# An Intelligent Stingless Bee System with Embedded IOT Technology

**Mustafa Man, Wan Aezwani Wan Abu Bakar, Muhammad Azri Bahruddin Bin Abdul Razak**

***Abstract*: *Stingless bee is one of the bees that produce expensive honey because stingless bee only produces less than 1kg honey per year. Due to improper management and security been imposed, stingless beehive is continuously been targeted by thief for its valuable honey production. The bee farmer also is facing difficulty in tracking and monitoring the number of their beehives that are scattered in certain area in their farm. Taking serious consideration on a good quality of honey production, temperature is the major issues to concern. Honey production can be affected by extreme temperature. When the temperature is too high, the stingless bees become irritable or contradictory, when temperature is too low, the stingless bees become motionless. Therefore, the need for continuously tracking and monitoring of the beehive is crucial to conserve the quality honey production. The objective of the research is to analyze the suitable temperature for bee productivity. Next is to design a system that gives ability for the bee farmer in monitoring of their bee hive from anywhere and anytime via web based. This paper presents the development of an IOT technology in our targeted stingless beehive system at Nature n Trigona Garden, a stingless bees company in Kemaman, Terengganu, Malaysia. We develop a device which is coded using Arduino IDE 1.8.9 underlying with a sensor and microcontroller with a low battery powered, and installed at each particular beehive. The results shows that our design and implementation of the IOT devices in each beehive has achieved a success. The main contribution of this research is such that the bee farmer is able to monitor their beehive in real time as well as the system can trigger notification to user when any abnormal incidents happens to their hive.***

***Index Terms*: *Stingless, beehive, honey, Arduino***

## I. INTRODUCTION

Stingless bees, sometimes called stingless honey bees or simply meliponines, are a large group of bees (about 500 species), comprising the tribe Meliponini [1]. A **beehive** is an enclosed, bee -made structure in which some honey bee species of the subgenus *Apis* live and raise their young. Though the word beehive is commonly used to describe the nest of any bee colony, scientific and professional literature distinguishes *nest* from *hive*. *Nest* is used to discuss colonies which house themselves in natural or artificial cavities or are hanging and exposed. *Hive* is used to describe an artificial, man-made structure to house a honey bee nest [2]. Due to high market demand for stingless bee honey, the bee farmer is facing three (3) major difficulties i.e. firstly, no tracking of stolen beehives, secondly insufficient beehive monitoring and thirdly due to the lack of beehive temperature control that results in low quality of honey production. When the temperature reaches 45 degrees Fahrenheit, the stingless bee becomes motionless or when the temperature is too high, it makes bee irritable.

In response to the scenario, Intelligent Stingless Bee Hive System (iBees) is developed to ease bee farmer or bee owner in monitoring and analyzing their hives in real time mode. It is equipped with devices i.e. global positioning system (GPS), temperature and humidity sensor and microcontroller to automatically monitor the temperature and humidity of beehive and the user (i.e. beehive owner or bee farmer) may monitor the status online. The iBees gets the information needed from device that consist of global positioning system (GPS), temperature and humidity sensor and microcontroller that combine with wireless fidelity (Wi-Fi), it sends all data such as longitude, latitude, temperature and humidity into online cloud database. In conclusion, iBees is needed to keep tracking stingless bee hive from stolen.

## II. RELATED WORKS

The review of literature is based on three (3) existing system namely 3Bees [3], Arnia [4] and Buzztech [5]. The 3Bee [3] is a company that develops latest generation of electronic device which is Hive-Tech. It revolutionizes apiculture helping bees to survive whilst looking for new and more effective treatment against pathogen. The device can record location, weight, temperature, humidity, sound and smells. 3Bee's device also powered by solar energy and have many kind of sensor which is e-Eye which mean able to analyze the intensity and spectrum of ambient light, e-Hand which to detect temperature and humidity inside the beehive as well as measured weight gain, e-Nose which to detecting the quality of air, oxygen and carbon dioxide. Lastly e-Ear which recording beehive's sound. The 3Bee's system can record data every minute and transmitted up to four (4) times a day to remote cloud platform. Thus, it provides continuous and accurate data collection from personal account to view, analyze, extrapolate and store data and graphics which can be shared or used to generate report. Besides, the system provides real-time alert through an automatic and instant notice via message in case of extraordinary or anomalous event occurred in apiary.

**Revised Manuscript Received on September 20, 2019**.

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Arnia [4] develops remote hive monitoring with the objective is to establish their monitor as essential tools. Arnia Remote Hive Monitor enables user to monitor the status of honey bee colonies regards to brood temperature, hive humidity, hive temperature and hive acoustics from any device. User can check the state of hives from anywhere. The system operation starts with hive monitors. Each hive to be monitored is fitted with selected sensors. The recorded data is transmitted wirelessly to a gateway. Gateway is required per apiary. It collects data from hive monitors at the apiary and transmitted to user interface for analysis and presentation. User interface is the place where users log in to a secure account from any device to access data.

BuzzTech [5] develops and commercializes unique hive management software and sensors. The objective is to improve the state of the art of apiculture industry through accurate data gathering. It develops a device named as Beehive GPS Tracker that is highly durable and weather tight and satellite-based. Beehive GPS Tracker also sizes of a box of matches but have GPS tracking and accelerometer for motion detection. The BuzzTech's system offers for an additional monitoring and police assistance options if user report about stolen beehive. It also provides automatic alert notification via email and text messages.

The development of a wireless platform weighing scales for smart beehives is done by Fitzgerald et al. [6]. Since one of the key metrics of the beehive is the weight of bee colony, thus changes in weight is reflecting to the colony productivity. Then, a single point impact load cell is selected as the most appropriate loads sensor and integrated into the design of scales of its smart beehive system.

Vladimir et al. [7] presents the design of several convolutional neural networks and compared their performance with four standard machine learning methods such as logistic regression, k-nearest neighbor (KNN), support vector machine (SVM) and random forest (RF) in classifying audio samples from microphones deployed above landing pads of Langstroth beehives. The authors demonstrate that a trained raw audio convolutional neural network can successfully operate on a low voltage Raspberry Pi computer for audio beehive monitoring.

Evans [8] discusses comprehensively on the electronic beehive monitoring from application base to research base. In actual words, smart hives means an integration of hive weight measurements with hive temperature and humidity from sensor readings. Thus, the author develops a unique system which combines hive acoustics monitoring with other parameters such as brood temperature, humidity, hove weight and apiary weather conditions. The sounds from bee colony are monitored and interpreted to access colony behavior, strength and health. All experiments are performed at apiaries located in Italy and UK in 2013 and 2014 where each bee colony is housed in 10 frame Dadant-Blatt hives and in UK were housed in National hives.

## III. SYSTEM DESIGN

### A. Research Framework Architecture

The framework architecture of IBees is based upon three (3) tier architecture [9] that comprises of three (3) layers i.e. Client layer (Client Application), Business layer (Application Server) and Data Layer (Data Store) as shown in Fig. 1. Client layer contains User Interface part which is makes input and gives output to the user. Business layer is the interface between client and data layers. All the logic such as validation, calculation, the data related operations exist at business layer. It helps communication fast between client and data layers. Actual database exists at data layer. It contains methods to connect with database. The operations such as insert, delete, update and get data lies here.

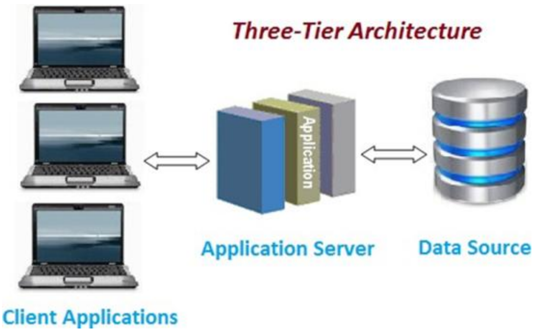



**Figure 1. iBees Architecture**

### B. Hardware Architecture

The internal hardware architecture of iBees is depicted in Fig. 2. It illustrates the flow of data from Global Positioning System (GPS) and temperature sensor to user. The data from GPS is transferred to base transceiver station and through GPRS gateway, to communicate with the Intelligent Stingless Beehive System (iBees) from browser's client. Similar analogy applies to data from temperature sensor is send to microcontroller and goes through gateway to enter the internet. Then the data is accessible to browser's client. The iBees system notifies user by sending message through email address when the distance from set location and current location is over the distance limit or the current hive temperature is higher than the setting of maximum temperature or lower than the setting of minimum temperature.

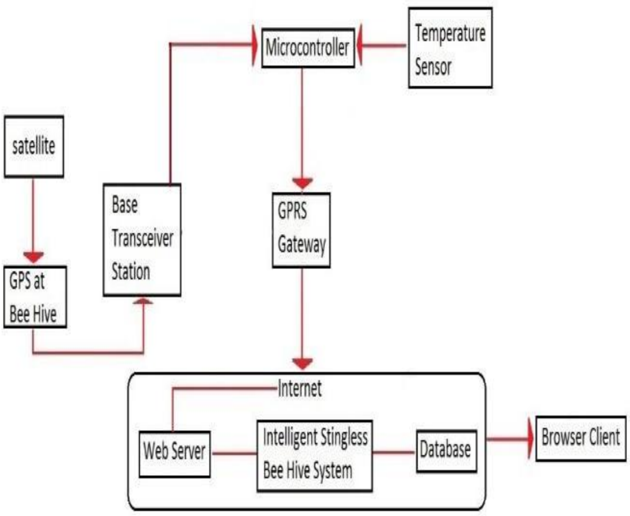



**Figure 2. iBees Internal Hardware Architecture**

### C. Database Architecture

Database of iBees is made of seven (7) tables consisting of farmer's info, address info, user info, tracking info, hive info, device info and temperature info as given in Fig. 3. The type of relationships between tables is shown by the distinct connection symbols between each interrelated tables.

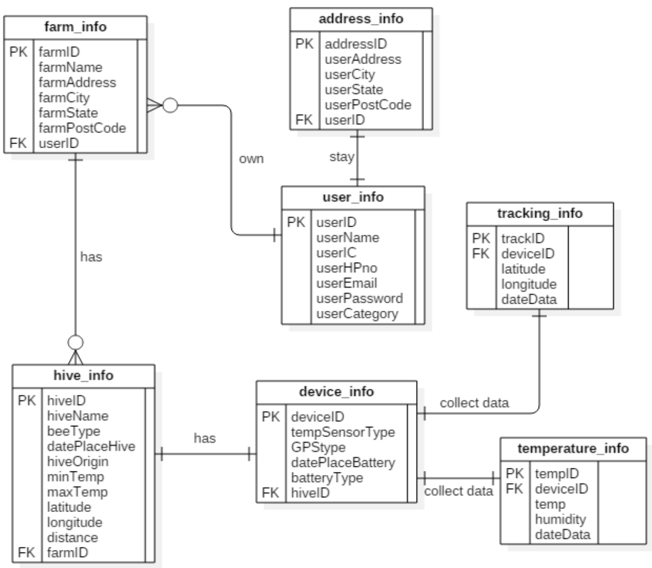



**Figure 3. Table Relationships in IBees**

## IV. EXPERIMENTATION

### A. Hardware and Software Specification

All experimentations are conducted in the platform of Intel Core i5 Processor, 4GB RAM, NVIDIA GeForce 940M with 2GB Dedicated VRAM and 120 GB SSD with 1TB HDD storage. Within Microsoft Windows 10 pro, the IBees system is accessible through Google Chrome, Internet Explorer, and Mozilla Firefox browsers. Using NetBeans 8.2 platform to develop software while Apache Tomcat is a web server that supports for the functionality of the modules. The programming languages used in iBees are MySQL to manage database of the system, Hypertext Markup Language (HTML5), JavaScript, Cascading Style Sheets (CSS), Java for page scripting. Refer to Table 1 for software specification.

TABLE 1. SOFTWARE SPECIFICATION

| | |
|---|---|
| **Microsoft Windows 8 and above** | Operating system (OS) |
| **Google Chrome, Internet Explorer and Mozilla Firefox** | Web browser |
| **Arduino IDE 1.8.9** | Coding for device platform |
| **PHP 7** | Page scripting |
| **Apache Tomcat** | Web server |
| **MySQL** | Database Management System |

The external hardware used in iBees are illustrated in Table 2. The device called Temperature Sensor DHT11 [10] is a low-cost and low-power wireless sensor node for collecting the information of temperature and humidity based on the requirements of greenhouse and hatchery. The low power consumption MSP430F122 as the core, temperature humidity sensor and single RF transceiver NRF401 is realized to be an effective data acquisition and reliable data transmission. It has many advantages such as low power consumption, low cost, high integration, small size and stable operation.

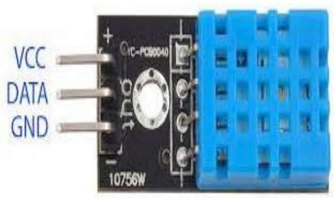
The second device, GPS GY NEO6MV2 [11] is a low cost yet powerful GPS receiver that based on the famous and high end u-Blox Neo-6M GPS module. It comes with small battery for hot-start, and there is built-in EEPROM too. To offer better signal reception, there is external ceramic antenna that connect to the board via U.FL connector, solid. It can operate from 3.3V to 5V system, so all those 5V Arduino board (CT-UNO, Maker-UNO, Arduino-UNO, Mega, Leonardo and many more) and 3.3V controller that include Arduino and Raspberry Pi, work perfectly with this GPS module.

The third device, Microcontroller Wemos D1 Mini PRO is a miniature wireless 802.11 (Wifi) microcontroller development board. It turns the very popular ESP8266 wireless microcontroller module into a fully fledge development board. Programming the D1 mini pro is as simple as programming any other Arduino based [12].

The fourth device, MT3608 [13] is a constant frequency, 6-pin SOT23 current mode step-up converter intended for small, low power applications. The MT3608 switches at 1.2MHz and allows the use of tiny, low cost capacitors and inductors 2mm or less in height. Internal soft-start results in small inrush current and extends battery life. The MT3608 features automatic shifting to pulse frequency modulation mode at light loads. The MT3608 includes under-voltage lockout, current limiting, and thermal overload protection to prevent damage in the event of an output overload. And the fifth device, the 3.7V 18650 3000mAh battery [14] is a Rechargeable Lithium Battery with No memory effect, recharge up to 1000 cycles. It is a 100% quality Japanese battery cells with 100% Q.C. of every battery. The last device, USB Solar Panel Portable 5W 5V [15] is made of high efficiency Monocrystalline silicon cells, the conversion rate is high. It offers small attenuation, good reliability and long servicelife.

The use of high-quality plastic frame, high strength, to ensure a higher degree of wind resistance and riot performance. It can adapt to a variety of complex and harsh weather conditions.

**TABLE 2. EXTERNAL HARDWARE SPECIFICATION**

| External Hardware | Functions |
|---|---|
| **Temperature Sensor DHT11 [10]**   | Collect temperature data |
| **GPS device GY NEO6MV2 [11]**  | Collect location data |
| **Microcontroller Wemos D1 Mini [12]**  | Control the behavioral of the device |
| **MT3608 [13]**   | Control the electric current |
| **3.7V 18650 3000mAh battery [14]**   | Power supply to the device |
| **USB Solar Panel Portable 5W 5V [15]**  | Power supply and charger for battery |

## B. IBees Casing

The casing for this device will be crate with 3D design using Tinkercad [16] which is an online 3D designing tool. The design is printed by 3D printer to create the prototype in iBees project. Fig. 4 shows the 3D design for the device's casing used in iBees.

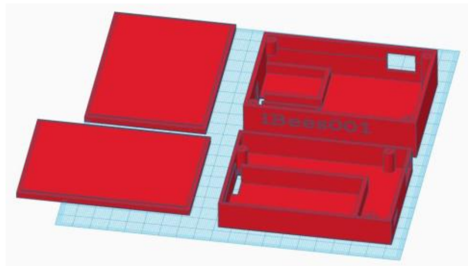


**Figure 4. The casing for sensor devices in iBees**

All the external hardware components as illustrated in Table 2 are assembled to become an iBees's hardware circuit as in Fig. 5.

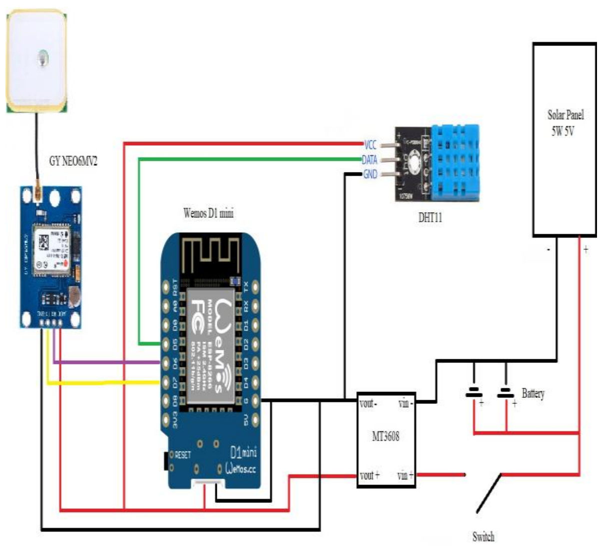



**Figure 5. Hardware Connection for iBees's Device**

## V. RESULTS AND DISCUSSION

This section discusses on the implementation of the coding for library for iBees devices (sensor) together with the Wi-Fi connection. The device needs to have the coding for the microcontroller to control the behavioral of the hardware and sensor. The code is written by using Arduino IDE 1.8.9 and send through micro USB into microcontroller Wemos D1 mini. Fig. 6, Fig. 7 and Fig. 8 illustrate the coding for library, configuration and WiFi and sensor setup for iBees respectively. The sample of snapshot screens are given in Fig. 9 and Fig. 10.

Retrieval Number C4124098319/19©BEIESP
DOI: 10.35940/ijrte.C4124.098319



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Blue Eyes Intelligence Engineering
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```
#include <ESP8266WiFi.h>
#include <WiFiClient.h>
#include "DHTesp.h"
#include <DNSServer.h>
#include <ESP8266WebServer.h>
#include <WiFiManager.h>
#include <TinyGPS++.h>
#include <SoftwareSerial.h>
```

**Figure 6. Library Coding in iBees**

```
static const uint32_t GPSBaud = 9600;
DHTesp dht;
// The TinyGPS++ object
TinyGPSPlus gps;

IPAddress server_addr(103,6,198,22);          // MySQL server IP
char user[] = "[redacted]";                   // MySQL user
char password[] = "[redacted]";               // MySQL password
WiFiClient client;
MySQL_Connection conn((Client *)&client);
MySQL_Cursor cur = MySQL_Cursor(&conn);
```

**Figure 7. The Configuration for MySQL and sensor**

```
void setup(){
  Serial.begin(9600);
  ss.begin(GPSBaud);
  //wifi config
  WiFiManager wifiManager;
  wifiManager.autoConnect("iBees001");
  wifiManager.setConfigPortalTimeout(60);




//--------------------------------------------------------mysql connect---
  Serial.begin(9600);
  dht.setup(D5, DHTesp::DHT11);
  ss.begin(GPSBaud);
  Serial.println("Initialising connection");
  Serial.println("Connecting to database");
  while (conn.connect(server_addr, 3306, user, password) != true) {
    delay(200);
    Serial.print ( "." );
  }

  Serial.println("");
  Serial.println("Connected to SQL Server!");
//--------------------------------------------------------mysql connect--- end---
}
```

**Figure 8. The Setup for Wi-Fi connection and sensor**

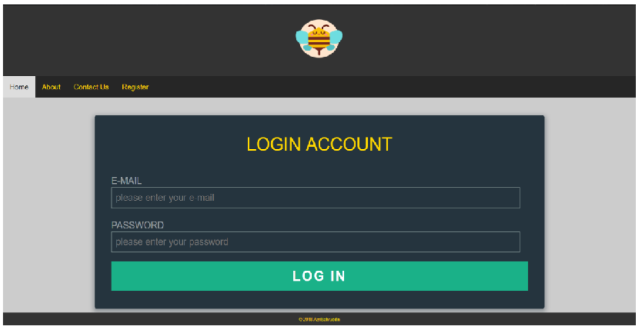


**Figure 9. Login Account for iBees**

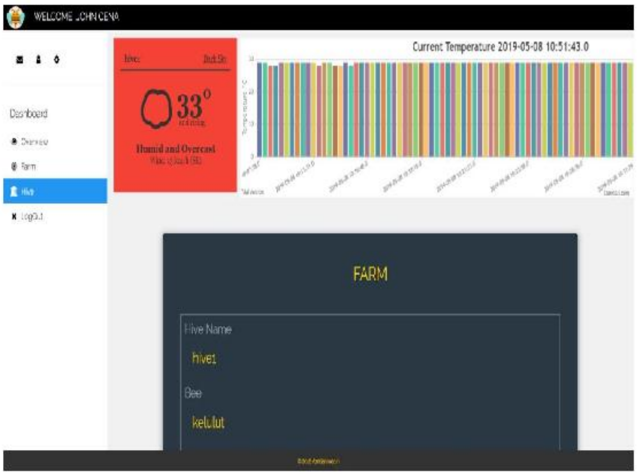


**Figure 10. Beehive Interface in iBees**

Fig. 11 indicates the user homepage of iBees. User can monitor his/her dedicated hive in real time through the location of the hive using Google map [17] through iBees dashboard. The bar graph for the latest temperature data is shown in colors (blue and red). From homepage also give user notification if the distance hive from set location is out of range or the temperature of hive is higher than maximum temperature or lower than minimum temperature. User can click on the white arrow to see the notification details.

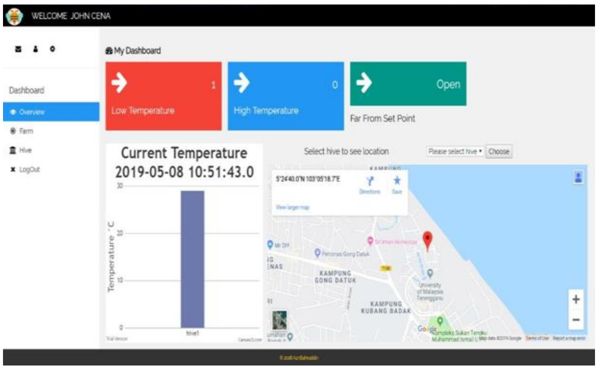


**Figure 11. Level of Temperature shown in Stingless Bee Hive System**

## VI. CONCLUSION AND FUTURE WORK

This system is developed for Nature n Trigona Garden to monitoring their hive with Global Positioning System (GPS) tracking and temperature and humidity sensor anytime and anywhere. This system is suitable for them because they have more than hundred bee hive at their garden. So they can monitor and take action when receive notification from the system. The system also helps to save time and money because they do not need to check each hive one by one. In addition, the system is safer and more efficient as user can only access after register to the system.

The future would be to improve in terms of internet access where the device should get the internet connection from the sim card in each device. So wherever the hive been take away, it still can send location data into the database. Second is the device need to be made in waterproof case to ensure the device condition and robustness.

## ACKNOWLEDGMENT

We wish to thank to our financial support under UMT Grant with Vot : 53258 : A GSM/GPS Tracker Technology In Tracking Monitoring Of Beehives. Also the bee farmers team from Nature n Trigona Garden company for the field site of Stingless Beehive, and all faculty members of UMT and UniSZA for supporting our work in reviewing for spelling errors and synchronization consistencies and also for the meaningful comments and suggestions.

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**Mustafa Man** is an Associate Professor in School of Informatics and Applied Mathematics and also as a Deputy Director at Research Management Innovation Centre (RMIC), UMT. He started his PhD studies in July 2009 and finished his studies in Computer Science from UTM in 2012. He has received Computer Science Diploma, Computer Science Degree, Masters Degree from UPM. In 2012, he has been awarded a "MIMOS Prestigious Awards" for his PhD by MIMOS Berhad. His research is focused on the development of multiple types of databases integration model and also in Augmented Reality (AR), android based, and IT related into across domain platform.

**Wan Aezwani Bt Wan Abu Bakar** received her PhD in Computer Science at Universiti Malaysia Terengganu (UMT) Terengganu in Nov, 2016. Her focus area is in association rule in frequent itemset mining. She received her master's degree in Master of Science (Computer Science) from Universiti Teknologi Malaysia (UTM) Skudai, Johor in 2000 prior to finishing her study in Bachelor's degree also in the same stream from Universiti Putra Malaysia (UPM) Serdang, Selangor in 1998. Her master's research was formerly on Fingerprint Image Segmentation in the stream of Image Processing. Currently joins UniSZA under Faculty of Informatics & Computing, Besut Campus, Terengganu since 01 January 2018. She led 2 grants with total of 40K. Her research involvement is mostly on setting the water based sensor in Aedes Mosquito Home System named as Intelligent Mosquito Home Systems (i-MHS).

**Muhammad Azri Bahruddin Bin Abdul Razak** currently study at University Malaysia Terengganu, Bachelor of Computer Science Software Engineering. He learns Java programming language using NetBeans, HTML, database using MySQL and phpMyAdmin and also Arduino. He has volunteered for Young Innovation Challenge (YIC) in his first year in university and in second year, he becomes a tutor and teach secondary school student about basic Arduino programming. Thus, he has gained experiences to work in his final year project.