Received: February 18, 2024. Revised: April 24, 2024.

INASS

International Journal of
Intelligent Engineering & Systems

http://www.inass.org/

MR^{2}LAR: Mobility and Range Restricted Location Aided Routing for Mobile Ad-Hoc Networks

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Abstract: In Mobile AdHoc networks, routing overhead is found as major problem at the time of route discovery process due to excessive Route Request (RREQ) Packets Rebroadcasting. To reduce the routing overhead, few researchers has been proposed Location Aided Routing (LAR) protocol by restricting the packets rebroadcasting to specific zone called as request zone. However, the LAR is static in nature and the sides of request zone are parallel to the horizontal and vertical axes of network. Such kind of zone still allows some nodes to rebroadcast the packets. In addition, LAR is much sensitive to mobility of nodes and results in huge delay at larger node speeds. Hence, this paper proposes a new protocol called as Mobility and Range Restricted LAR (MR^{2}LAR) which derives an adaptive request zone based on the node speed and location coordinates of source and destination nodes. MR^{2}LAR establishes a rectangular shaped tilted request zone which adaptively adjusts and keeps the sides of request zone parallel to the line connecting between source and destination nodes. Upon formation of request zone, the source node broadcasts the RREQ packets into the network by appending destination node location. After receiving the RREQ packets by intermediate node, it checks for rebroadcasting if it lies within the zone otherwise it simple drops the packet. An extensive simulation experiments are carried out over the proposed model and the performance is measured through Routing Overhead, Delay, Packet Delivery ratio and throughput at different node speeds and communication ranges. Further, the performance of proposed MR^{2}LAR is compared with state-of-the-art approaches such as P-LAR, EALAR - PSO, and EAMO-LAR and proves its effectiveness. On an average, routing overhead, route discovery delay, packet deliver ratio, and throughput of MR^{2}LAR mechanism for varying node speed are 26.5000, 268msec, 76.6780%, and 447.5000 Kbps respectively.

Keywords: Mobile AdHoc networks, Location aided routing, Request zone, Mobility, Routing overhead.

1. Introduction

Recently, research interest towards MANETs [1-3] has been increased due to their connection flexibility and information transferring capabilities. Due to these abilities, MANETs are majorly used in the applications such as delay sensitive applications, Rescue management systems, Battlefield, virtual and conference rooms, and military operations [4-5]. Majorly, the nodes in the MANETs does not consist of any fixed infrastructure and the communication between them can be done through hops [6].

Generally, the mobile nodes in the MANETs follow set of rules or protocols to establish proper network connection and to exchange the data between them. In this aspect, few past researchers have been developed standard routing protocols. Mostly in all routing protocols, the source node broadcasts its RREQ packet to all the nodes by appending destination node ID within it. Next, all the intermediate nodes receive these request packets and rebroadcasts if the corresponding node ID is not matched with the destination ID. Due to this type of transmission, the reception of control packets at each node increases and it results in larger control overhead. To solve this issue, few researchers suggested two efficient routing protocols namely "Location Aided Routing (LAR)" [7] and "Greedy Perimeter Stateless Routing (GPSR) [8]". These two protocols restrict the broadcasting of flood of RREQ packets within the specified area or region where rebroadcasting can also be allowed. Even though both are location aided protocols but Compared to GPSR, LAR is simple protocol which establishes a Request Zone (RZ) (See Fig. 1) within which the nodes can rebroadcast the RREQ packets. RZ reduces the control overhead by considering the sides of RZ which are parallel to horizontal and vertical axes. Even though, RZ restricts the broadcasting of RREQ packets but if the number of intermediate nodes increases within the RZ can create multiple rebroadcasting. Such kind of transmission won't reduce the control overhead effectively.

To reduce the control overhead with LAR in MANETs, this paper proposed an Adaptive LAR called as Mobility and Range Restricted LAR (MR^2LAR) which finds the request zone based on the constraints of mobility and communication range of source & destination nodes. The proposed mechanism concentrates on creating smaller and adaptive sized request zones to control the routing overhead by restricting flooding of RREQ packets. It considers the locations of source and destination nodes along with the communication ranges to determine adaptive request zone. After creating RZ, the source node starts broadcasting the RREQ packets by appending the location coordinates of RZ and destination ID in it. Further, the intermediate nodes which are present within the RZ rebroadcasts RREQ packets when the corresponding node ID is not matched with destination node ID. Next, if any node receives the RREQ packet which is outside of RZ simply drops the packet.

The structure of remaining paper is formulated as follows; the particulars about Related work on location constrained routing protocols is explored in 2nd section. Next, the particulars about the conventional LAR and proposed MR^2LAR are given in 3rd section. The experimental analysis about MR^2LAR is expressed in 4th section and finally 5th section concludes the paper.

2. Literature survey

Earlier, few authors discussed different challenging issues relevant to routing methods in LAR for MANETs and introduced various methods to provide the solution. For example, Bai Yuan et al. [9] suggested "Location Aided Probabilistic Broadcast (LAPB)" algorithm to reduce the flooding of RREQ packets broadcasting in MANETs. In this algorithm, the authors considered location coordinates and information about neighbor nodes which are located in the specified area. Here, the broadcasting region probabilities are inversely proportional to the coordinates of mobile nodes. As number of nodes in the broadcasting region increases control overhead increases.

Next, to reduce the routing overhead, Sumet Prabhavat et al. [10] proposed an effective method for MANETs named as "Low Overhead Localized Flooding (LOLF)" algorithm. It is the extended version of conventional Query Localization (QL) [11] routing protocol. This algorithm restricts the spreading of control packets during the route discovery phase. To achieve this, the additional control information is inserted and it introduced a smaller overhead in each packet.

Maen Saleh [12] proposed a "Secure Tilted Rectangular Shaped Request Zone LAR (STRS-RZLAR)" that aimed at the provision of secure communication between nodes in MANETs. Mainly, they aimed at the detection of "Man-in-the-Middle Attack (MITM)" and try to protect the overall communication system. For secure communication, they used the most popular Diffie-Hellman key Agreement protocol. Anna Saro Vijendran and J. Viji Gripsy [13] introduced a "Rectangular Zone based Location Specific Routing (RZLSR)" in MANETs to execute on-demand route discovery for secure multipath routing. Security, energy efficiency, and adaptivity is provided by this approach and they carry the disjointness threshold between the nodes by using the labels during the route discovery phase. To find out the route between the source and destination, this approach used rectangular shaped request zones.

With the help of Particle Swarm Optimization (PSO) through uniform mutation operation, a uniform Energy Aware LAR (EALAR) protocol is proposed by T.A.N. Abdali et al. [14]. PSO through Non uniform mutation operation makes traditional EALAR unsatisfactory and provide inadequate solutions. However, because of iterative problem solving property, the PSO based LAR protocols leads to huge computational burden. Likewise, Chaudhary. R. et al. [15] proposed an adaptively modified PSO (APSO). Slower convergence problem of PSO is solved by employing APSO in the "Forwarding Search Space (FSS) heuristic technique". The forwarding zone (FZ) between a source and a destination is selected in FSS, whereupon the best solution is found there. APSO is then used for efficient routing in the FZ area rather than throughout the entire network. However, when the number of nodes in the network increases delay and energy consumption increases.

E. Ahila Devi et al. [16] introduced an Energy Aware Metaheuristic Optimization with LAR (EAMO-LAR) protocol for MANETs. EAMO-LAR applies a Manta Ray Foraging Optimization (MRFO) Algorithm to find out the individual solution to pass through LAR. The MRFO algorithm is introduced to lessen the energy consumption during packet transmission in MANETs. P. Tamil Selvi, C. Suresh GhanaDhas [17] proposed a Game theory approach with energy efficient zone-based routing protocol to improve QoS routing for MANET. This approach controls the network topology by estimating node die out rate. Even though, both algorithms are utilized the energy efficiently but due to the shape of the broadcasting region the control overhead increases.

One of the weaknesses in LAR is the delay due to partial flooding of data packets throughout the adhoc network during route discovery. Mutuma Ichaba and Felix Musau [18] proposed the inclusion of periodic updates of location information among the nodes as a solution to minimizing latency. Proactive-LAR (P-LAR) eliminates partial flooding, thus reducing latency while advancing routing performance of traditional LAR. As a research scope, they used Angle of Arrival (AoA), Time of Arrival (ToA), Time Difference of Arrival (TDoA), the expected distance of nodes and the direction of movement as the only location information details. The authors considered only rectangular shaped broadcasting region and not concentrated on the lines connecting between the source and destination region.

Al-Dhief FT et al. [19] suggested using the LAR protocol for the detection of fire in forests. Towards such purpose, they proposed a routing protocol called LAR based Reliable Routing Protocol (LARR) which detects the fire in the forest in three criterions. They are busyness of route, temperature sensing and length of the route between nodes. Here the route busyness is measured as the total number of packets present in the buffer node. N. As the number of nodes increases the route discovery delay increases. Harrag and A. Harrag [20] proposed an improved version of Zone Routing Protocol (ZRP) which selects the optimal zone radius. Each node is associated with a fuzzy inference system which periodically fed with several parameters like zone radius, node's mobility and nodes' residual energy. These values help in tuning the zone radius according to the required routing standards. The authors considered the radius of the zone but not exact position of source and destination.

Recently, some authors introduced deep learning algorithms for the efficient routing in MANETs. For instance, A. Kumar et al. [21] applied a Reinforcement Learning (RL) algorithm for the improvisation of routing in Vehicular AdHoc networks through LAR. With the help of RL, the routing protocol will keep learning based on the past experiences and takes a perfect decision on the routing for current data transmission.

Problem Statement: Even though several methods focused on the reduction of control overhead in MANETs through location assisted routing, almost all of them considered that the sides of request zone are parallel to horizontal and vertical axes. In such case, the RREQ packets receive by larger number of nodes. Compared to the normal routing protocols, the LAR protocol and its variants reduces the control overhead effectively, but still there is a scope to reduce further. In addition, the mobility is a default nature of nodes in MANETs and it is not associated with the request zone assessment.

3. Proposed approach

3.1 Overview

In MANETs, reducing the flood of RREQ packets is one of the major issues. To address this issue, this work proposed MR^{2}LAR mechanism and it restricts the RREQ packets broadcasting by introducing adaptive Request Zone (RZ) unlike traditional LAR. RZ is the specific region where the RREQ packets are broadcasted. In LAR, there is no restriction on RREQ packets broadcasting and RZ is derived by considering the sides of source and destination nodes positions which are parallel to the horizontal and vertical axis. The proposed MR^{2}LAR mechanism is the extended version of earlier LAR. In order to determine RZ, the proposed mechanism considers source and destination node's locations as well as mobility. Next, MR^{2}LAR approach determines RZ adaptively i.e., where the sides of RZ are in parallel with the line connecting the source and destination nodes. Further, the MR^{2}LAR mechanism not only considers the range restricted RZ but also considers the nodes mobility constraint. Due to this, it achieves enhanced network performance when route failure occurs. After finding RZ, the source node broadcasts RREQ packets by appending destination node ID in it. Whenever the intermediate nodes receive it and they take the decision either to rebroadcast or stop. When the destination node ID is not matches with the corresponding node ID within the RZ then the respective intermediate node rebroadcasts. If any intermediate node in the outside of the RZ region simply drops the packet because the broadcasted packet consists of restricted region locations. Due to this restricted region, the MR²LAR mechanism efficiently reduces the control overhead than conventional LAR.

3.2 Location aided routing (LAR) protocol

In LAR protocol, RZ is determined based on the following steps: initially, the source node (S) determines Expected Zone (EZ) by considering the approximate location of the destination node (D). Next, the shape of the EZ is predicted as circular in shape and position of destination node is measured based on the destination node's past location history, time, and mean speed. Next, the size of RZ must be estimated as much as a smaller than the overall network size. Further, RZ should include S and the approximated destination node location i.e., EZ. For routing in LAR, source node wants to send a packet to the destination node, initially it discovers a path to the destination by appending RZ's four corner's location coordinates in RREQ packet and broadcasts it. Hence, the broadcasting region is limited i.e., each node within the RZ consist of information about RZ coordinates. Further, each node within the RZ receives the RREQ packet with destination ID and checks for the matching. If destination node ID matches with the corresponding node ID within the RZ then it stops broadcasting otherwise it rebroadcasts. Further, if any node lies outside of RZ receives the RREQ packet simply drops the packet. For example, consider the Fig. 1, the nodes A, C, and F are eligible for rebroadcasting whereas node B is not eligible for rebroadcasting and it simply drops the packet because it is outside of RZ.

Upon receiving the RREQ packet by the destination node it sends acknowledgement through Route Reply (RREP) packet back to the source node on the same path i.e., the RREQ received path. The RREP packet consists of destination node's current position, mean speed, and actual time instance. Upon acquired information the source node establishes an optimal path to the destination node. The source node has the information about the destination node's past location time instance t_1, the current time instant t_2 then the EZ is measured by considering the radius R as follows

$$R = (t_2 - t_1) \times v \tag{1}$$

Where R represents radius of EZ or communication range of destination node, v represents the average speed of destination node. However, the derived RZ is larger in LAR due to its sides parallel to the X and Y-axis and it becomes major drawback when the size of the network is large. In this case, the flooding of RREQ increases due to a greater number of intermediate nodes.

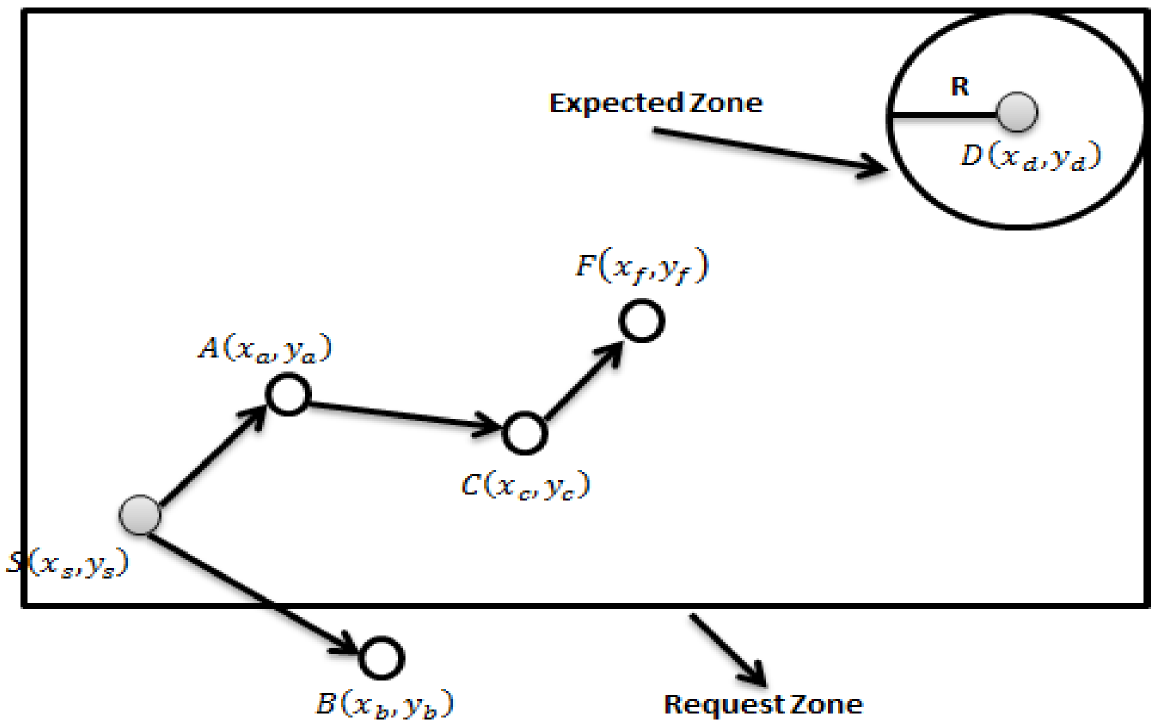

Figure. 1 Expected zone and RZ according to LAR

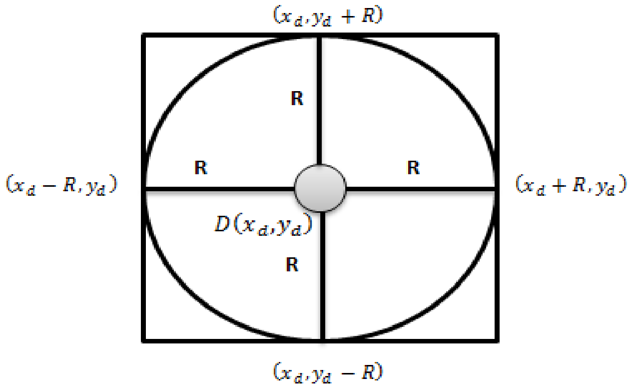

Figure. 2 Destination node's Expected zone Coordinates

Moreover, the LAR has no limit over the transmission range of S and only restricts the communication range of D during the determination of request zone.

3.3 MR²LAR

This approach derives the RZ by considering communication range and mobility of source node and destination node. This determination of optimal RZ restricts the control packets flooding in proposed approach. The RZ sides are straight sides in conventional LAR whereas they are tilted in nature in MR²LAR. Further, unlike the LAR the shape of RZ is anticipated approximately square but MR²LAR is expected as approximately rectangular. Moreover, the MR²LAR assumes uniform communication range for all nodes in the network. By considering all these constraints, the proposed approach derives an adaptive RZ of the shape rectangle and it consist of a smaller number of intermediate nodes. Hence, it attains reduced control overhead compared to conventional LAR. Let's consider the source and destination nodes locations are (x_s, y_s) and (x_d, y_d) respectively at the time instance t_1, and the Euclidean distance between them is measured as

$$d_{SD} = \sqrt{(x_d - x_s)^2 + (y_d - y_s)^2} \quad (2)$$

Next, let R be the coverage range of D, now the proposed mechanism expands R through (x_d, y_d) to compute the location coordinates in four directions of the expected zone. The Fig. 2 shows the computation process.

Let $C_1(x,y)$, $C_2(x,y)$, $C_3(x,y)$ and $C_4(x,y)$ be the location coordinates of on the four direction points of expected zones, they are computed as follows;

$$C_1(x,y) = (x_d + R,\ y_d) \quad (3)$$

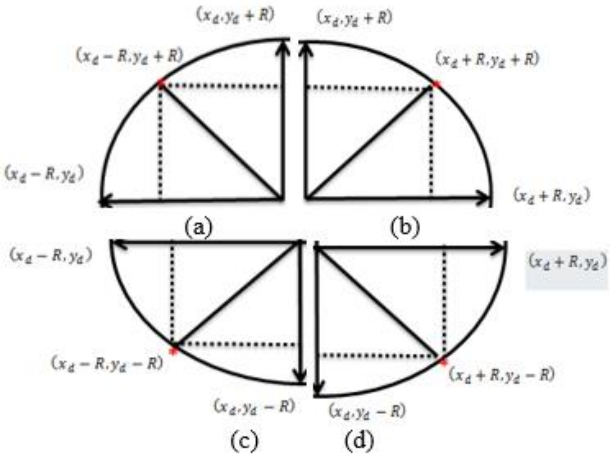

Figure. 3: (a) Top Left, (b) Top Right, (c) Bottom Left, and (d) Bottom Right

$$C_2(x,y) = (x_d,\ y_d + R) \quad (4)$$

$$C_3(x,y) = (x_d - R,\ y_d) \quad (5)$$

$$C_4(x,y) = (x_d,\ y_d - R) \quad (6)$$

In MR²LAR, the major locations such as $C_1(x,y)$, $C_2(x,y)$, $C_3(x,y)$ and $C_4(x,y)$ are considered as major contribution in order to derive RZ. After determining these major location coordinates, four more coordinates are derived and those four more coordinates are called as common coordinates.

In order to determine these common coordinates, this approach partitions the entire EZ into four sub regions namely top left, top right, bottom left, and bottom right. The Fig. 3 demonstrate the partitioning of EZ into four regions.

Next, the communication range of D is considered as reference coordinate to compute the common coordinates. For each region, the common coordinate is derived by considering the combination of major location coordinates. For example, let's pick up the top right region from Fig. 3(a) where the common coordinate is computed by the combination of $C_1(x,y)$ and $C_2(x,y)$ and it is named as $C_{12}(x,y)$. Therefore, $C_{12}(x,y)$ is computed as

$$C_{12}(x,y) = (x_d + R, y_d + R) \quad (7)$$

let's pick up the top left region from Fig. 3(b) where the common coordinate is computed by the combination of $C_2(x,y)$ and $C_3(x,y)$ and it is named as $C_{23}(x,y)$. Therefore, $C_{23}(x,y)$ is computed as

$$C_{23}(x,y) = (x_d - R, y_d + R) \quad (8)$$

let's pick up the bottom left region from Fig. 3(c) where the common coordinate is computed by the combination of $C_3(x, y)$ and $C_4(x, y)$ and it is named as $C_{34}(x, y)$. Therefore, $C_{34}(x, y)$ is computed as

$$C_{34}(x, y) = (x_d - R, y_d - R) \tag{9}$$

let's pick up the bottom right region from Fig. 3(d) where the common coordinate is computed by the combination of $C_4(x, y)$ and $C_1(x, y)$ and it is named as $C_{41}(x, y)$. Therefore, $C_{41}(x, y)$ is computed as

$$C_{41}(x, y) = (x_d + R,\ y_d - R) \tag{10}$$

After computing eight location coordinates, the length and width of RZ are computed. Next, the length of the RZ is determined by finding the maximum of all available X-coordinates. Let's assume maximum of all available x-coordinate is represented as M_d^X and it is computed as

$$M_d^X = maximum \begin{pmatrix} C_1(x), C_2(x), C_3(x), C_4(x), \\ C_{23}(x), C_{12}(x), C_{41}(x), C_{34}(x) \end{pmatrix} \tag{11}$$

Further, the width of RZ is computed by considering all eight location coordinates. Therefore, the width of RZ is equal to maximum of all available Y-coordinates. Let's assume maximum of all available Y-coordinates is represented as M_d^Y and it is computed as

$$M_d^Y = maximum \begin{pmatrix} C_1(y), C_2(y), C_3(y), C_4(y), \\ C_{23}(y), C_{12}(y), C_{41}(y), C_{34}(y) \end{pmatrix} \tag{12}$$

Here, Eqs. (11) and (12) represents the maximum length and width of EZ where the destination node can communicate with its neighbor nodes. The Eqs. (11) and (12) are restricted to only destination node's EZ but this mechanism also considers the source node's EZ to derive the RZ. Therefore, the length and width of RZ is computed at source node by considering minimum of all available x and y-coordinates. To accomplish this, Eqs. (3)-(10) are used to find out minimum length and width of source node's EZ. Therefore, the length of RZ is equal to minimum of all available X-coordinates at source node. Let's assume minimum of all available X-coordinates is represented as M_S^X and it is computed as

$$M_S^X = minimum \begin{pmatrix} C_1(x), C_2(x), C_3(x), C_4(x), \\ C_{23}(x), C_{12}(x), C_{41}(x), C_{34}(x) \end{pmatrix} \tag{13}$$

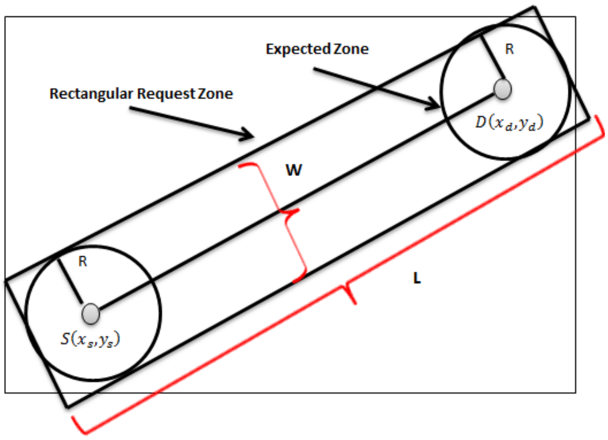

Figure. 4 Tilted and Rectangular shaped request zone derived through MR^2LAR

Similarly, Therefore, the width of RZ is equal to minimum of all available Y-coordinates. Let's assume minimum of all available Y-coordinates is represented as M_S^Y and it is computed as

$$M_S^Y = minimum \begin{pmatrix} C_1(y), C_2(y), C_3(y), C_4(y), \\ C_{23}(y), C_{12}(y), C_{41}(y), C_{34}(y) \end{pmatrix} \tag{14}$$

After computing four values which are represented with Eqs. (11)-(14), the length and width of the RZ are measured. Therefore, the length of RZ is expressed as L and it is given by

$$L = M_d^X - M_S^X \tag{15}$$

And width of RZ is expressed as W and it is given by

$$W = M_d^Y - M_S^Y \tag{16}$$

Finally, the rectangular shape of the RZ is constructed from the Eqs. (15) and (16) and it is shown in the Fig. 4. It is observed from the Fig. 4, the sides of RZ are parallel to the line connected between S and D. when the nodes are moving from the one location to other location then the length and width of RZ are updated automatically.

With the help of L and W, the rectangular shaped request zone is constructed by MR^2LAR and it is shown in Fig. 4. From the figure, it can be seen that the sides of request zone are parallel to the line connected between S and D. The length and width values update automatically in the case of node's movement from one location to another location. For every location change, the adaptive LAR forms an adaptive request zone which takes care about the presence of only few nodes. As much as less the

Received: February 18, 2024. Revised: April 24, 2024.

nodes present in the request zone, the control overhead is less. Moreover, the above derived length and width of request zone is purely dependent on the locations of nodes and they are independent on the velocity and time instances. Since, the request zone determination is purely dependent on the locations of nodes, the source updates the RREQ packet for every location change such that the control overhead always lies minimum.

4. Simulation results

Here, we explain the particulars of experimental analysis accompanied on developed MR²LAR. In this section, at first, we demonstrate the details of experimental setup, i.e., different types of network parameters used for the simulation purpose. Next, the effectiveness of MR²LAR is explored through several performance metrics. At the experimental analysis, we have considered several metrics like routing overhead, delay for varying network parameters like communication range, node count and node speed.

4.1 Simulation set up

Here, we considered random network which consist of varying number of nodes from 20 to 60. The network of size $1000 \times 1000\ m^2$ is assumed to simulate the proposed mechanism. Further, the mobility is considered i.e., for every simulation each node changes its position from one location to another location due to the random deployment of nodes. To examine the proposed mechanism effectiveness, here we varied the parameters like node count from 20 to 60, communication range from 10% to 25% of network length and width, and speed of the nodes from 5 m/s to 30 m/s. For mobility purpose, Random Way Point (RWP) model is considered, due to this model source and destination node positions are purely random in nature.

Table 1. Simulation set up

Network parameter	Value
Node count	20, 30, 40, 50, and 60
Range of communication	10-25% of Network Length or Width
Mean Speed	5-25 m/s
Placement of nodes	Random
Data packets size	512 KB
Data packets count	10
Mobility model	Random way point (RWP)
S & D selection	Radom

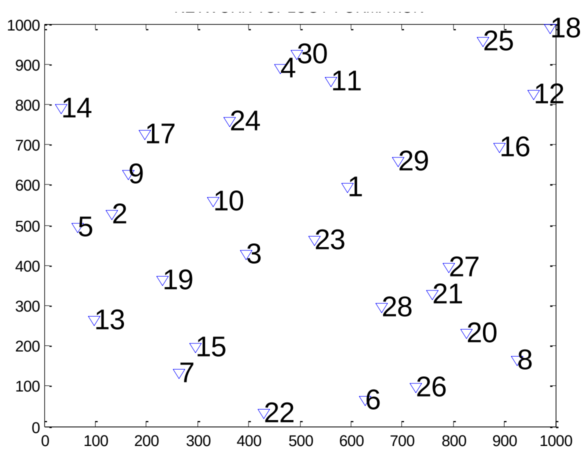

Figure. 5 randomly deployed network

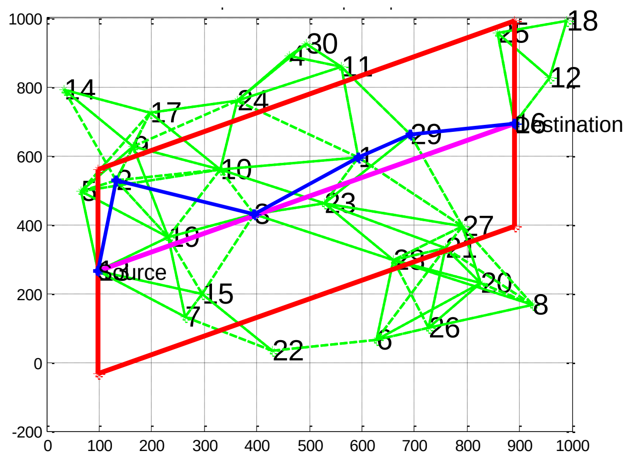

Figure. 6 Optimal path in the request zone between source node (13) and destination node (16)

Moreover, packet size of source node is considered as 512 KB and for each second it can transmit 10 data packets. During the simulation, if any packet not received by the corresponding node which is transmitted from source node it is considered as broken path. Since our method considers only few nodes for the data transmission, the lower data it is considered. The remaining simulation parameters are listed in Table 1. Further, Fig. 5 shows the randomly created network of size 30 nodes. In this network, 13th and 16th nodes are considered as source and destination nodes respectively.

4.2 Results

The performance of MR²LAR mechanism is evaluated after creating random network and the optimal RZ which is shown in Figs. 5 and 6 respectively. According to the proposed mechanism, the RZ is created and optimal routing path is established between 13th and 16th nodes to transfer the data packets as shown in Fig. 6. To evaluate the performance, Route Discovery Delay (RDD), Routing Overhead (RO), Packet Delivery Ratio (PDR) and Throughput parameters are considered. The performance is examined for 25 simulation runs and each Run has different node count, speed, and communication range. The effectiveness of proposed method is evaluated by comparing it with conventional methods such as P-LAR [18], EALAR - PSO [14], and EAMO-LAR [16] in each run.

4.2.1 Routing overhead

Generally, Routing Overhead (RO) is defined as number of control packets during route discovery process and it is considered for RREQ and RREP packets. Let's assume the number of control packets required to establish a path are N_{p_c} and the number of nodes over a path are N, the RO is given by N_{p_c}/N. The main aim of proposed mechanism is to reduce the routing overhead. For this purpose, we conducted two different simulation experiments for varying node speed, and communication range. For simulation, data packet size is kept constant i.e., 100KB and the performance of proposed and existing methods are compared for every simulation run. Here, the RO consider at both the RREQ and RREP packets.

Fig. 7 shows the measured RO for varying node speed. From results, we observed that as node speed increases the RO also increasing for all methods. When nodes move with increased speed then they may move out of RZ rapidly. For example, if one mobile node which was present already in RZ at current instant and it cooperates previous node for broadcasting can move out of RZ in the next instant. In such case, the source node searches for an alternate route to broadcast the control packets. It leads to increased RO and it further increases when intermediate nodes move with increased speed. Therefore, as node speed increases RO increases but proposed method attains less RO than existing methods. In P-LAR mechanism, the created RZ consists of a greater number of nodes and it increases the RO. Whereas, EALAR - PSO, and EAMO-LAR accomplishes less RO than P-LAR but it is higher than the MR^{2}LAR approach due to rectangular RZ. Hence, the proposed mechanism achieves less RO than all state-of-the-art methods due to tilted rectangular RZ and it consists of a smaller number of intermediate nodes to transfer the data. However, all the methods experienced more RO than the proposed MR^{2}LAR. On an average, the RO of MR^{2}LAR mechanism is observed as 26.5000 while it is observed as 49.8333, 40.6667, and 35.5000 for conventional methods such as P-LAR, EALAR - PSO, and EAMO-LAR respectively.

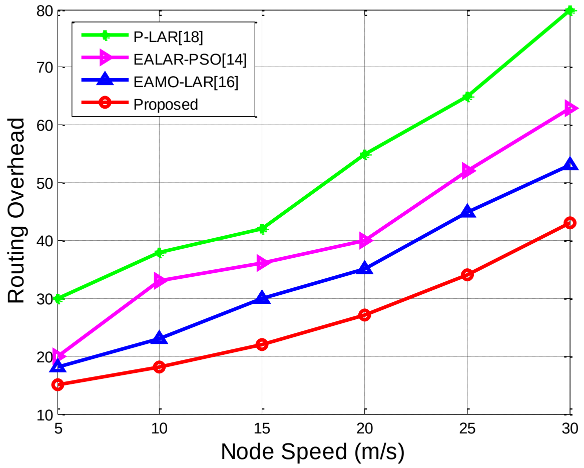

Figure. 7 Routing Overhead for varying node speed

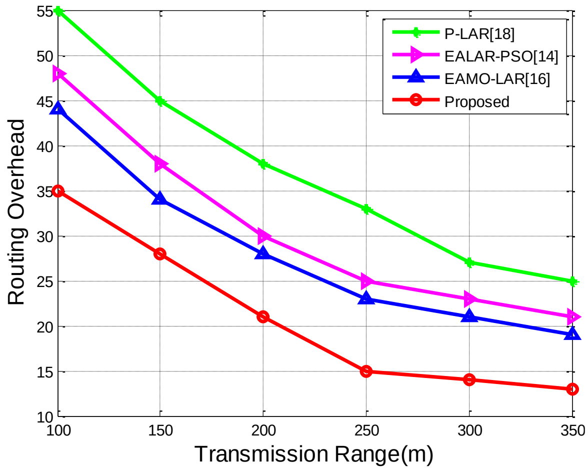

Figure. 8 RO for different Transmission Ranges

As a second case study, the performance of proposed approach is evaluated for varying communication range of mobile nodes and it is shown in Fig. 8. As communication range of each mobile node increases, the source node can communicate with far distant nodes easily. So, the intermediate mobile node cannot experience unnecessary rebroadcasting and it establishes routing path to the destination with the help of lesser nodes. Hence, it reduces RO and it further reduces when the nodes are location aware nodes.

From Fig. 8, we observe that proposed approach experiences less RO than all conventional approaches due to its adaptive RZ and optimal mobile nodes existence. As the MR^{2}LAR is restricted to the communication range of mobile nodes, it experienced a greater reduction in the RO than the existing methods, especially compared with the traditional P-LAR. On an average, the Routing Overhead of MR^{2}LAR is observed as 21.5320 while it is observed as 28.3640, 30.5770, and 35.6420 for

Received: February 18, 2024. Revised: April 24, 2024.

conventional methods such as EAMO-LAR, EALAR - PSO, and P-LAR respectively.

4.2.2 Route discovery delay

Route Discovery Delay (RDD) is the time taken to perform route discovery between set of node pair. Let the time instance t_1 is the packet arrival time at the destination and time instance t_2 is the packet departure time at the source, the RDD is given by $(t_2 - t_1)$. It must be minimum for efficient communication and it is achieved when there are less number of intermediate nodes. Here, we examine the performance of MR^{2}LAR through RDD by varying node speed and transmission range. Fig. 9 Shows the measured RDD with varying node speed from 5m/s to 30m/s. From Fig. 9, we observe that as speed of the mobile node increases the delay also increases. When node speed increases, the locations of node changes rapidly and it results into link breakages or route failures. In such aspects, the source node searches for new route to transfer the packets and it leads to more RDD. From the observations, the proposed mechanism attains less delay than remaining methods due to adaptive RZ. Further, the P-LAR method's RDD is higher than all approaches due to its larger sides RZ. Whereas, the remaining mechanisms such as EALAR - PSO, and EAMO-LAR, the RDD is observed as lesser than P-LAR and more than MR^{2}LAR due to a greater number of intermediate nodes. On an average, the proposed MR^{2}LAR mechanism is observed as 268msec while for existing approaches such as EAMO-LAR, EALAR - PSO, and P-LAR is observed as 282msec, 300msec, and 345msec respectively.

Fig. 10 shows measured RDD for varying transmission range of mobile nodes. As transmission range increases the delay decreasing due to its large coverage. As communication range is larger, the source node able to communicate directly with the destination node with less number of intermediate nodes. In such cases, the RDD is less and route can be established between the source and destination nodes with less number of nodes. Moreover, there is no possibility of rebroadcasting for multiple times at each intermediate node. In conventional LAR, the RZ size is large and it can broadcast control packets multiple times and the request packet get received at destination node with delay. However, the EALAR authors' assumption that a mobile node's communication range increases with its mobility but it is not a valid solution. Because a node's ability to communicate is static and entirely reliant on the availability of its energy supplies. Lastly, with the EAMO-LAR, the derived request zone also suffered

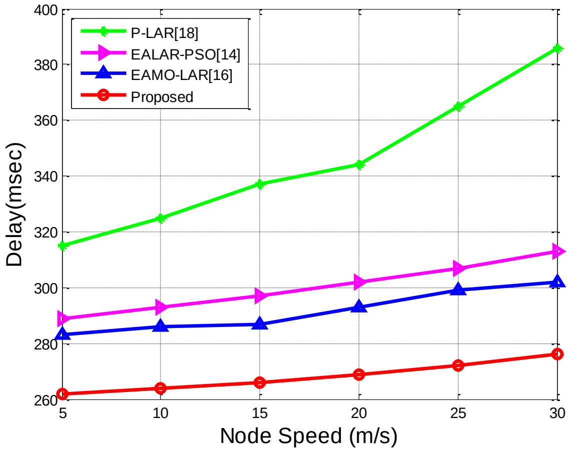

Figure. 9 RDD (msec) for different node speeds

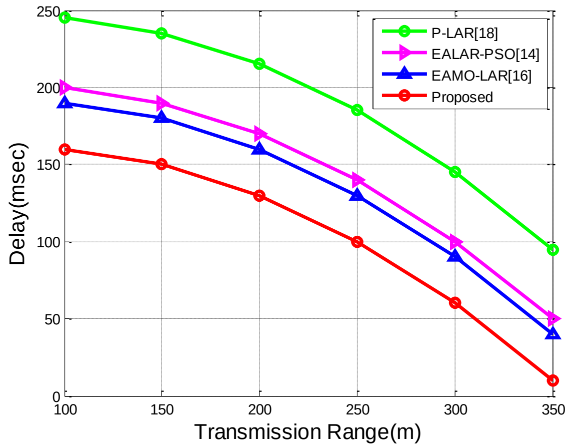

Figure. 10 RDD (msec) for varying Transmission range

a slightly higher RDD because it is not directly associated with the node's communication range. Therefore, among all the conventional methods the proposed method achieves less RDD. On an average, the RDD for MR^{2}LAR is observed as 100msec while it is observed as 130msec, 145msec, and 186msec for conventional methods such as EAMO-LAR, EALAR - PSO, and P-LAR respectively.

4.2.3 Packet delivery ratio

One more efficient parameter called as Packet Delivery Ratio (PDR) is considered to examine the proposed method's performance and the larger value of PDR represents high QoS. PDR is defined as the ratio of number of packets received at the destination (N_{p_r}) to the number packets sent at the source (N_{p_s}) and it is given by N_{p_r}/N_{p_s}. Fig. 11 explores the PDR for varying node speeds from 5 m/sec to 30 m/sec. From the results, we observe that as node speed increases the PDR decreases. When the speed of the node increases, it experiences more link breakages

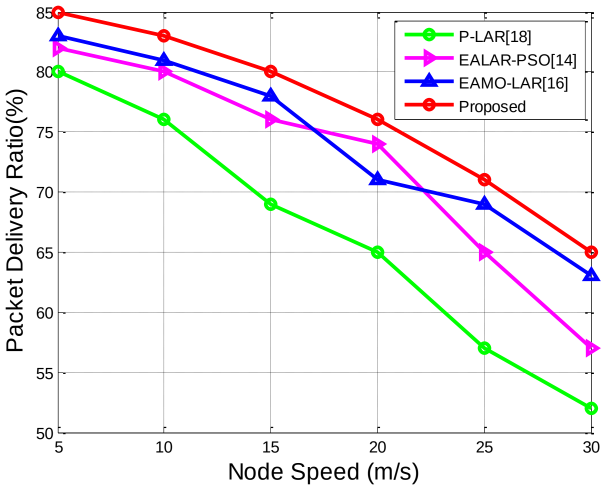

Figure. 11 PDR for varying node speed

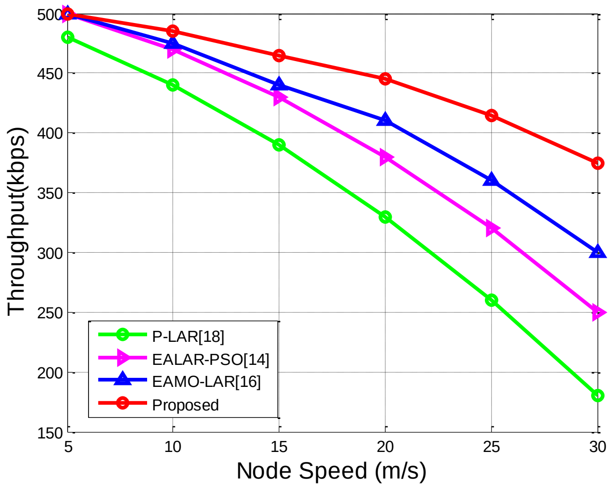

Figure. 12 Throughput (kbps) for varying node speed

and it results into drop of the packets and hence reduced PDR.

When, the source node experiences any link breakage then it needs to discover new path again to deliver the packets. So, as speed of the node increases the number of packets delivered within the specified time decreases due to more link breakages.

From the results as shown in the Fig. 11, the PDR of conventional LAR is less as it consumes more time to discover the route in the case of root failure. Compared to all the methods, the proposed MR^{2}LAR mechanism results in high PDR due to its adaptive RZ. In the MR^{2}LAR, the obtained RZ follows the accurate location information of source and destinations and can establish the route quickly in the case of route failures even at higher node speeds. On an average, the PDR for MR^{2}LAR is observed as 76.6780% while it is observed as 72.5180%, 70.2140%, and 62.3520% for conventional methods such as EAMO-LAR, EALAR - PSO, and P-LAR respectively.

4.2.4 Throughput

Throughput is considered as one of the important QoS metrics and it is evaluated for all the methods to examine the performance. In general, throughput is the ratio of number of packets received at the destination to the total time and the larger time periods takes less throughput. From the results as shown in the Fig. 12, we observe that as node speed increasing throughput decreasing. Here, the proposed method's throughput is higher than all existing methods throughput due to its adaptive RZ. As we know that the proposed method's RDD is less when speed of the node increases and it results in higher throughput. If there are less number of link failures, the data packets are delivered within less time.

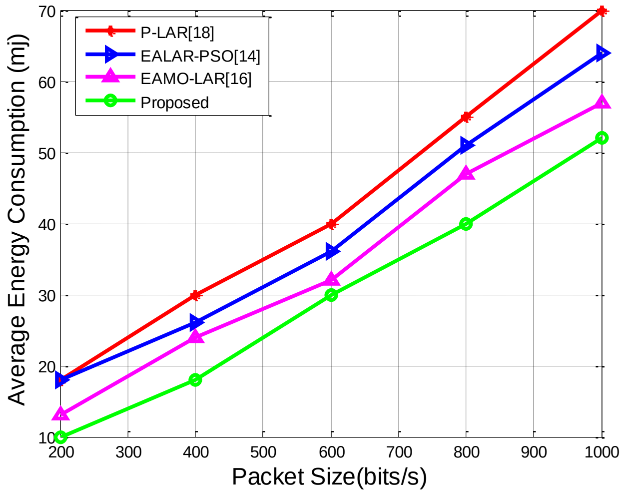

Figure. 13 Average Energy consumption with varying packet size

Whereas, the conventional methods such as P-LAR, EALAR - PSO and EAMO - LAR experienced higher RDD and its throughput is less. Moreover, the EALAR - PSO and EAMO - LAR don't follow the characteristics of the communication range and hence they experienced a lesser throughput than the proposed method. On an average, the throughput for MR^{2}LAR is observed as 447.5000 Kbps while it is observed as 412.6300 Kbps, 391.5200 Kbps, and 345.6200 Kbps for conventional methods such as EAMO-LAR, EALAR - PSO, and P-LAR respectively. Under this case study, the packet size is varied from 200 bits/sec to 1000 bits/sec. In general, as the packet size increases, the nodes have to spend more resources to forward the packets to their next hop nodes because larger sized data requires larger resources. Hence the energy consumption rises with a rise in the data rate, as shown in Fig. 13. However, with an appropriate selection of next-hop nodes, the energy consumption can be controlled. The proposed approach reduces the node count in the request zone and hence, the multiple hop based data transmission decreases in turn reduces the energy consumption at each node. The average energy consumption of proposed approach is observed as 30mj while at the existing methods, it is observed as 34.60mj, 39.00mj and 42.60mj at EAMO-LAR, EALAR-PSO and P_LAR respectively.

5. Conclusion

In this paper, a new LAR strategy MR^2LAR is proposed to control the routing overhead in MANETs during the route discovery process. The proposed method concentrated on to reduce the flooding of RREQ packets by determining small sized rectangular shaped request zones. According to the proposed method, the adaptive request zone is formed by source node between the source and destination nodes which consist of optimal number of intermediate nodes. Further, these nodes are eligible for rebroadcasting the packets. Even though, node have mobility the source determines adaptive request zone using proposed mechanism and controls the flooding of control packets. To examine the performance of proposed mechanism, we conducted few experiments based on varying transmission range and node speed. Approximately, an average routing overhead for MR^2LAR method is 26.8333 packets whereas for P-LAR is 48.2000 packets for each 100 packets. Next, RDD for MR^2LAR is 165msec whereas it is 255msec for LAR. Hence, the obtained results have been shown that the superiority of proposed method compared to state-of-the art methods in the reduction of control overhead.

Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

The paper conceptualization, methodology, software, validation have been done by all authors, formal analysis, investigation, resources, data curation, writing-original draft preparation, writing-review editing and visualization, have been done by 2nd and 3rd authors. writing— review and editing have been done by author 2. The supervision and project administration have been done by 2nd, 3rd authors.

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Received: February 18, 2024. Revised: April 24, 2024.

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