

Position-based QoS Multicast Routing Protocol for Mobile Ad Hoc Networks

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Abstract— Recently, the necessity of applications where many users have to interact in a close manner over mobile Ad-Hoc networks gains high popularity. Multicast communication is essential in this type of applications to reduce the overhead of group communication. For group-oriented multimedia applications Quality of Service (QoS) provision is a basic requirement, which makes an efficient QoS multicast routing protocol a very important issue. This paper proposes a location-based QoS multicast routing protocol via cooperation between Network and MAC layers. Along with this protocol, a location and group membership management scheme has been proposed. Unlike some of multicast routing protocols, the proposed approach limits maintaining the network topology to certain nodes to reduce control overhead and reduce bandwidth consumption. Our proposed protocol is scalable for large area networks with large multicast members regardless of the network density. Also, it achieves a significant reduction in processing overhead compared to flat QoS algorithms.

Keywords—component; *Ad-Hoc Networks*; *Multicast Routing*; *Position-based*; *QoS*.

I. INTRODUCTION

A Mobile Ad hoc NETWORK (MANET) is composed of collection of mobile nodes that communicate with each other over wireless links in the absence of any infrastructure or centralized administration. The nodes of MANETs intercommunicate through single-hop and multi-hop paths to forward messages to other nodes, which require cooperation between nodes to relay packets to their targets. MANETs are useful in many application environments, where instant deployment and dynamic reconfiguration are necessary and wired infrastructure is not available. Examples of these applications include disaster recovery efforts, military battlefields, conferences and classrooms without the support of a wired infrastructure, and communication among a group of islands or ships. However, this type of networks characterized by limited bandwidth, limited resources, dynamic mobility, and high contention radio medium. These characteristics pose extra challenges to the design of routing protocols.

Group communication becomes increasingly important in MANETs because a lot of applications rely on cooperation between a team. Thus, multicast plays an important role in this type of communication. In multicasting, the same packet is transmitted by the source to a group of zero or more nodes. This is efficient in saving the bandwidth and improving the scalability, which is essential in MANETs [1]. As a consequence, multicast routing has received significant attention over the recent days.

Multicast can be performed in MANETs routing protocols using three approaches. These approaches are flooding, proactive and reactive multicast [2]. Flooding is a simple approach, each node receive a packet forward it to all its neighbors. In proactive approach, the nodes are required to maintain the network topology information in the form of routing tables by exchanging the routing information periodically. While, reactive approach are appropriate for wireless environments, because they initiate a route discovery process only when data packets need to be routed [3]. Once the route is established, the route must be maintained until it is no longer needed or the destination node becomes inaccessible. This eliminates the overhead of maintaining routing tables for routes not currently in use.

In Ad-Hoc wireless networks, routing protocols in general can be classified based on the routing topology into two main categories: topology-based and position-based [4].

Recently, the availability of small, inexpensive, low-power Global Positioning System (GPS) receivers and techniques for calculating relative coordinates based on signal strengths realize the position-based routing for Ad-Hoc networks [5]. The position-based protocols use the nodes location and mobility information to improve protocol robustness and performance. In large scale networks, the performance of the protocols that based on topology construction of the multicast mesh or tree approaches gets poor with increasing the number of nodes over vast network area. This is because of the large overhead resulted from flooding the control and data packets to the entire network.

The increasing popularity of using multimedia and real time applications in different potential commercial in MANETs, make it logical step to support Quality of Service (QoS) over wireless network. QoS support is tightly related to resource allocation and reservation to satisfy the application requirements; the requirements include bandwidth, delay, delay-jitter and packet to loss ratio. It is a challenge to support QoS in MANETs due to rapidly changing environment, centralized design of the medium access layer and limited resources. So, combine QoS with Multicasting facing several challenges, due to the difficulty in finding paths between the source and all the destinations that satisfy certain QoS requirements.

In this paper, we investigate the problem of QoS routing in MANETs using multicast communication. In view of the advantages of location-based routing and due to the dynamic network topology. We propose a novel location-based QoS multicast routing protocol for MANETs. We use the geographical positions of the nodes to forward the data packets in order to provide robustness and scalability. Along with this protocol, a location and group management scheme has been proposed. We consider bandwidth and delay as QoS parameters; the available bandwidth is measured on the link between two successive nodes. The remainder of this paper is structured as follows: section 2 gives an overview on related work on multicast routing. Section 3 presents our model and finally a conclusion will be proposed.

II. RELATED WORK

Multicasting in MANETs is relatively unexplored research area, when it is compared with unicast routing [6]. Over the past few years, several QoS multicast routing protocols have been proposed for Ad-Hoc networks such as [7] [8] [9] [10] [11].

A recent survey that study the up-to-date QoS multicast routing protocols is presented in [12]. Also, many position-based multicasting protocols have been proposed including [13] [14] [15] [16] [17]. On the other hand, few works have been done in QoS position-based multicasting such as [18] [19].

The Lantern-Tree-Based (LTB) in [8] is a bandwidth constrain QoS multicast routing protocol. A lantern is defined as one or more sub-paths with a total bandwidth between a pair of two neighboring nodes. A lantern path is a path with one or more lanterns between a source and a destination. The multicast tree contains at least one lantern path between any of its source-destination pairs. Lantern-tree protocol measures the bandwidth as the available amount of free slots based on CDMA-over-TDMA channel model at MAC layer, which needs distributed time synchronization. One drawback of LTB is the long time needed to find all the paths and to share and schedule the time slots. Another drawback is the use of high

number of links, which increase the contention at the MAC layer.

QoS Multicast Routing Protocol (QMR) [9] is a hybrid scheme for supporting QoS routing. It is an on-demand mesh protocol connects group members using QoS paths. QMR define forwarding nodes that provide at least one path from each source to each destination. CDMA-over-TDMA is used to estimate the available bandwidth. A distributed admission control is used to enable intermediate nodes to reject the routes that not satisfy QoS requirement. The forwarding nodes are updated when multiple sources sending to the multicast group simultaneously. This prevents congestion and performs load balancing in the network.

A cluster-based QoS multicast routing protocol is proposed in [19]. This protocol partitions the network into square clusters and the nearest node to cluster center is elected as a cluster-head. A gateway node is selected between the adjacent clusters to rely the packets when the adjacent clusters out of the effective transmission range. The source node starts the multicast session by sending PROPE packet to the cluster-head. The gateway forward this packet to the proper neighbor cluster until the destination or intermediate node with valid route to the destination is reached. The destination or the intermediate node selects the optimal route using best predecessor replacement strategy [20], where the node chooses the next best predecessor that satisfies the QoS constrains (delay, cost). When the source receives the ACK reply packet, it starts data transmission. This protocol only uses cluster-head, source, gateway and destination nodes in routing. However, only the gateway is responsible for packet forwarding. Thus, the gateway selection becomes the key point of this protocol. Also, the paper doesn't mention the network structure and maintenance, which perhaps produce significant traffic. Another drawback appears when the network is sparse, in this case the gateway nodes may fail to reach the neighbor cluster-head and then the route cannot be established.

In [18], a Hypercube-based Virtual Dynamic back-bone (HVDB) model for QoS-aware multicast communication is proposed. The clusters are formed using mobility prediction and location-based technique used in [21]. The structure is abstracted into three tiers: mobile node (MN), hypercube tier (HT) and mesh tier (MT). The network area is partitioned into overlapped circular shape and a cluster-head (CH) is elected for each circle. The CH is mapped to a hypercube node at the HT tier. Each hypercube is mapped to as one mesh node at the mesh tier. The nodes periodically send the local memberships to its CH. Each CH periodically sends the group memberships to all CHs within the hypercube and one of the CHs periodically broadcasts the membership to all the clusters in the network.

III. DESIGN OF THE PROPOSED PROTOCOL

A. Overview

The physical area is partitioned into a number of equal-sized cells. In each cell, a selection algorithm is executed to determine a leader and backup nodes. The cell leader should be powerful enough to take charge of its connecting nodes. This leader is responsible for maintaining the positions of the nodes inside the cell and their group memberships.

When a source node wants to send data to a group of destinations, an efficient communication procedure is done between cell leaders to provide the source with all the nodes interested in this multicast session and their positions. Now the source will be able to divide the group members into manageable sub-groups and choose a coordinator for each sub-group to start the multicast session. The QoS requirements that have been taken into consideration in this paper are bandwidth and delay.

The Network layer interacts with the MAC layer to estimate the available bandwidth with no control overhead and with considering the activities of the neighboring nodes, which makes our protocol more practical.

B. Network Initialization

1. Network construction

Based on our assumption that the routing area is a two-dimensional plane and the borders of the routing area are previously known. The entire network is divided into several non-overlapping hexagonal cells and each cell has a Cell Identity (Cell_ID). The partitioning is created starting from the left-down point of the routing area. Also, the size of the cell is chosen to enable 1-hop communication among all the nodes inside a given cell to reduce communication overhead. The proposed self-mapping algorithm allows each node to determine the cell where it resides during the life of the network based on the information provided by the GPS device equipped with each node. The structure of the network structure is given in figure 1.

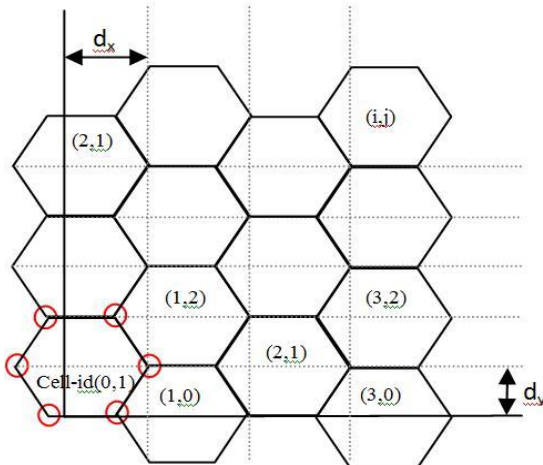


Figure 1: illustration of the network structure

2. Selection of cell leader

An election algorithm is developed to elect the nodes that satisfy different metrics in order to keep the leader role to serve the cell as much as possible. These metrics include the node position with respect to the cell center, the residual energy, CPU computing power, the available memory and mobility speed. Inside each cell, Cell Leader (CL) and Cell Leader Backup (CLB) nodes are elected. Each CL keeps information about the identity and position of the nodes in the cell it is responsible for, the membership of these nodes in different multicast groups and information about the 6-neighboring cells (including cell identity, identity and position of the CL and CLB). While, the CLB node is responsible for keeping a copy of the data stored in the CL node in order not to be lost when the CL node becomes off or moves outside the cell.

C. Location Service Algorithm

This algorithm enables the source to map the geographical positions of the destinations, this is done as follows:

The source node sends an invitation message to the CL node where the source is located to ask for nodes that are interested with this multicast group. This message needs only one hop unicast operation. When the CL node in the local cell receives this message, it checks its multicast table to check if there are nodes interested in joining this multicast group, then it reply by sending a reply packet directly to the source node. The search for additional destinations is continued by sending an invitation message to the CL of the 6-neighbor cells, and then it propagated cell by cell until it covers the entire network. Figure 2(A) shows the initiate of location service algorithm by the source.

When the CL node receives reply packets from all the cells, it forwards the position and IDs of the destination nodes to the source node. The source node waits for a predefined time to aggregate the reply packets from the CL nodes in the network in order to determine the nodes that want to participate in the group. Figure 2(B) shows the behavior on intermediate node when it receives an invitation packet to join a multicast session.

The intermediate nodes forward the location service packet using Restricted Directional Flooding (RDF). In RDF, the sender will broadcast the packet to all single hop neighbors towards the destination. The node which received the sent packet, compares its distance to the destination, with the distance of the previous hop to the destination. If the receiver node was closer to the destination, it retransmits the route request message; otherwise, it will drop the packet [22] [23].

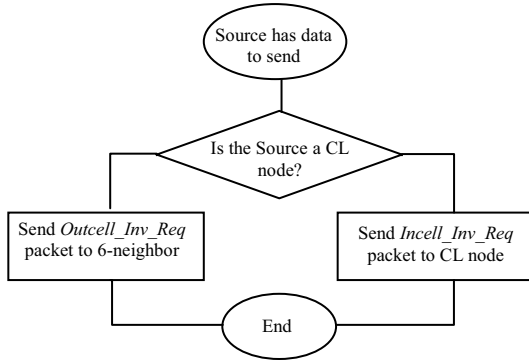


Figure 2 (A): Initiation of location service algorithm

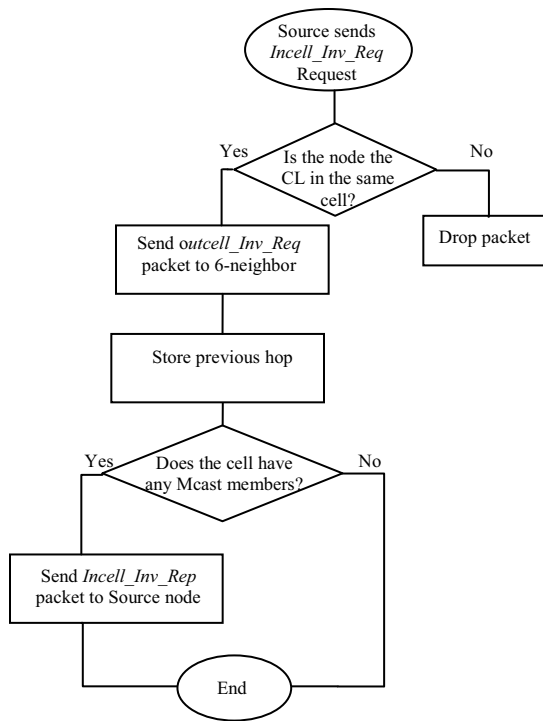


Figure 2 (B): Handling *Incell_Inv_Req* packet

D. Route Discovery Process

Multicasting in general refers to the communication with multiple participants. In our model, we consider the special case of point to multipoint communication, or source multicast. In source multicast the same packet is sent from the source node to a specified subset of nodes in the network (the multicast group) [24].

In this model a QoS path which satisfies a given bandwidth and delay requirements has to be found from the source to each destination from the destination list. The bandwidth requirement is represented in the request as an amount in Mb/s which represents the available bandwidth on a link between two successive nodes. The delay is represented as the number

of hops which is the upper limit of the delay value from the source node to any destination. After executing the location service algorithm, the source node partitions the destination list into sub-groups and chose a coordinator for each sub_group. After that, the search for a QoS path between the source and each coordinator is started. When the request packet arrived to each coordinator, a complementary route discovery process is continued between each coordinator and all the destinations that reside under the responsibility of this coordinator.

The forwarding of route request packet to each destination is done using RDF. Using RDF increases the probability of having a path satisfying the needed number of hops in addition to giving opportunity of finding multi-segment paths satisfying the required bandwidth. Figure 3 shows the behavior of intermediate node when it receives a route discovery packet between the source and coordinators.

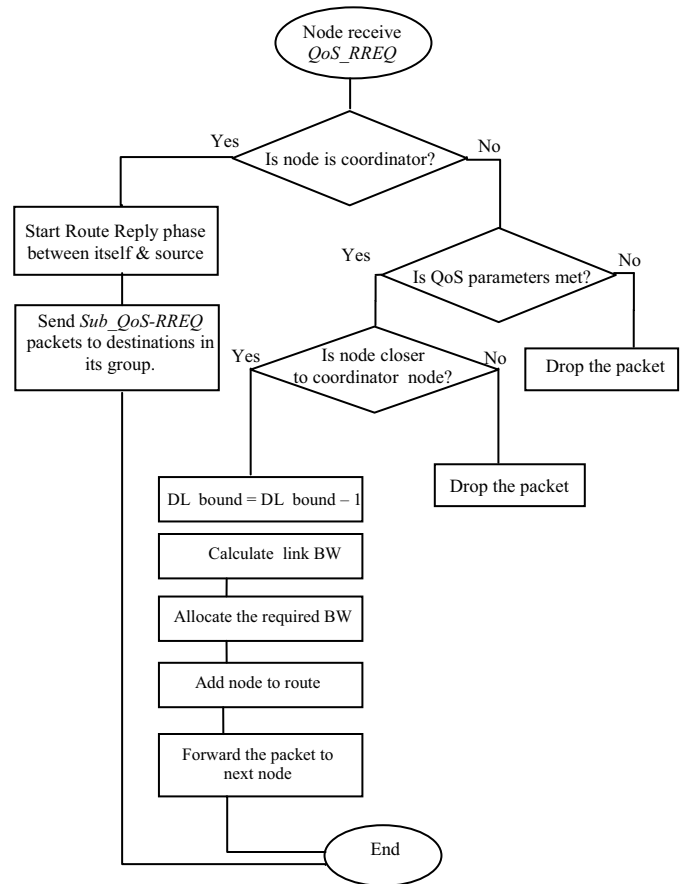


Figure 3: Route discovery between the source and coordinators

E. Route Reply Process

By the end of route discovery phase, different routes have been discovered between the source node and the coordinators of each sub-group and between the coordinators and the rest of the destinations in its sub_group. The request packets that reach the coordinator and the destinations comes from the paths that satisfy the delay bound. So, the coordinator needs to select a route that has the needed end-to-end bandwidth.

If the first route arrived to the coordinator satisfies the requested bandwidth at all the path nodes, then the coordinator select this route to be the optimal route, then it sends back this route to the source to inform him to start the data transfer because it is the route with less delay due to its early arrival. Otherwise, the coordinator waits for the second route and checks if that route satisfies the bandwidth requirement, if this is true, then it will be selected. If not, the coordinator will search for a segment that is parallel to the link that does not satisfy the bandwidth in the previous route in order to satisfy the requested bandwidth. If a parallel segment is found, then it will take the required amount of the bandwidth and splits the data on that branch node into two parallel paths. This process is continued path by path until a best route is chosen.

When the route reply traverses back from the coordinator to the source (or from the destinations to the coordinator), each node along the chosen paths reserves the amount of the bandwidth that is considered to be used in the route and relies the message to the node send to it in route discovery. During constructing the routes between the coordinator and its destinations, the source node start forwarding the data over the QoS route to coordinator. When the coordinator receives the data packets from the source node, it sends a copy of the data packet to each member of the sub-group. The same steps are done to select a route that satisfies the required end to-end bandwidth between the coordinator and each destination.

In our model the nearest node to the source will be chosen as the coordinator of the sub-group. The source will communicate with the coordinator in order to transfer data to all the sub-group members.

F. Multicast group Membership management

When the multicast session is held, the proposed protocol allows new members to join the held session. Also, any current member can leave the session without affection the constructed multicast tree. This feature adds more flexibility to the protocol to support dynamic movement of the network nodes. The join/leave requests are handled as follows:

When any member of the sub-group decides to leave the multicast group and move away, it sends a packet to the coordinator through its upstream nodes. When the coordinator node receives this packet, it checks if this node does not have downstream nodes, then it is removed from the destination list of the coordinator and is excluded from future forwarding computations. Otherwise, the coordinator should reconstruct new routes to the affected members of the sub-group by resending a Sub-QoS-RREQ packet. After that, the information associated with this multicast group member has to be removed from the coordinator and other members in the sub-group. Lastly, if the leaving node is the sole node in the sub-group, the source suspends sending data to this sub-group.

When new node wants to join the multicast session, the new node sends a join request packet to the CL of the cell where this node resides in order to add itself to the required multicast group. The CL use information about the previously joining nodes, to inform the new joining node the address of the nearest node that can connect it with the multicast group. When no multicast members available inside the same cell, communication is started between the CL and some neighboring CL (nearest to the new node) to select the node that can pass data to the new node. The new joining node waits for a period of time to collect the replies for the join packets, and then it choose the best route that connects it to the multicast group within the number of hops limitations. If this route satisfies the needed bandwidth, it will be considered as the final route to the new node. Otherwise, a new join packet is sent to the coordinator in order to begin a RDF to search for QoS-path to the new member.

IV. CONCLUSION

We have designed a robust and scalable position-based multicast routing protocol for MANETs with multiple QoS constraints. This protocol uses a hierarchical scheme to utilize the limited network resources. Based on the location information of the mobile nodes, our protocol explores the QoS paths in an efficient way. This approach is efficient in providing QoS capability with significant reduction in control, storage and processing overhead. Also, it is scalable for large area networks with large number of multicast members. The protocol performance will be evaluated using simulation. The simulation of proposed protocol is under way by using Glomosim simulator.

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