Journal of Applied Sciences

ISSN 1812-5654

science alert

ANSInet
an open access publisher
http://ansinet.com

OPEN ACCESS Journal of Applied Sciences

ISSN 1812-5654
DOI: 10.3923/jas.2017.126.134

Research Article
Smart Selection of Candidate Neighbors for Efficient Route Discovery in MANETs

[1]Sofian Hamad, [1]Salem Belhaj and [2]Muhana M. Muslam

[1]College of Science, Northern Border University, Arar, Saudi Arabia
[2]College of Computer and Information Science, Al-Imam Muhammad Ibn Saud Islamic University, Riyadh, Saudi Arabia

Abstract

Background: In most reactive routing protocols, the discovery process for any dictation starts by sending a RREQ (Route request) to neighboring nodes. Then, the intermediate nodes will rebroadcast the RREQ until the destination is found. **Objective:** In this study, new techniques have been suggested to reduce the broadcast of the RREQ packets in the network, when the reactive routing protocols are used. These techniques are Closest Candidate Neighbors for Rebroadcasting the RREQ (C-CNRR) and Furthest Candidate Neighbors for Rebroadcasting the RREQ (F-CNRR). **Methodology:** The key concept behind these two routing protocols is to divide the transmission range for each node that needs to find a path to a specific destination to four equal zones. Then, if no route is found in its routing table, one node per zone will be smartly selected to rebroadcast the received RREQ. **Results:** The simulation results show that in term of overhead, the C-CNRR and F-CNRR have better performance than the traditional *ad hoc* on-demand distance vector (AODV) routing protocol. **Conclusion:** Furthermore, reducing the overhead by more than 15% with our proposed techniques is reflected in an increase in the network throughput and a diminishing of data dropping.

Key words: MANETs, route discovery, position-based routing, forwarding RREQ, reactive routing protocols, candidate neighbors selection

Received: September 20, 2016 Accepted: December 28, 2016 Published: February 15, 2017

Citation: Sofian Hamad, Salem Belhaj and Muhana M. Muslam, 2017. Smart selection of candidate neighbors for efficient route discovery in MANETs. J. Applied Sci., 17: 126-134.

Corresponding Author: Sofian Hamad, College of Science, Northern Border University, Arar, Saudi Arabia

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In recent years, mobile *ad hoc* networks (MANETs) have been extensively studied in the literature due to their success in both civil and military applications[1,2]. These infrastructure-less networks are formed autonomously by mobile nodes connected via *ad hoc* links, which means that no predefined infrastructure is used[3]. The nodes are free to move randomly and arbitrarily in a self-organized manner, thus, the wireless network topology evolution fluctuates hastily and arbitrarily. *Ad hoc* mobile nodes play a double role as data-generating/receiving entities and as relay routers to forward packets to other nodes in a wireless multi-hop environment. One of the most challenging issues for MANETs is how to design an efficient dynamic routing protocol that is capable of discovering an end-to-end (e2e) route between nodes, particularly in multi-hop scenarios[3]. Overall, for MANETs, the topological routing protocols may be categorized into three distinctive groups, namely, hybrid, on-demand/reactive and proactive routing protocols[4]. The Destination Sequenced Distance Vector (DSDV)[5], Topology Dissemination Based on Reverse-Path Forwarding (TBRPF)[6] and Optimized Link State Routing (OLSR)[7] are all examples of proactive routing protocols. These are intended to ensure each node has current routing information tables that target each potential destination in the network, this is achieved by regularly exchange routing table data. In such protocols, any network changes induce the propagation of nodes update messages, which subsequently results in more overhead and consequently increases the misuse of the available bandwidth. In contrast, when considering on-demand routing protocols including, for example, the *ad hoc* on-demand distance vector (AODV)[8] and the Dynamic Source Routing (DSR)[9], there is a unique route discovery when and where it is deemed necessary. This means the routing overhead is decreased in reactive routing protocols because the information is sustained only for active routes. The features of the two aforementioned protocol types can be combined to form hybrid routing protocols, such as the Zone Routing Protocol (ZRP)[10].

In the traditional reactive routing protocols[8,9] such as AODV, when the mobile node needs to discover a route to a specific destination, it broadcasts a route request packet (RREQ). Then, the entire neighboring node will receive this request. The neighboring nodes check whether this RREQ has been received before and if so, the RREQ will be discarded. Otherwise, the node will examine its routing table and search for the specific destination attached to the RREQ. In the case that no route to the intended destination is found, the node will rebroadcast the same RREQ. This process is repeated until the destination is found or any intermediate node has a valid path to the destination. In other routing protocols such as DSR, the intermediate nodes attach their address to the received RREQ before rebroadcasting it. Therefore, this mechanism of broadcasting the RREQ is applied to the most of the reactive routing protocols. This is a well-known phenomenon, referred to as broadcast storm[11]. It increases the e2e delays and overhead a lot, which leads to less available bandwidth[11,4].

Two routing protocols have been proposed in this study to enhance the route discovery process in the reactive routing protocol by eliminating the RREQ redundancy. Our suggested algorithms smartly select four candidate neighbors to rebroadcast the RREQs, while eliminating the other neighbor from rebroadcasting the RREQs. This mechanism results in better bandwidth utilization and decreases contention on the wireless channel.

MATERIALS AND METHODS

Related work: In recent years, many researches have tackled the broadcasting problem in MANETs and have suggested several methods. Some of these methods have used the concept of probability. Abdulai[12] and Hanashi *et al.*[13], the probability of rebroadcasting is dynamically adjusted for each node, based on its number of neighbors. A high probability to rebroadcast the RREQ is assigned to nodes with few neighbors. Whereas a low probability is assigned to nodes with more neighbors, assuming that their neighbors have already received the same RREQ. Other techniques exist in the literature[14-16], such as location-based approaches, which reduce the number of rebroadcasts by exploiting wireless network geo-location using position information for mobile *ad hoc* devices, such as GPS receivers[17]. Moreover, to resolve the broadcast problem at the physical layer, two methods can be considered. The first is the one-to-all model and the second is the one-to-one model. In the first model, each node transmission is received by all other nodes within its transmission range, whereas, in the second model, every node transmission is received by only one neighbor, using narrow beam directional antennas or separate frequencies[18]. Nevertheless, most of the previous studies refer to the one-to-all model[19], this is mainly for a practical reason. In fact, most of the current mobile devices are often equipped with Omni-directional antennas, which propagate and receive signals in all directions.

Zhang *et al.*[20] use the estimated distance (EstD), which is a combination of the estimated topological distance and the estimated geometrical distance, to restrict the propagation range of the RREQ, in order to reduce the routing overhead in EDRP. They also used the EstD to split the network domain into three partitions, in which a different strategy for forwarding the RREQ is applied. Also, other researchers have proposed Preemptive Local Repairing Mechanism (PLRM)[21] to be used in wireless sensor networks. They monitor the link quality along the path between the source and the destination. Li *et al.*[22], suggested NER-DRP routing protocol, which is based on the epidemic routing and network layer error recovery method. Liu *et al.*[23], presented EMRP routing protocol, which is based on combining the prediction of the node mobility and residual energy state. Li *et al.*[24] proposed Global Ferry Scheme (GFS), which is based on the minimization of the average message delivery delay. Li *et al.*[25], suggested E-PROPHET routing protocol, which ensure the forwarding of message to accurate next hope.

This study is a development of our previous study[26], which considered only the F-CNRR. In this study, the F-CNRR by introducing the concept of the parameter β was improved, which defines a dead area in each zone, whereby no node will be selected from that area. Besides, the C-CNRR protocol was suggested, where the closest node to each zone will be chosen as a candidate neighbor.

Candidate neighbors to rebroadcast the RREQ: The concepts behind the suggested routing protocols are as follow, the transmission range of each active node is divided into four equal zones. Then, one node per zone will be selected and will be uniquely concerned by the re broadcast of the RREQ. The node selection process for each zone is based on its distance from the source node. Once selected, the RREQs are unicast to only the pre-selected nodes. Then, this process is reiterated for all the involved nodes until the destination is reached.

In order to find a path between the transmitter node "S" and the destination one "D", which must not be part of "S" routing table, the initiation process of the RREQ packet starts by partitioning the radio transmission range of "S" into four zones. Then, one node per zone should be smartly selected for the retransmission of the RREQ.

Two approaches have been suggested to enhance the route discovery process, which will be presented in this study.

Furthest candidate neighbors: Regarding this approach, the farthest candidate neighbors selection for RREQ rebroadcasting is handled by the active node, i.e., the one who wants to initiate or to continue the path discovery process by re broadcasting the RREQ packets. From now on, to make simple, the active node is denoted by the forwarding node 'X'.

As illustrated by Fig. 1, the suggested route discovery protocol proceeds as follows: each node "X" starts by partitioning its transmission range into four sub zones "Z". Then, each neighbor will belong to one of these zones from the forwarding node "X" prospective.

According to Algorithm 1, it splits the area around the 'X' node into four separated sub-zones: $Z = \{Z_1, Z_2, Z_3 \text{ and } Z_4\}$. Let R_{tx} represent the "X"-node transmission range and let "N" be the set of all its neighbor nodes $N = \{N_1, N_2, N_3, ..., N_{|n|}\}$ are set of neighboring nodes that lies within R_{tx}.

Algorithm 1: Transmission range partition of the forwarder node (or 'X'-node)

Input: Set of nodes $N = \{n_1, n_2, n_3, ..., n_{|N|}\}$ belong to transmission range of Sender S

Output: Partition Sender S' Neighbors into set of four separate zones Z = {Z1, Z2, Z3, Z4}

```
for i = 1 to |N|
    If $n[i]_x \geq S_x$ and $n[i]y \geq S_y$
        $n[i] \in Z_1$
    else if $n[i]_x < S_x$ and $n[i]_y \geq S_y$
        $n[i] \in Z_2$
    else if $n[i]_x \leq S_x$ and $n[i]_y > S_y$
        $n[i] \in Z3$
    else if $n[i]_x \leq S_x$ and $n[i]_y < S_y$
        $n[i] \in Z_4$
    end if
next I
```

Where, S_x determines the x-axis position of the node in the network area
And S_y determines the y-axis position of the node in the network area

As output, each neighbor node is localized in one of these sub-zones "Zn". The "X" node compares its own position with the neighbor node coordinates to place it in the appropriate zone. This approach is continued until the last node in the transmission range is reached (Algorithm 1). Then, Algorithm 2 will be invoked to perform the next step, which is dividing, once again, each zone, Z_n, into two sub-zones. The first zone will consider all the neighbors that fall within β; where β = 80% of "Z" areas (the distance between the forwarder "X" and the neighbor will be less or equal to the 80% of the "X" transmission range, as described in Fig. 1). Therefore, all the neighbors in this area will form the Candidate List (CL). In the second zone, all the neighbors will be excluded from the selection of the candidate list. Equation 1 is used for building the neighboring CL belonging to by calculating the distances between "X" and neighboring nodes for each zone (Zn):

Fig. 1: Farthest candidate nodes selection to rebroadcast the RREQ

$$\text{Distance (X, N)} = \sqrt{(X_x - N_x)^2 + (X_y - N_y)^2} \quad (1)$$

Algorithm 2 selects nodes as the Candidate List (CL) for each zone (Zn) shown in Fig. 1 as an inner circle. Then, Algorithm 3 calculates and compares the distances between the "X"-node and all the others and chooses the farthest one for each CL as the next forwarding node (A, B, C and D, as described in Fig. 1). Finally, the algorithm inserts an array of four fields (32-bits length each one) to hold the IP addresses of the last four candidate neighbors (A, B, C and D) into the CNRR field of the modified RREQ packet (Fig. 2). Then, the forwarding node "X" sends the modified RREQ packet.

Algorithm 2: Candidate list selection for each zone

Algorithm 2

Input:

Distance (S, N) = $\sqrt{(S_x - N_x)^2 + (S_y - N_y)^2}$,

β = 80% distance of source node S' transmission range

Output: Selection of the set Candidate Lists (CL) in each zone, Z = {Z_1, Z_2 , Z_3, Z_4}

```
for I = 1 to 4
        While (n∈z_i)
        if D (S, n) = ≤β
            CL = CL U {n}
        end if
        Do
next i
```

<table>
<tr><td>Type</td><td>J</td><td>R</td><td>G</td><td>D</td><td>U</td><td>Reserved</td><td>Hop count</td></tr>
<tr><td colspan="8">RREQ ID</td></tr>
<tr><td colspan="8">Destination IP address</td></tr>
<tr><td colspan="8">Destination sequence number</td></tr>
<tr><td colspan="8">Originator IP address</td></tr>
<tr><td colspan="8">Originator IP sequence number</td></tr>
<tr><td colspan="8">CCNR IP addresses</td></tr>
</table>

Fig. 2: Modified RREQ packet

Once RREQ has been received, each node verifies if the CNRR field contains its own IP address. If so, the active node (A, B, C or D, as presented in Fig. 1) continues the process as the next forwarding node "X" and rebroadcasts the RREQ in accordance with the F-CNRR protocol. If not, the RREQ will be discarded.

For instance, as shown in Fig. 1, when the forwarding node "X" sends the RREQ message, it includes the addresses of A, B, C and D in the CNRR field of the modified RREQ message. Then, only those nodes are able to process this RREQ further and all the other neighboring nodes will discard this RREQ.

Algorithm 3: Candidate nodes selection for each CL of each zone

Algorithm 3

Input: Z = {Z_1, Z_2 , Z_3, Z_4 }, CL = {n_1, n_2, ..., $n_{|CL|}$} in each zone

Output: Candidate nodes in each zone

```
        for i = 1 to 4
            for j = 1 to |CL|∈Z_i
//calculate the distances of each node in candidate
list from the source node calculate D (S, n_j)
            next j
//select the candidate node in the Candidate
```

```
List in the current Zone based on the maximum distance from the source
4.      for k = 1 to |CL|
5.          if $D (S, n_k) > D (S, n_k+1)$
6.              candidate node = $n_k$
7.          else
8.              candidate node = $n_k+1$
9.          end if
10.     next k
11. next i
```

Closest candidate neighbors: All the intermediate nodes involved in a link between the source and the destination nodes should remain available, so the link will be valid to carry any data from/to the source and destination. Otherwise any intermediate node fails, result in the link failure. The F-CNRR selects the farthest nodes from the forwarder node "X" to rebroadcast the RREQ. This means that all the intermediate nodes will be far from the forwarder node "X" that creating interference, collision and decreasing the channel capacity. All of this may cause link failure.

To overcome this issue, another mechanism is described in this study based on the closest candidate neighbors for RREQ rebroadcasting (C-CNRR).

In this approach, Algorithm 1 is reused to create the four zones "Zn". Then, Algorithm 2 will be used to build the CL for each zone by excluding all nodes belonging to the inner circle (Fig. 3), where $\beta = <20\%$ of the zone's area. In this case and to fit the requirements, line 3 in Algorithm 2 needs to be replaced by:

"if $D (S, n)>\beta$"

Furthermore, when the CL of the nodes is ready, Algorithm 3 calculates and compares the distances between the "X" node and all the other nodes in the CL. Then, it chooses, for each zone, the closest node as the next forwarding node (A, B, C and D). Similar to Algorithm 2, line 5 in Algorithm 3 must be replaced by:

"if $D (S, n_k) <D (S, n_k+1)$"

RESULTS AND DISCUSSION

Network Simulator-2 (NS-2)^{23} based simulations are conducted in order to evaluate the performance of the

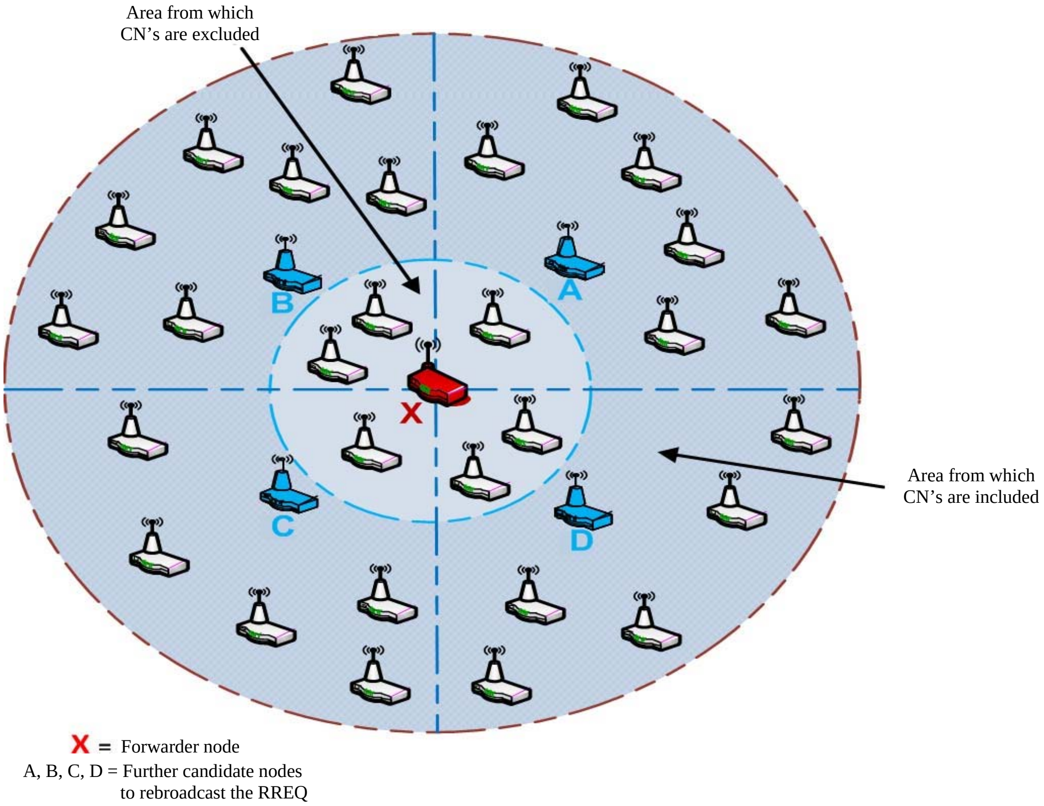

Fig. 3: Closest candidate nodes selection to rebroadcast the RREQ packet

suggested protocols, C-CNRR and F-CNRR. Many sets of experiments are performed. Only relevant examples are presented in this study.

Simulation environment: For the simulation setup environment, the Distributed Coordination Function (DCF)[27] was executed as the access mechanism on the IEEE 802.11 MAC layer. The transmission range of nodes was set to 250 m and the link bandwidth was set to 2 Mbps. To evaluate the network performance, 100 mobile nodes were randomly placed in a 600×600 m area. The random waypoint model[26] was selected as the mobility model, whereby any mobile node in the network starts moving from its current location to a random location with a random speed chosen within the interval (5 and 30 m h^{-1}). All tests used the same fixed packet size of 1 kb, generated at a constant interval rate of 5 packets sec^{-1} using Constant Bit Rate (CBR) as the flow type. Therefore, 20 flows were planned to randomly select a source and a destination over the simulation period, which was fixed a 500 sec. At the end of the simulation, the average results were collected, plotted and discussed.

The proposed routing protocols will enhance the network performance and solve the problems associated with redundant RREQs during the discovery process. In fact, the performance of both suggested protocols C-CNRR and F-CNRR has been deeply analyzed and compared with those of the on-demand routing protocols such as AODV and DSR[9].

Packets drop: The packet drop rates comparison between the F-CNRR[22], C-CNRR and AODV[8] routing protocols (Fig. 4). It can be seen that, the data drop rates in the AODV is more than in both protocols F-CNRR and C-CNRR, which implies that both protocols have more efficient flooding mechanisms than the AODV.

Moreover, C-CNRR presents a better performance than F-CNRR, because the e2e path chosen by C-CNRR concerns only the closest nodes, thereby improving channel quality. The e2e path chosen by the F-CNRR, on the other hand, concerns only the farthest nodes, thereby increasing the chances of collisions and errors, which increase the data drop.

Throughput: The total throughput associated to different simulated protocols (Fig. 5). It can be seen, as the mobility of a node increases, the total throughput decreases. More generally, a discontinuity to already established routes may be caused by the mobility of nodes and may make some destinations unreachable, which results in the discovery of a new route.

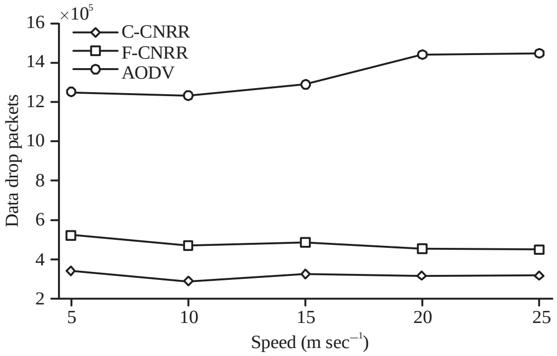

Fig. 4: Packets drop vs., speed

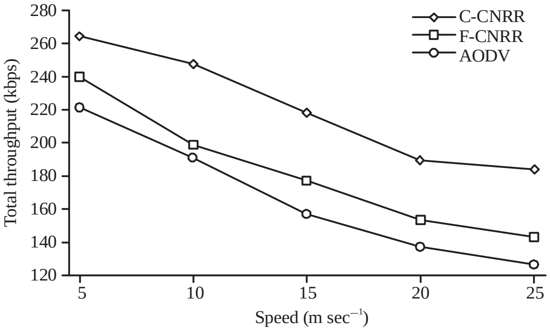

Fig. 5: Throughput (kb sec^{-1}) vs., speed

The rebroadcasting reduction in the C-CNRR leads to improvement in its throughput, which offers a higher probability of real data to be transmitted, rather than rebroadcasting the unnecessary RREQ. The F-CNRR rebroadcasts more RREQs than C-CNRR because when farther nodes are chosen as candidate neighbors, the links of most likely paths are unavailable or weaker due to being at farther distance from the source/forwarding node. On the other hand, when candidate nodes are chosen, the same as in the case of C-CNRR, these are at a shorter and more appropriate distance from the source/forwarding node. Fewer rebroadcasts involve less bandwidth consumption by redundant RREQs. Moreover, fewer rebroadcasts may evenly reduce collisions and competitions between nodes accessing the shared link.

Delay: For each packet, the average calculated time-delay from the sending of a packet to its reception has been recorded to illustrate the total e2e delay (Fig. 6). The e2e delay result broke the principle that C-CNRR has a better performance in most metrics. For routing protocols in MANETs, the available bandwidth is not a fundamental decision parameter and choosing the e2e path is merely based on the hop-count.

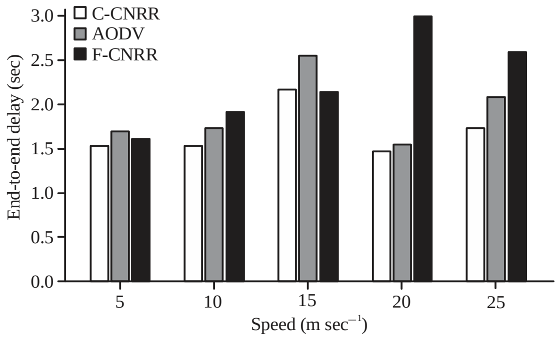

Fig. 6: Total end-to-end delay vs., Speed

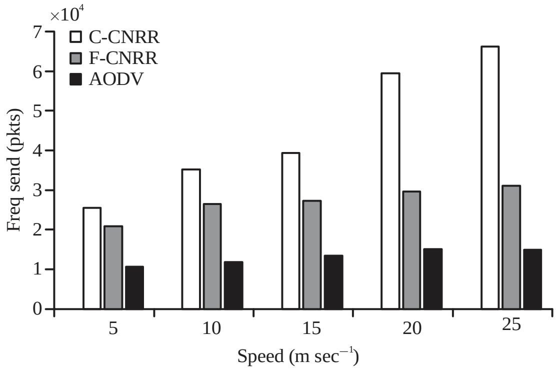

Fig. 7: Number of rebroadcast RREQs vs., speed

Choosing a routing path with few hop-counts can promote quick delivery of packets. From Fig. 6, it can plainly be seen that F-CNRR has a lower e2e delay compared to AODV and C-CNRR protocols. In fact, F-CCNR takes on the farthest forwarder nodes to rebroadcast RREQ packets and establishes an e2e route with a lower hop-count than those of the C-CNRR and AODV protocols. Ultimately, this leads to less time delay overall in the network.

In AODV, on the other hand, the e2e route is chosen randomly from both the closest nodes and the furthest nodes. This is why C-CNRR performs better in some cases than AODV and vice versa. The conclusion derived from the e2e delay results is that the F-CNRR protocol is the best choice out of the three routing protocols for delay-sensitive applications, such as video and audio streaming[1] where the delay is not an issue.

RREQ rebroadcasts: In C-CNRR and F-CNRR, every node determines whether to rebroadcast a RREQ or not in compliance with the proposed algorithms, while sustaining the intended reachability and connectivity level.

Therefore, a node that runs such routing protocols will definitely perform better than a node running AODV, because it rebroadcasts a fewer number of RREQ packets which reduce the contention on the wireless channels[4].

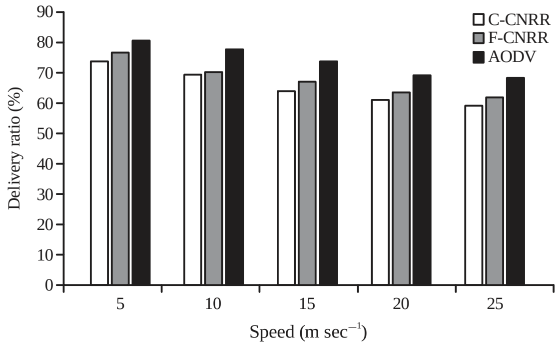

Fig. 8: Packet delivery ratio vs., speed

As illustrated by Fig. 7, with the high mobility of nodes, there are more route requests generated, particularly in the case of the AODV routing protocol. The e2e route created by C-CNRR will last longer than those created by both protocols AODV and F-CNRR. This is owing to the C-CNRR algorithm, which creates a route among the closest nodes, leading to less route discoveries as a result of less link failures, which in turn leads to fewer RREQ packets spread over the network to find out an alternate e2e route.

Packet delivery ratio: Figure 8 illustrates the performance comparison in terms of packet delivery ratios among the three protocols under study. The C-CNRR and F-CNRR perform better than AODV for all simulated scenarios using the NS-2[28].

This is due to the nodes' mobility, which makes both protocols update the positions of the nodes by exchanging hello messages and the four candidate nodes in the CNRR field are updated consequently. The AODV protocol, on the other hand, establishes e2e paths without prior knowledge of neighbors' positions and, as a result, all the nodes rebroadcast the RREQ, which leads to redundant RREQ packets. The RREQs' redundancy affects the network performance in terms of overhead, bandwidth, throughput, packet delivery ratio and delays.

CONCLUSION

The researchers proposed an improvement to the reactive routing algorithm that are, F-CNRR and C-CNRR. These mechanisms improve the utilization of the available bandwidth and reduce the contention on the wireless channel. Both suggested protocols achieved comparatively significant performance enhancements in terms of packet delivery ratio, number of RREQs, delay and throughput. Better network performances are achieved by preventing unnecessary RREQ packets from being disseminated in the network.

SIGNIFICANCE STATEMENTS

This study focuses on the flooding performance of reactive routing protocols such as AODV. Two routing protocols are suggested in on-demand routing protocols that initiate the RREQ process to find the route to a destination. The basic idea behind these two routing protocols is to smartly select four candidate neighbors to rebroadcast RREQs while preventing other nodes from performing unnecessary levels of rebroadcasting. Network Simulator-2 (NS-2) has been used to simulate the proposed routing protocols under different network environments and levels of mobility. Both suggested protocols achieved significant performance enhancements in terms of packet delivery ratio, overhead, number of RREQs and throughput.

ACKNOWLEDGMENT

Financial support for this study was provided by deanship of Scientific Research, Northern Border University under grant No. 5/1436/22/5.

REFERENCES

1. Akyildiz, I.F., X. Wang and W. Wang, 2005. Wireless mesh networks: A survey. Comput. Networks, 47: 445-487.
2. Benyamina, D., A. Hafid and M. Gendreau, 2012. Wireless mesh networks design-a survey. IEEE Commun. Surv. Tutorials, 14: 299-310.
3. Abdulai, J., M. Ould-Khaoua and L.M. Mackenzie, 2007. Improving probabilistic route discovery in mobile ad hoc networks. Proceedings of the 32nd IEEE Conference on Local Computer Networks, October 15-18, 2007, Dublin, Ireland, pp: 739-739.
4. Tseng, Y.C., S.Y. Ni and E.Y. Shih, 2003. Adaptive approaches to relieving broadcast storms in a wireless multihop mobile Ad hoc network. IEEE Trans. Comput., 52: 545-557.
5. Perkins, C.E. and P. Bhagwat, 1994. Highly dynamic destination-sequenced distance-vector routing (DSDV) for mobile computers. ACM SIGCOMM Comput. Commun. Rev., 24: 234-244.
6. Ogier, R., F. Templin and M. Lewis, 2004. Topology dissemination based on reverse-path forwarding (TBRPF). Network Working Group, February 2004. https://www.rfc-editor.org/info/rfc3684
7. Jacquet, P. and P. Muhlethaler, 2003. Optimized Link State Routing Protocol (OLSR). The Internet Society. https://www.rfc-editor.org/rfc/pdfrfc/rfc3626.txt.pdf
8. Das, S., C. Perkins and E. Royer, 2002. Ad hoc on demand distance vector (AODV) routing. Mobile *ad hoc* Network (MANET) Working Group, IETF, 2002.
9. Johnson, D.B., D.A. Maltz and J. Broch, 2001. DSR: The Dynamic Source Routing Protocol for Multi-Hop Wireless Ad Hoc Networks. In: Ad Hoc Networking, Perkins, C.E. (Ed.). Addison-Wesley, New York, USA., pp: 139-172.
10. Haas, Z.J., M.R. Pearlman and P. Samar, 2002. The Zone Routing Protocol (ZRP) for ad hoc networks. IETF Internet Draft, July 2002. https://tools.ietf.org/id/draft-ietf-manet-zone-zrp-04.txt
11. Tseng, S.C., S.Y. Ni, Y.S. Chen and J.P. Sheu, 2002. The broadcast storm problem in a mobile ad hoc network. Wireless Networks, 8: 153-167.
12. Abdulai, J.D., 2009. Probabilistic route discovery for wireless mobile ad hoc networks (MANETs). Ph.D. Thesis, University of Glasgow, Scotland.
13. Hanashi, A.M., A. Siddique, I. Awan and M. Woodward, 2009. Performance evaluation of dynamic probabilistic broadcasting for flooding in mobile ad hoc networks. Simul. Modell. Pract. Theory, 17: 364-375.
14. Basagni, S., I. Chlamtac and V.R. Syrotiuk, 1999. Dynamic source routing for ad hoc networks using the global positioning system. Proceedings of the IEEE Wireless Communications and Networking Conference, September 21-24, 1999, New Orleans, LA., USA., pp: 301-305.
15. Abolhasan, M., T. Wysocki and E. Dutkiewicz, 2004. A review of routing protocols for mobile ad hoc networks. Ad Hoc Networks, 2: 1-22.
16. Kuiper, E. and S. Nadjm-Tehrani, 2011. Geographical routing with location service in intermittently connected MANETs. IEEE Trans. Veh. Technol., 60: 592-604.
17. Kaplan, E.D. and C.J. Hegarty, 2006. Understanding GPS: Principles and Applications. 2nd Edn., Artech House, Inc. USA., ISBN: 1-58053-894-2006.
18. Nasipuri, A., J. Mandava, H. Manchala and R.E. Hiromoto, 2000. On-demand routing using directional antennas in mobile ad hoc networks. Proceedings of the IEEE 9th International Conference on Computer Communication and Networks, October 18, 2000, Las-Vegas, Nevada, pp: 535-541.
19. Wu, J. and F. Dai, 2003. Broadcasting in ad hoc networks based on self-pruning. Int. J. Found. Comput. Sci., 14: 201-221.
20. Zhang, X.M., E.B. Wang, J.J. Xia and D.K. Sung, 2011. An estimated distance-based routing protocol for mobile ad hoc networks. IEEE Trans. Veh. Technol., 60: 3473-3484.
21. Zhang, Z., Z. Li and J. Chen, 2014. An enhanced AODV route repairing mechanism in wireless *ad hoc* sensor network. J. Commun., 9: 651-657.
22. Li, Y., Z. Wang, X. You, Q.L. Liu and W. Zhang, 2012. NER-DRP: Dissemination-based routing protocol with network-layer error control for intermittently connected mobile networks. Mobile Networks Applic., 17: 618-628.
23. Liu, Z., R. Wang, Q. Liu, Y. Li, Q. Chen and P. Wang, 2009. An energy-constrained routing protocol for mobile *ad hoc* networks. Proceedings of the International Conference on Communication Software and Networks, February 27-28, 2009, Macau, China.

24. Li, Y., B. Weng, Q. Liu, L. Tang and M. Daneshmand, 2011. Multiple ferry routing for the opportunistic networks. Proceedings of the IEEE Global Telecommunications Conference, December 5-9, 2011, Houston, TX.
25. Li, Y., X. Li, Q. Liu and Z. Liu, 2009. E-PROPHET: A novel routing protocol for intermittently connected wireless networks. Proceedings of the 2009 International Conference on Wireless Communications and Mobile Computing: Connecting the World Wirelessly, June 21-24, 2009, Leipzig, Germany, pp: 452-456.
26. Hamad, S., H. Noureddine, N. Radhi, I. Shah and H. Al-Raweshidy, 2011. Efficient flooding based on node position for mobile ad hoc network. Proceedings of the 2011 International Conference on Innovations in Information Technology, April 25-27, 2011, Abu Dhabi, UAE., pp: 162-162.
27. Bianchi, G., 2000. Performance analysis of the IEEE 802.11 distributed coordination function. IEEE J. Sel. Areas Commun., 18: 535-547.
28. Anonymous, 2015. The network simulator-ns-2. November 2015. http://www.isi.edu/nsnam/ns/