International Journal of Current Engineering and Technology
ISSN 2277 - 4106

Available at http://inpressco.com/category/ijcet

Research Article

Performance Comparison of Mesh based and Tree based Multicast Routing Protocols in MANETs

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Accepted 5 Jan. 2013, Available online 1March 2013, **Vol.3, No.1 (March 2013)**

Abstract

Multicast routing is a key technology for modern communication networks. It sends a single copy of a message from a source to multiple receivers over a communication link that is shared by the paths to the receivers. This is especially appropriate in wireless environments where bandwidth is scarce and many users are sharing the same wireless channels. In particular, for WMNs, multicast can represent a huge enhancement of the network capacity by taking advantage of links which can be shared by multiple users to receive the same data, which is transmitted only once. To support multicasting, several multicast routing protocols are designed for Internet and Ad hoc networks. This paper presents the simulation and analysis of the performance of existing Mesh based and Tree based multicast routing protocols over WMNs. Three prominent multicast routing protocols are selected for performance comparison; they are On Demand Multicast Routing Protocol (ODMRP), Distance Vector Multicast Routing Protocol (DVMRP) and Protocol Independent Multicast –Dense mode (PIM-DM). Among Therefore, the performance comparison of existing multicast routing protocols over wireless mesh networks is essential in order to analyze their behavior and effectiveness. Qualnet 5.0.2.Our aim is to investigate the relative strength and weaknesses of each protocol.

Keywords: *DVMRP, ODMRP &PIM-DM ,Computer Network, Routing Protocols, Path loss Models.*

1. Introduction

An ad-hoc mobile network is a collection of mobile nodes that are dynamically and randomly located in such a manner that the interconnections between nodes are capable of changing on a continual basis. In order to facilitate communication within the network, a routing protocol is used to discover routes between nodes. The primary goal of such an ad-hoc network routing protocol is correct and efficient route establishment between a pair of nodes so that messages may be delivered in a timely manner. In this paper, authors describe PIM (Protocol Independent Multicast) capable of supporting sparse mode (SM) and dense mode (DM) operations. In sparse mode, PIM can use shared trees (RPT) or shortest path trees (SPT) to deliver data packets. The availability of these various modes opens questions regarding when each should be used, and the consequences of switching among them dynamically. This paper reports on two specific issues: 1) the overhead tradeoffs between dense mode operations and sparse mode operations. 2) the behaviors of PIM when receivers transitioning from RPT to SPT. Their results illustrate the cross-over point of sparse mode and dense mode overheads, which gives a hint for selecting protocol modes according to the group density metric.(Liming Wei et al, 1995)

In this paper, authors have developed a multicast routing architecture that efficiently establishes distribution trees across wide area internets, where many groups will be sparsely represented. Efficiency is measured in terms of the router state, control message processing, and data packet processing, required across the entire network in order to deliver data packets to the members of the group. The robustness, flexibility, and scaling properties of this architecture make it well-suited to large heterogeneous internetworks. (Stephen Deering et al, 1996)

In this paper, authors describe that a number of different routing protocols proposed for use in multi-hop wireless ad hoc networks are based in whole or in part on what can be described as on-demand behavior. By on demand behavior, they mean approaches based only on reaction to the offered traffic being handled by the routing protocol. In this paper, they analyze the use of on-demand behavior in such protocols, focusing on its effect on the routing protocol's forwarding latency, overhead cost, and route caching correctness, drawing examples from detailed simulation of the dynamic source routing (DSR) protocol. (K. Paul et.al, 1999)

In this paper the authors have proposed and evaluated the on-demand multicasting routing mechanism for ad hoc wireless network. This mechanism is a generalization of their previously proposed stability-based unicast routing scheme that relies on determining link stability and path

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stability in order to find out a stable route from a source to a destination. The proposed multicast routing mechanism depends only on local state information (at source) for constructing a multicast tree. (David A. Maltz et.al, 1999)

In this paper, authors investigate the performance of multicast routing protocols in wireless mobile ad hoc networks. An ad hoc network is composed of mobile nodes without the presence of a wired support infrastructure. In this environment, routing/multicasting protocols are faced with the challenge of producing multihop routes under host mobility and bandwidth constraints. In this study, they simulate a set of representative wireless ad hoc multicast protocols and evaluate them in various network scenarios. (Sung-Ju Lee et.al , 2000)

In this paper, authors describe that Multicasting is the ability of a communication network to accept a single message from an application and to deliver copies of the message to multiple recipients at different locations. Recently, there has been an explosion of research literature on multicast communication. This work presents a tutorial-cum-survey of the various multicast routing protocols for packet switched wide area networks. They examine various protocols that arc employed on the Internet, namely, Internet Group Management Protocol (IGMP), Distance-Vector Multicast Routing Protocol(DVMRP), Multicast Extensions for OSPF (MOSPF), Core-Based Tree (CBT), Protocol-independent Multicast (PIM), and Border Gateway Multicast Protocol (BGMP).(Laxman H. Sahasrabuddhe et.al , 2000)

In this paper, authors describe an important issue in reliable multicasting in ad hoc networks that is busty packet loss that arises .when a link breaks due to node mobility. In On Demand Multicast Routing Protocol (ODMRP), the source periodically initiates a mechanism for multicast tree creation, through Join Queries. The scheme has been simulated on Global Mobile Simulator (GloMoSim), and has shown to be effective in removing the busty data losses due to link failures. (A Ganguli et.al, 2000)

In this paper authors presents,On-Demand Multicast Routing Protocol for mobile ad hoc networks. ODMRP is a mesh-based, rather than conventional tree based, multicast scheme and uses a forwarding group concept [only a subset of nodes forwards the multicast packets via scoped flooding). It applies on-demand procedures to dynamically build routes and maintain multicast group membership. They also describe their implementation of the protocol in a real laptop test bed. They have studied the performance of ODMRP and DVMRP in a real ad hoc network test bed with four network hosts. From their experiments, they discovered that DVMRP suffered from high channel overhead due to control message loss in the wireless channel. Their study showed that ODMRP is more suitable in a multi hop ad hoc wireless environment than DVMRP. (Sang Ho Bae et.al , 2000)

In this paper authors describe an Ad hoc wireless networks are self-organizing, dynamic topology networks formed by a collection of mobile nodes through radio links. Minimal configuration, absence of infrastructure, and quick deployment, make them convenient for emergency situations other than military applications. In this paper, they have proposed an efficient multicast routing protocol for Ad hoc wireless networks.The major advantage of this protocol is its increased scalability. This can be mainly attributed to the reduced control overhead. They implemented DCMP using GlomoSim and the simulation results show that there is a 30% reduction in control overhead, while the multicast efficiency is increased by 10-15%, at the cost of a small (2%) reduction in packet delivery ratio for light network loads. They have also found that the packet delivery ratio is improved at high load.(Subir Kumar Das et.al, 2002)

In this paper authors propose a novel location management scheme tailored for multicasting in Mobile Ad-hoc Networks (MANETs). They furthermore propose AMDLM, location-based multicast algorithm relying on the location management service. Such an approach avoids fragile data structures such as trees or DAGs to manage multicast groups, without reverting to more reliable, yet overhead-prone mesh-based algorithms. AMDLM additionally enables us to derive analytical bounds due to its location-based nature. (Yoav Sasson et.al , 2003)

In this paper authors have presented that a new MAC protocol called RMAC that supports reliable multicast for wireless ad hoc networks. By utilizing the busy tone mechanism to realize multicast reliability, RMAC has the following three novelties: (1) it uses a variable-length control frame to stipulate an order for the receivers to respond, such that the problem of feedback collision is solved; (2) it extends the traditional usage of busy tone for preventing data frame collisions into the multicast scenario; and (3) it introduces a new usage of busy tone for acknowledging data frames. In addition, they also generalize RMAC into a comprehensive MAC protocol that provides both reliable and unreliable services for all the three modes of communications: unicast, multicast, and broadcast. Their evaluation shows that RMAC achieves high reliability with very limited overhead. (Weisheng Si et.al, 2004)

In this paper, authors describe the problem of controlling data overhead of mesh-based multicast ad hoc routing protocols by adaptively adding redundancy to the minimal data overhead multicast mesh as required by the network conditions. They show that the computation of the minimal data overhead multicast mesh is NP-complete, and they propose a heuristic approximation algorithm inspired on epidemic algorithms. In addition, we propose a mobility-aware an adaptive mesh construction algorithm based on a probabilistic path selection being able to adapt the reliability of the multicast mesh to the mobility of the network. Their simulation results show that the proposed approach, when implemented into ODMRP, is able to offer similar performance results and a lower average latency while reducing data overhead between 25 to 50% compared to the ODMRP. (Pedro M. Ruiz et.al, 2004)

In this paper the authors have presented 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, use of sending pattern, and increasing number of nodes in the network. They use mobile networks composed of 100 or 200 nodes, with both a single active multicast group and multiple active multicast groups in the network, in a wide range of multicast scenarios. Although some simulation results for these protocols have been published before, the three protocols have not been compared, and prior studies have paying attention on smaller networks by means of a small set of simulation scenarios, many with only a single active multicast group. They focus here on the effects of the protocol's relative degree of on-demand behavior and their performance in different multicast scenarios. (Jorjeta G. Jetcheva et.al ,2004)

In this paper, authors present a performance analysis of topological multicast routing algorithms on mobile wireless ad-hoc networks. Flooding and On-Demand Multicast Routing Protocol (ODMRP) are assumed and compared with Topological Multicast Routing Protocol (ToMuRo) over a pedestrian scenario. The scenario evaluated considers one multicast transmitter and one, two, and three multicast receivers below a range of mobility and transmission ranges. The behavior of 250 nodes is evaluated in terms of End to End Delay (EED), jitter, packet delivery ratio, and overhead. This paper has offered ToMuRo, a topological multicast routing protocol. The results of this paper show that the ToMuRo algorithm performs better than the ODMRP algorithm in terms of jitter and packet delivery ratio. The performance of ToMuRo, when compared with ODMRP, improves as node speed and the number of receivers increases.
(R. A. Santos et.al, 2007)

In this paper, authors present the performance of multicast protocols in mobile ad hoc networks using network simulator NS-2. A mobile ad hoc network is a network comprised of self- configuring mobile nodes lacking any fixed infrastructure. In such an environment, the multicast protocols face the challenge of producing multi hop routes from source to multiple destinations under node mobility and bandwidth restrains. In recent years, a number of new multicast protocols have been planned for ad hoc networks. A systematic performance evaluation of some well-renown multicast protocols like MAODV and ODMRP is done by performing assured simulations under NS-2. Multicasting of data packets in wireless ad hoc networks is demanded increasingly and several different multicast protocols are proposed recently. This paper shows how to perform simulations of some of the multicast protocols in wireless ad hoc networks like MAODV and ODMRP. The methods and commands that can be used to simulate these on-demand multicast protocols are studied and analyzed because of its different nature from those used for unicast protocols like AODV.(Jaspreet Kaur et.al,2007)

In this paper, authors present a performance analysis of topological and geographical multicast routing algorithms for mobile wireless ad hoc networks. Flooding and On-Demand Multicast Routing Protocol (ODMRP) are simulated and compared with two novels protocols planned: Topological Multicast Routing Protocol (ToMuRo) and Geographical Multicast Routing Protocol (GeMuRo) in pedestrian scenarios and vehicular scenarios. The scenarios evaluated consider one multicast transmitter and one, two, and three multicast receivers below different mobility and transmission coverage range. The behavior of 250 nodes is evaluated in terms of End to End Delay (EED), Jitter and packet delivery ratio and overhead. Results explain that ToMuRo is proper fit for pedestrian scenarios due to its tree-based architecture and GeMuRo is proper for vehicular scenarios because it is based on a mesh topology. Significantly, simulation results of the pedestrian scenario show that the ToMuRo algorithm performs better than the ODMRP algorithm in terms of jitter and packet delivery ratio. However, Flooding shows significantly better performance in term of jitter and packet delivery ratio. Results show that Flooding might provide a viable option for vehicular ad-hoc networks with high mobility and density. (Raúl Aquino Santos et.al , 2007)

In this paper, authors investigate about the issues of QoS multicast routing in wireless ad hoc networks. Due to limited bandwidth of a wireless node, a QoS multicast call could often be blocked if there does not be a single multicast tree that has the requested bandwidth, even though there is enough bandwidth in the system to hold the call. In this paper, they propose a new multicast routing scheme by using multiple paths or multiple trees to meet the bandwidth requirement of a call. Three multicast routing strategies are studied, SPT (shortest path tree) based multiple-paths (SPTM), and least cost tree based multiple-paths (LCTM) and multiple least cost trees (MLCT). The final routing tree(s) can meet the user's QoS requirements such that the delay from the source to any destination node shall not go beyond the required bound and the aggregate bandwidth of the paths or trees shall meet the bandwidth requirement of the call. The simulation results show that the new scheme improves the call success ratio and makes a improved use of network resources. Simulation results have demonstrated the effectiveness of their method in reducing the network blockings.(Huayi Wu et.al, 2007)

In this paper authors have presented that the multicasting is effective when its group members are sparse and the speed is low. They propose an ant agent based adaptive, multicast protocol that exploits group members 'desire to simplify multicast routing and invoke broadcast operations in appropriate localized regimes. By reducing the number of group members that take part in the construction of the multicast structure and by allowing robustness to mobility by executing broadcasts in densely clustered local regions, the proposed protocol achieves packet delivery statistics that are corresponding to that with a pure multicast protocol but with importantly lower overheads. By their simulation results, they show that their proposed protocol achieves increased Packet Delivery Fraction (PDF) with reduced overhead and routing load. (A. Sabari et.al, 2008)

In this paper authors proposed the Multicasting has been extensively studied for mobile ad hoc networks (MANETs) because it is fundamental to many ad hoc network applications requiring close collaboration of multiple nodes in a grouping. A general imminent is to construct an overlay structure such as multicast tree or mesh and to deliver a multicast packet to multiple receivers over the overlay structure. However, it either finds a lot of overhead (multicast mesh) or performs poorly in terms of delivery ratio (multicast tree). This paper proposes an adaptive multicast scheme, called tree-based mesh with k-hop redundant paths (TBM k), which constructs a multicast tree and adds some additional links/nodes to the multicast structure as demanded to support redundancy. It is planned to make a provident tradeoff between the overhead and the delivery efficiency by adaptively ascertaining the path redundancy reckoning on network traffic and mobility. In other words, when the network is Lacking stability with high traffic and high mobility, a large k is preferred to allow more rich delivery of multicast packets. On the other hand, when the network traffic and the mobility are low, a small k is chosen to abridge the overhead. It is observed via simulation that TBM k mends the packet delivery ratio as much as 35% compared to the multicast tree approach. On the other hand, it reduces control overhead by 23~87% depending on the value of k matched to the multicast mesh access. In TBM *k*, the performance and overhead depends on the choice of k. A single value of *k* cannot be optimal and thus each node comes up with its own optimal value and discovers a desired set of redundant paths in that specific area. (Sangman Moh1et.al,2009)

In this paper authors have presented that due to dynamism and frequent topology changes a design of a suitable routing protocol is difficult for mobile ad hoc networks. This paper delivers a state-of-the-art overview of multicast routing protocols for ad hoc networks. This survey will prove to be a great source of information for researchers in ad hoc networks. The survey tries to review typical tree-based and mesh-based multicast routing protocols, generally the tree based protocols are efficient than mesh based ones from the perspective of energy efficiency generated by the minimization of transmission redundancy, whereas mesh based protocols provide better reliability at the cost of redundancy. (Anuradha Banerjee et.al , 2010)

2. Experimental Setup

Qualnet 5.0.2 is a network modeling tool, which is used to model wired and wireless network. It uses simulation and emulation to predict the behavior and performance of the networks to improve the design, operation and management.

Performance matrices used:-

1) Packet Delivery Ratio (PDR): The ratio of the number of data packets received by the receivers verses the number of data packets supposed to be received.
2) Average End-to-end delay: End-to-end delay indicates how long it took for a packet to travel from the source to the receiver.
3) Throughput: The throughput is defined as the total amount of data a receiver actually receives from the sender divided by the time between receiving the fast packet and last packet.
4) 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.
5) Packet Delivery Ratio:
The ratio of data packet sent by all the sources that is received by a receiver.

Area	1500X1500 m^2
Transmission range	500 m
Number of nodes	200
Physical / Mac layer	IEEE 802.11 at 2 Mbps
Mobility model	Group model, Random waypoint model
Maximum mobility speed	1-20 m/s
Simulation duration	300 s
Pause time	30 s
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	20,40,60 nodes
No. of simulations	20

3. Description of Protocols

Distance vector multicast routing protocol (DVMRP)

DVMRP is a distance vector routing protocol. It uses flooding and pruning to build the multicast tree. The routers in the leaf subnets have group membership information. When a router receives a flooded packet, it knows whether that packet will be useful for its subnet or not. In case there is no group member on the subnet, the leaf router sends a prune message to its neighboring routers. In addition, a leaf router can send a prune message through all interfaces except for the one on the reverse shortest path to the sender. When an intermediate router receives prune messages from all interfaces except for the reverse shortest path interface, it forwards the prune message upstream. This way, the unwanted branches of the spanning tree get pruned off. When a router sends a prune message, it maintains information about the (Source, Group) pair for which the prune message was sent. This state is used to prevent propagation of the data packets when they arrive at those routers.

DVMRP is a soft-state protocol in the sense that the state in the routers times out, and hence the process of flooding and pruning needs to be repeated periodically. DVMRP allows the corresponding router to send a graft message. The graft message propagates upstream using the reverse path forwarding interface until it reaches a router that is part of the shortest path tree.

On-demand multicast routing protocol (ODMRP)

The On-Demand Multicast Routing Protocol (ODMRP) falls into the category of on-demand protocols since group membership and multicast routes are established and updated by the source whenever it has data to send. Unlike conventional multicast protocols which build a multicast tree, ODMRP is mesh based. It uses a subset of nodes, or forwarding group, to forward packets via scoped flooding. When a multicast source has data to send but no route or group membership information is known, it piggybacks the data in a Join-Query packet. When a neighbor node receives a unique Join-Query, it records the upstream node ID in its message cache, which is used as the node's routing table, and re-broadcasts the packet. This process' side effect is to build the reverse path to the source. When a Join-Query packet reaches the multicast receiver, it generates a Join-Table packet that is broadcast to its neighbors. The Join-Table packet contains the multicast group address, sequence of pairs, and a count of the number of pairs. When a node receives a Join-Table it checks if the next node address of one of the entries matches its own address.

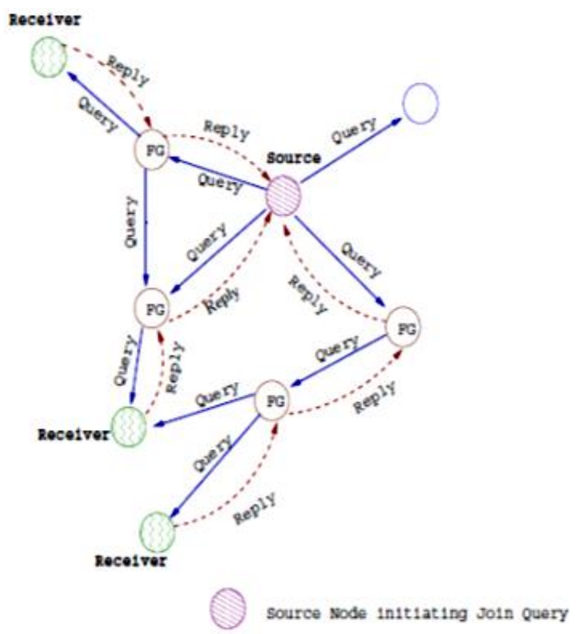

Fig.1 On-demand multicast routing protocol (ODMRP)

Protocol independent multicast (pim)

PIM is a multicast routing protocol that does not depend on a specific unicast routing protocol. PIM uses a set of special routers called Rendezvous Points (RPs) such that any receiver who wants to join the multicast group needs to send an explicit join request to a unique RP determined based on the multicast group address. The receivers explicitly join the RP resulting in the formation of a unidirectional shared RP-tree. Senders, on the other hand, do not explicitly join the RP but send their data encapsulated in register messages directly to the RP for distribution using the shared RP-tree. A sender who wants to multicast to the group starts by sending encapsulated packets to the corresponding RP, which then forwards the packets to the attached receivers. If the sender's traffic increases beyond some threshold, the shortest path route is set up between the sender and the corresponding RP. In addition ,the intermediate routers between the RP and the receivers switch from the RP-based shared tree to a source-based shortest path tree. PIM uses soft state mechanisms to maintain the tree. That is, control messages are sent periodically by the relevant routers to refresh the state information. No explicit teardown mechanism is needed to remove states when a group ceases to exist.

PIM (Protocol Independent Multicast) is capable of supporting sparse mode (SM) and dense mode (DM) operations.

PIM-DM (protocol independent multicast–dense mode)

This is PIM operating in dense mode (PIMDM), but the differences from PIM sparse mode (PIM-SM) are profound enough to consider the two modes separately. PIM also supports sparse-dense mode, with mixed sparse and dense groups, but there is no special notation for that operational mode. In contrast to DVRMP and MOSPF, PIM-DM allows a router to use any unicast routing protocol and performs RPF checks using the unicast routing table. PIM-DM has an implicit join message, so routers use the flood and prune method to deliver traffic everywhere and then determine where the uninterested receivers are. PIM-DM uses source-based distribution trees in the form (S, G), as do all dense-mode protocols.

PIM-SM (protocol independent multicast-sparse mode)

It allows a router to use any unicast routing protocol and performs RPF checks using the unicast routing table. However, PIM-SM has an explicit join message, so routers determine where the interested receivers are and send join messages upstream to their neighbors, building trees from receivers to RP. However, PIM-SM migrates to an (S, G) source based tree if that path is shorter than through the RP for a particular multicast group's traffic.

4. Results and Discussion

The performance of DVMRP, ODMRP and PIM-DM are investigated and analyzed based on the results obtained from the simulation. A number of experiments are performed to explore the performance of these protocols with respect to a number of nodes (UNIFORM).

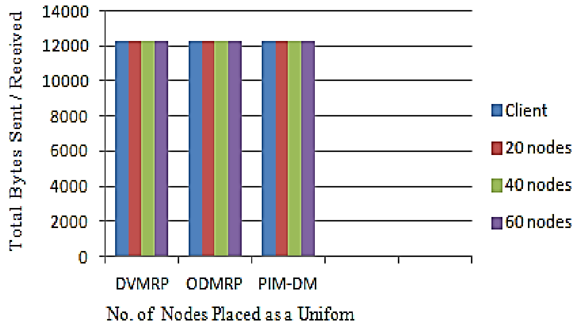

Fig. 2 No. of nodes Vs. Total bytes received

From Fig.2 to 8, it is observed that all protocols performance is affected by the increasing number of nodes in the network. Increased network traffic results in packet loss due to buffer overflow and congestion. Fig. 2 shows the variation in received bytes with no. of nodes when node placement is uniform. It states that no. of bytes received increase from 20 to 60 nodes for all three protocols.

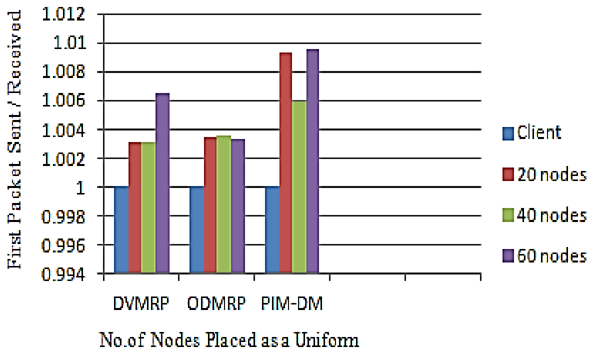

Fig 3 No. of nodes Vs. first packet received

Fig.3 shows the first packet sent from client and received at server. For 20, 40, 60 nodes delay is highest for PIM-DM and lowest for ODMRP and same for DVMRP but sharply increases for 60 nodes. The delay is lowest for ODMRP and highest for PIM-DM.

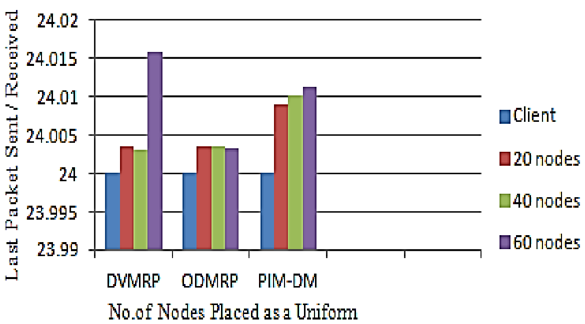

Fig 4 No. of nodes Vs. last packet received

Fig. 4 shows the last packet sent from client and received at server i.e. delay. It is highest for PIM-DM and lowest for ODMRP. For 20, 40 nodes DVMRP is lowest but after that 60 nodes delay packet of PIM-DM is highest and DVMRP is almost same

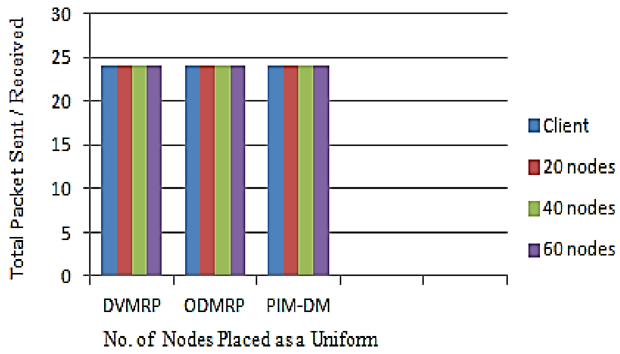

Fig.5 No. of nodes Vs. Total packet received

Fig. 5 shows the Total packet sent from client and received at server for three protocols when nodes are placed as uniform. For 20, 40 and 60 nodes, PDR is almost same for all three protocols.

Fig. 6 shows that for 20 nodes DVMRP, ODMRP and PIM-DM has highest throughput. For 40 nodes, throughput for both DVMRP and ODMRP is same but lowest for PIM-DM. For 60 nodes throughput of PIM-DM decreases sharply and DVMRP and ODMRP is same. The throughput highest for ODMRP and lowest for PIM-DM. The ODMRP and DVMRP is almost same throughput.

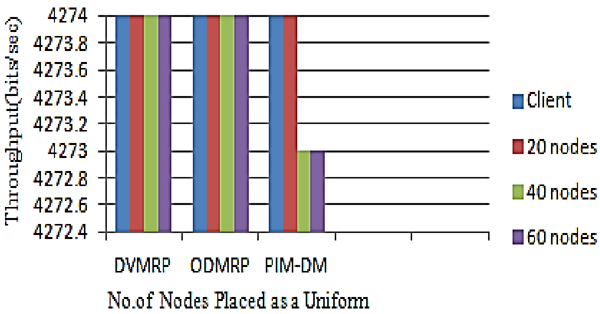

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Fig 6 No. of nodes Vs. Throughput

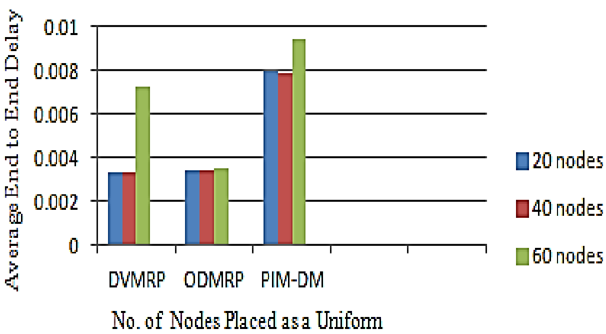

Fig 7 No. of nodes Vs. Average ETED

The average ETED increases as the no. of nodes increase for PIM-DM. Delay decreases for ODMRP and DVMRP as shown in Fig. 7. PIM-DM has highest average ETED and lowest for ODMRP.

Fig. 8 shows that the average Jitter for 20 nodes is almost same for DVMRP, ODMRP and PIM-DM increases sharply. For 40 & 60 nodes ODMRP jitter decreases, DVMRP decreases after that sharply increases and PIM-DM jitter increases. The average jitter is decreases for ODMRP and increases for PIM-DM on average.

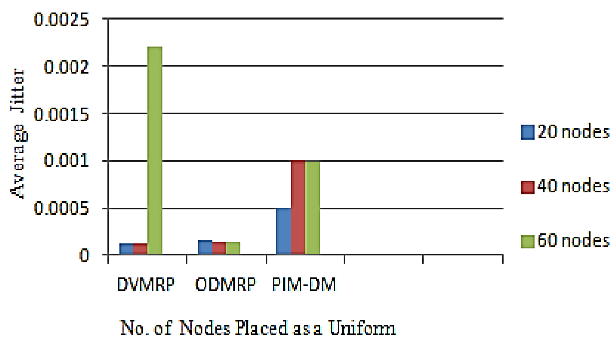

Fig 8 No. of nodes Vs. Average jitter

Conclusion

From the investigation, it can be concluded that proactive multicast routing protocols are not suitable for mobile ad hoc networks (MANETs), because of their huge routing overheads. Among the other two reactive routing protocols, mesh based (ODMRP) shows better performance than tree based routing protocol. ODMRP has low packet loss, high packet delivery ratio (PDR), less average end to end delay (ETED) high throughput as compared to other tree-based routing protocols. It was concluded that there is a trade-off between number of dropped packet and delay. If the number of dropped packets was decreased with the help of buffer, then average end-to-end delay will increase. ODMRP uses a forwarding group, to forward packets to receiver via scoped flooding. Topology, number of network nodes and node mobility are important parameters that can significantly affect the performance of the protocols being evaluated.

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