ASHESI UNIVERSITY

A TRACKING AND BILLING SYSTEM FOR COMMERCIAL VEHICLES

CAPSTONE PROJECT

B.Sc. Electrical & Electronic Engineering

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2019

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Capstone Project submitted to the Department of Engineering, Ashesi University in partial fulfilment of the requirements for the award of Bachelor of Science degree in Electrical & Electronic Engineering.

Kofi Anamoa Mensah

2019

DECLARATION

I hereby declare that this capstone is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:

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Candidate's Name:

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Date:

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I hereby declare that preparation and presentation of this capstone were supervised in accordance with the guidelines on supervision of capstone laid down by Ashesi University College.

Supervisor's Signature:

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Supervisor's Name:

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Date:

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Abstract

The Ghanaian transit system poses certain challenges to users, as it usually has passengers waiting at bus stops for a bus to their destination, for an unknown amount of time because there is no means of tracking the buses. The system is also problematic as passengers usually argue with bus conductors for change, when payments are made in high denominations, because there are no cashless payment methods available. This makes planning of journeys difficult to users of this system. Existing systems generally use a GPS receiver and cellular data network to transmit location information. Other public transportation systems incorporate additional systems that allow passengers to make cashless payments. This project solves the tracking problem on the Ghanaian transportation system by installing a GPS enabled device in the vehicle which would transmit the location coordinates to a server using long-range radio (LoRa) waves instead of the cellular data network. For payments, a system is developed that permits users to make payments using an NFC card or by scanning a QR code, unique to each bus which would then make a deduction from the users account.

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Chapter 1: Introduction

1.1 Introduction

Public transportation is a means through which citizens of a country can move from one location to another at a low cost. In any country, it contributes greatly to the country's economy and further improves the standard of living of its people [1] and can help them save approximately $10,000 a year on transportation [2]. Public transportation systems are such that a person would have to plan either formally or informally, to know which route to use, where to access the right bus, the cost, the bus capacity at a certain time, amongst other things.

For this planning to be efficient, public transportation systems need to provide users with information such as the bus stops to get a bus from, the estimated time of arrival of the bus, the route it uses and the number of available seats on the bus. Such information can be achieved using tracking technology such as Global Positioning System (GPS) and various routing and estimation algorithms. For even better convenience and the provision of better services, most public transportation systems provide digital payment means (cashless systems) to make payment hustle free through technology such as the use of Near Field Communication (NFC) cards, barcodes and QR codes.

A cashless transportation system provides several advantages for both the owners of the public transportation vehicles and the daily users. In a cashless system, there is accountability as conductors and drivers are unable to connive to take percentages of the fares, as the money goes directly to the company. This is mostly a problem in developing countries which causes transportation administrators to measure lower profits than were actually obtained. Most importantly, a cashless system would take away some of the hustle involved in dealing with physical cash, such as looking for change for the passenger, finding lower domination bills to make payments and eliminates the risk of losing the money to theft or human error.

1.2 Background

In Ghana, the most used public transportation system, the "Tro-tro" system, has for a very long time been very unreliable and unpredictable. These vehicles are not tracked nor scheduled, making the planning of trips very difficult as passengers have to wait by the road till a desired vehicle arrives. This especially makes the planning of multi-leg journeys at the start of the journey very difficult, and the one-time payment of this journey impossible. Another major challenge with the "Tro-tro" system is the lack of multiple forms of payment. At the moment, cash remains the only accepted form of payment on a tro-tro bus and many other transportation systems in Ghana. This method in itself poses several challenges. First, it is very time wasting as compared to other forms of payment where a transaction can be completed within seconds and tends to ruin the customer experience as quarrels usually sprout over change or the lack of it. This method also makes record keeping very difficult, thus measuring growth or improvement becomes problematic. The risk involved with a cash only system is the lack of security in the handling of the money and the issue of the accountability of the bus conductor who is the main entity in the system who interfaces with the money and could easily lose the money or intentionally make some deductions. Cashless payment systems can also be configured to record the number of passengers in a bus at any point in time. This information can help inform passengers who want to join the bus on the number of available seats on the bus.

1.3 Problem Definition

The lack of bus information in the public transportation sector of Ghana and the inability to make digital payments makes planning of journeys and bus transactions a hectic and time consuming. Some associated problems that arise from this problem are:

- Difficultly in planning multi-leg journeys
- Lack of accountability
- No means to determine the arrival time of a bus
- Inability to determine the number of seats available on a bus
- Inconvenience of high-denomination notes for which change is difficult to obtain.

This project thus seeks to develop a tracking system for public transportation vehicles using GPS, to enable passengers to know how far away from a bus stop a particular bus is and plan their departure accordingly. The project also presents the added benefits of eliminating and reducing the hustle in cash transactions through the introduction of some digital means of payment and provides transparency for transport companies and owners, as all transactions are recorded automatically without any human interference. This digital payment system would also be configured to provide information such as the number of available seats on a bus.

1.4 Justification / Motivation of Project Topic

In the world today, modern technology drives development and growth in various sectors of a country's economy, such as health, agriculture, education, amongst others. In the transportation sector for instance, several developing African countries such as Rwanda, make use of modern technology to improve the public transportation system and make it more convenient and easier to use. These systems give passengers real time information on how far a bus is, how long it would take to arrive, the number of seats available on the bus and the added benefit of several seamless digital means of payment. According to research conducted by Mohamed A. Abdel-ATY et al, 38% of passengers who do not use public transportation might consider using it, if the appropriate bus information was easily accessible [11].

1.5 Scope of Work

The scope of this project would be to build a tracking and billing system for company run buses, using Ashesi University as a use case. This system would consist of a device to track the bus using GPS as well as other supporting technologies to store and transmit data. The device would also be fitted with technologies to enable digital payments through NFC cards or NFC enabled phones. A Web application would then be designed and built to enable transportation administrators to manage the system. A mobile application would also be built for the user to view bus information, routes and other related information and view previous transactions. The system would mainly have the following features:

- A device to track the vehicle locations in real time.
- A device through which passengers could make cashless payments for transportation fares using NFC technology.
- Several means of digital payments such as QR codes and NFC.
- A Web and mobile application through which users can access bus information, routes, stops and the estimated time of arrival of each bus.

The reminder of the document is organized as follows: Chapter 2, takes a look at other research conducted in the various technologies and industries discussed and used in this project. The design considerations that were made to arrive at the desired solution as well as the system design and the various requirement expected by the various users are explored in Chapter 3. The next chapter walks through the various steps undertaken to achieve the desired results, the tools used and how they were combined to achieve the results. Chapter 5 observes the results obtained from the implementations and the final chapter discusses results obtained, the limitations of the project and some future works that could improve the work.

Chapter 2: Related Work

Around the world several technologies and approaches are used to track vehicles as they move around and deliver services from one location to another. Several other technologies also exist for making secure digital payments on the go. However, what differs, is the means and ways in which these technologies are combined to make life easier for people. In this section, relevant technologies that are used for location, estimated time of arrival, payment and to support smart transportation are discussed and compared to determine the best combinations to use for the system to be built. The mentioned system is to be used by the public transportation sector of Ghana, as such the main bus public transportation system in Ghana are explored.

2.1 Public transportation in Ghana

Currently in Ghana, there are three main public transportation systems: the tro-tro system, organized government run buses such as the MetroMass transport, and company run buses such as the Ashesi Staff bus which are organized specifically for members of the Ashesi community. Each of these systems differ in their means of operation, their accuracy in timing and their means of payments.

2.1.1 Tro-tro System

In the tro-tro system, buses owned by private citizens are made available to be used to serve the general public. In this system, the drivers and their conductors decide on a route along which they would be working, in consultation with some form of local regulatory body like the bus station operators, the driver's association and the taxi ranks. Depending on the selected route, these busses associate themselves with a bus station from which to load up passengers or drive along their selected route to fill up the bus from various bus stops along their route. This system due to the independence of the owners and drivers, allows a lot of citizens and buses to join the system, making public transportation cheap while increasing the availability of the public transportation system. Despite these advantages, this system tends to pose a lot more challenges. The tro-tro system is very unreliable as there is no means of knowing when the next bus to a destination would arrive or the route it would use. This causes passengers to spend a lot of time waiting for the next bus that would be going their way, and this could take between several minutes to an hour, as the buses have no frequency with which they operate. This makes the planning of one's route to a location very difficult as there is no information as to the available buses and how far they are upon arriving at the next bus stop. However, despite these issues, the independent nature of this system, allows for private individuals to invest in the public transportation system of the country easily due to its free entry nature.

2.1.2 Government run public transportation services

All over the world, the provision of good transportation systems has been one of the obligations of the government [4]. In Ghana, the most common of these public transportation systems are the Metro Mass Transit and the Ayalolo bus system, which seek to improve the public transportation sector in the country.

The Metro Mass Transit limited was established in 2001 by the then president to ensure the secure means of commuting for Ghanaians that was also reliable and affordable [5]. This system provides several advantages to the Ghanaian public, as students in uniform and the adults, 65 years and above, are permitted to ride freely on the buses [6]. Research conducted on customer satisfaction with using the Metro Mass Transit system, indicated affordability to be the greatest advantage of the transportation system, as it charged approximately 5% lower than the tro-tro systems [8]. In the study, of the many problems identified by passengers concerning the transportation system, untimely movement of the buses and the inadequate bus information were the highest ranking, respectively.

The Ayalolo transportation systems, is a smarter transportation system rolled out by the government of Ghana. Unlike the other transportation systems in the country, the Ayalolo system has its own designated routes and only operates from, Amasaman to Tudu, Ofankor to Tudu and Achimota to Tudu [7]. This system generally has better payment systems as compared to the other transportation systems in Ghana. Despite the ease with which payments can be made in this system, it still presents users with difficulty in planning journeys, as there is no means through which they can obtain reliable bus information. The limited coverage of this system also makes it unreliable and undesired when traveling within areas outside its three operating routes.

2.1.3 Private Company Run Buses

Unlike the government run public transportation services discussed above, private company run bus services such as the Ashesi Staff bus is more reliable and efficiently run. In such systems, passengers board the bus from various embarkation points along the route of the bus. Despite the timely nature of this system, there are still certain challenges faced such as the inability of the passengers to determine the capacity of the bus, prior to its arrival at their pick-up location. Passengers usually wait at the stop for the bus only to realize upon its arrival, that the bus has been filled to its capacity. The lack of a resource through which passengers can bus information also presents a situation whereby users may miss their bus due to the bus moving ahead of schedule because there was no passenger to pick at a particular stop.

2.2 Payment Systems in transportation

All over the world, different cities have positively embraced public digital payment into their public transportation system [9]. In Ghana, most transactions of goods and services are conducted strictly on a cash-based system [10], with a few transactions being made through credit/debit cards or through the various mobile money platforms. In the transportation sector however, most transactions are made on a cash only system.

In the tro-tro system, a few minutes after a pick up from a bus stop, the bus conductor requests payment from the passengers in cash and calculates the fare, based on the pick-up bus stop and the destination indicated by the passenger by word of mouth. This usually brings about misunderstandings and arguments, as large dominations of the currency are frowned upon due to the difficulty in obtaining change for the passenger.

On the other hand, in the transportation systems of private organizations such as the Ashesi staff bus, passengers either make payment in cash to the driver either upon arrival or before departure or passengers make payment to the accounts office of the organization through whatever means. This payment is then credited to the user, through an identification card or an identification number. This card would then be scanned on the bus while it is on route to its destination.

In government operated systems, the MetroMass transport operates such that, a passenger upon arrival at a bus stop would make a payment to a cashier in cash, who would then issue a ticket to the passenger to allow the passenger unto the vehicle. In instances where there is no cashier at the bus stop, the payment is made similar to that of the tro-tro system. However, with the introduction of the Ayalolo bus system, which addresses the problem of payments with the introduction of an e-card, through which passengers can make payments for the bus services before boarding. The system is designed to provides seamless means through which passengers can top up their cards, such as through mobile money platforms or from registered top up agents located across the region [7]. Despite the ease this system provides with payments, aside the option of mobile money, the system only offers 6 locations nationwide, where these e-cards can be topped up or purchased making it undesirable.

In 2012, the Transportation for London (TfL) company, which is the major operator of all buses in London, partnered with major payment technology companies such as American Express, Mastercard and Visa, to roll out an upgraded version of the Oyster system. The Oyster systems is a payment platform that permits users to make bus payments using any contactless credit or debit card. [13]. The ability to use a card issued by one's bank is an option that certainly brings speed and convenience to the process of making payment. This system presents a great advantage to users of the public transportation system in London, as passengers do would not have to lose any time queuing to purchase a ticket or to top up balance on a bus transit card.

Aleksander G. Budrin, and his colleagues in 2017 conducted a research to analyze existing payments on urban public transportation. The research was based on a hypothesis that innovative fare collection systems (FCS) are more suited for urban public transportation than traditional transportation systems. This research was based on St. Petersburg plan to implement an automated payment system that allowed the use of bank cards through systems such as PayPass and PayWave [14]. The research conducted was not able to confirm the stated hypothesis but rather further draw more benefits of such FCS.

The proposed system seeks to introduce various digital means through which payments can be made, to ensure seamless transactions when using public transportation or private bus systems in the country. This attempts to minimize the use of cash. However, although an attempt is made to execute real transactions or deductions, the system depends of cellular coverage. When said coverage is poor, transactions fail. There is no offline method for making payments without resorting to cash. The system also incorporates an offline structure such that passengers are able to make payments even when the system is offline through a negative balance system.

2.3 Location technologies

The ability to locate or track vehicles is an important feature of every advanced transportation system [4]. Various countries and companies adopt different techniques through which they successfully track vehicles or buses. Some of these methods include image processing-based tracking, Radio Frequency Identification (RFID) based techniques for vehicle tracking, signpost technology and Global Positioning System (GPS) based tracking [12].

Transportation technology companies such as Uber, Taxify and Bibi make use of Global Positioning System (GPS) in smart devices, to determine both a passenger's location and the location of a vehicle (through the driver's smart device) [15]. However, the average GPS device faces problems with interference and getting a clear line of sight when in the buildings, tunnels or around tall buildings. This problem is however solved with an improved version of GPS known as differential gps which has mechanisms in place to improve accuracy and location detection by calculating a user's position relative to another GPS receiver at a known location [12]. To improve real time gps tracking systems, Hind A. A. Dafallah, designed and built a gps tracking system making use of the Garmin 18 – 5 Hz gps receiver which has differential gps capabilities and thus improves the accuracy of readings [17].

2.4 Supporting Technologies

One other functionality required of the system is the ability to store internally store gps coordinates and card ID when the network is offline. In developing an offline tracking system for deep sea going vessels, researchers, stored location on a secure digital (SD) card while the vessels were at sea, where there is no network connection and transmits this information from the SD card to the server when the vessels get back to the harbor where network connection is restored [18]. Despite the cost's involved, the research makes use of GSM technology to transmit the data from the SD card when it gets to the harbor. However, compared to the price of proprietary software which the research seeks to find an alternative to, the cost in insignificant. Other researchers from the University of Hasanuddin in Indonesia, to tackle the limitation of internet connection in digital payment systems, made use of Near Field Communication (NFC) technology. In theier paper, A. Noer, et al, take advantage of the memory capabilities of NFC cards, such that passenger balance is stored on the NFC card rather than on a server, which would require internet connection to access [19]. This techniques despite solving the problem, would pose certain challenges to the passenger in the situation where the card gets missing or damaged. In such a situation the fact that the user balance is stored on the card rather than a server would make it challenging to retrieve such information to issue a replacement card.

Leveraging on theses gaps identified, this project seeks to design and implement, a tracking system for the public transportation sector in Ghana. This system would allow passengers to track the location of a desired bus, view its estimated time of arrival, the capacity of the bus in real time and all the buses that use a particular route.

Chapter 3 – Design

This chapter investigates the technical specifications and design considerations for the project. The entire proposed system would be introduced and the ways in which the various users would interface with the system to achieve the desired goal. The design and system requirements of the system would then be introduced, and then based on the discussed requirements, the system designed would be presented.

3.1 Design Proposal

The objective of this project is to build a system through which public transportation vehicles can be tracked and to enable digital payments as an option. This system would mainly be used in the public transportation sector of Ghana. To achieve this objective, both a hardware device and an application would have to be built.

3.2 User and System Requirements

These requirements for the system are taken from both the user's perspective and from the perspective of the system itself. The various functionalities of the system would be outlined to guide in the design and implementation of the system. The main users of people involved in this system are bus passengers, transportation managers and transportation owners. A passenger would make use the system, through the mobile application when planning a journey from one location to another, while at a bus stop awaiting a bus or when making paying for a bus ride. A transportation manager would make use of the system through the web application to either add, update or delete buses, bus routes and general bus information, that would be made available to the user. The objective of the transportation manager is to check up on his buses, by checking on the bus locations at all times and to ensure that enough transactions are being made in a day.

3.2.1 Use Cases

The system to be built would be used by several users and as such the scenarios below would help in extracting the various requirements each user would have of the system. This would go a long was to aid in the development of a functional and efficient system.

Scenario 1

Nii Otto is a new faculty intern with Ashesi University and has been registered unto the university's transportation application. Nii lives in Kwabenya and decides to use the bus to get to work every day since it passes his junction. On his first day, at about 7:00am, Nii reaches for his smart phone and opens the proposed system's mobile application and logs in. He sees his location on a map and a search box which he uses to input his destination. The next Ashesi bus to use the route close to his junction is shown to be at Atomic and to arrive in 15mins. To be sure, he would be able to secure a seat, Nii decides to check the seats available on the bus and it is shown that there are 10 seats available. Since the bus would arrive in the next 15 minutes, Nii decides to get breakfast in 10 minutes before making his way to the bus stop to meet the bus.

Scenario 2

Mr. Kwame Opoku has been employed by Ashesi University to manage their staff and to include the student buses to the school's system. To make the required additions, Kwame arranges a meeting with the drivers and the student council to determine the routes that would best serve a majority of the student body. After this meeting Mr. Opoku accesses the school's transportation system, using the Ashesi University manager code through the web application. Mr. Opoku then adds the new buses that would serve the students and adds the routes that were selected from the meeting and assigns them to the student buses.

Scenario 3

Baaba Kwakye is the logistics manager of Ashesi University. A report from her superiors, indicate that there is an increase in the amounts spent of the buses recently, despite no increase in fuel prices. This is possibly due to drivers using the buses for personal trips after assignments. Since the university has the proposed system installed, she gets onto her computer and uses her license key as a transportation owner to view the locations of all her school's buses and to review the transactions conducted on each bus over the past week.

3.2.2 User Requirements:

The user should be able to:

- Register when using the system for the first time
- Login to access previous transactions and card information
- Use NFC enabled cards to pay for transportation
- View card balance by keying Card ID in app
- View previous card transactions
- Make payment by scanning QR code of the bus
- Make payment using RFID tag or NFC card
- Make payment when system is offline – this is possible by having negative credit up to some point when system cannot reach server for card balance information.
- See buses arriving at bus stop
- See bus Estimated time of arrival
- View the bus capacity
- View a bus location in real time
- View all stops for a bus

- View all possible buses to use to get from one location to another

The transportation manager should be able to:

- Add / update bus information
- Add new / alter routes
- Add buses

The transportation owner should be able to:

- View location of each bus
- View all transactions for each bus per day

3.2.3 Non-functional Requirement

- Device should be low-cost
- Device should be energy efficient
- Device should have a suitable case
- Device should be portable
- Application should be user friendly
- Application should have a suitable interface for human interaction.
- System should be robust
- System should be able to work offline
- System must operate in real-time
- System must work on all platforms (Android, IOS, Windows)
- System should be able to store transaction data while offline and update when connection is reestablished

3.3 System Design

The general overview of the system designed can be seen in Figure 0.1 below. The system is broken down into two parts, the hardware device and the software application. The hardware device, which would be placed in the bus, would contain a GPS module through which the buses location would be determined. The main means through which digital payments would be made on this system is through NFC cards, as such the hardware device would have a RFID reader to enable it extract card identification numbers when the passenger scans his or her card. Both location information and card ID need to be accessed remotely through a database. As such, a communications module needs to be included in the device to enable the transmission of information from the device into a database.

A microcontroller unit which would serve as the logic point of the device and would be responsible for all the processing and intermediary roles in the system. The microcontroller unit (MCU), as can be seen in Figure 0.1 below, would be connected to the GPS tracker to provide real time location, the RFID reader to enable scanning of NFC enabled devices and cards, an SD card module to enable offline storage of data and the LoRa device to enable long range transmission of data to the database. This entire hardware system would be embedded onto a printed circuit board (PCB) and installed in the bus.

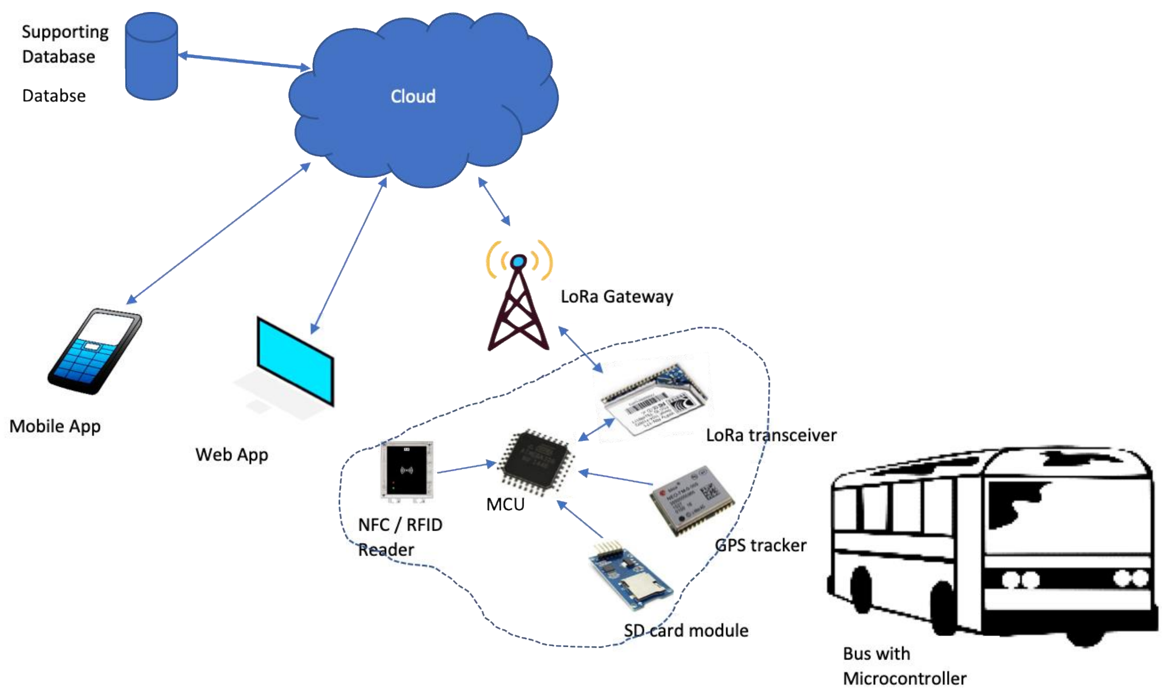

Figure 0.1 - General overview of system design

In the selection of the various components to be used in the proposed system, certain design considerations were made. Table 0.1 below, shows the various components needed to put this hardware device together as well as some useful technical information.

Table 0.1 - Component Specifications

Component	Type	Specification
Microcontroller unit	ATMEGA 328P	6 channels, 10-bit resolution ADC, 8Mhz internal oscillator, Flash memory, 1MHz CPU speed, watchdog timer, 23 programmable I/O lines, 8-bit AVR CPU
LoRa transceiver	Adafruit RFM69HCW Radio	500m line of sight, I = 50mA (+13dBm) to 150 (+20dBm) during transmission
GPS module	Adafruit Ultimate GPS Breakout v3	Vin: 5v, I in = 20mA, 10Hz update, 66 channels, -165 dBm sensitivity
PCB board		
NFC reader	RFID-RC522	Vin = 3.3v, working frequency = 13.56MHz, 60mm maximum reading distance, 10Mbps data communication speed
GSM module	SIM800L EVB	Vin = 3.4v to 4.4v, 1A input current, Quad-band 850/900/1800/1900MHz
Oscillator	16MHz	
Resistor	10k ohms	
Power Supply Unit		
Capacitors	0.33uF, 0.10uF	
Voltage Regulator	LM7805	Converts 12v to 5v DC
Voltage Regulator	LM317	Converts 12v to 3.3v DC

From the table above, a GPS module was selected as the location technology to use in tracking the buses and long-range radio as the communicating device. According to Kevin McKay, GPS is the best location technology to use in transit systems despite problems with interference and line of sight when in tunnels or around tall buildings [12]. GPS technology is easy to use and requires very little maintenance after installation. In addition, the only cost to be incurred using this technology would be the cost of a GPS device for each bus.

For the communication device, several technologies exist, the most common of them being Wireless Fidelity (WIFI) and the Global System for Mobile communication (GSM) module. These technologies nonetheless present various challenges that would be problematic to our device. WIFI for instance, has the advantage of long-distance and high data rates [16]. The disadvantage with WIFI, however, is its high-power consumption, which makes it unsuitable to be used in the device. In addition to this problem, finding a WIFI network to connect to around the country while the buses move around would pose a real challenge to the system. GSM on the other hand is the same technology used by mobile devices, as such coverage and connection would not be a problem. The problem would mainly be due to the cost involved. GSM modules are relatively more expensive and require additional cost in obtaining a data plan to enable the module to successfully communicate. As such LoRa was chosen mainly due to its low-cost, low-power consumption and long-range communication. LoRa mainly has the disadvantage of having a low-data rate, however, for the purposes of this application, a high-data rate would not be required.

LoRa devices also require a LoRa gateway to operate. This gateway serves as a point through which the end-point LoRa transceivers can send, that is to be forwarded to a database or cloud server via some channel (cellular, ethernet, WIFI or Satellite) [21]. For the purposes of this project, cellular internet would be used through a GSM module to communicate to the database.

The users of this system would be Ghanaians who want to move from one location to another. This includes but is not limited to existing users of public transportation, students, etc. Through the mobile application to be built in this project, users will be able to locate the relevant bus information they need to both plan and successfully arrive at their desired location. This information includes the available buses that the passenger can board to get to his/her location, the estimated time of arrival (ETA) of each of these busses, the various stops it would make on the way, amongst others. Users with NFC enabled phones would be able to make cashless payments for their journeys through the application or would have to purchase an NFC card which would be set up to enable easy identification and cashless payments.

On the software side, the web application will serve as a management and monitoring system through which all transactions and vehicle movements can be properly managed and monitored. Through the web application, the transportation manager can access the various recorded transactions and bus information stored in the database. He / She would also be able to set up the entire transportation system and make the necessary changes such as setting up the various stops a particular bus would make, the number of seats available on the bus and the routes the buses would use.

Chapter 4: Implementation

4.1 Overview

This section describes the various processes involved in implementing the tracking and billing system. This stage focuses on the company run buses, using Ashesi University as a use case. The chapter is divided into four main parts each covering a core component of the entire system. They consist of the hardware implementation, the database implementation, the front-end application for both the mobile application and the web application and finally the back-end computations which enable functionalities such as routing and the calculation of fares during journeys. The component diagram in Figure 0.1 below shows the relationship between the various sections described above.

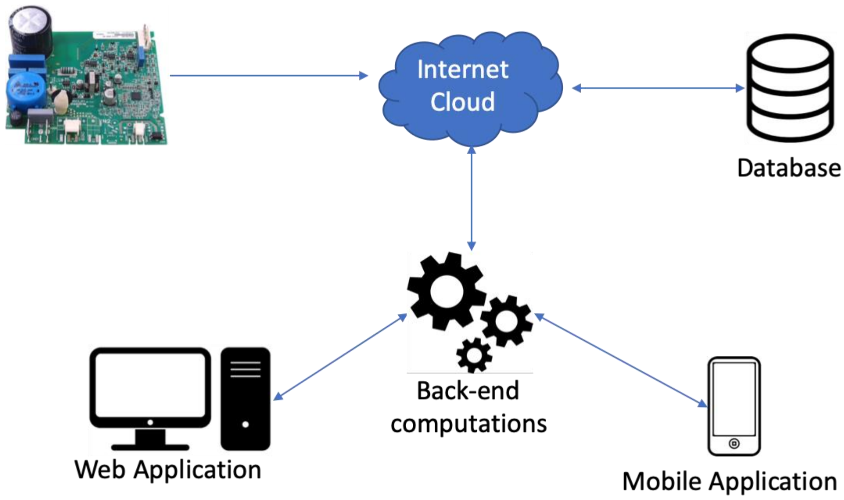

Figure 0.1 - Component diagram showing relationship between various components

4.2 Hardware [Device] Implementation

4.2.1 The Device

The tracking and billing device would be the primary resource through which gps coordinates and transaction information from the various buses would be sent to the database. The device would consist of an ATMEGA 328P microcontroller which would interface with all other hardware devices such as a GPS module to provide real time location information in the form of longitude and latitude, an SD card module to log transaction data and location information when system is offline, a LoRa transceiver to enable long range transmission on information and an RFID reader to enable payment through NFC cards and NFC capable mobile devices. However, to enable all these components to work, there needs to be a power source in the system, and this is provided by the 12V to 5V power regulator included as part of the device to convert the 12V from the car cigar lighter into a 5V power source. Other components in the set-up such as the RFID reader require lower voltages to operate, as such, an LM317 voltage regulator in conjunction with some resistor and capacitors designed to provide 3.3 volts to the components. The equation below was used to determine the right resistors to use, to be able to obtain the 3.3 volts.

$$V_{out} = 1.25 \times (1 + \frac{R_2}{R_1})$$

The circuit diagram to illustrate the connection between the various components is shown in Figure 0.2 below.

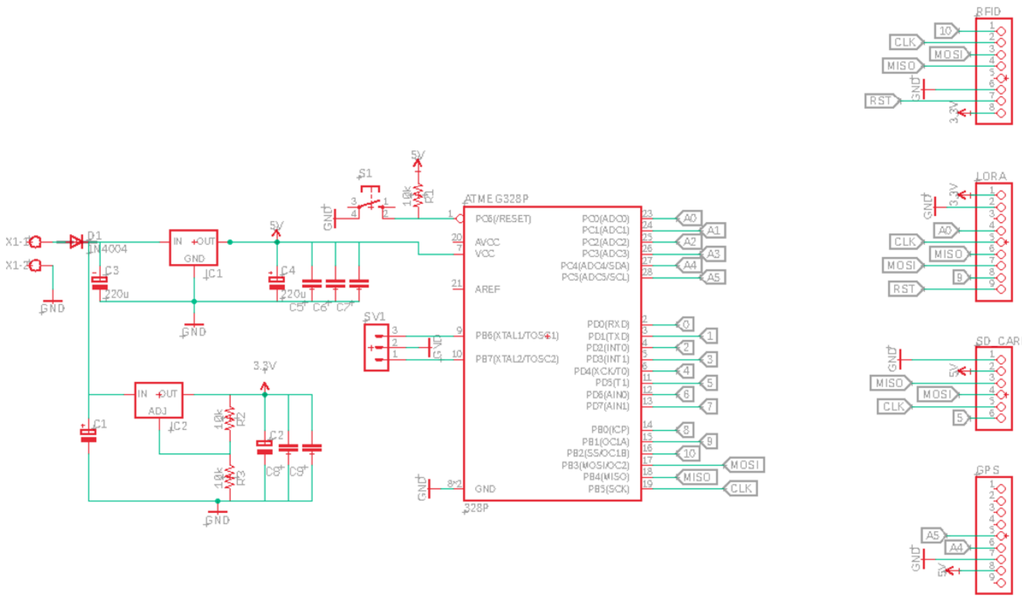

Figure 0.2 - Circuit diagram showing connection between components

A printed circuit board schematic was designed, to show the various components, their positioning and their connection to ever other component in the circuit and more importantly, other electronic components they may need such as capacitors or resistors.

Through the schematic, the connections between the various components were properly routed such that, connections do not interfere or cross each other. This circuit routing and the connections between the various devices can be seen from the circuit layout in Figure 0.3 below.

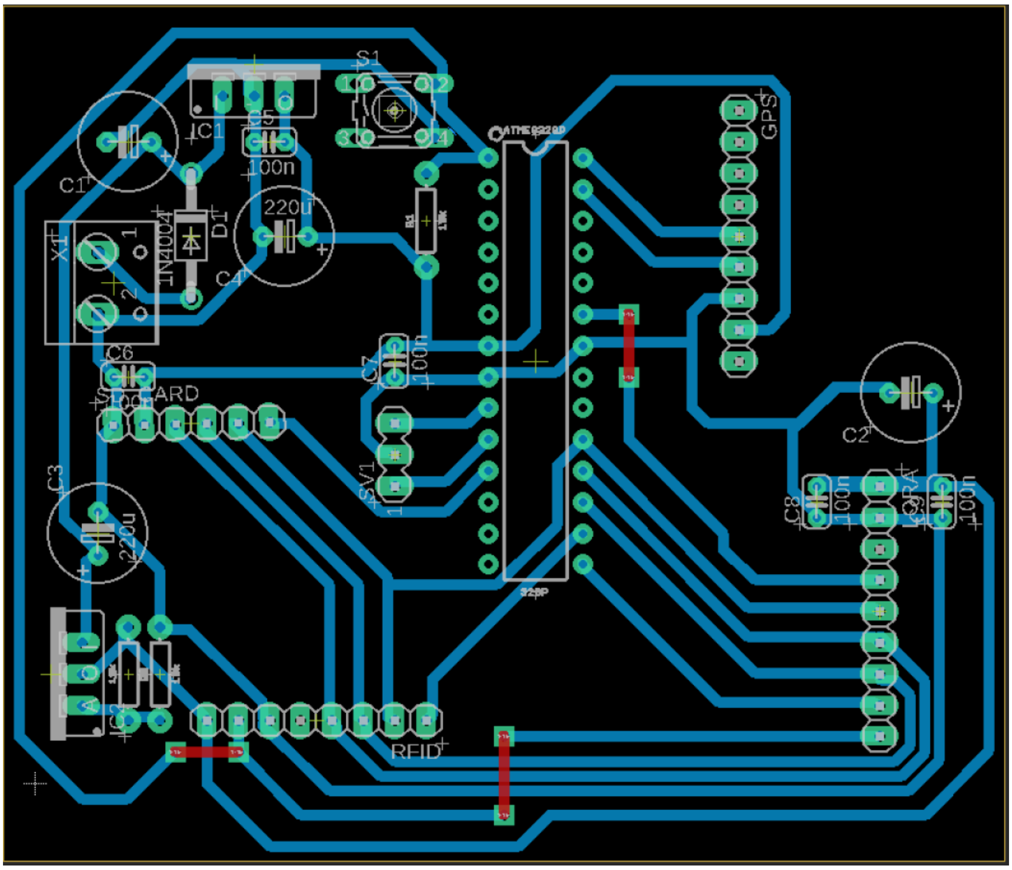

Figure 0.3 - PCB layout from Eagle

After the design stage, the PCB was then printed, the various components obtained and then based on the design, the device is set up. Using measuring tools, various parts of the circuit are tested to ensure the flow of current and voltage across the various components and to ensure that all the connections have been properly laid out such that there are no overlaps or short-circuits. Figure 0.4 below shows the final device with all components connected and tested to ensure that each component was working and receiving the right amount of voltage needed.

Figure 0.4 - Printed circuit board with all components connected

In building the LoRa gateway, an Arduino board was used to connect the LoRa transceiver with the GSM module. This would allow the location and transaction information being sent from the buses to be sent to the database for storage and further use. Figure 0.5 below shows the set-up of the LoRa gateway.

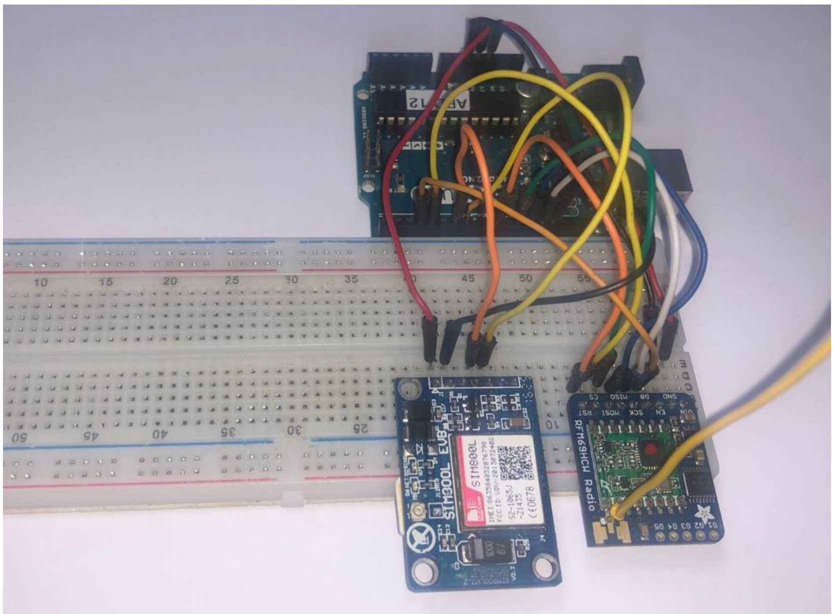

Figure 0.5 - LoRa gateway set-up showing LoRa and GSM module

The final stage of setting up of the device is the programming stage. The major advantage and motivation behind the use of the ATMEGA 328 microcontroller chip is due to its usage in the Arduino Uno microcontroller. As such the Arduino IDE can be used to program the microcontroller to perform the various functions that are required by the system. Using the Arduino IDE, the device was programmed through the microcontroller to send gps data to the database, to read NFC cards and devices and to store data on the device when the server is offline or unavailable.

4.3 Database Implementation

Based on the necessary data that would be needed by the various applications and the various data that need to be stored by the system, a database was designed and implemented in such a way that the various tables were properly linked, in order for it to work efficiently. Due to ease of use and familiarity, a MySQL database was used for the implementation of the database. Some data such as the various routes and stops for each of the buses were obtained from sources such as the internet, while others such as the transaction information are generated as the system is used. The data to be used for this system (routes and stops) was manually obtained from the operations department of the school and inserted into the database. The gps data and the information on transactions was transferred from the device to the database through the LoRa module. Figure 0.6 below shows the entity relationship diagram for the various tables in the database.

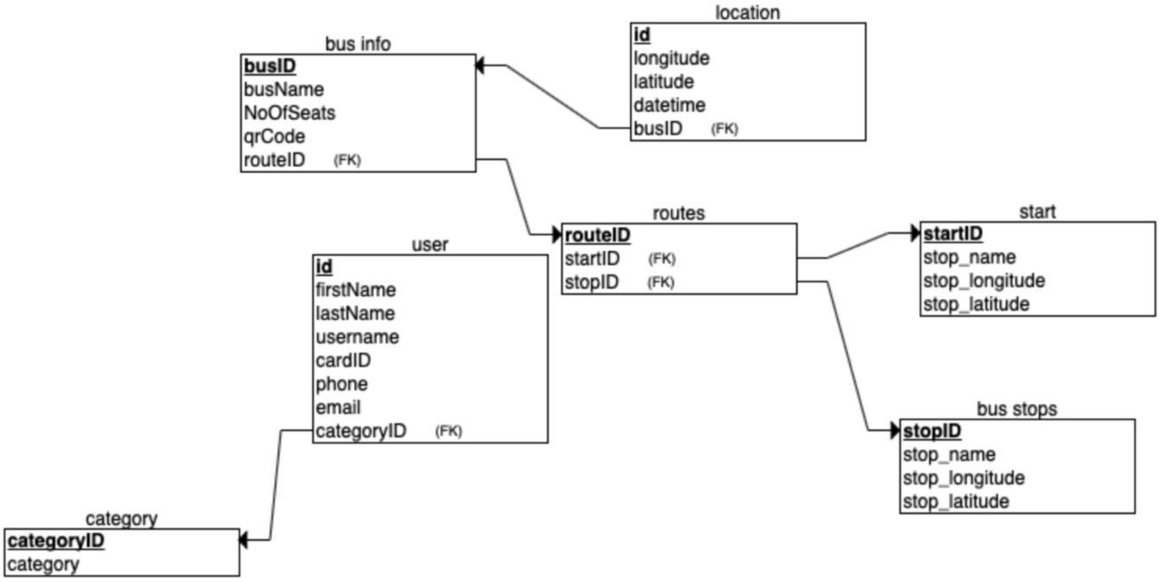

Figure 0.6 - Entity relationship diagram of tables the database

4.4 Front-End Web and Mobile Application Implementation

To build a complete and very interactive user interface, Bootstrap was used for the front-end development of the web application. Bootstrap is an open source toolkit used for developing front-end application with Hypertext Mark-up Language (HTML), Cascading Style Script (CSS) and JavaScript which are languages used in web development. Using toolkits such as Cordova and PhoneGap, the HTML, CSS and JavaScript components of the web application was converted to produce the mobile application. To aid in the plotting of the location coordinates obtained from the hardware device, the google maps java script api was embedded into the front-end development.

4.5 Back-end application implementation

To enable the various functionalities of the system, the backend application was developed to communicate and work in conjunction with the front-end application to deliver the expected results in the system. To build the back-end, Laravel was used to develop the PHP backend.

Chapter 5: Testing

This chapter discusses the various tests that were conducted on both the device and the application to ensure the objectives of the project have been achieved and that all the functionalities are working properly.

5.1 Test Description

For the system to work properly, both the device and the applications must be working properly. The device should be able to obtain, read and transmit user transaction and gps information to the database. The web and mobile applications should be able to fetch gps and user information from the database and display it in such a manner that the user would be able to easily understand and use. In addition, through the web application, a transport manager with the right credentials can make changes to bus information such as routes, stops and the number of seats available on the database. As such, this section, tested these basic requirements for both the device and the application.

5.2 Device Testing

The first requirement of the device is to be able to obtain gps data and to display it in a manner that can easily be understood by the data and the map plotting application. Since the device makes use of the same microcontroller chip as the Arduino microcontroller, the Arduino IDE was used to program the device and through the Arduino serial monitor, the results in Figure 0.1 below were obtained.

```
Time: 13:32:51.0
Date: 21/3/2019
Fix: 1 quality: 0
Location: 545.5501N, 13.1750W
Location (For Google Maps) 5.7592, -0.2196
Speed (knots): 0.01
Angle: 217.40
Altitude: 0.00
Satellites: 0
$PGTOP,11,2*6E
$GPRMC,133252.000,A,0545.5501,N,00013.1750,W,0.02,237.06,210319,,,D*73
$PGTOP,11,2*6E
$GPRMC,133253.000,A,0545.5501,N,00013.1750,W,0.06,284.92,210319,,,D*73
```

Figure 0.1 - GPS data obtained from GPS module

The application used in the map plotting, was the google maps JavaScript application which represents North and West with a plus (+) and South and East with a minus (-). As such, to achieve appropriate results, the location coordinates obtained had to be translated into this format. For instance, from Figure 0.1, the location information 545.5501N and 13.1750W were converted into 5.7592 and -0.2196 respectively. The desired format can be seen circled in the test output obtained.

The next stage in the process, requires the LoRa transceiver to transmit the obtained gps coordinates to the LoRa gateway. A constraint in the testing was that the LoRa library used only allowed integer values to be sent. As such, each gps coordinate obtained had to be separated into longitude and latitude values. These values are then multiplied by a thousand (1000) to convert them into integers. The integer is then sent to through to the gateway, where the values are then divided by a thousand to convert them back to decimal values before being sent to the database by the GSM module. Figure shows the transceiver sending the obtained coordinated and the gateway receiving the coordinates.

```
RFM69 radio init OK!
RFM69 radio @434 MHz
Sending 57592,-02193 #
No reply, is anyone listening?
Sending 57592,-02193 #
Got acknowledgement from #1 [RSSI :-32] : Acknowledge Receipt
```

Figure 0.2 - Transmission message

```
RFM69 radio init OK!
RFM69 radio @434 MHz
Got packet from #2 [RSSI :-27] : 57592,-02193 #
```

Figure 0.3 - Receiver acknowledgement message

During the testing, an observation was made concerning the transmission signal. When places in a building with few windows, the LoRa gateway was unable to transmit to long distances. However, when situated in a room with windows and a clear line of sight between the gateway and the transceiver, the signals were able to travel longer distances. The longest linear distance tested successfully for the LoRa signal was 429 m. This calculation was made using the google maps distance measurement option.

5.3 Application Testing

Another requirement of the system is to be able to obtain gps information from the database and to successfully plot the location on google maps with a marker to emphasize the location. Plotting, the location information obtained from the gps test, the result in Figure 0.4 below was obtained. In this result, since the test was conducted on the Ashesi University campus, the location obtained (Ashesi University) can be seen identified with a red marker on the application map.

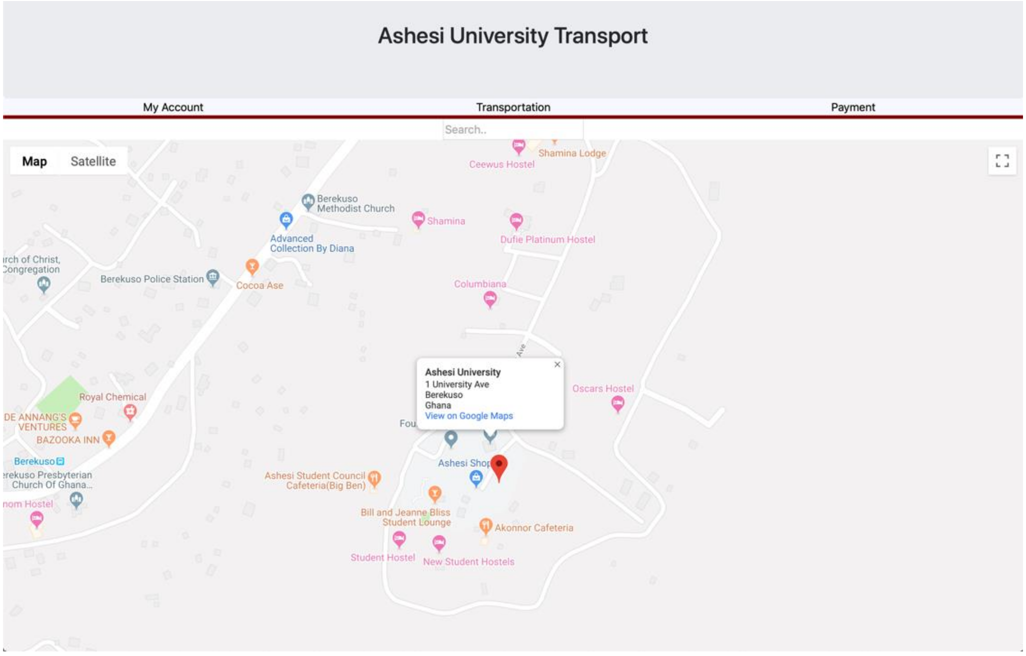

Figure 0.4 - Web Application displaying obtained GPS location

Since the application would have to display the location of several buses at a goal, the next test evaluates the ability of the application to display several points at the same time. This test was conducted by fetching gps coordinates from the database and plotting on google maps to represent bus locations. The obtained results from this can be seen in Figure 0.5 below.

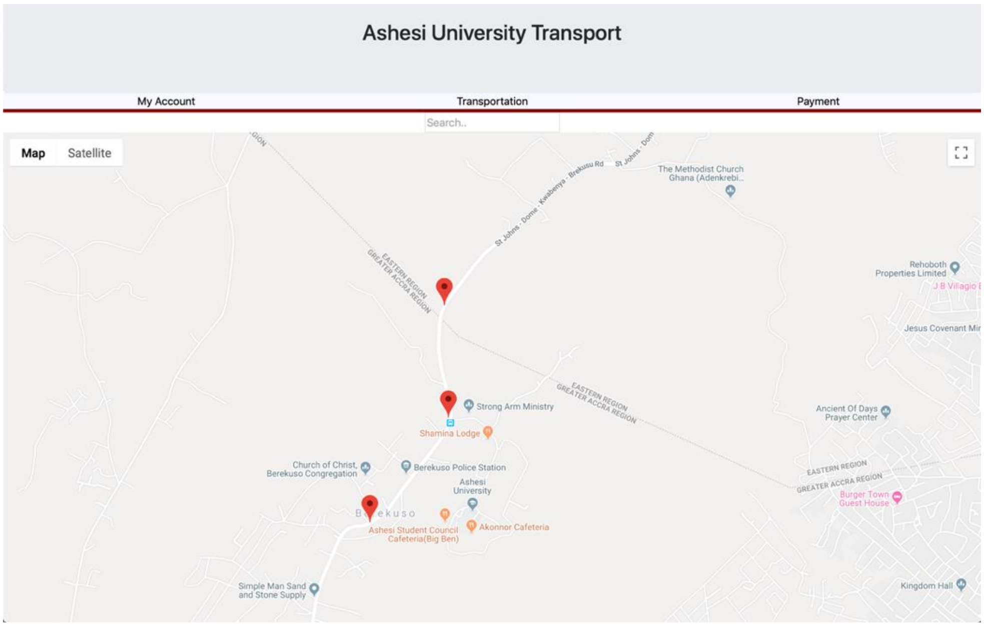

Figure 0.5 - Application displaying the location of several buses at the same time

Chapter 6: Conclusion

Through the use of technology, this project has been able to improve a system that is analogue in the most part. The application used for company run buses can be further developed into a more inclusive application where the system can be integrated for all forms of commercial transportation across the country. The payment system, on the other hand, can work perfectly for the transportation system in Ghana. With the hardware installed in the vehicles, passengers would only have to obtain the NFC cards which they can use for all subsequent journeys without trouble. Mobile money plans could even be integrated to allow users of the cards to top up the cards through the various mobile money platforms, to make the card usage even more seamless.

6.1 Limitations

Set challenges that reduced the scope of the project were the following:

1. Due to communications regulations, the LoRa was not used at a frequency that would allow maximum performance but rather at the frequency considered free range.
2. There was difficulty in obtaining a clear line of sight between the LoRa transceiver and the LoRa gateway due to the hilly nature of the test environment. This sometimes caused a delay in the transmission.
3. Long Range Radio library used about 50% of the memory capability of the ATMEGA 328P microcontroller.
4. The GPS module used was did not have differential capabilities, thus there was difficulty in obtaining coordinates when driving in tunnels and moving within building.

5. Passenger who do not have smart phones would not be able to take advantage of the developed system.

6.2 Future Work

This project sets a foundation upon which several applications can be designed and created to further improve the public transportation system in Ghana. This can be done through:

1. Integrating Mobile money and other digital means through which users can make payments.
2. Expanding the system to include the Metro Mass transportation company and the Ayalolo transportation company.
3. Mining the data obtained from the various transactions, to learn more about the users of public transportation in Ghana, such as determining the most used route between two locations, the route less likely to face traffic and several other bits of information.
4. Developing a short code application to help passengers without smart devices to make use of the system.

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