Analysis of Multicast Routing Protocols: Puma and Odmrp

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ABSTRACT: *In general, Wireless communication is defined as sharing of information between one or more systems through wireless links. Wireless networks can be categorized into two different modes as infrastructure based and infrastructure less. Infrastructure based mode is the most common use wireless mode for the end user loop. Infrastructure fewer modes also called as the Ad hoc mode relies on wireless communications without any fixed infrastructure. Infrastructure based networks are characterized by their use of access points (AP), or base stations. The most known example of infrastructure based wireless network is GSM and more recently, Wi-Fi. Ad Hoc networks introduce a new way of communication. An ad hoc network is a collection of wireless mobile nodes that dynamically functions as a network without the use of any existing infrastructure and centralized administration. Mobile Ad-hoc networking (MANET), an emerging field of wireless networking is an autonomous system of wireless mobile hosts, connected by wireless links that dynamically create a temporary network and establish an infrastructure less network. The topology of the network may change frequently and unpredictably. Multicast routing has been widely applied in mobile ad hoc networks (MANETs), to support different group oriented applications like video conferencing, interactions with Special interest groups etc., efficiently. This paper presents the comparative analysis of two multicast routing protocols, PUMA and ODMRP.*

Keywords: *MANET, PUMA, ODMRP, AODV, WMN's.*

I. Introduction

1.1 Ad hoc

Mobile Ad-hoc Network (MANET) is an autonomous system of mobile hosts, connected by wireless links that dynamically create a temporary network and establish an infrastructure less network [1]. The topology of the network may change frequently and unpredictably. Each and every node in the MANET should be aware of its neighbour and act as a router to forward datagram's to the specified destination. If two mobile nodes are located within the forwarding range, they communicate with each other directly over the wireless radio frequencies. Otherwise, they need intermediate node(s) to forward their datagram's using a multi-point hopping method. MANETs are characterized by non-restricted mobility and easy deployment, which makes them very popular. Mobile wireless nodes will typically have limited transmission range, which means that packets might have to be forwarded by several nodes in order to ensure communication between one node in the network to another. Fig 1 below illustrates how node A uses a route through node B to send data to node C, as C is out of A's transmission range.

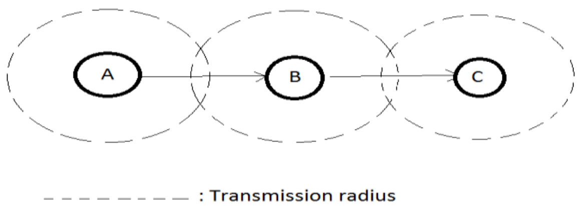

Fig 1. Routing in MANET

As a technology for dynamic wireless networks, ad hoc networking has been deployed in military since 1970s. Commercial interest in such networks has recently grown due to the advances in wireless communications. A new working group for MANET has been formed within the Internet Engineering Task Force (IETF), aiming to investigate and develop a framework for running IP based protocols in ad hoc networks. In recent years, many group oriented applications have gained a lot of importance. Multicast routing has been widely applied in mobile ad hoc networks (MANETs), to support different group oriented applications efficiently. Some of them are:

- Military applications used in the battlefield
- Search and rescue operations
- Temporary networks within meeting rooms and airports
- Personal Area Networks connecting mobile devices like mobile phones, laptops, smart watches, and other wearable computers
- Disaster recovery
- Video conferencing and multimedia streaming

The rest of the paper is organized as follows. Section 2 describes related work on unicast and multicast routing protocols for MANET. Section 3 describes PUMA routing protocol. Simulation setup and Performance analysis are described in section 4. Finally, section 5 follows with a conclusion and future enhancement.

II. Related Work

This section explains some of the most representative unicast and multicast routing protocols such as AODV, ODMRP and PUMA.

2.1 Routing Protocols

Routing protocol is a procedure used by router to determine the appropriate path onto which data should be forwarded. It also specifies how routers report changes and share information with the other routers in the network that they can reach. This decides whether the network should dynamically adjust to changing conditions, otherwise all routing decisions have to be predetermined and remain static. To achieve the preliminary objectives, several routing protocols in the area of mobile ad hoc networks should be examined. Routing Protocols can be classified based on message delivery semantics as unicast, multicast and broadcast showed in the Fig 2, Fig 3, and Fig 4.

- **Unicast** – to single specified node by the host
- **Broadcast** – to all nodes in the network
- **Multicast** – to a group of nodes that have expressed interest in receiving messages

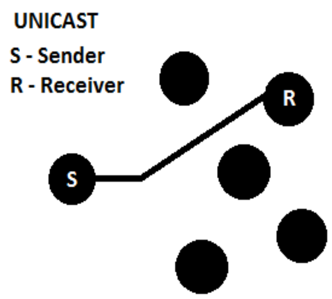

Fig 2. Unicast

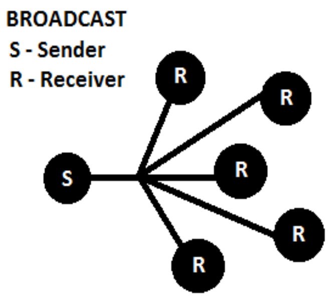

Fig 3. Broadcast

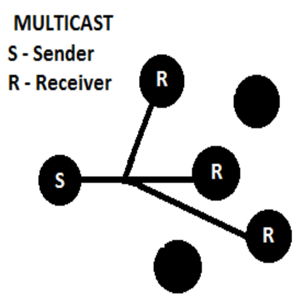

Fig 4. Multicast

2.2 Unicast Routing

Unicast routing refers to finding a feasible path between a single source and a single receiver. Unicast term is used to describe communication where a piece of information is sent from one point to another point. Some of the unicast protocols are AODV, DSDV and DSR

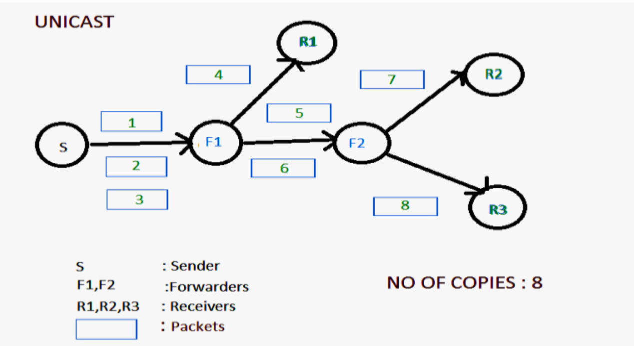

Fig 5. Packet Transmissions in Unicast

2.2.1 AODV

AODV [2] is a reactive distance vector routing protocol, which means routing decisions will be taken depending on the number of hops to destination on demand.

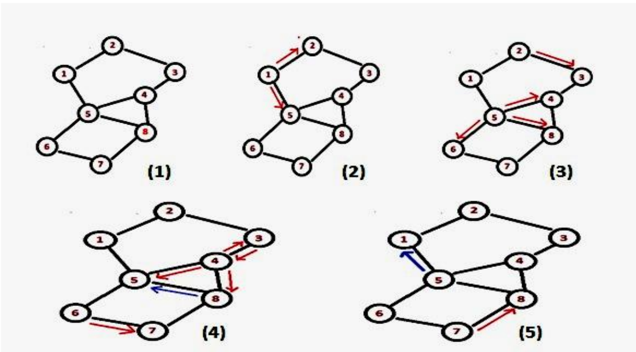

Fig 6. AODV Illustration

In the example illustrated by Fig 6, node 1 intends to send a packet to node 8.

"ROUTE REQUEST" packet will be generated by Node 1 and sent to node 2 and node 5. Node 2 and node 5 add node 1 in their routing table, as a reverse route, and forward the "ROUTE REQUEST" packet to their neighbors. The forwarding process continues while no route is known. Once node 8 receives the "ROUTE REQUEST" from node 5, it generates the "ROUTE REPLY" packet. Duplicate packets continue to be ignored while the "ROUTE REPLY" packet goes on the shortest way to node 1, using routing table of each node. The reverse routes created by the other nodes that have not been used for the "ROUTE REPLY" are deleted after a delay. Node 5 will add the route to node 8 once they receive the "ROUTE REPLY" packet.

2.2.2 Merits of AODV:

It does not need any central administrative system to control the routing process. It reacts relatively fast to the topological changes in the network and updates only the nodes affected by these changes. The HELLO messages supporting the routes maintenance are range-limited, so they do not cause unnecessary overhead in the network.

2.2.3 Drawbacks of AODV:

The performance of the AODV protocol is poor in larger networks. A long path is more vulnerable to link breakages and requires high control overhead for its maintenance. Furthermore, as a size of a network grows, various performance metrics begin decreasing because of increasing administrative work, so-called administrative load.

2.3 Multicast Routing

Multicast [3] is a bandwidth-conserving technology that reduces traffic by simultaneously delivering a single stream of information to thousands of recipients. Multicast routing refers to finding a feasible tree covering a single source and a set of receivers. Multicast transmission is a more effective mechanism when compared to unicasting in supporting group communication applications and hence is an important aspect of future network development. Multicast is used in videoconferencing, corporate communications, distance learning, and distribution of software, stock quotes, and news in real time.

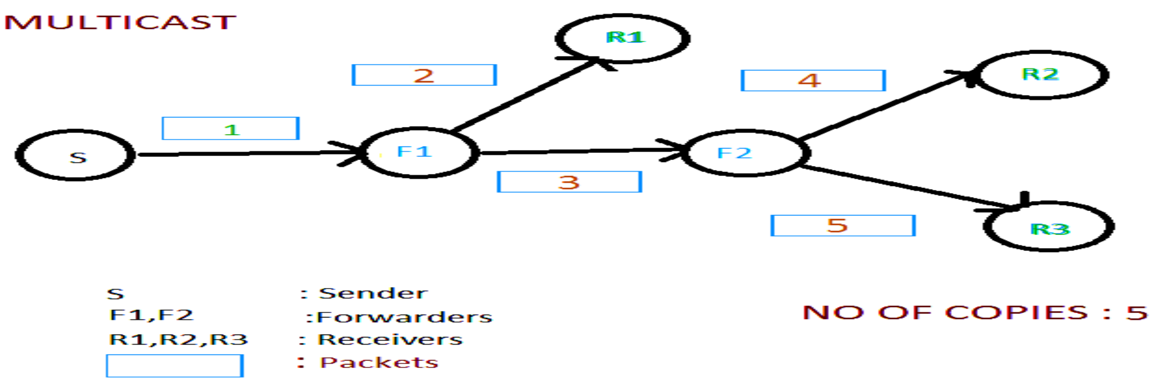

Fig 7. Packet Transmissions in Multicast

Since, MANETs have dynamic topology, the position of the nodes change with time resulting in wireless-link failure across nodes. If the mobile nodes in the MANET move too quickly, they have to repair the routes to achieve node to node communication to forward the packets. So, the multicast routing protocol should be capable of handling the link-breakages and find new optimal paths, if necessary. Several multicast routing protocols have been proposed to solve these problems. Every multicast routing protocol has its advantages and disadvantages, and aims at a specific application. Finally, the expected standard for multicast routing protocols in the Mobile Ad-Hoc Networks is very likely to minimize its energy consumption and control traffic overhead while at the same time, it should be capable of responding rapidly to link failure and addition caused by mobile node movements.

Existing protocols are either tree or mesh-based [4] or hybrid. Tree-based schemes establish a single path between any two nodes (generally sender and a receiver) in the multicast group. These schemes require minimum number of copies per packet to be sent along the branches of the multicast tree. Hence, they are bandwidth efficient. However, as mobility increases, link failures trigger the reconfiguration of entire tree. When there are many sources, network either has to maintain a shared tree, losing path optimality or maintain multiple trees resulting in storage and control overheads. Examples of tree-based schemes include: ad hoc multicast routing utilizing increasing ID-numbers protocol (AMRIS) [5], and multicast ad hoc on-demand distance vector routing protocol (MAODV)[6].

Mesh-based schemes establish a mesh of paths that connect the source and destinations. They are more resilient to link failures and also to various mobility conditions of ad hoc nodes. The disadvantage of a mesh based scheme is its increase in redundancy because multiple copies of the same packet are transmitted through the mesh, resulting in reduced packet delivery and increased control overhead under highly mobile conditions. Examples of mesh-based schemes include: on-demand multicast routing protocol (ODMRP) [7], Core Assisted Mesh Protocol (CAMP) [8].

2.3.1 On-Demand Multicast Routing protocol (ODMRP)

On- Demand Multicast routing protocol (ODMRP) [8] is a mesh based source-initiated protocol, i.e., it uses forwarding group concept and multiple paths exist between sender and receiver. It applies on-demand procedures to build route and maintain multicast group membership dynamically. By maintaining a mesh, instead of a tree, the drawbacks of multicast trees in ad hoc networks like frequent tree reconfiguration and non-shortest path in a shared tree are avoided.

2.3.1.1 Algorithm

In ODMRP, group membership and multicast routes are established by the source on-demand. When a multicast source has packets to send but no route to the multicast group, it broadcasts a Join-Query control packet to the entire network. This control packet is periodically broadcast to refresh the membership information and updates routes. When the Join-Query packet reaches a multicast receiver, it creates and broadcasts Join-Reply to its neighbors. When it has been received by the node, it checks if the next hop id is its own id. If it matches, the node realizes that it is on the path to the source and becomes the part of the forwarding group by setting the FG_FLAG (Forwarding Group flag). When receiving a multicast data packet, a node forwards it only when it is not a duplicate, hence minimizing traffic overhead. Because the nodes maintain soft state, finding the optimal flooding interval is critical to ODMRP performance. ODMRP uses location and movement information to predict the duration of time that routes will remain valid. With the predicted time of route disconnection, a "join data" packet is flooded when route breaks of ongoing data sessions are imminent. It reveals that ODMRP is better suited for ad hoc networks in terms of bandwidth utilization.

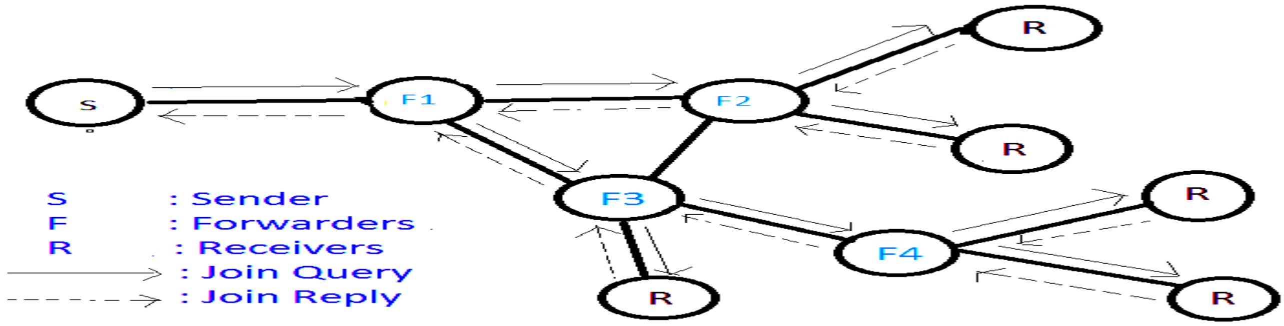

Fig 8. On-demand procedure for membership setup and maintenance

Fig 8, Fig 9 is an example to show the robustness of a mesh configuration. Sender 'S' send multicast data packets to three receivers (R1, R2, and R3) via three forwarding group nodes (F1, F2 and F3). In case the route from S to R1 is <S-F1-F2-R1>. In a tree configuration, if the link between nodes F1 and F2 breaks R1 cannot receive any packets from S until the tree is reconfigured but in ODMRP has a redundant route <S-F1-F3-F2-R1> to deliver packets without going through the broken link between nodes F1 and F2.

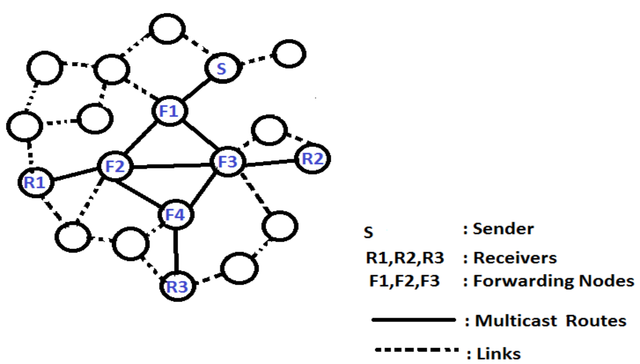

Fig 9. ODMRP Illustration

2.3.1.2 Merits of ODMRP

- Usage of up-to-date shortest routes
- Robustness in terms of host mobility
- Exploitation of the broadcast nature of the wireless environment
- Capability to perform Unicast Routing.
- multiple redundant paths are maintained and exploited

2.3.1.3 Drawbacks of ODMRP

- The main disadvantage of ODMRP is its excessive overhead, due to broadcasting of the reply packets to many nodes.
- As it is mesh based, topology is complex.

III. PUMA

Puma[9] is a receiver initiated routing protocol in which receivers join a multicast group using special address (core in CAMP protocol or group leader in Multicast AODV protocol).The flooding of data or control packets is reduced using special address (core of the group) by all sources.

Distributed algorithm is used to elect core among receivers of a multicast group. Election algorithm is same as the spanning tree algorithm to find loop-free shortest path between the core and group members. The elected core is connected to receivers in the network through all possible shortest paths. All intermediate nodes on shortest paths collectively form the mesh structure. Data packets are sent from sender to the group via core along any possible shortest path and flooded within the formed mesh whenever mesh member receives. All nodes in the network keep a packet ID cache to remove data packets that are duplicated [9]. Multicast announcement acts as a single control message to perform all tasks in PUMA.

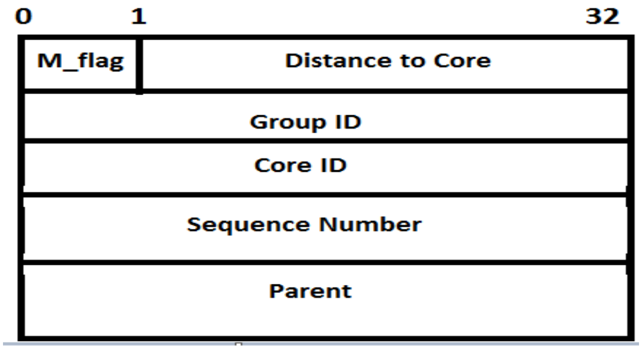

Fig 10. MAP Format

Each multicast announcement showed in Fig 10 specifies a sequence number, the address of the group(group ID), the address of the core (core ID), the distance to the core, a mesh member flag that is set when the sending node belongs to the mesh, and a parent that states the preferred neighbor to reach the core. With the information contained in such announcements, nodes elect cores, determine the routes for sources outside a multicast group to unicast multicast data packets towards the group, notify others about joining or leaving the mesh of a group, and maintain the mesh of the group. Connectivity list is established using multicast announcements at every node in the network. It is used to establish a mesh and keep track of multicast announcement received from neighbor by nodes. It also stores the receiving time and neighborhood details.

3.1 Establishment of Mesh

Initially mesh member flag of all receivers set to TRUE by considering themselves as mesh members in the multicast announcements they send. Non-receivers consider themselves mesh-members if they have at least one mesh child in their connectivity list. A neighbor in the connectivity list is a mesh child if : (a) its mesh member flag is set; (b) the distance to core of the neighbor is larger than the nodes own distance to core; and (c) the multicast announcement corresponding to this entry was received in within a time period equal to two multicast announcement intervals. Condition (c) is used to ensure that a neighbor is still in the neighborhood. If a node has a mesh child and is hence a mesh member, then it means that it lies on a shortest path from a receiver to the core.

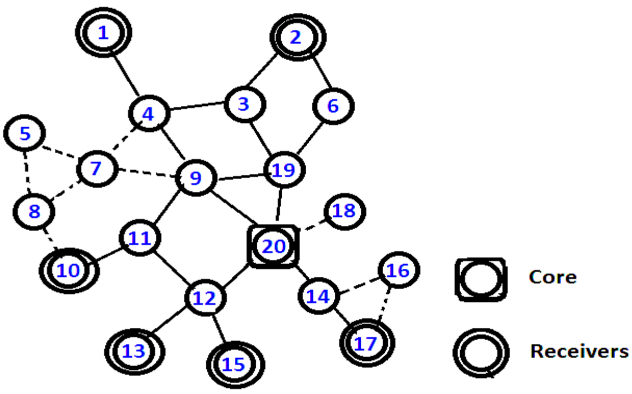

Fig 11.Mesh Establishment and Maintenance

As represented in Fig 11, node 20 is treated as core and other nodes in the group mark the connectivity list distance field by adding one to the finest entry. The receivers (nodes 1, 2, 10, 13, 15, 17 and 20 update the mesh member status to 1. node 3 and node 6 become mesh-members after receiving multicast announcement from qualified mesh child node2 as the distance to core is same. Similarly, nodes 4, 9, 12, 19 and 14 become the mesh members as the overall distance to the core node from mesh members is small. The procedure continues until the shortest paths are detected to the core from the receivers in the mesh. In this example, the route between the node 2 and core 20 of distance 3 exist through 2-3-19-20 and 2-6-19-20 and both paths are part of the mesh.

3.3 Core Election

If a node does not receive any multicast announcement for particular group, it assumes itself the core of the multicast group and transmits multicast announcements to its neighbors and set self-distance to 0.Nodes update their connectivity list based on multicast announcements with higher core ID. The receiver which joins the group first becomes the core of the multicast group. If two or more receivers join simultaneously, then the one with largest IP address becomes core [10].

3.4 Propagation of Data Packets

The best multicast announcement from neighbor is considered in order to fill the parent field of connectivity list. A node fills parent field with a node entry from which it receives a best announcement. This field allows nodes that are non-members to forward multicast packets towards the mesh of a group. A node forwards a multicast data packet it receives from its neighbor if the parent for the neighbor is the node itself.

Hence, multicast data packets move hop by hop, until they reach mesh members. The packets are then flooded within the mesh, and group members use a packet ID cache to detect and discard packet duplicates.

IV. Performance evaluation

4.1 Performance Metrics

Performance of MANET routing protocols can be evaluated using a number of quantitative metrics those are mentioned in RFC2501. We have used packet delivery ratio, throughput, end-to-end delay and normalized routing load for evaluating the performance of unicast routing protocol AODV and multicast routing protocols (PUMA & ODMRP).

4.1.1 Packet Delivery Ratio

It is defined as the ratio of number of data packets delivered to all the receivers to the number of data packets supposed to be delivered to the receivers. This ratio represents the routing effectiveness of the protocol:

$$PDR = \frac{\text{Packets delivered}}{\text{Packets sent}} \qquad (1)$$

4.1.2 Average End-to-End Delay

It is the average time taken for a data packet to move from the source to the receivers:

$$\text{Avg. EED} = \frac{\text{Total EED}}{\text{No. of packets sent}} \qquad (2)$$

4.1.3 Throughput

Throughput refers to how much data can be transferred from the source to the receiver(s) in a given amount of time:

$$\text{Throughput} = \frac{\text{Number of packets sent}}{\text{Time Taken}} \qquad (3)$$

4.1.4 Normalized Routing Load (NRL)

It is defined as the ratio of total no. of data packets received to the total no. of routing packets received:

$$NRL = \frac{\text{No. of data packets received}}{\text{No. of routing packets received}} \qquad (4)$$

4.2 Unicasting

4.2.1 AODV Simulation Setup

We compared the performance of AODV with two different transport layer traffic protocols TCP and CBR. We used NS-2 which is an event driven simulator targeted especially at network research. Experimental scenario considered with a network of 50 mobile nodes placed randomly within a 1500 x 300 m. Random waypoint is used as the mobility model. Radio propagation range for each node is 250 m and channel sensing threshold is set to 550 m. Packet size of each datagram is of 512 KB and maximum Queue length is set to 50 packets. Each simulation executes for 200 sec of simulation time. MAC_802.11 is used as medium access control protocol. Multiple runs by varying traffic and receivers are conducted for each scenario and the average of the collected data is obtained.

4.2.2 Results

TABLE I: AODV Metrics with TCP Traffic

Number of Receivers	PDR	Throughput (in kbps)	End to End Delay (in ms)	Network Routing Load
01	99.93	1072.53	37.18	0.003
05	98.92	666.79	231.18	0.060
10	97.24	732.17	216.70	0.472
15	95.73	745.25	225.27	0.578
20	95.29	748.90	234.29	0.580

TABLE II: AODV Metrics with CBR Traffic

Number of Receivers	PDR	Throughput (in kbps)	End to End Delay (in ms)	Network Routing Load
01	99.79	40.80	2.59	0.184
05	99.91	201.74	14.75	0.103
10	99.78	404.53	8.90	0.073
15	97.44	592.86	14.20	0.086
20	98.75	799.81	29.33	0.097

4.3 Multicasting

We compared the performance of PUMA and ODMRP using Network Simulator and Qualnet respectively. Experimental scenario considered with a network of 50 mobile nodes placed randomly within a 1500 x 300 m. Table III provides the details of the simulation setup.

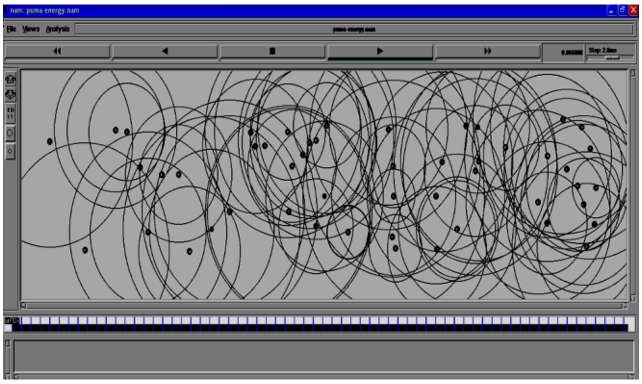

Fig 12. NS-2 Simulation Scenario

4.3.1 Simulation Setup

TABLE III: Simulation Parameters

Simulator	Network Simulator (NS-2)	QualNet 5.0.2
Total Nodes	50	50
Simulation Time	200 sec	200 sec
Simulation Area	1500x300	1500x300
Propagation Model	Two Ray Ground Model	Two Ray Ground Model
Pause Time	0 - 10 sec	0 -10 sec
Mobility Model	Random Waypoint Model	Random Waypoint Model
Radio Range	250 m	250 m
MAC Protocol	MAC_802.11	MAC_802.11
Data Packet Size	512 bytes	512 bytes
Data Rate	11 Mbps	11 Mbps
Antenna	Omni Directional Antenna	Omni Directional Antenna
IFQ Length	50 packets	50 packets
Bandwidth of Physical Layer	11 Mbps	11 Mbps
No. of Receivers	10, 20, 30, 40	10, 20, 30, 40
Routing Protocol	PUMA	ODMRP
Destination Address	224.0.0.1	225.0.0.1
No. of Packets Per Sec	10	10
Mobility Speed	0 – 10 m/sec	0 – 10 m/sec
Traffic	CBR	MCBR

4.4 Results and analysis

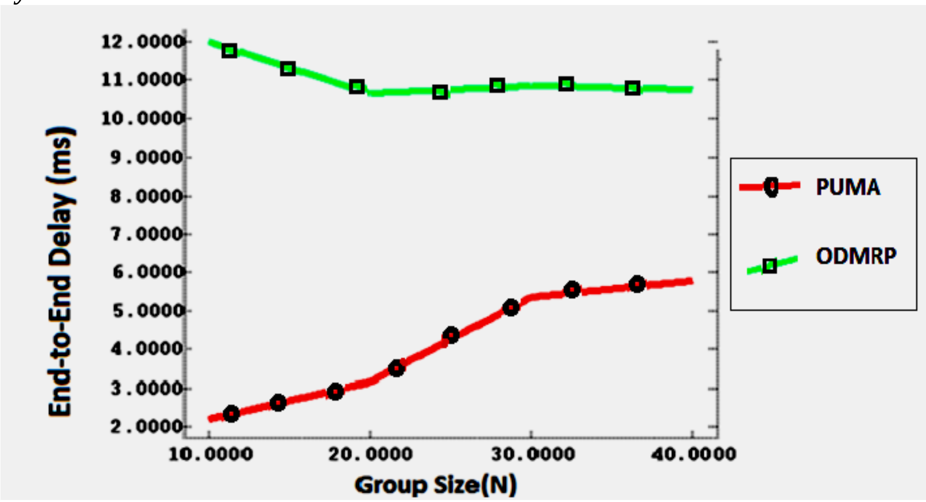

Fig 13. End-to-End Delay Vs Group Size [No. of nodes]

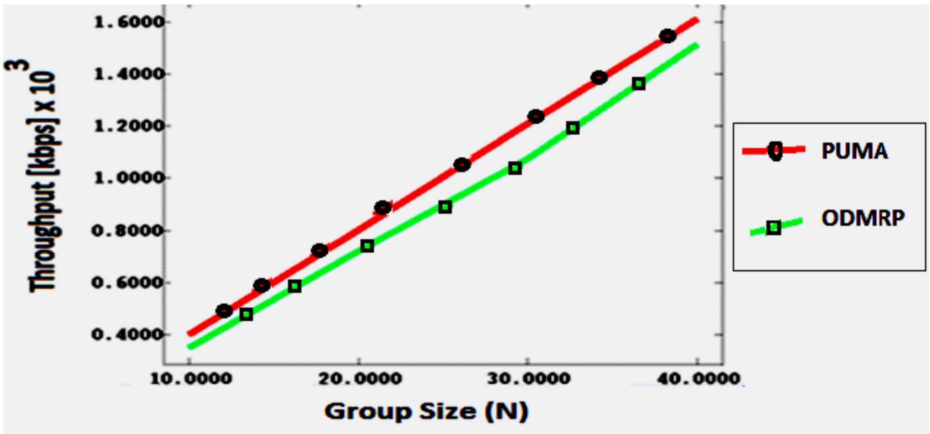

Fig 14. Throughput Vs Group Size [No. of Nodes]

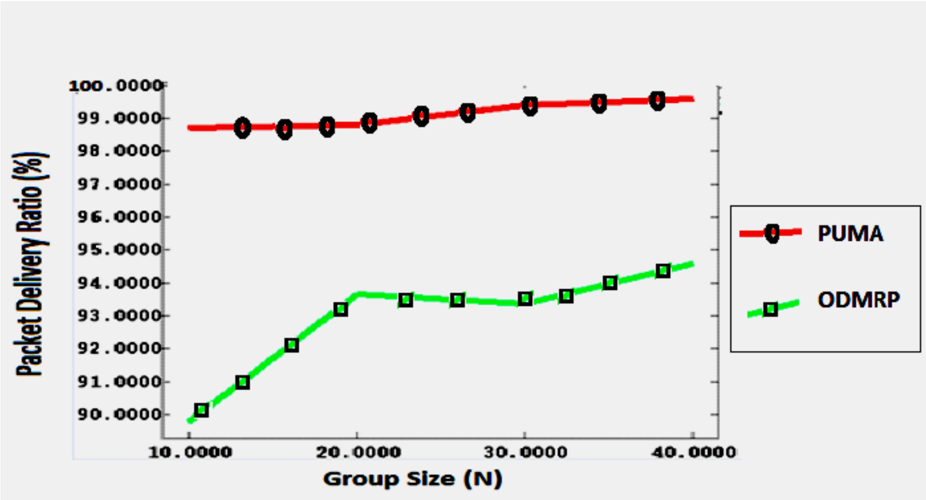

Fig 15. Packet Delivery Ratio Vs Group Size [No. of nodes]

4.5 Discussion

From the analysis of AODV, a unicast routing protocol, it can be observed that delay is high even though the group size is less. Hence, AODV cannot be used for group communications, specifically in the area of multimedia, where delay is considered to be an important metric. The same scenario is taken and simulated using multicast routing protocols, ODMRP and PUMA. For the chosen simulation parameters, it is observed that the average end to end delay is less in PUMA, compared to ODMRP and AODV. PUMA outperforms ODMRP with respect to the metrics like packet delivery ratio, average end-to-end delay and throughput. This is because the per-source flooding of ODMRP leads to significant number of packet drops due to congestion as the number of senders is increased beyond 10. On the other hand, the only node that floods the network in PUMA is the core. It is also observed that, when the number of multicast groups is increased, per source flooding per group leads to congestion [11] and packet drops. Increasing the number of multicast groups does not have a significant effect in PUMA, because the multicast announcements for multiple groups are aggregated by every node.

Similarly, the higher signaling overhead of ODMRP due to per-source flooding and higher data packet overhead due to its mesh structure results in network saturation much earlier. As a result, when the traffic load is increased beyond 10 packets per sec, the packet delivery ratio of PUMA is higher than that of ODMRP, as shown in Fig 15. It is also found that, PUMA maintains almost constant EED with multiple sender scenarios also. This makes, PUMA as a more suitable protocol for video streaming applications. As PUMA is a mesh based scheme, even if there is a link failure, the packets are transmitted using the redundant path in mesh for efficient group communication.

V. Conclusion

In MANETs, both unicasting and multicasting can be used. But according to the performance analysis, specifically for group communications, multicast routing increases the efficiency and provides better performance when compared to unicast routing.

5.1 Future Enhancements:

In PUMA, core is responsible for creation and maintenance of mesh and forwarding the data packets. If the core node fails, core election takes place among the receivers. During the core election, energy of the receiver node is not considered. We can introduce an energy field in the Message Announcement packet, which can be used for electing a core node. Electing a node which posses higher energy as core will serve better, as core takes all the responsibility of creating and maintaining mesh as well as forwarding the data packets.

WMNs have been widely accepted in the traditional application sectors of ad hoc network. With increasing demand for real-time services in the next generation wireless networks, quality-of-service (QoS)-based routing offers significant challenges in WMNs. The multi constrained QoS-multicast routing has been proved as NP-hard problem. Further, based on genetic algorithm approach, multiple QoS parameters can be optimized simultaneously.

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