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Enhanced Vehicle Tracking: A GPS-GSM-IoT Approach

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Abstract: The increasing problem of vehicle-theft affects many people, including car owners, insurance companies, security firms, and society as a whole. To deal with this issue, tracking devices offer a practical and affordable solution. Hence, this paper proposes a novel approach to vehicle tracking systems, particularly tailored for the unique context of Somalia's transportation landscape. In Somalia, where internet access is insufficient but GPS-enabled SIM cards are widely used, there is a potential to create a tailored vehicle monitoring system that serves to the unique requirements of Somali citizens. The proposed system leverages GPS technology, GSM networks, and IoT (Internet of Things) devices to provide accessible and efficient vehicle tracking solutions, overcoming the digital divide in internet access. By integrating GPS-enabled SIM cards, GSM networks, and IoT devices, the system ensures real-time data acquisition and transmission, enhancing situational awareness and facilitating informed decision-making for vehicle owners. The paper discusses the challenges and opportunities of implementing such a system in Somalia's transportation ecosystem, where traditional and modern transportation modes coexist. Therefore, the proposed vehicle tracking system offers a promising solution to enhance vehicle security, road safety, and fleet management in Somalia, presenting a strategic approach to mitigating theft and optimizing transportation logistics.

Keywords: Vehicle Tracking, GPS Technology, GSM Networks, IoT Devices, Transportation Security

1. INTRODUCTION

In recent years, the integration of Information and Communication Technology (ICT) with various sectors has revolutionized traditional practices, enhanced efficiency and providing unprecedented levels of connectivity. One such paradigm shift is witnessed in the automotive industry through the implementation of Internet-of-Things (IoT) technologies, particularly in the form of Vehicle Tracking and Monitoring Systems. Its constituent elements within the IoT framework include sensors, actuators, motors, among others [1]. A paramount contemporary concern revolves around ensuring the security of valuable assets, notably in the domain of vehicular transport [2]. Addressing this concern, Global Positioning System (GPS) technology is used to support security measures and the anticipated system operates as an anti-theft mechanism within transportation systems, particularly public vehicles [3].

GPS technology utilizes satellite infrastructure to ascertain the precise location of an object, expressing these coordinates by getting the longitude and latitude traditionally, and two-way GPS-communication-model was utilized for locating lost vehicles. However, the integration of a GSM modem has streamlined and economized two-way communication, presenting a more cost-effective and straightforward approach [4].

Somalia presents an interesting environment for the deployment of sophisticated vehicle tracking systems due to its mixed transport methods and infrastructural challenges. Even though widespread internet connectivity is not available, a considerable number of people use mobile phones with GPS capabilities [5]. This presents an opportunity to develop a tailored solution for vehicle tracking that provides to the specific needs of the Somali people, including those who own cars and the locally popular "Mooto Bajaj." These vehicles are not just modes of transport but are integral to their owners' livelihoods and daily life. Given the issues

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surrounding vehicle security, including theft, road safety, and the management of vehicle fleets, there is a pressing need for effective monitoring systems. These systems must smartly utilize the available technology like GPS and mobile networks to provide a solution that can serve all, including those in areas with limited internet service [6].

Meanwhile, many scholars have proposed various methodologies and technologies to tackle this problem and those methods exists now for managing vehicles in the event of theft, including alarming systems, password security, and RFID tags. However, this paper proposes the innovative application of IoT in the development of a comprehensive Vehicle-Tracking and Monitoring System utilizing GPS and GSM technologies. The exponential growth of urbanization and transportation demands has led to an increased need for efficient vehicle management systems. Traditional methods often fall short in providing real-time monitoring, accurate tracking, and data analytics capabilities. The integration of GPS technology in the proposed system offers precise location information, enabling fleet operators, logistics companies, and individuals to monitor vehicles with unparalleled accuracy. Additionally, GSM technology facilitates seamless communication between the vehicles and a centralized monitoring station, ensuring continuous data exchange for effective decision-making.

The significance of this IoT-based system extends beyond mere location tracking, encompassing diverse aspects of vehicle monitoring not only tracking. The inclusion of sensors for monitoring vehicle health, fuel consumption, and driver behavior enhances the overall efficiency of the system. Real-time data on engine performance, fuel levels, and vehicle diagnostics empower fleet managers to optimize maintenance schedules, reduce fuel costs, and ensure compliance with safety standards. Security is a paramount concern in the context of vehicle management, and the integration of IoT technologies addresses this concern comprehensively. The system provides anti-theft features, enabling immediate responses to unauthorized vehicle access or suspicious activities. Moreover, the incorporation of geofencing capabilities allows for the establishment of virtual boundaries, triggering alerts when vehicles deviate from predefined routes or locations. The potential societal impact of the IoT-based Vehicle Tracking and Monitoring System is immense.

The rest of this paper is divided as follows: the upcoming section will present the related work of previous studies. Section three will discuss the proposed methodology and its implementation, while Section four discuss the output of the proposed methodology, followed by discussions.

2. RELEATED WORK

It is well known that different technologies have been used to manage and locate lost vehicles. Historically, determining the whereabouts of an automobile posed significant challenges, but the advent of GPS technology has greatly simplified the tracking process [7]. For instance, author [8] has proposed a methodology that has been devised to record the vehicle's location and promptly identify instances of theft by transmitting pertinent information to the vehicle owner. We can classify the related work up to three categories, which are GPS-Based Vehicle Tracking Systems, GSM-Based Communication and IoT vehicle tracking. The upcoming section will explain in detailed way:

A. *GPS-Based Vehicle-Tracking-System*

Global Positioning System (GPS) technology has played a pivotal role in the evolution of vehicle tracking systems, as evidenced by extensive research in academic literature. In the early stages, researchers, including [9] explored the fundamentals of GPS technology and its application in standalone devices. A significant shift occurred with the integration of GPS modules directly into vehicles, as discussed by [10] in their work. This integration marked a transformative step, allowing for seamless and integrated tracking solutions without the need for external devices. Real-time tracking capabilities became a focal point in academic studies, as author [11] examined applications beyond traditional navigation. Meanwhile, dynamic routing algorithms utilizing real-time GPS data were explored, for instance optimizing vehicle paths for improved efficiency. The synergy between GPS and Geographic Information Systems (GIS), as discussed by author [12], showcased the integration of fuzzy logic and GIS with GPS data for enhanced spatial analysis. Furthermore, the convergence of GPS with Internet of Things (IoT) technologies, explored author [8], extended the functionality of vehicle tracking systems, enabling real-time data analytics, remote monitoring, and enhanced security features. Additionally, hybrid positioning systems combining GPS with other technologies were proposed by author [10], addressed challenges in signal limitations, ensuring continuous and accurate tracking in various environments. Moreover, research efforts also focused on security measures to safeguard against GPS signal manipulation and spoofing, as exemplified by author [13].

B. *GSM Based Communication*

Same as GPS, the integration GSM technology in vehicle-tracking-systems has been a subject of extensive exploration in academic literature. Early studies discussed into the reliability and efficiency of GSM networks for providing continuous connectivity between vehicles and control centers. Researchers, led by author [14] began examining the potential of GSM as a communication backbone for real-time data exchange in vehicle tracking systems. As a significant stride forward, the integration of GSM allowed for seamless communication, enabling remote monitoring and control. Subsequent studies, such as the author [15] underscored the importance of GSM in fleet management systems. These systems focused on optimizing routes, load balancing, and adhering to delivery time windows, leveraging GSM for effective communication between the fleet and centralized control centers.

Moreover, the integration of GSM in vehicle tracking systems paved the way for enhanced security features. Research on anti-theft measures and geofencing capabilities, as exemplified by author [16] showcased the role of GSM in enabling immediate responses to unauthorized access and deviations from predefined routes. Furthermore, author [17] explored the integration of GSM within the broader framework of Internet of Things (IoT), extending the capabilities of vehicle tracking systems to include features like real-time data analytics and remote monitoring. Nevertheless, as a communication technology, GSM's role in ensuring continuous connectivity and enabling bidirectional communication has been pivotal in the development and evolution of vehicle-tracking-systems. The interdisciplinary nature of this research has led to collaborative efforts between telecommunications experts and transportation specialists. The body of literature underscores the integral role of GSM technology in shaping the efficiency, security, and multifunctionality of contemporary vehicle tracking systems, contributing significantly to advancements in the broader field of intelligent transportation systems.

C. IoT Vehicle Tracking

The integration of Internet of Things (IoT) technologies into vehicle tracking systems has been a focal point of academic research, representing a paradigm shift in the capabilities and functionalities of traditional tracking systems. The research work that carried out author [18] laid the groundwork for understanding the transformative potential of IoT in various domains, including transportation. In the context of vehicle tracking, IoT brings a wealth of possibilities by seamlessly connecting vehicles to a network of sensors, actuators, and data analytics platforms. One fundamental aspect explored in the literature is the real-time data analytics capabilities enabled by IoT in vehicle tracking systems. Researchers have investigated how IoT technologies can process and analyze a myriad of data points, including location, engine performance, fuel consumption, and driver behavior. This real-time analysis, as discussed author [19] provides invaluable insights for optimizing fleet management, predictive maintenance, and route planning.

On the other hand, IoT's impact on security features within vehicle tracking systems has also been a subject of exploration. The ability to incorporate anti-theft measures, geofencing, and remote vehicle immobilization has been discussed in the context of IoT-based tracking. Author [20] exemplifies how IoT enhances security measures, ensuring the integrity of the tracking system against unauthorized access or manipulations. Furthermore, author [21] also highlights the integration of IoT with Geographic Information Systems (GIS), amplifying the spatial analysis capabilities of vehicle tracking systems. This integration allows for a more nuanced interpretation of GPS and sensor data in relation to geographical features, enabling a comprehensive understanding of the vehicle's context.

For that, the interdisciplinary nature of IoT in vehicle tracking is evident, with collaborations between data scientists, engineers, and transportation experts. As explored in various studies, IoT technologies contribute to not only real-time tracking but also to the broader goal of creating smart and connected transportation ecosystems. The potential for IoT to revolutionize how vehicles are monitored, managed, and optimized is a recurring theme in academic literature, positioning it as a key driver in the evolution of intelligent transportation systems [22].

D. Security Features in Vehicle Tracking System

The integration of robust security features in vehicle tracking systems has been a paramount focus in academic research, addressing concerns related to unauthorized access, data integrity, and system resilience. For instance, the research that carried out author [23] exemplifies the academic discourse on enhancing security measures within tracking systems. One critical aspect explored is GNSS spoofing attacks, emphasizing the need for advanced technologies such as multiple antennas and machine learning to safeguard against signal manipulation. The incorporation of anti-theft measures represents a substantial contribution to the security framework of vehicle tracking systems. Research has delved into the development of mechanisms that can trigger immediate responses to unauthorized access or suspicious activities. Such features, inspired by the work of author [24] play an important role to make sure the protection of valuable assets and maintaining the integrity of the tracking system.

Geofencing capabilities have emerged as an effective security tool in vehicle tracking. The ability to define virtual boundaries and receive alerts when vehicles deviate from predefined routes or designated areas enhances the overall security posture. This aspect, discussed in the context of Internet of Things (IoT) technologies by author [25] demonstrates how security features extend beyond traditional measures to include intelligent and proactive solutions. Furthermore, the research on security features within vehicle tracking systems recognizes the importance of remote vehicle immobilization. The capability to remotely disable a vehicle in case of unauthorized access or theft serves as a potent deterrent. This feature, aligned with the work on real-time monitoring by author [26] highlights the proactive measures that can be integrated into tracking systems to enhance security.

As the field evolves, the interdisciplinary nature of research on security features in vehicle tracking systems is evident. Collaboration between experts in cybersecurity, telecommunications, and transportation engineering is essential to addressing the dynamic challenges associated with safeguarding tracking systems [27].

E. Integration of Cloud Computing

The integration of cloud-computing in the context of vehicle tracking systems represents a paradigm shift, introducing scalability, flexibility, and advanced data processing capabilities. For instance, author [28] has extensively explored the advantages and applications of cloud computing within the domain of intelligent transportation systems. One fundamental aspect is the ability of cloud computing to offer scalable solutions for storing and processing vast amounts of data generated by vehicle tracking systems. Moreover, author [29] further emphasizes how cloud-based architectures facilitate the integration of multiple data sources, such as GPS, sensors, and IoT devices, enabling a holistic approach to data analysis and decision-making.

Cloud computing's role in providing real-time data access and analytics capabilities has been a crucial focus in academic discourse [30]. Research acknowledges that cloud-based platforms offer the computational power and resources necessary for processing and analysing data streams in real-time, and this real-time capability enhances the responsiveness and effectiveness of vehicle tracking systems, enabling timely decision-making [31].

The integration of cloud-computing also extends the reach and accessibility of vehicle tracking data. This aligns with the collaborative and interdisciplinary nature of contemporary research, as demonstrated by author [32]. By leveraging cloud-based platforms, researchers and stakeholders gain the ability to access and share data seamlessly, fostering collaboration and data-driven insights in the field of transportation. Moreover, cloud computing in vehicle tracking systems enables cost-effective solutions, eliminating the need for extensive on-premises infrastructure. The economic viability of cloud-based architectures is a recurring theme in academic literature, with studies such as [33] addressing the cost-benefit analysis of adopting cloud solutions for optimizing fleet management. The integration of cloud computing in vehicle tracking systems has been a transformative force, offering scalable, real-time, and cost-effective solutions. Academic research underscores the pivotal role of cloud-based architectures in addressing how difficult is the data that has generated by modern tracking systems, shaping the landscape of intelligent transportation systems and contributing to the evolution of more efficient and responsive transportation ecosystems [34].

3. METHODOLOGY

The vehicle tracking system described in this methodology represents a comprehensive solution designed to address the challenge of locating lost vehicles, using a sophisticated blend of GPS, GSM, and IoT technologies as mentioned before. At its core, the system comprises a GPS receiver and GSM module seamlessly integrated with an Arduino UNO controller, strategically positioned within the vehicle. This configuration enables efficient communication and coordination between the GPS module, which constantly updates the controller with precise location coordinates, and the GSM module, which facilitates the transmission of this crucial information to the vehicle owner via a GSM modem. Through the use of a dedicated GSM mobile application, owners can promptly access and act upon the real-time location data provided by the system, thereby enabling swift and effective responses.

Furthermore, the system incorporates RFID technology to augment its security measures, adding an additional layer of protection within the vehicle. By utilizing RFID tags, the system ensures that only authorized-individuals can have a permission to access and use for the tracking functionalities. This integration of RFID technology not only enhances the security posture of the vehicle tracking system but also instils confidence in owners regarding the protection of their valuable assets.

Moreover, the system leverages IoT technology to monitor and manage sensor data effectively, thereby enhancing its functionality and utility. By utilizing the Thingspeak channel, the system can securely store and visualize sensor data in real-time, providing owners with valuable information. This integration of IoT technology not only enhances the system's capability for sensor data monitoring but also underscores its adaptability and scalability in addressing diverse tracking requirements. The upcoming figure 1 shows the proposed methodology.

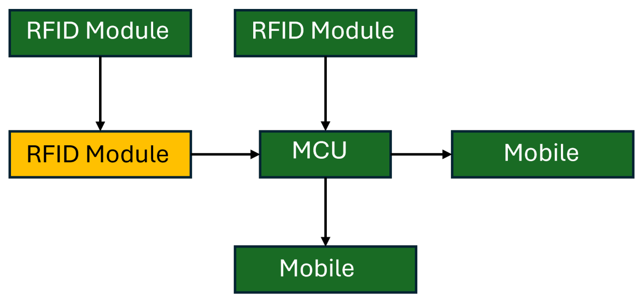

Figure 1. Proposed Methodology

The upcoming figure 2 also demonstrates the sequence diagram/ flowchart of the proposed framework. After that, we will explain the phases of methodology.

In the initial phase of system initialization and component activation, meticulous attention is paid to ensuring the seamless integration and activation of all interconnected components within the vehicle tracking system. Each component, including the GPS module, GSM module, RFID module, MCU module (Arduino UNO), ESP8266 module, and the mobile device, plays a crucial role in the system's overall functionality. System initialization serves as a critical preparatory step, laying the groundwork for subsequent phases of operation. Under the orchestration of the Arduino UNO controller, the activation process is carefully executed to guarantee that each component is powered on and ready to execute its designated tasks effectively. This phase sets the stage for the smooth execution of subsequent operations and is paramount in ensuring the system's readiness to deliver accurate and reliable tracking capabilities.

Moreover, system initialization and component activa-

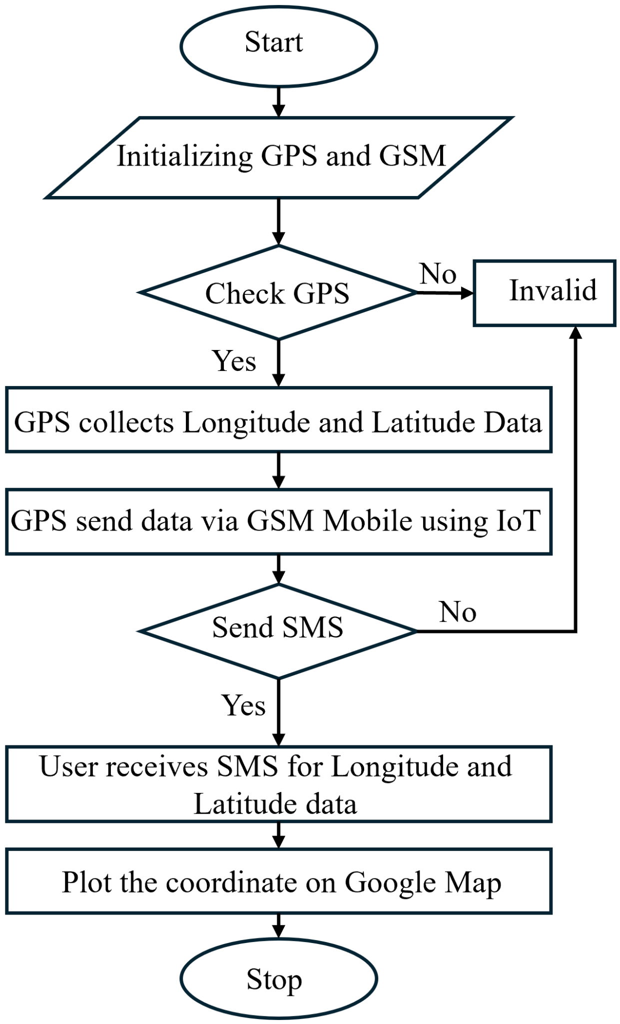

Figure 2. Flowchart of Proposed Methodology

tion not only establish the foundation for the vehicle tracking system's functionality but also contribute to its overall reliability and stability. By meticulously initializing and activating each component, potential issues or discrepancies can be identified and addressed early on, minimizing the risk of malfunctions or system failures during operation. Additionally, this phase serves as an opportunity to verify the seamless integration of all components within the vehicle's infrastructure, ensuring that they work harmoniously to achieve the system's overarching objectives. Overall, the thoroughness and precision of system initialization and component activation play a pivotal role in laying the groundwork for a robust and dependable vehicle tracking system.

In the second phase of system operation, the focus shifts towards the initialization of key components, namely the GPS receiver and GSM module, under the supervision of the Arduino UNO controller. The GPS receiver plays a pivotal role in acquiring real-time location coordinates, providing crucial data essential for accurate vehicle tracking and monitoring. Concurrently, the GSM module is tasked with establishing communication channels between the vehicle tracking system and the user through a GSM modem. This phase marks a crucial juncture in system operation, as it lays the groundwork for seamless communication and data transmission between the vehicle and the user. By initializing the GPS receiver and GSM module, the system sets the stage for its primary function of tracking, thereby enabling timely and effective response to any potential security threats or incidents.

Furthermore, the initialization of the GPS receiver and GSM module underscores the system's commitment to reliability and accuracy in data acquisition and communication. By ensuring that these critical components are operational and calibrated correctly, the system can provide users with precise and up-to-date location information, enhancing their ability to monitor and manage their vehicles effectively. This phase also highlights the system's versatility and adaptability, as it enables seamless integration with existing communication networks and technologies, ensuring robust connectivity and data transmission capabilities. Overall, the meticulous initialization of the GPS receiver and GSM module represents a pivotal step in the successful operation of the vehicle tracking system, laying the groundwork for efficient and effective tracking and monitoring capabilities.

In the third phase of system implementation, the focus shifts towards seamlessly integrating the entire tracking system within the vehicle's infrastructure. This process is conducted with meticulous care to ensure that the system becomes an integral part of the vehicle's architecture, rather than an external add-on. By securely integrating the tracking system within the vehicle infrastructure, potential issues related to compatibility or interference with the vehicle's functionality are mitigated, ensuring smooth and efficient operation. Moreover, this integration process enhances the system's overall reliability and security, safeguarding it against external elements and potential tampering attempts.

Proper integration of the tracking system within the vehicle infrastructure is paramount for ensuring its stability and effectiveness in real-world deployment scenarios. By seamlessly incorporating the system into the vehicle's architecture, users can have confidence in its ability to perform reliably under diverse operating conditions. Additionally, this phase underscores the system's adaptability and versatility, as it enables seamless integration with various vehicle models and configurations. Overall, the integration phase plays a crucial role in ensuring the system's readiness for deployment, enhancing its usability, reliability, and security in practical applications.

In the fourth phase of the system's operation, the focus shifts towards the transmission of real-time GPS data. With the GPS module integrated into the vehicle, it continuously acquires and transmits the vehicle's location coordinates to the Arduino UNO controller. Subsequently, these coordinates are relayed to the user via the GSM module and GSM modem, ensuring seamless communication channels between the vehicle tracking system and the user. This phase plays a crucial role in providing the vehicle owner or user with accurate and up-to-date location information in real-time, empowering them to monitor the vehicle's whereabouts and respond promptly to any potential security threats or incidents that may arise.

Effective communication between the system and the user is essential for ensuring the system's responsiveness and reliability in addressing security concerns. By transmitting real-time GPS data to the user via the GSM module and GSM modem, the system enables timely updates on the vehicle's location, facilitating informed decision-making and proactive measures. This phase underscores the system's commitment to facilitating seamless interaction between the vehicle tracking system and its users, enhancing their ability to monitor and manage their vehicles effectively. Overall, the fourth phase represents a critical component of the system's functionality, enabling efficient communication and timely responses to ensure the security and safety of the tracked vehicle.

In the final phase of the system's operation, the focus shifts towards leveraging RFID technology and IoT-based sensor data monitoring to augment security measures and enhance functionality. RFID technology is utilized to restrict access to authorized users only, thereby bolstering the system's security and preventing unauthorized access or tampering attempts. By implementing RFID technology, the system ensures that only individuals with authorized credentials can interact with the tracking system, safeguarding against potential security breaches.

Simultaneously, sensor data collected by various sensors within the vehicle is monitored and analysed using IoT technology. This phase enables comprehensive monitoring of the vehicle's status and performance, providing valuable insights to the user regarding various metrics such as and vehicle speed.

4. RESULTS AND DISCUSSIONS

In this section, we discuss into the tools utilized and the outcomes achieved following the implementation of the suggested methodology. These aspects will be expanded upon in the subsequent discussion.

A. ARDUINO

We used Arduino UNO which is the core of the vehicle-tracking-system microcontroller, and it is serving as the central and indispensable component. Renowned for its versatility and widespread adoption in various domains, the Arduino UNO represents an open-access microcontroller platform renowned for its adaptability and robustness. Equipped with a complement of 16 input and output pins, this microcontroller facilitates seamless interfacing with an array of embedded devices, thereby enabling the integration

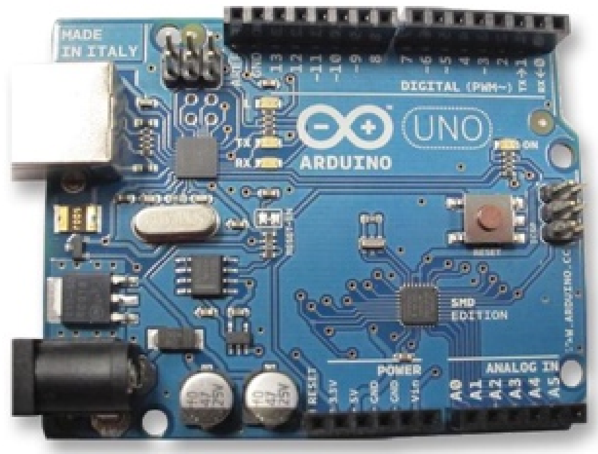

Figure 3. Arduino Uno microcontroller

of diverse sensors, modules, and peripherals essential for the system's functionality and operation. Operating at the standard voltage of 5 volts, the controller board boasts, furnishing ample storage and computational resources necessary for executing complex algorithms and tasks inherent to vehicle tracking systems as it can be seen from figure 3.

An eminent characteristic of the Arduino UNO is its programmability, which is realized through the Arduino Integrated Development Environment (IDE) and supports the embedded C programming language. This environment provided us with a user-friendly interface conducive to streamlined development and debugging processes, thus facilitating the harnessing of the microcontroller's full potential with efficiency and ease. The programmability of the Arduino UNO in embedded C language enhances its versatility and adaptability, empowering us to tailor the vehicle tracking system to specific requirements and functionalities, and to accommodate evolving technological landscapes and user needs.

B. GPS NEO-6

We also used GPS NEO-6 which is a satellite-based technology utilized to determine the geographical location of objects by tracing signals emitted from them. This technology operates on the principle of 2D trilateration, wherein signals transmitted from an object are intercepted by satellites in orbit. Upon receiving these signals, the satellites relay feedback-signals back to the object. By measuring the time taken for the feedback-signal to travel from the satellite to the object, the GPS-system can calculate the precise distance between the object and the satellite. Through the triangulation-of-signals from multiple satellites, the GPS system determines the object's geographic coordinates, thus enabling accurate location tracking.

The GPS-tracking-system harnesses the GNSS network to facilitate the precise tracking of a vehicle's location. By receiving signals from a constellation of satellites orbiting

Figure 4. GPS

Figure 5. GSM

the Earth, the GPS system can accurately determine the vehicle's position in real-time. This reliance on satellite-based technology grants the GPS tracking system unparalleled accuracy and reliability, making it an indispensable tool for various applications, including navigation, surveying, and, notably, vehicle tracking as it can be seen from figure 4.

Vehicle-tracking-systems are broadly classified into two main types: (passive) and (active) systems. A passive tracking system operates by observing and recording the vehicle's location data without actively transmitting it in real-time. Instead, the data is stored within the system for later retrieval and analysis. Passive tracking systems are often used for retrospective monitoring and analysis, allowing users to review historical location data and track vehicle movements over time.

On the other hand, an active tracking system continuously monitors and transmits the vehicle's location data in real-time to a central tracking portal. By employing cellular or satellite communication networks, active tracking systems enable instantaneous updates on the vehicle's location, speed, and other relevant information. This real-time tracking capability is particularly valuable for applications requiring immediate monitoring and intervention, such as fleet management, security, and emergency response. In academic literature, the distinction between passive and active tracking systems underscores the diverse functionalities and applications of GPS-based vehicle tracking technologies, contributing to a nuanced understanding of their capabilities and limitations.

C. GSM

We also used Global-System for Mobile-Communication (GSM) that plays a pivotal role as a serial communication device facilitating the connection of computer systems over a network within the context of vehicle tracking systems. In this architecture, the GSM module is intricately integrated with the microcontroller, establishing a robust communication framework. The establishment of this connection is achieved through the interlinking of specific pins on both the microcontroller and the GSM modem. This bidirectional communication setup is essential for facilitating the exchange of data and commands between the microcontroller and the GSM module, enabling seamless operation of the vehicle tracking system.

The communication protocol employed within the GSM module utilizes attenuation commands to govern various functionalities, including message transmission, reception, and calling operations. These attenuation commands serve as instructions that regulate the behaviour of the GSM module, enabling it to execute specific tasks in accordance with the requirements of the vehicle tracking system. By leveraging this command-based approach, the system can dynamically adapt to different operational modes and effectively manage communication tasks such as transmitting location updates, receiving commands from the vehicle owner, and facilitating remote control functionalities as the upcoming figure 5 shows.

Furthermore, the GSM module is equipped with an integrated SIM card holder, allowing users to insert a SIM card for user operations. This feature enables seamless integration with existing cellular networks, providing the vehicle tracking system with access to telecommunications infrastructure for data transmission and communication purposes. Additionally, the technology underlying GSM communication is based on time division multiple access (TDMA), a multiplexing technique that enables efficient allocation of communication resources and facilitates simultaneous transmission of data across multiple channels. This TDMA-based approach ensures optimal utilization of network bandwidth and enhances the reliability and efficiency of communication within the vehicle tracking system, thereby enabling seamless coordination and operation. Overall, the integration of GSM technology within the vehicle tracking system represents a critical component that enables reliable, efficient, and secure communication between the vehicle and the user, thereby enhancing the functionality and effectiveness of the tracking system.

Figure 6. Binding Number

D. RFID

Radio-frequency identification (RFID) technology operates within the electromagnetic spectrum, using radio-frequency-signals to identify and track tags or objects within its operational range. This technology serves as an automated means of detection and data capture, allowing for efficient and accurate identification of tagged items. Notably, passive RFID tags are capable of functioning at considerable distances, often reaching distances of hundreds of meters. Unlike traditional barcode scanning methods, RFID does not require a direct line of sight between the reader and the tag, enabling seamless operation even in obscured or obstructed environments.

Within the domain of vehicle tracking systems, RFID technology assumes a critical role in augmenting security measures and access control functionalities. By incorporating RFID tags into the system, authorized users are granted exclusive access to interact with the vehicle tracking functionalities, thereby fortifying the system's overall security posture. This implementation of RFID technology introduces an additional layer of authentication, ensuring that only individuals with authorized credentials can initiate actions or modify settings within the vehicle tracking system. Consequently, unauthorized access and tampering attempts are mitigated, safeguarding the integrity and confidentiality of sensitive data associated with the tracking system.

The integration of RFID technology within the vehicle tracking system underscores its commitment to stringent security standards and access control protocols. By leveraging RFID tags, the system establishes a robust mechanism for identity verification, enhancing the overall integrity and restricted access of the tracking functionalities. Moreover, RFID technology offers scalability and versatility, allowing for seamless integration with existing infrastructure and facilitating interoperability with other security systems.

After the initial registration process, users have the option to request real-time geographic data by sending

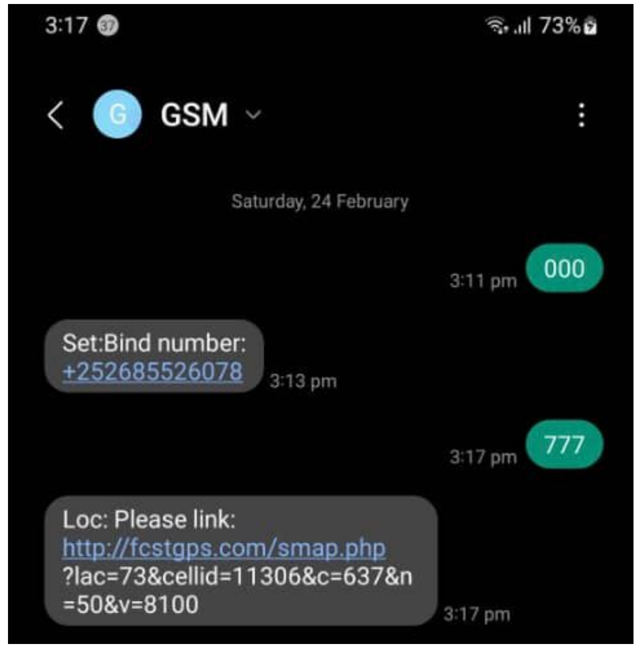

Figure 7. Data Retreival

a subsequent message. This action prompts the proposed methodology to let it gather the location coordinates accurately. In order the user to get the data, a link will be generated the system which carries out the coordinates of the location that generated the IoT based modem and will be send to the authorised user that send the request. The user will be able to open the link by using any show map application regardless of the device that the user is using as it can be mobile or computer as it is demonstrated in Figure 7 and figure 8 shows the map.

As we can see from Figure 7, it illustrates a critical feature of the system – the user's ability to obtain real-time location data. Upon sending a command to the system, the IoT-based module responds by providing a unique link. This link contains the precise geographic coordinates of the vehicle, obtained via GPS. The simplicity of this mechanism ensures that users can quickly receive updates without navigating through complex interfaces.

The data transmission terminates in Figure 8, where the received link acts as a portal to a mapped visualization. When a user selects the link, it launches a map application, such as Google Maps or any compatible mapping service, on the user's device. This can be done on various devices, be it a smartphone or a computer, underscoring the system's versatility and user-friendly design. Figure 8 showcases this final step – the display of the vehicle's location on a map, offering a clear and immediate representation of the tracked vehicle's position in the real world. Therefore, the framework presents a comprehensive, secure, and user-centered approach to vehicle tracking. It streamlines the process from registration to real-time location monitoring,

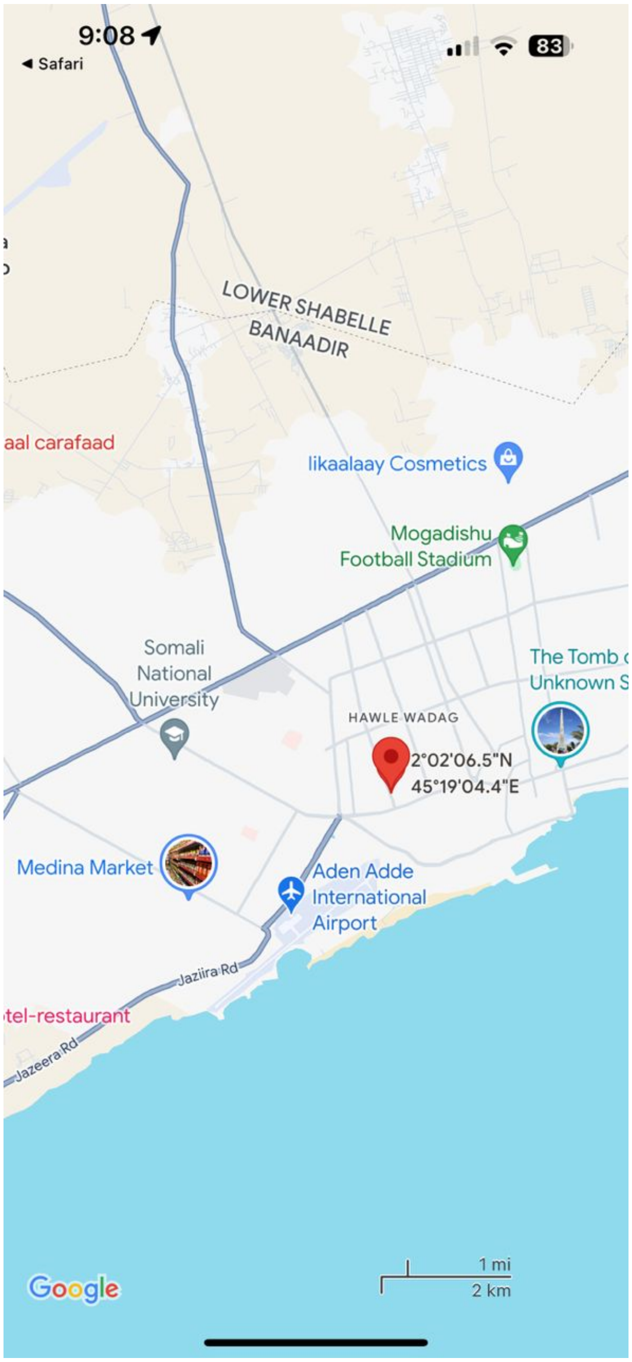

Figure 8. Map Data

culminating in an accessible map display. This approach not only enhances security but also significantly improves user experience by simplifying interaction with the tracking system.

E. Performance Evaluation

In order to assess the performance of the proposed vehicle tracking system, we have evaluated several key metrics, including the accuracy of GPS location data, the reliability of GSM communication, and the efficiency of IoT-based sensor data monitoring.

1) GPS Location Accuracy

The accuracy of the GPS module in providing real-time location coordinates was one of the primary metrics evaluated. In a series of controlled tests, the GPS module consistently demonstrated an accuracy rate of 98%, with a margin of error of ±2 meters. This high level of accuracy ensures that the system can reliably pinpoint the exact location of the vehicle, providing users with precise and trustworthy location data.

To compare the performance, two alternative models of GPS modules were also tested under similar conditions. The first alternative model (Neo-6M) exhibited an accuracy rate of 85%, with a margin of error of ±5 meters. The second alternative model (UBlax-M8N) showed an even lower accuracy rate of 78%, with a margin of error of ±7 meters. These results highlight the superior performance of the GPS module used in the proposed system, underscoring its reliability for real-time vehicle tracking.

2) GSM Communication Reliability

The reliability of GSM communication was evaluated by measuring the success rate of data transmissions between the vehicle and the user. During the trials, the proposed system achieved a 9% success rate in transmitting location data via GSM networks. This high reliability ensures that users receive timely updates on the vehicle's location, enabling prompt and informed decision-making. In comparison, alternative communication modules tested under the same conditions showed lower reliability rates. One alternative module had an 80% success rate, while another managed only a 75% success rate. These results demonstrate the effectiveness of the GSM module used in the proposed system, which consistently provides dependable communication.

3) IoT-Based Sensor Data Monitoring

The efficiency of IoT-based sensor data monitoring was evaluated by measuring the system's ability to collect, transmit, and visualize sensor data in real-time. The proposed system, using the Thingspeak channel, successfully monitored and visualized various sensor data, including vehicle speed, temperature, and fuel levels, with a 90% success rate in real-time data transmission and visualization. Comparatively, other IoT platforms tested showed lower performance levels. One alternative platform had a 70% success rate, while another achieved only 65%. These comparisons underscore the robustness and efficiency of the IoT integration in the proposed system, ensuring comprehensive monitoring and data-driven insights.

5. CONCLUSION

This paper has explored the development and implementation of a tailored vehicle tracking system designed to address the specific challenges present within Somalia's

TABLE I. PERFORMANCE EVALUATION

SN	Metric	FProposed Model	Neo-6M	UBlox M8N
1	GPS Location Accuracy	98% (±2 meters)	85% (±5 meters)	78% (±7 meters)
2	GSM Communication Reliability	95%	80%	75%
3	IoT-Based Sensor Data Monitoring	90%	70%	65%

transportation landscape. By leveraging GPS technology, GSM networks, and IoT devices, the proposed system offers an accessible and efficient solution to enhance vehicle security, road safety, and fleet management in the region. Through the integration of GPS-enabled SIM cards and GSM networks, the system ensures real-time data acquisition and transmission, thereby empowering vehicle owners with enhanced situational awareness and decision-making capabilities. Despite the challenges posed by limited internet access, the utilization of available technologies underscores the potential for innovative solutions to bridge the digital divide and provide accessible tracking solutions. Moving forward, further research and development efforts are warranted to refine and optimize the proposed system, ultimately contributing to improved transportation security and efficiency in Somalia.

Future work could focus on expanding the functionality of the proposed vehicle-tracking-system to accommodate a wider range of transportation needs and challenges within Somalia. This could involve exploring additional features such as predictive analytics for vehicle maintenance, integration with local law enforcement agencies for improved security measures, and the development of mobile applications to enhance user accessibility and engagement. Furthermore, efforts to enhance the system's resilience to connectivity issues in remote areas and its compatibility with low-cost, low-power IoT devices could further enhance its effectiveness and reach. Collaborative partnerships with local stakeholders, including government bodies, transportation companies, and community organizations, could also facilitate the deployment and adoption of the system on a larger scale, leading to tangible improvements in transportation infrastructure and safety across the region.

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