An IoT-Based Ovitrap System Applied for Aedes Mosquito Surveillance

Ismaliza Isa, Ahmad Razali Ishak, Nazri Che Dom, Zulkifli Mohamed, M. Azhan Anuar

Abstract**: *Since the number of dengue fever cases has become the endemic disease in Malaysia, it is urgently need for rapid and efficient calculation of mosquito populations particularly for early detection and control measures. An ovitrap surveillance is used to determine the density of Aedes mosquito and it is one of the implemented method for vector control application. In this study, the prototype of an IoT-based ovitrap system was developed to automatically and simultaneously detect the Aedes mosquitoes using NodeMCU as the main IoT platform. The existing sticky ovitrap was modified to integrate the selected IoT components and to ensure its functionality for automatic detection. There are two phases were conducted in this study, with phase 1 evaluating the right IoT components to be selected and applied for automatic detection. Integrating the selected IoT components and modification of present ovitrap was carried out in phase 2 and the final revised design was considered. SWOT analysis and Pugh chart analysis also known as decision matrix method were used to select the best IoT components and final ovitrap design. It has been observed that the prototype D was the best design and be able to detect the adult mosquitoes. The lessons learned in the development of the IoT-based ovitrap were discussed in order to be employed for Aedes mosquitoes surveillance in the future.***

Keywords **: *Aedes mosquito, IoT, NodeMCU, Ovitrap.***

I. INTRODUCTION

Dengue fever (DF) has been on the rise in Malaysia over the past 40 years. It is rarely fatal, however, if left untreated it can develop into hemorrhagic fever stage which can cause a higher fatality rate. DF is spread through the bite of the female *Aedes* mosquito which is infected by the dengue virus. It is more widespread in urban areas and attacks irrespective of age groups [1]. The primary preventative measure of dengue fever is the control of mosquito populations. The implementation of preventive measures requires efficient vector surveillance tools that sensitive enough to predict the actual mosquito population [2].

One of the most popular surveillance instrument to survey the density of vector mosquitoes is ovitrap. This approach is installed in high-risk dengue sites to determine the Ovitrap Index (OI). The index is an important tool to represent the adult mosquito population based on the number of *A*edes mosquito's eggs. However, the index appears to be inadequate to meet vector surveillance needs because it only represents indirect measurement of adult mosquito density, thus do not provide actual information about adult mosquito population [3].

Recently, modification of ovitrap has been extensively studied by the various researcher. Tien et.al. [4] monitor the density of *A*edes population using various level of concentration and different colours of the container trap. The study found that the difference of attractant concentration and the ovitrap colors gave significant effects in trapping the *A*edes egg-laying. Also, Paz-Soldan et al. [5] has studied the attractiveness design and placement of mosquitoes by evaluating the effectiveness of ovitrap in different colours, different sizes and placed under brighter or darker locations. However, this modification still gave indirect information on the mosquito population.

Another study to modified ovitrap using Gravid Ovipositing Stickt (GOS) trap was implemented and they found that *Aedes aegypti* was the predominant mosquito (95%) caught in GOS traps [6]. This method provides a direct measurement of adult mosquito abundance, however, it still requires to collect the ovitrap in the field. Meanwhile, the study conducted by Mackay, Amador, & Barrera [7] found that by increasing the size of the trap entrance, altering the color of trap components and increasing the volume or surface area of the aqueous bait significantly improved the performance of the gravid ovitrap.

In this study, the prototype IoT-based ovitrap system was developed to automatically detect the adult mosquito population in real-time. This modified ovitrap system is expected to measure the density of mosquitoes populations faster than the conventional method which requires personnel to perform fieldwork. Therefore, it is predicted that this improvement will save time, traveling cost and most importantly it can determine directly the density of mosquitoes in the certain locality through the Internet of Things (IoT) application.

II. METHODHOLOGY

As mentioned previously, the objective of this study is to modified and develop an IoT-based ovitrap system to automatically detect adult mosquitoes in real time. The final prototype design needs to be simple yet effective by focusing on low cost and robust IoT components and sensor.

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The feasibilities of design were considered and evaluated.

In order to achive the objective, 2 phase were implemented following the waterfall model of the system development life cycle (SDLC). In phase 1, the requirement and feasibility study to select IoT hardware and software components must be properly made. Table- I and Table- II show the comparison between available hardware to be applied in the IoT-based ovitrap system.

Based on the comparison provided in both tables, SWOT analysis is presented in the result section to select the final components.

Table- I: Comparison of available controller or IoT platorm

No.	Parameters	Arduino Mega 2560	Arduino Uno	NodeMCU ESP8266
1	Operating Voltage	5V	5 V	3.3 V
2	Clock Speed	16 MHz	16 MHz	26-52 MHz
3	System Memory	8kB	2 kB	45 kB
4	Flash Memory	256 kB	32 kB	Up to 128MB
5	Development Environments	Arduino IDE	Arduino IDE	Arduino IDE, Lua Loader
6	Size	101.6mm ×53.3mm	68.6mm ×53.3mm	49 mm x 24.5 mm
7	WiFi Integration	No	No	Yes

Table- II. Comparison of sensors to detect mosquitoe

No.	Parameters	Ultrasonic Sensor HC-SR04	VL53LOX V2(Distance Laser Range Sensor)
1	Measurement accuracy	3 mm	1 mm
2	Supply voltage	5 V	5.5 V
3	Weight	9g	0.5g
4	Dimension	45mm x 20mm x 18mm	12.5mm x 17.5mm x 2.13 mm
5	Principle of work	sound	laser

After the IoT components were selected, Fritzing software was used as a platform to carefully design and integrate the hardware connection to ensure it operation. The schematic design of hardware is illustrated in Fig. 1.

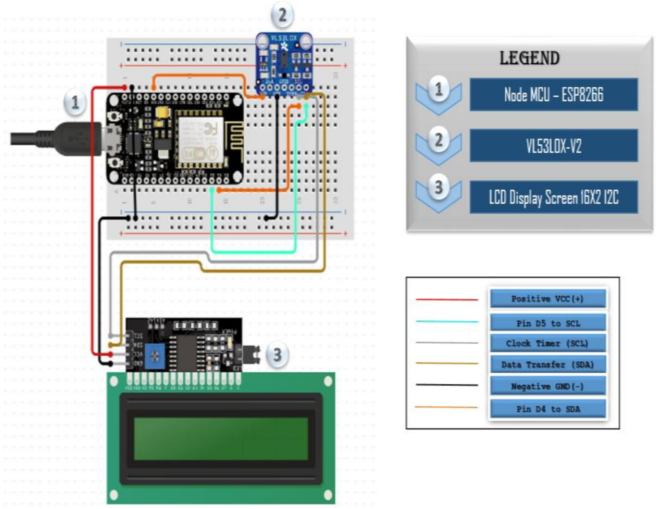

Fig. 1.Schematic design of hardware integration using Fritzing software.

In phase 2, the IoT-based ovitrap system was developed and analysed to integrate the selected IoT components with the modified ovitrap. Four (4) conceptual designs were considered for selection and the final prototype was selected based on Pugh chart result.

Finally, IoT-based ovitrap was tested for its functionality to detect mosquitoes automatically in real time.

The overall flow chart of the system development is illustrated in Fig. 2.

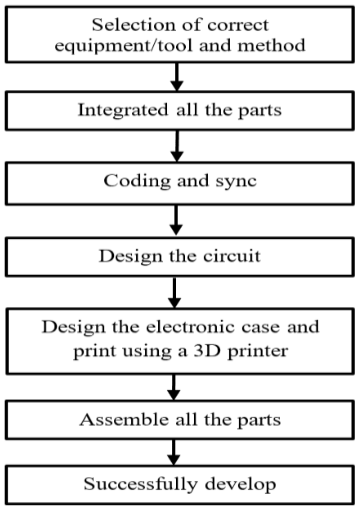

Fig. 2. System flowchart diagram.

III. RESULT AND DISCUSSION

A. Phase 1: System Requirement, Design and Integration

All related information was gathered and summarized accordingly using SWOT analysis as depicted in Table- III.

The important features needed for IoT components are listed as follow:

- The controller or IoT platform must have Wi-Fi integration. This is the requirement for IoT-based ovitrap system to send the data to mobile phone.
- The size of the controller must be small to attach with the modified ovitrap.
- The sensor must be able to detect adult size mosquito which approximately 4-7 mm in size.
- The sensor must be small and light weight.

Table- III. SWOT analysis of IoT hardware

Hardware	Strength / Opportunity	Weakness / Threat
Arduino Mega 2560	• There are 54 digital pins and 16 analog pins. • Has all basic features.	• No Wi-Fi integration. • Bigger size than NodeMCU.
Arduino Uno	• Has 14 digital pins and 6 analog pins.	• No Wi-Fi integration. • Come with usb type B connector only
NodeMCU ESP8266	• Low operating voltage. • Higher clock speed. • Bigger flash memory. • Small size. • **Can be used with Wi-Fi connection.**	• Has 10 digital pins and only 1 analog pin. • It consumes more power than both Arduino.
Ultrasonic Sensor HC-SR04	• Low cost. • Integrated support for WIFI network. • Low energy consumption.	• Bigger size that laser sensor • Accuracy is at 3mm (less accurate than laser sensor). • Heavy as compare to laser sensor
VL53LOX V2 (Laser Sensor)	• Low cost. • Integrated support for WIFI network. • **Reduce size of the board (smaller that Ultrasonic sensor).** • Low energy consumption. • **Able to detect up to 1mm accuracy.** • **Light weight.**	• Programming of ESP 8266 using Arduino IDE is not very straight forward.

The result was finalized from SWOT analysis in Table- III and the final IoT components were selected. NodeMCU (ESP8266) and VL53LOX V2 (Laser Sensor) were chosen since it satisfied all the required features.

In addition, LCD monitor is convenient to be included in order to directly show the data at the ovitrap location for on-site monitoring purpose.

All the selected hardware and software with it purposes are summarized in Table- IV and Table- V.

It is well aware that an open source microcontroller has become increasingly useful in the field of environmental monitoring due to its low cost and integrated development interface. Integration of the selected components enables the simultaneous and online surveillance of mosquito density in the specific area and the system design is shown in Fig. 3.

The aforementioned diagram simulates the process of detecting the mosquitoes when it enters ovitrap. The laser sensor sends signal to the NodeMCU for processing and the count will be displayed on the LCD screen. NodeMCU will then sends the signals and notification message to Blynk application through Wi-Fi. This message will be monitored by the personnel to record simultaneous and real time *Aedes* data at the location of interest.

Table- IV. Hardware and it purposes of use

Hardware	Purpose of use
NodeMCU (ESP8266)	Function as a controller to control all devices and send data to the internet via Wi-Fi connection.
VL53LOX V2 (Distance Laser Range Sensor)	To detect adult mosquitoes.
LCD monitor	To display on-site measurement data.

Table- V. Software and it purposes of use

Software	Purpose of use
Arduino IDE	The open-source Arduino Software (IDE) makes it easy to write code and upload it to NodeMCU.
Blynk	The system was connected with mobile application using Blynk software for online monitoring.
Fritzing	The perfect tool to design a schematic diagram

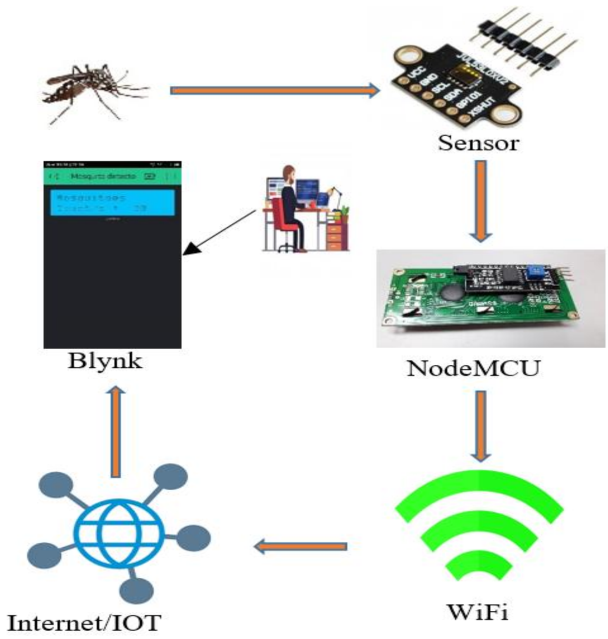

Fig. 3.System conceptual diagram.

B. Phase 2: IoT-Based Ovitrap Design and Functionality Test

A few prototypes design of ovitrap were considered in order to attach the IoT components to the modified ovitrap. The casing for NodeMCU, laser sensor and LCD monitor were designed and it final parts were fabricated using a 3D printer. Furthermore, the top opening and cover of the ovitrap were also developed and printed with 3D printer. The conceptual design and it components are portrayed in Fig. 4 to Fig. 7. The Pugh chart (also called as decision-matrix method) was used as a tools to choose the best design. The prototype design with the highest score was selected since this method will rank the prototypes concept with order of important.

The analysis of this method is presented in the following Table- VI.

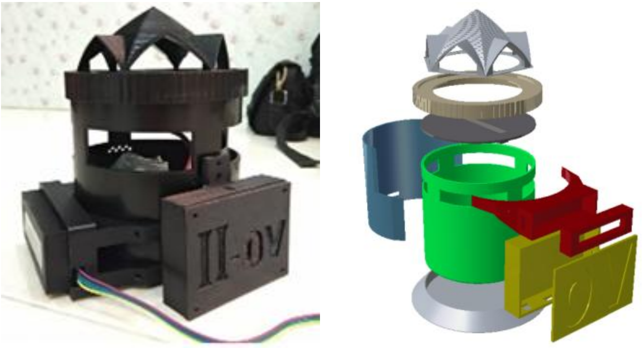

Fig. 4. Prototype A of IoT-based ovitrap system.

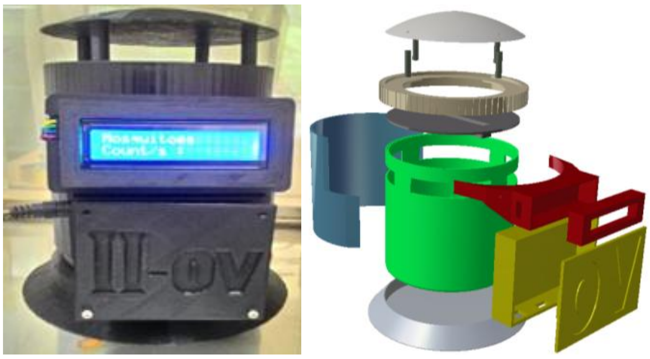

Fig. 5.Prototype B of IoT-based ovitrap system.

Fig. 6.Prototype C of IoT-based ovitrap system.

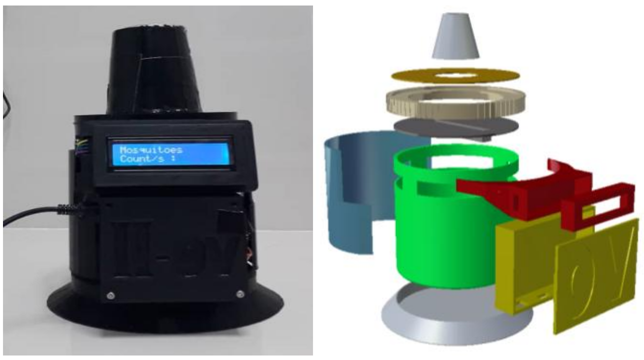

Fig. 7.Prototype D of IoT-based ovitrap system (The height of entrance cone was changed).

Table- VI. The Pugh chart with analysis

Description			Type A	Type B	Type C	Type D
Criteria	***Weight***	***Datum***				
Stability	1	0	0	+	+	+
Simple design	1	0	-	-	+	+
Component safety	3	0	-	+	-	-
Attractive to the mosquitoes	3	0	+	+	+	+
Measurement accuracy	5	0	-	-	0	+
+			3	7	5	10
0			0	0	0	0
-			9	6	3	3
Net score			**-6**	**1**	**2**	**7**

1) Design Optimization and Selection

All prototype designs were modified according to mosquitoes preference and the location of the sensor. As shown in Fig. 4, the first model of ovitrap (prototype A), was developed based on the conventional ovitrap which is black colour. Previous researchers have found that the black colour of ovitrap container has the highest positivity of oviposition [8]–[11]. Although the design was attractive, this design was not simple to fabricate especially at the top casing area. Besides, the placement of the hardware was not suitable that will likely be affected by the water in case of overflow. This prototype also failed to acquire and store the mosquito detection data due to the short life of Li-Ion battery. The surveillance of mosquito required 1-2 days monitoring as the mosquito will only come to ovitrap for lay eggs after mating and blood feeds within 48 hours [12]. Thus, the used of direct power sources was applied in the next models.

The second prototype B overcomes the weakness of power supply by changing the battery to a direct power source. Some modification have been done for top cover design and placement of hardware. All holes at the side were closed to ensure mosquito can only enter the entrance and pass through the sensor. However, the results of the laboratory experiment show that there was no mosquito has been able to enter and subsequently trapped on the attached sticky paper. However, the LCD monitor shows a large number of mosquitoes. Therefore, the design of prototype B should not be used. Probably, mosquitoes only fly around the sensor area but do not fly into the ovitrap.

In Prototype C, the top cover has been removed because it was believed, the gap between the top cover and the entrance hole affects the number of mosquitoes that can enter the ovitrap. Then, an additional entrance cone with a height of 4cm was added at the top of the entrance and sensor area. This is to ensure only female mosquitoes who want to lay their eggs will enter the opening and pass through the sensor location. The results show that the counts displayed on the LCD monitor and Blynk software were higher than to the number of mosquitoes trapped on sticky paper. The entrance cone height is insufficient to prevent the mosquitoes from flying in and out of the opening at the sensor area.

Therefore, the entrance cone height was increased to 8 cm in prototype D. It was observed that with this modification, the sensor recorded data shows better accuracy as compare to prototype C.

Finally, based on the description of each prototype and the net score from Pugh chart analysis, the prototype D was selected for further testing and validation. Issues to be taken care and lesson learned for future work were analyzed based on the selected prototype D.

2) Laboratory preparation for testing

The IoT-based ovitrap was tested for validation to ensure the VL53LOX V2 Distance Laser Range Sensor be able to measure the count of mosquito that enter the ovitrap, For this purpose, testing in a laboratory which involved the mass rearing of *Ae. aegypti* mosquitoes population was conducted at Insectorium Lab, UiTM Puncak Alam, Selangor. The procedure of mass rearing carried out under laboratory conditions which were maintained at 28 ± 2 °C and relative humidity of 75% to 85%.

In this study, the larvae were fed with chicken liver powder. After the emerging of an adult, sugar solution was supplied as carbohydrate and after five-to-seven days old adult female mosquitoes were supplying with restrained laboratory rat for blood meals. There were a group of 30 gravid *Ae. Aegypti* (15 female: 15 male) were released in the same cage after blood feed and mating processes. Afterward, the IoT-based ovitrap (Prototype D) was placed in the cage and the data measured was recorded within 48h after its placement. The steps for obtaining the data are shown in Fig. 8. The mosquitoes that were trapped were counted and recorded.

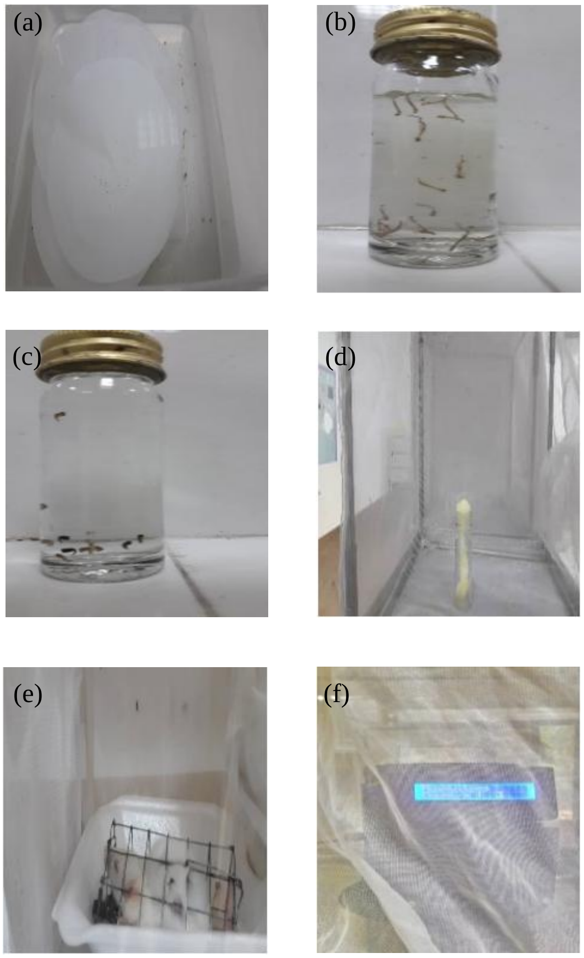

Fig. 8. Steps of collecting data, (a) the eggs are hatched in deoxygenated, (b) larvae emerge from mosquito eggs, (c) developed of pupae, (d) the emerging adult provided with sugar solution, (e) female adult provided with blood meals and (f) NodeMCU based ovitrap placed in mosquito cage for data collection.

3) Test and Validity

The IoT-based ovitrap was tested and able to transmit messaging alert via Blynk application. The count was recorded and send to the mobile phone as shown in Fig. 9. This indicate that the IoT-based ovitrap system is working and it will be easier for the public health officer to gain quick information in real-time.

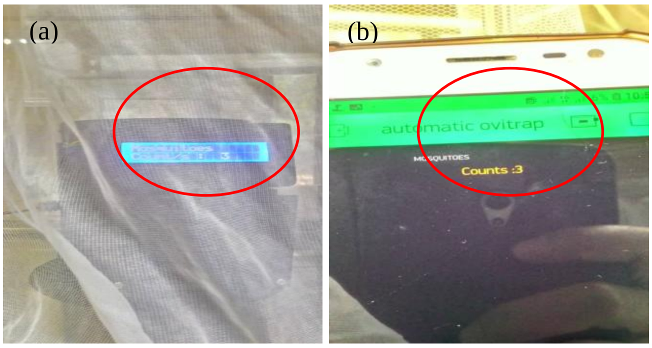

Fig. 9.Display current counts mosquitoes received from the system. (a) Count from the LCD monitor (showing amount of "3"), (b) Count from Blynk App (mobile phone) also showing amount of "3")

Laboratory testing shows that the VL53LOX V2 Distance Laser Range Sensor able to detect the adult mosquitoes. However, the modification has been made to certify that the sensor could provide readings comparable to the number of mosquitoes trapped on the sticky paper. It was found that the prototype D shows the number of mosquitoes detected by the sensor were higher than number of mosquitoes collected from the sticky paper. The amount of mosquitoes measured by the sensors and the actual amount of mosquitoes trapped on the sticky paper are shown in Table- VII for five (5) different measurements.

Table- VII. Count of mosquitoes detected by sensor and amount of mosquitoes trapped

Data	Counts of Sensor	Number of mosquitoes trapped
1	40	4
2	13	4
3	38	3
4	34	11
5	20	6

C. Critical Issues and Lessons Learned from IoT-Based ovitrap development.

This pilot study was conducted to assess the applicability of the system in order to detect the adult mosquitoes. Some recommendation are needed for future work to ensure that the IoT-based ovitrap system will be able to provide a more accurate measurement data.

Exploring the critical issues in IoT-based ovitrap system are result driven as this will be a good step for further modification especially in controlling the sensitivity of the laser sensor. The discussion on some of the experimental setup and planning issues are enlightened in Table- VIII.

Table- VIII. Critical issues to be taken care

Critical Issues	Discussion
1. Laser sensor sensitivity	This sensor is too sensitive for any kind of insects/disturbances and need to be properly placed for future work to ensure data reliability.
2. The size of entrance hole or sensor opening	In this study, the size of the entrance hole/opening is too small for the mosquitoes. This possibly the reason of high number of detection as displayed on the LCD screen due to the factor of mosquitoes continuously fly at the sensor area. This should be modified before the data collection begins. Increasing the opening size with attaching a trap cover is of the option to solve this issue as shown in Fig. 10.
3. The use of funnel	Funnel must be used in the ovitrap system under the sensor area to further trap and avoid the mosquitoes from flying in and out once they have entered the ovitrap.
4. Different height of entrance cone	Testing need to be done for different height of entrance cone in order to get the most optimum range for better result.

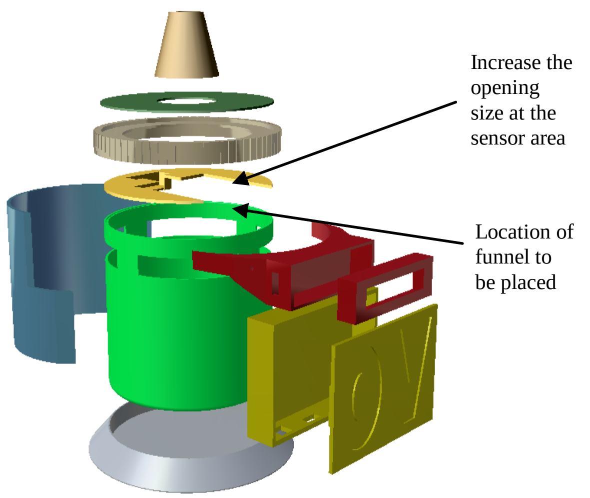

Fig. 10. Bigger opening size of IoT-based ovitrap system

IV. CONCLUSION AND FUTURE WORK

In this study, the feasibility of IoT-based ovitrap system for Aedes surveillance was successfully developed and evaluated. The heart of the test system is NodeMCU, which is the operator's communication to link hardware and software. The final selected model is prototype D as this design fulfill all the required criteria for IoT-based ovitrap system.

In future work, the sensitivity and attractiveness of the design must be fully evaluated with full attention shall be focused on the critical issues that are highlighted. Further analysis shall be made to evaluate the performance of the modified IoT-based ovitrap system.

The concepts and suggestions in this paper perhaps beneficial for future study to provide effective and appropriate ovitrap system using IoT application which intended for real-time monitoring.

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