Congestion Control Modified AODV(MAODV)

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***Abstract*— Mobile Ad-hoc network (MANET) is a collection of nodes which communicate with each other wirelessly without any central support or an established infrastructure. Each of these nodes consists of wireless transceivers and the transmission of data packets over wireless channels in these networks helps maintain the communication. AODV is a reactive routing protocol associated with MANET which creates a route to destination by broadcasting RREQ packets through the network. A link failure in this type of protocol causes the source to flood the network with these RREQ packets which leads to congestion in the network and degrades its performance. In this paper, we propose a modified congestion control AODV which uses the time to live (TTL) value and the predecessor address value of a RREQ packet to determine if a node is relaying or silent in the process of route discovery. Simulations were carried out on NS2 to compare the existing reactive protocols to the proposed one based on packet loss, packet delivery ratio, end-to-end delay and throughput. Lastly, an overall performance analysis shows that the proposed MAODV is a better protocol when compared to the existing ones.**

***Keywords*—AODV; reactive routing; DSR; MANET; RREQ; NS2**

I. Introduction

Mobile ad-hoc network (MANET) is a collation of mobile nodes that does not have a background network to determine the central control for any of the network operations. In these networks, intermediate nodes are used to forward data packets whenever the destination node is out of the communication range of the source node. Since there maybe constant changes in the topology of these networks, mobile nodes build their own routing networks dynamically. Hence there are multiple advantages associated with MANETs. These networks are scalable, have an improved flexibility and can be set up at any place at any time [2, 10].

MANETs are most appropriately used in circumstances where either setting up an infrastructure is not very cost-effective or where there are frequent losses in the infrastructure. Hence, MANETs find applications in various fields. For instance, highway control can use MANETs to check the direction and speed of a car, military can use these networks to determine and track the movement of an enemy [2] and in the commercial sector, these networks can be used to carry forward rescue operations during a disaster as the disaster struck regions most often lose communication infrastructures [3].

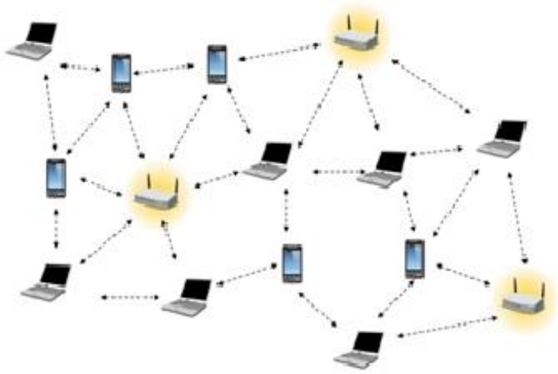

Fig 1: Mobile Ad-hoc Network (MANET) [9]

In MANETs, the nodes are to make a decision regarding the route of packet transmission between the devices or nodes. This decision for the nodes is facilitated by incorporating a routing protocol in the network. For MANETs, routing protocols are classified into three types [1]:

1. *Reactive routing protocols:* These types of routing protocols are on-demand routing protocols which initiate a route discovery process only when the source wants to communicate with the destination. When there is no communication, the nodes do not maintain the updated routing information. In these protocols, the source floods the entire network with route request (RREQ) packet in order to find a path to destination. A few examples of reactive routing protocols are Ad-hoc On Demand Distance Vector routing (AODV) and Dynamic Source Routing (DSR).
2. *Pro-active routing protocols:* These types of routing protocols are table-driven protocols in which every node of a network has a routing table to store the routing information. Every time there is a change in the network topology, the routing table of each of these nodes in the network is updated. A few examples of pro-active routing protocols are Destination Sequenced Distance Vector (DSDV) routing and Fisheye State Routing (FSR).
3. *Hybrid routing protocols:* These types of routing protocols are an amalgamation of the characteristics of both reactive as

well as pro-active routing protocols. An example of hybrid routing protocol is Zone Routing Protocol (ZRP) [1].
In this paper, an enhanced reactive routing protocol (MAODV) to control congestion in AODV has been proposed. MAODV addresses the rebroadcasting problem in AODV. AODV floods the entire network with route request packets (RREQ) during the route discovery process and hence to overcome the problem of congestion during rebroadcasting, MAODV determines a path to the destination using the relaying status of the nodes instead of flooding the network with RREQ each time a route discovery is initiated.
The paper has been organized into six sections where section II discusses two of the existing reactive routing protocols and section III presents the proposed MAODV protocol. The simulation setup has been discussed in section IV and the corresponding simulation results and justifications have been presented in section V. Lastly, section VI concludes the paper.

II. Existing Routing Protocols

In reactive routing protocols, the nodes are not required to update their routing table periodically. As and when a source wants to communicate with a destination, a route discovery mechanism is initiated. This route is later terminated once the communication ends.

A. Dynamic Source Routing (DSR):

In DSR, routing information sent by the source node is stored in route cache of the nodes. A source node checks the route cache for a valid route to destination whenever data is to be sent to the destination. When the source discovers that there is no valid route it starts the route discovery process by broadcasting route request (RREQ) packets. If a node that has a valid route to destination receives this RREQ packet, a route from source to destination will be established [4].

B. Ad-hoc On Demand Distance Vector Routing (AODV):

In AODV, the route is requested only when the source node wants to send data to the destination node. Route discovery process is initiated when the source node generates RREQ packets and broadcasts them to its neighboring nodes in the network.

The routing information from the RREQ packet is added to the node's routing table whenever a particular node receives these packets. From this routing information, a node determines whether the node itself is the destination node or not. If it has been determined by the node that it is not the destination node, it further checks if it has received the same RREQ packet with the same ID earlier. When a node receives an RREQ with the same ID earlier, the currently received RREQ is discarded by the node as it has already broadcasted this packet; else the node further broadcast this RREQ to its neighboring nodes.
Once a destination node receives an RREQ packet, it starts generating route reply packets (RREP).The destination node sends these route reply packets as an acknowledgment to the source node [5].

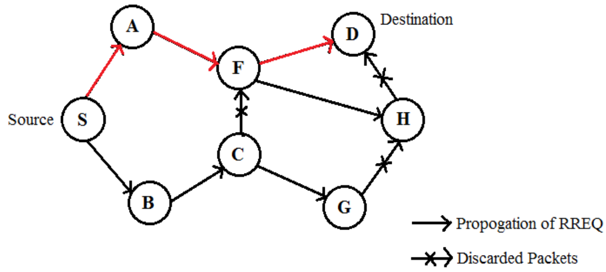

Fig 2: Propagation of RREQ Packets

The intermediate nodes propagate these RREP packets based on the routing table of the node. The path taken by the first RREP packet to reach the source node is utilized by the source node to send data packets to the destination.

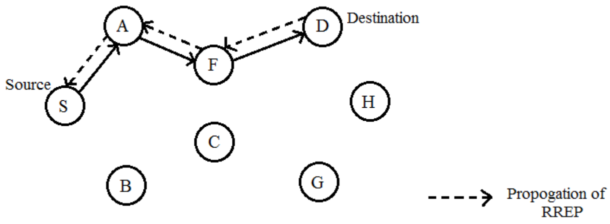

Fig 3: Propagation of RREP packets

In AODV, the process of route discovery is initiated by a source by flooding an entire network with RREQ packets. Sometimes, few nodes rebroadcast these RREQ packets unnecessarily which causes congestion in the network. The situation deteriorates when there is a link failure or a connection loss. In this scenario, a route error (RERR) packet is sent to a source node by a node that loses the connection. On receiving a RERR packet, the source node reinitiates the route discovery by flooding the network with RREQs all over again. This causes performance degradation as the delays is delivering packets increase and also the number of packets delivered reduces. To overcome this, the congestion control modified MAODV has been proposed.

III. Proposed MAODV

The proposed MAODV aims at lowering the performance degradations caused due to the route discovery process in AODV. Hence, MAODV determines a path for the route discovery by using the time to live (TTL) factor rather than just flooding the entire network with RREQ packets.
TTL is a factor that determines the hop range until which an RREQ packet can be propagated. Initially, the TTL value in the RREQ packet is set to some initial value by the source node and the RREQ packets are propagated within a hop range that is equivalent to the TTL value.

When an RREP packet from a destination is not received by the source within the route discovery period, this suggests that the destination is not located within the initial hop range. The source node then increments the TTL value to expand its search range and broadcast the RREQ packets in the new range. The value of TTL is incremented by a source node until a route to the destination node is determined at which point, the source node receives an RREP packet. For example, in figure 4 the initial TTL value is set to 1 and the route discovery is carried out in the first hop range of the source. However, the destination (as we can see from the figure) is in the second hop range. Hence, the source node increments the TTL value to two and reinitiates route discovery at which point it receives a RREP packet from the destination [6].

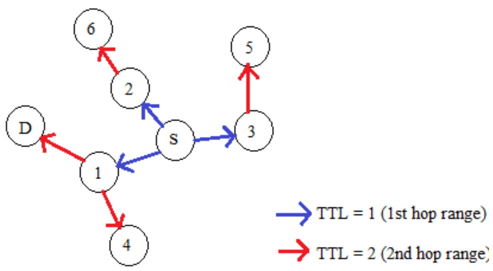

Fig 4: Route discovery by incrementing TTL value

Even in this process, instead of rebroadcasting of the RREQ packets by the same nodes whenever the TTL value is incremented, a path through this route discovery is determined by using the relay and forward values of nodes.

In MAODV, the status of each node is said to be either silent which means the node does not participate in route discovery or it is said to be relaying which means it does take part in the process of route discovery. The initial values of relay and forward of each node are set to 1. The relay value is further updated based on the Predecessor-address field whereas the forward value depends on the TTL value of the route request packet. To implement this protocol, changes have been made to the existing format of the route request packet by adding an additional field called the Predecessor-address (P-addr) field.

AODV Pkt Type	Bcast ID	Dest Addr	Dest Seq	Src Addr	Src Seq	Last Addr	P-Addr	TTL

Fig 5: Modified RREQ packet format [7]

Every RREQ packet has a field which determines the last node address from which the current node has received the RREQ packet. This field is known as the last address field in the RREQ packet. For example, in figure 6 node 2 receives the route request from node 1. Hence the last address of node 2 is 1.

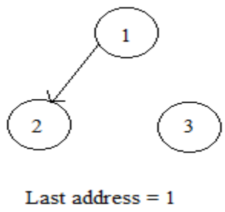

Fig 6: Last Address field

Whereas, the last address of the previous node which sends the RREQ to the current node is stored in the P-addr field of the packet at current node. For example, in figure 7 the last address of the packet received at node 2 is 1. Hence, the last address of the packet received at node 3 becomes 2 and the P-addr is the last address at node 2 which is 1.

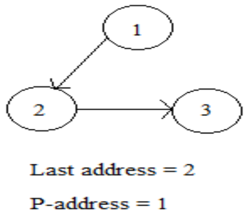

Fig 7: P-addr field

In MAODV, the initial relay and forward values are set to 1 which indicates that all the nodes in the network can participate in broadcasting the RREQ packets for the first time. Whenever a node receives an RREQ packet, it attaches its last address i.e., the node address from which it received the RREQ packet to the p-addr field and attaches its own address to the last address field before further broadcasting the packet to its neighbors. Once the node broadcasts the packet, the relay status of the node becomes zero which means that the node has already participated in route discovery. The forward value on the other hand depends on the TTL value. If a node is outside TTL range (hop range) of the source node, then the forward value of that particular node is set to 0 as it does not take part in route discovery [7].

The relay values of nodes are set to 1 only when a particular node receives an RREQ packet where the p-addr of the RREQ packet matches with the node's address. This indicates that the current node's neighbors have participated in route discovery by broadcasting the RREQ packet sent by the current node and may now stay silent without participating in route discovery.

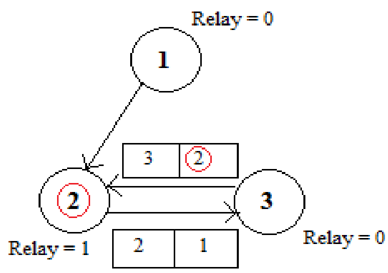

Fig 8: Setting the relay value

From figure 8, it can be seen that when node 2 sent a packet to node 3, the packet at node 3 has p-addr as 1 and last address as

2. When node 3 which is the neighbor of node 2 sends this packet back to node 2, the p-addr of the packet at node 2 now becomes 2 which is same as node 2's address. Hence the relay value of node 2 is set back to 1 which indicates that node 2 can participate in the route discovery.
Hence, all the nodes which have a relay value one can take part in the route discovery whenever the source increments the TTL and broadcasts RREQ packets else the node does not participate in route discovery. A node will not forward the RREQ if both of its relay and forward are 0 [7].

IV. Simulation Setup

To verify that the proposed MAODV performs better when compared to the already existing reactive protocols AODV and DSR, simulations have been carried out using the Network Simulator 2 (NS2) which is a simulator for wireless networks that works on the Linux Ubuntu environment.
The following table shows the parameters that have been used to setup the simulation environment.

Parameter	Value
Operating System	Ubuntu 14.04
Simulator	NS2 (ns-2.35)
Channel Type	Wireless Channel
Number of Nodes	10,60,100
Speed (m/s)	10
Data Type	UDP
Simulation Time	100
MAC Protocol	802.11
Data Packet Size	512
Simulation Area	1200*1200
Radio Propagation Model	Propagation/TwoRayGround
Routing Protocols	MAODV, AODV, DSR

Table 1: Parameter Setup for Simulation

Simulations have been carried out using different number of nodes in a network to symbolize different practical applications of wireless networks. For example, 10 nodes symbolize a small network that can be used in an agricultural setup. 60 nodes symbolize a medium size network that can be used in an industrial setup and a large 100 nodes network that can be used in an army base.

V. Simulation Results and Justification

MAODV has been compared with two other reactive protocols AODV and DSR based on four different performance metrics which are
1. Packet Loss
2. Packet Delivery Ratio
3. End-to-End Delay
4. Throughput

1. Packet Loss
It is the number of packets lost during the simulation. Table 2 shows the Packet loss values for the routing protocols over 10, 60 and 100 nodes.

Number of Nodes	DSR	AODV	MAODV
10	5935	6160	5960
60	5126	5557	5473
100	5391	7159	6912

Table 2: Packet Loss

Figure 10 shows that the Packet Loss has decreased in MAODV when compared to AODV. However, the Packet Loss for DSR is much lesser when compared to MAODV. Results in [4] show that DSR is the best among other reactive routing protocols in terms of the number of packets delivered. The number of packets lost therefore is less when compared to AODV and MAODV.

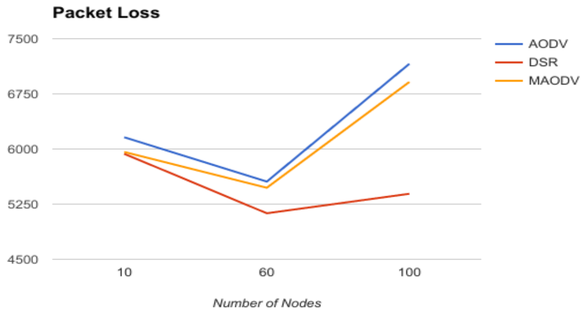

Fig 10: Packet loss for varying node densities.

2. Packet Delivery Ratio
It is the ratio of the number of packets received by the destination to the number of packets generated by the source node. Table 3 shows PDR for 10, 60 and 100 nodes.

Number of Nodes	DSR	AODV	MAODV
10	79.936	79.584	79.746
60	81.189	79.412	79.781
100	83.481	78.663	78.937

Table 3: Packet Delivery Ratio

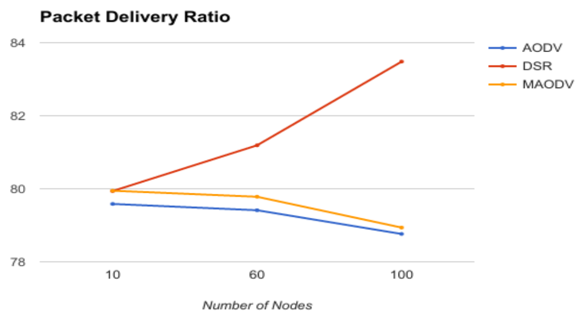

Fig 11: Packet Delivery Ratio for varying node densities.

From fig.11, it can be seen that MAODV has a better packet delivery ratio when compared to AODV. However, as DSR has a better packet deliver ratio among all the reactive protocols (which was shown in our previous paper [4]) it performs better even when compared to MAODV.

3. End-to-End Delay

It is the time taken for the delivery of packets from a source to a destination. Table 4 shows ETED for 10, 60 and 100 nodes.

Number of Nodes	DSR	AODV	MAODV
10	0.1471	0.1468	0.1453
60	0.1483	0.1472	0.1464
100	0.1512	0.1494	0.1492

Table 4: End-to-End Delay

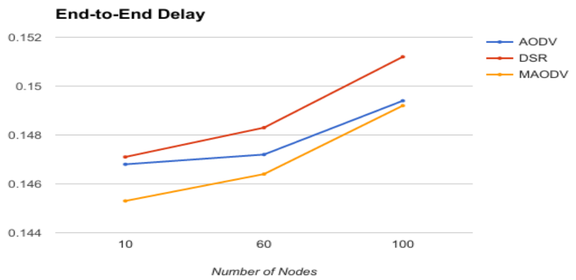

Fig 12: End-to-End delay for varying node densities.

From fig.12, it can be seen that MAODV has less delay when compare to both AODV and DSR.

4. Throughput

It is the ratio of number of packets received by the destination to the time taken for simulation. Table 5 shows throughput values for 10, 60 and 100 nodes.

Number of Nodes	DSR	AODV	MAODV
10	369.468	403.112	403.963
60	389.113	401.828	403.161
100	395.371	400.061	401.981

Table 5: Throughput

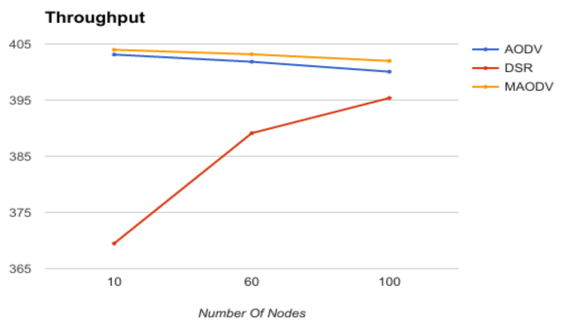

Fig 13: Throughput for varying node densities

Figure 13 shows that when the three reactive routing protocols are compared, MAODV has better throughput values whereas DSR has the least values.

5. Performance Analysis:

From Table 5:

DSR

The mean of DSR = 384.648

The variance of DSR = 182.675

Precision of DSR = 1/variance = 0.00547

AODV

The mean of AODV = 401.667

The variance of AODV = 2.346

Precision of AODV = 1/variance = 0.4261

MAODV

The mean of MAODV = 403.701

The variance of MAODV = 1.659

Precision of MAODV = 1/variance = 0.6027

MAODV has a higher precision value when compared to AODV and DSR. A higher value for precision indicates that the proposed protocol performs better when compared to the other reactive protocols.

VI. Conclusion

A new congestion control modified AODV (MAODV) has been proposed in this paper for reactive routing protocols. Simulations have been performed to compare the proposed routing protocol to the existing reactive routing protocols DSR and AODV based of four performance factors which are Packet Loss, Packet Delivery Ratio, End-to-End Delay and Throughput. Simulation results show that MAODV performs better when compared to DSR and AODV in the aspects of End-to-End Delay and Throughput. However since DSR has a better Packet Delivery Ratio and less Packet Loss when compared to all other reactive protocols [4] hence, DSR performs better than MAODV in this aspect whereas MAODV performs better than AODV. Lastly, an overall performance analysis shows that MAODV has the highest precision value which indicates it is more efficient when compared to both DSR and AODV.

VII. References

[1] A., & Dr. S.S., T. (may 2013). Study of MANET: Characteristics, Challenges, Application and Security Attacks. *International Journal of Advanced Research in Computer Science and Software Engineering, 3*(5), 2277128x. Retrieved from www.ijarcsse.com.

[2] Bakht, H. (2005, August 1). The History of Mobile Ad-hoc Networks. Retrieved from http://www.computingunplugged.com/article/the-history-of-mobile-ad-hoc-networks/

[3] Raja, L., & Dr.S.Babu, S. (2014). An Overview of MANET: Applications, Attacks and Challenges. *International Journal of Computer Science and Mobile Computing, 3*(1), 2320088x, 408-417. Retrieved from http://www.ijcsmc.com/

[4] Bai, Y., Mai, Y., & Dr.Wang, N. (2017). Performance Comparison and Evaluation of the Proactive and Reactive Routing Protocols for MANETs.
[5] Yoshimachi, M., & Manabe, Y. (2016). A New AODV Route Discovery Protocol to Achieve Fair Routing for Mobile Ad Hoc Networks . *6th International Conference on Information Communication and Management* . Retrieved from http://www.ns.kogakuin.ac.jp/~wwa1056/pdf/YoshimachiMANET2.pdf
[6] Jayakodi, A., & Jawadul, A. (2017). Modified Expanding Ring Search in Common Node Scenario for AODV. *6th National Conference on Technology and Management (NCTM)*.
[7] Mahajan, R., & Jagtap, R. (2013). Energy Efficient Routing Protocols for Mobile Ad-Hoc Networks. *International Journal of Science and Modern Engineering (IJISME), 1*(3), 23196386th ser.
[8] Usha, M., Jayabharathi, S., & Wahida Banu, R. (n.d.). RE-AODV: An Enhanced Routing Algorithm for QoS Support in Wireless Ad-Hoc Sensor Networks. *IEEE-International Conference on Recent Trends in Information Technology*.
[9] Mobile Ad-hoc Networks, Google Images. (n.d.). Retrieved from https://www.google.com/search?q=mobile ad hocnetworks&client=firefox-b-ab&source=lnms&tbm=isch &sa=X&ved=0ahUKEwjn4v3M6PTSAhUL9GMKHcpBDWIQ_AUICSgC&biw=1366&bih=633#imgrc=VbFOlba9NRmZgM.
[10] Mobile Ad-hoc Networks, WIKIPEDIA. (n.d.). Retrieved from https://en.wikipedia.org/wiki/Mobile_ad_hoc_network.