A Novel Approach to Support Scalable Multicast Routing in Wireless Ad Hoc Networks

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Abstract.

Nowadays, group communications over Mobile Ad hoc Networks (MANETs) have received significant attention. Multicasting plays an important role in simultaneous delivery of information to group of receivers. Thus, it is necessary to design efficient and effective multicast routing protocol to support group communication applications. Several efforts have been put to improve multicast routing. However, they do not consider scalability issue. This paper introduces a novel Scalable Geographic Multicast Routing Protocol (SGMRP). The main objective of this protocol is to design a lightweight scalable multicast routing scheme irrespective of the number of multicast members and network size. To achieve this, a virtual clustering strategy has been introduced. This strategy based on partitioning the network into sectorial zones. The proposed solution performs efficient packet forwarding with reduced communication overhead. The proposed scheme eliminates the duplicate packets between clusters and reduces the number of participating nodes.

Keywords: Mobile Ad hoc networks, Multicast routing, Scalable, Location-baed Routing, GPS

1. Introduction

Recently, the advances in portable computing and wireless technologies are opening up exciting possibilities for the future of wireless mobile networking. This rapid penetration has stimulated a change in the expectations of wireless users. MANETs have evolved a great deal over the past two decades and considered as one of the most important and essential technologies to support future pervasive computing scenarios (Huang & Liu, 2010).

Mobile Ad hoc Network (MANET) is a multi-hop autonomous network composed of self-organized mobile nodes connected through a wireless link without any network infrastructure. MANETs have gained significant interest and popularity since they have enormous potential in several fields of applications. Over the past few years, the necessity of applications where many users have to interact in a close manner over MANETs gains high popularity (Baskaran, Selvi, Dhulipala, & Information Sciences, 2018). Multicast communication is essential in such type of applications to reduce the overhead of group communication.

Multicast routing has many benefits. It is more efficient as it builds a multicast delivery infrastructure, which allows the multicast source to transmit only one copy of the information and the intermediate nodes will duplicate the information when needed. Only nodes that are part of the targeted group will receive the information. So multicasting plays an important role in MANETs (Robinson et al., 2019).

With the continuing revolution in wireless communications and decreasing cost of wireless hardware, a mobile device became able to obtain its location information (Wong & Wan, 2019). Awareness of position information has been utilized to improve network scalability and efficiency through restricting the broadcast region of routing packets. As a result, location-based routing has emerged as a promising routing technique. Location-aware multicast routing protocols use position information to establish reliable routing and reduce the maintenance overhead. However, many challenges face implementing reliable and scalable multicasting over wireless communication. For example, in geographic unicast routing, a data packet carries the position of the receiver in the packet header to guide the packet forwarding. On the other hand, multicast routing considers a group of nodes as multicast receivers which increases the packet size and the routing overhead, especially in large scale MANETs. Despite of these challenges, research efforts have recognized these challenges and worked on developing scalable and efficient multicast routing protocols (Rajkumar, Abinaya, Swaminathan, & Technology, 2014).

The rest of the paper is organized as follows: In the consequent section, some related works are discussed. Section 3 provides description of the proposed protocol. Finally, concluding remarks are summarized in section 4.

2. Related Works

Recently, location-based multicast routing protocols have attracted the attention of many researchers because these protocols scale quite well in large wireless networks in addition to the commercial proliferation of GPS devices. In position-based routing, geographical location information is used to localize the control message propagation and to help the routing layer scale to support very large networks (Stojmenovic, 2002). Position-based routing is scalable to large networks, since it uses only knowledge of the source and the destination locations and is independent of network topology and size.

The location Aware Multicast Protocol (LAMP) proposed in (Shankar & Ilavarasan, 2018) supports scalable multicast routing using greedy multicast forwarding. LAMP divides the network into hexagon zones to manage the group membership efficiently and to track the position of the multicast receivers. For each hexagon cell, the node closer to the center is elected as zone leader to maintain the membership table of the multicast receivers. The tree construction starts by initiating a broadcast packet to the whole network, containing all multicast members. Each node is aware if it is a multicast receiver, if yes, it replies by a join request message to its local zone leader to construct the tree. When a source node wants to send data packets to the list of receivers, it splits the network region into 3 regions (120o) and a copy of the data packets is sent to each region using greedy multicast forwarding. LAMP shows scalable performance, however the multicast tree construction results in large number of packets and increases the routing overhead. In addition to the overhead of network construction and node self-mapping.

An Efficient Geographic Multicast Protocol (EGMP) is proposed in (Xiang, Wang, & Zhou, 2006) to enhance scalability of location-aware multicast protocols by exploiting two-layer structure. EGMP partitions the geographic area into non-overlapping square zones, and a leader is selected in each zone to represent its local zone on the upper tier. The leader gathers the membership information for each zone to manage joining and leaving the multicast sessions. At the upper layer, the leaders of member zones contact directly with sources to report the zone memberships through a virtual reverse-tree-based structure or along the home zone.

Recent research efforts showns that geographical routing significantly improves the performance of MANETs. Based on this view, a new routing protocol has been designed to exploit the location information to eliminate flooding and simplify the routing strategy. The proposed protocol tries to overcome some of the problems of the existing schemes along with enhancing the scalability and reducing the control overhead. The details of this protocol are presented in the following sections.

3. Protocol Overview

The proposed protocol is a source-tree multicast routing protocol to enhance scalability of multicast routing over MANETs. The protocol aims to be implemented in large networks with large number of multicast members. To achieve this, a virtual clustering strategy has been introduced to partition the network coverage area into 8 sectors.

This protocol exhibits the efficiency of multicasting and forwards the packet to multiple destinations relies on the location information of the destination nodes, which is assumed to be known. The protocol exploits nodes positioning information to reduce the number of nodes participating in forwarding control packets. This is achieved through Restricted Directional Flooding (RDF) (Banka & Xue, 2002). Based on nodes positions and location information of the destination (obtained through location service algorithm), nodes in RDF only forward the packets if their positions are closer to the destination, this eliminates broadcast storm and utilizes the network resources efficiently.

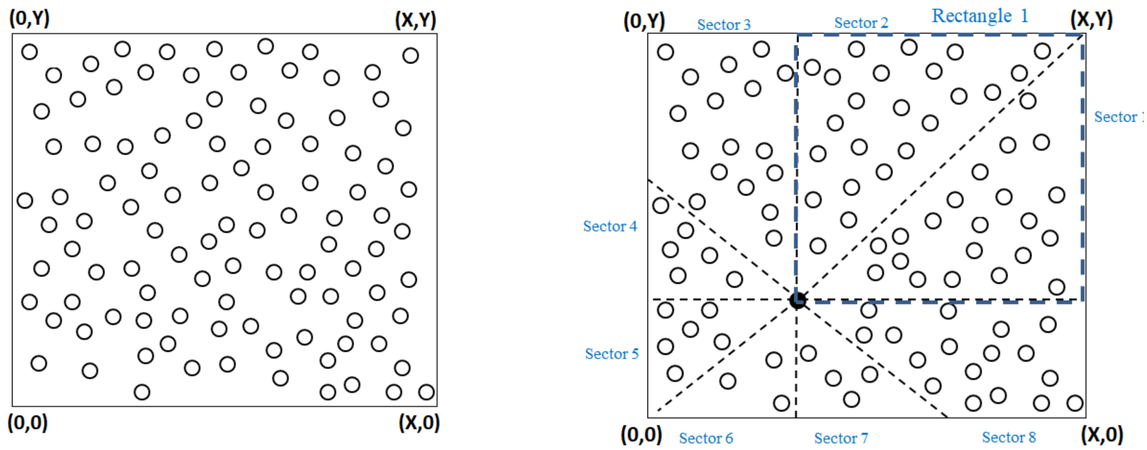
The protocol operation is divided into multiple phases. These phases include network construction, routing discovery and maintenance as well as data transmission. Network construction includes dividing the network area into several sections and determines the distrbution of multicast receivers within these sections. In network construction, the entire network area is partitioned into 8 sectors based on the location of the source node. This construction minimize the number of routing packets and accordingly reduce the routing overhead. Route discovery phase discovers the shortest paths towards each multicast receiver and establish a path for data transmission using the location information of the mobile nodes.

3.1 Route Discovery

In our protocol, the sender can transmit packets without specifying the next hop node, because the receiving node can decide to forward or drop the packet based only on its location and the location of the destination node. This mechanism does not require routing tables, neighbor tables, in addition to eliminating the need to tree creation.

When a source node decides to initiate a multicast session, it splits the network into four rectangles based on its network coordinates and then splits each rectangle into two sectors as shown in Fig. 1(b). After that, it sends a separate RREQ packet to each sector that contains multicast receivers. The sectors are numbered from 1 to 8 based on predefined algorithm.

In multicast session initiation, the source node “S” sends a Route Request (RREQ) packet including all multicast members identifiers and their position coordinates. The source node determines the sector numbers that contains one or more multicast members and splits a copy of the RREQ packets only to those sectors. This is performed based on the position of the source and the destination nodes. When a copy of the RREQ packet is received by the intended sectors, the packet is forwarded using RDF towards different destinations. Using RDF eliminates network flooding storm and restricts packet forwarding to the nodes in the way to the intended destinations. Since RDF is used for forwarding route discovery packets, the number of nodes that participate in forwarding these packets depends on the euclidean distance between the sending node and the intended destination. In other words, upon receiving the route discovery packets, a node with lower euclidean distance (towards any destination in the sector) will be considered as forwarding node. This strategy helps in reducing the resulted overhead compared to broadcast strategy (in which all nodes existing in the network participate in forwarding the route discovery packets).



(a): Network coordinates (b): Network construction

Fig. 1: Network partitioning based on source position

When an intermediate node receives a RREQ packet, if the node is a multicast member, it removes the fields belongs to that node (ID_D, (X_D, Y_D) and forwards the packet to next node using RDF. Otherwise, it computes the distance between itself and the destined multicast receiver node and compares it with the “Res_Dist” field which is stored in the packet. If the intermediate node is further than the previous node, the packet is dropped. Otherwise, it stores its previous hop node to be used in the reverse path and forwards the packet using RDF.

3.2 Route Reply Process

Upon receiving RREQ packet by each destination node, it replies by the following RREP packet shown in Fig. 2.

Pkt_ID (RREP)	RREQ_ID	ID_S	ID_D

Fig. 2: RREP packet format

Where Pkt_ID(RREP) is the ID for the first RREQ packet and RREQ_ID is the request ID for the received RREQ packet and the fields "ID_S and ID_D" contains the address of the sending source and the destination address respectively. When the RREP packet traverses back from each destination to the source, each node along the chosen path realizes that it becomes a forwarding node and re_forwards the packet until it reaches the source node. When the source receives the selected routes to the multicast members, it starts sending data packets to the multicast members using selected routes.

3.3 Route Maintenance

During data transmission, some nodes may not receive data packets due to broken links caused by nodes failure or movement. When a link break is detected, the upstream node of the broken link sends RERR packet backward to the upstream nodes to inform them about this failure until it is received by the source node. Intermediate upstream nodes, upon receiving this packet, re_forward the packet towards their upstream nodes. Also, the downstream nodes of the broken link clear related entry when a predefined time is elapsed without receiving data from the upstream nodes. When the source node receives the RERR packet, it initiates a new route discovery process towards the affected destinations as discussed previously.

4. Conclusion

The current paper proposes a tree-based multicast protocol called Scalable Geographic Multicast Routing Protocol (SGMRP) to solve scalability issue. The proposed protocol virtually divides the network plane into 8 sectors. This type of structure constructs a minimum length multicast tree with reduced communication overhead. The protocol performs restricted position-based route discovery which potentially reduces the number of packet transmissions with reduced hop count to each multicast receiver.

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