

A Caching Mechanism To Improve The Reliability Of Multicasting In Multihop MANET

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Abstract

Reliable multicasting takes help of re-transmissions from the source, to recover lost packets. This imposes a huge overhead on the bandwidth-constrained ad hoc network. In On Demand Multicast Routing Protocol (ODMRP), the multicast members send Join Replies to the periodic Join Queries initiated by the source, to maintain their membership. In this work, we present a mechanism to selectively cache the packets with the Forwarding Group members. This effectively distributes the retransmission responsibility among intermediate nodes. Acknowledgments are sent in the form of bitmaps that are piggybacked on the Join Reply packets. Through this peripheral buffer based approach we are able to provide reliable multicast without any increase in control overhead. The scheme has been simulated on GloMoSim 2.0, and has shown to be effective in improving the packet delivery ratio of ODMRP.

1. Introduction

A Mobile ad hoc network (MANET) is a dynamically reconfigurable wireless network with no fixed infrastructure or central administration. Due to limited radio propagation range of wireless devices, routes are often "multi hop". Nodes in MANETs move arbitrarily, thus network topology changes frequently and unpredictably. Moreover, bandwidth and battery power are limited. These constraints [6], in combination with dynamic topology make routing and multicasting in ad hoc networks a challenge.

The transmission of packets to a group of zero or more hosts identified by a single destination address is called multicasting. The membership of a host group is typically dynamic: that is, hosts are free to join or leave a group at any time. Also the location or number of members in a host group is unrestricted. A host may be a member of multiple

groups at any time. Membership is not a precondition to sending packets to a multicast group. Reliable multicasting implies that all nodes a multicast group should get a packet that is transmitted to the group address. In a typical ad hoc environment, network hosts work in groups to carry out a given task. Hence, multicast plays an important role in ad hoc networks.

Multicast protocols that were designed for static networks could not re adjust their multicast trees fast enough to incorporate connectivity changes. Therefore a number of specialized multicast routing protocols have been proposed for ad hoc networks. Some of these protocols use tree-based structures (e.g., LAM, AMRoute, AMRIS, MAODV), while others use more robust mesh-based structures (e.g., CAMP and ODMRP[13]). These multicast routing protocols are based on IP, which provides best effort data delivery, but does not guarantee any reliability of the delivery. For reliable data delivery, another protocol must run on top of IP that would detect packet losses and initiate mechanism to recover them.

The rest of the paper is organized as follows. Section II discusses the related approaches and their shortcomings. Section III presents an overview of ODMRP. Section IV explains RMRP. Section V presents simulations and performance evaluation. Finally, Section VI concludes the paper and suggests future work

2. Related Work

Pagani and Rossi [14] propose one of the earliest protocols for reliable multicasting in dense ad hoc networks. This was done with the aim to create a basic block for construction of fault tolerant distributed applications. Also this protocol assumes an underlying clustering protocol and therefore becomes inadequate for non clustered adhoc networks. Furthermore, the reliability is optimized for quasi static networks and degrades with increasing mobility. In

[11], Gupta and Srimani present a theoretical study of a reliable multicast protocol making use of a core-based shared multicast tree. However multicast trees need frequent reconstruction in a dynamic environment. The authors have introduced the concept of 'forwarding regions' to limit the flooding associated with the reconstruction messages. Data propagation takes place using the core. Therefore it is affected by traffic concentration and core vulnerability. Also, nodes are required to buffer packets irrespective of their group membership.

Tang and Gerla propose an extension of ODMRP in [10], to provide reliability at the network layer. RODMRP has a 'Round Robin Windowing' scheme, where outstanding packets are unicast to the downstream mesh members in a round robin fashion. Thus the whole session can be slowed down by overloaded or slow intermediate nodes. Also, the behavior of RODMRP, in situations where race conditions occur, is not clarified.

The instability of routes in MANET calls for a trade-off between reliability and scalability. This issue was addressed by probabilistic gossip based protocols. The Anonymous Gossip mechanism in [12] allows nodes to exchange received message list with nearby group members. This transaction allows each node to retransmit the messages available locally, which its peer is missing. In Route Driven Gossip (RDG) [7], members forward a received message to a small part of the group. Iteratively the entire network is covered, with controlled redundancy and high reliability. RDG is a pure gossip mechanism where control and data packets are gossiped. One considerable drawback of gossip based protocols is that they do not consider packet ordering or flow control.

In [9] a hierarchical Family ACK Tree (FAT) scheme is proposed to address the above mentioned problem of scalability verses reliability. FAT allows non leaf nodes to cache packets. Also, each node is responsible for reliably delivering data to its children. The inefficiency of [9] stems from the inability to handle high mobility networks.

While forward error correction is an effective technique to recover damaged packets, retransmission is the only solution to lost packets. Therefore another tradeoff is encountered between reliability and the congestion caused by retransmissions. In [8], Gerla et.al. showed the importance of congestion control in improving reliability. They proposed a multicast transport protocol called Congestion-controlled Adaptive Lightweight Multicast (CALM), on this principle. In [4], the authors propose Reliable Adaptive Lightweight Multicast (RALM). It is based on CALM and is able to recover from losses using source based retransmissions. In [3], the authors propose Reliable Adaptive Congestion-controlled Transport protocol (ReACT), with receiver based error recovery. ReACT differentiates between congestion and local losses and treats the later with a

local repair mechanism. In case of congestion, these protocols deliver data to each multicast member in a round-robin fashion. Since the focus is on reliability, therefore scalability and throughput issues have taken a back seat.

Some of the recent approaches to provide reliable multicasting in wireless ad hoc networks include Active Reliable Multicast Protocol with Intermediate Node Support (ARMPIS) [2] and Reliable Multicast Protocol for Wireless Mobile Multi Hop Ad hoc Networks (ReMHoc) [1]. ARMPIS distributes multicast message cache and retransmission tasks among intermediate nodes to offer a scalable reliable multicasting. On the other hand ReMHoc is a receiver initiated NACK-based protocol that ensures the eventual delivery of the multicast data. It uses a random timer based feedback suppression to avoid NACK and retransmission implosion. It has also incorporated a 'heart-beat' timer, which is used to keep peer members updated on multicast packets. But the Repeat and Request timers depend on the distance measurement between nodes which is not only accurate in a mobile scenario but also causes extra overhead.

It has been demonstrated that providing reliability of data delivery is a NP complete problem [6]. Moreover we observe that retransmission is the only way out to recover lost packets. A consequence of these two premises is the inevitability of caching packets at intermediate nodes. In this work we present a scheme to minimize the caching, while maintaining enough redundancy to tackle mobility/handoff related packet loss. We demonstrate our scheme as an extension to the ODMRP protocol. This allows us to take advantage of its inherent signaling mechanisms. We have chosen ODMRP because we felt that its mesh based approach was better suited to the multi hop ad hoc environment than most. Moreover the fact that ODMRP does not provide a retransmission facility, helped us to develop our control case.

3. ON DEMAND MULTICAST ROUTING PROTOCOL: An Overview

ODMRP uses the concept of a forwarding group, a set of nodes between the sender and the receiver, responsible for forwarding datagrams on shortest paths, to build a forwarding mesh for each multicast group. By using a mesh instead of a tree, drawbacks of multicast trees (frequent tree reconfiguration, traffic concentration, intermittent connectivity etc) can be overcome. Figure 1 shows the robustness of the mesh. Even if the link A-B goes down, it is possible to use the branch A-C-B to send packets from S1 to R2.

In ODMRP, group membership and multicast routes are established and updated by the source on demand, using a request and reply phase. Nodes will behave as routers if they determine they are on the optimal path between an ac-

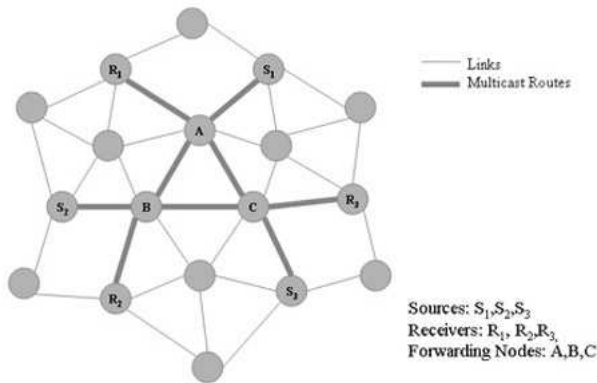


Figure 1. Forwarding Mesh in ODMRP

tive sender and one or more of its receivers. Whenever a multicast source has packets to send, it broadcasts to entire network a member advertising packet, called the JOIN REQUEST / JOIN QUERY. When a node receives a non-duplicate JOIN REQUEST, it stores the upstream node id (backward learning) and rebroadcasts the JOIN REQUEST. When the JOIN REQUEST packet reaches a multicast receiver, it updates the source entry in its Member Table, according to the packet traveled along the optimal path. As long as valid entries exist in the Member Table, JOIN TABLES / JOIN REPLY are periodically broadcast to the neighbors. When a node receives a JOIN TABLE, it checks if the next node id of one of the entries matches its own id. If it does, then this node is on the shortest path from source to the receiver, and thus is a part of the forwarding group. It then sets its FG FLAG and broadcasts its own JOIN TABLE built upon the matched entries. The JOIN TABLE is propagated by each forwarding group node until it reaches the multicast source.

4. RELIABLE MULTICAST ROUTING PROTOCOL (RMRP)

4.1. Data Structures

Each receiver maintains a data structure called the DATA_ACK_TABLE that contains packet receive status bitmaps (RMRP_BITMAP) for every source in every multicast group that the receiver is a part of. This bitmap is build relative to the last packet it received successfully.

The NEIGHBOUR LIST (NL) lists the downstream nodes. If a new node is reported from the lower layer it is added to the list. It is updated regularly to reflect active nodes only and eliminate the nodes, which have moved out of range. The BUFFER CACHE (BC) stores the packets, which have not been acknowledged by one or more

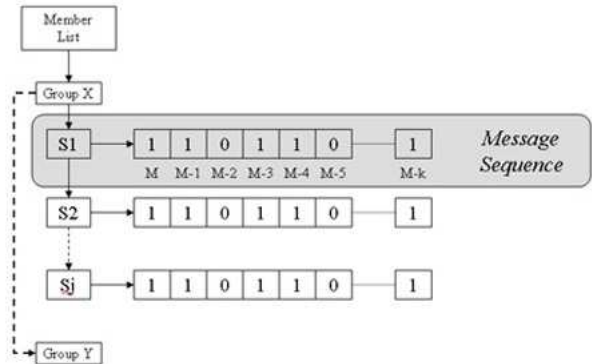


Figure 2. Format of DATA_ACK_TABLE

members in NL. The process of identifying a message to be flushed is shown in the figure 3. Each forwarding member maintains a DELIVERY TABLE, for each source of traffic, which keeps track of the packets, which have been successfully transferred to all the downstream nodes. The entries in the DELIVERY TABLE are initializes to . They are updated according to the bitmaps received from the downstream nodes.

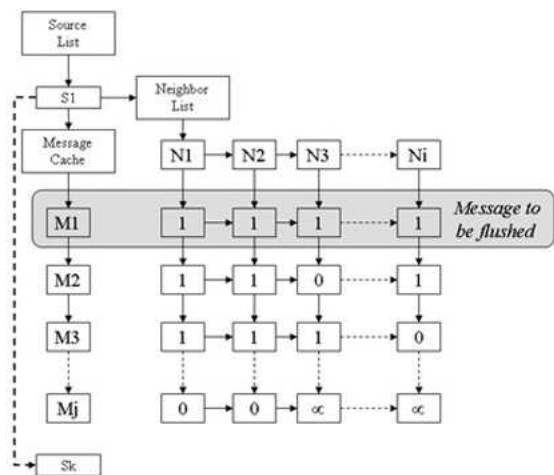


Figure 3. Format of DELIVERY TABLE

4.2. Protocol Description

The main motivation behind developing RMRP is to provide the multicasting mechanism with an acceptable level of reliability in a mobile and ad hoc environment. However we are also unwilling to compromise on throughput or scalability. Under the circumstances some degree of tradeoff was inevitable.

In our protocol the responsibility of detecting and sig-

nalizing errors is on the receiver. We assume that all packets in a multicast flow are timestamped using incremental sequence numbers. Therefore a node is able to identify a missing packet from the gap in the sequence number of received packets. Each node also maintains a k -bit bitmap to reflect the status of the k packets relative to the current one. This information is passed on to the immediate forwarding node, so that the missing packets can be resend. We observed that for ad hoc networks with moderate neighbor density, it is better if the receiving nodes send their bitmaps in a round robin fashion. However for sparsely connected or highly mobile networks it is better to transmit the bitmap as soon as an opportunity is available. This receiver initiated approach argues favorably with respect to scalability. This approach also minimizes acknowledgment implosions.

We stipulate that intermediate nodes will cache some packets of the multicast flow. We argue that the size of the cache is as large as the greater of the size of the bitmap and the number of downstream nodes. When an intermediate node receives a k -bit bitmap, it must be in a position to retransmit any of the previous k packets. Therefore the cache size must be at least equal to k . Also, we assume that the children of a node send their bitmaps in a round robin fashion, one after each transmission from the node. i.e. it receives a bitmap from child1 after the first transmission, then from child 2 after the next transmission and so on. Intuitively the contents of the bitmap from the n th child are relative to the n th transmission. If the number of intermediate transmissions exceeds the size of the bitmap then the bitmap will not reflect the receipt status of the initial transmissions. In this case the cache size should be equal to the number of downstream neighbors. A packet is deleted from the cache when it is acknowledged by all the downstream neighbors.

This selective caching ensures that that in case a receiver loses a packet, it is retransmitted from the preceding node, instead of the source. Since the forwarding nodes are also liable to lose packets, by induction, they would get the packet from their preceding node. Therefore the retransmission load is distributed over the forwarding members, instead of being localized at the source. Moreover these retransmissions can take place at multiple sites in parallel, thus reducing the effective time lost.

Due to mobility or otherwise, a situation may so arise when a node asks its forwarding node for a packet that is not in the cache of the later. In such a situation refetching the packet from the source is not a good idea, especially for networks where the forwarding node is distant from the source. Therefore we favor a local search heuristic. The intermediate node requests its one hop neighbors to unicast the packet to the destination. Eligible neighbors will choose a random backoff, and the winning node will pro-

ceed for the unicast. Losing nodes will overhear this transmission and cancel their timers.

When a node moves into the range of a new copy site, it has to first associate with the site before it can request service from it. However, a node will not able to associate if it keeps moving too fast. Therefore, a highly mobile node will not keep triggering the local packet recovery mechanisms throughout the network.

5. Performance Evaluation

RMRP was implemented and incorporated into ODMRP. The Global Mobile Simulator (GloMoSim) developed at Parallel Computing Laboratory, University of California; Los Angeles has been used for our simulation. GloMoSim is an event-driven simulator for parallel simulations, written in variant of C called PARSEC.

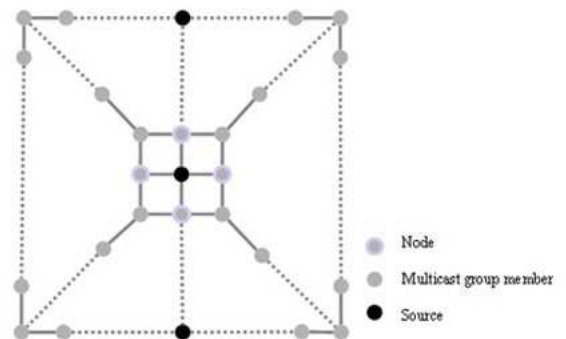


Figure 4. Simulation Topology

Our simulated network consists of a grid of nodes, where terminals along the diagonals are multicast members. Additionally nodes adjacent to the corner nodes are also group members. An example topology is shown in figure 4. So, for a 25 node network there are 19 members, for a 49 node network there are 23 members and so on. In fact for a $n \times n$ grid there are $10 + (2n - 1)$ group members. The traffic pattern consists of 3 CBR sources transmitting 512 byte packets at predefined time intervals. The nodes follow a random waypoint mobility model with speeds varying between 0 to 20 m/s. Each run is for a simulation time of 300 seconds. Comparisons are provided between the basic ODMRP protocol and RMRP. Nodes have a transmission range of 250 meters and only their adjacent nodes are within their transmission range.

Figure 5 demonstrates how RMRP is able to achieve greater reliability of data delivery. The statistics were collected with a network of 25 nodes. Figure 6 was achieved under similar network considerations. It demonstrates how the throughput varies with load.

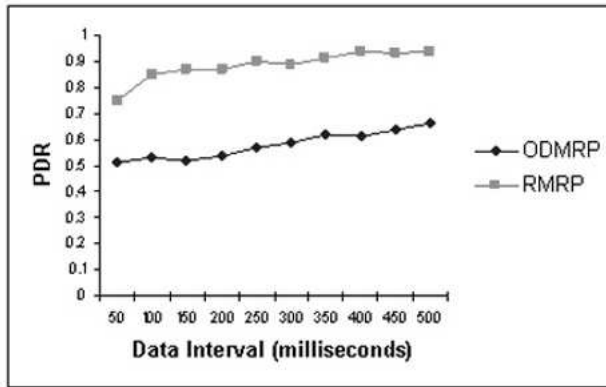


Figure 5. Performance Under Load

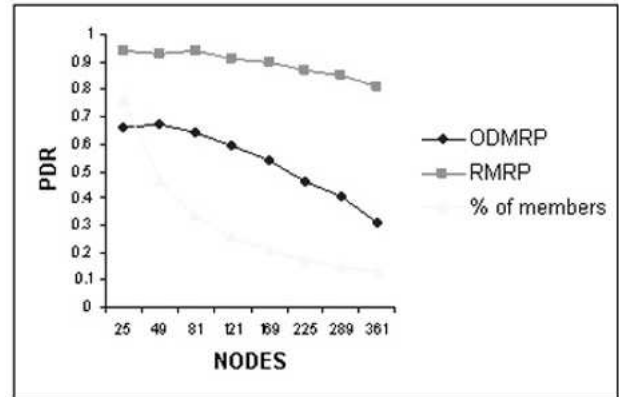


Figure 7. PDR vs Network Size

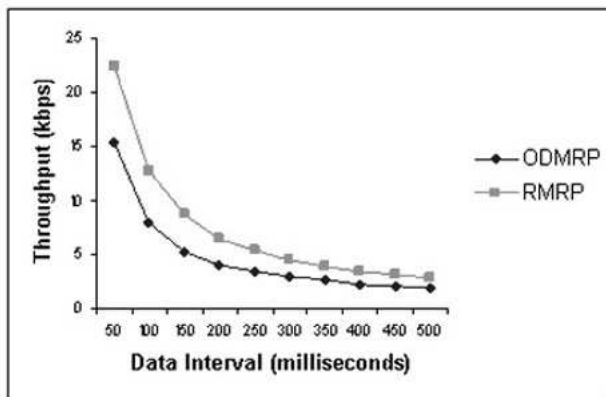


Figure 6. Throughput Analysis

Figure 7 is meant to demonstrate the scalability of RMRP. It demonstrates how RMRP is able to deliver an appreciable percentage of packets, in the face of increasing network diameter.

6. Conclusion

In this paper, we introduced our reliable multicast routing protocol, RMRP, to provide a high degree of reliability in multi hop ad hoc networks, without significant tradeoffs in throughput or scalability. We also demonstrated how the caching at intermediate nodes can be effectively minimized. Although we have simulated RMRP as a modification of ODMRP, its principles can be adapted for other protocols as well. The scheme has been implemented and tested on GloMoSim. The results validate our claims that RMRP is a conservatory protocol, which optimizes the caching mechanism to prevent expensive retransmissions from the source.

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