Development of a Wireless Sensor Network (WSN) Based Energy Efficient Cattle Monitoring System

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Authors' contributions

This work was carried out in collaboration among all authors. Authors AAI and OOA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors OWB, JZE, NEO and TAA managed the analyses of the study. Authors JAO and MSL managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study shows how to monitor the movement of cattle using wireless sensor nodes powered by a renewable energy source capable of detecting location. Performance analysis was carried out on the energy consumption pattern of the nodes which indicated that throughout the monitoring period, the average energy consumed by the nodes was thus; master node 6450 joules, node one 1680 joules, node two 1656 joules, node three 1676 joules, node four 1656 joules. The rate of energy consumption was sustained by the renewable energy source. It was equally observed that energy consumption increased depending on how often query was sent and how often the conditions of monitoring was violated. This is to guarantee that information about cattle location gets to the base without delay due to battery failure which has been a major challenge faced with the current existing systems in tackling cattle rustling.

Keywords: Wireless sensor; cattle rustling; energy consumption pattern.

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1. INTRODUCTION

The origin of the Wireless Sensor Network (WSN) concept is related to military applications and its appearance was motivated by the recent advances in Micro-Electro-Mechanical Systems (MEMS) area that has enabled the production of low cost, low power and multifunction sensor nodes [1]. In general, WSN concept concerns a large number of inexpensive small sensing self-powered and communicate in a wireless way, with the final goal of delivering their data to a sink node (i.e base station) which may be connected to other networks (e.g. internet) [2].

Wireless Sensor Network (WSN) is a widely used technology in the present world, given its rapid enhancement in data transferring techniques as well as in size and range give freedom for wide range of application. Applications of wireless sensor networks (WSNs) have been growing at a rapid rate over the past couple of decades. Since WSN has received attention, the accompanying technology also rapidly enhanced, leading to the design of small sensors that are capable of sensing, processing and communicating data [3]. Sensor networks are usually deployed at remote sites. They are charged with the responsibility of sensing and transferring data to the base station for processing and storage. These operations require uninterrupted power source, which constitutes a challenge even in the locations of the sensors [4]. In most cases, the cattle robbers kill and injure the farmers, abuse the women and take away their cattle [5]. This happens in Northern Nigeria especially in Plateau state. Cattle stealing activities are common in Barkin Ladi and some local government Area of the State [5], reports also have it that many villages in Kaduna, Zamfara have been constantly under the attack of the cattle robbers who intimidate the helpless cattle farmers. The Nigerian Special Task Force that is responsible in curbing the excesses of the cattle robbers confirmed that 2501 cows have been stolen and 260 agile persons have lost their lives [6]. Interestingly cattle stealing is common in rural communities but its attendant effect goes beyond the communities where the act is perpetrated.

In South Africa and in most African countries stock theft threatens the livelihood of livestock farmers. For example, in the period between 2010 and 2011, goats to the value of R36.3 million, sheep to the value of R 85.8 million and cattle worth R256 million Rand were stolen in South Africa [7] The impact of stock theft on resource-poor farmers is more severe than on commercial farmers, because they own small numbers of animals and often their livestock is their only source of income and sustenance. Stock theft also increases the cost of production to the agricultural sector and ultimately, food prices rise. There are numerous factors contributing to stock theft such as quick cash yield, unattended grazing as many subsistent farmers allow their animals to wander in search of suitable grazing land, and leaving their livestock in grazing fields for long periods without counting them.

Wireless sensor nodes have been used to optimize pasture utilization, monitor temperature changes and track an animal location [8]. The utilization of mobile wireless sensor nodes allows data collection which will help prevent livestock theft as well as unnecessary loss due to environmental stresses. This research work focuses on the source of energy that is available to the nodes. Since the generation and transmission of data is energy consuming, a solar panel was incorporated in addition to the rechargeable battery on each node and the local master.

Cattle rustling pose a serious security threat to the life and property of the people living in Nigeria and South Africa, and the use of Wireless Sensor Network (WSN) in combating the menace is faced with the challenges of battery lifetime. WSN has the abilities of sensing, processing and communicating over long distances. Its abilities are limited by the capacity of its battery. To use the full functionalities of WSN, either the battery needs to be replaced or recharged in a periodic manner [9]. According to [10], in tracking livestock there is always a give-and-take scene between the lifespan of the battery and how often data collection is taken because the GPS receiver consume more power. This research work makes use of a renewable energy source in powering the nodes.

1.1 Aim and Objectives

The goal of this work is to develop a WSN based energy efficient cattle monitoring system. To attain this goal, the following objectives are set, to

- Design an energy efficient cattle monitoring system using GPS enabled wireless sensor node capable of detecting cattle location.
Develop a prototype of the cattle monitoring system using electronic components.

Evaluate the developed system based on its energy consumption pattern.

2. MATERIALS AND METHODS

The system is made up of a master node or relay node, four slave nodes, farm or ranch. The slave nodes and the master node are mobile around the farm. Fig. 1 shows the Developed System Architecture.

2.1 Developed System Architecture

The wireless sensor network consists of a relay or master node that transmit the sensors information from the field to the end user, four slave nodes that are distributed around the master node. Fig. 1 shows the wireless sensor architecture for the research.

ATmega328p microcontroller was used as the brain chip for processing and execution of the tasks in the slave node. Receiver and transmitter terminals of the GPS module were connected to interrupt pin 0 and 1 of the microcontroller port while RF module transmitter and receiver terminals were connected to interrupt pins 22 & 23 respectively.

2.2 Energy Plot

The energy consumption plots of the nodes was plotted using MATLAB 2018b software developed by MATRIX Laboratory.

3. RESULTS AND DISCUSSION

3.1 Developed Master Node Prototype

Results of the implementation of the various components of the master node which includes the PVC panel that harness the solar energy that is used to charge the rechargeable battery which powered the system. GPS module that extracts the position coordinates from the satellite and passed it on to the microcontroller for processing.

Interaction between the nodes (between master node and slave nodes or between the slave nodes themselves) is via the RF module. In situation where information needed to be passed (on query or event-triggered) from the nodes.

Fig. 2 showed the developed slave nodes which is made up of the RF transceiver, GPS module, PVC panel and the battery charging system.

Fig. 1. Developed system architecture
3.2 Energy Consumption Plots of the Nodes

The plots given in Fig. 3a – f, are the energy (voltages and currents) consumption of the nodes which were plotted using MATLAB code.

3.3 Discussion

From Fig. 3(a), (b), (c) and (d) show voltages across the WSN when powered ON, between time interval of 1 to 2, it can be seen that all the nodes maintained constant voltage magnitude due to idle mode (no communication between the nodes).

Between time 3 to 5, there were changes in voltages and currents during communication between the nodes. During this time, the cattle are within 50 meters apart, i.e. they are within the selected distance threshold. At this point, the voltage level of the master node, slave node 1 and slave node 2 are 4.94 V, 4.98 V, 4.97 V and those of slave node 3 and slave node 4 are 4.98 V, 4.96 V respectively as shown in Fig. 3(a), (b), (c), (d) and (e). The nodes current consumption at this instance are 885 mA, 339 mA, 336 mA, 338 mA and 334 mA respectively.

While at interval 5 to 6, there is a noticeable change in master node voltage and current from 4.94 V to 4.88 V and 885 mA to 1933 mA as seen in Fig. 3(a) and 3(d) when compared to the previous energy consumption, this is due to the fact that, the master node was
queried from the User node in order to get their location. During this time, the slave nodes voltages and currents remain unchanged because they are only communicating with the master as usual. This shows that, the GSM module consumed greater current while sending or receiving messages when compared to it idle state.

At time interval 6 to 8, as can be seen in Fig. 3(e) that one of the slave nodes went out of the range. When one of the slave nodes is out of range, the node’s voltage and current return back to normal values because there were no communication with others any more. At this time, the master node send a notification message of a missing node to the User node.
Table 1. Energy Consumption pattern during idle mode and transmission mode between the nodes

| Time(s) | Master Voltage(V) | Slave 1 Voltage(V) | Slave 2 Voltage(V) | Slave 3 Voltage(V) | Slave 4 Voltage(V) | Master Energy (Joules) | Slave1 Energy (Joules) | Slave2 Energy (Joules) | Slave3 Energy (Joules) | Slave4 Energy (Joules) |
|---------|------------------|--------------------|--------------------|--------------------|--------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| 1       | 4.94             | 4.99               | 4.98               | 4.99               | 4.97               | 4365                   | 1635                   | 1620                   | 1635                   | 1615                   |
| 2       | 4.94             | 4.99               | 4.98               | 4.99               | 4.97               | 4365                   | 1635                   | 1620                   | 1635                   | 1615                   |
| 3       | 4.94             | 4.98               | 4.97               | 4.98               | 4.96               | 4425                   | 1695                   | 1680                   | 1690                   | 1670                   |
| 4       | 4.94             | 4.98               | 4.97               | 4.98               | 4.96               | 4425                   | 1695                   | 1680                   | 1690                   | 1670                   |
| 5       | 4.94             | 4.98               | 4.97               | 4.98               | 4.96               | 4425                   | 1695                   | 1680                   | 1690                   | 1670                   |
| 6       | 4.88             | 4.98               | 4.97               | 4.98               | 4.96               | 9665                   | 1695                   | 1680                   | 1690                   | 1670                   |
| 7       | 4.88             | 4.98               | 4.97               | 4.98               | 4.96               | 9665                   | 1695                   | 1680                   | 1690                   | 1670                   |
| 8       | 4.88             | 4.98               | 4.98               | 4.98               | 4.96               | 9665                   | 1695                   | 1680                   | 1690                   | 1670                   |

(a) Voltage drop across Master Node over Time

(b) Voltage drop across Slave Node over Time
Fig. 3. Voltage and current consumption in the WSN
4. CONCLUSION

In this research work we have been able to monitor cattle movement by using WSN that is capable of detecting location. The developed system architecture is such that the nodes (cattle) can communicate with each other just like in a mesh topology and the master node keep track the information so as to prompt the user node whenever the conditions of monitoring is violated. The threshold distance between the cattle is set at 50 m and the renewable energy source (PVC) ensures the longevity of the battery life which helps in achieving a sustained monitoring. The software part of the developed system was implemented using c language to program the control logic of the developed system and also proteus implementation software was used for the entire design. The hardware part which comprises micro-controller, wireless sensor, mini solar panel make up the prototype. The evaluation of the system energy consumption pattern was done using MATLAB which shows how energy was used in the monitoring process.

5. RECOMMENDATION

- A portable and more efficient source of energy for the WSN should be considered.
- Real time visualization system can be incorporated into the system

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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