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Real-time Multimedia Transmission in open group Environment of MANETsusing SLIM+ Protocol: A Performance Evaluation

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Abstract: Although the mobility of nodes or computing devices may cause problem of link failure, a careful strategy used for routing protocols resolve one of the major issue associated with MANETs. The multicast routing protocols adopt either a tree-based configuration structure or a mesh-based configuration structure to maintain their state in stressed conditions posed to them in various scenarios. The research paper focuses on evaluating the performance of routing scheme used by SLIM+ for real-time multimedia streaming multicast in open group environment of MANET. Performance metric used is Throughput and Normalized Routing Load; comparing SLIM+ with its competitive and most commonly used MAODV and PUMA routing protocols for multicasting. It then observed that performance of SLIM+ is promising.

Keywords: Real-time, Open Environment, SLIM+, Stress1, Stress2, MANETs.

1. INTRODUCTION

MANETs are considered as networks that are organized due to the absence of any fixed network infrastructure. Here in these networks a host node acts as a router node, meanwhile all nodes can perform as source nodes and also forwarders of data traffic (Viswanath *et al.*, 2005). A group of random mobile devices or nodes when interconnected dynamically, they forms MANET. The communication among these devices is facilitated using a routing protocol which determines the routes amongst these nodes. The reason of adopting a routing protocol in MANET is to establish a true and effective route among a pair of nodes (Boukerche and Azzedine, 2009). Thus the messages from source to destination node(s) delivered in a timely fashion.

Preferably, a routing protocol for MANET should possesses general characteristics as well as particular characteristics of a mobile environment such as mobility, scalability, minimum overhead and bandwidth (Boukerche and Azzedine, 2009).

In MANETs, multicasting can well upkeep a range of one-to-many type applications. A scenario where users freely move here and there with a handheld device to wait for their flight at airport terminal. He/She may want to pass the time and regardless of knowing whoever is in the neighborhood needs to interact. Thus switches on the mobile or handheld device and detects someone in the network if interested in playing games, sharing information or other application likewise, see the scenario depicted in **(Fig. 1).** This kind of local area networking type application is intended for attention in the world of the near future.

Fig. 1. People awaiting at airport lounge interacting in real-time environment of MANETs

Cordeiro *et al.*, (2003) also addressed distinctive ad hoc network application, wherein users are mobile and a "community-centric" networking is formed using portable devices, Multicast is the careful propagation of messages to the destinations of a group. The resources are saved by creating copies of these messages only if the links on the way of destinations split, see Fig. 2.The mobile node in MANETs is responsible to send the same message or a data stream to a group of nodes

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having the common interest, in a routing protocol for multicasting. Communicating via multicast enables nodes to join or leave a multicast group when required. Here the maintenance of a multicast route is based on a routing tree or mesh, and due to the dynamic nature of a MANETs multicast routing protocols faces challenges (Boukerche and Azzedine, 2009).

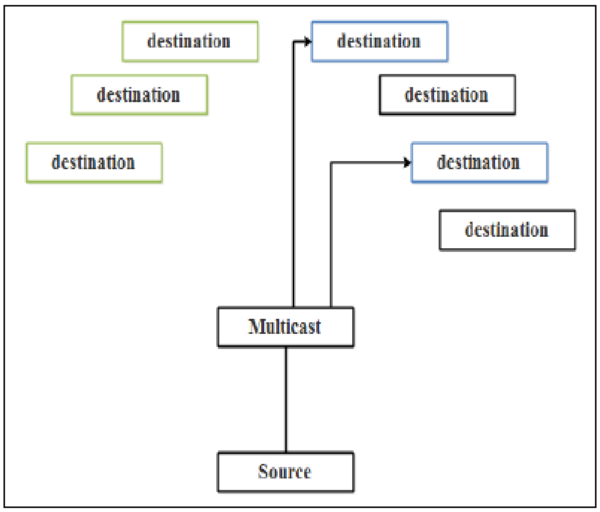

Fig 2. Multicast Message Transmission in MANETs (Adapted from Kaur, *et al.*, 2016)

The outline of the research paper is described as follows: Section 2. Endorses SLIM+ multicast routing protocol and its counterparts tree-based and mesh-based multicast routing protocols Section 3. Presents Simulation environment used. Section 4 is about results of performance evaluation and discussions.

2. SLIM+ AND ITS COUNTERPARTS: OPERATIVE STRATEGY USED BY MULTICAST ROUTING PROTOCOLS

This work mainly focuses on analyzing performance of SLIM+ by comparing it with a tree and a mesh based multicast routing protocols in MANETs. Specifically the study concentrates on the evolving need of real-time audio or video (multimedia) transmission in a one-to-many-type multicast scenario. Thus it is necessary to observe the impact of reconfiguration structure (tree/mesh) on join/leave of the nodes in such environment where rapid movement of nodes challenges the performance of protocols. There is very less work done yet for these type of applications so the gap/drawback possessed by these protocols is analyzed and their performance is observed while reviewing literature. Our study compares MAODV as a tree based and PUMA as a mesh based protocol with SLIM+. Various researchers (Sarwar, *et al.,* 2018); (Anwar *et al.,* 2012); (Werapun, *et al.,* 2007); (Aparna, 2010), worked on the performance evaluation of these multicast routing protocols. With the adaptation of MANETs in real-time scenarios the open group of nodes keep arriving and existing nodes departing the network as and when they like, the routing protocols need to be implemented to include the openness of the node set. The existing MANET protocols also lack their performance in applications offering real-time streaming in open groups. To address this gap, SLIM/Simple, Lightweight and Intuitive Multicast protocol is proposed (Shaikh, *et al.*, 2014). However during its implementation it was realized that the performance of SLIM varies with the choice of underlying unicast routing protocol. Further, for open groups, some kind of advertisement mechanism is much needed that lets the new comers inform about the availability of multicast stream. Then an improved version of SLIM termed as SLIM+ is developed to overcome the said limitations.

In SLIM+ protocol, the source node periodically advertises the availability of multicast stream by flooding an advertisement packet. An important aspect of this advertisement packet is that its propagation defines a distribution tree structure. Each node relays multicast data packets in the antenna range and interested listener nodes receives stream through them. Here each node gets flagged to multicast data steam. The source of the multicast transmission periodically floods an advertisement packet that announces the availability of the live stream. Each node upon receiving this broadcasted packet notes that the preceding node (that just relayed this packet) is actually the Next Hop to Source if it were to reach the source. Virtually this defines a dynamic distribution tree structure rooted at the source. The frequency of this Advertisement packet is soft defined and may be optimized to match with the mobility of the nodes in the network. Interested nodes periodically (after every seconds) sends MTREQ/Multicast Transmission Request to source node via Next Hop to Source to receive multicast transmission. All the nodes in that path of these MTREQs including the source node get set their forwarding flags to assure that they are intended to relay the transmission within T+D seconds. The cushion time here is D which is sufficient for the nodes to re-express their interest via the successive MTREQ packets. The intermediate nodes that are no longer in that path inevitably stop relaying the multicast stream on expiry of T+D interval of commitment.

Hence, nodes leaving the multicast session may simply stop sending their MTREQ packets. No information about the identification of the subscriber nodes is kept, hence resulting in a very low overhead. Each node including the source, will relay the data packets in its transmission range only if its Forwarding Flag is set. Thus data forwarding is achieved along optimal paths, see the pseudo-code for showing the mechanism.

Pseudo-code

```
Procedure SourceAdvertize(MulticastID)
1. AdvPacketNo = 0;
2. Do for ever
  2.1 AdvPacketNo++;
  2.2 P = new AdvPacket(MulticastID, AdvPacketNo)
  2.3 BroadcastPacket(P)
  2.4 Sleep(InterPacketGap);
Procedure JoinMulticast(MulticastID)
1. Set IamListening[MulticastID] = true
2. Do for ever
  2.1 P = new JoinRequestPacket(MulticastID)
  2.2 SendPacket P to Predecessor[MulticastID]
  2.3 Sleep(InterPacketGap);
Procedure OnReceivePacket(P)
1. if (P is an AdvPacket)
  1.1 if (LastAdvPacketNo[P.MulticastID] is undefined)
      1.1.1 Set LastAdvPacketNo[P.MulticastID] = 0
      1.1.2 Set Predecessor[P.MulticastID] = P.Sender
      1.1.3 Set IamListening[MulticastID] = false
      1.1.4 Set ForwardingFlag[P.MulticastID] = false
      1.1.5 Set FlagExpiryTimer[P.MulticasrID]=new
Timer(FlagExpiryTime)
  1.2 if P.AdvPacketNo>LastAdvPacketNo[P.MulticastID]
      1.2.1 Set LastAdvPacketNo[P.MulticastID] =
P.AdvPacketNo
      1.2.2 Set Predecessor[P.MulticastID] = P.Sender
      1.2.3 BroadcastPacket(P)
2. else if (P is a JoinRequestPacket)
  2.1 Set ForwardingFlag[P.MulticastID] = true
  2.2 Reset FlagExpiryTimer[P.MulticastID]
  2.2 if (ThisNode is not the Source of MulticastID)
      2.2.1 SendPacket P to Predecessor[MulticastID]
3. else if (P is a DataPacket)
  3.1 if (IamListening[P.MulticastID]==true)
      3.1.1 ConsumeDataPacket(P)
  3.2 if (ForwardingFlag[P.MulticastID]==true)
      3.2.1 Broadcast(P)
```

The pseudo code of SLIM+ shows the procedure of an advertisement packet when it is flooded. The response of nodes on receiving that. Multicast Transmission Request (MTREQ) packets moving via Next Hop To Source till reaches to source node. The pseudocode also informs about how duplicate packets are avoided. The minimum storage resource is used as flagged nodes and also presented the data forwarding mechanism.

MAODV routing protocol for multicasting is presented by Royer and Perkins. Royer and Perkins, (1999). It is a tree based protocol but depends on a unicast routing protocol i.e., AODV to create tree among the participating nodes. MAODV determines Route via Rreq (route request) and Rrep (route reply) cycle. A multicast source do broadcasting for aRreq packet in order to join a multicast group. This packet contains a join flag set and a destination address set (multicast group address). ARrep packet is sent back as a response by a multicast tree member which has a current route towards destination. Nonmembers rebroadcast the Rreq packet. Rreq packet when received then each node updates its route table and saves the sequence number also information of next hop for the source node, so that Rrep will be unicast to the source. On multiple replies the source node prefers the route with the newest sequence number or with the least hop count. The source then sends Mact (multicast activation) message activating the path from the source node to the node sending the reply (Viswanath, *et al.*, 2005). Whereas if a source node do not receives Mact message up to a certain time limit, it broadcasts other Rreq. Source node keeps on broadcasting Rreq and after a certain number of retries it assumes there are no members or unreachable nodes in the tree and declares itself as Group leader. The group leader periodically broadcast group hello (Grp-Hello) messages and thus maintains the connectivity. Rest of other nodes also broadcasts (Grp-Hello) message to maintain their local connectivity (Cordeiro *et al.*, 2003). A node when wishes to join in a multicast group, it then discovers a route to that group by using a broadcast Rreq to find the associated route to that group of a multicast tree.

In order to join a multicast group the node broadcasts a RREQ to determine route towards related multicast tree to that group. When a node leaves the multicast group, the tree structure needs pruning (Werapun, *et al.*, 2007; (Aparna, 2010).

The drawback of MAODV: Until the reconnection of broken tree MAODV suffers from long delays. Due to the shared tree based approach the protocol keeps more routing information which leads to overhead and poor PDR (Aparna, 2010).

PUMA is a protocol for Adhoc networks (Liu, *et al.*, 2010) and is proposed by Vaishampayan, in (2004). No pre-assigned core is required by PUMA to perform its operation. It is independent of using any unicast routing protocol for the routing. For the creation and maintenance of its mesh based routing structure PUMA signals out a multicast announcement via MA packet only. Between group members and non-group members a contact point is established as a core node which is elected by a receiver node. Here the multicast receivers join the core node through the shortest path thus creates a mesh routing structure. PUMA performs all the possible activities with MA control packet. This packet contains particulars such as sequence Number, group ID, core ID, distance To Core and parent information i.e., ideal neighbor to the core. Multicast announcements are transmitted by the core to the group periodically. If any change occurs in the status of core during this time, a new MA packet is then generated.

A receiver verifies the multicast announcement from the group on wishing to join that multicast group. If received then specified core in that announcement will be taken by receiver as its core. In other case if not received the announcement the receiver carries itself as a core and starts announcements for the neighborhood nodes. If there are various receivers to join a multicast group at the same time then the highest ID holding receiver is elected as core of the group. Due to mesh based routing structure PUMA delivers high robustness. A node forwards a multicast packet received from the neighborhood, on being the parent for that neighbor's node. The data packets when reaches the mesh, it then flooded within the mesh. Packet_ID cache is used to detect and dispose of the duplicate packets (Vijayalakshmi, *et al.*,2015).

The drawback of PUMA: The core of the mesh remains unchanged throughout the whole execution process (Nguyen et al., 2014). Congestion is a major problem with increased number of groups (Vijayalakshmi, *et al.*,2015).

3. LITERATURE REVIEW ON PERFORMANCE ANALYSIS OF PUMA AND MAODV

(Viswanath *et al.,* 2005)worked on multicast routing protocols. One of the protocols they observed is PUMA. The scenario used consisted of 45 nodes with up to 10 m/s mobility. Simulation is conducted on NS-2.35 Simulator and simulation time recorded is 200 sec. The concluded results shows that channel access of PUMA is more efficient. PUMA maintained stability for end-to-end delay metric among other metrics and thus it is witnessed more suitable for video streaming.

(Viswanath *et al.,* 2005) observed MAODV as unsuitable for mobility scenarios. The scenarios used consisted of 50 nodes with up to 15 m/s mobility. Simulation time recorded is 500 sec. It is perceived that increase in mobility requires MAODV to more frequently reconfigure the multicast tree structure and make it unable to keep the old routing information. This results in high control traffic and effects it negatively with the increase in loss of packets because of contention. The study observed that the ratio of successful packet delivery and group reliability in MAODV is not as good as of other routing protocols for multicasting but it has a low routing overhead.

(Aparna, 2010) worked on multicast routing protocols. One of the protocols they observed is MAODV. The scenario used consisted of 50 nodes. Simulation is conducted on NS-2.35 Simulator and simulation time recorded is 400 sec. In this performance evaluation MAODV is compared with a mesh based protocol to observe packet delivery ratio. It is concluded that the mesh based protocol was good at successful delivery of packets/PDR.

(Omari *et al.,* 2005); (Chen and Wu,2003)analyzed that PUMA has a very tight bound for the control overhead and high PDR compared to MAODV. The mesh constructed by PUMA provides redundancy to the region containing receivers.

4. SIMULATION ENVIRONMENT

(Fig. 3), (Table 1). Depicts simulation process and its environment and the description is as follows: NS2 (Network *et al.*,2.35) is an open source discrete event simulator used by scholars to carry research and education in networking. The community for NS2 has contributed a lot of code and it includes many protocols and traffic types. The latest simulator NS3 is still in the development phase and lacks the contribution from third parties (Font *et al.*,2011). Since NS3 is not backward compatible with NS2, many protocols as those we need for comparison with SLIM+ for our study were not available in NS3. Hence, NS2 is the most suitable simulator for the comparative assessment of different protocols. Our simulation network has 100 mobile nodes which are randomly placed within 800m x 800m area. The transmission range of nodes is 180 m and moves at a speed of 15m/s. Without any loss of generality, Random-way-point mobility model, which is easy to implement in the scenario, used in this study. For other mobility models, there is a need to graph the movement thus scenarios get complex. Data packet rate is 512 bytes. Simulation time for each scenario is 600 seconds. For efficient analysis, the performance evaluated with 20, 40, and 80 Simultaneous listener nodes as Stress1, For each of the group of these simultaneous listeners join- leave sessions per node as Stress2 is kept as 01 sessions, 02 sessions, 04 sessions, and 08 sessions. The reason to increase the number of simultaneous listeners is to check the scalability or handling of increased or almost doubled nodes. Whereas the join/ leave sessions observes the effect after the reconfiguration frequencies of distribution structures (tree based/ mesh based) on these protocols. As the protocol, SLIM+ developed for transmission of live multimedia streaming so the performance of SLIM+ analyzed and compared with respect to Throughput and Normalized Routing Load performance metric.

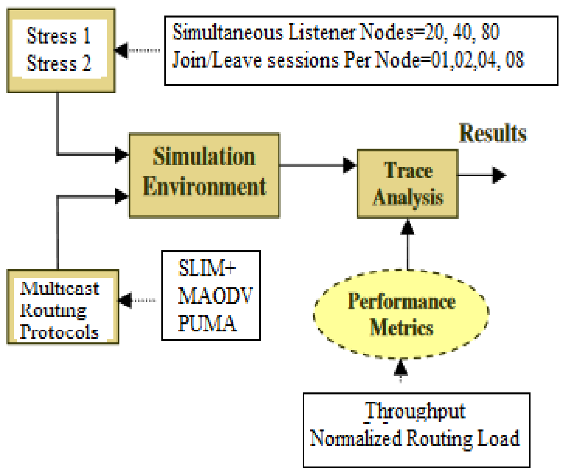

Fig. 3. Simulation Process

Table 1. Simulation Environment

Simulator	NS2.35
Total Nodes	100
Simulation Time	600 S (Seconds)
Node Placement	Random
Simulation Area	800x800 m^2
MAC Protocol	IEEE-802.11b
Transmission Range	180 meters
Speed Mobility	15 m/s Random Waypoint
Data Traffic Type	CBR 128 Kbps
Data Packet Size	512 bytes
Multicast Routing Protocols	SLIM+, MAODV and PUMA
Stress-1 (Simulation Listener Nodes)	20, 40, 80 Nodes
Stress-2 (Distribution Structure Reconfiguration	01, 02, 04, 08 Join-Leave Session Per Node

5. RESULTS AND DISCUSSIONS

There are 12 different executions conducted for each of SLIM+, MAODV, and PUMA protocols thus a collection of 36 different executions are considered to evaluate the performance metrics such as Throughput, and NRL/Normalized Routing Load. The advertisement or ADVmechanism is an exceptional functionality, which let the new nodes know about the availability of live multimedia streaming. Thus NRL of SLIM+ is evaluated with ADV(NRL of SLIM+) and also without ADV (NRL of SLIM+ w/o ADV). The results are depicted in section 4.1 and 4.2, **(Fig. 4-9).**

Discussion on Results of Throughput

Throughput Metric is the ratio of total data received by a receiver from a sender and the time spent till receiving the last message by the receiver. It is expressed in bits/sec or bytes/sec. Frequent topology changes in network, unreliable node communications, confined bandwidth and energy are the factors effecting the throughput results. In other words throughput is the received number of packets at destination in a certain time interval. Throughput is a metric used to show how much effective the routing protocol is (Goswami *et al.*, 2017). The Average network throughput is total amount of data received by the receiver from sender (s) of a multicast group divided to the time till a receiver takes the last packet (Badarneh *et al.*, 2009)

Throughput increases within the network capacity as the number of simultaneous listeners increases. When the stress1 is 20 and stress2 of join/leave sessions per node is 01 sessions then increases exponentially to 02, 04, and 08 the Throughput of MAODV, PUMA, and SLIM+ is between 1500 kbps to 2000 kbps. The graph in **(Fig.4),** shows that SLIM+ and PUMA both performed well than MAODV.

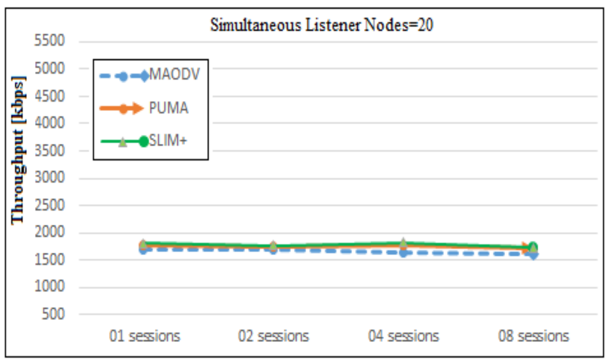

Fig.4.Throughput in kbps of MAODV, PUMA, SLIM+ with Stress1of 20 Simultaneous Listeners

When stress1 is 40 and stress2 is 01 sessions, 02 sessions, and 04 sessions, the Throughput of MAODV, PUMA get doubled and near to 3000 kbps approx. When stress2 is 08 sessions, it is observed that Throughput results of PUMA remained stable and MAODV abruptly dropped 2000 kbps whereas the Throughput results of SLIM+ are observed above 3000 and remained stable. The graph in **(Fig. 5)** shows that SLIM+ performed well than PUMA and MAODV.

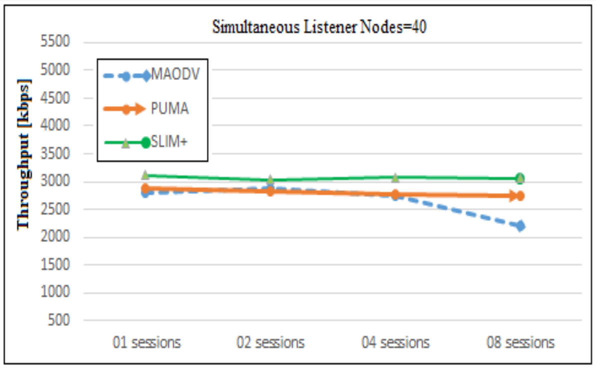

Fig.5. Throughput in kbps of MAODV, PUMA, SLIM+ with Stress1of 40 Simultaneous Listeners

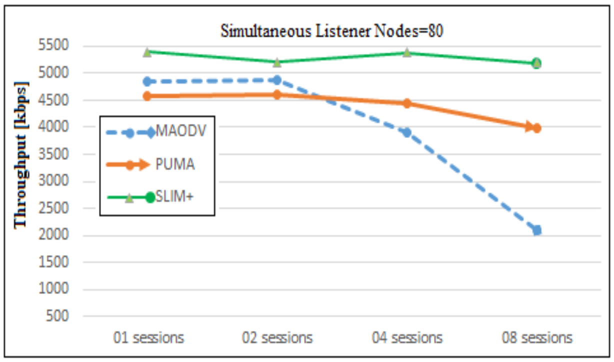

Fig.6. Throughput in kbps of MAODV, PUMA, SLIM+ with Stress1of 80 Simultaneous Listeners

When stress1 is 80 and stress2 is 01 sessions till 08 sessions, Throughput of SLIM+ get almost double and become 5500 kbps initially and then 5000 kbps. When stress2 is 01 sessions the Throughput of PUMA was initially 4500 kbps and MAODV was near to 5000 kbps. PUMA and MAODV did not maintain their Throughput due to unnecessary flooding and some redundancy of packets thus dropped to 3500 kbps and 2000 kbps one after the other respectively as stress2 increases exponentially from 02 sessions, 04 sessions and 08 sessions. SLIM+ ignores unnecessary flooding and redundant packets therefore it proves its stability as compare to PUMA and MAODV. The graph in **(Fig.6)** shows that SLIM+ still maintained the Throughput and performed well than PUMA and MAODV.

Discussion on Results of Normalized Routing Load or NRL

NRL metric is the ratio control packets used for the data transmissions in a simulation. This transmission relates to a node on sending or forwarding a packet. In other words, it is the routing load per unit data successfully delivered to the destination. Normalized Routing Load is therefore the total number of control packets a routing protocol generates while simulation (Goswami *et al.*, 2017). It is defined as the ratio of total number of data packets received to the total number of routing packets received.

When stress1 is 20 and stress2 of join/leave sessions per node is 01 sessions, NRL of MAODV, PUMA (Hussaini, 2019) and SLIM+ w/o ADV (Hussaini, 2019) is less than 0.1 whereas NRL of SLIM+ (Hussaini, 2019) due to performing additional advertisement function is approx.0.15. At the same stress1 when stress2 increases exponentially to 02 sessions, 04 sessions, and 08 sessions, the NRL of MAODV, PUMA, and SLIM+ w/o ADV gradually increased at around 0.2. The graph in **(Fig.7)** shows that SLIM+ without ADV, PUMA and MAODV has low NRL than SLIM+ with ADV.

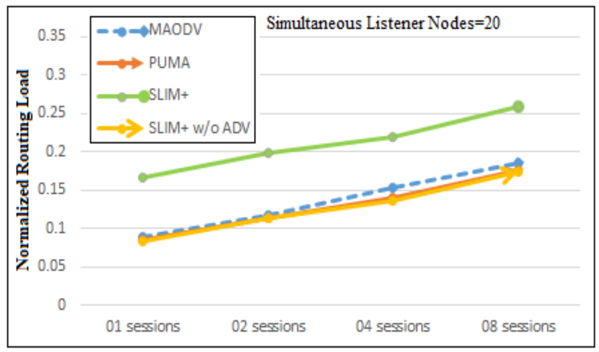

Fig.7. NRL of MAODV, PUMA, SLIM+ with Stress1of 20 Simultaneous Listeners

When stress1 is 40 and stress2 of join/leave sessions per node is 01 sessions, the NRL of MAODV, PUMA (Hussaini, 2019) and SLIM+ w/o ADV (Hussaini, 2019) decreased to half of the previous NRL i.e., 0.05, whereas NRL of SLIM+ with ADV [19] is also decreased to less than 0.1. At the same stress1 when stress2 is 08 sessions, it is observed that NRL of SLIM+ w/o ADV gradually increased to 0.1 and NRL of SLIM+ with ADV increased to 0.15, whereas NRL of PUMA and MAODV abruptly raised to 0.15. The graph in **(Fig.8)** shows that SLIM+ without ADV and PUMA has low NRL than SLIM+ with ADV and MAODV.

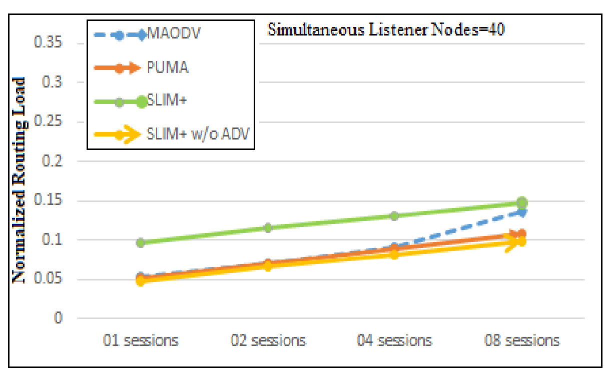

Fig.8. NRL of MAODV, PUMA, SLIM+ with Stress1of 40 Simultaneous Listeners

When stress1 is 80 and stress2 is 01 sessions, the NRL of MAODV, PUMA, (Hussaini, 2019) SLIM+ w/o ADV (Hussaini, 2019) and SLIM+ with ADV is less than or equal to 0.05. At the same stress1 when stress2 increases exponentially to 08 sessions, the NRL of SLIM+ w/o ADV observed same at approx. 0.05, while NRL of SLIM+ with ADV and PUMA gradually increased at more than 0.05 but less than 0.1, whereas NRL of MAODV is abruptly increased to 0.20. The graph in **(Fig.9)** shows that SLIM+ without ADV has low NRL than SLIM+ with ADV and PUMA. These protocols gives nearly same results but MAODV takes more NRL than rest of others.

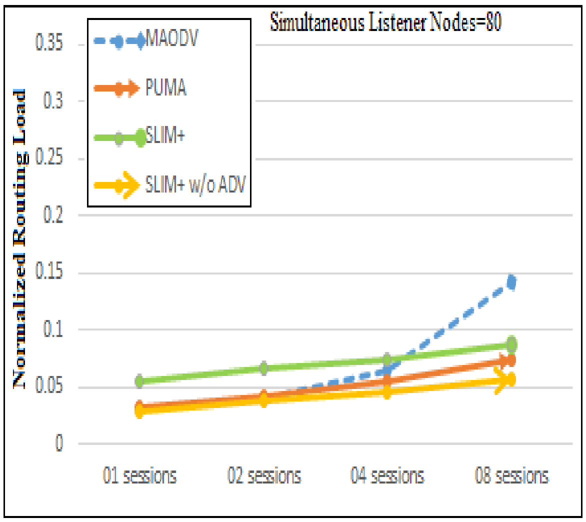

Fig.9. NRL of MAODV, PUMA, SLIM+ with Stress1of 80 Simultaneous Listeners

6. CONCLUSION

SLIM+ is a novel protocol in achieving multicast in open group MANETs. A lot of multicast routing protocols yet developed but they lacked their performance for one aspect or for the other. As most of them were designed to cater for teleconferencing type of multicast applications but nominal were targeted for one to many type multicast applications to facilitate real-time multimedia streaming, hence keeping the group membership was one of the major reason for their performance degradation under stress conditions. SLIM+ demonstrated through simulations and observed that it was indeed lightweight (as saves or note the preceding node and flag the nodes) and scalable; and is found fit for live streaming type multicast applications in open groups where tracking group membership is not easy. The contribution of SLIM+ is it fills a large gap that existed in the upcoming open-group type MANETs (like VANETs) and provide for media streaming applications e.g. TV/radio broadcast, advertising products and services, and community notice-boards and alerts. While performance evaluation SLIM+ was benchmarked against PUMA (a mesh based protocol) and MAODV (a tree based protocol). It was noted that under all stress conditions the new protocol SLIM+ outperformed PUMA and MAODV in all the dimensions observed.

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