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A Novel Neighbour Coverage-based Probabilistic Rebroadcast Protocol for Mobile Ad Hoc Networks

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Abstract: Because of high mobility of nodes in mobile ad hoc networks (MANETs), there exist frequent link breakages which lead to frequent path failures. This paper, proposes a novel neighbour coverage-based probabilistic rebroadcast protocol for reducing routing overhead in MANETs. In order to effectively exploit the neighbour coverage knowledge, a novel rebroadcast delay is used to determine the rebroadcast order, and then it can obtain the more accurate additional coverage ratio by sensing neighbour coverage knowledge. By combining the additional coverage ratio and connectivity factor, it can set a reasonable rebroadcast probability. This approach combines the advantages of the neighbour coverage knowledge and the probabilistic mechanism, which can decrease the number of retransmissions so as to reduce the routing overhead, and can also improve the routing performance.

Keywords: AdhocNetworks, Neighbour Coverage, Network Connectivity, Probabilistic Rebroadcast, Routing overhead.

I. INTRODUCTION

Mobile ad hoc networks (MANETs) consists 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) and Dynamic Source Routing (DSR) have been proposed for MANETs. The above two protocols are on demand routing protocols, and they can 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, which could increase the overhead of routing protocols and reduce the packet delivery ratio and increasing the end-to-end delay. Thus, reducing the routing overhead in route discovery is an essential problem.

The main contributions of this paper are as follows:
This paper proposes a novel 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. Therefore, this rebroadcast delay enables the information that the nodes have transmitted the packet spread to more neighbours, which is the key to success of the proposed scheme.

This paper also proposes a novel scheme to calculate the rebroadcast probability. The scheme considers the information about the uncovered neighbours (UCN), connectivity metric and local node density to calculate the rebroadcast probability. The rebroadcast probability is composed of two parts namely 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 connectivity factor, which reflects the relationship of network connectivity and the number of neighbours of a given node.

The rest of this paper is organized as follows: Section II introduces the related previous work. Section III proposes a Novel Neighbour Coverage-based Probabilistic Rebroadcast protocol for reducing routing overhead in route discovery. Section IV presents simulation parameters and scenarios which are used to investigate the performance of the proposed protocol. Section V concludes this paper.

II. 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. The broadcasting incurs large routing overhead and causes many problems such as redundant retransmissions, contentions, and collisions. This scheme determines the rebroadcast of a packet according to the fact whether this rebroadcast would reach additional nodes.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 Route Request (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. [8] proposed an AODV protocol with Directional Forward Routing (AODV-DFR) which takes the directional forwarding used in geographic routing in to AODV protocol.

While a route breaks, this protocol can automatically find the next-hop node for packet forwarding. Keshavarz-Haddady et al. [9] 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 for the situation of node failure and mobility, their schemes are robust.

Stann et al. [2] proposed a Robust Broadcast Propagation (RBP) protocol 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. The proposed protocol also sets a deterministic rebroadcast delay, but the goal is to make the dissemination of neighbour knowledge much quicker.

III.NOVEL NEIGHBOUR COVERAGE-BASED PROBABILISTIC REBROADCAST PROTOCOL

The objective of the rebroadcast delay is not to rebroadcast the Route Request (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.

A. Neighbour Knowledge and Rebroadcast Probability

The node which has a larger rebroadcast delay may listen to Route Request (RREQ) packets from the nodes which have lowered one. For example if a node receives a duplicate Route Request (RREQ) packet from its neighbour nj,it knows that how many of its neighbours have been covered by the RREQ packet from. Thus, node could further adjust its UCN set according to the neighbour list in the Route Request (RREQ) packet. Then that can be adjusted by calculating the rebroadcast delay and rebroadcast probability of the proposed protocol. The proposed system uses the upstream coverage ratio of an Route Request (RREQ) packet received from the previous node to calculate the rebroadcast delay, and use the additional coverage ratio of the Route Request (RREQ) packet and the connectivity factor to calculate the rebroadcast probability in this protocol, which requires that each node needs its 1-hop neighbourhood information.

B. Uncovered Neighbours Set and Rebroadcast Delay

When node receives an RREQ packet from its previous node s, it can use the neighbour list in the RREQ packet to estimate how many its neighbours have not been covered by the RREQ packet from s. 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.

C. A Neighbour Coverage- Based Probabilistic Rebroadcast

This defines the Uncovered Neighbours, the neighbours sets of node s and ni, respectively. s is the node which sends an RREQ packet to node ni and obtain the initial UCN set. Due to broadcast characteristics of an RREQ packet, node ni can receive the duplicate RREQ packets from its neighbours. Node ni could further adjust with the neighbour knowledge. In order to sufficiently exploit the neighbour knowledge and avoid channel collisions, each node should set a rebroadcast delay. The choice of a proper delay is the key to success for the proposed protocol because the scheme used to determine the delay time affects the dissemination of neighbour coverage knowledge. When a neighbour receives an RREQ packet, it could calculate the rebroadcast delay according to the neighbour list in the RREQ packet and its own neighbour list.

The rebroadcast delay of node is defined as follows: The delay ratio of node ni, and MaxDelay is a small constant delay. j_j is the number of elements in a set. The above rebroadcast delay is defined with the following reasons: First, the delay time is used to determine the node transmission order. 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 receive and process the RREQ packet. It assumes that node nk has the largest number of common neighbours with node s, according to (10)**,** node nk has the lowest delay. Once node nk rebroadcasts the RREQ packet, there are more nodes to receive it, because node nk has the largest number of common neighbours. Then, there are more nodes which can exploit the neighbour knowledge to adjust their UCN sets. Of course, whether node nk rebroadcasts the RREQ packet depends on its rebroadcast probability calculated in this. It does not need to adjust the rebroadcast delay because the rebroadcast delay is used to determine the order of disseminating neighbour coverage knowledge to the nodes which receive the same RREQ packet from the upstream node. Thus, it is determined by the neighbours of upstream nodes and its own. When the timer of the rebroadcast delay of node ni 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. Note that, if a node does not sense any duplicate RREQ packets from its neighbourhood, its UCN set is not changed, which is the initial UCN set. Then it describes how to use the final UCN set to set the rebroadcast probability. The above

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rebroadcast probability is defined with the following reason. Although the parameter Ra reflects how many next-hop nodes should receive and process the RREQ packet, it does not consider the relationship of the local node density and the overall network connectivity. The parameter Fc is inversely proportional to the local node density. That means 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. The calculated rebroadcast probability may be greater than 1, but it does not impact the behaviour of the protocol. It just shows that the local density of the node is so low that the node must forward the Route Request (RREQ) packet.

D. Protocol implementation and performance evaluation

This paper modifies the source code of AODV in NS-2 (v2.30) to implement the proposed protocol. The proposed NNCPR protocol needs Hello packets to obtain the neighbour information, and also needs to carry the neighbour list in the RREQ packet. Therefore, in this implementation, some techniques are used to reduce the overhead of Hello packets and neighbour list in the RREQ packet, which are described as follows:In order to reduce the overhead of Hello packets, this does not use periodical Hello mechanism. Since a node sending any broadcasting packets can inform its neighbours of its existence, the broadcasting packets such as RREQ and route error (RERR) can play a role of Hello packets. The following mechanism is used 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 Hello Interval, the node needs to send a Hello packet. The value of Hello Interval is equal to that of the original AODV. In order to reduce the overhead of neighbour list in the RREQ packet, each node needs to monitor the variation of its neighbour table and maintain a cache of the neighbour list in the received RREQ packet. The modified RREQ header of AODV, and add a fixed field num_neighbours which represents the size of neighbour list in the RREQ packet and following the num_neighbours is the dynamic neighbour list.

In the interval of two close followed sending or forwarding of RREQ packets, the neighbour table of any node ni has the following three cases:(i) If the neighbour table of node ni adds at least one new neighbour nj, then node ni sets the num_neighbours to a positive integer, which is the number of listed neighbours, and then fills its complete neighbour list after the num_neighbours field in the RREQ packet. It is because that node nj may not have cached the neighbour information of node ni, and, thus, node nj needs the complete neighbour list of node ni;(ii)If the neighbour table of node ni deletes some neighbours, then node ni sets the num_neighbors to a negative integer, which is the opposite number of the number of deleted neighbours, and then only needs to fill the deleted neighbours after the num_neighbours field in the RREQ packet; and(iii) If the neighbour table of node n_i does not vary, node.

E. Algorithm Description

The formal description of the Neighbour Coverage-based Probabilistic Rebroadcast (NCPR) algorithm for reducing routing overhead in route discovery is shown below:

Algorithm for NCPR

Definitions:

RREQ v: RREQ packet received from node v.
Rv:id: the unique identifier (id) of RREQ v.
N(u): Neighbor set of node u.
U(u,x): Uncovered neighbors set of node u for RREQ whose id is x.
Timer (u, x): Timer of node u for RREQ packet whose id is x.
{In the actual implementation of NCPR protocol, every different RREQ needs a UCN set and a Timer.}

1: if ni receives a new RREQ s from s then
2: {Compute initial uncovered neighbors set U (ni;Rs:id) for RREQ s:}
3: U(ni;Rs:id) = N(ni) _ [N(ni) (N(s)] – f(s)
4: {Compute the rebroadcast delay Td(ni):}
5: Tp(ni)== 1 _| N(s)_N(ni)|%|N(s)|
6: Td (niÞ) = MaxDelay * Tp(ni)
7: Set a Timer (ni;Rs:id) according to Td(ni)
8: end if
10: while ni receives a duplicate RREQ j from nj before Timer (ni;Rs:id) expires do
11: {Adjust U(ni;Rs:id):}
12: U(ni;Rs:id) = U(ni;Rs:id) _ [U(ni;Rs:id) \ N(nj)]
13: discard (RREQ j)
14: end while
16: if Timer (ni;Rs:id) expires then
17: {Compute the rebroadcast probability Pre(ni):}
18: Ra(ni)= |U(ni;Rs:id)|%|N(ni)|
19: Fc(ni) =Nc%jN(ni)|
20: Pre(ni) = Fc(ni). Ra(ni)
21: if Random (0,1) _ Pre(ni) then
22: broadcast (RREQs)
23: else
24: discard (RREQs)
25: end if
26: end if

IV. SIMULATION RESULTS

Fig.1 shows the Packet Delivery Ratio (PDR) when each node broadcast its own range vector. PDR is the ratio of sent and received packets. The PDR of each broadcast packet is calculated as the ratio between the number of neighbour nodes that receive the packet and the total number of neighbours that exist.

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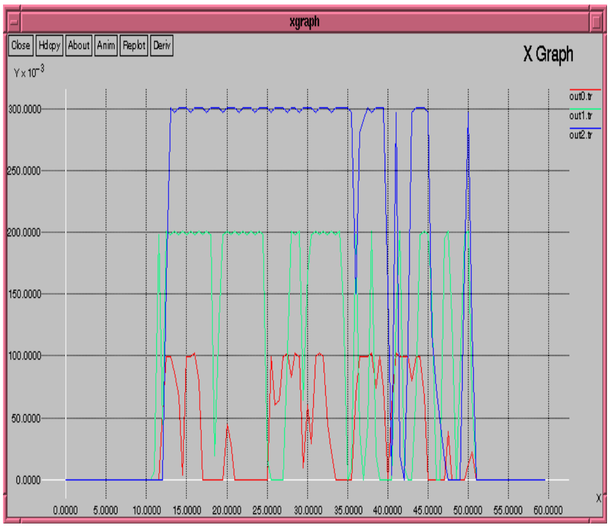

Fig.1. Packet Delivery Ratio

V. CONCLUSION

The proposed new scheme to dynamically calculate the rebroadcast delay, which is used to determine the forwarding order and more effectively exploit the neighbour coverage 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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BIOGRAPHY

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