RESEARCH ARTICLE OPEN ACCESS

Throughput-Aware Probabilistic Rebroadcasting Method to Reduce Routing Overhead in Mobile Ad Hoc Network

Mr. H. T. Gurme [1], Mr. B. R. Solunke [2]
PG Scholar, Assistant Professor
Department of Computer Science and Engineering
N. B. N. Sinhgad College of Engineering
Solapur -India

ABSTRACT

Mobile Ad hoc Networks (MANETs) consist of a collection of mobile nodes which can move freely. These nodes can be dynamically self-organized into arbitrary topology networks without a fixed infrastructure. All communications in MANET are done through the wireless media and hence do not required fixed lines or fixed topology. The communication in MANET is done by using routing protocols, whose task is to find out shortest path from source to destination, maintain route, rebuild path immediately during communication if nodes are moved. Routing is challenging task in MANET because there may be frequent link breakages due to node movements.

In this paper, new method is presented for MANET routing protocol with goal of improving routing performance in terms of network load, throughput, and delay. The presented method is for Neighbour Coverage Probabilistic Rebroadcasting (NCPR) protocol which combines probabilistic rebroadcast protocol technique and neighbor knowledge technique. Probabilistic rebroadcast method is based on neighbor coverage in order to reduce the routing overhead. This neighbor coverage knowledge includes additional coverage ratio and connectivity factor. The simulation study of this protocol is implemented by using NS2 and its performance is compared against Ad Hoc On-demand Distance Vector (AODV) routing protocol and Dynamic Probabilistic Route Discovery (DPR) routing protocol.

***Keywords* :-** Mobile ad hoc networks, neighbour coverage, routing overhead, rebroadcast.

I. INTRODUCTION

In the recent years, there has been an increasing interest in wireless networks, as the cost of mobile devices such as PDAs, laptops, cellular phones, etc have reduced intensely. The latest trend in wireless networks is towards extensive and universal computing - catering to both travelling and fixed users, anytime and anywhere. Many standards are evolved for wireless networks in order to address the needs of both industrial and individual users.

Today Wireless local Area Network (WLAN) is mostly in use which is form of wireless network. Numbers of nodes are connected to a fixed wired backbone and having short range and are usually deployed in places such companies, cafeterias, universities, etc. But where it is not feasible to deploy fixed wireless access points due to physical constraints of the medium there is a need for communication in many scenarios of deployment. For example consider soldiers needs communication among themselves in a battlefield where troops are spread over a large area. Considering this case, it is not feasible to deploy a fixed wireless access point, but also dangerous because the whole network would bring down by an enemy attack. This scenario has led down to an interest in mobile ad hoc networks, wireless networks consists of mobile computing devices without any fixed infrastructure.

A. Ad Hoc Network

Ad Hoc network consists of several mobile nodes formed a temporary network topology but there is no centralized access point. In this each node cooperate by forwarding packets to other nodes to communicate the nodes beyond their wireless range as shown in figure 1.1 a process of exchanging information from one station to other stations of the network is called as routing. Routing protocols of MANETs need different approaches from existing Internet protocols because of dynamic topology, movable nodes, distributed environment, low bandwidth, and low battery power.

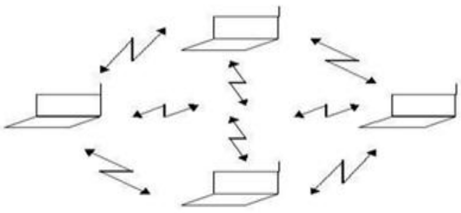

Figure 1.1 Ad-Hoc Network

B. Mobile Ad Hoc Network

As Mobile Ad Hoc Network i.e. MANET is group of self-organizing wireless devices, the deployment of such wireless devices is done without a fixed infrastructure or any centralized access point. Each mobile node in MANET acts as peer which can perform the task of sending and receiving data, each node can act as a router or host.

Mobile Ad Hoc Network does not have any fixed communication links like wired network, the communication is done by nodes by sending data in packets to each other still packets received by destination. Figure 1.2 is showing the MANET communication example.

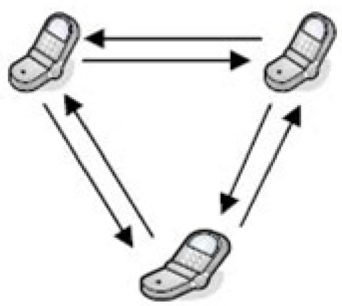

Figure 1.2: Mobile Ad-Hoc Network

The communication in MANET is done by routing protocols. Due to this the major challenge in MANET is the development of dynamic routing protocols those can efficiently find routes between the communicating nodes. Any MANET routing protocol should be able to keep up with highest degree of nodes mobility as nodes mobility frequently changes the MANET topology randomly and drastically.

As due to nodes mobility there is frequent change in the MANET topology therefore routing protocol should be able to keep up with large degree of nodes mobility. One of the basic challenges in MANETs is the design of dynamic routing protocols with good performance and less overhead [1].

Many routing protocols, such as Ad hoc On-demand Distance Vector Routing (AODV) [2] and Dynamic Source Routing (DSR) [3], have been proposed for MANETs. The above two protocols are on demand routing protocols, and they could improve the scalability of MANETs by limiting the routing overhead when a new route is requested [4].

C. Routing Protocols in MANET

The existing routing protocols for mobile ad hoc networks undertakes set-up and maintain routes between nodes. Ad Hoc routing protocols can be divided into two categories [5]: table-driven (proactive schemes) and on-demand routing (reactive scheme) based on when and how the routes are discovered.

In Table-driven routing protocols each node maintains one or more tables containing routing information about nodes in the network whereas in on-demand routing the routes are created as and when required. Some of the table driven routing protocols are Destination Sequenced Distance Vector Routing protocols (DSDV), Clusterhead Gateway Switching Routing Protocol (CGSR), Hierarchical State Routing (HSR), and Wireless Routing Protocol (WRP) etc.

The on-demand routing protocols are Ad Hoc On-Demand Distance Vector Routing (AODV), Dynamic Source Routing (DSR), and Temporally Ordered Routing Algorithm (TORA). There are many others routing protocols available. Zone Routing Protocol (ZRP) is the hybrid routing protocol.

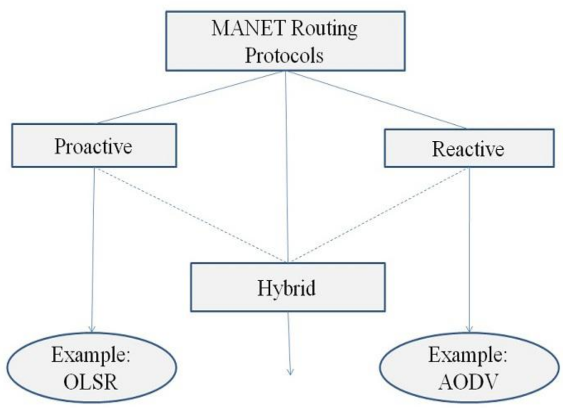

Figure 1.3: Routing Protocol Classification

In MANETs continuously changing network topology causes link breakage and termination of end-to-end route. The routing protocols need to resolve the link failure prediction. In conventional on-demand routing protocols use flooding to discover a route to a particular destination. They broadcast a Route REQuest (RREQ) packet to its immediate neighbours, and the broadcasting induces excessive redundant retransmissions of RREQ packet and causes the broadcast storm problem [5], which leads to a huge number of packet collisions, especially in dense networks [6]. Therefore, it is essential to optimize this broadcasting mechanism.

D. Broadcasting Protocols

Broadcasting protocols are classified into following four classes [7]:

1. Probability Based Methods
2. Simple Flooding
3. Neighbour Knowledge Based
4. Area Based Methods

The above four classes of broadcasting protocols if considered, an increase in the number of nodes in a static network will degrade the performance of the probability based methods and area based methods. Kim et al. [8] indicates that the performance of neighbour knowledge methods is better than the area based ones, and the performance of area based methods is better than that of probability based ones. These problems put in force to design a simple, scalable, robust and energy efficient routing protocol for multicast environment. A multicast Ad hoc on- demand Distance Vector routing protocol (MAODV) establishes and maintains a shared multicast routing tree to deliver data from a source to receivers of a multicast group. Then we propose a neighbor coverage-based probabilistic rebroadcast (NCPR) protocol.

The interest in wireless ad hoc networks stems from of their well-known advantages for certain types of applications. Since, there is no fixed infrastructure; a wireless ad hoc network can be deployed quickly. Thus, such networks can be used in situations where either there is no other wireless communication infrastructure present or where such infrastructure cannot be used because of security, cost, or safety reasons.

Ad-hoc networks were mainly used for military applications. Since then, they have become increasingly more popular within the computing industry. Applications include emergency search and rescue operations, deployment of sensors, conferences, exhibitions, virtual classrooms and operations in environments where construction of infrastructure is difficult or expensive.

E. Motivation of Study

The initial motivation of the protocol: Since limiting the number of rebroadcasts can effectively optimize the broadcasting and the neighbor knowledge methods perform better than the area-based ones and the probability-based ones. The node which has more common neighbors with the previous node has the lower delay. If this node rebroadcasts a packet, then more common neighbors will know this fact. This rebroadcast delay enables the information that the nodes have transmitted the packet spread to more neighbors, which is the success for the presented system. A novel scheme is presented to calculate the rebroadcast probability. It considers the information about the uncovered neighbors (UCN), connectivity metric and local node density to calculate the rebroadcast probability.

The rebroadcast probability is composed of two parts [1]:

1. Additional coverage ratio, which is the ratio of the number of nodes that should be covered by a single broadcast to the total number of neighbours.

2. Connectivity factor, which reflects the relationship of network connectivity and the number of neighbours of a given node.

II. LITURATURE REVIEW

Following are some work and researches done in the field of mobile ad hoc network to increase performance of network by optimizing broadcasting mechanism.

Due to redundant retransmission of packets of route request it utilises much network resources and which is very costly [5]. This retransmission causes more overhead on routing, leads to problems like collisions, contentions. Thus to avoid routing overhead optimization of broadcasting is an effective solution.

Probabilistic broadcasting approach based on coverage area and neighbour confirmation [8] uses the covering area of node to set the rebroadcast probability using the neighbour confirmation to guarantee ability of reaching the packet to its neighbour.

Where in the Gossip-Based Ad Hoc Routing [9] forwarding takes place with some probability at each node. This approach can save up to 35 percent overhead compare to the flooding of the packet. But, the improvement of this approach is limited, when the network density is high or the traffic load is heavy.

The Scalable Broadcast Algorithm (SBA) [10] is a new adaptive broadcast algorithm for the mesh. The SBA scheme considers the fact of reaching packet to the more nodes according to that retransmit the received packet. The unique feature of Scalable Broadcast algorithm is that it handles broadcast operations with a fixed number of message passing steps irrespective of the network size. This algorithm is based on the coded path routing. But Scalable broadcast algorithm does not consider the routing load caused due to rebroadcasting.

In Dynamic Probabilistic Route Discovery (DPR) [11] scheme is based on neighbour covering knowledge. In which forwarding of packet is take place according to the probability which is determined by considering the number of neighbours covered already by the packet along with number of its neighbour. However in DPR it only considers the nodes which are previously covered by the broadcast but ignoring the nodes which will receive the duplicate packets. Hence further optimization of DPR is necessary to increase the performance.

Also in the scheme [12] which combines AODV protocol with Directional Forward Routing (AODV-DFR) which takes the directional forwarding into AODV protocol used in geographic routing. When a route breaks, this protocol can automatically find the next-hop node for packet forwarding.

Keshavarz-Haddad et al. [13] proposed two deterministic timer-based broadcast schemes: Dynamic Reflector Broadcast (DRB) and Dynamic Connector-Connector Broadcast (DCCB). They pointed out that their schemes can achieve full reach ability over an idealistic lossless MAC layer, and for the situation of node failure and mobility, their schemes are robustness.

In Robust Broadcast Propagation (RBP) [14] protocol the approach is to provide near-perfect reliability for flooding in wireless networks, and this protocol also has a good efficiency. They presented a new perspective for broadcasting: not to make a single broadcast more efficient but to make a single broadcast more reliable, which means by reducing the frequency of upper layer invoking flooding to improve the overall performance of flooding.

Practically, these approaches show the improvement in conventional routing schemes. However, to investigate and improve the throughput by reducing routing overhead further work is needed, this imposes the next research problem of optimizing the rebroadcasting method in mobile ad hoc network.

III. PROPOSED WORK

The approach is neighbour coverage based probabilistic rebroadcasting by taking effectively advantage of the neighbor coverage knowledge and optimizing the rebroadcasting, by setting the rebroadcast delay and rebroadcast probability.

A. **Rebroadcast delay:** The rebroadcast delay is to determine the forwarding order. The node which has more common neighbors with the previous node has the lower delay, if this node rebroadcasts a packet, then more common neighbors will know this fact. Therefore, this rebroadcast delay enables the information that the nodes have transmitted the packet spread to more neighbors, which is the key to success for the implemented scheme.

B. **Rebroadcast probability:** The scheme considers the information about the uncovered neighbors (UCN), connectivity metric and local node density to calculate the rebroadcast probability.

The rebroadcast probability is composed of two parts:

a) Additional Coverage Ratio: Which is the ratio of the number of nodes that should be covered by a single broadcast to the total number of neighbors;

b) Connectivity Factor: This reflects the relationship of network connectivity and the number of neighbors of a given node.

The presented approach combines the compensation of the neighbor coverage knowledge and the probabilistic mechanism, which appreciably decrease the number of retransmissions so reducing the routing overhead, and with improved the routing performance.

The approach can be described as:

1) When node receives an RREQ packet from its previous node, it can use the neighbor list in the RREQ packet to estimate how many its neighbors have not been covered by the RREQ packet from its previous node.

2) If node has more neighbors uncovered by the RREQ packet from previous node, which means that if node rebroadcasts the RREQ packet, the RREQ packet can reach more additional neighbor nodes.

3) When a neighbor receives an RREQ packet, it could calculate the rebroadcast delay according to the neighbor list in the RREQ packet and its own neighbour list.

4) After determining the rebroadcast delay, the node can set its own timer.

5) If node receives a duplicate RREQ packet from its neighbor node, it knows that how many its neighbors have been covered by the RREQ packet from neighbour node. Thus, node could further adjust its UCN set according to the neighbor list in the RREQ packet from neighbor node.

6) After adjusting the Uncovered Neighbors set, the RREQ packet received from node is discarded.

7) When the timer of the rebroadcast delay of node expires, the node obtains the final UCN set. The nodes belonging to the final UCN set are the nodes that need to receive and process the RREQ packet.

8) Calculate the additional coverage ratio which is the ratio of the number of nodes that are additionally covered by this rebroadcast to the total number of neighbours of node.

9) Calculate connectivity factor which is the ratio of the number of nodes that need to receive the RREQ packet to the total number of neighbors of node.

10) Combining the additional coverage ratio and connectivity factor, the rebroadcast probability of node can be obtained to forward the packets.

11) If rebroadcast probability is not in range (0,1) then simply discard the packet else forward the packet.

C. **Algorithm:**

Definitions:

RREQv: RREQ packet received from node v.

R_v.id: the unique identifier (id) of RREQv.

N (u): Neighbour set of node u.

U (u, x): Uncovered neighbours set of node u for RREQ whose id is x.

Timer (u, x): Timer of node u for RREQ packet whose id isx.

[Note that, in the actual implementation of NCPR protocol, every different RREQ needs a UCN set and a Timer.]

if n_i receives a new $RREQ_s$ from s then

{Compute initial uncovered neighbours set U(n_i,R_s.id) for $RREQ_s$: }

$U(n_i, R_s.id) = N(n_i) - [N(n_i) \bigcap N(s)] - \{s\}$

Compute the rebroadcast delay $T_d(n_i)$:

$T_p(n_i) = 1 - \frac{|N(s) \bigcap N(ni)|}{|N(s)|}$

$T_d(n_i) = MaxDelay \times T_p(n_i)$

Set a Timer $(n_i, R_s.i_d)$ according to $T_d(n_i)$

end if

while n_i receives a duplicate $RREQ_j$ from n_j before Timer $(n_i, R_s.i_d)$ expires do

{Adjust $U(n_i, R_s.i_d)$:}

$U(n_i, R_s.i_d) = (n_i, R_s.i_d) - [U(n_i, R_s.i_d) \bigcap N(n_j)]$

$discard(RREQ_j)$;

end while

if Timer $(n_i, R_s.i_d)$ expires then

Compute the rebroadcast probability $P_re(n_i)$:

$R_a(n_i) = \frac{|U(n_i, R_s.i_d)|}{|N(n_i)|}$

$F_c(n_i) = \frac{N_c}{|N(n_i)|}$

$P_re(n_i) = F_c(n_i) \cdot R_a(n_i)$

if $Random(0,1) \leq Pre(n_i)$ then

broadcast $(RREQ_s)$

else

discard $(RREQ_s)$

end if

D. ***Modules Description***

1) Network Formation

a) The network contains number of nodes.
b) In this module, constructing a topology to provide communication paths for wireless network.

c) Here the node will give the own details such as Node ID and port number through which the transmission is done and similarly give the known nodes details such as Node ID, IP address and port number which are neighbours to given node.

2) Rebroadcast Delay determination

a) This module is to calculate the rebroadcast by using a novel scheme.
b) The rebroadcast delay is to determine the forwarding order.
c) The node which has the more common neighbours with the previous one has the lower delay.
d) In order to reduce the collisions in the network for each node maintains a delay time.

3) Rebroadcast Probability Determination

a) In this module novel scheme is use to calculate rebroadcast probability. The scheme considers the information about the uncovered neighbours.
b) The Rebroadcast Probability composed of two parts ,they are
   i) Additional coverage ratio
   ii) Connectivity factor

4) Neighbour Coverage-Based Probabilistic Rebroadcast

a) The proposed NCPR protocol needs Hello packets to obtain the neighbor information and also needs to carry the neighbor list in the RREQ packet.
b) Therefore, some techniques are used to reduce the overhead of Hello packets and neighbor list in the RREQ packet.
c) Since a node sending any broadcasting packets can inform its neighbors of its existence, the broadcasting packets such as RREQ and route error (RERR) can play a role of Hello packets. only when the time elapsed from the last broadcasting packet is greater than the value of Hello Interval, the node needs to send a Hello packet.
d) In order to reduce the overhead of neighbor list in the RREQ packet, each node needs to monitor the variation of its neighbor table and maintain a cache of the neighbor list in the received RREQ packet.

E. Simulation Environment

In order to evaluate the performance of the presented NCPR protocol, compare it with some other protocols using the NS-2 simulator. Broadcasting is a fundamental and effective data dissemination mechanism for many applications in MANETs. In this paper, only one of the applications is considered: route request in route discovery. In order to compare the routing performance of the proposed NCPR protocol have to compare with other routing protocol i.e. AODV protocol which is an optimization scheme for reducing the overhead of RREQ packet incurred in route discovery in the recent literature.

Sr. No.	Simulation Parameter	Value
1	Simulator	NS-2 (V2.30)
2	Topology Size	1000m X 1000m
3	Number of Nodes	50,100,....,300
4	Transmission Range	250m
5	Bandwidth	2Mbps
7	Interface Queue Length	50
8	Traffic Type	CBR
9	Packet Size	512 Bytes
10	Packet Rate	4 Packets/Sec
11	Pause Time	0
12	Min Speed	1 m/s
13	Max Speed	5 m/s

IV. RESULT AND ANALYSIS

F. Performance Metrics

We evaluate the performance of routing protocols using the following performance metrics:

1. **Packet Delivery Ratio:** It is the calculation of the ratio of packet received by the destinations which are sent by the various sources of the CBR.

2. **Normalized routing load:** This metrics is used to calculate the number of routing packets which are

transmitting with the original data packet over the network. This metrics indicates the efficiency of routing protocol in the MANET.

3. **End to end packet delay:** This metrics calculates the time between the packet origination time at the source and the packet reaching time at the destination. Here if any data packet is lost or dropped during the transmission, then it will not consider for the same. Sometimes delay occurs because of discovery of route, queuing, intermediate link failure, packet retransmissions etc are considered while calculating the delay. Such kind of metrics we have to measure against the different number of nodes, different traffic patterns and data connections.

4. **Throughput:** This metrics calculates the total number of packets delivered per second, means the total number of messages which are delivered per second.

G. *Performance with Varied Number of Nodes*

In the IEEE 802.11 protocol, the data and control packets share the same physical channel. In the conventional AODV protocol, the massive redundant rebroadcast incurs many collisions and interference, which leads to excessive packets drop. This phenomenon will be more severe with an increase in the number of nodes. The packet drops in MAC layer not only affect the number of retransmissions in MAC layer, but also affect the packet delivery ratio of CBR packets in the application layer. It is very important to reduce the redundant rebroadcast and packet drops caused by collisions to improve the routing performance.

Figure 4.1 shows the normalized routing overhead with different network density. The NCPR protocol can significantly reduce the routing overhead incurred during the route discovery, especially in dense network. Although the NCPR protocol increases the packet size of RREQ packets, it reduces the number of RREQ packets more significantly. Then, the RREQ traffic is still reduced. In addition, for fairness, the statistics of normalized routing overhead includes Hello traffic. Even so, the NCPR protocol still yields the best performance, so that the improvement of normalized routing overhead is considerable. This result indicates that the NCPR protocol is the most efficient than AODV and DPR protocol.

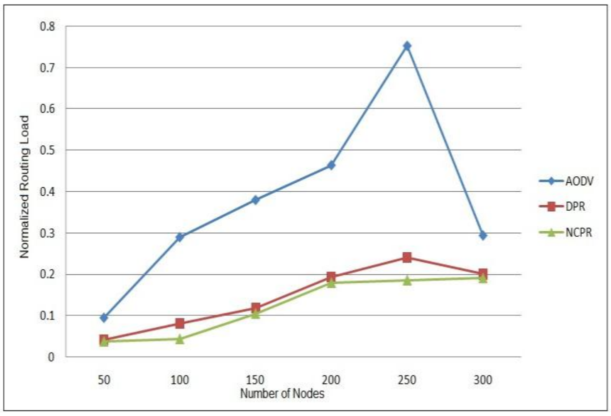

Figure 4.1 Normalized routing overhead with varied number of nodes

Figure 4.2 shows the packet delivery ratio with increasing network density. The NCPR protocol can increase the packet delivery ratio because it significantly reduces the number of collisions, which is shown in figure 4.2 so that it reduces the number of packet drops caused by collisions. On average, the packet delivery ratio is improved in the NCPR protocol when compared with the conventional AODV protocol and DPR Protocol.

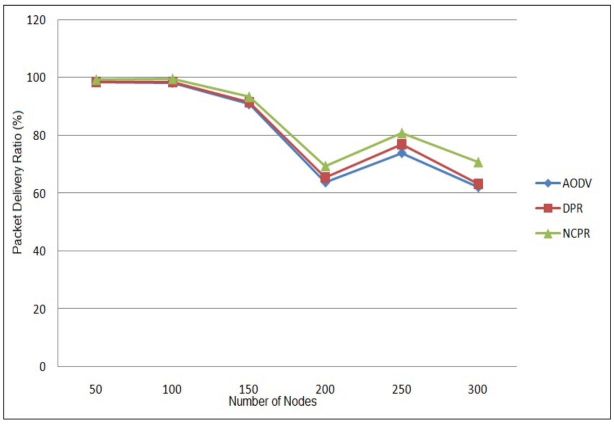

Figure 4.2: Packet delivery ratio with varied number of nodes

Figure 4.3 measures the average end-to-end delay of CBR packets received at the destinations with increasing network density. The NCPR protocol decreases the average end-to-end delay due to a decrease in the number of redundant rebroadcasting packets. The redundant rebroadcast increases delay because 1) it incurs too many collisions and interference, which not only leads to excessive packet drops, but also increases the number of retransmissions in MAC layer so as to increase the delay; 2) it incurs too many channel contentions, which increases the back off timer in MAC layer, so as to increase the delay. Thus, reducing the redundant rebroadcast can decrease the delay.

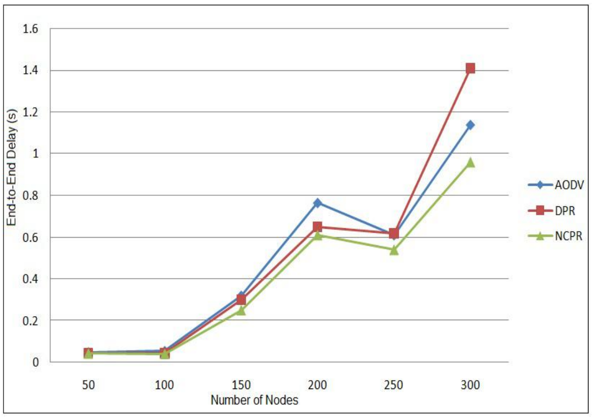

Figure 4.3: Average end-to-end delay with varied number of nodes

Figure 4.4 shows the throughput performance with increasing network density. The NCPR protocol has increased the throughput because it significantly reduces the number of collisions and routing load, so that it reduces the number of packet drops caused by collisions.

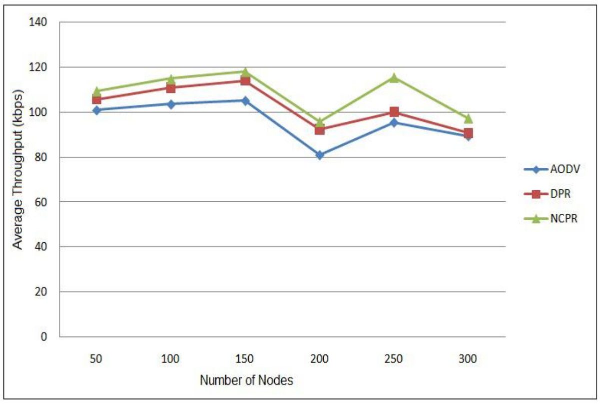

Figure 4.4: Average Throughput with varied number of nodes

V. CONCLUSION AND FUTURE SCOPE

This paper we introduces a neighbour coverage based probabilistic rebroadcast protocol: NCPR based on neighbor coverage technique and probabilistic technique to reduce the routing overhead in MANETs. The neighbor coverage technique includes additional coverage ratio and connectivity factor. This technique introduces broadcast delay used to determine the forwarding order by effectively exploiting the neighbour coverage knowledge. Simulation results show that the presented protocol NCPR generates less rebroadcast traffic than the flooding scheme discussed in literatures. Because of less redundant rebroadcast, the presented protocol mitigates the network collision and contention, so as to increase the packet delivery ratio and decrease the average end-to-end delay. The simulation results also show that the presented protocol has good performance when the network is in high density or the traffic is in heavy load.

By adding channel awareness mechanism the uncovered neighbour set with higher signal strength can be selected for easier and fast transmission of RREQ message and to improve the Quality of Service.

REFERENCES

[1] A Neighbour Coverage based Probabilistic Rebroadcast for Reducing Routing Overhead in Mobile Ad hoc Networks Xin Ming Zhang, Member, IEEE, En Bo Wang, Jing Jing Xia,and Dan Keun Sung, Senior Member, IEEE Transactions on Mobile Computing, VOL. 12, NO. 3., MARCH 2013.

[2] C. Perkins, E. Belding-Royer, and S. Das, Ad Hoc On-Demand Distance Vector (AODV) Routing, IETF RFC 3561, 2003.

[3] D. Johnson, Y. Hu, and D. Maltz, The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks (DSR) for IPv4, IETF RFC 4728, vol. 15, pp. 153-181, 2007.

[4] H. AlAamri, M. Abolhasan, and T. Wysocki, On Optimising Route Discovery in Absence of Previous Route Information in MANETs, Proc. IEEE Vehicular Technology Conf. (VTC), pp. 1-5, 2009.

[5] S.Y. Ni, Y.C. Tseng, Y.S. Chen, and J.P. Sheu, The Broadcast Storm Problem in a Mobile Ad Hoc Network, Proc. ACM/IEEE MobiCom, pp. 151-162, 1999.

[6] A. Mohammed, M. Ould-Khaoua, L.M. Mackenzie, C. Perkins, and J.D. Abdulai, Probabilistic Counter-Based Route Discovery for Mobile Ad Hoc Networks, Proc. Intl Conf. Wireless Comm. and Mobile Computing: Connecting the World Wirelessly (IWCMC 09), pp. 1335-1339, 2009.

[7] B. Williams and T. Camp, Comparison of Broadcasting Techniques for Mobile Ad Hoc Networks, Proc. ACM MobiHoc, pp. 194-205, 2002.

[8] J. Kim, Q. Zhang, and D.P. Agrawal, Probabilistic Broadcasting Based on Coverage Area and Neighbor Con_rmation in Mobile Ad Hoc Networks, Proc. IEEE GlobeCom, 2004.

[9] Z. Haas, J.Y. Halpern, and L. Li, Gossip-Based Ad Hoc Routing,Proc. IEEE INFOCOM, vol. 21, pp. 1707-1716, 2002.

[10] W. Peng and X. Lu, On the Reduction of Broadcast Redundancy in Mobile Ad Hoc Networks, Proc. ACM MobiHoc, pp. 129-130, 2000.

[11] J.D. Abdulai, M. Ould-Khaoua, L.M. Mackenzie, and A. Mohammed, Neighbour Coverage: A Dynamic Probabilistic Route Discovery for Mobile Ad Hoc Networks, Proc. Intl Symp. Performance Evaluation of Computer and Telecomm. Systems (SPECTS 08), pp. 165-172, 2008.

[12] J. Chen, Y.Z. Lee, H. Zhou, M. Gerla, and Y. Shu, Robust Ad Hoc Routing for Lossy Wireless Environment, Proc. IEEE Conf. Military Comm. (MILCOM 06), pp. 1-7, 2006.

[13] A. Keshavarz-Haddady, V. Ribeirox, and R. Riedi, DRB and DCCB: Efficient and Robust Dynamic Broadcast for Ad Hoc and Sensor Networks, Proc. IEEE Comm. Soc. Conf. Sensor, Mesh, and Ad Hoc Comm. and Networks (SECON 07), pp. 253-262, 2007.

[14] F. Stann, J. Heidemann, R. Shro_, and M.Z. Murtaza, RBP: Robust Broadcast Propagation in Wireless Networks, Proc. Intl Conf. Embedded Networked Sensor Systems (SenSys 06), pp. 85-98, 2006.