Efficient & Robust Multicast Routing Protocol in Mobile Adhoc Network

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Abstract- Group communications is important in supporting applications those include multimedia. To implement the group communications multicast proves to be an efficient method. It is very challenging to implement efficient and scalable multicast in Mobile Ad hoc Networks (MANET) due to the difficulty in group membership management and multicast packet forwarding over the infrastructure-less dynamic topology. Wired and infrastructure-based wireless networks are supported by many multicast routing protocols. In this paper, we address the multicast routing problem for infrastructure-less mobile adhoc networks (MANETs). We present the Source Grouped Flooding approach to achieve multicasting MANETs. The protocol creates multiple multicast routes between the source and group members based on hop count distance constraints. We also propose a selective or probabilistic data forwarding mechanism to achieve efficient data dissemination. The protocol aims to achieve the robustness of flooding and data distribution efficiency of tree based protocols. Simulation results verify performance.

Keywords – MANET, Multicast, Flooding, Forwarding.

I. INTRODUCTION

MANET is a collection of wireless mobile nodes [1], which dynamically form a temporary network, without having any existing network infrastructure or centralized administration. In Latin, adhoc literally means “for this,” further meaning “for this purpose only” and thus usually temporary [2].

These are also called infrastructure-less networking since the mobile nodes in the network dynamically establish routing paths between themselves. Current typical applications of a MANET include battlefield coordination and onsite disaster relief management.

In Mobile adhoc networks, each host must act as a router since routes are generally multihop. Nodes in such a dynamic network move arbitrarily, which causes the network topology to change frequently, unpredictably, and may consist of unidirectional as well as bidirectional links. Moreover wireless channel has limited bandwidth. The reduced bandwidth decreases even further due to the effect of multiple access channel fading and signal interference. Networks hosts of adhoc networks operate on constrained battery power which will be eventually exhausted. Limited bandwidth, energy constraints and unpredictable dynamic topologies pose difficult problems for the design of applications for these networks.

Many routing protocols developed for MANETs over the past years. Routing protocol is a convention or standard that controls how nodes select the route to route packets between computing devices in a mobile ad-hoc network (MANET). In Mobile adhoc networks, nodes do not have any prior knowledge of topological changes, they have to discover it. A new node announces its presence and listen the announcements of broadcasting from its neighbors. The node learns about new nearby nodes and routes to reach them, and the node may announce that it can also reach those nodes. With time, each node knows about all other nodes and one or more ways how to reach them. MANETs are inherently ready for multicast communications due to their broadcast nature. The main difficulty in designing a routing protocol for these networks is the dynamic topology, in which mobile nodes moves randomly.

Data communication in the network can be performed by any of the following mechanisms namely, unicast, multicast, anycast and broadcast. Unicast is a point-to-point communication mechanism with one sender and a receiver. Multicast is the one where the data from a single source is transferred to a group of receivers. In a network anycast is defined as when the data is transmitted to any one of the members selected to be pan of a group of members. Finally, broadcast is defined as when the data from a source is forwarded to all hosts in the network.

However, most of the today's applications demand group communications and hence the issues in multicast routing have been explored in this research work. Multicast applications like video conferencing and subscription services have become very popular with the advancements in current technology.

Several multicast routing protocols have been proposed for MANETs [3, 4, 5]. According to the topology Multicast routing protocols can be classified into tree-based and mesh-based on the basis of network structure along which multicast packets are delivered to multiple receivers. Mesh-based protocols are more robust to mobility so it have high packet delivery ratio, whereas, multicast trees are more energy efficient than multicast meshes. This is so because mesh-based protocols depend on broadcast flooding within the mesh and therefore, mobile nodes in mesh receive all multicast packets during the multicast communication. Tree based protocols like [13, 14, 15] achieve efficient data distribution; however suffer when the network is highly dynamic. Mesh protocols like [17, 18, 19] are robust against network dynamics due to redundant transmission of data, however at the cost of increased overhead. Flooding achieves network wide broadcast and hence it can be considered as a multicast routing protocol that is highly robust against topology changes.

Existing multicast protocols [6, 7, 8, 9, 10] mainly addresses the multicast sessions with small group size and they do not scale well for large multicast sessions. Managing large multicast session in MANET is difficult because of the mobility of the members. Moreover, the existing multicast routing protocols do not exploit team affinity model [11, 12] where the members have collaborative mobility pattern and common interest.

In this paper, multicast routing problem for adhoc networks is addressed. A novel multicast routing protocol called the source grouped flooding protocol is presented. The protocol creates multicast routes between the source and group members based on hop count distance constraints [19]. At the same time the protocol improves the efficiency of data delivery. A selective or probabilistic data forwarding mechanism to achieve efficient data dissemination is also presented. Simulation results that capture the performance of our protocol against parameters that characterize an adhoc network is presented. It is concluded that the protocol is robust against topology changes and achieves efficient data distribution.

II. BACKGROUND

Adhoc Multicast Routing using Increased Sequence ids (AMRIS) [21] creates a shared multicast tree structure rooted at a special node (Sid). Nodes adapt to connectivity changes based on id numbers obtained from the Sid. A multicast extension to Adhoc On-demand Distance Vector (AODV) [13] creates a shared multicast tree rooted at the group leader which periodically updates routes through destination sequence numbers. The Adhoc Multicast Routing Protocol (AMRoute) [14] creates a user level shared multicast tree consisting of unicast tunnels between the group members. The On-demand Multicast Routing Protocol (ODMRP) [16] creates a mesh of nodes connecting the sources and the group members. Multiple paths provide stability against topology changes. The Core Assisted Mesh Protocol (CAMP) [17] relies on affiliations to core nodes to create multicast structure. The core nodes forward the data. Flooding as a multicast protocol is discussed in [20].The broadcast storm problem and methods to reduce the overhead of flooding are discussed in [21].

III. FLOODING BASED MULTICAST ROUTING PROTOCOL

This is new on-demand protocol for mobile adhoc wireless networks that creates and maintains a source based mesh of nodes called the *flooding group* based on hop count distance metrics to distribute data for that source. Nodes in the network learn the metrics during a request-reply phase. The protocol aims to improve connectivity and data delivery amidst topology changes and node movement. It avoids the drawbacks of tree based protocols in adhoc networks viz. fragility against topology changes, non-optimal paths in the case of shared trees, frequent tree reconstruction tree partitions etc. Also the protocol avoids excessive redundant data transmission due to multiple paths by using probabilistic data forwarding. This protocol attempts to combine the robustness of the mesh structure by establishing multiple paths and improved efficiency by using selective or probabilistic data forwarding. This is an on-demand protocol that is control messages are distributed only when the source has data to send, which reduces channel overhead. The protocol uses a soft-state approach to maintain multicast group membership. The members do not send explicit messages to leave the group. The protocol is independent of the underlying unicast routing protocol.

A. Creation of the flooding group

1) Request Phase: When a source has packets to send to a multicast group it initiates the request phase by broadcasting a JOIN REQUEST message. The request message contains the *multicast group address* and a *hop count* field. When a node in the network receives a non-duplicate request packet, it stores the *hop count* for that source (D_{sn}) i.e., the hop count of the node from the source. The node then increments the hop count and rebroadcasts the packet. This is illustrated in Figure1 (a).'S' is the source and 'GM1'and 'GM2' are the multicast members. The number in each node indicates hop count to the source 'S'. A combination of the source address and a counter is used as a unique packet identifier to identify duplicate packets. An active source will periodically update the flooding group every *refresh_interval* seconds.

2)Reply Phase: A multicast group member upon receiving the JOIN REQUEST, stores the hop count distance to the source (D_{sm}), waits for a short fixed interval and then broadcasts a JOIN REPLY message. The delay prevents collision of the request and the reply messages in the region of the group member. The JOIN REPLY contains the multicast group information and the hop count distance from the group member to the source. The TTL (Time to Live field in the IP header) for this message is set to the hop count from the source (D_{sm}). This ensures that the reply message does not propagate beyond the source. When a node receives a JOIN REPLY the node will compare its stored hop count to the source (stored during the request phase D_{sn}), and the value in the hop count field of the reply message (D_{sm}). If the hop count distance constraint (1) is satisfied the node becomes a flooding node else the packet is dropped. The nodes marked 'FN' in Figure1 (b) are the flooding nodes for the source 'S'. The propagation of the reply message is limited by the distance constraint (2).Only nodes that are activated as flooding nodes propagate the reply message. The node re-broadcasts the reply message only if it is not activated as a flooding node during the current route refresh sequence. Therefore a node will re-broadcast only the first reply message for each source during a particular refresh sequence. The protocol thus creates the flooding group for each source consisting of nodes that satisfy hop count distance constraint (1); the set of nodes being determined by constraint (2). Constraint (2) directly follows from the fact that the group member sets the TTL in the reply message to D_{sm}, which was obtained during the request phase. Each source thus creates its own flooding group, connecting the source to all the group members. The source maintains a different flooding group for each multicast group, as the group membership is different for different groups.

$$D_{sn} \leq D_{sm} \quad (1)$$

$$D_{mn} \geq D_{sm} \quad (2)$$

Controlling group membership with the above relaxed distance constraint could lead to large flooding groups per source, as can be seen in Figure 1(b). An ideal flooding group would be one that consists of nodes that form the optimal paths or shortest paths between the source and the group members. We derive the following distance constraints recognizing that a node lies in the optimal path or shortest path between a source and a member if the sum of the node's distance to the source and the node's distance to the member is less than or equal to the distance between the source and the member.

$$D_{sn} + (D_{sm} - TTL_{rep}) \leq D_{sm} \longleftrightarrow D_{sn} \leq TTL_{rep} \quad (3)$$

D_{sm} is the initial value of the TTL in the reply message sent by the member, and TTL_{rep} is the decremented value of TTL in the reply message that the node receives. Thus (D_{sm}-TTL_{rep}) is the hop count distance between the node and the group member. The nodes use the reduced form of this constraint to decide to join the flooding group and thus only the nodes that form the shortest path can become members of the flooding group. This is illustrated in Figure1(c); clearly only the nodes in the shortest path between the source and the members become flooding nodes. As before the propagation of the reply messages is controlled by the distance constraint (2). If multiple shortest paths exist then all nodes in these paths are included in the flooding group. Thus, the reduced constraint limits the size of the flooding group while ensuring that the shortest path(s) between the source and the members are always included.

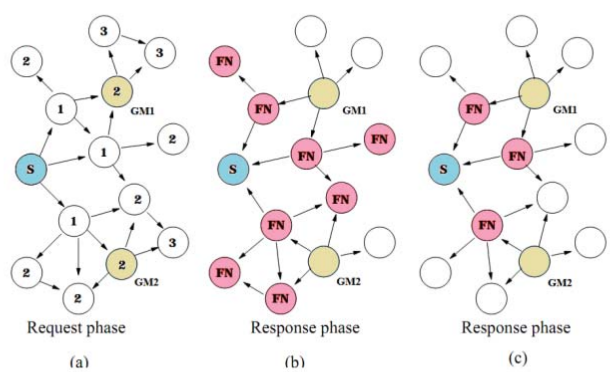

Figure.1.Creation of Flooding Group

B. Data Forwarding

1) Hop Count Data Forwarding: Only members of the flooding group forward data packets for that source. All duplicate packets are dropped. To reduce MAC layer contention and collision due to redundant transmission of data, a *hop count* field is included in the data packet, which is initialized to zero by the source. When an active flooding node receives a data packet, it compares its latest hop count value for this source (D_{sn}) with the hop count field in the data packet. The node re- broadcasts the packet only if the stored hop count is greater than the hop count value in the packet. The node stores its hop count distance to the source in the data packet before retransmitting it. This mechanism ensures that data packets are not repeatedly transmitted in the same region of the network and allows the flooding wave to progress towards the group members.

2) Selective or Probabilistic Data Forwarding: The flooding *group* provides multiple paths from the source to the group members. Redundant transmission of data along these paths will improve data delivery; however it will result in excessive overhead. We propose a selective or probabilistic data forwarding mechanism to reduce data overhead and describe a method to determine a meaningful value for the retransmission probability (P_{send}) of a packet. In this scheme, when a node receives a non-duplicate data packet, it stores the packet and waits for a short random interval of time for arrival of duplicate packets. The node increments a counter for every data packet received from a node in its peer distance level from the source, i.e., data packets having hop count value same as this node's stored hop count value. All other duplicate data packets are dropped. When the wait interval is over, the node calculates the retransmission probability of the packet using (4). The node decides to retransmit the packet with probability P_{send} and drop the packet with probability ($1-P_{send}$). Once the wait interval is over, all duplicates irrespective of hop count value will be dropped.

$$P_{send}=1/(1+n) \tag{4}$$

where, *n* is the number of duplicate packets received from the same hop count peer level.

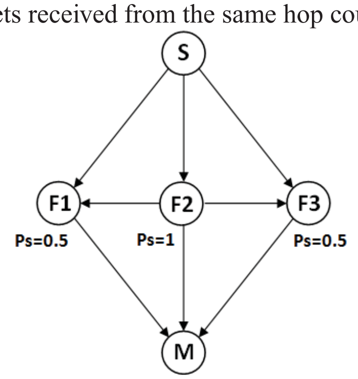

Figure.2.Probabilistic forwarding of data

Figure2 demonstrates the benefit of the selective or probabilistic forwarding scheme. Source S is connected to member M through flooding nodes F1, F2 and F3 that form the shortest paths between S and M. When the source S transmits a packet, F1, F2, and F3 receive the packet. Let us assume, node F2 times out first and transmits with probability 1. Nodes F1 and F3 which are in the same peer hop count level will increment their duplicate counters upon receiving the packet from F2. Thus F3 and F1 will retransmit the packet with probability 0.5. Thus the number of retransmissions is potentially reduced and at the same time, at least one packet is forwarded in each peer hop count level ensuring that the member receives the packet.

IV. SIMULATION SETUP AND PERFORMANCE EVALUATION

A. Simulation setup

OPNET 7.0 [22] is a network simulation tool used to simulate the algorithm. The simulation uses a network of 50 nodes randomly placed within a 1000 m x1000 m area. A node in the network move according to the "Billiard Mobility" model [23].This model is similar to random way point model with the wait period set to 0. At the physical layer, radio propagation distance for each node was set to 250 *m* and the shared channel capacity was 1 *Mbps*. Model does not support radio capture [24] so, in the case of packet collisions all packets are dropped. The IEEE 802.11 (DCF) was used as the Medium Access Control (MAC) protocol. The communication medium is broadcast and nodes have bi-directional connectivity. Group members and sources are randomly chosen from the nodes in the network. A source generates CBR traffic at 2 *packets/secs* with each packet having a payload of 128 bytes. Each simulation was run for 100 seconds. Multiple runs were conducted with different seed values for each scenario and the collected data were averaged over these runs. The multicast algorithms were developed as separate

OPNET routing layer protocols. The performances of the following schemes are evaluated:

1. *Flooding:* Flooding as a multicast routing protocol is used as a base line.
2. *Basic-SGFP:* This scheme uses the relaxed or basic distance constraints (1) and (2) to create the group and hop count data forwarding.
3. *OP-SGFP:* This scheme uses the optimal or shortest path distance constraints (3) and hop count data forwarding.
4. *S-SGFP:* This scheme uses relaxed distance constraints and selective or probabilistic data forwarding.
5. *SOP-SGFP:* This scheme uses optimal or shortest path distance constraints and selective or probabilistic data forwarding.

The following simulation metrics are considered for comparing the schemes:

1. *Packet Delivery Ratio:* The ratio of number of data packets received by the group members to number of data packets expected to be received by the group members (number of packets sent by the source times the number of members).
2. *Total Overhead:* It is defined as the ratio of total packets transmitted in network (control +data) to number of data packets received by group members.

Simulation Results

Figures 3 and 4 show the Packet Delivery Ratio (PDR) and the Total Overhead as a function of node speed (0−30*m/s*).

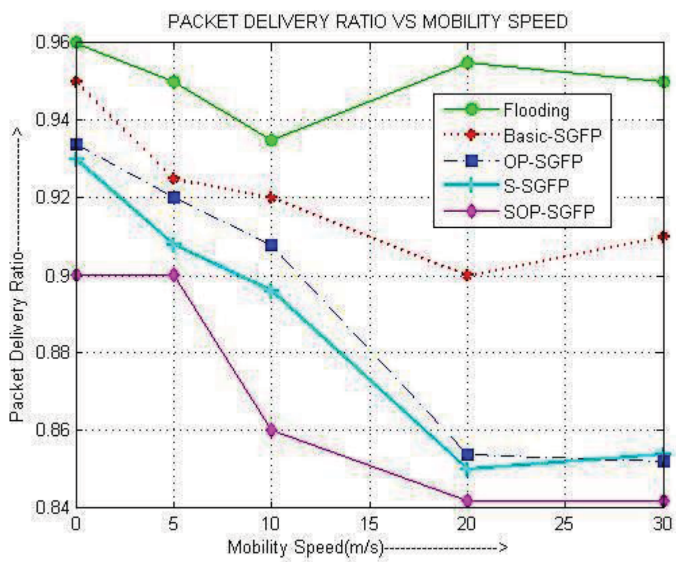

Figure. 3. Packet Delivery Ratio vs Mobility Speed

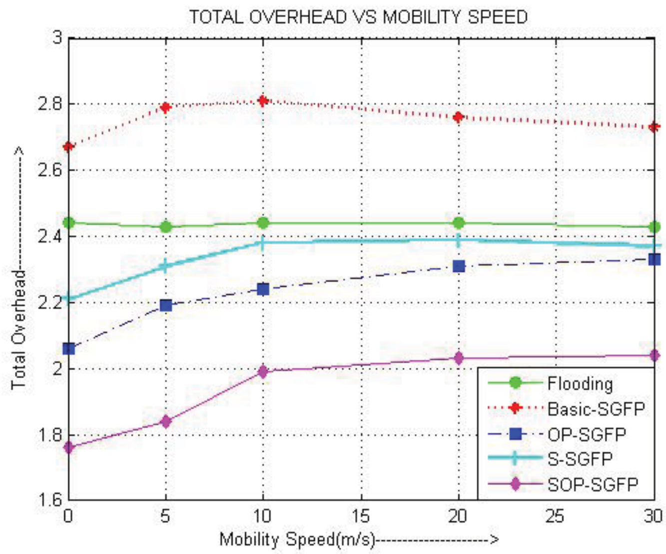

Figure. 4. Total Overhead vs Mobility Speed

The network has 5 sources and 20 group members. The refresh interval is 4 seconds. The *flooding* scheme has the best PDR performance (around 95%) for all mobility speeds as every node rebroadcasts every packet. Redundant data transmission contributes to total overhead and this remains constant against mobility as every node retransmits the packet. All the source initiated schemes show a linear decrease in packet delivery with increased mobility speed; this is to be expected as the movement of the nodes will disrupt the flooding group resulting in loss of packets. However, it should be noted that even at node speeds of $30m/s$ the PDR is around 84% indicating that the flooding group is a very robust multicast structure. The total overhead of the selective or probabilistic schemes is less than that of flooding. Particularly, the total overhead of SOP-SGFP is 20% less than that of flooding. Thus the source initiated multicast protocol using optimal or shortest path flooding groups and selective or probabilistic data forwarding achieves comparable robustness to flooding while significantly reducing the total overhead.

Figures 5 and 6 show the Packet Delivery Ratio (PDR) and the Total Overhead as a function of the number of sources (1−20). Node mobility was set to5m/s. The network had 20 group members. The refresh interval is 4 seconds.

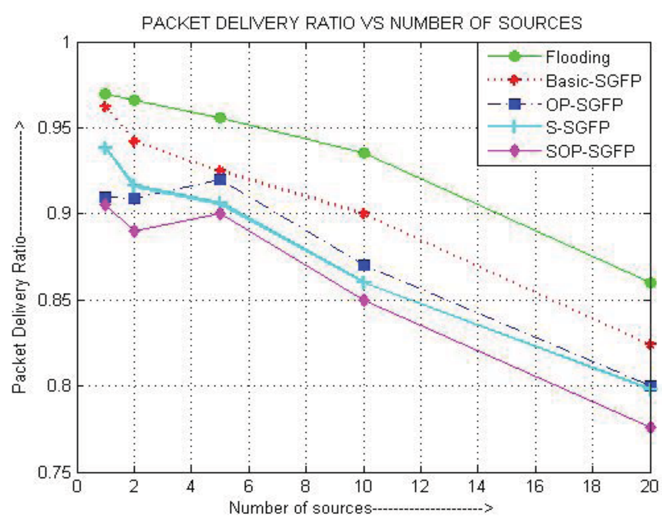

Figure.5.Packet Delivery Ratio vs Number of Sources

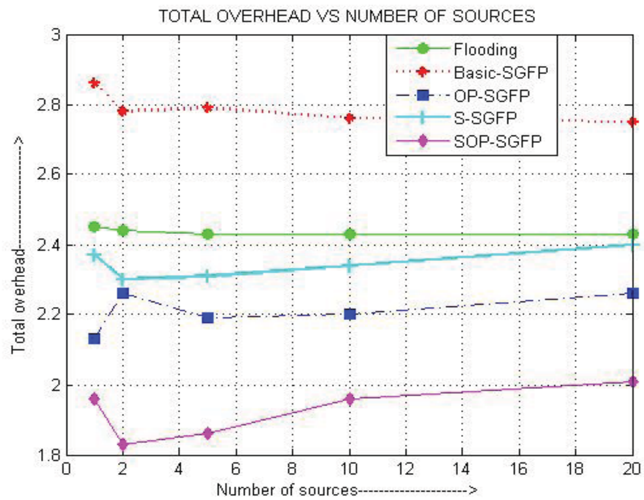

Figure.6.Total Overhead vs Number of Sources

The PDR decreases linearly with increase in the number of sources. This is due to increased MAC layer collisions resulting in loss of data packets and outdated flooding groups. The total overhead for all the schemes remains the same, as even though the control and redundant packets increase the number of data packets delivered also increases. The source initiated schemes imitate the performance of flooding. The sop-SGFP scheme achieves efficient data distribution while maintaining a comparable Packet Delivery Ratio to flooding.

Figures 7 and 8 show the Packet Delivery Ratio (PDR) and the Total Overhead as a function of the multicast group size (10−40). Node mobility was set to $5m/s$. The network had 5 sources. The refresh interval is 4 seconds.

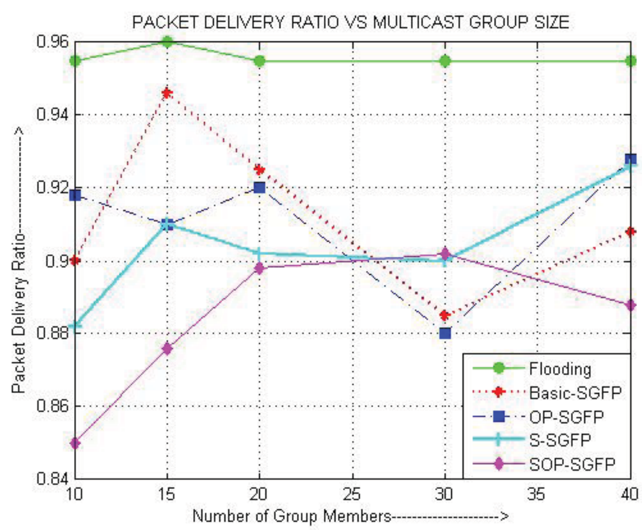

Fig.7.Packet Delivery Ratio vs Multicast Group Size

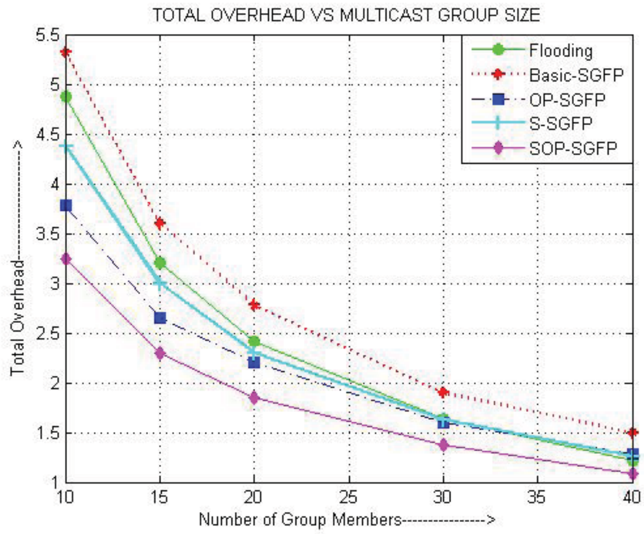

Fig.8.Total Overhead vs Multicast Group Size

PDR for the flooding scheme remains constant as the group size increases. Since every node rebroadcasts the packet, every node receives the packet irrespective of whether it is a group member or not. The source initiated schemes have packet delivery performance within 10% of that of flooding. Particularly, the PDR for SOP-SGFP is around 90% as the group size increases. This is because of the efficient data distribution achieved due to the optimal or shortest path flooding group and selective or probabilistic data forwarding. The total overhead decreases for all the schemes as the group size increases. We see that the overhead for all the schemes converges, this is because as the group size increases multicast resembles broadcast.

V. CONCLUSION & FUTURE WORK

There are multiple challenges in designing multicast routing protocols posed by various characteristics of MANET's viz. mobility, bandwidth and energy limitations. So, it is necessary for a multicast protocol to be efficient as well as robust against mobility and other network dynamics. The Selective or Probabilistic optimal Path Source Grouped flooding protocol (SOP-SGFP) achieves robustness similar to that of flooding while at the same time improving the data delivery efficiency. The steady packet delivery performance of the protocol even at high node speeds (30*m/s*) proves the robustness of the flooding group multicast structure. At the same time the total overhead is 20% less than that of plain flooding. The protocol provides a highly robust multicast structure for a wide range of node speeds while achieving significant reduction in overhead

REFERENCES

[1] M. Conti and S. Giordano. Mutihop Adhoc Networking: The Theory. IEEE Communications, 45(4):78-86. Apr. 2007. A. A. Reddy and B. N. Chatterji, "A new wavelet based logo-watermarking scheme," Pattern Recognition Letters, vol. 26, pp. 1019-1027, 2005.

[2] Mobile ad hoc networks (MANET). http: //www.ietf.org/ html.charters/manet-charter.html, 1997. IETF Working Group Charter

[3] Elizabeth M. Royer, Charles E.Perkins, "Multicast Adhoc On Demand Distance Vector (MAODV) Routing," IETF Internet Draft, draft-ietf-manet-maodv-00.txt, July 2000.

[4] E. Royer, C. Perkins, "Multicast Operation of the Ad Hoc On Demand Distance Vector Routing Protocol," Proceedings of ACM Mobicom '99 Conf., August 1999, pp.: 207-218.

[5] J.J. Garcia-Luna-Aceves, E.L. Madruga. "A Multicast Routing Protocol for Ad Hoc Networks," In Proceedings of the IEEE Conference on Computer Communications INFOCOM 99, pages 784–792, March 1999.

[6] C. E. Perkins and E. M. Royer, "Multicast ad hoc on demand distance vector (MAODV) routing," IETF draft, July 2001. Available: http://www.ietf.org/proceedings/00dec/ID/draft-ietf/manetmaodv-00.txt.

[7] T. Ozaki, J. Kim and T. Suda, "Bandwidth efficient multicast routing protocol for ad hoc networks," IEEE ICCCN, pp. 10-17, Oct. 1999.

[8] C. K. Toh, G. Guichal and S. Bunchua, "ABAM: On demand associativity based multicast routing for ad hoc mobile networks," in Proceedings of IEEE Vehicular Technology Conference, pp. 987-993, Sep. 2000.

[9] L. Ji and M. S. Corson, "Differential destination multicast-a MANET multicast routing protocol for small groups," in Proceedings of IEEE INFOCOM, pp. 1192-1202, Apr. 2001.

[10] S. J. Lee, W. Su and M. Gerla, "On-demand multicast routing protocol in multi-hop wireless mobile networks," Mobile Networks and Applications, vol. 7, no. 6, pp. 441- 453, 2002.

[11] Y. Yi, M. Gerla and K. Obraczka, “Scalable team multicast in wireless networks exploiting coordinated motion,” Ad Hoc Networks Journal, pp. 171-184, Aug. 2003.

[12] G. Pei, M. Gerla and X. Hong, “LANMAR: Landmark routing for large scale wireless ad hoc networks with group mobility,” in Proceedings of ACM Symposium on mobile ad hoc networking and computing, pp. 11-18, Aug. 2000.

[13] E. Royer and C. E. Perkins. Multicast operation of ad hoc on-demand distance vector routing protocol. In Proceedings of MobiCom,Seattle,WA,August1999.

[14] M. Liu, R. Talpade and E. Bommaiah. AMRoute: Adhoc multicast routing protocol. Technical Report8,University ofMaryland,1999.

[15] C. W. Wuand Y.C. Tay. AMRIS: A multicast protocol for adhoc wireless networks IEEE MILCOM, Atlantic City, NJ, November 1999.

[16] S.-J. Lee, M. Gerla, and C.-C. Chiang. On-demand multicast routing protocol. In Proceedings of IEEE WCNC, pages 1298–1304, New Orleans, LA, September 1999.

[17] E.L. Madrugaand J.J. Garcia-Luna-Aceves. Scalable multicasting: The core assisted mesh protocol. ACM/Baltzer Mobile Network and Applications Journal, Special Issue on Management of Mobility, 1999.

[18] P. Sinha, R. Siva kumar, V. Bharghavan. MCEDAR: Multicast core extraction distributed adhoc routing. In Proceedings of Wireless Communications & Networking Conference, 1999.

[19] K. Chandrasekhar. Multicast routing in mobile wireless adhoc networks using source grouped flooding. Master’s thesis, University of Maryland, 2002 www.glue.umd.edu/karthikc.

[20] C.Ho,K. Obraczka, and G. TsudikK. Vishwanath. Flooding for reliable multicast in multi-hop adhoc networks. In MobiCom Workshop on Discrete Algorithms and Methods for Mobility.

[21] S.Y.Ni,Y.-C.Tseng,Y.-S.Chen,andJ.-P.Sheu. The broadcast problem ina mobile ad hoc network. In Proceedings of MobiCom,August1999.

[22] Opnet modeler version7.0.www.opnet.com.

[23] Billiard mobility. http://w3.antd.nist.gov/wctg/manet/prdaodvfiles.html.

[24] C.Ware, T.Wysocki, and J.F. Chicharo. Simulation of capture behavior in ieee 802.11 radio modems. Journal of Telecommunications and Information Theory, 2001.