2016

Implementation of a framework for tracking school children while on transit

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Implementation of a Framework for Tracking School Children While On Transit

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Submitted in partial fulfillment of the requirements for the Degree of Master of Science in Mobile Telecommunications and Innovation at Strathmore University

Faculty of Information Technology

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Nairobi, Kenya

June, 2016

Declaration

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

Reward George Wambayi

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Approval

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Abstract

Child safety while on transit to and from school is a major concern for parents and school administrators. School buses are a popular means of transport for millions of children around the world and need to be effectively monitored to prevent abuse and ensure safety of the users. There have been systems to track the location and speed of the bus while on the move but parents have been left out of it. Parents are a major stakeholder in the transportation process and need to be regularly informed. Schools also need to know when and where a pupil was picked and how long it took them to get to school.

This thesis proposes a solution using student identification cards and Global Positioning System (GPS) in school buses to track and notify parents and schools on the location of the pupils. The identification cards will utilize NFC technology and store the pupil's details. Once the card is used, the pupil's parent is notified of their location. This solution involves tracking of the bus routes and estimating the speed of the bus. This information will be used to assure parents and schools of the safety of their children and pupils.

Tests were carried out on the system using smartphones to capture the location, and time of a pupil's pick-up and drop-off. Using Parse Push Notification (Parse), alerts were sent out to the test phones and all the parties informed on the location and time of a pupil's pick-up of drop-off. The system was validated against the requirements identified and end user feedback was found to be positive. This points to the effective use of the developed solution as an efficient framework to track school children and notify parents.

Keywords:

Location Based Systems, Child tracking, School bus tracking, NFC, GPS

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Acknowledgement

I would like to thank my friends and family for their input in terms of ideas and support during this project. Thanks to my supervisor Dr. Joseph Sevilla for his guidance in this research.

Chapter 1: Introduction

1.1. Background

Insecurity is one of the main concerns of residents in Nairobi. The city is ranked highly among most insecure cities in Africa with occurrences of terrorism related issues, mugging, robbery, kidnapping and other crimes. Majority of citizens are exposed to areas of crime especially in public transport where incidences of theft and bus hijacking. Crime in Nairobi remains a serious threat to Kenya's national security, and in some cases undermines the economy be negatively impacting on growth and discouraging investment (Kitiku, Musoi, Muthama & Waiya, 2012). This calls for a highly efficient means of ensuring the safety of the residents of the city.

Motor vehicle accidents have also been on the increase in Kenya with 2,907 cases in 2014 (NTSA, 2015). Over speeding and dangerous driving vehicles are among the causes of these accidents.

An area of concern for parents is the safety of their children on their way to school and from school. The parents need to be assured that their children arrive at school and return home safely. In Nairobi, kindergarten, primary and secondary schools are located all around the town and children travelling across town to get to school can be exposed to dangerous situations. The heavy Nairobi traffic also makes it time consuming for pupils to commute from home to school and back. Following September 11, 2001 attack in the United States, tracking school buses and students has become a mainstream issue due to the rise of violence, school shootings, and terrorists' threats (Obuhuma, Ondiek & Ombui, 2013).

Identification cards (IDs) have been used for many years to authenticate persons holding them. The cards have changed in form and function from paper IDs containing written information of the card holder to advanced cards with electronic information that can be used for electronic authentication and payments. A new technology for payment and identification is Near Field Communication (NFC). NFC is a standard bases short range wireless connection technology that enables simple and safe two-way interaction between electronic devices. It has a wide range of implementation in payments, access control, social networking and gaming (Agrawal & Bhuraria, 2012).

1.2. Problem Statement

The rate of school bus and van accidents in Kenya have been alarming to parent, relatives and Kenyans at the thought of young children losing their lives (Obuhuma, Ondiek & Ombui, 2013). Using school busses involves handing over children to persons who parents trust will deliver them to school. With the high number of pupils crisscrossing the City of Nairobi to attend school in school busses, there is need to track them at all times. Tracking the vehicles and as a result the children will provide peace of mind for parents and school administrators.

There is need for an integrated system for schools administrators, school buses and parents to automatically track the movement of pupils in real-time. This system would help reassure parents and school administration of the safety of the pupils.

1.3. Research Objectives

i. To investigate on the systems used around the world to track school children.
ii. To explore the child tracking solutions used in Nairobi County schools.
iii. To design, implement and test an application to track children while they travel in a school bus.
iv. To validate the developed application as an efficient child tracking solution.

1.4. Research Questions

i. What systems are being used is schools around the world to track school buses?
ii. What solutions are used in Nairobi County to track school children?
iii. What technology solution can be used to notify parents and schools on the location of pupils?
iv. Is the developed solution efficient in tracking school children while on transit?

1.5. Justification

This work helps in assuring parents and schools on the safety of pupils during transit. The data can be used by schools to know the pupils present in school, how long they took to get to school and how many trips they have taken with the bus. It can also be a guide for billing by the bus owners in case they are contracted.

1.6. Scope of Work

This thesis is aimed at linking junior primary school pupils with their parents during transit to and from school. It is limited only to notification of parents whenever the pupil boards and alights a school bus and tracking the bus via GPS though a mobile phone in the vehicle.

The study will be constrained to Nairobi County schools and parents and the devices to be used in this research are Android based smartphones with Internet, GPS and NFC capability.

Chapter 2: Literature Review

2.1. Introduction

This chapter discusses the need for child tracking solutions and the different solutions developed for this purpose. It also delves into the background of the different tools and technologies to be used in the solution proposed in this research.

2.2. School Transport

A school bus is used universally to transport school children to and from school and are an important component of the educational structure. It is a large, painted vehicle that takes children to school and returns them to their homes in many countries throughout the world. They are commonly painted yellow for purposes of visibility, safety and equipped with specialized traffic warning devices. The school buses are considered as the safest mode of transport in city areas in spite of poor ergonomic interior design and predominant unsafe condition (Gangopadhyay, Dev, Ara, Ghoshal & Das, 2011).

Nirupama and Hafezi (2014) state that decisions made by bus drivers, traffic authorities, school divisions and parents can have substantial influence on the safety of the school children. Each year, school buses are used for an estimated 10 billion student trips in the USA. Every school day, 475,000 school buses transport 25 million children to and from schools and school related activities. Numerous studies have been carried out on school bus and pupil safety over the last 40 years. An important result that emerged from the studies is that the school bus is the safest mode of transportation for children. The number of accidents, injuries and fatalities show that more school-aged children die in private cars than school buses.

2.3. Need for Tracking Children

Millions of children need to be moved from home to school and vice versa every day. For parents, obtaining safe transport for their children is a critical issue. Many children find themselves locked in a school bus in the bus parking lot after falling asleep on their way to school, miss the bus, step into the wrong bus, or leave at the wrong station with no means of track them (Shaaban et al., 2013). A research undertaken by the Scottish Executive Central Research Unit with the purpose of increasing the proportion of non-car travel to school reveals that travelling by bus or coach appears to be by far the safest mode (Shaaban et al., 2013).

In Kenya learners have to commute to school using ‘matatus’, buses, and bicycles. Many also walk to schools. There are many instances where learners have been involved in accidents as pedestrians or passengers, some culminating into fatalities due to negligence, ignorance or sheer irresponsibility in observing basic road usage rules (Ministry of Education, 2008).

School buses carrying children who are below the age of 10 who need careful handling need to be monitored. Such busses should move at a slower speed for the safety of the children who might not fit in the seat and normal safely belts. According to the Transportation Safety guidelines by the Ministry of Education in Kenya, school busses / vehicles should be driven at no more than 60kph (Ministry of Education, 2008). This needs to be monitored for the safety of the children.

2.4. Reasons for School Bus Accidents

A research carried out in China by Jie et al. (2012) list the main reasons for school bus accidents. They include school bus overloaded, the use of illegal school bus, irresponsible custodial teachers, traffic accidents and unqualified drivers.

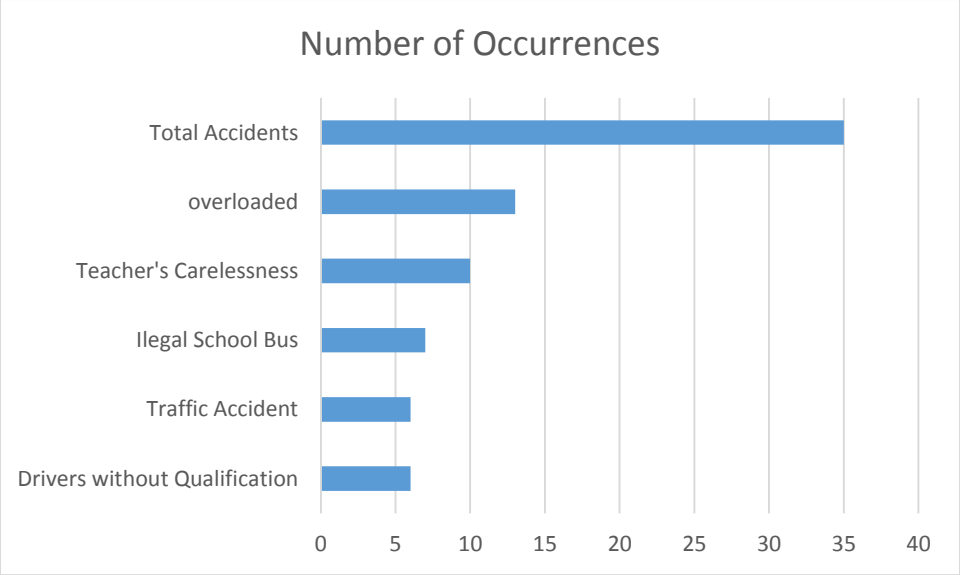

Figure 2.1 Causes of School Bus Accidents (Jie et al., 2012)

2.5. Child Tracking Solutions

Several child tracking solutions have been designed around the world to assist parents monitor their children. A solutions designed for Malaysia by Al-Mazloum, Omer & Abdullah (2013) describes a GPS and SMS based child tracking system using a smart phone. They proposed an android based solution to aid the parents track their children in real time. It works by a parent

sending a request location SMS to the child's smart phone. The child's devise will then reply with the GPS position to the parent's device. This solution takes advantage of the many children using smartphones these days and is aimed at locating missing or lost children.

Tekawade et al. (2014) have designed a mobile tracking app for locating friends using GPS. The application is implemented as a client server system to help users locate their friends and receive alerts when their friends are nearby. The application works in open space areas only since it relies on GPS by calculating the longitude and latitude values of the mobile.

A GPS model for school transport in Kenya by Obuhuma et al. (2013) propose a real-time solution for monitoring school buses toward the implementation of the over speeding rule. The model requires school bussed to be fitted with GPS tracking devices and configured to send the position speed and time to a GPS server. The model also required position information to be mapped using Map API to trace busses for route pattern analysis.

A child locating and tracking apparatus invented by Lowell Underwood (2001) describes a small disguised transmitter always carried by a child that uses a system of world wide receivers such as local cellular towers or low earth orbiting satellites for low power communication. A child can activate the transmitter in case of danger and a signal will be sent to a central reporting station where trained personnel will contact the respective parent or care givers to determine is the child could be in danger. If an affirmative decision is reached then the monitoring personnel or local law enforcement officials in the area where the alarm was received will locate the child and remove him from harm's path.

2.6. Location Based Services

With the rapid increase in the number of mobile devices such as smartphone, tablets and smartwatches, location based systems (LBSs) are increasingly becoming popular. In traditional cellular networks, users share their location with the network operator in order to obtain voice and data services. Data services have on the other hand led users to increasingly share their location with other parties. (Freudiger, Shokri & Habaux, 2012).

Implementations of LBSs are far-ranging. The services provide the ability to deliver high value content to the end user based on the knowledge of the user's location. Some of these applications include: Information Services which can be about events, traffic and services initiated by the

mobile handset user; Tracking which include fleet management, asset tracking and people tracking; Advertising and marketing involving location-based ads and location sensitive pages normally sent to a mobile handset user (Dialogic, 2007).

2.7. Near Field Communication

NFC is a standard based short-range wireless connection technology that enables simple and safe two-way interaction between electronic devices. It allows consumers to make contactless transactions, access digital content available on other NFC enables device and connect to electronic devices with a single touch. It enables the exchange of data between devices over a 10 centimeter distance (Agrawal & Bhuraria, 2012).

NFC offers its users an intuitive approach to exchange of information. When the user wants information from some NFC enabled source she only needs to bring her NFC enabled device in contact with that source and the content is transferred to her device. The same procedure is applied when the user wants to push information to another NFC device. This seamless and intuitive data exchange is only possible because NFC does not require any configuration such as other wireless communication technologies such as Wi-Fi or Bluetooth (Kilani & Jensen, 2013).

RFID which is considered as NFC predecessor considers participants in the communication as either a RFID reader or as transponder, which is a storage entity also referred to as a tag. This technology is used in many industrial applications especially to identify products from one another. Because the NFC technology is compatible with the RFID standard ISO 14443 many existing systems can be utilized by NFC enabled devices. Entities in NFC communication are referred to as peers this is because they can behave as both passive storage entities and as active reader/writers depending on which mode they are communicating in (Kilani & Jensen, 2013).

Modes of NFC Communication (Agrawal & Bhuraria, 2012):

2.7.1. Card Emulation

This mode is used when the NFC device works as a smart card e.g. an access card or a rail pass. The device in this mode can send messages. This mode can also be specially configured to send messages that will enable the NFC device to act as a contactless credit card

2.7.2. Reader Emulation

This mode is used when the NFC device is used to read data from passive NFC tags. This mode allows only one way communication from the passive NFC tag to the NFC device. The NFC tag can just send out the signal to the device but cannot receive the signal. An example of this is the NFC device as a reader of a passive tag on a poster.

2.7.3. Peer-to-Peer

This is used when communicating with another NFC enabled device. This mode enabled a link-level communication between two NFC devices.

2.7.4. Applications of NFC

Possible applications of NFC are all forms of electronic ticketing, but also for micro payments or smart posters. Ticketing is said to be one of the "killer applications" of NFC, since it can simulate to be a smart card and is thus compatible with the contactless card standards. Several public transport operators around the globe have launched pilot projects with NFC compatible technologies. Public transport is supposed to have the highest adaptation rates for NFC (Puhe, Edelmann & Reichenback, 2014).

2.8. Case Study: Reduction of Over Speeding Accidents: A GPS Model for School Transport in Kenya

The above mentioned study conducted by Obuhuma, Ondiek & Ombui (2013) describes a system for estimating the speed of buses in real-time. It was motivated by the need for schools to monitor school buses in order to reduce accidents caused by over speeding and reckless driving.

The research was aimed at answering several questions:

i. How can School Administrators monitor the driving speeds of their buses in real-time rather than trusting on their drivers?
ii. How can School Administrators monitor and analyze the routes used by their school bus drivers?
iii. Can the Ministry of Education keep track of all the operations of School buses without reliance on School Administrators?

It targeted public and private schools with busses. Using a descriptive research design and stratified random and judgmental sampling in selecting schools, a total number of 50 schools were targeted and a 10% sample used in the study.

A GPS tracker fitted in the school bus was used to periodically send GPS information to a Monitoring Station. The monitoring station analyzed the received data to check for any overspending incidences. In case an incident is discovered, the system would send email and SMS alerts to the relevant parties i.e. the school administrators and Ministry of Education.

The research identifies key stakeholders in the model namely; Ministry of Education, School Administrator and bus drivers.

The benefits of the model were listed as:

i. Real-time position monitoring on maps
ii. Auto SMS alerts on speed violation with position details
iii. Auto email alerts on speed violations with position details
iv. Driving route mapping
v. Reliability, flexibility and scalability.

2.9. Benefits of Tracking to Parents and Schools

An online article, Should Parents Use GPS Tracking on their Kids? (n.d.), lists some benefits of tracking children using GPS. With the increased availability and technology of GPS tracking now so easily accessible, it can be used to keep track of children at all times. If a child is young enough to get lost or be abducted, using GPS is not an invasion of privacy. A GPS tracker can be placed inconspicuously in a child's backpack, jacket or pocket, so the parent can always know that the child is safe in school, has made it home safely from school, or is where they're supposed to be.

Another great benefit of GPS tracking for kids is to help care for children that have mental disabilities or behavioral problems such as Attention Deficit Disorder (ADD). A child that has mental disabilities or behavioral issues may be more inclined to wander away from their guardian when they become distracted. Whether a child has ADD or Autism, a GPS tracking monitor can give you much needed peace of mind when he or she is not directly in your care.

2.10. Conclusion

This chapter has described the various technologies used in tracking school children. All the tracking solutions involve the use if GPS get the location co-ordinates using a GPS device. When GPS is linked together with a Map API, third parties are able to view not only the co-ordinates but also get the name of the location in terms of the country, city and even the road where the transmitting device is located. This research intends to use GPS a key component in designing the application to locating school children.

NFC has been found to be a practical solution for storing data offline in NFC cards. The cards can then be used for authentication using a NFC reader. The NFC technology and cards can be used to replace the pupil's school IDs therefore expanding their capability for other advanced solutions.

This research has also noted the clear gap in school children tracking solutions in the county of Nairobi. The proposed solution will try to fill in that gap by use of the available technologies that will be practical for the Nairobi environment.

Chapter 3: Software Development Methodology

3.1. Introduction

This chapter describes the process that was used to design and develop the child tracker and parent notification application. The methodology selected for this process was Rapid Application Development (RAD).

3.2. Rapid Application Development Methodology

The RAD methodology involves prototyping where the analysis, design and implementation are done concurrently. It focuses on building applications in a very short amount of time (Coleman & Verbruggen, 1998). Prototypes are tested, reanalyzed and redesigned until the final system is agreed upon (Konstantinou, n.d). RAD exploits automation tools and techniques to restructure the process of developing information systems. This involves replacing hand designs with automated designs and coding which is a more stable process.

The researcher's aim in selecting this methodology was in order to use already existing tools with capabilities as those intended to be developed. This would ease the development work and enable the solution to be quickly tested and validated. Figure 3.1 shows the features of RAD as an efficient and cost effective methodology for software development.

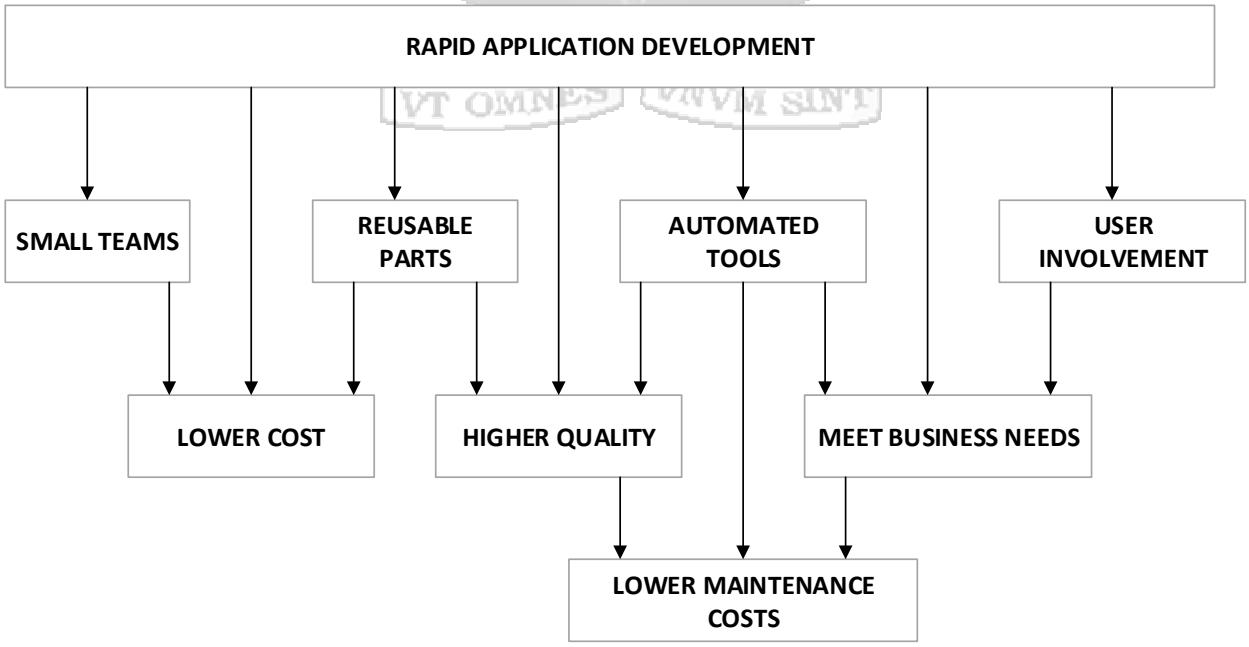

Figure 3.1 Features of Rapid Application Development (Source: Martin, 1991)

3.3. Rapid Application Development Lifecycle

The RAD lifecycle incorporates four major stages to ensure developers build systems that users really need. The stages are requirements planning, user design, construction and implementation (Konstantinou, n.d). This sections tries to describe how the different stages will be implemented.

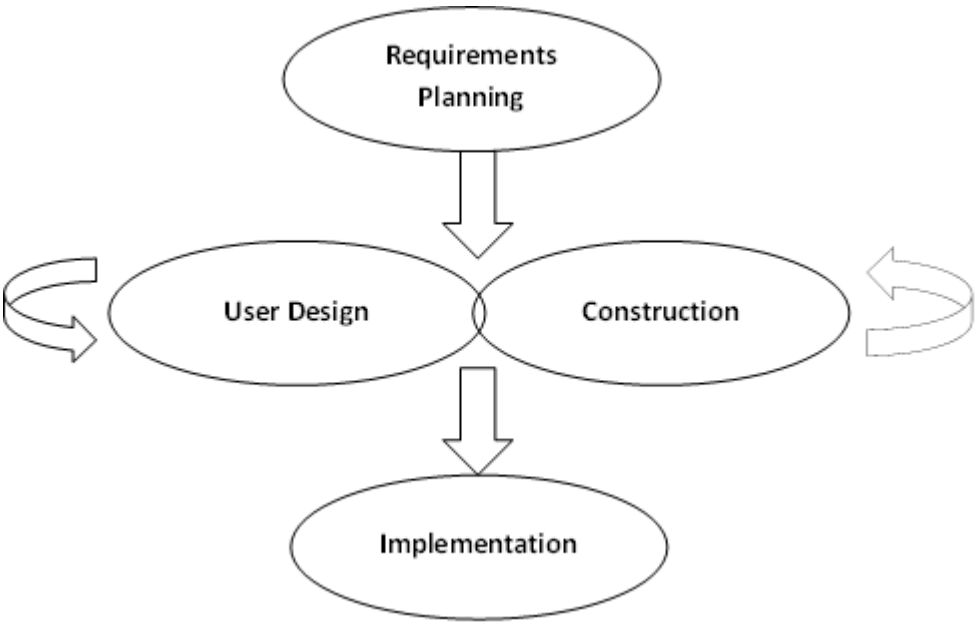

Figure 3.2. Rapid Application Methodology Lifecycle (Source: Konstantinou, n.d)

3.3.1. Requirements Planning

This stage is used to capture the functions, data subjects and business processes that are currently in use to aid in designing the proposed solution.

The research covers two main areas: the school management of the buses and the parents' knowledge of the location of their pupils. Using semi structured interviews and participant observation, the researcher gathered information from school managements, school bus drivers and conductors and parents whose pupil's use school buses.

The interview questions listed in Appendix I were used as a guide for the semi structured interviews. The aim of the interviews was to capture the current processes being used by the school, school bus conductors, drivers and parents to achieve a seamless process of transporting pupils.

Personal interviews provided the best source of information with the participants providing first-hand information on their experiences, challenges and ways of improving the process.

Judgmental sampling was used to select the interview participants. A set of both large schools with many buses and small schools with few vehicles were selected and interviewed. Parents were randomly selected based on the researcher's background knowledge of a set of parents whose children use school buses.

Obuhuma, Ondiek & Ombui (2013) states that there are 50 schools with school buses. The researcher selected a sample size of four schools two with more than five school buses and two with less than five school buses were selected, representing 12.5% of the population. Four parents, three having one child and one having two children were also taken through the semi structured interviews. One parent representing each of the selected schools in the sample size.

Responses from the interviews were jotted down and collated using Microsoft Excel to establish a list of similar processes and identify the areas that could be automated and incorporated in to the system to be developed.

3.3.2. User Design

This process models the system data and processes to build prototypes and mockups outlining the look and feel.

The information gathered from the requirements planning phase was used to design the data requirements for each process. The researcher used Use Case diagrams to aid in identifying the major actors in the school transport ecosystem and their core functions. Data flow diagrams were also used to outline the flow of information between the different processes and stakeholders. The researcher also used Use Case Scenarios to describe the major processes the system will incorporate, the steps taken for each task in line with what was collected from the observations and interviews.

An Entity Relational Diagram was used to visualize the information and their relations. Each entity was also described in detail using database schemas. The output of this process was the database design and application mockups.

3.3.3. Construction

The construction stage involves the actual product development using the selected tools.

The software development involved a modular approach with the system being divided into small components that were independently developed. Server backend and database platforms were developed using available open source technologies.

The main tool to be used was an online hosting and notification service called Parse.com (Parse). This eased the developers work in hosting the solution and developing notification solutions from the ground up. Parse.com has a ready built software development kit (SDK) that incorporates database storage, querying and notifications to mobile apps among others. The Parse JavaScript SDK (JavaScript Guide) was selected for developing the online module to be accessed by the school.

Android Software Development Kit was select to develop the mobile apps to be used to track the bus and the parent's app. This is in line with the research scope. The apps incorporated Google Android Maps Application Programming Interface (Google Android Maps API) for the location services to obtain GPS information and placing the information on a map. Android SDK together with Parse SDK for Android (Android Guide) was used to link the apps to the Parse Database to store and retrieve information.

3.3.4. Implementation and Testing

The final stage of the RAD methodology is the deployment and testing of the solution. This involves conducting functional and user test to ensure the solution has met all the requirements. Functional tests were conducted by the researcher to ensure the system performs optimally without any bugs and errors. Sample test cases were used to gauge the functionality developed in to the application.

User tests were also carried out using the target group selected in the requirements planning stage (Requirements planning, 3.3.1). The tests aided in establishing if the ease of use, responsiveness and functionality of the application. Questionnaires listed in Appendix II and III were issued to the target group to collect feedback on these tests.

3.4. Research Validation

Software validation is an activity in software quality assurance that aims to ensure the software system developed meets the customer's needs. Validation is about, "are we building the right product?" (Kung & Zhu, n.d.).

To validate the solution, the end product will be matched against the requirements identified in in the requirements gathering phase. This will ensure the system has captured all the features it set out to implement. Validation will also include the responses from the user testing phase. The feedback on usefulness will provide an accurate result on the potential success of the implementation of the solution.

3.5. Ethical Issues

This research uses the location details of school busses, young school children and parents. The information is stored securely and shared only with the relevant approved users who are the school and the pupil's parents. The information is not publicly accessible and only available to authorized individuals using the relevant credentials.

Chapter 4: Requirements Planning

4.1. Introduction

This chapter describes the requirements and major actors of the various components of the current school bus operations. The researcher used semi structured interviews and participant observation to identify the actors and processes of the school bus operations.

4.2. Discussion of Findings

The feedback provided by the school and parents was based on their experience and current practice of using the school bus. The feedback is divided into two sections, one from the School management and school bus operators and the other from parents whose children use the school bus.

4.2.1. School Management and School Bus Drivers Response

It was observed that all the schools use majorly the same process of prick up and drop off. In the schools interviewed 50 -60% of the pupils used the school bus. The others are dropped by parents or some pupils walk to school since they live nearby.

The two schools interviewed, having a population of more than 400 pupils each, had 8 school buses each. It was observed that the pupils were made to sit and occupy all the sitting space irrespective to the number of seats. Therefore the bus always carried more pupils than the capacity it was obliged to carry.

Each bus has a bus driver and a conductor and was designated to use specific routes and estates. The conductors had a list of pupils and their home locations. It was the responsibility of the conductor and driver to collect the pupil from the guardian at their home and drop them back after school. The parent or guardians therefore did not know if the pupil got to school and how long it took to get there.

All the schools did not issue pupils with identification cards since they were highly likely to lose them.

4.2.2. Parents Response

The semi-structured interviews targeted parents whose children use the school bus.

The parents handed over their children to the bus conductor who picked up the responsibility to transport the children to and from school. The conductor knew the pupils' home location from forms filled by the parents during registration with transport charges added to the child's school fees.

The parents always inferred on the quality and duration of transit from discussions with their children. Therefore they did not have any concrete facts on the quality of the transport service.

4.3. Summary of Requirements

From the information gathered on the current operations and experiences of the schools, drivers and parents, the following set of requirements are necessary to achieve an effective solution to track children.

i. Ability to link a school with all its buses, drivers, pupils and the pupil's parents.
ii. Ability to authenticate the driver and conductor operating a bus during a pick up or drop off trip.
iii. Ability to link a bus to a designated operation route.
iv. Ability to track the location of the bus at any point in time during the trip. The school and parents should be able to see the location of the bus in real time.
v. Ability to authenticate a pupil during pick up and drop off then notify the parent.
vi. Ability to get summary of trip details in terms of trip duration, number of students picked and route used.

Chapter 5: User Design

5.1.Introduction

The user design process utilized the requirements captured in the requirements planning phase together with components used in the applications described in the literature review to design the process and solution to be developed. It used modelling tools like use cases, data flow diagrams and process flows to define the requirements and functions to be developed.

5.2. Use Case and Data Flow Diagram

The use case diagram shows the actors in the system and the activities they perform. From Figure 5.1, the main system actors identified on the system are the pupil, bus driver, parent, school management and system administrator.

A data flow diagram (DFD) shows the interaction between the entities and the system and the flow of information. It also shows the processes being conducted by the entities and access of information by each process. The DFD in Figure 5.2 describes the information flow in the Child Tracking application.

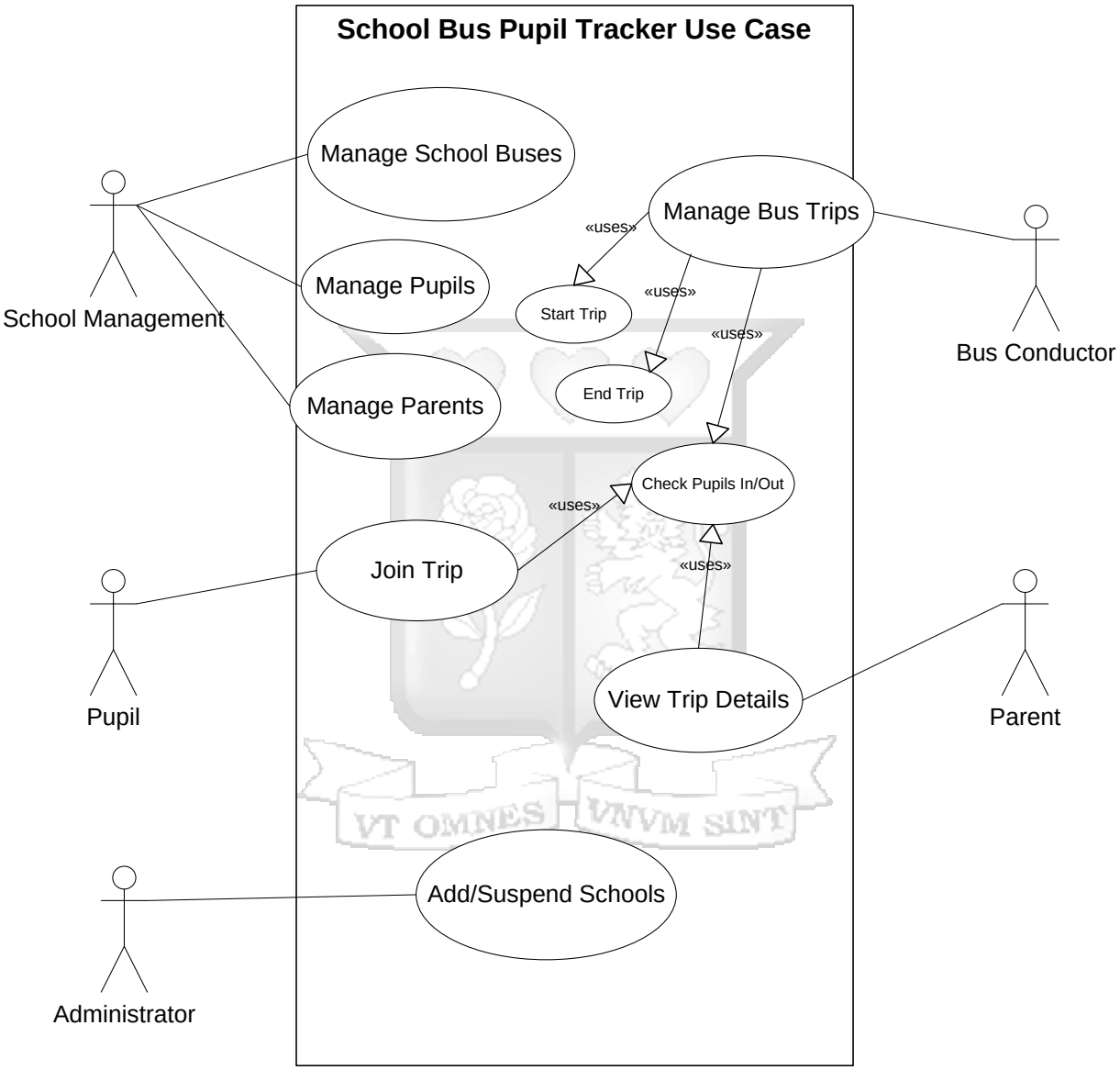

Figure 5.1 Use Case Diagram

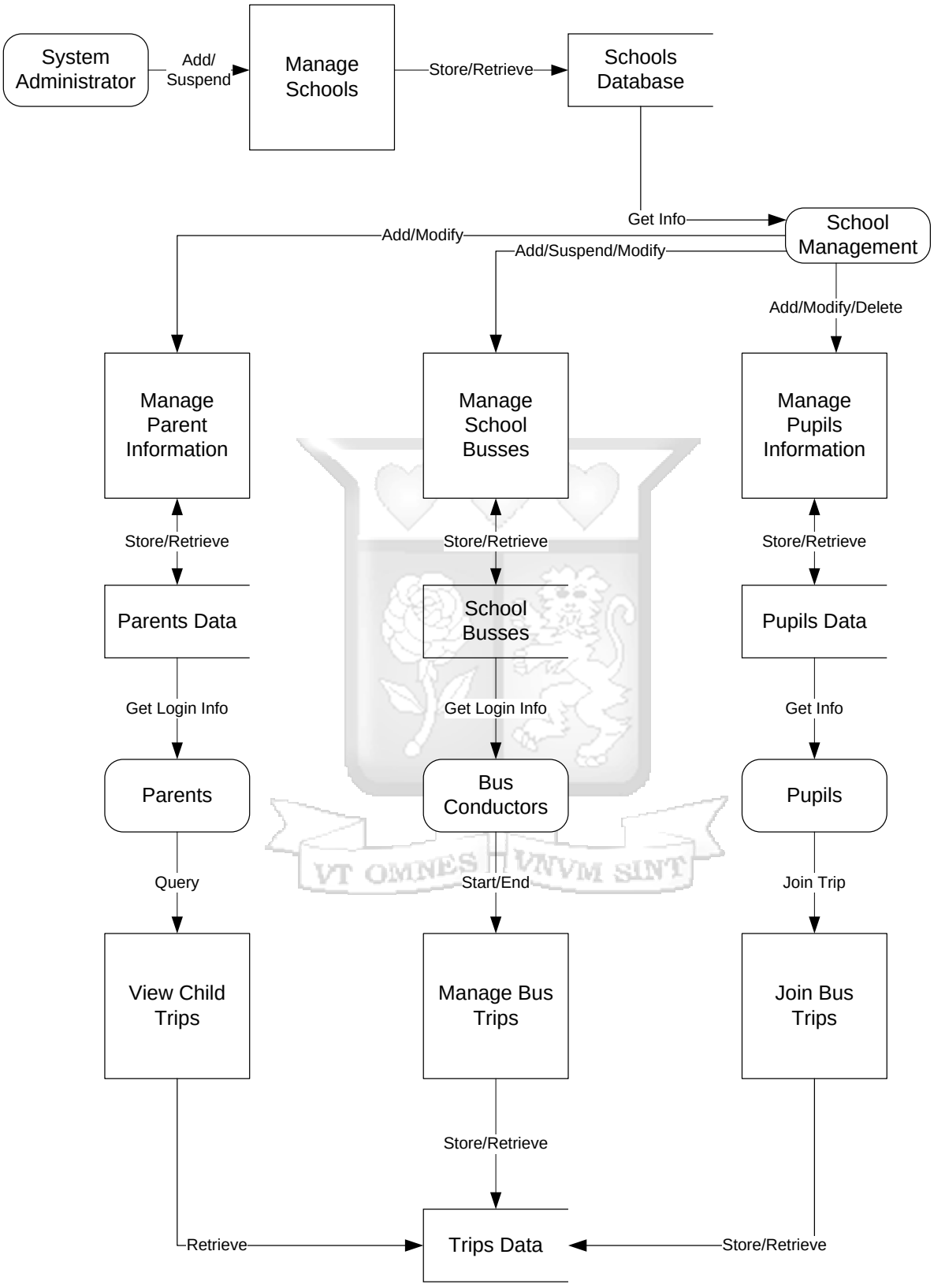

Figure 5.2 Application Data Flow Diagram

5.3. System Narrative

Figure 5.3 shows illustrates the main processes to be used to tracking the school bus, onboarding the pupil and notifying the parents.

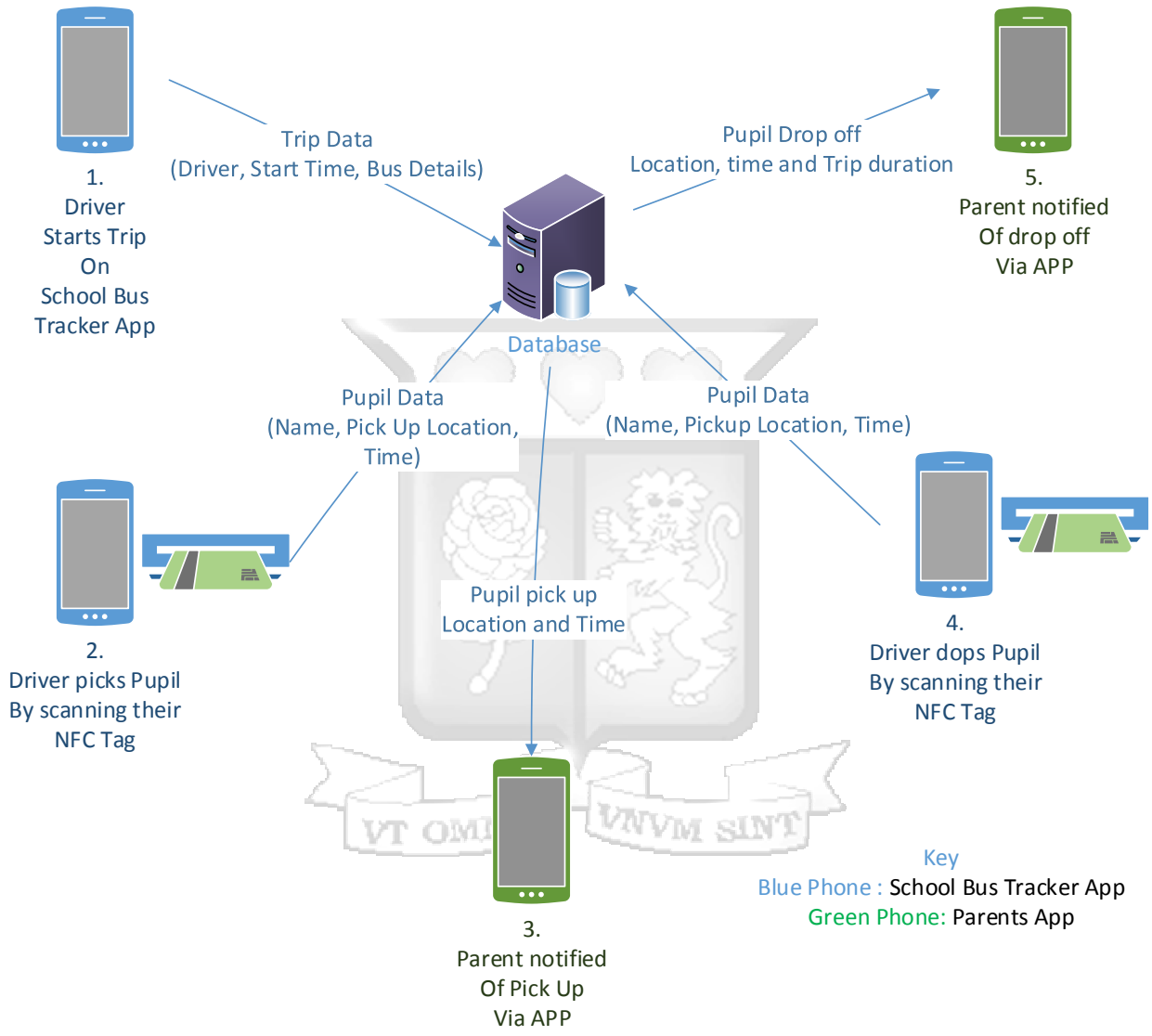

Figure 5.3 System Illustration Diagram

5.4. Use Case Scenarios

These scenarios are detailed descriptions of some of the major system process in the child tracking solution. They identify the actors in a particular scenario and the steps taken to accomplish a process. The scenarios are elaborates in Table 5.1 to Table 5.4. They include the process of starting a bus trip, picking a pupil, dropping a pupil and ending a bus trip.

Table 5.1: Start Trip Scenario

Title	**Start Trip**
Description	A school bus conductor wants to start picking up children from their homes or from school.
Primary Actor	Bus Conductor
Preconditions	Bus has to be registered and valid, The conductor needs to have the device credentials to start the tracking application.
Post Conditions	The bus is being tracked by the system and pupils can start check-in in.
Main Success Scenario	1. Bus Conductor Logs into the device. 2. Cloud module verifies the credentials. 3. The device GPS signal is activated. 4. Device starts sending GPS information periodically.
Extensions	None

Table 5.2: Pick Pupil Scenario

Title	**Pick Pupil**
Description	Bus stops to pick up pupil. Pupil displays his NFC identifier tag and taps on the bus device then boards the bus.
Primary Actor	Pupil
Preconditions	The conductor has started the trip. Pupil's tag is registered on the system.
Post Conditions	Pupil is recorded as having joined the trip. Pupil's parent is notified.
Main Success Scenario	1. Pupil is added onto the trip 2. Parent notified that child had boarded
Extensions	None

Table 5.3: Drop Pupil Scenario

Title	**Drop Pupil**
Description	A pupil in a trip alights from the school bus.
Primary Actor	Pupil
Preconditions	There is an ongoing trip. A pupil is registered in the trip
Post Conditions	Pupil checks out of the trip. Pupil's parent is notified. Bus trip continues.
Main Success Scenario	1. Pupil is removed from trip 2. Pupil's parent is notified 3. Trip continues
Extensions	None

Table 5.4: End Trip Scenario

Title	**End Trip**
Description	The bus has dropped off all the students. The trip has ended
Primary Actor	Bus Conductor
Preconditions	The bus was in a previous trip and had pupils. Bus has dropped off all the pupils.
Post Conditions	Bus trip ends. Location of the bus is not being monitored
Main Success Scenario	1. All the pupils have checked out 2. Bus Conductor selects end trip on Bus Device 3. Bus is no longer being tracked. 4. Trip information is stored.
Extensions	None

5.5. Entity Relationship Diagram and Database Design

The database was designed to capture all the relevant information for the solution. It also catered for future growth by providing capability to add more schools without changing the designs. Figure 5.4 shows the implementation of the database. It shows the connection of the various tables using the primary and foreign keys.

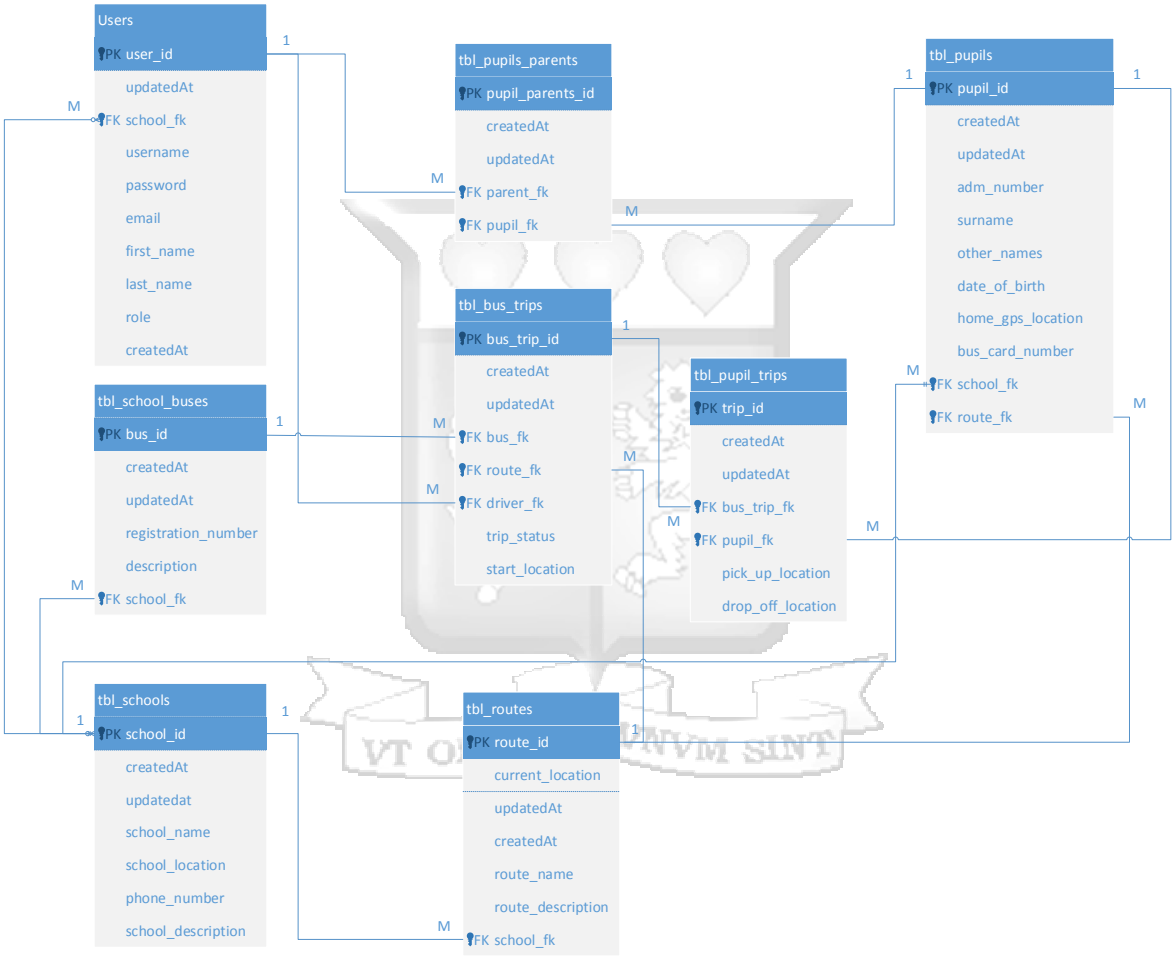

Figure 5.4 Entity Relationship Diagram

The Users table as described in Table 5.5 is used by all the system users. The administrator, school management, parents and driver information is stored here. The users are differentiated based on the role field.

Table 5.5 Users Table

Column Name	Attribute	Description
UserId [PK]	Integer	Driver Identifier
UpdatedAt	Timestamp	School identifier
SchoolFK	Integer	
username	Text(MD5)	
password	Text	
email	Text	
First_name	Text	
Last_name	timestamp	
Role	Text	
CreatedAt	Timestamp	

The Pupils table (Table 5.6) contains all the pupil information. Pupils are also linked to their school based on the School_FK foreign key. Other userful information in this table are the home identifier location (home_gps_location) and bus_card_number that is the identifier in the pupil's NFC tag.

Table 5.6 Pupils Table

Column Name	Attribute	Description
Pupil_id	Integer	Unique Pupil Identifier
School_fk	Text	School foreign key
Surname	Text	
Other_names	Text	
Adm_number	Text	Admission number
Home_gps_location	Point	Home Geo Location
bus_card_number	Text	Bus Tag Identifier
Route_fk	Integer	Route Identifier

The school bus table (Table 5.7) stores all the buses in the system and the schools the buses are linked to.

Table 5.7 School Bus Table

Column Name	Attribute	Description
Bus_id	Integer	Bus Identifier
Time_created		
Registration_number		
Description		
School_fk		

This solution supports multiple schools hence the need for the schools tables (Table 5.8). The table also contains general information about the schools.

Table 5.8 Schools Table

Column Name	**Attribute**	**Description**
School_id	Integer	School Identifier
Time_created	Timestamp	
School_name	Text	
Phone_number	Text	
School_description	Text	

Table 5.9 describes the routes table that stores all the routes to be used by the school buses.

Table 5.9 Routes Table

Column Name	**Attribute**	**Description**
Route_id [PK]	Integer	Route Identifier
Time_created	Timestamp	
Route_name	Text	
Route_description	Text	
School_fk [FK]	Integer	

The pupil trips table as described in Table 5.11 is used to store trip information for every pupil. Many pupils are picked and dropped in a trip. Therefore this table is used to identify where every pupil was picked and dropped from. Table 5.12 in the other hand is used to store bus trip information from like when the trip started, the current bus location, the driver of the bus, the bus details and the route.

Table 5.11 Pupil Trips Table

Column Name	**Attribute**	**Description**
Trip_id [PK]	Integer	Trip Identifier
Start_time	Timestamp	
End_time	Timestamp	
Pupil_fk [FK]	Integer	
Bus_trip_fk [FK]	Integer	
Pick_up_location	Point	GPS Location
Drop_off_location	Point	GPS Location

Table 5.12 Bus Trips Table

Column Name	Attribute	Description
Bus_trip_id [PK]	Integer	Bus Trip Identifier
Start_time	Timestamp	
Bus_fk [FK]	Integer	
Route_fk [FK]	Integer	
Driver_fk [FK]	Integer	
Trip_Status	Boolean	Trip Active or Not
Start_location	Point	GPS Location
Current_location	Point	GPS Location

Table 5.13 stores the link between the pupils and the parents. One parent can have many pupils in the same or different schools and equally one pupil can have more than one parent. This table handles that link.

Table 5.13 Pupil Parent table

Column Name	Attribute	Description
ObjectId [PK]	Integer	Bus Trip Identifier
createdAt	Timestamp	
UpdatedAt	Timestamp	
Parent_fk [FK]	Integer	Parent identifier
Pupil_fk [FK]	Integer	Pupil Identifier

5.6. Solution Design

The solution design describes the communication between the various components making up the complete solutions. Figure 5.4 shows the components communicating via a cloud Data Store and Notification Application.

The application consists of four major modules. These are: The school management module, parent's mobile app, bus mobile device app/pupil tracker app and the central data repository server application. Communication between the different components is via HTTP. The various components are described in detail below.

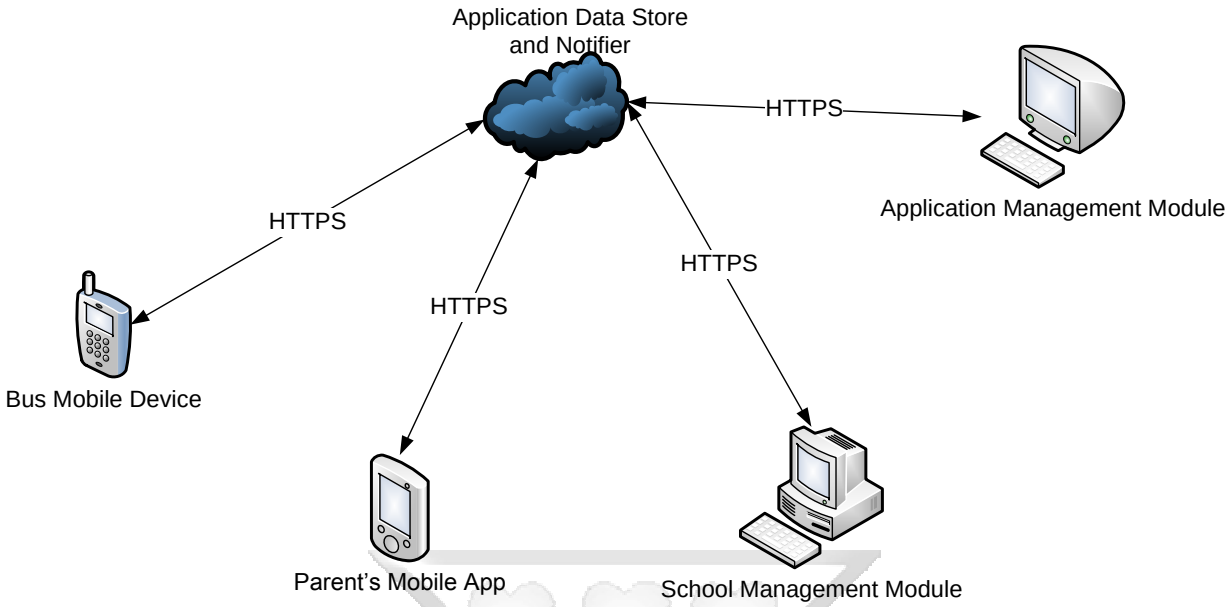

Figure 5.4 Application Integration Diagram (Source: Researcher, 2015)

5.6.1. Cloud Module

This is the backend of the entire system. It hosts the database, the school management module and application management module. It also contains the application programming interfaces (APIs) for communication to the Bus Device and Parent Mobile App.

Through the APIs, the Bus Device sends calls the Cloud module once a trip is started and a pupil checks in. The cloud module then sends a notification to the mobile app of the child's parent notifying the parent that the pupil is on board. The same happens when the pupil checks out of the bus.

5.6.2. School Management Module

This is a web interface targeted at schools for managing school busses, pupils and parents. The school administrators are able to map busses to bus devices. They can also add new pupils to the bus services view bus trips and students who we in a specific trip. They shall also have the capability of viewing the route the bus used while picking the pupils on its way to school.

5.6.3. Application Management Module

This is the administrative portal of the application. Its main function is to manage schools. Once a school signs up for the service, the administrator adds the school details and assigns permission to a user in the school. The administrator is also able to suspend the services to the school.

5.6.4. Bus Mobile Device

This module is responsible for tracking the location of the bus, starting and ending trips and checking-in and checking-out pupils in the bus. The module would typically work on a smartphone with GPS, NFC and mobile data capabilities. The GPS will be used to track the location of the bus, the NFC technology for reading the pupil NFC tags and the mobile data for communication with the cloud module. The NFC communication used will be reader emulation.

The bus device is an android phone with GPS and NFC technologies used for tracking and reading the NFC tags held by pupils. Figure 5.5 and 5.6 are designs of the application to be used in the school bus. The screens are main menu screen, current trip screen and pupil pick up notification screen.

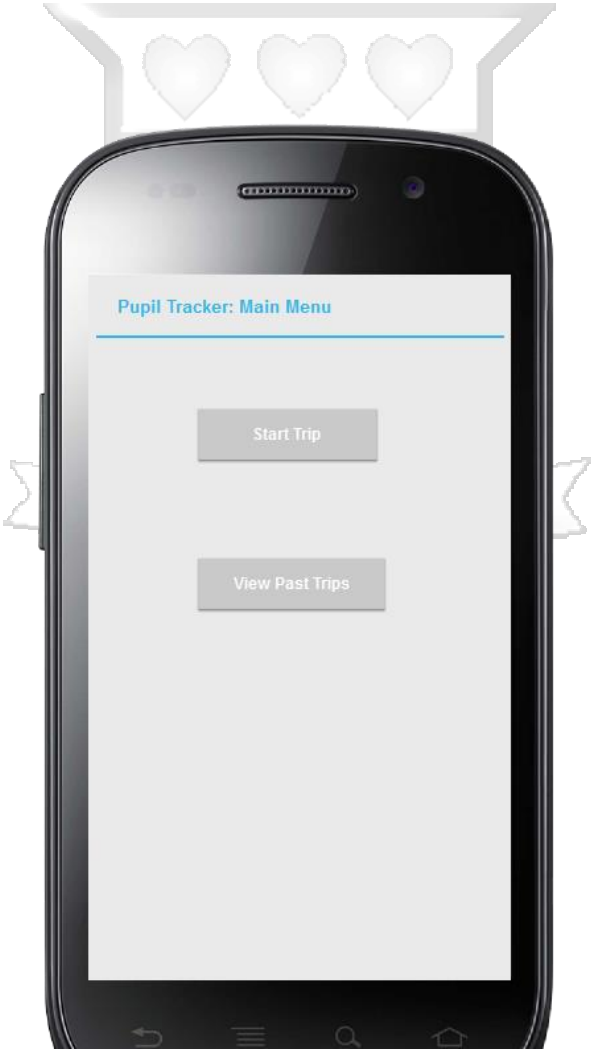

Figure 5.5 Pupil Tracker: Main Menu Mockup Screen

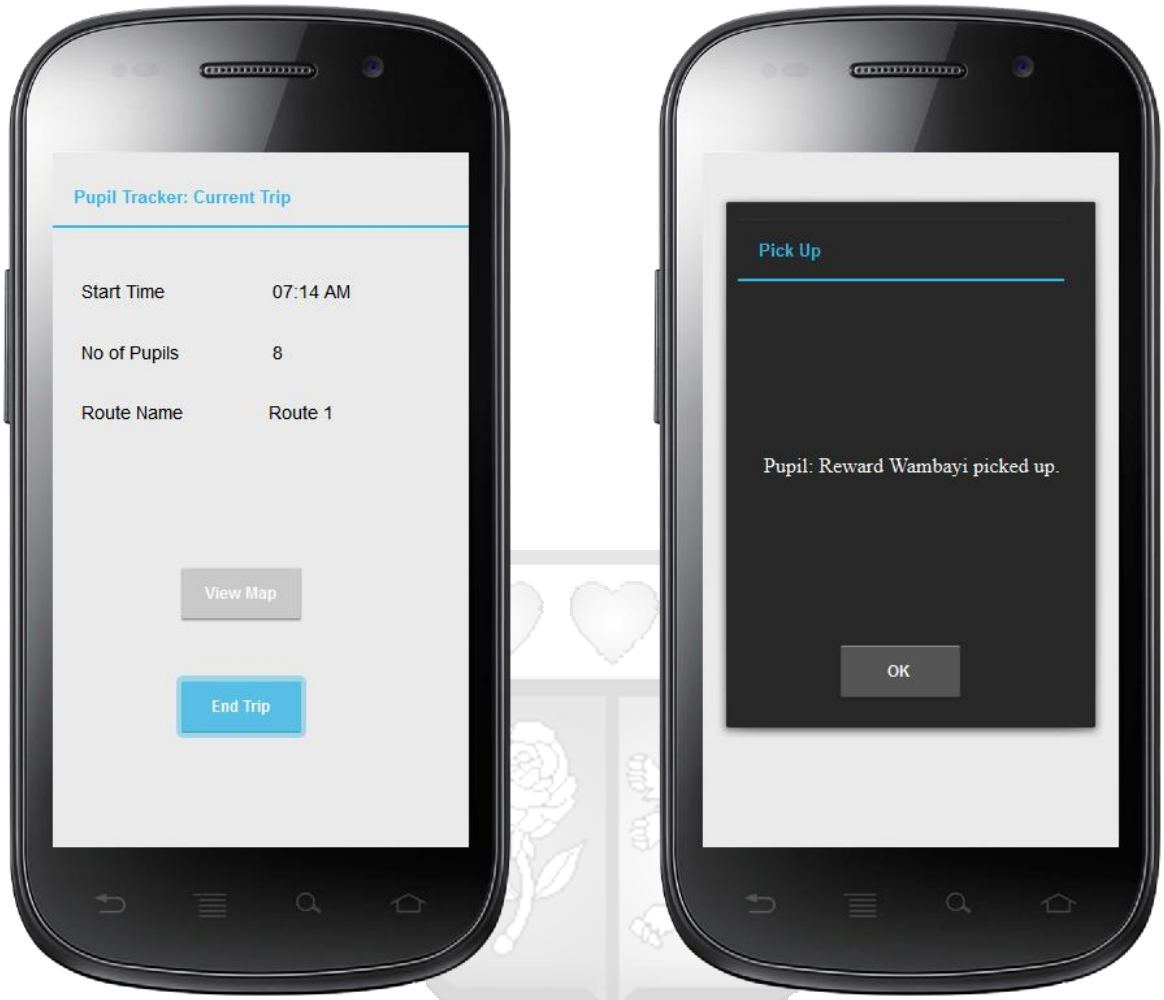

Figure 5.6 Pupil Tracker: Current Trip and Pick up Mockup Screens

5.6.5. Parents Mobile App

This app will be for notifications from the cloud module. Once a pupil checks-in or out of the bus, the parent is notified via communication from the cloud module to the parent app.

The parent mobile device will be an Android smartphone. It allows for third party applications to be installed and has internet capability. Communication with the cloud module is via HTTPS protocol. Figure 5.7 shows the login and main menu screen designs for the application to be used by parents.

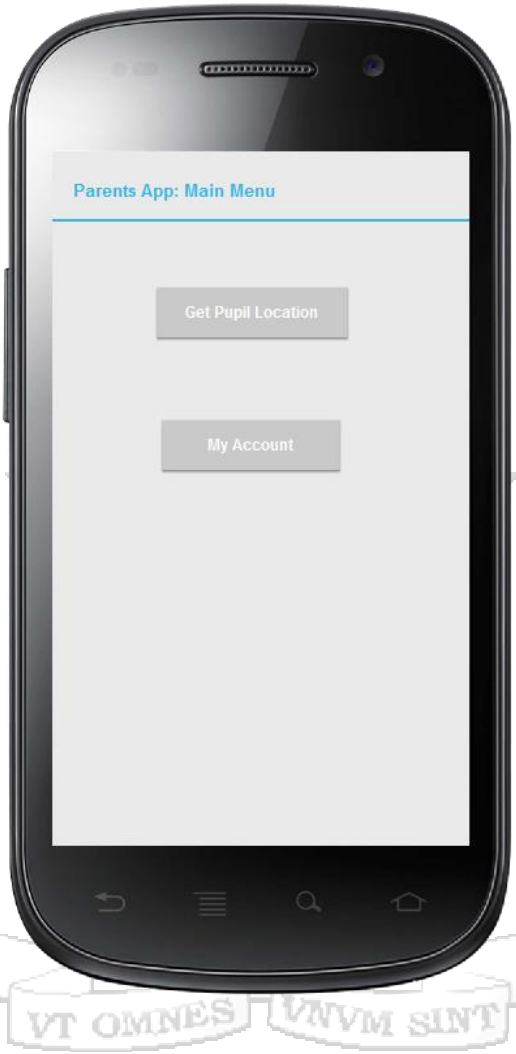

Figure 5.7 Parents App: Main Menu Mockup Screen

5.6.6. Pupil's NFC Tag

This will be the pupil's identifier on the system. It will be an NFC tag containing pupil data used for identification by the Bus Device. This will typically be a card or tag stuck on the pupil's bag or jacket. The tag is pre written with a unique identifier that is linked to the pupil's details.

Chapter 6: System Construction and Implementation

6.1. Introduction

System construction describes the actual tools and technologies used to develop the application. It also lists the Application Programming Interfaces (APIs) used between the different application modules. The system employed the client-server architecture where the cloud module was the server and the clients were the bus mobile device and parent mobile device. Implementation involves testing the developed solution, training users and understanding system acceptance.

6.2. Cloud Module

This is the server side of the system. It hosts the database and backend processing scripts. It also hosts the application management module and school management module.

6.2.1. Development Tools

The cloud module is built using the Parse Platform (Parse). This is a cloud platform for easy web and app development with rich backend tools. It contains the parse database, JavaScript and Php modules. The parse JavaScript and database were used to develop the backend of the child tracker and parent notification system.

Parse also contains modules for mobile applications to easily communicate with backend platforms. The Parse Push Notification and REST modules were used for communication between the server side and mobile applications.

Figure 6.1 shows the Parse Data Browser containing the various classes with data objects. Parse Data Browser is a NoSQL database where all data is tagged with IDs and different classes linked with pointers and relations. An example of a relation is the Pupils class containing data with pointers to the school class. Parse uses Classes instead of the regular tables. Each class when created automatically has fields like ObjectId, CreatedAt and UpdatedAt as default fields. The developer then adds the other relevant columns in the class. Parse also consists of a default User class with underlying authentication features. Therefore all the user tables in the design have been merged to use the User's class under Parse. The users are differentiated using the role filed.

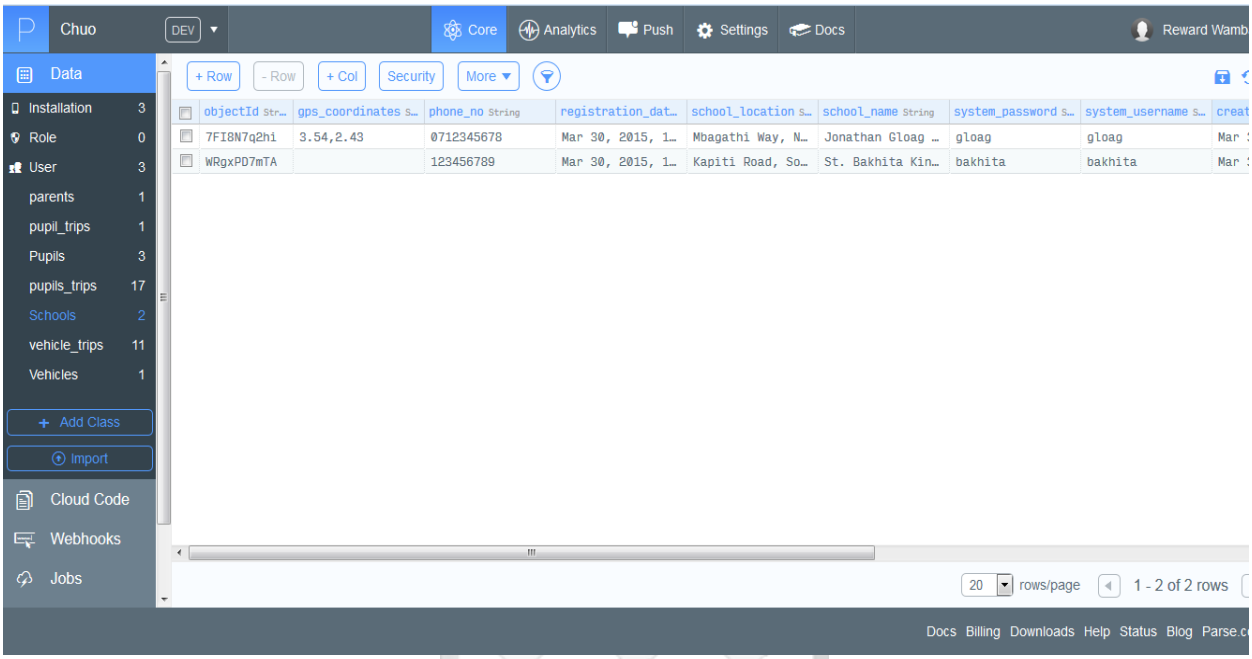

Figure 6.1 Parse Data Browser

6.3. School Management Module

The school management module is a web interface for use by the school to manage pupils, parents and school vehicles. The school has login credentials to the web module where they can add and view pupils, add parents and link them to the pupils, add school buses and view the trips taken by the buses.

Figures 6.2 and 6.3 are screenshots of web pages for listing pupils and adding vehicles respectively.

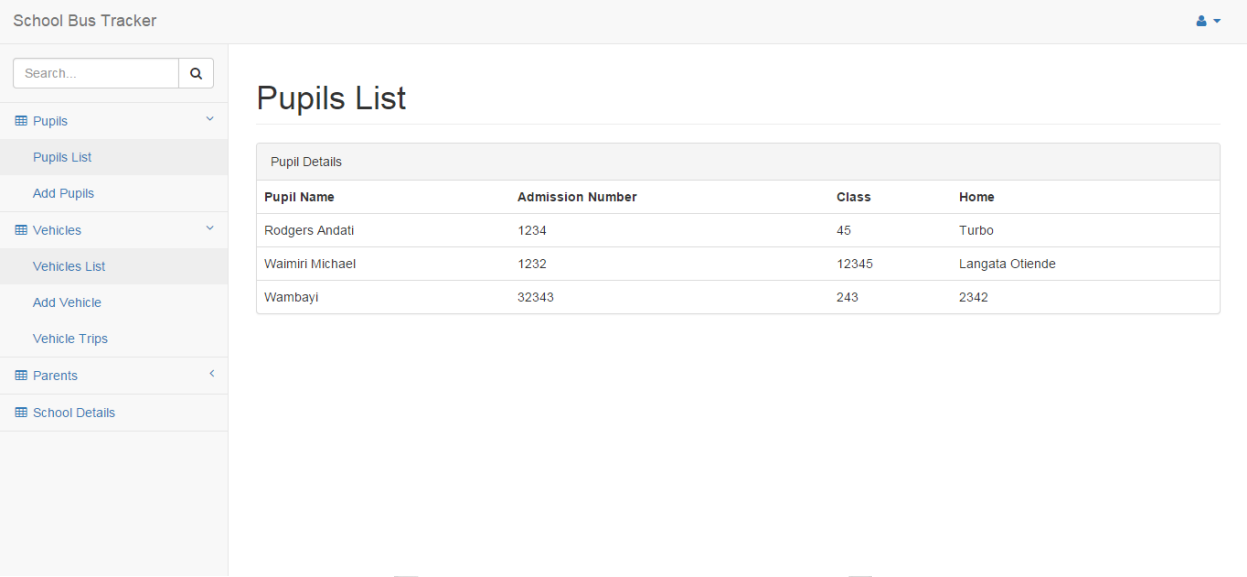

Figure 6.1: View Pupils Webpage

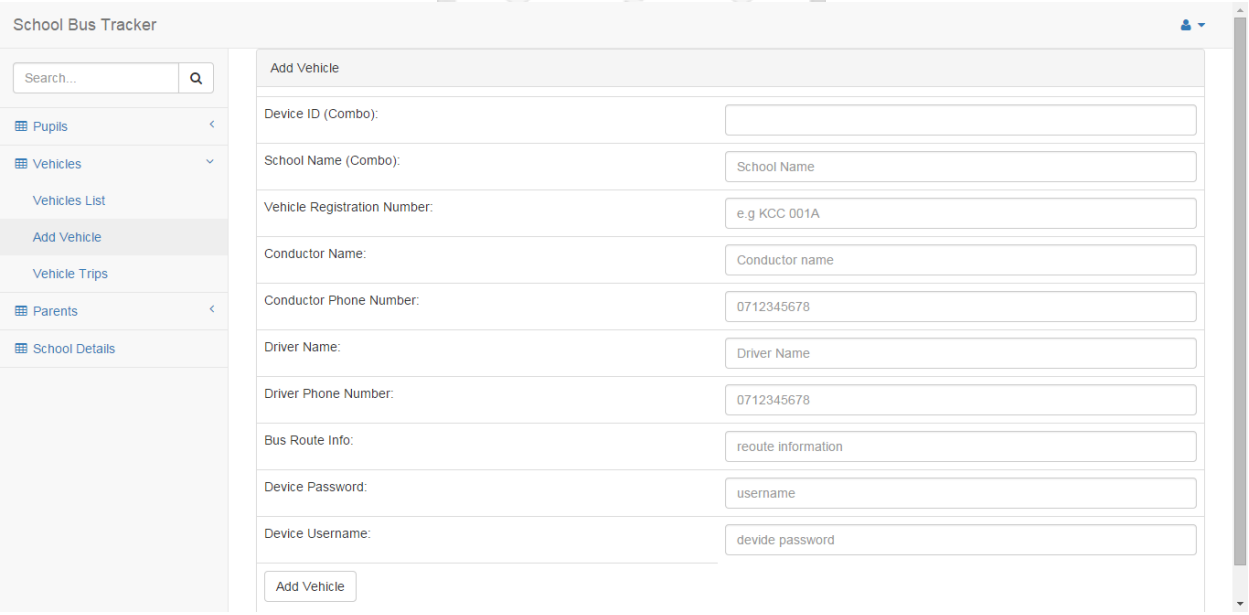

Figure 6.3: Add Vehicle Webpage

6.4. Bus Mobile Device

The bus mobile device is an Android mobile phone containing GPS, mobile data and NFC technologies. A mobile app named Pupil Tracker was developed to help in tracking the bus and registering the pupils when they enter the bus. The mobile app is handles by the bus conductor who logs in using his unique credentials, starts and ends trips, and registers pupils when they are picked and dropped by scanning their NFC tags.

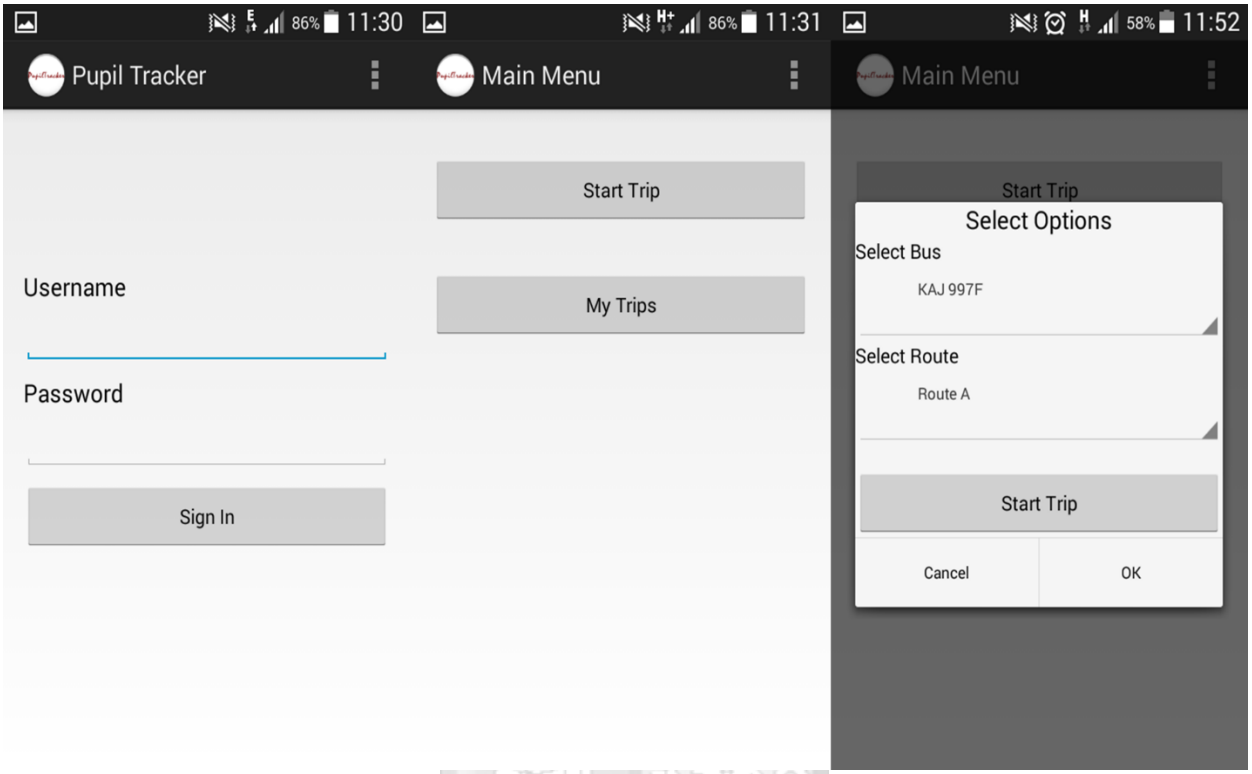

Figure 6.4 Pupil Tracker Log In, Main Menu and Start Trip Screenshots

Figure 6.4 shows the Log In screen, Main Menu screen and Start Trip screen for the Bus Device App. The bus conductors log in and choose the available bus and route they want to take. Start trip is selected when the school bus starts work in the morning ready to pick school children or before picking pupils from school to drop them home. Starting a trip creates a new trip record containing the start time, start location and a unique trip identifier. My Trips option is used to view a summary of all the trips previously taken by the bus.

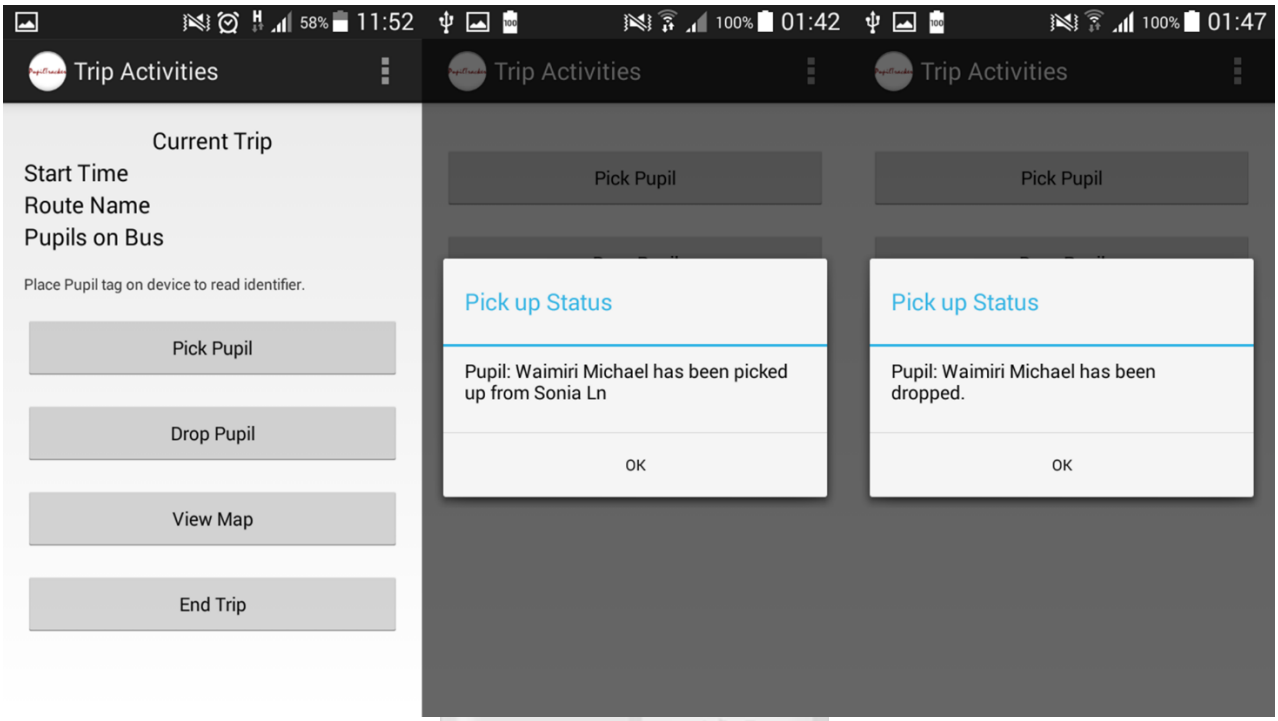

Figure 6.5 Pupil Tracker Current Trip, Pick Pupil and Drop Pupil Screenshots.

Figure 6.5 is a screenshot of the Current Trip, Pick Pupil and Drop Pupil Screens. The Current Trip screen can automatically scan pupil NFC tags to identify them. In case the tag is not readable, the Pick Pupil option starts shows a pop up screen for the bus conductor to enter the Pupil's card ID. A request is then sent to the cloud module to add the pupil to the pupil trips database table with the pickup location, pickup time and link the pupil to the ongoing trip. A response is send back the school bus app showing the status of the pickup.

Drop Pupil also involves scanning the pupil tag or entering the card id. On successful card validation, a response is sent to the bus app and a notification send to the pupil's parent.

6.5. Parent Mobile Device

The parent mobile device is an Android phone with a Parent's App developed to receive notifications on the location of the child and check the current bus location. The parent logs in and can only view the location of their child (Figure 6.6). The Parse Push Notification client is used in this app to receive notifications from the Parse server. The parent app has two main functions;

View Trips containing a summary of the trips the pupil has taken and Get Child Location to display the location of the pupil while in transit.

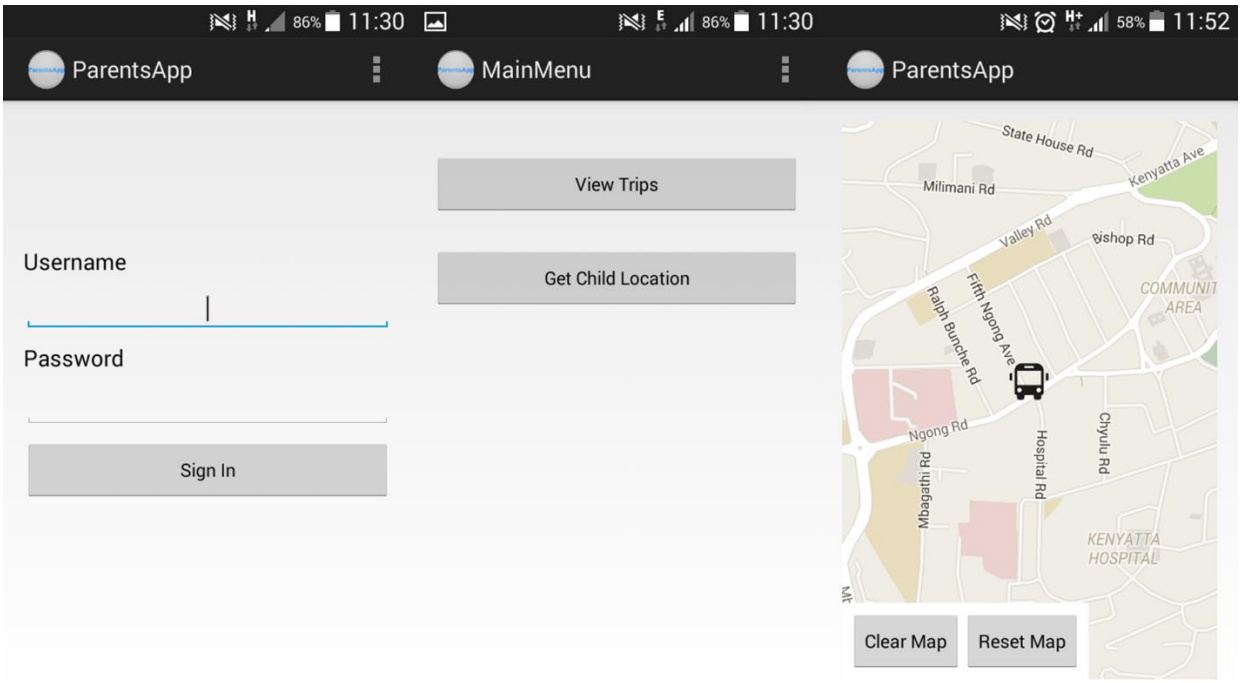

Figure 6.6 Parents App Log In Main Menu and Bus Location Screenshots

Figure 6.7 shows a sample notification sent to the parent's app detailing a pupil pickup from a specified location.

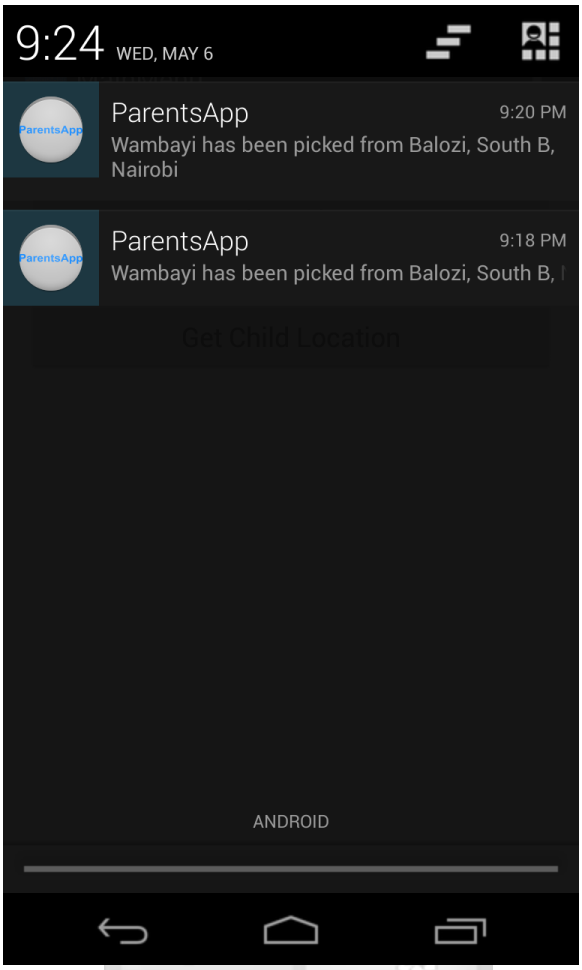

Figure 6.7: Parents App Notifications

6.6. Functional Tests

The various application components were tested to ensure they function seamlessly. This involved moving simulating the school bus trip process, pupil pick-up and drop-off. The parent's app was also tested. Different input types like wrong credentials, false student ids and various input combinations to ensure errors are appropriately handled.

6.6.1. School Bus App Functional Test

The main function of the school bus app is to keep track of the location of the bus, register pupils during pick-up and drop off. Table 6.1 shows the tests done on the Bus Tracking application for the "Start Trip" function. The tests were successful. The tests conducted in Table 6.2 for Pick Pupil and Table 6.3 for Drop Pupil were also successful. Table 6.4 with End Trip testes were also marked as having passed.

Table 6.1: Start Trip Test

Test Case	Start Trip		
Description	Test the process of Starting A Bus Trip		
Preconditions	The bus tracking application has been installed. Bus Tracking application has been started.		
Step	**Action**	**Expected response**	**Pass/Fail**
1.	Username and password allocated to the conductor are entered. Conductor clicks login.	Credentials are verifies and the application main menu displayed	Pass
2.	Conductor clicks on the "Start Trip" button.	The trip details are registered including the current location. The "Trip Activities" screen is displayed	Pass

Table 6.2: Pick Pupil Test

Test Case	Pupil Pick Up		
Description	Test the process of picking up a pupil		
Preconditions	The bus tracking application has been installed The conductor has logged into the device The conductor has successfully selected "Start Trip"		
Step	**Action**	**Expected response**	**Pass/Fail**
1.	Press "Pick Pupil" Button	Popup to scan card/ enter student card number	Pass
2.	Enter Student Card Number	Student number verified and a prompt on successful pickup displayed.	Pass

	Parent is Notified	Notification message sent to parent	Pass

Table 6.3: Drop Pupil Test

Test Case	Pupil Drop Off		
Description	Test the process of dropping off a pupil		
Preconditions	The bus tracking application has been installed The conductor has logged into the device The conductor has successfully selected “Start Trip” Pupil has been picked up		
Step	**Action**	**Expected response**	**Pass/Fail**
1.	Press “Drop Pupil” Button	Popup to scan card/ enter student card number	Pass
2.	Enter Student Card Number	Student number verified and a prompt on successful drop off displayed.	Pass
	Parent is Notified	Notification message sent to parent	Pass

Table 6.4: End Trip Test

Test Case	End Trip		
Description	Test the process of ending a trip		
Preconditions	The bus tracking application has been installed The conductor has logged into the device The conductor has successfully selected "Start Trip"		
Step	**Action**	**Expected response**	**Pass/Fail**
1.	Press "End Trip" Button	Trip is marked as ended with the end time and end location. Bus Application main menu is displayed.	Pass

6.7. User Testing

User tests were conducted using sample bus conductors, pupils and parents. The applications that were tested were the Pupil Tracker application and Parents application.

The sample group used for requirements gathering was used to conduct the tests. This provided an appropriate ground for evaluating the effectiveness of the solution compared to their processes.

6.7.1. Pupil tracker Tests

Tests on the pupil tracker were conducted using three Android devices namely, Samsung Galaxy J1, Samsung Galaxy S5 and Samsung Note 3. All the test phones had Internet capability, NFC chip and GPS capability. Three pupils were used to test the solution, each of them equipped with an NFC tag with a unique identifier written to it using an NFC writer application. The feedback from the users are listed below.

6.7.1.1. Ease of Use

All the users found the pupil tracking application very easy to use. This could be attributed to the few activities on the application thus making the main tasks accessible. Some key functions like location updating and notification push are also hidden from the user thus improving its ease.

6.7.1.2. Application Usefulness
The application was found to be very useful by the conductors.

6.7.1.3. NFC Scanning Response Times
The results varied based on the phone model due to the different specifications in terms of Random Access Memory (RAM) and processing speed. The Samsung J1 device was found to be slower.

6.7.1.4. Bus Location View
The school representative was able to view the bus location on the web portal.

6.7.2. Parents App tests

Tests on the parents' app were conducted using two android devices namely Samsung Galaxy J1 and Samsung Note 3. One of the parents' app was configured to receive notifications for two pupils. The main of the test was to view the location of the bus once the trip started, and check whether the notifications would be received once the pupils were dropped or picked from a specific location. The feedback from the users are listed below.

6.7.2.1. Ease of Use
The application was found to be very easy to use by the parents. This can be attributed to the basic functionalities of the app where the parent is required to add the child and view the bus on a map.

6.7.2.2. Locating on Map
Both parents were able to locate the bus on the map.

6.7.2.3. Map response times
The bus response times were found to be okay. The current setting for bus location update is every 30 seconds. This can therefore be viewed as quite a while when someone is keen to observe the movement in the map.

6.7.2.4. Notification Receipt
All the parents received notifications for pickup and drop off of their respective pupils.

6.7.2.5. App Usefulness
The application was found to be very useful. One parent commented that they would regularly use the application if fully implemented to monitor the movement of their child.

6.8. Conclusion

This chapter has elaborated a fully functional Child Tracking and Pent Notifying platform with all the modules for the school, bus and parents. A case study has also been used to show the successful

implementation of a bus tracking application using GPS. Different solutions have been used between the solution in the case study and the developed application. Tests have been carried out on the platform showing the successful implementation of the solution.

The user tests also show the successful implementation of the pupil tracking and notification solution thus validating the solution as a useful framework for tracking pupils in Nairobi.

Chapter 7: Research Validation

7.1. Introduction

This chapter tries to measure the effectiveness of the developed solution as an efficient means to locate school children who are on transit. It uses two validation techniques to ensure the system meets the specifications identified in the requirements planning and that users would adopt the system once it is implemented.

7.2. Validation against Requirements

Based on the requirements identified, this is how the developed system tries to achieve them:

i. Ability to link a school with all its buses, drivers, pupils and the pupil's parents.

The system had developed several channels to link all the actors. The Pupil tracking application has implemented an authentication feature to identify the driver and added an option for the driver to select the bus and route when starting the trip.

Pupils are identified using NFC cards with unique identifiers to authenticate then during pick up and drop off. The database has also linked the pupils and parents and a notification system implemented to inform parents through the parents app of pupil activities during the trip.

ii. Ability to authenticate the driver and conductor operating a bus during a pick up or drop off trip.

The system identifies drivers and conductors using unique credentials and tracks their movement via GPS.

iii. Ability to link a bus to a designated operation route.

Routes have been incorporated by linking pupils to specific routes. Before a trip is started, the bus driver selects a route to be taken (Figure 6.4). The route details are then linked to the parents and school to aid in tracking.

iv. Ability to track the location of the bus at any point in time during the trip. The school and parents should be able to see the location of the bus in real time.

The solution has incorporated GPS in the pupil tracking app and Google Map Android API to aid visualization of the GPS location on a Map for easy tracking (Figure 6.6). The tracking app also send regular location updates to the cloud database.

v. Ability to authenticate a pupil during pick up and drop off then notify the parent.

Using NFC technology, the pupil is authenticated on the pupil tracking app. A notification is then immediately sent to the parent (Figure 6.7).

vi. Ability to get summary of trip details in terms of trip duration, number of students picked and route used.

Through the school management module, the school is able to view all the buses, trips and driver details. Reports can also be generated to summarize the trips. This is specified in Chapter 6, 6.3. School Management Module.

7.3. Validation based on User Responses

The user testing questionnaire as identified in Chapter 6, 6.7 User Testing was used to capture feedback from the testing target group with respect to the functionality and the usefulness of the app. The target group being the actual eventual potential users of the system provide accurate feedback on the success of the application.

The rating on the apps usefulness by the school managements, bus drivers and parents provide sufficient validity to the successful implementation of the solution to track school children and notify parents.

7.4. Conclusion

Validation of the developed solution against the set requirements and based on user feedback provide verification that the system achieves the objective of efficiency in tracking school pupils.

Chapter 8: Conclusions, Recommendations and Future Work

8.1. Conclusions

The various solutions proposed by Obuhuma et al. (2013), Al-Mazloum et al. (2013), Shaaban et al. (2013) have focused on either bus tracking or child location but not both. The proposed framework tries to merge all the solutions in one by incorporating all the stakeholders; schools, parents, pupils and school bus administrators. Having all stakeholders integrated into one platform is advantageous because of the seamless flow of information to all parties. The parents and school administrators are therefore more at ease since real-time data of pupil movement is transmitted to them.

This study has discovered that location based services are the best means of obtaining the location of mobile devices. If these devices are fitted on other objects, like vehicles, these objects can also be tracked. This is the case of tracking the pupil and school bus using the mobile device in the bus.

Notification alerts are much cheaper and effective for sending alters to devices. All smartphone platforms have notification technologies that use mobile data. These notifications are linked to the mobile apps installed on the mobile device and come at no cost for the sender or recipient. In the case of the proposed framework, the school sends notification to parents at no cost.

Although the scope of the study was Nairobi County, this solution can be implemented in virtually all the urban cities and towns whose roads and buildings have been effectively mapped by online map providers.

8.2. Recommendations

This research used a smart phone with NFC and GPS capability to test the implementation of the child tracking solution. This is an ideal solution for both large and small capacity school buses. The smartphone can be used in the production environment because of its mobility and versatility.

Since the pupils are off different ages, different NFC tags can be used. Stickers or pins can be used for the younger pupils while the older ones can be issued with cards.

8.3. Future Work

The framework collects a lot of information that can be useful for other innovative solutions. Advancements to this framework can include bus overloading detection by comparing the bus capacity to the number of pupils picked.

Route management solutions can be built to generate the best routes to use by analyzing the location of the homes of pupils to map the fastest and most cost effective routes for the buses.

The findings of the research show the success of implementation of location based services to track pupils in buses. There are many pupils who use public means of transport. This solution can be modified to target such pupils by placing card readers in school to notify parents of the pupil's arrival. It can also be extended to track class attendance and access control in institutions.

The platform used in this research used Android and the target phone operating system. This study can be extended to use other operating systems like iOS and Windows and also implement different mapping and notification technologies.

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Appendix I: Interview Questions

The following questions were used to gather information on the school bus operations and how they link parents and teachers.

1. How many school buses does the school own or hire?
2. How many pupils use the school bus daily? How many use private means to school?
3. How do you know when and when to pick pupils from their homes?
4. How are parents informed that the pupil has arrived at school or home?
5. Do you have designated bus routes?
6. Does the school know the location of the bus in real time when picking or dropping the pupils?
7. Are pupils assigned identification cards?

Appendix II: Pupil Tracker App Questionnaire

Please take some time to fill this questionnaire with regards to the Pupil Tracking application

a. Please state the make and model of the device you are using to test the application.

   _____

a. How should you rate the ease of use of the app in terms of starting trips, picking and dropping pupils and stopping trips?
   - ☐ Very Easy
   - ☐ Moderately Easy
   - ☐ Okay
   - ☐ Moderately Difficult
   - ☐ Very Difficult

b. How would you rate the usefulness of the application?
   - ☐ Very Useful
   - ☐ Just Okay
   - ☐ Not Useful

c. How would you rate the response times in scanning the pupil NFC tag?
   - ☐ Very Fast
   - ☐ Moderately Fast
   - ☐ Okay
   - ☐ Moderately Slow
   - ☐ Very Slow

d. Were you able to view the location of the bus from the web portal?
   - ☐ Yes
   - ☐ NO

e. Please provide additional comments on your experience

   _____

Appendix III: Parents App Questionnaire

a. Please state the make and model of the device you are using to test the application.

_____

b. Was the app easy to use?

- ☐ Yes
- ☐ NO

c. Were you able to locate the pupil using the map?

- ☐ Yes
- ☐ NO

d. How would you rate the map response times in locating the bus?

- ☐ Very Fast
- ☐ Moderately Fast
- ☐ Okay
- ☐ Moderately Slow
- ☐ Very Slow

e. Did you receive notification of pick up and drop off?

- ☐ YES
- ☐ NO

f. How would you rate the usefulness of the application?

- ☐ Very Useful
- ☐ Just Okay
- ☐ Not Useful

g. Please provide additional comments on your experience:

_____