ISSN:0975-9646

Bandana Bhatia et al, / (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 5 (3) , 2014, 4570-4575

AODV based Congestion Control Protocols: Review

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***Abstract*— Ad- hoc network is defined as the network in which the users communicate with each other by forming a temporary network without any centralized administration. Here each node acts both as a host as well as a router. They have highly deployable, dynamic and self-configurable topologies. Various routing protocols are defined for MANETs. These protocols may follow proactive, reactive or hybrid approach. Due to many number of nodes transmitting packets over the network, the chances of losing the packets over the network increases to a great extent. Also, with the increase in size of data packets, the congestion over the network increases which may lead to packet loses. The existing routing protocols for MANETs do not support congestion control as they are not congestion adaptive. There are many proposed protocols that are congestion adaptive and deals with the congestion over the network. This paper discusses congestion control protocols in MANETs. Also, three congestion control protocols, EDAODV, AODV-I and CRP, are discussed. Simulation results are gathered for AODV by varying the number of nodes and size of the data packets for four performance metrics, namely, throughput, routing overhead, packet delivery ratio and end-to-end delay.**

Keywords- MANET; AODV; congestion; congestion control;

I. Introduction

Ad-hoc Network is defined as the collection of two or more wireless devices which have the capability of communicating with each other without the help of any centralized administrator. These networks are generally referred to as MANETs (Mobile Ad-hoc Networks) [1]. MANETs consists of collection of nodes which are free to move within the network and each node acts not only as a terminal but also as a router that has the functionality to forward the data. Mobile nodes can communicate directly via wireless link if they are within each other's radio range and if not, they rely on other neighboring nodes which act as routers to relay packets [2]. The designing of a reliable and efficient routing strategy is a very challenging problem in MANETs because of their mobile nature and limited amount of resources. In order to use these limited resources efficiently, an intelligent routing strategy is required which should also be adaptable to the changing conditions of the network, like, size of the network, traffic density and network partitioning [3].

Although MANETs are useful in providing communication support where no fixed infrastructure exists, but due to the mobility and limited resources in MANETs, various issues are there which require high research. Some of these issues include security, topology control, quality of service, routing, power management, congestion control etc. Congestion is one of the most important issues in ad hoc networks.

Due to multiple data streams, MANETs sometimes show unexpected behavior which leads to congestion resulting in high overhead, packet loss and long delays. Congestion is the condition when the offered load to the network exceeds the available resources. It can take place during the routing of packets from source to destination which ultimately leads to packet loss. Although some other factors are also there which leads to packet loss, such as mobility, link failures, interferences, etc., but congestion is at the top of the list. If no appropriate congestion control is performed, it can lead to a network collapse due to congestion, and so no data is successfully delivered [4]. It is assumed that packet loss during transmission due to damage is rare; hence, the most probable cause of packet loss is the network congestion. In order to avoid and react to congestion, various congestion control algorithms are defined both at proactive and reactive protocols by many authors. This paper focuses on controlling congestion in reactive protocols, specifically, in AODV routing protocol.

The rest of the paper is organized as follows. In Section II, MANET routing protocols are described. Section III describes working of AODV. Congestion control protocols are illustrated in section IV. Section V demonstrates the overview of related work about topic. Section VI shows the simulation results for AODV. Section VII concludes the paper.

II. Routing Protocols in MANETs

Whenever a packet is to be transmitted from source to a destination via number of other nodes, routing protocol is required which is responsible for finding routes to a particular destination and delivering packets to it. These routing protocols are broadly divided into three main categories.

A. On-demand Ad-hoc Routing Protocols

Reactive protocols are also called on-demand routing protocols in which the routes are created only when needed. A node initiates a route discovery process whenever it needs to send data and once a route is found or all possible route permutations have been examined the process is completed. After successful route establishment, route maintenance procedure is followed which keeps up valid routes and to remove invalid routes, thus reducing overhead over network [5]. Various on-demand routing protocols include ad hoc on-demand distance vector (AODV), dynamic source routing (DSR), temporarily-ordered routing algorithm (TORA), etc.

B. Table-Driven Ad-hoc Routing Protocols

They are also known as Proactive Routing Protocols in which protocols maintain consistent routing information from each node to every other node which is up-to-date, regardless of whether or not these routes are needed. Network nodes maintain one or many tables for routing information which help the host to quickly obtain route information and establish a session. Proactive routing protocols include optimized link state routing (OLSR), destination sequenced distance vector (DSDV), Cluster-head Gateway Switch Routing (CGSR), Wireless Routing Protocol (WRP) [5].

C. Hybrid Ad-hoc Routing Protocols

Hybrid routing protocols include the combination and advantages of both proactive and reactive routing protocols. Some hybrid routing protocols include zone routing protocol (ZRP), zone based hierarchical link state (ZHLS) and core extraction distributed ad hoc routing (CEDAR) [6].

III. AD-HOC ON-DEMAND DISTANCE VECTOR ROUTING PROTOCOL (AODV)

Ad-hoc On-Demand Distance Vector (AODV) is a routing protocol which is capable of both unicast and multicast routing. Being an on-demand algorithm, it generates routes among nodes only when source node desires and maintains them as long as they are required by source. It uses the concept of sequence numbers in order to ensure that the routes are fresh. It is self- starting and loop-free. Also, it can be used for large number of mobile nodes [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 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. Second, if it possesses a route to the destination. But in second case, the condition is that the corresponding sequence number of the node must be either greater than or equal to the sequence number contained in RREQ. In both cases, it unicasts RREP back to the source. If not, RREQ is rebroadcasted by it. Each node keeps track of source IP address and broadcast ID of RREQ. If a RREQ is received which is already processed by node, RREQ is discarded [7].

Nodes then set forward pointers to destination as the RREP propagate back to the source. When RREP is received by the source node, it begins forwarding data packets to the destination. Later, if the source receives RREP which contains greater sequence number or same sequence number with a smaller hop count; it updates its routing information for that destination and start using the better route. The routes are maintained as long as they are active, i.e. the data packets moving to the destination from the source along that same path periodically. When the sending of data packets stops, the links will time out and eventually deleted from the intermediate node routing tables. In case there is a link break during transmission, the node which is just before the node where link break occur generates a route error (RERR) message and sends it to source in order to inform it that the destination is now not reachable. On receiving RERR, if the source node still wants the route, it can reinitiate route discovery [7].

The generalized diagram for setting up the route is AODV is described by figure 1.

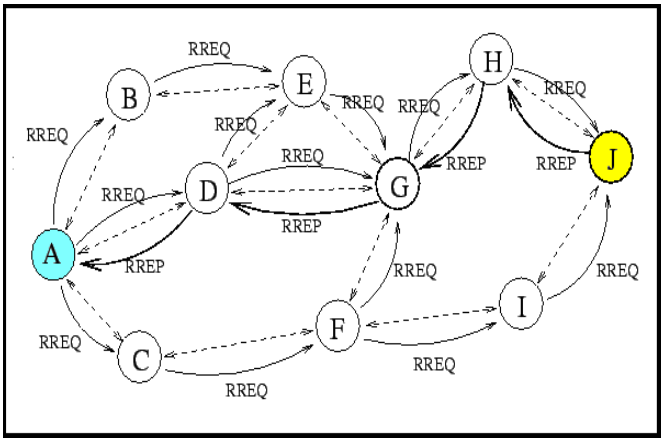

Fig. 1 Route Setup in AODV

IV. CONGESTION CONTROL PROTOCOLS

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 [8]. For this, 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. Here, 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 [9].

Various congestion control protocols have been designed in order to remove or lower the probability of the network being congested. In this paper, three such protocols are considered. These protocols based on AODV are explained below.

A. *Early Detection Congestion and Control Routing Protocol (EDAODV)* [9]

Early detection congestion and control routing protocol (EDAODV) is a unicast routing protocol for MANET proposed in [9]. In this protocol, alternate path if found bi-directionally by the predecessor and successor nodes on the primary path. On finding the alternate path, the previous node uses an alternate route and bypasses the congestion to the first non-congested node on the same primary route.
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 toward 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].

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.

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 from its primary path node of X regarding the destination D, 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.

B. *Improved Ad-hoc On-demand Distance Vector Routing Protocol (AODV-I)* [10]

AODV-I is the Improved Ad-Hoc On-demand Distance Vector Routing protocol based on congestion aware and route repair mechanism. AODV is widely deployed in Ad Hoc networks, but some deficiencies are there as it does not take into account congestion control. So, on deeply investigating AODV protocol, a new protocol was proposed in [10] known as AODV-I, in which congestion processing is added to the RREQ message which avoids selecting the busy nodes automatically during a new route establishment. The routing repair mechanism is also added to the RREQ message instead of initiating a new routing discovery whenever the route appears to be busy. In AODV, if source request node find a route whose destination sequence number is bigger or whose hop count is smaller, the new route replace the previous one absolutely, and the load of the previous will be transmit to the new. And if the new route is already busy, the traffic transmit from the previous node will make the new route more congested, which could increase the packet loss rate and data packet latency, then reduce the performance of the network. But AODV-I improves the traditional AODV by improving and repairing the route which is congested. This improvement reduces the packet loss rate, end-to-end latency and the utilization rate of the network resources.

C. *Congestion Adaptive Routing Protocol (CRP)* [1]

Congestion Adaptive Routing is a congestion adaptive unicast on-demand routing protocol for MANETs. It tries to prevent congestion from occurring in the first place. Here every node that appears on the route warns its previous node when likely to be congested. So, CRP uses the additional paths called as bypass for bypassing the congestion creating traffic to the first non-congested node appearing on primary route. It reduces packet delay. But, at the same time CRP tries to minimize bypass to reduce protocol overhead. Hence, the traffic is split over bypass and so it reacts adaptively to network congestion. Hence, power consumption is efficient, congestion is resolved beforehand and at the same time there is small packet loss rate.

V. RELATED WORK

M. Abolhasan *et. al.* [3] has discussed different routing protocols based on their proactive, reactive and hybrid nature. The performance comparison of all these routing protocols is also presented in this paper.

D. E. Perkins *et. al.* [17] have proposed an ad hoc on-demand distance vector routing protocol (AODV) for MANETs in which routes are maintained when required with no prior and periodic route advertisements. The overall bandwidth requirement of this protocol is less as compared to others because of its on-demand nature.

A. K. Gupta *et. al.* [18] shows the performance evaluation of three routing protocols, i.e., AODV, DSR and TORA with respect to two performance metrics, packet delivery ratio and end-to-end delay. The results show that AODV performs best while DSR is preferable for networks with moderate mobility rate and TORA is fit for operation in large mobile networks with dense population of nodes.

S. Yin *et. al.* [2] discussed multipath adaptive load balancing. Improper balancing of load over the network leads to congestion. So, the main goal explained in this paper deals with distributing traffic among multiple paths based on the measurement of path statistics for better utilization of the network resources.

D.A. Tran *et. al.* [11] proposed a new protocol named as Congestion–adaptive Routing Protocol (CRP). The author is of the view that congestion is the dominant cause for packet loss in MANETs. So, the proposed protocol prevents the congestion from occurring in the first place by using the bypass concept where a bypass is a sub-path connecting a node and the next non-congested node.

A. Hijazi *et. al.* [12] proposed a new protocol named as MACC-AODV (Mobile Agent based Congestion Control

AODV in which some mobile agents are added into the network. These mobile agents are responsible for carrying routing information and nodes congestion status.

M. M. P Shekhar *et. al.* [13] introduced a mobile agent aided congestion aware multipath routing protocol (MAMPR). Existing routing protocols proposed for MANETs uses shortest route as a metric to find routes. But MAMPR uses 'congestion' as a metric to find multipath routes based on quality of service. These agents move around the network, thereby, collecting and dispersing the network topology information based on the congestion status of the network.

L. Xia *et. al.* [10] proposed an improved AODV protocol known as AODV-I. In this protocol, congestion processing is added to the RREQ message which avoids selecting the busy nodes automatically during route establishment. If congestion is encountered during route establishment, the route repair mechanism is performed instead of initiating a new route discovery.

T.S. Kumaran *et. al.* [9] proposed another congestion control protocol for controlling congestion in AODV named as Early Detection Congestion and Control Routing in MANET (EDAODV) which detects congestion at the node. It calculates queue_status value and thus finds the status of the congestion. Further, the non-congested predecessor and successor nodes of a congested node are used by it for initiating route finding process bi-directionally in order to find alternate non-congested path between them for sending data. It finds many alternate paths and then chooses the best path for sending data.

L. Shrivastava *et. al.* [14] presented a survey of various congestion aware and congestion adaptive routing protocols. Some of such routing algorithms discussed are dynamic load-aware routing (DLAR), congestion aware distance vector (CADV), congestion aware routing protocol for mobile adhoc networks (CARM), hop-by-hop congestion ware routing protocol for heterogeneous mobile adhoc networks, congestion adaptive routing protocols (CRP), etc. The paper suggests that the problem of congestion is associated with the network and it has to be solved by having compromised solution rather than elimination.

H. Pingale *et. al.* [1] has described various congestion control protocols in his survey paper. One of the protocols described by him is Congestion Adaptive Routing Protocol (CRP). CRP is a congestion adaptive protocol which tries to prevent congestion to occur in the first place where every node on the route warns its previous node when it is prone to be congested. It makes the use of additional paths called bypass for passing the congested area to the first non congested node. It also describes various other protocols for controlling congestion. Amongst them, only CRP is based on AODV routing protocol. All others are based on proactive scheme.

G. Sharma *et. al.* [15] illustrated the concept of congestion control in adhoc networks by evaluating the effects of congestion in them. In this paper, three routing protocols AODV, AOMDV and DSR are analyzed on the basis of throughput and packet delivery ratio. A simple flow counting algorithm is demonstrated and implementation is done based on varying queue length and increasing the number of senders.

A.K. Mourya *et. al.* [16] have proposed a mobile agent based congestion control technique in which mobile agents can select the less loaded node whenever they travel through the network. They update routing table of the nodes according to their congestion status. On detecting congestion, the mobile agents move to adjacent nodes of that node which are not on path and move to destination. The mobile agents on reaching the destination calculate the data rate of their corresponding nodes and select the path that has highest data rate.

C. T. Cuong *et. al.* [19] proposed routing algorithm named as MAR-AODV (Mobile Agent- AODV) in which mobile agents are added to AODV for updating traffic density at each node, thereby improving the network performance. Mobile agents update traffic density at each node, thereby allowing selecting a route which is smallest and also congestion free.

H. Li *et. al.* [20] defines a mobile agent based congestion control AODV in which mobile agents are responsible for carrying routing information and congestion status of the node, thereby selecting less loaded neighbor node as the next hop and updating routing table accordingly.

M. Ali *et. al.* [21] introduced congestion adaptive multipath routing protocol. In this, whenever the existing path's average load increases beyond a set threshold and there is decrease in the bandwidth available and residual battery energy below a set threshold, the traffic is dispersed over fail-safe multiple routes in order to lower the congested link's traffic load.

VI. SIMULATION AND RESULTS

The simulation of AODV routing protocol is done based on two scenarios, varying number of nodes and varying size of data packets. Graphical results are presented below.

A. Scenario 1: Varying number of nodes

The scenario with varying number of nodes (10, 20, 30 and 40) in the area of 500*500 sq. m. is set based on AODV routing protocol and the values for the performance metrics, end-to-end delay, throughput, routing overhead and packet delivery ratio are obtained.

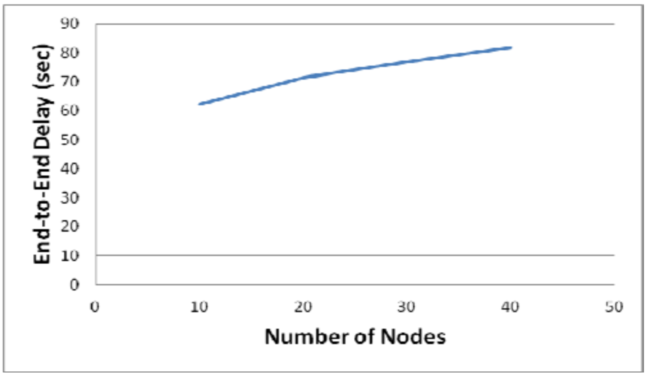

Fig. 2 Graph- End-to-End Delay v/s Number of Nodes

Figure 2 depicts that end-to-end delay increase with the increasing number of nodes.

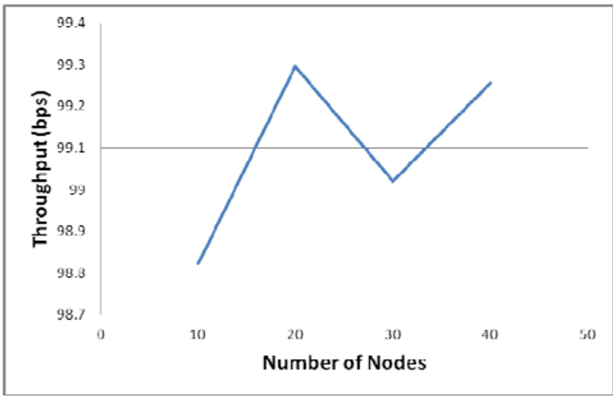

Fig. 3 Graph- Throughput v/s Number of Nodes

Figure 3 depicts that value of throughput shows fluctuating behaviour with respect to increasing number of nodes.

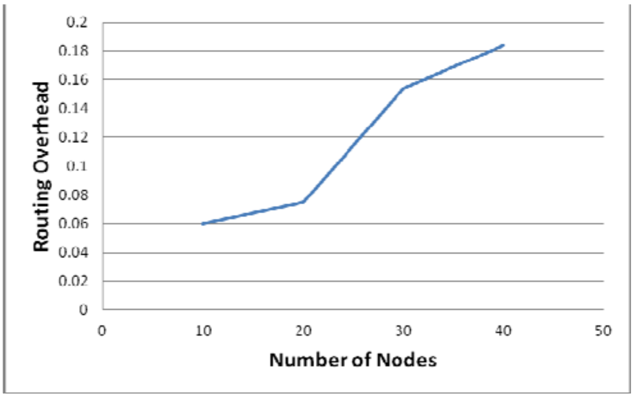

Fig. 4 Graph- Routing Overhead v/s Number of Nodes

Figure 4 depicts that as the number of nodes increase, the routing overhead over the network also increases.

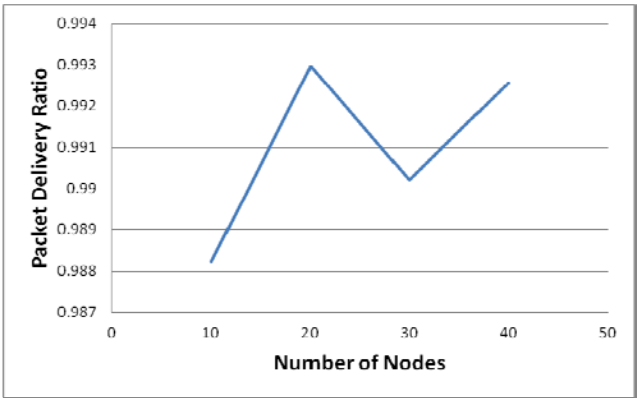

Fig. 5 Graph- Packet Delivery Ratio v/s Number of Nodes

Figure 5 indicates that PDR first increases, then decreases and then again increases as the number of nodes increase over the network area, i.e. it shows a fluctuating behaviour.

B. Scenario 2: Varying size of data packets

Another scenario of AODV with varying size of data packets is set. The values of above four performance metrics is calculated based on the data packet size (i.e. 512, 1024, 2048 and 4096) and the graphs are generated as illustrated below.

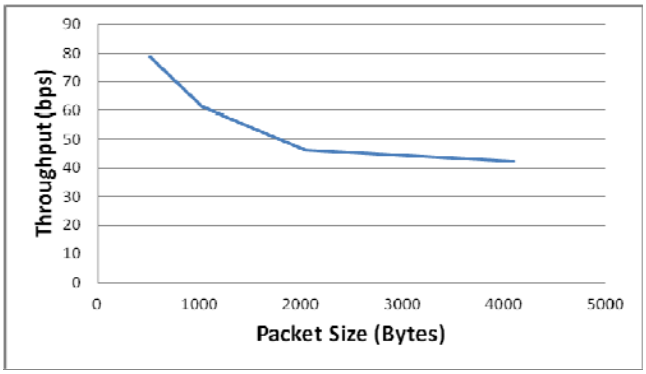

Fig. 6 Graph- Throughput v/s Packet Size

Figure 6 depicts a graph between throughput and size of data packets. The graph indicates that throughput decreases with the increase in the size of the data packets and hence the network performance decreases as well.

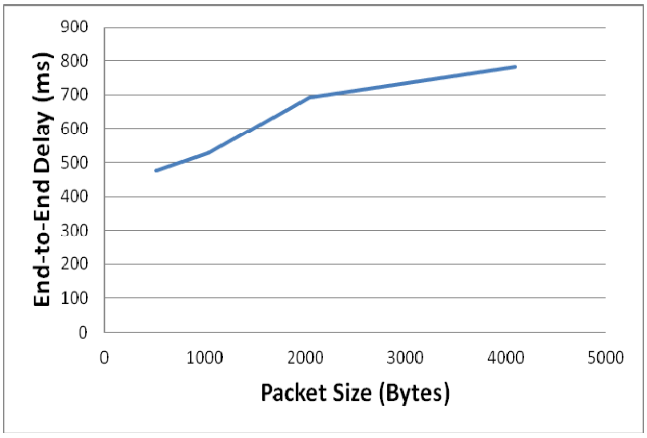

Fig. 7 Graph- End-to-End Delay v/s Packet Size

Figure 7 illustrates the graph between end-to-end delay and packet size. The graph shows an increase in the end-to-end delay with the increase in the size of data packets.

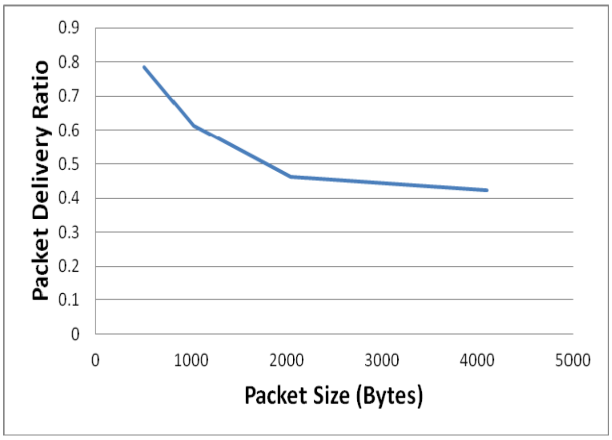

Fig. 8 Graph- Packet Delivery Ratio v/s Packet Size

Figure 8 depicts the graph of packet delivery ratio for varying size of data packets. The graph shows that PDR decreases with the increase in the size of data packets.

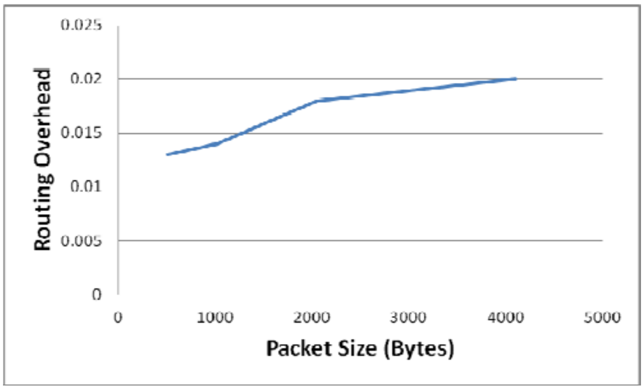

Fig. 9 Graph- Routing Overhead v/s Packet Size

Figure 9 shows the graph of routing overhead. It illustrates that as the packet size increases, the routing overhead over the network increases.

VII. CONCLUSION

Congestion is an important issue in mobile ad hoc networks leading to packet loss and degradation of the network. Since AODV has no congestion control mechanism, the congestion control protocols based on AODV, EDAODV, AODV-I and CRP are discussed. AODV routing protocol has been executed for varying number of nodes and size of data packets and the graphs depicts that the performance of the network degrades when number of nodes and the size of data packets increases based on the four considered parameters in case of AODV because of congestion.

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