Performance Analysis of Multicasting Routing Protocols in MANETs

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***Abstract*—Multicasting is intended for group-oriented communication services. One particularly challenging environment for multicast is a mobile ad-hoc network (MANET), where the network topology can change randomly and rapidly, at unpredictable times. As a result, several specific multicast routing protocols for MANET have been proposed. Multicast approaches can generally be categorized into two: Proactive and On-demand. The proactive approach pre-computes and maintains routes to all nodes, including nodes to which no packets are being sent. The on-demand approach creates the routes between nodes that are solely determined when they are explicitly needed to route packets. Multicasting protocols can also be categorized based on the structure used to forward multicast packets which are tree and mesh based. The uses of on-demand routing approaches have been shown to have significant benefits in terms of reducing the routing protocol overheads. Therefore, this paper focuses on performance of tree and mesh based multicast routing protocols over MANET. This paper also evaluates well known multicast routing protocols, like on-demand multicast routing protocol (ODMRP), protocol independent protocol- dense mode (PIM-DM) and multicast open shortest path first (MOSPF) under a wide range of network conditions and realistic scenarios. More specifically, the concern is to characterize the merits of tree and mesh-based protocols over various ranges of MANET scenarios based on representative performance metrics. The simulation environment is Qualnet-5.0. As a result this paper investigates the relative strength, weaknesses and applicability of each protocol to diverse situation.**

***Index Terms*—Computer network, routing protocols, path loss models.**

I. Introduction

An ad-hoc network is a collection of nodes forming a temporary network without the aid of any additional infrastructure and no centralized control. The nodes in an ad-hoc network [12] can be a laptop, PDA, or any other device capable of transmitting and receiving information. Nodes act both as an end system (transmitting and receiving data) and as a router (allowing traffic to pass through) resulting in multi-hop routing. Network is temporary as nodes are generally mobile and may go out of range of other nodes in the network.

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 [1].

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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 [2].

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 [3].

In this paper, authors investigate the performance of multicast routing protocols in wireless mobile ad hoc networks [4].

This paper presents different approaches of providing multicast traffic for mobile hosts. Mobile IPv6 is used for mobility support. The network employs Protocol Independent Multicast Dense Mode (PIM-DM) for multicast routing and Multicast Listener Discovery (MLD) to collect multicast group membership information [5].

This paper describes an IP multicast implementation based on Multicast Extensions to Open Shortest Path First (MOSPFP). The MOSPF Forwarding Model presented in this study is used to forward multicast datagram. The Forwarding Model has focused on interaction between MOSPF and OSPF in terms of group-membership-Link-State-Advertisement (type-6 LSA) as well as developing Multicast Routing Table (MRT) and Multicast Forwarding Cache (MFC). The MRT has been organized as a Patricia-based tree while the MFC has been maintained as hash-table data structures. The MFC entries are built from the local group database and the shortest path (SPF) tree calculation. [6]

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 [7].

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 [8].

In this paper, authors describe the On-Demand Multicast Routing Protocol for mobile ad hoc networks (ODMRP). 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 [9].

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 [10].

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 [11].

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 [12].

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. [13]

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 [14].

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 [15].

II. Problem Formulation

The overall goal of this simulation study is to evaluate and analyze the performance of three existing multicast routing protocols; they are: MOSPF, ODMRP AND PIM-DM over mobile ad hoc networks. Protocol performances are observed in several network configurations where some parameters evolve in order to measure the impact of these parameters on the protocol. The experiments are executed to study the effect of the node mobility, node placement, speed and number of nodes in the network.

III. Workdone

The network size is 1500m × 1500m area for scenario simulation. There is no network partitioning throughout the entire simulation. The data transmission rate (unicast and multicast) and data transmission rate for broadcast is 2Mbits/s. At physical layer PHY 802.11b and at MAC layer MAC 802.11 is used. The simulation time for each experiment is 300 seconds. Multiple runs with different seed numbers are conducted for each scenario and collected data is averaged over those runs.

The main traffic source in the simulation is Multicast Constant Bit Rate (MCBR) traffic. Each multicast group has one sender for each protocol every time but the number of receivers is different for different number of nodes. The number of receivers is 3, 6, 9 for 25 nodes, 50 nodes and 75 nodes respectively. The sender transmits multicast traffic at a rate from 10 to 60 packets/sec. The senders and receivers are chosen randomly among multicast members. A member joins the multicast session at the beginning of the simulation and remains as a member throughout the simulation. In the simulation, initial 10s is kept to perform this task. Once joining the multicast group, we let the source to transmit data for 300s simulation time. The packet size without header is 512 bytes. The length of the queue at every node is 50 Kbytes where all the packets are scheduled on a first-in-first-out (FIFO) basis. The parameters are summarized in Table I.

TABLE I: Summary of Simulation Environment

Parameters	Values
Network Size	1500m × 1500m
Path loss model	Two ray propagation model
Fading model	None
Simulation time	300 seconds
Physical layer protocol	PHY 802.11b
Data link layer protocol	MAC 802.11s
Data rate	2 Mbps
Shadowing model	Constant
Channel frequency	2.4 GHz
Pause time	30 seconds
Simulation time	300 seconds
Number of source	1
Traffic model	Multicast constant bit rate (MCBR)
Multicast routing protocol	MOSPF, ODMRP, PIM-DM

To evaluate the performance of routing protocols, both qualitative and quantitative metrics are needed. Most of the routing protocols ensure the qualitative metrics. Therefore, three different quantitative metrics are used to compare the performance. They are,

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. This number presents the effectiveness of a protocol.
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 first packet and last packet.

IV. Results and Discussion

The performance of MOSPF, 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 parameters such as multicast traffic load, mobility speed and node placement.

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. When nodes are placed randomly, no. of bytes received at server increased by increasing no. of nodes for ODMRP. For MOSPF, bytes received increase from 25to 50 nodes but after that remain same. The received bytes increase with no. of nodes for PIM-DM also. The average ETED (End to end delay) increases for MOSPF as no. of nodes increase. For ODMRP, the average ETED decreases but remains almost same for PIM-DM. It is also seen that PDR is highest for ODMRP and lowest for MOSPF. Throughput is highest for ODMRP and lowest for MOSPF. For ODMRP, throughput increases from 25 to 50 nodes but falls after that. The same thing happens for MOSPF and PIM-DM. For all kinds of traffic load, ODMRP outperforms other two protocols. ODMRP uses a forwarding group, to forward packets to receiver via scoped flooding. This path redundancy enables ODMRP to suffer only minimal data loss.

When nodes are placed as a grid, total bytes received at server decreases as the no. of nodes increases. For MOSPF, loss of bytes is higher as compared to ODMRP and PIM-DM. The average ETED is highest in case of MOSPF when nodes are placed as a grid. For ODMRP and PIM-DM, delay remains almost same as the no. of nodes increases.

The delay between the first packet sent from client and received at server. The delay is maximum for MOSPF and PIM-DM at 50 nodes but almost zero for ODMRP.The delay between the last packet sent from client and received at server when node placement is grid. For 25 nodes, delay is almost zero for all of three protocols but changes after that. It shows that ODMRP is better than other two.

PDR(Packet Delivery Ratio) decreases for MOSPF and ODMRP as the no. of nodes increase. For PIM-DM, PDR decreases from 25 to 50 nodes but slightly increase for 75 nodes. Packet loss is maximum for MOSPF. It states that throughput decreases as no. of nodes increases for all these protocols. Throughput is lowest for MOSPF and highest for ODMRP on average.

It states that no. of bytes received increase from 25 to 50 nodes but decrease from 50 to 75 nodes for all three protocols when node placement is uniform. The average ETED increases as the no. of nodes increase for MOSPF but it almost remain same for both ODMRP and PIM-DM. MOSPF has highest average ETED. The delay between the first packet sent from client and received at server. For 25 nodes, delay is highest for ODMRP and lowest for MOSPF and decreases sharply for 50 nodes and remains constant upto 75 nodes for all protocols. The delay between the last packet sent from client and received at server. The delay is almost zero for 25 and 50 nodes. For 75 nodes, delay varies. It is highest for MOSPF and lowest for ODMRP. It is also seen that for 25 nodes, PDR is highest for MOSPF and lowest for PIM-DM. PDR increases for 50 nodes and again decreases for 75 nodes. For MOSPF, Packet loss is higher for 50 and 75 nodes and PDR is less. ODMRP and PIM-DM has almost same PDR. It is seen that for 25 nodes, ODMRP has highest throughput and MOSPF has lowest. For 50 nodes, throughput for both ODMRP and PIM-DM is same but lowest for MOSPF. The throughput decreases sharply for 75 nodes for all protocols.

No. of bytes received at server is highest when node placement is grid and decrease for random node placement. The received bytes again increase for uniform node placement. ODMRP has highest throughput on average for all three node placement. The average ETED is highest for MOSPF when node placement is grid but decreases for random and remains same for uniform node placement. ODMRP has highest delay for random node placement but almost same for grid and uniform placement. The delay is almost same for all three node placement for PIM-DM. The delay for first packet is zero when node placed as a grid. For random node placement, delay remains same for ODMRP but increases for MOSPF and PIM-DM. The delay is highest for all three protocols when node placement is uniform. Almost no delay for all three protocols for grid and uniform node placement is observed. But some delay is present for random placement. ODMRP has lowest delay and MOSPF has highest delay. PDR is highest for all three protocols for grid node placement but decreases for random placement and again increases for uniform node placement. ODMRP has highest PDR on average. It is observed that PIM-DM has highest throughput for grid node placement. ODMRP has highest throughput among all three protocols for random and uniform node placement. The throughput for grid node placement is better than other two.

How does mobility affect the performance of MOSPF, ODMRP and PIM-DM is also studied. The variation in no. of bytes received at server with change in mobility model. For MOSPF and ODMRP, the received bytes are higher for random way point mobility than group mobility but reverse for PIM-DM. The change in mobility model does not affect so much the average ETED for all three protocols. ODMRP has highest ETED for both models. MOSPF and PIM-DM have almost same average ETED for both models.

The first packet sent from client is received at server almost at same time for all three protocols and for both mobility models. So chances of packet loss are negligible due to zero delay. The delay between last packet sent and received is almost zero for all protocols except ODMRP for group mobility. For random way point mobility, the delay is almost zero except for PIM-DM. PDR is highest for PIM-DM and lowest for MOSPF for group mobility model. In case of random way point, PDR is highest for MOSPF and almost same for ODMRP and PIM-DM. The throughput is highest for PIM-DM and lowest for ODMRP for group mobility model. In case of random way point mobility, throughput is lowest for PIM-DM and almost same for MOSPF and ODMRP.

It is also observed that how does node speed affect the performance of MOSPF, ODMRP and PIM-DM. The no. of bytes received increase as speed increase from 10 to 20mps but decrease sharply for 30mps. PIM-DM has received highest bytes and ODMRP has received lowest bytes for 10 and 20mps speed. For 30mps, PIM-DM has lowest no. of bytes. The average ETED (end to end delay) increase for all protocol as speed increases from 10 to 20mps but decrease gradually for 30mps. At 30mps speed, ETED is highest for

ODMRP. The first packet delay is highest for PIM-DM and lowest for ODMRP for 10mps speed. But for 20mps, delay decreases and remains same for all of three. For 30mps, delay again increases and is highest for MOSPF and lowest for ODMRP. The last packet delay is highest for PIM-DM at 10mps and 20mps speed. Delay is lowest for ODMRP at 20mps. The delay increases with speed from 10 to 20mps and decreases at speed 30mps. PDR is highest for PIM-DM and lowest for ODMRP at 10 and 20mps speed. At 30mps speed, PDR is lowest for PIM-DM and highest for MOSPF. PDR increases with speed from 10 to 20mps but decreases at 30mps speed. The throughput increases with speed from 10 to 20mps but decreases at 30mps speed. ODMRP has highest throughput for 10 and 30mps speed and lowest for 20mps. PIM-DM has lowest throughput at 10 and 30mps speed and highest at 30mps speed.

V. Conclusions

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 (PIM-DM) routing protocol. ODMRP has low packet loss, high packet delivery ratio (PDR), less average end to end delay (ETED) high throughput as compared to MOSPF and PIM-DM.

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