Development of Animal Health Monitoring System based on Wireless Sensor Network

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Abstract. Clinical methods for tracking animal health are inadequate as they only include intermittent data which entail too much time and veterinarian knowledge expenditure in equipment. The animal health monitoring system which allocates equipment to be installed on the animal body does provide way of keeping the health of the animal in check. This project seeks to solve the problem of integration in system developed. Also, monitoring of psychological parameters has to be consistent (precision), accuracy and the response time of the system has to be low for a real time monitoring system. The project seeks to achieve a level of accuracy and precision to help diagnose the health situation of the animal. The system consists of two sensors (a temperature sensor, a heart rate sensor). For the implementation of the temperature node, esp 32 which has wifi capability was used while in the case of heart rate, Arduino Nano was interfaced alongside with esp32. The sensor nodes communicate with the sink node which serves as the display unit and also transmit the data to the cloud for real time monitoring. The precision and accuracy achieved by the ECG, modularity built into the system and the deep sleep energy-saving mechanism of the sensor nodes are achievement made by this work.

Keywords: ECG, ULP, LiPo, WSN, Health Monitoring, User Education

1 Introduction

Innovation systems standpoints on agricultural research and technological variations are fast becoming a prevalent method to the study of how society generates,

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disseminates, and utilizes knowledge [1]. Agricultural operations work far differently than those a few decades ago, primarily because of developments in technology, including sensors, devices, machineries, and information technology [2]. These technologies have been applied into various facet of agriculture including livestock farming.

Livestock production is a crucial section of farm economies in developing countries, making contributions of not only food but also hides, fibers, fertilizer and fuel, as well as a modest, interest-producing capital which can easily be mobilized when unforeseen needs arise [3]. The contribution of livestock and animals in the universal worth of agricultural yield makes about 40% of it and add up to the security of food and means of support of virtually a billion people [4]. Figure 1 shows the contribution of livestock production in the agricultural sector. Health and wellbeing of the farm animals is essential and governs its growth and performance. The economic damage instigated by cattle disease is quite often calamitous. For example, in 2001, the foot-and mouth disease epidemic spurred a cull of 4 million animals in the United Kingdom [5].

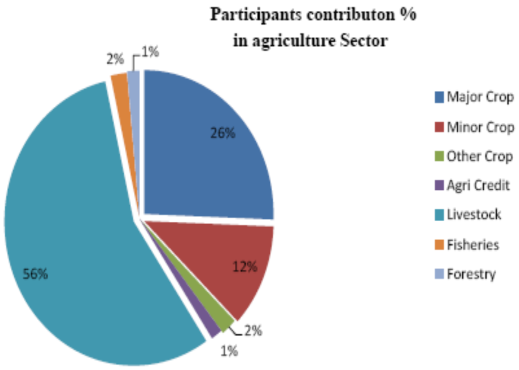


Fig. 1 Participants contribution in agriculture sector [6]

It can be difficult to diagnose infection and illness in pets, they can't tell anyone how they do, and early symptoms can go unseen, implying that serious problems can go undetected until it's too late. Having systems to keep the health state of the animal in check has become possible since the advent of biosensor. This has brought a need for the application of wireless sensor networks which is the next evolutionary step in IOT [7] in livestock farming.

Wireless Sensor Network is assembly of sensor nodes which comprise of sensing device, storage device, processing unit and antenna [8]. WSN create significant impact on a wide range of monitoring area by the coordinated effort of the wireless sensor nodes. The essentials of WSNs has become evident in many domains including industrial automation, infrastructure, healthcare, agriculture, environment, and military command [9].

2 Review of Fundamental Concept

Livestock farming is basically the method of animal breeding for consumption purposes only. Animal husbandry, some other word for livestock farming, is a rapidly expanding farming sector in Nigeria, and its productivity is mainly the explanation why more ambitious farmers participate in livestock farming [10].

2.1 Animal Health

Animal welfare and nutrition are important factors in increasing efficiency and supplying farmers with extra income, for example any disease outbreak or adverse environmental restriction can partially or entirely impact the production system and thus profitability [11]. Healthy animals lead to reducing poverty, making people happy, and making meat safe. It is projected that there will be a 70% rise in animal protein demand between now and 2050.

For time to time, everyone gets sick, and animals are no special. But how do farmers keep animals healthy and make them better when they're sick? Plenty of clean water, meat and a healthy environment are the most important things a farmer can provide to livestock. Such basic yet essential things allow the animals to act normally and go through natural processes such as feeding, sleeping, developing and producing milk for some animals [12].

Together with animal suffering itself, animal diseases are devastating some of the poorest communities in the world and damaging international trade. Preventing and managing diseases is increasing economies, supporting local societies, and enhancing the wellbeing of vulnerable populations, particularly young and elderly people. What's more, it depends on healthy, productive animals to secure a safe, adequate and nutritious food supply at a time of rapidly increasing population [13].

2.2 Health Monitoring of Animals

Most employees in many sectors are subjected to events that can affect them, health monitoring is a coordinated method to assess individuals for early effects from those experiences that could happen to them and ideally detect problems at very early stages before too much damage has happened. It also allows the employer to be provided with information, so they may be able to introduce better controls in the workplace in the first place to prevent injury [14].

Fig. 2 Remote Health Monitoring System

Figure 2 shows the architecture of a remote health screening system. Health screening is done under many different scenarios, from nurses and doctors observing people in clinics, or they may be tracked if an individual is hurt and subjected to dangerous chemicals. It can also be used by an individual to track industrial and environmental health risks in a working environment. With this in mind, there will be many different methods used to monitor health and qualifications needed to be able to participate in certain types of health monitoring. A medical practitioner eligible for the role should always carry out health monitoring [15]. Wireless sensor networks, wearables, tablets, online platforms, and other developments of health technologies are transforming many areas of medical care significantly [16].

2.3 Wireless Sensor Networks

A wireless sensor network is a community of advanced transducers with communications infrastructure at various locations to track and document conditions. Temperature, stress, air direction and speed, light intensity, movement frequency, noise intensity, power line voltage, chemical concentrations, rates of contaminants and critical body functions are generally controlled parameters [17].

2.3.1 Wireless Sensor Network in Health

For telemedicine uses, Wireless Sensor Networks (WSN) are becoming extremely important to monitor patients both in the clinical setting and at home. They reduce discomfort for the user, improve mobility and reduce costs. WSN is also important to Ambient Assisted Living (AAL), as these intelligent devices, customized to user needs, gather user information and its surroundings to provide direct input. [18]. Figure 3 presents a clear overview of WSN in health where with various communication technologies, nodes communicate with gateways to be accessed by medical experts.

Low-cost systems are expected to support service delivery and reducing costs at the same time. Wireless sensor networks can help meet some of these future challenges by simplifying the use of medical equipment, advancing medical care at home, and displaying health and wellness information to both providers and patients. Designing better wireless networks of medical sensors seems to be a good solution to some of the problem [19].

Despite a wider range of potential application frameworks — from pre-hospital, in-hospital, outpatient and home monitoring to long-term database collection for longitudinal trend analysis — the security gap between existing WSN designs and medical applications requirements remains unresolved. WSN are often installed in accessible areas, thus growing weaknesses in security. The complex ad hoc topology, multicast distribution, position recognition, critical data prioritization and synchronization of numerous healthcare software sensors further intensify the security challenges [20].

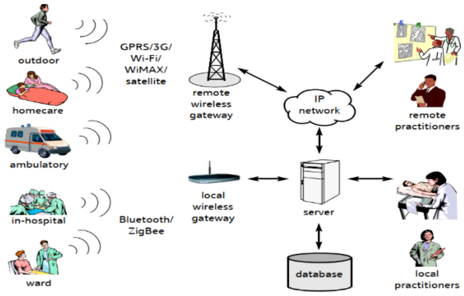


Fig. 3 Wireless sensor network device architecture in healthcare [20]

2.3.2 Wireless Sensor Network in Agriculture

In many plant schemes, effective water management is a major concern. WST has a great potential to reflect the natural soil variation in fields that are more robust than the currently available methods as shown in the figure 4. Therefore, the producers benefit from a better decision support system that allows them to increase their efficiency while saving water. WST also avoids problems in wired field-wide sensor stations and decreases maintenance costs. Since installing WST is easier than existing wired solutions, to provide detailed local data, sensors can be more densely deployed [21].

Fig. 4 Sensor nodes on a field of potato, Rumen Monitoring, Measuring the temperature in the greenhouse [22]

Developing WST technologies in precision agriculture makes it possible in many agricultural production processes to improve efficiencies, efficiency and competitiveness while reducing unwanted impacts on biodiversity and the ecosystem. The fields real-time information will provide a solid basis for farmers at any time to adjust strategies. Instead of taking decisions based on certain hypothetical average conditions that may not exist anywhere in reality, a precise farming approach recognizes differences and adapts management actions accordingly [21].

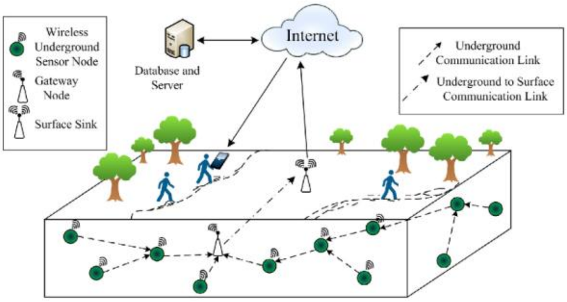


Fig. 5 A typical underground wireless sensor network for agricultural applications [23]

2.4 Review of Related Works

[24] proposed a model of mobile animal health monitoring system which is usable by the user at home and can be conveyed to the veterinarian physician for further examination or primary care. The system consisted of various biomedical sensor modules such as the device temperature, heart rate, cardiovascular, blood pressure, and electrocardiogram. This system had no modularity built into it. It has a central point of failure which is the whole system fails if the center controller fails.

[25] developed monitoring system for animal health which allocates equipment to install on the animal body. The system is made up of four sensors i.e. Sensor for temperature, sensor for measuring the heart rate and the sensor used for quantifying rumination. Use of the Zigbee system and microcontroller factory-made by arduino to activate the sensor unit. In this work, there was no form of remote monitoring in the system. The controller was only interfaced with a local display. This doesn’t give any form of remote monitoring to the farmer or veterinary expertise.

[26] proposed a dual monitoring system for crop and animal where smart irrigation, prediction of ailment and the care for animal health benefiting the farmers are performed using Wireless Sensor Network technology and IoT applications. This system helped in achieving farmer’s productivity. The user can supervise the animal's wellbeing from a distant location and be immediately notified to any transitions in the animal's health status via his smartphone. This system help cares for both animal and crop health but takes no consideration for local display and database.

[27] designed an Incorporated system for animal health control. He suggested a telemonitoring program that would provide continuous animal health information utilizing wearable technology. The system design anticipated that each individual should obtain a computer for health monitoring and a specific identification number. The machine regularly monitors the heart rate, core body temperature, head movement, and exact location of the individual (via GPS) as well as the ambient environment's temperature and humidity. Such information can be buffered by the device for several days. ZigBee-compatible download stations will be installed in high-traffic areas including holders for water, bunk for their feeding, and housing. Loss of power during the period of buffering can lead to inconsistency in data acquired from the node.

[28] for the aim of hasty detection of each individual animal's illness a wireless sensor network system was developed to monitor the animal's feeding and drinking behaviors. A directional antenna is being used to enable a router to concurrently track several species, and a power-efficient mesh networking technique for aggregating monitoring information is suggested.

The Iot-based physical condition testing program for animals was established (Kalaivani, Anitha, Anusooya, & Jean, 2019). Using the corresponding sensors for the critical parameters such as body temperature, heart rate and location monitoring are obtained. Using IoT technologies, the data collected was transmitted wirelessly over the Internet and returned to a server. The machine also alerts farmers / caretakers about the vital conditions. The use of photoplethysmography for the heart rate monitoring which gives a high degree of inaccuracy and bad usage record.

[29] incorporated a Sound-based PLF technique into the analysis of a Real-time Sound Analysis for Health Monitoring in Livestock. As an early warning device for respiratory problems in a pig room, the study examined the efficacy of the respiratory distress screen. He was able to show that the technique works for the early detection of animal reactions in commercial Europe pig houses due to technical difficulties (ventilation problems) and health complications in a variety of different circumstances. In a noise polluted environment, this approach of sound analysis for health monitoring is void.

3 Methodology

3.1 System Overview

This system consists of four (4) modules of which there are two sensor nodes and the software (AHMS website) and the sink/display node. The overall system is represented in Figure 6.

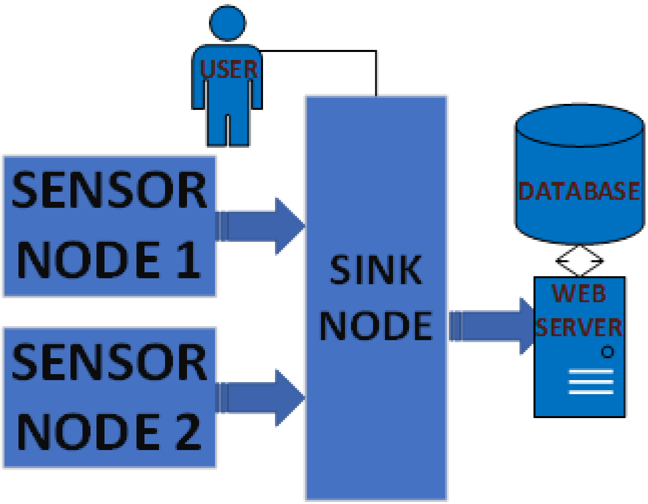


Fig. 6 Overall system block diagram.

The sensor nodes development was based on lolin D32 a version of esp 32. The Atmel Studio Ide (Integrated Development Environment) will be implored in writing the program using the C language programming. The choice of C language programming is because it enables the program to be in compressed format and enhanced faster execution. The block flow is shown in figure 7 and the flow chart of the system work flow is shown in Figure 8.

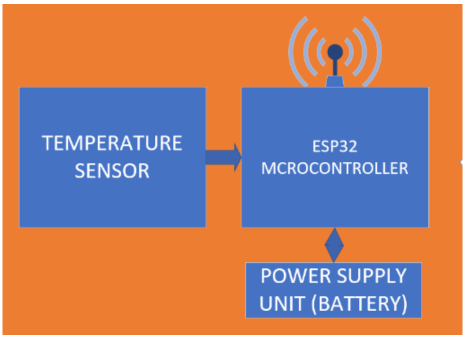


Fig. 7 Block diagram for Sensor Node 1

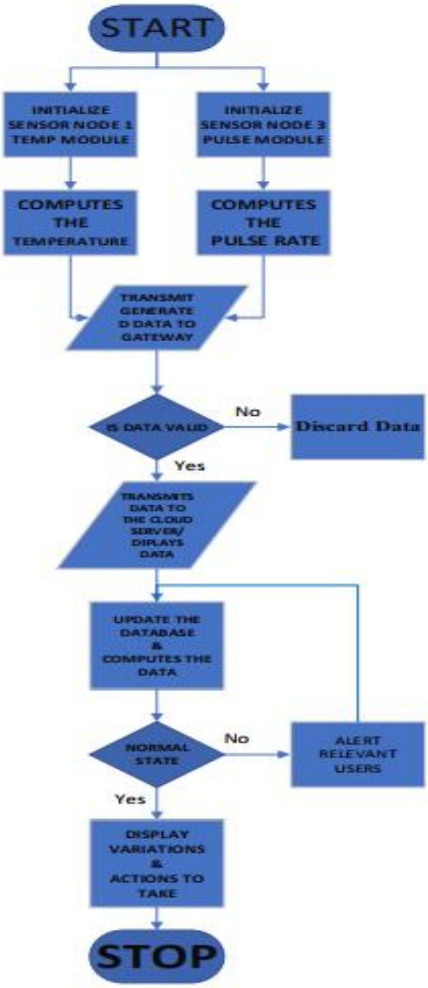


Fig. 8 System process flow chart

3.1.1 Sensor Node 1 (SN1)

This node whose block diagram is shown in figure 9, collects the information about the rectal temperature of the animal, send to the gateway for display and re-transmission to the web server for processing.

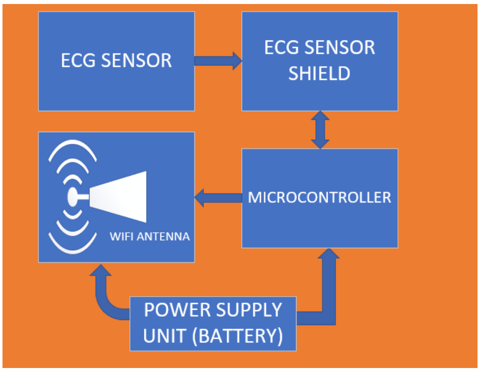


Fig. 9 Sensor Node 2 block diagram

3.1.2 Sensor Node 2 (SN2)

The node is used to collect information about the heart beat rate of the animal, this must be placed rightly as specified by a professional to be able to read correctly the heart beat per minute of the animal. Figure 7.

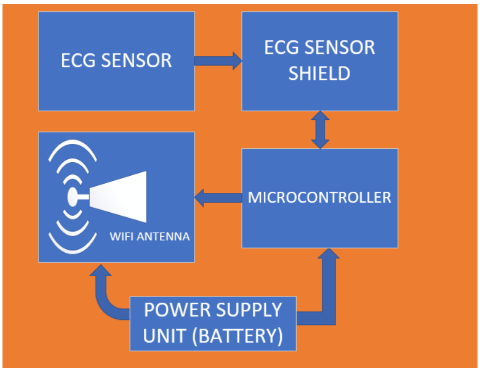


Fig. 10 Sensor Node 2 block diagram

3.1.3 Sink Node

This module is used in collecting data from all the sensor node, it serves as a gateway from which the data can be transmitted down to the web server.

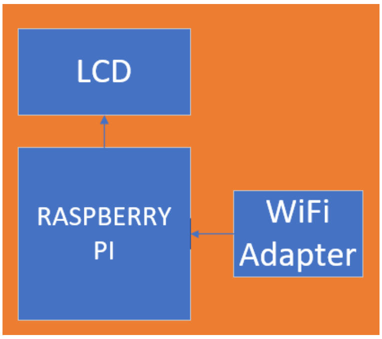


Fig. 11 Block diagram for gateway node

3.2 Hardware System Design

The hardware which are the sensor nodes consists of three or more of the following unit: Control/Processing unit, Sensory unit, Power unit, Display and Communication unit. Each of this is discussed as it is related to the research work.

3.2.1 Control Unit

Sensor node 1 consist of Lolin D32 which is a ESP 32 microcontroller which uses a Tensilica Xtensa dual-core (or single-core) 32-bit LX6 microprocessor, operating at 160 or 240 MHz , performing at up to 600 DMIPS [30] achieves this with ultra-low power consumption [31]. Sensor node 2 consist arduino nano using ATmega328P connected with the sensor computing the bpm and serially interfaced with Lolin D32 controlling the transmission of data from the node. The need for the ATmega328P was due to the reason that MyTimer2 library that the DFRobot shield does not support Esp32 architecture. The sink node uses raspberry pi 3b+ which is shown in figure 13.

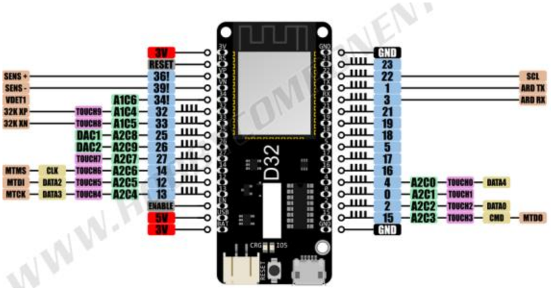


Fig. 12 Lolin D32 [32]

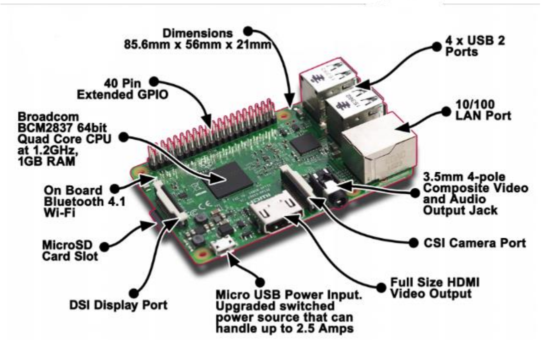


Fig. 13 The Raspberry Pi 3 Model B [33]

3.2.2 Sensory Unit

The sensing unit consists of the temperature sensor and the ECG sensor. Three DS18B20 whose values are averaged is used has the rectal temperature sensor for capability to coexist with other DS18B20 on the same 1-Wire bus [34]. The ECG sensor is used to determine the heartbeat of the animal per minute. This sensor is connected to Dfrobot AD8232 which is an integrated signal conditioner via a jack connector. In the midst of noisy environments, such as those produced by movement or remote electrode positioning, the AD8232 is designed to extract, amplify and filter tiny biopotential signals. The ECG measures the electrical activity produced by depolarizations of the heart muscle which spread towards the skin through pulsating electromagnetic waves. Even though the amount of electricity is actually very small, with ECG electrodes connected to the skin (µV) it can be picked up consistently. The components are shown in Figure 14.

Fig. 14 Analog Heart Rate Monitor Sensor (ECG) [35]

3.2.3 Power Unit

Liter energy 2500maH 1s LiPo battery is used in powering the sensing nodes. LiPos are light reason why they are used in UAVs considering the weight that the animal might have to carry around and the battery has an in-built charge/discharge cut-off voltage circuit. Sensor node 1 use a LiPo while sensor node 2 uses two LiPos parallelly powers the nano and Lolin D32 as shown in Figure 15.

Fig. 15 Lipo 3.7v 2500mAH battery 306080 Li-polymer rechargeable battery [36]

3.2.4 Communication Unit

Lolin d32 and raspberry pi 3b+ both have an inbuilt wifi which was used as a means of communication between the nodes.

3.2.5 Display Unit

A 3.5 touchscreen LCD was used for the sink node's display.

3.3 Performance Evaluation

To carry out performance evaluation for the system, the metrics considered were Response time, accuracy and precision.

Response Time: The time taken for a circuit or measuring device, when subjected to a change in input signal, to change its state by a specified fraction of its total response to that change.

$$\text{Average Response Time} = \frac{\sum(Response\ Time)}{\sum(Number\ of\ Instances)} \tag{1}$$

Accuracy and Precision: The degree to which the result of a measurement conforms to the correct value or a standard while precision refers to the closeness of the measurements to each other. Contrast it to the agreed standard to decide whether a value is accurate. Because such principles can be anything, there has been created a term called percent error. Consider the discrepancy between the accepted value and the experimental value (subtract) and then split by the accepted value [37].

$$\%\text{Error} = \frac{Actual - Measured}{Actual} * 100\% \tag{2}$$

Accessing the precision, we use a statistical method called standard deviation. [37]

$$\text{Standard deviation} = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{N}} \tag{3}$$

where x_i, is the measured value, $\bar{x}$ is the average of the measurement.

4 Testing and Discussion of Result

4.1 Introduction

This chapter discuss the result obtained from the system construction and development. This includes assembly of the hardware, Software Application Development and evaluating of the system performance.

4.2 Results

In this section, each part of the system is evaluated using response time, accuracy and precision.

4.2.1 Response Time

Temperature Sensor Response Time: Testing in different temperature degrees and the time taken to read was recorded as shown in Table 1and 2, and the corresponding relation in terms of graph is shown in Figure 16 and 17.

Table 1. Response Time of the Rectal Temperature Sensor

S/NO	Temperature reading(Degree Celsius)	Time Taken(s)
1	28.55	2
2	40.65	2
3	80.52	5
4	12.36	4
5	5.52	3
Average Response Time = 3.2s		

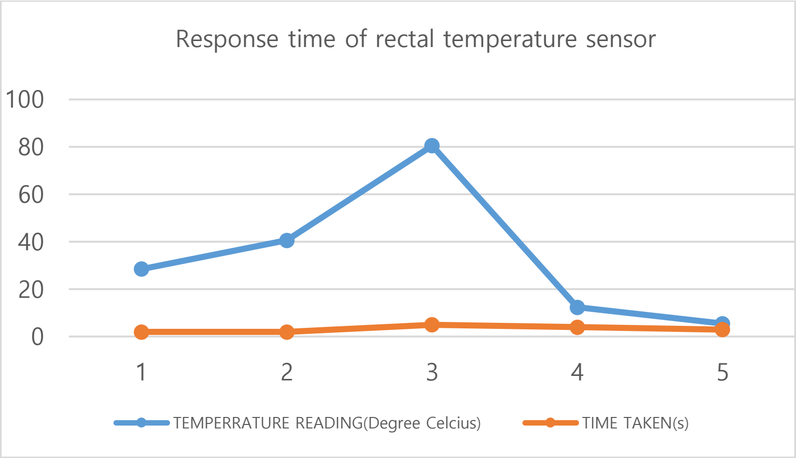


Fig. 16 Response time of rectal temperature sensor

Table 2. Response Time of the ECG Sensor

S/NO	Heart Rate(bpm)	Time Taken(s)
1	126	6
2	78	5
3	81	4
4	100	7
5	91	5
Average Response Time = 5.4 seconds		

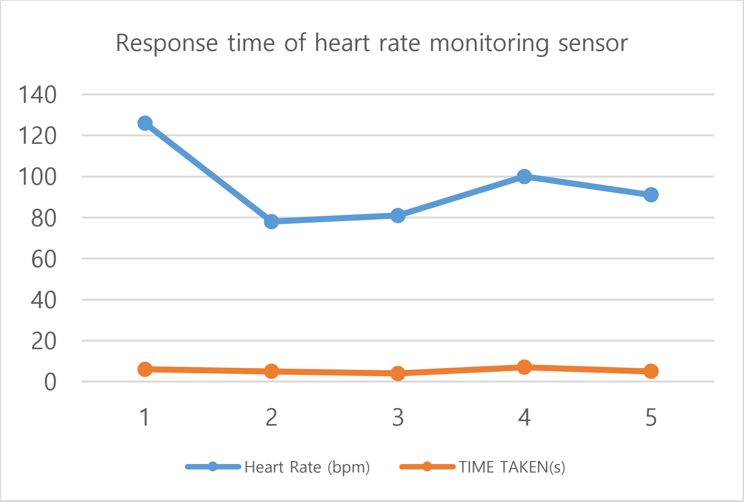


Fig. 17 Response time of the ECG sensor

4.2.2 Accuracy and Precision

Temperature Sensor Accuracy: A digital clinical thermometer was used to measure the rectal temperature of a cattle by the Veterinarian which gave a value of 28.65℃ and the system was also used to measure it as indicated in Table 3.

Table 3. Rectal temperature measurement of a cattle

S/N	Single Ds18b20 Rectal Temperature (℃)	System Rectal Temperature (℃)
1	39.15	38.62
2	38.95	38.45
3	36.98	38.25
4	38.2	38.74
5	37.59	38.86
6	38.04	38.22
Average	38.15	38.52
%Error	1.29	0.33
Standard Deviation	0.75	0.24

Heart beat sensor Accuracy: The veterinarian measured manually using a stethoscope the heart beat a sheep and gave a value of 93 bpm and the ECG was used for measurement as shown in Table 4 with different scenario Table 5 and 6.

Table 4. Heart Rate measurement of an adult sheep

S/NO	Heart Rate (Beat per Minute)
1	91
2	93
3	93
4	100
5	87
Average	92.8
%Error	0.21505376
Standard Deviation	4.2142615

Table 5. SN1 battery level reduction

Day	Scen. 1	Scen. 2	Scen. 3	Scen. 4
0	100%	100%	100%	100%
1	97%	90%	87%	83%

2	94%	75%	69%	64%
3	90%	70%	54%	39%
4	87%	58%	38%	25%
5	87%	47%	23%	6%

Table 6. SN2 battery level reduction

Day	Scen. 1	Scen. 2	Scen. 3	Scen. 4
0	100%	100%	100%	100%
1	97%	90%	84%	80%
2	94%	77%	68%	59%
3	90%	70%	52%	38%
4	87%	58%	36%	18%
5	83%	47%	20%	1%

4.2.3 Power Consumption

Each node has been configured to be able to report it battery level in percent-age till the cut-off is reached. This was done in percentage. Table 5 and 6 shows the decrease of the battery level tested within the period of five days for different scenarios. Scenario 1 is the use of the rectal and heart rate for a cumulative of 30 mins in a day, scenario 2 is for 2 hours cumulative, scenario 3 for 3 hours in a day, then for 4 hours in a day in scenario 4. Figure 18 and 19 show the plots of the different scenario for each day.

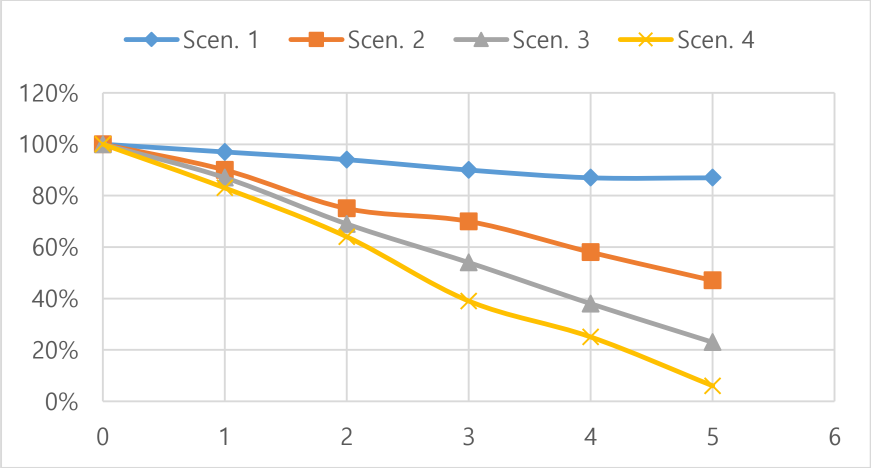


Fig. 18 Sn1 Battery Discharge

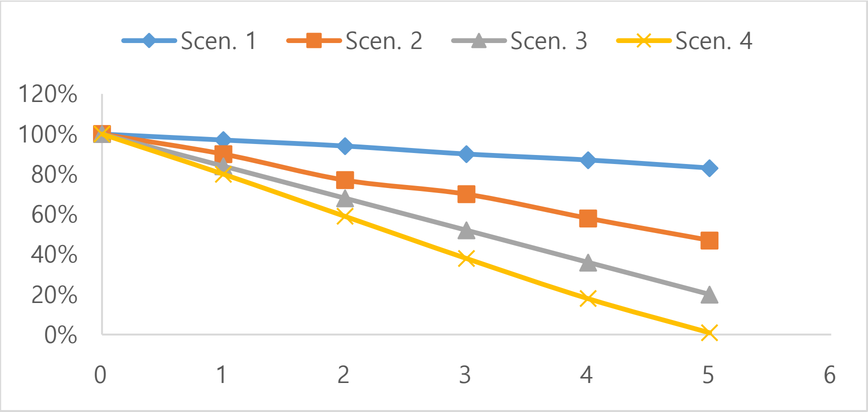
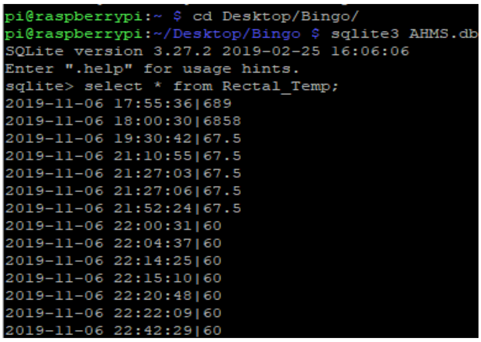


Fig. 19 Sn2 Battery Discharge

4.2.4 Display Unit and Local Database

The display unit and the terminal look of the local database is shown in figure 20 and figure 21 respectively.



```
pi@raspberrypi:~ $ cd Desktop/Bingo/
pi@raspberrypi:~/Desktop/Bingo $ sqlite3 AHMS.db
SQLite version 3.27.2 2019-02-25 16:06:06
Enter ".help" for usage hints.
sqlite> select * from Rectal_Temp;
2019-11-06 17:55:36|689
2019-11-06 18:00:30|6858
2019-11-06 19:30:42|67.5
2019-11-06 21:10:55|67.5
2019-11-06 21:27:03|67.5
2019-11-06 21:27:06|67.5
2019-11-06 21:52:24|67.5
2019-11-06 22:00:31|60
2019-11-06 22:04:37|60
2019-11-06 22:14:25|60
2019-11-06 22:15:10|60
2019-11-06 22:20:48|60
2019-11-06 22:22:09|60
2019-11-06 22:42:29|60
```

Fig. 20 Local Database on the Sink Node

4.2.5 IOT Platform and Database

The remote website was hosted on Google firebase and its database was used. This is to enhance the scalability of the database together with its realtime functionality. Figure 22 shows the dashboard of the remote website.

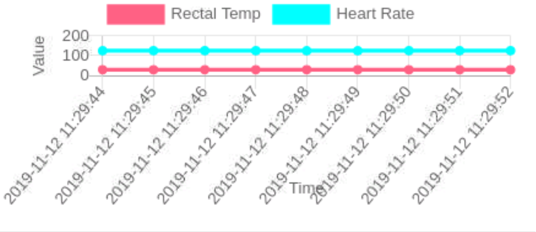


Fig. 21 Local Display dashboard.

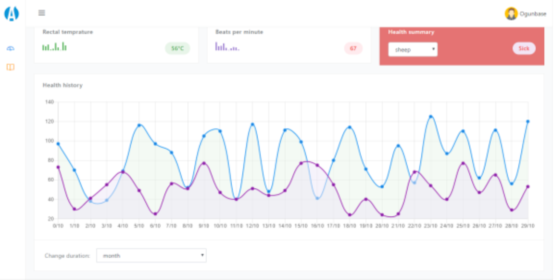
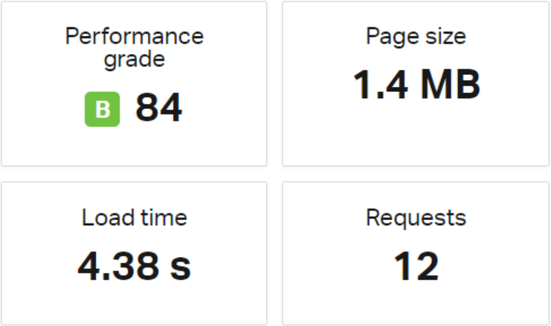


Fig. 22 Dashboard of the AHMS Website

4.2.6 Website Speed Test

Solarwinds Pingdom a tool designed to help make site faster by identifying what about a webpage is fast, slow, too big, and so on , is used to analyze the website for remote monitoring https://ahmsbashe.firebaseapp.com/ and the result generated are shown in the figure below:



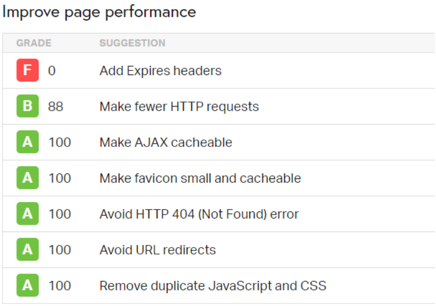
Performance grade
B 84

Page size
1.4 MB

Load time
4.38 s

Requests
12

Fig. 23 Result of the Pingdom Analysis



Improve page performance

GRADE		SUGGESTION
F	0	Add Expires headers
B	88	Make fewer HTTP requests
A	100	Make AJAX cacheable
A	100	Make favicon small and cacheable
A	100	Avoid HTTP 404 (Not Found) error
A	100	Avoid URL redirects
A	100	Remove duplicate JavaScript and CSS

Fig. 24 Individual Performance Analysis.

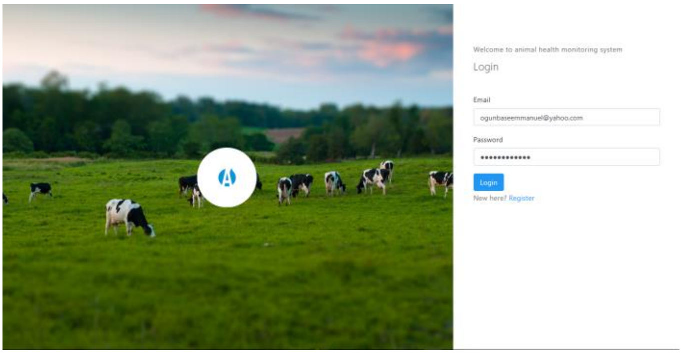
4.3 Overall System Implementation

The Animal Health Monitoring System was implemented so as to be deployed for use in animal farms The software is in two phase the local web platform: display Web platform and the AHMS website. The display web platform is developed using a python frame work called Flask and the front end using chart.js and bootstrap. Sqlite3 is used as the database for the local display unit. This also help the those around the reachability of the wifi signal to be able to view the local data without internet access. The figure below shows the local display dashboard and the database.

Fig. 25 Rectal Temperature Sensing and the Sink/Display Module.

Fig. 26 Heart Rate Measuring Module

The AHMS hosted was developed using Vue.js and chart.js and Google firebase was used as the database. This is to enable real-time monitoring and scalability which it offers and it offers a lot of functionality for free. The figure below shows the login page of the AHMS website. Figure 24 and 25 shows the learning page with the link https://ahmsbashe.firebaseapp.com/.



Welcome to animal health monitoring system

Login

Email: ogunbaseemmanuel@yahoo.com

Password: ••••••••••••

Fig. 27 Login page of AHMS Website

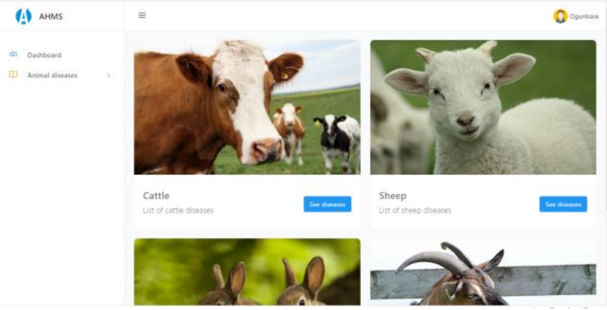


Fig. 28 Learning page of AHMS Website

4.4 Discussion of Results

It can be seen that the response time of the system temperature sensor is very reduced compared to that of a clinical thermometer that takes about 20 seconds and some which takes around 10 seconds to measure. This shows that this system can be deployed to monitoring of the animal rectal temperature and it can quickly detect the variations of the rectal temperature. The ECG is also seen to have a reduced time for sensing and computing the heart rate and shows a reduce rate to that of the manual measurement used by the veterinarian which takes almost a minute to measure.

It can be inferred from the value of the deviation calculated that the rectal temperature and heart beat measurement gives high precision and from the value of the percent error which is very low it can be said that the accuracy of the sensor of a high degree. The comparison between using one ds18b20 [24] with that used in this system was compared and a higher accuracy was obtained.

Lolin d32 has capability to go into deep sleep mode taking a current of about 0.071mA. This is very small compared to when it's fully connected via its WiFi which is 119mA which was measured during the development of the system not using USB power but liPo powered. Depending on the use of the system, the system can be scheduled to take measurement periodically then going into deep sleep. Different scenarios were recorded in Table 4.5 and 4.6. Looking at scenario 1 which depict the use of the system for 2hours day, this does not only mean the use of the system in for 2 long hours, the system can take measurements for 5 mins and goes to sleep for the rest of the hour.

The result of the analysis from pingdom shows that the AHMS website is very efficient and takes load time of 4.38s for first load. The page is responsive and does not require reloading to see new values.

5 Conclusion

The aim of developing the Animal Health Monitoring System based on wireless sensor Networks is to monitor the improvement or decline of health status farm animals (cattle, sheep, and goat) taking into consideration of the two physiological parameters which are rectal temperature and the heart rate. This system notifies users of any deviate from the normal state of the animal helping to take action against dangers of spread of infection amidst the herd, also those that might be zoonotic. This system prevents against loss of animal to un-notifiable disease, thus reducing financial loss and improving food security. This system monitors in real-time providing information both locally and remotely.

5.1 Future Recommendations

In furtherance for this work, multi-model expert system would be looked into to help to help achieve improved predictability of the system as a whole. Thus, offering better insights and benefits to the veterinarian and farmers.

Also, in seeing to both localization and energy consumption issues of the sensor nodes while operational, an algorithm that helps in determining the optimal communication protocol (BLE/Wifi) to be used based on least energy usage and proximity to gateway of the sensor nodes.

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