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AN OPTIMIZING REBROADCAST MECHANISM FOR MINIMIZING THE CONTROL OVERHEAD IN MOBILE AD-HOC NETWORKS

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ABSTRACT

Mobile Ad-hoc Network (MANET) is assumed an encouraging technology that constructs interim network connectivity without the aid of any prior architecture which is required during abnormal circumstances or in provisional events such as in emergencies, crisis conditions, and military conflicts. Source routing in MANET is challenged by arbitrary and random node mobility that triggers a lot of route discoveries due to frequent link breakages. This generates a massive number of Route Request (RREQ) packets resulting from the flooding procedure. The flooding procedure is used in the route discovery process and produces a storm of the broadcast, leading to an increase in packet loss and control overhead. Thus, the aim of this research is to enhance the source routing protocols by presenting an optimized route discovery strategy to minimize the RREQs flooding in the network that contributes to diminishing the overhead. The performance of the proposed routing mechanism was evaluated using NS3 and compared to DSR in terms of Normalized Routing Load (NRL) and Packet Delivery Ratio (PDR). The evaluation results showed that the proposed routing mechanism outperforms the well-known mechanisms such as Dynamic Source Routing (DSR) protocol.

Keywords: *MANET, Source Routing, RREQ, DSR, NRL*

1. INTRODUCTION

Mobile Ad-hoc Network (MANET) is a collection of mobile nodes that moves arbitrarily without any fixed infrastructure and centralized management [1]. MANET has been beneficially utilized in many domains which are described in Figure 1.

The nodes in MANET can be thought of as either data sources, data destinations, or router nodes. Therefore, generally, a node is capable of delivering a message directly to all of its immediate neighbours or an additional inaccessible node via other intermediary nodes(s) [2]. Multi-hopping is the primary mechanism for increasing network capacity and performance. Within the multi-hop paradigm, the source node can communicate with its destination through intermediate nodes as the destination is out of the communication range of the source node [3]. This means that even if the source is not in range, the destination can receive data from the source. According to Minhas et al. [4], the multi-

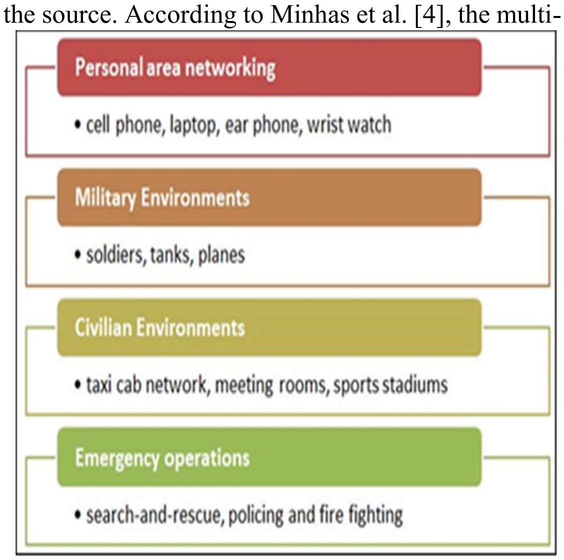

Figure 1: Domains of MANET Usage

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hopping mechanism aids in conserving energy resources, reducing interferences, and improving the network throughput.

The efficiency of the routing protocol is related to the reliability of MANET [5]. In MANET, the routing process discovers, establishes, and maintains a route between two mobile nodes [6][7][8]. Since routing protocols should be able to manage routing in MANET effectively. Dynamic Source Routing (DSR) [9] [10] is one of the commonly used on-demand reactive routing protocols, that uses flooding techniques to provide new routes to keep the network connectivity.

During the route discovery process, RREQ packets (control packets) move blindly in the entire network to discover new routes between a source and its destination. As a result, the flooding procedure generates high control overhead that might degrade the performance of MANET performance. [5], [9], [10]. Thus, monitoring flooding operations should be done selectively by reducing the number of mobile nodes broadcasting RREQs [11], [12].

This paper aims to improve network performance by proposing an optimized route discovery mechanism for minimizing the control overhead in on-demand source routing protocols. The remainder of the paper is structured as follows: Section 2 provides the related works on route discovery strategies and the limitation of their route discovery mechanisms. The description of our proposed mechanism is presented in Section 3. Section 4 presents the configuration of the simulation scenario. Sections 5 and 6 introduce performance evaluation and outcomes. Finally, Section 7 presents the conclusion and future work.

2. LITERTURE REVIEW

This section thoroughly elucidates the existing research work associated with route discovery mechanisms.

Shobha and Rajanikanth [13] proposed Relay Routed DSR (RDSR) to decrease the amount of control and RREQ packets by selecting relay nodes based on the mobility information of the nodes. Where, during the flooding stage, the mobility information is gathered from the neighbour nodes. However, the rapid speed of the node may run out of the transmission range of the current node before the transition to the relay phase that introducing redundant route discoveries which produce more overhead.

In the work of Sultana et al. [14] and Kaur and Singh [15], the authors come up with an Enhanced DSR (EDSR) to reduce the broadcasting overhead of RREQ by utilizing a multicasting approach. In this approach, the forwarder nodes rebroadcast RREQs packets to neighbour nodes that are not in the received Route Request option. However, the amount of flooding varies with the number of chosen nodes and can be significant.

Passive clustering was suggested by Barve et al. [16] to reduce flooding overhead in MANET and Optimize DSR protocol by creating network clusters during the initial stage of the discovery process. In this amended version, only specific nodes would forward the RREQ packets when the clusters are created. Hence, with limiting flooding of RREQ packets, the overhead of bandwidth is reduced, while at the same time, the packet delivery ratio increases. likewise, Shirke et al. [17] suggest a Cluster-Based Logical Hierarchical Addressing Scheme for Dynamic Source Routing Protocol (CBHDSR), to reduce the flooding of RREQ packets in the network which in turn enhance the DSR protocol by finding a direct path to transfer the data. However, the mobility of the nodes would increase the overhead which is associated with changing of cluster head.

Malwe et al. [18] proposed a “zone-based” technique to minimize the amount of broadcasted RREQ packets. The transmission range of each node is split into three zones which are (inner, middle, and outer zone) based on the received signal strength and two pre-specified thresholds. The nodes which are located in the middle zone help in the route discovery process. However, this technique suffers from packet looping and does not ensure route establishment that increases the routing overhead.

Allahham and Mohammed [19] presented a modified route discovery approach for DSR to improve performance especially in terms of delay as well as RREQ packets rate. This approach came with a new mechanism that is used throughout the route discovery process and modified the DSR algorithm to cache routes based on the node’s location and the direction of the broadcast. The proposed approach can reduce the collision problem and repeat receiving the same message. Furthermore, this mechanism enhances the probability of discovering the route that reaches the destination at a lower time. Compared to DSR, the evaluation results revealed a significant reduction in terms of the delay and overhead. However, it suffers from the delay due to the cache node’s location and direction of the broadcast.

Hamad et al. [20] proposed two techniques, called Furthest Candidate Neighbors for

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Rebroadcasting the RREQ (F-CNRR) and Closest Candidate Neighbors for Re-broadcasting the RREQ (C-CNRR) to reduce the overhead generated by the propagation of RREQ packets in MANET. Regarding the F-CNRR approach, when a route discovery process is initiated, the source node (forwarder node) divides its transmission range into four separate zones (Z1, Z2, Z3, and Z4). Then, each zone will be partitioned into two sub-zones. The first zone (the inner circle) will include the Candi-date List (CL) which involves all the neighbor nodes. The distance between the neighbor node and the forwarder node is 80% of the transmission range of the forwarder node. In the second zone (outer circle), all the neighbuors will be omitted from the CL. In this technique, only the farthest node for each CL will be selected as Candidate Neighbours (CN) to forward the RREQ. This process will be repeated by each for-warder node until a destination node is found.

The other mechanism which is abbreviated by C-CNRR is suggested to overcome the interference and collision problems that are generated in the F-CNRR technique. This approach is the modification of the F-CNRR, where for each zone, all the neighbouring nodes of the forwarder node are maintained into the CL, and all the nodes that belong to the inner circle are excluded. Furthermore, the closest node from the forwarded node will be selected as the next forwarding node for each zone. However, these mechanisms with selecting only one node from each zone at a time may not guarantee the route establishment and increase the probability of packet looping that will participate in increasing the overhead.

3. THE PROPOSED OPTIMIZED ZONE-BASED ROUTE DISCOVERY MECHANISM

The main inspiration behind this research design is based on the network management and performance perspectives. In this research, the Optimized Zone Route Discovery Mechanism (OZRDM) is proposed to enhance the source routing protocols, and the design of this mechanism requires the coverage area to be divided into three regions and determine the zone threshold values. The work also involves neighbouring nodes classification, identifying the minimum number of nodes in the forwarding zone, and designing the proposed route request process. Each of these topics is described in the subsequent sections.

3.1 Computation of Zone Threshold Values

Every node in MANET divides its coverage area into three regions as shown in Figure 2 [1]. Region 1 is at distance R/2, Region 2 is at distance 3R/4, and Region 3 is at the transmission range R. Indeed, the proposed OZRDM determines the threshold values based on the signal strength at these distances. Consider that the transmission range is known as it can be calculated using error probability and the threshold value of signal strength. The probability of error is typically known as Bit Error Rate (BER) that usually assumed to be 10^{-3} [21].

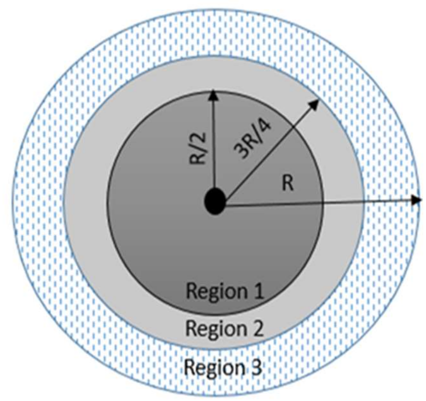

Figure 2: Three Regions of The Transmission Range

3.2 Neighbouring Nodes Classification

The coverage area of each node is divided into three regions, and each node knows the location of all neighbour nodes through exchanging the Hello messages. Through the exchanging process, every node can obtain its location (by considering two dimensions x and y) and mobility information (speed and direction) using GPS as it is assumed in several studies such as [22] [23]. Therefore, each node in the network preserves a neighbouring table. In addition, the location of neighbour nodes inside the transmission range is responsible for classifying the nodes into three regions (Region 1, Region 2, and Region 3). Furthermore, every node in the neighbouring table is allocated to its identical region, and each entry in the neighbouring table contains the information of the neighbour node. Such information includes ID, location, and mobility information of the nodes.

3.3 Computation of Minimum Number of Nodes in Forwarding Region

This section presents the minimum number of nodes according to their location to the sender node. To evade a high number of hops and packet looping to the destination, the selected zone should have at least one neighbouring node to be forward

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the RREQ packets in each direction; otherwise, the RREQ packets should for-ward through using the nodes in another zone. Consequently, performing this process may ensure that RREQ packets can reach their destination.

In addition, there are four possible directions utilized to make the sender node aware of the direction of its neighbouring nodes. Such directions are computed by considering two dimensions (x, y) obtained by using the GPS; these directions are Q1, Q2, Q3, and Q4. Therefore, the table entry in neigbouring table should contain information about the neighbouring node and their specified direction.

For neighbouring node (i), suppose that its location is at (xi, yi), and the sender node S is at (xs, ys), where the values of x and y are real numbers. To define the direction of node i, the following subsequent conjectures can be concluded [1]:

• If xj > xs, and yj >ys, the neighbouring node (i) is placed in Q1.
• If xj < xs, and yj >ys, the neighbouring node (i) is placed in Q2
• If xj < xs, and yj <ys, the neighbouring node (i) is placed in Q3.
• If xj > xs, and yj <ys, the neighbouring node (i)is placed in Q4.

Therefore, the S will forward RREQ packets only to the nodes in the selected region based on the availability of a minimum number of nodes in each direction. As shown in Figure 3 below (case 1), only Region 3 is selected to forward RREQ packets when it contains several nodes in each direction; otherwise, the nodes in another region should involve in the broadcasting of RREQ packets as in cases 2 and so on.

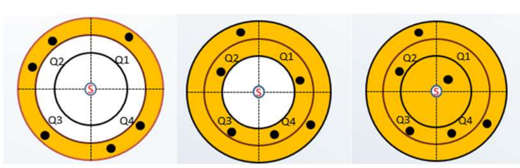

Figure 3: Classification of Nodes Within the Predefined Regions

3.4 Computation of Minimum Number of Nodes in Forwarding Region

The route discovery procedure is a core step of OZRDM, which aims to create the path between the source and destination node and avoid the consequences of blind flooding. The node distributes its location information with its neighbour nodes by exchanging the Hello messages, resulting in all the nodes being aware of each other. Therefore, the RREQ packet can be sent only to a group of neighbour nodes which can help to avoid blind flooding. As a result, it may significantly alleviate the overhead and improve the performance of the network.

In the proposed route discovery procedure, whenever there is a need for a new route to a specified destination and this route does not exist in the cache table of the source node (S), the S will generate an RREQ packet that includes a unique ID with its own and destination addresses. The RREQ packet will be forwarded to the destination node only if it is within the sending range of the source node (sender node); otherwise, the source node will append the IDs of all its neighbouring nodes into Neighbours IDs list. RREQ packets will be sent only to specified nodes in the selected zone (region). The choice of the zone depends on the number of neighbouring nodes in the zone associated with the direction. In addition, the priority for zone selection is given to zone 3 (Region 3). In this way, the number of RREQ packets is reduced, resulting in a decrease in the overhead of the route discovery process. The sender node should be aware of the direction of its neighbouring nodes; Q1, Q2, Q3, and Q4 are known as the four directions (as explained in Section 3.3). However, a region is chosen in the broadcasting of RREQ packets when it contains a neighbouring node in each direction, otherwise, another region will participate in the route discovery process if the above condition is fulfilled. Therefore, by performing this process, the RREQ packets may be reaching their destination successfully.

The mentioned process will be repeated by any neighbouring node M receiving the RREQ packet. Once the RREQ is forwarded to neighbouring node M, node M will append all its neighbours IDs that do not exist in the list of received RREQ into Neighbours IDs list of RREQ packet, where the IDs of the common nodes are excluded. Therefore, M will not forward RREQ packets to the nodes that already exist in Neighbours IDs list of received RREQ packets. In this way, the number of RREQ packets is reduced, resulting in less overhead of the route discovery procedure.

Meanwhile, a reduction in flooding of RREQ packets can also be obtained if a node received the same RREQ packet that was previously received from the neighbour then that node will ignore that RREQ packet and no additional action will be executed. Thus, this procedure achieves efficient flooding by reducing the broadcasting of multiple copies of RREQ packets to other nodes that can significantly alleviate the overhead of the route discovery process. Figure 4, illustrates the steps of the proposed mechanism.

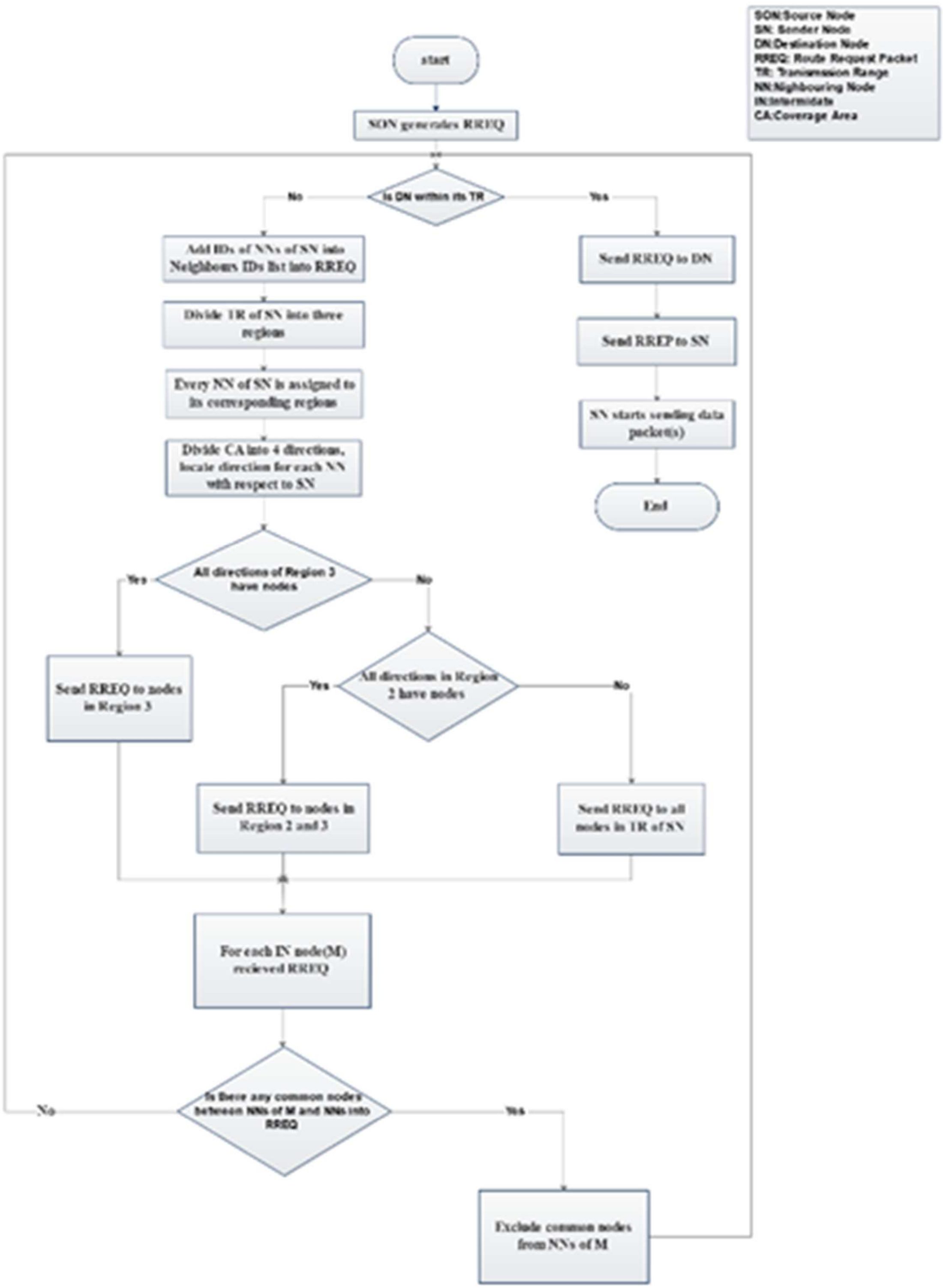

Figure 4: Flowchart of the Proposed Mechanism

4. SIMULATION SETUP

To validate the effectiveness of the proposed mechanism a number of nodes ranging from 20 to 140 nodes were simulated and deployed in the area of around 300 x1500 m^2. In this research, NS3 was used to conduct the research experiments, where NS3 is the most popular network simulator, the main objective is to improve a simulation environment with the help of C++ or Python programming language [24]. Several researchers like [25],[26],[27], and [28] used the NS3 to authenticate their proposed mechanism, which depends on source routing protocols. In addition, the distribution of nodes over the testing area in the network is identified by the Random Waypoint model that is used as a mobility model. Table 1 presents the simulation parameters utilized in the comparison scenario of OZRDM with DSR.

Table 1: Simulation Parameters Utilized in Comparison Scenario of OZRDM With DSR

Parameters	Values
Number of Nodes	20-140 nodes
Simulation Time	200-600 seconds
Simulation Area	300x1500 m^2
Packet Rate	4 Packet/s
Mobility Speed	0-20 m/s
Pause Time	20 seconds

5. EVALUATION OF OPTIMIZED ZONE-BASED ROUTE DISCOVERY MECHANISM (OZRDM) IN TERMS OF PDR

In this section, we illustrate the result of the proposed OZRDM in terms of PDR (which is known as the ratio of the number of data packets delivered to the destination nodes to the number of data packets that are sent by the source nodes [15]) compared with standard DSR.

Figure 5 shows the achieved PDR of the proposed OZRDM for sending RREQ packets, not like the traditional method that broadcasts RREQ packets to all neighbouring nodes during the route discovery process. The results demonstrate that when the number of nodes is between 20 and 40, the achieved PDR for OZRDM and DSR is (86%, 85.90 %), respectively, which are almost the same. Such results have been obtained due to the low number of nodes in the region and OZRDM in this case will perform like traditional DSR and select all the nodes in the transmission area for for-warding the RREQ packets. At 60 nodes, the OZRDM achieves PDR 92.00% which is near to PDR achieved by DSR is equal to 90.90%. The proposed OZRDM performs better than standard DSR, particularly with the increasing number of nodes for all testing values.

Therefore, it is clear that when the number of nodes in the network increased, the network overhead has raised which can lead to degradation in the network performance due to the increase of unwanted RREQ rebroadcasting for route discovery particularly, at the nodes that placed in Region 1 and 2. As a result, the highest enhancement for the proposed OZRDM is obtained when the number of the nodes achieve 140 nodes, where PDR improvement is 2.78%.

Furthermore, it is important to note that the node speed in this scenario is 5 m/s which is low speed; thus, a low number of link failures is detected due to the low movement of mobile nodes. So, this scenario shows an increase in the number of nodes will increase the receiving packets and network performance. Furthermore, the improvement achieved at the low speed of mobile nodes is observed when the number of nodes is increased, which can exponentially increase the network overhead with additional delay and drop of sending packets.

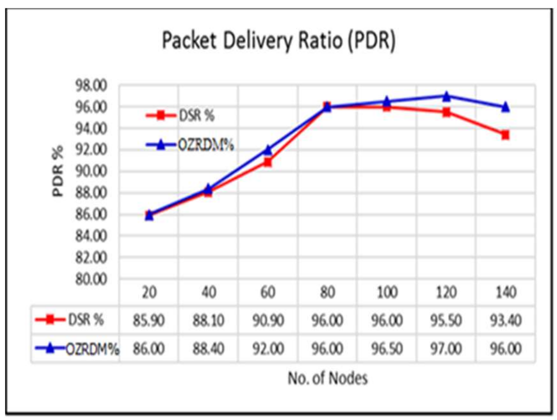

Figure 5: Result of PDR for the Proposed OZRDM Compared with Route Discovery Utilized in DSR

6. EVALUATION OF OPTIMIZED ZONE-BASED ROUTE DISCOVERY MECHANISM (OZRDM) IN TERMS OF NRL

The NRL of the proposed OZRDM compared with DSR is presented in this section. Generally, the enhancement of the proposed OZRDM over DSR is reflected in the performance metric NRL. Figure 6 shows the NRL which is described as the number of routing control messages produced in the network divided by the number of

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data packets delivered to the destination during simulation time [15].

From the results offered in Figure 6, it could be observed that when the number of nodes increases, the proposed OZRDM achieves a decrease in terms of NRL over DSR, where the impacts of the proposed mechanism of selecting a group of neighbouring nodes for route discovery takes place at high network density since the prob-ability of available neighbouring nodes at Region 3 or 2 becomes higher.

From Figure 6, the DSR produces more RREQ packets than the proposed OZRDM, and this is because every node that receives the RREQ packets must rebroadcast them which is high, and this could be observed when the simulated area contains more than 60 nodes. In addition, at 20 nodes, the NRL achieved by the proposed OZRDM and DSR is almost the same due to the number of nodes being very low, and the proposed mechanism considers the whole coverage area for route discovery.

Furthermore, the results show a reduction in the RREQ packets (routing overhead) compared with the DSR starts with a slight improvement at 40 nodes. However, by raising the number of nodes, the reduction in NRL increases. For instance, at 80 nodes, the NRL is 8.09% for the proposed OZRDM and 11.92 % for DSR.

Moreover, the result reveals a decline of 3.83% in NRL compared with DSR. Besides, it could be noted that when the number of nodes arises to 120, the NRL value for OZRDM achieved 18.98%. These results present the average reduction in NRL around 23.1 %. At 120 and 140 nodes, the NRL for OZRDM is 18.98% and 21.08 %., these results illustrate a reduction in NRL compared with DSR due to the proposed mechanism, taking into consideration only the nodes in Region 3 can propagate the RREQ packets when there are appropriate nodes are available in the route discovery process.

In this experiment scenario, the main goal is to investigate the effects of increasing the node density in network performance in terms of NRL. The proposed OZRDM improves the results mainly at a high number of nodes by reducing the routing overhead when it selects a group of neighbouring nodes instead of flooding the RREQ packets to all neighbouring nodes. Therefore, this plays a crucial role in avoiding unnecessary retransmission by not involving the nodes located in Region 1 and 2 in the route discovery process if there are enough nodes located in Region 3.

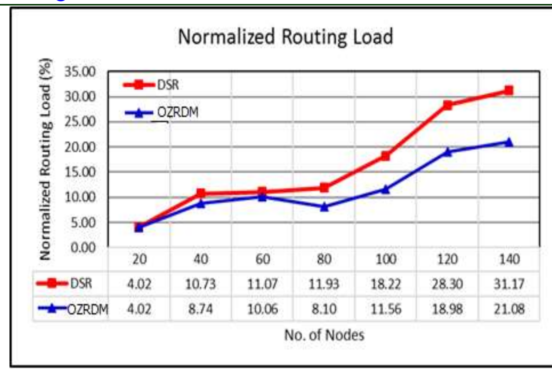

Figure 6: Result of NRL for the Proposed OZRDM Compared with Route Discovery of DSR.

7. EFFECTS OF NODE SPEED ON THE RECEIVED PACKET RATE

This section presents a simulation experiment for a scenario of two nodes' speed values to present the effects of mobility on the performance of receiving rate of the proposed mechanism during the simulation time (200 seconds). The simulation parameters used in the experiments follow the parameters addressed in Table 1, as follows: two cases are presented where the number of nodes is set to 20 and 40, while node speed is set to 5 m/s and 20 m/s for each case. The simulation area is set to 300 x 1500 m^2. Data start sending at 50 seconds for 10 different source and destination nodes. The purpose of this experiment’s scenario is to show the behavior of receiving rate at low mobility and high mobility in addition to the effect of the number of nodes in the network. Figure 7 illustrates the received rate of packet per second throughout the simulation time for 20 nodes used in the network. Generally, results show that the received rate of the packet at 5 m/s is higher than the received rate at 20 m/s, which shows the effects of mobility on the performance of the network. Results in Figure 7 show the receiving rate drops at certain times due to link disruption and increases at other times due to the use of a link failure prediction mechanism, so the data packets are kept in the buffer and waiting to establish a new route to the destination. In addition, some delays of the packet may occur because of high congestion in the network since all nodes in this scenario send or receive packets. Using the proposed mechanism helps the protocol to perform better even at a higher speed.

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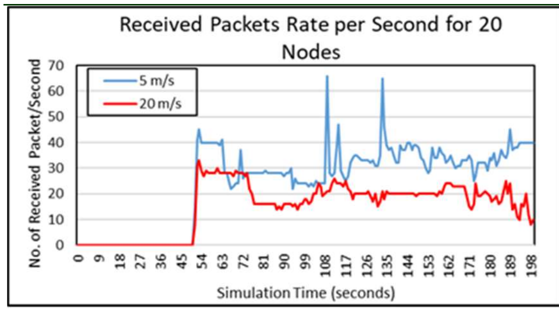

Figure 7: Received Rate of Packet per Second (20 Nodes)

Figure 8 shows the received rate of packets per second during the simulation time for 40 nodes in the network. In this experiment, the number of nodes is increased from 20 nodes to 40 nodes to investigate the effects of the number of nodes in the packet receiving. The experiment is performed in terms of 5 m/s and 20 m/s. The probability of link failure is increased when the speed of the node is 20 m/s, which is reflected in the low packet receiving rate than when 5 m/s is used. The PDR for both cases is about 80% and 60% for 5 m/s and 20 m/s respectively. The results show that the receiving rate is affected by link failure. For example, in the presence of link failure, the packet receiving rate will be low while a high packet receiving rate indicates that there is no link failure. Therefore, the results show the low receiving rate at a certain time which reflects the effect of link failure, and high packet receiving rate at another time which is due to buffering the packets and redirecting to an alternative route, so the purpose of this graph is to present the behavior of routing mechanism through the simulation time.

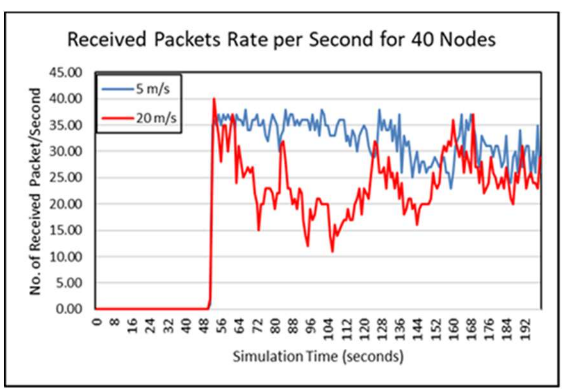

Figure 8: Received Rate of Packet per Second (40 Nodes)

8. CONCLUSION AND FUTURE WORK

During the route discovery process, conventional on-demand routing schemes tend to use the flooding operation of RREQ packets repeatedly until a destination is reached. This process has a high possibility of increasing the delay, overhead, and packet drops. Moreover, the overall throughput has significantly diminished. This paper presents a proposed mechanism for controlling flooding operation called the "Optimized Zone-based Route Discovery Mechanism" (OZRDM). The objective of this work is achieved by dividing the coverage area of each node into three regions (Region 1, Region 2, and Region 3) based on predefined threshold values where the source node categorizes the neighbouring nodes according to their locations in the predefined region. The region is selected based on the availability of a minimum number of nodes in each direction and only the nodes in the selected region should participate in the broadcasting of RREQ packets. The evaluation of OZRDM is performed as an alteration in the number of nodes that influences the increase in the routing overhead. The evaluation showed that OZRDM does well in dropping the routing overhead. On the basis of the numerical results acquired from the simulation experiment, it was shown the Packet Delivery Ratio (PDR) in enhanced source routing protocol compared with Dynamic Source Routing (DSR) has achieved an improvement which means that it contributes to high throughput and fewer packet drops. It was concluded that the use of ZRDM in the enhanced routing protocol helps in a noticeable reduction in the Normalized Routing Load (NRL) by around 23% since it can restrict the flooding of RREQs to other nodes in the network.

Furthermore, as revealed from the results obtained for NRL. The proposed route discovery process in OZRDM uses these enhancements by splitting the coverage area of each node into three regions (Region 1, Region 2, and Region 3). Furthermore, in this process, the source node uses a pre-assigned threshold value to classify the neighbouring nodes based on their location in the pre-defined region. The region is chosen according to the availability of a minimum number of nodes in each direction, and only the nodes in the chosen region should engage in the broadcasting of RREQ packets.

The limitation of this work is the enhanced routing protocol has been tested over a specific mobility model which is a random waypoint model. As mobility patterns may play a significant role in determining the protocol performance, the enhanced routing protocol can be evaluated over other

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mobility models that represent a different type of movement of mobile nodes in the network, and how their location and velocity change over time. The enhanced routing protocol can be examined over mobility models with temporal dependency (Gauss-Markov Mobility Model and the Smooth Random Mobility Model); mobility models with spatial dependency (Column Mobility Model, Pursue Mobility Model, and Nomadic Community Mobility Model); and mobility models with geographic restriction (Pathway Mobility Model and Obstacle Mobility Model) and the enhanced routing protocol does not consider the route breakage due to inefficient energy of node. Hence, one can explore the effect of such attributes on the performance of the enhanced routing protocol.

For future work, the proposed mechanism is gonging to implement and integrate with other hop-by-hop routing protocols like (AODV) and its optimized protocols to reveal the powerful traits that might be scored compared to the indicated protocols.

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