International Journal of Future Generation Communication and Networking
Vol. 8, No. 6 (2015), pp. 71-82
http://dx.doi.org/10.14257/ijfgcn.2015.8.6.07

Mobility Adaptive Ad-Hoc on Demand Distance Vector Routing Protocol in MANET

Tariq A. Murshedi and Xingwei Wang

College of Information Science and Engineering, Northeastern University, Shenyang 110819, China
tariq_alwan@yahoo.com, wangxw@mail.neu.edu.cn

Abstract

A Mobile Ad-Hoc Network (MANET) is an infrastructure-less, self-organized and multi-hop network with a rapidly changing topology causing the wireless links to be broken at any time. Routing in such a network is challenging due to the mobility of its nodes and the challenge becomes more difficult when the network size increases. In order to alleviate the node mobility problems which cause frequent link failures between source and destination nodes and data packets loss during transmission in MANETs, we propose a new routing protocol called MAD-AODV (Mobility Adaptive Ad-hoc On Demand Distance Vector) based on the well-known Ad-hoc On Demand Distance Vector (AODV) protocol. The proposed MAD-AODV protocol is capable of periodically predicting mobility, and then making useful routing decisions accordingly. The MAD-AODV protocol follows the basic AODV process, but it includes some modifications to adapt to the dynamic node mobility. The basic AODV consists of path discovery, route table management, path maintenance, and local connectivity management. The MAD-AODV modifies the techniques involved in basic AODV excluding path discovery. The work is implemented and simulated on NS-2. The simulation results have shown improvements in packet delivery ratio and throughput, along with a decrease in end-to-end delay, packet loss and communication overhead. The proposed MAD-AODV provides more consistent and reliable data transfer compared to general AODV.

Keywords: *Mobile ad-hoc networks, on-demand routing, mobility, MANET, MAD-AODV, AODV*

1. Introduction

A Mobile Ad-Hoc Network (MANET) [1-3] is a collection of wireless mobile nodes (or routers) dynamically forming a temporary network without the use of any existing network infrastructure or centralized administration. In this network, each node must discover its local neighbors and through those neighbors it will communicate to nodes that are out of its transmission range (multi-hop). Due to the limited transmission range of the nodes, multiple hops may be needed for a node to send data to any other node in the network. Thus each node acts as a host and router. The routers are free to move randomly and organize themselves arbitrarily; thus, the network's wireless topology may change rapidly and unpredictably. These networks suffer from nodes mobility causes continual link failures. This causes the routing protocol to use different techniques to update its knowledge about local neighbors, which is known as Local Connectivity Management (LCM). One of those techniques is periodically broadcasting short beacon messages (called hello messages). Hello message is an active approach. It is utilized by AODV [4] routing protocol for determining the link availability.

AODV [4, 5] is an on-demand (reactive) routing protocol for a mobile ad-hoc network. It is composed of two phases, route discovery process and route maintenance process, using the following four packets. 1) HELLO (a Hello message), 2) RREQ (Route

ISSN: 2233-7857 IJFGCN

Request), 3) RREP (Route Reply), 4) RERR (Route Error). The AODV provides reactive route discovery in mobile ad hoc networks. Like most reactive routing protocols, route finding is based on a route discovery cycle involving a broadcast network search and a unicast reply containing discovered paths.

In MANET's [6, 7], mobility is a crucial factor and it plays an important role in determining the overall performance of the network this is because the high mobility of nodes can cause frequent changes in network topology, leading to less reliable routes and frequent link breakages, hence, increasing the re-initiation of the route discovery process, resulting in more control packets overhead due to the extra use of RREQ, RREP, and RERR, and increasing the average end-to-end delay.

To alleviate such problems, nodes mobility should be taken into consideration when designing any routing protocol for MANETs. In this paper, we propose mobility adaptive ad hoc on demand distance vector (MAD-AODV) protocol based on mobility prediction. It can control node routing by keeping and switching route through calculating the neighbor node's distance value using Hello packets and predicting the neighbor node's mobility to fit network topology that has changed quickly.

The rest of this paper is organized as follows: In Section 2, we review the AODV protocol. In Section 3, we introduce our protocol MAD-AODV as an extension of AODV. In Section 4, we evaluate the performance of MAD-AODV using NS2 simulation. Finally, Section 5, we conclude this paper.

2. Ad hoc on Demand Distance Vector Routing

The AODV routing protocol [8] provides a good compromise between proactive and reactive routing protocols. AODV routing is essentially a combination of both DSR [9] and DSDV [10]. It borrows the basic on-demand mechanism of route discovery and route maintenance from DSR, plus the use of hop-by-hop routing, sequence numbers, and periodic beacon (Hello) messaging from DSDV. A periodic Hello message is used to detect and monitor links to neighbor nodes. The sequence numbering guarantees a loop free routing and fresh route to destination.

In the following subsections, we describe some primary phases of AODV protocol. In particular, we concentrate on four phases: path discovery, route table maintenance, local connectivity, and path maintenance.

2.1. Path Discovery

A node discovers [3, 11, 12] a route to another node, when it needs to communicate with another node and it has no routing information in its table to the particular destination. The source node initiates path discovery by broadcasting a route request Route REQuest (RREQ) packet to its neighbors. The RREQ contains the following fields:

< source addr, source sequence, broadcast id, dest addr, dest sequence, hop cnt>

There are two sequence numbers included in a RREQ packet such as the source sequence number and the last destination sequence number known to the source. To maintain freshness information about the reverse route to the source from the destination, the AODV employs a source sequence number. The destination sequence number specifies how fresh a route to the destination must be before it can be accepted by the source. The traveling route of RREQ from the source to the destination assists to sets up the reverse path from all nodes back to the source. These reverse path entries are maintained until the destination generates Route REPly (RREP) packet, and it reaches the nodes involved on a path. A RREP contains the following information.

<source addr, dest addr, dest sequence, hop cnt, lifetime >

2.1.1. Process of RREQ

If a node receives the RREQ packets, the following cases may occur in AODV.

Case 1) Send RREP.

When an intermediate node has a route entry for the desired destination attached in the received RREQ, it determines whether the route is current by comparing the destination sequence number in its own route entry to the destination sequence number in the RREQ. If an intermediate node's sequence number for the destination is greater than or equal to that contained in the RREQ, the intermediate node can use its recorded route to respond to the RREQ through RREP. If the receiving node is the destination, it issues the RREP through the stored reverse path to the source node.

Case 2) Broadcast RREQ

The intermediate node can broadcast only when it has a route with a sequence number that is less than to that contained in the RREQ. It broadcasts the RREQ packet to its neighboring nodes.

Case 3) Discard RREQ

The receiving node first checks that the RREQ was received over a bi-directional link. If it receives the RREQ with the same sequence and source-destination ID already, it discards the RREQ.

2.1.2. Process of RREP

A node receiving an RREP propagates the first RREP for a given source node. If it receives further RREPs it updates its routing information and propagates the RREP only if the RREP contains either a greater destination sequence number than the previous RREP or the same destination sequence number with a smaller hop count. It suppresses all other RREPs it receives.

2.2. Route Table Maintenance

A mobile node [3, 4, 13] maintains a route table entry for each destination of interest. Each route table entry contains the following information:

1. Destination
2. Next Hop
3. Number of hops (metric)
4. Sequence number for the destination
5. Active neighbors for this route
6. Expiration time for the route table entry.

Each node updates the routing information in a table based on the following cases.

Case 1) Timer Expiry

The reverse path routing entries associated with a timer, called the route request expiration timer. The purpose of this timer is to purge reverse-path routing entries from those nodes that do not lie on the path from the source to the destination. The expiration time depends upon the size of the ad-hoc network. Another important parameter associated with routing entries is the route caching timeout or the time after which the route is considered to be invalid due to node mobility.

Case 2) Active Neighbor change

A neighbor is considered active for that destination if it originates or relays at least one packet for that destination within the most recent active timeout period. This information is maintained so that all active source nodes can be notified when a link along with a path to the destination breaks. Active neighbor field of a node is updated if link disconnection occurs during mobility. The path from a source to a destination which is followed by packets along active route entries is called an active path.

Case 3) Number of hops and sequence number change

If a new route is offered to a mobile node, the mobile node compares the destination sequence number of the new route to the destination sequence number for the current route. The route with the greater sequence number is chosen. If the sequence numbers are the same, then the new route is selected only if it has a smaller metric fewer number of hops to the destination.

2.3. Local Connectivity

The local connectivity [3, 6, 14] refers to the active neighbor list. Each node broadcasts a hello packet within hello interval, and the fields inserted in the hello message are,

< Sender ID, TTL, Active Neighbor List, Common Neighbor List, Next hop, Link Break Flag, Sending Time >

The hello packet fields such as sender ID, TTL, active neighbor list, and sending time are always enabled. A node enables other fields only under link breakage condition. Whenever a node receives a broadcast from a neighbor it updates its local connectivity information to ensure that it includes this neighbor. Moreover, a node involved in the routing path stores the active neighbor list attached in the receiving hello packet that is sent by its next hop only. The hello message is prevented from being rebroadcast outside the neighborhood of the node because it contains a time to live TTL value of 1. In the event that a node has not sent any packets to all of its active downstream neighbors within hello interval, it broadcasts to its neighbors a hello message, a special RERR containing its identity and sequence number. The node's sequence number is not changed for hello message transmissions.

2.4. Path Maintenance

Movement of nodes [3, 13] not lying along an active path does not affect the routing to that paths destination. If the source node moves during an active session, it can reinitiate the route discovery procedure to establish a new route to the destination. In AODV, the link breakage is identified if hello messages are not received from the next hop along an active path, the node sends Route ERRor (RERR) packet towards the source node. Then the source node reinitiates the route discovery process. However, it may lead to packet drop. The path maintenance [15] is described in the following algorithm.

Path maintenance Algorithm
S: the source node
D: the destination node

```
        repeat
                S send a HELLO message to each neighboring nodes
                for all neighbor nodes do
                        if the neighbor node does not receive any packets within a certain
                        time then
                        the node assume the link is lost
                        the node send an RERR packet to all precursors
                end if
        end for
until Route Expired
S starts a new route discovery.
```


3. Mobility Adaptive Ad-Hoc on Demand Distance Vector Routing Protocol

Mobility is one of the key characteristics of MANETs [7] that introduce some limitations if not considered well. The Mobility Adaptive Ad-Hoc on Demand Distance Vector Routing (MAD-AODV) protocol was proposed for improving the performance of the AODV protocol.

In MAD-AODV, the path maintenance process includes the following processes to avoid the packet loss due to node mobility in AODV protocol.

3.1. Link Breakage Prediction

In MAD-AODV, each node in the path determines the distance from itself to previous and next hop node using hello packet's traveling time and speed (light speed $3 * 10^8$ m/s). If the distance exceeds the threshold range, it establishes the alternative link.

$$\text{Distance} = \text{packet's traveling time} * \text{speed} \quad (1)$$

3.2. Alternative Link Establishment

If a node predicts the link breakage between itself and previous hop:

1) It determines the common neighbors with next hop.
2) It sends the common neighbor list and next hop ID to the previous hop.
3) The previous hop selects its neighbor from the received common neighbor list.
4) Routing decision.
   i. Availability of common neighbor.
      a) The previous hop updates the selected neighbor ID in its next hop field.
      b) The previous hop sends the modified routing table to the selected neighbor. The modified routing table includes the same destination ID, sequence number, and expiration time, and moreover it makes changes in the following fields,

         Next hop = next hop to the mobile node

         Number of hops = Hop count -1
   ii. Unavailability of common neighbor.

      The previous hop sends RERR packet towards source node to reinitiate the route discovery process.

3.3. Mobility Impact on MAD-AODV

In MANET's [6, 7, 12], there are no restrictions on node mobility, *i.e.*, nodes are free to move at any time, towards any direction and at any speed; therefore, nodes may join or leave the network at any time. There is a unique challenge in MANETs created by node mobility. Nodes in a MANET may move and cause frequent, unpredictable topological changes. This changing network topology is the key challenge in MANET.

The node mobility impact on the proposed MAD-AODV is less when compared to AODV. It is because, the node in MAD-AODV predicts the node mobility and provides alternative link before the occurrence of link breakage. For example, consider the scenario shown in Figure 1. The source node S forwards the data packets through A-B-C-E to the destination D. In case of mobility of node B, the link A-B-C fails to forward the packet due to breakage. In this case, node A sends RERR packet to node S that initiates the route discovery process in AODV.

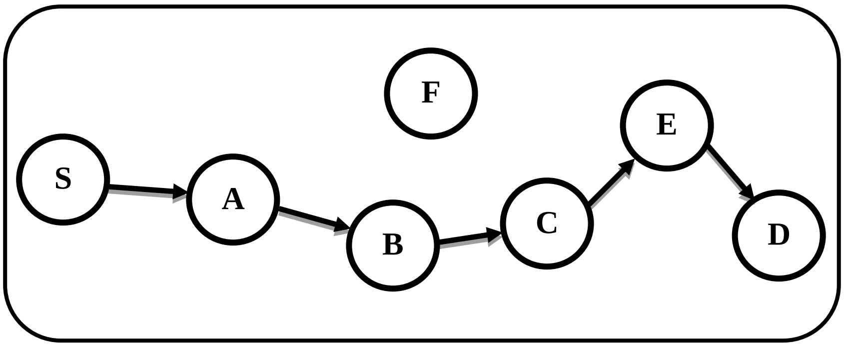

Figure 1. Initial Path

In MAD-AODV, the intermediate nodes A, B, C, and E periodically sends hello packet including their neighbor list. For instance, node B stores the neighbor list of node C. Node B predicts the break of link A-B and it determines the common neighbor list using the neighbor list of node C. It sends the hello packet including the common neighbor list and link break flag to node A. The node A selects and employs a common neighbor F by comparing the neighbor list with the received list as shown in Figure 2. The updated routing table of node A and C as shown in the Figure 3.

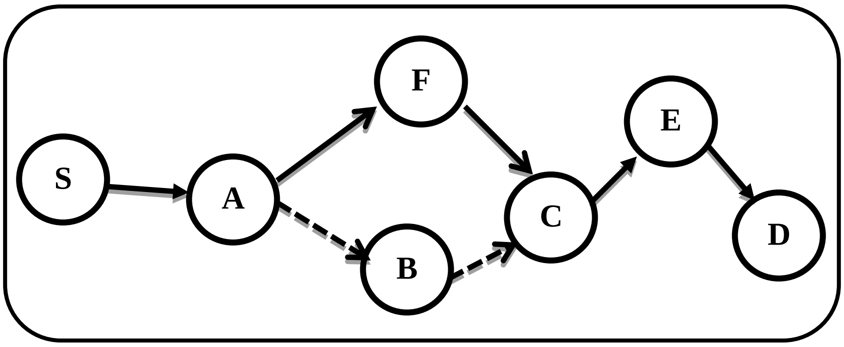

Figure 2. Mad-Aodv Process

Node	Destination	Next Hop	Previou s Hop	Number of hops	Destination Sequence No	Active neighbors	Expiration time (sec)
A	D	B	S	4	7	S, B, F	55
B	D	C	A	3	7	A, C	55
C	D	E	B	2	7	B, E, F	55

(a) Before Mobility

Node	Destination	Next Hop	Previous Hop	Number of hops	Destination Sequence no	Active neighbors	Expiration time (sec)
A	D	F	S	4	7	S, F	53
F	D	C	A	3	7	A, C	53
C	D	E	F	2	7	B, F, E	53

(b) After Mobility

Figure 3. Routing Table

In case the weak links A-B and B-C are identified at a time, node B provide preference to the link break of its next hop. It is because, if a link A-B breaks before providing the alternative link to B-C, it leads to packet drop. Figure 4 shows a block diagram for an AODV and MAD-AODV routing protocols.

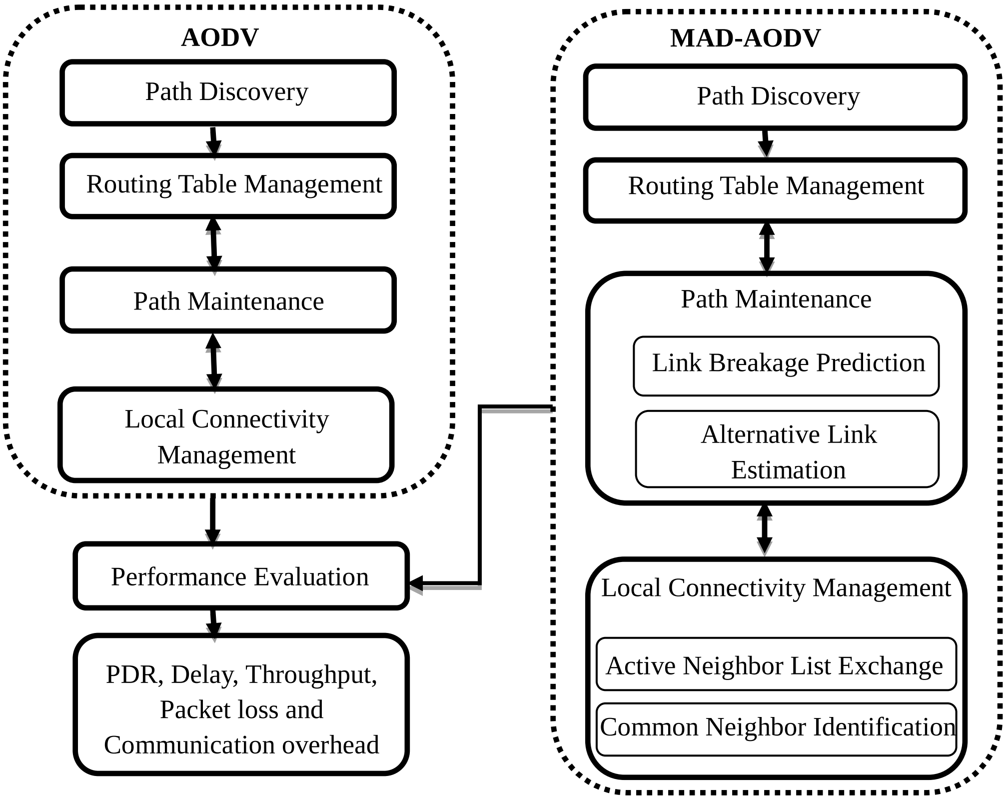

Figure 4. Block Diagram for an AODV and MAD-AODV

4. Performance Evaluation

To get updated information about neighboring nodes AODV uses Hello packets. By default HELLO packets are disabled in the AODV protocol. To enable broadcasting of Hello packets, comment the following two lines present in **aodv.cc.**

#ifndef AODV LINK LAYER DETECTION

#endif LINK LAYER DETECTION

To evaluate the performance of AODV and MAD-AODV routing protocols, we have used simulation based on NS-2.35. Parameters used in the simulation are listed in Table 1.

Table 1. Simulation Parameters

NUMBER OF NODES	30, 35, 40, 45
SPEED	10, 15, 20, 25
AREA	500m x 500m
COMMUNICATION RANGE	250m
INTERFACE TYPE	Phy/WirelessPhy
MAC TYPE	802.11
QUEUE TYPE	Droptail/Priority Queue
QUEUE LENGTH	50 Packets
ANTENNA TYPE	Omni Antenna
PROPAGATION TYPE	TwoRayGround
ROUTING PROTOCOL	AODV / MAD-AODV
MOBILITY MODEL	Random Way Point
TRANSPORT AGENT	UDP
APPLICATION AGENT	CBR
SIMULATION TIME	100seconds

4.1. Performance Metrics

The performance of our proposed protocols has been numerically evaluated by the estimation of the following parameters [1, 3]:

A) Packet Delivery Ratio

Packet delivery ratio (PDR) is the proportion to the total amount of packets reached the receiver and amount of packet sent by the source. If the amount of malicious node increases, PDR decreases. The high mobility of nodes causes PDR to decrease.

$$\text{PDR} = \frac{\text{Number of packets successfully delivered to the destination}}{\text{Number of packets generated by the source node}} \quad (2$$

a) Average End-to-End Delay

End-to-End delay is the time taken for a packet to reach the destination from the source node.

$$\text{End to End delay (s)} = \frac{\sum \text{(Delay for each data packet)}}{\text{Total number of delivered data packets}} \quad (3)$$

b) Throughput

Throughput is the amount of data successfully received at the destination.

$$\text{Throughput (bits/s)} = \text{Received data / Duration of transmission} \quad (4)$$

c) Overhead

Communication Overhead = Number of control messages involved in the routing process (5)

Storage Overhead = Number of bytes used by a node to store routing information (6)

d) Packet Loss

Packet loss is the number of packets lost during the data transmission.

$$\text{Packet Loss (\%)} = \frac{\text{Number of packets lost during data transmission}}{\text{Number of packets generated by the source node}} \quad (7)$$

4.2. Simulation Results and Analysis

The simulation is divided into two categories:
1.Impact of speed (*i.e.*, varying speed).
2.Impact number of nodes (*i.e.*, varying number of nodes).

5. Impact of Speed

Speed of the mobile node is varied from 10m/s,15m/s,20m/s and 25m/s. Parameters such as Packet delivery Ratio (PDR), Throughput, Packet Loss, End-to-End delay and Communication overhead are measured.

Figures 5, 6 and 7 show a comparison of packet delivery ratio, throughput and packet loss respectively. These figures show that the comparison can probably be approximately divided into three periods.

1) The first period is probably from 10 m/s to 15 m/s. This figures show that the proposed method performs is better than the AODV protocol.

2) The second period is approximately from 16m/s to 20 m/s. This figure shows that MAD-AODV method performs worst with other methods in the second period.

3) The third period is from 21 m/s to 25 m/s. This figures show that the PDR and throughput in MAD-AODV are increased when compared to PDR and throughput in AODV, but the packet loss in MAD-AODV is decreased as compared to the packet loss in AODV. While speed is increased, nodes connectivity gets affected. MAD-AODV continues the data transmission through alternative link. Hence packet delivery ratio and throughput are increased while the packet loss is decreased.

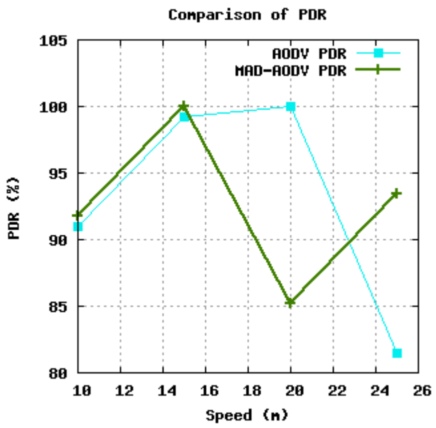

Figure 5. Packet Delivery Ratio

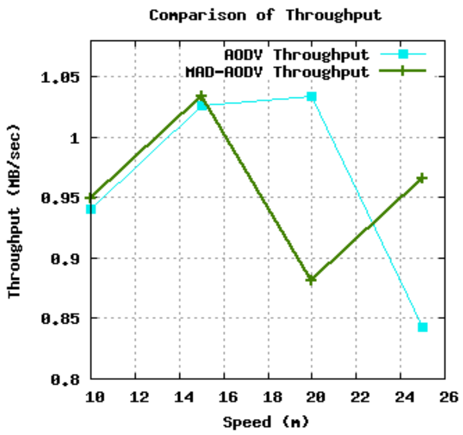

Figure 6. Throughput

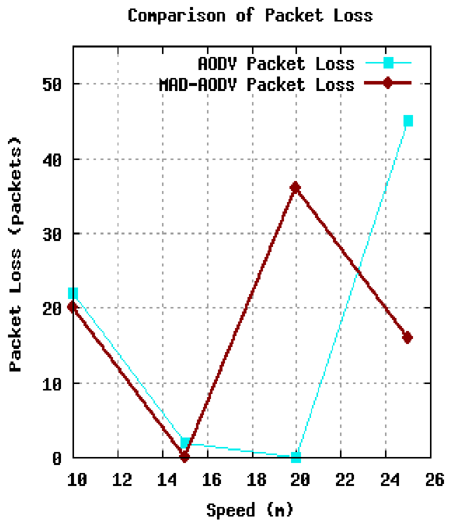

Figure 7. Packet Loss

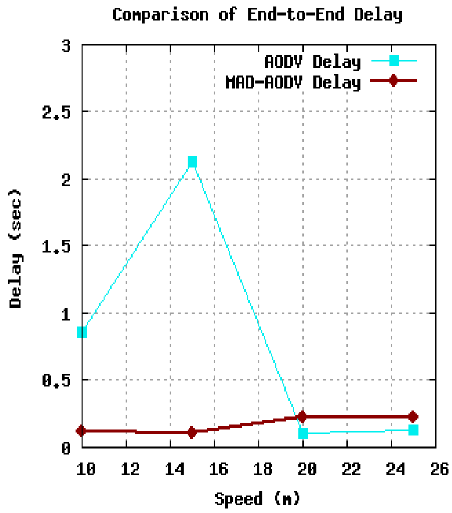

Figure 8. Average End-to-End Delay

Figures 8 and 9 show a comparison of end-to-end delay and communication overhead, respectively. This figures show that the comparison can probably be approximately divided into two periods.

1) The first period is probably from 10 m/s to 19 m/s. These figures show that the proposed method performs is better than the AODV protocol through decrease the end-to-end delay and communication overhead. While speed is increased, nodes connectivity gets affected. MAD-AODV continues the data transmission through alternative link immediately through link breakage prediction without causing the delay or incurring the control messages for identifying alternative path discovery after link breakage as in AODV. Hence delay and communication overhead are decreased in MAD-AODV.

2) The second period is from 20 m/s to 25 m/s. These figures show that the end-to-end delay and communication overhead in MAD-AODV are increased when compared to the end-to-end delay and communication overhead in AODV.

2. Impact Number of Nodes

Number of mobile nodes are varied from 30, 35, 40 and 45. Parameters such as Packet delivery Ratio (PDR), Throughput, Packet Loss, End-to-End delay and Communication overhead are measured.

Figures 10 and 11 show a comparison of packet delivery ratio and throughput, respectively. These figures show that the comparison can probably be approximately divided into two sets of node.

1) The first sets is probably with 30 or 45 nodes. These figures show that the proposed protocol performs is better than the AODV protocol. While number of nodes are increased, available nodes for the data transmission increases through alternative path are increased. Hence packet delivery ratio and throughput are increased.

2) The second sets is probably with 35 to 40 nodes. These figures show that the MAD-AODV performs worse than the AODV protocol through decrease the packet delivery ratio and throughput.

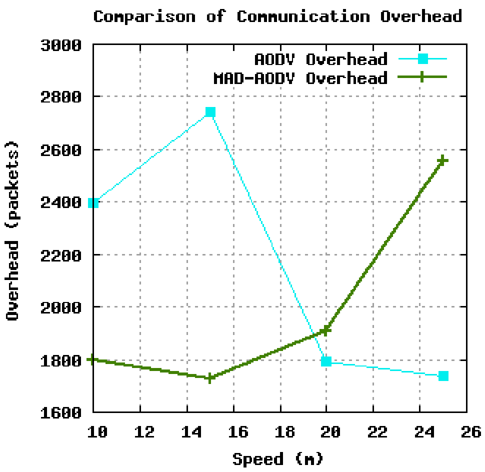

Figure 9. Communication Overhead

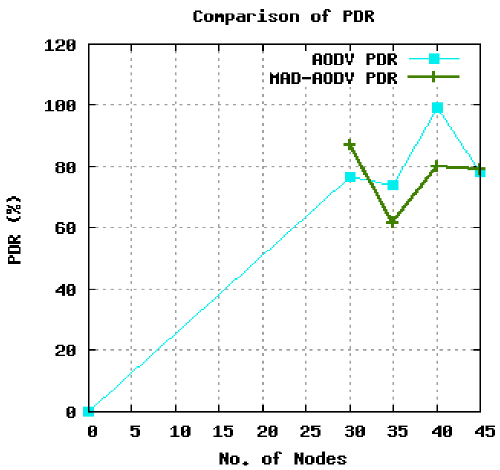

Figure 10. Packet Delivery Ratio

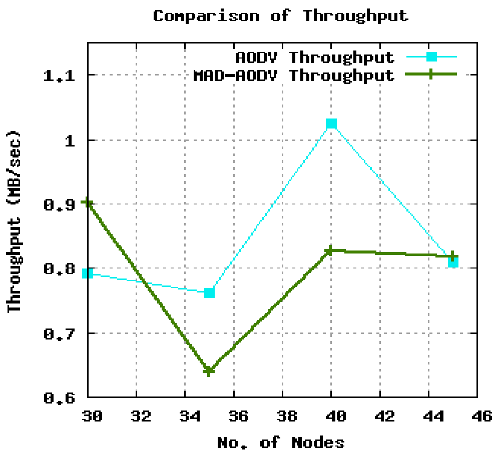

Figure 11. Throughput

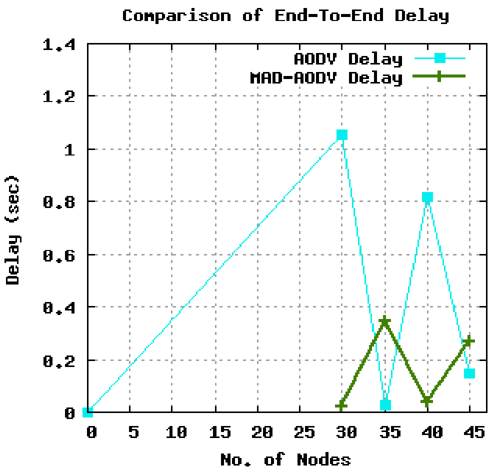

Figure 12. Average End-to-End Delay

Figures 12 and 13 show a comparison of end-to-end delay and packet loss, respectively. These figures show that the comparison can probably be approximately divided into four sets of node.

1) The first sets is probably with 30 nodes. These figures show that the proposed protocol performs is better than the AODV protocol.

2) The second sets is probably with 35 nodes. These figures show that the MAD-AODV performs worse than the AODV protocol through increase end-to-end delay and packet loss.

3) The third sets is probably with 40 nodes. These figures show that the MAD-AODV performs better than the AODV protocol through decrease end-to-end delay, but the proposed protocol performs worse than the AODV protocol through increase packet loss.

4) The fourth sets is probably with 45 nodes. These figures show that the MAD-AODV performs better than the AODV protocol through decrease packet loss, but the MAD-AODV performs worse than the AODV protocol through increase end-to-end delay.

Figure 14 show a comparison of communication overhead. This figure show that the comparison can probably be approximately divided into one sets of node.

1) The sets is probably with 30 to 45 nodes. This figure show that the proposed protocol performs is better than the AODV protocol. Communication Overhead in MAD-AODV is decreased when compared to Communication Overhead in AODV. While nodes are increased, nodes connectivity gets affected. MAD-AODV includes link breakage prediction without incurring the control messages for identifying alternative path discovery. Hence Communication Overhead is decreased in MAD-AODV.

5. Conclusion

In this paper, we designed and implemented a new MAD-AODV routing protocol which extends the AODV using Hello packet. The proposed MAD-AODV protocol is capable of periodically predicting mobility, and then making useful routing decisions accordingly. The simulation results show that the packet delivery ratio and throughput are improved in MAD-AODV compared to AODV. The end-to-end delay, packet loss, and communication overhead are decreased, and moreover the storage overhead is increased. As AODV initiates the route discovery process only after the link breakage, it leads to packet loss, increased delay, reduced packet delivery ratio and throughput when compared to MAD-AODV. In this proposed protocol the communication overhead is reduced because it repairs the link breakage in the local link and establishes the alternative link instead of initiating route discovery process as in AODV. But storage overhead is increased due to the maintenance of active neighbor listing of next hop to provide an alternative link during node mobility.

Acknowledgment

This work is supported by the National Science Foundation for Distinguished Young Scholars of China under Grant No. 61225012 and No. 71325002.

References

[1] E. Natsheh, A. Jantan, S. Khatun and S. Subramaniam, "Adaptive Optimizing of Hello Messages in Wireless Ad-Hoc Networks", The International Arab Journal of Information Technology, **(2007)**.
[2] S. Deepa and G.M. Nawaz, Mobility and Density Aware AODV Protocol Extension for Mobile Adhoc Networks-MADA-AODV", Journal of Computer Science, **(2012)**, pp 13-17.
[3] S.K. Sarkar, T.G. Basavaraju and C. Puttamadappa, "Ad Hoc Mobile Wireless Networks Principles", Protocols, and Applications Second Edition, Auerbach Publications, **(2013)**.
[4] C.E. Perkins and E.M. Royer, "Ad hoc On-demand Distance Vector Routing", in: Proceedings of the Second IEEE Workshop on Mobile Computing Systems and Applications, **(1999)**, pp. 90–100.
[5] S. Basagni, M. Conti, S. Giordano and I. Stojmenovic, "Mobile Ad Hoc Networking", IEEE, Inc, **(2004)**.
[6] A.Pansare, "A Review of AODV Based Routing Protocols for Mobile Ad-hoc Network", International Journal of Advanced Research in Computer Science, **(2013)**.
[7] Y. Khamayseh, O.M. Darwish and S.A. Wedian, "MA-AODV: Mobility Aware Routing protocols for Mobile Ad hoc Networks", Fourth International Conference on Systems and Networks Communications, IEEE, **(2009)**, pp. 25-29.
[8] C.d.M. Cordeiro and D.P. Agrawal, "Ad Hoc and Sensor Networks", World Scientific, **(2006)**.
[9] D.B. Johnson, D.A. Maltz and J. Broch, "DSR: the dynamic source routing protocol for multi-hop wireless ad hoc networks", in: C.E. Perkins (Ed.), Ad Hoc Networking, Addison-Wesley, **(2001)**, pp. 139-172.
[10] C.E. Perkins and P. Bhagwat, "Highly dynamic destination-sequenced distance-vector routing (DSDV) for mobile computers", in: ACM SIGCOMM, August–September, **(1994)**, pp. 234–244.
[11] W.G. Lol, "An Investigation of the Impact of Routing Protocols on MANETs using Simulation Modeling", Master thesis, School of Computing and Mathematical Sciences, **(2008)**.
[12] A. Boukerche, "Handbook of Algorithms for Wireless Networking and Mobile Computing", Chapman & Hall/ CRC Taylor & Francis Group, **(2006)**.
[13] S. Nandanwar, V. Jain and S. Sahu, "Survey of Adaptive On Demand Distance Vector Learning protocol (AODV)", International Journal of Scientific and Research Publications, **(2013)**.
[14] K. Patel, T. Vasavada and M. Vegad, "Effect of Hello Message on Performance of Ad-hoc On-demand Routing Protocol", National Conference on Recent Trends in Engineering & Technology, India, **(2011)**.
[15] X. Wang, "Mobile Ad-Hoc Networks: Protocol Design, InTech", **(2011)**.