IoT Platform for Precision Stingless Bee Farming

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Abstract— **In this paper, the construction of an IoT system for precision stingless bee farming is presented. In the proposed system, the weight, the internal and external temperatures and the relative humidity of the beehive are the data being monitored. Sensors utilized are load cell sensors and DHT22 temperature and humidity sensors. The main hardware setup was built using a NodeMCU microcontroller. Data from the proposed system were collected for 36 hours and the collected data was periodically saved into a cloud storage for an interval of every 7 seconds. From the results obtained, the honey produced by the beehives are recorded at 2.63 kg. Meanwhile, the maximum external temperature recorded was 30.6 ^{0}C, and the minimum external relative humidity was recorded at 67.6 %. From these information, the production of the stingless beehive honey production, as well as the security of the beehive from being stolen or vandalize can be predicted. Moreover, the health of the beehive from fungus growth can be estimated in the future. The platform has all functionalities of an advanced monitoring system, complete with an IoT application.**

Keywords—stingless beehive, IoT platform

I. INTRODUCTION

Meliponiculture is best referred to as stingless beekeeping with supportable activities that are good for the environment. This activity offers valuable produce, honey, and propolis. Furthermore, the activity could also improve the crop pollination process in many agriculture businesses. There are several difficulties that beekeepers face in rearing the stingless bee within their hives. This is due to several factors such as time-consuming, the need for prior experiences, pollination activities, weather condition and bee hive security and health. The health of global beehive is dwindling due to a massive land clearing for development or activities such as agriculture thus putting the risk of losing the important pollinators [1]. The increase in temperature within the hive and the ambient temperature around the hive could also be a main factor that bee colonies move to a more comfortable location [2-3]. In 2006, bee farmers face the crisis of Colony Collapse Disorder (CCD) where many honey bees disappeared and caused the extinction of certain bee species [4].

In recent years, bee hive monitoring system in Apiculture was introduced by many researchers to solve these issues and improve the beehive environment [1-5]. To ensure the survival of bee colonies from diseases, bacteria and mites, the ambient temperature and relative humidity inside the beehive must remain stable. Therefore, temperature sensors are the most important sensors used in beehive monitoring system. Traditionally, beekeepers used thermocouple to measure the temperature inside the beehive [4-6] by inserting the thermocouple rod into the beehive through a small opening or hole every time a measurement has to be carried out. This method introduces significant amount of stress to the beehive every time it was exposed. There are various types of digital temperature sensors by researchers such as LM35 by National Semiconductors, SHT15 by sensirion, and kinetis KL15 module introduces by freescale [1-2].

In addition to bee hive temperature monitoring, there are several other researchers conducted in monitoring the acoustic sounds produced by the bee colonies [7-9]. From the sound pattern analysis, the health of the queen bee can be measured [8-9]. In addition to that, parameters such as mass, gas level, air pressure and video images (bee counter) could also be monitored depending on the desired application and results [10]. Mass and bee counter sensors are normally used to keep track of honey and brood production while gas detector is used to detect and monitor bee pheromones. On top of that, video and images monitoring concept is a useful technique that could be applied. However, this method requires a very large amounts of data storage and signal processing skills. Externally, weather stations are widely used to monitor the weather in the surrounding habitat, such as rain, wind and temperature.

The main concept of this project is to present the development of a low power stingless bee monitoring system using an Internet of Things (IoT) platform. The proposed system is used to remotely monitor the beehive security and honey production. Meanwhile, the collected data will be stored in a google firebase cloud storage and could be extracted anytime, anywhere. The proposed system will be accessible to many beekeepers and could measure several general parameters such as temperature, humidity and weight.

In section 2 of this paper, the hardware and software setup are presented. In the following section, the android application development is presented. Meanwhile, in section 4, results obtained is discussed and analysed, followed by conclusion and future work.

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II. Hardware and Software Development

A. Prototype setup

The 3D design of the system on a stingless bee hive is shown in Fig. 1. The designed model is divided into three parts which are the base; which holds the prototype steady, middle part; which is the main hive and the top part; which is the extension box which commonly called as topping where the stingless bees keep the honey. The base is constructed using metal steel and elevated about 300 cm from the ground. The middle part is the main part of the stingless beehive and is made using logs (or cement), and the top part is made using wood planks. The electronic devices for hive monitoring system is installed at the top part.

B. Electronic setup

The hardware setup was built using NodeMCU controller as illustrated in Fig. 2. The proposed system utilizes NodeMCU ESP8266 as a controller. The controller is an open source firmware and the development kit that gives benefits to prototype an IoT product within a few Lua script lines. Moreover, NodeMCU has an added advantages of being low cost, integrated support for WiFi network, small board size and low energy consumption.

There are two types of sensors used in this system. Firstly, four units of strain gauge load cells sensors are integrated with a HX711 modules installed at each edges under the topping for weight measurement. The cell is made up of four strain-gauges and two precision resistors that are connected in a Wheatstone Bridge formation powered at V_{in} = 5 V as formulated in (1).

$$V_{out} = \left[\frac{R_3}{R_3+R_4} + \frac{R_2}{R_1+R_2} \right] \bullet V_{in} \qquad (1)$$

where

R_1 = the strain gauge resistance of the upper right load cell,
R_2 = the strain gauge resistance of the upper left load cell,
R_3 = the strain gauge resistance of the lower right load cell,
R_4 = the strain gauge resistance of the lower left load cell.

Secondly, two units of DHT22 sensor for measuring the inside and outside temperature and the humidity of the beehive are installed. In addition to that, one unit of buzzer was also installed with the load sensors input, to alert the beekeepers when beehive thieves are present.

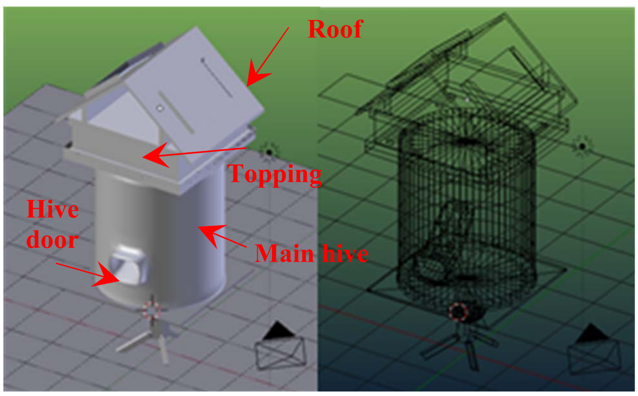


Fig. 1. The 3D Model of the Overall Prototype Design

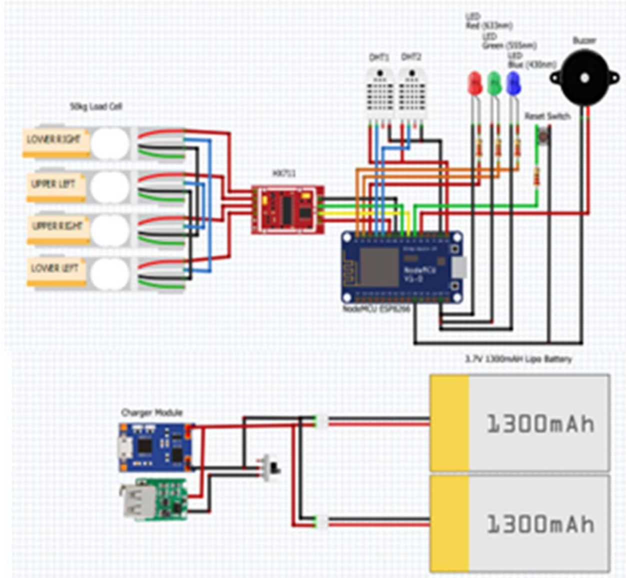


Fig. 2. Schematic diagram of main monitoring system

C. Software and application setup

The main purpose for software setup is to process the data from the sensors and send it to the cloud storage which is accessible to many beekeepers and useful for researchers to perform necessary improvement. This application is based on an android system which can run on any system with API 16 - SDK version onwards. In the proposed system, all information related to the hive will be pushed to Google Firebase database in real time. Also, in real time, this application (apps) fetches all the information from the database and represent it as in graph form for detailed information. The proposed android apps has an interactive graphical user interface (GUI) for user experience to analyse the value of temperature, humidity, and weight. All information are shown in a graph form and could be assessed in a real time.

The opening interface of the developed apps has the splash page. The splash page occurs about five seconds for giving the user overall overview of the brand as well as logo before going to the next login page. Login page was created to allow multiple users to use the system with their own hive data. Registered users could fill in their username and password which is normally an email address to access to the dashboard page. Dashboard page showed an averaged value of total estimated honey production and temperature readings of each registered hives.

Moreover, in the apps section menu, users could find detailed information for each hives in a hive page. Interface of dashboard and hive pages was shown in Fig. 3. The "Hive" tab as in Fig. 3 represents all information related for each registered hive which includes hive weight. On click of hive list, detailed information such as hive location, hive ID, hive weight, estimated time for harvesting, temperature and humidity of inside and outside the hive was shown.

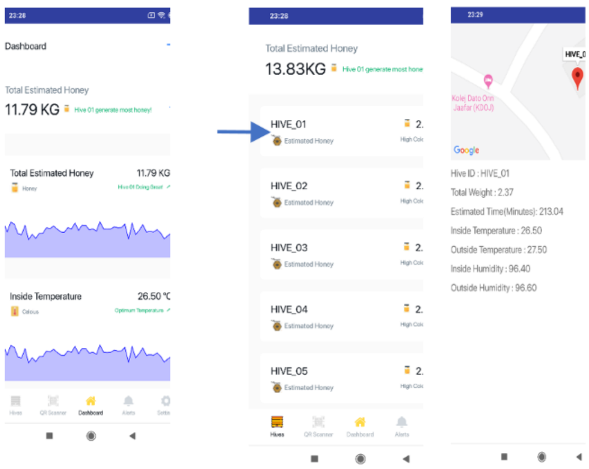


Fig. 3. Dashboard page and details of each registered hive

III. RESULT AND DISCUSSION

The proposed platform was assembled and tested on a beehive at a small colony located in Kolej Dato Onn Jaafar (UTM), Skudai Johor. The hive with an IoT platform mounted on was set in the colony and the data were recorded from 7th December 2018 at 4 pm to 9th December 2018 at 5am. The estimated time for data collected is approximately 36 hours and data are saved for every 7 seconds in a firebase cloud storage. Fig. 4 shows the actual process of pushing the data into google firebase cloud storage at site. The number of datasets extract from google firebase storage were around 12200 sample points that had been screened to produce some perceptions of output as illustrated in Figs. 5, 6, and 7.

Fig. 5 shows the graph of topping weight from 4 pm on December 7th to 5 am on December 9th. From the data, it can be shown that from around 4 pm, the overall topping weight was increasing from about 3 kg up to 4 kg. From this occurrence, it is proven that most stingless bee workers came back and stay inside the hive during evening until night. At around 7 am the next morning, the hive weight started to

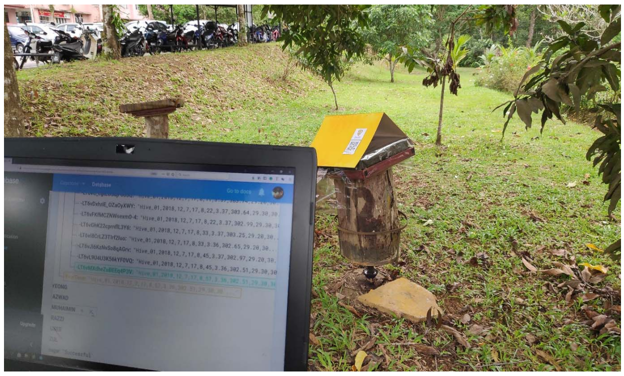


Fig. 4. The actual process of system pushing data into google cloud storage

decrease again which gives the early estimation and perception that most of the matured stingless bee workers left the hive to perform their foraging routine to collect honey, pollen, and resin. At 10 am in the same morning, the total weight is reduced to the lowest weight value at 2.6 kg. This value is referred to the minimum weight of product inside the hive that farmers could collect such as honey, resins, and pollens. It can be observed that some transient fluctuations of weight measurement in Fig 5. due to external force like gust of wind on the roof causing imbalance to the Wheatstone bridge strain gauges load sensors circuits.

Fig. 6 shows the graph of the outside temperature and the relative humidity from 4 pm on December 7th to 5 am on December 9th. The outside temperature data was stable during the 36 hours of the observation period. The temperature reading was steadily changing around 25 °C up to 30 °C during this period. Temperature monitoring is very important because overheating of the hive may cause adverse effect to the health of bee colony and the brood cells development. In a normal condition, the stingless bees can survive at temperature less than 40 °C.

On the other hand, the relative humidity reading is the second important factor to be considered instead of the

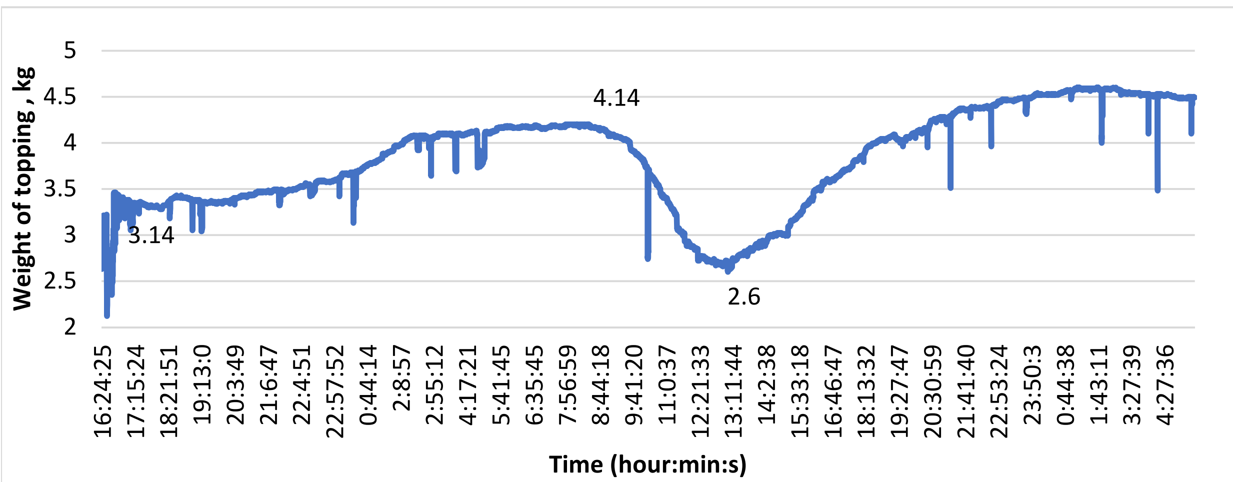


Fig.5 . The topping weight from 4 pm on December 7th to 5 am on December 9th

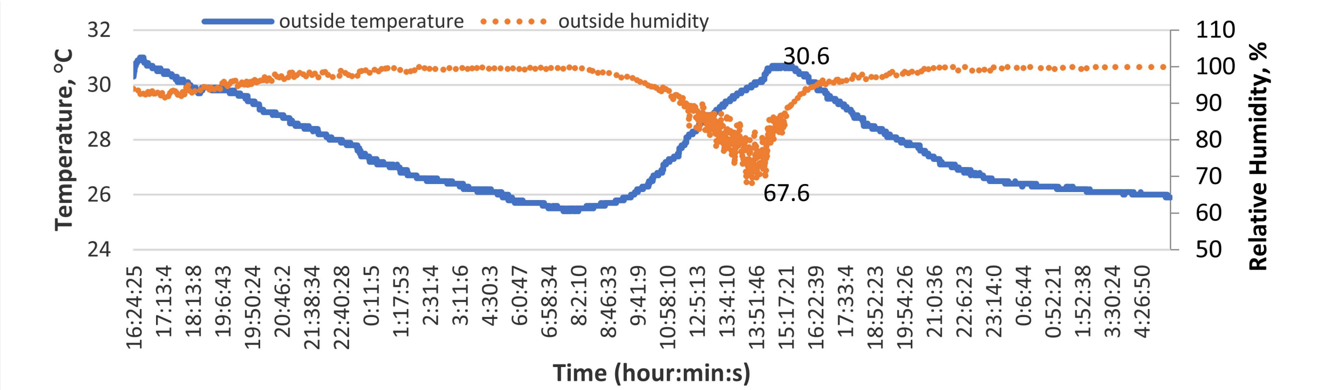


Fig. 6. The temperature and humidity of beehive from 4 pm on December 7th to 5 am on December 9th

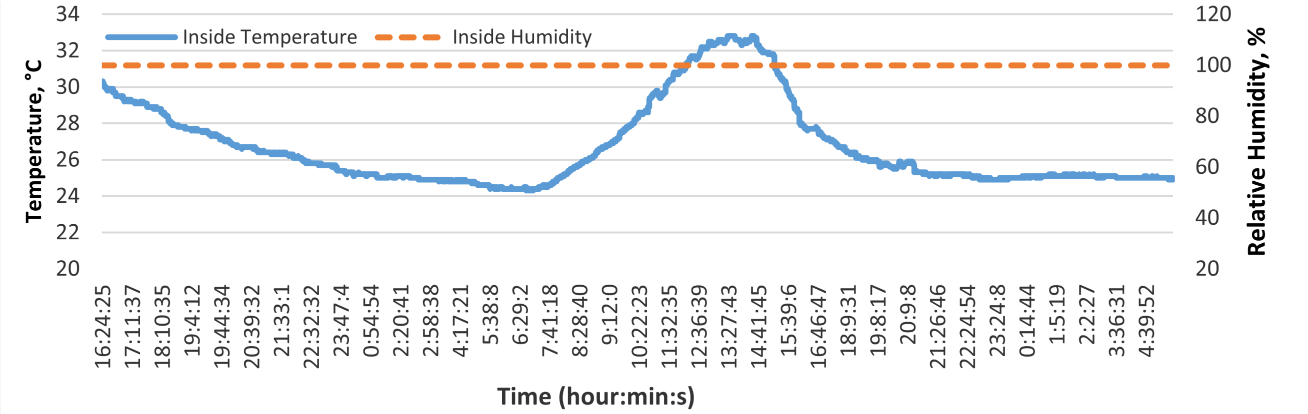


Fig. 7. The temperature and humidity of beehive from 4 pm on December 7th to 5 am on December 9th

temperature in order to predict the health of adult stingless bee and the habitat. From the collected data, it was observed that the outside relative humidity reading is slightly dropping during a sunny day at from around 90 % to 67.6 %. During the evening and night periods, the relative humidity is slightly increasing to 90 % in the evening and night.

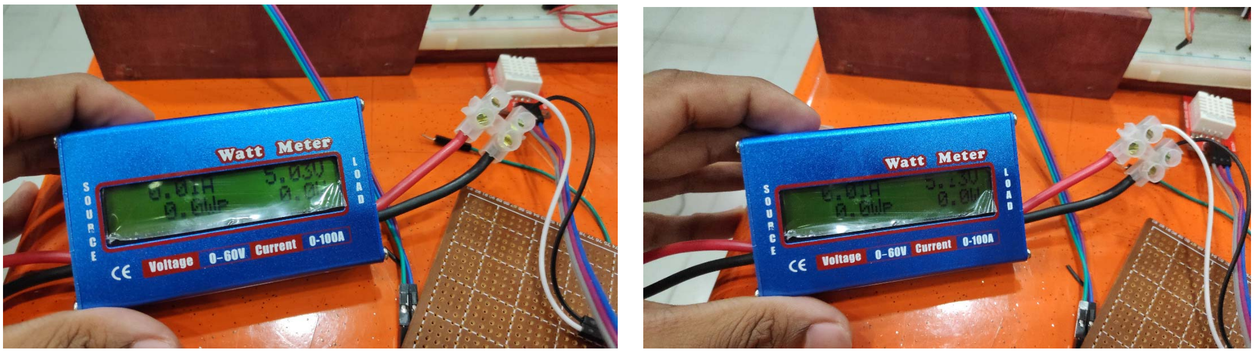
Fig. 7 illustrates the graph of the temperature and relative humidity inside the hive. The inside humidity was constant at 99 % in a 36 hours of the observation period. The inside temperature was slightly decreasing during the foraging time indicating that the bees were leaving the hive. The relative humidity inside the hive was saturated almost at 100 % due to several reasons: the humidity sensor was inside an enclosed inside the topping and within limited room of space. Furthermore, the stingless bees inside the hive contributed to the increase of humidity through respiratory process. The temperature reading inside the hive was slightly increase at night when all the bees were in the hive. The results of the temperature profile inside the bee hive was found to be related with the topping weight. It is seen that the temperature inside the hive is decreasing when the inside temperature is decreasing and vice versa. This information is important for the farmers to predict the possibility of fungus growth inside the hive and to monitor the colony activity. The extremely changing in temperature and humidity inside the hive could give the meaning of a possible extraordinary activity is happening inside the hive such as parasite attack, fungus growth, bacterial infection, or viruses outbreak.

The data from the system is pushed to the cloud every minute. This process consumes the highest rate of power. The power consumption of the system were recorded for two hours using a watt meter as shown in Fig. 8. It was recorded that the system steadily consumed 0.01 A at 5.31 V for two hours. Therefore, 2 hours of running of the system, costs the system 0.019 Ah of charge. For each hour, the system requires a mean charge of 0.0095 Ah. The system has 2 set of batteries, each of 1300 mAh capacity. Therefore, a total of 2600 mAh or 2.6 Ah. The total charge consumed by the batteries divided by the current rate equals a runtime of 274 hours which is equivalent to 11.4 or 12 days.

The final proposed product has quite a lot of valuable features as summarized in Table I. Several special features are the system can run for 12 days with a single full charging of the battery and the overall cost to construct the system is around RM 120. Other than that, the system is quite fast in response with low percentage of data transfer error.

IV. Conclusion and Future Recommendation

In this paper, a low energy platform for monitoring stingless bee foraging activity and beehive temperature and humidity level is presented. The system is a low energy



(a) (b)

Fig. 8. Power consumption at (a) 0 hour (b) 2 hours

TABLE I. PERFORMANCES ANALYSIS

No	**Performance analysis of the overall system**	
	Testing	***Result***
1	Power consumptions	12 days running with a single charging of battery
2	Response time	5 seconds
3	System cost	RM 120
4	Weight sensor accuracy	± 0.1 kg
5	Percentage error	4 %

consumption device and can operate for 12 days after a single full charging. The platform has all function of professional monitoring systems with a successful application development to integrate with an IoT platform. Data observation of the beehives' weight for a long duration will benefit stingless beekeeper to estimate the honey and brood cell production in the future. For future recommendation, the observation and analysis of temperature and humidity data at yearly period is required to produce a prediction of the patterns of beehive health and security using big data analysis and artificial intelligence techniques. In addition, a stingless bee counter sensors will be integrated at the entrance-exit hole of the hive log that will enhanced the system capability in monitoring the stingless bee activities.

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