Neighbor-Based Probabilistic Rebroadcast Routing Protocol for Reducing Routing Overhead in Mobile Ad Hoc Networks

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Summary
In Mobile Ad-Hoc Network (MANET) Application, routing protocol is essential to ensure successful data transmission to all nodes. Ad-hoc On-demand Distance Vector (AODV) Protocol is a reactive routing protocol that is mostly used in MANET applications. However, the protocol causes Route Request (RREQ) message flooding issue due to the broadcasting method at the route request stage to find a path to a particular destination, where the RREQ will be rebroadcast if no Request Response (RREP) message is received. A scalable neighbor-based routing (SNBR) protocol was then proposed to overcome the issue. In the SNBR protocol, the RREQ message is only rebroadcast if the number of neighbor nodes less than a certain fix number, known as drop factor. However, since a network always have a dynamic characteristic with a dynamic number of neighbor nodes, the fix drop factor in SNBR protocol could not provide an optimal flooding problem solution in a low dense network environment, where the RREQ message is continuously rebroadcast RREQ message until reach the fix drop factor. To overcome this problem, a new broadcasting method as Dynamic SNBR (DSNBR) is proposed, where the drop factor is determined based on current number of neighbor nodes. This method rebroadcast the extra RREQ messages based on the determined dynamic drop factor. The performance of the proposed DSNBR is evaluated using NS2 and compared with the performance of the existing protocol; AODV and SNBR. Simulation results show that the new routing protocol reduces the routing request overhead, energy consumption, MAC Collision and enhances end-to-end delay, network coverage ratio as a result of reducing the extra route request messages.
Key words:
Routing Protocol, AODV, SNBR, DSNBR, MANET

1. Introduction

A Mobile ad hoc network (MANET) is a set of mobile nodes connected temporarily for a specific purpose, these devices, MANET's applications vary from daily use to military operations. MANET is also raised as an important technology to be combined with IoT application as stated in [1]-[3]. In MANET application, routing protocol is a crucial technique to ensure efficient data transmission from network layers to upper layer [4][5].

Routing protocols can be classified into three main categories: proactive, reactive, and hybrid. In the proactive routing protocol, the route for each packet is ready without any request for any route, such types of protocols consume nodes' critical resources such as energy and impose some processing method. This type of protocol is commonly used in the wired networks with low mobility. On the other hand, in the reactive routing protocol, the route for any packet is built when needed. This type of protocol is mainly used in wireless networks such as MANET due to its high mobility. While the third type of routing protocol is the hybrid routing protocol which is a combination of both types of routing protocols, namely reactive and proactive [6].

MANETs network uses reactive routing protocols due to the dynamic character of its nodes [7]-[9]. The most commonly reactive routing protocols are AODV [10][11] and SNBR [12][13]. AODV is a reactive routing protocol is designed to find the route between some nodes in a network with low overhead and high performance. However, this protocol still has some issues such as flooding issue due to extra RREQ messages. Therefore, SNBR is an enhanced version of AODV designed to relieve the routing overhead because of flooding, using the neighbor information, to decide whether or not to drop the RREQ received messages. Nevertheless, such protocol still has some drawbacks such as the fix drop factor value. In the SNBR protocol, at the route discovery stage, each node that receives an RREQ message will calculate the total number of neighbors' it has, based on its neighbor table, to take decision either to drop or to rebroadcast the RREQ message. In the case, the total number of neighbors is less than the prefixed drop factor value (fourteen neighbors), the RREQ will be rebroadcast, otherwise, it will drop such RREQ to avoid any extra overhead [12].

However, the performance of AODV protocol is better than SNBR in the case of the low number of nodes. Therefore, this research is predicted to improve network performance in low-density nodes by proposing a dynamic drop factor value in Dynamic SNBR (DSNBR). The proposed DSNBR also is expected to provide a better network performance for a high-density nodes environment by reducing the routing overhead because of route discovery stages.

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In this paper, a new routing protocol names as DSNBR that aims to relieve the RREQ message flooding in broadcasting process at the route request stage is proposed by introducing dynamic drop factor. The study focuses on the route request stage only, to reduce RREQ messages using simulation method DSNBR. The performance of the proposed protocol DSNBR is evaluated using the NS2 the simulation tool and compared the performance with existing protocols, AODV and SNBR.

2. Literature Survey

In recent years, wireless networks have received enormous demand from the end-users and attracted many researchers aiming to solve many issues to enhance the network performance. Moreover, the cost and mobility advantages of such a network have brought many research gaps in this field. MANET is a temporary network for a specific purpose, easy to configure. This network has been used in a varied number of applications from the military to rescue systems during crises such as earthquakes or wars where the infrastructure network is no longer available.
Nevertheless, such a network has some issues due to the high mobility of its nodes routing process became very difficult. One of the well-known issues in the AODV routing protocol is the flooding issue because of broadcasting at the route request stage. Even though the enhanced versions of this protocol such as NCPR, SNBR, and NCFP, are mainly designed to overcome such issues using the probability method, still there are some issues that need to be addressed. One of the main issues of the base work protocol (SNBR), is the controlled flooding because of sending unneeded broadcasting messages of RREQ, where the method still degrading the network performance as a consequence of selecting the number of neighbors nodes in the controlled flooding which is fourteen [12].

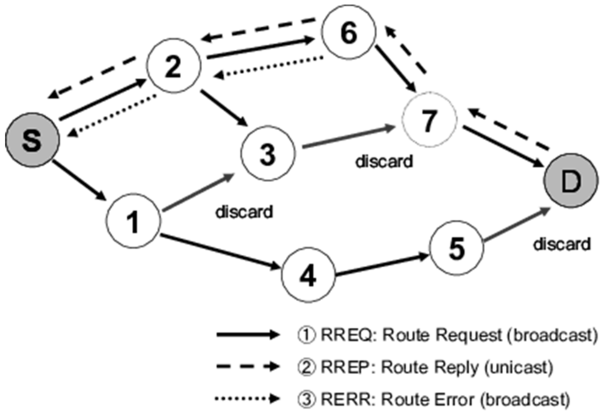

Figure 1 AODV Protocol Diagram

AODV is a reactive routing protocol design to find the route between some nodes in a network with low overhead and high performance, such protocol has three main messages as shown in Figure 1, which are RREQ, RREP, and route error RERR). For instance, in the AODV protocol at the route discovery stage, RREQ is broadcasted among nodes to find the route to a certain destination. When the sender doesn't receive any RREP, it considers the RREQ did not reach any node and will be discarded and dropped. Many of these messages are considered extra and can be dropped to improve network performance. The AODV algorithm is shown in Figure 2. Numerous routing protocols such as the AODV [10] and Dynamic Source Routing (DSR) [14] use broadcasting as a method to transfer messages between nodes. Even though the mechanism is easy, indispensable, and guarantees great reachability, it degrades the network performance due to flooding problem, as many unnecessary or duplicated messages are sent among nodes.

AODV Algorithm

At any Node
For every Received RREQ:
If the destination node is the node itself or has a route to it.
send RREP
Else
Rebroadcast or flood the RREQ to all neighbours.
End
Exit

Figure 2 AODV Algorithm Flow

To overcome flooding problem in AODV, SNBR Protocol is then proposed by Ejmaa [12], by mitigating the impact of broadcasting at the route discovery stage. The SNBR algorithm in shown in Figure 3. In the SNBR protocol, at the route discovery stage, each node receives an RREQ message that will calculate the total number of neighbours it has, based on its neighbour table, before determining to rebroadcast or drop the RREQ message. In the case, the total number of neighbours is less than the prefixed drop factor value (fourteen neighbours), the RREQ will be rebroadcast, otherwise, it will drop such RREQ to avoid any extra overhead. However, the main issues of the SNBR, is the controlled flooding because of sending unneeded broadcasting messages of RREQ, such a method still degrading the network performance because of selecting the number of neighbours in the controlled flooding which is fourteen. The number of neighbours (fourteen) is called the threshold value used to calculate the drop factor as in the following equation 1.

$$DF(\lambda_j) = 1 - \sqrt{1 - \lambda_j} \tag{1}$$

where $\lambda_{j=}\left(\frac{\alpha_j}{T}\right)^2$. At any node j, let α_j is the total number of neighbours is, λ_j the ratio of the number of neighbours a node has over the neighbour threshold value or drop factor, T. From [12], it has been proved that the fixed drop factor, which is 14, is the optimal number of neighbour nodes. However, in the SNBR algorithm, the threshold value is not suitable for all cases, for instance when the number of nodes is high, the network performance will be affected. This value we do believe it can be optimized or replaced by another value that will improve the overall network performance, in terms of end-to-end delay and packet delivery ratio

SNBR Algorithm

At any Node
For every Received RREQ:
  If the destination node is the node itself or has a route to it.
    send RREP
  Else If the number of neighbours is greater than fourteen then
    Drop RREQ
  Else
    Rebroadcast or flood the RREQ to all neighbours.

    End
  End
Exit

Figure 3 SNBR Algorithm Flow

3. Proposed Method: DSNBR

The proposed DSNBR has been developed to reduce the routing overhead at the route request stage by reducing the extra RREQ messages to improve the overall performance of the network. DSNBR uses dynamic threshold (DT) value instead of fixed threshold value as in the SNBR routing protocol. Moreover, this dynamic threshold value was developed based on network characteristics such as mobility and low power resource. Therefore, nodes in such a network need to save such power as the nodes have limited power resources. At any nodes which receive the RREQ message, it is necessary to make a fast decision whether to forward or drop the RREQ packet. Based on the AODV protocol the nodes blindly forward all the received RREQ messages, while in SNBR protocol each node only forwards such packet (RREQ) when the number of neighbors for the received nodes is less than 14. For the proposed DSNBR, the node will rebroadcast the RREQ message when the number of neighbors is less than the DT value.

The DSNBR routing algorithm and its flowchart is shown in Figure 4 and 5, respectively. In the first stage, DSNBR checks if there is a route or not, in the case of there is no route, the DSNBR will check the total no. of neighbors and compare it to the DT. If the number of neighbors is less than DT the DSNBR will rebroadcast the RREQ, otherwise, it will drop such packet. Moreover, the previously mentioned variables are α_j is the total number of neighbors the node j has during the receiving time of the RREQ message. While the βj is the total number of nodes in the simulation time. In addition, the DT is random value between 1 to 20 randomly generated using a random function.

DSNBR Algorithm

I1: On hearing RREQ P_j messages, It calculates the total number of neighbors it has α_j.
I2: Assign a new Dynamic Threshold-value (DT).
I3: If the α_j. is greater than DT then go to I5, else go to I6.
I5: α_j=DT
I6: Calculate the $\lambda_j$using Equation 2 and DF(λ_j) using Equation 1.
I7: If the (λ_j) is less than DT Goto I8, else goto I10.
I8: If DF(λ_j) is greater than Random value [0,1] then go I10, else goto I9.
I9: Foward RREQ message got to I11.
I10: Drop P_j.
I11: exist

Figure 4 DSNBR Algorithm Flow

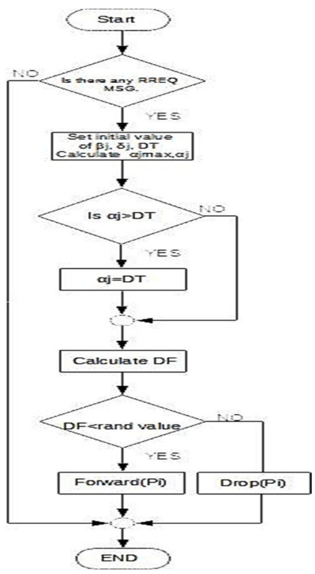

Figure 5 SNBR Algorithm Flowchart

4. Results and Discussion

Simulation environment is designed for existing AODV, SNBR techniques and the proposed DSNBR technique using NS2 simulator. Table 1 shows Simulation Parameter that has been used in NS2 simulator to create environment for AODV, SNBR and proposed DSNBR protocol. Figure 7 shows nodes distribution that has been created using NS2 simulator for the three protocols.

Table 1 Simulation Parameter

Simulation parameters	Value
Simulator	NS2.35
No of nodes	50 to 300
Size of the topology	1000*1000m
Transmission of the nodes	250 meters
Type of connection	CBR
Packet size	512 bytes
Node Speed (Min-Max)	1 to 5 m/s
Pause Time	0 s
No of Connections	10 to 20
Pkt. Rate	4 Packets per Second
Route Bandwidth	2 Mbps
Interface Queue Length	50

Table 2 Performance Evaluation Metric

Performance Metrics	Description
Normalized Routing Overhead.	The ratio of the total packet size of control packets (include RREQ, RREP, RERR, to the total packet size of data packets delivered to the destinations.[15].
Average End-to-End Delay.	The elapsed time between the broadcasting time of the RREQ at the source node, and the receiving time for the same packet at the destination node [16].
MAC Collision Rate	As the average number of data packets (CBR) and control packets (RREQ, RERR, RREP, and Hello) dropped at the MAC layer due to the collisions per second [17]
Mean Energy Consumption.	The mean of the total energy consumed by all the nodes during the simulation time. [17]
Network Connectivity Ratio	The total number of received RREQ divided by the total number of sent RREQ messages [18]

The performance of these three protocols, AODV, SNBR and DSNBR are analysed based on normalized routing overhead, average end-to-end delay, MAC collision rate, energy consumption and network connectivity ratio, described in Table 2. Performance of these protocols are summarized in Table 3 -5 and compared in Figure 6-10.

Table 3 Results for AODV Protocol

No. of Nodes	End-to-End Delay	Routing Overhead	MAC Collision	Energy Consumption	NW Connectivity Ratio
50	0.059	0.051	82.646	6.147	9.611
100	0.102	0.13	537.184	6.205	5.994
150	0.157	0.249	1897.086	6.379	4.425
200	0.585	0.978	6763.688	6.936	6.075
250	0.672	1.244	12170.299	6.968	6.122
300	0.94	2.11	20336.322	7.031	5.26

Table 4 Results for SNBR Protocol

No. of Nodes	End-to-End Delay	Routing Overhead	MAC Collision	Energy Consumption	Network Connectivity Ratio
50	0.085	0.043	61.648	5.999	11.47
100	0.102	0.091	320.687	5.93	7.567
150	0.138	0.14	899.866	6.088	7.013
200	0.246	0.214	1850.414	6.072	8.142
250	0.277	0.274	3172.175	6.016	8.388
300	0.251	0.328	4719.415	5.981	6.977

Table 5 Results for DSNBR Protocol

No. of Nodes	End-to-End Delay	Routing Overhead	MAC Collision	Energy Consumption	Network Connectivity Ratio
50	0.074	0.027	31.71	4.38	12.545
100	0.11	0.062	191.62	4.627	10.808
150	0.134	0.103	589.176	4.923	10.959
200	0.236	0.172	1433.065	5.046	13.246
250	0.231	0.201	2215.328	4.637	11.696
300	0.217	0.213	2641.456	4.651	12.192

Figure 6 shows the normalized routing overhead as against the number of nodes. As the number of nodes increases from fifty nodes to one hundred nodes, the routing overhead increases gradually as many nodes impose many routings' overhead messages such as RREQ, RREP, and RERR. Such overhead surely affected the network performance by delaying the other nodes from sending their messages on time or dropping another date or control packets. As it is clearly seen in Figure 6, the DSNBR routing protocol outperforms both the existing AODV protocol and SNBR as the number of nodes increases. Therefore, the DSNBR protocol provides better performance as the number of nodes increases

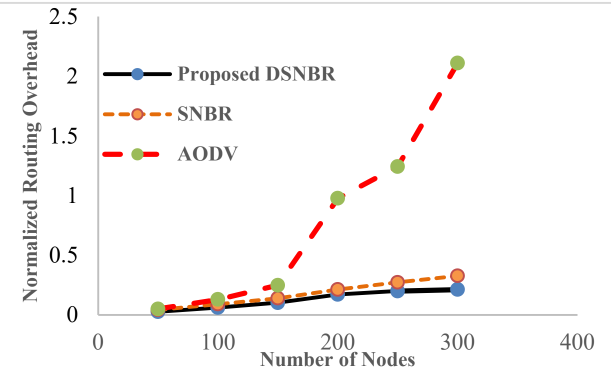

Figure 6 Routing Overhead vs No of Nodes

Figure 7 shows an average end-to-end delay performance for AODV, SNBR and proposed DSNBR. From Figure 9, it is clearly seen that the proposed DSNBR provides better performance compared to SNBR and AODV. The increase of delay in DSNBR stops at 200 nodes, showing that the protocol is suitable for a high-density nodes network. DSNBR provides a large improvement in delay performance compared to in AODV, while slight improvement compared to in SNBR

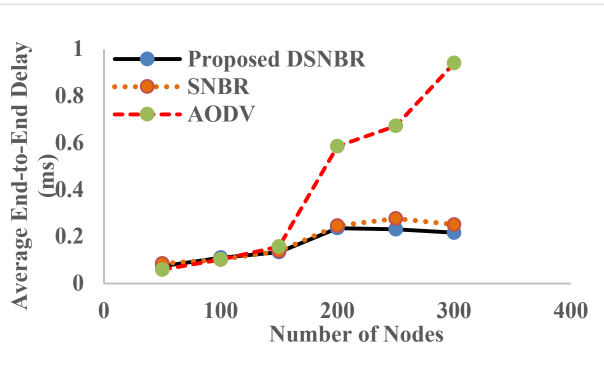

Figure 7 Average End-to-End Delay vs No. of Nodes

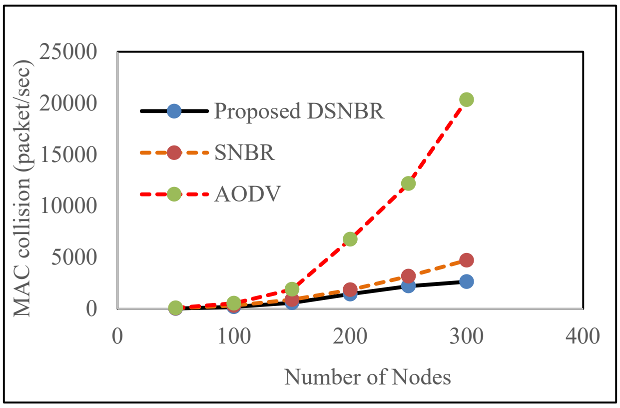

Figure 8 MAC Collision vs Number of Nodes

In Figure 8, the MAC collision rate is shown for three protocols AODV, SNBR, and DSNBR. Clearly, when the number of nodes increases, the MAC collision rate increases as well due to the increase of RREQ, RREP and RERR. In this figure, the DSNBR outperforms both protocols AODV, and SNBR where the packet collision can be reduced from 20,336 packets/sec in AODV and 4719 packets/sec in SNBR can be reduced to 2641 packet/sec at 300 nodes. It can be concluded that the proposed DSNBR can improve network performance by reducing MAC collision rate.

From Figure 9, as the number of nodes increases the mean average of the energy consumption increases. In MANET, energy consumption for mobile nodes is considered critical, as the nodes have a limited battery lifetime. Consequently, any routing protocol should consider such scarce resources, and consume as low power as possible. It is equally important to reduce wasted energy that nodes consume. For these nodes to find the path, they must broadcast the RREQ and flood the network with these packets which will reduce the battery lifetime. Even though, SNBR shows stable and good performance as compared to AODV using the fixed threshold method, still consumes more energy as compared to the DSNBR. The proposed DSNBR consume less power consumption because it applies the dynamic threshold method, that can reduce unnecessary RREQ message rebroadcasting. The performance gap between the three protocols is clearly shown that DSNBR outperforms AODV and SNBR protocol. As mentioned previously, the method of reducing the extra packets will reduce the energy consumption at the same time maintain good performance in the case of spare or low traffic network. As a result, the

SNBR compared to SNBR and AODV consume less energy, as shown in Figure 9.

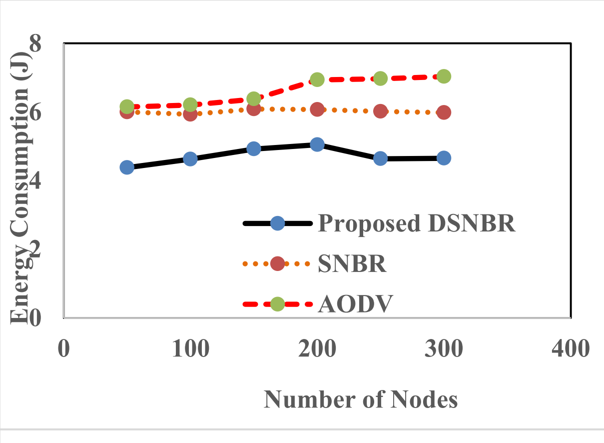

Figure 9 Energy Consumption vs Number of Nodes

Figure 10 shows performance comparison in term of network connectivity percentage. The network connectivity is measured based on received RREQ divided by sent RREQ message. High network connectivity represents high successfully received RREQ message. From the Figure we can see that the network connectivity percentage decreases when number of nodes increase, except for DSNBR. Contrary to performance in AODV and SNBR, in DSNBR, the increases number of nodes does not affect network connectivity percentage, where the is no severe performance degradation even if the number of nodes increase from 50 to 300. We also can see that, the proposed DSNBR outperforms both AODV and SNBR, in network connectivity performance where a better network connectivity rate can be observed in every number of nodes.

5.Conclusion

The broadcasting method in the Route request plays a critical role in any routing protocol because it may improve or reduce the routing performance. Therefore, it is critical to have an optimal broadcasting method to reduce redundant RREQ messages. AODV uses the blind flooding method, which will drop the network performance as many RREQ messages are extra. While the SNBR aims to enhance blind flooding in AODV by introducing another broadcasting method based on the total number of neighbors that each node has during the broadcasting time. However, such method uses a fixed threshold value, which is not efficient when the number of nodes increases gradually. As result, in this study, a new routing protocol is proposed called DSNBR which uses a newly developed broadcasting method based on a dynamic threshold. From the results, DSNBR protocol outperforms the AODV, SNBR routing protocols in terms of routing overheard, end-to-end delay, Mac collision rate, energy power consumption, and network connectivity ratio

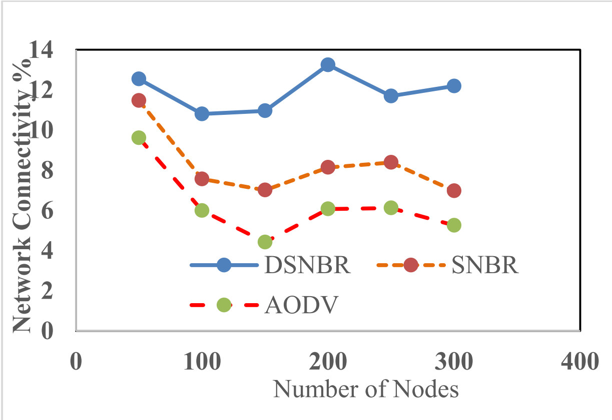

Figure 10 Network Connectivity vs Number of Nodes

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