QoS Analysis in Mobile Ad-Hoc Networks Using Bandwidth Utilization Technique

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***Abstract*—It is proposed to analyze the usefulness of Bandwidth Reservation Protocol (BRP) for mobile ad-hoc networks in improving the quality of service (QoS). There are two types of bandwidth reservation protocols namely, priority based and scheduling based. In this simulation the priority based bandwidth reservation protocols are used. These are Fair End-to-end Bandwidth Allocation (FEBA) and Priority based Bandwidth Reservation Protocol (PBRP) algorithms. PBRP protocol consists of two phases namely Bandwidth Request phase and Bandwidth Reply phase. In the former Phase, a Bandwidth Request (BREQ) message is forwarded from the node that requests the admission of a new traffic flow to its destination. In the later Phase, a Bandwidth Reply (BREP) message proceeds backwards, hop-by-hop, from the destination node to the node that originated the request along the path laid down by the corresponding BREQ message. The destination node precedes the reply according to the priority of traffic classes and reserves the bandwidth on the reply path. By simulation results, it is found that the use of these protocols achieve high bandwidth utilization and throughput with reduced delay. The simulation is done on mesh based On Demand Multicast Routing Protocol (ODMRP) by using QUALNET 5.0.**

***Index Terms*—mobile ad-hoc networks (MANETs), quality of services (QoS), bandwidth reservation protocol (BRP), bandwidth request (BREQ)**

I. Introduction

Mobile Ad-Hoc wireless network is a special case of wireless network devoid of predetermined backbone infrastructure. This feature of the wireless ad-hoc networks makes it flexible and quickly deployable. As the nodes correspond over wireless link, all the nodes must combat against the extremely erratic character of wireless channels and intrusion from the additional transmitting nodes. These factors make it a challenging problem to exploit on data throughput even if the user-required QoS in wireless ad-hoc networks is achieved

Wireless mesh networks (WMN's) contains several stationary wireless routers which are interlinked by the wireless links. Wireless routers acts as the access points (APs) for wireless mobile devices. Through the high speed wired links, some wireless routers act as a gateway for internet. Wireless mobile devices transfer data to the corresponding wireless router and further these data's are transferred in a multi-hop manner to the internet via intermediate wireless routers. The popularity of WMN's is due to their low cost and auto-organizing features [1].

In this paper the focus is on the problem of providing QoS support for real-time flows, while allocating bandwidth to elastic flows fairly. A protocol QUOTA (quality-of-service aware fair rate allocation) is proposed, a framework that combines QoS support and fair rate allocation. Their proposed framework QUOTA provides higher priority to real-time flows than elastic flows by reserving the necessary bandwidth for the former and fairly allocating the left-over bandwidth to the latter [2].

In this paper a Fair End-to-end Bandwidth Allocation (FEBA) algorithm is introduced. The FEBA algorithm is implemented at the Medium Access Control (MAC) layer of single-radio, multiple channels IEEE 802.16 mesh nodes, operated in a distributed coordinated scheduling mode. FEBA negotiates bandwidth among neighbors to assign a fair share proportional to a specified weight to each end-to-end traffic flow. Thus the traffic flows are served in a differentiated manner, with higher priority traffic flows being allocated more bandwidth on the average than the lower priority traffic flows [3].

A low-complexity intra-cluster resource allocation algorithm by considering the power allocation, sub-carrier allocation, and packet scheduling is proposed. The time complexity of their proposed scheme is on the order of $O(LMN)$, where L is the number of time slots in a frame, M is the number of active links, and N is the number of sub-carriers [4].

An efficient intra-cluster packet-level resource allocation approach is proposed. Their approach considers power allocation, sub-carrier allocation, packet scheduling, and QoS support. Their proposed approach combines the merits of a Karush-Kuhn-Tucker (KKT)-driven approach and a genetic algorithm (GA)-based approach. Their proposed approach achieves a desired balance between time complexity and system performance [5].

The problems of the reservation on a single hop are discussed. The reason for the inconsistencies in the existing approaches which lead to admission failures and present a protocol for preventing them is analyzed. This allows for increasing the reliability of established communication links in WMNs. They have focused only on the local admission control and not the various searching strategies for finding a suitable path [6].

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In this paper authors propose a new multicast protocol for Mobile Ad Hoc networks, called the Multicast routing protocol based on Zone Routing (MZR). MZR is a source-initiated on demand protocol, in which a multicast delivery tree is created using a concept called the zone routing mechanism [7].

In this paper, authors present a performance study of three multicast protocols: ODMRP, ADMR, and SRMP. Multicast Routing in Mobile Ad hoc NETworks (MANETs) is a recent research topic. Source Routing-based Multicast Protocol, (SRMP) is a new on-demand multicast routing protocol that applies a source routing mechanism and constructs a mesh to connect group members [8].

In this paper, authors focus on one critical issue in Mobile Ad hoc Networks (MANETs) that is multicast routing. In fact, optimal routes, stable links, power conservation, loop freedom, and reduced channel overhead are the main features to be addressed in a more efficient multicast mechanism [9].

In this paper, the authors describe the reliability of the On-Demand Multicast Routing Protocol (ODMRP) in terms of the delivery of data packets in response to the important role that multicasting plays in wireless mobile multi hop ad hoc networks. Using GloMoSim 2.0, the simulation results have shown that using ODMRP, the average miss ratio does not always increase with increasing the speeds of mobility of the mobile hosts in the ad hoc network. Instead, there is a "sweet spot" of values of the mobility speeds of the mobile hosts. In addition, the averages miss ratio decreases with increasing the number of multicast group members, which indicates that ODMRP has more packet delivery capabilities for denser multicast groups [10].

In this paper, authors present a comparative performance evaluation of three general-purpose on demand multicast protocols, namely ADMR, MAODV, and ODMRP, focusing on the effects of changes such as increasing number of multicast receivers or sources, application sending pattern, and increasing number of nodes in the network [11].

In this paper, authors analyze the performance of multicast routing protocol PIM-SM to provide suggestions of improving this protocol. PIM-SM is preferred among the current intra domain multicast routing protocols. But it is not widely deployed in Internet till now [12].

II. Bandwidth Reservation Protocol

A. Priority Based Bandwidth Reservation Protocol

Basically, the proposed protocol consists of two phases namely Bandwidth Request phase and Bandwidth Reply phase. In the Bandwidth Request Phase, a Bandwidth Request (BREQ) message is forwarded from the node that requests the admission of a new traffic flow to its destination. During this phase bandwidths are not reserved. The BREQ message consists of traffic flow specifications and the requested bandwidth [13].

Next in the Bandwidth Reply Phase, a Bandwidth Reply (BREP) message proceeds backwards, hop-by-hop, from the destination node to the node that originated the request along the path laid down by the corresponding (BREQ) message. The destination node precedes the reply according to the priority of traffic classes and reserves the bandwidth on the reply path.

In the Bandwidth Request Phase the bandwidths are not reserved and only the necessary messages are transmitted to the destination. The source is required to select the Traffic flow Identification (TFID) of any new flow in such a way that the source, destination, TFID uniquely identifies the traffic flow in the network.

In this phase, the destination sends back to the source a BREP message and it is routed through the same path that has been enclosed by the BREQ message. This is obtained by using the list of intermediate node IDs included in the BREQ message. On receiving the BREP message, each node reserves the bandwidths according to the priority of the traffic.

If the nodes do not receive packets until the traffic flow is dropped for a particular amount of time TS, then the bandwidth remains allocated. The source generates probe packets to guarantee an established traffic flow state on each node in the path to prevent premature termination of the traffic flow. Probe packets are the messages which include the information about their traffic and these packets are discarded by the receivers in the MAC layer. The generation interval of the probe packets must be smaller than the TS. Generally, by transmitting the probe packets it consumes the bandwidth which is already reserved for the traffic flow in the data sub-frame.

B. Fair End-to-End Bandwidth Allocation Algorithm

This algorithm is implemented at the medium access control layer of single-radio, multiple channel IEEE 802.16 mesh nodes, operated in a distributed coordinated scheduling mode. FEBA negotiates bandwidth among neighbors to assign a fair share proportional to a specified weight to each end-to-end traffic flow. Thus the traffic flows are served in a differential manner, with higher priority traffic flows being allocated more bandwidth on the average than the lower priority traffic flows.

III. Propagation Models

There is greater interest in characterizing the radio communication channel inside a building. The indoor propagation model differs from the outdoor propagation because of variation in fading rate and type of interference. For example floor attenuation factor and penetration attenuation factor are two main parameters of indoor propagation models. The ITU Model is applicable for frequency range 900 MHz to 5.2GHz. The ITU indoor path loss model is formally expressed as

$$L = 20 \log f + N \log d + P_f(n) - 28$$

where, N is distance power loss coefficient, $P_f(n)$ is the floor loss penetration factor. Propagation loss prediction model plays an important role in design of cellular mobile radio communication system. Propagation models are used extensively in network planning, particularly for conducting feasibility studies and during initial deployment. These are also very important for performing interference studies as the deployment proceeds. Propagation loss modeling of cellular mobile system is important for site planning; the transmission loss and signal coverage can be predicted by set of propagation loss modeling equations [14].

Propagation models in wireless communication have traditionally focused on predicting the average received signal strength at a given distance from the transmitter, as well as the variability of the signal strength in close proximity to a particular location. Propagation models that predict the mean signal strength for an arbitrary transmitter – receiver separation distance are useful in estimating the radio coverage area of transmitter and are called large scale propagation models, since they characterize signal strength over large T-R separation distance. On the other hand, propagation model that characterize the rapid fluctuation of the received signal strength over very short travel distances or short time duration are called small scale or fading models. As mobile moves over very small distances, the instantaneous received signal strength may fluctuate rapidly giving rise to small scale fading. The reason for this is that received signal is sum of many contributions coming from different directions [15].

The propagation models are generally used to characterize the quality of mobile communication. It can be used as prediction tool for those telecommunication engineers who deal with the site planning for base station.

IV. Network Topologies

Topology refers to the configuration of the hardware components and how the data is transmitted through that configuration. They describe the physical and logical arrangement of the network nodes. There are three network topologies.

A. Star Topology

The star topology consists of a coordinator and several end devices. In this topology, the end device communicates only with the coordinator. Any packet exchange between ends devices go through coordinator. The main advantages of star topology are its simplicity and predictable and energy efficient behavior. The limitations and drawbacks are scalability and coordinator as a single point of failure.

B. Mesh Topology

A mesh topology offers multiple paths for messages within the network. This lends itself to greater flexibility than other topologies. If a particular router fails, then the self healing mechanism allows the network to search for an alternate path for messages to be passed. Mesh topology is highly reliable and robust. The advantages being that if any individual router becomes inaccessible, then alternate routes can be rediscovered and used. The drawback of this topology has higher communications overheads than the star topology, which can result in increased latency and lower end-to-end performance.

C. Tree Topology

A tree topology consists of a coordinator, to which other nodes are connected as follows:

1. The coordinator is linked to a set of routers and ends devices- its children.
2. A router may then be linked to more routers and end devices-its children. This can continue to a number of levels.

For every child router connected, additional child routers can also be connected, creating different levels of nodes. In order the messages to be passed to other nodes in the same network, the source node must pass the messages to its parent, which is the node higher-up by one level of the source, and the messages is continually relayed higher-up in the tree until it is passed back down to the destination node. Because the number of potential paths a message can take is only one, a router therefore can be used in place of an end device in a Tree network, but the message relay functionality of the router will not be used- only its applications will be relevant

D. QoS Routing

If only two hosts are involved in ad-hoc network, no real routing decision is necessary. In many adhoc networks two hosts that want to communicate may not be within wireless transmission range of each other, but could communicate if other hosts between them are willing to forward packets for them. Routing problem in real adhoc network may be more complicated due to non uniform propagation characteristics of wireless transmission and due to possibility that any of the host may move at any time.

QoS routing protocols search for routes with sufficient resources for QoS requirements. QoS routing protocols should work with resource management to meet QoS requirements such as delay bounds, bandwidth demand. QoS routing is difficult in MANETs due to following reasons:

a) Overhead of QoS routing is too high for bandwidth limited MANETs because mobile host should have mechanism to store and update link state information.
b) Due to dynamic nature of MANET, maintaining link state information is difficult.

V. Results and Discussion

The QUALNET-5.0 simulator has been used for proposed protocol. It has the facility to include multiple channels and radios. It supports different types of topologies such as chain, ring, multi ring, grid, binary tree, star, hexagon, mesh and triangular. The supported traffic types are CBR and MCBR. In this simulation, 50 mobile nodes are arranged in a topology of size 1500 meter x 1500 meter region. All nodes have the same transmission range of 250 meters. In our simulation, the speed is set as 5m/s.

Performance matrices used:

Control packet load: the average number of control packet transmission by node in the network. Control packets include any of QUERY, REPLY, PASSREQ, CONFIRM, HELLOW and ACK packets.

Packet delivery ratio: the ratio of data packet sent by all the sources that is received by a receiver.

Data packet overhead: the number of data transmissions performed by the protocols per successfully delivered data packet.

Control packet overhead: the number of controlled transmissions performed by the protocols per successfully delivered data packet.

Total packet overhead: the total control and data overheads per successfully delivered data packet. This matrix represents the multicast routing efficiency.

End-to-End Delay: It is the average time it takes a data packet to reach the destination. This metric is calculated by subtracting time at which first packet was transmitted by source from time at which first data packet arrived to destination. This includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC, propagation and transfer times. This metric is significant in understanding the delay introduced by path discovery.

Throughput: It is the average rate of successful message delivery over a communication channel. It is defined as the amount of data successfully delivered from the source to the destination in a given period of time. It is the amount of data per time unit that is delivered from one node to another via a communication link. The throughput is measured in bits per second (bit/s or bps).

Bandwidth utilization: It is the ratio of bandwidth received into total available bandwidth for a traffic flow.

Routing overhead: This metric describes how many routing packets for route discovery and route maintenance need to be sent so as to propagate the data packets.

Media access delay: The time a node takes to access media for starting the packet transmission is called as media access delay. The delay is recorded for each packet when it is sent to the physical layer for the first time.

Path optimality: This metric can be defined as the difference between the path actually taken and the best possible path for a packet to reach its destination.

Here, we have considered end-to-end delay, throughput and bandwidth utilization as the performance metrics and no. of nodes and data flow rates as the variables.

The simulation environment for the proposed work consists of four models:

a) Network model
b) Channel model-fading channels.
c) Mobility model-random, grid and uniform.
d) Traffic model-CBR and MCBR.

Experimental Set-up: Table I shows the different parameters used in simulation on Qualnet-5.0.

TABLE I. PARAMETERS USED IN QUALNET SIMULATION TOOL

Area	2250000 m^2
Transmission range	500 m
Number of nodes	200
Physical / Mac layer	IEEE 802.11 at 2 Mbps
Mobility model	Random waypoint model with no pause time
Maximum mobility speed	1-20 m/s
Simulation duration	500 s
Pause time	0
Packet size	512 bytes
Traffic type	CBR (Constant Bit Rates)
Number of packets	5/second
Number of multicast sources	1,2,5,10,15 nodes
Number of multicast receivers	10,20,30,40,50 nodes
No. of simulations	20

A. *Effect of Varying No. of Nodes*

In the first experiment, the no. of nodes is varied as 10, 20, 30, 40 and 50 and the above metrics are examined.

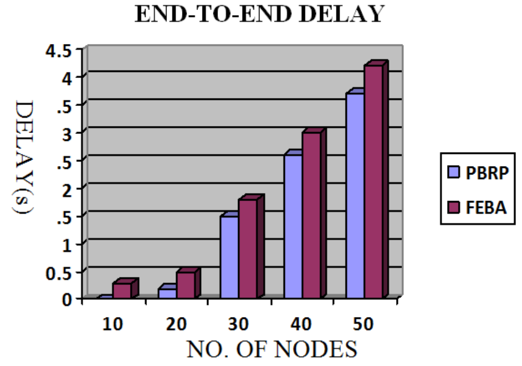

Figure 5.1. Nodes vs delay

It is evident from Fig. 5.1 that the end-to-end delay increases as the number of nodes is increased. It is clear that PBRP has less delay when compared to FEBA algorithm. The priority based protocol is more effective for wireless mobile ad-hoc network in mesh configuration.

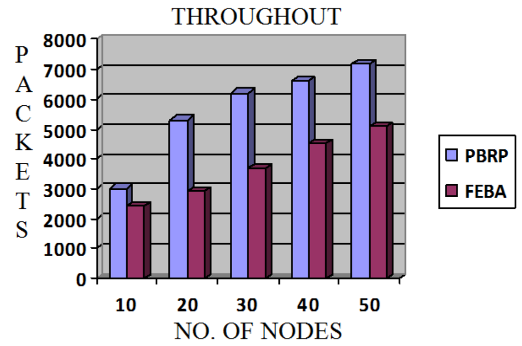

Figure 5.2. No. of nodes vs throughput

Fig. 5.2 shows the throughput values when the number of nodes is increased. From the figures, it can be seen that the throughput is more in the case of PBRP and outperforms the FEBA algorithm in mesh configuration of wireless mobile ad-hoc networks. Since the connection in wireless mobile ad-hoc network is unpredictable, the bandwidth utilization protocols save the bandwidth and reduce the delay in packet delivery.

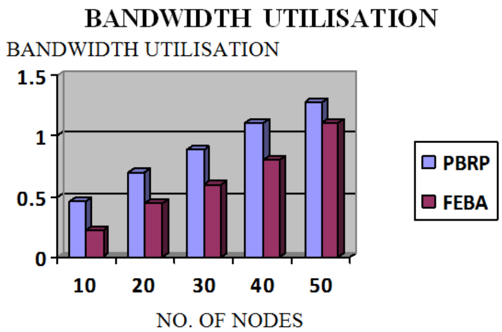

Figure 5.3. No. of nodes vs bandwidth utilization

Fig. 5.3 shows the bandwidth utilization obtained, when the number of nodes is increased. It shows that PBRP utilizes more bandwidth than the FEBA algorithm. As far as the bandwidth utilization is concerned, the FEBA protocol is less effective in comparison to PBRP.

B. Effect of Varying Data Flows

In the second experiment, we vary the number of data flows as 2, 4, 6, 8 and10 MBPS.

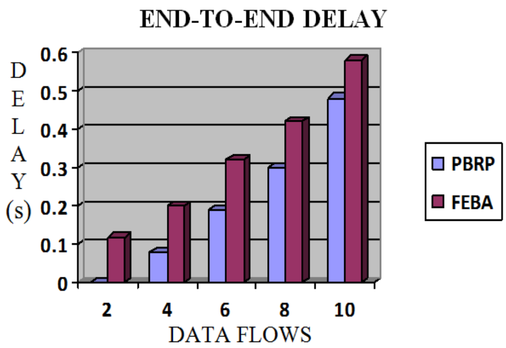

Figure 5.4. Flow vs delay

Fig. 5.4 shows the end-to-end delay values when the number of flow is increased. It is clear that PBRP has less delay when compared to FEBA algorithm. Here the delay is taken in second and data flow rate in MBPS.

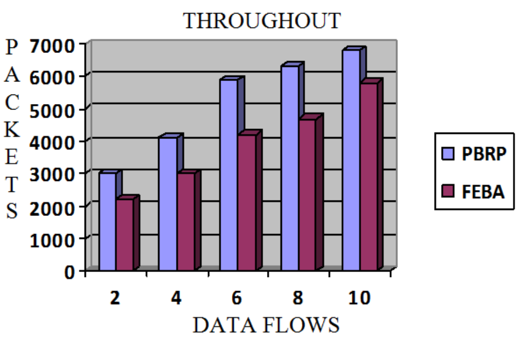

Figure 5.5. Flow vs throughput

Fig. 5.5 shows the throughput values when the number of data flow rates are increased. From the figures, it can be seen that the throughput is more in the case of PBRP and outperforms the FEBA algorithm. Overall, the use of bandwidth utilization protocol improves the quality of service parameters

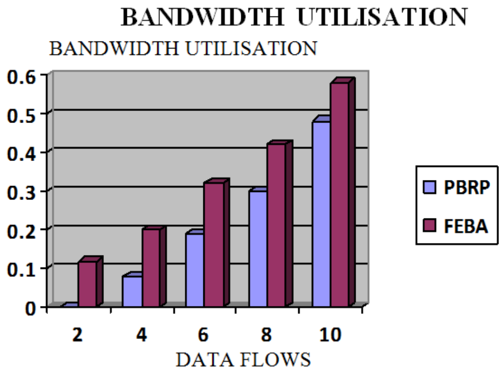

Figure 5.6. Flow vs bandwidth utilization

Fig. 5.6 shows the bandwidth utilization obtained, when the number of flows are increased. It shows that PBRP utilizes more bandwidth than the FEBA algorithm.

As the analysis shows that the PBRP algorithm outperforms the FEBA algorithm, hence all the following has been done by using FBRP algorithm.

The performance of ODMRP is investigated and analyzed based on the results obtained from the simulation. A number of experiments are performed to explore the performance of these protocol with respect to a number of parameters such as traffic load, mobility speed and node placement. Taking CBR as traffic model and uniform placement model the values of Throughput, Packet delivery ratio, End to End delay with respect to No of nodes and Mobility of nodes have been observed.

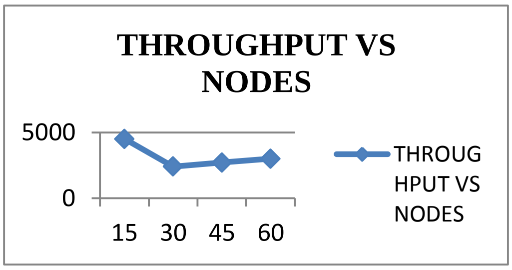

Figure 5.7. Throughput (bits/s) vs nodes values

It is observed from Fig. 5.7 that on increasing the nodes from 15 to 30 throuput slides down but after that when nodes are increased in numbers throughput also increases.

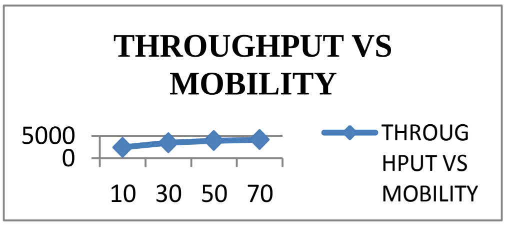

Figure 5.8. Throughput vs mobility values

Seeing above Fig. 5.8, it is observed that mobility of nodes is directly proportional to throughput, as here the value of throughput goes on increasing when mobility (m/s) increased from 10 to 70.

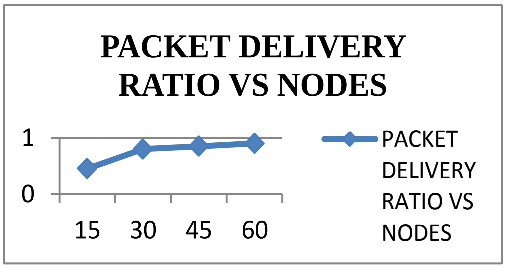

Figure 5.9. Packet delivery ratio vs no. of nodes

As Shown in Fig. 5.9, PDR value increases at very fast rate as the no of nodes changes from 15 to 30, after that the value of PDR increases at constant rate. Analysis is done when nodes vary from 15, 30, 45, 60.

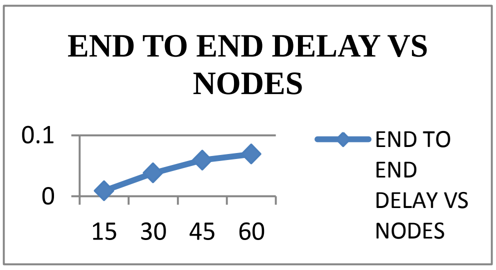

Figure 5.10. End to end delay vs no. of nodes

As Shown in Fig. 5.10, end to end delay in uniform model increases with the no. of nodes. It is observed that the variation of end to end delay with the nodes variation is very large.

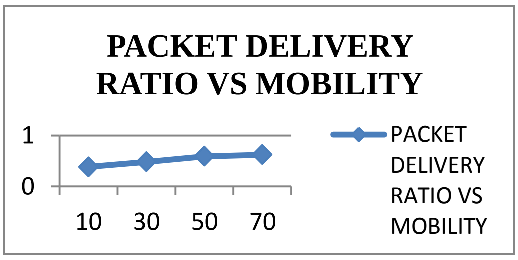

Figure 5.11. Packet delivery ratio vs mobility

It shows from Fig. 5.11 that the packet delivery ratio value is improved as the mobility of the node is increased. This factor is benificial for any Adhoc network.

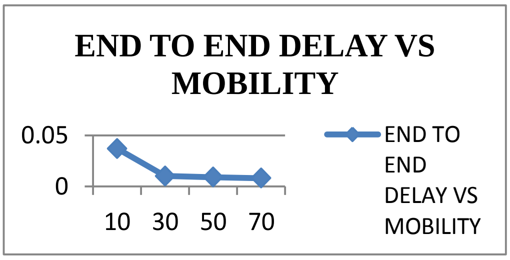

Figure 5.12. End to end delay vs mobility (m/s)

As Shown in Fig. 5.12, this factor also shows benificiary to any Adhoc network as the mobility is varied from 10 to 30. The end to end delay value slumps abruptly but decreases furthur at constant rate.

VI. Conclusion

By simulation results, it is shown that the proposed method achieves high bandwidth utilization and throughput with reduced delay, when compared with existing technique. Our results states that on increasing the no of nodes in the network leads to congestion which further degrades the performance of the ad hoc network. For better performance a trade off is made between different parameters.

To this end, we conducted extensive simulations employing a wide range of mobility models and traffic load conditions. We also compared the performance of this protocol with different node placement strategies and node speed variations. Topology, number of network nodes and node mobility are important parameters that can significantly affect the performance of the protocols being evaluated. Simulation results showed that more data packets were delivered to destinations, less control packets were produced in low mobility, control packets were utilized more efficiently in high mobility, and end-to-end delay was shorter. The ODMRP was scalable, robust to host mobility, and efficient in channel access. Simulation results show that ODMRP is effective and efficient in dynamic environments and scales well to a large number of multicast members.

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