Gauging the Scalability of SLIM+ Multicast Routing Protocol for Live Multimedia Streaming in MANETs

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Abstract
To propose and develop a multicast routing protocol for MANETs it is a challenge for a researcher to implement all possible characteristics of a multicast routing protocol to make it well performed. One of the major problem to cope with, is its scalability. It means if the number of nodes increases then the protocol should not intensely affected regarding the performance. For the transmission of live multimedia streaming or one-to-many type multicast applications in open-MANETs (any number of interested nodes which are in the transmission range may join in the network) a scalable multicast routing protocol is still in need by the researchers. SLIM+ (Advanced-Simple Lightweight Intuitive Multicast) which has a tree based distribution structure is introduced as a protocol to perform in open-MANETs for these type of multicast applications. SLIM+ ensures an advertisement mechanism that is much needed feature in open-MANETs (Vehicular Ad-Hoc Networks/VANETS and Local area social Networks). In this paper we gauged the scalability of SLIM+ protocol by comparing it with another popular tree based multicast routing protocol MAODV (Multicast Ad-hoc on-demand Distance Vector) with respect to its Packet Delivery Ratio (PDR) in a mobility scenario. The results clearly shows that SLIM+ routing protocol is indeed a scalable multicast protocol that performs well even in highly stressed scenarios where other protocol collapse. On increasing the number of simultaneous listener nodes and also varying the number of join/leave sessions per node as stress, the PDR of SLIM+ remained stable and successful. To gauge the scalability by increasing the number of nodes, SLIM+ out performed in delivering of packets where as the most renowned MAODV get affected and showed failure in successful delivering of packets (PDR).

Keywords:
open-MANETs, Scalability, Reconfiguration frequencies, Simultaneous Listener nodes, VANETs.

1. Introduction

Assemblage of wireless nodes to form an impermanent dynamic network due to lack of fixed infrastructure, for the exchange of information is designated as Mobile Ad hoc Network or MANETs [1]. MANETS also supposed to be, “networks without network”, because of its independence of relying on any fixed infrastructure [2]. The intermediate nodes perform like routers [3] and forwards data to other nodes in these networks. The communication established between distant nodes is consummate in a multi-hop fashion, thus a routing protocol is a need to find routes for end-to-end communication. Frequent and unexpected topological changes in MANETs due to extraordinary mobility of nodes is a very challenging task pertaining to routing.
MANETs are now used in several application areas in our daily life such as personal and commercial as well as for rare incidents like rescue operations [4].While deploying MANETs one of the major features which should be focused is scalability due to openness in these type of networks. Scalability in MANETs is referred to as an ability to efficiently handle the growth of network i.e. entertaining the increasing number of participating nodes [5]. Communication standards in these networks are termed as unicast or one-to-one communication, see Fig. 1(a) and broadcast or one-to-all communication, Fig. 1 (b).

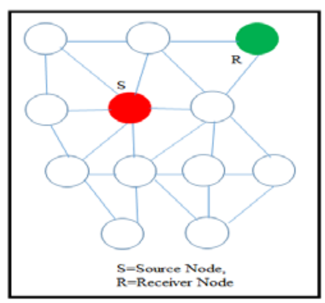

Fig. 1(a) Unicast communication

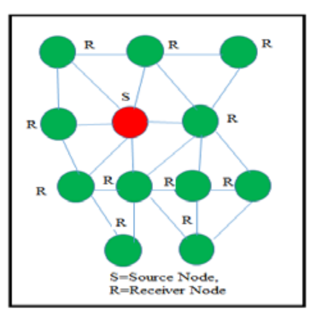

Fig. 1(b) Broadcast communication

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These both are two extreme modes of communications, but often a subgroup of nodes is the only target of a communication is termed as multicast, see Fig.1(c). Teleconferencing or live media streaming are the examples of Multicasting.

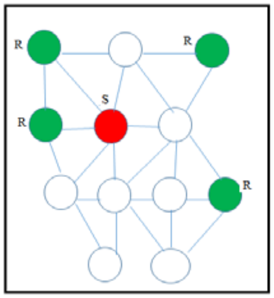

Fig. 1(c) Multicast communication

Further multicast can be enforced for one-to-many and many-to-many type of applications. Here in Fig.1 (a), (b), and (c) the node in red color is a sender node, and the node(s) in green color represents the receiver nodes while the white nodes are intermediate nodes (linked between red and green nodes) and also sometimes they are uninterested nodes. Intermediate nodes also acts as routers and forwards data to other nodes.

Communication in a multicast ad hoc network among a group of nodes gets affected from unsatisfactory consumption of inadequate resources. Therefore, the routing protocols for multicast should be competent enough for management of these resources. As the consumptions of resources relates to the factors like unicast or multicast network operations, topological changes due to freely movement of nodes, control overhead on growth of network i.e. scalability, loss of packets and need to retransmit because of crash and overcrowding. These are the factors that causes excessive load on the network, delay, and imbalanced utilization of resources. However, a clever scheme for multicast in routing protocols is more efficient than unicast routing in the protocols [6]. Some characteristics of a good multicast routing protocol [7] are:

Robustness: In MANETs some of the data packets may be dropped before delivering to the destination due mobility of nodes or topological changes, thus achieves a low packet delivery ratio or PDR. Therefore, a multicast routing protocol should greatly handle the issue of node movements and change in topology to achieve a high PDR and thus considered as robust.

Efficiency: Here efficiency means efficient multicast. It is defined as total number of packets received by the receivers to the total number of data packets and control packets sent or transmitted in the network.

Scalability: One of the significant characteristics, a multicast routing protocol should possess is providing an adequate service in a network when number of nodes increases [8], by taking into account of random mobility of nodes also. This characteristic is the main focus of our research.

Control Overhead: Low overhead by any multicast routing protocol is anticipated. So, keeping in view the bandwidth limitations for MANETs the protocols should be designed in such a way that they need less number of control packets transmissions for the maintenance of multicast group.

Unicast Routing Protocol Dependency: Sometimes routing protocols for multicast deals with different networks. To cope with different networks a multicast routing protocol should be independent of any unicast routing protocol.

Resource Management: Here the resources that a multicast routing protocol has to manage are like power management and memory management i.e. these should be used minimum.

In this research paper SLIM+ protocol is checked with respect to some of the possible characteristics addressed above and also the same are observed with another renowned tree based multicast routing protocol MAODV.

2. Working Of (Tree Based) Multicast Routing Protocols

The following detail provides working of tree based multicast routing protocols, SLIM+ and MAODV. Both are analyzed by keeping in view of the possible characteristics they adopt. While the main feature highlighted is their scalability. This feature is still being evolved by researchers for the protocols [12, 15]

2.1 Working of SLIM+

SLIM+ is an advanced and improved version of a previously proposed protocol SLIM (Simple Lightweight Intuitive Multicast) [13]. SLIM+ is a multicast routing protocol proposed and developed for multicasting live streams of multimedia in open MANETs. SLIM+ adopts tree based distribution structure and do not depends on any unicast routing protocol, fulfilling one of the characteristic discussed above [7]. The approach used here offers an open announcement of live multimedia stream like radio or TV type transmission availability. For that a source (S) node via an ADV (advertisement) packet periodically announces the availability of a multicast stream i.e., live multimedia transmission. The nodes on receiving this packet notes its preceding node which is then actually its Next_Hop_To_Source and thus creates a virtual link. The receiving nodes keep on advertising this packet to their neighborhood. This process continues like a wave front and finally creates a virtual tree. The frequency of this advertisement packet is soft defined and may be optimized to match with the mobility of the node in the network, see Fig. 2. Here node in red color is a source (S) node, the nodes in green color are the receiver (R) nodes interested in receiving the transmission whereas white flagged nodes are the intermediate nodes.

Join/Leave Mechanism: All the nodes of this tree are eligible to multicast the data packets in the aforementioned antenna range to the interested receiver nodes for the data stream. Now, after that if interested nodes (any) want to receive the radio/TV transmission they send MTREQ (Multicast Transmission Request) packet periodically in every T seconds to their preceding nodes via Next_Hop_To_Source. On receiving MTREQ packet the nodes in the path (including the source node) get flagged (for T+D seconds where D is a bonus time for the dependent nodes to re-respond) and this process continues until the MTREQ packet reaches to source (S) node. Any intermediate nodes which are no longer in the path of active subscribers automatically stops relaying the stream after the expiry of T+D commitment interval. Hence, nodes leaving the multicast session may simply stop sending their MTREQ packets. No information about the identification of the subscriber nodes is kept i.e. resources are efficiently managed, hence resulting in a very low overhead and satisfying two of the characteristics mentioned above[7].

Forwarding Data Packets: The data packet of Radio/TV Type multicast transmission by the source starts transmission following the path of flagged nodes until the data packet reaches to the receiver (R) nodes. The source node is also flagged to avoid unnecessary data transmission. Hence data forwarding is achieved along optimal paths.

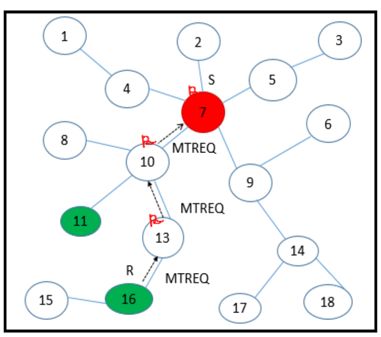

Fig. 2 Represents Working Of Slim+

2.2 Working of MAODV

MAODV is a tree based multicast routing protocol [9], Fig. 3. Shows the creation/construction of tree and the following description depicts its working. MAODV is an extension to a unicast routing protocol AODV, thus it depends on a unicast routing protocol overlooking one of the characteristics mentioned above.

Join/leave Mechanism: In this protocol a packet (with a joint flag and address of destination) for ROUTEREQUEST (RREQ) is broadcasted when source needs a route towards a multicast group. Using the up-to-date route towards the destination a member of multicast tree responds for it with ROUTEREPLY (RREP) packet. While the non-members rebroadcast RREQ packet, and on receiving this packet each node up-to-date its route table by recording sequence number and information of next hop to unicast the RREP towards source node. On receiving more than one RREP packets from receivers the source only accepts the route which has the least hop count or the newest sequence number. After this an (MACT) MULTICASTACTIVATION message is sent so that the route or path gets activated from the source to the node that sends the reply. If an MACT message is not received by the source in a certain time, it starts broadcasting another RREQ. Source keeps on trying for RREQ up till a certain period and if not received any response the source assumes that there is no member and thus it declares itself as a group leader. To maintain the connectivity in the group, the periodic broadcast (with Time-to-live/TTL=1) of GROUPHELLO message is the responsibility of the group leader [10].

Forwarding Data Packets: MAODV uses a bidirectional shared multicast tree. A periodic group Hello message is sent by a group leader maintains the multicast tree. The use of bidirectional tree in MAODV in comparison of any mesh based structure is considered as more efficient with respect to its control on receiving redundant data to the receivers. MAODV unicast the reply to source, the intermediate node then if goes out of way the reply is vanished and thus loses the route. Because there is no immediate activation to the multicast route in MAODV. The deserving multicast receiver waits for the stated time for the RREP to multiple receivers prior to send an MACT message, this shows ignoring of efficient handling of resources i.e., one of the characteristic mentioned above[7]. The MACT message guarantees that the multicast tree is without any multiple paths to the tree nodes. The nodes forward data packets using the activated routes according to their multicast route tables [11].

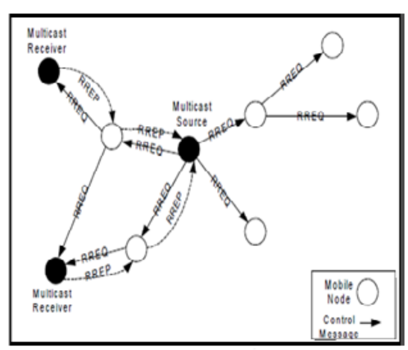

Fig. 3 Maodv Tree Creation (Adapter From [11])

3. Comparison of SLIM+ vs. MAODV

SLIM+ and MAODV both takes on tree based distribution structure, MAODV is an extended version of AODV (unicast routing protocol) while SLIM+ is an advanced version of SLIM. MAODV depends on a unicast routing protocol AODV whereas SLIM+ do not depends on any unicast routing protocol. SLIM+ efficiently manages resources such as requires less memory for the flagged nodes while forwarding data, and possesses low overhead. On the other hand RREQ and RREP mechanism in MAODV inefficiently handles the resources ignoring major characteristic i.e., resource management [7]. SLIM+ provides an advertisement service which supports it to announce for live multimedia among the newly coming nodes (open-MANETs). In contrast MAODV do not possess such feature. The other characteristics such as robustness, efficiency, and scalability are evaluated in a total of 24 experimentations in the results section.
Both multicast routing protocols described and compared in detail. Table-1. summarizes the main some of the main comparisons between them.

Table 1: Summarized comparison of MAODV vs. SLIM+

Protocol	Distribution structure	Control Packets	Unicast Dependency (Yes/No)
MAODV	Tree based	RREQ, RREP, GROUP_HELLO, MACT	Yes
SLIM+	Tree based	MTREQ, ADV, SLIM+	No

4. Simulation Environment

The simulation environment is shown in Table 2, while a few important things that need to be explained more are discussed here. There are two types of stress imposed in the scenarios to experiment the tolerance careful strategy of the protocols. Stress1 is no. of simultaneous listeners which observes the scalability. It reflects that as much as the simultaneous listener nodes increases the data should be delivered to that much number of nodes respectively. When 20 percent of nodes out of 100 nodes become the simultaneous listeners the data is delivered to a less number of listeners, this stress is considered a low stress in discussion. When 40 percent of nodes become the simultaneous listener nodes the data is delivered to a more increased number of listener nodes, this stress is considered a medium stress in discussion. When 80 percent of nodes out of 100 nodes become the simultaneous listeners then data is delivered to even more increased number of listener nodes and this stress is considered a high stress in discussion. These low medium and high stress are very carefully chosen after various experimentations. Finally, 24 executions (12 executions for each) of same scenarios on SLIM+ and MAODV were finalized to show the performance of the best protocol amongst them, see Table 3 and Table 4. It is to note that the stress1 (low, medium, high) is not increasing linearly but it is doubled. The stress1 is also investigated linearly in the beginning when the protocol was initially developed but to achieve promising results it was doubled.

Table 3: (No. of Executions for MAODV = 12)

Protocol	Stress1 Simultaneous Listener Nodes	Stress2 Join/ Leave sessions per node	PDR
MAODV	20	01 sessions	0.672
MAODV	20	02 sessions	0.676
MAODV	20	04 sessions	0.653
MAODV	20	08 sessions	0.648
MAODV	40	01 sessions	0.621
MAODV	40	02 sessions	0.637
MAODV	40	04 sessions	0.612
MAODV	40	08 sessions	0.488
MAODV	80	01 sessions	0.57
MAODV	80	02 sessions	0.572
MAODV	80	04 sessions	0.459
MAODV	80	08 sessions	0.248

Table 4: (No. of Executions for SLIM+ = 12)

Protocol	Stress1 Simultaneous Listener Nodes	Stress2 Join/Leave sessions per Node	PDR
SLIM+	20	01 sessions	0.723
SLIM+	20	02 sessions	0.708
SLIM+	20	04 sessions	0.73
SLIM+	20	08 sessions	0.691
SLIM+	40	01 sessions	0.691
SLIM+	40	02 sessions	0.673
SLIM+	40	04 sessions	0.683
SLIM+	40	08 sessions	0.68
SLIM+	80	01 sessions	0.635
SLIM+	80	02 sessions	0.612
SLIM+	80	04 sessions	0.633
SLIM+	80	08 sessions	0.611

The second type of stress2 is posed by the reconfiguration of distribution structure. Each time a node joins it creates a link or a branch in the distribution structure and when the node leaves the distribution structure must prone that branch. Every time when a node joins the network, it reconfigures the distribution structure i.e. tree. Likewise, when a node leaves it also creates a disturbance in the network and thus reconfigures distribution structure (tree). So, for the network of 100 nodes when a node joins 8 times (it may be any number of times) then 8 (join sessions)*100 (nodes) =800 is the reconfiguration frequency of the distribution structure. Similarly when a node leaves the network 8 times then 8 (leave sessions)*100 (nodes) =800 times the tree reconfigures. Thus, a total of 1600 reconfigurations are done in the distribution structure.
For those protocols that manage their distribution structure tediously, get stuck and their performance suffers whereas the protocols that uses the dynamic mechanism to manage their distribution structure could not perform worst. And that is actually depicts the best protocol for multicast routing. Without any loss of generality Random-way-point mobility model is used, see Table 2; it is easy to implement.

For other models there is a need to graph the movement of nodes thus the scenarios get complex.

Table 2: Simulation Environment

Simulator	NS2.35
Total Nodes	100
Simulation Time	600 sec.
Node Placement	Random
Simulation Area	800x800 m2
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+ compared with MAODV
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 Discussion

The main objective of the research was the development of a novel multicast routing protocol that particularly targets to multicast live multimedia streams to an open group of receivers (open for all in the transmission range), and the protocol should be scalable and acquire high PDR, i.e., rest of the above highlighted characteristics mentioned above[7]. For that multicast scenarios of varying complexities are prepared in order to gauge the performance of the protocols. The results presented cannot be obtained without designing scenarios, clearly seen in Table 3 and Table 4 also in Fig.4, Fig.5, and Fig.6. It is obvious that the results show the successful achievement of the objective. In a typical MANET scenario definition of PDR is the packets delivered/packets sent.

PDR=Packets_delivered/packets_sent

But for the multicast scenario definition of PDR is the successful delivery of data packets/no. of data packets supposed to be delivered.

PRD=Packets_delievered/packets_supposed_to_be_ delivered

Here, for each of the low, medium, and high stress of simultaneous listeners, 4 different reconfiguration frequencies (Join/leave sessions) are applied. It is observed that when the stress is low i.e. simultaneous listeners are 20 and join/leave sessions are 04 PDR of MAODV decreased a little bit compared to SLIM+, see Fig.4. Similarly, when the stress is medium i.e. simultaneous listeners are 40 and join/leave sessions are 04 PDR of MAODV obvious in showing worst performance with respect to delivery of packets compared to SLIM+, see Fig.5. Likewise when the stress is high i.e. simultaneous listeners are 80 and join/leave sessions are 02 PDR of MAODV starts behaving worst performance in the delivery of packets compared to SLIM+, see Fig.6.While in these scenarios the stress did not shows degradation in performance of SLIM+ i.e. it remained stable.

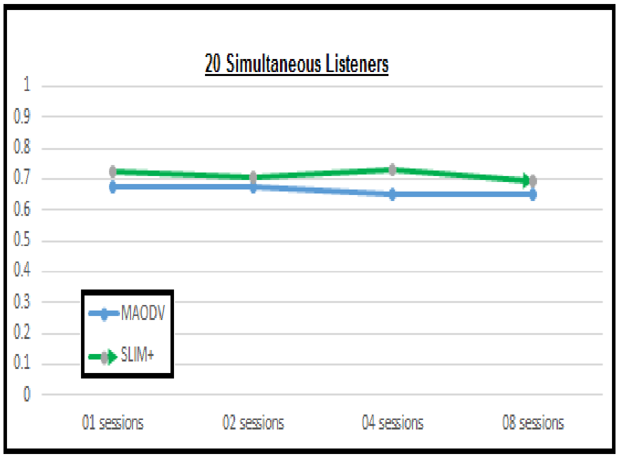

Fig. 4 Packet Delivery Ratio (PDR) When Simultaneous Listeners=20

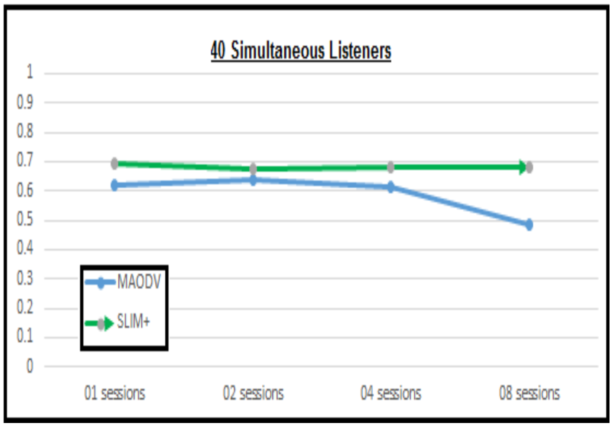

Fig. 5 Packet Delivery Ratio (PDR) When Simultaneous Listeners=40

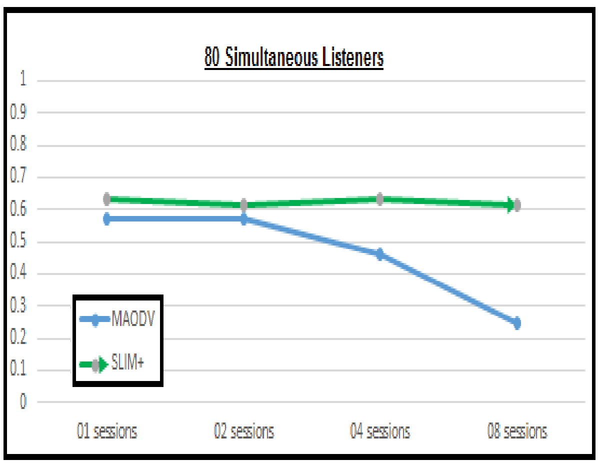

Fig. 6 Packet Delivery Ratio (PDR) When Simultaneous Listeners=80

6. Conclusion

From the working of SLIM+ and MAODV it is clear that SLIM+ do not suffer from long delays or high overhead as MAODV does. It is also discussed that regarding memory management a very less data is kept i.e., for the flagged nodes to forward data. While the results depicts the robustness via PDR. By increasing the number of simultaneous listener nodes scalability of SLIM+ is also proved. It is clear that SLIM+ efficiently handled multicasting thus achieved good PDR and well maintained scalability. It is natural that due to increased number of simultaneous listeners the PDR of good protocols slightly comes down but should remain stable at stress with all reconfigurations of the distribution structure. From the results it is concluded that SLIM+ is more scalable and group size does not affect its performance, i.e., it is efficiently handling the increased number of simultaneous listener nodes. Also with increased mobility speed of 15 m/s SLIM+ maintained itself in achieving high PDR.As the multicast routing protocols yet developed do not handles live multimedia streaming in open groups rather they work for closed groups. SLIM+ handles randomly selected increased number of nodes in static scenarios as well[14] .It is now obvious that on applying the same stress on MAODV in a mobility scenario, its PDR get worst and the protocol could not maintained its performance. This is the major contribution of SLIM+ that it successfully follows all the characteristics and provides its additional service of advertisement for every node to perform well in open-MANETs for live multimedia streaming.

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