IoT Based Smart Poultry Farm in Brunei

Muhammad Faiz Haji Hambali
School of Computing and Informatics
Universiti Teknologi Brunei
Bandar Seri Begawan, Negara Brunei Darussalam
muhammadfaizhambali@gmail.com

Ravi Kumar Patchmuthu
School of Computing and Informatics
Universiti Teknologi Brunei
Bandar Seri Begawan, Negara Brunei Darussalam
ravi.patchmuthu@utb.edu.bn

Au Thien Wan
School of Computing and Informatics
Universiti Teknologi Brunei
Bandar Seri Begawan, Negara Brunei Darussalam
twan.au@utb.edu.bn

***Abstract*— Most of the poultry farms in Brunei are manually monitored and controlled. Temperature, humidity, air quality level, lighting, ventilation and food feeding are the important factors that are needed to be monitored and controlled. These factors are directly related to the poultry production. Currently, the mortality rate of broiler chicken in Brunei is higher than the normal rate. This research project is aim to produce healthy chickens and reduce the mortality rate of chicken to improve the productivity in Brunei by automating the process of monitoring and maintaining the temperature, humidity, air quality level and food feeder effectively using Internet of Things (IoT) and Wireless Sensor Networks (WSN). A prototype was created using IoT and WSN technologies and the above parameters were tested against threshold values. When these parameters exceeded the threshold values, corrective processes are initiated automatically that can help to reduce the mortality rate of chickens in the farm. This system also sends automatic alert notification to the user through SMS, Email and WhatsApp. A Web interface is also created to monitor and display these parameters.**

Keywords*— *Smart Poultry Farm, Wireless Sensor Network, Internet of Things, RESTful Web service, Temperature, Humidity, Air Quality, Arduino

I. Introduction

Poultry is one of the fastest growing economic sectors of agriculture in the world, especially broiler chicken because of its rich nutrient value such as high protein, low fat and low cholesterol. In Brunei, broiler chicken has a steady demand. Brunei produced 25.387 metric tons of broiler chicken in 2018 [1]. Broiler chicken is the major contributor in the Livestock industry retail business in Brunei. In 2017, broiler chicken retail value was 111.11 million Brunei dollars out of 199.81 million Brunei dollars [2] of the Livestock industry. Also, the report says that 93.5% of broiler chicken are locally produced. In 2017, the mortality rate of broiler chicken is 10.3% [2] which is higher than the normal rate. A report from South Africa says that the mortality rate of broiler chicken is only 4.1% [3]. There are many factors for the mortality rate [4] and this research focuses on the environmental factors or thermal factors to reduce the mortality rate. Thermal comfort (temperature and humidity) plays a very important role in the broiler chicken production because it defines the relationship between food consumption and meat production [5]. In Brunei, most of the chicken farms, the temperature and humidity are monitored and controlled manually, so any human error can cause productivity problems.

IoT is the network of physical and virtual devices embedded with electronics, sensors, actuators, software and exchange data through Internet with or without human support [6]. The data collected from the devices are used for two purposes. The first purpose is to automate the process and the second purpose is with the support of data analytics, the collected data can be analyzed to predict any future event. IoT based smart systems are not only used for monitoring and controlling factors, but it can also be used to predict the future events.

There are three main objectives of this research project: the first one is to reduce the mortality rate of the chickens in the poultry farm in Brunei, the second one is to produce healthy chickens and the third one is to improve the productivity of the poultry farm in Brunei. This research uses IoT, WSN, Mobile technology and RESTful web services to automate the process of monitoring and controlling the temperature and humidity in the poultry farm.

II. Background Study

In the last few decades, there has been a demand for quality and safety food all over the world [7]. This makes most of the food industries started to automate their processes, including the poultry industries. Broiler industries can become one of the highest profit-making industries if proper management care, smart environmental control, quality assurance, hygienic conditions and automation are established. Temperature, humidity, lighting, ventilation, food feeding and air quality level are the important factors which are directly related to the productivity of the poultry farm [8, 9]. If the above parameters are taken care, the chicken growth can be steady and healthy. In a manually controlled poultry farm, it is very difficult to achieve a healthy production.

Many researches have been done on the smart poultry farm using IoT and WSN in different countries [6, 9, 10, 11]. According to Ahmadi et al. [10], when the temperature goes high, the chicken consumes less food and convert the feed less efficiently. When the temperature goes low, the chicken consumes more feed to sustain normal body temperature. The feed affects the growth rate of the chicken; hence the temperature has to be maintained at a constant level. Ahmadi et al. also says that an increase in the Relative Humidity (RH) favors the microbial pollution growth in the poultry litter which increases the ammonia (NH3) and the carbon dioxide (CO2) in the barn. High level of NH3 in the barn leads to poor feed conversion, reduced weight and augmented susceptibility of sickness. A high CO2 level leads to tired chickens and reduced weight gains. The air quality inside the barn is very crucial for the chicken because bad air quality increases the mortality rate [10, 12, 13].

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III. Existing System

Most of the poultry farms in Brunei use traditional poultry farming methods. In the traditional poultry farm, the day-to-day operations like temperature and humidity control, food feeding, water level, air quality level, lighting, ventilation and heating are manually monitored and controlled. It is difficult to improve the above productivity factors in the traditional farming methods because it involves large dedicated manpower with prompt manual operations. We visited two local poultry farms, Riza Fudhlana farm and QAF Farm and collected the ideal operating thermal conditions specially the temperature. The following Table I shows the ideal temperature for poultry farm in Brunei with respect to their age provided by Riza Fudhlana farm.

TABLE I. Recommended Temperature for Brolier Chicken

Days (Age of the chicken)	Recommended Temperature (Celsius Degree)
1	34
3	32.5-33.5
6	32-33
9	31.5-32.5
12	31.0-31.5
15	30.0-31.5
18	30.5-31.5
21	29.5-30.5
24	29.0-30.0
27	28.5-29.0

Riza Fudhlana farm uses the intensive production system which is a closed system where the climatic environment was controlled by technology but not automated. Each chicken barn has a supervisor and need to check and adjust the temperature manually in case if there is a change in the value. In the night time, if the supervisor forgot to check or adjust the temperature, it can affect the chicken's health. This farm uses the gas brooder for brooding the chicken, especially for the younger chicken and also when the temperature goes down. The ideal RH is 60 to 70%. Any variation in the humidity value can affect the growth of the chicken. If the RH value goes high, then a series of cooling (exhaust) fans are switched on to move the hot air out and bring in cooler air through proper ventilation. The barn always needs to have good air quality to improve the health of the chicken. Currently, there is no proper system for monitoring the NH3 gas in the barn and if they detect any excess NH3, operators switch on the exhaust fan manually and that will remove the gas to the outside of the barn. According to Sneha et al. [14], NH3 level should not exceed 20ppm over any 8-hour period or 35ppm over any 10-minute period during the poultry production cycle. Currently, food feeder in the barn is done through semi-automatic conveyor belting system. It can deliver food through the belting system, but the availability of food is monitored manually. Again, this becomes a human dependent process and mistake can happen.

IV. Proposed System

This prototype is designed based on the intensive closed production system. In this research project, we took only the four important productivity factors of the poultry farm namely, temperature, humidity, air quality level and the food feeder and automated the process of monitoring and controlling these parameters using IoT, WSN, Mobile Technology and RESTful web services. This IoT based smart system improves the overall health of the chicken, reduces the mortality rate and in turn improves the productivity of the poultry farm. This proposed system reduces the manpower and improve the efficiency of the poultry farm. Apart from alerting the supervisor, our proposed system acts automatically to bring back the thermal parameters within the threshold values.

V. System Design

Our proposed block diagram for the smart poultry farm is shown below in Figure 1. There are three important modules in the system, namely, Temperature and Humidity sensor module, Air quality sensor module and Feeder sensor module.

The main development board used is an Arduino Mega 2560 R3. All the sensors and the relay are connected to this development board. The Wi-Fi controller used in this system is the Arduino NodeMCU Lua IoT ESP 8266. Arduino Mega collect the thermal parameters through the temperature and humidity sensor module, air quality level from the air quality sensor module and the food level from the feeder sensor module and send to the database through the NodeMCU Wi-Fi controller. The database we used is XAMPP. The data are processed in application layer through application program and then through the Access Point, the alert can be sent to any user devices like smart phone, laptop or any devices. There is also a built-in LCD to display the parameters.

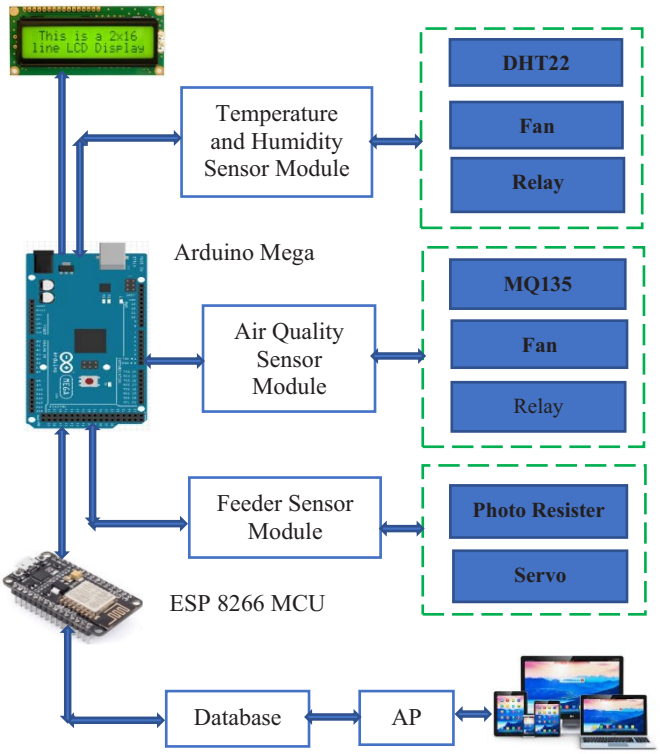


Fig. 1. Block diagram for the smart poultry farm.

A. *Temperature and Humidity Sensor Module*

The temperature and humidity sensor modules are responsible to collect the temperature and humidity on a regular interval and pass the data to the database through the Wi-Fi controller (Network layer). In the application layer, the data are processed as per the Table I and the program performs the necessary action.

B. *Air Quality Sensor Module*

The air quality sensor module is responsible to collect the level of air quality (ammonia gas) in the chicken barn on a regular interval and pass the data to the database through the Wi-Fi controller. In the application layer, the data are processed and the program performs the necessary action.

C. *Feeder Sensor Module*

The feeder sensor module is responsible to collect the status of the food in the bowl and pass the data to the database through the Wi-Fi controller. In the application layer, the data are processed and the program performs the necessary action.

D. *Overview of the Full System Design*

he following Figure 2 shows the full system design including all the sensors. The gas sensor (green) needs to be installed close to the ceiling because the ammonia gas is lighter than air and goes up to the ceiling. If it is above the threshold, then the exhaust fan at the top will be automatically switched on. The temperature and humidity sensor (red) is at the bottom of the barn and this will switch on the fan automatically when the temperature and humidity value is above the threshold value. The light sensor (blue) is used to detect the food level in the bowl and if it is goes below the threshold value, it will switch on the feeder using the servo motor.

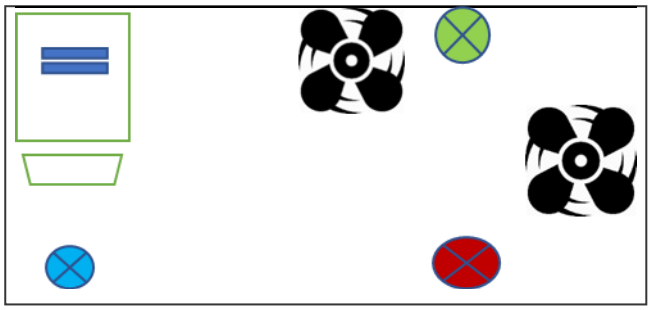
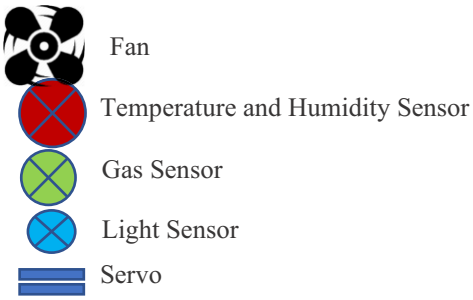


Fig. 2. Full System Design with all the sensors and Fans.

Legends:



VI. Implementation

The hardware used are: Arduino Mega 2560 R3 IoT development board, Arduino NodeMCU Lua IoT ESP 8266 Wi-Fi controller, Arduino 12C (16x9) LCD module, Arduino DHT22 Temperature and Humidity sensor, MQ135 Air Quality Gas sensor, KY-019 5V Relay module (to control AC devices), Servo motor and Photoresistor.

The software used are: Arduino C Programming, XAMPP and Amazon Web Services (AWS) cloud for Web server hosting.

The threshold parameters used for the prototype are shown below in the Table II:

TABLE II. Threshold parameters for the prototype

Parameter	Threshold value
Temperature	<= 32 degree Celsius
Humidity	<= 60%
Air Quality Level	<= 40 ppm
Light	<= 50 Lux

This system uses four types of alert notification. The first one is the LCD and LED alert attached to the prototype. The second one is an SMS alert notification through a mobile phone. Third one is email alert notification and the fourth one is WhatsApp notification.

We used only one temperature value, i.e. 32 degree Celsius for our prototype and if the temperature value goes above 32 degree Celsius, then alert notification will be sent to the supervisor using SMS, email and WhatsApp. At the same time, the cooling fan will be automatically on by the smart system. The inside view of the prototype shows both the fans, feeder, DHT22 sensor and the relay as indicated in Figure 3 (a). The top view of the prototype shows the Arduino Mega, NodeMCU 8266, LCD and the battery power as shown in Figure 3 (b). In IoT based system, power is a major issue. In our prototype, we used 9V battery backup for power. Arduino Mega 2560 takes 5V. For implementation, solar panels can be installed on top of the barn to supply the power for the sensors and other components since solar energy is abundant in this region.

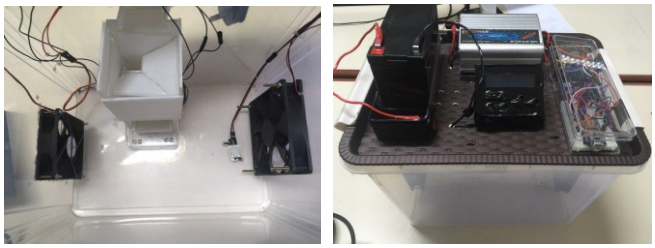


Fig. 3. (a) Inside view and (b) Top view of the prototype

A. *Alert Notification*

This system uses four types of alert notification. The first one is the LCD and LED alert attached to the prototype. The second one is an SMS alert notification through a mobile phone. Third one is email alert notification and the fourth one is WhatsApp notification.

1) LED Alert Notification: There are 6 LEDs included in the prototype, one for temperature, one for air quality and

one for the battery level. Green LED will be on when the parameters are under the threshold value. Orange LED will be on when the parameters are exactly matching the threshold value and the red LED will be on when the parameters are above or below the threshold value. This alert is useful only within the barn. The following Figure 4 shows the red LED is on which indicates that the temperature is above the threshold value.

Fig. 4. LED alert notification on temperature

2) SMS and WhatsApp Alert Notification: The second alert is through SMS notification to a mobile phone. This mobile phone is used by the supervisor of the chicken barn. This is very useful, especially during the night time and the chicken barn is in a remote place. Figure 5 (a) shows the SMS alert notification to the to the registered mobile phone. This is implemented using the Nexmo REST API [15] code inside the PHP program.

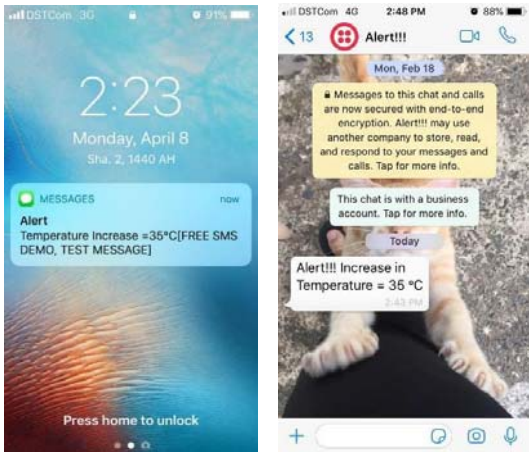


Fig. 5. (a) SMS alert notification and (b) WhatsApp alert notification

Figure 5 (b) shows the WhatsApp alert notification on temperature exceeding the threshold value. This WhatsApp alert notification is implemented using the Twilio REST API [16] code inside the PHP program. This notification also very useful during the night time and the chicken barn is in a remote place.

3) Email Alert Notification: Apart from SMS and WhatsApp alert notification, this system produces an email notification to the supervisor to alert on the thermal parameters. Figure 6 shows the email alert notification as indicated below:

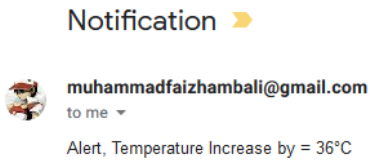


Fig. 6. Email alert notification

B. Farm automation (Smart farm)

Apart from the alert notification, this system automatically does the corrective action by switching on the cooling fans, exhaust fans, light, etc. When the temperature goes above the threshold value, for example if it goes above 32 degrees Celsius then the cooling fan will be switched on. At the same time when the temperature goes below the threshold value, the light will be switched on automatically to increase the temperature inside the barn. The following Figure 7 shows fan is on when the temperature goes above the threshold value.

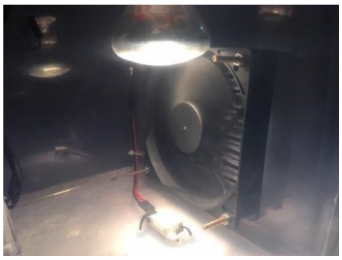


Fig. 7. Cooling fan automation

In the same way, when the humidity, air quality and the light values are above or below the threshold value, alert notification is sent to the supervisor through SMS, WhatsApp and Email and the automation action is also done by this system. For example, when the air quality level in the barn goes above the air quality threshold level, the exhaust fan near the roof will be switched on. Here, the exhaust fan and the air quality sensor are installed near the top in our prototype because NH3 is lighter than air and will be accumulating near the top. The following Figure 8 shows the Web interface of our chicken barn (coop):

Fig. 8. Poultry farm monitoring and control and main page

Our main page consists of temperature and humidity sensor, gas sensor, notification, statistics and log out.

VII. Results and Discussion

The following Figure 9 shows the graphical representation of the readings taken from the DHT22 and MQ135 sensors without and with cooling fan, exhaust fan and light. The results shows that the temperature with the use of cooling fan and light produces more constant temperature (around 32 degree Celsius) than without them, which makes the environment inside the barn is conducive

to produce healthy chickens. The relative humidity parameters also show that with the use of fan and light, it produces more stable RH (around 60%) than without them. This makes the chicken inside the barn to grow healthier. The third parameter, air quality sensor reading indicates that with the use of an exhaust fan reduces the bad air quality and bring the value around 40 ppm. This is another important productivity factor for the poultry farm. If these parameters are maintained along with good hygiene and proper food and water, the mortality rate of the poultry farm can be reduced and that will help to improve the productivity.

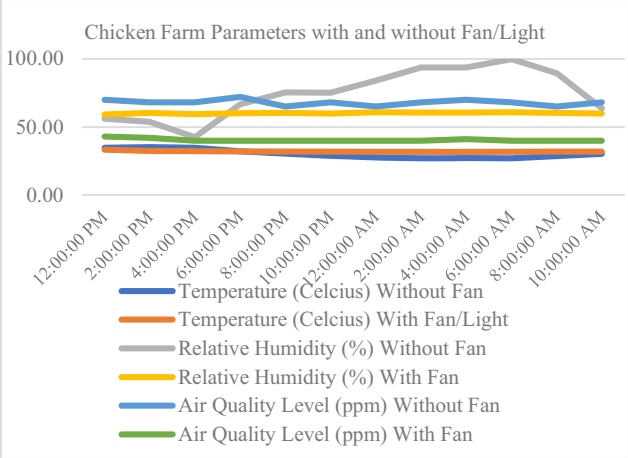


Fig. 9. Poultry farm parameters without and with fan and light

VIII. Conclusion and Future Work

The climate in the poultry farm is very important because it influences the health of the chicken and also the people working in the poultry farm. If the climatic conditions are not maintained well, it can affect the health of the chickens in terms of their digestive, respiratory and other health problems. Brunei being a tropical country with high humidity, maintaining the climatic condition is quite challenging. Our research prototype shows that using IoT and mobile technology in the poultry farm can better maintain the climatic conditions and will reduce the mortality rate of poultry farms in Brunei. In the future, the data collected from the barn can be analyzed using data analytics to predict bird diseases like bird flu and others that can have devastating effects on the productivity of the poultry farm eco-system to help farmers to take appropriate actions before it happens. Also, to save energy, sleep and wake up mode concept can be introduced to save the energy of the smart chicken coop.

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