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DESIGN AND DEVELOPMENT OF GLOBAL POSITIONING TRACKING SYSTEM FOR SECURITY SUIVELANCE IN CROSS RIVER STATE NIGERIA

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Abstract

This study delves into the design and development of Global Positioning Tracking System (GPTS) for quick surveillance response system in Cross River State Nigeria. Crime related activities have enveloped the state, and economy drive cannot strive in the environment, deployment of GPST equipment into the state security architecture can gradually ameliorate such activities. This system will allow for real-time location tracking of commercial and personal motorist in the state. Data from the National Bureau of Statistics (NBS) shows that 2,544 vehicles were stolen between 2016 and 2020, out of which 1,377 vehicles were recovered bringing the national recovery rate to 54 percent. This rate is will definitely increase due to the current method of vehicle identification system, which has not been effective, as replacing the plate numbers and vehicle color is the first thing done to a stolen vehicle. This research activity focuses on design and developed the operation of a unique tracking system. This study explores the design intricacies and simulation methodologies involved in integrating GPS trackers into vehicles to facilitate monitoring and tracking capabilities. The work utilized the Proteus-8 and other simulation tools. The outcomes of this work underline the effectiveness and precision of the proposed system, showcasing its ability to locate and identified vehicle theft. The results underscore the efficiency and precision of the existing system. It analyzes the challenges, considerations, and technicalities involved in integrating GPTS to the Nigerian vehicular landscape. Furthermore, it examines the system's accuracy, efficiency, and potential benefits in bolstering vehicle security surveillance, fleet management, and navigation within Cross River State transport system.

Keywords: Trackers, Satellite, Arduino, Nano technology.

1.0 Introduction

A Global Positioning Tracking System is a satellite/geo-tracking unit. Simply called a tracker. It is an equipment that utilizes the Global Positioning System (GPS) to determine the precise location of a person, vehicle, or object in real-time. With the ability to provide accurate location data, GPS trackers have become an essential tool for a wide range of applications, including fleet management, personal safety, asset tracking and security surveillance.

In 1957, Russia launched Sputnik, the first satellite to successfully orbit the Earth. The Sputnik spacecraft was the first artificial satellite successfully placed in orbit around the Earth and was launched from Baikonur Cosmodrome at Tyuratam (southwest of the small town of Baikonur) in Kazakhstan. The Russian word "Sputnik" means "companion"[1]. As Sputnik orbited the planet, the satellite emitted RF signal.

The frequency of radio signals transmitted by Sputnik increased as the satellite approached near an object, and the signal frequency decreased as it moved away from it. This shift is known as the "Doppler Effect" according to [3]. Utilizing the Sputnik's Doppler Effect enable the scientists to use radio signals to track the movement of the satellite from the ground. With new innovation in technology, a satellite location could be calculated from the ground by the frequency shift of its RF signal, then the location of a receiver on the ground could be determined by its distance from a satellite download and upload signals.

Also Frank McClure, the deputy director of the Applied Physic Laboratory (APL), asked Guier and Weiffenbach to investigate the inverse problem: pinpointing the user's location, given by the satellites. (At the time, the Navy was developing the submarine-launched Polaris missile, which required them to know the submarine's location. This led them and APL to develop the TRANSIT system in 1958 [4].

TRANSIT was first successfully tested in 1960. It used a constellation of five satellites and could provide a navigational fix approximately once per hour. The first satellite for Transit launched in 1960 and the concept, developed by John Hopkins University APL, was capable of providing navigation to military and commercial users, including the Navy's missile submarines. TRANSIT, was the world's first global satellite navigation system [4]. It provided accurate, all-weather navigation to both military and commercial vessels, including most importantly the U.S. Navy's ballistic missile submarine force.

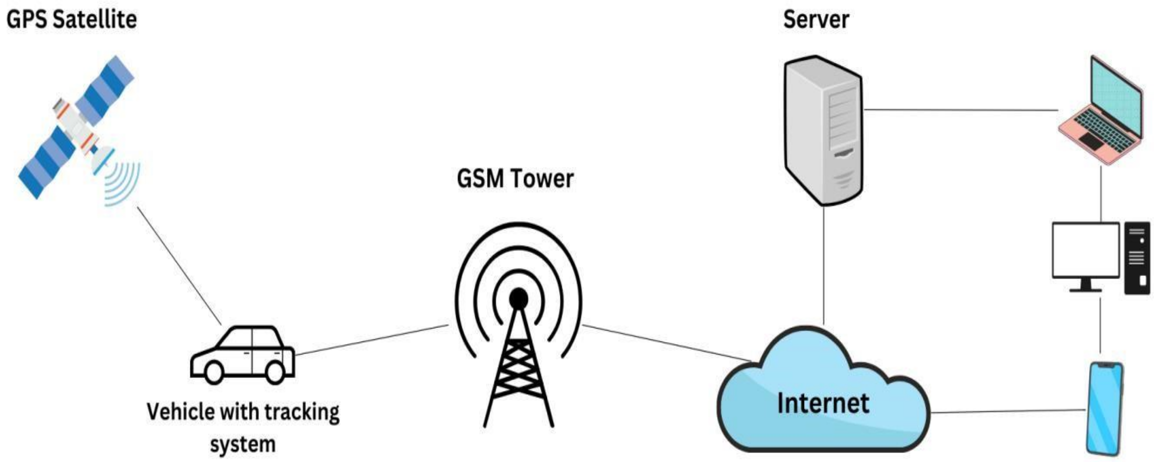

Figure 1. GPTS Technology

The program was transitioned to the Navy in the mid-1960s and by 1968 a constellation of 36 satellites were fully operational. TRANSIT's technology delivered accuracy to tens of meters and is credited with "improving the accuracy of the maps of Earth's land areas by nearly two orders of magnitude," helping to increase acceptance of satellite navigation. Transit operated for 28 years until 1996, when the Defense Department replaced it with the current Global Positioning System (GPS) [5].

A 2022 study estimated that between 2010 and 2021, GPS services such as navigation apps helped consumers save 52 billion gallons of fuel and drive over one trillion fewer vehicle miles. It also helped in the location of lost items worth the total estimate of 33 billion [2].

2.0 Satellite navigation:

Satellite navigation is based on a global network of satellites that transmit radio signals from orbit. Global Positioning System (GPS) satellites are located in the Medium Earth orbit (MEO) sphere. Specifically, they orbit at an altitude of approximately 20,200 kilometers (12,550 miles) above the Earth's surface. There are 31 GPS satellites developed and operated by the United States [8]. Three other constellations also provide similar services collectively, these constellations and their arrangement are called Global Navigation Satellite Systems (GNSS). The other constellations are GLONASS owned by the Russian Federation, Galileo owned by the European Union, and BeiDou owned by China [1].

GPS satellites carry Atomic clocks that provide extremely accurate time necessary for trilateration. The time information is placed in the codes broadcast by the satellite so that a receiver can continuously determine the time the signal was broadcasted [10]. The signal contains data that a receiver used to compute the locations of the satellites and to make other adjustments needed for accurate positioning. The receiver uses the time difference between the time of signal reception and the broadcast time to compute the distance, or range, from the receiver to the satellite [11].

As the signals travel through the ionosphere and troposphere it gets delayed, so the receiver must account for propagation delays or decreases in the signal's speed. With information about the ranges to three satellites and the location of the satellite when the signal was sent, the receiver can compute its own three-dimensional position. An atomic clock synchronized to GPS is required in order to compute ranges from these three signals. However, by taking a measurement from a fourth satellite, the receiver avoids the need for an atomic clock. Thus, the receiver uses four satellites to compute latitude, longitude, altitude, and time [12].

2.1 GPS satellite signals:

Each GPS satellite emits information on two frequencies, namely L1 (1575.42 MHz) and L2 (1227.60 MHz). The atomic clocks installed on the satellites generate the fundamental L-band frequency, which is 10.23 MHz by multiplying the fundamental frequency by 154 and 120, the L1 and L2 carrier frequencies are produced, respectively. The carrier frequencies, L1 and L2, are combined with two pseudorandom noise (PRN) codes, satellite ephemerides (known as Broadcast Ephemerides), and coefficients for ionosphere modeling, status information, system time, and corrections for satellite clocks.

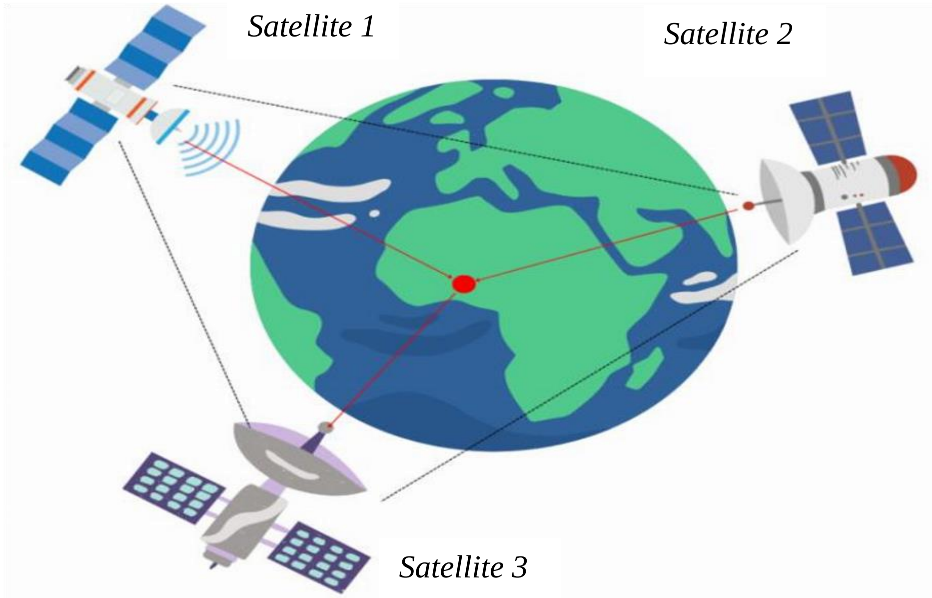

Figure 2. Satellite Trilateration system

These combined signals are then transmitted and the time it takes for the signals to travel from the satellites to the receivers is measured and used to calculate the pseudo-ranges [13]. After reviewing related literatures, it became evident that the predominant use of GPS trackers in Nigeria is for fleet tracking and commercial applications, with limited attention given to tracking personal assets. These trackers are also mainly limited to functioning with a Liquid Crystal Display (LCD) screen, which restricts remote access to coordinates and typically consumes more power compared to trackers without screens, leading to shorter battery life.

In this research, Global System for Mobile communication technology was deployed to establish a connection between the receiver's location and either the user or a ground station. Whose objective is to enable vehicle owners to send a message to the GSM module in the event of theft, receiving a reply from the module containing the coordinates and a URL link to Google Maps. Once the system is activated, it automatically updates the receiver's current location at per-minute intervals. By clicking on the provided URL link, the user is redirected to Google Maps, where they can visualize the vehicle's location with a marker. This feature allows the user to track the vehicle's route and path on the map, considerably reducing the time required for locating a stolen vehicle.

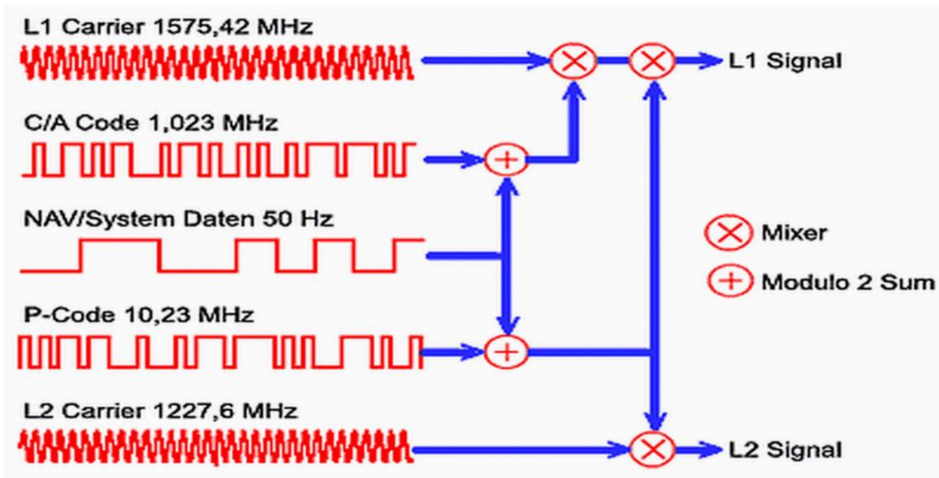

Figure. 3. GPS Satellite Signals **codes** [14]

However, the system can be improved with the integration of Artificial Intelligence (AI) techniques. AI potentials bring several benefits, including improved accuracy, predictive capabilities, and decision-making processes. AI algorithms can analyze large amounts of historical data, identify patterns, and make more precise predictions about future movements. Additionally, AI incorporating natural language processing can enable GPS trackers to understand contextual information such as traffic conditions, weather patterns, and user preferences, leading to better routing decisions. The following devices/components are used in the model.

Microcontroller:

The proposed system utilizes the Atmega328P microcontroller, which is integrated into an Arduino Nano board. The Atmega328P is a highly versatile microcontroller that enjoys widespread usage, thanks to its reputation for reliability, user-friendly nature, and the extensive support provided by the community. It offers a balanced blend of performance, features, and affordability, making it a favored option for numerous embedded systems and projects. The Atmega328P has variety of features which includes: 8-bit AVR microcontroller architecture, Clock Speed: Flash Memory:, SRAM, EEPROM, GPIO Pins, Analog-to-Digital Converter (ADC, Timers and Counters, Serial Communication and Low Power Consumption:

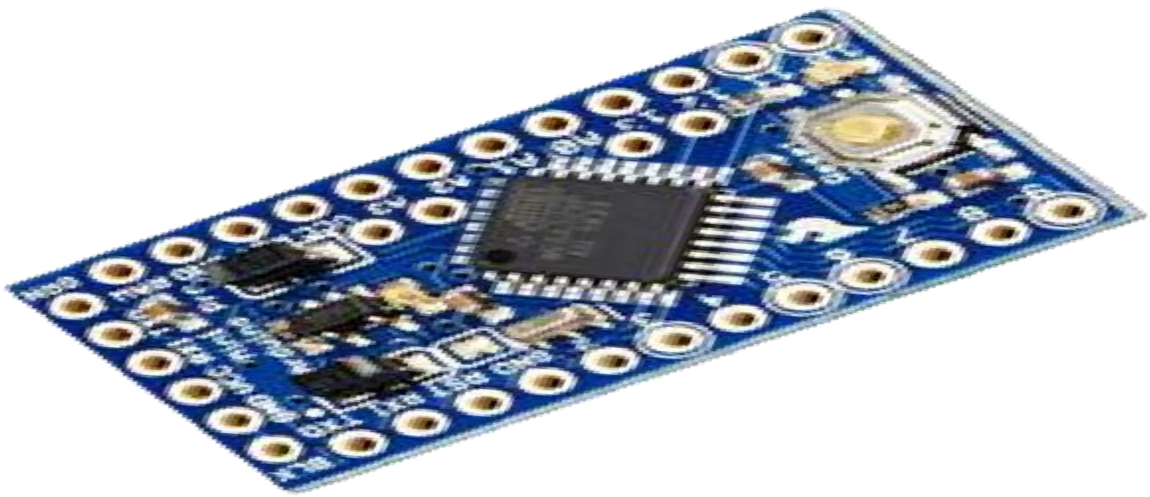

Figure 4. GPTS Nano Board design [3]

2.3 GPS Module:

The NEO-7 series of independent GNSS modules is constructed based on the remarkable capabilities of the u-blox 7 GNSS engine, which supports GPS, GLONASS, QZSS, and SBAS satellite systems. These modules are compact, measuring only 4 x 2.5 x 1.5 cm in size. It has a supply voltage: 3.3VDC to 5 VDC, With the NEO-7 series, you can expect excellent sensitivity and fast acquisition times, all within the well-established and reliable NEO form factor that has been widely used in the industry.

2.4 GSM Module:

The proposed system utilizes the use of SIM800L. At the heart of the module is a SIM800L GSM cellular chip from Sim.com. The operating voltage of the chip ranges from 3.4V to 4.4V, making it an ideal candidate for direct Lithium battery supply. This makes it an excellent choice for embedding in projects with limited space. All the necessary data pins of the SIM800L GSM chip are broken out to 0.1″ pitch headers, including the pins required for communication with the microcontroller over the UART. The module supports baud rates ranging from 1200 bps to

115200 bps and features automatic baud rate detection.

The module requires an external antenna in order to connect to the network. So, the module usually comes with a helical antenna that can be soldered to it. The board also has a UFL connector If you wish to keep the antenna at a distance from the board even though this module is incredibly small (only 1 square inch) it contains a surprising number of features and components: Regulator, Headers, Vero-board, Light Emitting Diode and Jumper wire.

3.0 Methodology

3.1 Power and attery charger system

The GPS tracker will require a power source to function, and batteries are a common option for providing power to the device. The proposed system would make use of a rechargeable 3.7V Lithium battery. A battery charger is a device designed to replenish rechargeable batteries by providing an electric current. Its function is to replenish the energy in batteries, enabling their repeated use.

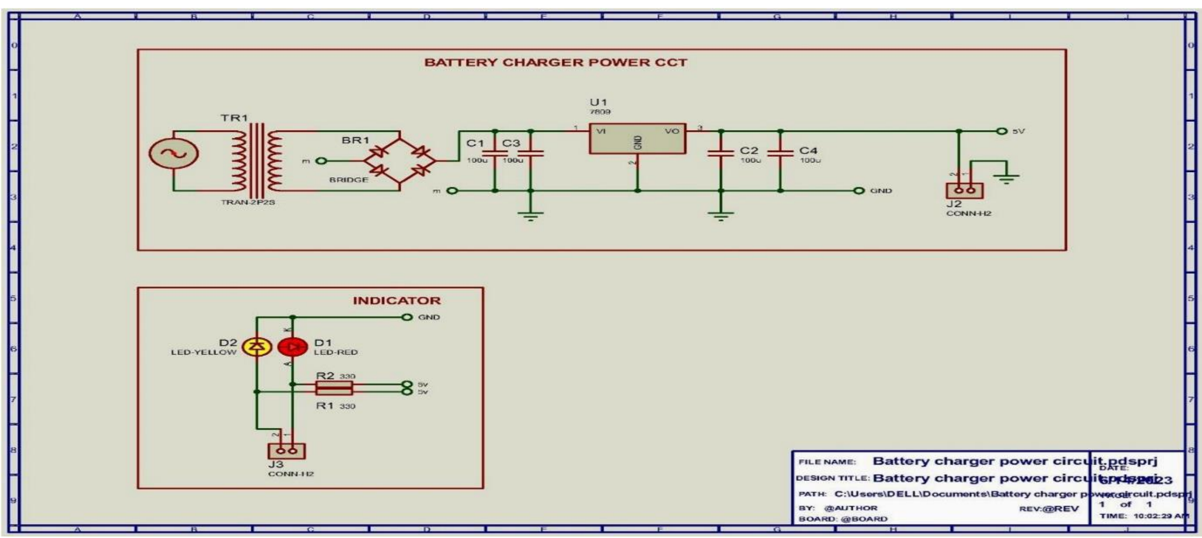

Figure. 5: schematic circuit for power/charging of GPTS system

3.2 Design Development:

In design development a tool called Arduino Integrated Development Environment (IDE) software is used. The software is an open-source Arduino Software, the codes is programmed on this software and is uploaded to Arduino board. The programming language used in the development of the system is the C++ programming language. The features of Arduino IDE are Simple Interface, Syntax Highlighting, Library Manager, Serial Monitor and Extensibility.

3.3 Arduino based GPS vehicle tracking system operation:

Based on the Figure 6, the Arduino Nano is utilized to oversee the entire process that takes place between the GPS module and the GSM module. The GPS module is employed to obtain the vehicle's coordinates, while the GSM module is employed to transmit these coordinates to the user via a text message. To track the location of the vehicle, the initial step involves obtaining its coordinates. [19] The GPS module continuously connects with GPS satellites to obtain these coordinates, which are subsequently transmitted to the Arduino Nano. The Arduino Nano then extracts the necessary data received from the GPS. When the GSM module receives a command from the user in the form of an SMS message, it collaborates with the Arduino Nano to compose a reply message, which is subsequently sent to the user using the GSM module. The message includes the vehicle's coordinates as well as a link to Google Maps.

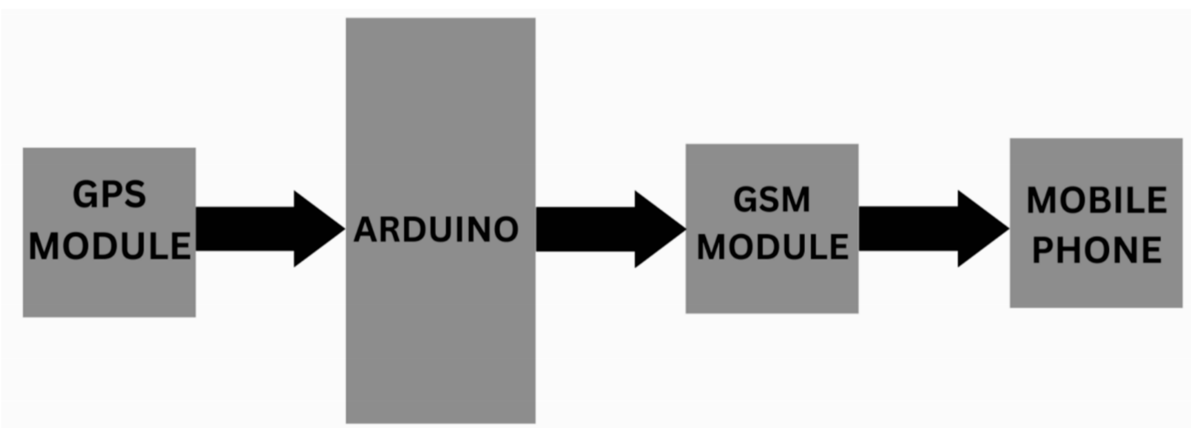

Figure. 6: Block Diagram of the GPS Based Vehicle Tracking System

Figure 7, illustrates the flowchart of the GPS Based Vehicle Tracking System. Initially, the GPS module establishes a continuous connection with satellites to receive the routing coordinates. The LED on the GPS module starts blinking, indicating that the location has been successfully locked. Subsequently, the LED on the GSM module is checked, which starts blinking once the mobile communication line is established.

Once all the LEDs are blinking, the user can send a message containing "START" to the GSM module. The GSM module responds to this message by sending a reply. The reply message includes the detailed location of the vehicle and a URL link to Google Maps. The location is updated every one minute. To terminate the system, the user simply needs to send "STOP" to the GSM module. Once the "STOP" message is received, the system ceases to send messages to the user's phone.

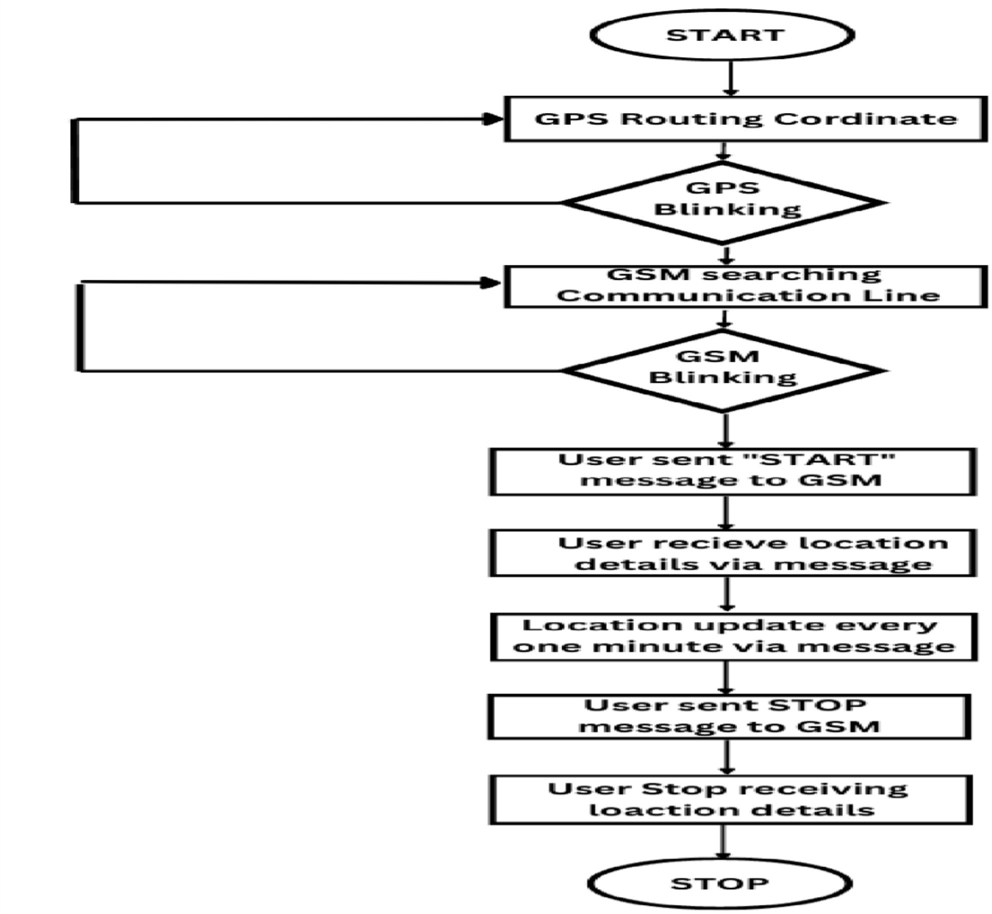

Figure 7. Flowchart of Global Positioning System

The unknown position of a GPS receiver can be determined mathematically as:

$$\begin{cases} d1 = \sqrt{(x1 - xu)^2 + (y1 - yu)^2 + (z1 - zu)^2} \\ d2 = \sqrt{(x2 - xu)^2 + (y2 - yu)^2 + (z2 - zu)^2} \\ d3 = \sqrt{(x3 - xu)^2 + (y3 - yu)^2 + (z3 - zu)^2} \end{cases} \quad (3.1)$$

Where {d1, d2, d3} represents the measured distance to each satellite, while {x1, x2, x3}, {y1, y2, y3}, and {z1, z2, z3} denote the known position of each satellite in the x, y, z directions, respectively. The unknown GPS receiver position is represented by {xu, yu, zu}. With three equations derived and three unknown variables, the equation becomes solvable [15].

3.4 An expression used in the modelling:

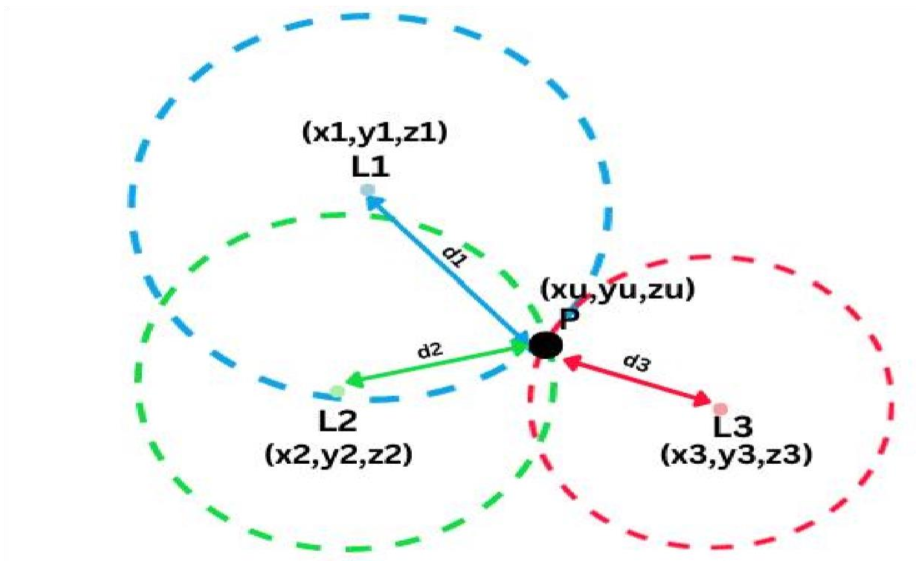

Figure. 8. The trilateration method to determine a position of an object in a 2D world.

Several factors affect the precision of GPS positioning, including satellite availability, refractions, and multipath propagation effects. Within GPS accuracy, key terms include Geometric Dilution of Precision (GDOP), Vertical Dilution of Precision (VDOP), and Horizontal Dilution of Precision (HDOP). An optimal GDOP value is achieved when the visible satellites are widely distributed across the sky. Conversely, if the satellites are closely aligned, resulting in the convergence of the mentioned circles, it leads to a less accurate position estimation as analysis in figure 8. The GDOP value is expressed as:

$$\mathrm{GDOP} = \frac{1}{\sigma}\sqrt{\sigma_x^2 + \sigma_x^2 + \sigma_x^2} \tag{3.3}$$

In this context, σ represents the Root Mean Square (RMS) error related to the pseudo range, signifying the distance between the user's position and the satellite's position.

Additionally, {σx, σy, σz} signifies the RMS error in the {x, y, z} directions of the position, while σb represents the RMS clock error between the satellite clock and the GPS user clock [15]. A poor Horizontal Dilution of Precision value results when the estimation of the position along the horizontal axis is inaccurately defined and is characterized by:

$$\mathrm{HDOP} = \frac{1}{\sigma}\sqrt{\sigma_x^2 + \sigma_x^2} \tag{3.4}$$

An unfavorable Vertical Dilution of Precision value is derived when the estimation of the position on the vertical axis is inaccurately defined and is characterized by:

$$\mathrm{VDOP} = \frac{\sigma_u}{\sigma} \tag{3.5}$$

Maintaining small Dilution of Precision (DOP) values is crucial for achieving accurate positioning. These mentioned factors collectively influence the precision of GPS positioning, particularly impacted by the arrangement of satellites in the atmosphere. To enhance accuracy, GPS users can mitigate multipath effects and interference from nearby objects by stationing the GPS receiver away from buildings and structures. Placing the GPS receiver indoors is discouraged due to signal interference caused by structural materials. Similarly, positioning the receiver on or near metal should be avoided to prevent signal disruption and subsequent inaccurate positioning [15]. Likewise, a mathematical representation of a position in terms of latitude and longitude can be expressed as follows:

$$\mathrm{latitude} = \tan^{-1}\left(\frac{Z_u}{\sqrt{x_u^2 + y_u^2}}\right) \tag{3.6}$$

$$\mathrm{longitude} = \tan^{-1}\left(\frac{y_u}{x_u}\right) \tag{3.7}$$

The development of the GPTS system is a systematic approach that involved several stages. These stages encompassed system requirements analysis, circuit design, programming, integration of components, and testing procedures. The following steps were taken to successfully develop the system, figure 9. Shown the programming technique we developed a programmed code. The first step involved gathering and analyzing the requirements for the GPS tracking system. This included identifying the desired functionalities, performance criteria, and constraints of the system.

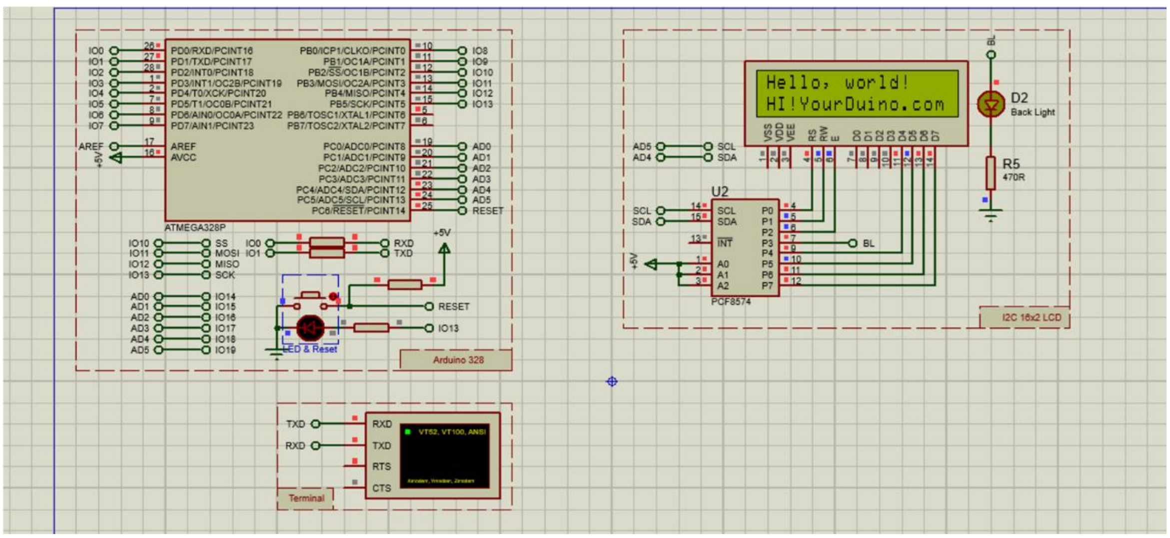

Figure. 9. Design of the Microcontroller

3.5 Configuration of the GPS Tracker:

To ensure that GPTS gadgets functions correctly, several key connections were made as follows: Battery Charger Circuit, Arduino Nano Power, GPS Module Power, Arduino Nano and GSM Module Communication gadgets as seen in figure 10. After uploading the program to the Arduino Nano microcontroller, it enters a waiting state. It patiently awaits signals from the GPS module to determine location coordinates and from the GSM module to establish a phone connection. The IDE program's serial monitor is a window that shows data, including longitude, latitude, and the time it takes to collect these coordinates.

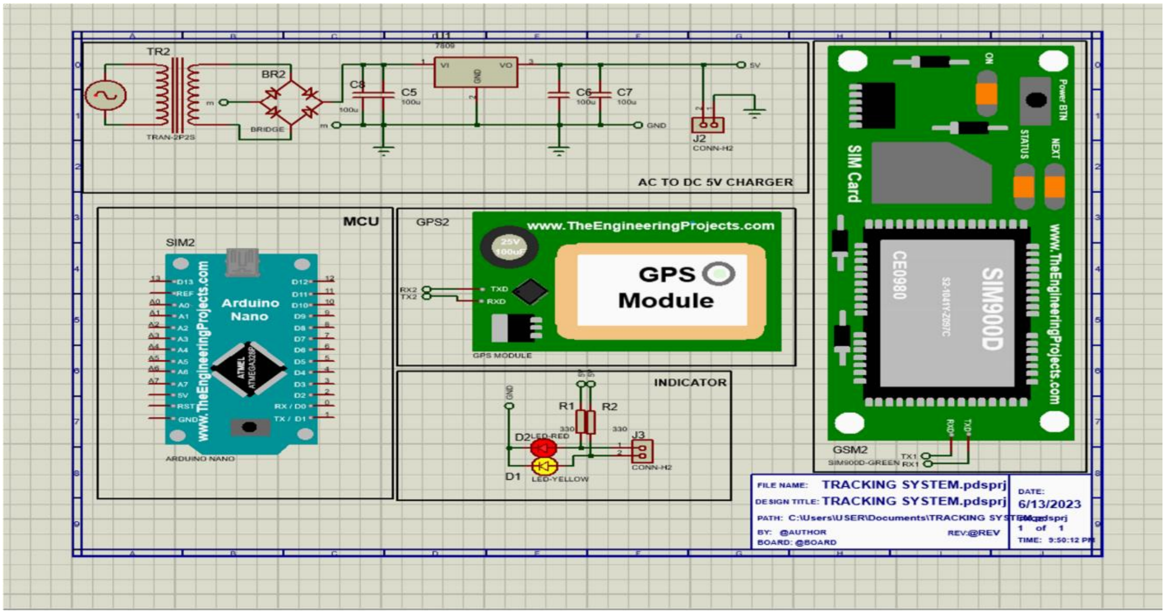

Figure 10. Simulation operation of the GPS Tracking System

Two specific commands were used; "START" to activate the system and "STOP" to shut it down. When a user sends a "START" command to the GSM module, it cooperates with the Arduino to fetch GPS data and sends a response back. If a "STOP" command is received, the system disconnects from the user but continues to track and transmit the latest coordinates.

The response messages sent to the user do not only includes the coordinates but also a URL link leading to Google Maps. Once the system is initiated, it consistently updates the current location every minute. Clicking the provided link will display the coordinates on a map. To end the system's operation, the user have to send a "STOP" command to the GSM module, which will promptly halt the system. To reactivate it, a simple "START" command from the user is all that is required.

The simulation process of this design successfully demonstrated the accurate transmission and reception of data between the GPS module and the GSM module. It confirmed the efficient exchange of location data obtained by the GPS module to the GSM module for potential communication or remote reporting. The simulation displayed the effective real-time tracking capabilities, imitating the process of obtaining GPS coordinates and sending this location information via GSM, mimicking the behavior expected in an actual GPS/GSM tracker system thereby providing a solid foundation for future development and potential real-world deployment.

Microcontroller voltage Levels is 5V, 1kΩ to 2kΩ resistors are used to decrease the voltage from 3.3V to 2V to ensure the optimal performance of the microcontroller most especially Nano technology system and the microcontroller has a feature called Universal Asynchronous Receiver/ Transmitter (UART) that converts analog signals to digital using an Analog-to-Digital Converter (ADC) and can convert them back to analog when communicating with other devices through a Digital-to-Analog Converter (DAC) system.

4.0 Conclusion

In conclusion, the endeavor to design and simulate Global Positioning tracking System (GPTS) to be deploy in Nigerian vehicles is a significant stride towards advancement in vehicle tracking technique and security surveillance activities in the region is a strive on innovation and technological exportation. This unique GPTS system demonstrates the potential to enhance vehicle security and monitoring by providing accurate and real-time location data. When deploy into Nigerian vehicles will improved asset protection, safety, and efficient fleet management. Due to increase in population of the nation, high rate of crime related activities are exponentially expanded. GPTS Nano technology has its capabilities and limitations offering a valuable platform for future research, optimization of such system, expand compatibility, and enable the user interface. All contributing to enhanced vehicle safety, reduced theft, and more efficient transportation systems. We encourage research activities trend on other new tracking technology to restore criminality in the nation.

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