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Forest Fire Detection using LoRa Wireless Mesh Topology

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***Abstract*—Events that causes delays in handling fires was a delay in information to warn of a forest fire. To overcome the problem, we conduct a research so that forest fires can be quickly detected. The problem is generally around the forests there is no data communication network available so that disable the delivery of information in the event of a forest fire. Therefore, we designed forest fire detectors that use LoRa mesh network. The detector is able to inform us where the fire location using Google map. Forest fire detector constitute of Arduino Uno, LoRa modules, DHT 11 humidity and temperature sensor and the MQ2 sensor. We put several nodes within a forest. In this case of forest fire alarm, the best LoRa configurations are BW 250 CR 4/5 SF 10. Using these configuration, we can send data to the LoRa gateway which is 500 meters away from the sensor nodes. With the distance between devices so far, the RSSI level received by the gateway is -136 dBm in addition to avoid collisions between four sensor node we recommended a transmission interval is equal 20200 ms.**

Keywords*—*fire detection, LoRa, DHT 11, MQ2, arduino, topology wireless mesh

I. Introduction

Forests are important in the ecosystem on earth. It is inseparable from the function of the forest itself, namely as a producer of oxygen to mankind even bearing the predicate as the lungs of the world. The problem is that when the forest experiences a fire, there will be a lot of harm to humans, ranging from air pollution and the destruction of natural ecosystems in the forest itself, starting from animals that will die a lot and to living animals can lose their place of residence [1]–[4]. Another thing that becomes a problem is that in the event of a forest fire, the authorities are slow in handling the forest fire, one of the reasons is the lack in information of forest fire. Therefore, we conduct a study that aims to detect fires and inform the authorities in the event of a fire.

Another problem is if there is no network service provider for sending information about fire around the forest [3]. The solution is to design public network so that fire detectors devices can send data out of the forest in the event of a fire. Therefore, we need a device that can send data cross the forest. In accordance with the range of possible data communication network, two wireless communication protocols can be classified into two categories, i.e., (i) a short distance and (ii) long distance. Wi-Fi, ZigBee, and Bluetooth represent short distance communication network, which are suitable for indoor environments. From existing research using ZigBee [1], [2], [4], the communication ranges between sensor-nodes and concentrators are too short especially if they were implemented in a forest. On the other hand, for long distances, various wireless networks can be used. One of them is LoRa technology [6] - [7]. Using LoRa wireless network, long range data communication range is close to 15 km on the ground [8]. Therefore, we make use of LoRa connectivity [5].

The system that we implement is placing several nodes in the forest where each node is equipped with a DHT 11 sensor as a reader of temperature sensor and humidity and MQ2 sensor as a smoke detector. We designed a wireless mesh network system [9].

II. System Architecture

A. Topology Wareless Mesh

A wireless mesh network (WMN) is a communications network made up of radio nodes organized in a mesh topology instead of star topology used in most of the networks, according to Akyildiz, X. Wang in the book of Wireless Mesh Networks [10].

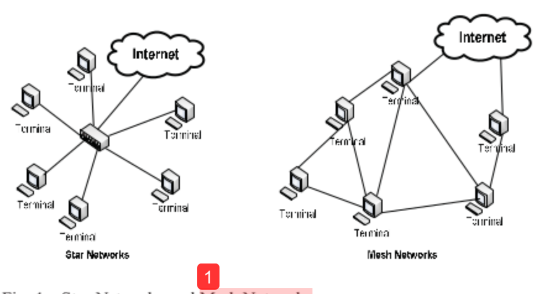

Fig. 1. Star Networks and Mesh Networks

The main difference between WMNs and star networks WMNs are wireless networks, which have the ability of dynamically self-organizing and self-configuration, and with mesh connectivity automatically establishing among nodes in the network while the conventional star network has a star topology which means all the terminal nodes are connected to a single central point which connects to the upper level of the network. Fig. 1 illustrates the topology of two networks [11].

B. *Sensor Node and Gateway*

In this research, we make use of Arduino Uno for sensor nodes. The Arduino Uno is attached DHT11 temperature sensor, MQ2 smoke sensor and Lora shield 915 MHz. MQ2 sensor is to detect the presence of smoke around. While the Dragino Lora Shield is to publish the acquired data. Fig. 2 shows the configuration for each the sensor node.

For the low-cost Gateway, we make use of Raspberry Pi and Dragino Lora GPS Hat v1.4. We installed Raspbian Stretch as operating system and LowCostLoRaGw[12]. Because incompatibility problem of Lora GPS Hat's CS pin, we modified raspberryPinNumber function (`ardupi.cpp line 1405`) such that the function return a value of 25. The values are correctly match to GPIO6.

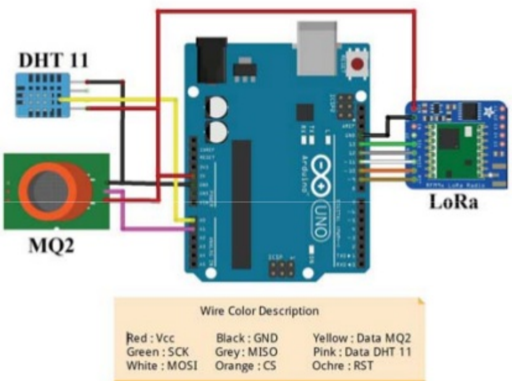

Fig. 2. The node using LoRa and Arduino

III. System Design

A. *General System Design*

This section explains the design of the system used in forests. Because in forest area, in general, there is no an Internet connection available. In such situation, it is difficult to get informed when there is a fire occurred. So, we need a designated network that can sent data from a forest, so our decision fall to wireless mesh topology. In general, as shown in Fig. 3, the communication pattern is from the node to the gateway, from the gateway send sensor data to a cloud service which can later be processed and monitored.

Fig. 3. Architecture Of Environment LoRa Network to Internet

B. *System Scenario*

In our experiment, we place 4 nodes in 4 different points of the forest. Let assume that there is no Internet service available around the forests but on one edge of the forest.

Fig. 4 shows that LoRa devices are arranged into two system parts. The first parts are on the no-internet-service area includes nodes that form a mesh network, another LoRa device is on the internet-service-area. This LoRa device forward data from nodes the cloud. E.g. If node 4 detected a fire, it cannot directly send data to the gateway because of a very long distance. Instead, node 4 sends to the nearest node first that is node 3. And then node 3 sends to node 2, after that node 2 forward the data to the gateway. Finally gateway forward the fire alarm to a cloud service.

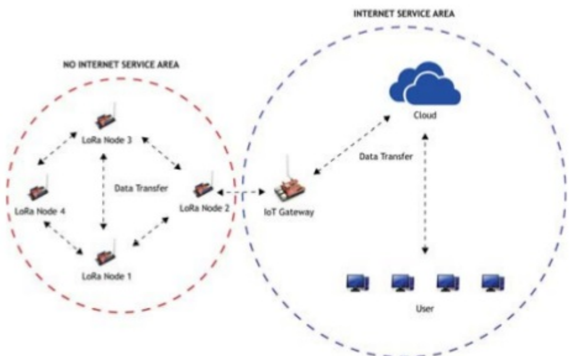

Fig. 4. Scenario for Overall system

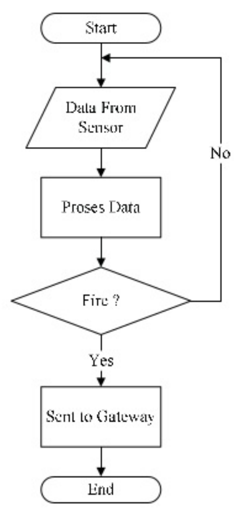

Fig. 5. Flowchart Data Transfer from Sensor Node

From the LoRa node, data acquisitions for temperature and humidity is by make use of a DHT 11 sensor. Detection of smoke is by make use of MQ2 sensor. Both sensor data acquired by Arduino from its I/O (digital and analog). Sensor node send data periodically via LoRa connection to a cloud. According to the data is received, a software application on the cloud may detect a forest fire. Following are the predetermined temperature, humidity and smoke particle concentration values as the basis of forest fire detection.

Temperature is up to 40 °C. Humidity data reaches the threshold of 50%. And particle smoke data reached the threshold of 2,368 ppm. That means this system may alarm a forest fire when all predetermined sensor value is perceived. In addition, location of sensor can be used to locate the forest fire. Fig. 5 shows a flowchart of forest fire detection and data transmission while Fig. 6 shows flowchart of forwarding data from sensor node to Internet.

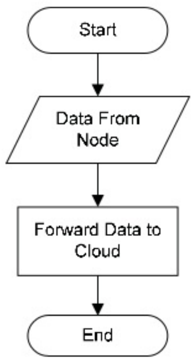

Fig. 6. Flowchart Data forwarding on Gateway

IV. Experiment and Result

We conducted experiments to collect performance data. There are three LoRa modes are set in these experiments. With 3 LoRa setting modes to find out which setting modes were effectively used in the forest. Where we use Tx Power 14 dBm, for nodes using 3 dBi antennas, and Ground Plane FPV Telemetry antennas on gateway 5dBi work at 915 MHz.

Fig. 7. Locations of sensor node in experiments

Fig. 7 shows the location experiment, we carried out data collection located in the Republic of Indonesia, South Sulawesi province, Gowa district. The coordinate point is 5°14 "S 119°33" E. Of the 5 types of forests in Indonesia, namely mangroves, swamp forests, savanna forests, seasonal forests, and tropical rain. We conduct research in seasonal forest types. Fig. 8 shows condition within the forest. We can see the condition of the forest has tight trees so it can weaken the signal from LoRa.

Fig. 8. Situational view of the forest

TABLE I. Distance Measurement Results and RSSI

LoRa Mode	LoRa Configuration			Distance (m)				
	BW	*CR*	*SF*	*100m RSSI*	*200m RSSI*	*300m RSSI*	*400m RSSI*	*500m RSSI*
1	250	4/5	12	-93	-110	-128	-138	-141
2	250	4/5	10	-91	-107	-127	-136	-136
3	250	4/5	9	-91	-112	-131	-	-

Table I, the result of RSSI measurement over distance and RSSI obtained from sending data of size 15 bytes + header of size 4 bytes. Hence total size of data is 19 bytes. In this experiment, we send data to a receiving node. The locations of receiver still in the same forest and have the distance of 100m, 200m, 300m, 400m, and 500m from the sender. We collect data repeatedly 50 times, every time we set new position for the receiver.

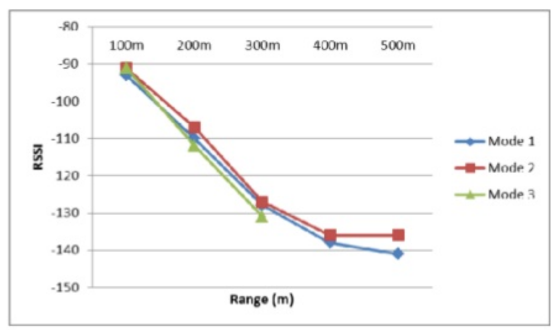

Fig. 9. Distance Measurement Results and RSSI

Table II shows the results of the Air Time Measurement directly on LoRa, we obtained the air time measurement data while collecting RSSI data shown in Table I. Hence, we conclude that air time is distance invariant.

TABLE II. Direct Air Time Measurement Results

LoRa Mode	LoRa Configuration			Air Time Direct Measure
	BW	*CR*	*SF*	
1	250	4/5	12	725
2	250	4/5	10	202
3	250	4/5	9	112

A. *Determination of the Number of Nodes to Cover Forest Areas*

In determining the number of nodes to cover forest areas, we first considered the signal range of LoRa while sending/receiving a data. This is important because by knowing the range of signal such that data can be sent by LoRa in the forest, we can also estimate the area of forest that LoRa may cover. Another thing to note in determining the distance between nodes is to consider whether the data is received or not. One way to determine whether or not the data sent is by paying attention to the quality of RSSI (Receive Signal Strength Indicator) on LoRa. And another thing to note is that data still can be received with low error rate.

In our experiment, we applied three setting mode in LoRa, shown in table I and table II. Of the three modes we tested, we can conclude that the best mode for the LoRa transceiver in the forest is mode 2 with specifications BW250 CR 4/5 SF10 Tx Power 14 with good RSSI results and a longer distance from mode 3. In addition, from data in the table I, we can also specify the number of nodes in 10 hectares of forest. The distance between nodes is 500m so for 10 hectares of forest can be covered by 4 nodes.

B. *Determination of Transmission Interval*

In this subsection, we discuss transmission interval. In our research, all sensor nodes transmit data periodically. We use a term of transmission interval T as the period of data transmission. This parameter is important to reduce the probability of data loss during transmission. With a duty cycle d [13] and air time T_{OA} transmission interval T is recommend using a formula $T = T_{OA}/d$. Therefore, with $T_{OA} = 202$ ms

$$T = (202\text{ms})/0.01$$
$$= 20200 \text{ ms}$$

Therefore, each node must be silent in 19998 ms.

V. Conclusion

In this section, we conclude our research. Our conclusion are as follows. First Within the forest, we can only send data using LoRa module at the longest distance of 500m. These results will be different if we were using the LoRa module in the open space. That is Line-of-Sight (LoS). Secondly, Acceptable RSSI level threshold to send data within the forest should be greater than -136 dBm. If the RSSI level was smaller than -136 dBm, then the data will be either partially or completely lost. Finally, the best LoRa setting mode within the forest is BW 250 CR 4/5 SF 10 Tx Power 14. With the setting, design is able to cover 10 hectares of forest, we only need 4 LoRa modules, and for a larger area, we only need to increase the number of LoRa modules. To avoid data collisions on a mesh network with 4 nodes, we recommend transmission interval greater than 20200 ms.

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