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DESIGN, FABRICATION AND DEPLOYMENT OF ANTI-RUSTLING TRACKING SYSTEM

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Abstract
The livestock owners need technology to combat theft (rustling) thereby preventing the perpetual loss of lives and properties as well as boosting the agricultural productivity and safety. This work is aimed at providing approach to reduce or completely solve the rustling problem through technology that tracks and monitors cattle movements. The proposed solution involves tagging each cow or bull with location reporting device. These devices allow owners of tagged cattle to monitor their movement from their phones, tablets or computers. The devise comprised of Google maps, GSM Module, GPS module and STM32L071KZU6 Microcontroller. Five devices were fabricated using 3D printer. The operations of these devices deployed on Cattle Farm showed 100% success with average battery life of 48 Hours. Implementing this work might provide security agencies with name of the place and coordinates of stolen or lost cattle, thereby, allowing such cattle to be quickly located and recovered.

Keywords: *Livestock, Safety, GSM, GPS, Microcontroller*

INTRODUCTION

Today many parts of African sub-region especially Northern Nigeria have been engulfed with different types of livestock theft leading unprecedented crises. Cattle rustlings are turned to be a lucrative business with the criminals normally going undetected and with impunity. The herd owners resort to attacking any

person suspected or close to the incident scene thereby causing severe lives and socio-economical losses. This work is aimed at providing approach to reduce or completely solve the rustling problem through technology that tracks and monitors cattle movements.. The solution provides security agencies with name of the place and coordinates of stolen or lost cattle, this allow such cattle to be quickly located and recovered. The spate of insecurity in African continent and Nigeria in particular can be traced to insurgency, banditry and livestock rustling. These dastardly acts are responsible for the avoidable loss of lives and properties. Several approaches adopted by the Nigerian Government yielded mixed results, indeed these problems are still lingering as of today. In this work technology is employed to fabricate a dedicated tracking system where livestock's location is obtained at any given time.

LITERATURE REVIEW

The advent of Global Positioning System (GPS) enhanced asset tracking on a global scale. It is important to remember that earlier GPS satellite transmitters and receivers had about five-meter (16 feet) accuracy. However, the latest accuracy when using L5 band allow GPS to pinpoint a receiving device/asset to within 30 centimeters or 11.8 inches (Kastrenakes, 2017).

Nonetheless, GPS accuracy is further enhanced via Internet and cellular data through triangulation. Triangulation uses both distances and angles to the sensor to determine the position of an object. Two angles and one length are required for a two-dimensional location determination. Angle of Arrival (AoA) is the angle at which the signal hits the receiver. The angle is measured using the delay of the signal ("Time of Flight" TOF). TOF measures the time it takes for a signal to travel between an object and the reference point, the known position of a transmitter (Kastrenakes, 2017).

Bhrati and Fernandes (2017) worked on vehicular tracking system using Global System for Mobile Communication (GSM), GPS and microcontroller. The tracking algorithm was coded using C programming language. Akinode *et al* (2011) have stated the security benefits embedded in the GPS tracking system in respect to the National Security dilemma and its deployment into Nigeria Security System.

METHODOLOGY

This research is realized according to the block diagram of Fig. 1.

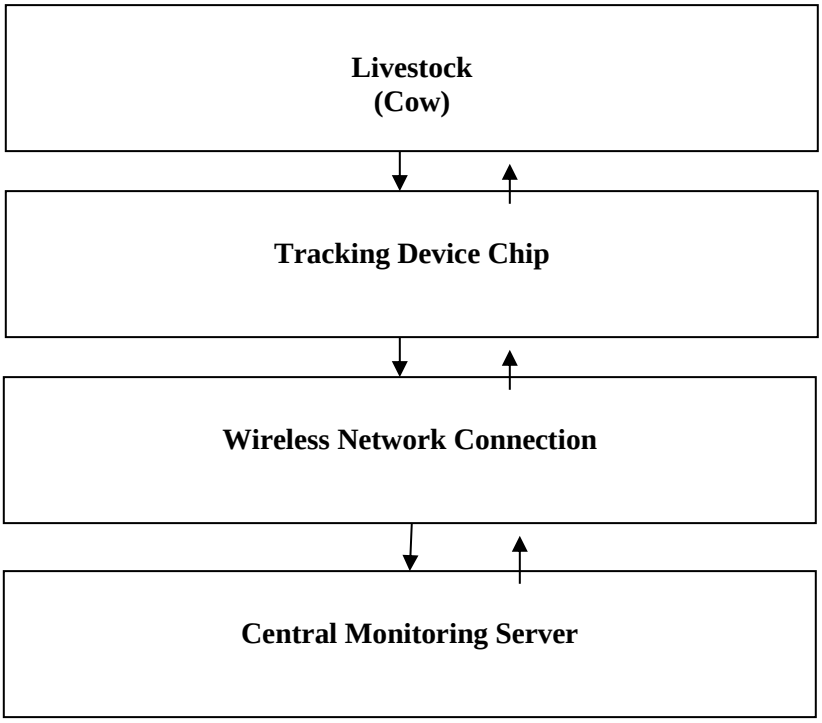


Fig.1: Block Diagram of Proposed Livestock Tracking System

The Fig.1 block diagram is explained in the following subsections;

Livestock Block

FIve physical cows were randomly selected from the Polytechnic Farm, the Polycon Farm. They were moved at different random locations.

Tracking Device Chip and Wireless Network Connection Block

The tracking device chip is a miniature programmable chip with embedded GPS and GSM capabilities. Its size is 1.8 x 1.8” with 1.2” in diameter as shown in Figure 2. This chip provides global positioning and wireless network connectivity to the central monitoring server. The chip is implanted on the cows at different unsuspected locations. The device is shown in Fig.2

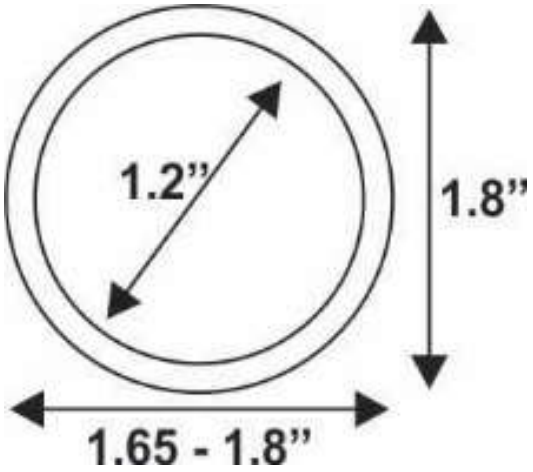


Fig. 2: Dimensions of Proposed Device (in inches)

Central Monitoring Server Block

High end remote server that can accept and server multiple tracking requests without downgrading response time. This server is installed with web services, database, tracking software and Google maps.

For this research purpose, each of the Five cows is allocated to owners who are registered at the Central Monitoring Unit hosting the Central Monitoring Server as clients. Bio-data profile is created on each client where its access is only through username and password to be managed by monitoring operator. The operator tracks the position of each cow whenever a complaint of theft is issued by a client. By so doing the position of the cow will be known instantly and can be continuously track until when it is rescued by the security personnel. The system is program to initiate automatic location update with the activation of tracking process. Figure 3 shows the implementation layout for the proposed tracking system.

RESULTS AND DISCUSSION

Results of System Design and Fabrication

The tracking device has three basic embedded components combined in a single chip as shown in Fig. 3. These components are the Global System for Mobile (GSM) communication module using 4G/LTE-A technology, Global Positioning System (GPS) and the STM32L071KZU6 microcontroller as presented in Fig.3. This components are fabricated in a single chip shown in Figs.4 and 5.

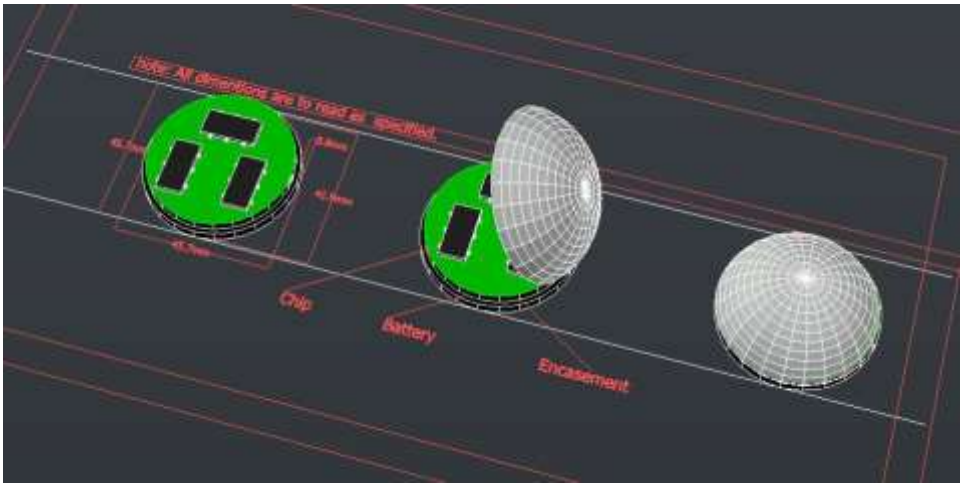


Fig. 3: Proposed Tracking Chip Fabrication

Fig. 4: 3-D Printed Cattle Tracking Chip

As a prototype device, jackets with tying ropes are sewn for each of the chip for installation during testing session. The complete chip arrangement is shown in Figure 5.

Figure 3: Fabricated Tracking chips with jackets

Device Operation

This section examines the following:

1. Steps on how to switch the device on and off.
2. Explanation on how to charge the device.
3. Important battery information.

Switching the device on and off

Switching the monitoring device is very easy. Follow the steps below to switch on the device as in Figs.4 and 7.

1. Locate the on and off hole
2. Gently insert an object with a blunt end (the blunt end of an office pin for example).
3. Remove the pin once you hear or feel a distinctive click. This indicates the pin has made contact with the power switch. A red LED will flash briefly indicating success.
4. Repeat the process to turn off the device.

Fig.6: Turning on the monitoring device.

Fig.7: Three green LEDs indicates the device successfully register itself with our servers

It is important to wait until three green LEDs stops blinking before attempting to monitor any cattle. The three green LEDs indicate the device can communicate geolocation information with our servers.

Charging the device

Charging the device is as easy as removing a protective dust/moisture plastic cover. This plastic cover protects the micro USB port from dust and moisture. The charging port is similar to what is found on most phones. Thus a normal

USB charging cable will charge the device once attached to a 5-volt, 400mA charger.

Battery information

The update frequency of the device determines if it will last a week, 3 weeks or 6 months. Frequent updates (every 3 seconds) reduce the battery energy lifespan, while longer updates in low power mode can extend the battery energy up to 6 months.

Device Deployment

Five tracking devices were successfully deployed. Each device was attached to different Polycon Farm's calf, cow or bull.

Thereafter the cattle Herder led the cattle out to pasture, while the Team of Researchers returned to their command center in order to monitor cattle movement remotely.

Fig. 8-10 represent device deployment on Cattle at Polycon Farm.

Fig. 8: Attaching a tracking Device on a Polycon cow.

Fig. 9: A Polycon Farm's calf with a tracker around its neck.

Fig. 10: Cow wearing tracker and ready for pasture

Device Monitoring

Application Programming Interface (API) was developed for the cattle tracking. It functions as a software intermediary that allows two separate applications to talk to each other. These APIs were converted into web based applications using PHP, MySQL, JQuery, Bootstrap, and vanilla JavaScript. Android APIs were equally deployed in order to produce a monitoring solution for users of Android phones. The developed APIs for the various section of the work is shown in Appendix I

This section details the steps necessary in order to monitor the devices attached to the cattle.

Steps to launch monitoring solution

1. Open your favorite browser (Firefox, Chrome or Edge).
2. Type www.artmanntech.com/fptb in the address bar and press **Enter** key on your keyboard.
3. Wait for the window (shown in Fig. 11) below to appear.

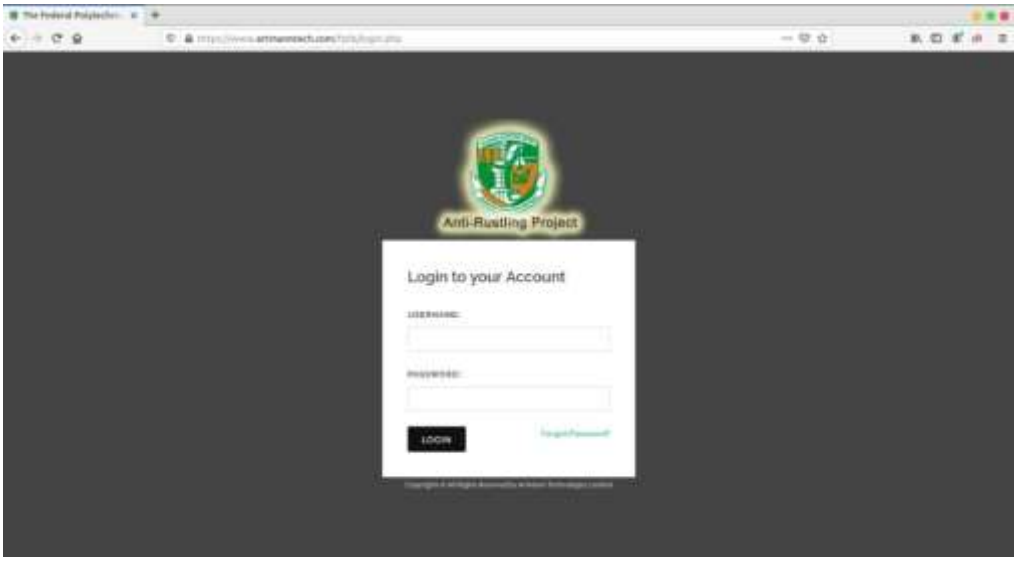


Figure 11: Launching Interface.

4. Type **admin** as the username
5. Type **admin** as the password
6. Press **Enter** key to continue or click/tap on **LOGIN** to continue

Error Message and Self Service Panel

Supplying a wrong password or username will display the error message in Fig. 12:

Fig.12: Showing error message when a user supplies wrong username or password.

On the other hand, supplying correct credentials will display a Self-Service panel, designed to allow users to interact with the solution. The Self-Service panel for **admin** username, and **admin** password is shown below in Fig. 13.

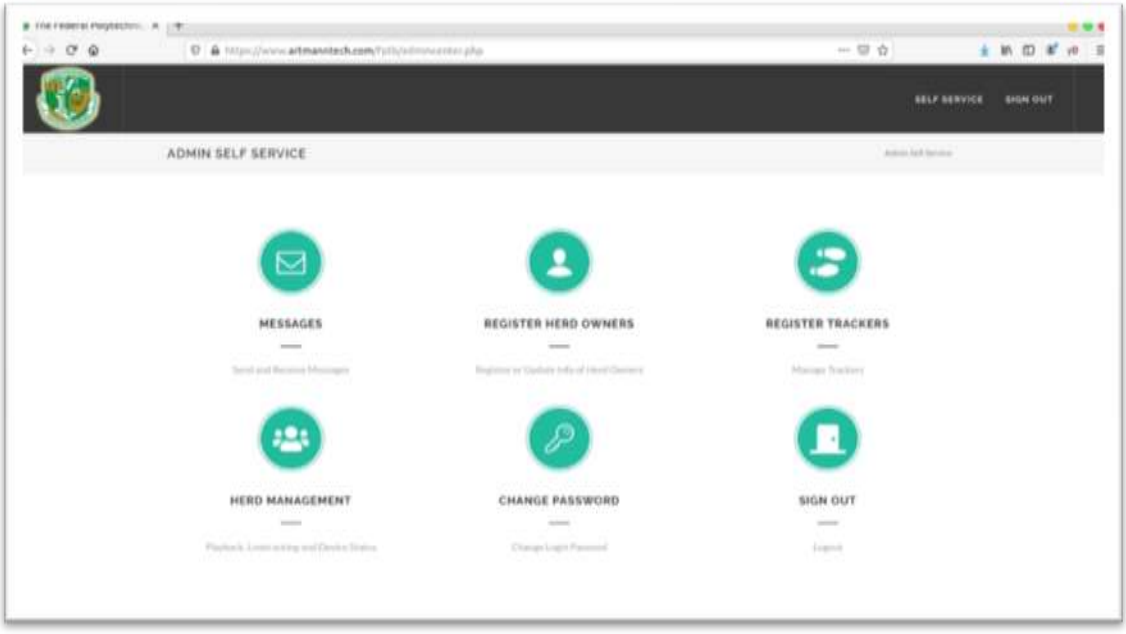


Fig. 13: Showing Admin Self Service Panel

Overview of Admin Self Service Panel

Enumerated below are the various mini-applications in the Admin Self Service panel.

1. **Messages**: This module allows Administrators and Cattle owners to communicate without using email services. It is convenient and easy to use.
2. **Register Herd Owners**: This module allows an Administrator to register Cattle Owners nationwide
3. **Register Trackers**: This module makes it easy to assign monitoring devices to cattle belonging to any owner nationwide. 10,000 devices can be assigned to a cattle herd with minimal effort.
4. **Herd Management**: This module is the primary focus of this section. It allows Cattle owners and Administrators to either monitor cattle location

in real-time, or to playback locations visited by different cattle herds within the last **15** days.

5. **Change Password**: Allow users to change their login password.
6. **Sign Out**: This option allows users to sign-out of the solution.

Herd Management

Herd Management module contains the following sub-modules (shown in Fig. 14), under **Action** column):

1. Playback Module
2. Live Tracking Module
3. Power Management Module

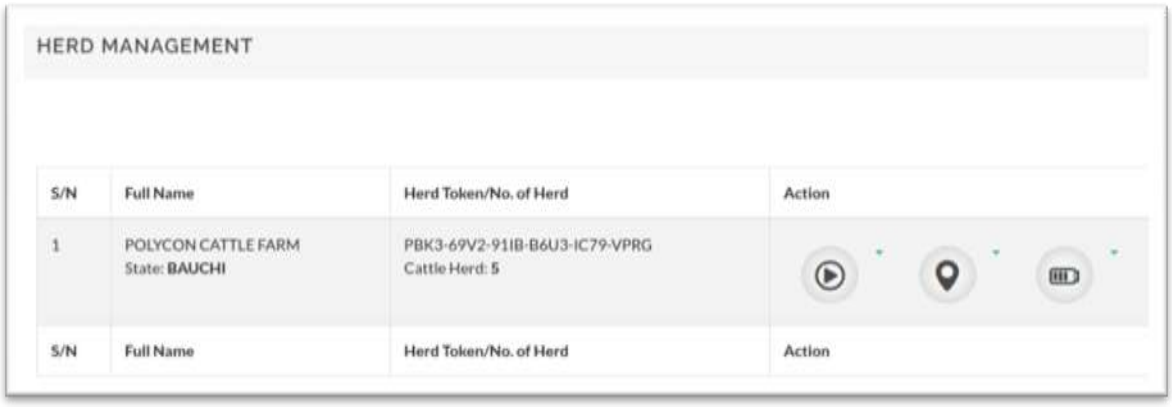


Fig. 14: Herd Management Module

The module equally allows Administrators to know the number of cattle belonging to each Cattle owner. This information is useful during tracking and playback, because it is easy to compare total

Playback Module

The playback module provides users with the ability to view historical movements of their cattle as they search for pasture. Playback equally assist herd owners to determine if hired Herders are taking proper care of their cattle herds.

Finally, the playback module is useful in determining when a calf, bull or cow went missing from the cattle herd.

The solution organizes playbacks by dates (as shown in Fig. 15) it can store as much as 15 days' worth of playback for each cattle. Playbacks above 15 days are stored in a backup system and are available on demand.

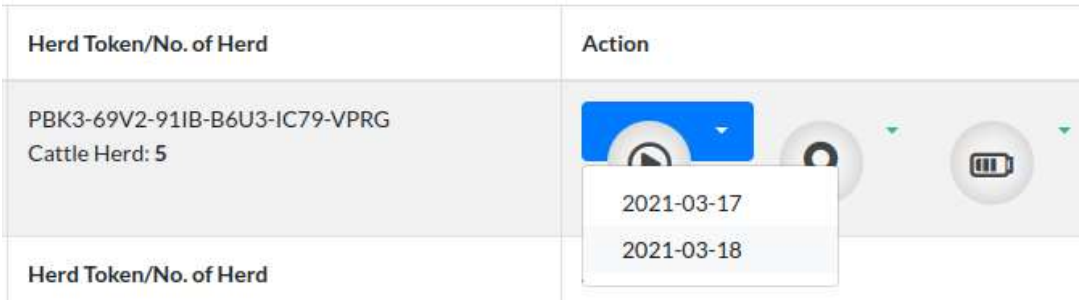


Fig. 14: Playback dates

How to Playback Cattle Historical Locations

1. Click on Playback icon.
2. Select a date from the dropdown (as shown in Fig. 15).
3. This action will automatically display a new Playback window, showing the progress of each cattle as they search for pasture (Fig. 16-19 below).

Figs. 16-19 represent the movement of each cattle from their pen to pasture, after device deployment at Polycon Farm.

Fig. 16: Showing Polycon Cattle inside their pen, after devices were attached to 5 cattle.

Fig. 17: Showing cattle leaving their pen for pasture.

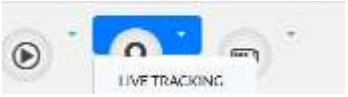
Fig. 18: Cattle are moving farther away from their pen

Fig.19: Cattle are grazing as they move.

Live Tracking Module

Live Tracking module provides users with the ability to quickly identify the last/current location of their cattle. Cattle locations are transmitted to our servers every 30 seconds by the monitoring device attached to each calf, bull or cow. Transmitted locations are converted into latitudes and longitudes, which are eventually plotted on Google Maps to show the exact location of each cattle in real-time. Note that daily Live Tracking locations are stored for future playback purposes.

Click on Live Tracking icon to start the application, then select **LIVE TRACKING** from the drop down.



Figs 20-23 represent the real-time movement of each cattle from their pen to pasture, after device deployment at Polycon Farm.

Fig. 20: Showing Polycon Cattle inside their pen, after devices were attached to 5 cattle.

Fig. 21: Showing cattle leaving their pen for pasture.

Figure 22: Cattle are moving farther away

Figure 23: Cattle are grazing as they move.

Power Management Module

This module allows Administrators and cattle owners to monitor the energy level of each monitoring device. It identifies devices whose battery levels are dangerously low, and allow an Administrator to switch the device to low power updates. Low power updates can prolong device battery lifespan by several months.

Click on Power Management icon to start the application, then select **POWER MANAGEMENT** from the drop down.

Fig. 24 below represents Power Management application interface:

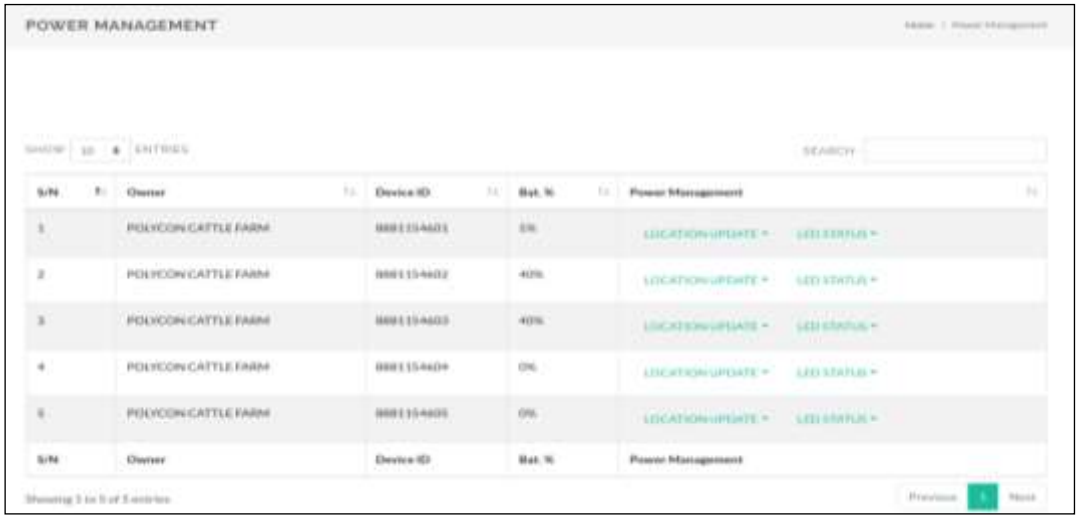
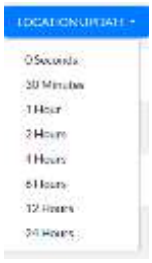


Fig. 24: Showing Power Management Module

Note that Power Management lists all monitoring devices belonging to Polycon Cattle Farm in Fig. 24 a. That's Owner's Name, Device ID, Battery Percentage and Action to perform on each device.
There are two actions that can be performed on each device, these are **LOCATION UPDATE** and **LED STATUS**.

Location Update

Location Update can prolong battery energy lifespan by increasing the delay between locations reporting, this compels the transceivers on the device to use less energy. For example, a device that reports cattle location every 30 minutes will consume less energy compared to a device that reports its location every 1 second.



LED Status

The three green LEDs on the monitoring device are useful network connectivity indicators. Without these LEDs, it is almost impossible to determine if the device has registered its' presence online or not. However, these lights equally consume energy and reveals the presence of the device in the dark. Thus, the lights could be turned off via LED status.

CONCLUSION

The primary objective in conducting this research is to determine the possibility of tracking cattle locations using home grown technologies with absolute device control. From the foregoing report, one can conclude that this research work was successful.
Future Research and Development
It is hoped that this work can be enhanced in future research areas enumerated below:

1. Miniaturizing the current device for easier concealment and reduction in power requirement. This is because producing a very small device for implant on cattle requires high technology (Hi-Tech) which involves collaborations and costs.

2. Incorporate other stake holders like Veterinary Doctors or Animal Scientists to advice on the safe location for device installation/implantation.
3. Measurement of radiation emitted from the device and determining its safety limits. This is done by investigating the electromagnetic field exposure parameters related to animal health and measuring the specific energy absorption rate (SAR) of the device for a period of 6 months to 1 year.
4. Deployment of Geofencing Module: This module will alert Cattle Owners (via SMS) when their cattle leaves a particular geographical location.

5. Development of Better Battery and Energy Saving Algorithms: Our primary objective under this research area is the design and development of a novel battery technology that can last four years.

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APPENDIX I
CATTLE TRACKING API

F.P.T.B Cattle Tracking Project

API is an acronym for **Application Programming Interface**. It functions as a software intermediary that allows two separate applications to talk to each other. For example, each time you use your debit card on a website, the website uses API to connect to the card issuer to validate your balance, thereafter the transaction is authenticated if the balance covers the service/product you purchased.
Enumerated below are various APIs that can be used to track and report on cattle movement.

VIEW CATTLE HERDS

To get the list of all the devices belonging to a Cattle-Owner, send a request to:
https://tracker.artmanntech.com/FPB/MyHerds

API Request Body:

{

```
        "HerdToken": "owners will be assigned tokens",
        "username": "username",
        "password": "password"
    }
```

Example
https://tracker.artmanntech.com/FPB/MyCattles?HerdToken=849SDJFSLe&username=alhajiabdul&password=8fksp=
Response:

```
    {
        "username": "",
        "DeviceDetails": [
            {
                "DeviceId": "",
                "Latitude":,
                "Longitude":,
                "LastLocation": "",
                "Speed_kmh": 0,
                "Heading": 0,
                "Elevation": 0,
                "Voltage": -1.0,
                "IsStopped": false,
                "CellularStrength": -1,
                "SatelliteStrength": -1,
                "Interval": 3,
                "Icon":
                "LastLocationTimestamp":
            }
        ],
        "message": {
            "result": true/false,
            "description": "success/ error message"
        }
    }·
```

LIVE TRACKING

To get the location of a cow/bull, call the following service:
https://tracker.artmanntech.com/FPB/CattleLocation
API Request Body:

```
    {
        "HerdToken": "enter your token here",
        "deviceId": "serial number",
        "username":"username",
        "password": "password",
        "beginAt":"format int WAT time: 2021-02-01T08:00:00.000"
    }
```

Note: API response will send the list of locations from '**beginAt'** till the time the device on the livestock last updated.
Response:

```
    {
        "deviceId": "",
        "username": "",
        "location": [
```

```
                {
                        "Latitude":,
                        "Longitude":,
                        "Location": "",
                        "Speed_kmh":,
                        "Heading":,
                        "Elevation":,
                        "Battery":,
                        "Icon":
                        "Timestamp": ""
                },
        ],
        "message": {
                "result": true/false,
                "description": "success/error message"
        }
}
```

HISTORY/PLAYBACK

To get the location history or playback (between start and end date) of a device, use the following service:
https://tracker.artmanntech.com/FPB/HerdMovement

API Request Body:

```
{
        "HerdToken": "enter your token here",
        "deviceId": "serial number",
        "username": "username",
        "password": "password",
        "start": "start day(MM/DD/YYYY)",
        "end": "end date (MM/DD/YYYY)"
}
```

Response:

```
{
        "deviceId": "",
        "username": "",
        "DeviceDetails": [
                {
                        "Latitude":,
                        "Longitude":,
                        "Location": "",
                        "Speed_kmh":,
                        "Heading":,
                        "Elevation":,
                        "Timestamp": ""
                }
        ],
        "message": {
                "result": true/false,
                "description": "success/error message"
        }
}
```

The API will return a maximum 10,000 locations from the database.

INSTANT GEOFENCE ALERT

Instant or rapid geofence automatically creates a perimeter around the cow or bull. The owner will receive SMS alert if the cow or bull leaves the perimeter. Use the following service to set up an instant or rapid geofence alert:
https://tracker.artmanntech.com/FPB/RapidFence

API Request Body:

```
{
        "HerdToken": " enter your token here ",
        "deviceId": "serial number",
        "username":"username",
        "password": "password"
}
```

Response:

```
{
        "username": "",
        "deviceId": "",
        "message": {
                "result": true/false,
                "description": "success/error message"
        }
}.
```

BATTERY ENERGY EXTENSION MODE

To put the device in Low Power mode (and extend the battery lifespan), send a request to:
https://tracker.artmanntech.com/FPB/ExtendBatteryMode

API Request Body:

```
{
        "HerdToken": "enter token here",
        "deviceId": "serial number",
        "username":"username",
        "password": "password",
        "hr": "--"
}
```

Available **hr** values:
30: Update location every 30 minutes
1: Update location every 1 hour
2: Update location every 2 hours
4: Update location every 4 hours
6: Update location every 6 hours
12: Update location every 12 hours
24: Update location every 24 hours
0: Full Tracking Mode
Response:

```
{
        "username": "",
        "deviceId": "",
        "message": {
                "result": true/false,
```

```
                "description": "success/error message"
        }
}
```

TWO-WAY COMMUNICATION TEST

To test if the device can receive remote commands, use the API below to turn-on or enable device LED (important – always turn LED OFF):
https://tracker.artmanntech.com/FPB/LEDOn

API Request Body:

```
        {
                "HerdToken" : " enter your token here ",
                "deviceId": "serial number",
                "username":"username",
                "password": "password"
        }
```

Response:

```
        {
                "deviceId": "",
                "username": "",
                "message": {
                        "result": true/false,
                        "description": "success/error message"
                }
        }
```

.

To turn-off or disable device LED, send a request to:
https://tracker.artmanntech.com/FPB/LEDOff

API Request Body:

```
        {
                "HerdToken": " enter your token here ",
                "deviceId": "serial number",
                "username":"username",
                "password": "password"
        }
```

Response:

```
        {
                "deviceId": "",
                "username": "",
                "message": {
                        "result": true/false,
                        "description": "success/error message"
                }
        }
```