Low Cost IoT Based Livestock Tracking System for Zimbabwe

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Abstract: ***This research is on establishing and developing a low cost IoT (Internet of Things) based Livestock tracking system. IoT technology is where non-intelligent objects sense and transmit data about the environment and be able to communicate the information to a receiver via the power of the internet and cloud computing. The model would be a non-evasive device that is fixed to a collar and fitted onto the neck of a cow. The collar should have a tracking device made up of GSM (Global System for Mobile communications) and GPS (Global Positioning System) Modules. It should have capabilities of sensing the live location of an animal and be able to give a farmer a near accurate live location of the sensed livestock. The model would have geofencing capabilities. This system should be able to assist the farmer in fighting cattle rustling as well as providing a PLF (Precision Livestock Farming) based approach to livestock management.***

Keywords: Cloud Computing, Geographical positioning systems (GPS), Global Positioning System (GPS), Internet of Things (IoT), Precision Livestock Farming (PLF), Livestock Tracking

1.Introduction

The global human population is gradually edging closer to 10 billion by year 2021, there is an urgent need to establish food prediction systems that double the current outputs, the need for effective food production has seen engineers harnessing the power of IoT to maximise Livestock farming. One of the key 2030 priorities of the Zimbabwean Government is Livestock production and the development and advancement of the Livestock production industry. Vision 2030 also prioritizes resuscitation of horticulture production and exports [1], dairy production anchored on small scale dairy farmers, as well as resuscitation of the Cold Storage Company. Resumption of beef exports is a key deliverable. One of the major threats to this objective is cattle rustling [2]. There are at least 20 cases of stock theft daily according to National anti-stock theft commission of Zimbabwe [3]. According to Dieng et al.2017, cattle rustling cost Senegal over 2 billion united states dollars per year [4]. The current and established mitigatory approach in the Zimbabwe is cattle branding, use of ear tags and bells. This research seeks investigate and propose an IoT based livestock tracking and identification system. Not only should the system be very effective, but also affordable as majority of livestock farmers are peasant farmers. The solution should curtail cattle theft and help with the monitoring and tracking of cattle. Cattle rustling is a very big crime in Africa, Zimbabwe in particular, current deterrent mandatory jail term is at 9 years.

A. Key Technologies

1. IoT

Vigneswari Et. al 2021 defines IoT as a network of physical items that are embedded with sensors, software and other technologies. It is used for connecting and exchanging data with other devices and systems with the help of the Internet [5].

The IoT network consists of interconnected devices, which can transfer data efficiently without human interference [6].

2. Cloud Computing

A key enabler of IoT is the capability to transmit sensed data to a remote storage location, Cloud computing offers a platform as a service solution where data can be stored on the cloud for access at a later time. Cloud computing is storing and accessing the data over the internet [5].

3. Wireless sensor Networks

Network of spatially dispersed and dedicated sensors that monitor and record the physical conditions of the environment and forward the collected data to a central location [7]

2.Literature Survey

Livestock farming is one of the oldest professions. It has been in existence from the first industrial revolution right through to the current 4th industrial revolution. While the concept remains around rearing cattle for meat and milk, the management of livestock has gone through tremendous metamorphosis.

The most common and probably most primitive method of animal tracking is physically monitoring livestock in their pastures (17th century). The Advent of the 1st industrial revolution introduced mechanisation, this introduced farmers to new farming methods, some even deserted farms in search of jobs in industries. The jump from 1st to 4th industrial revolution has brought exciting and advanced ways of aiding and managing livestock farming. The developing world however been slow to catch on. Use of branding, paddocking and bells is still the mostly used

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livestock tracking tool [8]. An image below shows typical branded cattle.

Figure 1: Typical cattle branding method used in Zimbabwe –source camera pictures 2021

A. Current Trends

1. Use of IoT, LoRaWan and Cloud computing

LoRaWan technology uses open specification model based on Lora (long range, low-data rate, low power consumption wireless technology developed by semtech corporation. The technology uses unlicensed radio spectrum (industry, scientific and medical networks band (ISM band)). LoRaWan based sensors have increased battery life. The gateways support large number of devices () and has a range of 2-5 km in cities and 15-20km in rural setups, making it ideal for livestock tracking. In their research paper, U. S. Abdullahi et al, defines IoT as a concept of sensors connected to gateways, cloud based interfaces and storage for further data analysis. A typical model implementation is displayed in table 2 below.

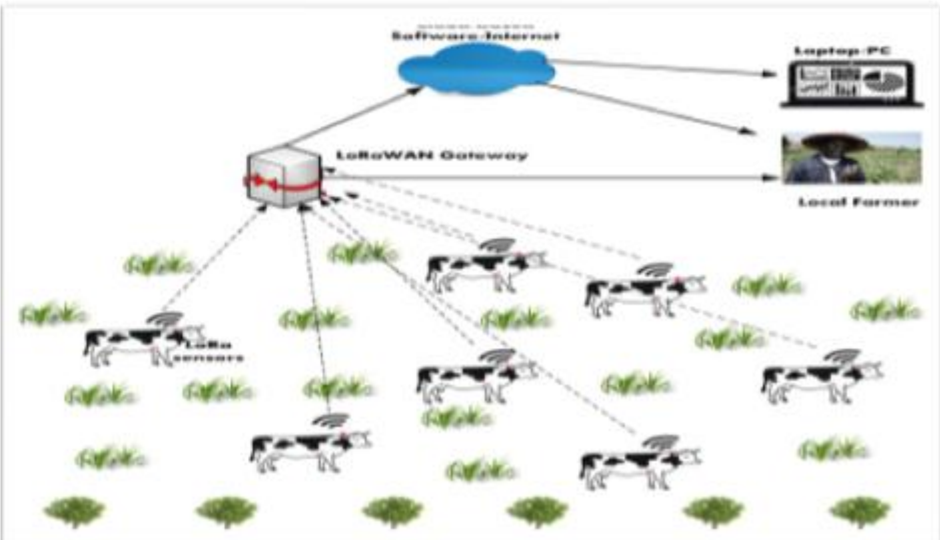

Figure 2: Typical LoRaWan based livestock monitoring solution-source references {5}

LoRaWan and IoT can be setup by having animals fitted with a wearable collar that acts as the sensor. A gateway is then installed at the center of the farm as the signal receiver from the sensors. Information is then forwarded to a cloud based storage for further analysis or sent straight to the farmer as depicted in fig2 above. Alternatively, cellular connectivity, if available can be used to send signal direct to the farmer's mobile phone or to a nearby Base Transceiver station (BTS) for uploading onto the cloud. where there is no cellular link, a satellite link can be set up which enables large area coverage ideal for the rural and farm setup, hundreds of km. satellite is also ideal for regional or nationwide coverage for ease of disseminating information on animal diseases, outbreaks or even tracking.

Benefits of Real-time livestock farming based on IoT, LoRaWan and Cloud computing as proposed by U. S. Abdullahi et al.

- Quick detection of sick animals and response as unusual movement patterns are detected quickly and early on
- Geofencing of animals can be used to track animals that have strayed or have been stolen, thereby curtailing rustling.
- Efficiency in management as real time data is collected and analysed
- Improved production on farms as manual labour is reduced and time is spent doing other chores

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Major drawbacks

- Most farmers have limited knowledge on setup maintenance and use of IOT and LORAWAN technologies
- Technology is fairly new in Africa, still a bit costly for most farmers

2. Use of wireless sensor networks (WSN) and Radio Frequency identification (RFID)

O. Dieng et al (2017) proposed the use IoT, Wireless sensor networks (WSN), wireless sensor actuator networks (WSAN), radio frequency identification (RFID) and Big Data technologies. The proposed alternative makes use of RFID based ear tags, these could be passive (use power from electromagnetic pulses), Battery assisted passive (uses a battery to power the IC) or an Active tag that uses peer to peer transmission and is always in need of battery power. Use of Aldino boards, raspberry Pi3 and mongo-db (database storage both locally and on the cloud) can complement the prototype proposed to come up with an efficient system.

Benefits of proposed prototype include:

- Affordable tracking solution Ideal for areas with minimal to no internet connectivity
- Makes livestock farming more productive and efficient in an African setup.
- Can be used to control diseases Issues

Challenges:

- Issue of how many sensors to put and gateways
- Issue of interference between animals
- How to use these technologies in large communal grazing areas of Zimbabwe?

3. Use of Wireless sensor networks and GSM and GPS

Casa et al. focused on a model that is centred on wireless sensor networks, GSM and GPS. They put forward 4 alternative models;

3.1 Use of Wireless Sensor networks and ZigBee

They studied WSN and pointed out that this approach used link quality indicators (LQI) for distance estimation instead of received signal strength indication (RSSI). It used ZigBee with 3 nodes (Coordinator, Router and end device nodes). The use of 3 separate nodes would ensure that the cost, weight and power consumption of the end device on the cow is greatly reduced.

3.2 Use of Wireless Sensor networks and GSM (Global system for mobile communications)

This alternative makes use of an Arduino based controller, GPS (global positioning system) to locate cattle and xbee technology for sending and receiving messages between devices

3.3 Ultrasonic sensors on geographically safe zone boundaries

With this option, navigation sensors are placed on cattle offering GPS functionality, cattle fixed with these are located via satellite using GPS coordinates.

3.4 RFID (Radio frequency identification device)

An RFID based ear tag is tagged to the cow, an RFID reader then reads radio frequency signals from the tag transmitter using Bluetooth capabilities. The RFID reader would send signals to a controller which would then transmit these to a cloud based storage for further processing or a farmer's mobile device

3.Findings

The following are the key elements to be considered when coming up with a low cost IoT based livestock tracking system for Zimbabwe;

A. Cost reduction

Any solution proposed should always focus on ensuring that the solution developed is very affordable, Odieng et. Al. emphasises that most livestock farmers are poor peasants who cannot afford expensive gadgets [4]. Connectivity in most developing countries, Zimbabwe included, suffer from high internet connectivity costs, it is therefore critical that a solution proffered should use minimal bandwidth or should employ alternatives that are less expensive. Any solution that is deemed too expensive can easily become a white elephant as farmers will opt for the seemingly more affordable but menial manual systems. O. Dieng et. al. highlight that Lora Technology can have one gateway covering hundreds of square kilometres. The Fact That Lora uses free frequency band means that there are no extra deployment costs. Craig et al in Tracking cows wirelessly highlights that using RFID and ZigBee technology can cost 1200 usd just for components [9].

B. Power consumption

Any proposed solution to be used for livestock tracking and monitoring should make efficient use of power, if possible solar driven gadgets in sunny climates would be ideal. Most farmers reside in rural areas where power supply is erratic or non-existent, self-sustained gadgets would be more ideal. According to Vigneswaria et. al., Solar energy can be harnessed to power IoT devices to alleviate issues of power demand. GPS based trackers would need to have a reliable source of power as they tend to be power intensive [10]

C. Signal transmission range

Any solutions to cater for livestock tracking should be able to handle larger areas of network coverage, pastures are never confined to small areas especially grazing areas in Africa as a whole and Zimbabwe in particular. According to Dieng et. al., the type of farm setup or

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grazing land will determine the deployment model; farm setup that has paddocks can make use of low range models using ZigBee or wireless technologies. Rural pasture setup may require LoRaWan technology and SIgFox that cover wide area data transmission.

D. Security

One of the key deliverables of the solution is to deter rustling, it therefore follows that security of the deterrent devices is of utmost importance, a solution picked should ensure that the IoT devices and the communication equipment is not tampered with. This can be physically or via intrusions.

E. Data collection, storage and analysis

Most papers reviewed seem to concentrate more of sensing rather than analyse collected data, there is need to use cloud based storage and mobile applications for purposes of analysing collected data.

4.Methods / Approach (System Modeling)

The proposed system is going to be an IoT based tracking system. The system will make use of a sensor, communication device, cloud based storage and a web app to view the live location.

1. GSM module

This is a collection of protocols (standard) used by cellular networks to send and receive messages. It covers both voice and data communications. The main purpose of the gsm module is to transmit data to the cloud based storage and or to the mobile application operated by the farmer [11]. A typical module is as depicted below.

Figure 3: GSM module with antenna and serial interface port. Source-Google images

The ideal GSM module should take Nano sim cards as they are the most popular one son the market. The gsm component gets affected in areas that have poor reception and performance may be compromised in such areas. Can operate pretty well from 2g networks right up to 5g enabled networks.

2. GPS Module

The GPS Module is tasked with the sensing the live location, based on current geo coordinates. It makes use of 4 satellites that enable it to compute longitude, latitude altitude and time. It does this by making use of at least 4 satellites. The receiver continuously listens to signals from the 30+ satellites in orbit to confirm their positions, once it has confirmed for at least 4 of these, it can then compute the location of the receiver. We will use the module to give us a near perfect location of the sensed livestock. Most GPS modules have an accuracy of between 5-30m [11]. The major players in GPS satellites are; Global Positioning System (GPS) by the United States, Galileo by Europe, GLObal Navigation Satellite System (GLONASS) by Russia, and BeiDou by China [8].

3. Microcontroller

This is a microcomputer that is used to control the functions of other embedded components. It is comprised mainly of memory, a processor and peripherals We will need it when we combine the GPS and GSM into a fully-fledged tracker. A typical model is the Arduino Nano, which is depicted below. [5]

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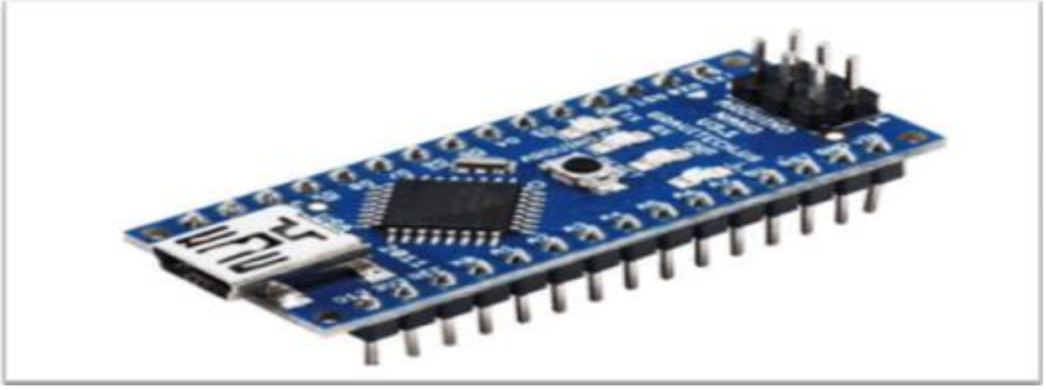

Figure 4: Arduino Nano microcontroller. Source - Google images

4. Power Source

Both GSM and GPS modules require power for sensing and transmission, this is provided by a 12v battery. This can be recharged once out of power.

5. Collar

The tracker will be put on a rigid collar that is strapped on the cow, the collar should be strong and durable to deter theft or accidental breaks. A typical collar would look like something below.

Figure 5: Typical cattle Collar. Source - Google images

5.System Design

The model under development seeks to establish a livestock tracking system that has basic entities as tracker, communication, storage and display. The general diagram below summarises these components.

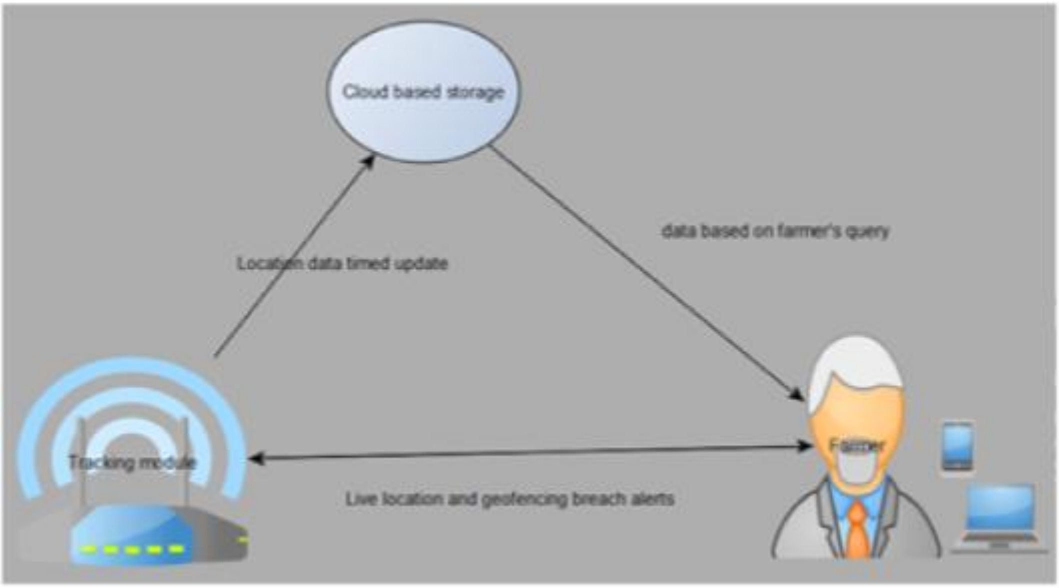

Figure 6: Basic architecture of proposed model

A. Model Block diagram

As has been discussed previously, the proposed model will use GPS and GSM modules, these form the core of the tracking module. The general block diagram of the tracker is as below;

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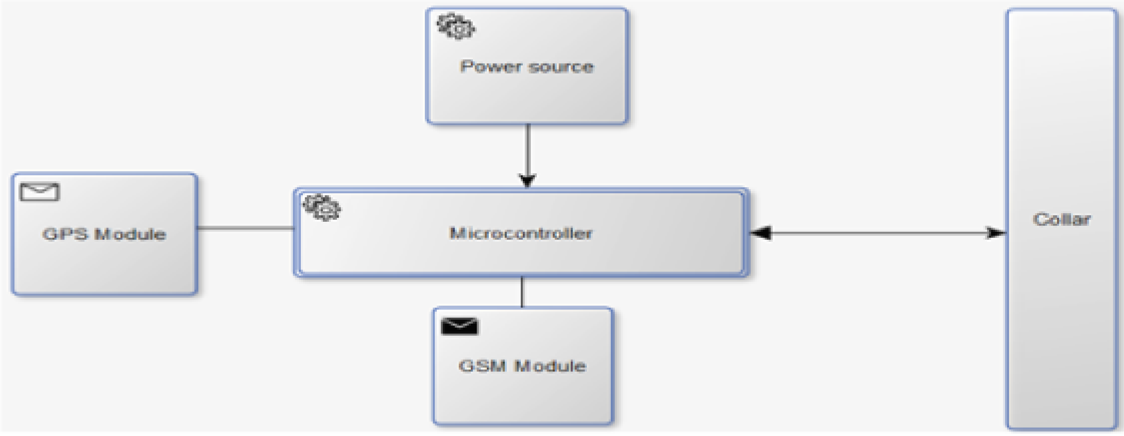

Figure 1: Block diagram of proposed IoT Based tracking system

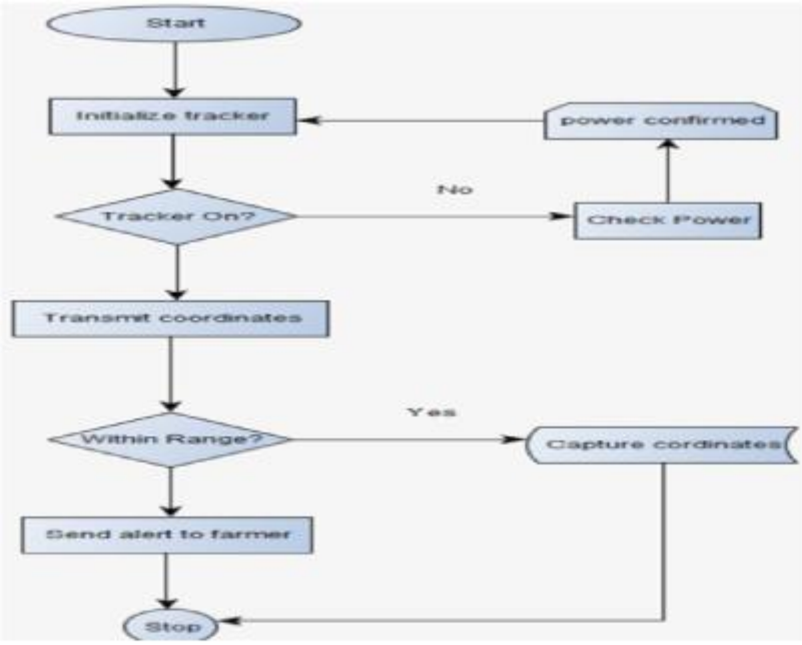

Figure 7: Livestock Tracking system flowchart

Figure 7 above has 5 main components making up our model, these are the GPS module, GSM Module, Power source, Microcontroller and the collar that is strapped to the livestock [5]. The general flow diagram of the system starts from the sensor and ends with the farmer viewing information on the web application.

B. Software components of the model

The software to be used as part of the model will encompass a tracker software, Google maps, backend software to manage upload of coordinates to a cloud based storage and mobile application. A hosting platform will be needed to host the web application.

1. Web Application (Frontend)

The web application is the interface that the farmer has with the tracker, this enables the farmer to view the location of his/her livestock. This portal is developed using Reactjs it is an open-source JavaScript library for developing web application components.

2. Tracker Application

We used Cordova for the tracker application. Cordova is an open source, cross platform mobile application development framework; it supports languages like html5, CSS3 and JavaScript.

3. Backend (Server)

Nodejs is an open source cross platform JavaScript runtime environment. It was used to develop the backend of the application. It manages server side communication and takes messages from the frontend web interface which interacts with the user.

4. Google Maps

This is a geolocation web based application developed by Google, it depicts the location of tracked device as a combination of longitude and latitude coordinates which can pinpoint the location on a live map.

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6.Model Testing

The mobile app which is used by the farmer to track livestock was developed first. Tests were conducted using a tracker simulator. Cordova was used to build the tracker simulator. It's a lightweight mobile app based tracker simulator that once loaded it starts send messages like an actual tracker. After login in, the farmer has to enter the animal to be tracked; this is usually for the most troublesome animals, or the most priced ones. In our demo we are using animal 1001. After login in, the tracked livestock is shown as a cow head on a Google map; this gives the farmer the live location of the animal. The icon circled in red depicts our cow 1001.

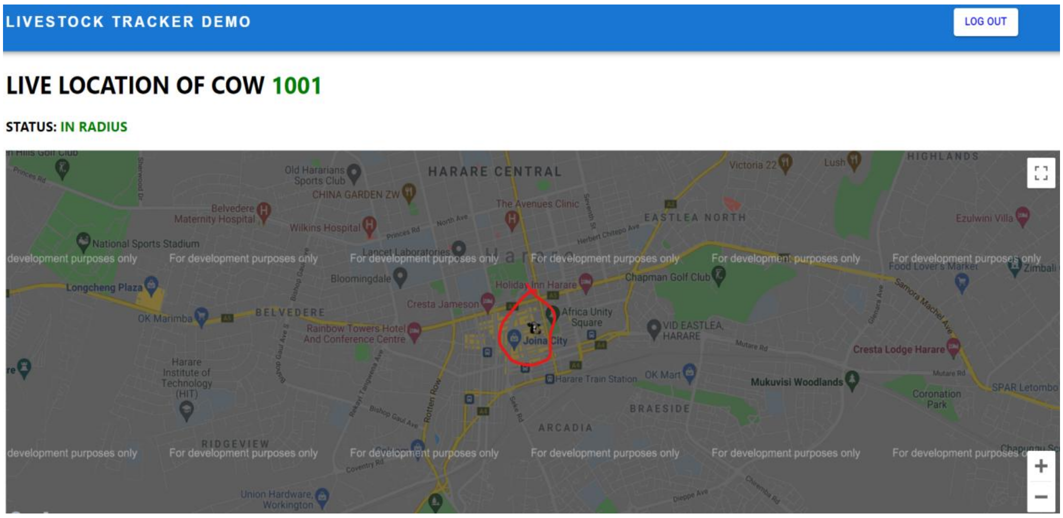

Figure 8: Livestock tracking view of the farmer

Having tested and confirmed that our software is perfect, work shifted to testing the actual tracker component. The first cycle of tests involved using a TK102 tracker. This had both GSM and GPS modules. This however failed to work as it was not working with our latest Nano sim cards.

We then built another tracker from scratch (gsm module, gps module, battery). The model tracker developed was then tested under the following test cases:-

Table 1: Tracker module tests

Test case		Test conducted	result	comment
1		Is GSM Module switching on	success	Tested on 20.10.2021
2		Is GPS Module Switching on	success	Tested on 20.10.2021
3		Is the sim card transmitting coordinates to the app and web storage	success	Tested on 20.10.2021
4		Can the farmer view live location	success	Tested on 22.10.2021
5		Can system trigger alerts for perimeter breach	success	Tested on 20.10.2021

Tests were also conducted to ascertain the functionality of geofencing.

A Geofencing region was setup by using Jameson hotel as the focal point, anything outside a radius of 10m was deemed to be outside the restricted zone (-17.82756580037137, 31.04415171786185).

The figure below depicts a snapshot of the geofenced zone.

Figure 9: Virtual Boundary for geofencing tests

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Initial tests were conducted to show on the web app that the livestock has gone beyond the perimeter fence, the following message was displayed when the tracker had moved outside the set zone.

Figure 10: View showing an animal that has breached the perimeter 'geofence'

More work was then done to ensure that instead of the farmer waiting to logon to discover that the tracked livestock has gone beyond the perimeter, Farmer should be notified if there is a breach in perimeter. This was configured and tested successfully. In this project, email notifications were used as shown below.

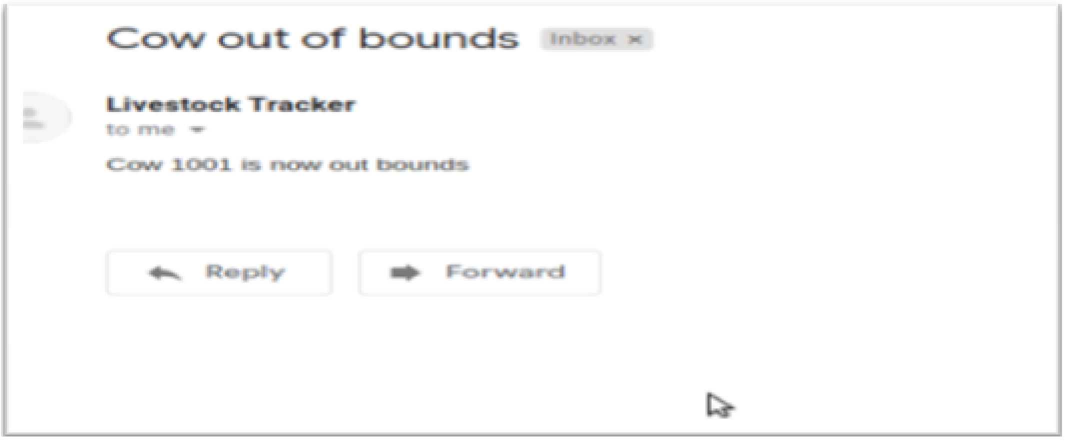

Figure 11: Email notification when cow is beyond the geofence

Tests were then carried out using different reference points in terms of distance from the marked focal point. The table below depicts the response in terms of notifications and display on the application.

Table 2: Tests for Geofencing

Test Instance	Cattle ID	Safe Zone (Distance from focal in meters)	Message notification	Status displayed as Out of Bounds
Test1	1001	10	yes	yes
Test2	1001	15	yes	yes
Test3	1001	5	no	no
Test4	1001	3	no	no
Test5	1001	17	yes	yes
Test6	1001	20	yes	yes
Test7	1001	2	no	no
Test8	1001	8	yes	yes
Test9	1001	25	yes	yes
Test10	1001	30	yes	yes

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7.Conclusion

It is very possible to come up with an IoT Based livestock tracking device for the Zimbabwean environment. Procurement of the GPS, GSM, Battery and sim card were well below 60United states dollars. This can further be reduced by using the energy efficient components and LoraWan technology for signal transmission which is a free service.

8.Recommendations

While lots of work has gone into designing and implementing IoT based livestock monitoring and tracking system ideal for the Zimbabwean environment, I believe there is no 1 size fits all. The model for implementation depends on a number of factors. These may include, size of grazing land, connectivity availability, availability of technical support. More work still needs to be done though to try and drastically reduce the cost of owning and running these systems on farms and on a rural homestead. The major players in IoT have not yet penetrated the Zimbabwean sphere. There is need for leading research and educational institutions to focus on this field and explore the most affordable and beneficial technologies. This will ensure that more and more models can be developed and implemented. This will ultimately reduce the costs of owning such systems.

An Ideal tracking system for Zimbabwe will need to be built with the following in mind;

- The sensing device should be GPS based, this is by far the best tracking platform in the industry
- In terms of communicating sensed data, there is more work needed to explore technologies like LoRaWan in the Zimbabwe environment. While this technology is regarded as the best in tracking, it has to withstand the conditions of the African savanna. From cold winter nights, to torrential downpours in the summer, the Hot Autumn days. These weather conditions coupled with erratic to limited connectivity should also be subjects under which the sensors should be tested.
- Power supply remains a critical component in animal tracking, there is need to augment Battery power with solar energy. This area can be researched on further to improve performance of automated monitoring systems.

9.Future Scope

An IoT based livestock system is the future, and it starts now, there is need for the government to fund research in this field, this will pretty much feed well into the National Agenda in Livestock farming. We need to have efficient systems of managing our livestock, cattle in particular.

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