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Smart Bus Route Monitoring System for Federal University of Technology, Minna, Niger State

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Abstract

Transportation between both university campuses of Federal University of Technology, Minna (FUT Minna) has become a tedious and tiring activity because of the existing disconnect between the university's transport system and the commuters due to the rapid increase in student population. The major factor responsible for this disconnect is the information gap between the passengers and the bus(es) en-route. This study therefore, proposes to bridge this gap by designing and implementing a system to monitor and estimate the time of arrival of buses via installed GPS tracking units, and relay the information over GSM/GPRS connection to a cloud server which processes and relays the information to waiting passengers via installed audio and video systems at a designated bus park, and a cross-platform Smartphone application to track the live-location and query bus(es) en-route using Here Maps Application Programming Interface (API). The system is coordinated by Arduino microcontrollers and the strong cohesion between obtained and calculated Estimated Time of Arrivals (ETAs) prove the efficiency of the designed system, in helping commuters make better decisions

Keywords: Smart Bus Route Monitoring System (SBRMoS), Global Positioning System (GPS), Estimated Time of Arrival (ETA), Longitude, Latitude

Introduction

The increase in population and the need to move from one place to another has created a problem in the transportation sector which researchers all over the world have proposed several solutions in an attempt to increase the efficiency of transportation systems (Cleophas *et al.,* 2019; Guerrero-Ibáñez *et al.,* 2018). Consequently, the population of Nigeria which has been on the increase makes transportation problems even more evident in the country (Ogunleye *et al.*, 2018). As a result of this increase, providing an effective means of transportation for all citizens poses to be a herculean task in major parts of the country (Gbadamosi and Akanmu, 2021). This is because existing transport infrastructure (if not improved upon) cannot effectively cater for the travel needs of the people. The case study of this research, FUT Minna is not left out as it shares in the transportation problems bugging the densely populated parts of Nigeria (Shehu *et al.,* 2020). The ever increasing population of students as admitted yearly, presents a problem to the existing transport infrastructure (Onwukanjo, 2017). Hence, the need to proffer a smart solution to the problem at hand.

Related Works

Most recent of the works in this field as solution is a system designed to monitor buses in transit between two campuses by comparing their location to the coordinates of predefined landmark locations along the route (Farouk *et al.*, 2021). The paper employs an array of GPS, GSM, and microcontroller units to achieve this aim. The approach was however limited as it only provided location details by carrying out a comparison, which means the consumers of the application could not get access to a real-time update actual bus location.

The approach proposed in Kamisan *et al.* (2017) uses GPS, Wi-Fi, and web technologies to achieve the aim of tracking the real-time location of a vehicle. The system, implemented using a database uploaded on a local server however limited the coverage area of the system.

Kumbhar *et al.* (2016) proposes an approach to monitoring using a web-based application that could communicate with an offline server remotely and exchange vital location information regarding the bus being monitored and feed to the waiting users. This approach, though flexible is limited in terms of storage and processing capability because of the architecture of the server deployed for this purpose.

The design by Eddie *et al.* (2013) is mentioned because it is in the same field as the system been designed and aims to tackle a similar problem. University College Sedaya International (UCSI), University in Kuala Lumpur, Malaysia, is presently making use of the system. The University has two campuses, just like Federal University of Technology Minna and is approximately 40 minutes away. To track down the whereabouts of the buses, this basic tracking system makes use of 2.4G network facilities. It was not intended to provide accurate bus positions, but it will record the bus arrival and departure times at each stop.

The approach by system Kadam *et al.* (2018) is noteworthy since it makes use of a comparable mix of two of the technologies discussed in this study. It also provides passengers with all processed information via a mobile application. It uses a mix of Bluetooth, GPS, and GPRS technologies. Two pairs of infrared sensors were installed on the bus trackers, the estimated time of arrival (ETA) was calculated using the Euclidean Distance Formula and was also displayed on the android application alongside the number of passengers aboard as at the time of query.

Using sensors and a GPS device, the proposed system by Shinde and Ansari, (2017) automatically gathered information such as the bus's fuel level, the driver's alcohol level, the bus's current position the distance travelled by the bus, and the vehicle's arrival time. The data was then sent over a GSM module and stored on a cloud server. The expected time of arrival of the bus was calculated on the web server, and approved users were granted access to the online portal through secure login credentials. The suggested approach successfully located the buses during testing, transmitting all required information about the bus. The method, however, might be improved because it only allowed for a limited amount of mobility via the web interface. Furthermore, the system was designed in favour of those who had access to the internet and cellphones, leaving those who did not to wait in long queues.

The system presented by Peter *et al.* (2018) is significant in this study due to the combination of technologies used. The system employed GPS and GSM technology to track and monitor cars in the event of theft, which was the system's primary application. A GPS module, GSM modem, LCD display, GPS receiver, motors, and a power supply unit were used to achieve the goal. All of this was controlled by a PIC16F72 (microcontroller) that had been configured to control all of the various components.

The system mentioned by Peter, *et al.* (2018) primarily functioned by receiving pre-programmed messages from a certified mobile device. The GPS module monitored and tracked the car by collecting the vehicle's coordinates (longitude and latitude) and communicating them to the microcontroller, whose job it was to make the information accessible to a confirmed user by SMS upon request. When the preset command was delivered, it activated the GPS modem, which acquired the controller's current latitude and longitude and sent the information to the confirmed phone number. In addition, the system displayed the vehicle's position on the connected LCD to ensure that the microcontroller was in good working order.

The system by Peter, *et al.* (2018) also included a Smartphone app that allowed customers to track the vehicle's real-time position using Google Maps API, allowing them to track its whereabouts remotely and predict its arrival time on their phones. The system, however, confined these functions to Android Smartphone users alone, limiting the system's utility and mobility.

The method proposed by Mrudula *et al.* (2018) deployed a system to track three (3) buses and communicate remotely with a Smartphone over the internet. The buses which had GPS units onboard were in constant communication with a mobile Smartphone unit which was designed to display the current location of the bus, bus route details, driver's contact number, estimated time of arrival, real time traffic to diverse route in case of heavy congestion, and an emergency module. The real time traffic feature was introduced to aid the driver in making quick decisions regarding the fastest and least busy route to his/her destination.

Because the mobile application used the Google Maps API, it had access to all of the information and parameters stored on Google Maps, which were presented to the user when they made a query. In the event of an emergency, the built system may potentially convey messages (i.e. when a user tapped on the emergency icon on the Smartphone application).

Despite the fact that the system by Mrudula *et al.* (2018) met its objectives during testing, the tracking system was not protected, allowing unauthorized users to alter it. Furthermore, the system lacked an alarm warning system that would alert passengers when the bus(es) passed by a bus stop on a regular basis.

The proposed method by Singla and Bhatia, (2015) employs GPS and GPRS technology, as well as a prediction system, to track and forecast when the bus (es) will arrive at the bus stop. The bus's arrival time was calculated utilizing the bus's speed, as well as the GPS tracking of the bus's and passengers immediate locations to obtain a more precise expected arrival time. Client-server technology was used to communicate between the bus tracking unit and the mobile application, with two types of client-side apps and a server side.

All processing task were handled by the server side of the web application, which used MySQL server 5.6.23 to store tables for all of the routes. Google Maps was also utilized to map the bus's location, with specific coordinating points placed throughout the route to help plot the real-time GPS coordinates against the Google Maps road layout. The passenger's android application received all of the results and information via Position Based Services (LBS), and the arrival time was projected based on the distance between the bus's present location and the passenger's nearest bus stop. The information was also made available on request of the passenger via a query.

When an internet connection was made available for communication between the tracking unit and the client-server system, the implemented project proved to be useful in controlling bus transportation systems. The implemented system, on the other hand, was open to anyone, enabling unauthorized access to the system and potentially overwhelming it. Additionally, the system did not allow users or passengers who did not have access to cell phones to utilize the Android application.

The design by Saad *et al.* (2018) is mentioned here because of the parallels it shares with the designed project in terms of the technology it made use of to track and monitor the bus, as well as the issues it seeks to address. Commuters, however, are hesitant to use public transportation, particularly public buses, due to a lack of information about the bus's projected time of arrival (ETA), present location, and occupancy (number of seats available). This project is only for public transportation, and it aims to provide commuters with real-time information on the bus's current location. Furthermore, the ETA will be calculated using real-time data on the bus speed, remaining distance, and the destination bus stop.

In all the systems mentioned above one of the limitation include the having the accurate information from the system when it is queried, but this system gives a more precise ETA which is the main focus of this design.

Methodology

The SBRMoS is broadly divided into two sub-systems: The Hardware Subsystem, which consists of all hardware components and software subsystem, consisting of all software sections of the system. The principles of operation of both sub-systems are explained further in the next sub-section.

This sub-system is divided into two major units: The Tracking Unit, and the Monitoring Unit which is further sub-divided into two: The Bus Park Monitoring Interface and the Mobile Application/Web Platform. The tracking system, controlled by an Arduino Nano microcontroller board consists of a combination of the NEO-6M GPS tracker, a SIM900A GSM module, and a 5V Lithium Polymer (Li-Po) rechargeable.

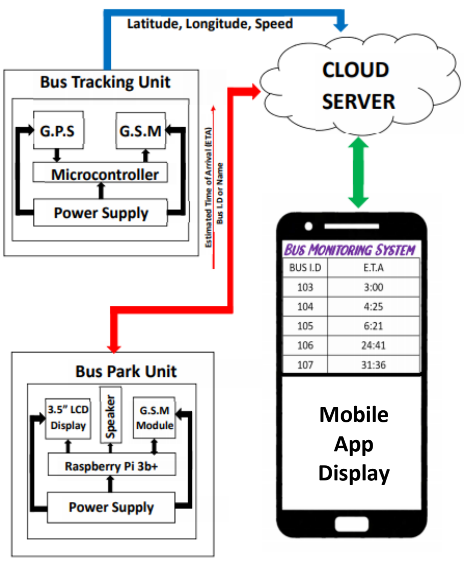

Fig. 1: Block diagram of the designed system.

This combo of components is utilized to instantaneously obtain certain parameters from the GPS satellites in space in order to pinpoint the location of the bus and Calculate its Estimated Time of Arrival (ETA) to the designated bus parks. These parameters are:

i. Speed of vehicle
ii. Longitude of vehicle
iii. Latitude of vehicle
iv. Angle of vehicle

Hardware Sub-System

The NEO-6M obtains GPS data (longitude, latitude, speed, and angle) from launched

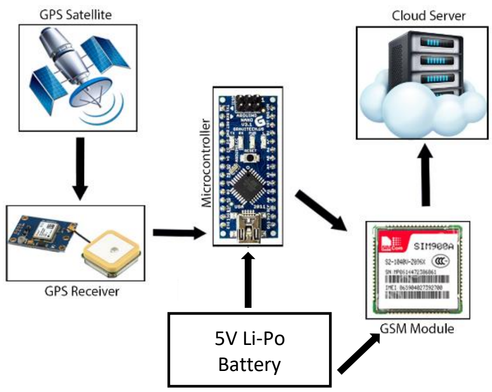

Fig. 2: Block diagram of the tracking system.

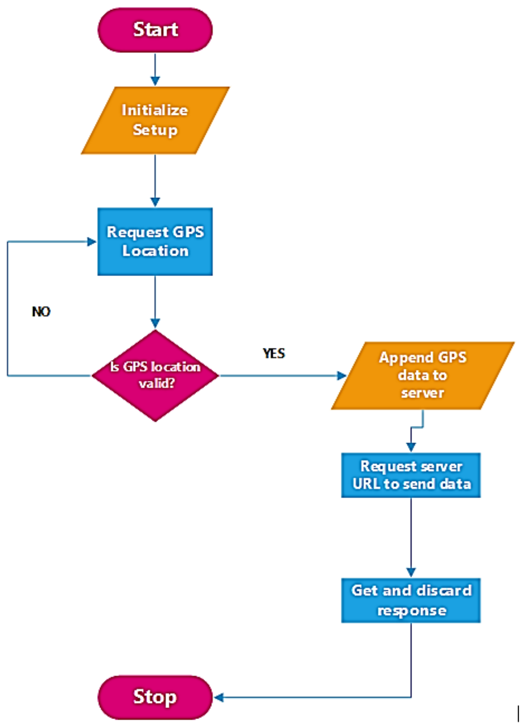

Fig. 3: Flow diagram of the tracking system.

Satellites and transmits the obtained data over the internet to the web server via the SIM900A GSM module and the whole process is coordinated by the Arduino Nano microcontroller. The block diagram and flow diagram of the tracking system are visualized in Figs. 2 and 3 respectively.

The second set of hardware components are installed on the monitoring unit. These devices communicate with the web server to retrieve uploaded and processed data.

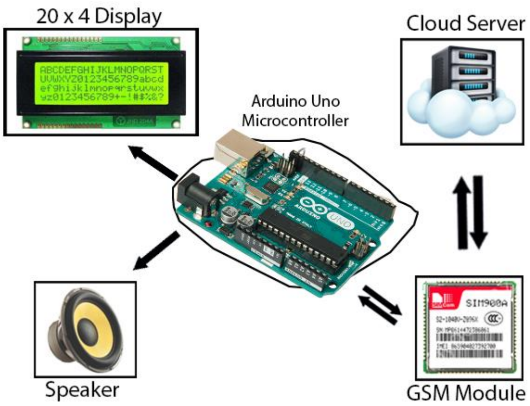

Fig. 4: Block diagram of the hardware monitoring system.

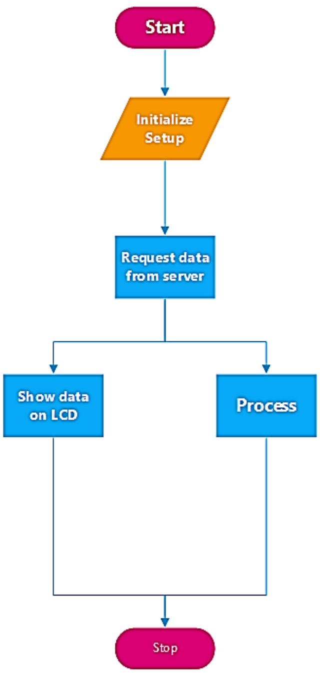

Fig. 5: Flowchart diagram of the hardware monitoring system.

The SIM900A module retrieves the information (Bus ID and ETA) after processing from the web server and stores it on the Arduino Uno board from which it is forwarded to the installed 20x4 LCD for display to passengers at the bus parks. The flow of instructions round the system and the block diagram of the system are shown in Figs. 4 and 5.

Software Sub-System

The software subsystem consists of all software components of the system including the web server, mobile application, and the IDE for compilation of codes for hardware components, web server, and the web platform. The server calculates the ETA using the Euclidean Distance Algorithm as described in the series of equations below:

$$Velocity\ (v)\{kmhr^{-1}\} = \frac{distance\ (s)\{km\}}{time\ (t)\{hr\}} \quad (1)$$

where: v = Average velocity of bus in motion.

s = Distance in km between the coordinates from which the query is initiated and the location of the bus as at the time of request.

t = Time taken to cover the distance (s) above.

The distance between the coordinates from which the query is initiated is calculated using the Google Distance Matrix which is a service that provides travel distance and time for a matrix of origins and destinations using an Application Programming Interface (API). The Google

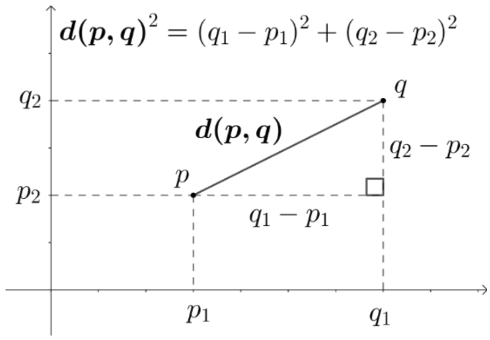

Fig. 6: Proof of Euclidean Distance Formula using Pythagoras' theorem.

Distance Matrix obtains this distance from the map using the Euclidean Distance Algorithm. Consider the right-angled triangle below with point p on coordinates (p1, p2) and point q on coordinates (q1, q2). The straight-line distance between point's p and q is given by the expression in equation (2).

$$s(\boldsymbol{p},\boldsymbol{q}) = \sqrt{(p_1 - q_1)^2 + (p_2 - q_2)^2 + \cdots + (p_n - q_n)^2} \quad (2)$$

Note that;

(p,q) = |*p* - *q*| (3)

Hence, equation (2) denotes the Euclidean Distance Formula.

Assume the query was initiated from point X with coordinates (p_1, p_2) and the location of the bus at the time of query was point Y with coordinates (q_1, q_2), the distance between points X and Y is given by:

$$s(\boldsymbol{X},\boldsymbol{Y}) = \sqrt{(p_1 - q_1)^2 + (p_2 - q_2)^2} \quad (4)$$

where: p_1 = longitude of point X

p_2 = latitude of point X

q_1 = longitude of point Y

q_2 = latitude of point Y

The ETA is then computed by substituting the values obtained from equations (4) into equation (1) and solving for the unknown as shown below:

Recall that;

$$v = \frac{s}{t}$$

$where; \quad t = Estimated\ Time\ of\ Arrival\ (ETA)$

Therefore,

$$v = \frac{s}{ETA} \quad (5)$$

Hence,

$$ETA = \frac{(s)}{(v)} \quad (6)$$

but,

$$s = \sqrt{(p_1 - q_1)^2 + (p_2 - q_2)^2}$$

Therefore,

$$ETA = \frac{(v)}{\sqrt{(p_1 - q_1)^2 + (p_2 - q_2)^2}} \quad (7)$$

Equation 7 therefore gives the relation to estimate the time of arrival of each bus with respect to its speed and position.

Results and Discussion

The functional testing involved deployment of the system in real-life application to measure its efficiency in estimating the time of arrival to-and-fro the popular Bosso – Gidan-Kwanobus route and also monitor and validate the behavior and response of the system when deployed in various scenarios.

Table 1: Results of the trip from Gidan-Kwano to Bosso campus.

S/N	Base	Landmark Locations	Distance from Bosso Campus (km)	ETA (m:s)	Average Observed Velocity {V} (km/hr.)	Calculated Velocity {V_0} (km/hr.)	Velocity Deviatio {$V_d = V_0$ - (km/hr.)
1	Gidan Kwano	Gidan-Kwano Mosque	19.60	18:33	60.00	63.43	03.43
2		Gidan Mangoro	13.90	13:58	54.42	59.66	05.24
3		Talba Estate	12.00	12:38	50.39	56.87	06.48
4		Gbeganu	10.80	10:12	48.65	63.52	14.87
5		Kpakungun	08.00	08:49	38.89	54.42	15.53
6		Kure Market	07.40	06:42	60.23	66.25	06.02
7		Dutsen-Kura Gwari	04.70	05:20	51.65	52.87	01.22
8		Bosso Estate	02.80	02:45	56.84	61.14	04.30
9		Abu-Turab Schools	00.80	01:29	27.62	32.39	04.77

The trip from Gidan-Kwano to Bosso according to Here Maps was estimated to last for 19 minutes, 38 seconds upon system initialization when the speed of the test vehicle was in the range of 0 – 10Km/hr (relatively slow). However, upon acceleration, the ETA to Bosso was updated to 18 minutes, 33 seconds. Furthermore, the trend of the ETA as the test vehicle arrived at popular landmark locations was further observed, documented and presented in the Table 1.

$$\textbf{*Actual Velocity} = \frac{\text{Distance from Bossocampus}}{\text{ETA}} \qquad (8)$$

From Table 1, the ETA is observed to maintain a steady decrease which is proportional to the approximate distance between the base and the selected landmark locations. This downward trend is proof that the system carried out actual computations using the instantaneous velocities and location of the test vehicle at various points to continuously estimate its time of arrival at Bosso campus. The relationship between V and $V_0$is termed the ***velocity deviation*** and is equal to the difference between V and V_0.These parameters can be used to generate an error margin for the average observed velocity from the system as shown below:

$$\text{Error} = \frac{(\Sigma V_0 - \Sigma V)}{No\ of\ landmark\ locations} \qquad (9)$$

$$\text{Error} \ = \frac{(510.55 - 448.69)}{9}$$

$$\text{Error} \ = 6.87$$

Therefore, % Error is calculated as;

$$\%\text{Error} = \left\{\frac{|avg(V) - avg(V_0)|}{avg(V_0)}\right\} \qquad (10)$$

$$= \frac{|49.85 - 56.73|}{56.73} \text{x}100\%$$

$$= \ 12.13\%$$

From the above computation, the error observed is computed to be approximately 12%. Such low value of percentage error indicates the presence of only minimal limitations in each unit of the system, some of which might arise as a result of poor network coverage.

Fig. 7 shows the performance of the observed velocity against the velocity calculated using the time difference and covered distance and a plot to visualize the close relationship between both parameters.

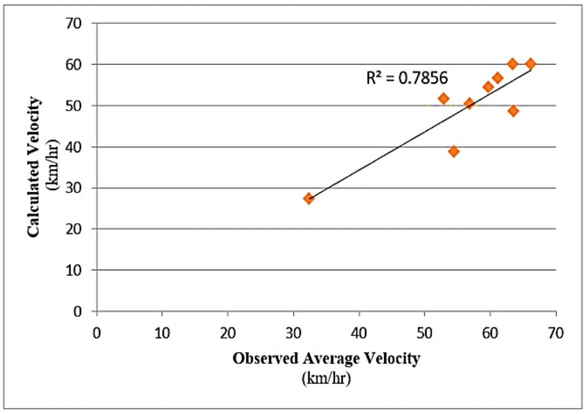

Fig. 7: Relationship between the calculated velocity and the observed average velocity.

The correlation coefficient (R) as calculated using the Pearson Correlation Coefficient Formula in a data analysis package was obtained to be ***0.88633***, indicating positive association between both parameters. The Pearson Correlation Coefficient Formula is given below:

$$r = \frac{N\sum xy - (\sum x)(\sum y)}{\sqrt{[N\sum x^2 - (\sum x)^2][N\sum y^2 - (\sum y)^2]}} \qquad (11)$$

Fig. 8: Monitoring system showing welcome screen and ETA of a bus respectively.

Upon substitution, the coefficient of correlation between both parameters was computed to be 0.88633. This value indicates a strong positive association between the calculated velocity and the observed average velocity, i.e. the calculated measured velocity in transit is in close relation to the calculated velocity.

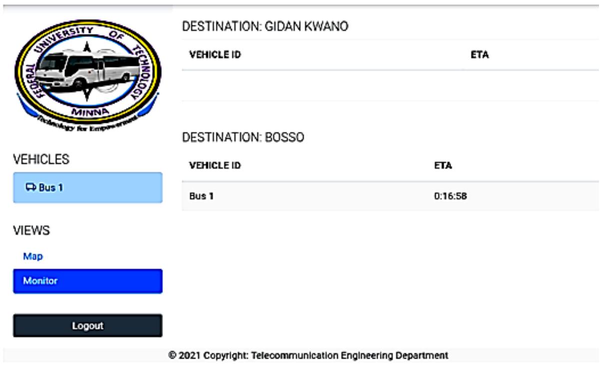

Fig. 9: Interface of the web platform showing the ETA of a bus headed towards the Bosso campus.

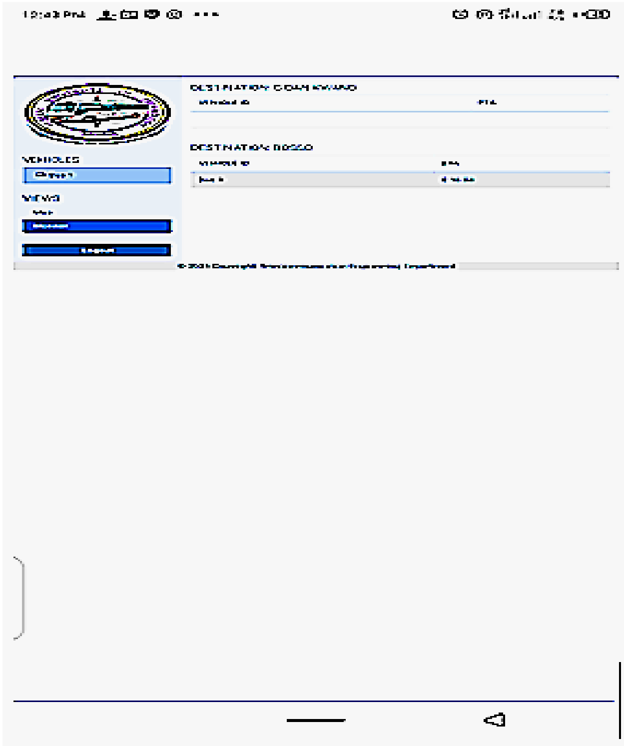

Fig. 10: Interface of the mobile application showing the ETA of a bus headed towards the Bosso campus.

Fig. 8 shows the final constructed system showing the welcome screen and the ETA of a bus en route. Figs. 9 and 10, on the other hand, show Mobile interfaces from the remote monitoring unit which is made up of the online web platform and the mobile application.

Conclusion

The observed close relationship as observed in Fig. 7 shows that the ETA provided by the system corresponds to that derived by calculations using the actual speed and distance travelled by the vehicle. This project is designed to proffer solution to university bus system, designed, constructed and tested. From the results above, the design will help the university bus system and also reduce aimless waiting time of students in the bus park. The project is a low power solution, which will save students energy and resources. This system can also be implemented outside the university system.

Recommendations

The following improvements are recommended to improve the efficiency and multi-functionality of the system to further benefit the staff, students, and university community at large:

i. The GSM module for establishing internet connection should be replaced with one with 3G or 4G standards (preferably 4G) in order to reduce the effect of poor or slow internet connection on the efficiency of the system.

ii. There is the need for expansion of the existing 20 x 4 LCD screen to a larger color screen to allow for tracking of more buses and also displaying more information to the end user.

iii. A backup solar power system should be incorporated in the system as an alternate source of operating power in the event of unavoidable power failure.

iv. To achieve a wholesome transport management system for the university, the database of students and staff should be incorporated into the system to allow for remote booking and reservation of seats on the buses being monitored or en-route.also added in this section. If no acknowledgement is necessary, this section should not appear in the paper.

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