Node Disjoint Minimum Interference Multipath (ND-MIM) Routing Protocol for Mobile Ad hoc Networks

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Abstract—Node-disjoint routing in MANETs is very essential to reduce the end-to-end packet delay and increase the packet delivery ratio. AODV (Ad Hoc On-demand Multipath Distance Vector) which is widely used for MANETs creates single-path route between a pair of source and destination nodes. Node disjoint paths may have worst performance then single path if they interfere with each other due to the broadcasting nature of wireless communications. Greedy-based Interference Avoidance Multipath Routing (GIMR) protocol (2011) is an interference free node disjoint protocol but it uses GPS to discover the paths. In this paper, I proposed a Node disjoint minimum interference multi-path (ND-MIM) routing protocol for MANETs that establishes the main route by the mechanism based on AODV, then backup route search process is taking place while data is transmitted to reduce the transmission delay. This process finds the route that is node-disjoint and have less interference from the main route by not selecting nodes participated in the main route using Hello packet. When either of the main route or the backup route is broken, data is transmitted continuously through the other route and the broken route is recovered by the route maintenance.

Keywords—AODV; MANET; Multipath Routing; Node-disjoint; transmission delay.

I. INTRODUCTION

A mobile ad hoc network (MANET) represents a system of wireless mobile nodes that can self-organize into temporary network topologies, allowing devices to inter-network in areas without any pre-existing communication infrastructure. Mobile nodes in MANETs are constrained by their limited power, processing, memory resources and high degree of mobility. In such networks, the wireless mobile nodes may dynamically join or leave the network topology. In conventional wired networks, each node does not frequently change the network topology. Routing protocols for wired networks are therefore inadequate for ad hoc network where the network topology changes dynamically. Ad hoc network required the frequent rebuilding of routes, so maintaining stable routes may be infeasible. Based on above criterion, on-demand routing protocols are generally used since they consume less routing load (in terms of signaling traffic) than proactive protocols. The Ad hoc On-demand Distance Vector (AODV) [1], one of the most popular reactive routing protocols, offers quick adaptation to dynamic link conditions and low network utilization. However, AODV is a single path routing that requires a new route discovery procedure whenever a link breaks along the route. Such frequent route discoveries result in a high routing overhead and increase end-to-end delay.

Using a single path, it is difficult to respond to a large burst in traffic even though additional network resources may be available. Further, if the path fails, and source has data to send, a new route discovery must be initiated resulting in significant delay and packet loss. In ad hoc networks, multiple paths are desirable since they provide fault-tolerance and can be used simultaneously for data transfer.

Various multipath routing protocols have been suggested as extensions to conventional single-path routing protocols AODV. For example, the Ad Hoc On-demand Multiple Distance Vector (AOMDV) [2] protocol discovers multiple routes by recording the path over which RREQ packets have been sent, and the Ad Hoc On-demand Distance Vector Backup Route (AODV-BR) [3] and AODV-Multipath (AODVM) [4] protocols use overhearing to send RREP packets for discovering multiple routes.

In this paper, I proposed a node disjoint minimum interference multipath routing protocol that is based on the AODV protocol for MANETs. This protocol improves the packet transmission rate and reduces the end-to-end delay by utilizing backup route that is node-disjoint and has no interference from the main route.

II. RELATED WORK

Multipath routing is supposed to reduce the end-to-end packet delay and increase the packet delivery ratio. However, in wireless networks, multiple paths are exposed to mutual interference or path coupling, which impairs efficiency. The efficiency of multipath routing depends on the construction and physical distribution of paths. If the selected paths are independent of each other or cooperative, multipath routing could improve the performance, if paths compete for shared resources, performance may even degrade and be worse than that of single path routing.
There are two types of disjoint paths: link-disjoint and node-disjoint. In node-disjoint paths no node in common other than the source and the destination, while in link-disjoint paths only links are disjoint but may have nodes in common.

Disjoint paths may still interfere with each other due to the broadcasting nature of wireless communications, thus resulting in worse performance than expected. If a node on one path is in the transmission range of a node on the other path, contention occurs. At most one node is allowed to transmit or receive at any time in a neighborhood. Thus, severe contention would cause reduced throughput and longer delay. Therefore, paths that are out of each other’s interference zone could be utilized to improve the performance.

Several implementations of multipath routing are based on AODV [2]; typical examples are AOMDV [2], AODVM [4] and AODV-BR [3] protocols. The AOMDV [2] protocol establishes loop-free link-disjoint paths in the network. When intermediate nodes receive the RREQ packet from the source node, AOMDV [2] protocol stores all RREQ packets, unlike conventional AODV [1], which discards duplicates. So, each node maintains a firsthop list where information from additional field called first hop in RREQ packet to indicate the neighbor node of the source nodes. If firsthop of received RREQ packet is duplicated from its own firsthop list, the RREQ packet is discarded. On the other hand, the RREQ packet is not duplicated from previous RREQ packets. Then the node updates the nexthop, hopcount and advertised hopcount in routing table. At the destination, RREP packets are sent from each received RREQ packet. The Multiple routes are made by RREP packets that are follow the reverse routes that have been set up already in intermediate nodes.

In AODVM [4] protocol, intermediate nodes are not allowed to send a RREP packet directly to the source node. Also, intermediate nodes do not discard the duplicate RREQ packets. But the intermediate nodes record all received RREQ packets in routing table. The destination node sends an RREP for all the received RREQ packets. An intermediate node forwards a received RREP packet to the neighbor in the routing table. Whenever a node overhears one of its neighbors broadcasting RREP packet and it removes that neighbor from its routing table, because nodes cannot participate in more than one route. For the AODV-BR [3] protocol, neighbor nodes overhear the RREP packets for establishing and maintaining the backup routes during the route initiation process. If part of the main route is broken, nodes broadcast error packets to neighbor nodes. When neighbor nodes receive the error packet, they establish an alternate route using information about the overhead RREP packets previously.

In AODV based backup routing scheme (AODV-BBS) [5], HELLO message has been modified to generate 2-hop neighbor knowledge. Each node periodically broadcasts HELLO message containing a list of all neighbors it can reach in one hop. When a node receives a HELLO message it updates its local routing table with the HELLO messages information. Nodes that cannot reach neighbors in two hops directly can learn about 2-hop neighbors from the neighbor that sent the HELLO message. After a node receives a HELLO message from all of its neighbors, it has 2-hop neighbor knowledge. In this protocol each node uses 2-hop neighbor knowledge to generate backup paths during route discovery and maintain up-to-date knowledge of up to date links.

Multipath Routing Protocol Based on AODV (MP-AODV) [6], a node disjoint multipath protocol, establishes the main route by the mechanism based on AODV, and then the data transmission starts immediately. The backup route search process is taking place while data is transmitted to reduce the transmission delay. This process finds the route that is node-disjoint from the main route by not selecting nodes participate in the main route. MP-AODV [6] uses the modified RREQ and RREP packet that has additional 1bit flag ‘F’ which distinguishes the packet into the main route (RREQ, RREP) or backup route (RREQ_2, RREP_2) route discovery processes. Unlike a conventional AODV, intermediate nodes that receive the RREP packet increment the RREP ID value in the seen table. By incrementing the RREP ID value, the protocol ensures that a backup route will not use any nodes that belong to the main route. Nodes belonging to the main route always have a RREQ ID value one higher than nodes in the backup route for the route maintenance process when the backup route has been broken. New field named ‘Route flag’ is added to the routing table for the source node to distinguish between main and backup routes, a value of zero for ‘Route flag’ indicates the main route, and a value of one indicates the backup route. MP-AODV also modifies the routing table of conventional AODV and adds a 'Source' field, that records information about the source node. In New multipath node-disjoint based on AODV (NMN-AODV [7]), three control packets have been used for setup two node-disjoint routes while MP-AODV uses five control packets, which reduce control overhead in the network. Similar to MP-AODV, This protocol uses the ‘F’ flag in the RREQ and RREP packets for distinguishes the main route or backup route packet route discovery processes.

III. NODE DISJOINT MINIMUM INTERFERENCE MULTIPATH (ND-MIM)

This work enables discovery of two node disjoint minimum interference paths from source to destination. In this protocol Hello messages have been used to identify two node disjoint and minimum interference paths. Three control packets are required for setup two node-disjoint routes, which reduce control overhead in the network and also setup backup route faster that reduces the end to end delay.

ND-MIM has two main components: Local connectivity management and Path Discovery. The following describes each of the components in detail.
A. Local Connectivity management

In conventional AODV, each node periodically broadcasts HELLO messages to inform its neighbors that it has not moved away. When a node receives a HELLO message from a neighbor, a route to this neighbor is only added to the routing table when the neighbor does not already exist. If the neighbor exists, its lifetime is increased. When the network topology changes and HELLO message does not received for a defined period of time the route expires. This work modifies Hello packet, by adding hello_flag and source-destination address of the active path as shown in Table I. Nodes that receive hello packet from active neighbor’s (nodes of main path) rebroadcast it further to find first hop neighbors acknowledge. Default value of hello_flag is HF=0, HF=1 used to identify nodes of main path and first hop neighbors of active nodes.

<table>
<thead>
<tr>
<th>Type</th>
<th>R</th>
<th>A</th>
<th>HF</th>
<th>Reserved</th>
<th>Prefix Size</th>
<th>Hop Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node’s IP Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Node’s Sequence Number</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source IP Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Destination IP Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Life time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table I ND-MIM Hello packet

B. Path Discovery

To establish main route source node broadcasts the RREQ packet similar to AODV. Intermediate nodes take similar action as AODV. If the destination node receives RREQ packet, sends the RREP packet the source node, and after NET-TRAVERSAL-TIME milli-seconds sends second RREQ packet (with ‘D’ =1) to the source node. If the source node receives the RREP packet the main route is established and starts data transmission. If the source node receives RREQ packet with ‘D’=1, the backup route is established and starts data transmission with piggybacking RREP on this path simultaneously sending data on main route. When an intermediate node receives RREQ packet (with ‘D’ =1) it first checks hello_flag in its routing table if hello_flag=1 then compares <Source IP, Destination IP> in the RREQ packet with <Destination IP, Source IP> pairs in the itself routing table, if a match case is found, then discard RREQ packet. If a match case is not found or Hello_flag=0, then forward RREQ further till the destination reached. In this protocol two new field named ‘Hello-flag’ and ‘Source’ field have been added to the routing table. Source node distinguishes between first and second RREQ using ‘D’ flag. RREQ and RREP packet format are similar to AODV; routing table for ND-MIM has been given in Table II. Fig 2 illustrates the algorithm for Route discovery process in ND-MIM. Here Des-IP-T: Destination IP Address in the routing table of the current node, Sou-IP-T: Originator IP Address in the routing table of the current node.

### Table II Routing table

<table>
<thead>
<tr>
<th>Destination</th>
<th>…</th>
<th>Source</th>
<th>Hello_flag</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>…</td>
<td>S</td>
<td>0</td>
</tr>
<tr>
<td>…</td>
<td>…</td>
<td>…</td>
<td>1</td>
</tr>
</tbody>
</table>

Input: RREQ packet with ‘D’ flag
IF (packet’s ‘D’=0) {
    if (packet’s Des-IP ≠ My-IP)
        {Conventional AODV algorithm is used}
    else
        {
            The destination node sends RREP,
            After NET-TRAVERSAL-TIME millisecond
            Broadcast RREQ with ‘D’=1 and Des-IP=Sou-IP
        }
    ELSE
        {
            if (packet’s Des-IP = My-IP)
                {Transmit data packets with piggybacking RREP .}
            else if (Hello_flag=1)
                if (Sou-IP-T=Des-IP and Des-IP-T=Sou-IP)
                    {Discard RREQ packet}
                else
                    {Forward RREQ packet.}
        }

Fig 1. ND-MIM Path Discovery
In this paper, I proposed a routing protocol that establishes two node-disjoint minimum interference routes between source and destination nodes based on AODV protocol for MANETs.

In addition, two routes will not break at the same time because the protocol uses node-disjoint multiple routes that are not duplicated between main and backup routes. ND-MIM establishes two node-disjoint minimum interference paths because it starts to establish backup route using nodes that are not belonging to main route or first hop neighbors of main route nodes. In this case backup path is node disjoint as well as less interference from main path.

Thus end-to-end delay is lower than other multipath node disjoint protocols. Also this protocol sends the data immediately after the main route is found by separating the main route and backup route discovery process to reduce the data transmission delay. In the future work, I will compare ND-MIM with other multipath routing protocols based on AODV such as MP-AODV and NMN-AODV.

REFERENCES