SCALABLE MULTICAST ROUTING PROTOCOLS FOR MOBILE AD HOC NETWORK

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Abstract

In MANET mobile nodes are able to communicate with neighboring nodes either one hop away or a few hops away from the source node. As the network size grows, the performance of the transmission will be degraded due to network congestion and network splitting. Due to the increased route length between two end nodes in a multi-hop MANET, the challenge is in the limited scalability despite the improved spatial diversity in a large network area. The density and the mobility factors may influence the scalability of the ad hoc routing protocols. This paper present review on the scalable multicast routing protocols and intend to include the survey fall into three categories: Zone based, mesh based and group management scheme and further this paper compares the scalability properties and operational features of the protocols and discusses challenges in future routing protocol designs.

Keywords: scalability, MANET, scalable routing protocol, multicast, cluster.

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1. Introduction

Multicast routing algorithms have become increasingly important in the field of wireless ad-hoc networks because they effectively communicate and coordinate with sets of nodes [1]. Multicast routing algorithm provides a more efficient routing strategy for multimedia applications in mobile environments with large numbers of simultaneous receivers. In this paper, we divide the multicast routing protocols into three different categories: The first type, Zone based routing protocols (ZBRP) divides the network into number of zones. ZBRP takes the advantages of the both proactive and reactive approaches by maintaining an up-to-date topological map of a zone centered on each node. Within the zone, routes are immediately available. For destinations outside the zone, ZBRP employs a route discovery procedure, which can benefit from the local routing information of the zones, e.g. Efficient Geographic Multicast Protocol (EGMP) [2]. The second type is mesh-based multicast protocol. Mesh-based multicast routing protocols are more than one path may exist between a source receiver pair, Core-Assisted Mesh Protocol (CAMP)[3] and On-Demand Multicast Routing Protocol (ODMRP)[4] and Forwarding Group Multicast Protocol (FGMP)[5] are the examples for this type of classification. The third type is hierarchical group management scheme. It uses knowledge about geographic positions for a hierarchical aggregation of membership information. Main prerequisite for position-based routing is that a sender can obtain the current position of the destination. Examples are Scalable Position-Based Multicast (SPBM) [6] and Position-Based Multicast (PBM) [7]. With the increased interest in the mobile communications in the wireless communication community and the promise of convenient infrastructure-free communication of ad hoc networks, the development of *large-scale* ad hoc networks has drawn a lot of attention and the scalability of ad hoc networks has been the subject of extensive research [8]. As the network size grows, the performance of the transmission will be degraded due to network congestion and network splitting. The density and the mobility factors may influence the scalability of the ad-hoc routing protocols.

In this paper, we are discussing various issues in scalable multicast network architectures for MANETs and observe the performance of routing protocols when network size (scalability) grows and also consider some problems in MANETs arise due to scalability such as packet delay, and high control overhead. Finally, this paper concludes with a summary of the scalable features of protocols in the four categories and future research directions.

2. Previous Work

Many different protocols for multicasting in mobile wireless networks have been proposed in recent years. Acharya and Badrinath [9] were the first to address the issue of wireless multicast. In ad hoc networks, routing protocols are challenged with establishing and maintaining multihop routes in the face of mobility, bandwidth limitation and power constraints. Multicast routing protocol plays an important role for these issues. Multicast protocols used in static networks (e.g., Distance Vector Multicast Routing Protocol (DVMRP) [10], Multicast Open Shortest Path First (MOSPF) [11], Core Based Trees (CBT) [12], and Protocol Independent Multicast (PIM) [13]) do not perform well in wireless ad hoc networks because multicast tree structures are fragile and must be readjusted as connectivity changes. Furthermore, multicast trees usually require a global routing substructure such as link state [14] or distance vector [15]. The frequent exchange of routing vectors or link state tables, triggered by continuous topology changes, yields excessive channel and processing overhead. Hence, the tree structures used in static networks must be modified, or a different topology between group members (i.e., mesh) need to be deployed for efficient multicasting.

The remainder of this paper is structured as follows: In the next section, we discuss classification of multicast routing protocols in three categories. Section 4 contains simulation results on the performance of scalable routing protocols. Section 5 concludes the paper and gives an outlook on future work.

3. The Classification of Scalable Routing Protocol for MANET

We are giving the review of scalable multicast routing protocols in ad hoc networks in three different categories (Fig. 1):

- Zone Based Topology.
- Hierarchical Group Management Scheme.
- Mesh Based Topology.

The scalability of a network protocol could potentially be defined in many different ways, and at several different levels. Typical parameters that are studied for ad hoc networks are the number of nodes, and the average rate of mobility in m/s under various mobility models. Other parameters that have an impact on scalability include node density, number of links, the frequency of connection establishment and the average number of concurrent connections [6].

Routing with assistance from geographic location information requires each node to be equipped with the Global Positioning System (GPS) [16]. This requirement is quite realistic today since devices are inexpensive and can provide reasonable precision. Each node participating in routing plays an equal role. Multicast is an efficient method to realize group communications with one-to-many or many-to-many transmission patterns.

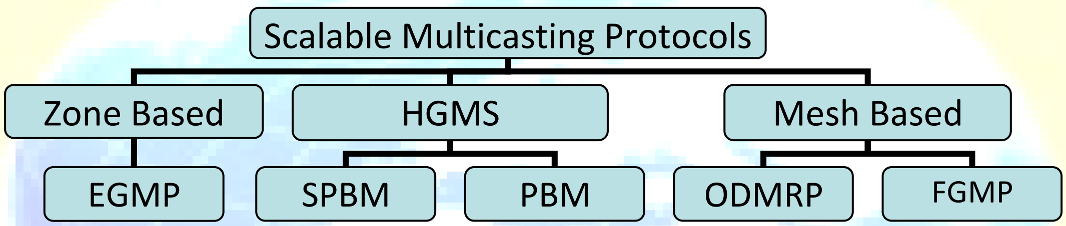

Figure 1: Classification of Scalable Routing Protocol.

3.1. Zone Based Multicasting

Zones may be built, disbanded or combined dynamically according to the change of network topology. The size of the zone can be changed adaptively, and neighboring zones may be lapped over. Example of zone-based multicast routing approaches is EGMP.

EGMP (Efficient Geographic Multicast Protocol) uses a virtual-zone-based structure to implement scalable and efficient group membership management and EGMP constructed bidirectional tree for network wide zone-based. Through position information it build the zone structure, construct the multicast tree, and forward the multicast packet, which efficiently reduces the overhead of route searching and tree structure maintenance. EGMP handle empty zone problem faced by most routing protocols using a zone structure. In summary, EGMP:

a) Making use of the position information to design a scalable virtual-zone-based scheme for efficient membership management, which allows a node to join and leave a group quickly.

Geographic unicast handles the routing failure due to the use of estimated destination position with reference to a zone and applied for sending control and data packets between two entities so that transmissions are more robust in the dynamic environment.

b) Supports efficient location search of the multicast group members, by combining the location service with the membership management to avoid the need and overhead of using a separate location server.

c) It introduced an important concept i.e. zone depth, which is efficiently guide the tree branch building and tree structure maintenance, especially in the presence of node mobility. With nodes self-organizing into zones, zone-based bidirectional-tree-based distribution paths can be built quickly for efficient multicast packet forwarding.

d) Addresses the empty zone problem, which is critical in a zone-based protocol, through the adaption of tree structure.

Routing Protocol	**Routing Philosophy**	**Routing Metric**	**Frequency Update**	**Use Sequence Number**	**Loop Free**	**Multiple Paths**	**GPS**
EGMP	Proactive	zone-based bidirectional-tree-based distribution paths	Periodically Multilevel	Yes	Yes	Yes	Yes

Table 1: *Characteristics of Zone Based Scalable Routing Protocols.*

3.2 Hierarchical Group Management Scheme

Hierarchical Mobile Ad-hoc Network (HMANET) architecture is formed by multiple groups in a hierarchical network structure in which each group consists of multiple mobile nodes.

1. Scalable Position-Based Multicast (SPBM) is based on multicast forwarding decision on whether there are group members located in a given direction or not, allowing for a hierarchical aggregation of group members contained in geographic regions: the larger the distance between a region containing group members and an intermediate node, the larger can this region be without having a significant impact on the accuracy of the direction from the intermediate node to that region. Because of aggregation, the overhead for group membership management is bounded by

a small constant while it is independent of the number of multicast senders for a given multicast group.

SPBM uses two building block algorithms: The *group management scheme* is responsible for the dissemination of the membership information for multicast groups, so that forwarding nodes know in which direction receivers are located. The *multicast forwarding algorithm* is executed by a forwarding node to determine the neighbors that should receive a copy of a given multicast packet. This decision is based on the information provided by the group management scheme.

2. A generalization of position-based unicast forwarding has been discussed in [7]. In this protocol, the sender includes the addresses of all the destinations in the header of the packet. Based on the nodes position information, each node determines the neighbors, to which it should forward the packet. When the current node selects more than one next hope node, then the multicast packet is split. Also, when there is no direct neighbor to make progress toward one or more destination a repair strategy is used. Position-Based Multicast (PBM) is limited to groups with small number of nodes because the location and group membership information is included in the data packets.

For multicast it is necessary to establish a distribution tree among the nodes, along which packets are forwarded toward the destinations. PBM uses local available information to approximate the optima for both properties. Given this information the main task of a forwarding node in PBM is to find a set of neighbors that should forward the packet next, called these neighbors as the *next hop nodes*. The current node will assign each destination of the packet to exactly one next hop node. Each next hop node then becomes forwarding node for this packet toward the assigned destinations. If the current node selects more than one next hope node, then the multicast packet is split. This is required in order to reach destinations which are located in different directions relative to the forwarding node.

Routing Protocol	**Routing Philosophy**	**Routing Metric**	**Frequency Update**	**Use Sequence Number**	**Loop Free**	**Multiple Paths**	**GPS**
SPBM	Proactive	Quad-tree based	Periodicall	No	Yes	Yes	Yes

		path	y				
PBM	Proactive	Either Steiner trees [A] and Shortest path	Periodicall y	Yes	No	Yes	Yes

Table2: Characteristics of Hierarchical routing protocols

3.3 Mesh Based Routing Protocols

A mesh-based multicast routing protocol sustains a mesh consisting of a connected component of the network containing all the receivers of a group. Example of mesh-based multicast routing approaches is On-Demand Multicast Routing Protocol (ODMRP).

1. ODMRP (On-Demand Multicast Routing Protocol) [17] applies on-demand routing techniques to avoid channel overhead and improve scalability. It uses the concept of forwarding group [5], a set of nodes responsible for forwarding multicast data on shortest paths between any member pairs and to build a forwarding mesh for each multicast group. No explicit control message is required to leave the group.

In ODMRP, group membership and multicast routes are established and updated by the source *on demand* (see Fig. 2). A multicast source periodically broadcasts the packets to the entire network a member advertising packet, called a JOIN REQUEST. This periodic transmission refreshes the membership information and updates the route as follows. When a node receives a non-duplicate JOIN REQUEST, it stores the upstream node ID and rebroadcasts the packet. When the JOIN REQUEST packet reaches a multicast receiver, the receiver creates or updates the source entry in its Member Table. While valid entries exist in the Member Table, JOIN TABLES are broadcasted periodically 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, the node realizes that it is on the path to the source and thus is part of the forwarding group. It then sets the FG Flag and broadcasts its own JOIN TABLE built upon matched entries. The JOIN TABLE is thus propagated by each forwarding group member until it reaches the multicast source via the shortest path. This process constructs (or updates) the routes from sources to receivers and builds a mesh of nodes, the forwarding group.

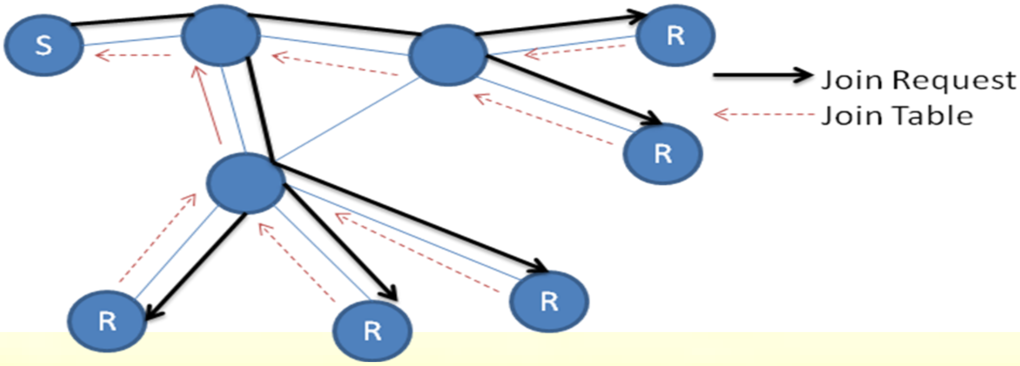

Figure 2: On-Demand Procedure for Membership Setup and Maintenance.

2. Forwarding Group Multicast Protocol (FGMP) is a multicast protocol for multihop mobile wireless networks [5]. Instead of forming multicast trees, a group of nodes in charge of forwarding multicast packets is designated according to members' requests. Multicast is then carried out via "scoped" flooding over such set of nodes. The forwarding group is periodically refreshed to handle topology/membership changes. The dynamic reconfiguration capability makes this protocol particularly suitable for mobile networks.

FGMP keeps track not of links but of groups of nodes which participate in multicast packets forwarding. To each multicast group G is associated a forwarding group (FG). Any node in FG is in charge of forwarding (broadcast) multicast packets of G. That is, when a forwarding node (a node in FG) receives a multicast packet, it will broadcast this packet if it is not a duplicate. All neighbors can hear it, but only neighbors that are in FG will first determine if it is a duplicate and then broadcast it in turn. Figure 3 shows an example of a multicast group containing three senders and three receivers.

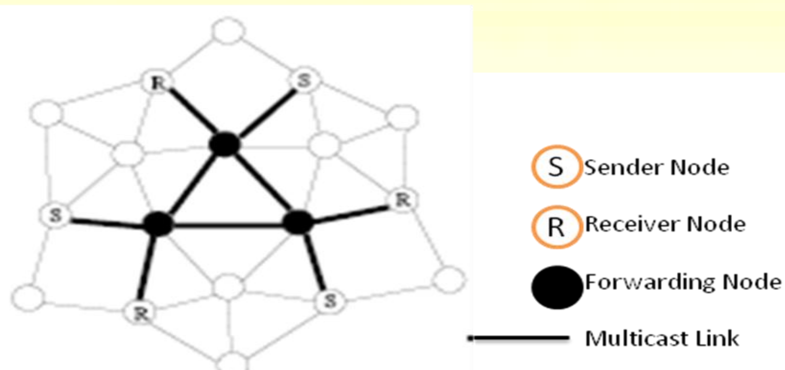

Figure 3: An example of FGMP

Three forwarding nodes take the responsibility to forward multicast packets. This scheme can be viewed as "limited scope" flooding. That is, flooding is contained within a properly selected forwarding set. It is interesting to note that with proper selection of the forwarding group, the FG scheme can emulate any of the existing schemes. For example, to produce global flooding, the FG includes all nodes in the network. Only one flag and a timer are needed for each forwarding node. When the forwarding flag is set each node in FG forwards data packets belonging to G until the timer expires.

Routing Protocol	**Routing Philosophy**	**Routing Metric**	**Frequency Update**	**Use Sequence Number**	**Loop Free**	**Multiple Paths**	**GPS**
ODMRP	On demand	Mesh-based Shortest path	Periodically	Yes (Join Table)	Prevented	No	Yes
FGMP	Flooding	Multihop	Periodically	Yes	Prevented	No	Yes

Table 3: *Characteristics of Mesh based Routing Protocols.*

4. Performance Comparison of Scalable Routing Protocol

The performance of Scalable Routing protocols are evaluated by keeping the network speed and pause time constant and varying the network size (number of mobile nodes).Table 4 show the simulation parameters used their evaluation.

Scalable Routing Protocol	**No. of Nodes in** m^2	**Mobility Speed Maximum**	**Network Size in meter**^{2}	**Control Overhead**	**Packet Delivery ratio**	**Compared Protocol**	**Network Simulator**
EGMP[2]	756	40 m/s	3900×3900	Low	high	ODMRP and SPBM	GloMoSim [18]
SPBM [6]	100	50 m/s	1400×1400	High (due to increase no. of	Satisfactory (Lower	ODMRP	NS-2 [19]

				data forwarding operation)	than of EGMP)		
PBM [7]	50	High	8000×8000	Prevents the overload of the network	100% in static network	No data given	C++
ODMRP [17]	50	72km/hr	1000×1000	Lower	95% (high mobility)	No data given	GloMoSim
FGMP [5]	100	Average	1000×1000	High (due to redundant transmission)	Packet loss due to temporary topology	DVMRP [6]	Maisie [20]

Table 4: *Performance Metrics and Results of Multicast Scalable Routing Protocol*

Packet Delivery Ratio (PDR) which is used to measures of effectiveness, reliability and efficiency of a routing protocol, in the simulation is defined as the percentage of the ratio between the number of received packets at destinations and the number of packets sent at source.

Control Overhead is the sum of all transmissions of routing packets per total delivery packets at the destination. Each hop-wise transmission of a routing packet is counted as one transmission and network formation and maintenance cost.

5. Conclusion and Summary

This paper reports the scalability studies on multicast routing protocols. We also presented the review of geography based routing protocol that has great advantages of correct node position availability and high packet delivery rate, the study being done using EGMP, SBPM, PBM, ODMRP and FGMP. In these protocols, routing overhead is efficiently reduced. In EGMP, the scalability is achieved through a two-tier virtual-zone-based structure. EGMP significantly reduces the tree construction and maintenance overhead, and enables quicker tree structure adaptation to the network topology change. It also develops a scheme to handle the empty zone problem, which is challenging for the zone-based protocols. SPBM introduces a hierarchical organization of nodes for membership management as well as packet forwarding. PBM is very well suited for highly dynamic networks without resorting to flooding of the data packets. ODMRP is based on mesh forwarding and provide on demand multicast route construction and membership maintenance. The advantages of ODMRP are storage overhead, shortest routes, robustness to host mobility, maintenance and exploitation of multiple redundant paths and unicast routing capability. FGMP provides a simple and efficient way for multicasting in multihop, mobile wireless networks. It leads to a more prompt adjustment to topology changes and to a reduction of redundant transmissions, resulting in higher throughput and multicast efficiency.

To summarize, a hierarchical approach for routing is a very promising solution if the protocol is intended to scale to a reasonable number of nodes.

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