PERFORMANCE EVALUATION OF WIRELESS SENSOR NETWORK ROUTING PROTOCOL FOR VOLCANO ACTIVITY MONITORING

Juan Enrico Lorenzo[1]; Fransiska Sisilia Mukti[2]
Program Studi Teknik Informatika
Institut Teknologi dan Bisnis Asia Malang
www.asia.ac.id
cerberus050135@gmail.com[1], ms.frans@asia.ac.id[2]

Abstract— *As a country with the most volcanoes in the world, the Indonesian government must provide accurate and up-to-date information on the activity of active volcanoes. Until 2021, only 59% of mountains were directly monitored. Monitoring volcanic activity is not an easy thing to do. Visual observation alone is not enough, and instrumental comment is needed. Wireless Sensor Network (WSN) is a new opportunity to conduct a real-time and low-cost monitoring system for volcanic activity. However, the placement of independent WSN sensors in locations that are difficult to access creates new reliability and energy consumption problems. Therefore, we need a reliable communication line design for data transmission and path determination that does not drain sensor energy. This study specifically evaluates the performance of several routing protocols on WSN (proactive, reactive, and hybrid) to provide recommendations for the best routing design for volcanic activity monitoring needs. The simulation results of 6 WSN routing protocols using the NS-2 simulator show that the proactive protocol provides the smallest delay value, and the reactive protocol shows the highest data transmission success ratio but with the best residual energy. In contrast, the hybrid protocol could maintain a stable throughput value during data transmission.*

Keywords*: monitoring, volcano, routing, own, ns-2*

Intisari—*Sebagai negara dengan gunung api terbanyak di dunia, pemerintah Indonesia dituntut untuk dapat menyediakan informasi yang akurat dan terkini mengenai aktivitas gunung-gunung berapi yang masih aktif. Hingga akhir tahun 2021, tercatat hanya 59% gunung saja yang terpantau secara langsung. Melakukan pemantauan terhadap aktivitas gunung berapi bukan merupakan hal yang mudah untuk dilakukan. Pengamatan secara visual saja tidak cukup, diperlukan pengamatan secara instrumental. Wireless Sensor Network (WSN) hadir sebagai peluang baru dalam melakukan sistem pemantauan aktivitas gunung berapi yang bersifat real-time dan low-cost. Namun penempatan sensor-sensor WSN yang bersifat independent dan berada di lokasi yang sulit diakses, menimbulkan problematika baru dalam hal reliabilitas dan energi yang dikonsumsi. Untuk itu, dibutuhkan sebuah desain jalur komunikasi yang handal dalam hal pengiriman data maupun penentuan jalur namun tidak menguras energi sensor. Penelitian ini secara khusus mengevaluasi kinerja dari beberapa protocol routing pada WSN (proaktif, reaktif dan hybrid) untuk memberikan rekomendasi desain routing yang terbaik untuk kebutuhan pemantauan aktivitas gunung berapi. Hasil simulasi 6 protokol routing WSN dengan menggunakan NS-2 simulator menunjukkan bahwa protocol proaktif memberikan nilai delay terkecil, protokol reaktif menunjukkan rasio keberhasilan pengiriman data tertinggi namun dengan residual energy terbaik, sementara protocol hybrid mampu menjaga kestabilan nilai throughput selama pengiriman data.*

Kata Kunci*: monitoring, gunung berapi, routing, wsn, ns-2*

INTRODUCTION

Indonesia is located between three major tectonic plates in the world (Indo-Australia, Eurasia, and the Pacific) and is traversed by two young world volcano routes, namely Circum Pacific and Circum Mediterranean. The impact of this geological condition causes Indonesia to have many volcanoes, which are also prone to geological disasters such as earthquakes, landslides, volcanic eruptions, and tsunamis. Recorded that as many as 127 volcanoes are still active in Indonesia, which makes Indonesia the owner of the most volcanoes in the world (Pamungkas, 2016).

The Indonesia Government, through the Ministry of energy and Mineral Resources, specifically established a mountain potential information management and geological disaster mitigation management unit called Pusat Vulkanologi dan Mitigasi Bencana Geologi (PVMBG) or the Center for Volcanology and Geological Disaster Mitigation. This institution was formed as a follow-up to the eruption of Mount Kelud in East Java in 1919. Until the end of 2021, only 59% had been directly monitored by PVMBG through seismometers and acoustic microphones placed at Volcano locations (Kementerian Energi dan Sumber Daya Mineral, 2022).

In particular, the method of monitoring volcanic activity can be carried out in two schemes, visually and instrumentally. The visual monitoring system is carried out through human senses, namely direct observation, to determine changes in parameters that indicate the tendency of the volcano to erupt. Meanwhile, instrumental monitoring is carried out through sensing carried out by tools or sensors that cannot be seen by humans (Lara Cueva et al., 2013).

Monitoring volcanic activity is a crucial issue considering the importance of providing an early warning system, especially for people living in volcanic areas (Lopes Pereira et al., 2014). The use of distributed sensors such as seismic, acoustic, til-meter, optical thermal, and flux and typical of the most common sensors used in monitoring volcanic activity. Unfortunately, cost limitations, accessibility, power, and the amount of data that can be transmitted are inevitable limitations that must be faced in the field.

Wireless sensor networks (WSN) are generating new opportunities in volcano activity monitoring systems through increased scale and resolution (Werner-Allen et al., 2005). Implementation of the WSN for monitoring volcanic activity began in 2004 on Tungurahua Mountain, central Ecuador. WSN was first developed still ad hoc, single-hop, and not real-time (Werner-Allen et al., 2005). Research continues to be developed to collect multihop data to the base station, the mint route routing algorithm, and the Deluge protocol (Werner-Allen et al., 2006). Further research was developed through the DORSIVA project (Zhang, 2005) and the optimized Autonomous Space in Situ Sensow Web (OASIS) project in 2008-2009 (Peterson et al., 2009) which resulted in several designs of data resolution optimization algorithms and energy efficiency on sensors.

WSN technology in Volcano Activity Monitoring Systems faced several challenges, such as real-time communication systems, energy efficiency in sensors, high data rate, reliability of communication lines built, and data security. An effective data exchange mechanism must offset the limited energy on the sensor (generally using batteries). The biggest energy use in WSN is when the data transmission takes place. Therefore it takes a proper communication protocol design in the routing process or path selection (Mukti, Junikhah, et al., 2022).

In establishing a communication path, WSN classifies routing protocols into proactive, reactive, and hybrid or combined protocols. Some examples of routing protocols included in the bold classification include Destination-Sequenced Distance Vector (DSDV), Optimized Link State Routing (OLSR), Fisheye State Routing (FSR), and Interzone Routing Protocol (IARP). Protocol Ad Hoc on-Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Location-Aided Routing (LAR), and On-Demand Multicast Routing Protocol (ODMRP) is an example of reactive routing classification. While Zone Routing Protocol (ZRP), temporarily Ordered Routing Algorithm (TORA), Greedy Perimeter Stateless Routing (GPSR), and Directed Diffusion (DD) are examples of hybrid routing protocols that combine proactive and reactive routing mechanisms at once (Mukti, Lorenzo, et al., 2022).

Each protocol has its strengths and weaknesses, depending on the ultimate goal of the protocol selection. Therefore, this study evaluated the six WSN routing protocols (AODV, DSDV, DSR, OLSR, TORA, and ZRP) on volcanoes' activity monitoring systems. Parameters used as a reference in evaluating include throughput, packet delivery ratio, delay, and residual energy. These four parameters were selected to provide a routing protocol recommendation that best suits the volcano activity monitoring system's real-time and less-energy needs.

RESEARCH METHODS

Performance determination of six WSN routing protocols, a simulation was built using the NS-2 simulator. NS-2 is a network simulator that uses C++ and OTCL programming languages that support substantially simulating WSN. Simulation is run on several scenarios number of sensors, namely 25. 50. 75 and 100 nodes. Details of the parameters used in the simulation process are shown in Table 1.

Table 1. Simulation Parameters

No	Parameters	Values
1	Nodes	25, 50, 75, 100
2	Channel Type	Wireless
3	Radio propagation model	TwoRayground
4	Network interface Type	WirelessPhy
5	MAC Type	802.11
6	Interface queue type	Queue/DropTail/PriQueue
7	Link layer type	LL
8	Antenna model	Omni
9	Max packet	50
10	Time of simulation end	25

The simulation and evaluation of WSN routing protocol performance begin with creating node patterns formed randomly. After the node is made, the route pattern is built to determine the source node as the sender of the data and the destination node as the recipient. Figure 1 shows an example of a node pattern for 100 nodes.

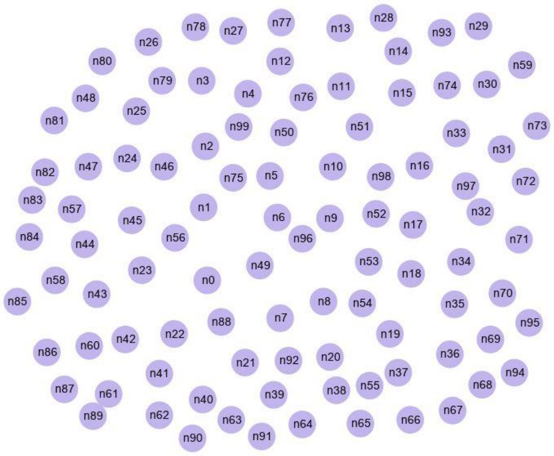

Figure 1. Pattern Formation 100 Nodes

Furthermore, the simulation process for each routing protocol is AODV, DSDV, DSR, OLSR, TORA, and ZRP. Each simulation process will produce output in the form of .tr files and files .nam is used as numerical analysis and graphical display of the simulation. Figure 2 shows a list of configuration programs from TCL files that are run to generate .tr files and files .nam.

```
#Create a ns simulator
set ns [new Simulator]

#Setup topography object
set topo       [new Topography]
$topo load_flatgrid $val(x) $val(y)
create-god $val(nn)

#Open the NS trace file
set tracefile [open AODV25.tr w]
$ns trace-all $tracefile

#Open the NAM trace file
set namfile [open AODV25.nam w]
$ns namtrace-all $namfile
$ns namtrace-all-wireless $namfile $val(x) $val(y)
set chan [new $val(chan)];#Create wireless channel
```

Figure 2. Configuration File.TCL

The simulation process provides additional parameter information for analysis, namely throughput, packet delivery ratio, delay, and residual energy.

Throughput is defined as the speed of data transfer in a real communication line in units of bits per second (bps) (Susdyastama Putra et al., 2020).

Packet delivery ratio (PDR) is the ratio of the number of data packets received by the destination node compared to the number of data packets sent as a whole. Increasing the value of PDR indicates better network performance (Khan & Ramesh, 2019). However, this value is also influenced by the presence of obstacles or obstacles and weather conditions around the node (Dani Prasetyo Adi et al., 2021)

Delay indicates the time taken by the packet in the process of sending data with units of milliseconds (ms). While residual energy is obtained from the average power required by a node in the communication process. These two parameters are benchmarks in terms of energy efficiency in the WSN network (Pella, 2018)

These four parameters will be included in the configuration file .awk, which is then used as an input value to evaluate the performance of each protocol. Figure 3 shows a sample execution file .awk for throughput parameters on AODV and DSDV routing protocols for 25 nodes.

```
roid@DESKTOP-BAUHH5E:/mnt/c/Users/Lenovo/Desktop/ns2/Bu_Frans/25NODE$ gawk -f average_throu.awk AODV25.tr
Start Time 1
Stop Time 15
Received Packets 15782
The throughput in kbps is 8.699242

roid@DESKTOP-BAUHH5E:/mnt/c/Users/Lenovo/Desktop/ns2/Bu_Frans/25NODE$ gawk -f average_throu.awk DSDV25.tr
Start Time 0
Stop Time 24
Received Packets 1024
The throughput in kbps is 0.330764
```

Figure 3. File execution .awk

RESULTS AND DISCUSSION

In analyzing the performance of the simulated routing protocol, performance evaluation is grouped into two schemes, namely the level of reliability of communication lines and energy efficiency. The communication reliability story used is based on throughput, PDR, and delay parameters. At the same time, the level of energy efficiency is measured based on the residual energy generated by each node.

One of the parameters measuring the performance of WSN communication is determined through a high throughput value (Mukti, Lorenzo, et al., 2022). The high throughput value will also be affected by the number of actively communicating nodes. Figure 4 shows the simulation result of throughput value calculation for the six WSN routing protocols.

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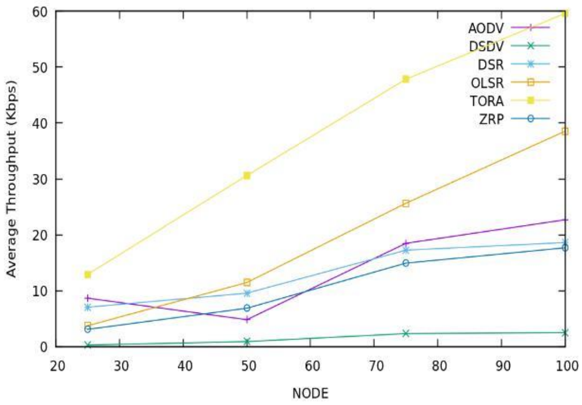

Figure 4. Comparison of Throughput performance

It can be seen that the TORA routing protocol dominates the resulting throughput value even though there is an increase in the number of simulated nodes. It may happen because TORA can provide multiple routes (multi-route) between the sending node and the destination node. It is inversely proportional to the DSDV protocol, which shows the lowest throughput value performance with an average of 2.5 kbps for 100 nodes.

The next Parameter that is considered in building reliable WSN communication is PDR. This value determines the success of WSN in sending data packets to the destination, especially considering the interference in the volcano environment is very diverse. Figure 5 shows the PDR value simulation results for the six WSN routing protocols.

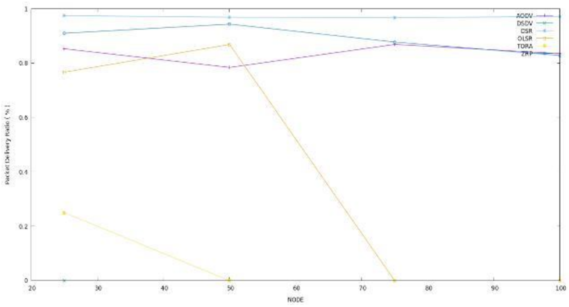

Figure 5. Comparison of PDR performance

It can be seen that the DSR routing protocol shows its consistency in sending packets despite the increase in the number of nodes involved in communication. However, this is inversely proportional to the DSDV and TORA routing protocols that perform worse when transmitting data at higher node density levels.

The end-to-end delay Parameter is also one of the parameters closely related to the throughput and PDR values generated in a WSN communication. The delay or time delay is very likely due to the queue of packets in the data transmission process. However, in its implementation in the volcano monitoring system environment that is required to be real-time, it is necessary to have a routing protocol that can minimize the delay value as small as possible so that that information can be immediately conveyed (especially in the event of an eruption). Figure 6 shows the delay values for the six WSN routing protocols.

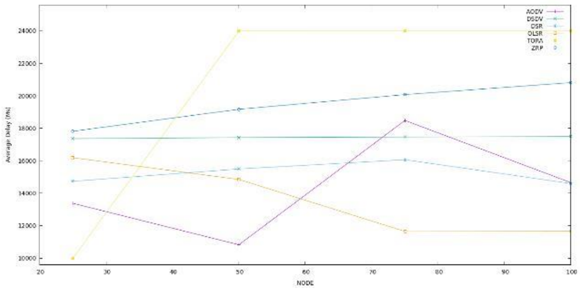

Figure 6. Comparison of Delay performance

The Results of the Simulation show that the value of delay will increase in all routing protocols when the number of active nodes in communication increases. However, the OLSR routing protocol offers the best delay performance (with the smallest value) for 100 nodes. It indicates that this protocol is well recommended for network scalability.

Meanwhile, a WSN network also must be balanced with energy efficiency procedures considering that the nodes used are independent nodes that get energy sources only in the form of batteries. Therefore, the residual energy parameter becomes an important segment to be evaluated in a WSN routing protocol, as seen in Figure 7.

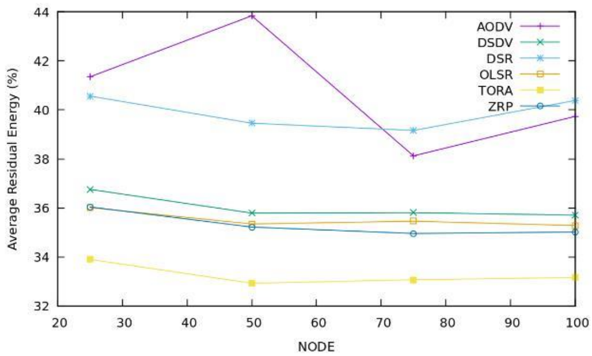

Figure 7. Comparison of Residual Energy performance

AODV routing protocol shows a much higher residual energy value than the other five protocols on the number of active nodes, as many as 25-50 nodes, but the energy consumed decreases dramatically as the number of active nodes increases. It is inversely proportional to the DSR routing protocol, which shows its stability in maintaining power during the data transmission. It can be seen that DSR has the highest residual energy at the highest number of nodes in the simulation process.

Based on the results of testing the four main parameters that evaluate the performance of proactive, reactive, and hybrid routing protocols, a conclusion is obtained, as shown in Table 2. Hybrid protocol (TORA) provides a high throughput value, proactive protocol (OLSR) offers the best delay value even though the number of nodes increases, while reactive protocol (DSR) dominates in showing its performance in terms of PDR value and the highest residual energy even though the number of active nodes increases significantly.

Table 2. Performance Evaluation Conclusion

No	Parameters	OLSR	DSDV	DSR	AODV	ZRP	TORA
1	Throughput						✓
2	Delay	✓					
3	PDR			✓			
4	Residual energy			✓			

CONCLUSION

The main purpose of using WSN technology in the Volcano Activity Monitoring System is to provide a real-time monitoring system in a low-cost technology corridor. The advantages of independent WSN sensors must also be balanced with the design of a reliable communication system in terms of the data transmission process and energy consumed. This research specifically conducts a comprehensive evaluation of the routing mechanism in WSN, which is divided into three main classifications: proactive, reactive, and hybrid routing protocols. Simulations are carried out using the NS-2 simulator in stages for the number of nodes from 25 to 100. The results show that each routing protocol has its advantages and disadvantages. The TORA (hybrid) routing protocol works better in throughput but results in a fairly high delay for an increasing number of nodes. OLSR routing protocol (proactive) shows the optimal data transmission mechanism because it can keep the delay value to a minimum during the data transmission process. However, reactive routing protocol (DSR) performs better than the other five routing protocols since it can maintain energy stability during the data transmission process, and the results of PDR are better than others, making it valuable to manage communication lines within increasingly high network density.

REFERENCES

Dani Prasetyo Adi, P., Arman Prasetya, D., Arifuddin, R., Puspita Sari, A., Sisilia Mukti, F., Sihombing, V., Anjar, A., Sagala, E., & Juni Yanris, G. (2021). Application of IoT-LoRa Technology and Design in irrigation canals to improve the quality of agricultural products in Batu, Indonesia. *2nd International Conference On Smart Cities, Automation & Intelligent Computing Systems (ICON-SONICS)*, 1–7. https://doi.org/https://doi.org/10.1109/ICON-SONICS53103.2021.9617175

Kementerian Energi dan Sumber Daya Mineral. (2022). *Pusat Vulkanologi dan Mitigasi Bencana Geologi - Badan Geologi*. https://vsi.esdm.go.id/

Khan, M. K. U., & Ramesh, K. S. (2019). Effect on Packet Delivery Ratio (PDR) & Throughput in Wireless Sensor Networks Due to Black Hole Attack. *International Journal of Innovative Technology and Exploring Engineering*, *8*(12S), 428–432. https://doi.org/10.35940/ijitee.l1107.10812s19

Lara Cueva, R., Orquera, R. G., & Londoño, I. (2013). Towards a New Volcano Monitoring System Using Wireless Sensor Networks. *The International Conference Series on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP)*, 1–5. www.wicom.espe.edu.ec

Lopes Pereira, R., Trindade, J., Gonçalves, F., Suresh, L., Barbosa, D., & Vazão, T. (2014). A wireless sensor network for monitoring volcano-seismic signals. *Natural Hazards and Earth System Sciences*, *14*(12), 3123–3142. https://doi.org/10.5194/nhess-14-3123-2014

Mukti, F. S., Junikhah, A., Putra, P. M. A., Soetedjo, A., & Krismanto, A. U. (2022). A Clustering Optimization for Energy Consumption Problems in Wireless Sensor Networks using Modified K-Means++ Algorithm. *International Journal of Intelligent Engineering and Systems*, *15*(3), 355–365. https://doi.org/10.22266/ijies2022.0630.30

Mukti, F. S., Lorenzo, J. E., Zuhdianto, R., Junikhah, A., Soetedjo, A., & Krismanto, A. U. (2022). A Comprehensive Performance Evaluation of Proactive, Reactive and Hybrid Routing in Wireless Sensor Network for Real-Time Monitoring System. *2021 International Conference on Computer Science and Engineering (IC2SE)*, 1–6. https://doi.org/10.1109/ic2se52832.2021.9791992

Pamungkas, J. (2016). *Desain Real-Time Monitoring Berbasis Wireless Sensor Network Upaya Mitigasi Bencana Erupsi Gunung Api*. Institut Teknologi Sepuluh November.

Pella, S. I. (2018). Simulasi Dampak Parameter protokol MAC Terhadap Unjuk Kerja dan Konsumsi Energi Jaringan Sensor Nirkabel. *Jurnal Media Elektro*, *VII*(2), 50–54.

Peterson, N., Anusuya-Rangappa, L., Shirazi, B. A., Song, W., Huang, R., Tran, D., Chien, S., & LaHusen, R. (2009). Volcano Monitoring: A Case Study in Pervasive Computing. In *Pervasive Computing: Innovations in Intelligent* (pp. 201–230). https://doi.org/10.1007/978-1-84882-599-4_10

Susdyastama Putra, Y., Indriastuti, M. T., & Mukti, S. (2020). Optimalisasi Nilai Throughput Jaringan Laboratorium Menggunakan Metode Hierarchical Token Bucket (Studi Kasus: STMIK ASIA Malang). *Jurnal Ilmiah NERO*, *5*(2), 83–90. https://doi.org/http://dx.doi.org/10.21107/nero.v5i2.161

Werner-Allen, G., Johnson, J., Ruiz, M., Lees, J., & Welsh, M. (2005). Monitoring volcanic eruptions with a wireless sensor network. *Proceedings of the Second European Workshop on Wireless Sensor Networks, EWSN 2005*, *2005*, 108–120. https://doi.org/10.1109/EWSN.2005.1462003

Werner-Allen, G., Lorincz, K., Welsh, M., Marcillo, O., Johnson, J., Ruiz, M., & Lees, J. (2006). Deploying a Wireless Sensor Network on an Active Volcano. *IEEE Internet Computing*, *10*(2), 18–25. www.computer.org/internet/

Zhang, Y. (2005). *Wireless Sensor Network for Volcano Monitoring*. KTH Microelectronics and Information Technology.