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Development of a Real Time Trains Monitoring System:Case Study of Tanzania Zambia Railway Authority

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***Abstract*—With the evolution of technology that has occurred in digital systems, new services have appeared that can be applied in railways. Radio communications play an important role in the management of, exploration and maintenance of railway transports. Due to the importance of efficient service delivery and security in railways, there is need to integrate the use of the Global System for Mobile communication and global positioning systems. Transportation is a large and important part of the economy of any country. Railway transportation is one of the main transportation systems worldwide. To this effect, we should have a good and strong monitoring system that can locate a train at every instant. In this research, a proposal has been made for the implementation of a Global Positioning System (GPS) and global system for mobile communication (GSM) based train monitoring system on Tanzania Zambia Railway Authority (TAZARA) railway network that will enable controllers locate their trains at every instant. The GPS-GSM/GPRS (General Packet Radio System) module will be incorporated in the system. A GSM/GPRS module will transmit the location information to a web server. Every track and locomotive will be assigned a unique number for identification. The information of the train location will be continuously updated when the train is moving and the users will be accessing the information via the web. The updated information will be stored in the web server. Clients will request for particular train status and a designed web application will show the status in a Google map. An alternative radio voice communication system will be incorporated in the locomotives in case of failure on the monitoring system. This implementation will greatly improve service delivery to the company.**

Key words: Global Position System (GPS), Global System for Mobile Communication (GSM), General Packet Radio System (GPRS), Railway system, train.

I. INTRODUCTION

Railway transport is mainly used to transport industrial and private goods as well as passengers. Accordingly [1], railway industry contributes a lot economically in many countries and the Indian railway is the largest railway network in Asia and second largest under one management.

Real time systems are classified into two ways: 1) Hard real-time system and 2) Soft real-time system. It is said that in hard real time systems, timing is very critical and cannot be substituted for other gains for the instance, the control of nuclear power plant. In terms of soft real time, timing is not so critical and this applies to computerized banking, ticket reservation, etc [2].

According to [1] though real time tracking of an item may be difficult, it is quite an important practice these days. There are several methods existing now for tracking the position of train along its route. Global Navigation Satellite System is one of the methods used in to locate the coordinates of the train. The other method is the use of RFID (Radio Frequency Identification) [3]. Though methods of coordinates location may be the same, the transmission of the captured coordinates to a processing centre vary. There are basically two modes of transmission of data applied in tracking systems namely cable and wireless methods. The most common are optic fibre and most recent radio system is the Global System for Mobile communication (GSM). Most of the GSM systems utilized is the sending of location coordinates via Short Message text System (SMS). This method has its own disadvantage in that sending of one text message attracts charge per message sent. However, with the developments in the telecommunications industry, another feature has been added which uses data packets to transmit the coordinates via the internet. The charge depends on the amount of data sent. Since the railway companies are supposed to manage their own systems in terms of signaling, communication and tracking, they are supposed to have their own telecommunication network so as to carry the required data. This is quite an expensive venture.

In Zambia trains run late due to various reasons. This has brought the desire to develop a real time train tracking system looking at Tanzania-Zambia Railway Authority (TAZARA) trains and track from New Kapiri Mposhi to Nakonde on the Tanzania Zambian boarder as a case study. TAZARA railway currently uses manual methods to monitor the position of their trains. Station masters on main stations communicate through telephone with the controllers at Mpika headquarters who then give the messages to the train drivers. The drivers have to stop at each station to get authority whether to proceed or not. Frustrating enough to the passengers on the platform, the information about train location or arrival is written manually on the notice boards. This data in most times is un reliable. There is always delay of train position knowledge by controllers as they rely on the remote station masters to alert them of the train's arrival at that particular station.

Problem Statement

Train railway line is divided into blocks. There are two types of block systems;1) fixed block system and non-fixed block system.

1. Fixed block system

Fixed block System refers to a system whereby railway lines are segmented into sections known as blocks and only a single train is allowed to run in each block at a given time.

Non-fixed block system

This system involves running trains on real time. Blocked stretches are monitored such that each train position is known through coordinates geographically or coordinates sent via a transmission medium and the position determined using Geographical Information System and Google maps.

However, two systems can still be employed simultaneously when there is need for maintenance works on certain stretches of the railway line. The pictorial presentation of the two systems is shown in figures 1 and 2 respectively. In non-fixed block systems, two trains can be allowed to run on the same track between two stations as long as their actual positions on the track are known. This is quite an efficient system in that waiting time at the stations is reduced.

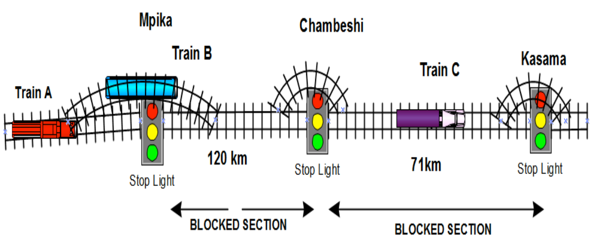

Figure 1: Example of Fixed block system.

(Only one train between stations in the same direction)

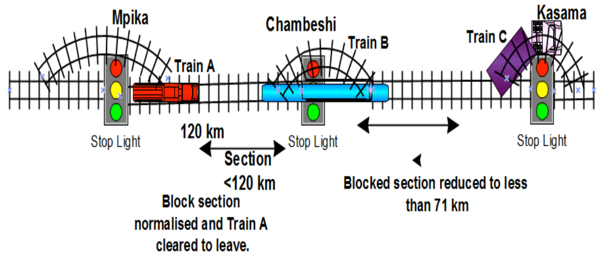

Figure 2: Example of Non-fixed block system. (Two trains moving along same stretch in the same direction.

Over the years, the signaling and telecommunications installations have been subjected to vandalism such that the existing system is non- functional in some sections hence operating below expectation. During the tour of TAZARA regional offices in October, 2015, the author noticed that they had challenges on train's movement monitoring as well as communication with the crew.

In order to provide excellent customer service at a minimal cost, TAZARA needs communication and signaling systems that are safe, efficient and accurate and function in real time. In addition, the systems should be easier to use and with replaceable parts.

Though the Company has plans to install modern signaling and telecommunications equipment, to address the current challenges, implementation has been hampered by financial constraints.

Tanzania -Zambia Railway Authority controllers have no way of determining the actual position of any train on the track at any time except when it reaches certain designated areas or side stations. This can lead to delayed train schedules and to some extent accidents.

This research project will present a solution to the current problem of not knowing the exact location of the trains through the use of a combination of Global System for Mobile Communication (GSM), Global Positioning System (GPS) and Geographical Information System (GIS) (online Google earth maps) technologies and software.

II. Aim of the Research

The aim of the research is to develop a Real time Tracking and Monitoring system for TAZARA trains using Global Positioning System (GPS), Global System for Mobile communication (GSM) and Geographical Information Systems (GIS) technologies.

The main objective of this research is to design a model system to track and monitor train locations whilst stationary and in motion for TAZARA in real time.

Preliminary survey was done to capture the coordinates of the railway line side stations covering a stretch from Kapiri Mposhi to Nakonde station on the Zambian side. This was necessary so as to plot the route for the research. The GSM coverage and received signal strength levels for the three cellular operators existing in Zambia namely, ZAMTEL, Airtel and MTN were also measured to determine which network covers most of the stretch under study. Table 1 shows the coordinates and GSM received signal strength levels of the stations covered under this research.

The graphical representation of the signal levels along the track is shown in figure 3.

Table 1: Waypoints and GSM Signal levels (RSSI)

	WAYPOINT	COORDINATES		GSM RECEIVED SIGNAL STRENGTH (RSSI) dBm
		S	E	AIRTEL
1	NAKONDE	-9.30965	32.75797	(-81)
2	MWENZO	-9.33059	32.67132	(-71)
3	MSANZA	-9.31307	32.6111	(-73)
4	KAPWILA	-9.30957	32.47543	(-67)
5	CHOZI	-9.39727	32.24868	(-71)
6	LUCHEWE	-9.45964	32.02312	(-51)
7	KALULU	-9.60744	31.98633	(-105
8	MAKASA	-9.66559	31.8977	(-69)
9	CHANDAWEYAYA	-9.79903	31.64026	(-109)
10	CHIMBA	-9.88485	31.53798	(-69)
11	NSELUKA	-9.94324	31.23986	(-67)
12	KUNGU	-10.18381	31.20667	(-85)
13	KASAMA	-10.24346	31.2067	(-93)
14	NKOLE MFUMU	-10.5365	31.20667	(91)
15	ISHITU	-10.6917	31.10771	(-103)
16	CHAMBESHI	-10.96279	31.07134	(-69)
17	MPEPO	-11.08366	31.10771	(-61)
18	KASONGO	-11.31298	31.23329	(-73)
19	KABUKA	-11.55157	31.27557	(-63)
20	SABWA	-11.75733	31.34721	(-65)
21	MPIKA	-11.8476	31.39091	(-87)
22	CHILONGA	-12.02592	31.27572	(-93)
23	KAPOKO	-12.17642	31.17782	(-83)
24	KALONJE	-12.37535	31.1021	(-99)
25	MULUNGA	-12.64817	31.01661	(-93)
26	FINKULI	-12.71922	30.98391	(-105)
27	LUKULU	-12.86471	30.84312	(-95)
28	LUSIWASI	-12.95048	30.68652	(-77)
29	KANONA	-13.0487	30.65509	(-93)
30	CHANKALAMU	-13.043	30.48574	(-93)
31	KABULUMA	-13.17494	30.33411	(-97)
32	SERENJE	-13.23396	30.21656	(-89)
33	CHISANGWA	-13.49239	29.81941	(-83)
34	NDABALA	-13.56463	29.71029	(-85)
35	NKOLONGA	-13.60067	29.61797	(-100)
36	MKUSHI BOMA	-13.64005	29.40443	(-87)
37	NGAMBWA	-13.71699	29.25523	(-73)
38	LUNSEMFWA	-13.78962	29.05089	(-79)
39	LUANSHIMBA	-13.90452	28.84679	(-107)
40	KAPIRI MAIN STN.	-13.9545	28.68178	(-57)

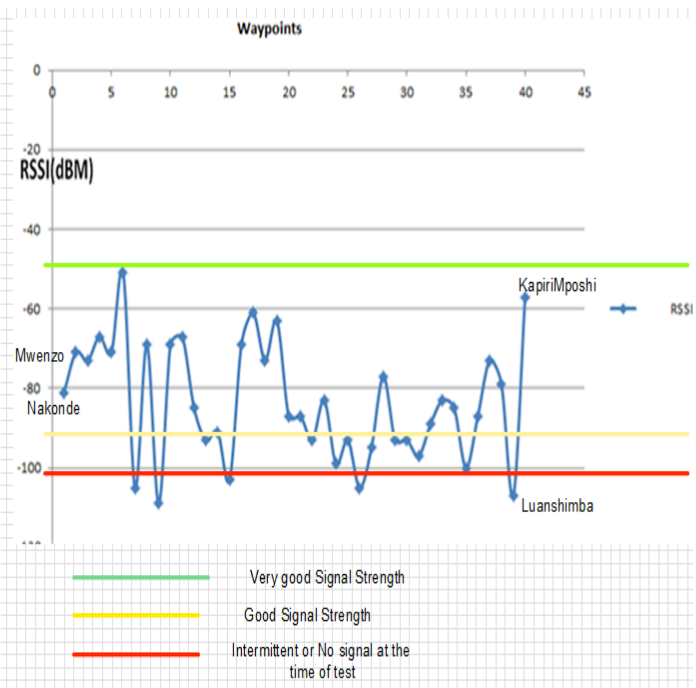

Figure 3: Graphical presentation GSM signal levels for Airtel.

III. REAL TIME SYSTEM

The proposed real time system for TAZARA aims to show that it is possible to achieve real time monitoring systems utilizing existing radio transmission networks for example, the Global System for Mobile Communication Systems (GSM) owned by other cellular companies and Global Navigation Satellite Systems (GNSS) along the railway line and eventually reducing the cost of the system. The proposed system further shows that it is possible to transmit the location coordinates via data packets using General Packet Radio System (GPRS) modules that can ride on G2 or G3 networks. Other scholars have come up with efficient real time location systems to track trains that require the railway companies to construct their own cellular network known as Global System for Mobile Communication-Railways (GSM-R) along the railway network for communication and tracking ability [4]. They have come up with improved methods of increased accuracy of coordinates capturing by upgrading sensitivity of Global Positioning Systems receivers. Figure 4 illustrates the approach taken for this research.

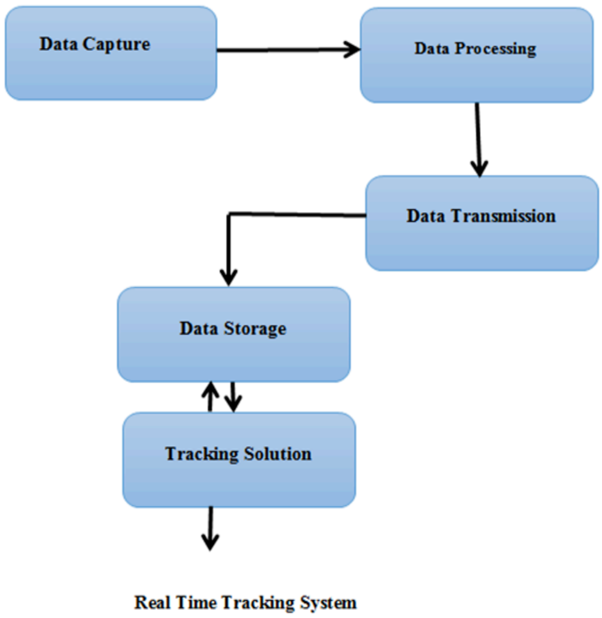

Figure 4: Real-time tracking solution approach

- Data Capture

The location coordinates will be received by the GPS receiver in a general National Marine Electronics Association (NMEA) format. The GPS receiver locks to the satellites upon the vicinity of three satellites and the fourth one is for time. The general NMEA sentences have several parameters that can be decoded according to the requirement of the system or use. The NMEA sentences contain information such as altitude, speed, latitude, longitude and real time clock. From the proposed structure of the research, the captured data by the GPS will serially be sent to the data processor.

- Data Processing

The data processor is the ATMEGA 328P an 8 bit microcontroller attached to the Arduino development board. The Arduino development board is a board where different components can be connected to do several researches. It uses Integrated Development Environment (IDE) software with an embedded C language. It allows the researcher to filter the received information and only the required data for display or transmission. The board is relatively cheap. The destination may be via SMS or Server for online display.

- Data Transmission

The Arduino development board will be connected to a shield called the GSM/GPRS module to transmit the train location details as processed by the microcontroller to the remote server. SIM 900 GPRS module which conforms to 2.5G General Packet Radio Service to send information via existing GSM networks along the line of rail. However GPRS modules have now been upgraded to 3G which even improves the speed of data transmission.

- Data storage

The transmitted location information will be transmitted to a remote server. Once the GPS is powered on and the Internet connection has been established, we obtain the longitude, Latitude, Speed, Time and Date. Using the AT-Commands like AT+HTTPPARA=URL we are able to define the URL concatenated with Longitude, Latitude, Speed, Time and Date respectively directing us to a .PHP web page. It's from this page where the respective selected values are extracted from the URL using Get Methods and inserted into the database table called train1 sitting on a XAMP server or on the hosted domain tazaratracking.co.za.

- Tracking Solution Display

The information will be accessed by authorized users only through Internet using the domain tazaratracking.co.za. After logging in, authorized users will be able to see recent train location coordinates, time, speed and date as determined by the microcontroller. The location coordinates of the train can now be pasted on Google map to see the exact location visually on the map. The proposed login window is shown in figure 5.

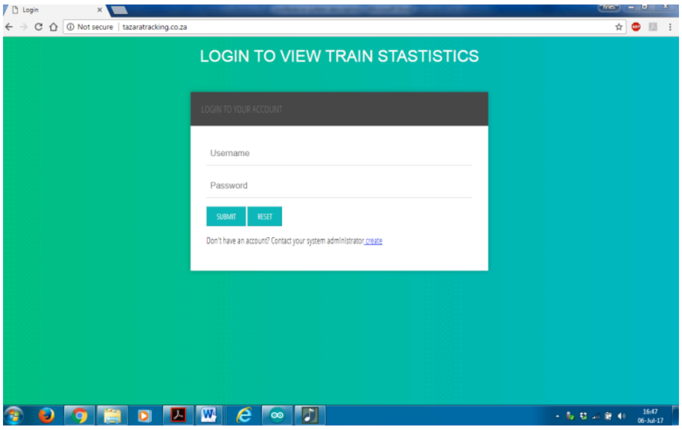

Figure 5: Logging in window demonstration

After logging in the display changes to the one shown in figure 6 where one is prompted to choose which train to monitor.

So far only one train has been considered for the research and clicking on Train 1, one will be directed to the page showing location coordinates, speed and time when the coordinates were captured. Table 2 shows how the display with information looks like.

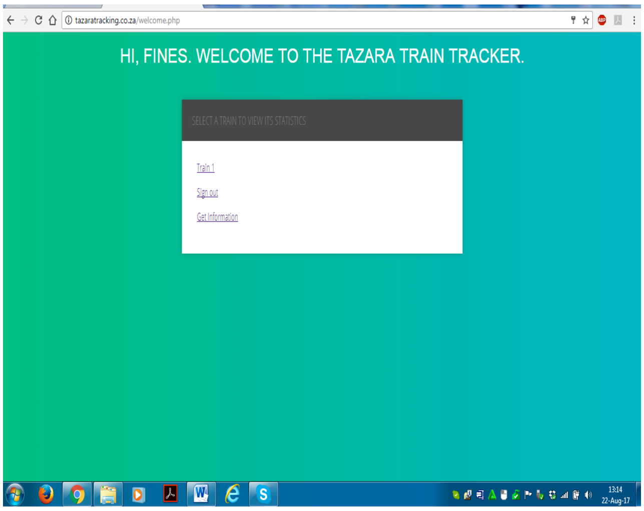

Figure 6: Train selection window

Table 2: Train location information display

TRAIN LOCATION STATISTICS

ID	TRAIN 1	LATITUDE	LONGITUDE	SPEED (Km/h)	TIMESTAMP	DATE
105		-12.806319	28.238592	0.000	18:37:19	0000-00-00
106		0.000000	0.000000	0.000	00:00:00	0000-00-00
108		-12.779920	28.187340	0.000	23:04:08	0000-00-00
109		0.000000	0.000000	0.000	00:00:00	0000-00-00
110		-12.779894	28.187361	0.020	23:12:59	0000-00-00
111		-12.779879	28.187355	0.020	23:15:49	0000-00-00
126		-13.010000	28.630000	0.020	22:56:04	0000-00-00
127		-13.010407	28.631565	0.010	23:03:00	0000-00-00
128		-13.010412	28.631563	0.050	23:04:18	0000-00-00
129		0.000000	0.000000	0.000	00:00:00	0000-00-00
130		-13.010411	28.631573	0.120	23:05:30	0000-00-00
131		-13.010406	28.631580	0.120	23:06:50	0000-00-00
132		-13.010407	28.631552	0.010	23:11:43	0000-00-00
133		-13.010396	28.631552	0.030	23:13:32	0000-00-00
134		0.000000	0.000000	0.000	00:00:00	0000-00-00
135		-13.010395	28.631557	0.010	23:16:36	0000-00-00
136		-13.010409	28.631563	0.050	23:17:46	0000-00-00
137		-13.010422	28.631575	0.050	23:18:55	0000-00-00
138		-13.010414	28.631556	0.050	23:20:05	0000-00-00
139		-13.010410	28.631531	0.050	23:23:35	0000-00-00
140		-13.010404	28.631517	0.050	23:24:45	0000-00-00
141		-13.010409	28.631538	0.070	23:26:05	0000-00-00
142		-13.010409	28.631554	0.050	23:27:18	0000-00-00
143		0.000000	0.000000	0.000	00:00:00	0000-00-00
144		0.000000	0.000000	0.000	00:00:00	0000-00-00

The display shows the same coordinates for a particular location because the GPS receiver was stationery at the time.

As an example, coordinates for Nakonde station were pasted on Google map and the result is as shown in figure 7. The red line is the mapped route of the track from Nakonde to Kapiri Mposhi.

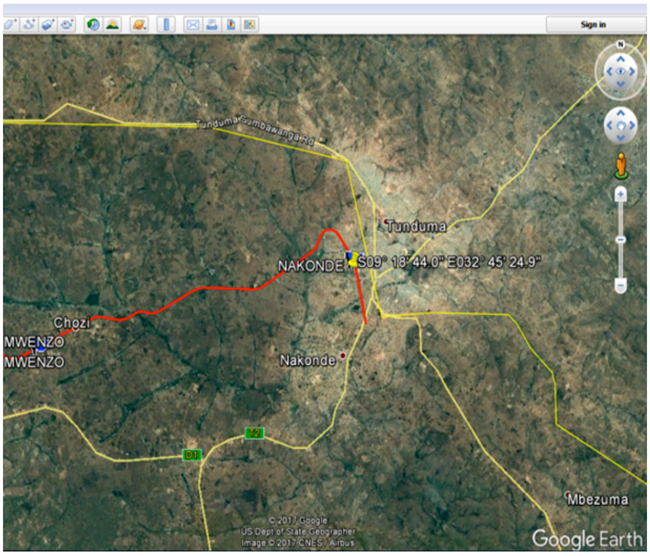

Figure 7: Location showing Nakonde station on the Zambian side.

V CONCLUSION

From the research, it is possible to develop a low cost real-time train tracking system using the existing GSM network and also using open source software that are available. Surface installations are prone to rampant vandalism along the railway lines which in turn raise maintenance costs. For developing countries, putting up an independent cellular network (GSM-R) along the line of rail can be very costly and this research offers the affordable solution to improve operational activities of the affected railway companies. In case cellular network failure along the railway track, an alternative voice radio communication system will have to be installed in the locomotive driver's cabins. The current High Frequency (HF) radio communication system, whose radio transceivers are only limited to side station controllers, should be extended to train crews so that drivers are easily reached and also use the radio as a backup.

IV FUTURE WORKS

For Tazara Railway Company to utilize this facility on commercial basis and appreciate the technology, it is recommended that they consult the telecommunications providers to acquire the Colocation facility to host their server and also boost speed and security of their system. Colocation will provide them with the dedicated Internet Protocol (IP) address. Tazara should lobby for more grid power installation along the line of rail as this will attract cellular companies to put more towers closer to the line of rail and will in turn improve signal quality for easy transmission of data from the trains to the server. With the presence of 3G or better cellular networks, many researches can be conducted to improve this research.

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