IoT-Based Environmental Monitoring System for Brunei Peat Swamp Forest

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***Abstract* – Brunei Darussalam is largely covered by the tropical rainforest. Around 16% of Brunei total land area is Peatland. This peatland is under the protection of the Heart of Borneo initiative. This peatland forest plays a very important role in the region's rainforest ecosystem. However, this type of forest is vulnerable to fire outbreak, and hence the forest needs to be sustained. By using an Internet of Things (IoT) -based remote monitoring system, peat swamp forest areas can be monitored for long term management and short-term natural disaster preparedness. The proposed monitoring system is a solar-powered system equipped with built-in Long Range (LoRa) network to allow the data collection via a gateway. The system is designed to measure environmental conditions such as soil and water temperature, soil moisture, water level, wind direction and atmospheric humidity and pressure. The data collected by the system is programmed to be displayed on a dashboard which can be viewed remotely by respective agencies. The proposed system has been lab-tested on various conditions of peat soils giving measurement results which are usable for data reference.**

I. Introduction

Peat swamp forests are formed under wet conditions when dead plant materials are unable to decay in the flooded environment. This leads to the formation of partially decomposed organic matter which becomes trapped in the peatland area, including chemicals such as carbon for many years. Human activities, such as clearing the forest, has caused the water in the peatland area to be drained and carbon released to the atmosphere as carbon dioxide (CO_2). The peat that is buried over thousands of years will eventually become coal [1]. As the peatlands become very dry, it will trigger the ignition of fire. Hence, it is why the peat swamp is prone to fire outbreak, especially during the hot and humid season.

Brunei Darussalam experiences a tropical equatorial climate with temperature ranges from 23°C to 32°C, at high altitudes with heavy rainfall. The dry season in Brunei is extremely hot with temperature as high as 36°C [2]. The ignition of forest fires has caused the destruction of habitat and the production of tiny particles that lead to the formation of haze, which can be spread further to nearby areas and neighboring countries. Consequently, leading to serious health and environmental problems [3]. This is why the conditions of the peat swamp forest such as: the temperature of the peat soil, soil moisture and the water level drained in the peatlands, should be monitored to prevent the outbreak of forest fires.

A number of discussions and speculations had been done on the monitoring system for the prevention of forest fires. For example, South Korea has developed a Forest Fire Surveillance System (FFSS) based on Wireless Sensor Networks. The system observes real-time data that can alarm the fire station or nearby residents if a forest fire breaks out and thus providing an early extinguishing of forest fire [4].

DIMAP-FactorLink have also developed and integrated a forest fires detection system in the region of North Spain. They have used the Smart Environment Pro as their sensor nodes, whereas our approach uses the Smart Agriculture Pro as the sensor nodes [5]. With Meshlium, a multiprotocol router, it receives the data from the sensor nodes and stores it in a database, which can be shown on a graphic interface in a 2D or 3D maps. Thus, providing an accurate position and information on any forest fires incident to the firefighters [6].

The Internet of Things (IoT) is a network system which connects physical devices with the Internet. The IoT allows these devices and the Internet to communicate in real-time data without having any human action in the process. The main advantage of IoT is that it allows devices to be controlled remotely through the network infrastructure. [7].

This paper demonstrates the effectiveness and reliability of IoT-based environmental monitoring system for a peat swamp forest in Brunei. The monitoring system consists of the products of Libelium as the sensor nodes, equipped with sensors that measure environmental conditions: soil moisture, soil temperature and water level of the peatlands. The readings can be collected via a gateway and transferred to a dashboard for easy viewing and thus allow the monitoring of the area where the sensors are planted.

II. The Architecture of the Monitoring System

A. Site Location

The proposed monitoring system is focused on the Badas peat swamp forest area in Belait district, the largest district in

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Brunei. This district contains the most extensive peat swamp forest that can be found in the country. The peat swamp in Badas is continuous with the peat swamps extending over the border in Sarawak [8].

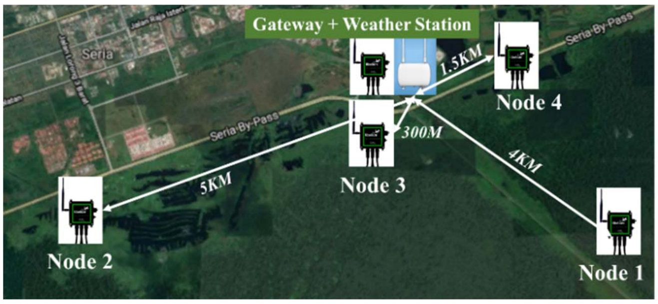

Fig. 1. Proposed locations for each sensor nodes and gateway.

The monitoring system contains the sensor nodes, will be installed at 4 different locations around the peatland area. Node 1 is the Badas peatland area, Node 2 is Lorong Tiga Seria, Node 3 is Sungai Bera, and Node 4 is Seria bypass highway. Areas along with Node 2 to Node 4 have experienced frequent forest fire outbreak during the hot and humid season. Placement of the four sensor nodes in the various locations can help in assessing the effectiveness of the monitoring system on the four different landscape environments that have different peatlands conditions. Upon the site inspections, it was found that Node 1 has very wet peatlands filled with drained water, Node 2, has very little wet area that is located near to a small river; Node 3, has dry peatlands located next to the industrial area; and Node 4, has dry peatlands located at the side of a highway.

B. System Architecture

The architecture of this project is as shown in Fig. 2. The project is an IoT-based environmental monitoring system in a peat swamp forest. The sensor nodes from all 4 locations will transmit data information via Long Range (LoRA) network communication technology to the gateway [9]. The gateway is a device that transmits the data from the sensor nodes to the cloud, which can be accessed online[10].

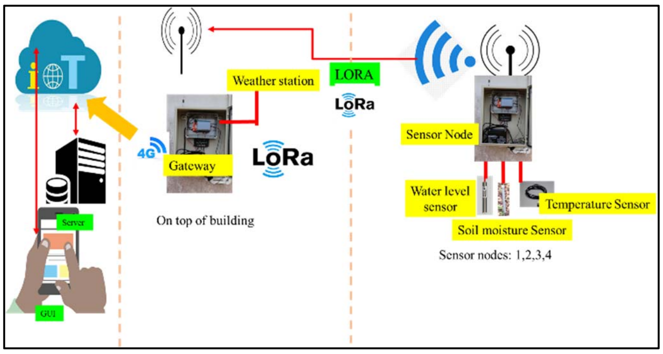

Fig. 2. Proposed system architecture Brunei-Networked ASEAN Peat swamp forest Communities (Bru-NAPC).

The sensor nodes consist of sensors that measure the soil temperature, soil moisture and water level of the peatlands. The gateway will be installed about 20 meters above the ground in one of the buildings at Sg Bera. Here, all of the 4 sensor nodes are within 5 km radius from the gateway.

C. Device and Equipment

The devices used for the monitoring system are:

i. Long Range Wide Area Network (LoRaWAN) Gateway
ii. Waspmote Plug & Sense! Device: Smart Agriculture PRO [11]
iii. Sensors
   a. Soil Moisture Sensor
   b. PT-1000 Soil/Water Temperature Sensor
   c. Rugged TROLL 200 Water Level Sensor
iv. Solar Panel
v. Weather Station: Wind Vane, Anemometer, Rain gauge

D. Block Diagram

The concept of the monitoring system is illustrated in block diagram as shown in Fig. 3.

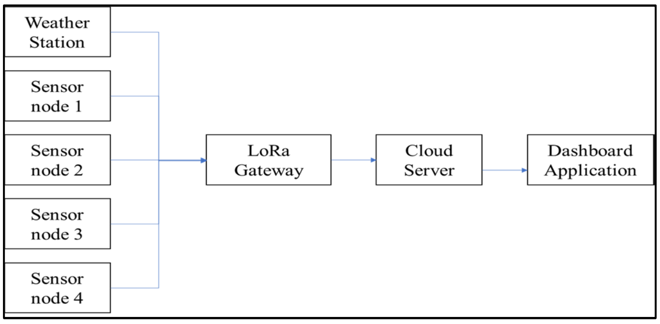

Fig. 3. Block diagram of the peat swamp forest fire real-time monitoring system.

The weather station consists of the wind vane, anemometer, and pluviometer, which are located on the same location as the gateway as shown in Figure 1. The sensor nodes are equipped with soil temperature, soil moisture and water level sensors. These sensors are used to measure the peatlands parameters.

The data from the sensors are programmed to be transmitted to the gateway in hexadecimal format every 5 minutes. LoRa is used because of its wide range, low power and low-cost connectivity. Its network protocol LoRaWAN, which offers a number of benefits in terms of bidirectionality, security, mobility and accurate localization that are not addressed by other Low Power Wide Area Network (LPWAN) technologies. From the gateway, the data is transmitted to the cloud via the 4G network connection as shown in Figure 2. The gateway is capable of transmitting data about 920-928 MHz and receiving data about 915-928 MHz of frequency band.

The Cloud server is a virtual server which can be accessed in a cloud computing environment. Transmitted data are stored in the cloud where users can access them remotely.

E. Flowchart

The sequence of the monitoring system is illustrated further as shown in Fig. 4.

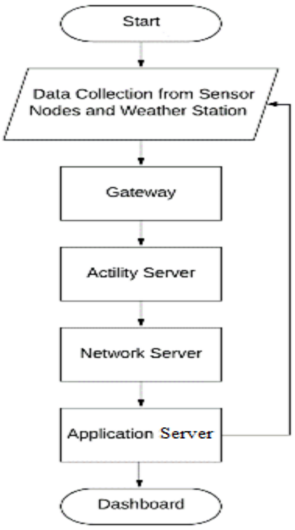

Fig. 4. Flowchart of the monitoring system.

The functions of each of the modules of the monitoring system are as follows:

1. The sensor nodes measure the soil and water temperature, soil moisture and water level.
2. The weather station measures the wind speed, wind direction, atmospheric temperature and pressure.
3. The LoRa Gateway is a networking hardware used for sending and collecting data from the sensors.
4. The actility server is used to redirect the data from the gateway to the server.
5. The network server is used to port forward the server to have a public address.
6. The application server is used to display or store the data received. Then, the received data is presented on a dashboard for viewers.

III. IN-HOUSE INSTALLATION

Prior to installing the monitoring system to the four site locations, the system was first installed at the Universiti Teknologi Brunei for experimental demonstration.

A. Weather Station Installation

The weather station was set up at one of the rooftops of the campus. Here, the weather station is placed below the gateway as shown in Fig. 5.

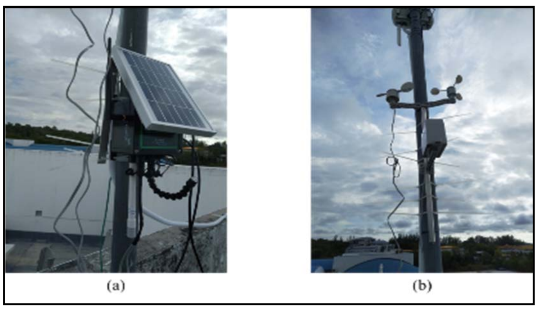

Fig. 5. (a) Solar panel above Waspmote Plug & Sense! device (b) Anemometer, wind vane and pluviometer.

B. Sensor Nodes

The sensor nodes were set up and used to experimentally measure the conditions of peat soils taken from three weather conditions; (i) normal, (ii) dry and (iii) wet, as shown in Fig. 6. The samples of the peat soils were taken from the exact locations as the proposed locations as show in Fig. 1.

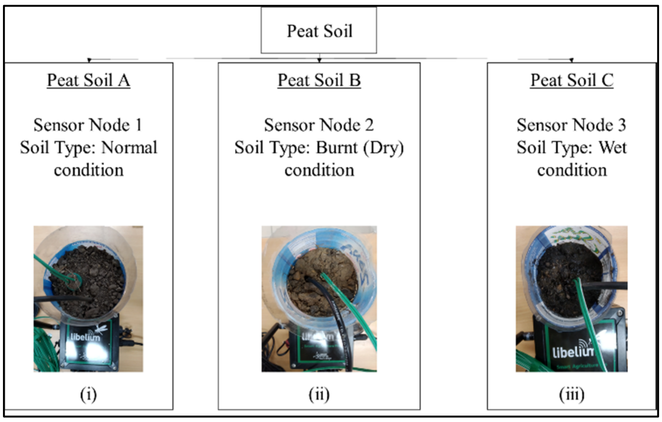

Fig. 6. Peat soils condition (i) Normal (ii) dry (iii) wet.

Each Sensor Nodes were set up as shown in Fig. 7.

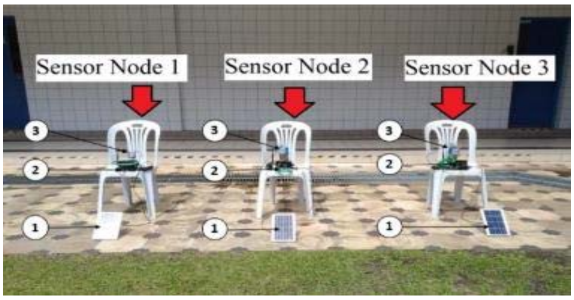

Fig. 7. Sensor Nodes. Label: (1) Solar Panel (2) Plug & Sense! device (3) Peat Soil.

C. Integration of Water Level sensor to the Sensor Node

As the water level sensor is a product of In-Situ and not Libelium's product, consequently the water level sensor was configured before connecting it to communicate with the sensor node. This was done by connecting the water level sensor to the Win-Situ 5 software, a software that is used to configure and calibrate In-Situ products. In calibrating the water level sensor, the sensor is dipped into a gallon full of water, as shown in Fig. 8(a). Fig. 8(b) demonstrates the results of the reading, displayed on the home tab of the software.

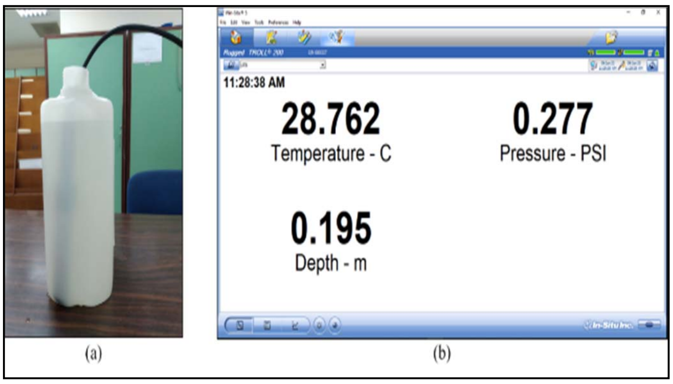

Fig. 8. (a) The in-situ water level sensor is dipped into the water gallon, (b) Result of the measurement from the in-situ water level sensor

IV. .RESULTS

A. *Weather Station Testing*

The measurements for atmospheric temperature, humidity and pressure were recorded over time by the weather station, as shown in Fig. 9.

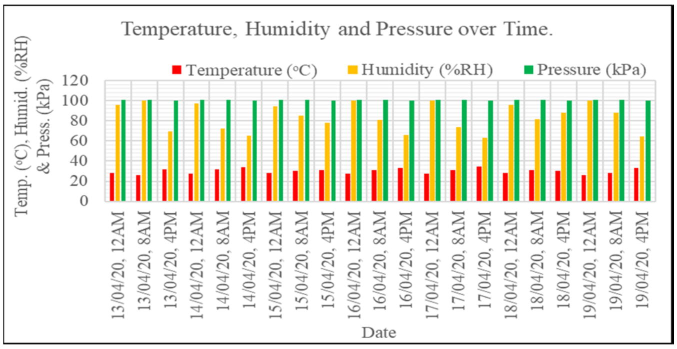

Fig. 9. Weather station recorded data on temperature, humidity and pressure.

These data are programmed to be displayed on the dashboard as shown in Fig. 10.

Fig. 10. Data recorded and displayed on dashboard.

The wind speed recorded by the weather station is illustrated as shown in Fig. 11.

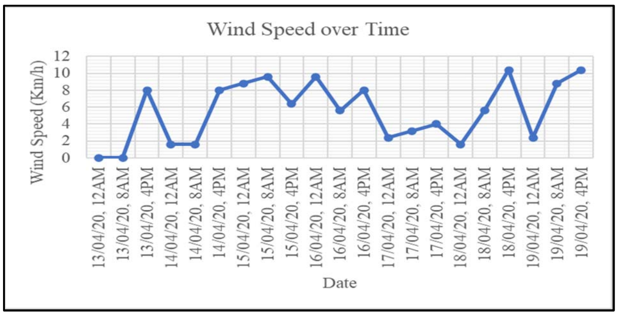

Fig. 11. Wind Speed over Time.

The wind speed and wind direction can also be viewed on the dashboard as shown in Fig. 12.

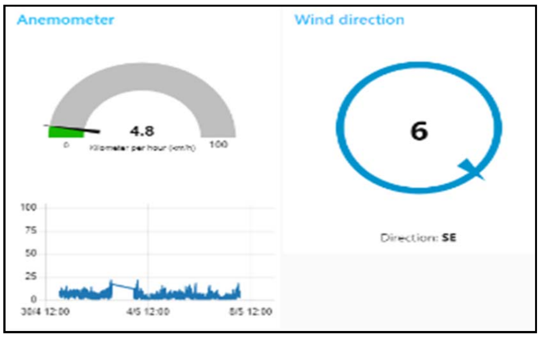

Fig. 12. Anemometer and wind vane pointing towards South East.

B. *Water Temperature Sensor Measurement*

Rugged TROLL200 and PT-1000 are the two sensors used to measure the temperature of the water. An experiment was carried out to determine the sensitivity of the two types of sensors. The comparison of the water temperature measurements by the two sensors is illustrated by a graph as shown in Fig. 13.

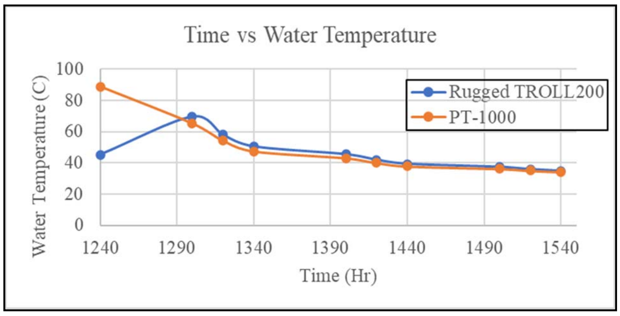

Fig. 13. Comparison between the two sensors for Water Temperature.

Fig. 13 shows that the PT-1000 sensor is more sensitive as it responded faster when it was dipped into the hot water compared to the Rugged Troll 200 sensor. It takes about 2 hours before both sensors measure the same result of water temperature.

C. *Sensor Nodes Testing*

Referring to Fig. 7, the conditions of the three types of peat soil were measured. However, there were some errors in getting the data reading from the sensor node 3, which resulted in no data being recorded in the initial stages. Fig. 14 shows the results obtained for soil moisture from the three sensor nodes.

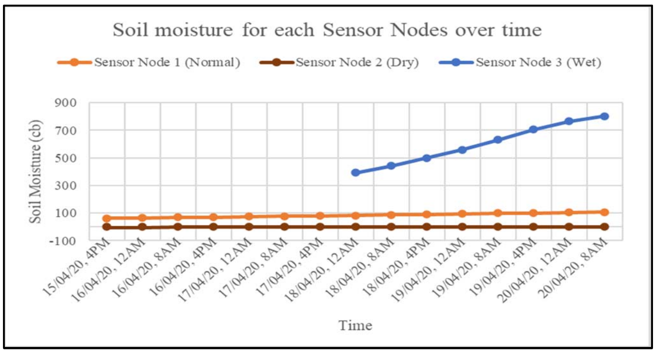

Fig. 14. Soil moisture from each sensor nodes.

As shown in Fig. 14, the soil moisture for Sensor Node 2 is very low in the range -0.6cb to 0.9cb. For sensor node 2, the samples of the peat soil were taken at the Sg. Bera peatland area where peat forest fires occured a few days before the sample was taken. Hence, it is why the data shows very low moisture in the dry peat soil. The soil moisture for peat soil with normal condition from sensor node 1 ranges from 62cb to 108cb. Whereas the Sensor Node 3 that measured the wet peat soil, shows very high values of moisture ranging from 394cb to 803cb.

The soil temperature from the three sensor nodes is as shown in Fig. 15.

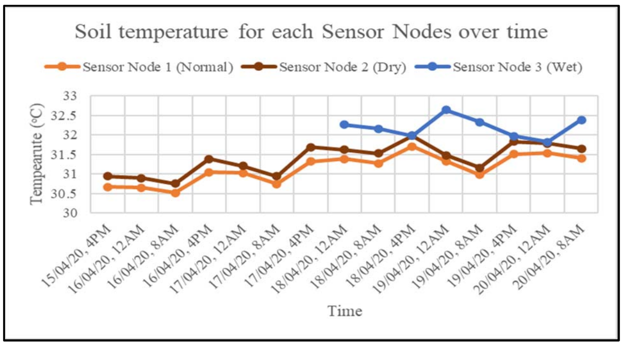

Fig. 15. Soil temperature from each sensor nodes.

Fig. 15 shows that the soil temperature for Sensor Node 1 in the range 30.6°C to 31.4°C. Soil temperature for Sensor Node 2 ranges 30.9°C to 31.7°C. Whereas soil temperature for Sensor Node 3 is within 32°C.

Note that the water level was not recorded because it was not used during the in-house testing due to the integration of the water level sensor that was still in progress during the testing.

Overall, the in-house testing has been successfully able to display the data reading from the weather station and the Sensor Nodes as shown in Fig. 16.

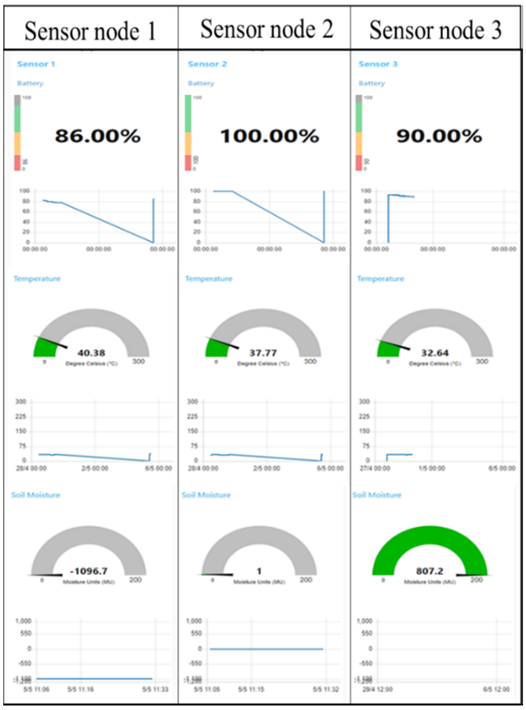

Fig. 16. Data reading from sensor nodes are shown on the Dashboard.

V. Conclusion

Peat Swamp Forest is known to be highly vulnerable to fires especially during the hot and dry season, which can be spread rapidly, making them difficult to stop. Hence with the IoT proposed solution, the peat swamp forest can be monitored with better data collections, coordination and decision making, which can help to reduce the consequences of forest fires. This can be achieved by using the monitoring system which is an IoT-based, where data collections such as temperature, water level and soil moisture from the Sensor Nodes are transmitted through the Gateway and to be monitored on the Dashboard. Water Level Sensor has been tested using various software for its data reading before it can be deployed onto the monitoring system. Based on the in-house testing results, each Sensor Node was able to collect the data and transmit them to the dashboard, where public can view the data remotely. The integration of the water level sensor into the monitoring system will be carried out in the upcoming work to provide more data collections.

Acknowledgment

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