Reducing Message Overhead in On-Demand Mesh based Multicast Routing Protocols

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Abstract— **In wireless networks, due to limited battery power, it is crucial to reduce the transmission overhead and power consumption. In this paper we discuss how to achieve low transmission overhead and reduced power consumption by minimizing the transmission of redundant control messages. The popular on-demand multi cast routing protocols like AODV and ODMRP has drawbacks due to transmission overhead. As the mobility of communicating nodes increases the transmission overhead also increases as the number of specific control messages used for the protocol functioning are high in number. In a communication network where the high mobility is not demanding, ODMRP generates transmission overhead and thereby power loss due to unnecessary retransmission. In this paper we are discussing a method where the control messages used is considerably reduced. The broadcast of control messages for route establishment as well as route maintenance is done when the existing reliable path becomes invalid or unreachable. This method can be considered as an efficient protocol for on-demand ad hoc multicast routing protocols. This technique helps to achieve high packet delivery ratio but low delay, congestion and there by low power consumption.**

Keywords—**ad hoc, on demand, multi cast, routing protocols, ODMRP, AODV**

I. Introduction

Mobile Ad hoc NETwork (MANET) is a kind of self-configuring network of mobile nodes or hosts connected by wireless links [8]. The network topology can change randomly and rapidly, at unpredictable times. Since wireless links generally have lower capacity, congestion is typically the norm rather than exception. The majority nodes will rely on batteries, thus routing protocols must limit the amount of control information that is passed between nodes [6].

The major application areas of MANET technology are in areas were rapid deployment and dynamic reconfigurations are necessary and the wire line network is not available. Some among those areas are military battle fields, emergency search and rescue sites, class rooms, and conventions. In all these application areas participants share information dynamically using their mobile devices [11].

Multicasting can improve the efficiency of the wireless link when sending multiple copies of messages by exploiting the inherent broadcast property of wireless transmission. Multicasting reduces the communication costs for applications that send the same data to multiple recipients. Instead of sending via multiple unicasts, multicasting minimizes the link bandwidth consumption, sender and router processing, and delivery delay [16]. Multicast gives robust communication whereby the receiver address is unknown or modifiable without the knowledge of the source within the wireless environment.

The approach to do multicasting is classified into tree-based and mesh-based approaches [8]. A tree based multicasting routing protocol maintains and enhances a multicast tree structure specialized in MANET scenarios. The drawbacks maintaining multicast trees in ad-hoc network are frequent tree configuration and non-shortest path in a shared tree. Mesh based routing protocol maintains mesh of the connected components of the network and has multiple paths from sources to multicast destinations [8]. This reduces the repairing overhead due to presence of alternate paths available in the network. Mesh based routing protocols lead to congestion under the conditions of high traffic load which can result in low packet delivery ratio [8].

ODMRP (on demand multicast routing protocol) [3]is a mesh based on demand multicast routing protocol. ODMRP is effective and efficient in dynamic environments and scales well to a large number of multicast members. The advantages of ODMRP are: low channel and storage, usage of up-to-date and shortest routes, robustness to host mobility, maintenance and exploitation of multiple redundant paths, scalability to a large number of nodes, exploitation of the broadcast nature of wireless environments, Unicast routing capability [3].one of the disadvantage of ODMRP is frequent retransmission of control messages for route refreshment by every source could result in scalability issues.

AODV (ad hoc on demand distance vector routing protocol)[1] is a popular tree based on demand multicast routing protocol. The merits of AODV are: low congestion, usage of up to date shortest route on demand, reliable route using route discovery period. The demerits are: increased number of control messages that may lead to traffic overhead as mobility of host increases, and also the link breaks that lead to frequent tree reconfiguration overhead.[6]

The organization of paper is as follows. Section II describes the related works in this area. Section III describes how the communication nodes establish routes. Section IV details about how the established route to be maintained. Section IV contains the details of routing after applying the method. Section V concludes the paper.

II. RELATED WORKS

ODMRP is proposed as well suited for ad hoc wireless networks with mobile hosts where bandwidth is limited, topology changes frequently, and power is constrained. Simulation results show that ODMRP is effective and efficient in dynamic environments and scales well to a large number of multicast members [3].

The minute details of ODMRP are explained and illustrated in detail in the internet draft [2].

An investigation on the performance of multicast routing protocols in wireless mobile ad hoc networks is done [13]. As a result of that it is found that mesh protocols performed significantly better than the tree protocols in mobile scenarios. Five protocols that were considered for the analysis were AMRoute (Ah hoc Multicast Routing), ODMRP (On Demand Multicasting Routing Protocol), AMRIS (Ad hoc Multicast Routing protocol utilizing Increasing id numberS), CAMP(Core –Assisted Mesh Protocol), and flooding. AMRoute uses virtual mesh links to establish the multicast tree. AMRoute depends on the underlying Unicast routing protocol. The trees need to be reconfigured only when the virtual mesh links also fail. The transmission overheads are associated only with member nodes only. The disadvantage is that it suffers from temporary loops and creates non optimal trees when mobility is present. ODMRP maintains route information when required only. it uses forwarding group concept and also uses soft state approach for group membership. As ODMRP has the ability to Unicast it does not require another Unicast routing protocol. AMRIS uses a shared tree to forward multicast data. Each node in the network has a session ID number that is used to direct the multicast data. AMRIS does not require separate Unicast routing Protocol. AMRIS detects the link breakage by beaconing mechanism. If beacons are not heard for considerable interval of time the node considers the neighbouring node to be out of radio transmission range. Packets from the registered parent and child are forwarded. If the tree breaks the packets are lost till the tree from parent to child is recreated. CAMP creates shared mesh to support multicasting. All nodes maintains table for routing and maintenance information. CAMP has two types of nodes simplex and duplex. Simplex for one way connection and duplex for two way connection. The member nodes caches details of the data packet forwarded by each. AMRoute performed well when the mobility and number of senders are small. Inefficient formation of trees and increased loops seriously affect the performance of AMRoute. ODMRP has good result as no control packets are triggered by link breaks thereby reducing overhead for multicast member nodes. AMRIS was sensitive to mobility and traffic load. The number of retransmission and the size of beacons lead to poor performance of AMRIS.CAMP has good traffic scalability for increasing multicast group size.

The comparative simulation analysis as per [6] shows that while dealing with the specific characteristics of MANETs, A mesh based protocol can out perform tree based protocols due to the availability of alternative paths, which allow multicast datagram to be delivered to all or most multicast receivers even if links fail . ODMRP uses forwarding group concept. No explicit control message is required to leave the group. ODMRP maintains a mesh topology rooted from each source. ODMRP provides alternative paths and link failure need not trigger the recomputation of the mesh, broken links will time out. Routes from multicast source to receivers in ODMRP are periodically refreshed by the source. ODMRP broadcast the reply back to the source, advantage is that this allows multiple possible paths from multicast source to receiver, but the disadvantage is that broadcasted reply requires intermediate nodes not interested in the multicast group to drop the control packets, resulting in extra processing overhead. ODMRP activate a multicast route immediately [6]. AODV discovers routes on demand by route discovery mechanism. AODV builds a shared multicast tree based on hard state, repairing broken links and explicitly dealing with network partitions .Tree based protocols suits best for the network with low mobility. As the tree is based on hard state any link breakages force actions to repair the tree. A multicast group leader maintains up to date multicast tree information by sending periodic group hello messages. A bi directional tree is more efficient and avoids sending duplicate packets to receivers. AODV unicasts the reply. Since unicasted reply back to the source, if an intermediate node on the path moves away, the reply is lost and the route is lost. AODV does not activate a multicast route immediately. A potential multicast receiver should wait for a specified time allowing for multiple replies to be received before sending an activation message along the multicast route that it selects [6].

Simulation and analysis of multicast protocols is done using NS2 as simulation tool. A detail regarding how the compared protocols are implemented in ns2 is given with a little details [8]. The protocols compared are MAODV (Multicast Adhoc On demand Distance Vector), AMRoute, AMRIS, ODMRP and CAMP. This papers result also underlines that ODMRP outperforms the rest protocols considered.

In [15] authors make a novel approach to switch between the most efficient protocol adapting to the changing network conditions. This proposal has come from the fact that certain ad hoc routing protocols perform better than others under specific mobility and traffic patterns.

III. ROUTE ESTABLISHMENT

In a mesh based multi cast routing protocol, it uses a subset of nodes to forward the multi cast packets. It uses no explicit control message to leave the group, hence called the soft state approach to maintain multi cast groups.

When a multi cast source has data to send, but no route to the multi cast group, source initiate route discovery phase. Source broadcasts Join Query control packet to the entire network. This Join Query is periodically broadcast to refresh the membership information and to update routes. When a node receives the Join query packet, it stores the source id and sequence number in message cache. Later join query duplicates can be detected by matching with message cache details. The routing table is updated with appropriate node id from which the message was received. If the TTL value is greater than zero the message will not be a duplicate.

Considering a real time scenario of military deployment in an emergency area, there are three different levels of mobility. At the starting stage all the vehicles and army people will be highly mobile to get a reliable stationary position. After considerable period of time many army vehicles and army people would have find their reliable positions. Only very few would not have achieved the stationary position. At the third phase all would have found their position reliable and stable for a considerable period of time.

In the described scenario at the first stage as the mobility of the nodes are too high the route finding overhead will be very high. So the control messages need to be transmitted and retransmitted many times. So the control message transmission redundancy is very high. At the second stage almost all the mobile nodes would have find a reliable and stationary position. Hence the overhead associated with route finding will be comparatively reduced than the first stage. At the third stage almost all the mobile nodes will be relatively stable. Very much similar to stationary mesh for a reasonable period of time. So the frequency at which the route needed to be refreshed is comparatively low. So the overhead due to the redundant transmission of control messages is reduced.

In First Phase it initiates the route discovery by request and reply cycles. During the route initiation phase the Join route request messages (JRQ) (with the data to be send attached) are broadcast to the network. When a node in network receives this JRQ, if the destination id is not its own id it stores the id of the node that forwarded the message to it (i.e. the just previous node by backward learning) in the routing table and rebroadcasts the JRQ. When JRQ reaches the destination the destined node creates a Join Response (JRP) and broadcast that to network.

In Second Phase when a node receives the Join Response it checks if the next node id of one of the entries matches its own id. If it is matching it indicates that it is one intermediate node in the route between the source and destination. It then sets the Group Flag (GF) and broadcasts its own JRP built on match entries. This process of JRP broadcast continues till it reaches the multi cast source via shortest path. These JRQ / JRP cycles finally leads to a mesh of nodes called the forwarding group.

In Third phase when no acknowledgement is received within the timeout interval the node retransmits the message. The retransmission is carried to selected neighbors with reduced sub tables. If the packet delivery cannot be verified after an appropriate number of retransmissions, the nodes consider the route to be invalidated. On link failure the node transmits JRQ specifying next hop cannot be reached for a set of sources cannot be reached. On the receipt of these messages each node builds the JRP to its next hop on having route to set of sources. If no route is available the node simply broadcast message by setting the Group Flag.

When a Join Query reaches a multi cast receiver it creates and broadcasts a Join Response to neighbors following the reverse path to the source node. When a node receives the Join Response it checks the next hop node id of one of the entries matches its own id. If it matches then it sets the forwarding group flag, knowing that it is on the path to source. Then the node broadcasts its own Join Table upon the matched entries. The next hop id is filled by extracting information from routing table, like wise the Join Response is propagated till it reaches the source. This whole process yields a mesh of nodes, the forwarding group. As shown in fig 1.

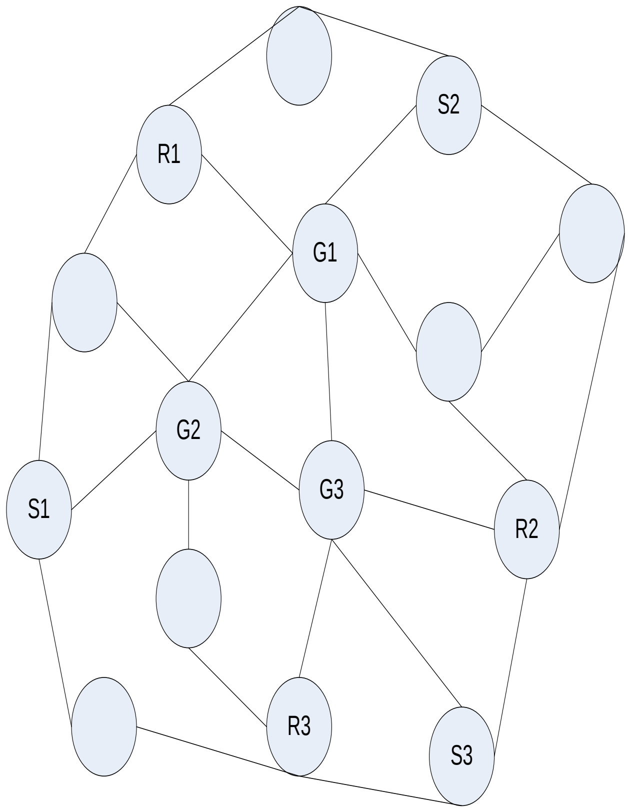

Figure 1. Mesh created by nodes within the transmission range

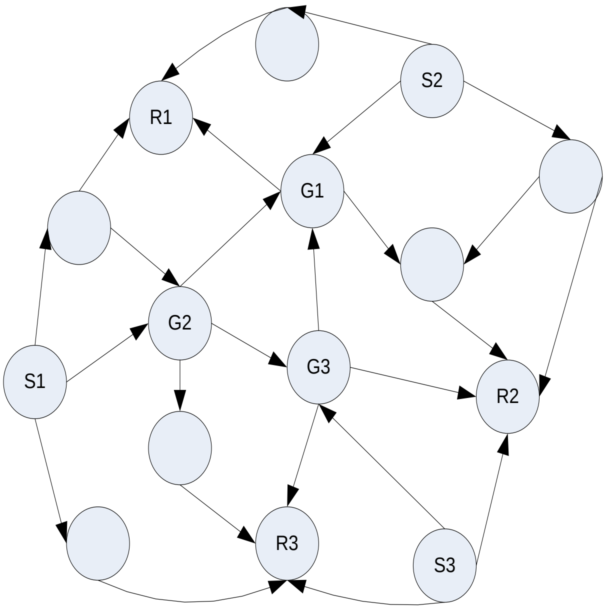

Figure 2. Propagation of Join Query among the mobile nodes

In the figure 1 S1, S2, S3 are sources, they have data to send to the receivers. R1, R2, R3 are the multi cast receivers. G1, G2, G3 are the forwarding group nodes, the set of nodes that are used to forward the data. All of these nodes are mobile. Those nodes with a line linking in between them are within the transmission range of its neighbors. The transmission range is used to make a communication link in between. Here G1, G2, G3 are considered as more reliable node than other mobile nodes that are not named, hence called forwarding nodes. If the visibility from the sources decreases to G1, G2 and G3 alternate routes has to be found by re initiating join query from sources through the probable routes as shown in mesh. If the forwarding nodes G1, G2, G3 move away from within the transmission range, new nodes from the mesh will be considered as new set of forwarding nodes.

In the figure 2 the propagation of JRQ is shown. S1, S2, S3, are the multi cast sources which have data to be transmitted to R1, R2, and R3. All the sources propagate the JRQ to the nearest neighbors within the transmission range. All the nodes that receive the JRQ checks for available routes. If routes are available, the data can be forwarded through the valid route to the destination. Else the propagated JRQ has to be forwarded by the neighbors till it reaches the destined receiver nodes. The arrows indicate the propagation of JRQ among the mobile nodes that are communicating.

In Figure 3 the propagation of Join responses from receivers to sources is shown. As the JRP propagates backward to the sources on the way the nodes will set the forward group flag. Group flag indicate the forwarding nodes who will participate in communication.

IV. Route Maintenance

While the source has data to send, the source periodically sends Join Query packets to refresh the forwarding group and routes. When a node receives a data packet it rebroadcast that data packet only when it is not a duplicate and the setting of forwarding group flag for multi cast group has not expired. This procedure minimizes the traffic overhead and prevents sending packets through stale routes.

If a multi cast source wants to leave the group, it simply stops sending Join Query packets since it does not have any multi cast data send to the group. If a receiver no longer wants to receive it stops sending join Reply for that group hence soft state approach is achieved. Forwarding nodes are changed to

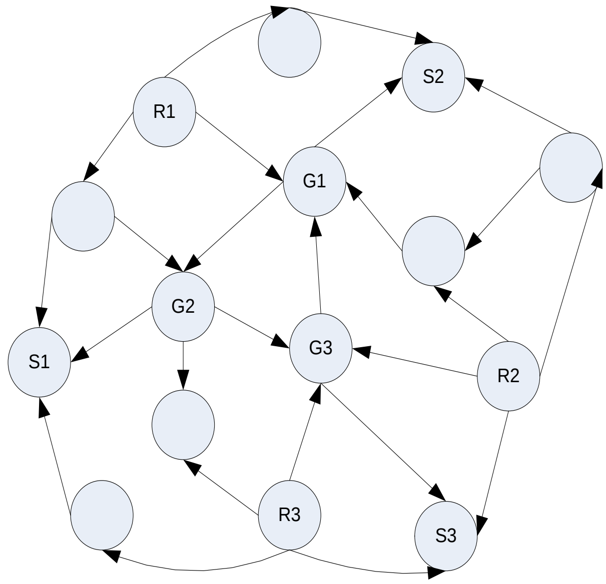

Figure 3. Propagation of Join Response from receivers to sources

non forwarding nodes if not refreshed i.e. no Join Tables received before they time out. No explicit control messages are used to enter or leave the group hence this method uses soft state approach for membership maintenance.

A routing entry not recently used is expired. Next hop routing information for destination nodes is also maintained in the routing table. Once the source does not receive the response message from the destination it should reinitiate route discovery to establish a route. As network nodes join a multicast group, a mesh composed of the multicast group members and intermediate nodes needed to connect the group members are created. This sequence number is used to maintain the freshness of routing information for the multicast group. Source node wishing to join the multicast group broadcasts a Join Query message with the join flag set. Any member node of the multicast mesh can respond by communicating a Join response back to originator of Join query.

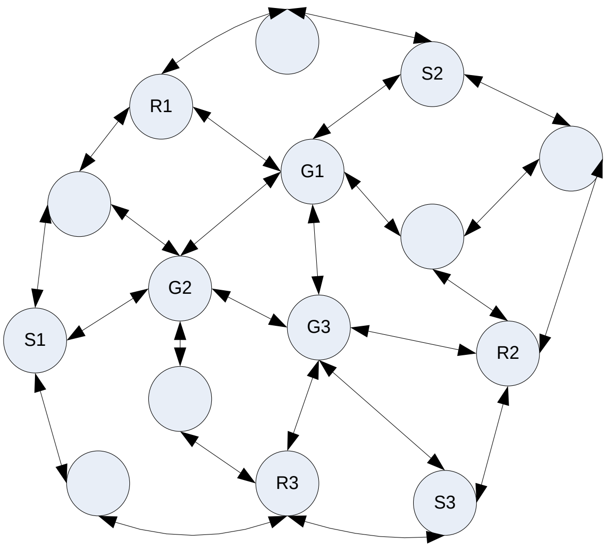

Figure 4. Mesh of possible routes between mobile nodes.

In figure 4 the mesh created after route initiation phase is shown. The bidirectional arrows indicate the possible alternate path. The absence of the arrows indicates that the nodes are not in the visibility range. When the JRQ is propagated for the purpose of route refreshing, if the existing route is still valid the route refresh interval has to be incremented so as to avoid the unwanted retransmission of control messages till existing path goes invalid.

IV. CONCLUSIONS

In this paper, we propose a method to eliminate the unnecessary transmission of control messages in an ad hoc network. Mesh based protocols are the well suited ones for highly mobile networks. In our method the retransmissions are carried out only when the routes become invalid. The check for validity of route is done during route refresh interval. When route is invalid, retransmission of control messages meant for route establishment and maintenance is carried out.

Consider a real time scenario like rescue operation after a natural calamity. At the initial phase the mobility of nodes are unpredictable. But as the mobile nodes achieve relatively stable positions, the mobility of nodes become predictable, i.e. the communication routes between the multi cast sources and destination may not be changing for a reasonable time period. Then the periodical broadcast to the entire network to refresh the group membership information and update of routes are not required for that reasonable time period, or at least till the valid path breaks. The retransmission of JRQ/ JRP cycles for route maintenance is required only after the validity of path identified expires. The link failure of valid path can be identified when no JRP messages are received for respective JRQ for a predefined period of time. No specific control message is required for link failure intimation. In AODV the specific control messages are required for link failure intimation, identifying the active neighbors, and activating the multi cast transmission. These increased number of control messages adversely affect the performance of AODV in highly mobile network. Another drawback of AODV is that considerable amount of time is required for rebuilding the shared tree after a link break occurs. In ODMRP, as the mobility of nodes increases, the increased retransmission of control messages for route establishment and route maintenance consume the limited battery power of the mobile nodes. Frequent broadcast of JRQ/JRP requires intermediate nodes not interested in multicast group to drop the control messages resulting in extra processing overhead. As the number of multicast sources increases, the control messages transmitted by each source for route refresh cycle leads to increased transmission overhead. This will consume the limited power available of mobile nodes. In our method, these unwanted retransmissions that are present in ODMRP are eliminated. Hence, our method has significant advantages in comparison with AODV and ODMRP.

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