

# **A Neighbor Coverage-Based Probabilistic Rebroadcast for Reducing Routing Overhead In Mobile Ad Hoc Networks**

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**ABSTRACT:** Due to high mobility of nodes in mobile ad hoc networks (MANETs), there exist frequent link breakages which lead to frequent path failures and route discoveries. The overhead of a route discovery cannot be neglected. In a route discovery, broadcasting is a fundamental and effective data dissemination mechanism, where a mobile node blindly rebroadcasts the first received route request packets unless it has a route to the destination, and thus it causes the broadcast storm problem. In this paper, we propose a neighbor coverage-based probabilistic rebroadcast protocol for reducing routing overhead in MANETs. In order to effectively exploit the neighbor coverage knowledge, we propose a novel rebroadcast delay to determine the rebroadcast order, and then we can obtain the more accurate additional coverage ratio by sensing neighbor coverage knowledge. We also define a connectivity factor to provide the node density adaptation. By combining the additional coverage ratio and connectivity factor, we set a reasonable rebroadcast probability. Our approach combines the advantages of the neighbor coverage knowledge and the probabilistic mechanism, which can significantly decrease the number of retransmissions so as to reduce the routing overhead, and can also improve the routing performance.

**KEYWORDS:** Mobile ad hoc networks, neighbor coverage, network connectivity, probabilistic rebroadcast, routing overhead

## **I. 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. 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 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. [3]. However, 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 protocols 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 [6]. Therefore, it is indispensable to optimize this broadcasting mechanism. Some methods have been proposed to optimize the broadcast problem in MANETs in the past few years. Williams and Camp [7] categorized broadcasting protocols into four classes: "simple flooding, probability-based methods, area based methods, and neighbor knowledge methods." 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 neighbor 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. We now obtain the initial motivation of our protocol: Since limiting the number of rebroadcasts can effectively optimize the broadcasting [5], and

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the neighbor knowledge methods perform better than the area-based ones and the probability-based ones [8], then we propose a neighbor Coverage-based probabilistic rebroadcast (NCPR) protocol. Therefore, 1) in order to effectively exploit the neighbor coverage knowledge, we need a novel rebroadcast delay to determine the rebroadcast order, and then we can obtain a more accurate additional coverage ratio; 2) in order to keep the network connectivity and reduce the redundant retransmissions, we need a metric named connectivity factor to determine how many neighbors should receive the RREQ packet. After that, by combining the additional coverage ratio and the connectivity factor, we introduce a rebroadcast probability, which can be used to reduce the number of rebroadcasts of the RREQ packet, to improve the routing performance.

The main contributions of this paper are as follows:

1. We propose a novel scheme to calculate the 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 proposed scheme.
2. We also propose a novel scheme to calculate the 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 and
  - b. connectivity factor, which reflects the relationship of network connectivity and the number of neighbors of a given node.

## II. NEIGHBOR COVERAGE-BASED PROBABILISTIC REBROADCAST PROTOCOL

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 neighborhood information.

### 2.1. UNCOVERED NEIGHBORS SET AND REBROADCAST DELAY

When node  $n_i$  receives an RREQ packet from its previous node  $s$ , 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  $s$ . If node  $n_i$  has more neighbors uncovered by the RREQ packet from  $s$ , which means that if node  $n_i$  rebroadcasts the RREQ packet, the RREQ packet can reach more additional neighbor nodes.

### 2.2 NEIGHBOR KNOWLEDGE AND REBROADCAST PROBABILITY

The node which has a larger rebroadcast delay may listen to RREQ packets from the nodes which have lowered one. For example, if node  $n_i$  receives a duplicate RREQ packet from its neighbor  $n_j$ , it knows that how many its neighbors have been covered by the RREQ packet from  $n_j$ . Thus, node  $n_i$  could further adjust its UCN set according to the neighbor list in the RREQ packet from  $n_j$ .

### 2.3 ALGORITHM DESCRIPTION

The formal description of the Neighbor Coverage-based Probabilistic Rebroadcast for reducing routing overhead in route discovery is shown in Algorithm 1.

Algorithm 1.

NCPR Definitions:

- RREQ packet received from node  $v$ .
- The unique identifier (id) of RREQ  $v$ .
- Neighbor set of node  $u$ .
- Uncovered neighbors set of node  $u$  for RREQ whose id is  $x$ .
- Timer of node  $u$  for RREQ packet whose id is  $x$ .

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## III. PROTOCOL IMPLEMENTATION AND PERFORMANCE EVALUATION PROTOCOL IMPLEMENTATION

We modify the source code of AODV in NS-2 (v2.30) to implement our proposed protocol. Note that the proposed NCPR protocol needs Hello packets to obtain the neighbor information, and also needs to carry the neighbor list in the RREQ packet. Therefore, in our implementation, some techniques are used to reduce the overhead of Hello packets and neighbor list in the RREQ packet, which are described as follows:

In order to reduce the overhead of Hello packets, we do not use periodical Hello mechanism. 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. We use the following mechanism [17] to reduce the overhead of Hello packets: Only when the time elapsed from the last broadcasting packet (RREQ, RERR, or some other broadcasting packets) is greater than the value of HelloInterval, the node needs to send a Hello packet. The value of HelloInterval is equal to that of the original AODV.

**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 DPR and NCPR protocols include a neighbor 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.

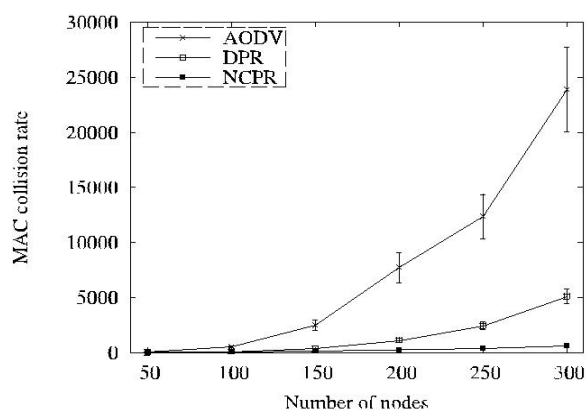
**Average end-to-end delay:** the average delay of successfully delivered CBR packets from source to destination node. It includes all possible delays from the CBR sources to destinations.

The experiments are divided to three 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.

**Random packet loss rate:** We use the Error Model provided in the NS-2 simulator to introduce packet loss to evaluate the impact of random packet loss. The packet loss rate is uniformly distributed, whose range is from 0 to 0.1. In this part, we set the number of nodes to 150 and set the number of connections to 15.



Performance with Varied Number of Nodes Fig. 1 shows the effects of network density on the MAC collision rate. In the IEEE 802.11 protocol, the data and control packets share the same physical channel.

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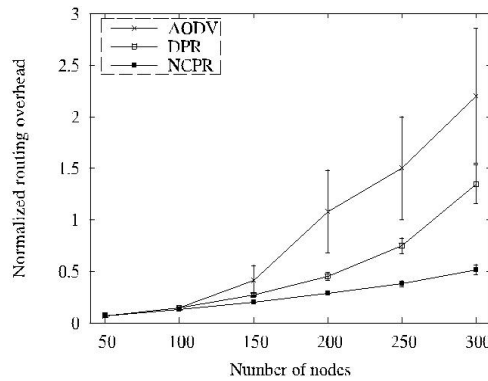


Fig. 2 shows the normalized routing overhead with different network density.

### 3.1 PERFORMANCE WITH VARIED NUMBER OF NODES

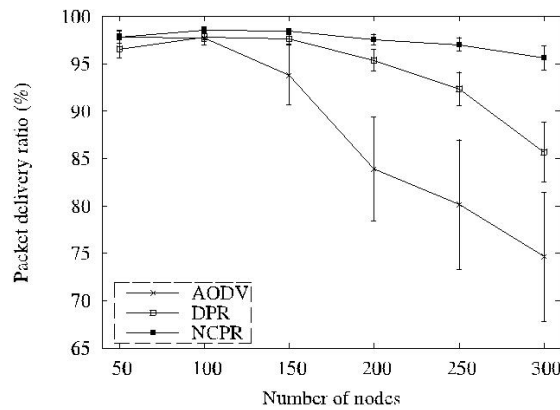


Fig. 3 shows the packet delivery ratio with increasing network density. The NCPR protocol can increase the packet delivery ratio because it significantly reduces the number of collisions.

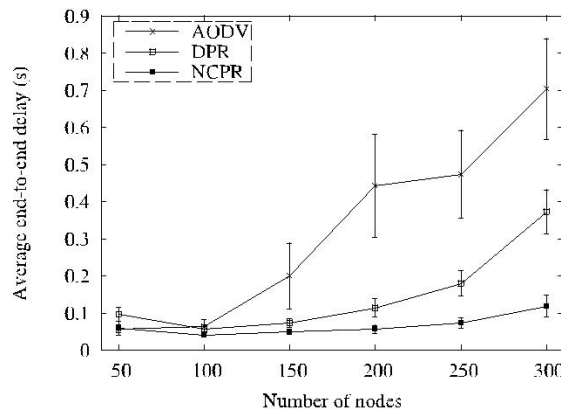


Fig. 4 measures the average end-to-end delay of CBR packets received at the destinations with increasing network density. The NCPR protocol decreases the average end-to-end delay due to a decrease in the number of redundant rebroadcasting packets.

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## 3.2 PERFORMANCE WITH VARIED NUMBER OF CBR CONNECTIONS

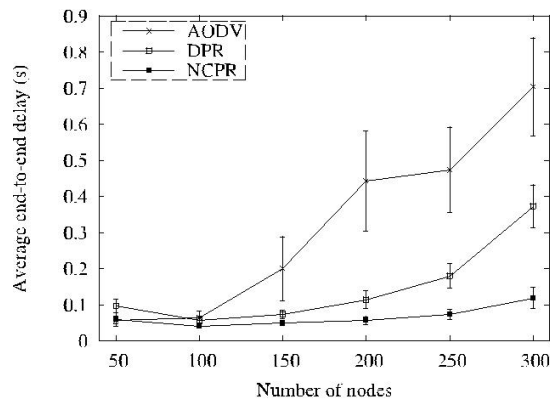


Fig. 5. MAC collision rate with varied number of CBR connections and It shows the effects of the traffic load on the MAC collision rate

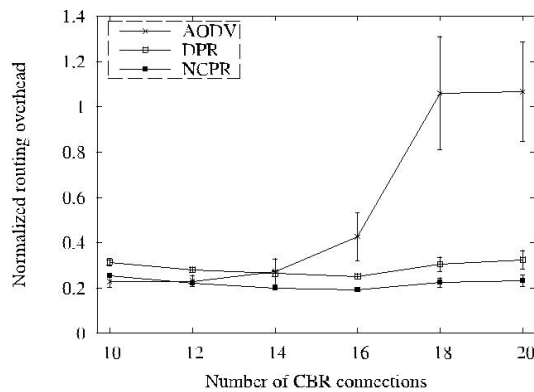


Fig. 6. Normalized routing overhead with varied number of CBR connections.

## 3,3 PERFORMANCE WITH VARIED RANDOM PACKET LOSS RATE

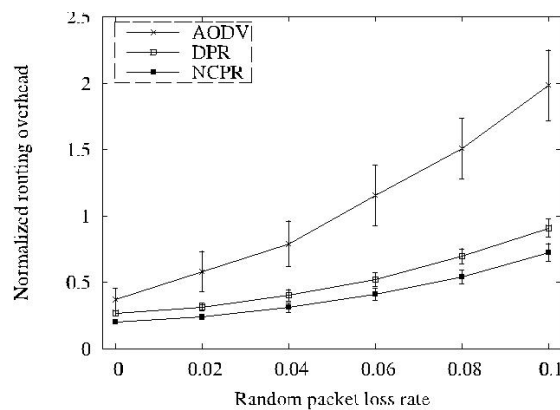


Fig. 7 shows the effects of the packet loss rate on the MAC collision rate.

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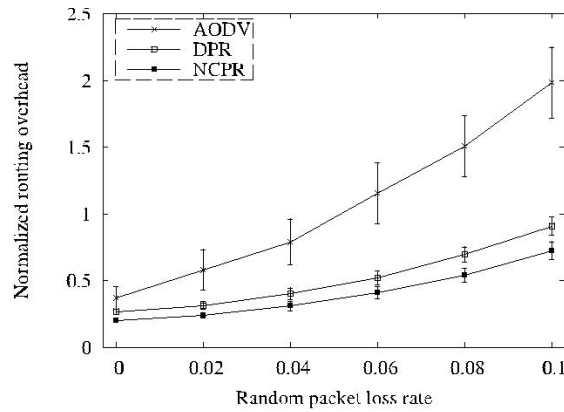


Fig. 8 shows the normalized routing overhead with different packet loss rate. As the packet loss increases, there will be more link breakages and route discoveries, and then there will be more routing overhead (such as RREQ packets and RERR packets).

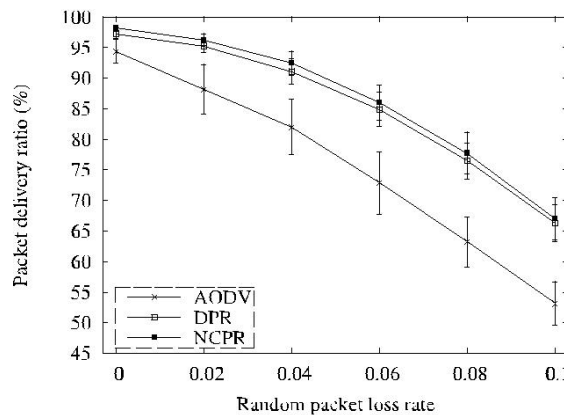


Fig. 9 shows the packet delivery ratio with increasing packet loss rate. As the packet loss rate increases, the packet drops of all the three routing protocols will increase. Therefore, all the packet delivery ratios of the three protocols increase as packet loss rate increases.

Both the DPR and NCPR protocols do not exploit any robustness mechanism for packet loss, but both of them can reduce the redundant rebroadcast, so as to reduce the packet drops caused by collision. Therefore, both the DPR and NCPR protocols have a higher packet delivery ratio than the conventional AODV protocol.

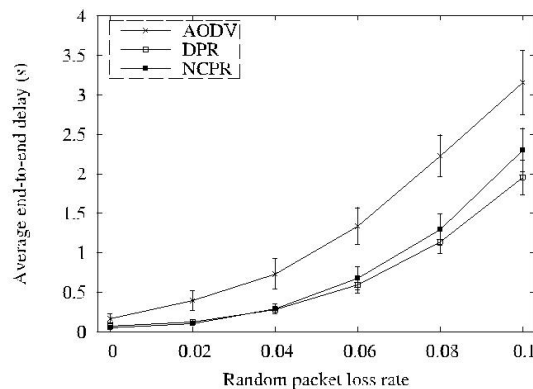


Fig. 10 measures the average end-to-end delay of CBR packets received at the destinations with increasing packet loss rate. Due to the increase of packet loss, the retransmissions caused by random packet loss at MAC layer will increase so as to increase the end-to-end delay. Both the DPR and NCPR protocols alleviate the channel congestion and reduce the retransmissions caused by collision at MAC layer, thus, both of them have a lower end-to-end delay than the conventional AODV protocol. On average, the end-to-end delay is reduced by about 53.9 percent in the NCPR protocol

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when compared with the conventional AODV protocol. Under the same network conditions, the delay is increased by about 0.6 percent when the NCPR protocol is compared with the DPR protocol.

## IV. CONCLUSION

In this paper, we proposed a probabilistic rebroadcast protocol based on neighbor coverage to reduce the routing overhead in MANETs. This neighbor coverage knowledge includes additional coverage ratio and connectivity factor. We proposed a new scheme to dynamically calculate the rebroadcast delay, which is used to determine the forwarding order and more effectively exploit the neighbor cover-age knowledge. Simulation results show that the proposed protocol generates less rebroadcast traffic than the flooding and some other optimized scheme in literatures. Because of less redundant rebroadcast, the proposed 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 proposed protocol has good performance when the network is in high density or the traffic is in heavy load.

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