

# A survey on Efficient Geographic Multicasting Protocol

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**Abstract-** There is an increasing demand and a big challenge to design more scalable and reliable multicast protocol over a dynamic ad hoc network (MANET). An efficient and scalable geographic multicast protocol, EGMP for MANET which uses a virtual-zone-based structure to implement scalable and efficient group membership management. A network-wide zone-based bi-directional tree is constructed to achieve more efficient membership management and multicast delivery. The scalability of EGMP is achieved through a two-tier virtual-zone-based structure, which takes advantage of the geometric information to greatly simplify the zone management and packet forwarding. A zone-based bi-directional multicast tree is built at the upper tier for more efficient multicast membership management and data delivery, while the intra-zone management is performed at the lower tier to realize the local membership management. The position information is used in the protocol to guide the zone structure building, multicast tree construction, maintenance, and multi-cast packet forwarding. Compared to conventional topology-based multicast protocols, the use of location information in EGMP significantly reduces the tree construction and maintenance overhead, and enables quicker tree structure adaptation to the network topology change. We also develop a scheme to handle the empty zone problem, which is challenging for the zone-based protocols. Additionally, EGMP makes use of geographic forwarding for reliable packet transmissions, and efficiently tracks the positions of multicast group members without resorting to an external location server.

**Keywords—** Put your keywords here, keywords are separated by comma.

membership management, and takes advantage of the membership management structure to efficiently track the locations of all the group members without resorting to an external location server.

## I. INTRODUCTION

Ad-Hoc Networks also called as Mobile Ad-Hoc Network (MANET) is a group of wireless mobility nodes which is self organized into a network without the need of any infrastructure. It is a big challenge in developing a robust multicast routing protocol for dynamic Mobile Ad-Hoc Network (MANET). MANETs are used in many magnificent areas such as disaster relief efforts, emergency warnings in vehicular networks, support for multimedia games and video conferencing. As a consequence, multicast routing in mobile ad-hoc networks has attracted significant attention over the recent years.

Multicast is the delivery of a message or information to a group of destinations simultaneously in a single transmission using routers, only when the topology of the network requires it. Multicasting is an efficient method in realize group communications with a one-to-many or many-to-many relationship transmission pattern. However, there is a big challenge in enabling efficient multicasting over a MANET whose topology may change constantly.

A Modified Efficient Geographic Multicast Protocol, MEGMP, which can extent to a large group size and large network size. The protocol is designed to be comprehensive and self-contained, yet simple and efficient for more reliable operation and consumes less energy when compared to existing one. Instead of addressing only a specific part of the problem, it includes a zone-based scheme to efficiently handle the group

MEGMP uses a virtual-zone-based structure to implement scalable and efficient group membership management. A network wide zone-based bidirectional tree is constructed to achieve more efficient membership management and multicast delivery. The position information is used to guide the zone structure building, multicast tree construction, and multicast packet forwarding, which efficiently reduces the overhead for route searching and tree structure maintenance.

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 is enhanced to handle 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 supporting 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. An important concept zone depth, which is efficient in guiding the tree branch building and tree structure maintenance, especially in the presence of node mobility. Nodes self-organizing into zones, zone-based bidirectional-tree-based distribution paths can be built quickly for efficient multicast packet forwarding.

To improve the stateless multicast protocol using location aware approach for more reliable membership management and packet transmission and also supporting scalability for large group and network size. A Modified Efficient Geographic Multicast Protocol (MEGMP) that uses concept of zone depth, which is efficient in guiding the tree branch building and tree structure maintenance, especially during node mobility. Nodes self-organizing into zones, zone-based bidirectional-tree-based distribution paths can be built quickly for efficient multicast packet forwarding. The scalability and the efficiency of MEGMP are evaluated through simulations and quantitative analysis. Based on the density of nodes, neighbor zones are aggregated to one zone. This way the communication overhead between the zones can be reduced.

## II. MOBILE ADHOC NETWORKS

A mobile ad hoc network (MANET) is a continuously self-configuring, infrastructure-less network of mobile devices connected without wires. Ad hoc is Latin and means "for this purpose. Each device in a MANET is free to move independently in any direction, and will therefore change its links to other devices frequently. Each must forward traffic unrelated to its own use, and therefore be a router. The primary challenge in building a MANET is equipping each device to continuously maintain the information required to properly route traffic. Such networks may operate by themselves or may be connected to the larger Internet. They may contain one or multiple and different transceivers between nodes. This results in a highly dynamic, autonomous topology.

MANETs are a kind of Wireless ad hoc network that usually has a routable networking environment on top of a Link Layer ad hoc network. MANETs consist of a peer-to-peer, self-forming, self-healing network in contrast to a mesh network has a central controller (to determine, optimize, and distribute the routing table). MANETs circa 2000-2015 typically communicate at radio frequencies (30 MHz - 5 GHz).

Multi-hop relays date back to at least 500 BC. The growth of laptops and 802.11/Wi-Fi wireless networking have made MANETs a popular research topic since the mid-1990s. Many academic papers evaluate protocols and their abilities, assuming varying degrees of mobility within a bounded space, usually with all nodes within a few hops of each other. Different protocols are then evaluated based on measures such as the packet drop rate, the overhead introduced by the routing protocol, end-to-end packet delays, network throughput, ability to scale, etc.

For MANET unicast routing geographic routing protocols have been proposed in recent years for more scalable and robust transmissions. The existing geographic routing protocols generally assume mobile nodes are aware of their own positions through certain positioning system and a source can obtain the destination position through some type of location service. To reduce the topology maintenance overhead and support more reliable multicasting an option is to make use of position information to guide multicast routing. There are many challenges in implementing an efficient and scalable geographic multicasting scheme in manet. A straightforward way to extend the geography based transmission from unicast to multicast is to put the address in all the members into packet headers however header overhead will increase significantly as the group size increases which constrains the application of the geographic multicasting only to small group. Besides requiring efficient packet forwarding, a scalable geographic multicast protocol also needs to efficiently manage the membership of

the possibly large group obtain the positions of the members and build the routing paths to reach the members distributed in the possibly large terrain of networks. The existing small group based multicast protocols generally address to such problems hence an efficient geographic multicast protocol was proposed.

## III. EFFICIENT GEOGRAPHIC MULTICAST PROTOCOL

An efficient geographic multicast protocol, EGMP, which can scale to a large group size and large network size. The protocol is designed to be comprehensive and self-contained, yet simple and efficient for more reliable operation. Instead of addressing only a specific part of the problem, it includes a zone-based scheme to efficiently handle the group membership management, and takes advantage of the membership management structure to efficiently track the locations of all the group members without resorting to an external location server. The zone structure is formed virtually and the zone where a node is located can be calculated based on the position of the node and a reference origin. In topology-based cluster construction, a cluster is normally formed around a cluster leader with nodes one hop or k-hop away, and the cluster will constantly change as network topology changes. In contrast, there is no need to involve a big overhead to create and maintain the geographic zones proposed in this work, which is critical to support more efficient and reliable communications over a dynamic MANET. By making use of the location information, EGMP could quickly and efficiently build packet distribution paths, and reliably maintain the forwarding paths in the presence of network dynamics due to unstable wireless channels or frequent node movements.

The steps involved in the EGMP includes:

- 1) 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 is enhanced to handle 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.

- 2) Supporting 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.

- 3) Introducing an important concept zone depth, which is efficient in guiding the tree branch building and tree structure maintenance, especially in the presence of node mobility. With nodes self-organizing into zones, zone-based bi-directional-tree-based distribution paths can be built quickly for efficient multicast packet forwarding.

- 4) Addressing the empty zone problem, which is critical in a zone-based protocol, through the adaptation of tree structure.

- 5) Evaluating the performance of the protocol through quantitative analysis and extensive simulations. The analysis results indicate that the cost of the protocol defined as the per-node control overhead remains constant regardless of the network size and the group size

EGMP uses a location-aware approach for more reliable membership management and packet transmissions, and supports scalability for both group size and network size. However, at the similar mobility and system set-up, the delivery ratio of is much lower than that of EGMP, and the delivery ratio in varies significantly as the group size changes. In addition, topology-based routing by nature is more vulnerable to mobility and long path transmission, which

prevents topology-based protocols from scaling to a large network size

EGMP uses more efficient zone-based tree structure to allow nodes to quickly join and leave the group. EGMP introduces root zone and zone depth to facilitate simple and more reliable group membership management. EGMP does not use any periodic network-wide flooding, thus it can be scalable to both the group size and network size. EGMP takes advantage of the promiscuous mode transmission to forward packets along more efficient transmission paths.

#### IV. EGMP PROTOCOL OVERVIEW

##### 4.1 Protocol Overview

EGMP supports scalable and reliable membership management and multicast forwarding through a two-tier virtual zone based structure. At the lower layer, in reference with a pre-determined virtual origin, the nodes in the network self-organize themselves into a set of zones as shown in Fig. 1, and a leader is elected in a zone to manage the local group membership. At the upper layer, the leader serves as a representative for its zone to join or leave a multicast group as required. As a result, a network-wide zone-based multicast tree is built. For efficient and reliable management and transmissions, location information will be integrated with the design and used to guide the zone construction, group membership management, multicast tree construction and maintenance, and packet forwarding. The zone-based tree is shared for all the multicast sources of a group. To further reduce the forwarding overhead and delay, EGMP supports bi-directional packet forwarding along the tree structure. That is, instead of sending the packets to the root of the tree first, a source forwards the multicast packets directly along the tree. At the upper layer, the multicast packets will flow along the multicast tree both upstream to the root zone and downstream to the leaf zones of the tree. At the lower layer, when an on-tree zone leader receives the packets, it will send them to the group members in its local zone.

Many issues need to be addressed to make the protocol fully functional and scalable. The issues related to zone management include: the schemes for more efficient and robust zone construction and maintenance, the strategies for election and maintenance of a zone leader with minimum overhead, zone partitioning as a result of severe wireless channels or signal blocking, potential packet loss when multicast members move across zones. The issues related to packet forwarding include: the efficient building of multicast paths with the zone structure, the handling of empty zone problem, the efficient tree structure maintenance during node movements, the reliable transmissions of control and multicast data packets, and obtaining location information to facilitate our geometric design without resorting to an external location server.

For the convenience of presentation, we first introduce the terminologies used in the paper. In EGMP, we assume every node is aware of its own position through some positioning system (e.g., GPS) or other localization schemes. The forwarding of data packets and most control messages is based on the geographic unicast routing protocol GPSR. EGMP, however, does not depend on a specific geographic unicast protocol.

##### 4.1 Zone structure and multicast session example

##### 4.2 Terminologies used in zone construction

**Zone:** The network terrain is divided into square zones as shown in Fig. 6.1

**r:** Zone size, the length of a side of the zone square. The zone size is set to  $r \leq r_t / 2$ , where  $r_t$  is the transmission range of the mobile nodes. To reduce intra-zone management overhead, the intra-zone nodes can communicate directly with each other without the need of any intermediate relays.

**zone center:** For a zone with ID (a,b), the position of its center (xc , yc ) can be calculated as:  $x_c = x_0 + (a + 0.5) \times r$ ,  $y_c = y_0 + (b + 0.5) \times r$ . A packet destined to a zone will be forwarded towards the center of the zone.

**zLdr:** Zone leader. A zLdr is elected in each zone for managing the local zone group membership and taking part in the upper tier multicast routing.

**Tree zone:** The zones on the multicast tree. The tree zones are responsible for the multicast packet forwarding. A tree zone may have group members or just help forward the multicast packets for zones with members.

**Root zone:** The zone where the root of the multicast tree is located.

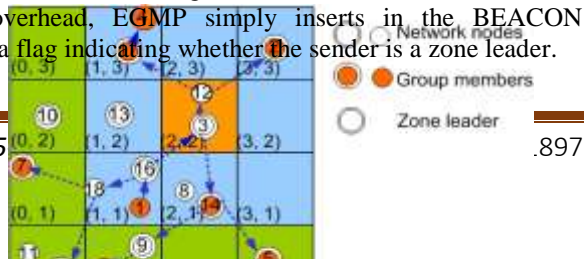
**Zone depth:** The depth of a zone is used to reflect its distance to the root zone. For a zone with ID (a, b), its depth is:  $\text{depth} = \max(|a_0 - a|, |b_0 - b|)$ , where (a<sub>0</sub> , b<sub>0</sub> ) is the root-zone ID. For example, in Fig.6 1, the root zone has depth zero, the eight zones immediately surrounding the root zone have depth one, and the outer seven zones have depth two.

**Zone ID:** The identification of a zone. A node can calculate its zone ID (a, b) from its position coordinates (x, y) is the position of the virtual origin which can be known as reference location or determined at the network setup time. A zone is virtual and formulated in reference with the virtual origin.

In EGMP, the zone-structure is virtual and calculated based on a reference point. Therefore, the construction of zone structure does not depend on the shape of the network region, and it is very simple to locate and maintain a zone. The zone is used in EGMP to provide location reference and support lower-level group membership management. A multicast group can cross multiple zones. With the introduction of virtual zone, EGMP does not need to track individual node movement but only needs to track the membership change of zones, which significantly reduces the management overhead and increases the robustness of the proposed multicast protocol. The zone without considering node density so it can provide more reliable location reference and membership management in a network with constant topology changes

##### 4.3 Neighbor Table Generation and Zone Leader Election

For efficient management of states in a zone, a leader is elected with minimum overhead. As a node employs periodic BEACON broadcast to distribute its position in the underneath geographic unicast routing to facilitate leader election and reduce overhead, EGMP simply inserts in the BEACON message a flag indicating whether the sender is a zone leader.



With zone size  $r \leq rt/\sqrt{2}$ , a broadcast message will be received by all the nodes in the zone. to reduce the beaconing interval for the underneath unicast protocol will be adaptive. A non leader has to send out the beacon every period of time. A zone leader has to send out a beacon every period of  $I$  nvalmin to announce its leadership role. or when it moves to a new zone.

A node constructs its neighbor table without extra signaling. When receiving a beacon from a neighbour a node records the node id position and the flag contained in the message in the neighbor table of 18 in the fig 6.1. The zone id of the sending node can be calculated from its position. To avoid routing failure due to outdated topology information, an entry will be removed if not refreshed within a period  $T$  imeoutN T or the corresponding neighbor is detected unreachable by the MAC layer protocol

nodeID	position	flag	zone ID
16	$(x_{16}, y_{16})$	1	(1, 1)
1	$(x_1, y_1)$	0	(1, 1)
7	$(x_7, y_7)$	1	(0, 1)
13	$(x_{13}, y_{13})$	1	(1, 2)

A zone leader is elected through the cooperation of nodes and maintained consistently in a zone. When a node appears in the network, it sends out a beacon announcing its existence. Then it waits for an  $I$  nvalmax period for the beacons from other nodes.

Every  $I$  nvalmin a node will check its neighbor table and determine its zone leader under different cases:

- 1) The neighbor table contains no other nodes in the same zone, it will announce itself as the leader.
- 2) The flags of all the nodes in the same zone are unset, which means that no node in the zone has announced the leadership role. If the node is closer to the zone center than other nodes, it will announce its leadership role through a beacon message with the leader flag set.
- 3) More than one node in the same zone have their leader flags set, the one with the highest node ID is elected.
- 4) Only one of the nodes in the zone has its flag set, then the node with the flag set is the leader.

#### 4.4 Multicast Tree Construction

The multicast tree creation and maintenance schemes. In EGMP, instead of connecting each group member directly to the tree, the tree is formed in the granularity of zone with the guidance of location information, which significantly reduces the tree management overhead. With a destination location, a control message can be transmitted immediately without incurring a high overhead and delay to find the path first, which enables quick group joining and leaving. In the following description, except when explicitly indicated, we use  $G$ ,  $S$  and  $M$  respectively to represent a multicast group, a source of  $G$  and a member of  $G$ .

##### 4.4.1 Multicast session initiation and termination

When a multicast session  $G$  is initiated, the first source node  $S$  (or a separate group initiator) announces the existence of  $G$  by flooding a message  $NEW\ SESSION(G, zoneID)$  into the whole network. The message carries  $G$  and the ID of the zone where  $S$  is located, which is used as the initial root-zone ID of group  $G$ . When a node  $M$  receives this message and is interested in  $G$ , it will join  $G$  using the process described in the next subsection. A multicast group member will keep a membership table with an entry  $(G, root\ zID, isAcked)$ , where  $G$  is a group of which the node is a member,  $root\ zID$  is the root-zone ID and  $isAcked$  is a flag indicating whether the node

is on the corresponding multicast tree. A zone leader (zLdr) maintains a multicast table. When a zLdr receives the  $NEW\ SESSION$  message, it will record the group ID and the root-zone ID in its multicast table. Table 2 is an example of one entry in the multicast table of node 16 in Fig. 1. The table contains the group ID, root-zone ID, upstream zone ID, downstream zone list and downstream node list. To end a session  $G$ ,  $S$  floods a message  $END\ SESSION(G)$ . When receiving this message, the nodes will remove all the information about  $G$  from their membership tables and multicast tables.

group ID	$G$
root-zone ID	$(2, 2)$
upstream zone ID	$(2, 2)$
downstream zone list	$(0, 1), (0, 0)$
downstream node list	1

Table 6.2 : The entry of group  $G$  in multicast table of node 16

##### 4.4.2 Multicast group join

When a node  $M$  wants to join the multicast group  $G$ , if it is not a leader node, it sends a  $JOIN\ REQ(M, PosM, G, \{Mold\})$  message to its zLdr, carrying its address, position, and group to join. The address of the old group leader  $Mold$  is an option used when there is a leader handoff and a new leader sends an updated  $JOIN\ REQ$  message to its upstream zone. If  $M$  did not receive the  $NEW\ SESSION$  message or it just joined the network, it can search for the available groups by querying its neighbors. If a zLdr receives a  $JOIN\ REQ$  message or wants to join  $G$  itself, it begins the leader joining procedure as shown in Fig. 3. If the  $JOIN\ REQ$  message is received from a member  $M$  of the same zone, the zLdr adds  $M$  to the downstream node list of its multicast table. If the message is from another zone, it will compare the depth of the requesting zone and that of its own zone. If its zone depth is smaller, i.e., its zone is closer to the root zone than the requesting zone, it will add the requesting zone to its downstream zone list; otherwise, it simply continues forwarding the  $JOIN\ REQ$  message towards the root zone.

If new nodes or zones are added to the downstream list, the leader will check the root-zone ID and the upstream zone ID. If it does not know the root zone, it starts an expanded ring search. As the zone leaders in the network cache the root-zone ID, a result can be quickly obtained. With the knowledge of the root zone, if its upstream zone ID is unset, the leader will represent its zone to send a  $JOIN\ REQ$  message towards the root zone; otherwise, the leader will send back a  $JOIN\ REPLY$  message to the source of the  $JOIN\ REQ$  message (which may be multiple hops away and the geographic unicasting described in Section 3.3 is used for this transmission). When the source of the  $JOIN\ REQ$  message receives the  $JOIN\ REPLY$ , if it is a node, it sets the  $isAcked$  flag in its membership table and the joining procedure is completed. If the leader of a requesting zone receives the  $JOIN\ REPLY$  message, it will set its upstream zone ID as the ID of the zone where the  $JOIN\ REPLY$  message is sent, and then send  $JOIN\ REPLY$  messages to unacknowledged downstream nodes and zones.

An example is given in Fig. 6. 1, in which the root zone of  $G$  is  $(2, 2)$ , and the double circled nodes are zone leaders.

Suppose currently zone (0, 0) and (1, 1) are not on the multicast tree, and their leader nodes 15 and 16 already know the root zone ID from the NEW SESSION message. Now node 15 plans to join G with the leader joining procedure. As it finds its upstream zone ID is unset, node 15 sends a JOIN REQ message towards root zone (2, 2). The message reaches zone (1, 1) and is intercepted by leader node 16, which then starts its leader joining procedure. Node 16 compares the depths of zone (0, 0) and its own zone. Since  $\text{depth}(0,0) = 2$  and  $\text{depth}(1,1) = 1$ ,  $\text{depth}(0,0) > \text{depth}(1,1)$ , node 16 adds zone ID (0, 0) to its downstream zone list. As node 16 finds its upstream zone ID is unset, it sends a JOIN REQ message towards the root zone. This message is received by the leader of the root-zone, node 3, and triggers the joining procedure of node 3. Node 3 adds the zone ID (1, 1) to its downstream zone list after comparing the depth. As the root zone does not have an upstream zone, node 3 sends back a JOIN REPLY message to the zone (1, 1). On receiving this message, node 16 sets the upstream zone ID as (2, 2) and sends a JOIN REPLY message to its unacknowledged downstream zone (0, 0). Node 15 sets its upstream zone as (1, 1) on receiving the JOIN REPLY message and the joining process is completed, with two multicast branches built between zones (2, 2) and (1, 1), and between zones (1, 1) and (0, 0) respectively.

Through the joining process, the group membership management is implemented in a distributed manner. An upstream zone only needs to manage its downstream zones, and the group membership of a local zone is only managed by its leader. The zone depth is used to guide efficient tree construction and packet forwarding.

#### 4.4.3 Multicast group leave

When a member M wants to leave G, it sends a LEAVE(M,G) message to its zone leader. On receiving a LEAVE message, the leader removes the source of the LEAVE message from its downstream node list or zone list depending on whether the message is sent from an intra-zone node or a downstream zone. Besides removing a branch through explicit LEAVE, a leader will remove a node from its downstream list if it does not receive the beacon from the node exceeding  $2 \times \text{Intervalmax}$ . If its downstream zone list and node list of G are both empty and it is not a member of G either, the leader sends a LEAVE(zoneID, G) message to its upstream zone. Through the leave process, the unused branches are removed from the multicast tree.

#### 4.5 Multicast Packet Delivery

The multicast packets are forwarded to the members by few simple steps

##### 4.5.1 Packet sending from the source

After the multicast tree is constructed, all the sources of the group could send packets to the tree and the packets will be forwarded along the tree. In most tree-based multicast protocols, a data source needs to send the packets initially to the root of the tree. If this scheme is used and node 5 in Fig. 1 is a source, node 5 needs to unicast the packets initially to root zone (2, 2). The sending of packets to the root would introduce extra delay especially when a source is far away from the root. Instead, EGMP assumes a bi-directional tree-based forwarding strategy with which the multicast packets can flow not only from an upstream node/zone down to its downstream nodes/zones, but also from a downstream node/zone up to its upstream node/zone.

A source node is also a member of the multicast group and will join the multicast tree. When a source S has data to send and it is not a leader, it checks the isAked flag in its membership table to find out if it is on the tree. If it is, i.e., its zone has joined the multicast tree, it sends the multicast packets to its leader. When the leader of an ontree zone receives multicast packets, it forwards the packets to its upstream zone and all its downstream nodes and zones except the incoming one. For example, in Fig. 1, source node 1 sends the packets to its leader node 16, which will send the packets to its upstream zone (2, 2) and its downstream zones (0, 1) and (0, 0), but not to the downstream node 1 which is the incoming node. When the packets are received by leader node 3 of the root zone, it continues forwarding the packets to its downstream zones (1, 3), (3, 3), (2, 1) except the incoming zone (1, 1). The arrows in the figure indicate the directions of the packet flows.

When a source node S is not on the multicast tree, for example, when it moves to a new zone, the isAked flag will remain unset until it finishes the rejoining to G through the leader of the new zone. To reduce the impact of the joining delay, S will send packets directly to the root zone until it finishes the joining process.

#### 4.5.2 Multicast data forwarding

In our protocol, only zLdrs maintain the multicast table, and the member zones normally cannot be reached within one hop from the source. When a node N has a multicast packet to forward to a list of destinations (D1,D2,D3,...), it decides the next hop node towards each destination (for a zone, its center is used) using the geographic forwarding strategy described in Section 3.3. After deciding the next hop nodes, N inserts the list of next hop nodes and the destinations associated with each next hop node in the packet header. An example list is (N1 : D1,D3;N2 : D2;...), where N1 is the next hop node for the destinations D1 and D3, and N2 is the next hop node for D2. Then N broadcasts the packet promiscuously (for reliability and efficiency). Upon receiving the packet, a neighbor node will keep the packet if it is one of the next hop nodes or destinations, and drop the packet otherwise. When the node is associated with some downstream destinations, it will continue forwarding packets similarly as done by node N.

For example, in Fig.6.1, after node 3 receives the multicast packet from zone (1, 1), it will forward the packet to downstream zones (2, 1), (1, 3) and (3, 3). It determines the next hop node for each destination and inserts the list (12: (1,3),(3,3); 14: (2,1)) in the packet header. After broadcasting the packet promiscuously, its one-hop neighbors node 12, node 14 and node 8 will receive the packet. Node 8 will drop this packet, while node 12 and node 14 will continue the forwarding. Node 12 replaces the list carried in the packet header with (17: (1,3); 2: (3,3)) and broadcasts this packet. Node 14 finds group information from its multicast table, and broadcast the packet with a header (9: (1,0); 5:(3,0)).

#### 4.6 Multicast Route Maintenance and Optimization

In a dynamic network, it is critical to maintain the connection of the multicast tree, and adjust the tree structure upon the topology changes to optimize the multicast routing. In the zone structure, due to the movement of nodes between different zones, some zones may become empty. It is critical to handle the empty zone problem in a zone-based protocol. Compared to managing the connections of individual nodes, however, there is a much lower rate of zone membership change and hence a much lower overhead in maintaining the zone-based tree. As the tree construction is guided by location

information, a disconnected zone can quickly re-establish its connection to the tree. In addition, a zone may be partitioned into multiple clusters due to fading and signal blocking. In this subsection, we discuss our maintenance schemes.

#### 4.6.1 Moving between different zones

When a member node moves to a new zone, it must rejoin the multicast tree through the new leader. When a leader is moving away from its current zone, it must handover its multicast table to the new leader in the zone, so that all the downstream zones and nodes will remain connected to the multicast tree.

Whenever a node M moves into a new zone, it will rejoin a multicast group G by sending a JOIN REQ message to its new leader. During this joining process, to reduce the packet loss, whenever the node broadcasts a BEACON message to update its information to the nodes in the new zone, it also unicasts a copy of the message to the leader of its previous zone to update its position. Since it has not sent the LEAVE message to the old leader, the old leader will forward the multicast packets to M. This forwarding process helps reduce the packet loss and facilitates seamless packet transmissions during zone crossing. When the rejoining process finishes, M will send a LEAVE message to its old leader.

To handle leader mobility problem, if a leader finds its distance to the zone border is less than a threshold or it is already in a new zone, it assumes it is moving away from the zone where it was the leader, and it starts the handover process. To look for the new leader, it compares the positions of the nodes in the zone it is leaving from and selects the one closest to the zone center as the new leader. It then sends its multicast table to the new leader, which will announce its leadership role immediately through a BEACON message. It will also send a JOIN REQ message to its upstream zone.

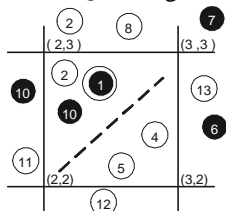


Fig. 6.1: Multiple clusters in one zone.

During the transition, the old leader may still receive multicast packets. It will forward all these packets to the new leader when the handover process is completed. If there is no other node in the zone and the zone will become empty, it will use the method introduced in the next subsection to deliver its multicast table. In the case that the leader dies suddenly before handing over its multicast table, the downstream zones and nodes will reconnect to the multicast tree through the maintenance process

#### 4.6.2 Dealing with empty zones

A zone may become empty when all the nodes move away. The probability that a zone is empty is approximately  $P = e^{-\rho r^2}$  when the node density is  $\rho$  and the zone size is  $r$ . Assume  $r = 150m$ , which is the zone size that allows all the nodes in the same zone to be within the transmission range, the probability of the zone being empty is:  $P = 0.207$  if  $d = 70nodes/km^2$ , and  $P = 0.509$  if  $d = 30nodes/km^2$ . The probability of a zone becoming empty is not negligible and it is critical to address the empty zone problem.

In EGMP, if a tree zone becomes empty, the multicast tree will be adjusted correspondingly to keep the multicast tree connected. Because of the importance of the root zone, we will

treat it differently. When a leader is moving away from a non-root tree-zone and the zone is becoming empty, it will send its multicast table to its upstream zone. The upstream zone leader will then take over all its downstream zones, and delete this requesting zone from its downstream zone list. The new upstream zone needs to send JOIN REPLY messages to all the newly added downstream zones to notify them the change. When receiving the JOIN REPLY messages, these downstream zones will change their upstream zone ID accordingly.

If the to-be empty zone is the root zone, since the root zone has no upstream zone, the leader will check its neighboring zones and choose the one closest to the root zone as the new root zone. The leader then forwards its multicast table to the new root zone, and floods a NEW ROOT message to announce the change.

#### 4.6.3 Handling Multiple Clusters per Zone

When there is severe shadowing/fading or a hill/building that prevents the radio communication between nodes in a zone, the nodes in the same zone may form multiple clusters as shown in

Fig6. 4, where the two clusters are not connected in the zone although they are connected through some nodes outside the zone. In this case, two nodes in different clusters can communicate with each other by using unicasting because they are connected on the network topology graph, but an intra-zone flooding message initiated in one cluster may not reach other clusters. This problem is also a key problem for zone-based protocols.

EGMP handles the zone partitioning problem as follows. If there are multiple clusters in a zone, because these clusters are not aware of the existence of each other, each cluster will elect a leader. When an upstream zone leader receives JOIN REQ messages from multiple leaders of the same zone and the new message is not sent as a result of leader handover (in which case the old leader's address needs to be carried), it detects that the downstream zone has partitioned into multiple clusters. It identifies a cluster by its zID and the leader's address. When sending a packet to the cluster, it uses the leader's position instead of the zone center (in which case the zone ID is carried as the destination) as the transmission reference. Even though the leader may move, its position carried in JOIN REQ message can still be used as a reference to forward packets to its cluster. When receiving a packet with the position of the leader as the reference, a cluster leader can learn that multiple clusters exist within its zone. In case that not all the clusters of a partitioned zone send JOIN REQ messages, the upstream zone leader may not be aware of the partitioning of the downstream zone. When a cluster leader receives a packet destined to its zone but does not match its status, it will send an update message to its upstream zone. For example, when a cluster leader receives a JOIN REPLY message or a multicast packet but did not send JOIN REQ message, it will send a LEAVE message to the upstream zone. When receiving messages from multiple leaders of the same zone, the upstream leader can detect zone partitioning. It will resend the previous message to the target cluster with the position of the zone leader as the destination.

When the leader of a cluster changes, if the cluster is on-tree, the new leader sends a JOIN REQ message to its upstream zone immediately which also carries the old leader's address. With multiple clusters in its upstream zone, the JOIN REQ message from a zone leader will generally be intercepted by one of the clusters, which will be responsible for forwarding the packets to the zone. Some clusters may merge later into a

larger cluster, and through the leader election procedure, only one of the leaders will win as the new cluster's leader. The new leader will send a JOIN REQ message to the upstream zone to refresh the cluster's information. The leaders of the other merged-in clusters will also send LEAVE messages to the upstream zone, which will remove their information from the multicast table.

#### 4.6.4 Tree branch maintenance

To detect the disconnection of tree-branches in time, if there are no multicast packets or messages to deliver for a period of  $Intvalactive$ , the leader of a tree-zone will send an ACTIVE message to its downstream nodes and zones to announce the activity of the multicast branches. The message is sent through multicast to multiple downstream entities. When a member node or a tree-zone fails to receive any packets or messages from its leader or upstream zone up to a period of  $2 * Intvalactive$ , it assumes that it loses the connection to the multicast tree and restarts a joining process.

#### 4.6.5 Route Optimization

A zone leader may receive duplicate multicast packets from different upstream zones. For example, as described in the above subsection, when failing to receive any data packets or ACTIVE messages from the upstream zone for a period of time, a tree-zone will start a rejoining process. However, it is possible that the packet and message were lost due to collisions, so the old upstream zone is still active after the rejoining process, and duplicate packets will be forwarded by two upstream zones to the tree-zone. In this case, the one closer to the root zone will be kept as the upstream zone. If the two upstream zones have the same distances to the root zone, one of them is randomly selected.

### V. CONCLUSIONS

There is an increasing demand and a big challenge to design more scalable and reliable multicast protocol over a dynamic

ad hoc network (MANET). An efficient and scalable geographic multicast protocol, MEGMP, for MANET is proposed. The scalability of EGMP is achieved through a two-tier virtual-zone-based structure, which takes advantage of the geometric information to greatly simplify the zone management and packet forwarding. A zone-based bi-directional multicast tree is built at the upper tier for more efficient multicast membership management and data delivery, while the intra-zone management is performed at the lower tier to realize the local membership management.

Simulation results demonstrate that MEGMP has high packet delivery ratio, and low control overhead and multicast group joining delay under all cases studied, and is scalable to both the group size and the network size

### Future Enhancement

A secured election scheme ECDSA algorithm for multicasting over MANETS in a virtual zone based network can be used to elect a zone leader through voting and handle security of votes.

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