Asian Journal of Advanced Research and Reports

1(2): 1-9, 2018; Article no.AJARR.41445

Design and Implementation of a Cattle Grazing Tracking and Anti-theft Alert GPS/GSM Collar, Leveraging on Improvement in Telecom and ICT Infrastructure

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Authors' contributions

This work was carried out in collaboration between all authors. Authors AF, US and MD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author AII managed the analyses of the study. Author IJ managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJARR/2018/41445
Editor(s):
(1) Muge K. Davran, Associate Professor, Department of Agricultural Economics, Faculty of Agriculture, University of Cukurova, Adana, Turkey.
Reviewers:
(1) Oladimeji Tolulope Tunji, The Federal Polytechnic, Nigeria.
(2) Hermes José Loschi, State University of Campinas, Brazil.
Complete Peer review History: http://www.sciencedomain.org/review-history/24793

Original Research Article

Received 13th March 2018
Accepted 22nd May 2018
Published 25th May 2018

ABSTRACT

The objective of this study is to develop a cattle monitoring system for tracking cattle combating rustling in extensive grazing areas, grazing reserves, grazing routes and ranches. The system is majorly made up of a collar that consists majorly of a GSM & GPS module. This system would not only combat cattle rustling activities but would also serve as an anti-theft system. When cattle wearing the collar exits the virtual fences, an SMS containing the coordinates of the collar is sent to the cattle farmer enabling him to check the cattle's position and ward off a potential danger or theft. SMS alerts are also sent to the farmer also when the battery of the collar is low, the collar is unbuckled from the cattle and when the farmer calls the collar to know its location. This system would provide cattle farmers with the opportunity to fully monitor their herd within a particular grazing region.

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Keywords: GSM module; PIC18F4550 microcontroller; GPS module.

1. INTRODUCTION

In Northern Nigeria, cattle raising constitutes an essential occupation in like manner cattle stirring. Cattle robbery (stirring) has turned into an enormous issue that has been increased by the rising occurrence of rancher/herder clashes and also the Boko Haram insurgency [1]. Indeed, even with the rare accessibility of information to demonstrate unmistakably and through and through examples and figures on cattle stirring in Nigeria, there is few remote information that is accessible to show the current strength of cattle stirring and related clashes in the nation. Late examinations by the Pan-Nigerian relationship of cattle raisers, Miyetti Allah Cattle Breeders Association of Nigeria (MACBAN) uncovered that 322 herders were slaughtered in the seven conditions of Nigeria (Kaduna, Benue, Plateau, Taraba, Nasarawa, Zamfara and Niger) in 2013 with contemplates likewise uncovering that around 60,000 cattle were stolen in the occasions of cattle stirring in a similar period [2]. These contentions resulting from cattle stirring have been a noteworthy danger to open wellbeing and security in Nigeria causing; loss of lives, human damage, the decimation of homesteads and properties, populace relocations, and additionally loss of cattle in expansive numbers. It has made a feeling of weakness that could impede the profitability of the grouping endeavour. The loss of cattle to rustlers and demolition of ranches by pastoralist implies consumption of family unit wage and mutual asset of the grouping and cultivating group in this manner prompting a drop in the total supply of staple sustenance, natural protein and dairy in Nigeria. All of which can be avoided by minimizing cattle rustling activities technologically with the aid of the cattle monitoring and anti-theft system.

The cattle monitoring system is a system that would enable herders monitor their cattle along their allocated grazing routes or reserves, enabling them to remotely check cattle's positions and also curb the threat of theft or wandering into farms. It is a system which serves as both a tracker and an anti-theft system for cattle. The core of this system is its collar technology which majorly consists of a GPS and GSM module which aids in transmitting the coordinates of the cattle to the user via SMS whenever; the user dials to know the position of the cattle, the collar gets broken or removed, cattle crosses the virtual fence (i.e. a fence created from the coordinates of the allocated grazing routes/reserves for the cattle) and the battery of the collar runs down. Cattle equipped with the collar technology can be easily tracked and followed on google earth maps therefore making the management, security and automation of the herd more efficient.

2. LITERATURE REVIEW

Animal tracking and identification go as far back as ancient civilizations. Ancient civilizations attached much value to domesticated animals, especially horses [3]. Since the Neolithic period, animal identification techniques have been used by herders. It is said that "Different methods of marking animals were used by Egyptians, Greeks, Romans, nomadic people of Scandinavia, Asia and Africa, and Pre-Hispanic Americans for different purpose" [4]. For centuries, tattooing, ear tags, giving names and branding were used as animal identification techniques. In recent times, electronic identification systems have been developed that store more information of an animal apart from only its identification number [5]. As far back as the early 1800's and early 1900's, documentation of livestock identification was carried out in the United States. Hot iron branding was and is still used by cattle ranchers to indicate ownership and deter theft [6]. A study showed that after the outbreaks of rabies and tuberculosis near the end of World War 1, livestock identification became more important for tracking diseased animals [7]. Ear tagging of cattle was one of the first identification systems for the federal tuberculosis eradication program, which was initiated shortly after WWI [8]. In the early 1960s, ear tags, back tags, tattoos and face brands were employed by APHIS. Metal ear tags later became the standard form of identification. Eventually automated identification systems were used as a way to help producers manage and record data for large herds of livestock [9]. In April of 2004, the U.S. Department of Agriculture (USDA) announced plans for utilization of radio frequency identification (RFID) technology for universal tagging of livestock in the nation with implementation of various databases all of which would enable animal tracking from birth to eventual inclusion in the nation's food supply chain [6]. One study indicated that "Despite the key role of electronic identification in the retail industry for over 50 yrs, its use in animals was not explored until 1970s" [10]. This discovery was confirmed as the first applications of electronic identification were to monitor wildlife behavior. In the early 1970s, research institutes in different countries developed the first electronic animal identification systems which were built with conventional components and attached to a collar around the cow's neck [9]. These early devices were large, awkward, susceptible to damage, expensive, and not suited to livestock [11]. But with the advancement in solid state electronics, tiny electronic transponders were developed which could be injected under the skin. Under development currently is the third generation which includes read/write possibilities and sensor technologies for automatic monitoring of animal health and performance [12]. Electronic identification systems have great performance potential at this time as they can be used not only for process control on farms, but can also be implemented for control tasks such as animal disease monitoring [13]. They are currently used also as anti-theft devices. Because of most farmers not owning any committed tracking and monitoring system for their animals, their animals are presented to risks, for example, burglary and predator assaults. This threat can hurt agriculturist funds particularly for little and medium farmers as they possess just modest number of livestock and their fundamental pay originates from offers of the creature. The SMART Livestock Tracker application was created to check to a level the issue of stolen and missing livestock. The SMART {Self-Monitoring Analysis and Reporting Technology} Livestock Tracker works with GPS collar which is secured with a lash on the creature's neck. The capacity of GPS collar is to refresh the area of the creature by means of GPS. To find the area of their livestock, agriculturist needs to ask for the area of their livestock through the Android gadget. Once asked for, ask for information from the gadget will provoke the GPS collar to give its present area. At long last, the GPS collar will send its present area back to the Android gadget. This procedure will just take not as much as a moment relying upon organize speed and scope. This application gives better other option to agriculturist to track their livestock whether it is missing or stolen [13].

The short advancement of untamed life tracking advances which have additionally fit be utilized to screen, track, and find distinctive sorts of residential animals too steers from the 1950s and to what's to come are featured beneath. Numerous people who have enthusiasm for monitoring and tracking natural life, steers and pets incorporate scholars, logical analysts, farmers, farmers and traditionalists. Biotelemetry is the term used to depict "the instrumental procedure for picking up and transmitting data from a living creature and its condition to a remote onlooker" [13].

3. SYSTEM MODELLING AND DESIGN

This section discusses the design methodology and basic theory of components of the project with the section further divided into sections for components theory and system design & analysis.

3.1 Component Theory

The theory of the components employed in this work ranging from their basic principles of operation to their applications in this research work is explained in this sub-section. The components used in this work includes; GPS module, GSM module, PIC microcontroller, Light emitting diode, crystal and other passive components.

3.2 GPS Module

The Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. The system provides critical capabilities to military, civil and commercial users around the world. The GPS module consists of an antenna, receiver processor, highly stable clock, a display for showing location and speed information, the receiver performs tasks of selecting one or more satellites, acquiring GPS signals, measuring and tracking and recovering navigation data. The receiver's position is found out using Trilateration.

Fig. 1. GPS Module

3.3 GSM Module

A GSM module is a device which can be either a mobile phone or a modem device which can be used to make a computer or any other processor communicate over a network. A GSM module requires a SIM card to be operated and operates over a network range subscribed by the network operator. The GSM module has a wide range of applications such as in transaction terminals, tracking, security applications, weather stations and GPRS mode remote data logging.

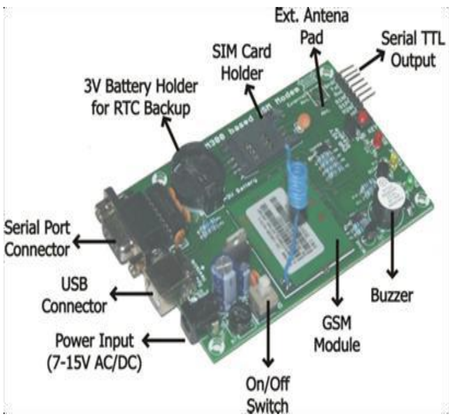

Fig. 2. GSM module [7]

3.4 PIC Microcontroller

The PIC family used in this project was the PIC18F4550 microcontroller. C is the predominant development language of this class of microcontroller. The PIC18F4550 possesses some features such as a 21 bits wide/deep call stack, read and the writeable call stack, conditional branch instructions, indexed addressing mode, 12 bits FSR registers and three FSR registers. In more advanced PIC 18 families, there is an addition of several new instructions notable for manipulation of the FSR registers and a new offset addressing mode

Fig. 3. PIC18F4550 Microcontroller [7]

4. SYSTEM ANALYSIS AND DESIGN

4.1 Principle of Operation

The system is an alert based system which is majorly made up of the GPS & GSM module. Both modules are embedded in a circuit which is placed in a collar worn on the cattle. As such, the collar calculates the coordinates of the cattle with the aid of the GPS module and transmits the detected coordinates as well as warning messages as an SMS to the cattle farmer with the aid of the GSM module. There are conditions that are met before which the system transmits the location of the cattle to the cattle farmer. These conditions include; when the collar is broken from the cattle via thieves or by the cattle itself when the cattle exceeds the crosses the virtual fence or assigned grazing route when the battery of the collar is low and whenever the cattle farmer calls to interact and know the position of the collar.

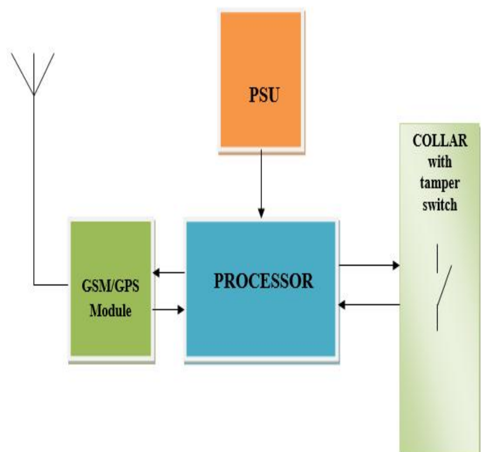

Fig. 4. Block diagram of the cattle monitoring system

4.2 Power Supply Stage

The power source employed in this project is a 3.8 V/ 750 mAh Li-Po (Lithium Polymer battery). The output voltage of Li-Po battery depends up on the technology used behind it. It is 2.7-3.0 V (discharged) to 4.20-4.35 V (charged) for cells based on Lithium Metal Oxides and it is 1.8-2.0 V (discharged) to 3.6-3.8 V (charged) for cells based on Lithium Iron Phosphate. The charging current is usually 1/5 of the mAh rating of the battery. Li-Po batteries are prone to problems related to over charging, deep discharging, over temperature, short circuit etc. Any of these problems may result in permanent damage to the battery or even explosion. In order to avoid such problems, a USB port Li Po charging module was included in our collar design. The design of this system required the determination of the battery life of the whole system as it was the most limiting factor of the GPS-GSM collar function as a result of the high-frequency requirement of the GPS.

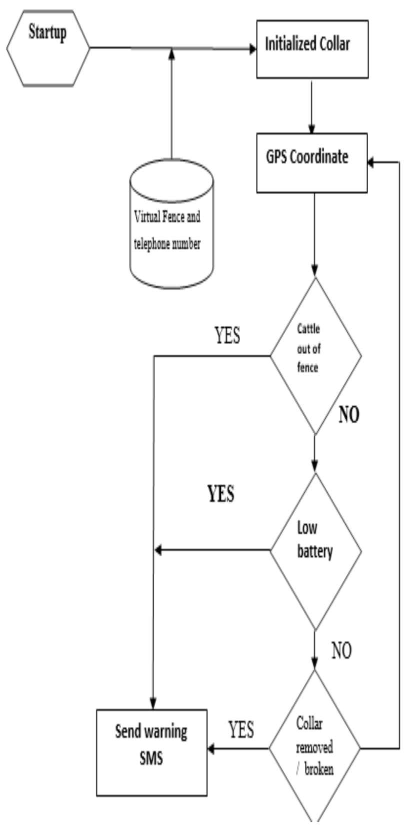

Fig. 5. Cattle monitoring system flow chart

(i) Energy consumed by GPS module = current consumption x supply voltage [Whr]

35 mA x 3.7 V = 0.13 Whr

(ii) Energy consumed by GSM module = current consumption x supply voltage [Whr]

100 mA x 3.7V = 0.37 Whr

(iii) Energy consumed by PIC18F4550 = current consumption x supply voltage [Whr]

10 mA x 3.7 V = 0.04 Whr

(iv) Energy consumed by Collar

E_{collar} = GPS+ GSM +PIC18F4550 = 0.13 W/hr + 0.37 W/hr +0.04 Whr = 0.54 Whr

The watt-hour available on the battery is given by:

$b_{attery} = I_{Battery} \times V_{Battery} \times \eta_{Supply} = x$ [Whr]

Where ,

b_{attery} - energy available on the battery [Whr]
$I_{Battery}$ - the current output of battery [A]
$V_{Battery}$ - battery voltage [V]
η_{Supply} - battery supply efficiency [%]

The efficiency of the supply was assumed to be 80% since the various components that make up the collar were powered directly from the battery. Substituting value in table 3 in equation

$b_{attery} = 750 \times 3.7 \times 0.8 = 2.4$ Whr

Battery support life is given by the expression

$Battery_{supportlife} = E_{Battery}$ [hr]/E_{collar}

Substituting values from Table 1

2.4 Whr/0.54 Whr = 4.44 hrs

Table 1. Expected power usage of the various collar components

Component	Efficiency	Current	Voltage	Energy
SIM800L	-	100 mA	3.7V	0.37 Whr
GPS Module	-	35 mA.	3.7V	0.13 Whr
PIC18F4550	-	10 mA	3.7V	0.04 Whr
Total: mWhr ($E_{-collar}$)				0.54Whr
LiPo battery				
Component	Efficiency	Current	Voltage	Energy
Battery	80%	750 mA	3.7V	2.4 Whr

4.3 Control Program

The Control Program was developed with the aid of the MikroC package software as the C-platform was employed in writing the control program codes and compiled by the MikroC compiler. After compilation, HEX codes generated were then transferred into the PIC18F4550 microcontroller after which the microcontroller was transferred to the target board. Program codes were written for the major functions carried out by the system.

4.4 Crystal Element

The 20MHz crystal element was employed in this system. It is the oscillating element of the internal oscillator of the PIC-microcontroller which serves to make up for frequency drift, therefore, allowing the microcontroller and USB module to run at different clock speeds.

4.5 Resistors (10KΩ)

R_1 is the pull-down resistor for the MCLR (Master Clear Reset) the push button switch during development has been removed and converted to a software reset. While R_2 is the pull-down resistor selected such that minimum current is drawn by the input pin of the collar Rc2 of the microcontroller.

4.6 Google Maps

This is a web-based application developed by Google. It provides coordinates of any desired coordinates of the user. Google maps were employed in locating the desired grazing route and developing a virtual fence around the grazing route in Osogbo, as a result, testing the reliability of the system. The coordinates of the four points squaring the grazing route are employed to carry out perimeter calculations for the virtual fence as seen.

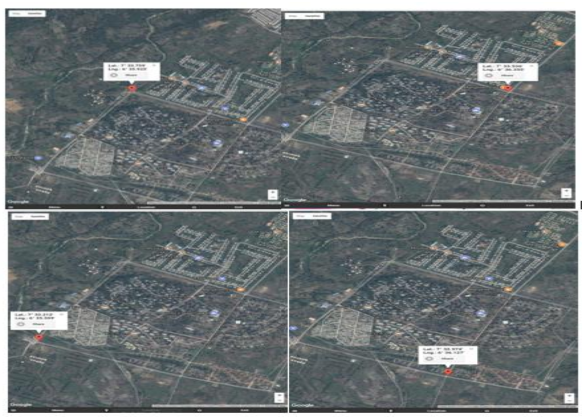

Fig. 6. Google map view of the virtual fence

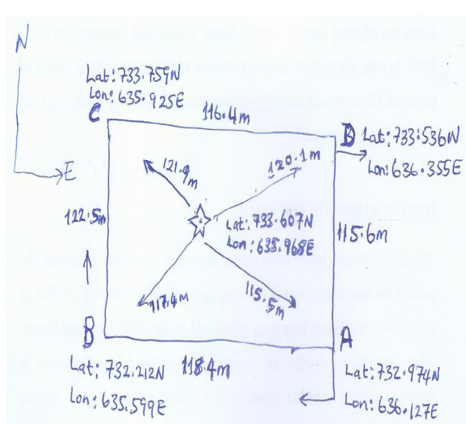

Fig. 7. Showing perimeter coordinates of the virtual fence

5. CALCULATION OF VIRTUAL PERIMETER SIDES

Using successive GPS coordinates in Fig. 7 and inserting in equation (I) we have moving clockwise as shown Fig. 7;

D = 6378.388 × arccos (sin (lat1) × sin (lat2) + cos (lat1) × cos (lat2) × cos (lon2 – lon1))/1000 ------ [I]

Where D= Distance between two coordinates

Distance between A & B

A (Lat 732.974N, Lon 636.127E); B (Lat 733.212N, Lon 635.599E)
Inserting in equation (I)
6378.388/1000{Cos^{-1}(sin732.974) x sin (733.212) + cos (732.974) x cos(733.212)x cos(636.127-635.599)} = 6378.388/1000{77.03 x 0.2286 + 0.9487} = **118.4 m**

Distance between B & C

B (Lat 733.212N, Lon 635.599E); C (Lat 733.759N, Lon 635.925E)
Inserting in equation (I)
6378.388/1000{Cos^{-1}(sin733.212) x sin (733.759) + cos (732.212) x cos (733.759) x cos (635.599 - 635.925)} = 6378.388/1000{77.02 x 0.2378+0.3327} = **122.5 m**

Distance between C & D

C (Lat 733.759N, Lon 635.925E); D (Lat 733.536N, Lon 636.355E)
Inserting in equation (I)
6378.388/1000{Cos^{-1}(sin732.759) x sin (733.536) + cos (732.759) x cos (733.536) x cos (635.355-635.925)} = 6378.388/1000{76.24 x 0.2341+0.4061} = **116.4 m**

Distance between D & A

D (Lat 733.536N, Lon 636.355E); A (Lat 732.974N, Lon 636.127E)
Inserting in equation (I)
6378.388/1000{Cos^{-1}(sin733.536) x sin (732.974) + cos (733.536) x cos (732.947) x cos (636.127-636.355)} = 6378.388/1000{76.40 x 0.2245 + 0.9774} = **115.6 m**

Equation (i) was also employed in determining the distance of the collar from the various set limits of the fence with the results being (109.4 m, 115.5 m, 117.4 m and 120.1 m)

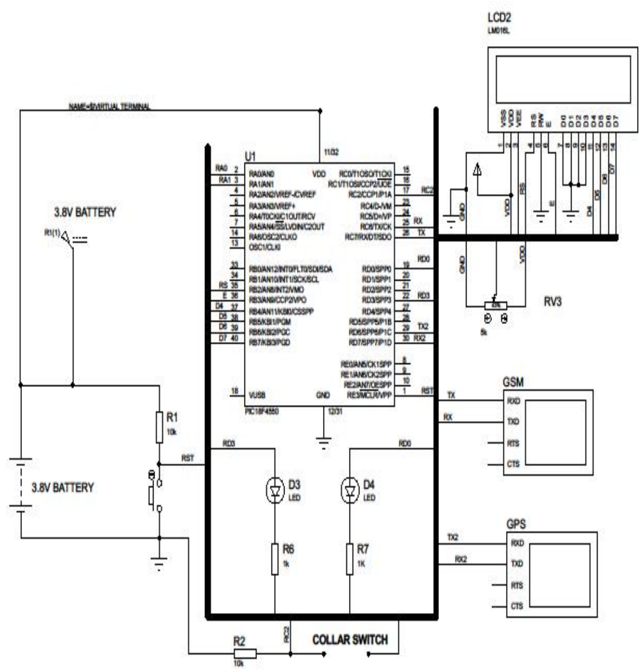

Fig. 8. Complete circuit diagram of the cattle monitoring system

6. TESTING

The following tests were carried out with the system with results shown below.

The collar was unbuckled, replicating a case of theft; and within 10 minutes of collar removal, a warning message was received. The screen shot of the warning message received is shown in Fig. 9.

Fig. 9. Collar unbuckled alert

When the collar operator calls to know the position of the collar; an interaction was initiated with the collar by the handler by sending a text to know the position of the collar, within 10 minutes, the message below was received as shown in Fig. 10.

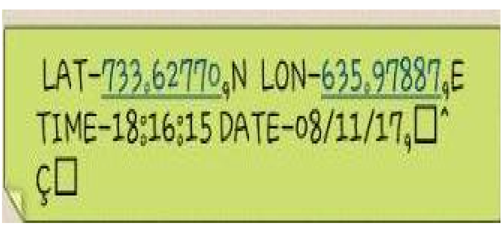

Fig. 10. Screen shot of the alert showing location

When the battery level is low; Key to the efficient performance of this system is the battery level. From power consumption calculations, the collar's battery ran out after 4.4 hrs and a warning alert was sent as shown in Fig. 11

Fig. 11. Cattle outside virtual fence

Cattle straying out of the assigned grazing area or virtual fence; The warning message below was received within 10 minutes of the fence being breached by the herd. Fig. 12 is a screen shot of the warning message sent.

Fig. 12. Screen shot of the warning message received when battery level was low

7. PROBLEMS ENCOUNTERED

The poor quality of service of the local network service provider in Nigeria was the major difficulty that was encountered during the tests and developments of the system.

Another means in which the network service put the performance of the system into question was that of delay in arrival of warning messages (8hours delay) making it looks like the GPS module wasn't performing properly only for messages to arrive suddenly showing the exact time at which they were sent by the GPS but was delayed by the shoddy services of the local network provider.

8. CONCLUSION

This study was done so as to develop a cattle monitoring system consisting of a GPS-GSM collar for tracking cattle so as to tackle rustling in extensive grazing areas. On some occasion, the warning message was received very close to the virtual fence while the GPS & GSM module needs to be recalibrated to improve accuracy. With the aid of field tests, the system's potential as an anti-theft system was confirmed. When cattle wearing the GPS collar exited the virtual fence, an SMS displaying the main GPS data (date, time, latitude and longitude) was sent to the cattle farmer enabling him to check the cattle's position and ward off a potential danger or theft. During field tests, the collar provided evidence and was able to identify: (i) when cattle walked out of the virtual fence; and (ii) any tampering with the collar. (iii) Responded when a farmer called to know the location of the collar by sending date, time, latitude and longitude. In conclusion, this can be considered to be an interesting sample of a cattle tracking and anti-theft system. Future studies should be working towards reducing the energy requirements of the collar.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/24793