Self adaptive on demand real time Multicast geographic routing for Mobile ad hoc Network

Poonam S. Mantri [1], S.T. Patil [2]
Dept of Computer science & Engineering (Information Technolgy)
Vishwakarma Institue of Technology Pune. India
poonam.mantri25@gmail.com,
stpatil77@gmail.com

Abstract—In this paper, we present Self Adaptive On-demand geographic real time Multicasting through Time Reservation using Adaptive Control for Energy efficiency (SAOG MC-TRACE), an energy-efficient real-time data multicasting architecture for mobile ad hoc networks. SAOG MC-TRACE is a cross-layer design, where the medium access control layer functionality and the network layer functionality are performed by a single integrated layer combined with geographic routing to build efficient paths based on need of user applications and adapt to various scenarios to provide efficient and reliable routing. Energy efficiency is achieved by enabling the nodes to switch to sleep mode frequently and by eliminating most of the redundant data receptions. The main architecture is integration and reengineering of the tree and mesh structures to make them highly energy efficient and robust for real-time data multicasting in mobile ad hoc networks. Our contribution to existing work is achieve reduction in Packet delivery latency at high mobility of nodes and high PDR with very low forwarding overhead and transmission delay.

I. INTRODUCTION

THE first objective of a multicast protocol is to convey packets from a source to the members of a multicast group with an acceptable quality of service (QoS)[1]. QoS is the performance level of a service offered by the network, in general specifically; QoS in voice communications necessitates 1) maintaining a high enough packet delivery ratio (PDR), 2) keeping the packet delay low enough, and 3) minimizing the jitter in packet arrival times. Thus, the goal in QoS provisioning is to achieve a more deterministic network behavior (i.e., bounded delay, jitter, and PDR). The second objective of a multicast routing protocol is to utilize the bandwidth efficiently, which is directly related with the number of retransmissions (throughout this paper, the term retransmission is used for relaying) required to deliver generated data packets to all members of a multicast group with a high enough PDR. This is achieved by geography based greedy forwarding technique integrated with MC-TRACE[5] architecture. The third objective of a multicast protocol is to minimize the energy dissipation of the network. In this paper, we propose a self adaptive on demand real time geographic multicast routing architecture based on cross-layer design. MC-TRACE[5] inherits its cross-layer architecture from the MH-TRACE[4] architecture. In recent years, geographic routing have drawn a lot of attentions. They assume mobile nodes are aware of their own positions through GPS or other localization schemes [10], [11] and a source can obtain the destination's position through some kind of location service [12] We propose self adaptive on demand geographic routing to reduce control overhead, the routing path is built and the position information is distributed on the traffic demand. Secondly, through a more flexible position distribution mechanism, the forwarding nodes are notified of the topology change in a timely manner and thus more efficient routing is achieved. Thirdly, optimization schemes are designed to make routing paths adaptive to the change of topology and traffic, and robust to the position inaccuracy. Fourthly, the routing schemes in the protocols naturally handle the destination position inaccuracy. Lastly, each node can set and adapt the protocol parameters independently based on the environment change and its own condition.

II. RELATED WORK

There are many multicast routing protocols designed for mobile ad hoc networks [6], [7], [8], and they can be categorized into two broad categories: tree-based approaches and mesh-based approaches. Tree-based approaches create trees originating at the source and terminating at multicast group members with an objective of minimizing a cost function. A multicast protocol for ad hoc wireless networks (AMRIS) [2] constructs a shared delivery tree rooted at one of the nodes, with IDs increasing as they radiate from the source. Local route recovery is made possible due to this property of the IDs, hence, reducing the route discovery time and also confining route recovery overhead to the proximity of the link failure. Mesh-based multicasting is better suited to highly dynamic topologies, simply due to the redundancy associated with this approach [13]. In mesh-based approaches, there is more than one path between the source and the multicast group members (i.e., a redundant multicast tree). One such mesh-based multicast protocol, On-Demand Multicast Routing Protocol (ODMRP) [3], is based on periodic flooding of the network by the source node through control packets to create a multicast mesh. This basic operation is used both to create the initial multicast forwarding state and to maintain the mesh in case of node mobility and other network dynamics.

In ODMRP[3], an active source periodically floods the network with JOIN QUERY control packets. When a node receives a JOIN QUERY packet, it marks the first node it receives the packet from as the upstream node and rebroadcasts the JOIN QUERY packet. When a multicast group member receives a JOIN QUERY packet, it replies back with a JOIN REPLY packet, which is forwarded back to the source node via traversing the reverse path. Each upstream node sets a group forwarding flag for the multicast group indicated in the packet header and becomes a member of the multicast mesh. The forwarding state expires after a predetermined time. As far as we know, there are no geographic routing integrated with existing multicasting protocol. The MC-TRACE[5] active multicast backbone is a highly pruned tree. However, the tree branches are cushioned within a passive outer crust formed by the nodes passively monitoring the backbone, and any collapse in the active tree is rapidly repaired or replaced by the passive nodes, which form a condensed mesh around the active tree. Thus, MC-TRACE[5] protocol provides high enough PDR compared to existing multicast protocols a such as ODMRP[3]. Our contribution to existing work is to minimize packet delay with minimum control overhead for topology discovery mechanism. We propose SAOG MCTRACE multicasting can be interpreted as an integration of tree- and mesh-based approaches with self adaptive on demand geographic routing in mobile ad hoc network.

III. MH-TRACE MEDIUM ACCESS CONTROL ARCHITECTURE

Multi hop Time Reservation using Adaptive Control for Energy efficiency (MH-TRACE) is a MAC protocol for energy-efficient real-time data communications [4]. In MH-TRACE, the network is partitioned into overlapping clusters through a distributed algorithm. Time is organized into cyclic constant duration super-frames TSF consisting of several frames. Each cluster head (CH) chooses the least noisy frame to operate within and dynamically changes its frame according to the interference level of the dynamic network. Nodes gain channel access through a dynamically updated and monitored transmission schedule created by the CHs, eliminating packet collisions within the cluster. Collisions with the members of other clusters are also reduced by the CH's selection of the minimal interference frame. Nodes that are scheduled to transmit data send a short IS packet prior to data transmission. The IS packet includes information about the data packet, for example, in an IS slot, the ID of the corresponding upcoming data packet is announced so that the nodes that have already received the data packet do not waste energy receiving a previously received data packet. Channel access is automatically renewed by the continuous use of a reserved data slot. Each frame consists of a control sub frame for transmission of control packets, and contention free data sub-frame for data transmission

IV. SAOG MC-TRACE ARCHITECTURE

Functions performed by MH-TRACE[4] are cluster creation and maintenance, medium access control, topology control, distributed data transmission scheduling but not perform routing. SAOG MC-TRACE is an architecture built on MH-TRACE[4] and is capable of multicast routing with geographic forwarding. In SAOG MC-TRACE multicast tree creation and maintenance mechanisms should be carried out through IS packet rather than through independent control packets transmitted in data slots. Hence, it is more efficient to reserve the data slots for data packets and use other mechanisms to transmit control packets. Information in header packet is used to transmit data transmission schedule of coming frame. Every node that is scheduled to transmit data in the current frame transmit its own schedule prior to data transmission through the use of the IS slots. This information is used by the nodes that receive the header packet to schedule reception time of data packet they are interested.

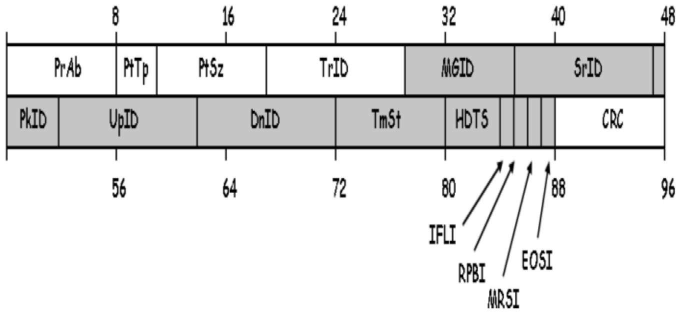

Fig.2. IS Packet format and field. PrAb (8 bits, preamble), PtTp (3 bits, packet type), PtSz (8 bits, packet size), TrID (10 bits, transmitter node ID), MGID (8 bits, multicast group ID), SrID (10 bits, source node ID), PkID (5 bits, packet ID), UpID (10 bits, upstream node ID), DnID (10 bits, downstream node ID), TmSt (8 bits, time stamp), HDTS (4 bits, hop distance to source), IFLI (1 bit, initial flooding indicator), RPBI (1 bit, repair branch indicator), MRSI (1 bit, multicast relay status indicator), EOSI (1 bit, end-of-stream indicator), and CRC (8 bits, cyclic redundancy check). packet fields shown with light background are mandatory fields of an IS packet and the dark background fields are the payload of the IS packet.

4.1 SAOG MC-TRACE Working

Building blocks in SAOG MC-TRACE as follows:

1. Initial Forwarding
2. Maintain branch (MNB),
3. Repair branch (RPB), and
4. Create branch (CRB).

In SAOG MC-TRACE the next-hop of a forwarding node is determined reactively with the combination of geographic-based and topology-based mechanisms. Normally source initiate session by broadcasting a packet to all its neighbor. Each retransmitting node acknowledges its upstream node by announcing the ID of its upstream node in its IS packet, which precedes its data packet transmission. Rather than using existing broadcasting mechanism such as flooding for topology discovery and setting an end-to-end path as for routing packets to destination, the position information is used to guide the searching and selection of relay node(s) towards the destination. Path searching overhead and delays are much smaller than conventional topology-discovery using flooding in MC-TRACE. Multicast group member nodes indicate their status by announcing their multicast group ID in the IS packet. Nodes that are not members of the multicast group set their multicast group ID to the null multicast group ID. If an upstream node receives an acknowledgement ACK from a downstream multicast group member, it marks itself as a multicast relay and announces its multicast relay status by setting the corresponding status (*i.e.*, multicast relay bit) in the IS packet. The same mechanism continues in the same way up to the source node. In other words, an upstream node that gets an ACK from a downstream multicast relay marks itself as a multicast relay. Furthermore, a multicast group member that receives an ACK from an upstream multicast relay marks itself as a multicast relay also. Multicast relay status expires if no ACK is received from any downstream (for both members and non-members of the multicast group) or upstream (only for members of the multicast group) multicast relay or multicast group member for *TRLY* time. Links between nodes is assumed to bidirectional. Initial flooding in existing protocol MCTRACE results in a highly redundant multicast tree, where most of the nodes receive the same data packet multiple times. Thus, a pruning mechanism is needed to eliminate the redundancies of the multicast tree created by the initial flooding. Pruning mechanism is performed if required in SAOG MC-TRACE because initial forwarding is performed on a branch consists of multicast group using geographic forwarding technique. Purpose of Initial forwarding is to determine multicast relays in a distributed fashion. Pruning uses the multicast relays to create an efficient multicast tree. As described previously, a multicast relay node that does not receive any upstream or downstream ACK for *TRLY* time ceases to be a multicast relay (for the sake of simplicity, we assume the multicast group members are always the leaf nodes). Furthermore, a node, which is not a multicast relay, also ceases to retransmit the multicast data if it does not receive an ACK from any downstream node. Although in most cases initial forwarding is capable of creating an initial efficient multicast tree, they are not always capable of maintaining the multicast tree in a mobile network. Thus, the need for additional mechanisms to repair broken branches is obvious.

*2) Maintain Branch***:** Some of the multicast group members are not multicast relays. The upper panel of Figure 3 illustrates such a situation. Multicast node (node-M1) is a multicast relay, which is indicated by the two-way arrows; whereas node-M2 is not a multicast relay **-** it just receives the packets from the upstream node (node-2). Hence, node-M2 does not acknowledge node-2 (node-2 is acknowledged by node-M1. Note that any node can acknowledge only one upstream and one downstream node with a single IS packet. When node-M1 moves away from node-2's transmit range and enters node-1's transmit range, it either begins to acknowledge node-1 as its upstream node if the transition happens in less than *TRLY* time (*i.e.*, node-M1's multicast relay status does not expire before *TRLY* time) or just receives the data packets from node-1 without acknowledging node-1 if node-M1's transition takes more than *TRLY* time. In any case, node-2 does not receive any ACK from node-M1, and starts to set its downstream node ID as the null ID. However, node-2 does not cease retransmitting data packets that it receives from its upstream node (node-1) instantly, because, a multicast relay does not resets its status for *TRLY* time and continues to retransmit data packets. Although node-M2 does not acknowledge any node, it monitors its upstream node through IS and data packets. When the upstream node of a multicast group member node (*i.e.*, node-M2) announces null ID as its downstream node ID, the multicast node (M2) starts to acknowledge the upstream node by announcing the ID of the upstream node (node-2) as its upstream node in its IS packet. Thus, node-2 continues to be a multicast relay and node-M2 becomes a multicast relay after receiving a downstream ACK from its upstream node (node-2). The MNB mechanism does not necessarily create a new branch, yet it prevents an existing operational branch from collapse. However, just maintaining the existing multicast relays is not enough in every situation. There are situations where new relays should be incorporated to the tree.

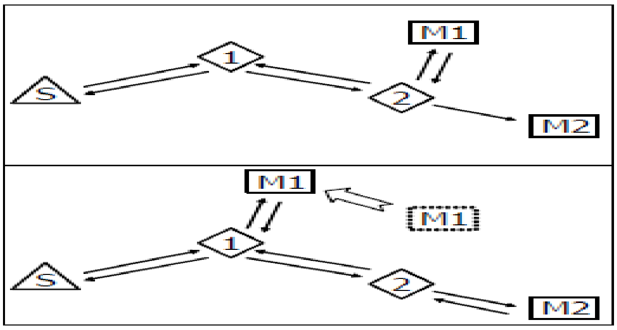

Fig. 3 Illustration of Maintain Branch Mechanism

3) Repair Branch: After a node marks itself as a multicast relay, it continuously monitors its upstream node to detect a possible link break between itself and its upstream multicast relay node, which manifests itself as the interruption of the data flow without any prior notification. If such a link break is detected, the downstream node uses the RPB mechanism to fix the broken link. Figure 5 illustrates an example of a network topology where a branch of the multicast tree is broken due to the mobility of a multicast relay and fixed later by the RPB mechanism. In Figure 4 If node-2 moves away from its original position and node- 1 and node-2 cannot hear each other; thus, the multicast tree is broken. At this point node-2 realizes that the link is broken (*i.e.*, it does not receive data packets from its upstream node anymore) and the RPB mechanism is used to fix the broken tree. Node-2 sets its RPB bit to one in the IS packets that it sends. Upon receiving a RPB indicator, all the nodes in the receive range start to retransmit data packets as they do in the initial flooding stage. One of these nodes, which is node-3 in this scenario, replaces node-2 as a multicast relay node and the multicast tree branch is repaired. We assumed node-3 remains in the transmit range of node-1, node-2, and node-M even after node-2 moved away from node-1's transmit range. However, even if node-3 was not in the transmit range of node-2, the tree can again be fixed. Since node-M does not receive any data packets from its upstream node (node-2), it sets its RPB bit to one and announces this in its IS packet. Upon receiving the RPB of node-M, node-3 starts to relay data packets, and upon receiving an upstream ACK from node-M, marks itself as a multicast relay.

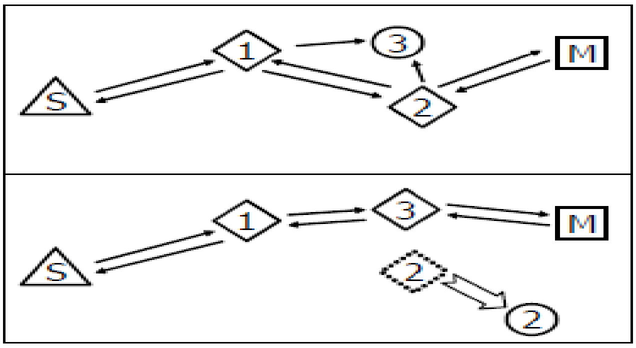

Fig 4. Illustration of Repair Branch mechanism

Both MNB and RPB are limited scope maintenance algorithms (*i.e.,* they can fix mostly one-hop tree breaks).These mechanism are not capable of completely eliminating multicast tree breaks or, in some cases, the total collapse of the multicast tree. Thus, the create branch (CRB) mechanism is needed.

4) Create Branch: It is possible that due to the dynamics of the network (*e.g.,* mobility, unequal interference) a complete branch of a multicast tree can become inactive, and the leaf multicast group member node cannot receive the data packets form the source node. In fig. 5 double arrows indicate an active link with upstream and downstream ACKs. Dash dotted arrows indicate an inactive link. The numbers below the nodes show their HDTS, which they acquired during previous data transmissions. One situation that can create such inactivity is that the upstream ACKs of nodes 8 and M1 are colliding and node-5 cannot receive any downstream ACK. Thus, node-5 ceases to relay packets, which eventually results in silencing all the upstream nodes up to the source (*i.e.,* if node-5 does not get any downstream ACKs it ceases acknowledging its upstream node, node-4, after *TRLY* time, which results in silencing ofnode-4 in 2*TRLY* time and node-3 in 3*TRLY* time). If a multicast group member, which is node-M2 in this scenario, detects an interruption in the data flow for *TCRB* time, it switches to Create branch status and announces this information via a CRB packet. A CRB packet is transmitted by using one of the IS slots, which is chosen randomly. Upon receiving a CRB packet, all the nodes in the receive range of the transmitting node switch to CRB status if their own HDTS is lower than or equal to the HDTS of the sender. When a node switches to CRB mode, it starts to relay the data packets if it has data packets for the desired multicast group. If it does not have the desired data packets, it propagates the CRB request by broadcasting a CRB packet to its one-hop neighbors.

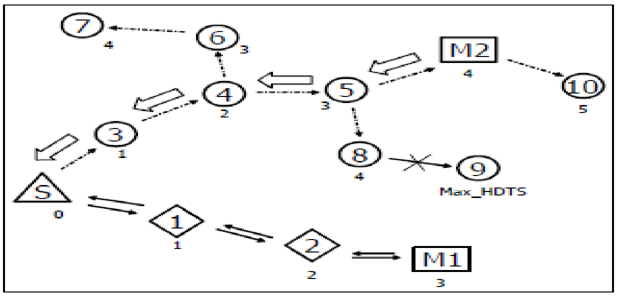

Fig 5. Illustration of Create Branch mechanism

This procedure continues until a node with the desired data packets is found, which is illustrated by the block arrows in Figure 6. After this point, the establishment of the link is similar to the initial flooding followed by pruning mechanisms. However, in this case only the nodes in CRB mode participate in data relaying. Looking at the initial collapse of the branch, we see that node-8 does not participate in CRB due to its HDTS and it does not create interference for node-M2 in this case.

V. SIMULATION ENVIORNMENT

We have implemented geographic MC TRACE protocol and compared the performance with MC-TRACE and ODMRP because to achieve high QOS it is necessary to achieve high PDR and less packet delay. All the simulations are run for 10s and averaged over 5 runs. The metrics that we used in this study are average PDR, packet delay and energy dissipation. PDR is the ratio of the number of packets delivered to the multicast nodes to the number of packets generated by the source node, normalized by the number of multicast nodes. Average packet delay is obtained by averaging the delays of all data packets that are received for the first time at the multicast nodes.

1) Analysis of geographic MC-TRACE

We investigate the performance of MC-TRACE and ODMRP and GEO MC-TRACE as a function of multicast nodes in simulation scenario. Average PDR results for MC-TRACE and ODMRP and GEO MC-TRACE are presented in following figures as a function of multicast nodes size. In the low node density/low data rate regime, Geographic MC-TRACE PDR is above 99 percent varies from 99.32 ± 89.32 percent, and the PDR is always high for all multicast node sizes compared to OMDRP and MC-TRACE thus provides a certain level of QoS. MC-TRACE PDR also stays above 80 percent from 85.32 ± 9.81 percent although ODMRP PDR slightly decreases from 34.56 ± 9.98 percent (with 8 multicast nodes) and 32.13 ± 11.46 percent (with 64 multicast nodes) due to the increase in the control and data packet traffic, creating congestion in the network In the high node density/high data rate regimes, MC-TRACE PDR shows a decrease from 85.32 ± 9.81 percentage (mc8) to 24.63 ± 8.64 percent (mc64) due to the increasing interference within the network

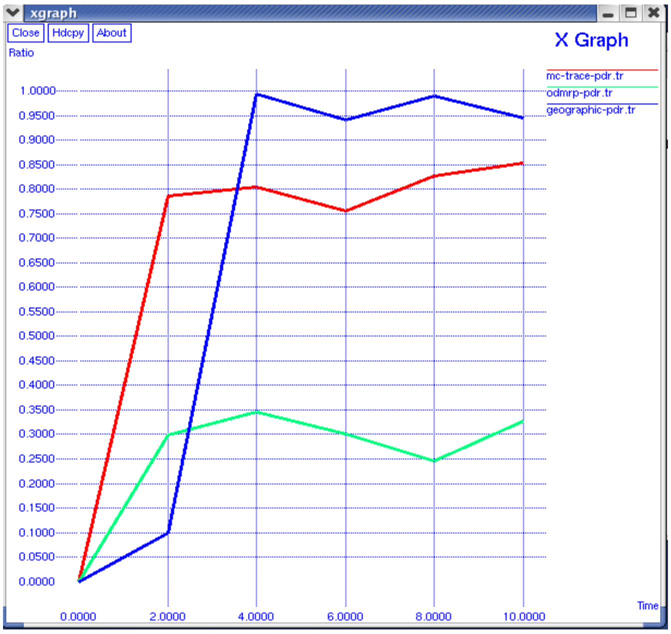

Fig 6 PDR in ODMRP MCTRACE and GEO MCTRACE for 8-nodes

On the other hand, ODMRP-I PDR drops significantly from 34.56 ± 9.98 percent (mc8) to 32.13 ± 11.46 percent (mc64) due to the high bandwidth utilization and the resulting congestion in the network. Following figure shows the performance of ODMRP, MC-TRACE and GEO MC TRACE for 64-nodes. GEO MCTRACE PDR is relatively higher varies from 37.65 ± 9.0 percentage compared to both.

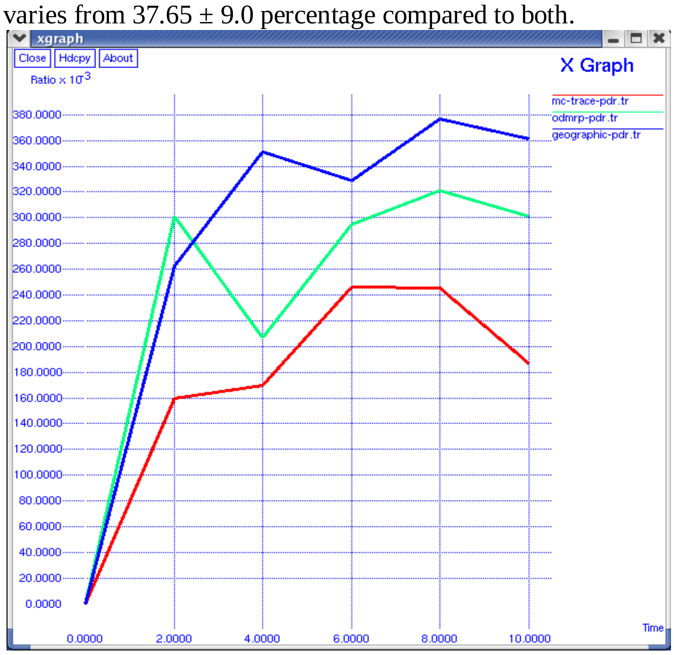

Fig 7 PDR in ODMRP MCTRACE and GEO MCTRACE for 64-nodes

In the low data rate regime, ODMRP-I delay stays below 5.0 ms increasing from 4:362 ± 1:105 ms (mc8) to 4:936 ± 0:8274 ms (mc64). The increase in delay is due to the increase in the traffic in the network with an increasing number of multicast nodes. Yet, ODMRP-I delay is much lower than MC-TRACE delay. MC-TRACE packet delay is much higher than ODMRP-I due to the super frame structure of MC-TRACE, where nodes can only transmit one data packet of each flow in one super frame, which is matched to the periodic rate of data generation (32 ms). MC-TRACE delay starts at 4: 848 ± 0:318 ms (mc8), decreases to 4:606 ±1.407 ms (mc32) and reaches it value of 4:67±1:43 ms at mc64. There are two mechanisms that create such a behavior: 1) multicast tree creation is more robust, and thus, packet delay decreases with a higher percentage of the nodes being multicast group members and 2) multicast tree size increases with increasing multicast node members, which, in turn, increases the traffic, and thus, packet delay increases.

In the high data rate regime, ODMRP-I packet delay increases substantially from 4:362 ± 1:105 ms (mc8) to 4:936 ± 0:8274 ms (mc64). At higher multicast nodes, network traffic increases beyond the level that can successfully be handled by ODMRP-I, causing congestion in the network. MC-TRACE delay also shows an increasing trend in the high data rate regime, from 4: 848 ± 0:318 (mc8) to 4:606±1.407 ms (mc64). MC-TRACE delay is higher than ODMRP-I delay at mc8 but for multicast node sizes larger such that at 32 nodes, ODMRP-I delay exceeds that of MC-TRACE and at mc64 ODMRP-I delay is larger than MC-TRACE delay.

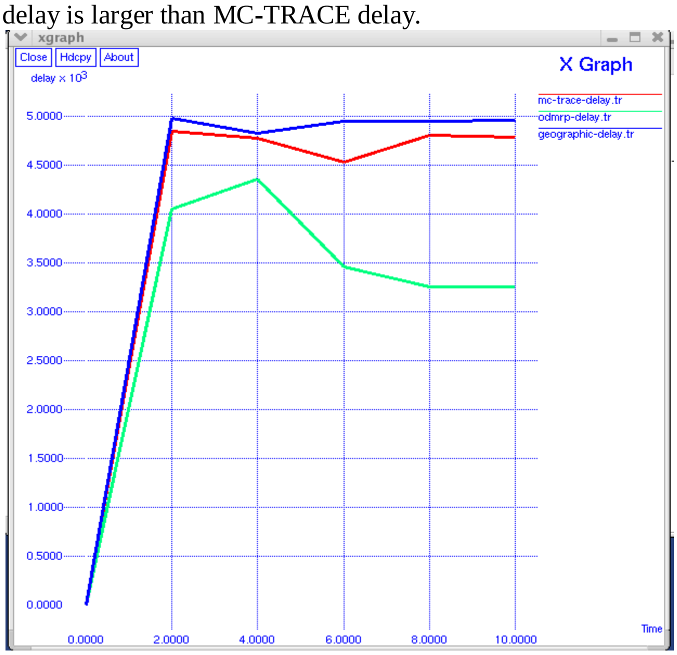

Fig 8 Delay in ODMRP MCTRACE and GEO MCTRACE for 8-nodes

Nevertheless, the MC-TRACE delay pattern stays relatively stable under all conditions when compared to the ODMRP-I delay pattern, thus providing a predictable level of QoS. than 32 nodes. GEO MC-TRACE delay is less compared to both MC-TRACE and ODMRP because of aid of geo graphic routing with MC-TRACE mechanism. By taking benefits of geographic location based services it is possible to decide the appropriate intermediate nodes in forwarding path and forward the data on selected path in order to reach destination reduces end to end delay of packet. As the no. of nodes are increases substantially in the simulation scenario end to end delay is reduces. Delay of GEO MC-TRACE is varies from 4:979 ± 0.148 ms (mc8) to 4:673 ± 1.107 ms (mc64). Delay is reduces substantially in GEO MC-TRACE as increase in no of multicast nodes in simulation scenario. Energy dissipation results for ODMRP-I and MC-TRACE in the low data rate regime are presented in Fig. ODMRP-I average energy dissipation increases linearly with increasing multicast node size, and the maximum deviation between the data points is less than 1.0 percent. Maximum energy dissipation also lies within 13 percent of the average energy results.

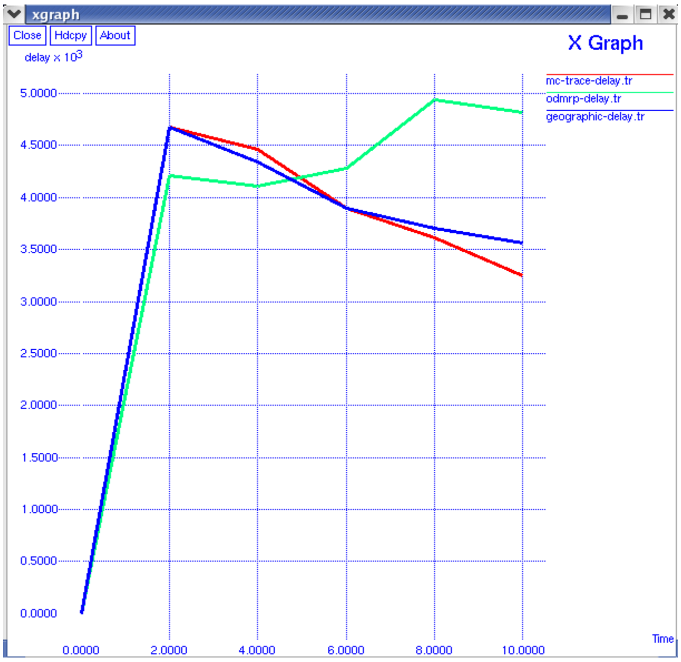

Fig 9 Delay in ODMRP MCTRACE and GEO MCTRACE for 64-nodes

Energy dissipation of the maximum energy dissipating node is defined as the maximum energy dissipation of the network. The increase in energy dissipation is mainly due to the increase in receive and carrier sense energy dissipation terms with increasing multicast size.

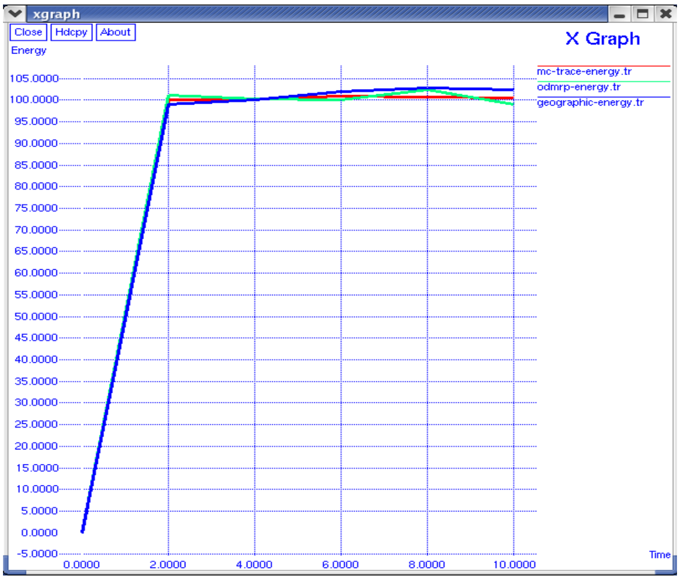

Fig 10 Energy in ODMRP MCTRACE and GEO MCTRACE for 8-nodes

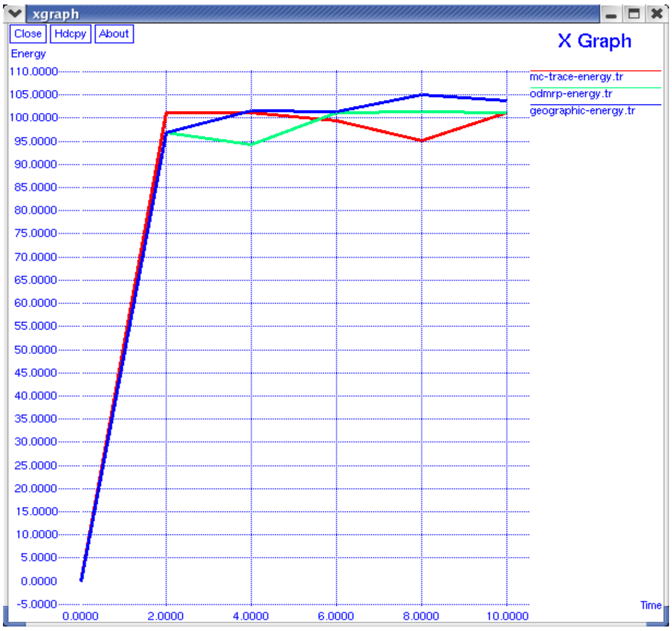

Fig 11 Energy in ODMRP MCTRACE and GEO MCTRACE for 64-nodes

Conclusion:

GEO MCTRACE is targeted at reducing the end to end delay, Packet Delivery Ratio and total energy consumption which consists of not only transmit energy dissipation but also receive, carrier sense, idle, and sleep energy dissipations as well. In this paper, We proposed self adaptive on demand real time Multicast geographic routing for MANET which gives an improvement in Packet delivery ratio and end to end delay latency at high mobility and gives high PDR have very low forwarding overhead and transmission delay compared performance existing multicast protocol such as MC-TRACE, flooding and ODMRP.

References:

[1] B. Tavli and W. Heinzelman, Mobile Ad Hoc Networks:Energy-Efficient Real-Time Group Communications. Springer, 2006.

[2] C.W. Wu and Y.C. Tay, "AMRIS: A Multicast Protocol for Ad Hoc Wireless Networks," Proc IEEE Military Comm. Conf., vol. 1, pp. 25-29 1999.

[3] S.J. Lee, W. Su, and M. Gerla, "On-Demand Multicast Routing Protocol in Multihop Wireless Mobile Networks," Mobile networks and Applications, vol. 7, pp. 441-453, 2002.

[4] B. Tavli and W. Heinzelman, "MH-TRACE: Multi Hop Time Reservation Using Adaptive Control for Energy Efficiency," IEEE J. Selected Areas Comm., vol. 22, no. 5, pp. 942 953, June 2004.

[5] B. Tavli and W. Heinzelman, "Energy Efficient real time multicast routing in Mobile Ad hoc network," IEEE J. selected area computer, vol 60 no. 5 may 2011

[6] H. Moustafa and H. Labiod, "A Performance Comparison of Multicast Routing Protocols in Ad Hoc Networks," Proc. IEEE Personal, Indoor and Mobile Radio Conf.,pp. 497-501, 2003.

[7] S.J. Lee, W. Su, J. Hsu, M. Gerla, and R. Bagrodia, "A Performance Comparison of Ad Hoc Wireless Multicast Protocols," Proc. IEEE Conf. Computer Comm., pp. 565-574, 2000.

[8] L. Junhai, Y. Danxia, X. Liu, and F. Mingyu, "A Survey of Multicast Routing Protocols for Mobile Ad-Hoc Networks," IEEE Comm. Surveys and tutorials, vol. 11, no. 1, pp. 78-91, First Quarter 2009.

[9] J. G. Jetcheva and D. B. Johnson, "Adaptive Demand-Driven Multicast Routing in Multi-Hop Wireless Ad Hoc Networks," Proc. ACM Int'l Symp. Mobile Ad Hoc Networking and Computing, pp. 33-44, 2001.

[10] Z. Yang, Y. Liu, and X.- Y. Li. Beyond Trilateration: On the Localizability of Wireless Ad-hoc Networks. *IEEE/ACM Transactions on Networking*, 18 (6) pages. 1806 - 1814, Dec. 2010.

[11] W. Xi, Y. He, Y. Liu, J. Zhao, L. Mo, Z. Yang, J. Wang, and X.-Y. Li.Locating Sensors in the Wild: Pursuit of Ranging Quality. *ACM Sensys*, 2010.

[12] J. Li, J. Jannotti, D. S. J. D. Couto, D. R. Karger and R. Morris. A scalable location service for geographic ad hoc routing. In *Proceedings of the ACM/IEEE International Conference on Mobile Computing and Networking(MOBICOM)*, pages 120–130,2000.

[13] B. Tavli and W. Heinzelman, Mobile Ad Hoc Networks: Energy-Efficient Real-Time Group Communications. Springer, 2006.

