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Passenger Destination System for Commercial Vehicles

Benjamin Kommey [a, *], Elvis Tamakloe [a], Eric Tutu Tchao [a]

[a] *Dept. of Computer Engineering, Kwame Nkrumah University of Science and Technology, Kumasi - Ghana*

bkommey.coe@knust.edu.gh, tamakloe.elvis@gmail.com, tutucharmin9@gmail.com

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ABSTRACT

Public vehicles are predominantly the commonest and most widely used means of transport for humans in this current time. However, passengers who often commute with public vehicles mostly encounter the challenge of missing their destination primarily due to difficulties in communicating their destination to the driver, sleeping in the case of long-distance travel or the inability to recognize their destinations, and many more. In this paper, a fully functional and cost-effective passenger destination alert system for commercial vehicles (PDSCV) was developed. This designed passenger destination alert system provides solutions to the problems and as well meets the needs of some target groups such as the physically challenged. To solve these challenges, a GPS-based location module interfaced with a microcontroller unit was employed in the hardware prototype design. Destination stations were displayed and announced via an LCD and audio system respectively to generally alert all passengers on board the vehicle. The prototype also includes alert buttons beside every seat which were to be used by passengers in emergencies and to alert the driver to skip a particular terminal provided the bus is fully occupied and no passenger intends to alight. In addition to the hardware prototype, a software application was developed to provide further information to first-time travellers. The test and results from the entire system indicate a bridge in the communication gap between the driver and the passengers of commercial vehicles.

* Corresponding author at:
Department of Computer Engineering, Kwame Nkrumah University of Science and Technology
PMB UPO, Kumasi, 00233
Ghana
E-mail address: bkommey.coe@knust.edu.gh

ORCID ID:
First Author: 0000-0003-3145-0066

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1. Introduction

Although there are many transportation systems here in Ghana, the well-known means of transportation of people, goods, and services from one particular destination to another is through commercial vehicles. Vehicular transportation, therefore, contributes a substantial amount to the economic development of every nation. A higher percentage of the population use public transport as the medium to commute daily from one place to another. This is primarily because it is less expensive as compared to other alternative means of transportation and for many other reasons.

Despite the numerous advantages that passengers benefit from this system of transportation, there exist some associated challenges that make commuting with public vehicles often problematic. Communication difficulties between the driver and passengers are essentially the root cause of passengers sometimes missing their destination. Other factors such as passengers sleeping through long-distance travel are self-inflicted. In most developing countries, vehicles with large carrying capacities employ the services of bus conductors to help bridge the communication gap. Even though this has created a few menial jobs for the unemployed, it has only provided a partial solution to the said problem. Due to other multi-tasking activities performed by the bus conductors, a passenger who intends to alight at a particular destination must send multiple reminders to the bus conductor in order not to miss his or her destination. First-time travelers and physically challenged people are not left out of this ordeal.

The emergence of GPS technology has significantly changed the landscape of identifying locations with ease. GPS technology primarily employs satellite communication to identify the location of an object in real-time.

In this paper, GPS technology was incorporated into an intelligent hardware onboard system that constantly displays and announces the current and the next destination points to all passengers and provides an alternative alert system for the marginalized people to solve the problems related to vehicular transportation. Additionally, a mobile application provides first-time travelers with real-time information in the desired languages based on GPS location technology.

2. Related Works

Vehicular transportation has essentially improved human mobility and benefited several facets of the economy at large. Despite these benefits, there exist the problem of missing destinations for passengers using public transport with a few proposed models developed to resolve this challenge.

A short message service (SMS) based alerting system for train passengers was presented in [1]. This proposed system primarily consists of an infrared (IR) transceiver, liquid crystal display (LCD), keypad, and a global system for mobile communication (GSM) modem connected to a microcontroller unit. A passenger upon receiving a ticket enters the required destination station number and personal mobile phone number via a keypad. An LCD displays the input data to the passenger to ensure that the user information provided is accurate. An IR sensor located before each destination station is activated based on the train's arrival and a signal is sent to the microcontroller. The received signal which contains a particular predefined station number is processed and relayed to a GSM modem for the passenger to be alerted via SMS. Although this system provides easy identification of destination stations and access to arrival time, the use of SMS for destination alerts renders the system inefficient in times of packet delays or losses due to network congestion or traffic.

In [2], the model presented is composed of a transmitter and receiver section. The transmitter section is essentially made of a keypad, power supply unit and a radio frequency (RF) transmitter interfaced to a microcontroller unit. Similarly, the receiver section consists of an RF receiver, global positioning system (GPS) module, voice chip, amplifier, loudspeaker, power supply, and an LCD connected to a microcontroller. Upon the purchase of a ticket, a passenger's destination is taken, stored, and transmitted to the receiver section. The transmitted data is received by the RF receiver, stored in the microcontroller, and fetched upon request. The GPS module simultaneously tracks and relays the area GPS coordinates to the microcontroller for processing. Based on the programmed algorithm, the area GPS and the passenger's destination GPS coordinates already stored in memory are compared and an announcement is made when a match is found. An LCD is provided as further notice to passengers. This model is user-friendly nonetheless it requires DC to DC converters since the system has no independent power supply unit.

Regarding the model showcased in [3], an android based mobile application was developed for alerting passengers upon arrival to their destination based on a GPS location system. The application provides options for bus selection, city to commute to and destination station with a switch button to set an alarm corresponding to the selected destination. Based on the selected arrival point or destination station, its coordinates and radius of geo-fence 300m from the destination station are called up upon arrival. An alarm is triggered upon entry into the predefined geo-fence to notify passengers. A dismissal and reset buttons are provided to deactivate and apply modifications respectively. Even though the development of this model is economical, it is, however, dependent on an internet connection, and network strength to provide accurate data and alert passengers. These requirements increase battery drainage thus less effective for long travels.

A few other works presented the use of both global systems for mobiles (GSM) and GPS technology in passenger destination alert systems in vehicles [4,5]. The design developed in [4] offers a smart real-time alerting system for passengers with android mobile phones assisted through GSM and GPS location identification. The system principally employed a GSM and GPS module, IR sensors, power supply, and LCD interfaced to a microcontroller unit. A passenger's information is taken with an onboard touch screen, processed, and stored by the microcontroller. A signal is returned by the GPS module once the destination station has been reached and an alarm in the passenger's mobile phone is triggered via SMS through the GSM module. Though this design is simple to implement and cost-effective, it is only for android platform users.

About the model in [6], a GPS-based passenger alert system was proposed to provide a convenient location of destination stations. This system primarily utilizes a GPS module, LCD, and an audio or voice system connected to a microcontroller unit. The GPS module receives real-time location coordinates which are fed to a microcontroller for processing. The designated bus stops are displayed on an LCD and announced via the audio system upon arrival to alert passengers. This system is economical, but there are no test results to project the efficiency of the system.

The model in [7,8] implemented a real-time passenger information system (RTPIS) that employs GPS and GPRS via server communication. In [7], the system was developed to track the real-time location of vehicles, predict arrival time using the estimated time of arrival (ETA) algorithm, and alert passengers. The system consists of a vehicle unit, station unit, and a centralized data processing server. The vehicle unit which represents the hardware incorporates a memory, audio, and display unit, keypad, GPS, and GPRS module interfaced to a microcontroller unit.

Table 1 Already Existing Passenger Destination Systems

Country	System
USA bus [17]	The metro bus destination system of the USA is a system incorporated into the metro bus in Houston. The Houston system is made up of a cord or rope, LCD, and a recording system with a speaker. When a passenger is getting closer to his/her destination, the rope is pulled, and it causes a ding sound. The LCD then displays "stop requested" and the driver stops at the nearest bus stop. If a passenger does not know his/her destination visually, the speaker announces the destination, as the bus gets closer to the bus stop.
Germany bus [20]	The public transport system in Germany is generally very good. It is very practical to live in any large German city or metropolitan area without owning a car. Even medium-sized cities have good public transportation networks that use buses, trams, and urban/suburban rail lines to move people around. A round sign with a green H in a yellow circle identifies a Haltestelle, a bus, or a tram stop. At some stops, there may be an electronic sign that indicates the route number and when the next bus or tram will arrive. In almost all cases, you will find a framed timetable on a post at the stop. In a bus, there are buttons on posts along the aisle that you press to signal when you want to get off. Modern buses and trams have an electronic sign (display unit) above the driver's compartment that indicates the name of the next stop, and "Bus hält" ("bus will stop") if someone has pressed the stop button. In some cases, you will hear a chime and a recorded voice that announces the name of the next stop.
Singapore bus [18]	Public transport systems in Singapore are good. The buses are spacious which makes the passenger very comfortable. Even when the bus gets full and some of the passengers must stand, it does not get too congested. Stop buttons are placed at vantage points in the bus for easy accessibility by the passenger. When the passenger gets to his or her destination, the passenger needs to press a button to open the gate. Passengers pay transportation fare to the bus conductor before boarding the bus.
London bus [21]	The London bus system is more advanced compared to Singapore. London uses so many forms of buses including the double-decker buses. The communication system between the passenger and the driver concerning when the passenger wants to get off is also good. When a passenger wants to alight at a place, the passenger must press a button indicating that he/she wants to alight. When the button is pressed a display unit displays the information "Bus Stopping" on the screen. There are at least two display units on the bus. One in front of the driver and the other one in front of the passengers. Buttons are fixed on the pillars in the bus. When the button is pressed it takes about five seconds to display the information "Bus Stopping" on the screen. There is also a beeping sound whenever the button is pressed. This is simply to inform the passenger that the command has been sent. It also indicates that the button is working and in good condition. In cases where the button fails, the passengers must shout to the driver when they want to alight.
Taiwan bus [19]	The transportation system in Taipei is advanced in terms of technology and comfortability. There is an electronic board in front of the passengers that displays the stations as well as announces three (3) languages including English. There are stop buttons placed at vantage points for the passenger to press when getting close to his or her destination. Payment systems are also available for the passenger. Payment can be made with physical cash or a pay-as-you-go card which the passenger swipes on the device to deduct the amount of money to be paid.

The current location of a vehicle is computed via a GPS module and transmitted periodically to a central server through the GPRS module. These coordinates are compared with the coordinates of expected bus terminals initially obtained from the server via the microcontroller. Based on the program, a match is found upon arrival at the bus terminal and the result is displayed and announced to passengers. Although this system is highly efficient and has other functionalities, it is nevertheless capital intensive. A few works have been conducted to provide destination alert and navigation assistance to marginalized people [9-11]. An alert system using radio frequency identification (RFID) technology was proposed to assist the blind [9]. A stationary bus terminal unit and a mobile bus unit each containing an RF module were interfaced to separate microcontroller units. An impaired passenger at a bus terminal provides an input to the stationary bus terminal unit via an RFID tag. The signal generated is transmitted to the bus unit and a voice synthesizer converts the bus routes into audio outputs. A buzzer is used to notify the arrival of a bus at a destination terminal thus ready for boarding or alighting. This model effectively aids the visually impaired, but it is not cross-platform.

Information systems for urban passenger transportation are currently based on the Internet of Things (IoT) [12]. Although this type of information system is capital intensive to implement on a larger scale, it provides an intelligent and reliable platform for passenger transportation in auto-piloted electric vehicles [13] as well as improving the information system by employing cloud services [14] and critical appraisal of web-based information systems [15]. Based on GPS communication, real-time tracking, monitoring, and alerting of vehicles [16] are readily interfaced to the cloud and easily accessible in real-time.

The Table 1 contains countries where there is a complete similar system in use.

3. Material and Methods

The passenger destination system for commercial vehicles (PDSCV) has its objective to provide effective and easy communication between drivers and commuting passengers. Communication in terms of where the passenger will alight, alerting or informing the driver timely about his or her wish, and the system also informs users of the possible next bus stops were implemented. The PDSCV system as opposed to the existing systems would provide a more responsive and efficient system.

3.1. PDSCV System Architecture

Figure 1 PDSCV System Architecture

As illustrated in the PDSCV system architecture in Figure 1, the embedded onboard unit (EOU) is fitted in the bus or the commercial vehicle. The EOU is equipped with all the hardware and software necessary for the reception, processing, and transmission of any input and output signals. Besides every seat on the bus is a press button wired to the ports of the microcontroller embedded in the EOU. These press buttons are used to send hardware interrupts to the microcontroller unit, after which an alert is triggered to signal a passenger wishes to alight. At a bus stop, the EOU will display with the aid of the GPS module the current location and the next three (3) possible stops. A passenger can then press the alert button to inform the driver about the intention to alight and the LCD will display the text "stop requested" as shown in Figure 1. Through the GSM interface, departure information could be sent to passengers to aid in the smooth and efficient usage of the bus or commercial vehicle and to reduce commuter waiting times.

3.2. PDSCV System Block Diagram

The PDSCV system has mainly four (4) units or blocks as shown in Figure 2, namely the Embedded System On-board Unit (EOU), Communication Unit (CU), Audio Visual Unit (AVU) and the Alert Unit (AU).

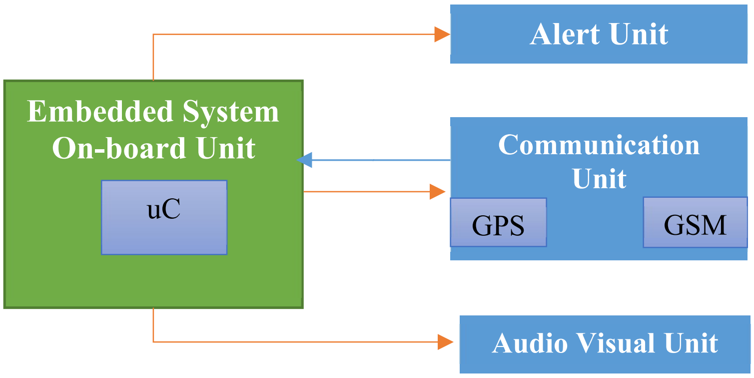

Figure 2 PDSCV System Block Diagram

The EOU receive and process all incoming signals from the CU with the aid of the GPS and GSM communication modules and transmit outgoing signals to their respective destination and or take necessary actions where possible. Depending on the information received by the EOU, it may trigger an alert via the AU or display additional information via the AVU.

3.2.1. Embedded System On-board Unit (EOU)

The EOU is the intelligent unit of the PDSCV system. All data processing, manipulations, forwarding, and transmissions are done here. The embedded software was written using the Arduino Uno platform. The source code contains logic to facilitate the operation of the GPS and GSM modules. It has programs to control the operations of the LCDs and all the menus presented to the driver as further depicted in the hardware use case diagram in Figure 6.

*3.2.2. Communication **Unit (CU)***

The CU contains a GPS module, GSM module, and an SD card module. The GPS module used is the Ublox Neo 7M. This component constantly provides the EOU with the current position of the bus. It supplies the microcontroller with strings from which the latitude position, longitude position, time, and date are retrieved. This receiver receives and tracks L1C/A signals provided at 1575.42 MHz by the GPS module. These modules use a software serial library to communicate information to the microcontroller. The library allows some digital pins say 3 and 4 others than the usual UART pins 0 and 1 to be used as Rx and Tx respectively. The SD card module is a breakout board, specifically the Catalex SD Card Module and is used to interface an SD card with the microcontroller. Upon constantly receiving the current positions of the bus from the GPS, the microcontroller checks from a pre-selected list of known coordinates of a bus stop to inform passengers of the next available stops on the route. This module uses the SPI protocol to interface the SD card with the microcontroller to facilitate communication. The SPI is a fast and synchronous serial communication protocol that is usually used for short-distance communication in embedded systems. It uses four wires to facilitate communication – SCLK (serial clock), MOSI (master output slave input), MISO (master input slave output), and SS (slave select, often active low).

3.2.3. Audio Visual Unit (AVU)

The AVU contains three LCDs and a piezoelectric buzzer. Each LCD comes soldered with an I2C backpack. This backpack allows the microcontroller to communicate with the LCDs using the I2C bus. The LCDs were used to display information to both drivers and passengers. The buzzer is used for audio signaling information to the passengers and the driver as well. The piezoelectric buzzer sends different frequencies to aid the provision of different pitches of tones. It works like the drum, the intensity of hitting the surface of the drum with the drumstick gives out a corresponding change of sound – in this case, the frequency change produces a corresponding sound.

3.2.4. Alert Unit (AU).

The alert system in the PDSCV is used to alert the driver that a passenger on the bus will alight at the next bus stop. It is made of a pushbutton placed at a vantage point in the bus. The pushbuttons were implemented with the help of the Arduino Uno’s inner pull-up resistors. The legs of the pushbutton are used to connect a sub-circuit, one leg is connected to the ground and the other is connected to a digital pin on the Arduino Uno which is connected to +5V. When the pushbutton is not pressed, the microcontroller reads a HIGH since the leg connected to the digital pin is always pulled to +5V and therefore the microcontroller reads a HIGH. When the pushbutton is connected, the connection to the ground becomes complete and it is now pulled to GROUND making the Arduino read a LOW. Therefore, the pushbutton is implemented as an ACTIVE LOW component.

3.3. PDSCV Prototype Design

A prototype was designed for the PDSCV system and tested. The results of the System tests are discussed under the subsection “results and discussions” in this paper. Figure 3 shows the schematic of the PDSCV system prototype. Table 2 contains a list of components used for the prototype implementation as well as the specifications of the various hardware components.

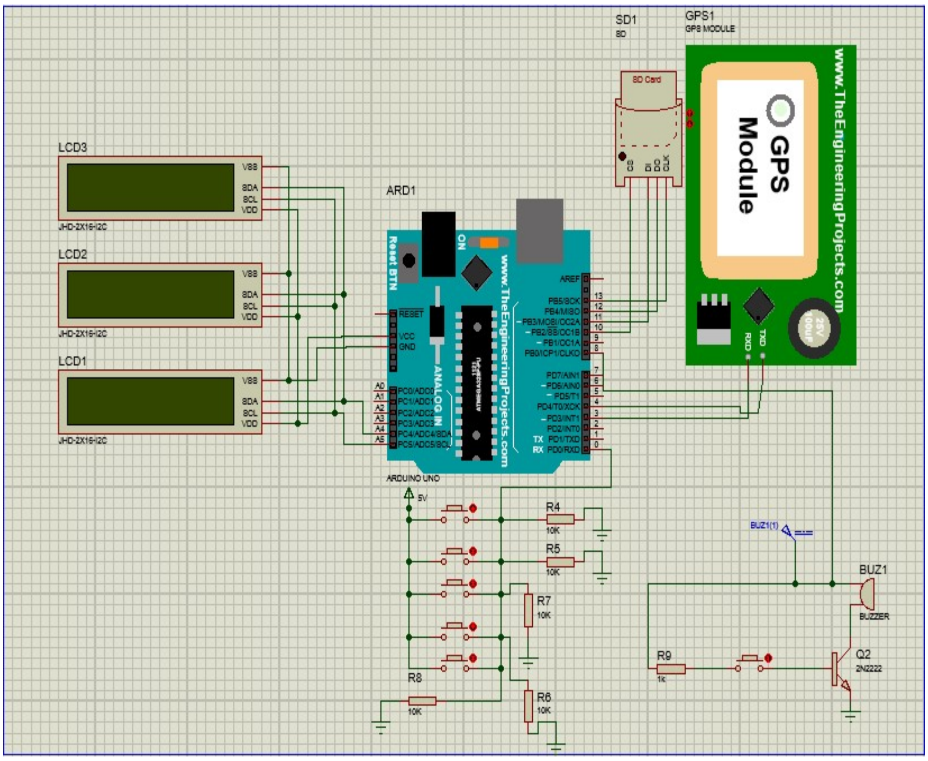

Figure 3 PDSCV System Prototype

Table 2 Hardware Components and Specifications

Hardware Component	Specifications
Buzzer [25]	Low power consumption. No contacts, therefore, no noise and highly reliable. Sound pressure level: 70 dB Operating voltage range – 25V p-p max Capacitance – 19nF ± 30% Operating Temperature Range: -20 to + 70°C
LCD [26]	Interface with 8 bit or 4bit MCU available 192 kinds of alphabets, numerals, symbols, and special characters (ROM) Other preferred characters can be displayed by character generator (RAM) Compact and light weight design Single power supply drive Supply current: 2mA Operating voltage: 3.0 – 11.0 V
GPS Module [24]	GNSS engine for GPS / QZSS, GLONASS. Combines low power consumption and high sensitivity. Internal oscillator and a real time clock crystal Active antenna/LNA supply TTL level, compatible with 3.3V/5V systems Baud rate 9600 only Power supply voltage: min :1.65V Max: 3.6V Operating voltage: 2.7V-5.0V (VCC input) Operating current: 35mA TXD/RXD impedance: 510 Ω Minimum gain of antenna: 15dB Maximum gain of antenna: 50 ^{15} dB / 30 ^{16} dB
GSM Module	SIM9000 Module

Hardware Component	Specifications
Arduino Uno [22-23]	Based on Atmega328P chip. 14 Digital I/0 Pins (6 for PWM output). 6 analog input pins. 32kB Flash memory (500B used by boot loader). 2 kB SRAM. 1 kB EEPROM. Clock speed of 16 MHz Operating voltage: 5V Recommend Input Voltage: 7 – 12V Input voltage limit: 6 – 20V DC current per I/O pin: 20mA DC Current for 3.3V pin: 50mA
SD Card Moule	Catalex SD Card Module
Push button [27]	Crisp clicking by tactile feedback Prevent flux rise by insert-molded terminal Ground terminal attached Snap-in mount terminal Operating Temperature Range: -20 to +70 °C Type of operation: Tactile feedback Circuit configuration: Push-on Momentary Power rating: MAX 50mA 24VDC

3.4. PDSCV Workflow and Use Case Diagrams

The PDSCV system workflow is shown in Figure 4. At the start of each journey, the driver set the route and final destination after which the travel or journey information is displayed on the LCDs. As soon as the vehicle moves or takeoff, additional routing information stored in the ROM of the EOU are fetched and the various bus stops along the chosen route are displayed on the LCDs for the passenger's attention. A passenger wishing to alight at a particular stop can then notify the driver by pressing on any pushbutton close to his seat position after which the LCD would display the "stop requested" message and the driver would stop upon reaching the said spot.

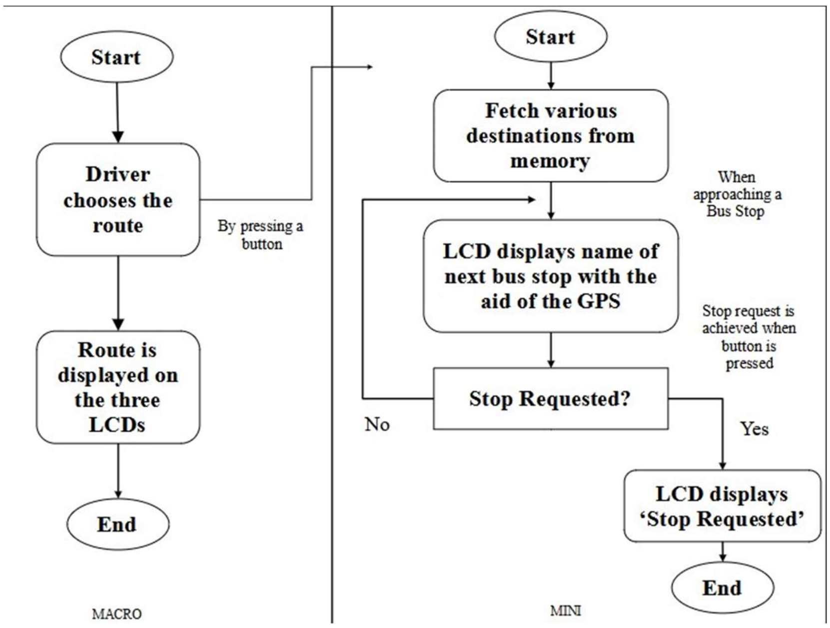

Figure 4 PDSCV System Workflow

The PDSCV has mainly two (2) use cases, namely the software and hardware use cases as shown in Figure 5 and 6. Detail description is given under the subsection "results and discussion" in this document.

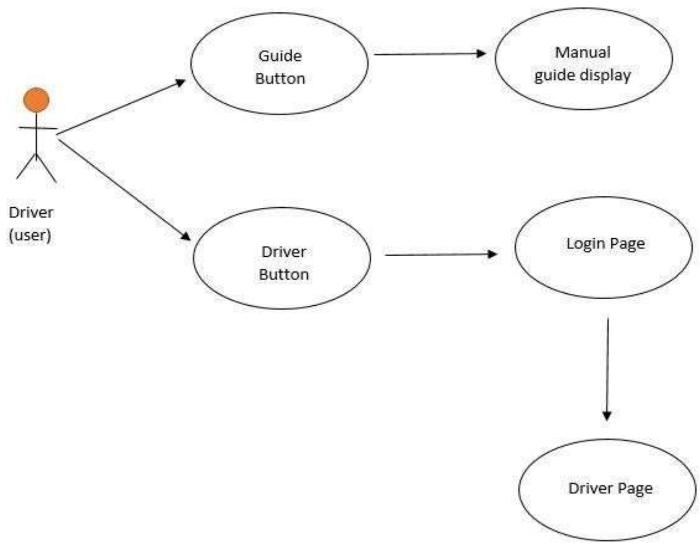

Figure 5 PDSCV System Software Use Case Diagram

The system software use case is shown in Figure 5. A driver has two (2) options: As a new driver to read the user guide or manual or as a known driver to activate the driver button to initiate the start of the journey. A new driver upon activating the guide button, the user manual would be displayed in a step-by-step function. The "results and discussion" section contains self-explanatory screen shoots for this.

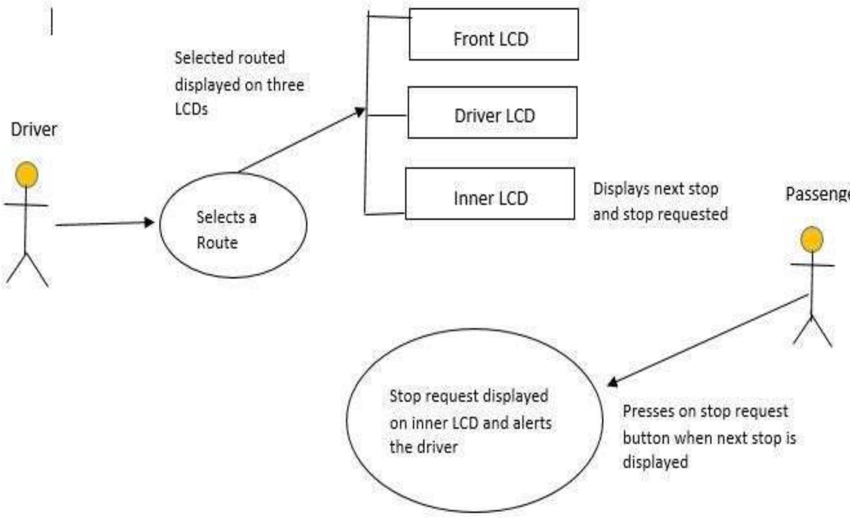

Figure 6 PDSCV System Hardware Use Case Diagram

The system hardware use case, as illustrated in Figure 6, has two actors: the driver and the passenger. The driver can select a route for the journey and trigger events for cloud database query of journey information to be sent to the various LCDs (Front, Driver, and Inner LCD). The LCDs would then display at regular intervals the possible next bus stops to the passenger. The Inner LCD display mainly the next stop and passenger stop request to such wish has been received from any passenger. The passenger on the other hand would notify an alight wish to the driver by pressing on any of the pushbuttons when the next possible stop is displayed.

A mobile software application for the PDSCV system was developed mainly to aid the drivers on how to use the system and to report issues during driving whenever it happens. The mobile application was developed using Java as the programming language. The mobile user application has two (2) main buttons: Guide and Driver buttons and these are described in detail under subsection "results and discussion" in this document. The mobile software application receives via the intelligent hardware onboard unit pre-departure information and therefore saves passenger waiting time at bus stops.

4. Results and Discussions

Figure 7 shows the first page of the PDSCV mobile software application when run. The user has the option to choose a tour guide or to register or login as a driver.

Figure 7 PDSCV System Mobile Software Application

The Guide button when selected, would activate a system manual or user guide. It is designed to give the driver an idea of how to use the PDSCV system and how to go about using the driver page on the application. This button when clicked displays swipe images with text to aid the driver.

Figure 8, 9 and 10 contains various self-explanatory screen shots.

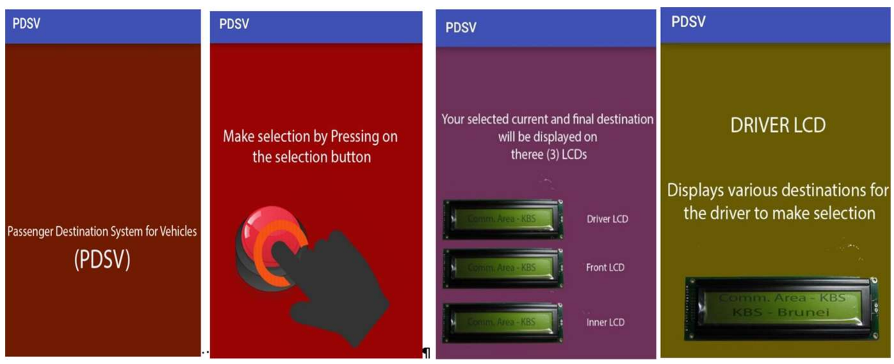

Figure 8 PDSCV System Guide 1

Figure 9 PDSCV System Guide 2

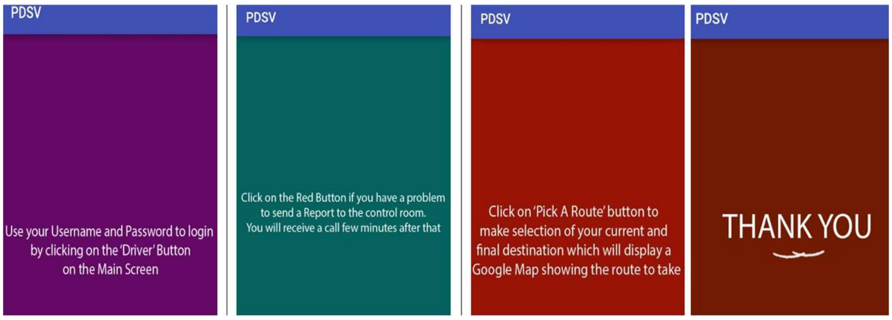

Figure 10 PDSCV System Guide 3

The Driver button when selected leads to a login page, where a driver is required to input his username and password. Upon successful login, the drive page is launched. There is no registration section with this system software application. Drivers are provided with already registered credentials such as the username and password to login into the application. Figures 11 and 12 show some screenshots during the test process.

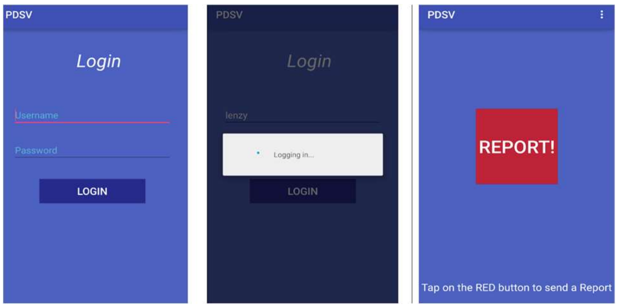

Figure 11 PDSCV System Driver Page 1

The driver page has a report button which helps the driver to make a report whenever a problem is encountered. By clicking on the 'Report Button', a message and for that matter, a problem encountered is sent to a cloud database against the driver's name indicating that, the said driver is having a challenge and needs assistance. An alert dialogue is used to determine if the driver wants to send the report. The driver is later informed if the message has been successfully transmitted or otherwise. Figure 12 shows screenshots during the test process.

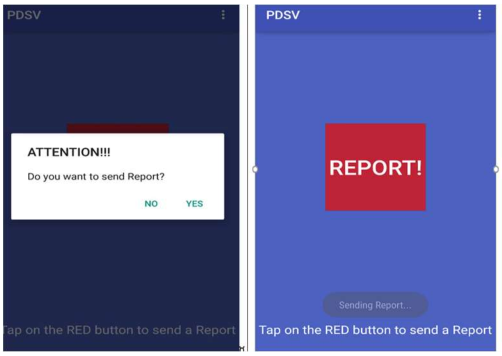

Figure 12 PDSCV System Driver Page 2

The system cloud database interface as depicted in Figure 13 would log all activities. Credentials of drivers, passenger alert notifications, and other journey challenges are all recorded into the cloud database for future retrieval, system maintenance, and possible upgrade.

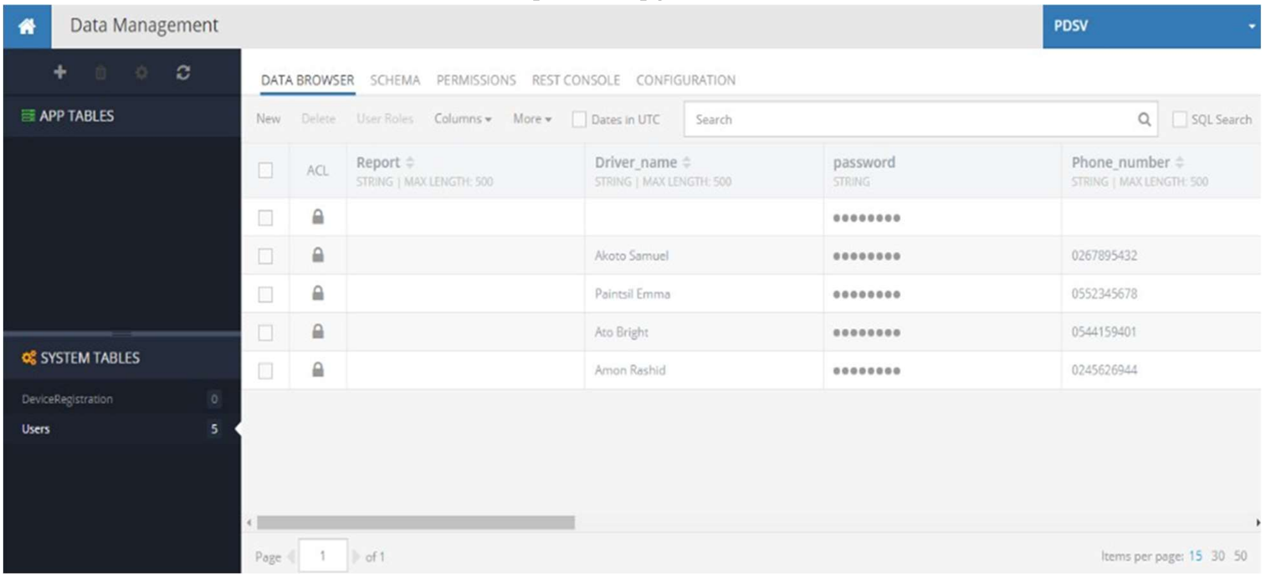

Figure 13 PDSCV System Cloud Database

Table 3 contains a comparison of the designed PDSCV system with other existing systems.

Table 3 Comparison of Some Existing Systems with PDSCV

Parameters	Mohd *et al* [3]	Hugo *et al* [12]	Jagadale *et al* [1]	Gholap *et al* [9]	This work
Installation Cost	High	Higher	High	Low	Low
Maintenance Cost	High	Higher	Low	Low	Low
Platform	Mobile phone (Android) Application	Mobile App, Web server and GPS	Mobile App GSM	RFID tag, reader and Microcontroller	GPS and GSM
Coverage perimeter	Less than 300m from destination point	1m-35km	1m-35 km	7cm-30m	1m-35km
Response time (Timeliness of information content)	Not precisely accurate	76.6%	After 8s	After 2s	After 2s

5. Conclusions

In this paper, the design of a passenger destination system for commercial vehicles has been proposed and implemented and tested. Controlled by GPS technology, the alert system has real-time functionality which provides accurate data. The system covers all groups of people with a variety of alert options or mechanisms. The performance of the developed passenger destination alert system was tested, and it achieved good results in terms of real-time notification and bridging the communication gap between the drivers and passengers. Predeparture information is sent to passengers, thus, this can serve as a cost-effective and efficient passenger destination alert solution for travelers who commute with public vehicles in developing countries.

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