Sindh Univ. Res. Jour. (Sci. Ser.) Vol 49(1) 219-224 (2017)

SINDH UNIVERSITY RESEARCH JOURNAL (SCIENCE SERIES)

Evolution of a Robust Multicast Routing Protocol for Open-MANETs

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Received 14th July 2015 and Revised 17rd May 2016

Abstract: Despite huge research available on MANET, a lot is yet to be done, particularly the development of routing protocols optimized for specific applications. Since infancy, MANETs were optimized for applications where group management is strict. However, with the advent of VANETs and local area social networks as offering of MANETs to common people (we call open-MANETs), there is a need to revise routing protocols to allow for this open-ness. In this paper we draw our attention to multicast routing protocol for applications where group management is not an essential aspect to deal with. A brief survey of existing multicast routing protocols including MAODV and PUMA is accompanied by a discussion regarding the evolution of SLIM+ protocol; that is specifically targeted for such open-MANETs. In this paper we also compare these three multicast routing protocols with respect to their robustness.

Keywords: One-to-Many Multicasting; VANETs; Local Area Social Networks; SLIM

1. INTRODUCTION

MANETs (Mobile Ad-Hoc Networks) are self-organizing networks, consist of mobile nodes communicating with one another through wireless links without any fixed infrastructure (Mukherjee, *et al.*, 2003), (Kumar, and A. Kush, 2012).The communication between nodes in these networks is therefore multi-hop in which intermediate nodes are routers that forward data packets for other nodes (Leung, *et al.*, 2001). As the intermediate nodes also acts as routers, the network topology becomes highly dynamic and unpredictable. Routing (i.e.: discovery and maintenance of efficient routes (Leung., *et al.*, 2001) is quite challenging in such environments. Unicast routing can connect a single source to a single destination in the network, which is not feasible for real-time applications of MANET thus require multicasting (Kumar, and Dev, 2014), (Meghanathan, 2011), (Perkins, 1997). Multicasting enables a group of nodes to receive data sent by a single sender. Some examples of Multicast applications include: Traffic advisory, Multimedia streaming like radio or TV, and teleconferencing between rescue workers or military officers.

MANETs can be classified specifically with respect to group management. Typically MANETs used to be a closed group of hosts communicating each other. In closed group multicast, group members are well-defined, anyone else cannot join or leave the network due to group management as the example of teleconferencing between rescue team or group of military officers is mentioned previously. With the of time MANETs are becoming popular in common people, we see VANETs (Memon, *et al.*, 2014) and local area social networks (Stefan Stieglitz , Christoph 2011) evolving as open-MANETs. In open-MANETs multicast anyone can join and be the member of the group, as there is no need of group management required for real-time streaming or TV/Radio streaming in open groups. The routing protocols need to be re-addressed to include the openness of the node set. The existing MANET protocols lack their performance in maintaining the group membership which can be quite big and highly volatile in applications offering real-time streaming.

In this paper Section 2 will describes working of most commonly used multicast routing protocols and SLIM to be compared with Section 3 that discusses SLIM+. Section 4 will present the simulation environment followed by the results and conclusion in sections 5 and 6 respectively.

2. MULTCAST ROUTING PROTOCOLS

2.1. The MAODV (Multicast Ad-hoc On-Demand Distance Vector

MAODV routing protocol is an enhancement to AODV (Moustafa, 2004) (Perkins, 1997). It uses a shared tree based approach and is a reactive protocol which means for tree construction and maintenance it creates routes when needed or on demand. Its working (Royer and Perkins, 2000) and then shortcomings observed are described as:

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2.1.1. Tree construction

The multicast routes in MAODV are constructed through a broadcast discovery mechanism. The leader is the first member of the multicast group, which monitors the multicast group sequence number and propagates a group HELLO message to the multicast group. This information is consumed by nodes to update their Route_Request table.

2.1.2. Tree maintenance

The expending ring search or ESR is used to keep the MAODV tree maintained. The broken links between nodes is repaired on circulating a RREQ packet by ESR through the downstream node. A node with the lesser or equal Hop count towards the multicast group leader with respect to the value indicated in the RREQ packet can response. The downstream node when does not get reply, it acknowledges as the multicast tree is divided, and it becomes designated as the new leader of the multicast group. Till the reconnection, the multicast tree remains in parts which may lead to problems.

2.1.3. Observed shortcomings

Its dependency on AODV. The protocols using shared tree based or core based approach keeps more routing information which leads to overhead, this implies to MAODV also. MAODV behaves critical while fixing broken links. Also it suffers from long delays and high overheads in high mobility and traffic load situations (Sutariya, 2016).

2.2. The PUMA-Protocol for Unified Multicasting through Announcements

PUMA (Vaishampayan, and Garcia-Luna-Aceves, 2004) is still a most commonly approached mesh-based multicast routing protocol for MANETs. It uses a unique control packet called Multicast Announcement/MA for all mesh maintenance routines. In this protocol, every source is eligible to send multicast data packets towards a multicast group. The unique announcements in PUMA are capable of performing the following (Mohammed, 2009), (Wang and Gupta, 2003), (Chiang and Huang, 2003):

2.2.1. Multicast announcement

MA packet is composed of Group ID, Core ID, Distance to Core, parent node sending latest announcement and notifies other nodes while an announcement is been sent.

2.2.2. Dynamic election of core node

Among the receiver nodes of the group, PUMA elects a node as a core node and inform every router about the relative next hop to the elected core in each group. Each router may have one or more than one path towards the core. Receiver follows the shortest path towards the elected core. Each mesh member then flooded with the data packets and to avoid the duplicate transmission these packets are numbered. On receiving duplicate data packets, there numbers are checked and thus dropped if redundant (Mohammed, 2009).

2.2.3. Mesh construction and Maintenance

The M_Flag that indicates that the node is a mesh member, is set TRUE for all the receiver nodes initially. Whereas the nodes which are not receivers are considered as mesh membersif:(i) in the connectivity list there is a minimum of one mesh child. (ii) a neighbor in the connectivity list is considered to be a mesh child if its M_Flag is set Trueor the distance to neighbor’s core is more than the nodes own distance to core. The MA here must be received in within a time which is equal to two MA intervals, ensuring that neighbor lies in the neighborhood. An immediate mesh child is a mesh member whose path is the shortest from a receiver to the core.

2.2.4. Observed shortcomings

The performance of the protocol may weakens if a multicast message once reaches a mesh member, it floods in the entire mesh. This flooding increase the overhead due to mesh-based distribution structure and may receive a redundant multicast message(S. Sumathy, *et al.*, 2012). Its group management may be challenging for the applications offering real-time streaming in open groups.

2.3. The SLIM-Simple Lightweight IntuitiveMulticast

SLIM is proposed for real-time video multicast. The approach suggests construction and maintenance of multicast tree-based distribution structure in the dynamic and highly volatile environment of MANETs. The novelty of SLIM is its multicasting in MANETs for live multimedia streams. As the name implies SLIM is simple lightweight, intuitive and protocol but used with any underlying unicast routing protocol (Shaikh *et al.*, 2014).

2.3.1. Tree construction and maintenance

For the construction of a dynamic multicast tree based structure the intermediate nodes are responsible to transmit or multicast the packets in their range as long as the receivers or other intermediate nodes show their concerned to receive the stream. In order to receive transmission a single flag is used to indicate that the nodes are interested as routers or receivers. The interested receiver(s) periodically sends a Multicast_Transmission_REQuest (MTREQ) message on the way to the source node through a unicast routing protocol. All the intermediate nodes whose flag is set TRUE including a source node, also transmits the multicast stream for the next T+D seconds i.e., including the cushion time D, for the routers or receiver nodes to re-express their interest.

2.3.2. Join/leave mechanism

The intermediate node or routers are responsible to transmit within T+D seconds from the last MTREQ received by the subscribers or receivers. For that only a single flagis required as the routing record. If a router or intermediate node does not exists in the path of any the subscribers it will automatically stops transmitting the stream after the committed interval i.e., till T+D expires.

2.3.3. Observed shortcomings

SLIM is proposed but lacks implementation so performance metrics are not evaluated thus results are unavailable. SLIM is dependent on any underlying unicast routing protocol. It is also deficient in advertisement mechanism that makes the new comers informed about the availability of live media streams in open-MANETs.

2.4. The SLIM+: Advanced Simple Lightweight Intuitive Multicast

SLIM+ periodically advertises availability of multicast stream through the source node by flooding an advertisement (ADV) packet. A distribution tree structure is defined by the propagation of this advertisement packet. The nodes in the tree are committed to transmit the multicast data packets in their antenna range on request of interested receiver nodes. For that a single flag is set in the path of each node including source and intermediate node (s). The procedures followed by SLIM+ are described as (Hussaini, and Shaikh, *et al*, 2016):

2.4.1. Advertisement Packets and Distribution Tree

An advertisement packet is flooded periodically by the source of multicast stream to announce the

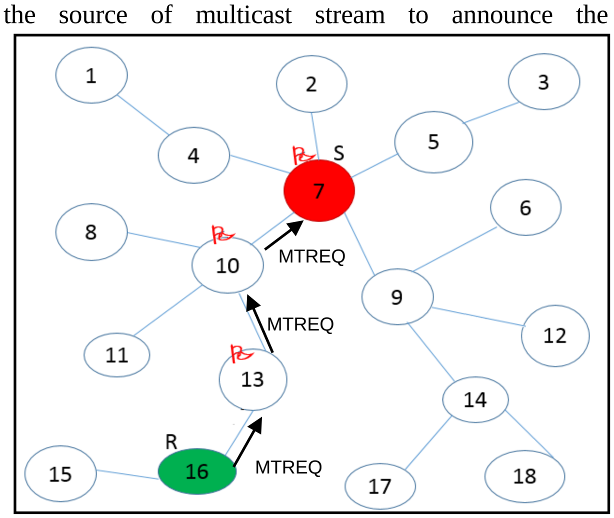


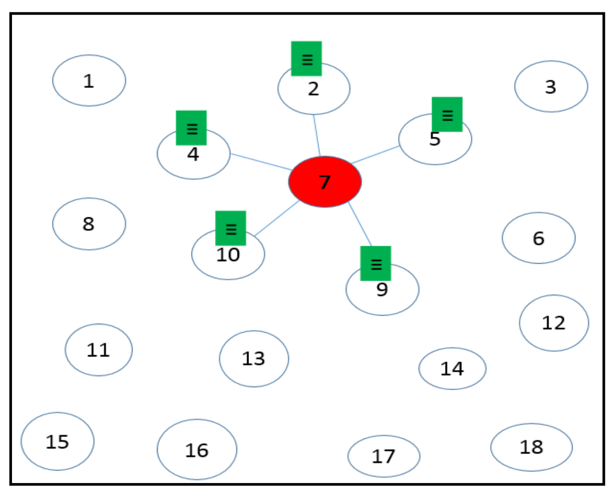
Fig. 1. Propagation of MTREQ within TreeDistribution of

availability of live stream. On receiving this broadcasted advertisement packet each node notes its *Next Hop To Source* which is actually its preceding node, finally reaches to source. Practically this describes a dynamic distribution tree structure rooted at the source. The frequency of the advertisement packet is soft defined and may be optimized to match with the mobility of the nodes in the network .

(Fig. 1). Shows a small network of 18 nodes. Node 7 is the multicast source, transmitting the ADV packet in its antenna range. The receiver nodes of this ADV packet are 2, 4, 5, 9, and 10. These nodes repeats the same process to propagate the ADV packet through the intermediate nodes and so on, forming a wave front across all the network. The ADV packet is having a sequence number to avoid the cycles. Thus creates an optimal distribution tree, **(Fig. 2).**

2.4.2. Joining/leaving multicast session

To receive the transmission the interested nodes send MTREQ (Multicast_Transmission_REQuest) packet to the source node through *Next Hop To Source*, periodically after every T seconds. The nodes including the source in the path of this MTREQ message sets it Forwarding_Flag to relay the transmission for the next T+D seconds. Here D is the spare time adequate enough for the dependent subscribers or receivers to re-express their interest in receiving the transmission through the MTREQ packets. The intermediate nodes which are not being the active subscribers i.e., out of path stops transmitting the stream automatically when the said T+D committed interval expires. Thus, nodes leaving the multicast session simply stops sending their MTREQ packets (Hussaini, *et al.*, 2016).



Advertisement Packet

In Fig. 2 node 16, being a receiver, sends MTREQ packet towards node 7 (the source) hence committing nodes 13, 10 and 7 to relay the transmission for next T+D seconds by setting their Forwarding Flags.

Forwarding Data Packets

Each node including the source, will relay the data packets in its transmission range, only if its Forwarding Flag is set. Hence data forwarding is achieved along optimal paths (Hussaini, *et al.,* 2016).

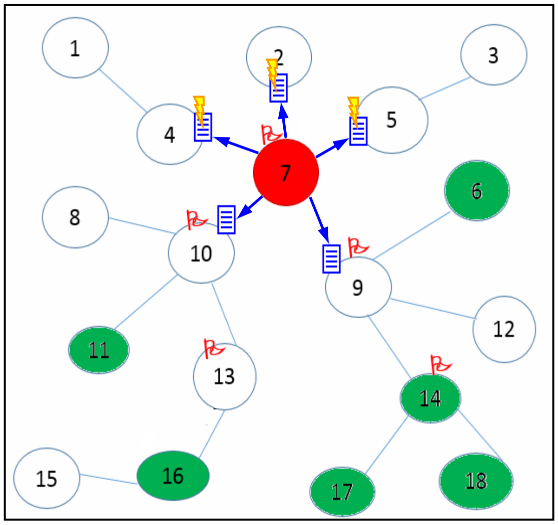


Fig. 2. Data Forwarding

In **(Fig. 3),** the packet sent by node 7 is shown to be received by all of its neighbors 4, 2, 5, 9 and 10; however, only nodes 9 and 10 will retransmit the packet as their forwarding Flag is set and the other nodes will ignore the packet. The packets forwarded by nodes 9 and 10 will subsequently be received by nodes 6, 12, 14, 13, 11 and 8; of these, nodes 6, 14 and 11 will consume the packet and 14 and 13 will relay it again in their neighborhood delivering it to the rest of the recipients.

The working and deficiencies of most commonly approached routing protocols Like MAODV, PUMA, and SLIM are discussed. One of the most important metric used to evaluate a multicast routing protocol is its robustness which determines that how strong it survive and resist in high mobility environment and achieve a high packet delivery ratio (Baker and Akcayol, 2011). Experimentations are conducted to compare the robustness of the evolved protocol SLIM+ with MAODV and PUMA.

3. SIMULATION ENVIRONMENT

In order to gauge the performance of SLIM+, MAODV and PUMA Network Simulator NS2.35 is used.

The scenarios designed offer two types of stress to the multicast protocols under study. One is the size of the multicast group (the number of simultaneous listener nodes) and the other the other is the join leave sessions per node. The distribution structure (tree or mesh) is subject to change its topology each time a node joins or leaves the group. So number of join-leave session per node was used to vary the frequency of change in distribution structure. **(Table-1)** summarizes the variations in the scenarios that we chose to compare the performance of SLIM+ MAODV, and PUMA protocols. The table also displays other simulation parameters used in this study.

Tabke -1, Simulation Parameters

Parameter (s)	Value (s)
No. of Nodes	100
Area	810m x 810m
Simulation Time	110 sec
Transmission range	180m (optimized)
DataRate	128 Kbps
PacketSize	512 bytes
MAC Protocol	IEEE 802.11b
Node Placement	Random
Protocols Used	SLIM+,MAODV, PUMA
Simultaneous Listeners Stress1 (Avg group size)	20, 40, 80
Num. of sessions (join-leave) per node Stress2	5, 10, 20

4. RESULTS

SLIM+, MAODV and PUMA protocols were simulated under the stress conditions indicated in Table 1. QoS parameters –viz. Packet delivery ratio is observed as performance metric. **(Fig. 4, Fig. 5, Fig. 6)** compares the observations made. In the following sub section the observations are discussed.

4.1. Packet Delivery Ratio

In multicast, Packet Delivery Ratio (PDR) is the ratio of the number of data packets delivered to the number of data packets that were supposed to be delivered (S. Sumathy, *et al.,* 2012).

4.1.1. PDR achieved after 20 Simultaneous Listeners

The **(Fig. 4).** Shows that on implying Stress1 of 20 simultaneous listeners and Stress2 of 5, 10sessions, MAODV initially perform well than PUMA but suddenly crash when stress2 increased to 20 sessions. In the same scenario PUMA remained consistent in Stress1 and Stress2, while its PDR remained low. Whereas SLIM+ remains stable in the scenario in 5, and 10 sessions with a slight degradation when the Stress2 reaches to 20. Overall PDR of SLIM+ out performed PUMA and MAODV

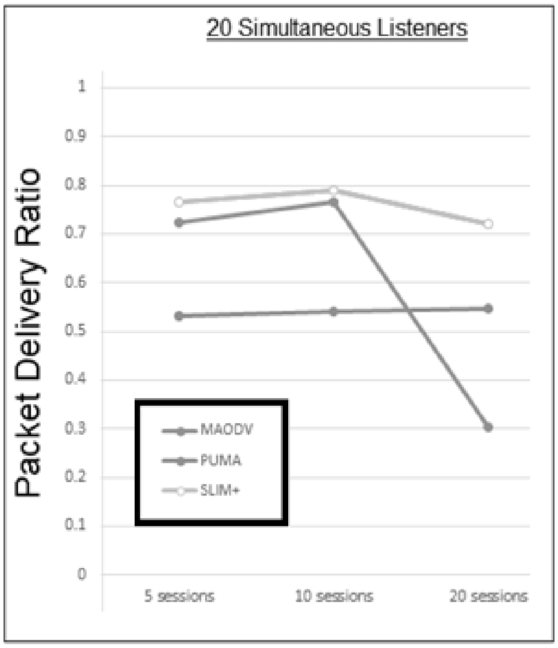


Fig. 4. PDR achieved with 20 Simultaneous Listeners

4.1.2. PDR achieved after 40 Simultaneous Listeners

The **(Fig. 5).** Shows that on implying Stress1 of 40 simultaneous listeners and Stress2 of 5 sessions, MAODV initially outperformed than PUMA and SLIM+, but suddenly starts degrading its performance when stress2 increased to 10, and 20 sessions. In the same scenario PUMA remained consistent in Stress1 and Stress2, while its PDR remained low. Whereas SLIM+ kept its state stable in the scenario with a high PDR than PUMA and MAODV.

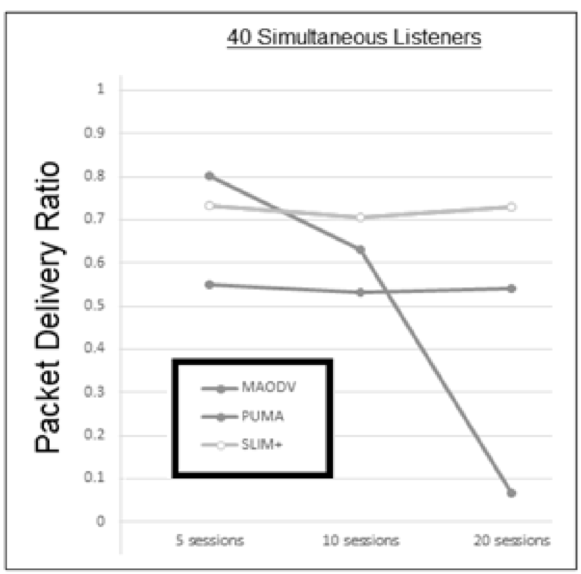


Fig. 5. PDR achieved with 40 Simultaneous Listeners

4.1.3. PDR achieved after 80 Simultaneous Listeners

The **(Fig. 6).** Shows that on implying Stress1 of 80 simultaneous listeners and Stress2 of 5 sessions, MAODV performed worse than PUMA and SLIM+, but slightly starts improving its performance when stress2 increased to 10 sessions, however cannot maintained its state and crash in stress2 of 20 sessions. In the same scenario PUMA remained consistent in Stress1 and Stress2, while its PDR remained low. Whereas SLIM+ kept its state stable in the scenario and achieved high PDR than PUMA and MAODV but while dealing with stress1 of 80 simultaneous listeners PDR slightly decreased but compete and become robust than PUMA and MAODV.

5. CONCLUSION

Existing multicast routing protocols in MANETs are targeted towards many-to-many type of multicast applications and there was a need for a protocol that is particularly optimized for one-to-many type of multicast applications (like TV/radio streaming). Further MANETs are typically considered to be a closed group of nodes, but with the shift of focus toward VANETs and Local Area Social Networks, a multicast protocol was needed that could deliver to an open-group of nodes and scalable enough to support large number of nodes without keeping membership information. We have discussed the evolution of a new routing protocol called SLIM+ as a solution to this problem. The comparative study of SLIM+ with existing counter parts reveal that it is indeed a scalable, lightweight and simple multicast protocol.

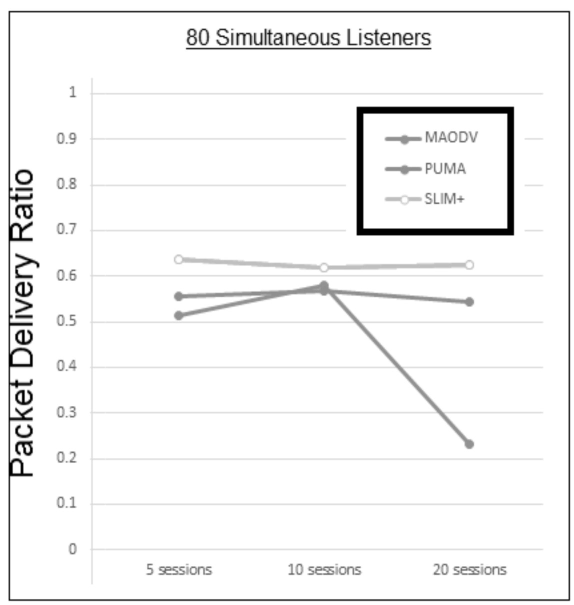


Fig. 6. PDR achieved with 80 Simultaneous Listeners

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