Mobility Prediction Aided Dynamic Multicast Routing in MANET

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Abstract—**Nodes in mobile ad hoc network (MANET) are free to move at anytime and to anywhere. This mobility feature makes the multicast in MANET a typical dynamic multicast case, where group members are likely to leave and rejoin the multicast session frequently. To provide an efficient routing scheme in such a dynamic multicast environment, we propose a mobility prediction aided dynamic multicast routing (MPADMR) algorithm in this paper. This algorithm contains two steps, the construction of link lifetime constrained minimum hop-count multicast tree and the dynamic multicast tree maintenance procedure. We employ OPNET simulation to evaluate the performance of this dynamic multicast routing algorithm. The simulation results show that MPADMR has strong capability of handling the dynamics of group members.**

Keywords-MANET, dynamic multicast routing, mobility prediction

I. Introduction

The development of pervasive computing and proliferation of portable computing devices have raised the importance of mobile and wireless networking. Mobile ad hoc network (MANET) is an economic solution for wireless communications, because it doesn't require any prior investment in fixed infrastructure. At the same time, the popularity of group computing has grown rapidly. Example applications include audio/video conferencing as well as one-to-many data dissemination in critical situations such as disaster recovery or battlefield scenarios. Multicast is a very useful and efficient means of supporting group-oriented applications, especially in mobile/wireless environments where bandwidth is scarce and equipment has limited power. With the rapid growth of demand, the multicast technology in mobile ad hoc network (MANET) has attracted a lot of attention recently [1~9].

In MANET, the nodes are free to move randomly and can organize themselves in an arbitrary manner. As a result, group members are likely to leave/rejoin the multicast session frequently, and an efficient dynamic multicast routing algorithm is urgently needed to solve this problem. Although the dynamic multicast routing has been discussed extensively for wired networks [10~13], it is scarcely investigated in MANET. To meet this shortage, we propose a mobility prediction aided dynamic multicast routing (MPADMR) algorithm in this paper.

In order to attain good routing performance in MANET, MPADMR mainly has two objectives. Firstly, the multicast tree should maintain relatively stable during the whole multicast session despite the frequent join/leave events. Secondly, the tree's hop-count should stay approximately minimal without the need to reconstruct the entire multicast tree from the beginning. To reach these two goals, MPADMR consists of two steps. In the first step, with the aid of mobility prediction [14~17], a link lifetime constrained minimum hop-count multicast tree is constructed at the beginning of a multicast session. In the second step, a dynamic multicast tree maintenance procedure is employed to rearrange the existing multicast tree when a group member joins/leaves the multicast session.

The rest of the paper is organized as follows. Firstly, we introduce the mobility prediction aided dynamic multicast routing algorithm in Section 2. Then, we employ OPNET simulation to evaluate the performance of this dynamic multicast routing algorithm in Section 3. In the end, Section 4 summarizes our results.

II. The Mobility Prediction Aided Dynamic Multicast Routing Algorithm

A. Construction of Link Lifetime Constrained Minimum Hop-Count Multicast Tree

The primary goal of the conventional multicast routing protocols has been to reduce the delay since most multicast applications, such as audio/video conferencing tend to be delay sensitive. Hence, most of the existing multicast routing protocols in MANET are designed to construct a multicast tree that minimizes the communication latency. Because the number of hops is a good heuristic metric for capturing this latency, a multicast tree with the minimum number of hops has been favored by most routing protocols. Some good examples include On Demand Multicast Routing Protocol (ODMRP), Core Assisted Mesh Protocol (CAMP), and Multicast Ad hoc On-Demand Distance Vector (MAODV) Routing Protocol. However, in MANET, there is another factor that makes routing design an even more complicated task, i.e. the mobility. Due to frequent topology changes caused by node mobility, it is possible that a route with minimal delay is the least stable one. As a result, except the criterion of minimum hop count, the lifetime of multicast tree must be taken into account as well. The lifetime of a multicast tree is determined by one particular link who has the minimum link lifetime (link lifetime means how long a link can exist) among all the links of that multicast tree.

To create a multicast tree of long lifetime, we take the link lifetime as a constraint for multicast tree finding. In our algorithm, links of a multicast tree are classified into 2 categories, the intermediate link (a link ends with intermediate nodes) and the terminal link (a link ends with a group member). We only apply link lifetime constraint on intermediate links, since the multicast tree has to contain all the group members, while the intermediate node can be chosen with freedom. To implement the link lifetime constraint, threshold Thr_{inter} is defined for intermediate links. The intermediate links whose lifetime is below Thr_{inter} are removed from the network topology before the conventional routing protocol (ODMRP or MAODV) tries to find a minimum hop-count tree. By this way, the lifetime of the whole multicast tree is improved substantially. Furthermore, we hypothesize that the lifetime of a link only relies on the mobility feature of that link's beginning node and ending node. Other factors, such as battery power, are not considered in this paper.

We predict the lifetime of a certain link by using the mobility prediction approach proposed in [14]. This prediction method assumes a free space propagation model, where the strength of received signal solely depends on the distance to the transmitter. It also assumes clock synchronization exists among all the nodes in the network. Therefore, if the mobility feature of two neighbors (e.g., speed, direction, and radio propagation range) is known, we can estimate the duration that two nodes remain connected. By utilizing Global Positioning System (GPS) to get the mobility parameters of moving nodes, we can predict the lifetime of any link in MANET.

B. Dynamic Multicast Tree Maintenance Procedure

Once a multicast tree is created by the first step, the second step is taken to cope with the join/leave events of group members. In wired network, two approaches, the *naive* algorithm and the *greedy* algorithm, have been proposed by previous literature for multicast tree maintenance. The *naive* algorithm attempts to find the shortest path from the source to accommodate a new joining group member. This strategy is simple but does not guarantee a low hop-count tree. The *greedy* algorithm gets rid of this drawback by using the shortest path from any node of the existing multicast tree. Nevertheless, this approach is not applicable for MANET. Its weakness is that a new joining group member may choose the subtree of an existing group member whose lifetime is shorter than the session duration, and the *greedy* algorithm may thus have to look for another shortest path after that group member leaves. In fact, the *greedy* algorithm doesn't consider the group members who are going to leave before the end of the session. To overcome this shortcoming, we propose a group member lifetime constrained greedy algorithm for the multicast tree maintenance. The Join and Leave sub-procedures are depicted briefly as follows.

Join Sub-Procedure: When a new group member wants to join, firstly we use the mobility prediction approach to estimate the lifetime of each terminal link in the multicast tree. The lifetime of a terminal link is equal to the lifetime of the group member who is its end node. Secondly, subtrees of the group members whose lifetime is less than threshold $Thr_{terminal}$ are removed from the original multicast tree for the purpose of path finding. Thirdly, the *greedy* algorithm is employed to find a path for the new joining group member based on the pruned multicast tree.

Leave Sub-Procedure: Before a group member leaves the multicast session, it sends a leaving request. If the leaving group member is a leaf node, its subtree will be removed instantaneously from the multicast routing table. If it is an intermediate node, a local recovery algorithm will find an alternative long lifetime path in its neighborhood to take over the multicast relay task.

III. Simulation Results

We employ OPNET simulation to evaluate the performance of MPADMR. The simulation is conducted using a network topology consisting of 40 nodes over a 1100m x 1100m area. Moreover, in the simulation, the velocity of each node varies between 0 and 16m/s, the group size changes from 0 to 40, and the radio transmission range is 120 meters. The simulation results are demonstrated from Fig.1 to Fig.4. To show the advantage of our algorithm, the performance of ODMRP and MAODV is also illustrated in those figures for the purpose of comparison.

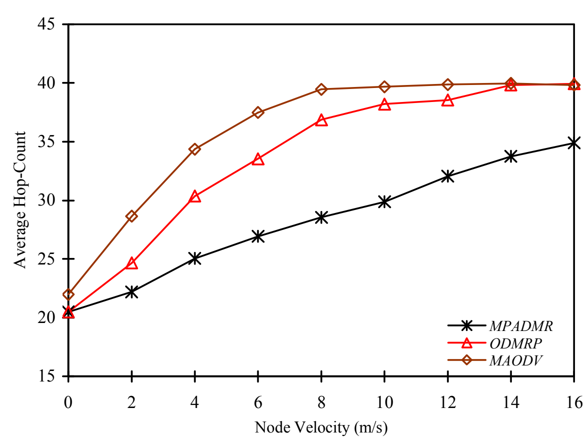

Fig.1. Average hop-count of the multicast tree VS. node velocity (With 15 group members)

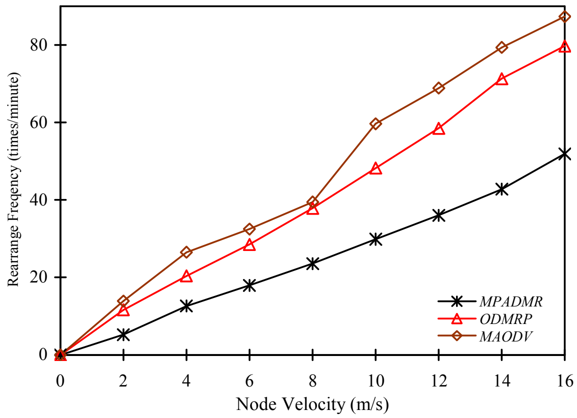

Fig.2. Rearrange frequency of the multicast tree VS. node velocity (With 15 group members)

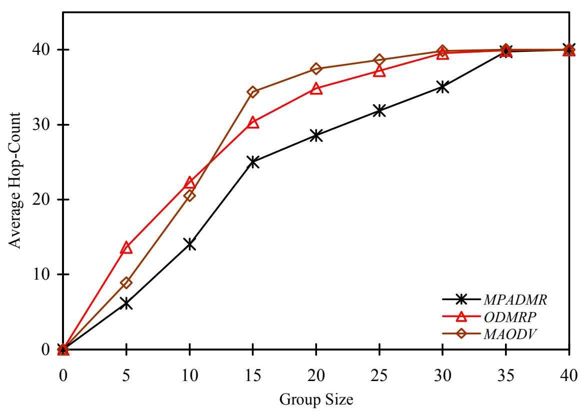

Fig.3. Average hop-count of the multicast tree VS. group size (Node velocity is randomly chosen from 0 to 8 m/s)

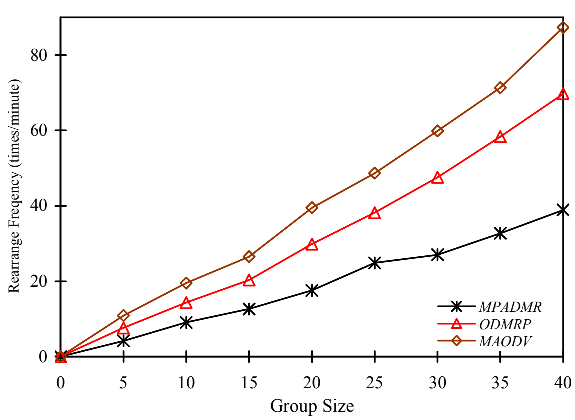

Fig.4. Rearrange frequency of the multicast tree VS. group size (Node velocity is randomly chosen from 0 to 8 m/s)

Fig.1 and Fig.2 illustrate that MPADMR has lower hop-count and rearrange frequency than ODMRP and MAODV when the nodes of MANET move in various speeds. Fig.3 and Fig.4 show that MPADMR can outperform ODMRP and MAODV while the group size is changing. From the above discussion we can conclude MPADMR is an efficient solution for handling the dynamics of group members in MANET.

IV. Conclusions

In mobile ad hoc network, a good multicast routing algorithm should ensure that a join or leave event does not require widespread routing table changes in the whole network. In this paper we present a mobility prediction aided dynamic multicast routing algorithm, i.e. MPADMR, to achieve this goal. The simulation results demonstrate that this routing algorithm has better performance than ODMRP and MAODV in the dynamic multicast environment of MANET.

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