Android-based Public Transport Infotainment System in Uganda

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Abstract: Typically, in Uganda, information about public transport such as departure time and destination is passed through oral communication. However, the use of both static and real-time passenger information systems for public transport have in the last few decades been widely adopted in most of the developed world. Therefore, this paper proposes a practical implementation of a real-time passenger infotainment system for a public transport system such as a fleet of buses in Uganda. An android development board based on Rockchip's former flagship RK3399 was used to develop the proposed system. The resultant prototype has been tested on 64 informal bus-stops along the Kampala-Soroti route in Uganda. Journey information such as destination, next stops and off-route notifications are shown on a televison inside the bus. At designated bus stops, arrival and departure information are also displayed. The proposed system further gives the bus managers the ability to monitor the locations of all their buses in real-time on a map. This is promising for sustainable transportation development for modernization of public transport management systems in Uganda.

Keywords: Intelligent routing; Passenger Information; Public Transport

1 Introduction

The discovery of Global Positioning System (GPS) and Global System for Mobile Communication (GSM) made it easy for real time vehicle tracking (Figure 2) and transport management of automobiles [1]. The transport management system can be used in public transportation especially buses which travel long distances with many stops. In most cases especially on high ways, buses move at a very high speed which makes difficult for passengers to determine their stopping centers, hence making buses un attractive for passengers due to these uncertainties [2]. A real time passenger information system utilizes a number of technologies to determine the buses' locations and then utilize this real time information to make predictions of bus arrivals at different bus stops along the route. The passengers in the buses are informed about the next stop through the displays and the speakers installed in the buses [3]. This will make public transport especially buses in Uganda more friendly to passengers, and this will in turn reduce passenger uncertainties in determining their final destinations or bus stops [4-6]. A lot of research has been undertaken on passenger information systems but most work focuses on pre-recorded information with an assumption that the location coordinates have been already captured by GPS [7-10]. This is done especially where automobiles such as buses move along the same route always. In addition, the system controller is supposed to manually operate the system at each and every bus stop. However, in some countries like Uganda, buses keep on changing routes depending on traffic jam in a given route. Therefore, a system should be able to automatically capture new coordinates in case a bus moves along a new route such that real time information can be displayed to passengers. In addition, the system should automatically inform the next bus stop to passengers by using different monitors and speakers installed in a bus [2, 4]. This is because, the night buses move at a very high speed and sometimes conductors sleep which makes it impossible to inform the passenger about their next stops if the system is manually operated. Furthermore, from the research paper published by Amin T. Kiggundu in 2020, they confirmed that, "Passenger information systems (PIS), is the area the bus companies have not paid much attention to. Findings show that, on average, 46.1% disagreed, 20.4% were neutral and 31.5% agreed about the use of passenger information systems by the two bus companies. There is need for the two companies to improve the information management and dissemination to the passengers to be able to make informed travel decisions in the areas of transit fares, travel timetables and general bus services" [4]. They also recommended the promotion of systems in Uganda which can help passengers in planning their journeys as going to bus station without any prior knowledge on when the buses are leaving thus causing uncertainties. In this study therefore, the focus is put on investigating the practical development of a system which can be implemented as a real-time passenger information system for a public transport system like a fleet of buses in Uganda.

2 Principle

This section briefly explains the theoretical principle behind the operation of GSM, GPS and MQTT.

2.1 Global System for Mobile Communication (GSM)

Mobile cellular technologies have evolved through a series of generations. The first generation was known as 1 G where voice calls were bounded to one country and only analog signals were used with speeds of 2.4 Kbps [11]. Around 1980's, the second generation known as 2 G or global system for mobile communication (GSM) emerged. In this generation, services such as digital voice, picture, text and multimedia messaging were rendered with speeds of up to 64 Kbps. Thereafter, 2.5 G emerged which was like a hybrid of 2 G and 3 G with general packet radio service (GPRS). Services rendered in 2.5 G are phone calls, web browsing, e-mail messaging with speeds of up to 144 Kbps. In 2000, 3 G egressed thereby enabling services like videocon- ferencing, faster web browsing and TV streaming with speeds of up to 2 Mbps [12, 13].

Then in 2010, a fourth generation known as 4 G in which there are higher data rates, high-quality video streaming and other highly improved communication services with enormous speeds was introduced. Today, the technology world in Uganda is eagerly waiting for 5 G which is anticipated to be a substantial advance on previous networks with enormously enhanced data speeds, high capacity, low latency and dynamic information access. The GSM architecture (Figure 1) is a basic architecture in cellular network consisting of four subsystems which include, Mobile subsystem (MS), base station subsystem (BSS), network switching subsystem (NSS) and Operation support subsystem (OSS).

Mobile subsystems. It consists of a mobile equipment and a subscriber identity module (SIM). A mobile equipment is a hardware used by a subscriber to access a network and it is identified by international mobile equipment identity (IMEI) number. A SIM is a detachable smart card containing an international mobile subscriber identity (IMSI) number. It allows users to send and receive calls. Base station subsystem. It consists of two components which include base transceiver (BTS) and base station controller (BSC). The BTS sends and receives signals from mobile phones, performs functions like encoding, multiplexing, encryption and modulation. BSC controls a group of BTS through allocating radio channels and handovers from one BTS to another.

Network switching subsystems (NSS). It contains mainly five components which include mobile switching center (MSC), home location register (HLR), visitor location register (VLR), equipment identity register (EIR) and authentication center (AUC). Mobile switching center (MSC) is the heart of GSM network, manages services like registration, authentication and also performs call routing, call setup and call switching. In addition, it communicates with other NSS components such as HLR, EIR, VLR and others. Home location register is a central master data base of all subscribers' current location and information. Visitor location register is a subset of HLR and holds local database of users currently visiting location in other domain. Equipment identity register is a database that contains all valid handsets on a network using their IMEI numbers and marks invalid IMEI number if a handset is stolen. Authentication register. It is a protected database that has acopy of IMSI number for authentication and encryption task. It can also protect a user from any kind of fraud on a network. Operation support subsystem. It is connected to all components in the switching system on a GSM network. It performs different tasks on the network such as, security operations, performance management, network configuration and maintenance tasks [16, 17].

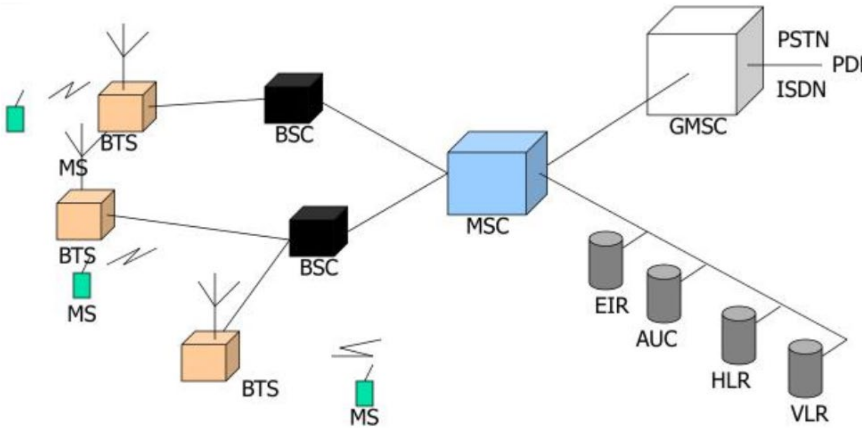


Figure 1
GSM archtecture

2.2 Global Positioning Network (GPS)

Global Position System is a satellite system which is used to give information of the current location and time. This navigation satellite system which incorporates GPShas a number of satellites ranging between 24 and 33 satellites [18, 19]. In 1995, the United States launched the global positioning system which was fully working or functioning well. Unlike other systems, GPS does not necessarily require active internet to operate even though its presence improves its efficiency. Since GPS is not highly affected by the weather conditions such as temperature and humidity, the results obtained while locating the position of an object using GPS are highly accurate and can be relied on.

GPS navigation system can be used in vehicle tracking and transportation navigation systems, incorporated in smart watches, laptops, mobile phones and many other electronic components used in tracking applications [20]. At over 20,000 km above the sea level is a constellation of satellites each orbiting the Earth approximately for 12 hours. These satellites are continuously beaming data down to the Earth, which in turn is received by devices such as phones or navigational units in cars, allowing people to see where they are on the planet.

GPS works through trilateration, not triangulation or multilateration, which commonly misconceived.

There are many different types of navigational satellite systems from countries across the world, but the most popular and commonly used system is Navstar, which is commonly known as GPS, a system in United States of America. Although most phones and devices tend to have capabilities to use both GPS and GLONAS, GPS satellites are set in such away that from almost any where on the surface of the Earth, you should have a direct line of sight of at-least four GPS satellites. This is quite important on the basis that GPS position requires atleast four satellites to calculate three position coordinates and clock deviation [9, 21]. GPS units are receivers, there needs to be something sending sort of signals to devices such as phones to receive.

Each GPS satellites broadcasts a navigational message towards Earth which contains an extremely accurate timestamp (obtained through atomic clocks on-board the satellite), and the satellites also broadcast their position at the time of broadcast, which all GPS signals broadcasting at 1.57 GHz (L1 signal) and 1.23 GHz (L2 signal). These two bits of information allow to begin working out on the current positions on the Earth. With satellites all sending exceptionally accurate time down to the Earth, phone or GPS receiver can compare the difference between the signal being sent and received to calculate the distance between the GPS receiver and the satellite [22, 23]. By multiplying this time difference with the speed of light, the distance between the GPS receiver and satellite can be obtained [24].

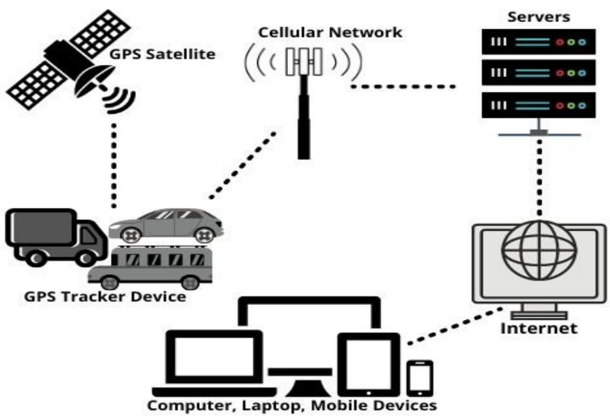


Figure 2
Basic diagram of GPS tracking architecture [1]

2.3 Message Queue Telemetry Transport (MQTT)

MQTT is a simple light weight protocol for transmitting data between machines and it has become one the most important protocols in the internet of things especially machine to machine communication [25, 26]. In 1999, Dr. Andy Stanford- Clark and Arlen Nipper developed a light weight protocol (MQTT) with low band width and power requirements which was intended to transfer monitoring data from an oil pipe line by an expensive satellite link. In 2013, it was standardized as open source under the Organization for the Advancement of Structured Information Standards (OASIS). Later in 2016, it was approved as an ISO standard [27]. The main purpose of MQTT is to maximise the available bandwidth. MQTT has a communication model called publish/subscribe (pub/sub) which is used to directly send/receive signals to and from endpoint.

In this type of model (pub/sub model), the device or a client (publisher) that sends a message to another device or client (subscriber) are separated from each other as shown in Figure 3. In other words, the publisher and subscriber are decoupled from each other. The broker acts as a middle man between a publisher and a subscriber since they do not communicate to each other directly, a broker connects them as indicated in Fig. 3. The term ”publish” is primarily used when a device is sending data to a server or a broker, and the term ”subscribe” is used when a broker or a server is receiv- ing data.

In addition, the pub/sub model allows a number of clients to connect to a broker to subscribe to topics of their own interest [28]. However, in case of broken connection between a subscriber and a broker, a broker buffers the communi- cated messages and then sends them to clients when the connection is again established. And for the case of lost connection be- tween a broker and a publisher, the broker can opt to transmit a cached massage accompanied by instructions from a publisher to a client [29, 30].

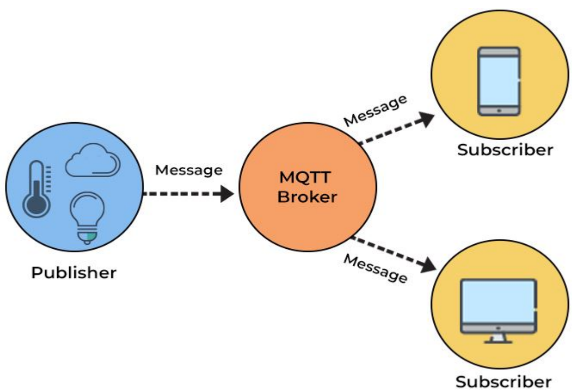


Figure 3
Block diagram of MQTT [29, 31]

3 System Model

The system consisted of an on-board displays, bus stop displays, monitoring stations as shown in the block diagram Figure 4. The bus was equipped with a low power micro-computer with GSM and GPS capabilities. After receiving gps coordinates from the satellites, the micro-computer used this information to compute passenger information for on-board display as well as for further transmission to the server. The server hosted relevant services for the monitoring station, the bus stop display as well as mobile phone apps which can be accessed through the internet.

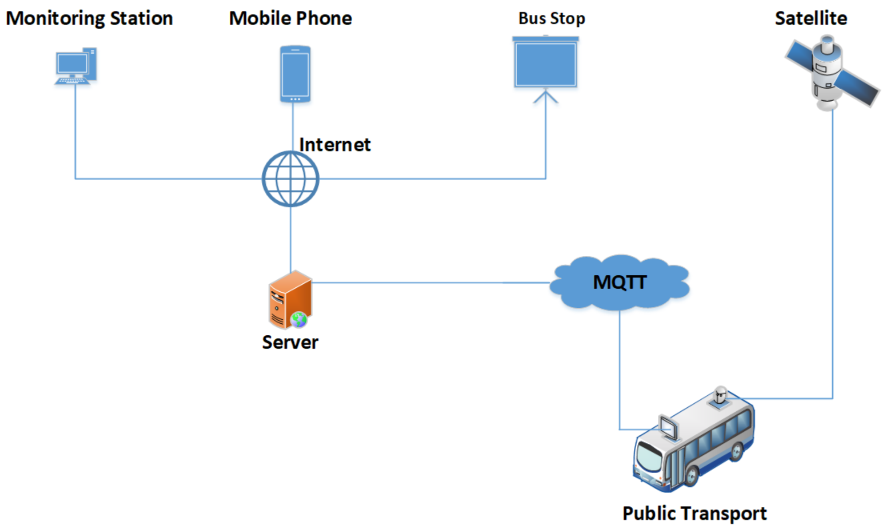


Figure 4
Block diagram of the passanger information system

3.1 On-Board System Design

For this study, an android development board shown in Figure 5 which is based on Rockchip's former flag-ship RK3399 was used. RK3399 is a low power, high performance processor for computing, personal mobile internet devices and other smart device applications. This board was used because it is relatively cheap, has high definition medium interface (HDMI) output and can easily integrate GPS and GSM capabilities. Moreover, the use of android greatly simplified the task of designing user interface.

Every second, GPS signals are received by the GPS module. The micro-computer uses the GPS signals received from GPS satellites as well as the destination details provided by the bus driver to compute the next stops as well as their remaining distances. This information is then displayed on a display unit for the passengers as shown in Fig. 8. In case the bus is off-route, the words ”OFF-ROUTE” are displayed on the screen so as not to give incorrect information. In locations with no GPS coverage, the display shows ”NO GPS”, so as not to give incorrect travel information. Furthermore, tracking information is relayed to to a web server using MQTT.

The web server then uses this information to transmit the appropriate information to various stake holders such as the managers at the monitoring station, the waiting passengers through their mobile phones and bus stop information centers. The block diagram in Figure 4 shows the working principle of the developed system.

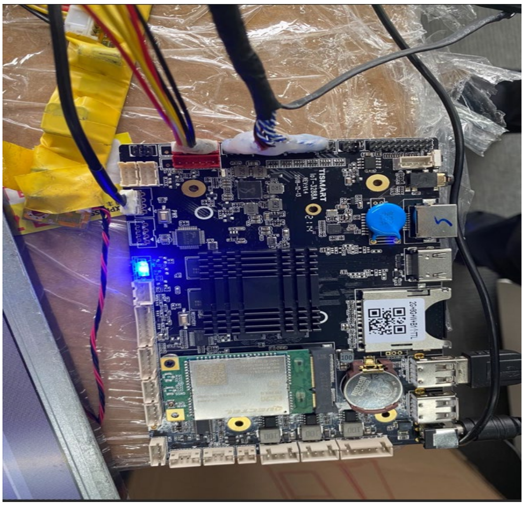


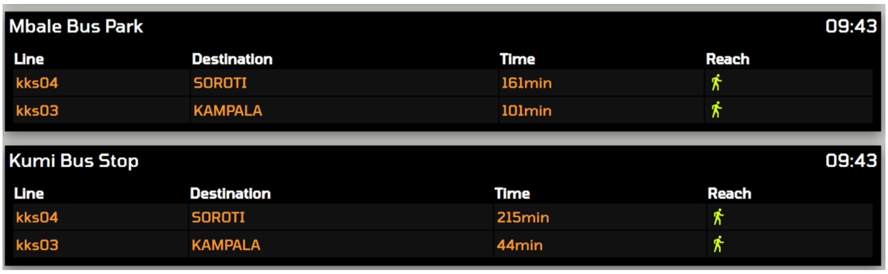
Figure 5
The RK3399 development board used in the experiment

In addition, the system provides the option of having onboard entertainment (infotainment) in form of music or movies. To do this, a USB flash drive containing music or movies is inserted into the micro-computer allowing the files to be played. The display section is divided into two parts with the upper part playing the files while the bottom section displays the next stop as shown in Figure 9.

3.2 Bus Stop Display

Just like for the monitoring station, a web server was used for the design as shown in Figure 6. In Figure 6, the time column indicates the minutes remaining for the bus to arrive at the bus stop. The destination column indicates the final destination of the bus. The line column indicates the bus number for example kks03.

The reach column of a man walking indicates that a bus is more than five minutes away. However, when the bus is less than five minutes to arrive, the walking symbol is replaced by a man riding a bicycle.



Mbale Bus Park 09:43

Line	Destination	Time	Reach
kks04	SOROTI	161min	🚶
kks03	KAMPALA	101min	🚶

Kumi Bus Stop 09:43

Line	Destination	Time	Reach
kks04	SOROTI	215min	🚶
kks03	KAMPALA	44min	🚶

Figure 6
Display showing arrivals at two bus stops

3.3 Monitoring Station Design

A web server was used to design the user interface used to display an interactive map, which showed the real-time positions of the buses along the kampala-Soroti route as shown in Figure 7.

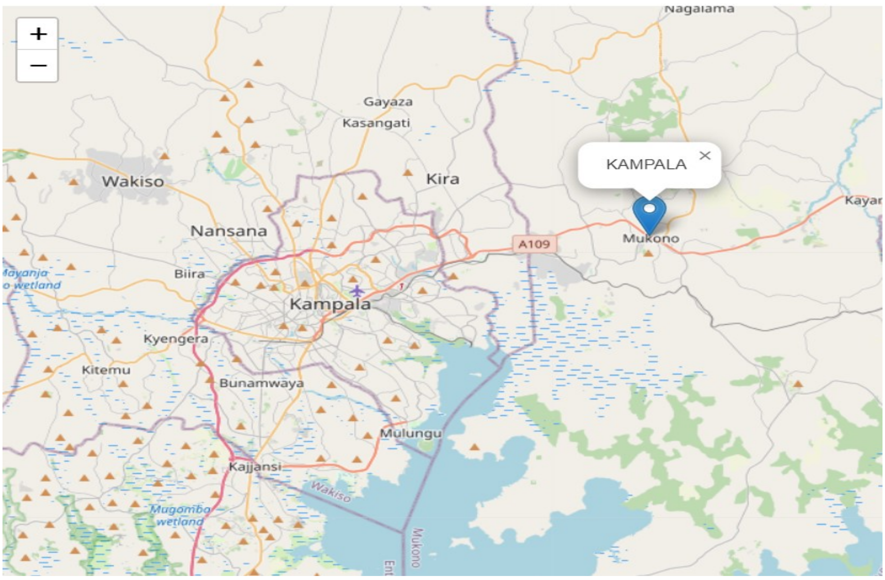


Figure 7
Bus tracking interface showing a bus destined for Kampala

4 Results

4.1 Simulation

Before the results could be tested on the route, a program was written in python to simulate the movement of the bus. This program would sequentially and periodically (typically after 1 second) send GPS coordinates of the route to the system using MQTT.

This allowed the system to first be tested without actually travelling the route thus saving costs. Snapshots from the simulation are shown in Figure 8.

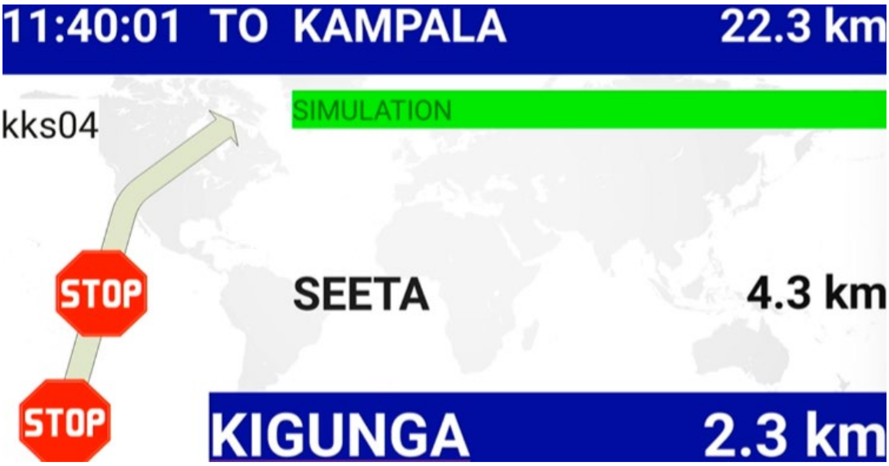


Figure 8
On-Board trip simulation

4.2 Experimental Results

After simulations were carried out, the system was tested on Kakise Company buses along the Kampala-Soroti Route in Uganda. Of the 64 informal bus stops, about 58 of them on average had constant available GPS coverage enabling reliable positioning while remaining 5 had unreliable GPS coverage.

The availability of GPS coverage for the same locations along the route varied depending on on different factors such as the time of the day as well as on the weather conditions.

Cloudy conditions caused poor GPS reception. These factors affected the reliability of the system. Parts of the route especially those with little settlement did not have reliable GSM coverage making tracking in these areas unreliable.

Figure 9
On-board system display on kakise bus

Conclusion

In integrated public transport infotainment system has been done. Based on the results of our study, an automatic GPS based real-time passenger information system for Ugandan transportation sector is tenable and it is empirically based on GPS data. This is promising for development of a semi-automatic transport infotainment system in Uganda.

However, such a system still requires manual input such as pressing of a button in the areas with unreliable GPS coverage in order to display the correct passenger information. Accordingly, this research is promising for sustainable ICT development and growth through harnessing responsible innovative solutions.

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