EMMR: A Multicast Protocol for Mobile Ad Hoc Networks

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Summary
This paper proposes a new multicast protocol for Mobile Ad hoc networks, called Efficient Mobile Multicast Routing (EMMR) The protocol is designed with the intention of reducing unnecessary traffic to non-interested nodes in MANET multicast operations. When members of a multicast group form clusters within the MANET, EMMR should allows more traffic to be sent simultaneously because traffic is confined to the cluster. When applied to a partitioned multicast group, EMMR has to perform well as long as there is enough bandwidth to accommodate the extra traffic generated. The simulation and performance analysis is as well presented in this paper.

Key words:
Ad hoc Networks, Emmr, Multicast Routing, Mobile Communications.

1. Introduction

The packets are routed in many ways depending upon the requirement, there are many point-to-point routing algorithms existing. In this routing generally a Source Node wants to send a message to a destination node called Unicasting. Whereas Broadcasting is a special case of multicasting when all the nodes in the network is in the multicast group. However, in many situations a node wants to send a message to group of nodes in the network. This is called multicasting and the group is called multicast group. Multicasting has emerged as one of the most focused areas in the field of networking. As the technology and popularity of the Internet have grown, applications that require multicasting (e.g. video conferencing rescue patrol, battalion, scientists, etc) are become more widespread. Another interesting recent development has been the emergence of dynamically reconfigurable wireless ad hoc networks to interconnect mobile users for applications ranging from disaster recovery to distributed collaborative computing. Multicast plays a key role in ad hoc networks because of the notion of teams and the need to show data / images to hold conferences among them. Protocols used in static networks (e.g., DVMRP [13], MOSPF[14], CBT[15], and PIM [16]), however, do not perform well in a dynamically changing ad hoc network environment. Multicast tree structures are fragile and must be readjusted continuously as connectivity changes. Furthermore, typical multicast trees usually require a global routing substructure such as link state or distance vector. The frequent exchange of routing vectors or link state tables, triggered by continuous topology changes, yields excessive channel and processing overhead. Limited bandwidth, constrained power, and mobility of network hosts make the multicast protocol design particularly challenging.

2. Relevance of the Research (Related Works)

A few protocols have been created to provide the multicast communication which other protocols lack. MANETs are a young class of networks. The Internet Engineering Task Force (IETF) is very actively developing the basics of MANET operation, e.g. the layer 3 routing protocols. The first MANET routing protocol accepted as a standard was AODV in 2003 [1]. In comparison, RIP, one of the first routing protocol for the Internet, has been described as a standard in 1988 after being in use as a de facto standard quite some time before that. Research in the area is still very active as lots of different approaches to the problem are being considered and tested. We aim to contribute to this field by comparing various existing approaches and implementing novel ideas of my own. A promising approach is to extend current (implemented and working) protocols to contain transmission to only relevant parts of the network, as will be explained further on. The Lightweight Adaptive Multicast (LAM) protocol [18] is an example of one of these protocols. LAM is tightly coupled with the Temporally-Ordered Routing Algorithm (TORA) [19] as it depends on TORA's route finding ability and cannot operate independently. An advantage of LAM is that, since it is tightly coupled with TORA, it can take advantage of TORA's route finding ability and thereby reduce the amount of control overhead generated. However, LAM has the disadvantage that it relies on a core node, thus has a central point of failure. Other protocols specified in internet drafts are also able to provide multicast communication, but they too depend on an underlying routing protocol for correct operation. Additionally, the routing protocol described in [17] can suffer from transient routing loops. On-Demand Multicast

Manuscript received April 5, 2009
Manuscript revised April 20, 2009

Routing Protocol (ODMRP) [20] is a mesh based multicast protocol in which a mesh of nodes for forwarding packets is created between the senders and receivers. The mesh is created using the forwarding group concept. The main disadvantage with ODMRP is the excessive overhead incurred in keeping the forwarding group current and in the global flooding of the JOIN-REQUEST packets. The Adhoc Multicast Routing Protocol (AMRoute) [21] is a shared tree based protocol, in which a bi-directional shared user-multicast tree is created involving only the group members. The tree links are created as unicast tunnels between the tree members. The problem with AMRoute is that it depends heavily on an underlying unicast protocol for creating these unicast tunnels. AMRoute is shared tree based protocol. The shared tree approach has a few drawbacks. First, paths are non-optimal and traffic is concentrated on the shared tree, rather than being evenly distributed across the network. Secondly, all shared tree based protocols need a group leader (or a core or a rendezvous point) to maintain group information and to create multicast trees. Two well-known examples of mesh-based multicast routing protocols are the core assisted mesh protocol (CAMP) [22] and the on-demand multicast routing protocol (ODMRP) [23]. A new Multicast protocol is developed named Efficient Mobile Multicast Routing (EMMR). The Description of the protocol is given in Section-3 the type of the network used is explained in section 3.1, Section 3.2 tells what are MPRs. Sections 3.3 and 3.4 describes the relay selection, Forwarding and rules, the experimental results are shown in Section 4.

2.1 Approaches to Multicast

At this point, solutions for multicast fall into several categories: flooding data through the network by copying incoming data to all outgoing connections and variations thereof [5], creating one or several trees of participating nodes over which to forward the data ([6], [7], [8]) and distributing the data through a client-centric protocol in a peer-to-peer network. Flooding is a very simple technique wherein participating nodes simply copy incoming data to all outgoing connections, thereby quickly propagating the data through the network. In any network that is not tree-shaped, it is likely that nodes receive messages more than once, so a duplicate message detection algorithm has to prevent retransmissions which would cause infinite loops. However, it is also clear that this duplicate reception means that bandwidth is wasted because data is sometimes sent to a node that has already seen it and thus no interest in it (anymore). This makes flooding less than optimal in terms of bandwidth efficiency, to the point that the flooding of all the messages in the network blocks out any other traffic. However, propagation speed of data is very high because all available network paths are used to transmit the data, so a message always travels on the shortest path from source to destination. There are approaches that try to combine less wasteful methods of propagation with the speed of flooding [5], [9].

The idea of a tree-based approach is that through some algorithm a spanning tree is constructed that starts at the data source and connects all recipients. By selecting high-bandwidth connections as edges of the tree, a large amount of data can be spread throughout the network in a short time. By charging non-leaf nodes of the tree with the responsibility of forwarding the data they receive over the edges that connect them to the rest of the tree, the source node is relieved of some of its work, because it has to send its data to less recipients to reach the same amount of nodes. An important aspect of tree based multicast is that constructing the trees is a complex task. To calculate an optimal (or at least good) tree, information is required about the network links. Because the topology of wide-area networks can change without warning and the amount of available bandwidth of an link is subject to fluctuations because of other data traveling over it as well, this data needs to be updated for (nearly) every situation, which can be a time-consuming task. Also, because these trees are calculated at the beginning of a transfer, their optimality may decline during a transfer as the performance of the various network links changes [6], [10]. Client-centric approaches try to bypass this problem by abandoning the concept of pre-constructed distribution paths and instead let clients control the transfer by having them cooperate to all get a different part of the data and then redistribute the pieces each client downloaded among themselves, thereby lessening the load on the data source [10], [11].

3. Description of EMMR:

EMMR uses relay nodes for forwarding multicast data. However, EMMR takes into account the multicast group membership of each node. Nodes that are not member of a certain multicast group will never be selected as relay for that specific multicast group. Relay node selection occurs on a per-group basis. If a multicast packet comes in, a node will only rebroadcast it if it is selected as relay node for that specific group. This slight modification of operation guarantees proper operation with possibly less unnecessary transmission, under the condition that the set of group members is connected, i.e. there is a path from every node in the group to every other node, using only members of the group as intermediate hops. If this condition is not met, some nodes will be denied service because their part of the multicast group is unreachable from the data source. If there *is* a path using all nodes (not just group members), a path will be found while this modified version fails to. To provide delivery of multicast data in situations where the members of the multicast group do not form a connected set, EMMR employs an overlay network to connect all relay nodes. Overlay networks are commonly proposed as solutions for providing multicast functionality in situations where the underlying network does not support it [12]. By making sure that all relay nodes are part of the overlay and that any multicast packet will be disseminated throughout the overlay, each relay node will receive the packet and thus be able to rebroadcast it locally. By choosing the right overlay structure, failures can be dealt with up to a certain degree.

In our implementation we chose to use a ring as the structure for the overlay network. Rings have certain qualities that make them suitable to use as overlays in dynamic networks [12]. Rings are graphs with a connectivity of 2, meaning that if 1 node goes down the graph (overlay network) is still connected. Furthermore, each node in a ring has a degree of two. This means that the load from forwarding overlay packets is distributed over all nodes in the overlay. Trees on the other hand often contain a ”trunk” consisting of a few nodes that relay most of the traffic.

3.1 Value of Overlay Structure

Normal relaying transmits IP packets with a *multicast* destination address, wrapped into a layer 2 frame, also with a multicast destination address. Packets forwarded through the overlay are the same IP packets, tunneled in their entirety inside another IP packet with a *unicast* destination address, namely the address of the next member in the overlay path. This unicast packet can travel multiple hops, each time in a different layer 2 frame, but always in a frame that also contains a unicast destination address. This distinction is important because the type of destination address of an L2 frame usually determines how it is treated by the L2 protocol (e.g. IEEE 802.11).

3.2 Multipoint Relay (MPR)

MPRs are selected nodes which forward broadcast messages during the flooding process. This technique substantially reduces the message overhead as compared to a classical flooding mechanism, where every node retransmits each message when it receives the first copy of the message. In link state information is generated only by nodes elected as MPRs. Thus, a second optimization is achieved by minimizing the number of control messages flooded in the network. As a third optimization, an MPR node may chose to report only links between itself and its MPR selectors. Hence, as contrary to the classic link state algorithm, partial link state information is distributed in the network. This information is then used for route calculation.

3.3 EMMR Relay selection:

EMMR relay selection is very simpler algorithms. However, in our test implementation we limited ourselves to the E-CDS algorithm with a minor variation: in regular, a node never selects itself as relay if it is alone or has only one other node in its vicinity. In EMMR, lone nodes (relative to their multicast groups) still need to connect to the overlay network in case there are other multicast group members in the MANET, just none close by. For similar reasons, when two nodes form a pair without any other node near, one of them needs to select itself as relay (to service the other one) and attach itself to the overlay network. In all other cases, regular E-CDS relay selection works for EMMR as well.

3.4 Forwarding and Relaying rules in EMMR

Nodes selected as relay in EMMR need to forward packets in two ways: once as a local broadcast and once through the overlay network. Whenever a multicast packet is received by a node, it is determined whether or not to forward / relay the packet. First, if a node is not selected as a relay, it will not forward the packet. Secondly, it is determined if the packet is a duplicate, as per the specification. If it is, it has been seen (and forwarded) before and is not forwarded again. If it passes these tests, the packet is always rebroadcast locally. Lastly, it is determined whether or not the packet needs to be forwarded through the overlay. In situations where ring neighbors are also directly connected to each other (a realistic situation when the ring is optimized), it would be wasteful to transmit the packet again through the overlay. Normal relaying has already delivered the packet to its destination. Only in situations where reliability is very important could one decide to always forward a packet through the overlay if it passes duplicate detection.

4. Experimental Results

To determine the added value of EMMR, experiments have been conducted. We have considered AODV which is accepted as a standard multicast protocol (see section 2) for our comparison. These experiments have been conducted on ns2. The Delay is termed as the time taken for a packet to reach from the source to destinations. Fig. 1 and Fig. 2 shows the delay graph for speed 10 and 30. Routing Load is calculated as the ratio of control packets sent to the nodes versus overhead. It is a measure of efficiency of the protocol in terms of channel access and is very important in ad hoc networks. Highly mobile nodes cause more tree links and therefore more branch reconstructions. Since tree reconfiguration involves control traffic, the node mobility is an important factor influencing the routing overhead. The below fig.3 and fig. 4 illustrates the decrease in the Routing Delay. The green line shows the Routing Load for AODV and the red line shows for the EMMR.

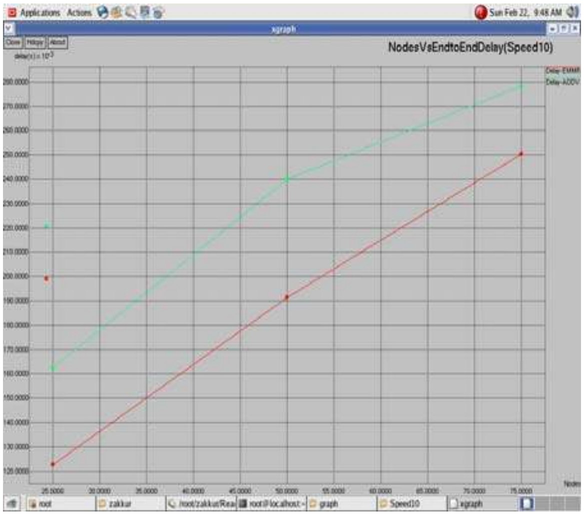

Fig. 1 Delay Speed10

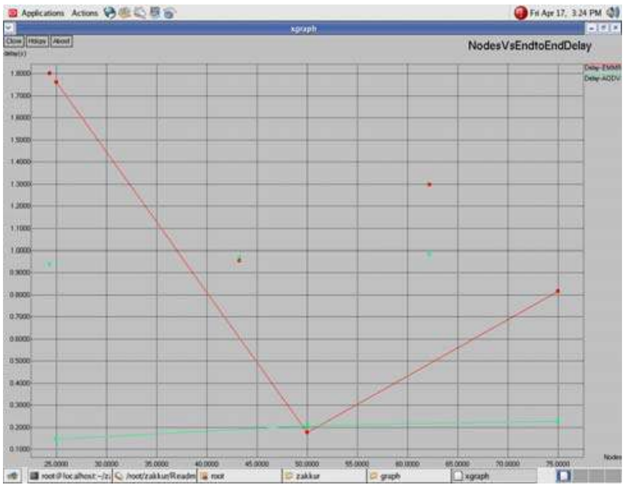

Fig. 2 Delay Speed 30

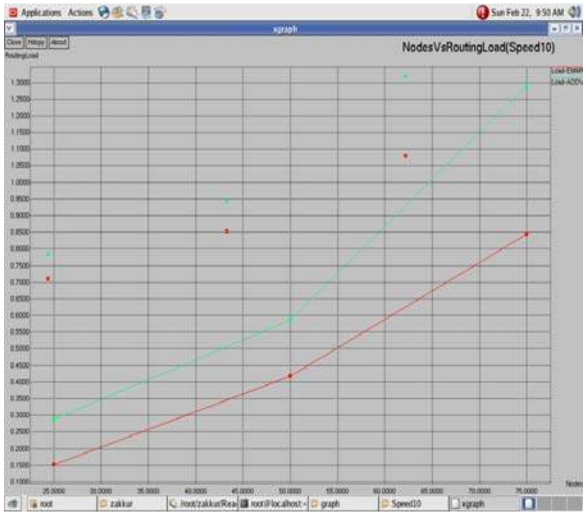

Fig. 3 Routing Load at Speed 10

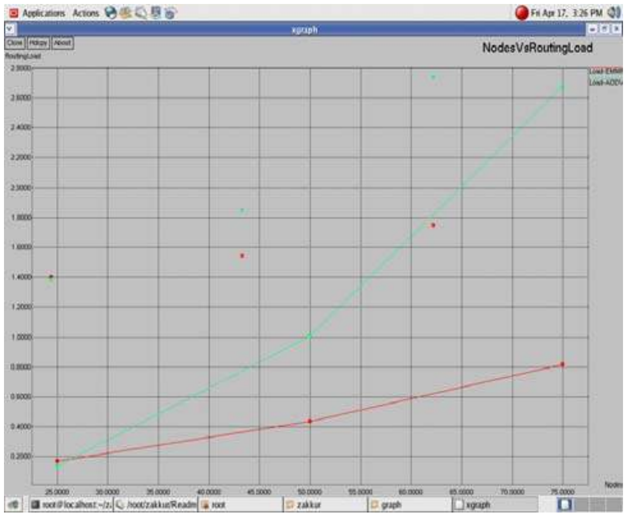

Fig. 4 Routing Load at Speed 30

5. Conclusion

We have designed and implemented an EMMR protocol with the intention of reducing unnecessary traffic to non-interested nodes in MANET multicast operations. We have done it so using our own neighborhood technique build on the top that enables the combining of several messages, such as neighborhood information per multicast group, into one packet, implementation of our making. We have tested our solution, EMMR, as well as an existing AODV implementation on NS2 network simulator. Our experiments have shown that there is no significant difference in performance between EMMR and AODV concerning broadcast operations. When members of a multicast group form clusters within the MANET, EMMR allows more traffic to be sent simultaneously because traffic is confined to the cluster. When applied to a partitioned multicast group, EMMR performs well as long as there is enough bandwidth to accommodate the extra traffic overlay forwarding generates. When bandwidth demand increases, the extra traffic that EMMR's overlay network generates causes the network to get congested sooner than without EMMR. EMMR would therefore operate best in larger MANET's with clusters of multicast group members.

Acknowledgments

I would like to thank my parents for giving me the opportunity to study and bring me up. I would like to thank my wife Shabana to allow me to do so at my own pace, giving me time and space to develop myself and do the things I like to do. Finally I would like to thank my Head of the Computer Science Department Prof. N. Kasiviswanath for sparing and allow me to do the research and my college management for providing me the facilities necessary for my research.

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