Multipath Routing for Mobile Ad Hoc Network

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Abstract—Multipath routing allows the establishment of multiple paths between a pair of source and destination node in mobile ad hoc network. It is typically proposed in order to increase the reliability of data transmission or to provide load balancing and has received more and more attentions. In this paper, we present a multipath source routing protocol with some QoS guarantee. During the routing discovery, the source node firstly checks whether it has the routing information to the destination node. If not, it begins to broadcast RREQs to its neighborhoods and finally to the destination. From the received RREQs, the destination node can construct a certain topology for network and the path that is maximally disjoint from the shortest delay path is selected as our desirable routing. Simulation results show that comparing with traditional unipath routing scheme, the proposed protocol can greatly increases the packet delivery rate and extend the life-span of network.

Index Terms—multipath routing; mobile Ad Hoc network; dynamic source routing

I. INTRODUCTION

Mobile ad hoc network (MANET) consists of several wireless mobile nodes which dynamically exchange data among themselves without the reliance on a fixed base station or a wired backbone network. Due to the limited transmission power, multiple hops are usually needed for a node to exchange information with any other node in the network. So routing discovery and maintenance is crucial issues in MANET.

Work on unipath routing has been proposed in many literatures [1][2][3][4][5]. There two main classes of routing protocols in MANET, i.e., table-based and on-demand protocols. In table-based protocols, each node maintains a routing table containing routes to all nodes in the network. Nodes must periodically exchange messages with routing information to keep routing tables up-to-date. Since the routes between nodes need be computed and stored, even when they are not needed, such protocol may be impractical, especially for large, highly mobile networks. In on-demand protocols, nodes only compute routes when they are needed. Therefore, on-demand protocols are more scalable to dynamic, large networks. When a node needs a route to another node, it initiates a route discovery process to find a route.

Nowadays, Multipath routing is also being taken into consideration. Multipath routing allows the establishment of multiple paths between a pair of source and destination node [6][7][8]. It is typically proposed in order to increase the reliability of data transmission or to provide load balancing and has received more and more attentions. Wang proposes a multipath routing protocol for MANET which based on the measurement of RTT to distribute load along multiple paths. It can decrease the network congestion while bring with little overhead [9]. C. Giruka etc. present a generic mechanism to transform any table-driven multipath routing protocol into a truthful one, and prove that it guarantees truthfulness. Furthermore, they propose the truthful multipath routing protocol based on AOMDV protocol, which incurs only 2n control packets for a route discovery and does not require new types of control messages over AOMDV [10]. Lee and Gerla propose a scheme to improve existing on-demand routing protocols by creating a mesh and providing multiple alternate routes. Their algorithm establishes the mesh and multipath without transmitting any extra control message [11]. In [12], T. Calafate etc. propose an admission control strategy that can operate both over single and multipath routing protocols. The QoS framework can perfectly coexist with multipath routing protocols, achieving significant improvements on the overall network performance, especially from the point of view of demanding applications such as real time video and voice applications. Marina and Das propose a multipath protocol extended from AODV. It computes multiple loop-free and link-disjoint paths which is able to reduce routing overheads. Loop-freedom is guaranteed by using a notion of advertised hop-count [13]. Based on the study of a large number of multipath routing schemes, we propose a dynamic multipath source routing (MSR) protocol with QoS supporting in this paper. The simulation results show it has higher performance comparing with the traditional unipath protocol.

II. PRELIMINARIES

We attempt to find multiple paths that satisfy the bandwidth and reliability requirements. Below, the calculation of these QoS metrics will be given.

A. Bandwidth Calculation

The idle period of the wireless channel is a very important parameter for the calculation of bandwidth. It is determined by the traffic traveling along the mobile nodes as well as their neighborhoods. During the period the mobile nodes can successfully transmit data packets. The available bandwidth can be calculated as follow:

\[
B(i) = B_{\text{max}}(i) \cdot T_{\text{idle}} / T_{\text{trans}}
\]

Carrier sense mechanism of IEEE 802.11 adopted in MANET can judge whether the wireless channel is idle or busy. So it can be used to monitor the transition of channel state. In this paper, we use virtual carrier sense mechanism provided by the MAC layer to determine
whether channel is busy. In a unit interval, the period during which the channel changes its state from busy to idle is defined as $T_{idle}$. Thus $T_{idle}$ can be denoted by $T_{active} - T_{idle}$. Putting the value of $T_{idle}$ into Eq.(1), $B(i)$ can be easily calculated.

The statistics of available bandwidth in a unit interval will be informed to network layer. The sliding window with size at 5 is used to avoid fluctuations of statistical information. Once a new statistical parameter arrives, sliding window will forward a place to move the oldest parameter out of the queue. The values in the window are always measurement results during the recent 5 unit of interval. Using smoothing technology, different weights will be assigned to calculate the current available bandwidth as follow:

$$B(i) = \sum_{j=0}^{4} (w(j) \cdot T_{active}(j)) \cdot B_{max}(i)$$

(2)

Empirically, the weights from $w(0)$ to $w(4)$ are set to 0.1, 0.1, 0.1, 0.2 and 0.5 respectively.

B. Reliability Calculation

End-to-end reliability is defined as the probability of sending data successfully within a time window [5]. The end-to-end reliability is calculated from the reliabilities of the paths used for routing. The path reliability is calculated from the link availabilities. Link availability is defined as the probability that a link is available from time $t_0$ to $t_1$, given that it is an active link at time $t_0$ [14]. Path reliability is the product of the link availabilities along the path, assuming the link availabilities are independent. The end-to-end reliability is defined as

$$1 - \prod_{k \in K} (1 - k)$$

(3)

where $k$ is the path reliability of a path, and $K$ is the set of all paths. Essentially, the end-to-end reliability is the probability that at least one path does not fail within the given time window.

III. MULTIPATH ROUTING

Multipath routing aims to find multiple routes between source and destination node. These multiple paths between source and destination node pairs can be used to compensate for the dynamic and unpredictable nature of MANET, and support QoS. Multipath based routing protocols can discover node disjoint, link disjoint, or non-disjoint routes. Node disjoint routes, also known as totally disjoint routes, have no nodes or links in common. Link disjoint routes have no links in common, but may have nodes in common. Non-disjoint routes can have nodes and links in common [5]. Non-disjoint routes may have lower aggregate resources than disjoint routes, because non-disjoint routes share links or nodes. While the advantage of non-disjoint routes is that they can be more easily discovered, since there are no restrictions that require the routes to be node or link disjoint. In QoS routing, only a subset of paths that satisfies the QoS requirement will be selected. In this section, we present an on-demand multipath source routing method (MSR) which extends DSR protocol to find multipath routing coupled with bandwidth and reliability constraint. It consists of three phases: routing discovery, routing maintenance and traffic allocation.

MSR will send RREQ to discover routing which is similar to DSR. The MSR RREQ mainly includes the following fields:

- SourceID and RREQID, which are used to uniquely identify a QoS routing request.
- Routing list, which is used to keep track of the RREQ traveling along nodes and so that the destination node can select node disjoint multipath routing.
- $H_{max}$, which is used to avoid overhead brought by routing with too many hops.
- $B_{min}$ and $R_{min}$, which denote the minimum bandwidth and reliability requirements.

Routing discovery can be triggered upon failure of the route and initiating new QoS request. The source node firstly checks whether it has the routing information to the destination node. If not, it begins to broadcast RREQs to its neighborhoods. Once intermediate nodes receive this RREQ, Unlike DSR, they do not keep a route cache and therefore, do not reply to RREQs. This helps to allow the destination node to receive all the routes so that it can select the maximally disjoint paths. Duplicate RREQs are not necessarily discarded. Instead, intermediate nodes forward RREQs that are received through a different incoming link, and whose hop count is not larger than the previously received RREQs.

The process on each intermediate node can be described as follows:

- **Step 1** If current node itself is within the Routing list recorded by RREQ, it will discard the RREQ because of the routing loop. Otherwise, goto step 2.
- **Step 2** If the tuple (SourceID, RREQID) of RREQ is not included in the routing table, which means the current node is the first time to receive this RREQ, it calculates the corresponding value of the bandwidth according to Eq.(1) and (2). If the value is not less than $B_{min}$, the RREQ will be discarded. Otherwise, goto step 3.
- **Step 3** Append the value of bandwidth to the corresponding fields of the RREQ. Then the RREQ will be continually forwarded. Goto step 1.

The destination sends an RREP for the first RREQ it receives, which represents the shortest delay path. The destination then waits to receive more RREQs. From the received RREQs, the destination node can construct a certain topology for network and the path that is maximally disjoint from the shortest delay path is selected. If more than one maximally disjoint path exists, the shortest hop path is selected. If more than one shortest hop path exists, the path whose RREQ was received first is selected. The destination then sends an RREP for the selected RREQ. The process can be described as follows:
Step 1 Initialize the maximal number of routes $N$ and $H_{max}$.

Step 2 Calculate end-to-end reliability according to Eq.(3), and sort the sequence($Routing_{list_1}$, $Routing_{list_2}$, ...$Routing_{list_n}$) in descending order based on the reliability values. $Routing_{list_i}$ denotes the $i$th $Routing_{list}$ in the corresponding field in RREQ. RREQ recording with $Routing_{list_i}$ will be added into the responding buffer.

Step 3 From $Routing_{list_2}$ to $Routing_{list_n}$, find all $Routing_{list_i}$ ($i=2, 3, ..., n$) which disjoint with $Routing_{list_1}$ [15]. If the number of the multipath routes founded is no more than $N$ and the hops of each route is less than $H_{max}$, the corresponding RREQ will be added into the responding buffer and the count of routes will be increased by 1;

Step 4 If the iteration finished or the routing number exceeds $N$, terminate the process. Otherwise, goto step3.

IV. PEERFOMANCE EVALUATION

We have evaluated the performance of the two algorithms (MSR and DSR) for many network scenes. Networks with a specified number of nodes are randomly generated within a 1000×1000 square region. The link reliability is randomly set in the interval [0.5, 0.9]. One pair of the nodes is randomly chosen to be the source and destination. The IEEE 802.11 MAC protocol is used in the network. Random way-point is selected as movement model and the CBR is used to send data. In all cases, our results are based on the performance of 20 randomly generated networks.

A. Results for traffic load

In this scene, we generate a network with 60 nodes, and the pause time of mobile nodes is set to 90s. The number of QoS request connection, which represents the degree of traffic load, varies from 10 to 60 (See Fig. 1 to Fig. 3). With the increasing traffic load, the burden of intermediate nodes will be aggravated and in turn resulting the failure of resource reserving. The performance of both MSR and DSR are getting worse. By using multipath method, MSR can balance the traffic load through sending data along different paths which is responsible for reducing the packets collision. Hence, MSR can always keep higher packet delivery ratio. Furthermore, using alternate paths reduce the impact brought by routing failure, the routing overhead of MSR is lower. We observe that DSR provides lower end-to-end delays when the traffic load is below some threshold. In higher load case, however, the traffic allocation adopted by MSR will improve the delay.

B. Results for mobility

In this scene, we generate a network with 60 nodes, and the number of QoS request connection is set to 40. The pause time of mobile nodes varies from 0 to 150s.
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REFERENCES


V. CONCLUSIONS

In this paper, we propose a new multipath source routing protocol with bandwidth and reliability constraints for MANET. It extends DSR’s routing discovery and maintenance mechanism to obtain multipath routing. Simulation results show that MSR can improve the packet delivery rate and routing overhead. Additionally, it is energy efficient and can be help to prolong the life-span of network.

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