern hardware and software components that facilitate online and offline vehicle tracking. Typically, a tracking system consists of three key elements: the vehicle unit, a fixed-based station, and a database with accompanying software. This enables users to view the asset's location on Google Maps in real time or retrieve the data later for further analysis. However, like many transportation systems, it faces challenges related to tracking, scheduling, and optimizing routes. These have been persistent issues that need to be addressed. Though there are many existing technologies, our main focus is to make a completely new roadmap based on the RUET campus and the teachers' bus.

RUET provides essential bus transportation services to its faculty members. However, the existing bus monitoring system faces limitations in terms of accuracy, real-time tracking, and user experience. To address these shortcomings, there is a need for the development and implementation of an advanced bus monitoring system. The current system relies on manual tracking methods, making it challenging to provide the real-time information about bus locations and arrivals, leading to unpredictable wait times and inconvenience. Furthermore, without real-time data, it is challenging to monitor the routine maintenance needs and safety of the buses. With this system, pinpointing a vehicle's exact location will be a straightforward and rapid procedure.

A GPS-GPRS comprehensive location information about vehicles. It relies on geographic position and time data from Global Positioning Satellites (GPS) to monitor a vehicle's movements. The GPS coordinates are obtained via a GSM modem and transmitted to a server using GPRS based tracking system offers. Generally, it is an all-inclusive solution containing both hardware and software components. The hardware system includes electronic devices like GPS, microcontrollers, and GSM technology, while the software system encompasses various software applications like Arduino IDE, EasyEDA, and MIT App Inventor. In this work, a GPRS- based data transferring system has been used, which is able to send data to the internet without wi-fi network. To track the location's coordinates, The Arduino UNO R3, U-Blox NEO-6M GPS module, GSM SIM 800L, SIM card, LM2596 DC-DC buck converter, battery are used basically as the core hardware components.

Most vehicle tracking systems rely on GPS and GSM technologies. Short Messaging Service (SMS), a common feature on all mobile phones, enables the exchange of small text messages between users. Basically, several automobile tracking systems rely on this SMS exchange technique which is neither suitable for the age nor reliable.

A lifetime gathering architecture for automobiles was proposed by Aravindhan Athavan et al. [1] that allows for real-time data access and analysis while using the least amount of memory. The system's main data gathering and processing device is a µBlox C027-G35 kit, which has an integrated GSM/GPRS modem. The data obtained from the microcontroller is processed first by the framework before being saved on the server.

Jheng-Syu Jhou et al. [2] developed a real-time vehicle diagnostic system that utilizes CAN/OBD-2 to gather key data about a car's condition, including engine RPM, speed, coolant temperature, fault codes, and other parameters. Additionally, the system integrates a GPS receiver to obtain

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velocity, coordinates, and approximate error locations. Llarri et al. [3] created a context-aware smart bus guide application tailored for Seoul's smart buses. The system helps users locate nearby bus stops and provides detailed information about the bus routes available at those stops.

With advancements in wireless communication technology, new applications emerged, including the use of public network text messages to share mobile location data, marking the first generation of GPS dynamic positioning technology [4]. Morallo [5] introduced a tracking system utilizing a GPS module (NEO-6m) and a SIM900 GSM module. However, the system incurred higher costs as the GPS and GSM modules needed to be purchased separately. Additionally, the GPS module (NEO-6m) featured a very short antenna, making it challenging to capture GPS locations effectively. Furthermore, the system only provided users with latitude and longitude coordinates.

Chandurkar et al. [6] proposed a monitoring system designed to inform passengers of the current location of buses and their estimated arrival times at various stops along the route. The system uses a link updater to determine the bus's real-time location and route. It also updates commuters by displaying the predicted arrival times on a digital board installed at bus stops, ensuring timely and accurate information.

A GPS device to determine the vehicle's exact location. Simultaneously, they integrated Google’s geolocation service to provide real-time latitude and longitude data as a backup when the GPS system malfunctions [7]. A notable feature of their system is the inclusion of emergency cameras positioned at various angles inside the vehicle, offering a comprehensive view of the interior. Additionally, they implemented Flocks of Trackers (FoT) to estimate displacement and measure motion effectively.

The proposed system aims to improve vehicle detection with greater precision, offering a unique and easily maintainable solution. A robust database will be utilized to store trip records regularly. Additionally, the system will reduce waiting times for faculty members by providing the vehicle's exact location. The developed project includes notable features and, with future updates, is expected to evolve into a smart bus technology system.

2. Methodology

An Arduino Uno R3 and SIM800L module with a GPS and GSM antenna make up the vehicle tracking device. The microcontroller, Arduino Uno, is the primary component of the tracking system. A vehicle's geolocation can be recorded using a GPS receiver, and utilizing GSM technology, that data can be sent to a web server. A database will be used to store that data. We created a web application to track the vehicle's whereabouts on a map. This web application was created using PHP and HTML. MIT App Inventor to create a mobile application that enabled users to view the position of a vehicle on a mobile device.

The SIM800L module is initialized to begin collecting geolocation data from satellites; device initialization is carried out using AT commands and involves the GPS and GSM module; the GPS must first be powered on and placed in reset mode in order to be turned on. The module is then prepared to receive satellite coordinates.

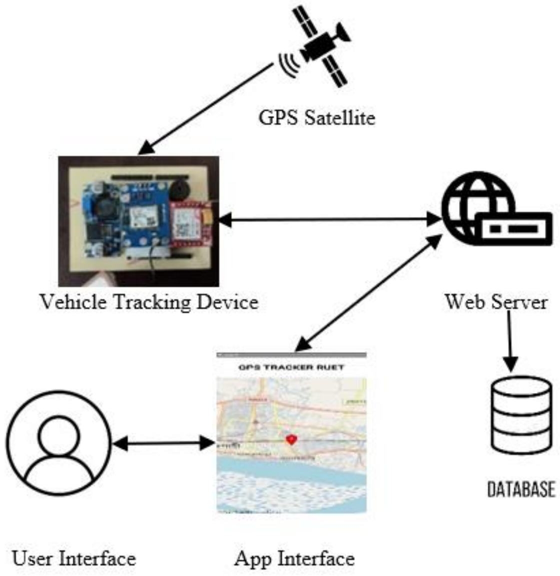

Fig.1 Data Flow Diagram of Tracking System

Next, the GPRS is activated, which entails activating the GPRS, configuring the service provider's APN, starting the HTTP protocol, and configuring the protocol method (Get method). The device could take up to one minute to initialize and calculate the precise position. When a network is unavailable, acquired GPS coordinates and additional information like time and speed are temporarily kept until the network becomes available again, at this point, they are stored. All the components are arranged in a correct order so that the accurate result can be required.

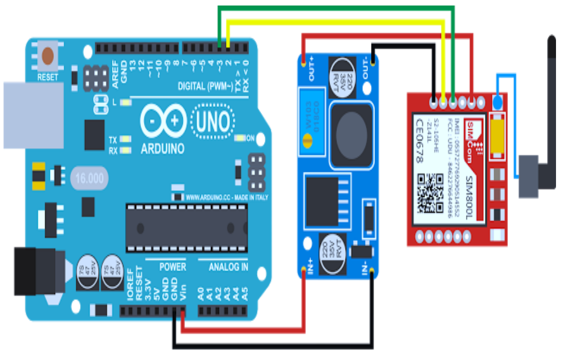

Fig.2 Connecting GSM module with Arduino pins and Buck Converter.

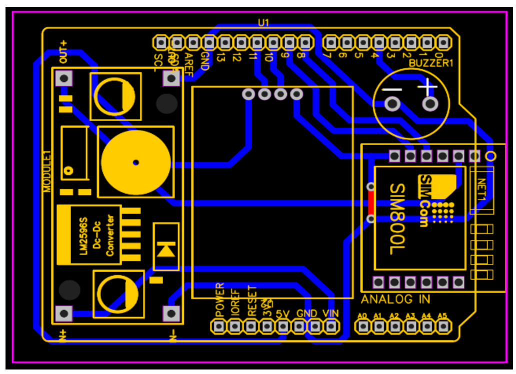

Fig.3 PCB layout.

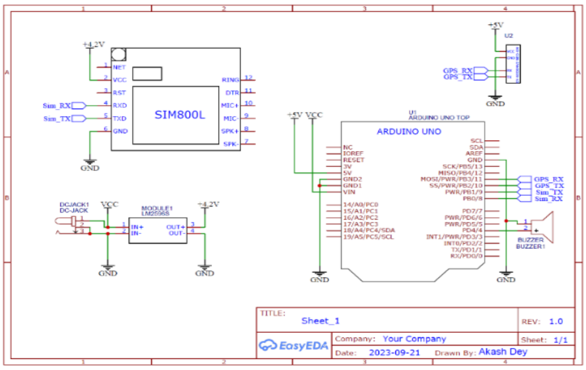

Fig.4 Analysis of wiring diagram.

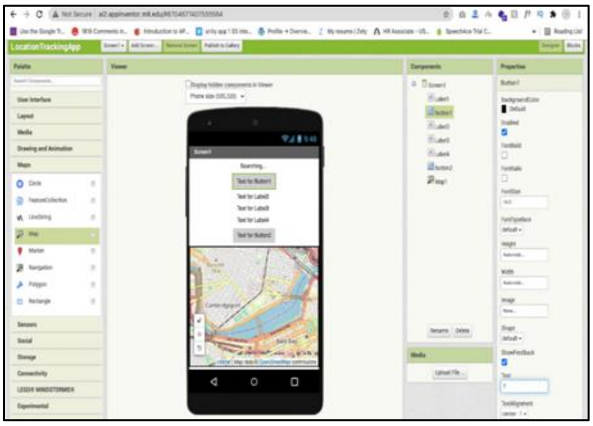

Fig.5 MIT app inventor surface.

The GPS antenna and GSM antenna are both connected to the SIM800L module, and the module and Arduino share a common ground connection (Fig.2). The program for the Arduino microcontroller is written in the C++ programming language and is uploaded using the Arduino Integrated Development Environment (IDE) software. Designing and creating printed circuit boards (PCBs) is done using EasyEDA (Fig.3). It appears to be providing wiring instructions for the specific electronic project involving GPS and GSM modules as well as an Arduino board and buck converters (Fig.4). These instructions outline the connections and power requirements for the components. We created a web application to track the vehicle's whereabouts on a map.

This web application was created using PHP and HTML. The location information had been saved in a text file. The app was developed using MIT App Inventor (Fig.5) and includes a feature for continuous location tracking.

The vehicle tracking system operates by receiving location data, such as latitude and longitude, from a GPS receiver installed in the vehicle. This information is then sent to a web server via HTTP request. To view the vehicle's location in real-time, an API with Google Maps is loaded through a browser. During the initial phase, the SIM800L module was powered by a 12V battery instead of the 5V from Arduino. However, due to the module's 2A peak current, there was a significant voltage drop, resulting in the automatic shutdown of the module. Thus, an external power source is required to ensure the system's functionality. As the tracking system is meant for cars, the car battery can be utilized as a power source.

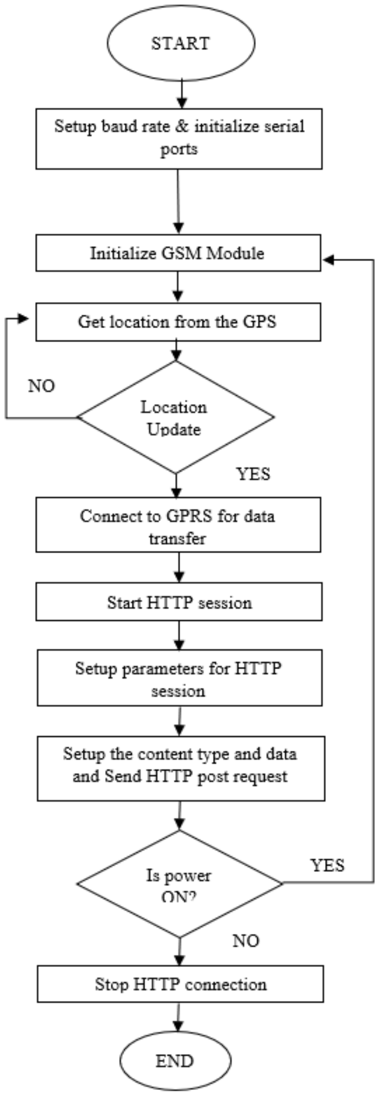

Fig.6 Flowchart of the complete setup.

To activate the SIM800L module in an Arduino program, use the AT command. Begin by registering the network with AT+CREG and setting the Access Point Name (APN), username, and password. Then, use the CGPSPWR command to power on the GPS and retrieve current location information with the AT+CGPSINF command.

Two methods have been employed to transmit the location data of the vehicle to the user end. The first method involves sending continuous SMS updates of the current location to the user's mobile number, via the SIM card inserted in the SIM800L module, upon receiving an SMS from the user or owner of the vehicle. The second method involves sending the data through an HTTP request to a web server (Fig.6). To send SMS updates, the AT+CMGS command is used in the program, while the AT+CMGR command is used to read SMS messages sent by the user. An application had developed to view the location of the vehicle on the map in the working system. This was done by the MIT App Inventor and Firebase real-time data. It contains a Google-embedded map that shows the map and gives parameters to the user. A Google Map API key is used for embedding the map into the PHP script. The script is also used to handle POST and GET functions to fetch or store the data in the database.

3. Results

After completing the hardware and software integration, the developed prototype device is installed at “RUET Teachers’ Bus” for collecting and comparing data with the existing technologies (Fig.7). A SIM card is added to the GSM module for providing continuous internet supply. Then, after locking the satellite with the help of Ublox GPS, the device provides continuous data. The accuracy of the implemented system in determining the position and tracking units is assessed by comparing the coordinates obtained by the system with the actual positions obtained from Google Maps.

Data analysis and performance evaluation have been yielded significant insights into the operation of our RUET Teachers' Bus monitoring system. The gathered information and our analysis's findings show that the system can track bus routes, deliver information in real time, and keep an eye on a number of other characteristics that are essential for effective bus management.

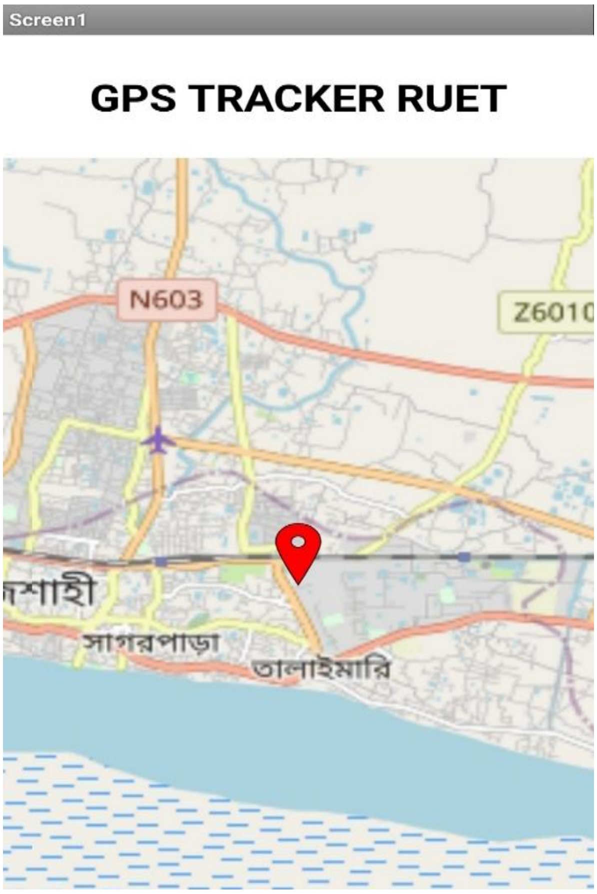

Fig.7 Initial Interface of the GPS TRACKER RUET App

Cost analysis also have been done in the last section that depicts why we have developed this project though there are many existing systems in the market. During the testing of the entire system, a delay analysis setup is conducted to measure the time it takes for the in-vehicle device to respond to the end user's request. Three different SIM cards from different operators are used, and delay time is recorded for each pair of SIM cards. Delay is comparatively less in Grameenphone SIM and high in Robi SIM (Fig.9).

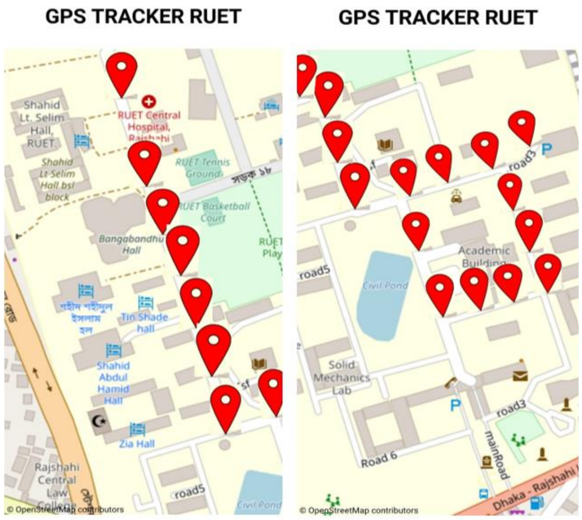

Fig.8 Continuous location tracking inside RUET campus.

Table 1 Comparing latitude and longitude between GPS tracker and android google map (RUET Campus).

Location	Location From Tracker		Actual Location at Phone		Diff.
	Latitude	Longitude	Latitude	Longitude	
Garage, RUET	24.3623765	88.6282567	24.3623481	88.6282311	2.3 m
High Voltage Lab	24.3659325	88.6282522	24.3659048	88.6282311	1.7 m
Machine Shop	24.3659567	88.6282643	24.3659048	88.6282311	4.6 m
Bangabondhu Chottor	24.3659879	88.6282452	24.3659048	88.6282362	7.6 m
Central Library	24.3659879	88.6282452	24.3659048	88.6282362	7.6 m
Wood Shop	24.3658487	88.627456	24.3658293	88.627299	2.5 m
Foundry Shop	24.3659021	88.627106	24.3658835	88.626996	2.8 m
Welding Shop	24.3662904	88.6267575	24.3662864	88.6267256	8.6 m
Tin Shed Hall	24.3665543	88.6266587	24.3665381	88.6266874	2.7 m
Shahid Shahidul Islam Hall	24.3672487	88.6265934	24.3672101	88.6265832	4.5 m
Shahid Lt. Selim Hall	24.3682245	88.6260654	24.3682016	88.6260305	2.7 m
RUET Central Hospital	24.3686923	88.6258765	24.3686625	88.6258349	3.1 m
Near Seikh Hasina hall (LH)	24.369765	88.6255954	24.369441	88.6255776	8.4 m
Boiler Lab	24.3649542	88.6268376	24.3649264	88.6268155	2.9 m
Heat Engine Lab	24.3657123	88.6268463	24.3656917	88.6268155	9.6 m
GCE Building	24.3657267	88.6268510	24.3656917	88.6268155	11.2 m
Fluid Mechanics Lab	24.3651393	88.6269678	24.3651125	88.6269408	7.8 m
Admin Building	24.3641564	88.6272738	24.3641315	88.6272611	12.3 m
RUET Main Gate	24.3632654	88.6268892	24.3632323	88.6268573	3.5 m
RUET Auditorium	24.3633898	88.6289901	24.3633614	88.6289997	2.8 m
CSE Building, RUET	24.3638453	88.6290894	24.3638293	88.6290733	6.7 m
EEE Building, RUET	24.3646768	88.6289476	24.3646478	88.6289177	1.3 m
RUET Guest House Rd	24.3656243	88.6287238	24.3655909	88.6287112	2.1 m
EEE Building, RUET	24.3646674	88.6289345	24.3646478	88.6289177	3.9 m

Table 1 compares the GPS location coordinates captured by a tracker and a phone, identifying differences in positioning accuracy across various locations at RUET. Most locations show a minor positional error ranging between 1.3 m to 12.3 m, with the highest deviation observed at the Admin Building (12.3 m).on the other hand, the EEE Building exhibited the most precise tracking, with a minimum error of 1.3 m. The majority of locations recorded differences around 2 to 5 meters. Moreover, locations like the GCE Building (11.2 m), Fluid Mechanics Lab (7.8 m), and Near Sheikh Hasina Hall (8.4 m) displayed larger deviations. Whereas, locations like the High Voltage Lab (1.7 m), Wood Shop (2.5 m) and RUET Garage (2.3 m) displayed larger deviations. The overall accuracy of the tracker demonstrates consistent accuracy, providing usable data for most practical applications.

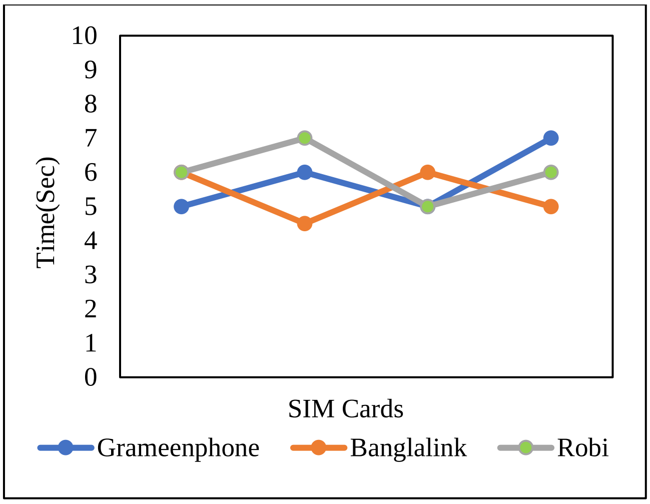

Fig.9 Delay analysis on various SIM cards.

4. Cost Analysis

Table 2 Total Cost of Our Project.

Sl. No.	Items	Cost (BDT)
1	Arduino UNO R3	900
2	Neo 6M GPS	650
3	GSM SIM 800L	400
4	Buck Converter	10
5	High Discharge LiPo Battery	300
	Total =	2260

From table 2, it is noticed that the developed tracking system costs around 2300 Tk, whereas all other trackers cost about 4500 TK. Sinotrack st-901 costs around 3000 Tk, but its accuracy is quite lower. On the other side, Seeworld w15 and another Sinotrack product, Sinotrack st-915, cost 6000 Tk, which is more than double of this project (Fig.10). The developed trackers also have a double price than our GPS-GSM based project with almost the same accuracy.

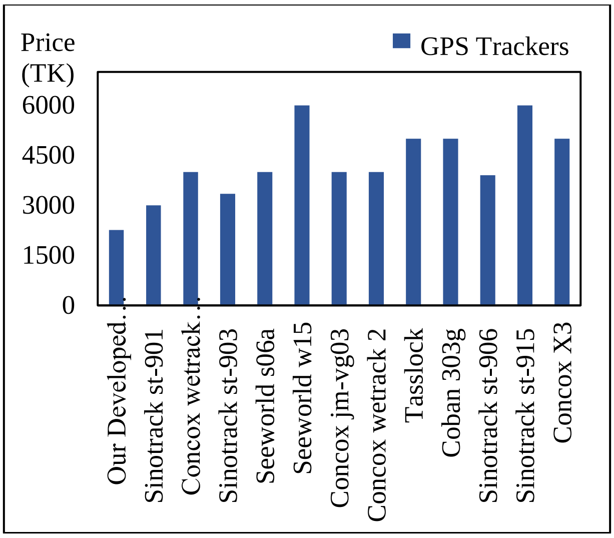

Fig.10 Cost comparison among various GPS trackers.

5. Discussion

A flexible, customizable, and accurate vehicle tracking system is successfully developed. This system utilizes a GSM modem, which has been configured to monitor and track a vehicle's location both via SMS and online through Google Maps integration. The core of this system is Arduino, which controls the GSM modem through AT commands for data transmission over the GSM network, while GPS provides precise location data.

Though this research utilized a free GPS service, it was expected that the coordinates of the moving units might not have been highly accurate. The precision of the positioning was likely influenced by various factors, such as weather conditions, the presence of obstacles in the surrounding environment, and the signal strength of available satellites during coordinate measurements. The GPS tracking technology has certain limitations, as it may be ineffective indoors due to its reliance on satellite signals. Signal interruptions can occur due to obstructions or atmospheric conditions. Battery failures can lead to device downtime. Over-reliance on GPS without backup navigation can pose risks. Regular maintenance is necessary for optimal performance. Privacy and data security concerns must be addressed. GSM SIM 800L also requires a specific voltage range for operation.

6. Conclusion

In conclusion, with the installation of the GPS, GSM, and IoT-based bus monitoring system, the RUET Teachers' Bus has significantly improved transportation services and increased the safety and efficacy of the bus fleet. Future improvements will include fuel monitoring, accident detection, and the use of anti-theft technology. Using a fingerprint sensor, the anti-theft technology offers an affordable alternative for tracking and vehicle protection. In the event of an accident, the accident detection system can notify pre-designated contacts via a GSM module and vibration sensor. Based on GSM and Arduino technology, the gasoline theft detection system keeps track of the vehicle's fuel levels and notifies the owner when necessary.

This project serves as a model for similar endeavors at other organizations and institutions through implementing future work into action and making ongoing improvements.

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