AODV-OF: An overhearing based route repair process for reactive routing protocols

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Abstract— **Mobility of nodes causes frequent link breaks and decreases the performance of routing protocols in Mobile Ad hoc Networks. Overhearing of packets can be used as a passive update mechanism for routing and alternate route tables. Hello packets are used to discover new neighbor nodes and refresh the routing entries. Proper neighbor node selection by upstream nodes is an important issue during link breaks. We employ overhearing and present an efficient method of neighbor node selection on the basis of its overhearing capacity, Overhearing Factor (OF), for a dense network. In simulation, we implement the proposed scheme on AODV routing protocol. We evaluate the performance of proposed scheme and compare it with that of the existing method of AODV routing protocol.**

Keywords— Overhearing; AODV protocol; Overhearing Factor (OF); nodes; hello messages; network simulator (ns-2.34)

I. INTRODUCTION

A Mobile Ad hoc Network (MANET) is a set of nodes that can establish connections without any access points or backbone. Routing protocols are used to provide the most efficient path for the delivery of packets. The primary requirement of routing is that the set of nodes should be within the transmission range of each other. A node willing to start communication may not be in the range of the destination node. In that case, it forwards the packets to the node(s) in its range and finally the packets reach the destination node, hence establishing multihop routes.

In AODV when there is a link break, the upstream node checks the location of the link break. If it is near the destination node, then the node performs local repair. It broadcasts RREQ (Route Request) packets and waits for the discovery period to receive RREP (Route Reply) packets. If it fails to receive RREP within the stipulated time period, it sends an RERR (Route Error) message to the source for the destination.

If however, it receives multiple RREPs, the node compares the hop count of the new route with the value in the hop count field of the invalid route table entry for that destination. If the hop count of the newly determined route to the destination is greater than the hop count of the previously known route, the node issues a RERR message for the destination. On the other hand, if the upstream node does not repair the link, then also a RERR message is sent to the source node. This shows that a link break causes transmission of additional control packets to repair the route or reestablish a new route. These additional control packets increase the routing overhead [14]. Moreover, establishing a new route or repairing it traditionally causes packet drop, thereby decreasing the packet delivery ratio and the throughput.

Instead of repairing a broken link or rediscovering a route, the upstream node should be able to choose a suitable neighbor to forward the packets without the help of any control packets. If there are no such neighbors then the existing route maintenance is the only option. For choosing such a neighbor at the time of link break, the nodes in the active route should maintain and update the list of neighbors.

During a link break, the upstream node selects a neighbor node to deliver the data packets. Such a neighbor node cannot forward the packets if it itself does not have any neighbors. This results in packet drop. Our objective is to select suitable neighbor nodes to avoid such a situation, thereby creating alternate paths. Usage of such paths reduces packet drop and routing overhead. In this paper, we are using hello packets to update neighbor tables, which maintain the connectivity among neighbors.

Organization

Rest of paper is organized as follows: section II provides the background for routing protocols and their issues. Section III presents proposed method (and pseudo code). Section IV shows the performance evaluation and results. Finally the paper is concluded in section V.

II. RELATED WORK

In this section we discuss the routing protocols for mobile ad hoc networks. Routing protocols in MANETs are classified as proactive, reactive and hybrid [1].

A. *Proactive Routing Protocol*

Proactive routing protocols are derived from distance vector and link state protocols, which are used in wireline networks. In proactive routing protocols, a node keeps the route information of all the other nodes. Destination-sequenced distance vector (DSDV) is a distance vector routing protocol, which is based on the Bellman-Ford algorithm. Nodes use sequence numbers to avoid the count to infinity problem. In the case of any changes in network topology, the subject nodes increment their sequence numbers. The neighborhood connectivity of nodes is maintained by periodic broadcast of hello messages in a single hop. Because of mobility, the positions of nodes change in random manner, so the topology of network changes and results in poor performance of the protocol. In short span static network (e.g. 10-20 nodes [10]) DSDV routing protocol gives effective results for the performance metrics like throughput and end-to-end delay. Multi-point relay concept (MPR) has been considered in OLSR routing protocol [3] to deal with the problems of routing overhead and bandwidth consumption. Multi-point relay (MPR) is used to diminish the routing overheads. MPR efficiently disseminates link state updates across the network. It allows nodes to generate the link-state update message. Proactive routing protocols do not use the overhearing process because they use periodic updates for refreshing the entries in routing tables.

B. *Reactive routing protocol*

A reactive routing protocol establishes a route only when any data transmission is required. It performs better than the proactive routing protocols, considering metrics: packet delivery ratio, throughput, and end-to-end delay. These routing protocols are further classified as source routing and hop-by-hop routing. The intermediate nodes have complete route information in their route cache in source routing whereas in hop-by-hop routing, they have route information only for the next hop. Route maintenance process in reactive routing protocols is used to increase the lifetime of the existing route and thus increasing the protocol performance.

Dynamic source routing (DSR) is a source routing protocol in which source node extracts the complete route information while receiving route reply (RREP) packets. DSR routing protocol is a beacon-less protocol (no hello packets), hence the bandwidth consumption is reduced. Overhearing is allowed to update the routing entries so there is a high chance of route update. It means active routes are maintained by overhearing the traffic (data packets). In the case of route failure, affected (upstream) node immediately sends a route error (RERR) message to source node and starts global repair (reroute discovery) [4]. The performance of DSR protocol degrades when active nodes start to move. In mobility, multiple link breaks is a serious problem, which causes rapid degradation of the performance. In DSR, maximum number of attempts is used to search the shortest path. If the path is not established, then the source waits for the network to become stable and then again starts the route discovery. In a dynamic environment, DSR's performance is further affected by stale route entries because of the lack of update (hello) process and local repair, thereby increasing the routing overhead and end-to-end delay.

Ad-hoc On-demand Distance Vector (AODV) [5], routing protocol is based on hop-by-hop routing mechanism. In AODV, set of intermediate nodes makes the multihop path to deliver data packets. In a large scale network, flooding of control packets is used to find destination node in single attempt but this method is useful in highly dynamic network. Methods like expanding ring search [13] and probabilistic broadcast have been used to minimize the control packets in the network [14]. These broadcast control mechanisms reduce the high routing overhead and bandwidth consumption. AODV uses destination sequence numbers to avoid routing loops and count to infinity problem. For the detection of link failure, hello-based link failure detection mechanism [11] is used in MANETs. Reroute discovery (after a link failure), increases routing overhead, bandwidth consumption and delay, and hence reduces throughput. Our goal is to control these metrics by improving the route maintenance process. Backup path routing approach gives an improvement over the route maintenance process of the existing reactive routing protocols. We are following the backup path routing approach for improvement in the performance of routing protocols [4], [8], [9].

In AODV-BR backup routes are used when links break, to continue the delivery of data packets without sending error message to source node. Sometimes the length of backup routes become large which may increase the delay, but the delivery of data packets with minimum packet drop is more important. The route repair process is classified into local repair and global repair. The global route repair starts due to unsuccessful attempts of local repair process [9]. Alternate paths are used to reduce the use of route repair process because in both the processes, unnecessary routing overheads are produced. The operation of alternate path works efficiently if adequate number of adjacent nodes exists along active route. After link break, the upstream node sends the packets through the alternate path and sends an RERR packet to the source node. This process increases routing overhead and congestion in network. AODV-ABR also uses alternate paths and shows improvement over AODV-BR. In sparse networks, the node density around active route is low; hence the alternate path approach may give ineffective result in route maintenance.

In this paper we observe the performance of AODV routing protocol and focus on its inefficiency during high node density, and mobility. AODV-BR establishes a small mesh structure along active route (*fish bone structure* [8]) with alternate paths, which are formed by overhearing RREP packets. The maintenance of alternate paths is possible by overhearing data packets only [9]. Hence, the alternate paths created are inefficient in dynamic environment.

AODV-ABR uses overhearing to update or add active route information in the alternate route tables along with hop count value. These alternate route entries are periodically updated by overhearing data packets. Alternate route table entries are deleted when neighbors move outside the coverage region of active node. If a new node comes inside the range of active node then the former adds entries in its alternate route table by overhearing data packets.

III. PROPOSED METHOD

On the occurrence of a link break, instead of establishing a new route or repairing the existing route, a neighbor can be selected based on its neighbor relationship (neighbor discovery [12]) with the active members of the concerned active route.

This is determined by the overhearing factor (OF) of the neighbor node. If a neighbor is sharing relationships with only one member then it has OF (overhearing factor) value 1. Similarly, if such relationships are shared with two members by a neighbor then it's OF is 2. In the Figure 1 neighbor F is having overhearing factor 1 whereas neighbor E is having overhearing factor 2. A member establishes relationship with its neighbor(s) by exchanging hello packets periodically. In the proposed method, a new field, OF, has been added in the header of the Hello packet.

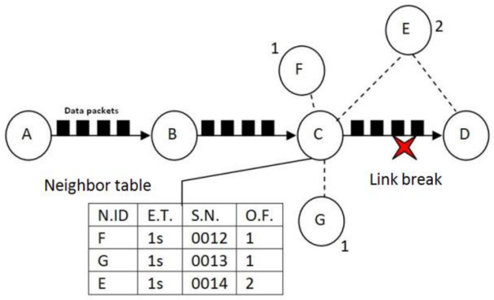

Figure 1: Route maintenance using overhearing factor (OF)

A. *Overhearing*

Overhearing is the phenomenon of receiving packets by a node when it is not the intended recipient. It is an approach of exploiting the broadcast nature of the wireless network as an advantage, which is otherwise considered an interference problem. A node that overhears packets is said to be in promiscuous mode. In the above Figure 1 neighbor nodes F, E and G are overhearing node C whereas node E is overhearing both the nodes, C and D.

a. *Overhearing factor*

On overhearing a RREP/data packet, a neighbor node constructs or updates Alternate Route Table (ART). Figure 2(a) shows the format of ART of a node. After adding the entry, the node checks its ART and finds out the number of entries having the same destination field value. This gives the OF value for the node which it inserts it in the Hello packet header and then broadcasts the packet. On receiving a Hello packet, if there is no entry for the node from which the Hello packet is received, then the receiving node adds an entry for it in its neighbor table (NT). The default value of OF is set to 1. The Hello packet header format for the proposed method is given in Figure 2(c).

Destination ID	Next hop ID	Expiry time (Second)	Flag

(a). Alternate route table

Neighbor ID	Expiry time (Second)	Sequence number	Overhearing Factor (OF)

(b). Neighbor table format

Destination ID	Destination Sequence Number	Hop Count	Lifetime (Second)	Overhearing Factor (OF)

(c). Hello Packet Format

Figure 2: Modified formats of packets and tables of AODV for the proposed solution

B. *Example: Handling a link break*

Two new fields, OF and sequence number are added in the NT as shown in Figure 2(b). Once a link is broken, the upstream node searches its NT for a neighbor having the maximum OF value. Only a neighbor having at least OF value 2 is entertained. If no such neighbor is found, then the existing method of link management is exercised. If a suitable neighbor is found, then the neighbor replaces the broken neighbor with this neighbor in the corresponding routing table entry. After this, the upstream node puts the data packet in its queue. On the other hand the new next node in other words the selected neighbor receives the data packets. On receiving the first such data packet, it does not have any entry in its routing table for the destination of the packet. Hence, it checks its ART and finds the entry for a node with the same destination field as that of the packet. Such a search will always be successful as this selected neighbor has at least an OF = 2. Finally, it adds an entry in its routing table and updates it. The sequence number field is updated with the sequence number found from the NT. The hop count is updated with the hop count = 1 and the next node field is updated with the node found from the ART. Thus, the link is repaired without the help of any control packets, thereby reducing routing overhead, increasing packet delivery ratio, and the throughput.

C. *Proposed method: psuedo code*

I. updateOF: Updating the Overhearing Factor

1. countEntries = 1;
2. while entries in ART
   2.1 if dest_id(current_ptr) == dest_id(next_ptr)
      2.1.1 countEntries++;
3. OF = countEntries;
4. exit;

II. fetchNeighbor : Fetching Neighbor from Neighbor list

arguments: *id*, it is the neighbor id

return value: neighbor entry corresponding to id if successful, otherwise NULL

1. return_nb = nb_list.head;
2. while nb_list not empty
   2.1 if OF(current_ptr) < OF(next_ptr)
      2.1.1 if OF(next_ptr) > OF(return_nb) && neighbor(next_ptr) != id
         2.1.1.1 return_nb = next_ptr;
   2.2 else if OF(current_ptr) > OF(return_ptr) && neighbor(current_ptr) != id
      2.2.1 return_nb = current_ptr;
3. if return_nb not NULL
   3.1 if OF(return_nb) > 1
      3.1.1 return return_nb;
   3.2 else
      3.2.1 return NULL;
4. exit;

III. rt_ll_failed : Handling Link Break
args: Packet p
functions: findNeighbor(nbr_id);

```
1. if (nb = fetchNeighbor(ch->prev_hop) != NULL)
    1.1 rt_entry = findNeighbor(broken_nbr);
    1.2 if (rt_entry)
            1.2.1 next_hop(rt_entry) = neighbor(nb);
    1.3 enqueue(p);
    1.4 return;
2. exit;
```

IV. PERFORMANCE EVALUATION

A. *Simulation environment*

In this section an ad-hoc network is simulated in Network Simulator (NS2.34) to compare the performance of the proposed scheme (AODV+OF) with that of the existing scheme (AODV) of route repair process in AODV [7]. In total, four different scenarios are simulated with number of link breaks from 1 to 4, and the results are averaged. Channel bandwidth is 2 Mbps. The path loss model is Two-Ray Ground Model. The CBR data packet size is 512 bytes and the packet rate is 5 packets per second. After a link break, the upstream node selects the neighbor with the highest OF value as its successor in the chain.

Simulation parameters

Parameter	**Value**
Simulation time	600s
Topology size	2000*1000 m^2
Number of mobile nodes	50
MAC type	MAC 802.11
Radio propagation model	Two ray ground
Range	250m
Size of packet	512 Bytes
Transmitter power	0.281W
Receiver threshold	$7.69113*10^{-8}$ W
Traffic type	CBR
CBR rate	1Mbps
Promiscuous mode	Enable
Hello interval	1000msec
Data size	5MB
Speed	10-40 m/s

B. *Results and discussion*

a. *Impact of link breaks*

Overhead

Routing overhead occurs due to the transmission of additional control packets for successful delivery of data packets. It is the ratio of the total number of routing control packets sent by all nodes to the number of data packets received at destination node. Route Request (RREQ), Route Reply (RREP), Route Error (RERR) and Hello packets comprise the control packets in AODV protocol. In the existing route repair process of AODV, after a link break, the source node starts reroute discovery, but in case of local repair, the upstream node broadcasts RREQ packets and waits for RREP packets. In either case, extra control packets, viz., RERR, RREQ and RREP packets are generated. Reroute discoveries result in considerable increase in the routing overhead in a dynamic network where nodes move and cause numerous link breaks. Increase in routing overhead is directly proportional to the number of the link breaks occurrence.

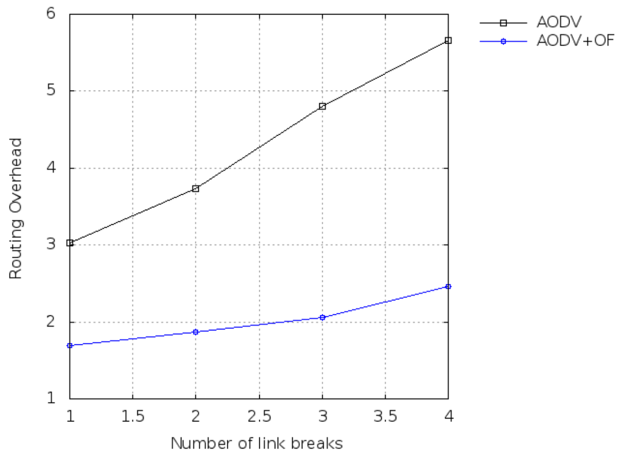

Figure 3.1: Comparing Routing Overhead of existing and proposed methods

In the above figure 3.1, it is observed that the routing overhead is more in the case of existing method than that of the proposed method, when there is a single link break. With increase in the number of the link breaks, the routing overhead increases more in existing method than when proposed method is used.

Packet delivery ratio

Packet delivery ratio is defined as the total amount of data received divided by the total amount of data transmitted during the simulation. AODV performs a local repair when the distance to the destination is not farther than MAX_REPAIR_TTL [7], or initiates a new route discovery. During local repair or reroute discovery, the data packets are queued. But, delay in the repair process causes packet drop, especially in case of high data rate sessions.

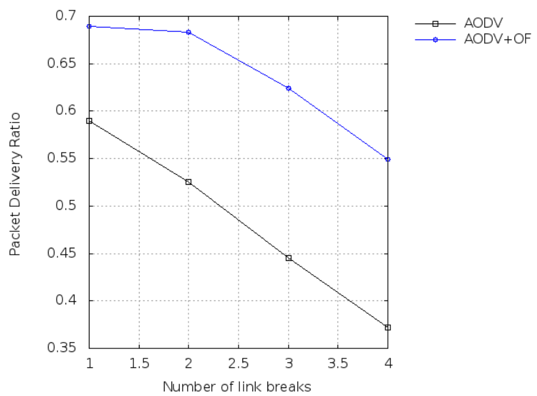

Figure 3.2: Comparing Packet Delivery Ratio of existing and proposed methods

In the above figure 3.2, it is observed that the packet delivery ratio is more in the case of proposed method than that of the existing method, when there is a single link break. The difference in the packet delivery ratios remains same in both the cases with the increase in number of link breaks.

Throughput

Throughput is the average rate of successful message delivery over a communication channel. It is usually measured in bits per second (bit/s or bps). The process of reroute discovery or local repair causes packet drop. The number of packet drops increases with the length of the route and the number of link breaks. Hence, there is a considerable decrease in throughput in such cases of increased packet drops.

The proposed method doesn't rely on such route discovery or maintenance processes and grabs the best possible neighbor for forwarding the data packets.

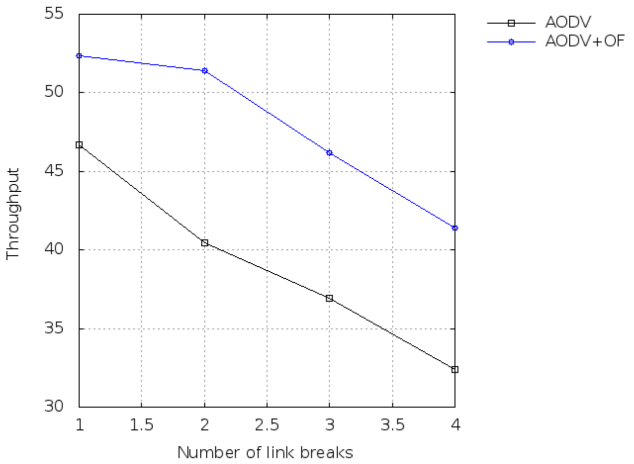

Figure 3.3: Comparing Throughput of existing and proposed methods

In the above figure 3.3, it is observed that the throughput is more in the case of proposed method than that of the existing method, when there is a single link break. The difference in the throughputs remains same in both the cases with the increase in number of link breaks.

b. Impact of mobility

In this section we are going to describe the impact of mobility on the performance of the proposed scheme (AODV+OF) and compare it with that of the AODV routing protocol. We are employing 7 different speed values (m/sec) for the nodes which are 10, 15, 20, 25, 30, 35 and 40. There are 50 nodes spread in a terrain of area 2000 x 1000 m^2 with each node having a range of 250 meters. Several CBR applications are run for 600 seconds. The routing overhead values for all these node speeds show a great difference, both in the proposed and the existing methods. So, for a wide range of speed, we observe that the proposed method incurs routing overhead, which is comparatively very low as shown in Figure 3.4.

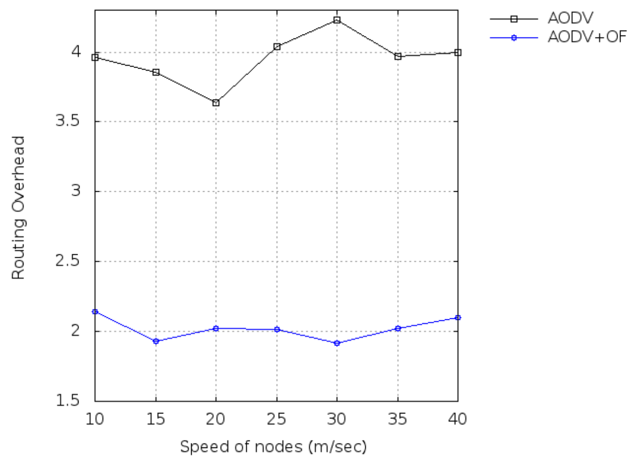

Figure 3.4: Comparing Routing Overhead of existing and proposed methods

For the same set of speed values, the packet delivery ratio for the existing method is a downward sloping line with small variations. The graph for the proposed method however is having a lot of variations, but the values fall inside a small range as shown in Figure 3.5. These values are not decreasing and always better than the corresponding values of the existing method. The graphs for the throughput are somewhat similar to that of the packet delivery ratio. Although, the existing method graph does not resemble a line but the values do decrease with speed. The values of the proposed method are far superior to the corresponding values of the existing method as shown in Figure 3.6.

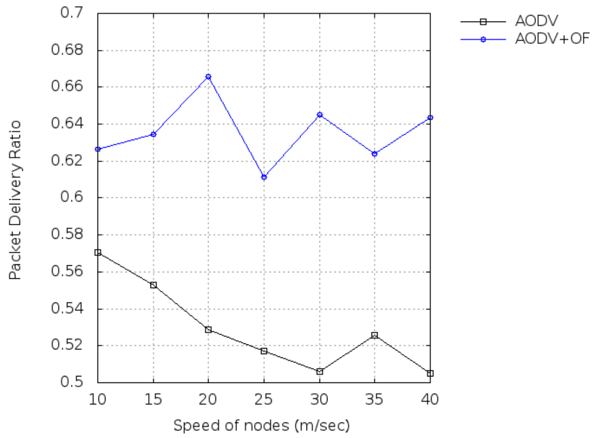

Figure 3.5: Comparing Packet Delivery Ratio of existing and proposed methods

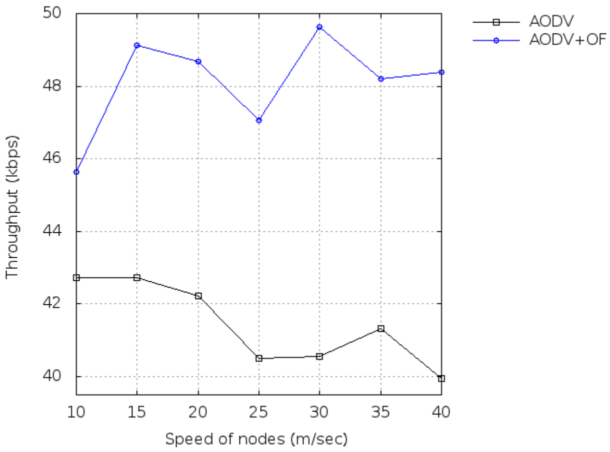

Figure 3.6: Comparing Throughput of existing and proposed methods

V. CONCLUSIONS AND FUTURE WORKS

The proposed method doesn't rely on additional control packets. It depends on overhearing which the neighbor nodes perform throughout the simulation time. The overhearing does not affect any network metrics except energy metric.

As observed from the results for routing overhead, packet delivery ratio and throughput, in the previous section, it is evident that there is a dramatic improvement in these network metrics. With the increase in the number of link breaks, these metrics in the existing method deteriorate, thereby degrading the routing protocol performance.

However, if our proposed method of link break handling is used, then there is a striking improvement in these metrics. Moreover, the increase in link breaks does not affect the metrics much, hence, improves the performance of the routing protocol.

We are planning to implement the proposed method in large-scale networks and to simulate the proposed method in different mobility patterns, like Manhattan Mobility Model, Random Incremental Mobility Model, Reference Point Group Mobility Model and Random Walk Mobility Model [12].

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