2013 3rd International Conference on Instrumentation, Communications, Information Technology, and Biomedical Engineering (ICICI-BME)
Bandung, November 7-8, 2013

Design Technology in Wireless Mesh Network System for Eruption Disaster Mitigation of Merapi Volcano

Firdaus[1], Syarif Hidayat[2], Alvin Sahroni[1], Hendra Setiawan[1], Rois Akbar[1]
[1]Department of Electrical Engineering, Universitas Islam Indonesia, Yogyakarta, Indonesia
[2]Department of Informatics Engineering, Universitas Islam Indonesia, Yogyakarta, Indonesia
(e-mail: firdaus@uii.ac.id ; syarif@uii.ac.id ; alvinsahroni@uii.ac.id ; hendrasetiawan@uii.ac.id)

Abstract- Indonesia is one country in the world that has the biggest natural disaster risk. That is because the position of Indonesia which is located at the confluence of three plaques Indo-Australian, Eurasian and Philippines. One of the disasters that often occur is the eruption of a volcano that is indeed one of the most active volcanoes in the world located in Indonesia called Merapi volcano. Currently, monitoring a volcano still rely on measurements on site and remote monitoring using camera and outposts near Merapi volcano. It is becoming less effective due to the efficiency and effectiveness of the key staple of disaster mitigation process. This paper provides a new approach to monitor the state of the Merapi based on ambient temperature in Merapi using wireless mesh network system based on Zigbee modules, effectiveness and reliability found in volcano monitoring which the level of reliability of a particular node at a distance of 200m and can perform data transmission when multiple nodes are damaged and the data is sent successfully.

Keywords:Wireless Mesh Network System, Merapi Volcano, monitong, disaster mitigation

I. Introduction

Indonesia is one country in the world that has the biggest natural disaster risk. Some of these natural disasters are earthquakes, tsunami, volcanic eruptions, floods, landslides, tidal waves, cyclone, and another natural disaster that occurred by geological form. The main cause is related the position of Indonesia which is located at the confluence of three plates, there are Indo-Australian, Eurasian and Philippines. Directorate of Volcanology and Geological Hazard Mitigation (DVMBG), and Ministry of Energy and Mineral Resources reported that the number of Indonesian volcanoes that reach 129 volcanoes with 79 of them of A-type (very active) increases the chances of natural disasters (Fig1.). However, with the high frequency of disasters are often not accompanied by a preparedness and disaster response.

Various programs such as early warning systems, disaster mitigation, and evacuation process not quite optimal. Previous studies include the early warning system in Indonesia using the DVB-T [1]. The previous investigation not mentions the method for the early detection that can be potential in reducing enormous number of casualties and extent of damage. Currently eruption detection is done using seismographs and direct observations, but it highly dependent on weather conditions. A technology that can be used to improve the performance of previous detection tool is to use sensor networks (heat, humidity, vibration, etc.).

Some limitations of the sensor networks are transmission media used to transmit the sensor data that have been collected. One of the technologies that could be used is a mobile technology-based infrastructure. However, it always been a problem when a disaster is occurred, caused damage to the infrastructure and transportation of communications. This is due to the communication models used is generally based on infrastructure.

Reliable broadband communication becomes very important in the event of a disaster, especially during emergency response operations and recovery state. In this condition, using common based communication infrastructure cannot be disturbed or even used. IEEE 802.11 Wireless Mesh Network (WMN) is a multi-hop wireless network capable with the ability to adjust to the changes. This feature makes the WMN as a promising communication technology in the event of a disaster. Several studies have proposed the establishment of SafeMesh and Hybrid WMN to provide temporary network to provide communication services that can be used for efficient crisis management at the disaster site. However, both the above methods are not able to form a stable network with a large throughput.

All sorts of advantages above are not without obstacles. WMN create a computer network environment is much more complex than other connectivity such as LAN or MAN as security, privacy, reliability, energy use. Therefore it takes more planning in order to mature the technology according to the situation and condition of the area concerned.

This research is an initial part of a large study that aims to implement the WMN as a communication technology that can be used for early detection of natural disasters volcanoes. The focus of research in this study was to measure the potential and the difficulties that may arise during the implementation of this technology by implementing WMN in a limited scope.

Figure 1. Main mapping of Indonesia's disaster (Siebert 2010).

II. Preliminary Study

A. Early Warning in Merapi Volcano

One of the most active volcanoes in the world is also found in Indonesia, the Merapi volcano is located at the center of the island of Java. This mountain is very dangerous because according to modern records having eruption (peak activity) every two to five years and is surrounded by a very dense settlement. Since 1548, this mountain has erupted 68 times. Magelang and Yogyakarta is the nearest large town, is under 30 miles from the peak. On the slopes there is still a settlement to a height of 1700 m and its just 4 kilometers from the summit. Because the importance related to the conditions, Merapi became one of sixteen volcanoes in the world which includes project Volcanoes of the decade [2]. Early detection is needed in order to improve the effectiveness of disaster mitigation process with the aim to reduce the loss of material and non-material [3]. The early warning system can using ambient temperature as the early warning detection within volcano merapi disaster. Based on [4] provided related investigation of correlations between temperature around merapi volcano and it status(Table.1).

TABLE 1.
TEMPERATURE AS THE INDICATORS OF VOLCANO [4]

Surface	10m	15m	Status
0ºC - 32ºC	0ºC - 35ºC	0ºC - 37ºC	Normal
32ºC - 37ºC	35ºC - 38ºC	37ºC - 39ºC	Alert
37ºC - 39ºC	38ºC - 40ºC	39ºC - 41ºC	Standby
39ºC - <ºC	40ºC - <ºC	41ºC - <ºC	Beware

B. Wireless Mesh Network for Early Warning

Wireless Mesh Network (WMN) is a method of networked communications that consists of mesh client (node), mesh routers and gateways and connected using a mesh topology. Node can be a laptop, cell phones and other wireless devices. WMN mesh allows the client to communicate without the need to connect to the communications server/coordinator or better known as the Access Point (AP). Covered area was a set of communication nodes which are connected to each other is known as the mesh cloud. WMN offers a reliable computer network protocols and redundant. When a node ceases to operate, all the other nodes able communicate with each other, directly or through one or more intermediate nodes. One of the WMN feature is its ability to form new dependent networks or in other words can heal itself if one node cannot work or the performance reduced. WMN can be implemented with a variety of other wireless technologies, including 802.11, 802.15, 802.16, cellular technologies or combinations of more than one type.

WMN is the development of an ad-hoc network. Ad-hoc networks are typically formed when a device comes within range of the wireless communication with each other. Compare with ad-hoc network, WMN is often more planned configuration, and can be used to provide dynamic and cost effective connectivity in specific geographic areas. Mesh router itself can be a mobile device that can be moved as needed in the network. Mesh routers generally have more computing resources than the other nodes in the network. Based on this side, a WMN and ad-hoc network typically has difference related to the limitation of computation capability.

III. Proposed Method

Location of this investigation will be held in Laboratory of Communication in UII Yogyakarta, and Surrounding Merapi volcano area to collecting data. The step of general investigation provided in (Fig.2).

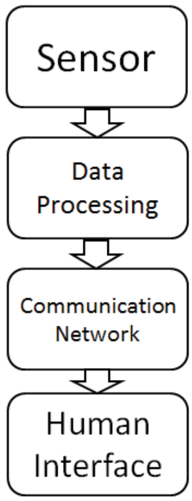

Figure 2. General Step for investigation

To support this investigation, it require several equipment such as IC LM35 as the sensor temperature, AVR ATMEGA8 as the CPU or computation purpose, Zigbee device for communication, and IDE software to develop human interface (Fig.3.). The overall system (fig.3) conduct several phase. Firstly the sensor (IC LM35) of temperature will be sensing the physical condition. It will be processed by microcontroller / CPU to transmitted using Zigbee interface and finally processed by the server/coordinator to provided information using human interface (fig. 4). For each node (B, C, D, and E) will placed a sensor, and node A as the main coordinator for overall signal. There will be 2 parts in design of the hardware, a transmitter and a receiver. Both of them are using Xbee ProS2B device which is connected to the microcontroller as the CPU (Fig 5.).

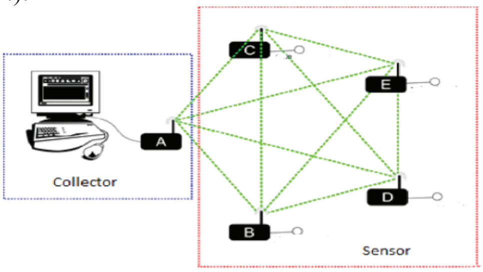

Figure 3. Illustration of overall system

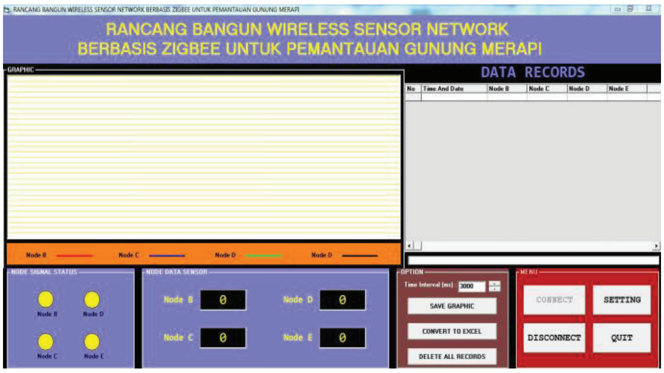

Figure 4. Design of human interface

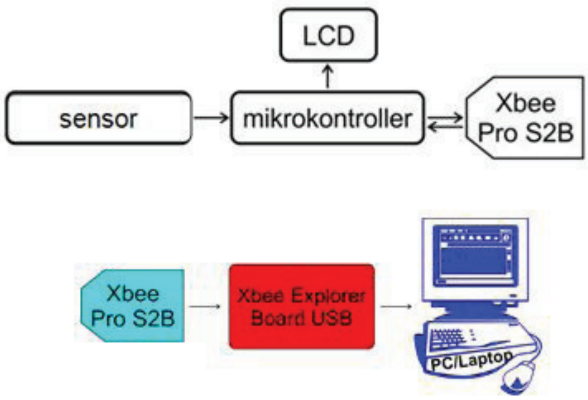

Figure 5. Trasmitter and Receiver

The software implementation will be conducted into 2 sides, the microcontroller and PC and both of it using basic language programming that integrated with serial communication library. The development of software section within microcontroller for each sensor within WMN node, it will contain procedure in transmitting and receiving data (Fig. 6.). Microcontroller task is to process sensor value provided by IC LM35 and then transmitted using Xbee Pro2SB. The receiver will read the value of transmitted data and then through the local network that connected into server/PC side, will be processed by IDE based on human interface software. Data packets that received by the coordinator/main server will be informed by using graphical user interface using Visual Basic. And for each node will provide plot graphs and can be save as .jpeg file format. The software section on PC side, it will provide an algorithm (Fig.7.) that act as the coordinator for WMN. The main algorithm's aim is to collect and reroute the new network during the damaged of certain sensor.

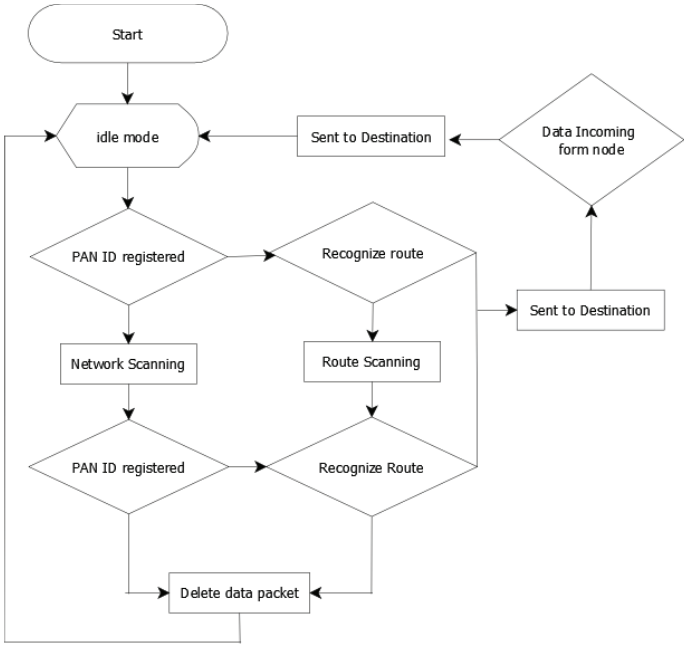

Figure 6. Flow chart of data collection using Xbee Pro2SB

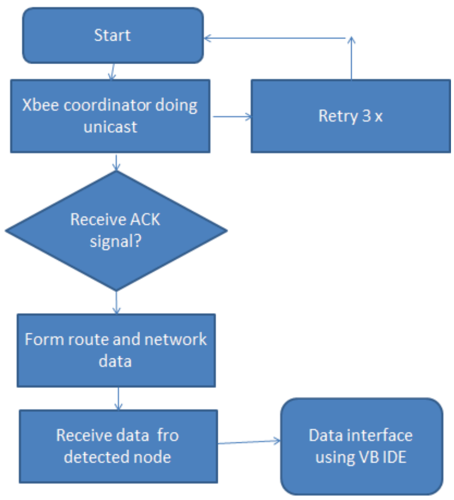

Figure 7. Flow chart of data collector node

Data analysis also provided within investigation. The analysis will be conduct related to the certain parameter such as:

- Success of communication between sensor/node and coordinator/human interface
- Validation of data transmission between transmitter and receiver

- Sensor acquisition will be compared between the real condition and reference condition based on literature review.

IV. ANALYSIS AND DISCUSSIONS

This section will provide validation of the system that focused on investigation of sensor transmitting and receiving performances. This section will be separated into several parts such as system testing, validation of transmitting distances using various scenarios system.

A. System Validation

Area used for testing is Wukirsari, Cangkringan, Sleman, Yogyakarta. This area is quite close to Merapi volcano which is 13 km from the summit of Merapi volcano (Fig 8.). This region has fairly dense population. Due to the limitations of the module that using the adapter as a power source, then the area is suitable for testing because there are many houses that can be used as source of electrical power. Before the system testing conducted, firstly it will decided the pattern of each node by consider the maximum capability of each node to communicate each other.

This investigation also related to compare the sensor measurement based on theory and investigation result. The Mean Square Error (MSE) provides 17.80615ºC (fig.10) between the theory approach to measure sensor of LM35 and investigation result using Zigbee modules communication.

Figure 8. Wukirsari area for system testing

B. Validation of Transmitting Distances Using Various Scenarios

This section will provide various investigations of scenario of node B, C, D, and E to node A as the coordinator. Firstly, the task is to find the maximum distances that can be reach by transmitter device with obstacles consideration. After getting the maximum distances for each node, then it will be tested for several scenarios of nodes combination. First investigation, it will testing between node A and node B to communicate each other. During several testing to find maximum distances was held such as 326m, 287m, 277m, 215m, 222m, and 185m. From the various optional of distances, 185m provided successful data transmitting without any packet loss. And then, by increasing the distance, we provide our preliminary hypothesis that the maximum distances with obstacles by using WSN is ±200m. And based on the result, it will be used for another sensor as the main purpose to locate another node ±200m from another node.

The scenario was the combination between 5 node of wireless sensor (B, C, D, and E to A)(fig.9). First scenario is by locating each node (A, B, C, D, E) to connect each other or it means that overall sensor in active conditions during connections into the server (A). Next phase is how to test certain scenarios , and the scenario is conduct based on certain node will be deactivated to test whether the A node still can receive any sensor data from transmitter node (B, C, D, and E).

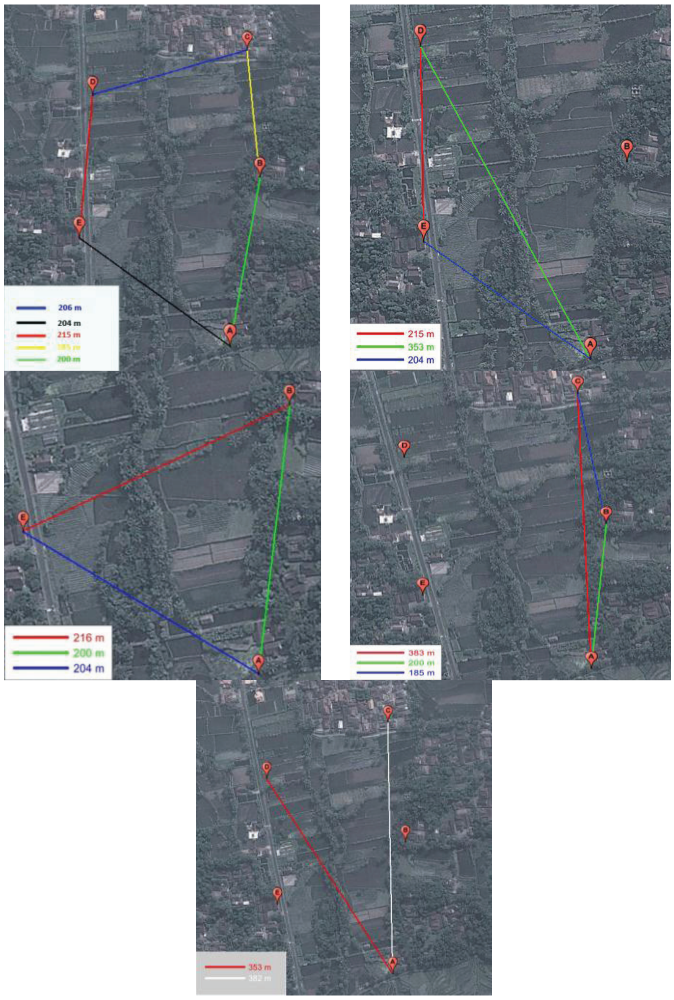

Figure 9. Various scenarios for investigation

1st scenario

TABLE 2.
ALL NODES ACTIVATED

Node	Node Status	Node A Status	Data Status
B	ON	SENT	Success
C	ON	SENT	Success
D	ON	SENT	Success
E	ON	SENT	Success

2nd scenario

TABLE 3.
ONE NODE DEACTIVATED

Node	Node Status	Node A Status	Data Status
B	OFF	NOT SENT	Not Success
C	ON	SENT	Success
D	ON	SENT	Success
E	ON	SENT	Success

3rd scenario

TABLE 4.
TWO NODES DEACTIVATED

Node	Node Status	Node A Status	Data Status
B	OFF	NOT SENT	Not Success
C	OFF	NOT SENT	Not Success
D	ON	SENT	Success
E	ON	SENT	Success

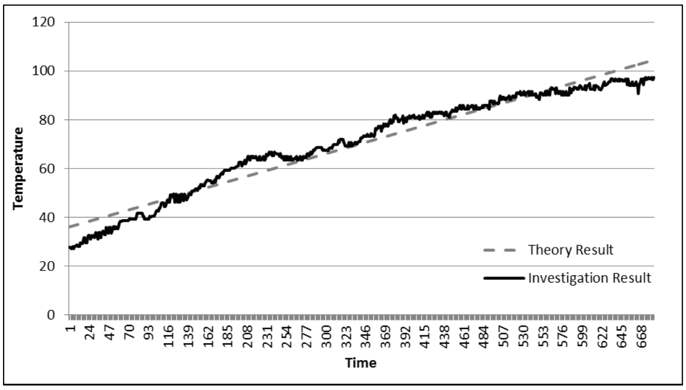

Figure 10. Sensor acquisition

The 1st scenario was conduct with one nodes deactivated. The deactivated assume that in reality when the disaster occurred, it possible to harm sensors while monitoring process still held. The damaged caused will not affect the monitoring because the WMN procedure will re-route the networks and monitoring process will able to continue. Testing procedure of this investigation does not only for B node to be deactivated. By doing alternately to another node, gives 100% successfully data sent to A node as the collector. It cause the distance of each sensor to A node is not greater than 200m. 2nd scenario was tested by doing certain node to deactivated, and it gives result that the A node still able to monitoring sensor acquisition. 3rd scenario has different result. By deactivating the farthest node, it failed to send sensor data to A node. It's based on the previous explanation that the maximum distance which allowed sending data through WMN not excess 200m. However, with certain configuration the data can be sent successfully. The overall schematics appropriate to the Fig.9 as an illustration for each scenario.

V. CONCLUSIONS

From the testing that has been done, it can be concluded as follows.

1. The maximum safe distance between two nodes using Zigbee modules within the conditions which are many obstacles in the form of houses, trees, and uneven contours of the land is 200 meters
2. Based on the maximum distance conditions that 200m distance, the data had been sent 100% successfully without any error within data collector/server.
3. Disturbances that occurred during transmitting signal (certain node is off/damage) can be solved by re-routing the networks automatically.

REFERENCES

[1] A. Budiarto, "A Proposed Disaster Emergency Warning System Standard Through DVB-T in Indonesia," in *ELectrical Engineering and Informatic (ICEEI)*, Indonesia, 2011, pp. 1-4.

[2] IAVCEI. (2012, 26 july) http://vulcan.wr.usgs.gov/. [Online]. HYPERLINK "http://vulcan.wr.usgs.gov/Volcanoes/DecadeVolcanoes/" http://vulcan.wr.usgs.gov/Volcanoes/DecadeVolcanoes/

[3] Sarwidi, "Mitigation of Merapi Volcano based on national disaster mitigation system," in *National Conference Merapi Environment Development*, Yogyakarta, 2011.

[4] W.E Mineral. (2012, July) http://portal.vsi.esdm.go.id. [Online]. HYPERLINK "http://portal.vsi.esdm.go.id" http://portal.vsi.esdm.go.id

[5] L. Siebert, "Volcanoes of the World," Berkeley:University of California Press, California, Article 2010.

[6] I Akyildiz. (2005) Wireless Mesh Networks:a survey computer networks. Magazine.

[7] Kemenristek, "Iptek sebagai Asa dalam Penanggulangan Bencana di Indonesia," Kementerian Riset dan Teknologi, Jakarta, 2007.

[8] Sukiwo, "Design of Temperature Telemetric with Digital Modulation FSK-FM," *Transmisi*, pp. 1-8, 2005.