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Minimizing Routing Overheads in Zone Routing Protocol (ZRP); Replacing Zone Radius with Node Location Information

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Abstract: There are many routing protocols suggested for use in Mobile Ad Hoc Networks (MANETs). Among them (the routing protocols) is the Zone Routing Protocol (ZRP). ZRP uses the concept of zones to ensure that proactive activities are limited to a defined area around a node. The zone is determined by the radius (hops). By limiting a proactive zone on the radius, the transmission of data packets is made effective. However, any node that resides beyond the zone, is reachable reactively. The literature review indicates that one of the shortcomings in ZRP is the overlapping of zones. Furthermore, the exercise of determining zone radius is complicated. The overlapping of zones occurs because individual nodes and their zones are determined by a hop-count radius. Consequently, this overlapping of zones leads to increased routing overhead in ZRP. In an effort to resolve zone overlapping and thus reduce routing overheads, this study suggests the application of the Location-Aided Routing (LAR) Scheme I in the Interzone Routing Protocol (IARP) scheme of ZRP. By applying LAR Scheme 1 algorithm, the need for a hop-count-based radius is eliminated. Location information of nodes in IARP ensures that zones do not overlap, resulting in reduced routing overheads. This study simulates elementary parameters of delay, drop rates, deliver ratio, and the general throughput of ZRP based on the number of nodes, the area, and the size of the data packets. The conventional algorithm of ZRP was rendered on NS-2 and while the nodal-location enhanced ZRP algorithm on OMNET++. Simulation results suggest that the positionally enhanced ZRP algorithm minimizes zonal overlapping hence better data packets throughput, minimized delay and drop rates, and augmented data packets delivery ratio.

Keywords: Zone Routing Protocol (ZRP), Zonal Overlapping, Routing Overheads, Data Packets Throughput, Mobile Ad Hoc Networks (MANETs)

1. INTRODUCTION

Mobile ad hoc networks (MANETs) are the mobile networks created "for the purpose of" responding to a particular situation [1, p.2]. They are made up of mobile devices(nodes) that connect to form autonomous networks independent of infrastructure [1]. Due to this autonomy—nodes can leave and join the network willingly, MANETs are very dynamic. Mostly, MANETs are temporary because they are established in emergency situations such as rescue operations. Another application of MANETs is the formation of military communication networks in war zones. More recently, however, MANETs' applications have extended to education in the form of mobile learning (m-Learning) and e-Learning [2],[4]. Due to their extemporaneity, MANETs do not need pre-existing infrastructure.

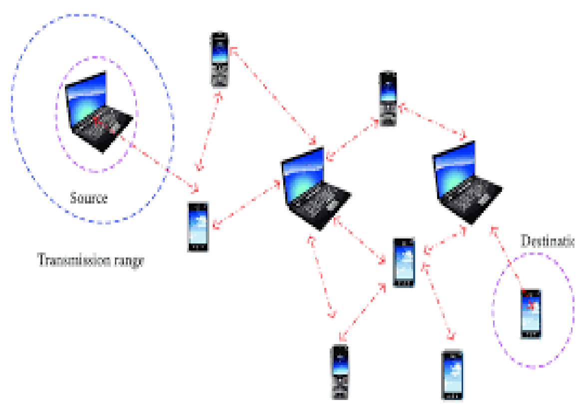

Figure 1: An example of a Mobile Ad Hoc Networks (MANETs) [2]

Routing protocols are used in data packets or signal propagation among nodes—from the host to the receiver. However, since MANETs adjust their topological structure continuously, its routing protocols must be robust enough to accommodate these updates. For instance, as nodes autonomously leave and join the network, previously-stored topological information must change. In the process, routing tables are updated according to these changes. Due to this dynamism, MANETs routing protocols should be vigorous enough to support signal and data transmission. Critically, selected routing protocols must select the most proficient route from the host node to the destination node.

Categorization of routing protocols can be accomplished through consideration of the topology of the network. By using this criterion, routing protocols can be categorized as either proactive or reactive. Moreover, routing protocols can be classified based on the style deployed for communication. This method of classification yields a unicast, broadcast, and multicast routing [20]. Regardless of the routing group, however, all routing protocols should be able to efficiently support data packet propagation from one node to another.

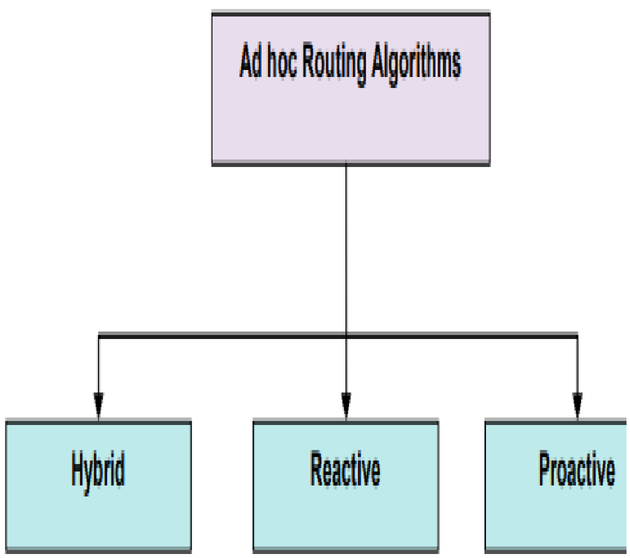

Figure 3: Generalized MANETs Routing Protocols Classification [17]

Proactive routing protocols maintain routing information during network operation. This happens regardless of the need for information by the network nodes. Without reception of a trigger route discovery request, proactive routing continuously updates routing tables as nodes join or leave a network. Routing tables maintain the topological information of every node within a network. Routing tables necessitate sporadic updating as autonomous nodes either connect or disconnect from a network.

Because proactive routing protocols preserve and maintain the topological routing data of the entire network nodes, they are wasteful and unfitting for use in highly interconnected networks. Constant updates produce increased overhead such as bandwidth, thus making proactive routing protocols wasteful—they may need more power to operate. Oppositely, routing table-dependent— reactive protocols, avoid continuous updates of their routing tables with nodal topological information. Routing tables updates occur only on-demand basis. That is, upon route discovery request by the neighboring nodes. The absence of continuous updates of routing tables yields lower overhead such power, hence making reactive routing protocols viable for large networks. However, a lack of constant updates of routing tables may result in an amplified latency [34].

When the strengths of individual proactive and reactive protocols are combined, hybrid routing is created. The concept of hybrid routing protocols is intended to moderate the overhead shortcoming of proactive routing and reduce data packet latency. Route discovery service and process in reactive protocols create latency inside an ad hoc network. Primarily, Hierarchical routing is installed in highly interconnected networks.

The core objective of this study was to use simulation and scenario illustration to determine a suitable algorithm to reduce overhead and increase transmission capacity by ZRP as a result of minimizing routing zones overlaps. The explicit aims of this study comprised the following goals:

1. To create an appropriate algorithm to reduce routing zones overlap and consequently minimize overhead in ZRP and increase the transmission capacity of selected scalar parameters.

2. To empirically (through simulation) demonstrate the viability of the created algorithm.

2. ZONE ROUTING PROTOCOL

Several studies indicate that proactive routing creates a lot of overheads as a result of utilizing excess power to maintain routing information [35]. Moreover, reactive routing protocols experience long delays in the route request. Another shortcoming of the reactive routing protocols is their tendency to flood all the nodes with route request information. The flooding technique is inefficient because it can lead to added routing overheads [35].

The Zone Routing Protocol (ZRP) is proposed in [6], [7], [8], and [13] with an intention to address the shortcomings of both pure reactive and proactive routing protocols. According to [14], this is only achievable by merging the strengths of both reactive and proactive routing protocols. ZRP is regarded as a hybrid routing protocol because it combines the advantages of reactive and proactive routing protocols. In an ad-hoc network, route request is based on neighbor discovery service [6], [32]. Consequently, ZRP decreases the proactive coverage to a zone centered around every node. According to [20], a reduced zone helps in increasing the effectiveness of data packets transmission. In addition, a limited zone is critical in ensuring reduced data packets loss and wastage of the power. As a result, the proactive overhead goes down.

However, the nodes outside individual zones are reachable reactively—the reactive routing is called to action. Because nodes in specific zones keep up-to-date local routing information, route requests are better conducted proactively by avoiding the flooding of all nodes with request messages. According to [40], regardless of the use of zones in ZRP, the organizational overhead is avoided because of its flat view nature. Unlike the hierarchical routing protocols, ZRP views the network flatly thus avoiding the overheads that accompany network levels. ZRP does not need to strategically assign gateways or landmarks to nodes for access to the entire network. In ZRP a node can reach the rest of the network nodes because there is no hierarchy. Congestion in ZRP is avoided because there are no subnets [33]. The overlapping property of network zones in ZRP makes it a flat protocol. Therefore, it is possible to determine optimal routes and reduce congestion [6]. Notably, ZRP is an adaptive routing protocol whose use is highly dependent on the existing configuration of the network.

Suggested by Haas and Pearlman in 1997[7], ZRP has been lauded for its robustness, particularly in large network implementation. However, a key shorting is the overlapping of it routing zones thus augmenting overheads—such as power consumption. Every node in ZRP belongs to a zone within a MANET. The size (radius) of routing zones in ZRP is determined by the number of hops from the transmitting node to the receiver node. Because ZRP is a hybrid routing protocol, it combines favorable features from proactive and reactive routing protocols [22]. A single local zone uses proactive routing while the inter-zonal transmission is realized through reactive routing. Although proactive routing risks an increased routing overhead, this shortcoming is compensated through reactive routing in interzonal communication [7].

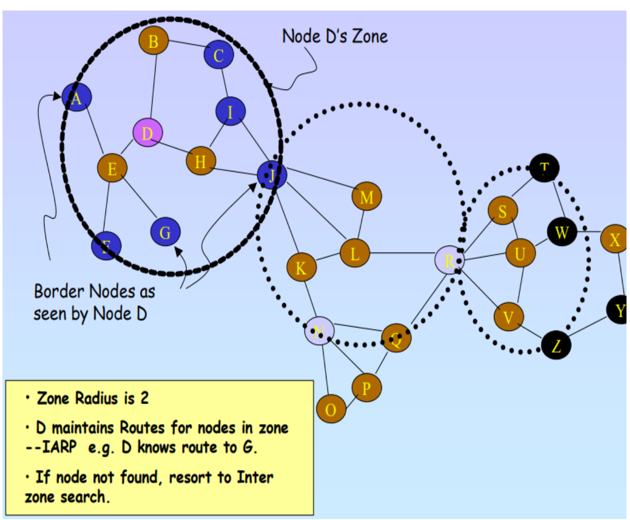

Figure 5: A 2 hops radius routing zone [38]

Figure 5 demonstrates the idea of a 2 hops radius routing zone. For demonstration purposes, most illustrations in research papers use radius of 2. All nodes within this routing zone lie within the radius of D, measured in 2 hops. Node D is the central node from which the location of every node within or without the radius is referenced. For example, if a node is within the radius of 2 hops of central node D, it is considered to lie within the routing zone. However, if a node lies beyond 2 hops from the central node D, it is considered to be outside the routing zone. For communication to be established, the nodes within the routing zone centered at D must use a border casting service.

Referring to figure 4, nodes that belong to the routing zone centered at D, are A through J. However, node L is not within the routing zone because it is beyond the radius of 2 hops. That is, in reference to node S, node L is 3 hops—exceeding the 2 hops radius. Peripheral nodes are composed of nodes whose radius is exactly the number of hops used to define a routing zone. In figure 4, nodes A, F, and J are peripheral nodes in reference to central node S. Characteristically, ZRP routing zones are illustrated as a circle containing a central node—such as node D in figure 4. It is critical, nonetheless, to note that a routing zone does not correspond to an actual representation of the physical distance of mobile devices. The circular representation of routing zones in ZRP characterizes connectivity in form of hops radius. Illustration of ZRP routing zones demands neighbors discovery. Neighboring nodes are the node that communicates directly because they have a single hop between them.

Neighboring nodes in a ZRP routing zone can recognize each other through media access control (MAC) addresses. However, the neighbor discovery process can be achieved Neighbor Discovery Protocol (NDP) service. In NDP, beacons are utilized in broadcasting frequent "hello" messages to identify neighboring nodes. Upon reception of the beacon messages ("hellos"), a node assesses its quality to gauge the status of connectivity.

Connectivity status information generated by the neighbor discovery protocol is applied in the proactive routing in the Interzone Routing Protocol (IARP). Because IARP is proactive in its routing, its functionality can be generated from pre-existing and well-known proactive routing protocols such as Open Shortest Path First (OSPF). Proactive link-state routing protocols offer a comprehensive representation of network connectivity. However, the substitute proactive link-state routing protocol should be altered to restrict its operations within the defined radius of the routing zone.

There are two routing concepts used in ZRP. The Intrazonal Routing Protocol (IARP) is used for routing among the nodes in a single zone. Nodal communication beyond the IARP is executed by the Interzone Routing Protocol (IERP). Peripheral nodes in a zone ensure communication between the IARP and the IERP. Peripheral nodes achieve this feat through border casting service called Neighbor Discovery Protocol (NDP).

By using the route information as generated on IARP, the reference source node establishes the location of the destination node. That is, whether a node is within or without the local routing zone. If the node is found within the local zone, routing is conducted proactively. Reactive routing is used if the destination node lies beyond the local zone [9]. During the reactive route discovery procedure, two stages are involved. That is the route request phase and the route reply phase. During the route request phase, the source node transmits a route request data packet to the peripheral nodes by deploying BRP. When the request message arrives at a receiver node that knows the destination node, a message is sent to the source node. Else, the process of border casting the data packet continues. This continuous propagation of data packets ensures that every node in a network is contacted. According to [10] and [11], if a copy of a request data packet is sent to several nodes, they are labeled redundant and consequently discarded.

For a node to reply to the source node, it is necessary to accumulate routing information along the way—as the packet is transmitted from one node to another. Such network routing topological information is recorded in either the route request packet or as next-hop addresses in the nodes together with the transmission route. On the route request packet, the route discovery request node attaches its address and the pertinent node/link metrics to the data packet.

Upon the packet arriving at the destination node, the sequence of addresses is reversed and copied to the route reply packet. Afterward, the sequence is used in forwarding the reply message back to the source node. Alternatively, the forwarding nodes may record "routing information as next-hop addresses, which are used when the reply is sent to the source" [8]. In the second case, it is particularly advantageous because it can lead to the reduction of transmission overheads because the request and reply packets are comparatively reduced. Furthermore, the source node can receive the entire source route to the destination. Otherwise, the nodes situated along the route to the destination node record the next-hop address in their routing table.

During the border casting exercise, a source node transmits a route request packet to each of its peripheral nodes. Because border casting occurs in one-to-many transmission, it deploys multicasting hence lowering the route discovery overheads. Allowing the source node to compute the multicast tree and append the route discovery information to a packet is one of the approaches used in ensuring that route overheads are lowered. Resultantly, this approach is called Root-Directed Bordercasting (RDB). Alternatively, it is possible to recreate the tree at each node, while omitting the routing instructions. However, such a procedure necessitates that every internal node knows the topology seen by the border casting node. Accordingly, it is essential that the nodes preserve and sustain a protracted routing zone with radius 2ρ-1 hops. Markedly, the distance of the peripheral nodes to which the request is transmitted is *p*. As a result, this method is known as Distributed Bordercasting (DB) [6].

According to [3], zone radius is a critical feature in the performance of ZRP. A zone radius of one hop leads to the use of pure proactive routing resulting into bordercasting that is dependent on flooding route requests throughout the network. Oppositely, an infinite radius size leads to reactive routing. Subsequently, the selection of radius is a compromise among the routing effectiveness of proactive routing and augmenting traffic in a network.

3. THE PROPOSED LAR-ZRP ENHANCED ROUTING PROTOCOL

Since in ZRP, proactive routing zones severely overlap, query control traffic may increase [15]. Besides, "since the actual implementation of IARP and IERP is not defined, the performance can be further improved by adapting other routing protocols as ZRP components" [15]. Furthermore [16] notes that one of the shortcomings of ZRP is the lack of use of location information in route discovery query. Location-aware routing helps in reducing some of these shortcomings to some degree [9]. Through the use of a Global Positioning System (GPS), it is possible to minimize the query traffic [16].

In this study, a position algorithm that replaces the hop-count-based radius is proposed—figure 12. Because the implementation of IARP is not defined—it is open to be modified based on scenario needs, we propose that instead of defining zone radius with the hops counts to the peripheral nodes, an expected zone and a request zone is determined based on the transmission range of a node.

While the IARP can be implemented through various proactive protocols, this study considers the algorithm of the Distance Vector as presented in [7] and [9]. The algorithm is modified to fit the location information of a node, thus eliminating the need for a zone radius.

The modified algorithm allows the reception of new route information by a source node as transmitted within the request zone. In case a node is not found within the request zone, the invocation of Neighbor Discovery/Maintenance occurs. Communications between the source node and the destination node takes place if the two nodes are within the request zone; with radius r as indicated in figure 12. The location information exchanged include the distance between the nodes and the Angle of Arrival (AoA). The received new location information can then be stored by the source node in its Intrazone Routing Table. Updating of location information is carried out in the IARP through the Neighbor Discovery/Maintenance Protocol. The following pseudo code explains the role of introducing the LAR scheme 1 into the IARP of ZRP.

Because the hypothetical nodes serve both as receiver and transmitter, they are technically hosting. Therefore, the 100 in a characterized scenario are the hosts.

4. RESEARCH METHODOLOGY

Comparative literature process as outlined in [36] was used in identification of the routing protocols for study and simulation. As part of this study, documentation of possible complementary behavior of MANETs routing protocols was conducted. Consequently, selection of the routing protocols carried out on [12], [37], [38] and [39] categories. Two routing protocols are selected arbitrarily from each of the categorizations, with DSR and AODV representing the flat-proactive grouping. In the flat-reactive category, DSR and AODV are selected. However, automatic selection of a routing protocol was done if a routing protocol appeared more than once in categories [24], [25], [26], [27 and [28].

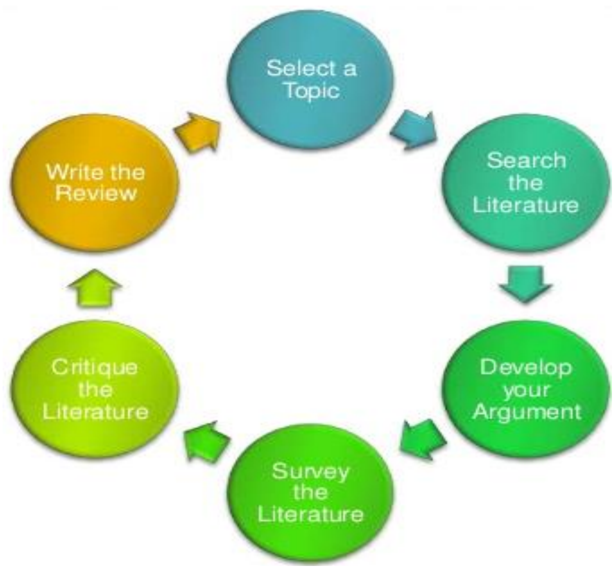

Figure 13: Literature Review Process. Adopted from [31]

Purposive sampling was applied in the identification of ZRP as the routing protocol for simulation. Because purposive sampling relies on the experience and intentions of the researchers based on the subject under investigation, it was decided that ZRP is robust for a highly interconnected MANET network [43]. Since ZRP combines reactive and proactive properties in its routing, its operational performance is a reasonable representation of the cumulative benefits from both categories. Through experience as network engineers and administrators, ZRP is a robust and dynamic routing concept applicable in vastly interconnected MANETs networks. Additionally, literature review identifies ZRP as a viable MANET routing protocol because it combines both reactive and proactive routing properties.

To ensure some level of consistency, reliability and validity of results, this study used two simulators. First, the conventional ZRP was simulated on NS2—which works best with linux systems. The proposed position-location boosted ZRP algorithm was simulated on OMNET++ [42]. Metrics collected and analyzed on data packet size, number of nodes and the characterized area. On network simulator NS2, this study used the simulation trace file which is formed during simulation. Later the metrics from the simulated parameters were rendered into plotting graphs and the available animation properties. Simulation platform on NS2 are built on C++ and Object-oriented Tool Command Language (OTcl).

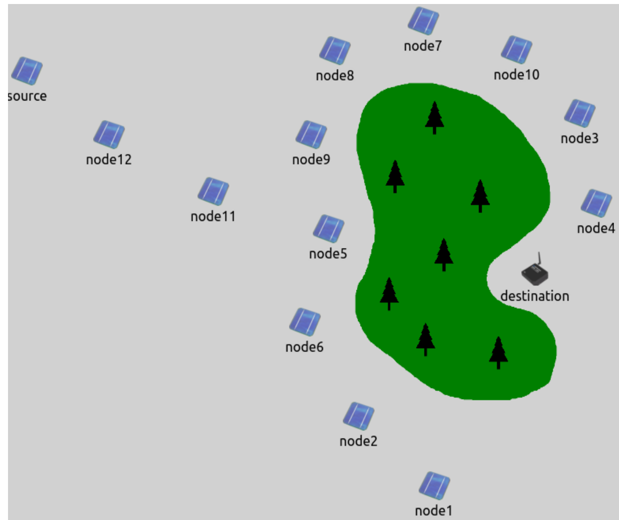

Figure 15: A Simulation scenario characcterization with 12 nodes

5. RESULTS AND DISCUSSIONS

A comparative simulation of conventional and location-position enhanced algorithm of Zone Routing Protocol (ZRP) was conducted on data packets received successfully, average data packets delay, data packets drop rate and data packet general throughput. It is paramount, nonetheless to note that simulation parameters are elementary. This was done purposively because there are no similar studies on which to build. In the future, studies may build on the findings of this research to include more advanced parameters such as nodes' density, power consumption, and transmission noise. Figure 16 represents the first rendering of the position-location enhanced simulator. The positions of the mobile devices are selected randomly.

Figure 17 represents the first test run screen shot. The approximation of the centralized database is at the center of the node. For example, the central server could be at host or node 42.

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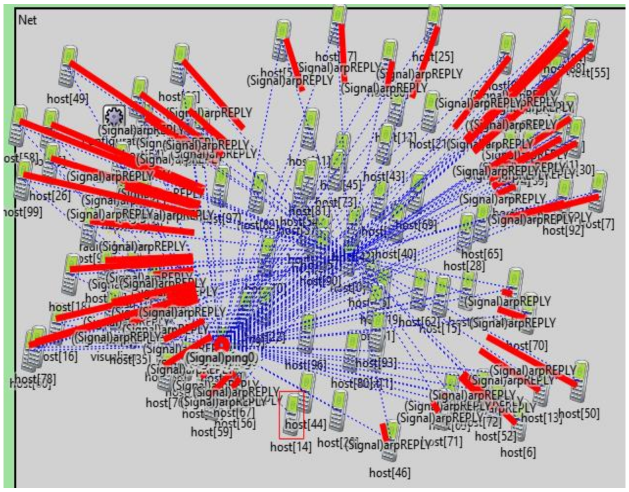

Figure 18: Initial Instance of Signal Transmission

Table 1: Preliminary elementary parameters

Elementary Parameter	**Metric Value**
Number of simulated nodes/devices	100
Estimated Area of Simulation	500m*500m
Simulation data packet size	1024 bytes
Simulation duration	300s
Simulation frequency	50

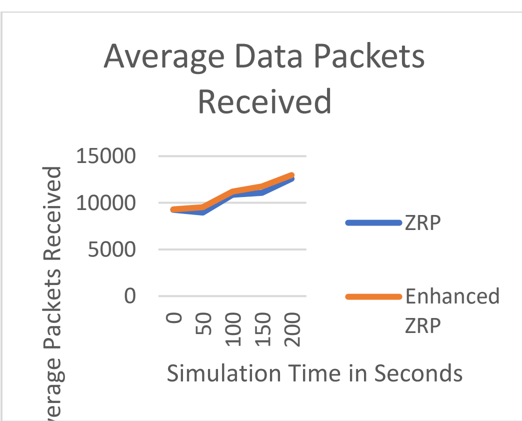

Figure 19: Average Packet Received

Average data packets are the packets that reached that were successfully delivered from the source node to the destination node. Received data packets is the difference between the packets sent from the source node and the data packets received at the destination node. The results are represented in chart figure 14. The following formular was used to arrive at the results represented in figure 14. However, average data packets received does not provide a detailed explanation between the data packets sent, the data packets lost and the data packets successfully received.

$$Average\ Packets\ Received = (Source\ Transmitted\ Packets - Destination\ Received\ Packets) \quad (3)$$

From the average data packets received successfully, it is possible to calculate the Packets Delivery Ratio (PDR). Such a ratio offers a mathematical representation of extent of data packets loss and the overall quantitative representation of the association among the data packets transmitted effectively and the initial data packets sent from the source node. But because there is insufficient studies on overhead reduction in ZRP, this study uses basic analysis of parameters. Ratio to represent successfully delivered data packets is realized by using the following formula.

$$PDR = \frac{Packets\ Succeffuly\ Received}{Packets\ Successfully\ \ Sent} \quad (4)$$

A high PDR—more than half, indicates that the network loses less data packets, thus an indication of efficiency. The optimal ration should be 1:1, whereby for every data packet received, there is an equal number of packets sent. A lower PDR, on the other hand, siginifies a possibly flawed network with a big data packets dropage. Consequently, network engineers and administrators must strive to realize the highest PDR possible.

Based on the simulation results, location-position enhanced ZRP outperforms traditional ZRP, however with small but steady margin. Although the differences form the curves may not seem large, its cumulative effects can be enormous in large networks. As the number of nodes increases, the seemingly subtle difference adds to augment effieciency. Results analysis and the overall cumulative principle hold true in other basic scalar parameters as shown in figures 15, 16 and 17.

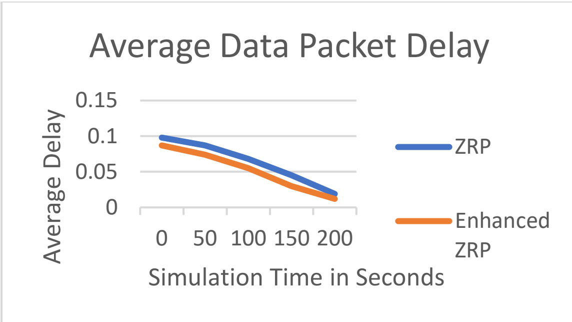

Figure 20: Average Delay

Average delay is the duration or time taken by a data packet from the source node to the destination node. An effective network should expose data packet to the minimal delay. That is, the time taken to successfully transmit a data packet from the source node to the destination node should be negligible as possible. High delay in data packets transmissions means that few data packets are delivered per unit time. This is so because a data packet takes more time to move from the source node to the destination node. Indeed, average delay in indirectly proportional to the overall data packets throughput. Once the delay is up, the general data packets throughput goes down. Data delivery delay can be caused by various network parameters. Some of the factors causing delay can be attributed to either the network topology or the or technical failure in the network. In most cases, data packets delay occurs in the network layer of the OSI model. Rarely does the Transport Layer affects the delay of data packets. For instance, a faulty or malfunctioning Address Resolution Protocol (ARP) can cause delay in data packets delivery.

However, data packets delivery delay can be caused by a fault in either Transport or Network layers. A faulty in both layers can also cause heighted delay in data packets delivery. Some of the network factors causing delay in data packets delivery include packets congestion, network topological mishaps, network technical faults, inept and low network capacities. To obtain average delay, the initial packet transmission time (IPTT) is subtracted from eventual packets reception time (EPTM). The resulting difference is then distributed among the number of packets received successfully at the eventual packet reception time. Average Packets Delay (APD) metric is measured by using the following formula:

$$APD = \frac{(EPTM) - (IPTT)}{Successfully\ Received\ Data\ Packets} \quad (5)$$

Figure 14 indicates a consistent less data packets delay in location-position enhanced ZRP. The reduced data packets delay suggests that as a result of inclusion of location-position information in ZRP algorithm, overlapping is minimized. With overlapping of zones minimized, the associated overhead power is likely to go down, hence increasing the routing efficiency of ZRP. Absence of overlapping in ZRP augments its ability and routing robustness. It is paramount to always keep in mind that due to combining both reactive and proactive properties of routing, ZRP is an already relatively sturdy routing protocol. A minimization of overlapping and overhead, it serves to only add more routing efficiency to ZRP.

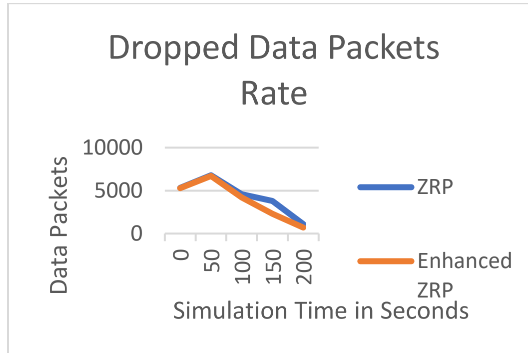

Figure 21: Data Packets Dropped

Data packets dropped is used to determine the packets lost during data transmission from the source node to the destnination node. Data packets loss is particularly critical because it is a possible indication of a defective network configuration or technical failure within the network. Loss of data packets can occur either in Transport or Netwok layers of the OSI models. Packets loss can also take place in both of the layers. No level of packets droppage is acceptable in a network. Any error message from the Internet Control Message Protocol (ICMP) is an indication of an incomplete delivery of the sent message. Incomplete received message affects the flow of communication by introducung uncessary unclarity.

In figure 15, the position-location enhanced ZRP consistently outperforms the traditional ZRP in the number of data packets dropped. The difference in the data packets droppage is attributable to the inclusion of the position-location information in the algorithm of ZRP. Inclusion of location-aware information ehnaces the accuracy of route discovery in ZRP. Such precision augments the overall delivery of data packets from the source to the destination. Some of the causes of data packet delivery delay include retransmission re-quests, broadcasting/transmission buffer, general signal latency or route discovery process.

Calculation of the data packets droppage rate is achieved by subtracting the number of pakcets succeffully transmitted from the source node from the number of data packets successfully received at the destination node. The difference between two metrics is then distributed over the time period from initiatial transmission to the eventual data packets reception at the destination node.

$$\text{Data Packets Drop Rate} = (\text{Successfully Eventual Received Packets} - \text{Successfully Initial Transmitted Packets}) / (\text{Transmission Time}) \quad (6)$$

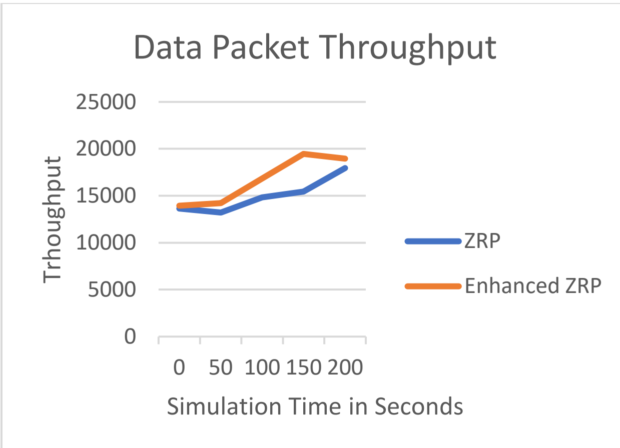

Figure 22: Data Packets Throughput

Data packets throughput represents the overall performance of a network over a period of time. Indeed, data packets throughput can be viewed as a summary of other basic scalar parameters such as delay, delivery and data packets drop rates. A combination of these metrics provides the overall performance of the network, measurable on data packets throughput. A low data packets through put may result from either of the issues associated with the outlined factors. An increased delivery delay due to congestion, for instance, may lower the general ultimate data throughput. Oppositely, a high packets throughput is an indication of maximized operationalization of other variables such as delay and drop rates. The metric measurement of data packets throughput is megabits per second (mbps) and lately gigabits per second (Gbps). Based on figure 17, a position-location enhanced ZRP consistently outperforms the conventional ZRP. Noticeably, however, the difference in the overall data packet throughput reduce after 175th second of simulation. Afterwards, the performance effectiveness of the two routing protocols begin to converge and become similar.

6. CONCLUSION AND RECOMMENDATIONS

This study proposes a technique to enhance ZRP through Scheme 1 of LAR. This is achieved by replacing the proactive algorithm code of IARP of ZRP with algorithm code of Scheme 1 of LAR. By doing so, the zones overlapping is eliminated, thus reduced overhead. The enhanced ZRP algorithm outperforms the traditional ZRP in the number of successfully delivered data packets, delay in delivery of data packets, the rate of data packets droppage and the general throughput of data packets. From the simulation results, it is clear that position-location enhanced ZRP outperforms the conventional ZRP on key basic scalar metrics. This is an indication of possible reduction of the zone overlaps during routing.

Inclusion of physical geographical information as a supplement to augments precision in the location of a node in a network. Increased precision of location of a node in a MANET network improves the efficiency of route discovery process within the IARP part of ZRP. The selected metrics include; data packet throughput, delay, and the number of data packets dropped. Generally, due to this enhanced performance, the location-position ZRP experiences less overhead as a result of minimized overlapping in routing zones. Such simulation results is a further prove that various properties of MANET routing protocols can be combined to produce supplementary effects in performance. Consequently, it is possible to create robust routing by combining favorable routing traits from various classes of protocols. For instance, hybrid routing can be improved by borrowing advantageous routing characteristics from location-aided routing.

However, due to limited number of studies examining combinational effects of MANETs routing properties, this research is limited to basic scalar parameters of delivery, delay, drop rate and general data packets output. The metric variables of the simulation were fixed on area and the number of nodes or devices. Therefore, it is suggested that more similar studies be conducted to include other intricate parameters such as jitter and power consumption. Security is also an area of MANETs that requires thoughtful inspection. Upon combining various aspects of MANET routing protocols, it is paramount to investigate some of the security effects that may result from such exercises.

REFERENCES

[1] N. Islam and Z. Shaikh, Arxiv.org, 2020. [Online]. Available: https://arxiv.org/ftp/arxiv/papers/1711/1711.08405.pdf. [Accessed: 09- May- 2020].

[2] A. Veerasamy, S. Madane, K. Sivakumar and A. Sivaraman, "Angle and Context Free Grammar Based Precarious Node Detection and Secure Data Transmission in MANETs", The Scientific World Journal, vol. 2016, pp. 1-12, 2016. Available: 10.1155/2016/3596345 [Accessed 9 May 2020].

[3] M. Tareq, R. Alsaqour, M. Abdelhaq and M. Uddin, "Mobile Ad Hoc Network Energy Cost Algorithm Based on Artificial Bee Colony", Wireless Communications and Mobile Computing, vol. 2017, pp. 1-14, 2017. Available: 10.1155/2017/4519357 [Accessed 5 April 2020].

[4] N. Chaamwe and L. Shumba, "e-Learning Using Wireless Ad-Hoc Networks to Support Teaching and Learning in Rural Zambia", in *Proceedings and report of the 7th UbuntuNet Alliance annual conference*, 2014, pp. pp 51-58.

[5] S. Jadhav, A. Kulkarni and R. Menon, "Mobile Ad-Hoc Network (MANET) for disaster management", *2014 Eleventh International Conference on Wireless and Optical Communications Networks (WOCN)*, 2014. Available: 10.1109/wocn.2014.6923074 [Accessed 5 April 2020].

[6] N. Beijar, "Zone Routing Protocol (ZRP)."

[7] Z. Haas, M. Pearlman and P. Samar, "draft-ietf-manet-zone-iarp-01 - The Intrazone Routing Protocol (IARP) for Ad Hoc Networks", *Tools.ietf.org*, 2001. [Online].Available: https://tools.ietf.org/html/draft-ietf-manet-zone-iarp-01. [Accessed: 06- Oct- 2018].

[8] Z. Haas, M. Pearlman and P. Samar, "draft-ietf-manet-zone-ierp-01 - The Interzone Routing Protocol (IERP) for Ad Hoc Networks", *Tools.ietf.org*, 2001. [Online]. Available: https://tools.ietf.org/html/draft-ietf-manet-zone-ierp-01. [Accessed: 06- Oct- 2018].

[9] Z. Haas, M. Pearlman and P. Samar, "draft-ietf-manet-zone-iarp-01 - The Bordercast Resolution Protocol (BRP) for Ad Hoc Networks", *Tools.ietf.org*, 2001. [Online]. Available: https://tools.ietf.org/html/draft-ietf-manet-zone-iarp-01. [Accessed: 06- Oct- 2018].

[10] M. Pearlman and Z. Haas, "Determining the optimal configuration for the zone routing protocol", *IEEE Journal on Selected Areas in Communications*, vol. 17, no. 8, pp. 1395-1414, 1999.

[11] Z. Haas and M. Pearlman, "The performance of query control schemes for the zone routing protocol", *IEEE/ACM Transactions on Networking*, vol. 9, no. 4, pp. 427-438, 2001.

[12] A. Gupta, "Review of Various Routing Protocols for MANETs", *International Journal of Information and Electronics Engineering*, 2011.

[13] N. Beijar, *Citeseerx.ist.psu.edu*. [Online]. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.444.753&rep=rep1&type=pdf. [Accessed: 08- Oct- 2018].

[14] H. Zygmunt, P. Marc and S. P, "The Zone Routing Protocol (ZRP) for Ad Hoc Networks", *Tools.ietf.org*, 2001. [Online]. Available: https://tools.ietf.org/id/draft-ietf- manet-zone-zrp-00.txt. [Accessed: 08- Oct- 2018].

[15] "Analysis of the Zone Routing Protocol", *Netmeister.org*. [Online]. Available: https://www.netmeister.org/misc/zrp. [Accessed: 08- Oct- 2018].

[16] Y. Ko and N. Vaidya, "Location-aided routing (LAR) in mobile ad hoc networks", *Proceedings of the 4th annual ACM/IEEE international conference on Mobile computing and networking - MobiCom '98*, 1998.

[17] A. Husain, B. Kumar and A. Doegar, "A Study of Location Aided Routing (LAR) Protocol for Vehicular Ad Hoc Networks in Highway Scenario", *International Journal of Information Technology and Web Engineering*, vol. 2, no. 2, pp. 118-124, 2010.

[18] M. Mikki, "Energy Efficient Location Aided Routing Protocol for Wireless MANETs", *Arxiv.org*, 2009. [Online]. Available: https://arxiv.org/abs/0909.0093. [Accessed: 30- Jul- 2018].

[19] Y. Ko and N. Vaidya, "Location-aided routing (LAR) in mobile ad hoc networks", *Proceedings of the 4th annual ACM/IEEE international conference on Mobile computing and networking - MobiCom '98*, 1998.

[20] Z. Haas and M. Pearlman, *Cs.cornell.edu*. [Online]. Available: http://www.cs.cornell.edu/people/egs/615/zrp.pdf. [Accessed: 10- Oct- 2018].

[21] A. Zafar, "An overview of Zone Routing Protocol", *Journal of Advances in Science and Technology*, vol. 3, no. 4, 2012.

[22] Z. Haas and M. Pearlman, *Pdfs.semanticscholar.org*. [Online]. Available: https://pdfs.semanticscholar.org/142b/380259630af52fb37e280d08013f3597062c.pdf. [Accessed: 10- Oct- 2018].

[23] A. Rai, V. Srivastava and R. Bhatia, "Wormhole Attack Detection in Mobile Ad Hoc Networks", *International*

Journal of Engineering and Innovative Technology (IJEIT), vol. 2, no. 2, 2012.

[24] K. Gorantala, "Routing Protocols in Mobile Ad-hoc Networks", Graduate, Umea University.

[25] S. Goswami, S. Joardar and C. Das, "Reactive and Proactive Routing Protocols Performance Metric Comparison in Mobile Ad Hoc Networks NS 2", *International Journal of Advanced Research in Computer and Communication Engineering*, vol. 3, no. 1, 2014.

[26] N. Verma and S. Soni, "A Review of Different Routing Protocols in MANET", *International Journal of Advanced Research in Computer Science*, vol. 8, no. 3, 2017.

[27] S. Vijayalakshmi and M. Sweatha, "A Survey on History and Types of Manet", *International journal of Emerging Trends in Science and Technology*, vol. 3, no. 7, pp. 4310-4315, 2016.

[28] N. Saeed, M. Abbod and H. Al-Raweshidy, "MANET Routing Protocols Taxonomy", in *2012 International Conference on Future Communication Networks*, 2012.

[29] G. Kapil, "AUGMENTED ZRP AS A ROUTING PROTOCOL FOR MANET", *International Journal of Computational Engineering Research*, vol. 3, no. 6, 2013. Available: http://www.ijceronline.com/. [Accessed 8 January 2020].

[30] M. Oo, "Performance Analysis of GPSR and ZRP over TCP and CBR Connection in MANET", *International Journal of Science, Engineering and Technology Research (IJSETR)*, vol. 8, no. 7, 2019. Available: http://ijsetr.org/wp-content/uploads/2019/07/IJSETR-VOL-8-ISSUE-7-335-339.pdf. [Accessed 8 January 2020].

[31] A. Rao, N. MuraliVishnu, K. Swathi, K. Hanisha and N. Anand, "Performance Evaluation of DSR, AOMDV and ZRP Routing Protocols in MANETS by using NS2", *International Journal of Computer Science and Information Technologies*, vol. 5, no. 1, pp. 711-714, 2014. Available: http://ijcsit.com/docs/Volume%205/vol5issue01/ijcsit20140501154.pdf. [Accessed 8 January 2020].

[32] "Performance Enhancement of ZRP For MANET", *International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)*, vol. 5, no. 12, pp. 2530-2356, 2016. Available: http://ijarece.org/wp-content/uploads/2016/12/IJARECE- VOL-5-ISSUE-12-2530-2536.pdf. [Accessed 8 January 2020].

[33] D. Sudarsan, P. Mahalingam and G. Jisha, "Distance Aware Zone Routing Protocol forLess Delay Transmission and Efficient Bandwidth Utilization", *Advances in Computer Science, Eng. & Appl*, pp. 63–71, 2012. Available: https://link.springer.com/chapter/10.1007/978-3-642-30111-7_7. [Accessed 8 January 2020].

[34] "Performance Analysis of DSDV, AODV and ZRP Routing Protocol of MANET and Enhancement in ZRP to Improve its Throughput", *International Journal of Scientific and Research Publications,*, vol. 3, no. 6, 2013. Available: http://www.ijsrp.org/research-p aper-0613/ijsrp-p1836.pdf. [Accessed 8 January 2020].

[35] A. Subramaniam, "Power Management In Zone Routing Protocol (ZRP)." Available: https://www.ee.ucl.ac.uk/lcs/previous/LCS2003/76.pdf. [Accessed 8 January 2020].

[36] B. McEvoy and L. Machi, "The Literature Review: Six Steps to Success", *Amazon.com*, 2009. [Online]. Available: https://www.amazon.com/Literature-Review-Six-Steps-Success/dp/1506336248. [Accessed: 23- Dec- 2019]..

[37] N. Saeed, M. Abbod and H. Al-Raweshidy, "MANET Routing Protocols Taxonomy", in *2012 International Conference on Future Communication Networks*, 2012.

[38] N. Verma and S. Soni, "A Review of Different Routing Protocols in MANET", *International Journal of Advanced Research in Computer Science*, vol. 8, no. 3, 2017.

[39] X. Hong, K. Xu and M. Gerla, "Scalable routing protocols for mobile ad hoc networks", *IEEE Network*, vol. 16, no. 4, pp. 11-21, 2002.

[40] H. Zygmunt, P. Marc and S. P, "The Zone Routing Protocol (ZRP) for Ad Hoc Networks", *Tools.ietf.org*, 2001. [Online]. Available: https://tools.ietf.org/id/draft-ietf- manet-zone-zrp-00.txt. [Accessed: 08- Oct- 2018].

[41] T. Issariyakul and E. Hossain, "Introduction to Network Simulator 2 (NS2)", 2019. [Online]. Available: https://link.springer.com/chapter/10.1007%2F978-1-4614-1406-3_2. [Accessed: 16- Dec- 2019].

[42] "What is OMNeT++?", *Omnetpp.org*, 2019. [Online]. Available: https://omnetpp.org/intro/. [Accessed: 16- Dec- 2019].

[43] J. Guarte and E. Barrios, "Estimation Under Purposive Sampling", *Communications in Statistics - Simulation and Computation*, vol. 35, no. 2, pp. 277-284, 2006. Available: 10.1080/03610910600591610 [Accessed 12 May 2020].