

MPR selection to the OLSR quality of service in MANET using minmax algorithm

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ABSTRACT

Optimized link state routing (OLSR) is a routing protocol that has a small delay, low traffic control, support the application of denser networks, and adopts the concept of multipoint relays (MPR). The problem of OLSR is routing table updating which continually causes excessive packet delivery, and energy consumption becomes increased. This article proposes the improvement of OLSR performance using the min-max algorithm based on the quality of service (QoS) with considering the density of the node. The Min-max algorithm works in selecting MPR nodes based on the largest signal range. The QoS parameters analyzed with a different number of nodes are packet delivery ratio (PDR), throughput, delay, energy consumption, and topology control (TC). Simulation result of network simulator version 2 (NS-2) shows that OLSR performance using the min-max algorithm can increase PDR of 91.17%, packet loss of 60.77% and reduce topology control packet of 8.07%, energy consumption of 16.82% compared with standard OLSR.

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1. INTRODUCTION

The development of mobile ad hoc network (MANET) becomes attractive because it deals with various issues [1] and has quick characteristics, capable of managing topology changes independently, cost-effective of dissemination [2], and can apply to emergency locations such as natural disaster recovery [3], military operations, and monitoring health. The challenges and problems that occur in MANET are dynamic

tions built between dynamic topology changes and the energy consumption generated by the routing protocol will affect the quality of the network [10, 11] and cause excessive packet delivery in each neighboring node.

OLSR is a proactive routing protocol that has small delay variations [12], supports denser networks [13], and adopts the MPR concept. However, the MPR concept applied to the OLSR protocol still has a disadvantage when continuous routing update that causes excessive packet delivery [14] and energy consumption becomes to increase. The Excessive packet delivery occurs due to the greedy algorithm used OLSR in the selecting MPR does not work optimally. The performance of OLSR needs to be upgraded as a solution to overcome redundant packets and energy consumption across each node. This article proposes min-max algorithm as a solution to enhancing OLSR performance based on QoS with considering the node density. The min-max is an algorithm that can select MPR nodes based on the largest signal range.

Some researchers have proposed the topic of MPR selection in improving quality of service (QoS). The MPR selection in reducing the number of topology control (TC) packet using the two algorithms based on three hops and the concept of OLSR-New Degree-MPR [15]. The results research show that both proposed algorithms can reduce TC, energy consumption and the increase packet delivery ratio (PDR) compared to the standard OLSR. However, the change in the number of nodes has not evaluated.

The selecting MPR on OLSR uses the necessity first algorithm (NFA). The simulation results using OPNET show that the proposed algorithm can reduce TC and MPR amount by 0.7% to 11.2% compared with greedy algorithm [16]. However, parameters such as PDR, throughput, delay, and energy consumption have not evaluated.

Reducing and stabilizing the MPR on the OLSR by proposing two strategies, namely maximize MPR elections globally and maintain the MPR [17]. The result of the simulation using OMNET shows that both the proposed method can improve the performance of OLSR significantly. However, parameters such as PDR, throughput, delay, and energy consumption have not evaluated.

The MPR selection on OLSR based on a local database of neighboring nodes extended into three hops [18]. The MPR selection aims to reduce TC packet overhead by marking its neighbor subset as MPR. Simulation results using the NS2 indicate that OLSR variants are better than standard OLSR based regarding the number of TC packets, cost, and routing efficiency.

The selection of additional MPR nodes based on strong broadcasts on wireless ad hoc networks. The proposed method selects the other MPR node so that it can include two hop MPR nodes [19]. The number of additional MPR nodes was analyzed using mathematical modeling and simulation. Simulation results show that the proposed method can improve throughput and delivery ratio compared to standard OLSR. However, dynamic environmental conditions have not evaluated.

The selection of multipoint relay kinetic (KMMPR) in OLSR based on mobility prediction [20]. Simulation results using NS2 indicate that the proposed KMMPR method can reduce routing overhead (RO) and delay compared to the standard OLSR. However, parameters such as packet delivery ratio, throughput, and energy consumption have not evaluated.

MPR selection using the concept an enhanced MPR (EMPR) in OLSR wireless ad hoc networks [21]. EMPR take into consideration the cost value as an additional factor in MPR elections. The proposed EMPR concept producing a more extensive cover range for the MPR set compared to that provided by MPR-based OLSR heuristics. The simulation results using OPNET show that EMPR can decrease packet loss value based on speed changes. However, the development of parameters such as PDR, throughput, delay, and energy efficiency has not evaluated.

MPR selection on OLSR in MANET environment based on lifetime [22]. The consideration of the energy factor in selecting MPR makes the lifetime of the node becomes to better. Simulation result using network simulator version 3 (NS-3) show that the MPR selection based on lifetime can increase PDF and decrease packet loss in every addition of times. However, the change in the number of nodes has not evaluated.

The development of algorithms in improving the Multipoint Relay selection process (MPR) based on mobility rate (MR) [23]. MR concept proposed to reduce mobility in MANET. Simulation results using NS3 show that the proposed mobility concept can improve network performance such as throughput, a packet received, packet loss, packet delivery ratio, and packet forwarding. However, the parameters such as delay and energy consumption have not evaluated.

The improved OLSR performance through new MPR elections using PSO. This article proposes particle swarm optimization of sigmoid increasing inertia weight (PSOSIIW) to improve OLSR performance in the reduce message load during flooding process [24]. Simulation results using NS2 show that OLSR-PSOSIIW performance is better than OLSR standard and OLSR-PSO, particularly of delay and throughput. However, parameters such as PDR and energy consumption have not evaluated.

MPR selection based on residual energy called energy efficient optimized link state routing (EOLSR) [25]. The EOLSR method is an OLSR variant, in which the MPR selection and path calculation determined by the energy level and the number of neighboring nodes. The simulation results show that the EOLSR method can reduce residual energy in every addition number of nodes. However, such parameters as PDR, throughput, packet loss, and delay have not evaluated.

2. RESEARCH METHOD

The research method used is simulation-based research. Figure 1 shows the flowchart of research methodology consisting of simulation design, running simulations using NS2, and analyzing simulation results based on QoS parameters such as PDR, throughput, packet loss, delay, topology control, and energy

consumption by considering node density. The node density factor affects the performance of the routing protocol in determining the route from the source node to the destination node.

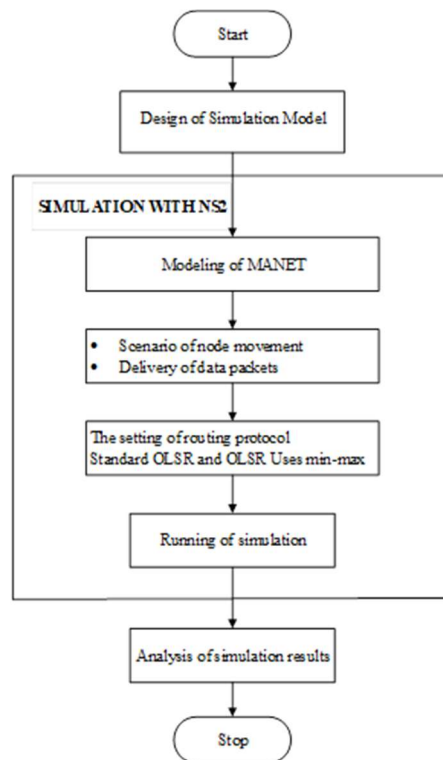


Figure 1. Flowchart of research methodology

2.1. Design of simulation

The simulation model design used consisted of the simulation program, number of nodes, packet size, simulation area, simulation time, simulation speed, mobility model, and propagation model. The MANET model selection used consisted of a node movement scenario with a two-ray ground propagation model and random waypoint mobility model. The choice of two-ray ground model based on the conditions for direct path propagation and surface reflection (ground reflection) between the sender and receiver [26, 27]. The two-ray ground model is very accurate in estimating signal strength in large area scales. The selection of random waypoint mobility model based on moving nodes with direction and speed randomly to reach the destination node [28]. The area of simulation used is 1000 meters x 1000 meters with the random waypoint model.

2.2. MANET simulation with NS-2

The research method used is simulation-based research using network simulator version 2.35 (NS2) [29] and listing program in the form of AWK script [30]. NS2 is a simulator based an open-source, object-oriented written in C ++, and has an OTcl (Object Oriented Tool command language) as its frontend [31]. The purpose of simulation testing is to improve the performance of OLSR routing protocol in the selecting MPR based on the range of the most significant signal. The simulated routing protocols are standard OLSR and OLSR uses min-max. Both routing protocols gave the same treatment with the number of nodes varying from 25 to 200 and distributed randomly. The simulation area is 1000 x1000 meters with a fixed speed of 20 m/sec and duration for 300 seconds. The purpose of giving a different number of nodes in both protocols is to determine the resulting QoS performance effect. The change number of nodes affect the performance of the routing protocol in determining the route from the source node to the destination node or neighboring nodes. The routing protocol simulation using NS2 file type (* .tr) and the simulation results visualized in the file (* .nam).

2.3. Simulation analysis

The OLSR standard simulation analysis and OLSR using min-max are performed based on QoS parameters such as PDR, throughput, packet loss, delay, topology control, and energy consumption by considering node density. The simulation result using NS2 gives a conclusion about the performance of standard OLSR and OLSR uses min-max. The simulation parameters can see in Table 1.

Table 1. Simulation Parameters

Parameters	Description
Network Simulator	NS 2.35
Operation System	Ubuntu 14.04
Routing Protocols	Standard OLSR and OLSR uses min-max
Number of Nodes	25, 50, 75, 100, 150, 200
Radio Propagation Mode	Two Ray Ground
Transport Protocol	UDP
RTS/CTS	None
Packet Size	512 bytes
MAC Protocol	IEEE 802.11
Mobility Model	Random Waypoint
Time Simulation	300 seconds
Simulation Area	1000 m x 1000 m
Fixed Speed	20 m/sec

3. RESULTS AND ANALYSIS

3.1. Packet Delivery Ratio (PDR)

PDR is the ratio between the numbers of packets received by the destination node by the packet sent by the source node [32]. Figure 2 shows the PDR of the standard OLSR and OLSR uses min-max on the number of different nodes. The performance of OLSR uses min-max more steady and increases on denser nodes, especially at nodes 75 and 200. The increased PDR caused by the ability of min-max algorithms that selectively select MPR nodes. Selection of particular MPR nodes causes some packets to successfully received by the destination node. The performance of standard OLSR tends to the decrease on denser nodes, especially at nodes 200. The reduction in packet loss on standard OLSR caused by the mobility levels between nodes one with other nodes becomes increased in the number of denser nodes. This effect of increased mobility causes some packets to fail to be received by the destination node. The simulation results show that the average value of the PDR for OLSR using the min-max better than the standard OLSR. The average of PDR for OLSR uses the min-max algorithm of 76.46% and standard OLSR of 39.99%.

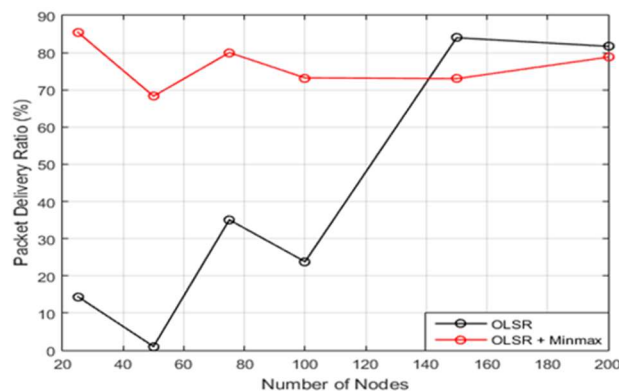


Figure 2. Simulation result of packet delivery ratio

3.2. Packet loss

Packet Loss is a percentage of the packets loss in connection with packets sent between the source node to the destination node. Figure 3 shows the packet loss of the OLSR standard and OLSR uses min-max on the number of different nodes. Performance of OLSR uses min-max is likely to be unstable and decreases in denser nodes, especially at nodes 75 and 200. The decreasing in packet loss caused by the missing packet from the source node to the destination very few. The performance of standard OLSR tends to be unstable,

and the resulting packet loss value increases in the denser nodes, especially at nodes 200. The increased packet loss on standard OLSR occurs due to the number of missing packets in the destination node. The average of packet loss for OLSR uses min-max of 23.54% and standard OLSR of 60.03%.

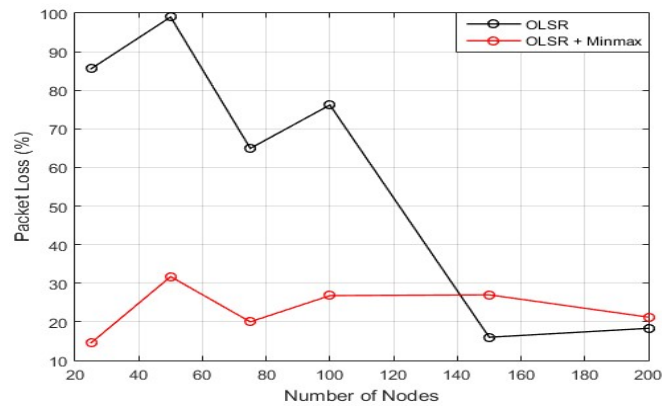


Figure 4. Simulation result of packet loss

3.3. Throughput

Throughput is the rate of effective data transfer calculated in bytes per second (Bps) as the total number of packets received successfully in units of time [33]. The performance of the routing protocol become better if the resulting throughput increased. Figure 4 shows the throughput of OLSR and OLSR standard using the min-max on the number of different nodes. The throughput performance of OLSR uses the min-max tends to be stable on denser nodes, especially at nodes 150 and 200. The throughput performance of the standard OLSR tends to be unstable and decreases in the denser nodes, especially at node 200. However, the original OLSR performance better than OLSR using the min-max particularly in each node addition. The increased throughput of standard OLSR caused by routing table update to all nodes, although nodes in the condition do not transmit data. Update of the routing table in each node shorten in finding the route. The average throughput value generated by OLSR uses min-max of 353.33 Kbps and standard OLSR of 417.38 Kbps.

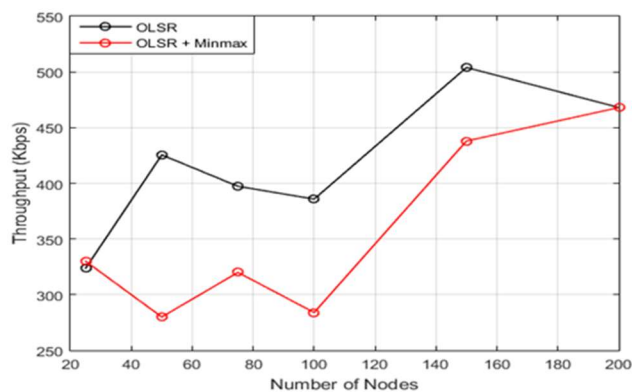


Figure 4. Simulation result of throughput

3.4. Delay

Delay is the average time required to send packets from the source node until successfully received by the destination node [34]. Figure 5 shows the delay of standard OLSR and OLSR using the min-max on the number of different nodes. Delay in standard OLSR tends to increase on each additional node. The delay in OLSR using the min-max tends to decrease in the more dense nodes. However, the delay on the standard OLSR better than OLSR uses min-max in finding the route. The decreases of delay because standard OLSR always updates routing tables that have compiled before data packets sent. The OLSR uses min-max to find

the route long enough because the selection of routing table updates collected based on signal coverage. Signal coverage on the number of denser nodes needs a long time to find the route. The average delay for standard OLSR of 15.42 milliseconds and OLSR uses min-max of 24.76 milliseconds.

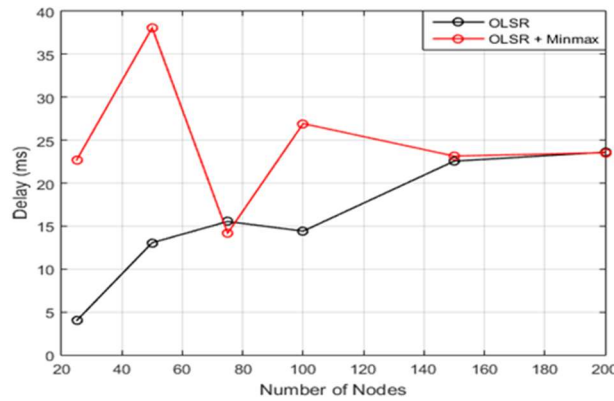


Figure 5. Simulation result of the delay

3.5. Topology Control (TC)

TC is the total number of routing packets transmitted during the simulation. The Packets that sent over multiple hops counted as one transmission (one jump). Figure 6 shows the TC on standard OLSR and OLSR using the min-max based on the number of different nodes. Movement of TC on OLSR uses the min-max at nodes 25 to 100 tends to increase. However, the number of denser nodes TC values tend to decrease, especially at nodes 150 and 200. The reductions of TC in OLSR using min-max occurs because of the absence of excessive data transmission. Movement of TC on standard OLSR tends to increases every addition number of nodes. The average value of TC on OLSR using the min-max of 1171.67 packets and standard OLSR of 1266.17 packets. This decreases of TC indicate that OLSR using min-max provides a small data redundancy effect compared to standard OLSR.

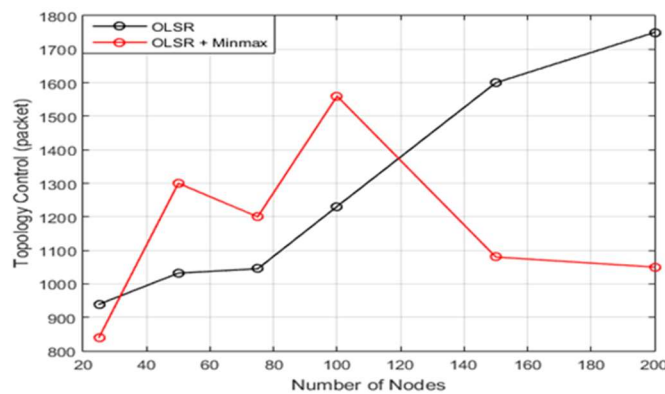


Figure 6. Simulation result of topology control

3.6. Energy consumption

Energy consumption is the number of energy required by a node to transmit and receive packets. Figure 7 shows the performance of energy consumption in the standard OLSR and OLSR uses min-max based on the number of different nodes. The performances of standard OLSR and OLSR using min-max regarding energy consumption tends to be unstable and decreases in the denser nodes, especially at nodes 100 to 200. However, standard OLSR consumes more energy than OLSR uses min-max. The decrease in overhead in the determination of the route on OLSR using the min-max causes resulting energy consumption

lesser than the standard OLSR. The average energy consumption value of OLSR using min-max of 14.08 milliwatts and standard OLSR of 16.4542 milliwatts.

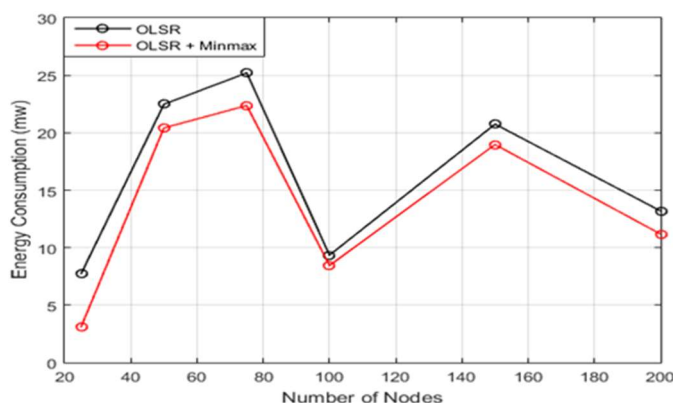


Figure 7. Simulation result of energy consumption

4. CONCLUSION

This study proposes a min-max algorithm to improve OLSR. The performance of standard OLSR and OLSR using the min-max analyzed based on service quality (QoS) parameters such as PDR, packet loss, throughput, delay, and energy consumption with considering node density. The simulation results show that OLSR using min-max can increase PDR, packet loss and decrease TC, energy consumption compared to standard OLSR. The throughput and delay generated by the OLSR standard are better than OLSR using min-max. However, increased throughput and delay in OLSR using min-max tends to be stable and increase on denser nodes. Increased PDR, packet loss, and TC decrease, energy consumption shows that OLSR performance using min-max is highly selective in selecting MPR nodes.

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REFERENCES

- [1] P. K. Krishnappa and B.R. Prasad Babu, "Investigating Open Issues in Swarm Intelligence for Mitigating Security Threats in MANET," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 5, no. 5, pp. 1194-1201, October 2015.
- [2] P. Ghosekar, et al., "Mobile ad Hoc Networking: Imperatives and Challenges," *International Journal of Computer Applications*, vol. 1, pp. 153-158, 2010.
- [3] I. Chlamtac, et al., "Mobile ad Hoc Networking: Imperatives and Challenges," *Ad Hoc Networks*, vol. 1, no.1, pp. 13-64, July 2003.
- [4] V. Rishiwal et al., "Stable And Energy Efficient Routing for Mobile Adhoc Networks," *Information Technology: New Generations, 2008, ITNG 2008. IEEE Fifth International Conference*, pp. 1028-1033, 2008.
- [5] A. Tiwari dan I. Kaur, "Performance Evaluation of Energy Efficient for MANET Using AODV Routing Protocol," *Computational Intelligence and Communication Technology, CICT, 2017. IEEE 3rd International Conference*, pp. 1-5, 2017.
- [6] K. B. Wane et al., "Effect of Propagation Models on Energy Consumption of MANET," *Computing Communication Control and Automation, ICCUBEA, 2015. International Conference*, 2015.
- [7] W. Abdou, et al., "Using an Evolutionary Algorithm to Optimize the Broadcasting Methods in Mobile Adhoc Networks," *Journal of Network and Computer Applications*, vol. 34, no. 6, pp. 1794-1804, November 2011.
- [8] S. Mohapatra and P. Kanungo, "Performance Analysis of AODV, DSR, OLSR and DSDV Routing Protocols using NS2 Simulator," *Procedia Engineering*, vol. 30, pp. 69-76, 2012.
- [9] N. Nigar and M. A. Azim, "Fairness Comparison of TCP Variants over Proactive and Reactive Routing Protocol in MANET," *International Journal of Electrical and Computer Engineering (IJECE)*, Vol. 8, No. 4, pp. 2199-2206, August 2018.
- [10] Y. Wu, M. Li, and X. Ao, "QoS-Aware Directional Flooding Based on Redundant Route for Mobile Ad Hoc Network," *Journal of Internet Technology*, vol. 18, no. 3, pp. 677-684, May 2017.

- [11] R. Havinal, et al., "EASR: Graph-Based Framework for Energy Efficient Smart Routing in MANET using Availability Zones," *International Journal of Electrical and Computer Engineering (IJECE)*, Vol. 5, No. 6, pp. 1381-1395, December 2015.
- [12] M. H. Satria, et al., "Emergency Prenatal Telemonitoring System in Wireless Mesh Network," *TELKOMNIKA*, vol. 12, no. 1, pp. 123-134, March 2014.
- [13] Alamsyah, et al., "Performance of the Routing Protocols AODV, DSDV and OLSR in Health Monitoring Using NS3," *International Seminar on Intelligent Technology and Its Application, ISITIA, 2016. IEEE International Seminar*, pp. 323-328, July 2016.
- [14] K. Yamada, et al., "Cooperative MPR Selection to Reduce Topology Control Packets in OLSR," *TENCON, 2010. IEEE Region 10 Conference*, pp. 293-298, January 2011.
- [15] A. Boushaba, et al., "Multipoint Relay Selection Strategies to Reduce Topology Control Traffic for OLSR Protocol in MANETs," *Journal of Network and Computer Applications*, vol. 53, pp. 91-102, July 2015.
- [16] Z. Li, et al., "NFA: a New Algorithm to Select MPRs in OLSR," *Wireless Communications, Networking and Mobile Computing, WiCOM, 2008. IEEE 4th International Conference*, pp.1-6, November 2008.
- [17] L. Maccari and R. L. Cigno, "How to Reduce and Stabilize MPR Sets in OLSR Networks," *Wireless and Mobile Computing, Networking and Communications, WiMob, 2012. IEEE 8th International Conference*, pp. 373-380, December 2012.
- [18] A. Boushaba, et al., "Optimization on OLSR Protocol for Reducing Topology Control Packets," *Multimedia Computing and Systems, ICMCS, 2012. IEEE International Conference*, October 2012.
- [19] J. H. Ahn and T. J. Lee, "Multipoint Relay Selection for Robust Broadcast in Adhoc Networks," *Ad Hoc Network*, vol. 17, pp. 82-97, June 2014.
- [20] J. Harri, F. Filali and C. Bonnet, "Kinetic Multipoint Relaying: Improvements Using Mobility Predictions," *7 st International Working Conference on Active and Programmable Network*, pp. 224-229, 2005.
- [21] T. H. Lin, et al., "An enhanced MPR Based Solution for Flooding of Broadcast Messages in OLSR Wireless Adhoc Networks," *Mobile Information Systems*, vol. 6, no. 3, pp. 249-257, September 2010.
- [22] Prathviraj N and P. Kumar A, "Lifetime Aware MPR Selection in OLSR for MANET," *Electronics, Communication and Computational Engineering, ICECCE, 2014. IEEE International Conference*, pp. 153-156, November 2014.
- [23] H. Amraoui, et al., "Mobility Quantification for Multipoint Relays Selection Algorithm in Mobile Ad Hoc Networks," *Multimedia Computing and Systems, ICMCS, 2016. IEEE 5th International Conference*, September 2016.
- [24] R. F. Malik, et al., "The New Multipoint Relays Selection in OLSR using Particle Swarm Optimization," *TELKOMNIKA*, vol. 10, no. 2, pp. 343-352, June 2012.
- [25] S. Mahfoudh and P. Minet, "EOLSR: an Energy Efficient Routing Protocol in Wireless Adhoc Sensor Networks," *Journal of Interconnection Networks*, vol. 9, no. 4, pp.389-408, December 2008.
- [26] B. M. Mughal, et al., "Analyzing Safety Beacon Loss Rate in Vanets with Two-Ray Ground and Nakagami Propagation Models," *IEEE National Postgraduate Conference, NPC, 2011*, pp. 1-6, September 2011.
- [27] Naseeruddin and V. C. Patil, "Performance Evaluation of MANET Protocols: a Propagation Model Perspective," *Applied and Theoretical Computing and Communication Technology, iCATccT, 2016. IEEE 2nd International Conference*, pp. 55-61, July 2016.
- [28] J. Rangaraj dan M. Anitha, "Performance Analysis of Proactive and Reactive Protocol under Different Mobility Models for MANET," *IoT in Social, Mobile, Analytics and Cloud, I-SMAC, 2017. IEEE International Conference*, pp. 637-643, February 2017.
- [29] K. Fall and K. Varadhan, "The ns Manual (Formerly Ns Notes and Documentation)," *The VINT Project, Xerox PARC*, 2011.
- [30] A. D. Robbins, "GAWK: Effective AWK Programming," Ed. 4.2 A User's Guide for GNU Awk, Boston, USA; Free Software Foundation, 2016.
- [31] G. Borboruah and G. Nandi, "A Study on Large-Scale Network Simulators," *International Journal of Computer Science and Information Technologies*, vol. 5, no. 6, pp. 7318-7322, November 2014.
- [32] T. Adame, et al., "Capacity Analysis of IEEE 802.11ah WLANs for M2M Communications," *MACOM 2013, Proceedings of the 6th International Workshop on Multiple Access Communications*, vol. 8310, pp. 139-155, December 2013.
- [33] D. Perdana and R. F. Sari, "Mobility Models Performance Analysis using Random Dijkstra Algorithm and Doppler Effect for IEEE 1609.4 Standard," *International Journal of Simulation, Systems, Science, and Technology*, 2013.
- [34] A. Muhtadi, et al., "Performance Evaluation of AODV, DSDV, and ZRP Using Vehicular Traffic Load Balancing Scheme on VANETs," *International Journal of Simulation, Systems, Science, and Technology*, 2015.

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