Abstract

In mobile ad hoc network (MANETs) the nodes are continuously moving, this mobility of nodes causes continuous link breakage due to which frequent path failure occur and route discoveries is required. The fundamental mechanism for route discoveries is broadcasting in which the receiver node blindly rebroadcast the first received route request packet unless it has route to the destination. This mechanism incur retransmission which causes overhead and decrease the packet deliverance ratio and increase the end delay, which cannot be avoided. In this paper we proposed reducing routing overhead in mobile ad hoc network using probabilistic rebroadcast mechanism. In which rebroadcast delay is introduced to determine the neighbor coverage knowledge which will help in finding accurate additional coverage ratio and rebroadcast order. We also define connectivity factor to provide node density adaptation. By combining the additional coverage ratio and connectivity factor, rebroadcast probability is determined. The approach can signify improvement in routing performance and decrease the routing overhead by decreasing the number of retransmission.

1. Introduction

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; it is a self- configuring infrastructure less network of mobile devices connected by wireless links. No base stations are supported in such an environment. Due to considerations such as radio power limitation, channel utilization, and power-saving concerns, a mobile host may not be able to communicate directly with other hosts in a single-hop fashion. In this case, a multi hop scenario occurs, where the packets sent by the source host are relayed by several intermediate hosts before reaching the destination host. However, due to node mobility in MANETs, frequent link breakages may lead to frequent path failures and route discoveries. It increases the overhead of routing protocols which reduces the packet delivery ratio and also increases the end-to-end delay. Thus, reducing the routing overhead in route discovery is an essential problem. The conventional on demand routing protocols use flooding to discover a route. They broadcast a Route Request (RREQ) packet to the networks, and the broad casting induces excessive redundant retransmissions of RREQ packet.

The MANET is a special type of wireless mobile network in which mobile host can communicate without any aid of established infrastructure and can be deployed for many applications. MOBILE Ad hoc networks (MANETs) consist of a collection of mobile nodes which can move freely (See Fig 1). These freely moving nodes without any fix infrastructure can dynamically self-organized into arbitrary topology network. One of the fundamental challenges of MANETs is the design of dynamic routing protocols with good performance and less overhead. Many routing protocols, such as Ad hoc On-demand Distance Vector Routing (AODV) [1] and Dynamic Source Routing (DSR) [2], have been proposed for MANETs. The Ad hoc On Demand Distance Vector (AODV) routing algorithm is a routing protocol designed for ad hoc mobile networks. AODV is capable of both unicast and multicast routing. AODV is an on demand algorithm, meaning that it builds routes between nodes only as desired by source nodes. It maintains these routes as long as they are needed by the sources [19]. The Dynamic Source Routing protocol (DSR) is a simple and efficient routing protocol designed specifically for use in multi-hop wireless ad hoc networks of mobile nodes. DSR allows the network to be completely self-organizing and self-configuring, without the need for any existing network infrastructure or administration [20]. 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.
However, due to node mobility in MANETs, frequent link breakages may lead to frequent path failures and route discoveries.

Fig1: Mobile Ad hoc Network

Which could increase the overhead of routing protocols and reduce the packet delivery ratio and increasing the end-to-end delay [4]. Thus, reducing the routing overhead in route discovery is an essential problem. A fundamental operation in all kinds of network is broadcasting. It may be used for the following:

- Determining neighbours.
- Collecting global information.
- Naming.
- Addressing.
- Assisting in the multicasting.

Williams and Camp [7] categorized broadcasting protocols into four classes: “simple flooding, probability-based Methods, area based methods, and neighbour knowledge methods.”

- Each node should rebroadcast all packets in simple flooding.
- In order to assign a probability to a node to rebroadcast, probability based method use some basic understanding of the network topology.
- Area based methods assumes that nodes have common transmission distances. If the rebroadcast reaches sufficient additional coverage area, then only the node is capable to rebroadcast.
- Through “Hello” packets neighbour knowledge methods maintain state on their neighbourhood which is used in the decision to rebroadcast.

For the above four classes of broadcasting protocols, they showed that an increase in the number of nodes in a static network will degrade the performance of the probability-based and area-based methods [7]. Kim et al. [8] indicated that the performance of neighbour knowledge methods is better than that of area-based ones, and the performance of area-based methods is better than that of probability-based ones.

Thus we can say that, the broadcasting can be effectively optimized by limiting the number of broadcast, and the performance of neighbour knowledge method is better than area based one and the probability based one is the initial motivation behind this paper, then we proposed a neighbour coverage based probabilistic rebroadcast (NCPR) protocol.

2. Literature Review and Related Work.

Broadcasting is an effective mechanism for route discovery, but the routing overhead associated with the broadcasting can be quite large, especially in high dynamic networks [9]. Ni et al. [5] studied the broadcasting protocol analytically and experimentally, and showed that the rebroadcast is very costly and consumes too much network resource. The broadcasting incurs large routing overhead and causes many problems such as redundant retransmissions, contentions, and collisions [5]. Thus, optimizing the broadcasting in route discovery is an effective solution to improve the routing performance.

Haas et al.[10] proposed a gossip based approach, where each node forwards a packet with a probability. They showed that gossip-based approach can save overhead compared to the flooding. However, when the network density is high or the traffic load is heavy, the improvement of the gossip-based approach is limited [9]. Kim et al. [8] proposed a probabilistic broadcasting scheme based on coverage area and neighbour confirmation. This scheme uses the coverage area to set the rebroadcast probability, and uses the neighbour confirmation to guarantee reach ability. Peng and Lu [11] proposed a neighbour knowledge scheme named Scalable Broadcast Algorithm (SBA). This scheme determines the rebroadcast of a packet according to the fact whether this rebroadcast would reach additional nodes.

Abdulai et al. [12] proposed a Dynamic Probabilistic Route Discovery (DPR) scheme based on neighbour coverage. In this approach, each node determines the forwarding probability according to the number of its neighbours and the set of neighbours which are covered by the previous broadcast. This scheme only considers the coverage ratio by the previous node, and it does not consider the neighbours receiving the duplicate RREQ packet. Thus, there is a room of further optimization and extension for the DPR protocol. Several robust protocols have been proposed in recent years besides the above optimization issues for broadcasting. Chen et al. [13] proposed an AODV protocol with Directional Forward Routing (AODV-DFR) which takes the directional
forwarding used in geographic routing into AODV protocol. While a route breaks, this protocol can automatically find the next-hop node for packet forwarding.

Keshavarz-Haddad et al. [14] 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 reachability over an idealistic lossless MAC layer, and at a lower cost of node failure and mobility, their schemes are robustness. Stann et al. [15] proposed a Robust Broadcast Propagation (RBP) protocol to provide near-perfect reliability for flooding in wireless networks, and this protocol also has a high efficiency. They presented a new perspective for flooding: 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. The proposed protocol set a deterministic rebroadcast delay, but the goal is to make the dissemination of neighbour knowledge much quicker. One of the earliest broadcast mechanisms is flooding, where every node in the network retransmits a message to its neighbours upon receiving it for the first time. Although flooding is extremely simple and easy to implement, it can be very costly and can lead to serious problems, named as broadcast storm problem, which is characterized by redundant packet retransmissions, network bandwidth contention and collision. Ni et al. [5] studied the flooding protocol analytically and experimentally and showed that a rebroadcast can provide only 61% additional coverage at most and only 41% additional coverage in average over that already covered by the previous transmission. So, rebroadcasts are very costly and should be used with caution.

### 3. Analysis of Problem

In Mobile Ad Hoc Network nodes are moving continuously due to node mobility in MANETs, frequent link breakages may lead to frequent path failures and route discoveries, which could increase the overhead of routing protocols and reduce the packet delivery ratio and increasing the end-to-end delay [4]. Thus, reducing the routing overhead in route discovery is an essential problem. The conventional on-demand routing protocol use flooding to discover a route. They broadcast a Route REQUEST (RREQ) packet to the networks, and the broadcasting induces excessive redundant retransmissions of RREQ packet and causes the broadcast storm problem [5], which leads to a considerable number of packet collisions, especially in dense networks.

#### 3.1. Broadcasting Issue in MANET:

The following describes the major issues in designing a localized broadcast protocol while ensuring broadcast coverage [21].

- Even during the broadcast process, the network topology changes over time.
- Based on “Hello” intervals, the local 1-hop information is constructed. It is difficult to ensure consistent local or global views among nodes, since the nodes start their intervals asynchronously.
- When there are mobile nodes, the k-hop collection recess information acquires delay even for small k in localized solutions which may not reflect the current network topology.

Due to the broadcasting nature of radio transmission, the most fundamental task in MANETs is the broadcast operation. Moreover, due to this transmission all the nodes within the sender’s transmission range will be affected, when a sender transmits a packet. Therefore, the problems such as exposed terminal problem and hidden terminal problem are created.

A. **Exposed Terminal Problem:** The exposed terminal problem is created because of interference between one transmission and the other.

B. **Hidden Terminal Problem:** If an outgoing transmission collides with an incoming transmission then the hidden terminal problem is created where two incoming transmissions collide with each other.

C. **The Broadcast Storm Problem:** A straightforward approach to perform broadcast is by flooding. A host, on receiving a broadcast packet for the first time, has the obligation to rebroadcast the packet. Clearly, this costs n transmissions in a MANET of n hosts. Drawback of flooding includes.

- **Redundancy:** When a mobile host decides to rebroadcast a broadcast packet to its neighbours, all of its neighbours might already have heard the packet
- **Contention:** After a mobile host broadcasts a packet, if many of its neighbours decide to rebroadcast the packet, these transmissions (which are all from nearby hosts) may severely contend with each other.
Broadcasting is a special routing process of transmitting a packet so that each node in a network receives a copy of this packet. Flooding is a simple approach to broadcasting with no use of global information; in flooding, a broadcast packet is forwarded by every node in the network exactly once. Simple flooding ensures the coverage; the broadcast packet is guaranteed to be received by every node in the network providing there is no packet loss caused by collision in the MAC layer and there is no high speed movement of nodes during the broadcast process. (Fig. 2) shows a network with six nodes. When node v broadcasts a packet as shown in Fig. 1b, all neighbouring nodes, u, w, x, and y, receive the packet due to the broadcast nature of wireless communication media. All neighbours will then forward the packet to each other. Apparently, the two transmissions from nodes u and x are unnecessary. Redundant transmissions may cause the broadcast storm problem [18] in which redundant packets cause contention and collision.

4. Neighbour Coverage Based Probabilistic Rebroadcast (NCPR) Protocol

This paper proposes neighbour coverage based probabilistic rebroadcast protocol [1] which combines both neighbour coverage and probabilistic methods. In order to effectively exploit the neighbour coverage knowledge, we need a novel rebroadcast delay to determine the rebroadcast order, and then we can obtain a more accurate additional coverage ratio. In order to keep the network connectivity and to reduce the redundant retransmissions, we need a metric named connectivity factor to determine how many neighbours should receive the RREQ packet [9]. After that, by combining the additional coverage ratio and the connectivity factor, we introduce rebroadcast probability, which can be used to reduce the number of rebroadcasts of the RREQ packet and to improve the routing performance.

4.1. Rebroadcast Delay.

We proposed a scheme to calculate the rebroadcast delay. The rebroadcast delay is to determine the forwarding order. The node which has more common neighbours with the previous node has the lower delay. If this node rebroadcasts a packet, then more common neighbours will know this fact [10]. Therefore, this rebroadcast delay enables the information about the nodes which have transmitted the packet to more neighbours, which is the key success for the proposed scheme. When a node ‘ni’ receives an RREQ packet from its previous node ‘s’, node ‘s’ can use the neighbour list in the RREQ packet to estimate how many its neighbours have not been covered by the RREQ packet. If node ‘ni’ has more neighbours uncovered by the RREQ packet from s, which means that if node ‘ni’ rebroadcasts the RREQ packet, the RREQ packet can reach more additional neighbour nodes. To sufficiently exploit the neighbour coverage knowledge, it should be disseminated as quickly as possible. When node s sends an RREQ packet, all its neighbours ni, i = 1, 2 … receive and process the RREQ packet. We assume that node ‘nk’ has the largest number of common neighbours with node ‘s’, node ‘nk’ has the lowest delay. Once node ‘nk’ rebroadcasts the RREQ packet, there are more nodes to receive the RREQ packet. Because node ‘nk’ has the largest number of common neighbours. Node ‘nk’ rebroadcasts the RREQ packet depends on its rebroadcast probability calculated in the next subsection. The objective of this rebroadcast delay is not to rebroadcast the RREQ packet to more nodes, but to disseminate the neighbour coverage knowledge more quickly. After determining the rebroadcast delay, the node can set its own timer.

4.2. Rebroadcast Probability

We also proposed a novel scheme to calculate the rebroadcast probability. The scheme considers the information about the uncovered neighbours, 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 neighbours, and b) connectivity factor, which reflects the relationship of network connectivity and the number of neighbours of a given node. The node which has a larger rebroadcast delay may listen to RREQ packets from the nodes which have lowered one [9]. We do not need to adjust the rebroadcast delay because the rebroadcast delay is used to determine the order of disseminating neighbour coverage knowledge. When the timer of the
rebroadcast delay of node ‘ni’ expires, the node obtains the final uncovered neighbour set. The nodes belonging to the final uncovered neighbour set are the nodes that need to receive and process the RREQ packet. Note that, if a node does not sense any duplicate RREQ packets from its neighbourhood, its uncovered neighbour set is not changed, which is the initial uncovered neighbour set. Now we study how to use the final uncovered neighbour set to set the rebroadcast probability. The metric Ra indicates the ratio of the number of nodes that are additionally covered by this rebroadcast to the total number of neighbours of node ‘ni’. The nodes that are additionally covered need to receive and process the RREQ packet. As ‘Ra’ becomes bigger, more nodes will be covered by this rebroadcast, and more nodes need to receive and process the RREQ packet, and, thus, the rebroadcast probability should be set to be higher.

Xue [7] derived that if each node connects to more than 5.1774 log n of its nearest neighbours, then the probability of the network being connected is approaching 1 as n increases, where n is the number of nodes in the network. Then we can use 5.1774 log n as the connectivity metric of the network. We assume the ratio of the number of nodes that need to receive the RREQ packet to the total number of neighbours of node ‘ni’ is Fc(ni). If the local node density is low, the parameter ‘Fc’ increases the rebroadcast probability, and then increases the reliability of the NCPR in the sparse area. If the local node density is high, the parameter Fc could further decrease the rebroadcast probability, and then further increases the efficiency of NCPR in the dense area. Thus, the parameter ‘Fc’ adds density adaptation to the rebroadcast probability.

In this section, we calculate the rebroadcast delay and rebroadcast probability of the proposed protocol. We use the upstream coverage ratio of an RREQ packet received from the previous node to calculate the rebroadcast delay, and use the additional coverage ratio of the RREQ packet and the connectivity factor to calculate the rebroadcast probability in our protocol, which requires that each node needs its 1-hop neighbourhood information.

4.3. Algorithm Description.

Algorithm 1. NCPR
Definition:

\( RREQ_v \): RREQ packet received from node v.
\( R_s, id \): the unique identifier (id) of \( RREQ_v \).
\( N(u) \): neighbour set of node u.
\( U(u,x) \): Uncovered neighbour set of nodes u for RREQ whose id is x.
\( T_{d(ni)} \): Timer of node ni for RREQ packet whose id is x.

1. if ni receives a new RREQs from s then
2. \{Compute initial uncovered neighbors set \( U(ni,Rs.id) \) for RREQs:\}
3. \( U(ni,Rs.id) = N(ni) - [N(ni) \cap N(s)] - \{s\} \)
4. \{Compute the rebroadcast delay \( T_{d(ni)} \):\}
5. \( T_{d(ni)} = \frac{\max \{N(s) \cap N(ni)\}}{|N(s)|} \)
6. \( Td(ni)=\max \{\text{MaxDelay} \times Tp(ni)\} \)
7. Set a Timer(ni,Rs.id) according to \( Td(ni) \)
8. end if
9. while ni receives a duplicate RREQj from nj before Timer(ni,Rs.id) expires do
10. \{Adjust U(ni,Rs.id):\}
11. \( U(ni,Rs.id)=(ni,Rs.id)\cap[U(ni,Rs.id)\cap N(nj)] \)
12. discard(RREQj);
13. end while
14. if Timer(ni,Rs.id) expires then
15. \{Compute the rebroadcast probability \( Pre(ni) \):\}
16. \( Ra(ni) = \frac{|U(ni,Rs.id)\cap N(ni)|}{|N(ni)|} \)
17. \( F_s(ni) = N_s/N(ni) \)
18. \( P_r(ni) = F_s(ni) \times P_r(ni) \)
19. if Random(0,1) \leq Pre(ni) then
20. broadcast(RREQs)
21. else
22. discard(RREQs)
23. end if
24. end if


5.1 Protocol Implementation.

We enhance the source code of AODV at MAC in NS-2 to implement our proposed protocol. The proposed NCPR protocol needs Hello packets to obtain the neighbour information, and also needs to carry the neighbour list in the RREQ packet. In our implementation we have used some technique to reduce the overhead of sending RREQ packet to each node. In order to reduce the overhead we do not send RREQ packet to each node but prior to sending RREQ packet we insert the queue of id’s of all nodes who have received the RREQ packet from the corresponding node. We compare the queue id of two nodes and discard the common neighbour and obtain only that nodes who have not received the RREQ packet thus reducing the overhead of sending RREQ packet.

Evaluating the performance of routing protocol using following performance matrix.

- **Normalized routing overhead**: the ratio of the total packet size of control packets (include RREQ, RREP, RERR and Hello) to the total packet size of data packets delivered to the destinations. For the control packets sent over multiple hops, each single hop is counted as one Transmission. To preserve fairness, we use the size of RREQ packets instead of the number of RREQ packets, because the protocols include a neighbour list in the RREQ packet and its size is bigger than that of the original AODV.
- **Packet delivery ratio**: the ratio of the number of data packets successfully received by the CBR destinations to the number of data packets generated by the CBR sources
- **Average end-to-end delay**: the average delay of successfully delivered CBR packets from source to destination node. It includes all possible delays from the CBR sources to destinations.

The experiments are divided to two parts, and in each part we evaluate the impact of one of the following parameters on the performance of routing protocols:

- **Number of nodes**: We vary the number of nodes from 50 to 300 in a fixed field to evaluate the impact of different network density. In this part, we set the number of CBR connections to 15, and do not introduce extra packet loss.
- **Number of CBR connections**: We vary the number of randomly chosen CBR connections from 10 to 20 with a fixed packet rate to evaluate the impact of different traffic load. In this part, we set the number of nodes to 150, and also do not introduce extra packet loss.

5.2. Simulation Parameter.

<table>
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<tr>
<th>Simulation Parameter</th>
<th>Value</th>
</tr>
</thead>
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<tr>
<td>Simulator</td>
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<tr>
<td>Topology Size</td>
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<td>Number of Nodes</td>
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<td>Transmission Range</td>
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<td>Bandwidth</td>
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<td>Interface Queue Len</td>
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<tr>
<td>No. of CBR connection</td>
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<td>Packet Rate</td>
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<td>Max Speed</td>
<td>5m/s</td>
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</table>

1. Performance with Varied Number of Nodes

![Fig 4. Node Vs Packet Delivery Ratio](image)

Fig 4. 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, so that it reduces the number of packet drops caused by collisions.
Fig 5. shows the normalized routing overhead with different traffic load. At very light traffic load (10 CBR connections), both the DPR and NCPR protocols have more routing overhead than the conventional AODV protocol. This is because that the Hello packets and neighbour list in the RREQ packet add extra overhead, and the effect of reducing redundant rebroadcast is not significant when traffic load is light. As the traffic load increases, the routing overhead of the conventional AODV protocol significantly increases, but the overhead of the DPR and NCPR protocols are relatively smooth.

2. Performance with varied number of CBR Connection.

Fig 7. shows the packet delivery ratio with increasing traffic load. As the traffic load increases, the packet drops of the conventional AODV protocol without any optimization for redundant rebroadcast are more severe. NCPR protocols increase the packet delivery ratio compared to the conventional AODV protocol, because of the significantly reduce the number of collisions and then reduce the number of packet drops caused by collisions.

Fig 6. measures the average end-to-end delay of CBR packets received at the destinations with increasing traffic load. The end-to-end delay of the conventional AODV protocol significantly increases with the increase of traffic load, which is the same as the MAC collision rate and routing overhead. When the traffic load is heavy, by reducing the redundant rebroadcast, NCPR protocols alleviate the channel congestion and reduce the retransmissions at MAC layer, thus, to reduce the end-to-end delay.
protocol. Routing Overhead than the conventional AODV of RREQ packets, NCPR protocols incur less rate increases. By reducing redundant rebroadcast connections will drop more packets as packet loss retransmissions mechanism; thus, the CBR connection using UDP protocol does not have any routing overhead. On the other hand, the CBR connection is in high density. The proposed protocol has good performance when delay decreases. Simulation result also show that flooding in (AODV), because of which packet delivery ratio increases and average end to end delay decreases. Simulation result also show that the proposed protocol has good performance when the network is in high density.

5. Conclusion
In this paper to reduce routing overhead in MANET, based on neighbour coverage knowledge we proposed a probabilistic rebroadcast protocol. To determine the forwarding order and more effectively exploit the neighbour coverage knowledge, we proposed a new scheme to dynamically calculate the rebroadcast delay. Simulation result shows that modified protocol (NCPR) generates less rebroadcast traffic than the flooding in (AODV), because of which packet delivery ratio increases and average end to end delay decreases. Simulation result also show that the proposed protocol has good performance when the network is in high density.

References