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A Vehicle Tracking System Using Greedy Forwarding Algorithms for Public Transportation in Urban Arterial

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ABSTRACT A vehicle tracking system assists public transportation users in their movements by providing real-time information on the locations of vehicles in transit. Public transportation in parts of developing nations, especially Nigeria is ineffective. The system is chaotic and frustrating, especially at peak traffic periods. In a bid to address the problem, a vehicle tracking system was developed as a component of an Advanced Public Transportation System to improve commuting in an urban arterial. The developed system is based on wireless technologies of the Global Positioning System (GPS) and Global System for Mobile Communication module. It records and displays real-time vehicle location using a GPS-based greedy forwarding algorithm, computes route distance information using distance-time based algorithm and radar range sensor (RRS). A pseudo-range mathematical model using the Haversine formula was adopted in determining the accurate position of an object during signal transmission from GPS satellites to the receiver message module. The minimum inversion matrix method was used for the GPS-based geometric dilution of precision (GDoP) selection of satellite approximation and distance. Atmega328P controller chip was used as the logical control unit for processing activities in the tracking system and programming in Arduino IDE using C-language. The system was deployed to a university transportation system in Nigeria: a journey to and from the Bosso and Gidan Kwano Campuses route in the Federal University of Technology, Minna. The vehicle tracking system was tested with 11 tracked satellite and minor dilution error (PDoP error = 1.9, HDoP=0.9, and VDOP=1.7) was recorded. The system is efficient and accurate in distance and time information display with a minor delay. The system would enhance fleet management schemes for urban arterial and can be adopted universally.

INDEX TERMS Arduino board, bus terminal, global positioning system, google map, longitude, pseudo-range, public transportation, Raspberry Pi, satellite, vehicle tracking system.

I. INTRODUCTION

The public transport system (PTS) remains the easiest and cheapest means of moving passengers or groups of people from one point to another in vehicles. Its transformation is indispensable and it was reported [1] that about 20% of the gross domestic product of Europe equating to billions of euros and millions of jobs is generated through the transport sector. Also, the Census Bureau Statistics of 2019 in the United States of America (USA) claimed that the average citizen spends about 25.9 minutes per day on traveling to work and four hours per week in transit through the PTS, and over 15.9% of his budget on transportation [2]. In line with the trend in PTS, Sub-Saharan African countries are promoting the system. For example, the Trans-Africa project is focused on the provision of sustainable and efficient transport systems in Africa cities for improving the production process and growth, as well as reducing congestion and traffics on the

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roads [3]. Effective PTS as well as information and communication technologies (ICT) are essential to national economic growth and social development [1]. PTS are typically managed on a schedule and functioned on time-honored routes [4]. It may be operated on a trip charge fee as found in the city buses, tram (a rail vehicle along public urban streets that runs on tramway tracks), trolleybuses, ferries, mass rapid transit (MRT), and metro [5], [6]. Several technologies have emerged over the past decade in the form of real-time vehicle tracking systems that utilize remote wireless expertise techniques like GPS, GPRS, and other navigation systems for determining vehicle location and enhanced fleet management. These wireless technologies operate through satellite and ground-based stations [7], [8].

Software tools have been developed to improve fleet productivity [9]. Fleet tracking device offers numerous advantages such as high visibility of geographic location, monitoring the vehicle speed, and other related activities [10]. It also assists in vehicle tours planning, optimizing, and improves customer services (passengers) by keeping passengers informed about the journey distance and arrival time. Other benefits include business workflow scheduling and service delivery period. A tracking system is capable of rendering virtual space to a human through the observer's coordinates [11]. Other functions of the vehicle tracking system in fleet management support include displaying vehicle speeding information reports, harsh braking, driver's acceleration, and the route which can be downloaded to a computer and used for analysis in the future [12].

The understanding of environmental correlations associated with vehicle route selection and scheduling during transportation was discussed with a useful tip [13]. By relating the features of the route linkages between the possible source path to the shortest destination way. An improved vehicular routing protocol that considers the street/route density and direction called GyTAR (Greedy Traffic-Aware Routing) was discussed. It utilizes GPS to determine the vehicular speed and position on a digital map [14]. The connectivity of the vehicular pathway between the source and the destination track was model and discussed as illustrated in Fig. 1. This is to measure the average delay of the vehicle on the transit using a Genetic Algorithm (GA) as an optimization routing trail technique for the vehicular area network [15], [16].

The investigation about the choice of early morning commuter route behavior using Global Positioning Systems (GPS) and Multi-Day Travel Data (M-DTD) approaches was reported [17]. This considered the factors that influence early morning commuters traveling choice and route switching based on objective observations of travel behavior during a multi-day period in the real-world.

The socioeconomic characteristics is another influence in fleet management that comparing the transportation systems in Maputo and Nairobi [3]. The demand and supply of bus services in each city were influenced by the mode of transportation trips. Two logistic regression models were studied and analyzed. It was discovered that age decreases the likelihood of choosing buses and residence location in Maputo. Other factors affecting bus shuttle customized in both cities include employment, income, vehicle ownership, and residential location.

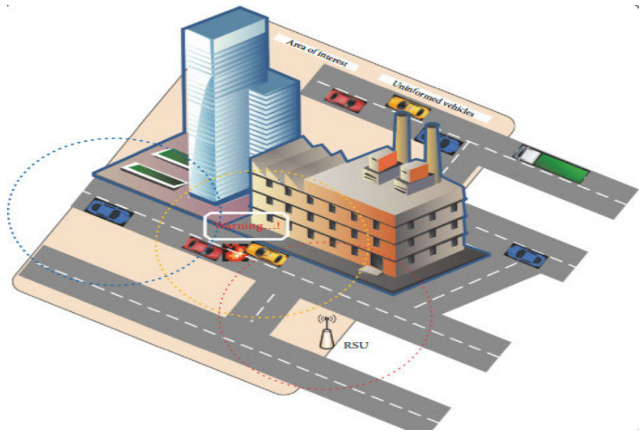


FIGURE 1. A city vehicular pathway/route traffic scenario [18].

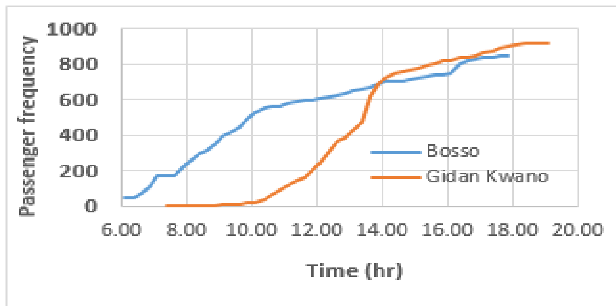


FIGURE 2. Frequency of passenger arriving terminals.

Some of the universities in Nigeria operate campus systems with students on off-campus residence arrangements. This results in a transportation problem for movement into and between campuses. Therefore, Federal University of Technology, Minna (Nigeria) operates on two campuses (Gidan Kwano and Bosso), a distance of 28 km apart. The Bosso Campus is cited within the city where students find suitable accommodation for off-campus residency. About half of the students in Gidan-Kwano are resident in the Bosso area. The implication is that there are captive commuters seeking transportation services from Gidan-Kwano and departs at the respective terminal when filled without on schedule. But only registered vehicles are allowed to operate as public transport into the campuses. Fig. 2 illustrates a typical passenger frequency into the two terminals, which is a time-based schedule and found to be uneconomical because traffic is one-way at certain times. The solution to the identified technical challenges in this public transportation system would involve an economic schedule system and dissemination of information to commuters remotely. This paper addresses the component of the dissemination of information to commuters and operators remotely.

A geographical map location-based vehicle tracking system was developed and tested on the public transportation

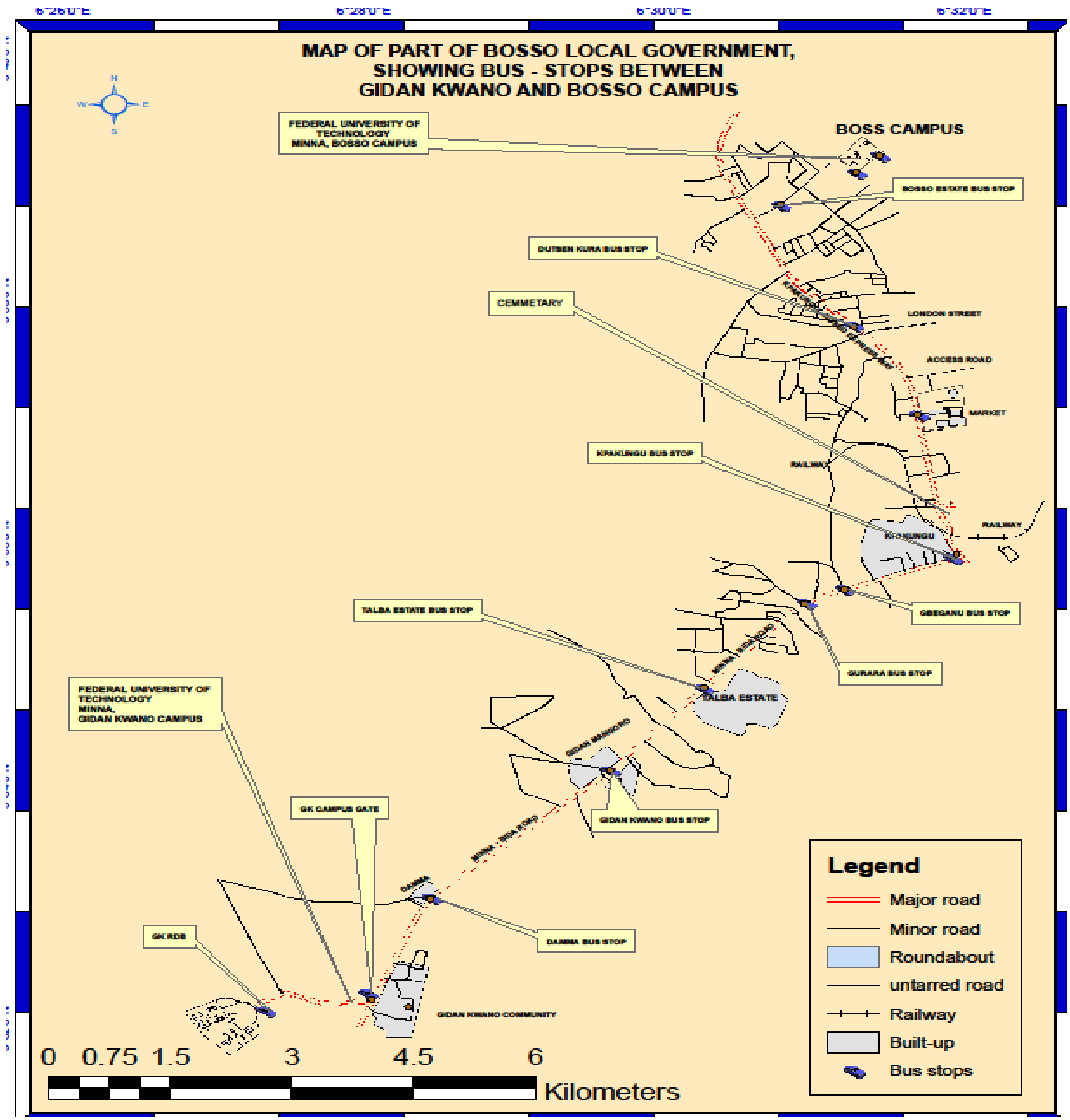


FIGURE 3. Geographic map location of the bus terminals between the two campuses in Minna metropolis.

system between the Gidan-Kwano campus and the Bosso campus. It is a component of the fleet management system to improve the efficiency and effectiveness of transportation as the first stage in a confrontation of this universal challenge. The objectives include: (i) providing real-time tracking of the bus shuttles on inter-campus metropolis routes, and (ii) displaying vehicle location and arrival time at terminals. Different algorithms and mathematical modeling were adopted and considered for the geolocation coordinate tracking, distance calculations, and display of remote geo-position information on the dashboard and google map respectively. In the future objectives, the traffic route (noise) will be studied and analyzed using an optimized technique for the efficient time table development in scheduling. A digitized Google map that illustrates the details of the geographical location of the bus parks at both campuses with route analysis was presented in Fig. 3.

In this research, a minimum inversion matrix geometric dilution of precision (minGDoP) method was adopted in the GPS satellite selection for accuracy and precision.

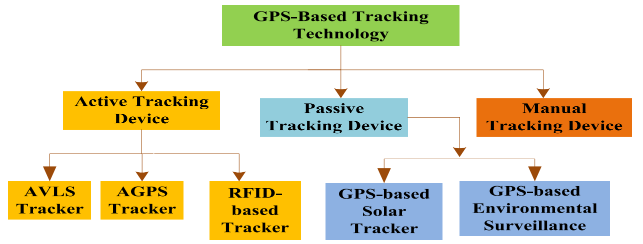


FIGURE 4. GPS-based vehicular technology classification.

More emphasis is on the development and implementation of the schedule vehicle tracking system for public transportation on urban arterial using different novelty algorithms, mathematical computations, and modeling of distance detection width estimation as contains in section III. This includes distance-time based parameter tracking using pseudo-range and Haversine formula. Modeling of the distance detection width calculation was done using a GPS-based greedy forwarding algorithm for the estimation and in the selection of the best possible response at every distance covered with time relation. Section IV discussed details of system design and implementation for both hardware and software coding with performance evaluation. This section includes a novel algorithm for remote transmission and distribution of vehicle data (messages) called wheel wagon data dissemination protocol. Section V presents detailed results and discussion, and section VI concludes the research work with a recommendation and future works.

II. OVERVIEW OF RELATED WORKS

The vehicle tracking system is a technology used in monitoring, safeguarding, and providing directions for both private and public commuter users. It enables the owner to virtually keep an eye on the vehicle arrival through the route and also aids the public commuter users to manage their time resulting in cost-efficiency. It can determine the exact position of space object which includes longitude, latitude, and height [19]. Data from a GPS-based tracking device can be viewed on electronic maps, google maps, or mobile applications connected to the internet. Several techniques can be used in tracking vehicles on the arterial route and include indicators or 'lag time'. For example, using a bar code or choke point or gate for vehicle data collection when passed a point. The bar-code systems require scanning of the personal items for automatic identification using RFID auto-id. A real-time tracker like Global Positioning Systems (GPS) operation is another type which depends on how often the data is refreshed or updated for prompt display. The most common world tracking system consists of discrete hardware and software systems for different applications [20].

GPS-based or assisted GPS (AGPS) sensors technology for the vehicle tracking system can be classified into three parts as illustrated in Fig. 4.

Both active tracking technology (energetic) and passive tracking technology (reflexive) use GPS or assisted GPS sensors like radar sensors for execution. The energetic tracking systems utilize wireless connection modules that include Global System for Mobile communication (GSM) and General Packet Radio Service (GPRS) for data transmission over the internet. The components besides the central server (database) receive, process, and store the generated information [21]. But, the integration of both components (GPS and GSM) into a single module was adjudged the best in terms of cost and configuration [22]. This active tracking technology can be classified into three types, which include Automatic-Vehicle Location System (AVLS), Assisted-Global Positioning System (AGPS), and Radio Frequency Identification (RFID) technology [23]–[25].

The reflexive (passive) tracking devices focus majorly on downloading, recording, and storing tracking information using a GPS module for future view [26]. This type of tracking technology is embedded with onboard memory but does not report or function in real-time. The GPS-based tracking devices are widely adopted in the vehicle tracking technology, security, energy-harvesting tracker (solar-energy tracker), and geolocation coordinate tracing [27], [28]. The manual type is locally designed majorly for solar panel trackers, surveillance, and so on.

An automobile tracking system was developed [29], [30] to secure oil and gas distribution using the telematics approach and blockchain technology. The tracking system addressed the high-level susceptibility of illegal diversion of automobile crude oil conveyance along the route. A telematics approach using GPS/GPRS and GSM module was used in tracking the geo-location, speed, and volume of products conveyed by the automobile system. The performance of the GPS system-based satellite tracking was evaluated based on the success rate, sensitivity, and location accuracy.

In the study [31], a mobile phone-based vehicle positioning and tracking system were developed for an urban traffic state estimation with an emphasis on the mobile positioning and navigation of the vehicular environment. The Kalman-filter based hybrid technique was adopted in tracking and positioning the mobile phones traveling onboard vehicles. The simulation processes of the universal mobile telecommunications system (UTMS) was carried out in the MATLAB environment using combined standard methods of observed time difference of arrival (OTDOA) and assisted global positioning system (A-GPS) location estimate as to the state vector level. The simulation result statistically demonstrated that the hybrid technique of the Kalman-filter method shows better performance in position determination and velocity estimation.

A simulation analysis of geographic location and distance routing on the vehicle area network (VANET) was carried out [32]–[34] using the wireless technology approach (IEEE 802.11p). The work addressed the issue of routing in VANET due to road constraints like over-speeding of vehicles and road barriers. The system performance evaluation was based on the routing overhead, throughput, packet loss, and delay using network simulation-2 (NS-2).

TABLE 1. Related works analysis.

Title	Methods	Purposes	Performance evaluation metrics
Towards efficient geographic routing in urban vehicular networks [14].	Improved greedy traffic-aware routing (GyTAR).	This protocol was developed for the selection and forwarding of data intersection of the vehicular area network (VANET) in the intelligent transport system (ITS). It is utilizing for the detection of vehicular traffic density and road topology network. Also, to guarantee an end to end communication.	Using quality simulator (QS) for analyzing optimality (accuracy), sensitivity, and the end to end delay.
A simulated analysis of location and distance-based routing in Vehicular area network (VANET) using WiFi (IEEE802.11p) [33].	Predictive hierarchical location service (PHLS) such as Greedy perimeter stateless routing (GPSR).	The study is on city and highway vehicular performance analysis using location aided-routing (LAR) and distance-effect routing algorithm for mobility (DREAM). This is to provide insight into the realistic vehicular traffic movements to an intelligent driver model on the route.	NS-2 simulator was used for the detection of a packet drop rate (PDR), routing overhead, delay, throughput, and packet loss ratio.
Genetic algorithm (GA) application for the speedy and precision of GPS satellite selection [12].	Genetic algorithm (GA).	This is proposed for the classification and approximation of GPS GDOP satellite selection and cost calculation.	Minimum-maximum and means square error is used to determine the accuracy.
A novel technique for the vehicular network routing optimization based on multi-objective metrics and minimum spanning tree [16].	The multi-objective routing protocol (MO-RP).	For the interference minimization in the transmission channel of co-channel interference (CCI), selection of stable path through link duration probability (LDP), calculation of end-to-end delay, and synchronization of packets received in the channel.	NS-2 simulator was used for the detection of packet delivery ratio, routing overhead, end to end delay, and throughput.
A reliable data dissemination solution for vehicular ad-hoc networks in IIoT [19].	Data dissemination protocol for vehicular ad hoc networks (DDP4V).	Utilize to disseminates emergency messages in different scenarios under varying traffic conditions. This method is efficient in highway and urban VANET set-ups within the diverse traffic conditions and to prevent broadcast storm through the number of redundant transmissions.	Network simulator OMNET++ was used, and the metric includes coverage, network overhead, collision, and end-to-end delay.
A robust H∞ path-tracking control for network-based autonomous vehicles [56].	Robust closed-loop $H\infty$ controller system with linear matrix inequality (LMI) that is asymptotically stable.	This scheme is proposed to achieve the desired path tracking in the network-based autonomous vehicles by induced the delay and packet dropout in the control system design. It also handling uncertainties parameter with exterior variabilities. The sideslip angle of the vehicle model and yaw rate are controlled promptly to improve the stability of the vehicle.	The simulation was based on the single-lane change operation and double-lane variation maneuver for a plain driving state. The feasibility metric was used as a performance index.
Genetic algorithm-based QoS perception routing protocol for VANETs [37].	Genetic algorithm (GA) and greedy carry forward algorithm	These optimization techniques were adopted to improve the global vehicular path tracking and quality of service optimum.	The performance index is based on connectivity probability and the transmission delay.
A novel method for optimum global positioning system satellite selection based on a modified genetic algorithm [53].	Hybrid and Improved genetic algorithm (HIGA) using fault detection and exclusion (FDE) approach and/or receiver autonomous integrity monitoring (RAIM).	This technique is proposed for a better accuracy selection of GPS-based satellite navigation. It also adopted to selects the accurate number of optimum satellite subsets.	Convergence speed and accuracy was used as a performance index.
A Vehicle Tracking System using Greedy Forwarding Algorithms for Public Transportation in Urban Arterial.	A minimum inversion matrix geometric dilution of precision (minGDoP).	This research addresses components of the dissemination of information to commuters and operators remotely. More emphasis is on the development and implementation of the schedule vehicle tracking system for public transportation on urban arterial using different novelty algorithms, mathematical computations, and modeling.	The navigation U-Blox GPS software simulation tool was used by considering a metric index such as accuracy, precision, convergence, and sensitivity.

The inversion matrix technique is commonly used in GPS-based GDoP selection of satellite to achieve an optimal approximation subset [35], but the computational complexity is highly intensive to be practical and it is time-consuming. A stochastic global search algorithm like the Genetic Algorithm (GA), Artificial Neural Network (ANN) has been used for the optimization and fast selection of GPS-based GDoP approximation [36]. Although the ANN approach gives better performance, it requires a long time in training and ends up with difficulty in the architecture determination. The performance evaluation of adopting GA in GPS-based GDoP satellite selection is fair when compared with the inversion matrix or Neural Network (NN) approach. The GA application offers a reduced cost of calculation, fast and precise in GPS-GDoP classification, and approximation [37]. Other related works with modeling and simulation of vehicular area network tracking are presented in Table 1.

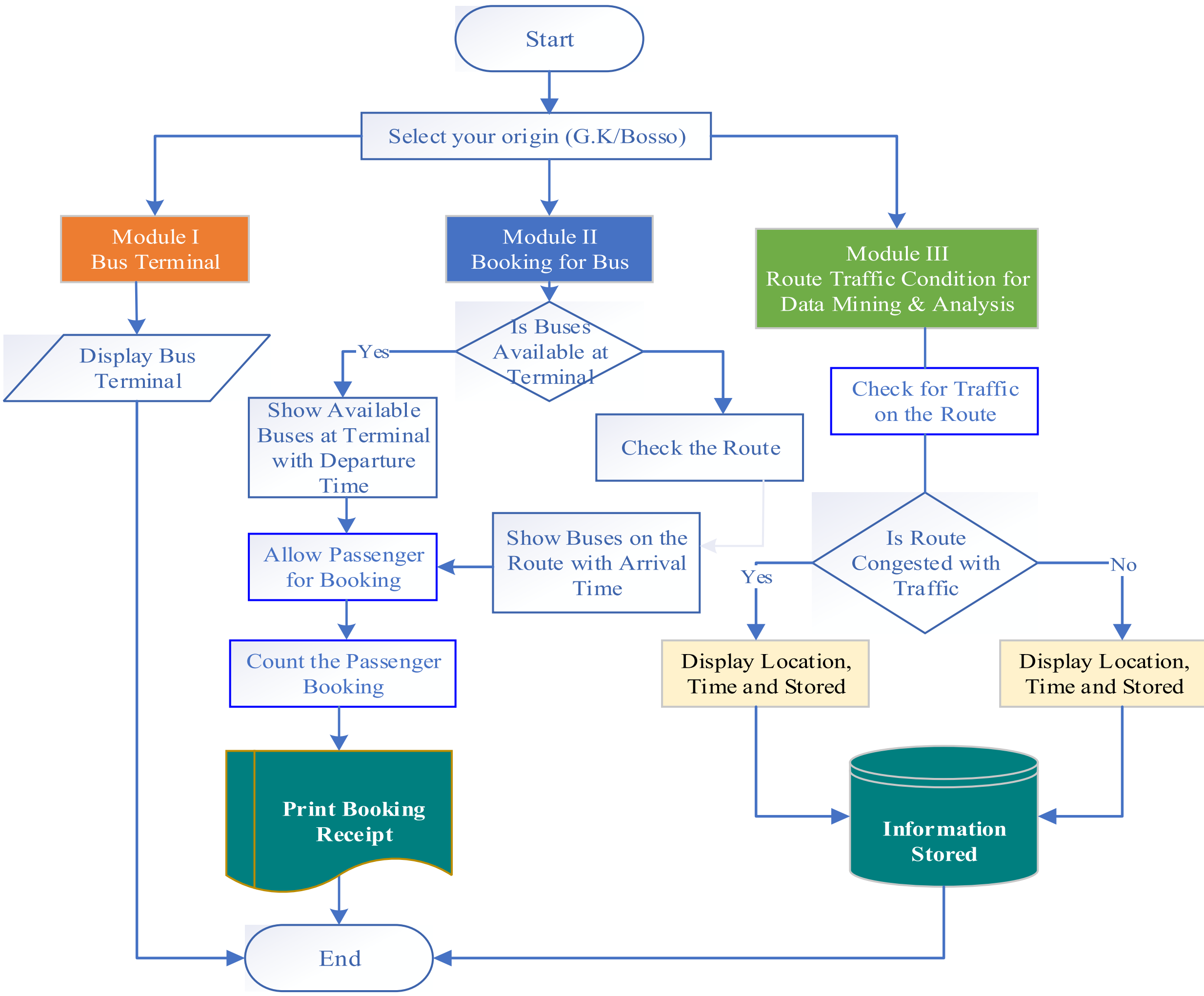


FIGURE 5. Public transportation statistics system.

III. MATERIALS AND METHODS

The development of an advanced public vehicle tracking system for captive commuters on urban arterials using geographical map location and GPS for tracking involves hardware component integration with software design coding. A vehicle tracking device was embedded in each vehicle and a google map location software was designed for monitoring vehicle positions, data collection in the field, and delivering information to visual display stations. In the visual display station, a Raspberry Pi ARM Cortex A53 processor with a universal modem was embedded and utilized for the ease of inter-communication between the base station and remote area. The Atmega 328P was used as the central controller for the in-vehicle tracking device and the programming was achieved in the Arduino Integrated Development Environment (AIDE) using C-language. The advanced public transportation statistics system for data collection, data fusion, and information dissemination are illustrated in Fig. 5. The system operation flowchart is presented in Fig. 6.

The real-time data acquisition and vehicle location algorithm for a vehicle in transit areas contained in Table 2. The bus shuttle operates on a demand-supply basis. The minimum safe headway (that is, a distance measured with time) was calculated by the decelerating performance using Anderson techniques as in "(1)". The total time taken for the vehicle and headway is calculated as in "(2)".

$$\aleph_{\min-safe} = R_{time} + \frac{1}{2}kv\left(\frac{1}{\alpha_f} - \frac{1}{\beta_l}\right) \tag{1}$$

$$T_{total} = \frac{L}{V} + R_{time} + \frac{1}{2}kv\left(\frac{1}{\alpha_f} - \frac{1}{\beta_l}\right) \tag{2}$$

where $\aleph_{\min-safe}$ is the minimum safe headway in seconds, R_{time} is the reaction time (the maximum time it takes for the following vehicle to detect a malfunction in the leader and to fully applied emergency brakes), k is an arbitrary safety factor which is ≥ 1, V is the speed of the vehicles in (m/s), α_f is the minimum deceleration braking of the follower (m/s^2), β_l is the maximum deceleration braking of the leader in (m/s^2), L

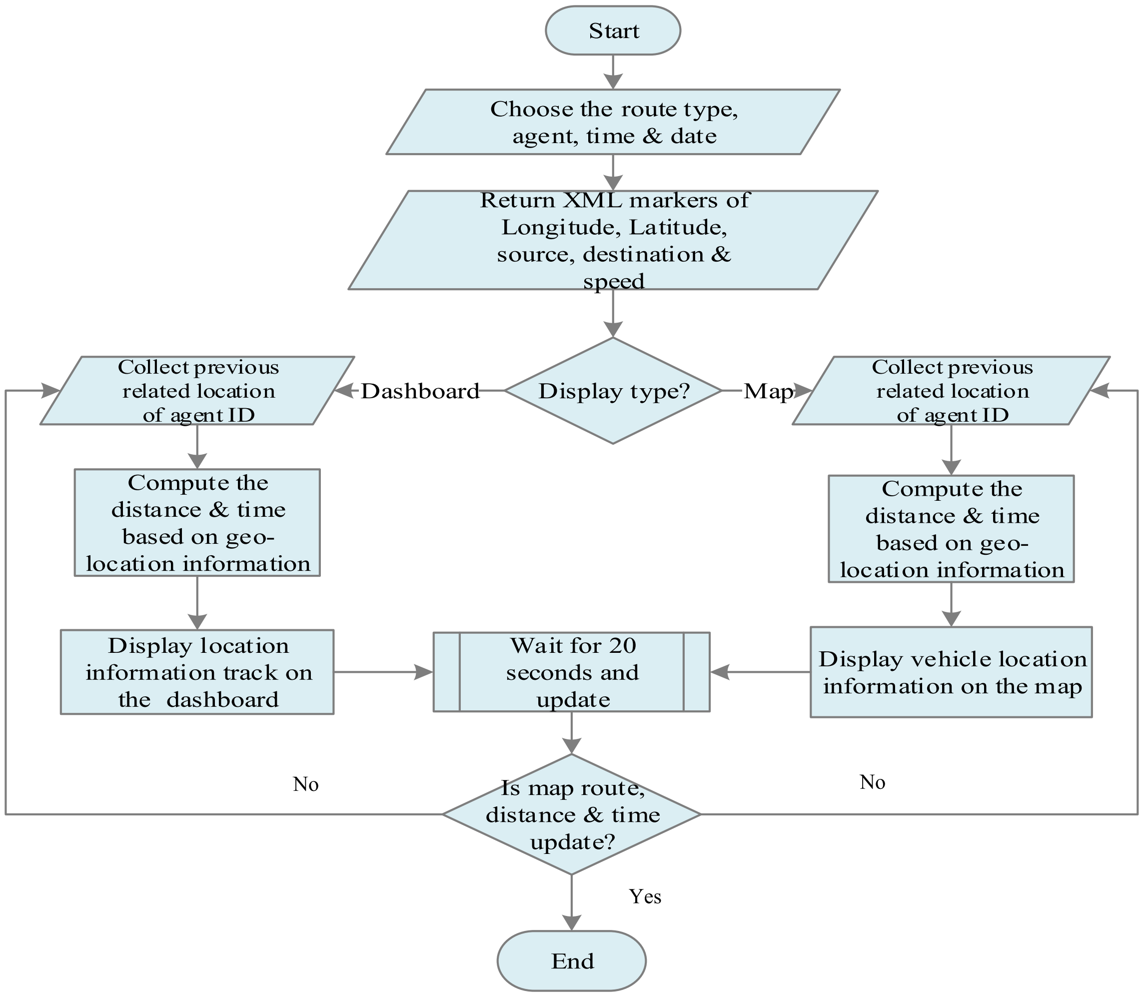


FIGURE 6. An algorithm for a vehicle tracking system.

TABLE 2. The algorithm I data acquisition and position.

Steps	Data acquisition and position algorithm
1	Use the remote asset tracker LP1 to communicate the remote server or display unit.
2	Connect the asset tracker to the vehicle for the position/location in a real-time data acquisition through the GPS.
3	Transmit the position data to a relay communication satellite using the fleet minder of the tracker.
4	Connect to the internet and fleet minder web-server of tracker for receiving ground station data transfer.
5	Display the position or geographic location of the vehicle with the coordinate on the remote display unit.
6	Record the live tracking information and store all the data (coordinate) in the storage system.

is the vehicle length (m) and T_{total} is the time for a vehicle (s) and headway to pass a point.

A. PSEUDO-RANGE METHOD

The pseudo-range method was used to determine the accurate position of a vehicle during signal transmission from GPS satellites to the receiver message module as in "(3)".

$$\begin{aligned}(P_1-\alpha_p)^2+(Q_1-\alpha_q)^2+(R_1-\alpha_r)^2 &= (\rho_1-v\Delta T_x)^2,\\ (P_2-\alpha_p)^2+(Q_2-\alpha_q)^2+(R_2-\alpha_r)^2 &= (\rho_2-v\Delta T_x)^2,\\ (P_3-\alpha_p)^2+(Q_3-\alpha_q)^2+(R_3-\alpha_r)^2 &= (\rho_3-v\Delta T_x)^2,\\ (P_n-\alpha_p)^2+(Q_n-\alpha_q)^2+(R_n-\alpha_r)^2 &= (\rho_n-v\Delta T_x)^2,\end{aligned} \tag{3}$$

where, $\alpha_p, \alpha_q, \alpha_r$ are receiver positions for the components of *(p, q, and r)*, v is the speed of light (velocity), ΔT_x is the time difference between the receiver and satellite. P_1, Q_1, R_1 are known as the three components of satellite positions, and ρ_i is the accurate distance of *ith* satellite from the receiver in ideal situation.

The pseudo-range computation determines the difference between satellite and GPS receiver [38]. The expression in "(3)" can be re-written using Taylor's series as expressed in "(4)", "(5)" and "(6)", respectively. If the initial coordinates of the receiver are known to be (p_0, q_0, r_0), the actual receiver coordinates are (p_0, q_0, r_0) at epoch time 1 (t_1). The summary of the developed formula for all the satellite observation can

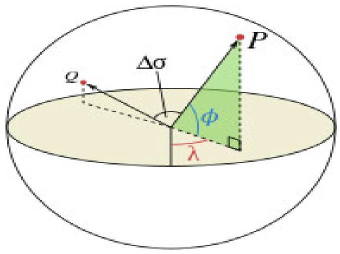


FIGURE 7. An illustration of the central angle, $\Delta\sigma$, between two points, P and Q (longitudinal (λ) and latitudinal (φ) angles of P respectively).

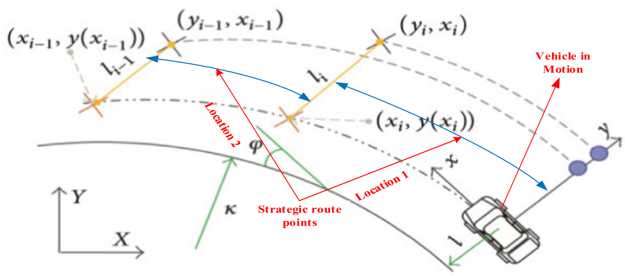


FIGURE 8. The radar sensor detection of the closest distance.

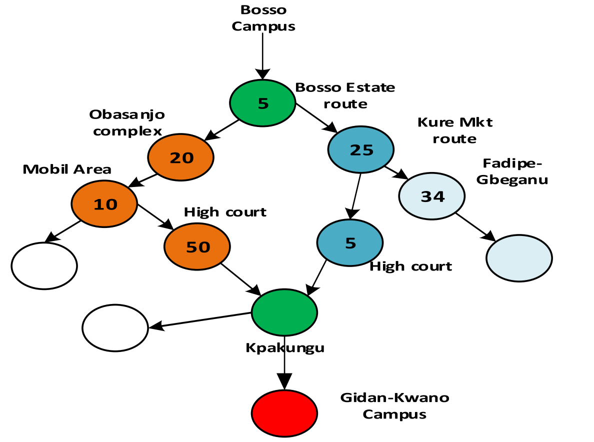


FIGURE 9. GPS-based vehicular route decision tree.

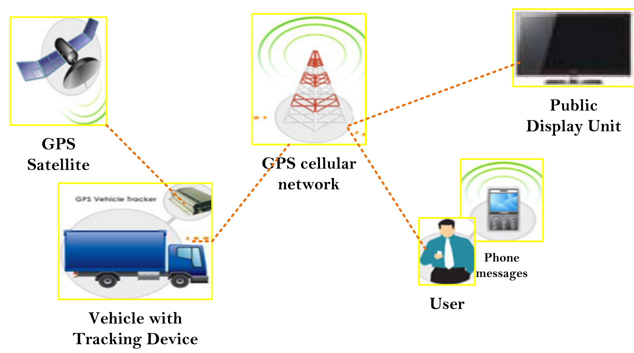


FIGURE 10. Public transportation vehicular tracking system architecture.

be given as in "(7)".

$$\rho_i^j = \mu_i^j + v\Delta T_x \tag{4}$$

$$\rho_i^j = \sqrt{(p^j - p_i)^2 + (q^j - q_i)^2 + (r^j - r_i)^2} + v\Delta T_x \tag{5}$$

$$l^j = \mu_{pi}^j \Delta p_i + \mu_{qi}^j \Delta q_i + \mu_{ri}^j \Delta r_i + v\Delta t_i \tag{6}$$

where, p^j, q^j, r^j is the coordinate of the jth satellite, ρ_i^j indicate the distance between the jth satellite and the pseudo-range between satellite, and receiver at epoch time t_1 is μ_i^j.

$$\begin{bmatrix} l^1 \\ l^1 \\ l^1 \\ . \\ . \\ . \\ l^j \end{bmatrix} = \begin{bmatrix} \mu_{pi}^1 & \mu_{qi}^1 & \mu_{ri}^1 & v \\ \mu_{pi}^2 & \mu_{qi}^2 & \mu_{ri}^2 & v \\ \mu_{pi}^3 & \mu_{qi}^3 & \mu_{ri}^3 & v \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \mu_{pi}^j & \mu_{qi}^j & \mu_{ri}^j & v \end{bmatrix} \begin{bmatrix} \Delta p_i \\ \Delta q_i \\ \Delta r_i \\ \Delta t_i \end{bmatrix} \tag{7}$$

The distance-time-based parameters (DTBP) approach was used for the detection of geo-location tracking of vehicle position [39]. The Haversine formula [40], [41] was used for the computation in determining coordinate (latitude and longitude) distance of a great circle as illustrated in Fig. 7. This is because the time-distance based parameters offer the advantage of accuracy and flexibility in the server update. The Haversine (ξ) formula is used in the algorithm for calculating the reference points of the geo-location coordinates (longitude and latitude) to reduce rounding errors that may be generated before communicating with remote locations (refer to the expression in "(8)").

$$\left(\frac{d}{r}\right) = \xi(\varphi_2 - \varphi_1) + \cos(\varphi_1)\cos(\varphi_2)\xi(\lambda_2 - \lambda_1) \tag{8}$$

The distance d from "(8)" is solved using the inverse sine function as in "(9)" and "(10)".

$$d = r\xi^{-1}(h) = 2r\sin^{-1}(\sqrt{h}) \tag{9}$$

$$d = 2r\sin^{-1}\left(\sqrt{\sin^2\left(\frac{\varphi_2 - \varphi_1}{2}\right) + \cos(\varphi_1)\cos(\varphi_2)\sin^2\left(\frac{\lambda_2 - \lambda_1}{2}\right)}\right) \tag{10}$$

where, r is the radius of the earth (r = 6371 km), d is the space between the two points (m), φ_1, φ_2 is the latitude of two points, and the longitude of the two points is λ_2, λ_1.

B. MODELING OF DISTANCE DETECTION WIDTH

The radar sensor was used to measure the distance covered. This sensor sends a command to the digital signal processing board (controller) through a serial port about the velocity of target detection and vehicle positions. The mathematical modeling [42], [43] for the distance detection ranges estimation of a vehicle in motion using the radar sensor is presented in Fig. 8. The motion characteristic for determining the vehicle states which is either in dynamic or stationary is given in "(11)", and can be computed using discrete Kalman filters expression in [44] as in "(12)".

$$\rho i = \begin{cases} dynamic \quad if\ |v + (\Re_i + y_i\mu\ )| \\ stationary \quad otherwise, \end{cases} \tag{11}$$

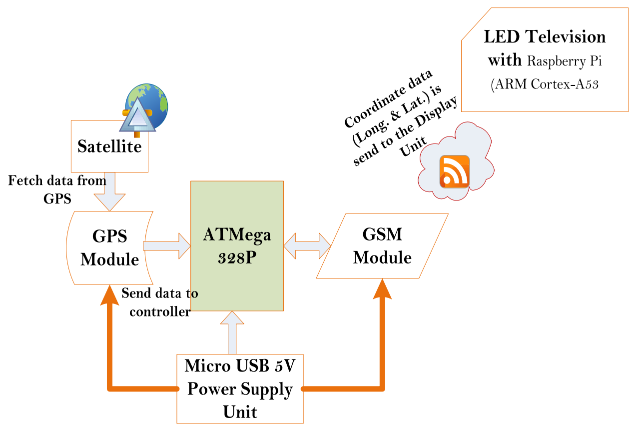


FIGURE 11. **The architecture of an advanced public vehicle tracking system.**

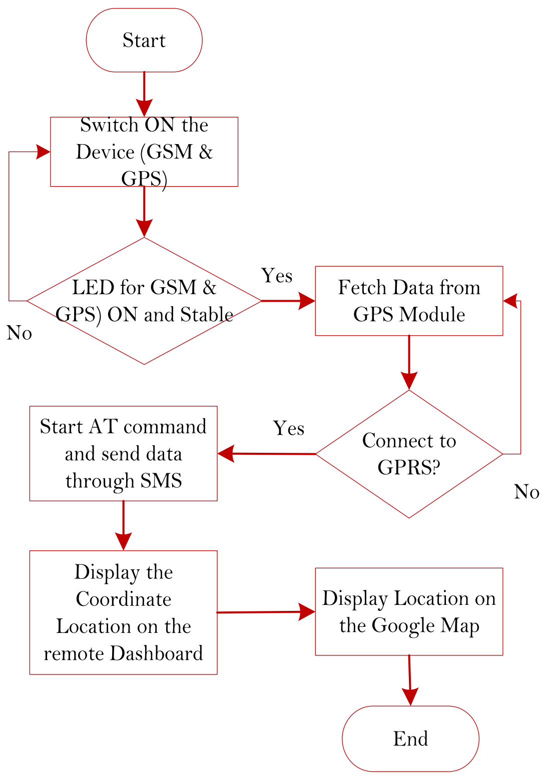


FIGURE 12. **GPS-based vehicular tracking flowchart.**

where x and y represent longitude direction and lateral positions of a fixed coordinate body respectively. κ is curvature, φ is the angle that exists between the road lane and longitude axis of the vehicle sensor, v is the vehicle speed, μ is the yaw rate, $\Re$ is the range rate, subscript i is the ith radar track.

$$\bar{x}(\kappa+1 \mid \kappa) = A\bar{x}(\kappa \mid \kappa),$$
$$P(\kappa+1 \mid k) = AP(\kappa-1 \mid \kappa-1)A^T + Q[\kappa], \quad (12)$$

The updated equations for the measurement along the route or lane can be expressed as in "(13)". Then, since a constant speed or velocity is considered with a vehicle in motion,

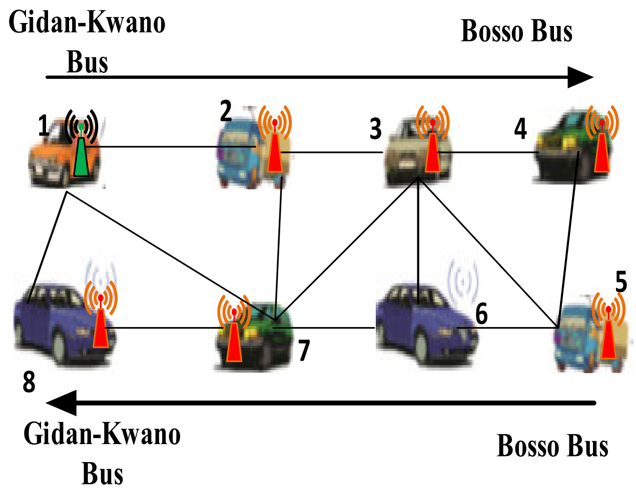


FIGURE 13. **Scheduling of vehicle tracking on a fixed urban arterial route in Minna.**

TABLE 3. **Algorithm 2 global positioning system greedy forwarding.**

Steps	GPS greedy algorithm
1	**Input:** Source Campus ξ, Destination campus ω, Strategic route locations $(\Re)$.
2	**Auxiliary Variables:** *Process* (ξ,σ) where $\sigma \in Location\_List(\xi)$ *Maximum-process.*
3	**Output:** *Next-Location_List*// If Greedy source is successful Null// If Greedy source is not successful and the perimeter is needed.
4	**Initialization:** *Next-Location_List*=Null *Maximum-process*←0.0
5	**Begin:** *GPS Greedy Forwarding Algorithm*
6	$Dis\tan ce_{\xi\omega} = \sqrt{(X_\xi - X_\omega)^2 + (Y_\xi - Y_\omega)^2}$
7	For every strategic location, route $\sigma \in Location\_List(\xi)$ **do**
8	$Dis\tan ce_{\xi\sigma} = \sqrt{(X_\sigma - X_\omega)^2 + (Y_\sigma - Y_\omega)^2}$
9	**If-Then**
10	Process $(\xi.\omega) = \dfrac{Dis\tan ce_{\xi-\omega} - Dis\tan ce_{\xi-\sigma}}{Dis\tan ce_{\xi-\omega}}$
11	If (Maximum-Process < Process (ξ,σ) **Then**
12	(Maximum-Process = Process (ξ,σ)
13	Strategic-Route_Location ←1 **End If**
14	**End If**
15	**End For**
16	**If** (Maximum-Process > 0.0) **Then**
17	**return** Strategic-Route_Location// Greedy forwarding (source) is successful
18	**Else**
19	**Return** NULL// Greedy forwarding (source) is successful is not successful // Perimeter forwarding is required
20	**End If**
21	**End** GPS Greedy Forwarding Algorithm

the equation matrix of Λ, and the measurement matrix Π can be formulated as in "(14)" and "(15)".

Where $x = (y\ v_y\ x\ v_x)^T$, x and y is the relations longitude axis and lateral positions, v_x and v_y are the relation of

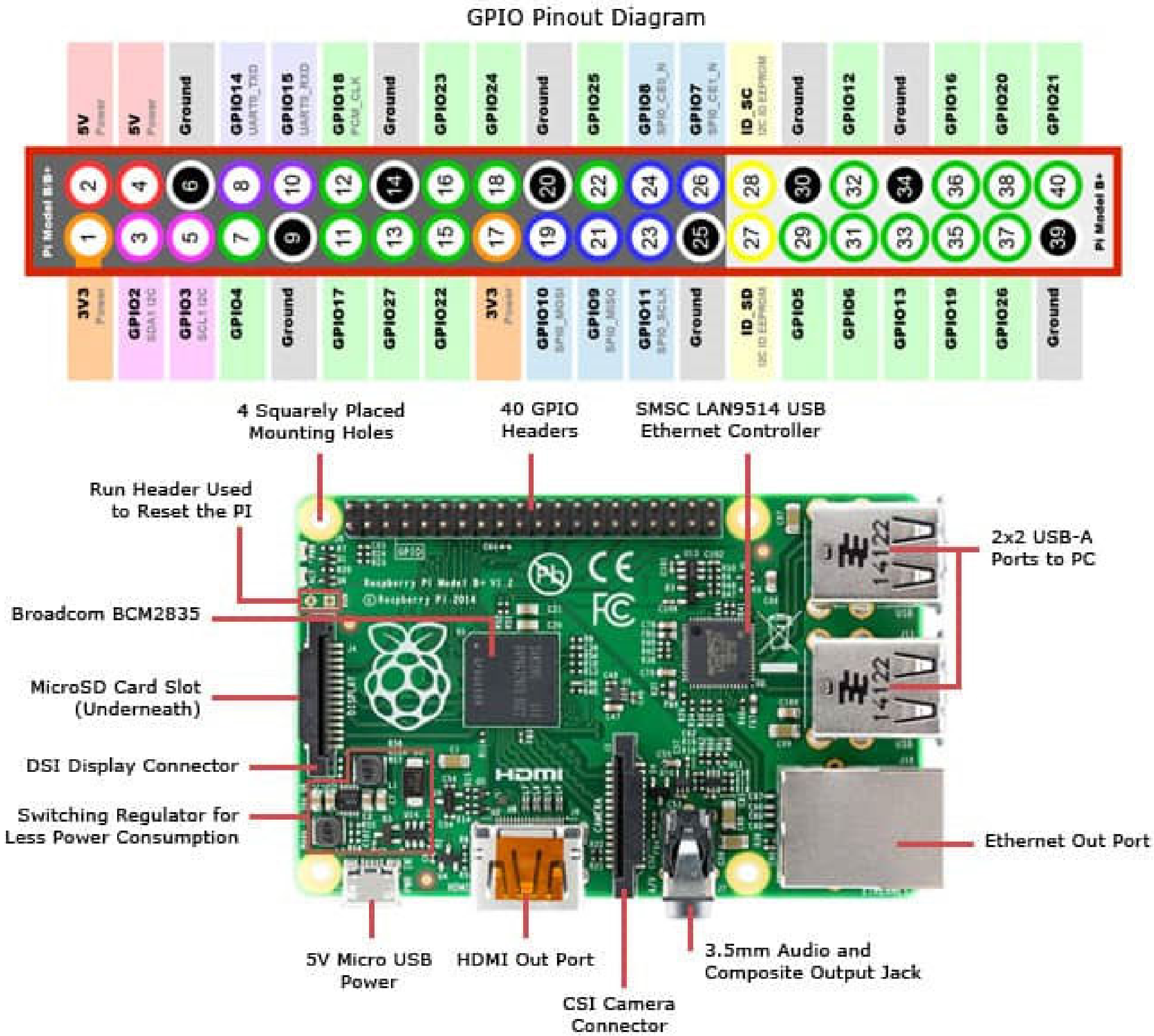


FIGURE 14. **Raspberry pi processor architecture [50].**

longitude axis and lateral velocity or speed, and T is sampling time.

$$\begin{aligned}\kappa(\kappa+1) &= P[(\kappa+1)\,|\,\kappa]H^T(HP[\kappa+1\,|\,\kappa]H^T+R[\kappa+1])^{-1}\\ &\quad\times\bar{x}[\kappa+1\,|\,\kappa+1]=\bar{x}[\kappa+1|]\\ &\quad+K[\kappa+1](z[\kappa+1]-H\bar{x}[\kappa+1\,|\,\kappa])\end{aligned} \tag{13}$$

$$\begin{aligned}P[\kappa+1\,|\,\kappa+1] &= P[\kappa+1|\,\kappa]-K[\kappa+1]HP[\kappa+1\,|\,\kappa])\end{aligned} \tag{14}$$

$$\Lambda=\begin{bmatrix}1&T&0&0\\0&1&0&0\\0&0&1&T\\0&0&0&1\end{bmatrix},\quad \prod=\begin{bmatrix}1&0&0&0\\0&0&0&0\\0&0&1&0\\0&0&0&1\end{bmatrix} \tag{15}$$

C. GPS GREEDY FORWARDING ALGORITHM

In the vehicle tracking, Greedy Forwarding Algorithm (GFA) was adopted in selecting the best possible response at every distance covered per kilometer in relation to time, the subsequent steps were calculated until the vehicle reaches its destination as illustrated in the decision tree of Fig. 9. The route colored in blue was identified as the optimum and best route to the destination. The GPS-GFA is presented in Table 3. This algorithm assists in achieving the globally optimum path selection [45]. The Haversine formula was used for the accurate computation of the distance between the two points (latitude and longitude) of the great circle as in "(10)".

IV. SYSTEM DESIGN AND IMPLEMENTATION

A. HARDWARE COMPONENTS INTEGRATION

The combination of components used in the design of the Public Transportation Vehicular Tracking System (PTVTS) includes the Atmega 328P controller, Sim 900 GSM module, Ublox NEO6MV2 GPS module, Button, connecting wires, and power supply. Other standalone system involved in the PTVTS architecture includes smart LED TV, android mobile phone, Huawei universal MiFi, Raspberry Pi (ARM cortex A53) processor and GPS cellular network as

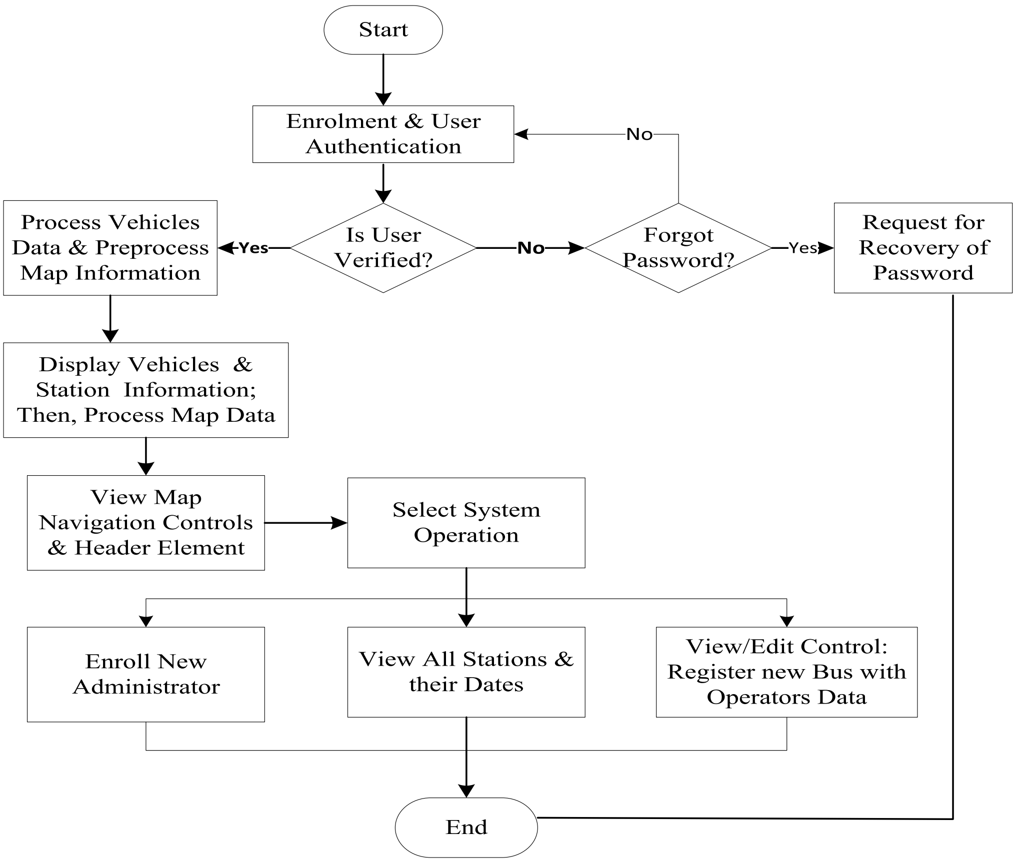


FIGURE 15. Geographical vehicular information display flowchart.

illustrated in Fig. 10. The block diagram of PTVTS is illustrated in Fig. 11. The flowchart in Fig. 12 illustrates the logical principle of the tracking device operation.

1) COMMUNICATION TRACKING SYSTEM MODULE

The in-vehicle tracking device transmits the geo-location information to the remote base-station through the integrated Global Positioning System (GPS) and Global System for Mobile communication (GSM) module with the system controller (Atmega 328P chip). The GPS module consists of three components that are responsible for navigation in tracking such as the airspace section, control section, and use section [46], [47]. A GSM component (SIM 900) is an embedded memory chip with available space for the subscriber identification module (SIM) card. This module was used to establish communication (that is, the transmission of data rate) between a GPRS and computing system. The essential pins connection and configuration of this module with ATmega328P for message forwarding and receiving includes +5 power (PWR), ground (GND), Receiver (RX), transmitter (TX), and reset (RST) button.

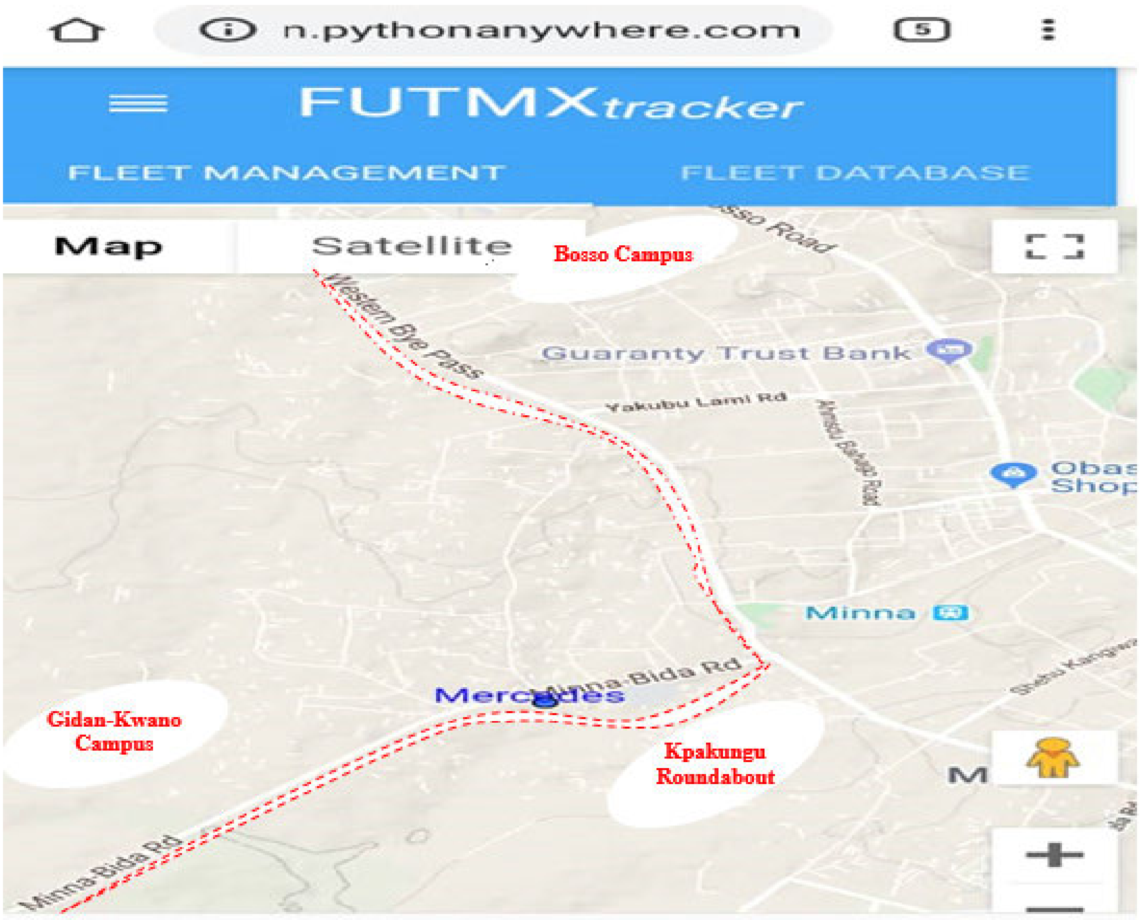
The remote transmission and distribution of vehicle data (messages) were achieved through the adoption of data dissemination protocol using Wagon Wheel (WW) approaches for the segmentation of message transmission range [19], [48]. The proposed protocol moderates the message broadcast storm communicated from different vehicles on the route and controls some redundant transmissions as shown in Fig. 13. The WW data dissemination algorithm guarantees the distribution of vehicle messages (data) across the network partitions and periodically connects through the available vehicle service on the route as presented in Table 4.

The vehicle position ($\wp$), distance (∂_{st}), and direction (γ) are the parameters coding in routing information to the target remote display board. The cumulative value η for each or individual vehicle message received R_i on the urban arterial routes is given in "(16)".

$$\eta_{Ri} = \Sigma\{\wp_i + \partial_i + \gamma_i\} \tag{16}$$

2) THE CONTROLLER MODULE

The Atmega 328P microcontroller was used as the logical control unit that processes all the activities in the tracking system. This controller was integrated on the Arduino board with 80mA, 5volt power when no component is connected. The microcontroller board can be powered either from the DC power jack (7-12V), the USB connector (5V), or the Vin pin of the board (7-12V). The maximum current draw is 50mA from the supply voltage of 3.3-5V, while the clock speed is 16 MHz so it can perform tasks faster.



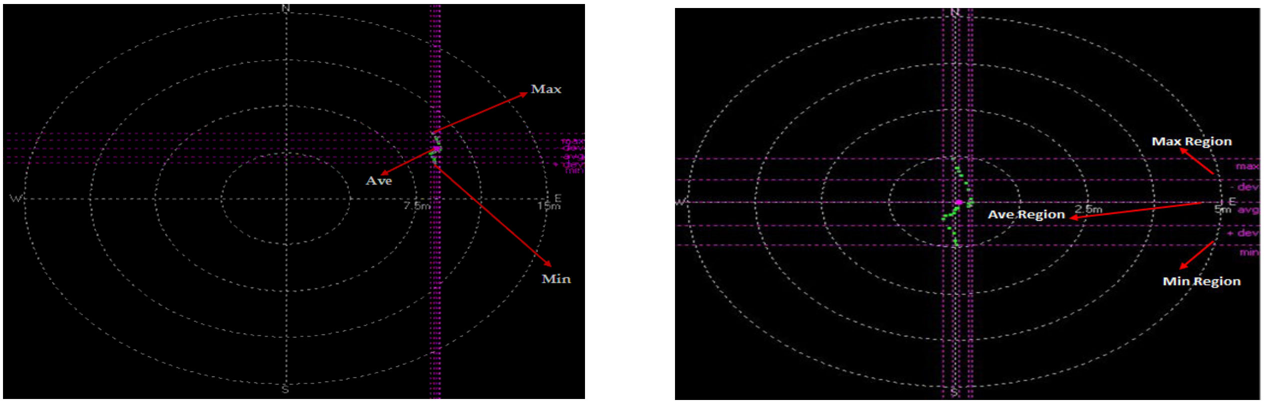
(a) Google map route graphical user interface

(b) Google map route dashboard display

FIGURE 16. An inter-university campuses route google map app. (a) Illustrate the geo-position and location of each Bus-Shuttle on the transit. (b) Display readable information about the vehicle on the transit.

3) THE DISPLAY SYSTEM UNIT

The smart light-emitting diode television (LED-TV) was adopted as a dashboard module for displaying information. This system was subjected to an engineering re-design with the integration of some components. The process involved integrating a microcomputer system (Raspberry Pi ARM Cortex A53 processor) into the smart television for logical control and receiving remote geolocation information from the GPS/GSM module. The collection and display of remote information were achieved through a High-Definition Multimedia Interface (HDMI) connection enable and universal mobile wireless communication device, which was connected through the universal serial bus (USB) port to provide a stable/strong network



(a) (b)

FIGURE 17. The satellite selection of geolocation accuracy and precision. (a) The circular area is 15 meters apart, and the satellite selection of the geo-location accuracy value is within 7.5 meters to 10.5 meters of the circular radius. (b) The precision was determined to be the difference between two coordinates distance measured for a fixed location which is 1.24 meters for the received data.

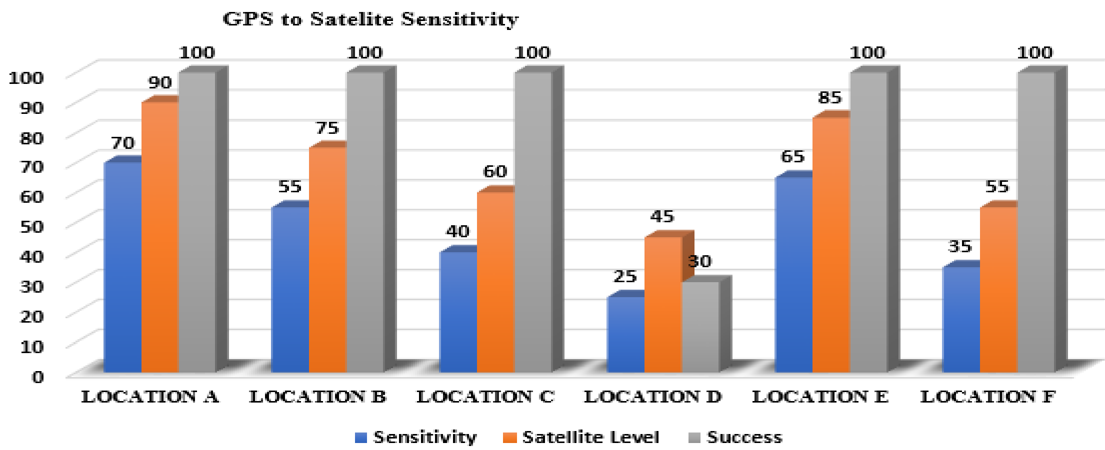


FIGURE 18. Satellite selection sensitivity and success rate.

(received signal strength RSS) for the consistent functioning of the microcomputer system.

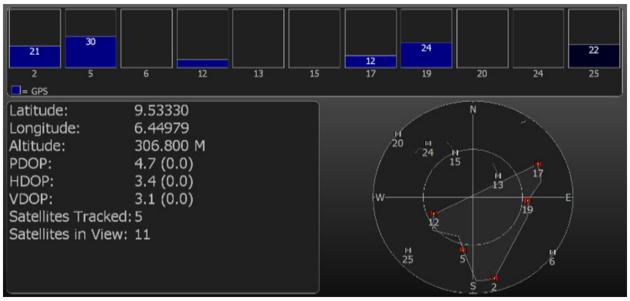
The Raspberry Pi ARM Cortex A53 processor is a 32-bit quad-core processor that operates on the frequency of 900 MHZ. It supports Android OS, Linux, OpenBSD, RISC OS, Windows 10 ARM64, and Windows 10 IoT core. It utilizes the CPU of 1.5 GHz 64/32-bit quad-cores, a micro-SDHC slot with 4GB LPDDR4-3200 RAM [49]. The microcomputer is a system-on-chip (SoC) that uses Broadcom BCM2711 and operates on a full power delivery to USB devices of 5V/3A as illustrated in Fig. 14 with ports connection pins.

B. SOFTWARE SYSTEM DEVELOPMENT

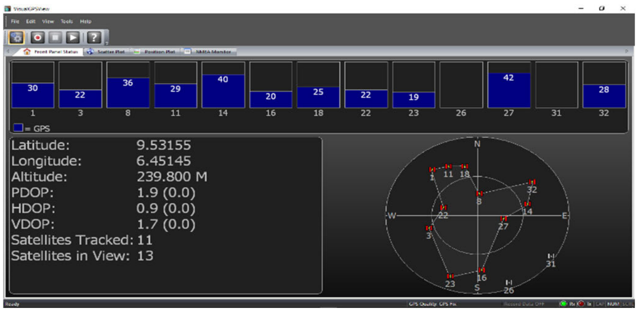
The software design coding for hardware components, C-language was used to program the microcontroller and other peripherals including the GPS module and GSM in Arduino IDE. Google maps geolocation tracking was developed using Python programming language. The user interface designs for the system utilized Microsoft Visio, while the implementation was programmed using HTML, CSS, JavaScript, and Python. The HTML was used to provide the visual elements on the webpages, CSS was used to style the content to provide good aesthetics, JavaScript for HTML manipulation, and to provide meaningful content for the webserver. Python was adopted to manipulate and process the real data (from the database) in the web hosting sites services (Website). The flowchart for geo-location information display is depicted in Fig. 15. Also, virtual network computing (VNC) viewer software was used as virtual control of the dashboard message display. A VNC is a graphical inter-relaying screen (desktop-sharing screen DSC) direction on the network, which employs a Remote Frame Buffer Protocol (RFBP) to control another computer in a network remotely [51].

C. PERFORMANCE EVALUATION

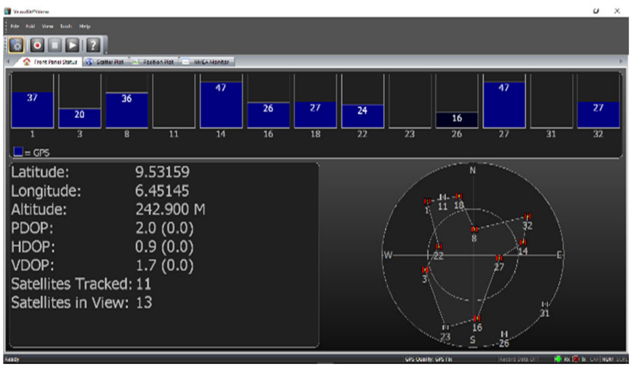
The accuracy and precision of the system performances were carried out using the Ublox Neo 7M GPS receiver software.



(a)

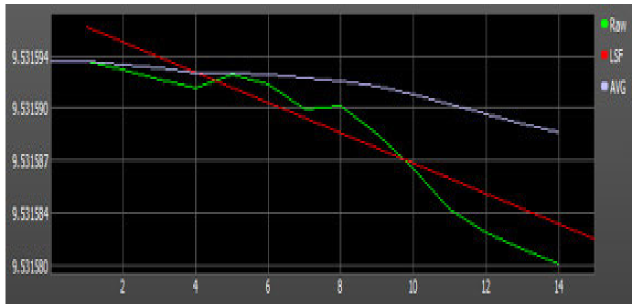


(b)

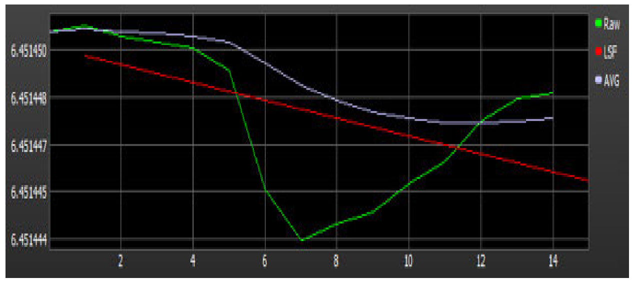


(c)

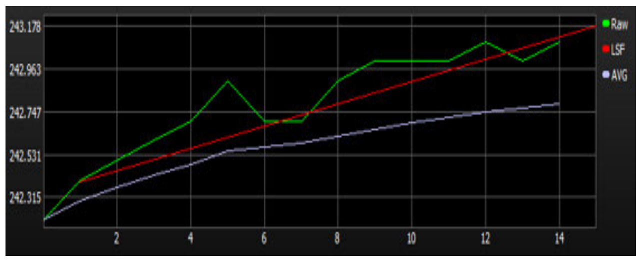
FIGURE 19. **GPS tracking simulation for the error view.**



(a) Latitude vs Location.



(b) Longitude vs Location.



(c) Altitude vs Location.

FIGURE 20. **Simulation result of tracking position plot in Visual-GPS-View (690 data samples).**

The vehicular position tracking accuracy of the system was defined in terms of GDoP [52], which is the ratio of the square root of MSE to standard deviation as expressed in "(17)", "(18)" and "(19)".

$$GDoP = \frac{\sqrt{MSE}}{\sigma_r} \tag{17}$$

$$MSE = E\left|(x-\bar{x})^2 + (y-\bar{y})^2 + (z-\bar{z})^2\right| \tag{18}$$

$$\sigma_d = \sqrt{2\sigma_{E^2}} \tag{19}$$

The GDoP is a non-linear function that can be linearized with the Taylor series mathematical model [53] as in "(20)" and given in a matrix form (Ψ) as in "(21)".

$$\Delta\rho \approx \Psi\Delta x = \psi\Delta x + c \tag{20}$$

$$\Psi = \begin{pmatrix} \alpha_{x1} & \alpha_{y1} & \alpha_{z1} & 1 \\ \alpha_{x2} & \alpha_{y2} & \alpha_{z2} & 1 \\ \dots & \dots & \dots & \dots \\ \alpha_{xn} & \alpha_{yn} & \alpha_{zn} & 1 \end{pmatrix} \tag{21}$$

We assumed that the measurement error of GDoP has an independent Gaussian distribution, so the least-squares error solution for the matrix is given as in "(22)".

$$\Delta x = (\Psi^T\Psi)^{-1}\psi^T\Delta\rho \tag{22}$$

For the position accuracy, it can be proven in terms of covariance ($\Im$) of Δx as in "(23)" to "(25)":

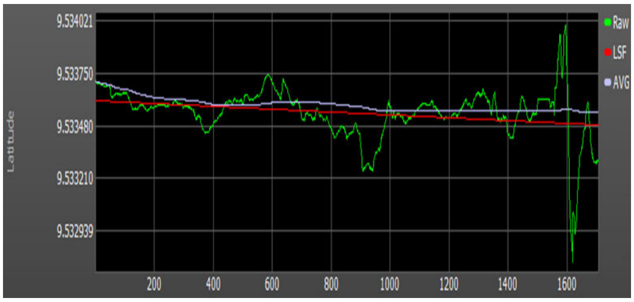
$$\Im\Delta x = \varepsilon[(\Delta x)(\Delta x)^T] \tag{23}$$

$$\Im.\Delta x = \varepsilon(\Psi^T\Psi)^{-1}\psi^T(\Delta\rho.\Delta\rho^T)\psi.(\psi^T\psi)^{-1}] \tag{24}$$

$$= (\Psi^T.\psi)^{-1}\Im\Delta\rho \tag{25}$$

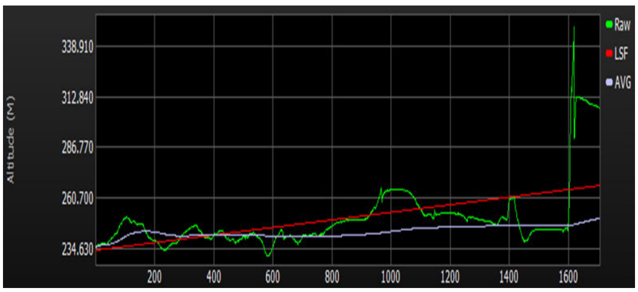
Therefore, it is rational to assume that all the errors in the pseudo-range measurements are motionless of the random processes for a short period. They are identical and independent distributed with a variance of σ^2 and is expressed as in "(26)".

$$\Im\Delta x = \begin{pmatrix} \sigma_{xu}^2 & . & . & . \\ . & \sigma_{yu}^2 & \dots & . \\ . & \dots & \sigma_{zu}^2 & \dots \\ . & . & . & \sigma_{ctb}^2 \end{pmatrix} \tag{26}$$



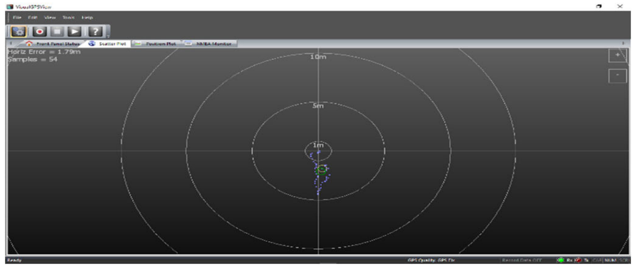
(a) Latitude vs Location.

(b) Longitude vs Location.

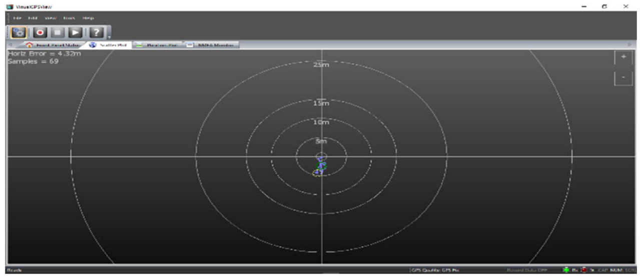


(c) Altitude vs Location.

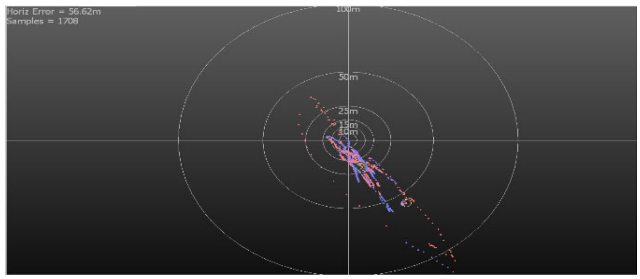
FIGURE 21. Simulation result of tracking position plot in Visual-GPS-View (1700 data samples).



(a)



(b)



(c).

FIGURE 22. Simulation result samples of scattering plot of tracking position in Visual-GPS-View.

The amplification of the equivalent error range measurements of the receiver position is calculated using GDoP as given in "(27)".

$$GDoP = \sqrt{\sigma_{xu}^2 + \sigma_{yu}^2 + \sigma_{zu}^2 + \sigma_{ctb}^2 \Big/ \sigma^2} \tag{27}$$

The matrix analysis and applied theory of linear algebra in [54] considered that, if the λ_i is recognized as the eigenvalues of a converse matrix Λ, then it is expected that λ_i^{-1} it can represent eigenvalues of the inverse matrix of Λ^{-1}. Therefore, the matrix Π measurement can be expressed as $\Pi = (\Psi^T \psi)^{-1}$ which is always reversible and be solved using $\lambda_i(\Psi^T \psi)$. This process can result in a significant reduction of inverse matrix calculation using QR decomposition with Gram-Schmidt [55] for geometric dilution of precision (GDoP) as given in "(29)" to "(30)".

$$GDoP = \sqrt{\Gamma((\psi^T \psi)^{-1}} \tag{28}$$

$$GDoP = \sqrt{\Gamma(\Pi)} \tag{29}$$

$$GDoP = \sqrt{\lambda_1^{-1} + \lambda_2^{-1} + \lambda_3^{-1} + \lambda_4^{-1}} \tag{30}$$

Therefore, the visible selection process of the satellite in the present view for the best positioning accuracy corresponding to the row selection of the matrix form ψ observability will result in minimum geometric dilution of precision (GDoP) as in "(31)". $S - \{s_i\}, 1 \leq i \leq k, k \in (4, 5, 6, 7)$.

$$\begin{aligned} \min GDoP &= \sqrt{\Gamma((\Psi_k^T \Psi_k)^{-1}} \\ &= \sqrt{\lambda_1^{-1} + \lambda_2^{-1} + \lambda_3^{-1} + \ldots + \lambda_k^{-1}} \end{aligned} \tag{31}$$

where Γ is the trace function of the matrix, c is the constant speed of light, s_i is the number of identifying satellite that is currently view.

The Position Dilution of Precision (PDoP) is given as $PDOP = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2}$, Time Dilution of Precision (TDoP) is expressed as $TDOP = \sqrt{\sigma_t^2}$, where Vertical Dilution of Precision, $VDOP = \sqrt{\sigma_z^2}$, and Horizontal Dilution of Precision $HDOP = \sqrt{\sigma_x^2 + \sigma_y^2}$. For the local horizontal and vertical plane corresponding, x, y, and z are coded for the down coordinate system (North, East), and up coordinate system (East, North).

TABLE 4. Algorithm 3 wheel wagon data dissemination protocol.

Steps	Wheel wagon data dissemination algorithm
1	**Process** Next Forwarder Vehicle Selection Locations Message (NFVSLM).
2	**Input: N** // all vehicles involved in the campus bus shuttle area.
3	**Source** // vehicle (ς) to initiates the data dissemination processes
4	**(Γx, Γy)** // x and y-axis are the coordinates of vehicle transmitter **(Γ)** in the hops
5	**(Ꞧx, Ꞧy)** // x and y-axis are the coordinates of vehicle receiver (**Ꞧi**) in the hops
6	**Output:** number of the vehicle involved in the data or information dissemination process
7	**if** the geo-positional messages are received for the first interval, **then**
8	the route bearing **Ꞧi** to **Γj** $= \angle \lvert (\Gamma^{\rightarrow}.\Gamma \quad \Re^{\rightarrow}.\Re) \leq \theta \rvert$, **for** the preset threshold value of θ // **Ꞧi & Γj** /opposite bearing path (direction)
9	Positions **Ꞧi** to **Γj** $= \angle = a\tan 2(\Gamma_y - \Re_y,\ \Gamma_x - \Re_x)$ // they are two influences function of arc tangent2 (arctangent function)
10	$\partial_{st}\, of\ \Re_i\ \&\ \Gamma_j = \sqrt{(\Gamma_x - \Re_x)^2} + (\Gamma_y - \Re_y)^2$ // distance (∂_{st}) between *Ꞧi* and *Γj*
11	$\delta_{delay} = 0.01 * \left(\frac{\partial_{st}\Re, \varsigma}{r_{comm}}\right)$ // default_delay (δ_{delay}) of *Ꞧi* is divided by the communication radius (r_{comm})
12	**If** the *Ꞧi* is within the sector or segment, that is $(\angle \geq 181^0\ and\ \angle \leq 360^0)$ **then** the waiting time is for priority vehicle 1 and 2
13	**If** ***Ꞧi*** is found within the normal sector/segment of the area $(\angle \geq 226^0\ and\ \angle \leq 324^0)$ **then,**
14	**Delay** = defaualt_delay + random nmber (0, 0.01); //waiting time is for priority 1
15	**End If**
16	**Else** // set the waiting time for priority 2
17	**Delay** = default_delay + randomnumber (0.05, 0.07);
18	**End If**
19	**End**
20	**Else** // if it is within the segment or sector, set the waiting time for priority 3
21	**Delay** = default_delay + random number (0.05, 0.0);
22	**End**
23	**Ri.**Schedule_Message(Delay); // Ꞧi will schedule the data transmission
24	**End**
25	**Else**
26	**If** Scheduled message **then**
27	**If** $\gamma(\Re_i, \varsigma) > \gamma(\Gamma_j, \varsigma)$ **then** // Calculate the distance and transmit information for display on the dashboard and google map respectively
28	Stored the received message into the database;
29	**End**
30	**End**
31	Cancel message scheduled;
32	**End process** for the Next Forwarder Vehicle Selection Locations Message

V. RESULTS AND DISCUSSION

The developed Google Map API using python language display information about the vehicles on transit (such as vehicle ID, origin, destination, and arrival time) as shown in Fig. 16.

TABLE 5. Geo-location coordinate tracking information.

Actual Coordinate Measurement			GPS Device Coordinate Measurement		
Location	Lat.	Long.	Lat.	Long.	Satellite view
1	6.451576	9.531347	6.451829	9.531222	4
2	6.449162	9.533510	6.449241	9.533539	6
3	6.449688	9.536088	6.449667	9.536154	9
4	6.452325	9.535278	6.452507	9.535301	5
5	6.451862	9.533240	6.451966	9.533134	7
6	6.452790	9.534655	6.452748	9.527481	6

TABLE 6. Simulation result of the average geo-location information.

Samples	Horizontal Error (m)	Latitude	Longitude	Altitude (M)
690	43.20	9.53158	6.45145	243.100
		LSF	LSF	LSF
		Latitude	Longitude	Altitude
		9.53158	6.45145	243.182
		AVG	AVG	AVG
		Latitude	Longitude	Altitude
		9.53159	6.45145	242.787
1700	56.62	9.53330	6.44979	306.800
		LSF	LSF	LSF
		Latitude	Longitude	Altitude
		9.53349	6.44962	266.875
		AVG	AVG	AVG
		Latitude	Longitude	Altitude
		9.53355	6.44955	250.180

The simulation result carried out in U-Blox GPS software shows the accuracy and precision of the geo-location coordinate information achieved. The circular area is 15 meters apart, and the satellite selection of the geo-location accuracy varied between 7.5 meters and 10.5 meters of the circular radius as illustrated in Fig. 17. The precision was determined to be the difference between two coordinates distance measured for a fixed location which is 1.24 meters for the received data. The sensitivity to satellite and success rate is presented in Fig 18.

The vehicle tracking system was tested with different sample sizes of GPS received information and simulated in the Google View Software. The GDoP errors such as (PDoP), (HDoP), and (VDoP) for the different sample sizes as illustrated in Fig. 19. In Fig. 19(a), 11 satellites were viewed but only 5 satellites could be tracked as a result of poor network, resulting in PDoP error = 4.7, HDoP error = 3.4, VDoP = 3.1. The result shows a fair navigation in-route precision. In Fig. 19(b), 13 satellites in view but 11 was tracked resulting

TABLE 7. Simulation results of geo-location tracking system.

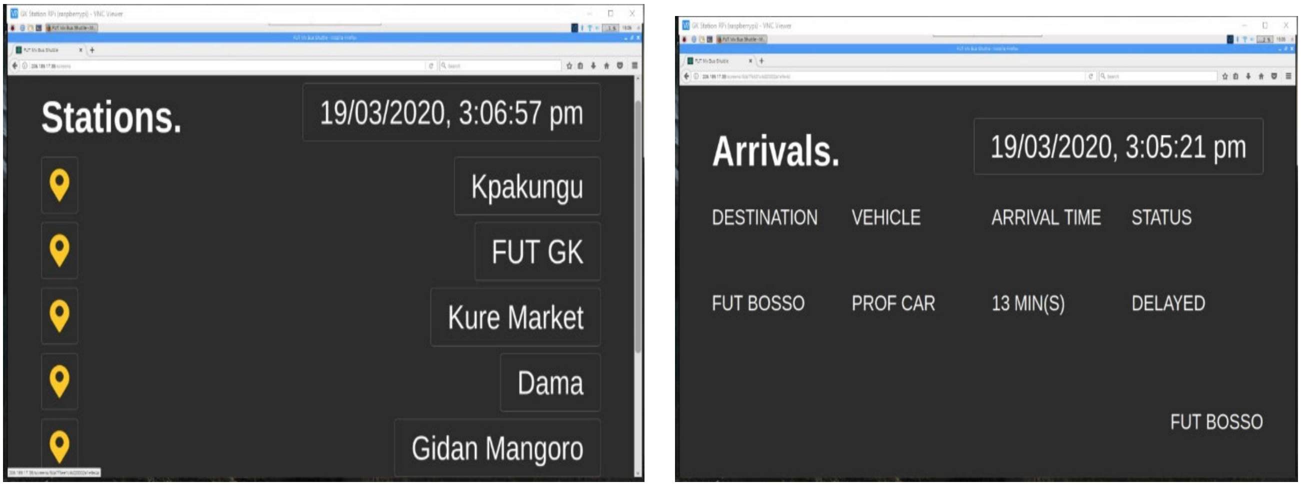
Time	Satellite Number	Speed (KM/h)	Longitude	Latitude
07:15:44	5	35.50	6.519418	9.602320
07:16:17	6	37.50	6.519421	9.602321
07:16:50	5	59.00	6.519423	9.60232
07:17:23	6	44.00	6.519426	9.602319
07:17:56	5	19.10	6.519428	9.602316
08:45:25	5	21.00	6.519430	9.602314
08:57:58	4	81.00	6.519431	9.602311
08:59:32	5	41.00	6.519430	9.60231
09:02:05	8	15.00	6.519428	9.602308
09:05:38	6	1.98	6.519425	9.602307
09:06:11	5	2.85	6.519422	9.602306
09:08:44	6	1.87	6.519419	9.602306
10:20:29	9	20.00	6.519416	9.602306
10:21:02	9	15.00	6.519416	9.602307
10:21:35	10	1.11	6.519417	9.602308
10:22:08	10	20.00	6.519417	9.602310
10:22:41	9	74.00	6.519415	9.602311
10:23:14	10	63.50	6.519408	9.60231
18:23:47	10	57.00	6.519404	9.602308
18:24:20	10	44.00	6.519399	9.602306
18:24:53	9	61.00	6.519397	9.602306
18:25:26	9	61.00	6.519395	9.602309
18:25:59	5	60.00	6.519392	9.602312
18:26:32	7	72.80	6.51939	9.602312
18:27:06	0	93.00	6.519389	9.602310
18:27:40	9	63.00	6.519388	9.60231
18:28:13	8	24.00	6.519387	9.602308
00:37:47	9	74.00	6.519387	9.602306
00:38:34	9	11.00	6.519387	9.602305
00:39:21	9	6.00	6.519418	9.602304

TABLE 8. Comparison analysis of the satellite selection sensitivity of geo-location tracking system.

Methods	Satellite selection (%)	Min. GDoP	Max. GDoP	Ave. GDoP	No. of satelite. sellection
Minimum IGDoP	100	1.70	4.70	3.20	11
Optimal Selection [56	100	2.12	6.79	3.16	7
Neural Network [40]	92.90	2.38	7.14	3.34	7
MGA [56]	99.60	2.12	6.82	3.19	7
Fast Selection [35]	93.20	2.32	7.23	3.32	7

in minor dilution error. PDoP error = 1.9, HDoP = 0.9, and VDOP = 1.7. This result is excellent, and the positional measurement is considered accurate and precise based on the principle of the dilution error range. In Fig. 19(c), 13 satellites in view, 11 tracked with minor dilution error. PDoP error = 2.0, HDoP = 0.9, and VDoP = 1.7. This result is also excellent, and the positional measurement is accurate and precise based on the principle of the dilution error range.

The geographical location tracking based on the latitude, longitude, and altitude is presented in Table 5, with the average prediction in Table 6. The simulation was carried out in Google View software to evaluate the system performance on the coverage area of the satellite precision and accuracy. The graphical results are illustrated as in Fig. 20 and 21. The HDoP error from the simulation analysis for different samples is presented in Fig. 22.



(a) (b)

FIGURE 23. Bus shuttle information display on the dashboard for departure and arrival time.

Figure 22(a) shows 540 samples simulated with the HDoP error of 1.79m which shows high accuracy and good precision of geolocation tracking. Figure 22(b) shows 690 samples simulated with an HDoP error of 4.32m, while in Fig 22(c), we have 1700 samples with HDoP error of 52.62m. The measurements at this level are inaccurate with poor precision of geo-location.

The geo-location and positional information were sent remotely to the server database and displayed on the dashboard with the aid of a Raspberry Pi ARM Cortex A53 processor integrated with smart LED television using Hyper-text Transfer Protocol (HTTP). The vehicle tracking position information displayed is presented in Fig. 23. Table 7 contains information received during system testing which includes time, date, speed, longitude, latitude, and distance. The implementation cost of this proposed vehicle tracking system for public transportation on urban arterial can be widely adopted and scaled up to a minimal amount of $2,570.00. The comparison analysis result of satellite selection sensitivity using different techniques for the geo-location vehicular tracking system is presented in Table 8.

VI. CONCLUSION

The vehicle tracking system for public transportation on urban arterial was developed, implemented, and demonstrated using novelty algorithms. The GPS-GFA receiver was used to collect data on remote vehicle state (geo-location, distance, and time to arrival). GSM module was used to transmit information to remote server base station using wheel wagon data dissemination protocols (WWDDP). The general packet radio service and Google Map software were adopted for geo-location tracking and identification. Both the time and distance to arrival achieved were found to be accurate with low latency. The minimum inversion matrix GDoP method for GPS satellite selection approach proof efficient with an excellent performance recorded in the measurement of accuracy and precision. The vehicle tracking system was tested with 13 satellites in view but 11 was tracked with minor dilution error (PDoP error is 1.9, HDoP is 0.9, and VDOP is 1.7 respectively). Therefore, the developed vehicle tracking system for public transport on the urban arterial route can be scaled up for city-wide application with minimal cost of $2,570.00 per terminal. This system would help to reduce unnecessary anxiety experienced while waiting for vehicles at bus terminals/stops without knowledge of the vehicles' locations and arrival times. It would help to guard against diversion of fleet or vehicle to unauthorized routes, enhance fleet management, and reduce environmental pollution. Future work will be focusing on the development of an intelligent transport fare billing system, analysis of traffic (noise) on urban arterial routes, and scheduling of bus shuttle timetable.

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