Simulation of AODV Routing Protocol & Local Repair and Next-Hop Backup Route Based Improvements

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\textbf{Abstract:} As Mobile Ad hoc Networks (MANETs) continue to experience increasing popularity, several different protocols have been proposed to efficiently transmit data among the participating nodes. These protocols have to be robust and flexible to respond to the dynamic topology and decentralized nature of MANETS. The Ad hoc On Demand Distance Vector (AODV) Routing Protocol is one of the most commonly used reactive protocols for routing information in MANETS. Even though AODV performs well, it suffers from several shortcomings. This paper aims to modify and upgrade the performance of AODV. Two different schemes are proposed which improve upon different aspects of the standard AODV routing protocol. In the first scheme, the AODV protocol is improved by adding the Local Repair feature. In this protocol, intermediate nodes in existing paths try to find new paths to the destination in the event of a link breakage. In the second scheme, Next-hop Backup Route is introduced. According to this scheme, once a path is established, every upstream node on an active route creates a backup path for its next-hop node. Thus, when link breakage happens, the upstream node can depend upon its backup node to forward the packet to the node that was previously its next-hop. Both these schemes increase the number of data packets successfully transmitted to the destination.

\textbf{Keywords:} MANET, AODV, Routing Protocol, Dynamic Routing, Route Maintenance.

1. INTRODUCTION

In recent years, mobile computation has enjoyed an unprecedented rise in popularity which has largely been facilitated by the improvements in software and processing power of the devices. The IEEE 802.11 subcommittee defines an ad hoc network as a wireless network composed of stations within mutual communication range of each other, created in a spontaneous manner and is limited only by temporal and spatial constraints. A very popular ad hoc wireless protocol is the Ad Hoc on Demand Distance Vector (AODV) Protocol. It provides quick and efficient route establishment between two nodes desiring communication. Several researchers have modified and upgraded the AODV depending on their needs. In our particular iteration, we modify the AODV protocol to make it more robust and adaptable for large number of nodes.

2. ROUTE REPAIR IN MANET

On demand routing protocol discovers the route only when it is needed. Once a route is established, the node uses it until the destination is reached or the route expires. Due to node mobility, node move away from the path thus link breaks. When a link breaks, there are two possibilities either the data transfer is stopped permanently or link is repaired for further data transfer. Link repair is of two types as in [2], one is source repair and the other is local repair. In source repair, route is repaired by path maintenance [3] method, when the link is broken, an error message is sent to notify the source node. Then the source can reinitiate the route discovery process again if the route is still needed. In this mechanism, the network is flooded with routing messages. Source repair works fine for small network but in large networks it induces more routing overhead. In local repair [4], when the link breaks, the node upstream to that link can repair the link, by initiating a route discovery process. As intermediate node may be closer to the destination than the source node, so the route discovery must be fast with less routing overhead. In AODV both route repair can be implemented. A brief description of AODV is as follows:

2.1 On Demand Routing Protocol

These routing protocols discover routes between a pair of source and destination only when it is needed. On demand routing protocol eliminates the
additional cost of maintaining routes that are not used. But in on-demand routing protocol, as time progresses a route may not remain optimal to use. With movement of nodes, link breaks occur frequently in these routing protocols. In on-demand protocol, a route is used until it expires. On demand routing protocol examples are AODV, DSR and TORA etc. On demand routing protocols, reduces the number of routes in between source and destination thus saves a lot of space on each node. This saved space can be used for storing extra information in routing table like bandwidth and power utilization at each node.

2.1 Ad hoc On Demand Distance Vector (AODV) Routing Protocol

AODV [3] is an on demand routing protocol. AODV supports both unicast and multicast communication between nodes. AODV uses hop by hop routing which means routing not only involve source node but also intermediate node takes part in it. AODV is most used protocol in ad hoc networks. AODV uses symmetric links between neighboring nodes. To maintain the most recent routing information between nodes it borrows the concept of destination sequence numbers from DSDV. AODV involves separate process for route discovery and for Route maintenance. AODV also uses routing table for maintaining routing information. This is called route table management [3].

1. Route Discovery: First source node initiates the Route Discovery [3] process when it needs to communicate with another node. To discover a new path, source node broadcast a route request (RREQ) packet to all its neighbors. When the RREQ packet goes to intermediate nodes that node first check its routing table. If a valid route is present then the node reply with a RREP packet and if not then the node rebroadcast the RREQ packet to its own neighbor. If a node gets more than one copy of a RREQ packet for the same broadcast id then the node drop that packet and does not forward duplicate copy.

1.1 Reverse Route set-up: For reverse route formation, a node must store the address of the neighbor in its routing table from which the RREQ packet has been received first [3].

1.2 Forward Route Set-up [3]: When an intermediate nodes receive RREQ packet. The node first checks the RREQ destination sequence number with the one that is present in its routing table. If the intermediate node’s sequence number is less than that in RREQ packet, then the intermediate node does not use that route and send no reply to sender. If sequence number at intermediate node is larger or equal to the RREQ sequence number, then the node reply to the neighbor from which the RREQ packet has been received with a RREP packet. As the RREP travels back to the source, each node along the path set up a forward pointer to the node from which the RREP came. If a node receive more than one route reply, then it forward that route reply RREP to the source only whose current destination sequence number is high or at least equal to the destination sequence number present at node but with small hop count. It also ensures that the routing information is up to date and quickest. As the source node receives first RREP, it starts transfer of data.

2. Routing Table: AODV has separate routing table for both unicast and multicast routing. The routing table has all the useful information for a node like sequence number, lifetime of a route, hop count etc. Besides these values it also has an entry for a timer called route request expiration time [3] and route cache timeout [3] after which the route is considered as invalid. Like DSDV, its routing table also has sequence number for all routes. These sequence number ensures loop free path. This information helps when any link between the paths breaks. When a new route is discovered then the node first checks the destination sequence number present in its table.

3. Route Maintenance [3]: During data delivery if the source node moves away the path is lost than it can reinitiate the route discovery process. When an intermediate node on the route moves away from the path then a route error message is sent to source. To detect link failure hello messages and link layer acknowledgement is used [3]. When a link break is noticed on source node then the source node can re-initiate route discovery if the route still needed by the source.

AODV used so much because it can handle different types of mobility rate with different types of data traffic. AODV also reduces routing overhead of control packets and modifications are further applied to improve scalability of the protocol. AODV applies local repair when the upstream node is closer to the destination [4]. There are many ways to improve the local route repair in AODV. Some of these methods are described in next section.

3. EXISTING APPROACHES FOR LOCAL ROUTE REPAIR IN MANET

Many researchers have done a lot of work on local route repair on reactive routing protocols. Some provides techniques to improve the existing method...
of local route repair. Some provides new method to be included in the routing protocol.

3.1 Extended Ad hoc On Demand Distance Vector Local Repair (EAOVDVLRT) For MANET

P. Priya Naidu and M. Chawla presented a novel approach to minimize the routing overhead of AODV local repair trail as in [2]. The route is searched for two times by default in the previous AODV model but in EAOVDVLRT protocol it can be maximized to seven times in the particular route. In the EAOVDVLRT algorithm Flooding can be minimized by the local repair technique. The main idea of this paper is to use perimeter routing for neighbor discovery. In this paper the pre-existing local repair mechanism of AODV is extended. In perimeter routing protocol a planar graph is constructed by using RNG. Use of perimeter routing prevents the overlapping of links between neighbor nodes. Perimeter routing forwards the packets by using the right hand rule across the faces in the planar graph. In the network perimeter model described in this paper, a packet traverses successively through closer faces of a planar sub graph of the full radio network connectivity graph, until reaching a node closer to the destination. This new protocol performs better in terms of throughput, packet delivery ratio, routing overhead and end-to-end delay [2].

3.2 An Algorithm For Improvement Of Link Failure (ILFRP) in MANET

V. K. Goal, R. Shrivastava and V. Malik proposed a routing protocol which provides better performance for link failure in [5]. The protocol described that the path between source and destination considers the remaining power of node and available bandwidth. This paper presented three methods for detection of failed link and then provides a way to improve the link failure problem. These are Hello messages, MAC feedback and Passive acknowledgment. Hello messages are used to determine link existence. This paper used bandwidth and power information available at each node. For this, the available power list and bandwidth list is contained in the RREQ packet. It determines the minimum available power between source and destination. Then the source chooses the path which has maximum power. This new protocol called as ILFRP improves the link failure problem [5].

3.3 AODV with break-avoidance (AODV-BA)

A. Akbari, M. soruri and A. Khosrozadeh in [6] proposed a new route maintenance algorithm to avoid route breaks based on AODV and called it as AODV-BA(AODV with break avoidance). This new route maintenance algorithm avoids route breaks. The main idea of this approach is to detect the link break before it happens and then try to overcome the problem. For this in this algorithm, each intermediate node on an active route detects the danger of a link break to the upstream node and reestablishes a new route before route breaks. The proposed algorithm is based on four elements which are the received radio, the overlap of routes, the battery and the density. On detecting the danger of the link break, it notifies the danger to the upstream node. Received radio detects the danger of the link break due to the distance between nodes being farther than the communication range. Two-Ray Ground Reflection model is used as the radio propagation model. When there is a certain intermediate node on several active routes, the transmission delay increases by the traffic loads and also the battery of the node is quickly consumed. When the battery is less than the threshold, the node notifies the upstream node the danger of the link break. When the number of neighbor nodes around each intermediate node increases and the density rises, the transmission delay increases by competing of acquiring the wireless channel [6]. By using all these approaches, the possibility of link break is detected. Then further improvement can be implemented to handle the problems Performance evaluation of AODV-BA composed with AODV id has been done by the computer simulation using ns-2 [6].

3.4 Congestion Controlled Route Repair

K. S. Rao, L. Shrivastava [9] proposed a modified AODV to controlled congestion by applying efficient local route repair method. The main idea of this approach is to use binary exponential back off strategy for route discovery. In this method, first time a source node broadcasts a RREQ, it waits for some time for the reception of RREP. If a RREP is not received within that time, then the source node sends a new RREQ with waiting time equal to twice of previous. For calculating waiting time for the RREP after sending the second RREQ, the originator node must use a binary exponential back off. If a RREP is not received within this timeout, another RREQ may be sent, up to a limit. For each additional attempt, the waiting time for the RREP is multiplied by 2, so that the time conforms to a binary exponential back off. In this proposed modification, the local repair has invoked according to of hop count distance. It has invoked only when the broken link is closer to destination than the source [9].

4. Enhancements for the AODV Routing Protocol

The AODV routing protocol has been enhanced, optimized and improved in several ways depending upon various parameters. Some researchers have tried to focus on some intrinsic aspects of AODV
like Local Connectivity [37], Local Repair [38, 41] and security where as others focus on external aspects like energy efficiency [39] and node density.

AODV is expected to perform at varying speeds of nodes and varying pause times. The pause time here is defined as the time for which a particular node remains stationary after moving to a new destination. The greater the speed, the faster scenarios change and new routes need to be created. The lesser the pause time, the quicker the response has to be for finalizing new paths.

There are several metrics with which we measure the success of an enhancement or an improvement of a routing protocol. Some improvements focus on increasing the number of packets delivered, some others focus on reducing the end to end delay time and some just focus on reducing the overhead. Depending on the scenario, one or more of these features may be more desirable.

4.1 Scheme 1 - Local Repair based improvement for the AODV Routing Protocol

In the regular AODV protocol, after a route has been established and been declared as an active route, if a link breakage happens, the node upstream of the break creates a Route Error message listing all the destinations which have become unreachable due to the break. If instead of sending an error message to the source node, if the upstream node attempts to repair the broken node itself, less number of data packets will be lost and the route may be restored with a lower overhead. Also, the source node is not at all bothered with another Route Discovery process.

Local Repair makes the node upstream of the break to attempt a repair of the route. This is done by broadcasting a Route Request with a TTL set to the last known distance of the destination plus an increment value. This TTL value is used with an assumption that the destination is not likely to be far away from where it was before the break.

![Figure 4.1 Link breaks in an active route [40]](image1)

For smaller routes, Local Repair is not expected to show many advantages but for larger routes, especially with 10 or more than 10 hops, Local Repair is extremely beneficial. This is because in larger routes, the links are expected to break more often and if the intermediate nodes always keep sending Route Error packets to the source which in turn keeps initiating Route Discovery, huge number of control packets are consumed and the performance will deteriorate.

![Figure 4.2 Intermediate node broadcasts RREQ packets [40]](image2)

This node increments the sequence number of the destination in the RREQ packet by 1 before transmitting it. This prevents the nodes further upstream of this node from replying to the RREQ. Thus, this mechanism prevents loop formation.

![Figure 4.3 New Route is being created after receiving RREP [40]](image3)

Note that this RREQ broadcast is done only once. If no node replies to this broadcast, the intermediate node simply sends a RERR back to the source node.

There are several important features of the Local Repair improvement in the AODV Routing Protocol which need to be discussed:

1. Local Repair helps increase the number of data packets that reach its destination.
2. As the network size increases, it becomes more and more difficult for AODV to deliver packets to their destinations. The path length of these routes increases and a single route may have multiple points of breakage. In Local Repair based AODV, we initiate the repair from an intermediate node which is nearer to the destination than the source, hence routes are expected to get repaired quickly and with lesser overhead.
3. Local Repair based AODV may cause longer paths to the destination than regular AODV. This is because the intermediate nodes do not change the source to intermediate node path at all.
They try to generate a path from the intermediate node to the destination regardless of the destination's new position with respect to the source. There could be an example in which the destination is very close to the source but because of local Repair, packets may have to traverse a longer route path. The source will not know about the nearby destination until it receives a RERR and performs a fresh Route Discovery.

4. Local Repair AODV reduces the number of RREQ transmissions and therefore reduces the control overhead of the protocol. The ratio of number of all packets (RREQ, RREP and RERR) per data packet is lower for Local Repair AODV than for regular AODV.

5. The end to end delay for Local Repair AODV is expected to be much lower than that of regular AODV. This is because the in regular AODV, when a break happens, the RERR packet has to travel to the source and the source has to initiate a RREQ for the destination. This process takes much more time than Local Repair AODV in which an intermediate node transmits RREQ to initiate a route reconstruction.

4.2 Scheme 2: Next-hop Backup based improvement for the AODV Routing Protocol

Several backup based improvements have been proposed for AODV. The challenge with backup based routes is to avoid loops and keep the number of control packets in check. In this paper, we propose a backup node for every link in the active route. This is accomplished by proposing two simple control packets which are used to identify the backup node.

When a link breaks, the upstream node transmits the packet to this backup node which in turn transmits it to its ex next-hop. When a source needs to communicate with a destination, it sends out an RREQ, this RREQ creates a reverse route as it progresses until we find a path to the destination or the destination itself. When the destination is located, an RREP is unicast back to the source through all the intermediate nodes.

In the above figure, there are n intermediate nodes I_1 to I_n. The RREQ is sent along the path from source to destination and the RREP is sent along the path from destination to source. Consider the two intermediate nodes in the figure a and b. The node b is sending an RREP to a which it received either from the destination or from some other intermediate node that has route to the destination.

According to our scheme, the moment a receives this RREP, it tries to locate a backup node for the a-b link. It sends out a special packet called the Backup Route Request (BUREQ). This BUREQ is sent out only once, therefore it does not need any sequence numbers. This packet has a's IP address, b's IP address, destination IP and sequence number and a TTL of 1. Through this BUREQ, we are trying to locate a node x such that node x can become a backup node for a-b link.

The Backup node establishment is undertaken as follows:

1. When a node receives this BUREQ, it checks the destination IP address and sequence number and checks its own route table to see if it has a route to this destination. If it has an active route to the destination, it drops this BUREQ packet.
2. The node b itself gets this request and it drops the BUREQ packet because it has a direct path to the destination.
3. All such nodes which are eligible to be a backup node reply with a Backup Reply (BUREP). These nodes add extra rows to their routing table declaring themselves as Backup nodes for a-b link.
4. When node a receives the first BUREP, it registers this node as a Backup node for b. The node a adds this information to its routing table.

When the primary link a-b gets broken, four cases may arise.

Case 1: Check a's route table for a backup entry to b. If there is no entry, send RERR back to the source.

Case 2: If there is a backup node listed in a's route table, send the packet to the backup node. This backup node receives the packet and checks its own routing table. The backup node will forward all the packets it receives for the destination to the node b.

Case 3: The node a checks its routing table and forwards the packet to x. By now, the node x has moved away and the packet does not reach x. Node a sends a RERR back to the source.

Case 4: The packet reaches x but its route table entry has expired or become corrupted and it cannot send a packet to b. Node x sends a RERR back to the source.

Figure 4.4 Node a locating a backup node x for a node b on its active path
Scheme 1 – Local Repair based improvement for the AODV protocol

We first compare the Local Repair scheme with the regular AODV protocol. After the incorporation of Local Repair, the protocol shows an average improvement of around 15 percent. Because these scenarios are randomly generated and their topology can vary immensely from scenario to scenario, the performance of the new protocol may differ significantly from scenario to scenario.

Figure 4.5 Number of packets successfully delivered to destination
The above graph is obtained by calculating the aggregate of all the received packets in the network. AODV with Local Repair performs better because in Local Repair the nodes closer to destination than the source initiate route discovery and hence the path is resolved quickly. This results in less number of packets dropped.

Figure 4.6 Number of control packets
In regular AODV, RERR is initiated as soon as a link breakage is detected. This RERR travels back to the source which initiates a new route discovery. In AODV with Local Repair, RERR packets are eliminated in some cases as the intermediate node itself initiates a route discovery. Also, the Route Discovery from an intermediate node to the destination takes less number of control packets when compared to that from the source.

In accordance with our expectations, the number of control packets for AODV with Local Repair is always less than that of regular AODV.

Figure 4.7 Packet Delivery Ratio
In AODV with Local Repair, the Packet Delivery Ratio is expected to increase as the Route repairs by intermediate nodes ensure that paths stay valid and those packets that leave the source reach the destination. Once again, the number of control packets and the packet delivery ratio may vary significantly from scenario to scenario because of the random nature of our topologies.

Scheme 2- Next-hop Backup based improvement for AODV protocol

Figure 4.8 Number of packets successfully delivered to destination
AODV with backup route can compensate for link breakages by using the backup node. Once the packet is back on the path, it follows its usual active route. Apart from this, all other parameters are same in AODV and AODV with next-hop backup.

Just like in the Local Repair case, scenario generation in Next-hop Backup Route based improvement is also completely random. These random topologies will react differently in different cases. However, the Backup Route based improvement shows an average improvement of 10 percent when compared to the regular AODV.
In AODV with next-hop backup, when a link breaks, the protocol works out a patch for that link and the remaining part of the link works as it is. Thus, all those packets which are sent are more likely to be delivered than in the regular AODV.

5. CONCLUSION

This paper describes two different schemes which can be applied to the AODV Routing Protocol. We have shown that both AODV with Local Repair and AODV with Next-hop Backup Route improve the number of packets and the packet delivery ratio. Both Local Repair and Next-hop Backup Route based improvements make small changes in the operation of AODV. In Local Repair, we force an intermediate node to perform Route Discovery instead of the source node. In Next-hop Backup repair, we designate a backup node for a particular link. Packets are routed through this backup node when the link breaks. In both cases also have their disadvantages, in local repair, we are missing out on simpler routes which may be found by the source and instead opting for routes from the intermediate node. In some cases, this might create an unnecessarily long path. However, in most cases Local Repair performs excellently and is definitely an improvement over regular AODV. In the next-hop based backup node repair, we have to generate additional control packets and additional entries in the routing table. This does not necessarily slow down the route generation process because it happens after the active route has been created. Nonetheless, extra control packets are always a burden on the processor.

Several suggestions can be made for future work. Perhaps the most obvious one is a combination of both these schemes. Another improvement would be to develop a protocol such that the nodes nearer to the source undertake Next-hop Backup Route based improvement whereas those closer to the destination can perform Local Repair.

REFERENCES


