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Development of a Network-Tolerant Vehicle and Personnel Tracking System

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Abstract
Security issues in developing countries have been on the rise ranging from kidnapping to secessionist killings and banditry which have had a terrible ripple effect on the overall affairs of these states. The proliferation of security issues and social problems have continued to permeate developing countries due to drivers being kidnapped, vehicles get missing and poor network coverage in the remote locations where the crimes are perpetrated. The existing tracking solutions have the following shortcomings: tracks only the vehicle or the personnel and none tracks both, they are network intolerant, relied on car battery which may drain over time especially when the vehicle is not started for a long time. This paper proposed the development of a network tolerant solution that tracks both vehicle and personnel. The developed system queries an online database via a developed android application and returns the last known location of both vehicle and personnel on a Google map. It is equipped with renewable energy capabilities. The location data is fetched with GPS Module for vehicle tracking and transmitted to the database through a Global System for Mobile (GSM) communication, while personnel location data is fetched using the Global Positioning System (GPS) capabilities of android devices. Performance evaluation of the developed system showed a good accuracy in location reporting for both personnel and vehicle. Successful queries to the database were recorded in few seconds; hence, the developed system is adequate for a typical tracking application. An adoption of this device will aid the security in the rescue and recovery of personnel and vehicles respectively.

Keywords: *Security, Tracking, Kidnapping, Personnel, Solar, Network-Tolerant.*

Introduction

Insecurity in developing countries, has recently assumed an alarming rate, affecting every facet of human life and public infrastructure facilities with no end in sight. The dynamics and sophistication of security crisis, has led to very serious consequences, particularly the direct negative impacts on social and economy. Commercial activities have become skeletal and paralyzed in the areas worst hit by insecurity . Criminal activities such as ritual killings, militancy, secessionism, oil bunkering, terrorism and recently kidnapping of personnel and vehicles carrying goods across the country has become a trending headline. Researchers have proposed the use of tracking systems to monitor personnel and vehicles Yuan et al., (2015). Vehicle tracking systems are used to determine the location of a vehicle, using different methods like GPS and other navigation system operating via satellite and ground-based stations. Modern vehicle tracking systems uses GPS technology to locate vehicles, however, different types of automatic vehicles' location retrieval technology are also used . Other methods of vehicle tracking involve the use of Internet of Things (IoT) technology , Video based approach , Mobile crowd sensing methods and UAV based tracking .

Most vehicle tracking devices are powered from the vehicle's battery. However, recent researchers proposed the use of solar renewable energy as alternative Woldeyohannes et al., (2016). This becomes necessary for the assurance of system reliability, due to the fact that the vehicle battery may get drained if it is taken to a bush and kept for a long time without charging. Again, the communication of the vehicle location is done mostly using a GSM network of varying network providers. However, in developing countries like Nigeria, the service providers are not readily available in all locations especially in the bush areas where kidnappings are perpetrated Ekechukwu et al., (2020). These has limited the efficiency and reliability of the existing tracking devices in countries like Nigeria. In this research, a network-tolerant, solar-powered vehicle and personnel tracking system is proposed. The proposed vehicle tracking system is designed around GPS/GSM, powered by solar and controlled by ATMEGA microcontroller. Users will make use of a developed Android application to interact with the system. The remaining section of this paper is organized into: section II for review of relate works, section III for in-depth methodology, and section IV for results and discussions.

II. RELATED WORK

Myint & Khin (2018) made use of GPS and GSM modules to track and communicate vehicle location. A desktop application was made using JavaScript –MYSQL to design the database and the location was accessed through Google map API. A number of related works exists in the domain of remote object surveillance and tracking. Among them are the works of) and), that developed a GPS/GSM based systems, to track vehicle's location. While the former added lock and unlock functions remotely, the later developed a desktop application using a JavaScript. Location of the vehicle was viewed through a Google map. Performance evaluation of both systems showed that they were robust, but did not consider worst scenarios where GSM network is unavailable in remote areas.

Similarly, the authors in developed a GPS-based vehicle tracking system. A dead reckoning and assisted GPS methods were added, to overcome the drawbacks of conventional GPS methods in position tracking. The developed system was highly accurate, however, the authors traded off complexity and reliability for accuracy.

In a view to prevent vehicle theft, developed an anti-theft tracking system based on GPS, GSM and RFID. The RFID was used for authentication and a tilt sensor was provided to detect window breakage. The system was designed to stop the fuel injector in the case of theft and alert the user via SMS with the location information of the vehicle. The system was efficient in the antitheft function; however, it depends on the car battery solely which may drain over time if vehicle is not moved.

A cargo vehicle monitoring system was also developed by incorporated Geofencing for lane restriction and also solar as a renewable energy to power the system. This system was GPS and GSM based therefore, restricting communication to users only when a GSM signal was available. This work also utilized solar tracking technology but was restricted to single axis tracking for harvesting solar energy. An anti-theft vehicle tracking system was developed by based on GPS navigation method. This work featured real-time tracking of a vehicle location through an android application with added function of vehicle locking in case the vehicle was stolen. Similarly,), developed an offline GPS/GSM anti-theft tracker that communicates coordinates through a Google maps link to a designated number. In both works, the vehicles are tracked in real-time, however, they rely on GSM networks and the vehicle battery to operate. developed a GPS-GSM based guided system for tracking vehicles. This system employed the use of command words to get the coordinates of the vehicle at any point in time. In the case of theft, the system sends coordinates to the pre-assigned designated authority numbers. The drawback of this work is that it depends on the availability of GSM network to communicate the vehicle location to the users. developed a GPS-Based Tracking system using the idea of boundaries, such that if the target GPS leaves a specific area, an alarm is triggered and SMS is sent to notify relevant authorities about the escape. The study is limited to organizations such as schools and prisons but could also be applied to vehicle monitoring. However, it only monitors the vehicle and not the personnel. Equally, provided a novel application of Light Detection and Ranging (LiDAR) sensor for collection of real-time information of vehicles without IoT in a mixed traffic situation. This study majorly focused on background filtering, lane identification, and vehicle tracking of unconnected vehicles. The study was mainly used to determine vehicle speed from the LiDAR readings in order to alert other vehicles about the none-connected vehicle as they are incapable of communicating with connected devices in a mixed traffic situation. This literature focusses on the tracking of vehicles and solar tracking. This work intends to shift focus from just the vehicles to the personnel who drive these vehicles.

proposed the use of Unmanned Aerial Vehicles (UAV) to detect and track vehicles accurately. This method had advantage over conventional video-based vehicle tracking systems which use feed from stationary cameras. UAV proved more flexible as it artificially controls its flight and also has an aerial view which provides far better but complex parameters. The study involved a detection stage which used R-CNN and a tracking method based on Kalman filtering. The detection method is robust; however, it is not suitable long distance vehicle tracking.

III. METHODOLOGY

The system methodology is divided into: vehicle tracking method, solar tracking method and personnel tracking method.

Hardware and Software Design Considerations

The system's major functional components consist of Arduino ATMega microcontroller, Neo 6M GPS module, SIM 800L EVB GSM module, LDR, SG 90 Servo motor, charge controller, Lithium-ion battery and solar PV cells. The choice of the components was strongly based on their characteristics, suitability and design specifications. The block diagram of the hardware interfaces is shown in Figure 1, while the schematic circuit connections is shown in Figure 2.

The software components of the system are basically in the development of application interfaces and Arduino Integrated Development Environment (IDE), which was considered for the configuration of the Arduino ATMega. For the application interface development, Flutter programming language was used to develop a master and slave applications. The choice of the considered software was based on their ease of use and support for the considered hardware components.

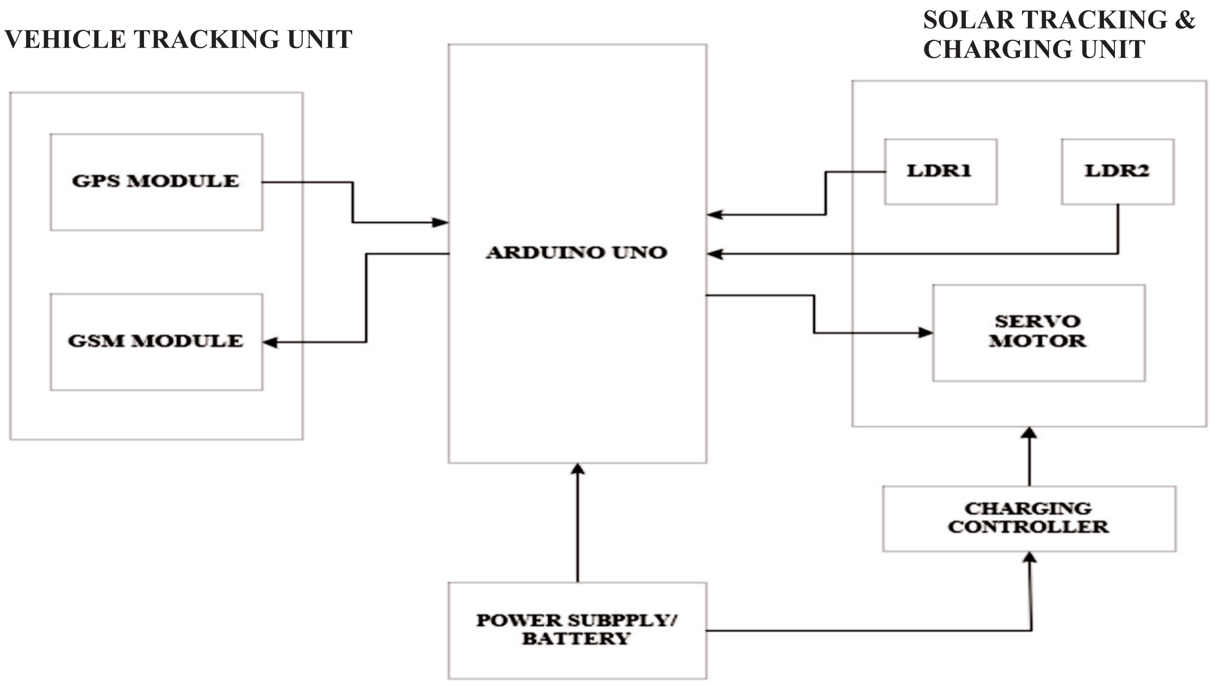

Figure 1: Hardware Interfaces of the system

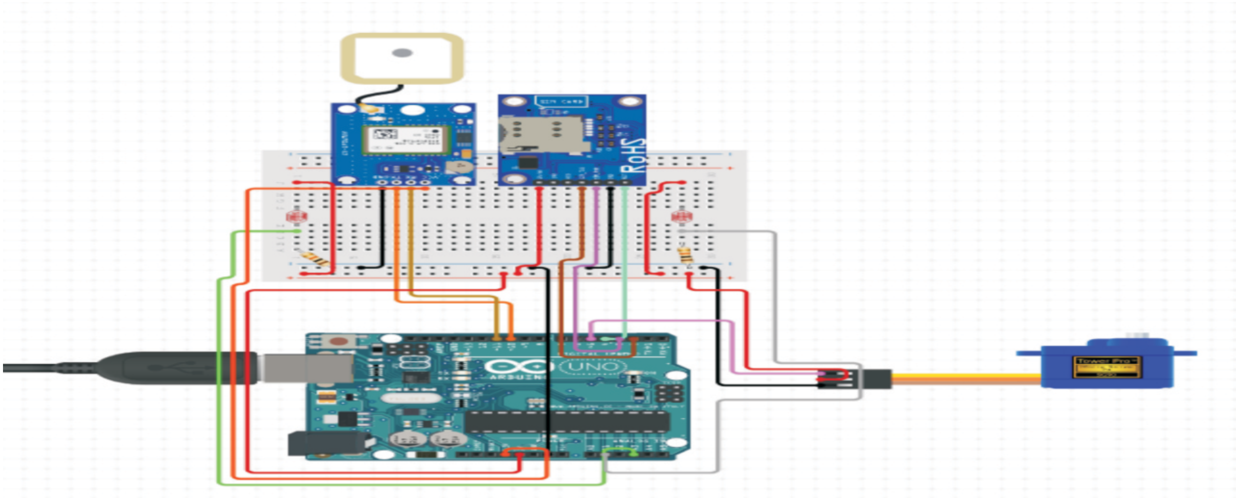

Figure 2: Schematic circuit connections

Vehicle Tracking Method

The function of the vehicle tracking is to get the location of the vehicle at any instance. This was done using the GPS device, which reads and transmit the coordinates every 10 minutes to an online database using the GPRS network provided by the GSM module. The flow diagram of the process is depicted in Figure 3. To handle the issue of unavailable GSM network, the system remains in a loop, checking every 5 seconds until the network is available to update the database with its current location. After which it returns to the normal 10 minutes interval updates. The database used in this work is the Firebase from firestore. The developed master application interface is used to query and visualize the last location of the vehicle via a Google map.

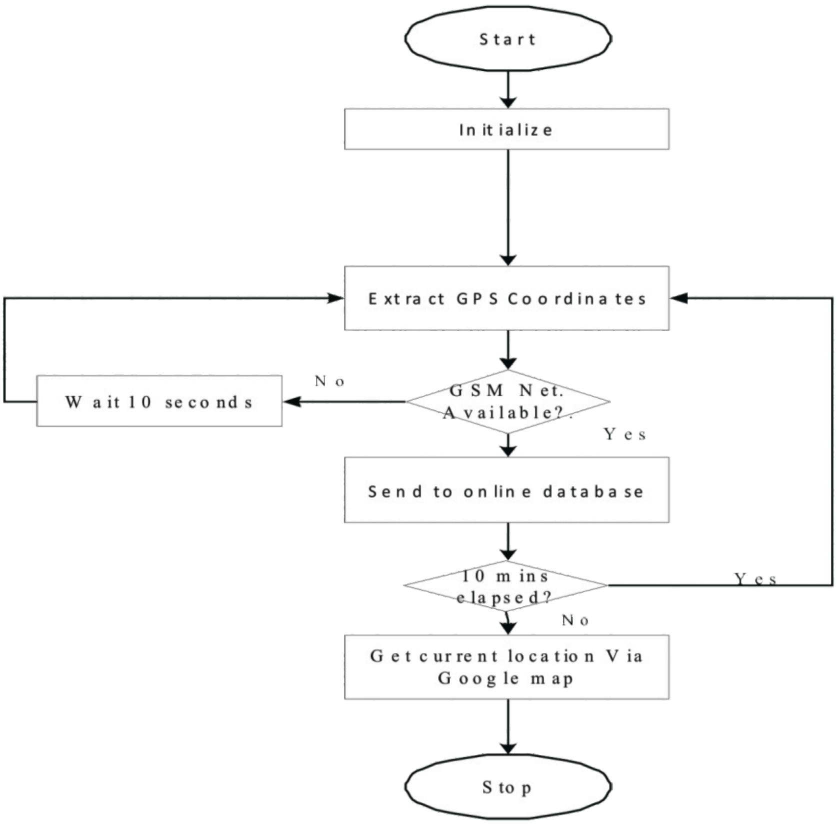

Figure 3: Vehicle Tracking Flowchart

Personnel Tracking Method
Similar to the vehicle tracking method, the slave application interface installed on the android phone of the personnel is enabled at the start of every journey. It utilizes the GPS capabilities of android mobile phones to fetch the GPS coordinates of the android phone every 10 minutes and send directly to the online database using the internet connection on the phone, provided by the one of the GSM service providers. The coordinates are fetched from the database and plotted on the Google map by the master application. When the GSM network is not available, the system also remains in a loop, checking every 5 seconds, until it becomes available to update the last known location. The process is shown in Figure 4.

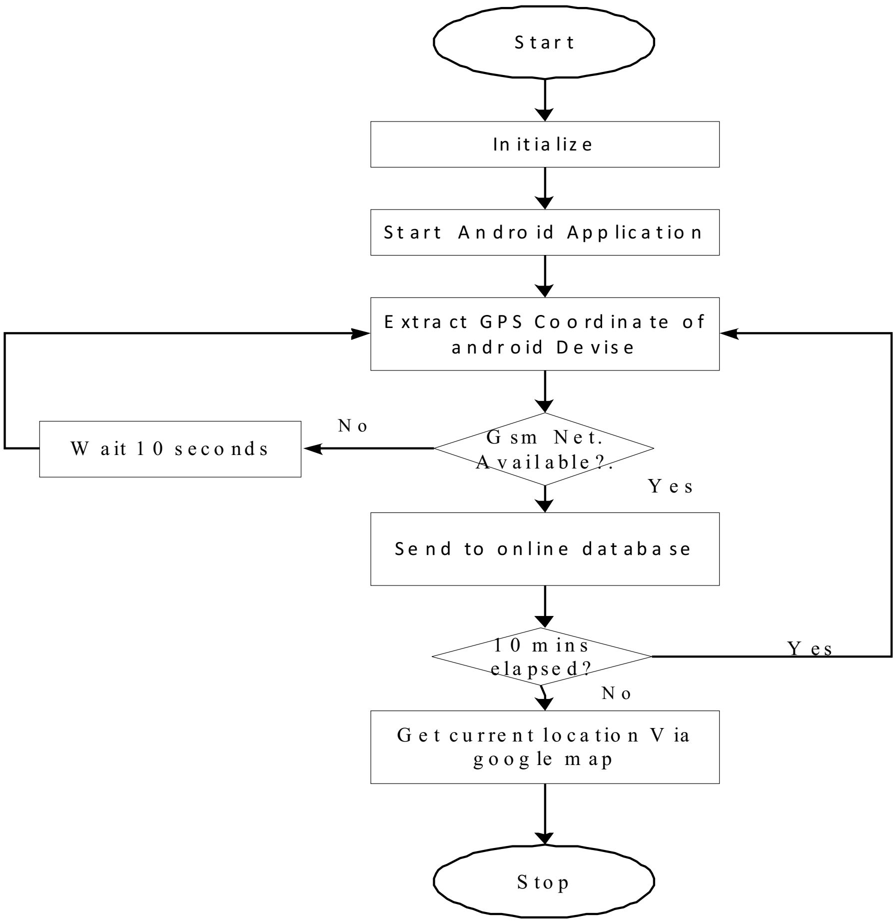

Figure 4: Personnel Tracking Flowchart

Solar Tracking Method
This solar tracking unit makes the use of Light Dependent Resistors (LDR) and Servo motors, to detect and rotate the PV panel to the direction with highest sunlight intensity in order to harvest maximum energy. The process flow is shown in Figure 5. The PV cells are meant to charge a Lithium-ion battery through a charge controller only when the vehicle is not in motion. Therefore, an accelerometer sensor is used to detect when the vehicle is in motion, so that charging is suspended and the panel is returned to a safer position. The system compares between the values of LDR1 and LDR2, positioned opposite each other, to determine the direction in which the servo motor will rotate the PV panel. When LDR1 receives more energy than LDR2, it denotes that the sunlight is more in the direction of LDR1, hence the PV panel is rotated towards it and vice-versa. Until the battery is fully charged, the system continues to charge it. The process is shown in Figure 5.

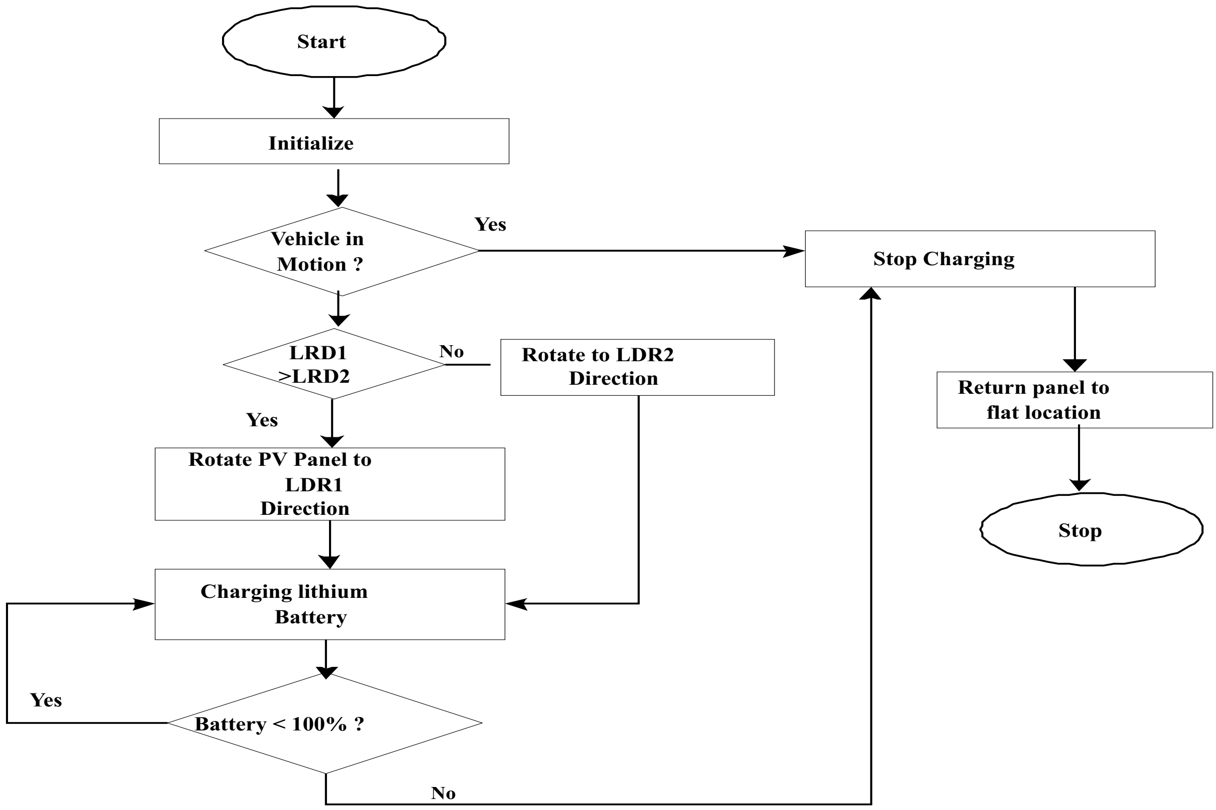

Figure 5: Solar Tracking Flowchart

IV. RESULT AND DISCUSSION

The results obtained from system evaluation are presented in Tables 1, 2 and 3. The system was evaluated by determining the response time and position accuracy of GPS coordinates of both vehicle and personnel tracking units. From the results obtained, the developed system showed average response times of 8.8 and 5.9 seconds for the vehicle and personnel tracking units respectively. The positional accuracies of both units were also measured as shown in Table 2 and Table 3.

Table 1: System Response Time

No. of Messages	Elapsed Time for Vehicle tracker (seconds)	Elapsed Time for personnel tracker(seconds)
1	9	4
1	4	3
1	6	9
1	10	3
1	7	13
1	11	3
1	7	4
1	10	9
1	15	5
1	8	6

Total number of messages sent is 10, therefore,

For vehicle tracking, the Average response time can be calculated as:

$$Average\ Response\ Time = \frac{88}{10} = 8.8 seconds$$

For personnel tracker, the Average response time can be calculated as follows:

$$Average\ Response\ Time = {}^{59}/_{10} = 5.9 seconds$$

The above results indicate that the location of both vehicle and personnel are transmitted in good time and the system responds within a relatively short amount of time which could make the difference when tracking vehicles and personnel to save lives and properties.

Table 2: Showing Position Accuracy for Vehicle Tracking Device

	Actual Coordinates (Latitude, Longitude)	Vehicle Tracker Coordinates (Latitude, Longitude)	The difference in distance (in meters)
1.	9.536293, 6.454562 (Round About)	9.536600, 6.454825	65
2.	9.537124, 6.467559 (Front of School)	9.537098, 6.467040	57
3.	9.543869, 6.470590 (Front of SMS)	9.544031, 6.470659	20
4.	9.535496, 6.446887 (Engineering Junction)	9.535593, 6.446899	11
5.	9.533717, 6.447639 (Volleyball Court)	9.533720, 6.447801	8
6.	9.531846, 6.452085 (Front of SICT)	9.531384, 6.452143	40

Table 3: Showing Position Accuracy for Personnel Tracking Device

Position	Actual Coordinates (Latitude, Longitude)	Personnel Tracker Coordinates (Latitude, Longitude)	The difference in distance (in meters)
1.	9.536293, 6.454562 (Round About)	9.536710, 6.452840	220
2.	9.537124, 6.467559 (Front of School)	9.537452, 6.468827	260
3.	9.543869, 6.470590 (Front of SMS)	9.546046, 6.471491	260
4.	9.535496, 6.446887 (Engineering Junction)	9.536050, 6.451175	600
5.	9.533717, 6.447639 (Volleyball Court)	9.533623, 6.445991	500
6.	9.531846, 6.452085 (Front of SICT)	9.533091, 6.453031	550

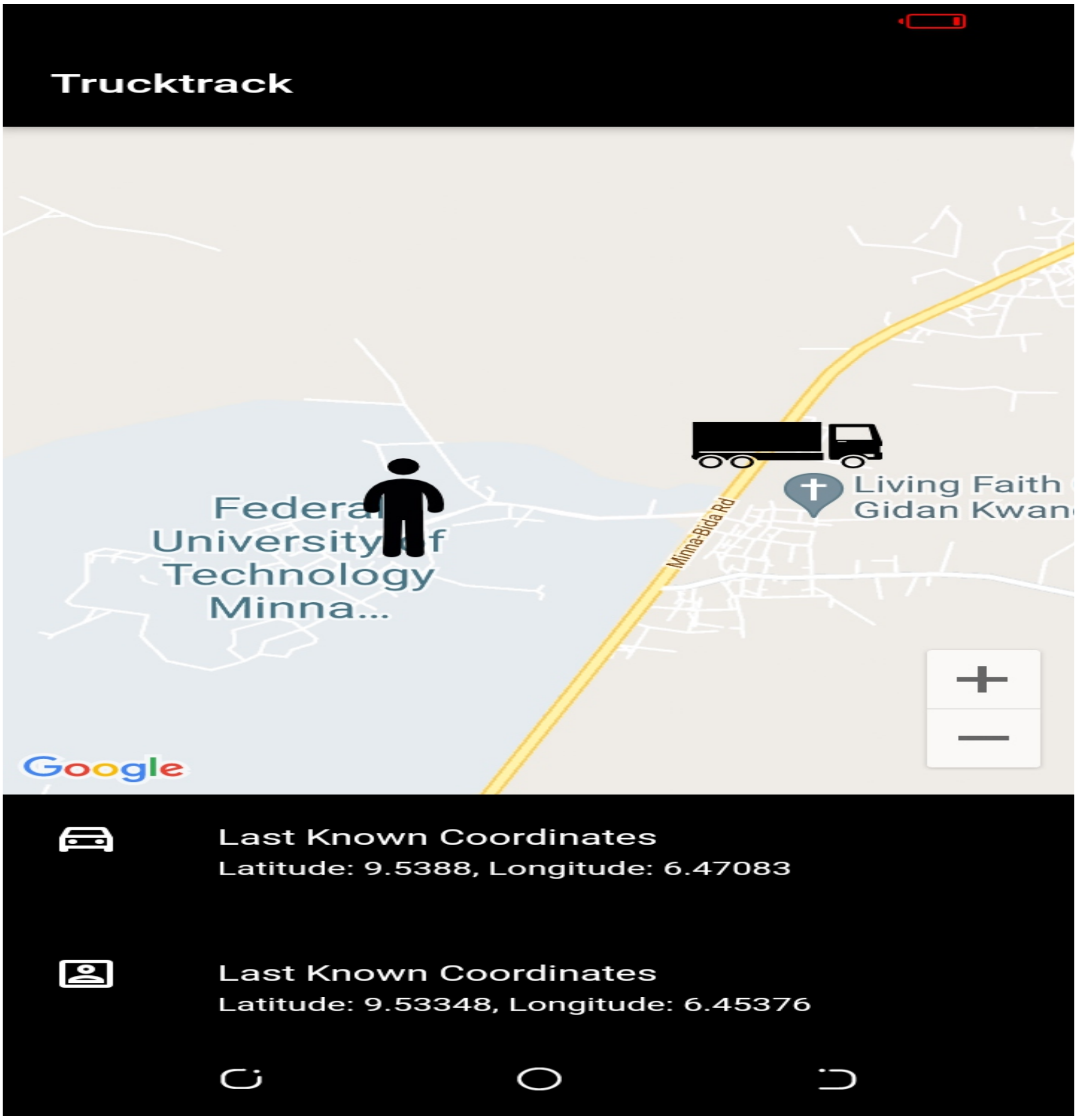

Figure 6: Screenshot of master mobile application.

V. CONCLUSION AND FUTURE WORK

The objective of this paper is to develop a system that tracks the location of vehicles and personnel. An android interface was developed to enable the visualization of the last known location of the personnel and vehicle via a Google map. A mechanism is provided to make the system tolerant to GSM network unavailability. Solar tracking capabilities was added to the system design to charge a battery when the vehicle is not in motion, so that the system is available even during the dark or cloudy hours. Performance evaluation of the system showed a good accuracy level in location reporting and the response time was quite fast in query servicing. Adoption of the developed system could help in providing quick response to kidnaped personnel or the recovery of a hijacked vehicle. The future work will look into incorporating an intelligent technique to make the system provide more information about the vehicle and personnel, which could help the security agencies in their recovery.

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