A framework for Poultry weather control with IoT in sub-Saharan Africa

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***Abstract*—Poultry farming in the sub-Saharan region of Africa is fraught with a lot of challenges among which are high temperature and humidity. In this paper, the authors proposed an Internet of Things (IoT) framework that will help in regulating the various climatic conditions that will help at providing a high yield of poultry products. This framework is aimed at providing proactive and preventive ways to avert or reduce the high mortality rate in a flock of birds as a result of heat stress. IoT which is a connected environment of monitoring sensors with high precision and an accurate decision taken would be presented in managing environmental conditions of poultry house that will gather information, analyze it and effect an action based on the predetermined weather conditions that are suitable for bird's existence.**

I. Introduction

Heat stress is an uncomfortable period in the life of poultry birds. It is a situation where too much heat is absorbed into the body system of a person, plant or animal and causes stress, illness or even death in living things [1]. High ambient temperatures have a major impact on the performance of commercial poultry birds. When coupled with high humidity, the combination usually becomes critical. Heat stress does not only cause suffering and a high mortality rate in the birds but also results in reduced or loss of production. This adversely affects the return on the investment. Birds generally do not have sweat glands[2]. They depend on evaporation, mainly by gasping, spreading out their wings or panting, to control body temperature as shown in Figure 1.

Excessive panting together with high atmospheric conditions results in increased body temperature above the required level. This leads to death in birds within a very short period. Poultry birds are generally comfortable in a range of $45^oF - 70^o$F ($7^oC - 21^o$C)[2]. Temperatures above this could be disastrous to birds. There is a lot of work being deployed in the area of monitoring poultry houses. This framework is going to be advantageous in the sense that it's portable, very cheap to implement and manage, and users' independent. Hence, making it be fast in response to birds' needs. The availability of the system will be maintained with a regular supply of power through a solar energy solution. This system is going to be different from others in this area because some were designed to be remotely controlled by their users. Practically at times, this may lead to response delay at the critical point.

Fig. 1: Open pen poultry birds exhibiting heat stress features

II. Literature Overview

Information technology, as can be seen nowadays. People's way of life is now being influenced technologically up to the area of farming. Automated systems are being deployed that are drastically changing farming processes. In the area of

IoT, sensing devices are introducing to monitor atmospheric parameters like Ammonia gas, Temperature range, and Earth water level and so on. In this our work, authors looked at relevant research papers on the IoT in farming. These were among those works that were reviewed: Santoshkumar et al [3] presented a system that monitors the poultry farm to detect the highly pathogenic avian influenza virus in chicken. The system monitored the body temperature and movement of the chickens when a sudden variation in body temperature and slow movements of the chicken has noticed it gives the possibility of virus detection. The system made use of a wireless system that was implemented with ARDUINO UNO. Raj and Jayanthi [4] proposed an IoT based real-time poultry monitoring and health status identification, the system was integrated with a server to monitor the poultry birds and distinguished the affected ones from the group. This system is user dependable and may result to response delay compare to what we proposed. Zhang et al in [5] proposed IoT based system to monitor and detect the presence of harmful gases that can pollute the air around the livestock and poultry animals thereby leading to declining in their health, growth, reproduction and final products. The design of the system was done by acquiring parameters like light intensity, temperature, humidity, and gas within the animal breeding environment. The data was transmitted into a server through the wireless sensing network (WSN) and mobile communication technology. The data gathered was then compared with the standard data on livestock and poultry growth model stored in a database. In [6], authors developed a Novel Smart IoT based Agriculture Stick to assist farmers in getting Live Data (Temperature, Soil Moisture) for efficient environment monitoring which enables them to do smart farming and increase their overall yield and quality of the product. The Agriculture stick was integrated with various sensors and live data feed obtained online from Thingsspeak.com. It was tested on Live Agriculture Fields with high accuracy over 98% in data feeds. Hazael Phiri in [7] proposed a system for the poultry farmers in Zambia where environmental conditions (such as increased carbon dioxide, high humidity, presence of ammonia gas) and theft were being monitored. The information from the sensor node is sent to the gateway using the ZigBee protocol. Short Message Service (SMS) was also incorporated to alert farmers about the conditions in a poultry house. The work is related to our work by allowing devices to function independently of users i.e. farmers. However, it is different in the way data acquired being used. Heat stress, among those factors responsible for the high mortality rate in poultry farming in the region, is capable of claiming the lives of birds in hundreds within a very short time while other factors have incubating periods. For instance, Coccidiosis in poultry animals. It is an intestinal disease caused by intracellular protozoan parasites with the life-cycle of approximately 4-5 days [8]. Heat stress, on the other hand, occurs as a result of the high-temperature range above 21^{o}C [2].

III. SYSTEM DESIGN METHODOLOGY

We proposed a model to monitor temperature and relative humidity within the poultry. Chicken houses in most cases are either closed or opened. Our proposed model is going to be suitable in either case. In Figure 2, it was shown by the authors how this work is being segmented into stages.

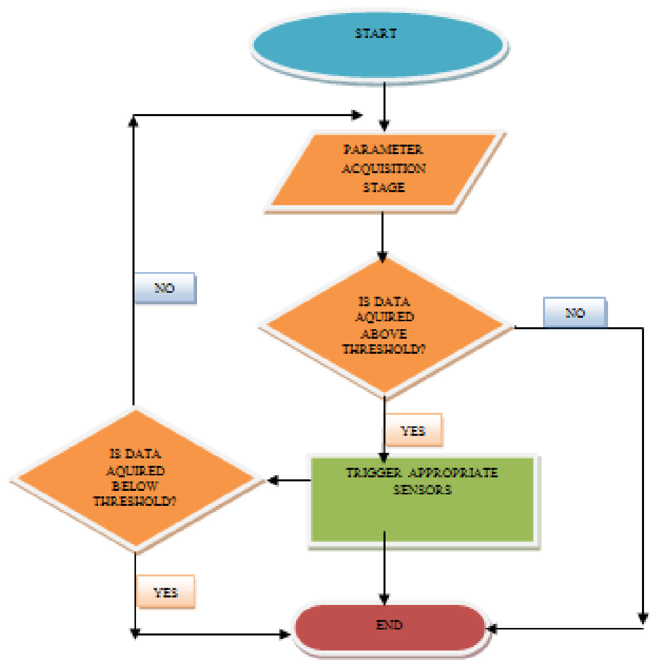

Fig. 2: Chicken house sensing and monitoring flow chart

We segmented our work to contain the parameter acquisition stage and triggered sensor devices based on data acquired by acquisition stage devices. The parameter acquisition stage comprises of IoT sensor devices like a thermostat, temperature sensor, and humidity sensor. The temperature sensor measures the poultry temperature while the humidity sensor measures the relative humidity of the air around the poultry. Immediately the temperature acquired reached the required level, ceiling sprinkler and air cooler connected to a thermostat will be triggered. Ceiling sprinkler will be invoked to control both the broiler body and house temperature so that it does not increase above the normal level. At this point, the air within the chicken house might be warm; air cooler will then be triggered to cool the temperature and also reduces humidity to provide a favorable atmospheric environment for the birds. This method integrates different sensors to form a wireless sensor network via a Cisco home gateway. The proposed framework will be simulated using the CISCO PACKET TRACER package for a better understanding of our proposed integrated environment.

A. *Wireless Sensor Network*

Wireless sensor network (WSN) consists of spatially distributed autonomous sensors connected to monitor real-time physical or environmental conditions such as temperature, sound, vibration, etc. The network is built from a few nodes to several hundred or more, where each node is connected to one or sometimes several sensors. Each one of these sensors in the network has typically several parts like a radio transceiver, microcontroller, an electronic circuit for interfacing with other sensors and an energy source (usually a battery or an embeded form of energy harvesting). They can be configured to effect actions on other network components locally or transfer data across the network over the internet. Figure 3 is an example of a wireless sensor network

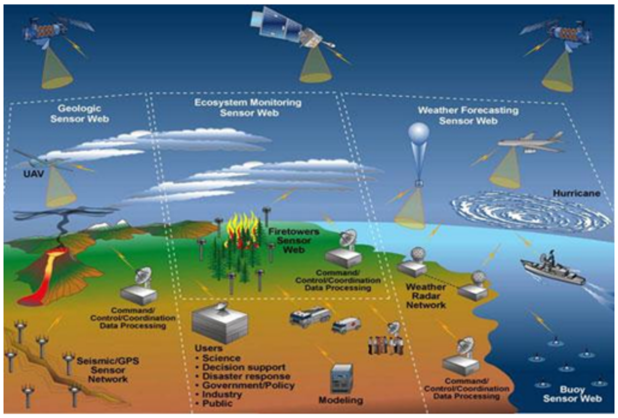

Fig. 3: Source: CISCO Wireless Sensing Network

B. Internet of Thing (IoT)

IoT is a system of wirelessly connected devices using embedded sensors, processors with software and communication hardware which allow connectivity over the internet. IoT ecosystem collects, sends and acts on data or information acquired through an IoT gateway or other edge devices where data is either sent to the cloud to be analyzed or analyzed locally. Sometimes, these devices communicate with other related devices and act on the information they get from one another [9]. In the concept of IoT, every object is connected uniquely through identifier (IP address) so that every object will be accessible on the internet either to transfer or receive data over the network without a human to human interaction. In this work, we will like to take advantage of these connected devices over the internet to monitor the chicken house temperature and relative humidity of their surrounding environment during the hot and dry climatic period.

C. Wi-Fi (wireless networking)

Wi-Fi (wireless fidelity) is a popular wireless networking technology that can exchange information between two or more devices. It provides a high-speed connection with low power consumption through the use of radio waves. According to the latest white paper from the Wireless Broadband Alliance (WBA) on IoT, Wi-Fi is preferred access technology to support IoT deployments [10]. With this characteristic, the design of this work would be beneficial to poultry farmers both on a small and large scale. It's going to be presented based on WIFI (802.11) infrastructure, powered by solar energy system, backup home gateway router will be provided to guard against system failure. Users also will be updated on the situation of things in his/her farm at a particular point in time by way of messaging.

D. DLC100 Home Gateway

This is an IoT registration server configured with the Internet of Everything (IoE) services. The smart devices can directly register to it for accessing IoE services. This gateway provides modules for wire connections i.e. Ethernet ports and wireless (250 meters coverage) access point with secured Wired Equivalent Privacy (WEP) and Wi-Fi Protected Access (WPA). These are the evolution of wireless encryption standard security. We presented the latest encryption protocol on this work i.e. Wi-Fi Protected Access II (WPA2) with the use of optional Pre-Shared Key (PSK) authentication. This gateway is connected to the internet through WAN Ethernet port. It has a default IP address 192.168.25.2 as shown in Figure 4.

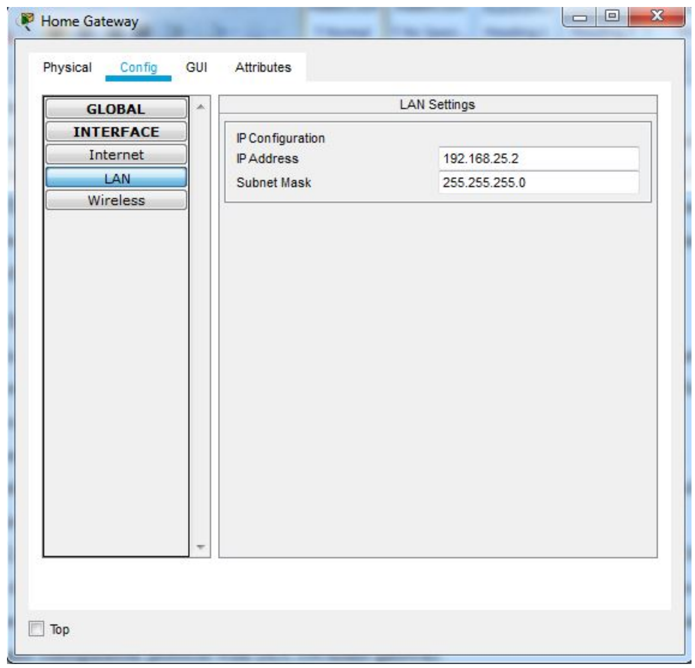

Fig. 4: IP address configuration of Home Gateway

This serves as a gateway address for other smart devices connected to the network [11]. In other to maintain system availability, backup is provided using the same configuration protocol with the DLC100 home gateway.

E. Solar Panel

The power supply in most of our rural area settings has always being a challenging issue. Therefore, this framework design is good implemented using a solar panel. On the Internet of Everything (IoE) services, IoT solar panel is also available, connected over the network. It is home gateway compatible, detects and displays the amount of power being generated. It generates power based on the amount of SUNLIGHT in the environment and sends generated power to another device such as Battery. Since our focus is to deploy a system that will be relatively cheap for the farmers. And on the fact that this work is to combat the effect of heat stress. We found it unnecessary to make use of any battery either to store or supply power. The home gateway needs only 20 watts, whereas this solar panel can generate up to 100 MW.

F. IoT Monitoring Devices

IoT monitoring devices are computing devices connected wirelessly to a network and have the ability to receive and transmit data. Through embedded software and sensors, these devices can communicate and interact over the internet, and they can be remotely monitored and controlled. However, due to the nature of the challenge we are looking at i.e. heat stress. For optimum results, our proposed system design will be user-independent. These smart devices such as temperature sensors, thermostat, air-cooler, and ceiling sprinkler will be simulated via the Cisco Packet Tracer software.

1) Temperature Sensor: Temperature Sensor is a sensor that outputs temperature in Celsius and operates at -100 degrees Celsius to 100 degrees Celsius. The temperature sensor can be controlled locally by connecting it to a Microcontroller Unit board (MCU). From MCU, "analogRead" will be used to read current temperature from the sensor, which gives values from 0 to 1023 mapping to -100C to 100 C. Its data specifications output value: analog output in range 0 to 255, representing -100 C to 100 C temperatures range.

2) Thermostat: A thermostat is one of the IoT devices that is capable of controlling temperature either to cool or heat based on the predefined temperature range. It can be locally or remotely controlled. It works with a temperature sensor to show changes ranging from heating to cooling. In this work; the thermostat is connected to the home gateway wirelessly. Aircooler was connected to it through port D2. The thermostat is configured and set to Auto Mode, immediately it sensed or received a temperature of 20^{o}C - 21^{o}C. Aircooler will be triggered so that temperature is not increased above the threshold (7^{o}C - 21^{o}C). This is shown in Figure 5.

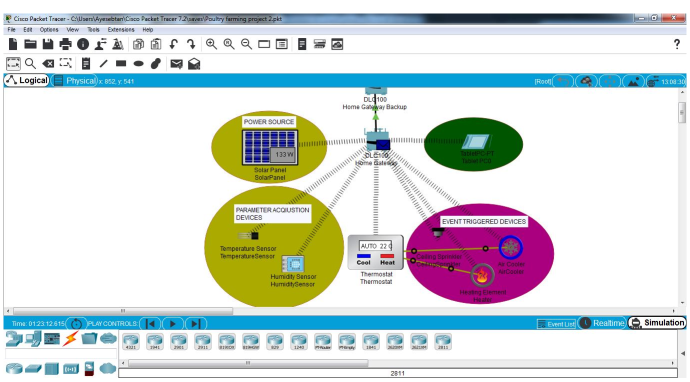

Fig. 5: Air cooler changed blue, showing cooling process

IV. RESULTS

The framework of our proposed work was simulated over the Cisco packet tracer and the result obtained is given. The authors were able to show how frame/packet is sent, received and processed across the nodes over the network. The smartphone connected is used to show those devices connected through the home gateway by login into the home gateway as shown in Figure 6. The output of our login into the home gateway server is presented in Figure 7, showing smart devices connected to it. Home Gateway IP address serves as their gateway address. Simulation results are also presented on the figures thus: Figure 8 is showing Cisco Packet Tracer simulation mode.

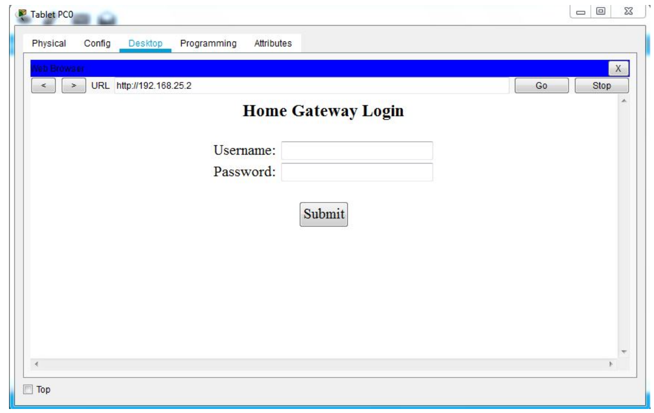

Fig. 6: IoT Home Gateway Login

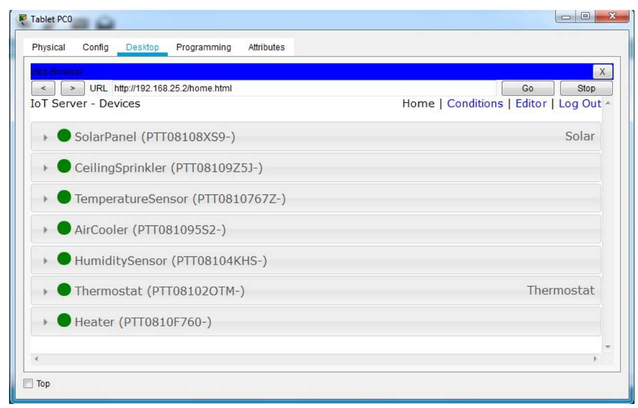

Fig. 7: IoT user device showing smart devices connected to Home Gateway

Figure 9 is the Thermostat simulation interface mode depicting how data is being received from Home Gateway Figure 10 presents how signals from Thermostat is sent to AirCooler through port D2. In Figure 11, a triggered smart device CeilingSprinkler is showing, receiving frame from TemperatureSensor through Home Gateway wirelessly.

V. CONCLUSION AND RECOMMENDATION

In this framework, the authors presented a system that can be used to monitor temperature and humidity levels of the air around the poultry house. The system is to control heat stress in poultry broilers and thereby avert the losses poultry farmers usually faced at the hot period of the year. The method is based

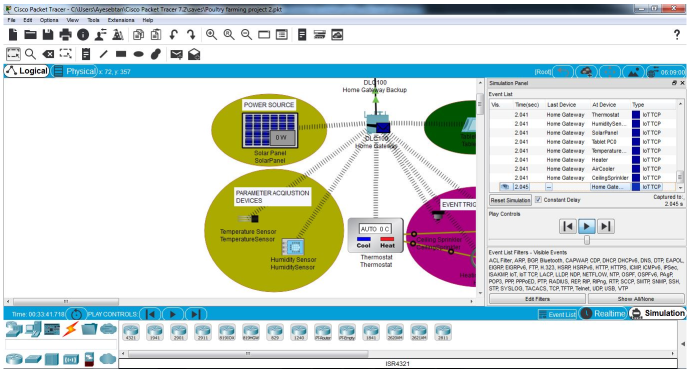

Fig. 8: Cisco Packet Tracer showing IoT simulation mode

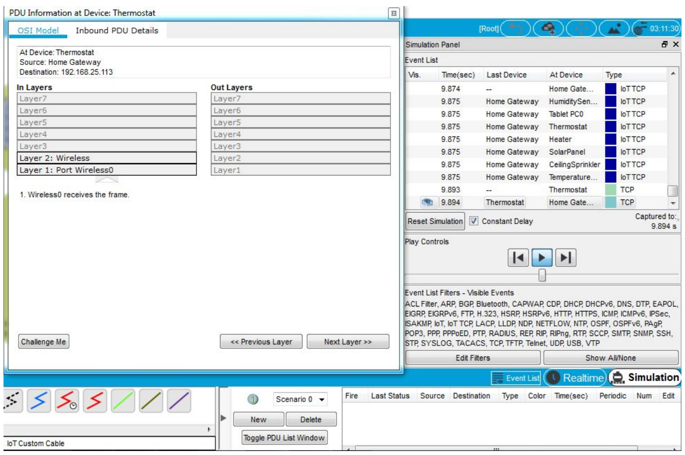

Fig. 9: Thermostat receiving data from Home Gateway

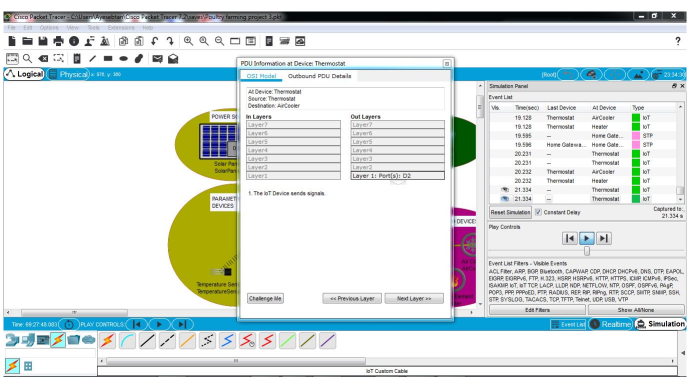

Fig. 10: Thermostat sending signals to AirCooler through port D2

on IoT wireless communication using the WIFI application network. The system designed was simulated on Cisco Packet Tracer to analyze the performance of the proposed system. The method presented provides real-time access to humidity and temperature powered by solar energy to reduce cost and maintaining system availability. Importantly, the system is user-independent to avoid any delay that might occur due to human inconsistency. In the future, we recommended implementing the system with a remote server to obtain empirical data about

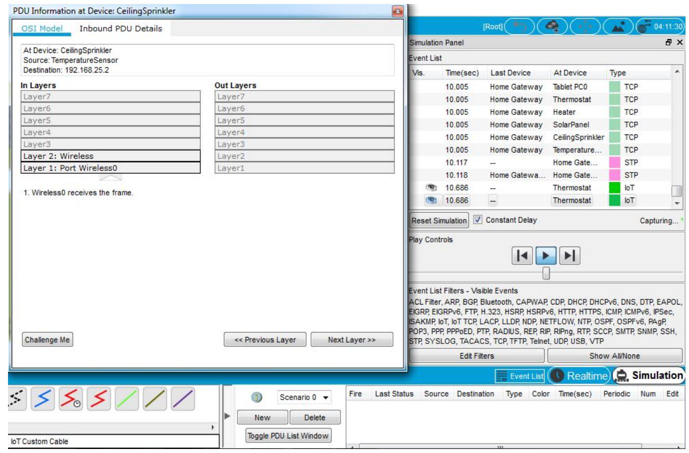

Fig. 11: CeilingSprinkler receiving frame from TemperatureSensor through Home Gateway

its performance and carry out analysis on the period in which heat is at its peak in a year around the sub-Saharan region of Africa. Furthermore, Governments or authorities in the region should also help in contributing to the development of agricultural practice via IoT. This will help in reducing the poverty level of farmers in the region and thereby encouraging some others to participate in farming.

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