Design and Implementation of An Efficient Multipath AODV Routing Algorithm for MANETs

Harshdeep Jhajj
Dept. Electrical and Computer
California State University, Fresno
Fresno, California, USA
harshdeepjhajj@mail.fresnostate.edu

Rijutha Datla
Dept. Electrical and Computer
California State University, Fresno
Fresno, California, USA
rijutha@mail.fresnostate.edu

Dr. Nan Wang
Dept. Electrical and Computer
California State University, Fresno
Fresno, California, USA
nwang@mail.fresnostate.edu

***Abstract*— A Mobile Ad-hoc Network (MANET) is a collection of nodes that communicate with each other wirelessly without any central support or conventional structure. The transmission of data packets over wireless channels in MANETs helps to maintain communication. Ad-hoc On-Demand Distance Vector Routing is a reactive routing protocol associated with MANET which creates a route to destination by broadcasting route request packets through the entire network. A link failure in this type of protocol causes the source to flood the network with these Route Request packets that leads to congestion in the network and performance degradation. This paper proposes an Efficient Multipath AODV routing algorithm that determines if a node in a network is relaying or is silent in the process of route discovery to send data packets from the source to destination. Simulation results show the proposed routing algorithm controls congestion and enhances performance in the network as not all network nodes have to participate in the route discovery for a particular source-destination pair.**

Keywords*— *MANET; Reactive Routing; Proactive Routing; AODV; DSR; EMAODV

I. INTRODUCTION

Mobile Ad-Hoc Network (MANET) consists of many wireless nodes that form a temporary network in a certain region. Mobile nodes in MANETs communicate over a shared wireless medium using packet radios. Operations in a MANET are not controlled by any single node's central network, as these networks lack infrastructure. Rather, the control is distributed among all nodes within the network. The communication among these nodes is the backbone for all network operations, including routing and security. The mobile nodes in MANETs require very few CPU capability, power storage, and memory size, hence are generally light weighted.

MANETs are employed in many areas, such as data collection, seismic activities, medical applications, military applications, rescue operations, wearable devices, and in other places where pre-installed infrastructure are not possible [1, 2]. These networks have two major challenges in terms of node mobility and energy efficiency. Link breaks, power efficiency and network density are the three main factors of the effects caused by node mobility on a routing protocol's performance. The network load is proportional to the network density, while throughput is affected by the control overhead in the network. [3].

Routing information of a node and its neighbors is propagated through the network using certain routing protocol. This helps all the nodes in a network gain knowledge regarding the topology of a network [4]. Three types of MANETs routing protocols are shown in Fig.1.

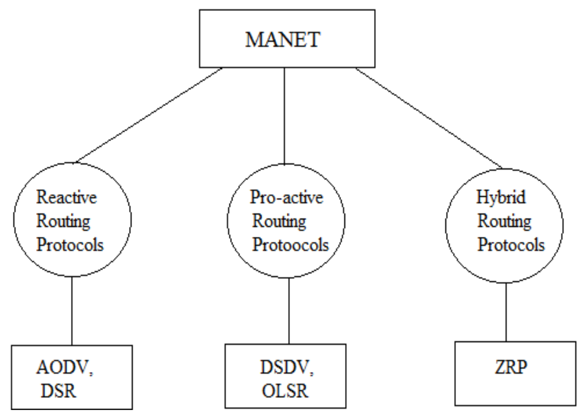

Fig. 1. Types of Routing Protocols for MANET

Reactive routing protocols are on-demand routing protocols. A route search process is created only when the source node wants to communicate with the destination. Updated routing information will not be kept in the nodes when no communication is active [5]. Ad-hoc On-Demand Distance Vector routing (AODV) and Dynamic Source Routing (DSR) are typical reactive routing algorithms. Proactive routing protocols are table-driven protocols. Every nodes in the network keeps a routing table to store the routing information. The routing tables will be updated when the network topology is changed [5]. Destination Sequenced Distance Vector (DSDV) routing and Fisheye State Routing (FSR) are the existing proactive routing protocols. Hybrid Routing Protocols, such as Zone Routing Protocol (ZRP), combine characteristics from the aforementioned Reactive and Proactive protocols [5].

This paper proposes an Efficient Multipath AODV (EMAODV) that determines if a node in a network is relaying or silent in the process of route discovery to send data packets from the source to destination. This can be done by using the Time to Live (TTL) value, which determines the number of hops a route request can go through, and by adding a new field, the Predecessor address (P-addr), in the packet format of the

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Route Request Packet (RREQ) packet, which determines the predecessor address value of a node. A relaying node takes part in the route discovery process whereas a silent node drops the route request packet and does not participate in further forwarding of the route request packets throughout the network. This controls congestion in the network and enhances performance, as not all the nodes of the network participate in the route discovery for a particular source-destination pair.

Simulations were carried out on NS2 to compare the existing reactive protocols to the proposed EMAODV based on packet loss, packet delivery ratio, end-to-end delay, and throughput. The results show that the proposed EMAODV performs better in all four aspects when compared to the existing reactive routing protocols.

The organization of this paper is as follows. Section 2 discusses related works. Section 3 describes the proposed EMAODV protocol. Section 4 presents the simulation techniques and result justifications. Finally, Section 5 concludes the paper.

II. RELATED WORKS

DSR protocol consists of route detection and route preservation. When employing DSR protocol, Nodes in the network may keep information of multiple routes for a single destination and can select any of the route at any time to send packets to the destination node [6].

In this protocol, the source node first broadcasts a route request packet to start the route searching process. The node receiving the request packet will check its route table to find out if it has a route to the destination and reply accordingly. If the node does not have any routing information for the destination, it inserts its own address to the route record field of the request packet and locally rebroadcasts the packet to its neighbors. On receiving the RREQ packet, the destination node generates a route reply packet that has all the addresses received in the packet and sends it back along this path to the source. The source node saves the information in its routing table and may use it to send subsequent packets. [7]

In AODV, all nodes in the network need to keep a routing table that stores routing information of its neighboring nodes. A node sequence number and a broadcast-id will be maintained for each of the nodes. When a source node needs to talk to the destination node, it first increments its broadcast-id and broadcast a request packet to its neighbors to set up the route [8].

Route discovery in AODV is executed to blindly forward the request packets from the source node to all its neighbor nodes in the network. Then, the neighbor nodes will receive and process the information. All nodes receiving the request packet for the first time check their routing tables for a possible route. If there is a route, the nodes send out a RREP packet to its neighbors. Nodes silently discard the RREQ packets that do not arrive first. If the node is at the destination, it sends out a Route Reply Error Packet (RREP) to the source.

As AODV blindly floods the entire network with route request packets for route discovery, congestion builds up in network. The situation deteriorates when there is a link failure or a connection loss. In this scenario, a Route Error Packet (RERR) is sent to a source node by a node that loses the connection. On receiving a RERR packet, the source node re-initiates the route discovery by flooding the network with RREQ packets all over again. This causes performance degradation as the delay in delivering packets increases and the number of packets delivered decreases. To overcome this, a new AODV Route Discovery has been proposed in [9].

III. PROPOSED EMAODV PROTOCOL

The proposed EMAODV determines a path for the route discovery by using the time to live (TTL) factor that reduces the overhead rather than flooding the entire network with RREQ packets. TTL is a factor that determines the hop range until an RREQ packet can be propagated. Initially, the TTL value in the RREQ packet is set to some initial value INITIAL_TTL 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, 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 the source node until a route to the destination node is determined after which the source node receives an RREP packet. A path through this route discovery is determined by using the relay and forward values of nodes[10].

Steps involved in the EMAODV protocol are:

- As shown in Fig.2, 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 request packet, to the p-addr field and attaches its own address to the last address field before further broadcasting the packet to its neighbors.

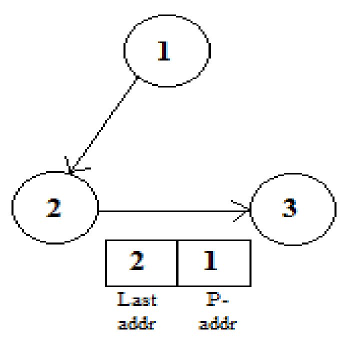

Fig.2. Last address and P-addr

- Whenever an intermediate node broadcasts an RREQ packet for a source-destination pair, the relay status of the node becomes zero that means that the node has already participated in route discovery as shown in Fig.3.

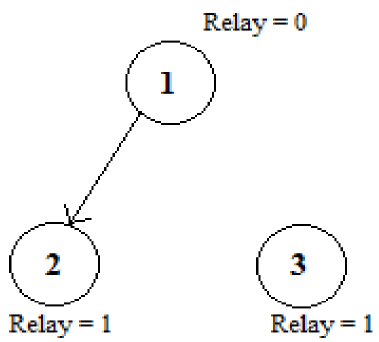

Fig.3. Relay value set to 0

- If a node is outside the TTL range (hop range) of the source node, the forward value of that node is set to 0 as it does not take part in route discovery.
- The relay values of nodes are set to 1 only when a 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.

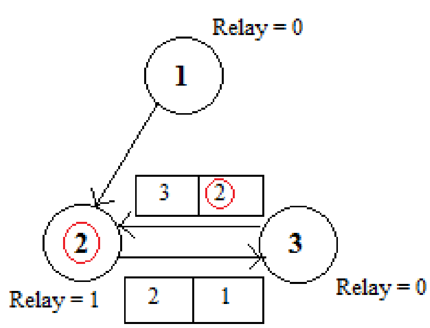

Fig.4. Node address is equal to P-address

In Fig.4, 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 nodes that have a relay value 1 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. When the node S in figure 8 generates the request packets to find the node D, the relay and the forward value of the nodes will be changed based on the EMAODV. The final relay and forward values, which have been determined using the EMAODV, are shown in Fig.5.

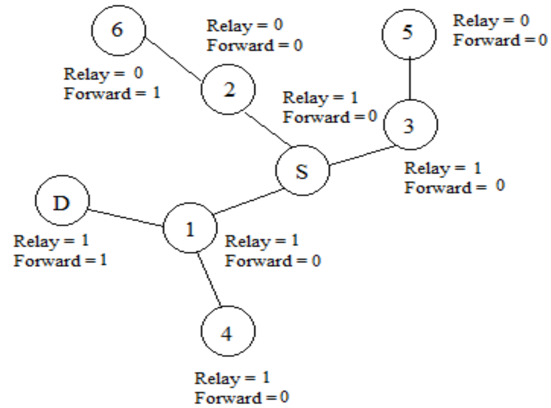

Fig.5. Final relay and forward values

Fig.6. portrays the method to determine the relay and forward values in EMAODV.

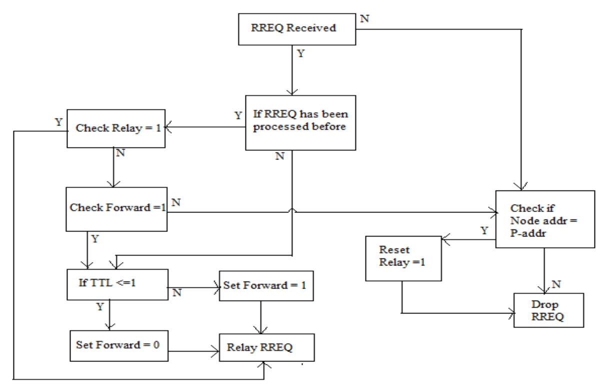

Fig 6. Flow chart for EMAODV routing protocol

When a request packet with the same broadcast id has been received, the P-Addr in the packets will be checked and based on what, the node will decide whether to reset the relay value or to just drop the RREQ packet. If the RREQ packet has not been processed earlier, it will be checked for its relay and forward value. Then based on the TTL value and the P-addr value, the relay and forward values are set. The nodes with relay values 1 can take part in the route discovery and the nodes with relay value 0 do not take part in route discovery.

IV. Simulation and Results

A. Parameter Setup

Network Simulator 2 (NS2) has been used to carry out the simulations. Parameters used to setup the simulation environment as shown in Table I [11].

TABLE I. PARAMETER SETUP

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	EMAODV, AODV, DSR

These parameter values have been kept consistently even for varying network sizes i.e. 10 nodes, 60 nodes and 100 nodes.

B. *Performance Metrics*

Performance of the proposed EMAODV protocol was simulated and compared to the two existing reactive protocols, AODV and DSR based on four performance metrics [12].

- Packet Loss: the number of packets dropped during the simulation, which is determined by the difference in the number of packets sent, and the number of packets received.
- Packet Delivery Ratio (PDR): the ratio of the number of packets received by the destination to the number of packets sent by the source.
- End-to-End Delay (ETED): the time taken for the delivery of packets from a source to a destination.
- Throughput: the ratio of number of packets received by the destination to the time taken for simulation.

C. *Simulation Results and Justification*

The simulation results based on Packet Loss, PDR, ETED and Throughput of the proposed EMAODV routing and two existing AODV and DSR protocols are shown in Fig.7, Fig.8, Fig.9 and Fig.10 respectively. [13]

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

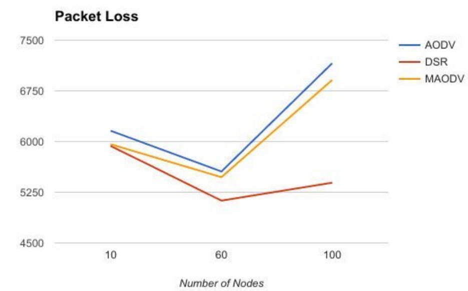

Fig 7. Packet Loss Comparison

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

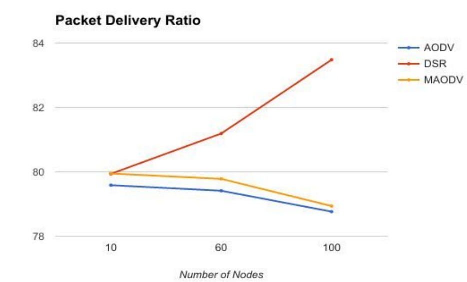

Fig 8. Packet Delivery Ratio

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

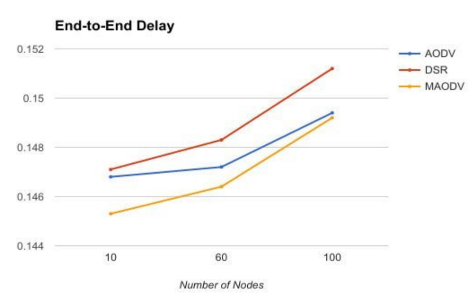

Fig 9. End to End Delay Comparison

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

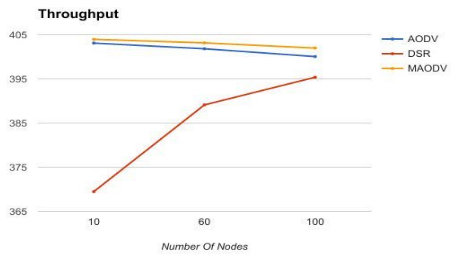

Fig 10. End to End Delay Comparison

Packet Loss and PDR for DSR are better when compared to AODV and EMAODV. This is because DSR is known as the best among other reactive routing protocols in terms of the number of packets delivered.

On the other hand, the aim of the proposed EMAODV was to reduce congestion in AODV and increase the packet delivery ratio that has been achieved as the EMAODV yields lower Packet Loss and higher PDR compared to AODV.

EMAODV performs better on ETED and Throughput compared to both AODV and DSR. [14] [15]

D. *Performance analysis*

A performance analysis has been done to determine the overall performance of the three routing protocols, AODV, DSR and EMAODV. The mean, variance and Precision of protocols are calculated based on Throughput.

TABLE II. PERFORMANCE COMPARISON

Protocol	**Mean**	**Variance**	**Precision**
DSR	384.648	182.675	0.00547
AODV	401.667	2.346	0.00547
EMAODV	403.701	1.659	0.6027

A higher value of precision indicates a better performance of the proposed EMAODV protocol when compared to the other reactive protocols.

V. CONCLUSION

This paper focuses on congestion alleviation of the AODV routing protocols due to link failures and rebroadcasting of the RREQ packets. This has been achieved by creating a path for route discovery in the proposed EMAODV routing protocol rather than just flooding the entire network with route request packets every time. An overall performance analysis shows that the EMAODV has the highest precision value, which indicates it is more efficient when compared to both DSR and AODV. The authors hope to show in the future that many real-world MANET applications can benefit from the proposed EMAODV routing protocol design.

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