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Design and Development of Stingless Beehive Air Pollutant Monitoring System

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ABSTRACT

Currently, the presence and levels of air pollution in most stingless bee farms are not measured periodically nor there are proper monitoring levels that can be attributed to hive productivity. Long-term measurement and monitoring of air pollution for hive productivity and honey yield have not been performed. Therefore, this research proposes long-term and real-time air pollution measurement and monitoring techniques that are important for correlation analysis and parameter modeling. By using air pollution detection sensors through a wireless sensor network topology in stingless bee farms, details of pollutant presence and levels will be available in real-time over a long period of time for hive productivity correlation analysis. With such deployment using IoT -based systems, data can be easily accessed from anywhere thus ensuring data continuity. This paper describes a preliminary study on the design, development, and testing of real-time air pollution measurement and monitoring systems capable of determining the health status of stingless bee nests in mixed livestock crop farms. The goal of this research is to help beekeepers/users maintain control and be able to take quick action on the hive from the information obtained.

Keywords: Air pollutant, Stingless Bee, IoT, Wireless sensor Network

1. INTRODUCTION

Stingless bees are found throughout the tropics and subtropics of the world between 30 degrees north and south. These bees are known for their harmless stings which are useless as weapons. Honey from these bees has been used as medicine to cure varieties of ailments since a very long time ago. There are numerous uses and benefits of honey that have been documented for the treatment of eye infections, open wounds, wounds, diabetes and hypertension, and other diseases as reported in several studies [1][2][3][4]. The stingless bee farming industry in Malaysia has been gaining popularity in recent years. The number of bee farmers has increased dramatically over the years, and on the record, there are more than 1000 registered farmers nationwide in the last 5 years. The honey bee industry is a very profitable industry and in 2013 alone Malaysia imported more than RM50 million worth of honey products and the number is in increasing trend [5].

Precision apiculture allows the beekeeper to manage their beehives for many possible reasons, including research, daily management of bee information without being intrusive by caregivers, and learning how to reduce resources and time without reducing production [6]. Recently, automatic monitoring systems have grown rapidly due to the use of wireless sensor networks (WSNs). WSNs consist of embedded devices that can obtain data from different sensors, process it, and communicate with a computer or through a cloud database. These devices are known as nodes or motes and are the core of the Internet of Things (IoT). Humans have used WSN in many activities of daily life, such as agriculture [7].

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WSN also began to be used to monitor stingless bee colonies. WSN nodes can be used to access data from sensors and monitor the environmental conditions of the beehive (temperature, humidity, CO_2, etc.) and even its weight [8]. Nodes communicate through a gateway and transmit data from the motes to the database for storage and processing. This has improved the features of the monitoring system, leading to what is now known as precision apiculture.

This paper presents a low-cost wireless monitoring system for stingless beehives. The system architecture allows for ease of use in the field and ensures scalability. This paper is organized as follows: Part 2 provides an overview of stingless bee monitoring. Section 3 presents an overview of the proposed system architecture. Section 4 describes the hardware and software implementation of a wireless node. Section 5 discusses the installation of the system and results. Finally, Section 6 allocates our results, analysis, and conclusions.

2. RESEARCH BACKGROUND

Based on apiculture history, Gates published hive temperature data collected manually every hour for several days in 1907 [9] and Dunham measured the temperature inside the hive using a thermocouple in 1926, [10]. The development of sensor and system technology has given a new lease of life to electronic data acquisition to enable the improvement of the measurement process. With this development, various types of monitoring methods have been adopted, ranging from observation of data in hives [11] to systems that can analyze such data [12]. Meikle and Holst summarize several monitoring methods in [13], specifying for each author method, the parameters measured (temperature, O_2, CO_2, relative humidity, weight, vibration, etc.), and the length of each method. However, in their method the authors focused on honey whereas this paper focused on the stingless bee.

Recently, stingless beehive monitoring systems technologies based on WSNs have been applied in precision apiculture works. These systems have the advantage of being able to perform remote monitoring of the hive without disturbing the environmental conditions. Kviesis et al. has developed a main unit system that communicates wirelessly with each node located inside each hive, simultaneously acting as an Internet gateway. The system monitors temperature and relative humidity using an integrated SHT15 sensor. The collected data is transmitted by the main unit to a remote database server [14]. Zacepins et al. has used a temperature monitoring system based on the Raspberry Pi that acts as an Internet gateway. The temperature sensor found in the hives is connected to the Raspberry Pi via a single-wire network. The authors emphasize the low cost of the solution if only one use of the Raspberry Pi to accommodate all hives [15].

In [16], Murphy et al. applied WSN technology to monitor hive colonies and gather the most important information about activities and the environment inside and outside around the hive. Each hive was monitored using two nodes, and each node was implemented via Waspmote by Libelium (Zaragoza, Spain). For beehive monitoring, several heterogeneous sensors (temperature, CO_2, pollutants, NO_2, etc.) are used. Due to the high number of sensors, two commercial development boards were used, one for each Waspmote. Each sensor was read at a frequency of six samples per day. The collected samples are stored on an SD card for backup and broadcast via the Zigbee network every 24 hours to the base station. The base station acts to send data to a remote server via a 3G / GSM connection. This monitoring system is also the one that has been used by Murphy et al. to propose several algorithms to automatically detect changes in the current state of the hive and warn beekeepers of possible colony threats [17]. Based on nest CO2 levels, algorithms have been proposed to predict weather conditions. System based on the Arduino platform developed by Kridi et al. to measure the temperature of the hive using the LM35 sensor [18]. Data is sent wirelessly through the XBee-Pro module to the base station desktop PC connected to the Internet. The collected data is processed to find patterns that determine the thermal pressure of the hive to detect conditions that may migrate.

A Harun et al. proposed three preparations that were designed and used for data collection. The first preparation is data collection in a healthy hive. The second preparation was inside the unhealthy hive while the third preparation was outside the hive in the shade of a tree. Temperature, humidity, and light intensity sensors connected to the WSN node for automatic data collection. This integrated system ensures that the transformation into a stingless beehive and colony development can be monitored in real-time and the necessary steps and actions can be taken to avoid any problems on the colony or loss of yield [19]. Some studies show that the temperature, humidity, and presence of smoke or toxins around the hives can have a significant impact on the honey production process and can cause the colony to leave the hives [20]. Theoretically understanding the level of pollutants affecting the productivity of the hive plays important role in securing stingless bee colonies and ensuring good productive yield for each hive. Most of these researches demonstrated the system specifically in apiary whereas in this paper, our research work is conducted in mixed crop–livestock farm whereby the methods include pollutant effect where no other authors have considered in previous literature works.

3. SYSTEM ARCHITECTURE

The proposed Stingless Beehive monitoring system in this paper must meet several important conditions: (i) environment friendly; (ii) sustainable/robust, (iii) real-time monitoring (iv) power efficieny. Kviesis and Zacepins in [21], describe automated monitoring systems, different systems for real-time hive monitoring, distinguishing their advantages and disadvantages. From that fact, a three-tier hierarchical model based on wireless communication have been chosen. This is an easy-to-use model that can be easily adapted to any geographical distribution of the hive, can be scaled to one of three levels, and meets the requirements of the conditions stated above.

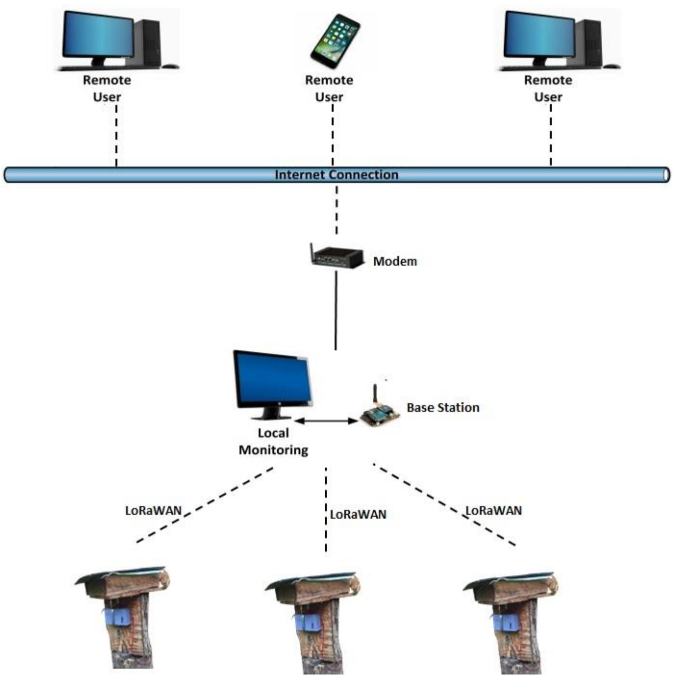


Figure 1. Architecture of the system

Figure 1 provides an overview of the general structure of the system being used, this system is explained at the lowest level, Sensors such as temperature, humidity, and air gases (CO, CO_2, NH_{4+}) are connected to a wireless sensor node placed along with the hive and data is sent to a wireless base station. Network of hives with sensor attachments is built around the apiary to provide sufficient data for rigorous monitoring. LoRa could be used as wireless nodes that monitor the stingless beehive and sends data wirelessly. Recently, LoRa as a new wireless node has gained popularity as low data rate wireless technology at the intermediate stage with the advantage of being able to communicate as far as 10 kilometers, it can manage a wireless network from a large group of stingless beehives, in addition to that a computer with LoRaWAN communication could also act as a base station.

In the apiary monitoring network, a star topology is used to form the communication. The local computer acts as a coordinator. All nodes installed near the stingless beehive must be accessible by the coordinator. Communication can be realized without implying problems because the hive is in the area and as a result, there are usually no significant barriers. The computer is equipped with an application that collects the information sent by the nodes of each hive and stores it in a local database. Communication with a global server database is carried out over other communication networks that allow longer distances, such as 3G / 4G / GPRS, WIFI, or WiMAX. And the last level, the top floor contains a cloud server database, which clusters several hives and contains a copy of the local database of each hive group.

Figure 2 shows the flow for the system from the sensing apiary to data collection and processing so that the data can be accessed to the internet network. Next, all the data will be received by the beekeepers/users before it is uploaded to the database for future use and work. From that, the choices can be determined by beekeepers/users to trigger any appropriate action after they receive information from the data.

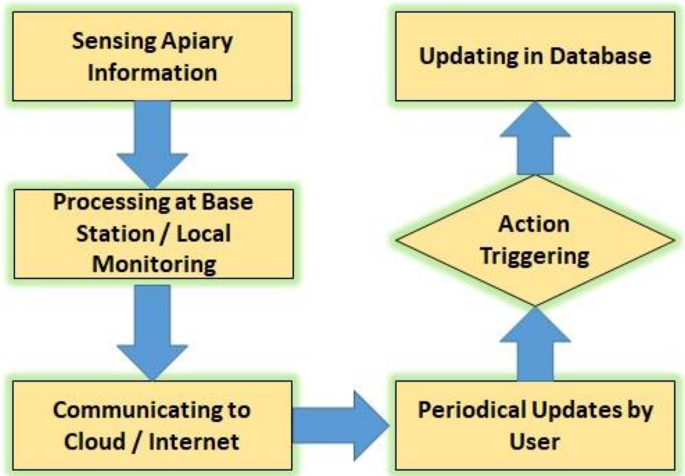


Figure 2. Flow chart showing the process designed for the system

This system ensures changes in conditions and activities into a stingless beehive and possible colony development monitored in real-time and the necessary perfect steps and actions can be taken immediately to prevent colony deterioration and causing resulting loss of yield.

4. HARDWARE AND APPLICATION IMPLEMENTATION

This section will explain briefly the installation and use of hardware and software to complement the overall system. The description discusses each level found in the architecture system that has been described in section three; starting with the lowest level related to the wireless sensor node, the second level as a coordinator and cloud storage which is the top level.

4.1 Wireless Sensor Node

The system has been set up so that each stingless beehive has its own wireless sensor node that operates continuously. The importance of this node acts as the main body collecting current data from the sensors attached to it. Figure 3 shows one of the beehives in the study had a wireless sensor node installed. Wireless sensor nodes are built with several main components that perform functions that allow it to be characterized as wireless sensor nodes. These components can be divided into three important parts, namely (i) Operating board, (ii) Wireless module and (iii) sensors.

Figure 3. Placement of monitoring system at stingless beehive

4.1.1 Operating Board

The operating board is the most important component that acts as a body that controls the actions of other components. By programming the board to differentiate as desired, the mainboard can run the system comprehensively and reach the necessary data to the user. Arduino UNO is taken as the operating board for implementing the node, the widespread use of this product globally and the good characteristic of the board made us choose it as an important body for this node project. This board is based on the ATmega328P microcontroller by Atmel (San Jose, CA, USA) with an operating voltage of 5 volts. Applications that run on wireless networks are developed using an open resource-based environment. The C language is used and the libraries are provided by the manufacturer. As in all Arduino circumstances, this application has SETUP and loop, which run indefinitely.

4.1.2 Wireless Module

As mentioned in section 3, LoRaWAN became a wireless communication medium between each node and the base station as a transmit/receive of data packets. As the latest technology with relatively long distance communication capabilities, LoRaWAN could meet the character in any wide fieldwork area. SX1278 Ra-02 LoRa module is capable of meeting the criteria required to carry out the work of this study. With a programmable bit rate of up to 300kbps and a working voltage between 1.8-3.7v, LoRa Node supports FSK, GFSK, MSK, GMSK, LoRa, and OOK modulation modes.

4.1.3 Sensor

Based on some of the studies related to the correlation effect of temperature and humidity in apiaries, stingless bees could survive temperatures less than 40 ° C and relative humidity readings could be considered to predict adult stingless bee health and habitat [22]. Continuous monitoring of temperature and humidity is very important because overheating the stingless beehive could cause adverse effects on the health of stingless bee colonies and stem cell expansion. In order to measure temperature and humidity around stingless beehives, DHT11 sensors were used. These sensors were chosen because of their ease of management, excellent reliability and stability, and low power consumption. They are equipped with a special NTC (Negative Temperature Coefficient) to measure temperature and an 8-bit microcontroller to generate temperature and humidity values as serial data. DHT11 is capable of measuring temperatures from 0 ° C to 50 ° C and humidity from 20% to 90% with an accuracy of ± 1 ° C and ± 1%.

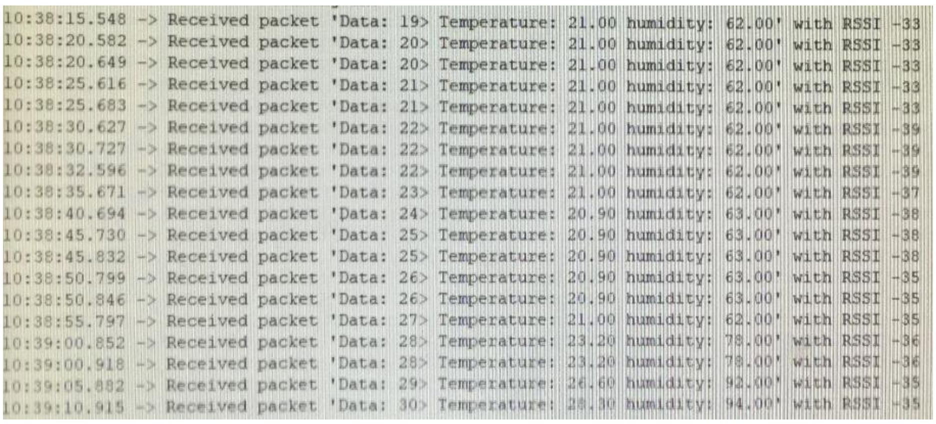
The comportment of air pollutants in most bee farms is not measured regularly although accurate monitoring of levels can be associated with hives productivity. Existing measurements are only physical and based on requirements when the area is very close to the pollutant source. Real-time air pollution measurement and monitoring techniques are extremely important for correlation analysis and parameter modeling. To measure air quality readings near the stingless beehive, an MQ135 gas sensor was installed on each wireless sensor node. MQ135 gas sensors are used in air quality control equipment and are suitable for detecting or measuring NH_3, NOx, Alcohol, Benzene, Smoke, CO_2.

4.2 Base Station and Local Monitoring

The base station is a single-stand wireless node that serves as a receiver of data from all other wireless sensor nodes. It is connected directly to the main computer of the apiary which embodies local monitoring. All nodes installed near the stingless beehive are accessible by the base station unit. The computer is equipped with an application to store all collected information directly as a backup in the computer before the data are send to the cloud for further processing. This local monitoring means that the data can be accessed on this computer by the beekeeper/user directly without the need for an internet connection to retrieve the output data from the base station in local monitoring computer. Any form of modification in terms of information or instructions desired can be made here.

4.3 Cloud Database

The local database of each stingless beehive is performed on a cloud database server. This server ensures an extra level of security, provide backup and access stingless beehive information and send the collected data to the cloud. Hence, through this server, the beekeeper / user can access all the data concerning stingless beehive from anywhere via the Internet and can also automatically receive alarms or further actions required to the stingless beehive with this data analysis. The data query shown in local monitoring computer before all the information are store in cloud database as shows in Figure 4.



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10:38:15.548 -> Received packet 'Data: 19> Temperature: 21.00 humidity: 62.00' with RSSI -33
10:38:20.582 -> Received packet 'Data: 20> Temperature: 21.00 humidity: 62.00' with RSSI -33
10:38:20.649 -> Received packet 'Data: 20> Temperature: 21.00 humidity: 62.00' with RSSI -33
10:38:25.616 -> Received packet 'Data: 21> Temperature: 21.00 humidity: 62.00' with RSSI -33
10:38:25.683 -> Received packet 'Data: 21> Temperature: 21.00 humidity: 62.00' with RSSI -33
10:38:30.627 -> Received packet 'Data: 22> Temperature: 21.00 humidity: 62.00' with RSSI -39
10:38:30.727 -> Received packet 'Data: 22> Temperature: 21.00 humidity: 62.00' with RSSI -39
10:38:32.596 -> Received packet 'Data: 22> Temperature: 21.00 humidity: 62.00' with RSSI -39
10:38:35.671 -> Received packet 'Data: 23> Temperature: 21.00 humidity: 62.00' with RSSI -37
10:38:40.694 -> Received packet 'Data: 24> Temperature: 20.90 humidity: 63.00' with RSSI -38
10:38:45.730 -> Received packet 'Data: 25> Temperature: 20.90 humidity: 63.00' with RSSI -38
10:38:45.832 -> Received packet 'Data: 25> Temperature: 20.90 humidity: 63.00' with RSSI -38
10:38:50.799 -> Received packet 'Data: 26> Temperature: 20.90 humidity: 63.00' with RSSI -35
10:38:50.846 -> Received packet 'Data: 26> Temperature: 20.90 humidity: 63.00' with RSSI -35
10:38:55.797 -> Received packet 'Data: 27> Temperature: 21.00 humidity: 62.00' with RSSI -35
10:39:00.852 -> Received packet 'Data: 28> Temperature: 23.20 humidity: 78.00' with RSSI -36
10:39:00.918 -> Received packet 'Data: 28> Temperature: 23.20 humidity: 78.00' with RSSI -36
10:39:05.882 -> Received packet 'Data: 29> Temperature: 26.60 humidity: 92.00' with RSSI -35
10:39:10.915 -> Received packet 'Data: 30> Temperature: 28.30 humidity: 94.00' with RSSI -35
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Figure 4. View of Data Query in Local Monitoring Computer

4.4 Power Generation

An important aspect in the installation of the sensor network used on this system is to know the dependent-free power source when there is a disturbance in the power supply. Green technology is applied to this system for savings in electricity consumption and is also environmentally friendly. Under normal circumstances, the node is turned on from an independent power source which is solar power and at the same time, every wireless node also has its own backup battery. Issues that cause power outages will not occur, this allows the entire node sensors to operate 24/7.

5. SYSTEM IMPLEMENTATION AND RESULT

This system has been applied in a farm that uses the concept of mixed crop-livestock farming in the rural tropics. This farm is located in the north of peninsular Malaysia consists of several types of crops such as bananas, mangoes and several types of herbaceous crops. There are also two main types of livestock that are kept independently and organically such as chickens and rabbits.

Wireless nodes equipped with ambient sensors and gas sensors were installed in several stingless beehives selected from several hives located on the farm. For this experiment, temperature and humidity were measured outside the hive area by using the DHT11 sensor and the MQ135 Gas sensors are installed adjacent to the stingless beehive exit/entry funnel as shown in Figure 5. This is to find out the level of air quality on the route.

Figure 5. Gas Sensor attached near at the funnel of stingless beehive

5.1 Stingless Beehive Category

Initially, in the first stage experiment, the system is attached to three selected stingless beehives. The selected stingless beehive is divided into three categories namely; (i) healthy hive state, (ii) medium-healthy hive state, and (iii) least-healthy state. Figure 6 shows the stated category differences of the stingless bee condition.

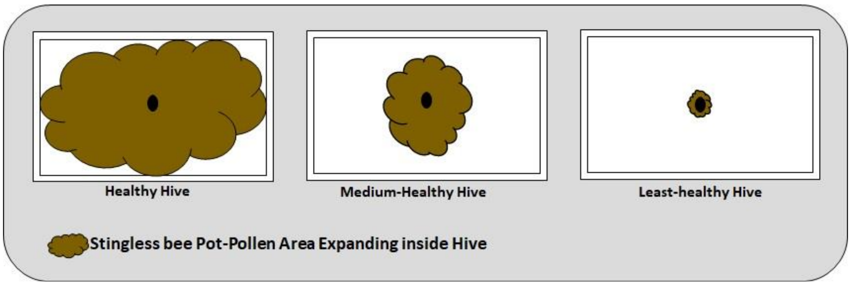

Figure 6. Three differentiate category of stingless beehive

5.1.1 Healthy Hive

A Healthy hive refers to the expansion of pot-pollen in the hive in excess of 70%. This also shows that the colony's activity rate and population of the stingless beehive are very high. The rate of honey production is also very satisfactory

5.1.2 Medium-Healthy Hive

With a rate of around 30% to 70% expansion area, it is considered as Medium-Healthy Hive. A Medium-Healthy hive can be an active colony with a low stingless bee population but this type of colony causes the hive to not be able to produce more pot-pollen and honey.

5.1.3 Least-Healthy Hive

Arguably there is no periodic expansion of this stingless beehive categorized as Least-Healthy Hive since only less than 30% pot-pollen development for this hive can be seen. It could also be seen that the population level and colony activity are very low for this type of hive.

5.2 Research Outcomes

The system began testing in mid-May 2021 on an ongoing basis, whereby the stingless bee response is chosen to be monitored for the first three days prior to installation. Temperature, humidity, and air quality at the selected stingless beehive are logged in every 5 minutes into a local monitoring computer. Each wireless node is installed on each type of hive category, namely node 1 for Healthy hive, node 2 for Medium-Healthy hive and node 3 for Least-Healthy hive. The system has provided a large amount of experimental data that is very useful for researchers and beekeepers for further processing. For example, some graphs of the three stingless beehives selected during the evaluation are shown below.

5.2.1 Temperature and Humidity

On average, the temperature and humidity measure shows the normal conditions for the three hives; Healthy, Medium-Healthy or Least-Heathy but the difference is in the maximum and minimum reading levels for both temperature and humidity, which are influenced by the conditions of the surrounding area for each hive.

Figure 7. Healthy Hive Condition Position

Figure 8. Medium-Healthy Hive Condition Position

Figure 9. Least-Healthy Hive Condition Position

Figure 10 shows a graph of data readings from node 1 that represents information about temperature and humidity for the Healthy-Hive. It can be observed that the temperature around the stingless beehive is in a very comfortable condition with the highest temperature recorded is 32.2 ^{0}C during the day time and the lowest temperature 24.7 ^{0}C at night time. This is influenced by the surrounding conditions for the Healthy hive covered with large trees. So the hive is in the shade of large trees that are on the side of that beehive (see Figure 7). The influence of these trees and their shade also has a good effect on the atmospheric humidity of the area since the humidity level observed in this area is very high with the highest and uniform reading of 95% for three consecutive nights. During the day the lowest humidity was recorded at 60% on the third day. From the observation, the third day was the hottest.

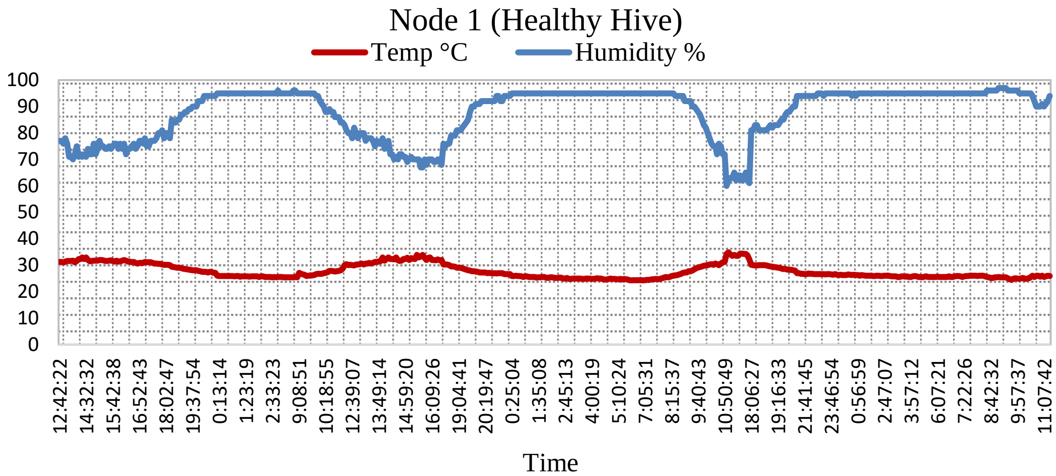

Figure 10. Graph of Temperature and Humidity for Healthy Hive Environment

The information from node 2 as shown in Figure 11 illustrates the highest day time temperature for the Medium-Healthy hive was 34 ^{0}C on the third day and the lowest temperature was uniform for the three nights which was 24.7 ^{0}C. While the humidity level for this hive environment is 74% for the highest reading at night and the lowest reading during the day is 21%.

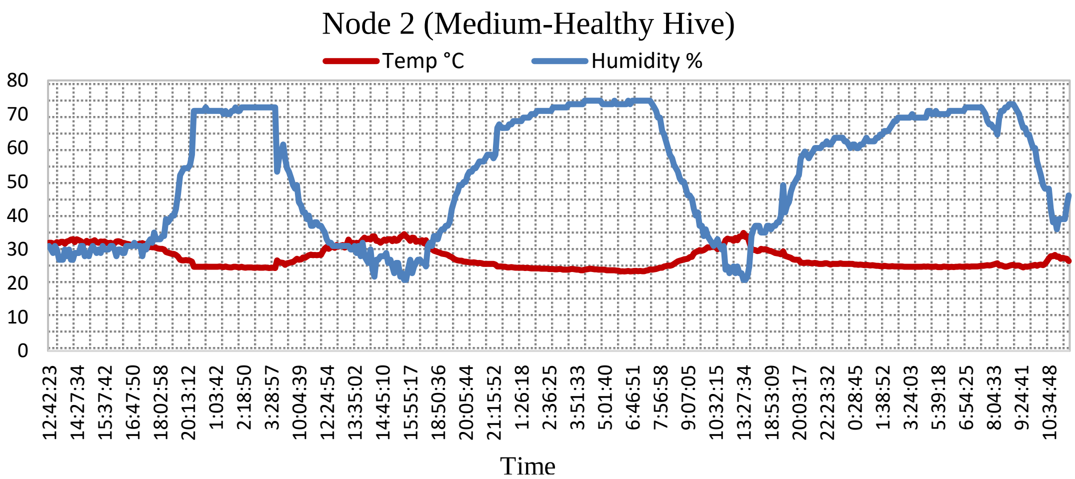

Figure 11. Graph of Temperature and Humidity for Medium-Healthy Hive Environment

With the condition of the hive located in a semi-open area between some banana trees and open ground (see Figure 8), the comparison in temperature readings between Healthy-Hive and Medium-Healthy Hive is not very significant with only 2 ^{0}C differences. However, a significant difference can be seen in the humidity readings which shows that the Medium-Healthy Hive surrounding area is drier during the day due to lack of tree shade.

For the Least-Healthy hive, the highest temperature shown in Figure 12 is 46.9 ^{0}C, this occurs on a hot day on the third day while the normal temperature recorded at night is similar to other hives and the lowest temperature recorded is 24 ^{0}C. The recorded humidity showed a high rate at night time with the highest reading of 94% for each night and relatively dry conditions with the lowest reading of 29% during the very hot and scorching on the third day time. Based on observation, the environmental conditions for the position of Least-Healthy hive which is a relatively open field area as shown in Figure 9 causes sunlight to radiate directly towards the hive. That can be ascertained by looking at the extra high day time temperatures on the third day which hit up to 46.9 ^{0}C. However, the lack of trees results in a lack of wind resistance allowing the wind that carries moisture to always pass through the hive causing a sudden drop in temperature which can clearly be seen in the graph and at night time the humidity level observed is at its highest.

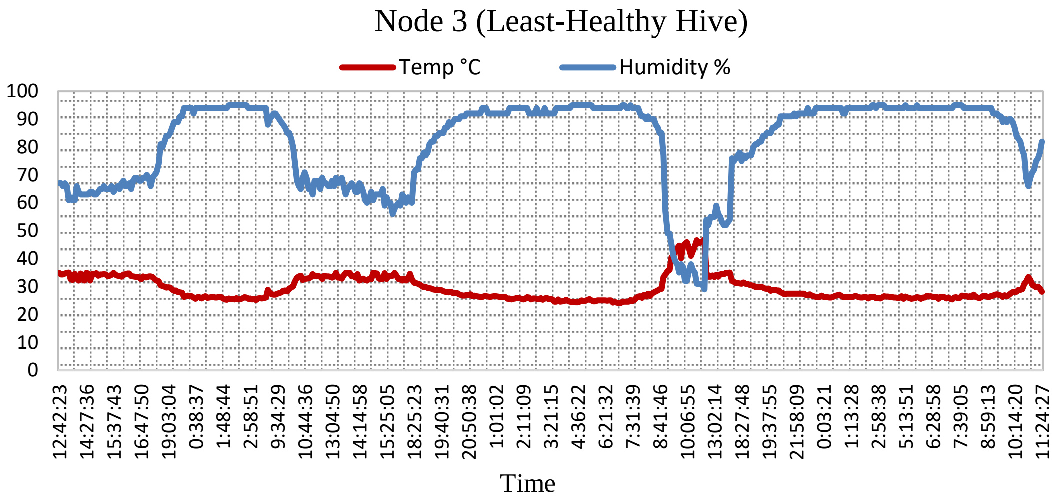

Figure 12. Graph of Temperature and Humidity for Least-Healthy Hive Environment

5.2.2 Air Quality

There are three types of gaseous elements that have been considered to measure the level of air quality in this experiment such as Carbon Monoxide (CO), Carbon Dioxide (CO_2) as well as Ammonia ($NH4+$). All wireless nodes attached to all selected stingless beehives for each category are equipped with MQ135 able to track these gases and all gases are read in units of parts per million (ppm). Air quality data were collected together for the duration of the temperature and humidity data for three days. Unfortunately, one of the sensors did not work properly and was damaged. The air quality sensor is mounted on node 2 to test on the Medium-Healthy hive conditions. In this paper, only information on air quality conditions in Healthy hive and Least-Healthy hive will be described.

Based on Healthy Hive result shown in Figure 13, the carbon monoxide(CO) rate showed a healthy reading with the highest reading rate being 37.85 ppm and 22.8 ppm for the lowest. Figure 14 shows the graph of Carbon Dioxide (CO_2) reading between 2169 ppm at the highest reading to the lowest 1181 ppm whereas the Ammonia (NH_{4+}) reading from Figure 15 shows the highest level is 17.92 ppm and the lowest is 13.3 ppm.

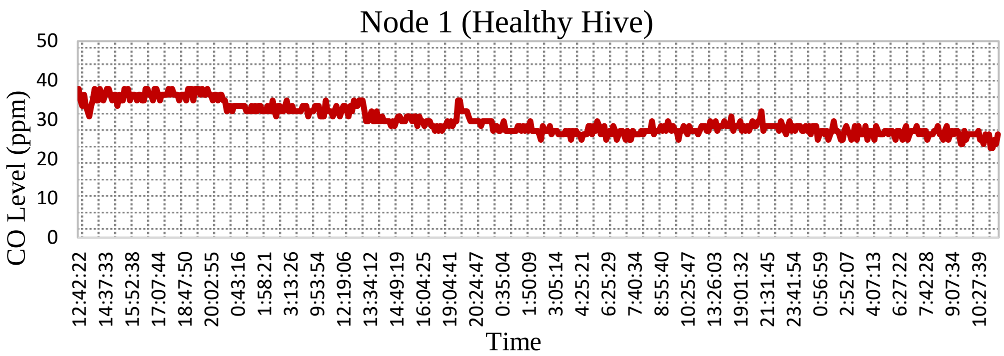

Figure 13. Graph of Carbon Monoxide level for Healthy Hive Environment

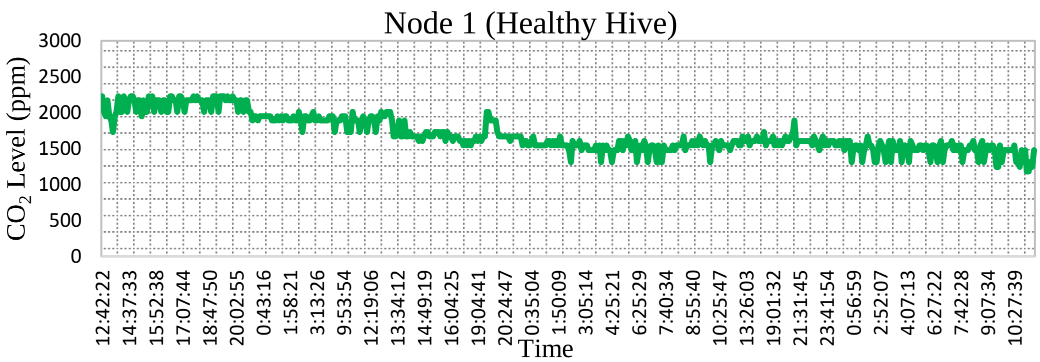

Figure 14. Graph of Carbon Dioxide level for Healthy Hive Environment

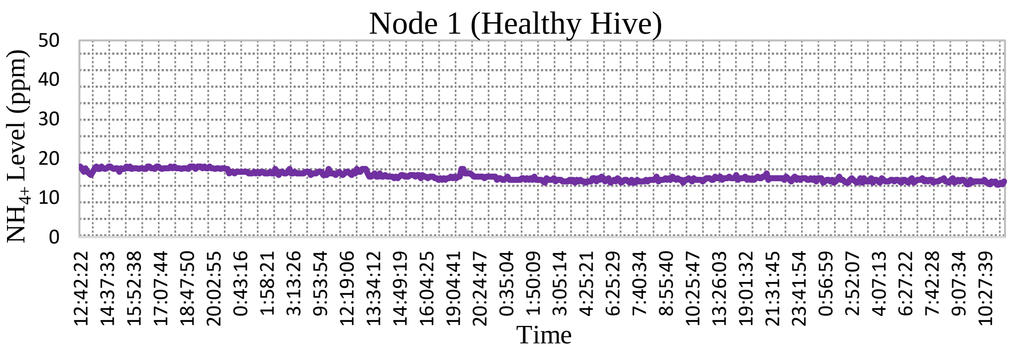

Figure 15. Graph of Ammonia level for Healthy Hive Environment

Based on Figure 16, the results from the Least-Healthy hive show the carbon monoxide(CO) rate at the highest reading rate of 37.85 ppm to lowest reading rate of 28.26 ppm level. The graph in Figure 17 shows the level of Carbon Dioxide (CO_2) reading between 2523 ppm at the highest reading to the lowest 1608 ppm. The Ammonia (NH_{4+}) level in the graph in Figure 18 shows the highest level is 17.92 ppm and the lowest is 13.3 ppm. All measurements are subject to the duration of the three days for both Healthy and Least-Healthy hive.

The observations result on air quality readings in both Healthy and Least-Healthy hive show that the levels of CO and NH_{4+} in the atmosphere are normal or in a safe condition that does not exceed 50 ppm readings. According to the Occupational Safety and Health Administration (OSHA), NIOSH, the standard permissible exposure limits (PEL) for CO is 50 ppm the PEL for ammonia set by OSHA is 50 ppm on average [23]. However, it can be seen that the reading level for CO_2 shows to be higher than the normal state level of 400 ppm. Still based on the current OSHA standard, it is 5000 ppm as the time-weighted average (TWA) concentration.

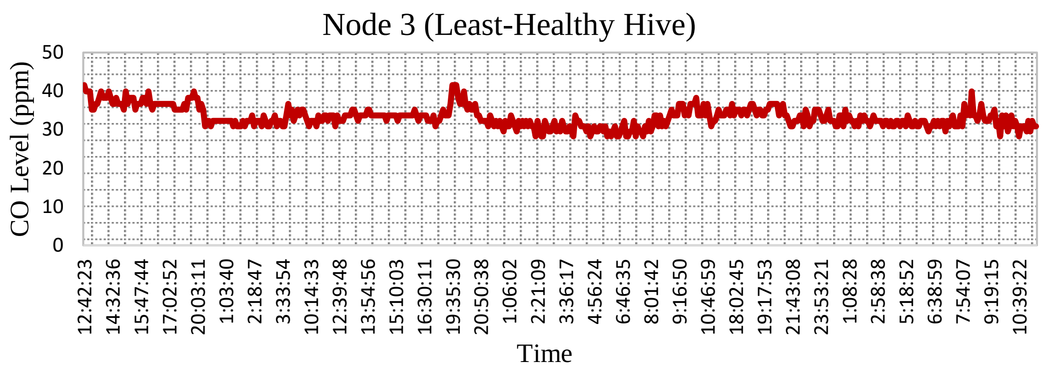

Figure 16. Graph of Carbon Dioxide level for Least-Healthy Hive Environment

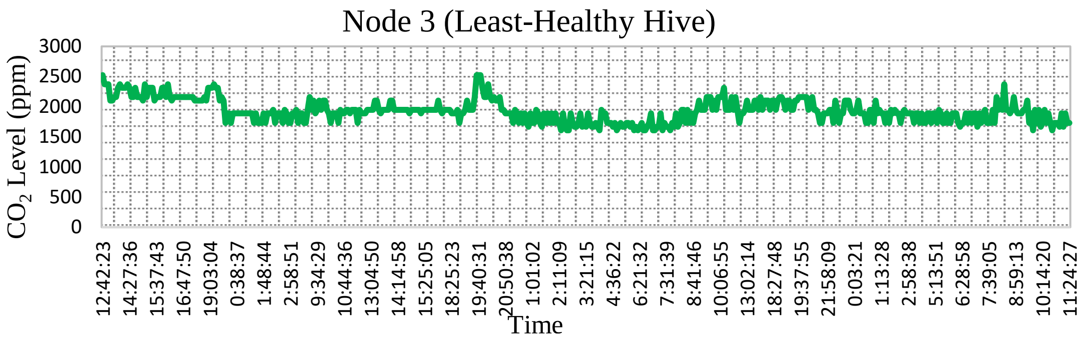

Figure 17. Graph of Carbon Monoxide level for Least-Healthy Hive Environment

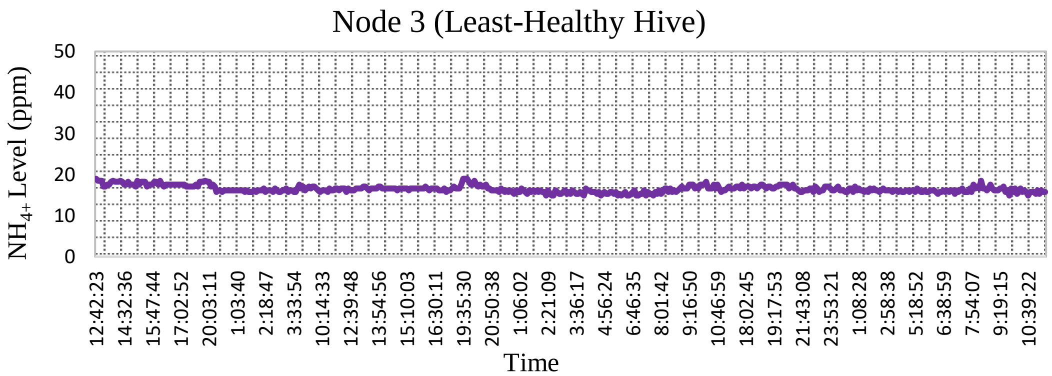

Figure 18. Graph of Ammonia level for Least-Healthy Hive Environment

There are several other factors that cause high carbon dioxide levels in this area. As mentioned earlier, all of these Stingless beehives are in mixed crop farming areas there will inevitably be livestock roaming there. Even a low hive position on the soil surface plays a role in high carbon dioxide readings. There are many ways that animal agriculture can produce CO_2. For instance, the cultivation of food crops, chemical fertilizers usage and cutting of grass [24]. Based on The Humane Society of the United State, the act of cultivation of food crops on soil can release 28 million tons of CO_2 since the soil is a carbon absorber. Moreover, FOA has estimated that the use of chemical fertilizer emits 41 million tons of CO_2 whereas wedding grasslands cause dry soils which indirectly 100 million tons of CO_2. Under all these circumstances, animal agriculture alone has contributed to a massive release of CO_2 into the atmosphere every year.

6. CONCLUSION

Based on our research findings, the influence of temperature and humidity on the health of Stingless beehives and colonies is very significant but the effect of air quality in this study is still in search. Further features on the experiment setup and longer data collection are needed to strengthen the results of this study. This paper has presented the design, development, and test of a real-time time air pollutants measurement and monitoring system capable of determining the level of health of stingless beehives in mix crop-livestock farms. The system is based on LoRa technology and consists of a set of nodes and base stations. Each node has sensors to measure the temperature, relative humidity, CO, $CO_{2,}$ and $NH_{4\ +}$ of the environment to assess the level of environmental quality of the stingless beehive. Data is successfully sent to the responsible network server process and display graphically. This is all to help beekeepers/users sustain control and be able to take quick action on the hive from the information obtained. In can be concluded that the first phase of pilot study in the basis of healthy, medium and least-healthy hives have been demonstrated. The temperature and humidity measurement for healthy hives show the readings are uniform at a normal rate of about 30 – 32 ^{0}C whereas unhealthy hives show a drastic rise in temperature at a certain time especially from noon to evening. The number of pollutants recorded shows that comparing all three hives, there is a significant rise of pollutant levels of CO, CO_2, NH_{4+} at the peak of dawn and dusk. However, these results are applicable for 3 days set of samples in which this research requires further data collection that will be included in our future work.

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