Performance Comparison of Routing Protocols in MANET

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Abstract
A mobile ad hoc network (MANET) consists of mobile nodes that are capable of communicating with each other in multihop trend without centralized control and fixed based station. As the nodes are mobile, so topology changes frequently that leads to link failure. For finding a route to destination, new route discovery is initiated. Frequent discoveries lead to more routing overhead. To avoid this multipath routing protocols have been proposed as they find multiple routes to destination and switch on to alternate path in case of route failure. In this paper an attempt has been made to compare the performance of two major on demand reactive routing protocols for MANETs that is Ad hoc On Demand Distance Vector (AODV) and Ad-hoc On-demand Multipath Distance Vector Routing (AOMDV). AODV is reactive gateway discovery algorithm where a mobile device of MANET gets connected to gateway only when it is needed. AOMDV was designed generally for highly dynamic ad hoc networks where link fails and route breaks occur frequently. It maintains routes for destinations and makes use of sequence numbers to determine the freshness of routing information to prevent from the routing loops. The performance metrics are analyzed by varying simulation time. These simulations are taken out using the ns-2 network simulator. The results of this work illustrate the importance in carefully evaluating and implementing routing protocols in an ad hoc environment.

Keywords
AODV, AOMDV, MANET.

1. Introduction

MANET[25] is a network having dynamic topology that consists of mobile nodes without Base Station or centralized control. MANET is a self-organized and self configuring multihop wireless network. Due to the less transmission range of mobile node, multihop pattern is followed for passing the information. Packets passed through intermediate nodes while moving from source to destination. All mobile nodes perform functioning of routers that search and maintain routes to other nodes in the network. Problem in adhoc network is that for communication with other nodes, a node must be in the transmission range of base station but sometimes a node moves and network fails. MANET has solved this problem as in MANET nodes follow multihop pattern for communicating with other nodes. Routing is the process of moving information across internetwork from source to destination by selecting best outgoing path that a packet has to take in internetwork. To perform this, a set of routing protocols needed that uses metrics to find optimal path for a packet to travel. Routing protocols designing goals are optimality, simplicity, low overhead, robustness, reliability and flexibility. It is very difficult to design an efficient routing protocol. Routing protocols are classified in MANET in many ways. According to routing strategy routing protocols are classified in two parts, proactive and reactive routing protocols. Proactive routing protocols are also known as table driven protocols. In table driven protocols like DSDV, one or more routing tables are maintained by nodes about nodes in network and network topology packets are exchanged at regular intervals of time between nodes of network. The main disadvantage of proactive routing protocols is that routing overhead increases because of the periodic exchange of messages that results in more use of bandwidth and power. That’s why proactive protocols are not suitable for MANET. Next category is reactive routing protocols that are also known as On-demand routing protocols[12]. Reactive protocols like DSR, AODV[1] overcome the problems of proactive protocols. This protocol initiates a route only when a node wants to start communication with another node. Route request and Route reply messages are used to discover and store the paths found from the source to destination. After finding the paths, shortest path is selected by the source node. Paths discovered by shortest path algorithm cause problems like congestion problems as the centre of network carry more traffic. This results in poor performance. To remove all these shortcomings, multipath routing protocols have been proposed.

Multipath Routing In MANET
In single path routing protocols, a single route is discovered between source and destination. Discovery of multiple routes between source and destination in single route discovery is done by multipath routing[12]. Multipath Routing is the process of distributing the data from source node to destination node over multiple paths. Multipath algorithms permit traffic multiplexing over multiple paths. Multipath Routing performs better by

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proper usage of network resources. Multipath routing protocols provides better throughput and reliability than single path protocols. The main goals of multipath routing protocols are to maintain reliable communication, to reduce routing overhead by use of secondary paths, to ensure load balancing, to improve quality of service, to avoid the additional route discovery overhead.

2. RELATED WORK

This work evolves the previous work that has been undergone in this field. AODV[1] has been extended by AOMDV[2] to discover multiple paths between Source and Destination in a single route discovery. The essential condition for finding multiple paths is that they must be loop free and disjoint. Two major components of AOMDV[2] are- Route Update Rule and the Distributed Protocol to calculate Loop free paths find Link disjoint paths respectively. Obaidat and Ali[3] proposed a novel multipath routing protocol. This proposed protocol is a version of AODV protocol. This settles node-disjoint paths with minimum delays. Existing delay aware doesn’t provide correct end to end delay result as they don’t take in consideration the source node contribution in the overall load of network. The proposed protocol proved that multipath outperforms the unipath protocols in terms of end to end delay, throughput and number of dropped packets. Then the work is carried out in improving the performance of AOMDV like on the basis of energy saving strategy given by Yang and Wang[4]. In this AOMDV protocol has been implemented with CMMBCR that evolves energy saving strategy. This improved version evolves three node status and state of unused nodes that converted to sleep state when not used for a long time and hence reduces the energy consumption. Further the work proceeds in removing the congestion problem that is so common in MANET. Chugh and Jain[5] surveyed some of congestion removal and load balancing techniques. In multipath routing congestion problem is less as comparison to unipath protocols as in multipath routing, balancing of load and thus reducing congestion by dispersing traffic on multiple paths. Performance improved more than this traditional mechanism by using load balancing mechanism that transfers load of congested node to nearby less loaded nodes. Then a load balancing strategy for congestion control is given by Shrivastava, Tomar and Bhadoria[6] in which metrics used like traffic density that determines the traffic density of nearby nodes to determine the congestion status of route and that traffic is distributed to routes according to traffic density. Then a multipath Load balancing and rate-based congestion control method to avoid congestion given by Soundararjan and Bhuvaneshvaran[7].This method evolves a technique in which destination point copies the estimated rate of neighbored nodes and sends that as the feedback to source point. The source node then adjusts the sending rate according to rate estimated. This method then improved the congestion problem provides better throughput and packet delivery ratio. Further, Ali, Stewart and Shahrabi[8] proposed congestion adaptive multipath routing protocol to increase throughput and to avoid congestion. In this technique when load increases beyond threshold and bandwidth decreases below threshold then data traffic disperses over multipath routes to reduce load on congested link and that resulted increase in throughput. Further Diavajane, Agrawal[9] evaluated and compared the performance of different routing protocols for different topologies. DSR, AODV, DSDV and AOMDV are the protocols that are compared on different scenarios like one hop and two hop and the on the basis of performance metrics like throughput and delay. In case of 2 hop, AODV throughput is good but its delay is not so good, throughput and delay of DSDV is poor and DSR throughput and delay are balanced. In case of 1 hop, AODV and AOMDV fairness is good but other protocols fairness is poor. Then more emphasis has been laid out in implementing security in routing protocols. As the dynamic nature of MANET permits nodes to connect or disconnect from network at any time. So security becomes difficult to be implemented. Sherril, Vincent and Meshach [10] proposed a technique to save the network from blackhole attacks. Also, Baboo and Chandrasekar[11] implemented cryptography in order to provide security to data packets that are being broadcasted in wireless communications. Enhanced information security can be induced by integrating AOMDV with Shamir's secret sharing scheme. More and more emphasis is being laid out in order to form the secure, reliable and congestion free network.

3. Background

On-demand routing protocols create routes whenever there is need of communication between source and destination. AODV and AOMDV are the unipath and multipath routing protocol respectively. AODV is reactive gateway discovery algorithm where a mobile device of MANET gets connected to gateway only when it is needed. AOMDV was designed generally for highly dynamic ad hoc networks where link fails and route breaks occur frequently.

A. AODV(Adhoc On-demand Distance Vector Routing Protocol)

The Ad hoc On-Demand Distance Vector (AODV) [1] routing protocol is intended for use by mobile nodes in an ad hoc network. It gets quickly adapted to dynamic link conditions and quickly determines unicast routes to destinations within the ad hoc network. One distinguishing feature of AODV is its use of a destination sequence number for each route entry. Destination sequence numbers ensures loop freedom. The Ad hoc On-Demand Distance Vector (AODV) algorithm enables dynamic, multihop, self-starting routing between participating nodes that wants to make and maintain an ad hoc network. AODV permits mobile nodes to respond quickly to link breakages or any other changes in network topology on timely basis.

Maintaining sequence numbers- Each entry in route table maintains the current information about the destination sequence number. This is known as "destination sequence number"[1]. Destination sequence number is updated when a node gets recent information about the sequence number from RREQ, RREP, or RERR messages. Destination node increments its own sequence number in two circumstances either when a node initiates a new route discovery or when the destination node sends a RREP message. AODV is a reactive routing protocol, and it manages the route table. Route table includes destination IP address, destination sequence number, hop Count, next hop and lifetime.

Generating Route Requests and route replies- When a node needs a route to destination then it broadcasts RREQ packets. The Destination Sequence Number field in the RREQ message is the last known destination sequence number for this destination. The Originator Sequence Number[1] in the RREQ message is the node's own sequence number, which is increased before inserting in a RREQ. Normally the RREQ ID field is incremented by one from the last RREQ ID. Each node maintains only one RREQ ID. The Hop Count field is set to zero. Bidirectional Communication is present. If RREP could not be received until Net_traversal_time then broadcast another RREQ, having incremented RREQ Id. After doing maximum RREQ retries, the route is declared unreachable. When intermediate node receives RREQ, it creates or updates route to previous hop, check previous details. It then increments the hop count by 1. And then the reverse path is maintained. A node generates a RREP if either it is itself the destination or it knows an active route upto the destination.

Route Error Messages-When node X is unable to forward packet P (from node S to node D) on link (X,Y), it generates a RERR message. Destination sequence number for D is incremented by node X. The RERR includes the incremented sequence number N. When received by node S it starts a new route discovery for D using destination sequence number more than N. On receiving route request with destination sequence number, node D will set its sequence number to N.

B. AOMDV(Adhoc On-demand Multipath Distance Vector Routing Protocol)

The derivation of AOMDV[2] is from AODV[1]. In AODV, when a route is needed from source to destination, then source starts a route discovery process by flooding a RREQ for destination. With the help of sequence numbers, RREQs are uniquely identified so that duplicate RREQs can be identified and discarded. When a non-duplicate RREQ is received then intermediate node records previous hop and search for a fresh route entry to the destination in routing table. If fresh route is present then the node sends a RREP to the source but if fresh route is not present, it rebroadcasts the RREQ. The routing information is updated by a node only if a RREP contains either a larger destination sequence number than previous one or a route with less hopcount found.

AOMDV Route Discovery and Maintenance

Source node pass RREQ to neighbours and this process continues until it reaches the destination. A reverse path to source is built by node in case of RREP. For each RREQ, respective RREP reaching at a node specifies an alternate path to source or destination. When a link breakage occurs RERR packets are broadcasted till it reaches the source node. Then source node removes every unreachable entry from the routing table and then uses smallest backup paths.

Maintain Loop Free Paths-

Necessary conditions for Loop freedom are-

1. Sequence number rule: Multiple paths kept by a node must have same destination sequence number.
2. Route advertisement rule: A route shorter than the previously advertised route should not be advertised.
3. Route acceptance rule: A route longer than the previously advertised route should not be accepted.

Route Update Rules

For maintaining loop free multipaths[2], each node keeps variable known as 'advertised hop count' for each destination. The value of this variable is set at the time of first advertisement to the length of the 'longest' available path upto the destination. Each duplicate route advertisement(like RREQ, RREP) received signifies an alternate path to the destination. After receiving route advertisement, next hop list and hop count reinitialized. Loop freedom is achieved by accepting paths having less hop count. Nexthop is replaced by route_list that signifies multiple next hops with their respective hopcounts. This advertised_hopcount field is updated by node i for a destination d whenever a route advertisement is sent for d[2].

$advertised\_hopcount_i^d := \max_k \{hopcount_k \mid (nexthop_k, hopcount_k) \in route\_list_i^d\}$

In AOMDV, duplicate copies of a RREQ are not immediately discarded. Each packet is checked to see whether it provides a node-disjoint path to the source or not. For node-disjoint paths all RREQs need to reach via different neighbours of the source. This is checked with the firsthop field in the RREQ packet and the firsthop_list [2]for the RREQ packets at the node.

Computation of Disjoint Paths: At the destination a slightly different approach is used, the determined paths are link-disjoint. To maintain the link disjoint property, the paths must have unique next hops as well as unique last hops. This helps in determining whether two paths via downstream neighbours are link disjoint.

4. SIMULATION setup

A. Simulation Environment

The NS-2 which is a discrete event driven simulator developed at UC Berkeley is used in this simulation process. Network Simulator NS-2 is useful in designing new protocols, comparison of different protocols and for evaluating the traffic. NS2 is an object oriented simulation that is written in C++ and OTcl interpreter as a frontend. A scenario file is taken as input in the NS-2 simulation process that shows the motion of each node and the originating packets by each node. The trace file generated is stored to the disk and that is observed using scripts like *.tr that calculates the number of successfully delivered packets and covered path length by each packet. This data is further observed by AWK scripts.
The simulation models are built using the Network Simulator tool (NS-2) version 2.34 and it is run under bandwidth of 40 MHz. The experiments use a fixed number of packet sizes (512-bytes). The simulation uses 50 nodes. Maximum number of nodes in queue length is 50. The mobility model used is a random waypoint model in a rectangular field having dimensions 1000m X 1000m and the stations are evenly distributed in this rectangular field. The journey of each packet starts from a random location to a random destination with a randomly chosen speed. When destination is reached then another random destination is focussed after a pause.

Table1: Simulation Parameters

ENVIRONMENT SIZE	1000 X 1000
CHANNEL TYPE	WIRELESS
PROPAGATION MODEL	TWO RAY GROUND
QUEUE LENGTH	50
NUMBER OF NODES	50
SIMULATION TIME	50 sec
PACKET SIZE	512 bytes
BANDWIDTH	40 MHz
TRAFFIC TYPE	CBR
PROTOCOLS	AODV, AOMDV
BNDWIDTH	40 MHz
PACKET SIZE	512-bytes
PAUSE TIME	50 sec

B. Performance Results

The results for the above mentioned simulation experiment is shown with the help of Xgraphs. In this section the comparison of AODV and AOMDV is made and the metrics used for the analysis of results are throughput, packet delivery ratio and end to end delay.

1. END-TO-END DELAY:

End to end delay metric[9] calculates the time difference between the sending time and receiving time of packet. This end-to-end delay metric shows the packet delivery time. Lower the end-to-end delay, the better the performance of protocol.

End to End Delay =

$$\frac{\sum_i^n CBR\ Senttime - CBR\ RecvTime}{\sum_i^n CBR\ Recv}$$

Fig. 1 Xgraph shows End-To- End Delay comparison between AODV and AOMDV.

Xgraph indicates that AOMDV has more average end-to-end delay than the AODV. AOMDV has average delay of 134ms but AODV has average delay of 29ms. AODV has a better average delay than AOMDV because if a link breaks then AOMDV would try to search for an alternate path from among the alternative routes between the source node and the destination node that result in the additional delay to the packet delivery time. While in AODV, if a link breaks, the packet would not reach the destination due to unavailability of alternative path from source to destination, as in AODV only a single path exists between a source and destination node.

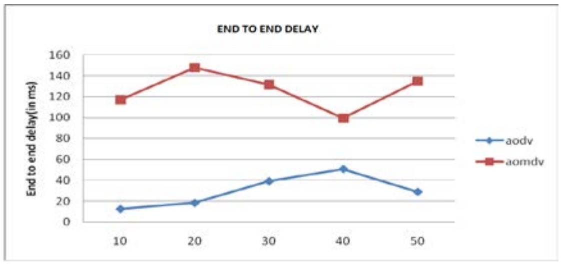

Fig.2 End to end delay versus number of nodes

Figure 2 shows the result of end to end delay of the two protocols. The graph shows number of nodes in horizontal axis and end to end delay as vertical axis. As the number of nodes increases end to end delay increases in case of AODV but reduces in case of AOMDV. That means, in larger networks, the end to end delay decreases in case of AODV. So we can grade that AODV has less end to end delay, but in case of link failure AOMDV is best.

2. PACKET DELIVERY FRACTION (PDF) :

PDR[9] is known as the ratio of the data packets delivered to the destinations to those generated by the CBR sources. This ratio shows the successful delivery of packets to destination from source. The higher the value of PDF, the better would be the results. This metric proves the reliability of routing protocol by giving its effectiveness.

$$PDF = \frac{\textit{Number of packets received}}{\textit{Number of packets sent}}$$

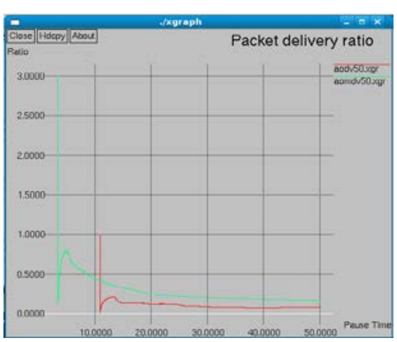

Fig. 3 Xgraph shows Packet delivery Ratio comparison between AODV and AOMDV.

Xgraph indicates that the AOMDV gives better performance while increasing pause time. So, at 50 sec the packet delivery ratio of AOMDV is much better than the AODV because in case of link failure, AOMDV discovers an alternate path but AODV becomes useless at this point.

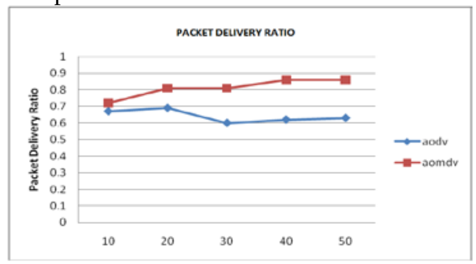

Fig.4 Packet Delivery Ratio versus number of nodes

Figure 4 shows the result of packet delivery ratio of the two protocols. This set of study describes the performance of AODV and AOMDV. The line graph shows number of nodes in horizontal axis and packet delivery ratio as vertical axis. The packet delivery ratio of AODV and AOMDV are very similar when the node number is very less but as the number increases the packet delivery ratio decreases in AODV. The packet delivery ratio is less for AODV routing protocol than AOMDV. As AOMDV is a multipath protocol, it can change its path or it can choose other alternate path in case of congestion or if the primary link has broken but single path protocol cannot do this. So we can grade that AOMDV performs better than AODV.

3. THROUGHPUT:

Throughput[9] is defined as the number of packets flowing through the channel at a particular instant of time. This performance metric signifies that the total number of packets that have been successfully delivered from source node to destination node.

$$\text{Throughput} = \frac{\text{Received packet size}}{\text{Time}}$$

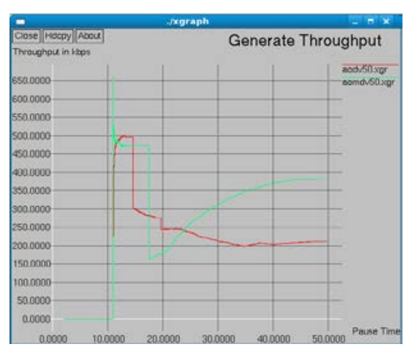

Fig. 5 Xgraph shows Throughput comparison between AODV and AOMDV.

From the xgraph it is concluded that the average throughput of AOMDV is better than AODV. Average values of AODV in 10nodes scenario and 50 nodes scenario are 91.26 kbps and 211.26 kbps respectively and that of AOMDV are 378.02 and 382.10. AOMDV gives better performance while increasing pause time as while increasing pause time there is more stability in mobile nodes. This shows that the throughput is maximum in case of AOMDV at high pause time.

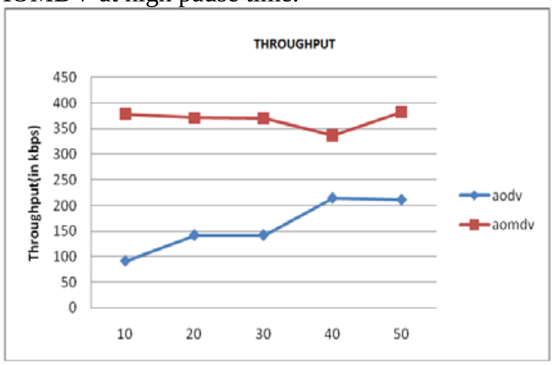

Fig. 6 Throughput versus number of nodes

Figure 6 shows the result of throughput of the two protocols. This set of study describes the performance of AODV and AOMDV. The graph shows number of nodes in horizontal axis and throughput as vertical axis. The throughput of AOMDV is good than AODV. In case of AOMDV the throughput initially decreases as the number of node increases and then increased in last case but AODV throughput continuously increases as the number of nodes increases. As AOMDV provides load balancing feature and solves the congestion problem by transferring load through the alternate routes. So, more packets delivered to destination without failure and that resulted in performance improvement of AOMDV.

From the above results it has been concluded that the AOMDV incurs more overhead and more delay than AODV but overall efficiency of AOMDV is better in case of packet delivery ratio and throughput.

5. Conclusions and future work

AOMDV, the multipath enhancement to AODV was designed generally for highly dynamic ad hoc networks where link fails and route breaks occur frequently. The comparison was done on basis of packet delivery fraction, average end-to-end delay, and throughput. On the basis of simulation results it is concluded that AOMDV is better than AODV. AOMDV outperforms AODV due its ability to discover alternate routes when a current link fails. Although AOMDV incurs more routing overheads because of flooding the network and packet delays due its alternate route discovery process, it is very much efficient in case of packet delivery for the same reason. AOMDV proves to be more efficient than AODV as it provides better throughput. Finally the conclusion is that when network load increases, AOMDV is a better on-demand routing protocol than AODV as it gives better statistics for packet delivery and throughput. But in case if delay time is a concern, then AODV routing protocol is preferred.

Future work includes the simulations performed on the basis of other metrics. Concept of power consumption or security can be included to explore the future areas of research.

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