Performance Analysis of AODV Based Congestion Control Protocols in MANET

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***Abstract*—MANETs are highly deployable, dynamic and self-configurable because of which routing is an extremely challenging task in them. AODV routing protocol used for routing purposes in MANETs is an on-demand routing protocol which do not support congestion control as it is not congestion adaptive. This paper discusses two congestion control protocols based on AODV in MANETs. Many authors have proposed protocols based on AODV which are congestion adaptive and deal with the congestion over the network. AODV-I and EDAODV are two congestion control protocols which deals with the congestion reactively. These two protocols are simulated on NS2 by varying the size of data packets. The analysis of these protocols is done with AODV by calculating the values for four performance metrics, namely, throughput, packet delivery ratio (PDR), routing overhead and end-to-end delay.**

Keywords—congestion; congestion control; AODV

I. INTRODUCTION

Ad-hoc Network is defined as the collection of two or more wireless devices which communicate with each other directly and does not require the help of any centralized administrator. These networks are generally referred to as MANETs (Mobile Ad-hoc Networks) [1]. The word ‘ad hoc’ can be described as ‘unorganised’ or ‘improvised’, i.e. the nodes over the network are not organised in any particular fashion and so are free to move anywhere over the network and hence depicts the situation of the dynamic network. The ad hoc mode directly connects the wireless and mobile clients [2]. Each node in MANET operates not only as a terminal but also as a router that has the functionality to forward the data [3]. Ad-hoc On-Demand Distance Vector (AODV) is a routing protocol which generates routes among nodes only when source node desires and maintains them as long as they are required by the source. It uses the concept of sequence numbers in order to ensure that the routes are fresh. It is self- starting and loop-free [4]. The most important applications where ad-hoc networks are used include rescue mission team, military, emergency services (accidental fires), etc. [5].

AODV generates routes using a route request / route reply cycle. A route request is broadcasted over the network when source node wishes to set a route to destination for which it does not possess a route already. Every node receiving this packet updates the information of source node and then set backward pointers to it in the routing table. The RREQ (Route Request) contains the IP address of the source node, its current sequence number, broadcast ID and the latest sequence number of destination for which source node is aware of. A node receiving the RREQ sends route reply (RREP) in two cases, first, if it itself is the destination and, second, if it possesses a route to the destination, provided, the corresponding sequence number of the node must be either greater than or equal to the sequence number contained in RREQ [6].

Due to the mobile nature of the MANETs and their limited resources, there exist various issues which require high research. Some of these issues include security, topology control, quality of service, routing, power management, congestion control, scalability, etc. Although all the issues are equally important for any network to work efficiently and reliably, but congestion is on the top of the list. Lack of congestion control leads to unnecessary packet loss which results in the degradation of the network, thereby losing important data and resulting in its unsuccessful delivery to the destination.

II. CONGESTION IN MANET

Congestion is one of the most important issues in ad hoc networks. Congestion, in general, is defined as the condition when the traffic flowing over the network exceeds the capacity of the network. In traditional approaches, the congestion is avoided over the network by limiting the rate of the traffic sent over the network by the sender. Another way of controlling and

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reducing congestion is to re-route the packets over the network to those areas with less congestion status. In traditional wired networks, the causes and the consequences of the congestion are well known. But controlling the congestion in mobile ad hoc networks poses new and different challenges that limit the usage of traditional methods for solving the problem. Congestion in the networks is not uniformly distributed over any region, but it depends on the location of nodes over the network. Congestion can become high or low with the changes in the position of the nodes [7].

Although some other factors are also present which leads to packet loss, such as mobility, link failures, interferences, etc., but congestion is the main cause. It is assumed that packet loss during transmission due to damage is less. Thus the probable cause of packet loss in the network is congestion. So, if no appropriate congestion control is performed, it can lead to a network collapse due to congestion, and so no data is successfully delivered [8].

MANETs use shared broadcast medium for transmission. While delivering data to multiple destinations, multicast communication is of great concern in these networks, since it helps saving resources. While transmission, there are chances that the route gets busy due to greater traffic or some node may fail which rush the traffic to other nodes which can be the cause of congestion. So, it is important to avoid congestion collapse in wireless multi-hop networks in order to perform efficient congestion control [9]. Measures have been taken by author to free the network from congestion and repair the damaged routes as is illustrated in [10].

For this reason, many authors have proposed various congestion control algorithms in an attempt to avoid packet losses and to ensure reliable delivery of packets from source to destination. In this paper, the congestion control protocols based on AODV will be discussed. Since AODV has not much of congestion control mechanisms, congestion may happen due to routing. It may also lead to long delays, packet losses and low throughput. Also it is expensive to recover from congestion in terms of time and overhead. So, packet losses are to be reduced which involves congestion control running on top of mobility and failure adaptive routing protocols at the network layer [11].

III. PROTOCOLS RELATED TO CONGESTION BASED ON AODV

Various congestion control protocols have been designed in order to remove or lower the probability of the network being congested. This paper works on two congestion control protocols. These protocols based on AODV are explained below.

A. Early Detection Congestion and Control Routing Protocol (EDAODV)

Early detection congestion and control routing protocol (EDAODV) [11] is a unicast routing protocol for MANET. In this protocol, alternate path is found bi-directionally by the previous (predecessor) and the next (successor) node on the primary path. On finding the alternate path, the previous node of the congested node uses an alternate route and bypasses the congestion to the non-congested node which is first on the primary route as set previously during route establishment.

EDAODV comprises of following three components:

1) Route Discovery: It includes discovering the route to the destination by the source by broadcasting an RREQ packet towards the destination which responds back by sending an RREP packet. The RREP then travels in the path the RREQ travelled earlier and adds this entry in its route table. Each node has two routing tables, Primary Routing Table (PRT) and Alternate path Routing Table (ART). Every entry in PRT is distinct to a destination node. Here, entry for any destination D in routing table of node X is denoted by PRT[X, D] [11].

2) Early Congestion Detection: Congestion can occur at any interval in the network. It occurs mainly because of the reason that the number of packets coming to a particular node exceeds buffer capacity assigned to it. This leads to congestion at that node and it starts losing data packets. So, to detect the congestion in advance, congestion metric can be used at that node [11].

3) Bi-directional Path Discovery: A node's primary path predicts its congestion status and broadcasts a congestion status packet (CSP) periodically with TTL (Time To Live) = 1. The CSP packet contains the congestion status of the node and parameter set for each destination appearing in the routing table. The parameter set contains Source S, Destination D, previous ZoneI node P_ZoneI, Previous ZoneI hop count P_Zhop, Next ZoneI node N_ZoneI, Next ZoneI hop count N_Zhop. When a CSP packet is received by the predecessor node of the congested node over the primary path, the predecessor node becomes aware of X's congestion status, non -congested node in the primary path and its hop count. The primary table of predecessor and successor node is updated accordingly. This information is breakthrough to find the bidirectional non-congested alternate path [11] as shown and described by Fig. 1.

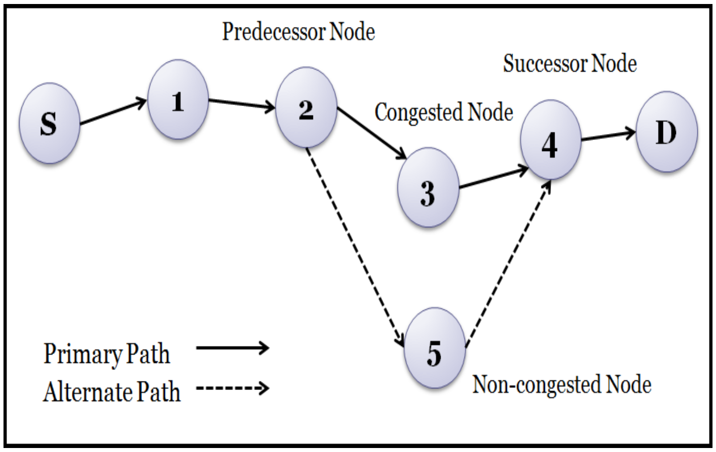

Fig. 1. Finding Alternate Path to reduce Congestion

B. Improved Ad-hoc On-demand Distance Vector Routing Protocol (AODV-I)

AODV-I is the Improved Ad-Hoc On-demand Distance Vector Routing protocol [12] which is based on congestion aware and route repair mechanism. AODV is widely deployed in Ad Hoc networks, but there exists some deficiencies because it does not take into account congestion control. So, on deeply investigating AODV protocol, a new protocol was proposed in [12] known as AODV-I.

AODV-I deals with the congestion processing to the RREQ message thereby avoiding the selection of the busy nodes automatically during the establishment of new route. AODV lacks congestion processing in RREQ and so, is not able to avoid the busy routes automatically during the route establishment. Also, no guarantee mechanism is added to RREP messages because of which whenever the RREP is not received by the source, it re-initiates route discovery process, which further adds to unnecessary overhead.

These all limitations are removed in AODV-I. Congestion processing is added to RREQ, thereby allowing it to avoid selecting the busy routes automatically and the routing repair mechanism is also added to the RREQ message which prevents the network from initiating a new route discovery whenever the route appears to be busy. This improvement reduces the packet loss rate, end-to-end latency and the rate of utilization of the resources available in the network [12].

The flow chart explaining the processing of RREQ and RREP in AODV-I is explained with the help of Fig. 2.

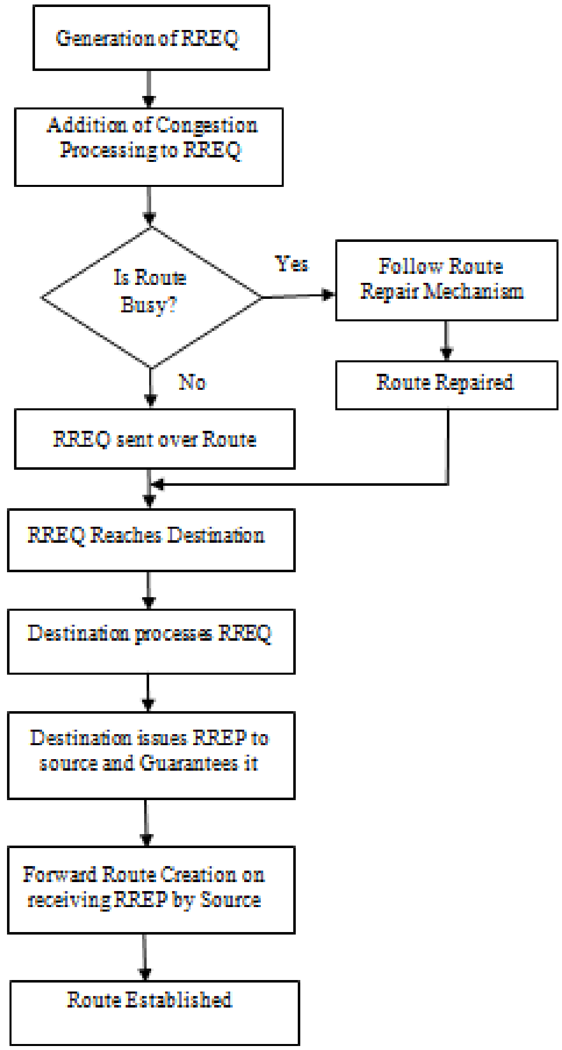

Fig. 2. Flow chart explaining the process of AODV-I

IV. SIMULATION AND RESULTS

Simulator used for this research is NS2 which is a freeware. Performance analysis of three protocols AODV, AODV-I and EDAODV is conducted based on four performance metrics, by varying the size of data packets, i.e. 512, 1024, 2048 and 4096.

The network area taken is 1200m*1200m with CBR traffic pattern. IEEE 802.11 MAC protocol is used with Two Ray Ground propagation model and omni-antenna. The scenario is created for 60 mobile nodes and the simulation is carried out for 10 seconds. The behaviour of 60 nodes is studied by varying the size of data packets and the analysis is done based on packet delivery ratio, throughput, routing overhead and end-to-end delay.

TABLE 1. CONFIGURATION TABLE FOR SIMULATION

Parameters	Values
Number of Nodes	60
Channel Type	Wireless Channel
Radio Propagation Model	TwoRayGround
Antenna Type	Omni Antenna
Maximum Packets in IFQ	50
MAC Type	802_11
Traffic Type	CBR
Area	1200m * 1200m
Simulation Time (s)	10
Ad-hoc Routing Protocols	AODV, AODV-I, EDAODV
Packet Size (Bytes)	512, 1024, 2048, 4096

With the help of NS2, tcl scripts were executed using the scenario described in Table 1. Using the AWK scripts, trace files were obtained and data were extracted. The graphs were generated from the obtained results for above mentioned four parameters. The parameters are described below in detail.

A. Parameters Used

The following performance metrics are used for analyzing the three protocols AODV, AODV-I and EDAODV.

1) End to end Delay: The time taken by the packet to be transmitted across a network from source to destination is known as end-to-end delay. It also includes the delays due to route discovery process and the queuing delay during transmission of data packets [13]. It is calculated using the below formula:

$$\sum (\text{Arrival Time} - \text{Sending Time}) / \sum \text{Number of connections}$$

2) Throughput: It is defined as the total number of the packets delivered to the destination over the total time of simulation [14]. Throughput is measured in bits per second (bit/s or bps).

3) Routing Overhead: When nodes change their location within network, some extra routes get generated in the routing table. These routes generate unnecessary overhead. This is known as routing overhead [15]. Formula to calculate routing overhead is:

$$\text{Routing Overhead} = \text{rt\_pkts}/\text{recvd}$$

where, rt_pkts is the total number of data packets received, and recvd is the total number of routing packets received

4) Packet delivery ratio: The ratio of the total number of data packets delivered to the destination to the total number of packets sent is known as packet delivery ratio. The performance of the protocol is high if the value of packet delivery ratio is high.

PDR= Total number of packets received at the destination / total number of packets sent by the source

B. Simulation Results

This section gives the analysis of three protocols, AODV, AODV-I and EDAODV based on the variation in the packet sizes.

1) Throughput

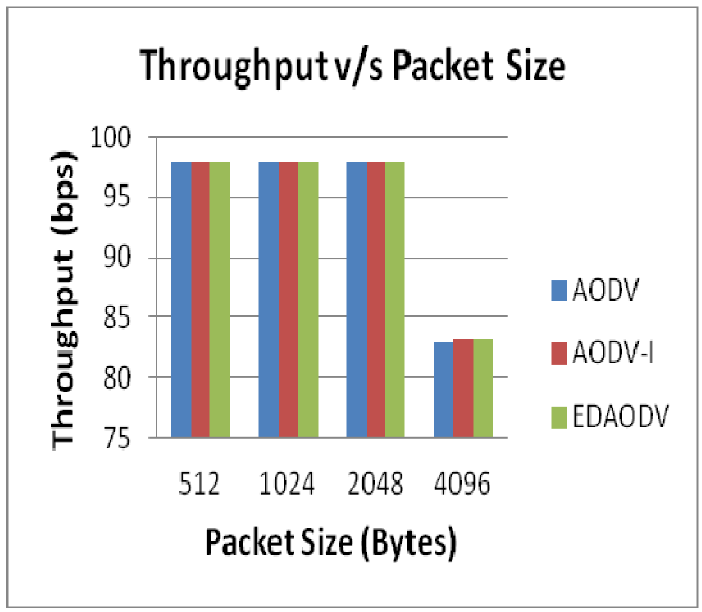

Fig. 3. Graph for Throughput v/s Packet Size

Fig. 3 indicates that throughput for first three packet sizes is constant with the increase in the size of data packets but decreases greatly for packet size 4096. Also, on comparing AODV, AODV-I and EDAODV, it becomes clear that although throughput shows the same results for first three packet sizes but it is high in case of AODV-I and EDAODV as compared to AODV in case of 4096 packet size, thereby proving that both these protocols show high performance than AODV in case of controlling congestion. As throughput is directly proportional to packet delivery ratio, lesser number of delivered packets leads to lower throughput which is illustrated by the graph.

2) Routing Overhead

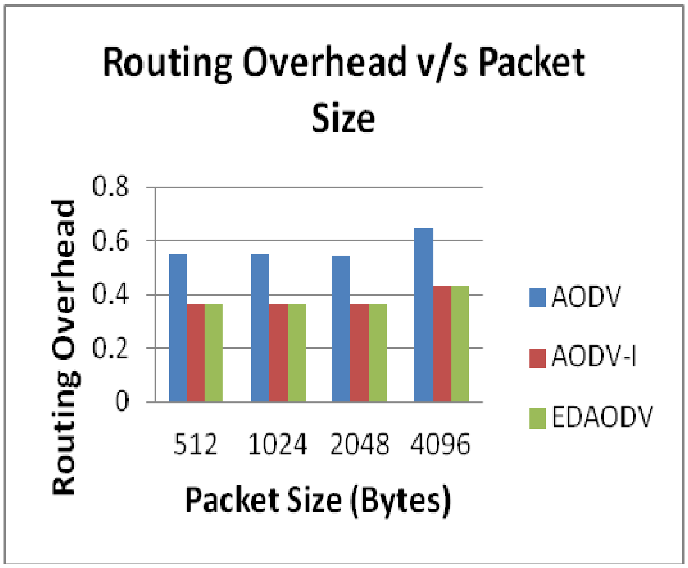

Fig. 4. Graph for Routing Overhead v/s Packet Size

Fig. 4 indicates that routing overhead increases with the increase in the data packet size. Also, from the graph, it is clear that congestion control protocols AODV-I and EDAODV show lower routing overhead as compared to AODV routing protocol. This indicates that they show better performance as compared to normal AODV. The reason behind lower routing overhead of AODV-I and EDAODV is the congestion processing and route repair mechanisms applied to RREQs.

3) End-to-end Delay

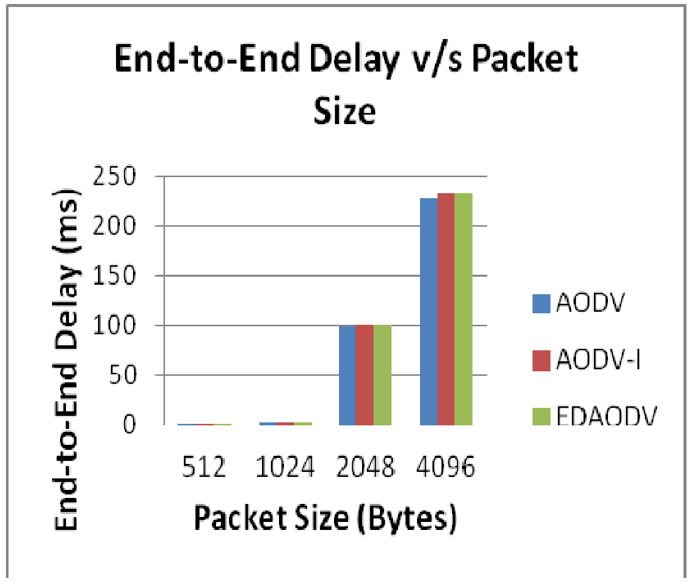

Fig. 5. Graph for End-to-end Delay v/s Packet Size

Fig. 5 indicates that end-to-end delay in case of packet size less than 2048 is almost negligible (very low). But there is a rapid increase in end-to-end delay when the packet size is greater than 1024 because more the size of the packet, greater is buffer capacity required by it which may not be possible at all times during transmission. So, packets have to follow some other routes in order to reach the destination which leads to increase in end-to-end delay with the increase in packet size. The results also suggest that the end to end delay in case of AODV-I and EDAODV is higher as compared to AODV. This is because of the fact that both the protocols try to find the alternate paths based upon their respective logics. So, more time is required for the packets to reach the destination through alternate paths in comparison to the original path. This leads to the increase in the end to end delay in AODV-I and EDAODV.

4) Packet Delivery Ratio

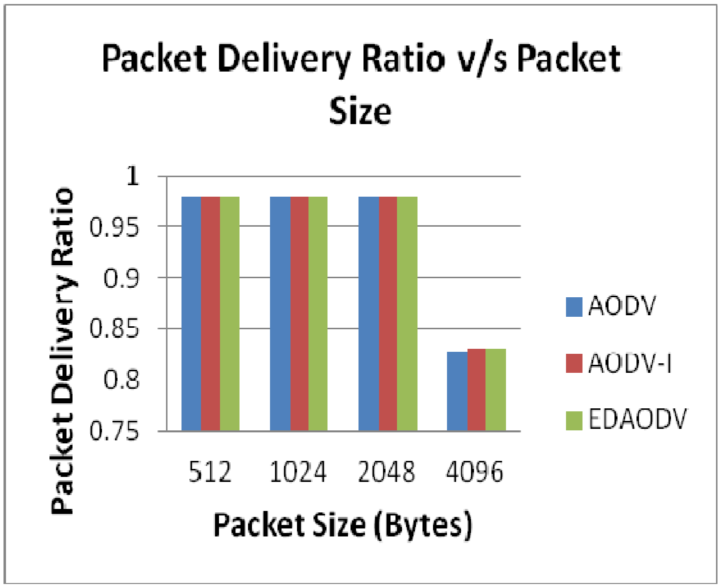

Fig. 6. Graph for Packet Delivery Ratio v/s Packet Size

The graphical results in Fig. 6 suggests that packet delivery ratio is constant up to packet size 2048 but it decreases drastically after 2048. This is because of the fact that the packet size is large and buffer capacity is constant. Because of this, greater capacity is utilized by packets with large size and the rest of the packets did not get chance to enter into the queue and as a result get discarded. This results in the decrease in packet delivery ratio. But the results show that PDR for AODV-I and EDAODV is higher as compared to AODV.

V. Conclusion

This paper discusses the two protocols, AODV-I and EDAODV for four quality parameters, throughput, end-to-end-delay, packet delivery ratio and routing overhead for varying packet sizes (512, 1024, 2048 and 4096) for 60 nodes. The graphical results show that with the increase in packet size, throughput of the network degrades but by small amount. This implies that throughput is not much affected by the changes in packet size. Routing Overhead is not much affected by the increase in the packet size but up to some limit, which when exceeded results in higher routing overhead. End-to-end delay varies greatly with the increase in the packet size because more buffer capacity is utilized by the packets of larger size and so, other packets have to face delay. Packet Delivery Ratio is nearly stable for varying size of data packets except when packet size becomes greater than 2048. This is because more packets get dropped due to larger packet size. So, end-to-end delay and routing overhead are the most affected entities by congestion and packet delivery ratio and throughput are least affected by congestion. Also, it can be concluded that AODV-I and EDAODV perform almost at same level but are better than AODV. In future, this work can be extended to multicast ad hoc networks.

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