Reliable Group Communication in an Ad Hoc Network

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Abstract

In this paper an enhancement to the reliability of the ODMRP multicast ad hoc protocol is described. The enhancement attempts to increase the overall data packet delivery ratio by adding packet storage and retransmit operations coordinated by the multicast source.

1. Reliable Group Communication

Reliable group communication has a relatively long history in wired networks. Reliable distributed group communication began with solutions to basic distributed problems and moved on to protocols for static group memberships. To get past certain limitations in the solutions for static memberships, the dynamic group membership model was proposed[1]. This introduced the concept of a Group Membership Service, responsible for group management.

In this model a sender or third party based GMS has the following responsibilities: 1. handle group joins and leaves, 2. identify and remove 'dead' nodes from list, 3. distribute group membership list to group, 4. flush unresolved messages from system before new group view is distributed, 5. sequence all messages uniquely, 6. coordinate a reliable delivery protocol (2pc), 7. coordinate storage of messages for retransmit, and 8. retransmit stored messages to requesting nodes.

In this model, an individual node has the following responsibilities: 1. receive, order and deliver messages to the app. layer, 2. originate and transmit new messages.

In wired group communication protocols, research has differentiated between *sender* based and *receiver* based responsibility for reliable message delivery [2]. In a *receiver*-based model, a clear advantage is that no overall group membership list is necessary.

For a receiver based model, the top four GMS responsibilities listed disappear, leaving four remaining. Additionally, a third responsibility is added to the individual nodes, to NACK unreceived messages. For the four remaining GMS responsibilities, this paper takes the following approach: sequencing messages uniquely can be a standalone problem, as can the coordination of message delivery. These two responsibilities provide message-ordering guarantees in wired networks.

This paper focuses on a technique to coordinate the remaining two responsibilities of message storage and retransmission. Section 2 presents a brief overview of the ODMRP protocol, section 3 outlines the reliability enhancement, and finally section 4 concludes the paper.

Though expired from IETF, ODMRP was chosen as the protocol to work with because simulations have shown it to be one of the most reliable ad hoc multicast protocols, short of flooding, created to date.

2. ODMRP overview

ODMRP[3] is a mesh-based on-demand ad hoc multicast protocol. It performs scoped flooding of data packets to all group members by establishing a 'forwarding group' of network nodes between a source and the group members. Timeout driven periodic route refreshes update the broken links due to node mobility or resource changes. Route setup and route refresh both consist of two phases: a Request phase and a Reply phase.

Request phase: When a source has multicast data packets to send, it broadcasts a "Join Query" packet. Each node receiving the Join Query packet will add the IP addresses of the upstream node and originating source to its routing table, add its own IP address into the last hop IP address field, and rebroadcast it.

Reply Phase: A group member, on receiving a Join Query packet, initiates a "Join Reply" packet once the route is selected. First the receiver node pulls all source and next hop IP addresses for the group from its routing table, adds its own IP address into the previous hop field, and broadcasts the packet. Each neighbor node receiving this packet looks at the series of next hop IP address entries. If a next hop IP address matches its own address, the node is on the forwarding path between source and receiver. It sets its Forwarding Group Flag to reflect this, and builds its own Join Reply packet to broadcast.

Forwarding Data and Maintenance: If a node receives a multicast packet, it checks the setting of its Forwarding Group Flag. If the flag is set, the node is a forwarding group member for the group. It rebroadcasts the packet to its neighbors. Periodically, the source will refresh routes with another Join Query packet.

Unicast Functionality: Using the same Join Query/Join Reply protocol with a target unicast IP address, a sender can discover a route to a unicast receiver. With duplicate Join Query packets being dropped, the forwarding group route created by the unicast operation of ODMRP is a single path.

3. Reliable ODMRP

In recent simulations[4] ODMRP has been shown to be very reliable. Only flooding outperforms it. ODMRP's delivery ratio rises above that of flooding when either the sender count or the network traffic load is increased.

For ad hoc networks, guaranteed ad hoc reliability is currently infeasible, however increases in the sliding scale of a protocol's 'reliability ratio' are positive additions. This technique allows each source to work with the two parameters of reliability and overhead cost, dialling the reliability ratio up or down as desired.

Overview: The responsibility for the tasks of packet storage and retransmission is assigned to all members (not forwarders) of the multicast group, with the source of each data stream coordinating responsibilities. The source node is a single point of failure, but this is immaterial, since this node dying or partitioning away from the group halts the data stream anyway. With each group member storing a portion of the data packets, the group as a whole can store a larger distributed "sliding window" of data packets. A node requesting packets will first broadcast a local request, followed by a network wide request after a timeout. If no reply is forthcoming, the assumption is that the node is partitioned away from the group. In this case, the node will boost its transmission range, attempting to reconnect by a stronger signal, as described in [5], broadcasting a third packet request.

Packet Storage: The Reliability component is projected to add packet storage to ODMRP as follows; when a new source initially sends out a Join Query, it becomes a "Reliable Join Query" protocol phase. Each receiver replies with a Join Table modified to add the receiver's IP address to a list structure. This list is gathered by all forwarding group members. All Reliable Join Tables are forwarded to the source. The source obtains a full list of all receivers in the group. Reliable Join Queries occur periodically, but at a much lower frequency than the standard Join Query.

The source will then take the list of receivers and divide the task of packet storage evenly between them. On the next multicast data packet, the source piggybacks a table of IP addresses/sequence numbers ranges. Each receiver then begins storing data packets. The multicasting of this storage responsibility table is similar to a "network snapshot"; nodes will begin their storage responsibilities at 'close to' the same time, and 'almost all' packets will be stored somewhere. This recovery scheme does not depend on which node stores the packets, only that they are stored somewhere.

As more and more nodes join, duplicate storage responsibilities can begin to be assigned. Ideally, duplicate copies of the same packets will be located remotely from each other in the network.

Packet Retransmission: On noticing a packet gap, a receiver broadcasts a Join Query Retransmit Request packet with a local time-to-live, listing the packets needed along with its IP address. A group node receiving this packet checks its storage and unicasts back any packets found. If the reply is incomplete, the requestor will set a network time-to-live and try again. If no replies have been received, the requestor will assume it is partitioned from the network, boosting its transmission range for a third Retransmit Request attempt.

This method takes advantage of a large group membership in order to conserve bandwidth. It also begins to build upon the concept of a sliding scale of reliability for ad hoc networks. The parameters of overhead cost versus degree of reliability are configured by each source. For example, in a network with a set number of receiver nodes, the source could specify that each node store all data packets all the time; the storage overhead on the system would be great, but a relatively greater degree of reliability would result.

4. Conclusion

This paper described reliability enhancements to ODMRP, consisting of store and retransmit operations between receiver nodes, coordinated by source nodes.

In addition to standard ns-2 simulations, various realistic conditions will be modeled, such as traffic congestion followed by periods of relief, or a node being partitioned for an extended period of time.

References

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