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LECTURE NOTES

Doing network-wide broadcasting in ad hoc networks requires one device to broadcast the information to all its neighbors. For far-away devices, the message is rebroadcasted which could cause collision if multiple device broadcasts the same time and are in the neighborhood. This is also known as the broadcasting storm problem [Nil999] and in this section we discuss ways to perform efficient broadcasting ofmessages.

we assume that MHs in the MANET share a single common channel with carrier sense multiple access (CSMA) [Agrawal2002], but no collision detection (CD) capability (e.g., the IEEE standard 802.11 [IEEE-802.111997]). Synchronization in such a network with mobility is unlikely, and global network topology information is unavailable to facilitate the scheduling of a broadcast. Thus, one straightforward and obvious solution is to achieve broadcasting by flooding (for example, as it is done by mostly all MANET routing algorithms). Unfortunately, as we will see later, it is observed that redundancy, contention, and collision could exist if flooding is done blindly. Several problems arise in these situations including:

- As the radio propagation is omnidirectional and a physical location may be covered by the transmission ranges of several hosts, many rebroadcasts are considered to beredundant
- Heavy contention could exist because rebroadcasting hosts are probably close to each other; and
- As the RTS/CTS handshake (e.g., employed in the IEEE standard (802.11) is inapplicable for broadcast transmissions, collisions are more likely to occur as the timing of rebroadcasts is highlycorrelated.

BROAD CASTING OF MANET

A MANET consists of a set of MHs that may communicate with one another from time to time, and here no base stations are present. Each host is equipped with a CSMA/CA (carrier sense multiple access with collision avoidance) [Agrawal2002] transceiver. In such an environment, a MH may communicate with each other directly or indirectly. In the latter case, a multi-hop scenario occurs, where the packets originated from the source host are relayed by several intermediate MHs before reaching the destination. The broadcast problem refers to the transmission of a message to all other MHs in the network. The problem we consider has the followingcharacteristics.

• **The broadcast is spontaneous:** Any MH can issue a broadcast operation at any time. For reasons suchastheMHmobilityandthelackofsynchronization,preparinganykindofglobaltopologyknowledge is prohibitive (in fact, this is at least as hard as the broadcast problem). Little or no local information may be collected in advance.

• **The broadcast is frequently unreliable:** Acknowledgement mechanism is rarely used. However, attempt should be made to distribute a broadcast message to as many MHs as possible without putting too much effort. The motivations for such an assumptionare:

1 .A MH may miss a broadcast message because it is off-line, it is temporarily isolated from the network, Or it experiences repetitive collisions;

2. Acknowledgements may cause serious medium contention (and thus another "storm")surrounding the Sender

3. In many applications (e.g., route discovery in ad hoc routing Protocols), a 100% reliable broadcast is Unnecessary.

We focus on the flooding behavior in a MANET – the phenomenon where the transmission of a packet will trigger other surrounding MHs to transmit the same (or modified) packet. We shall show that if flooding is used blindly, many redundant messages will be sent and serious contention/collision will be incurred.

MULTICASTING

In this section, we investigate the problem of multicasting in MANETs where the problem is to broadcast a message to a subset of MANET MHs. We begin by understanding the hard task of multicasting to a group of mobile nodes, together with the various issues behind the design and implementation of a multicast protocol for MANETs. Next, we study the existing multicast protocols for MANETs and show how different they are as compared to broadcasting.

3.3.1 Issues in Providing Multicast in a MANET

Well-established routing protocols do exist to offer an efficient multicasting service in conventional wired networks. Protocols, designed for fixed networks, may fail to keep up with node movements and frequent topological changes as MHs become increasingly mobile, these protocols need to evolve to cope up with the new environment. But the host mobility increases the protocol overheads substantially. the message while all multicast algorithm depend on the topology of the network and do not consider whether a node belongs to a group or not. Rather, new protocols are being proposed and investigated which take issues such as locations of nodes belonging to a multicast group, and all associated topological changes. Moreover, the nodes of MANET run on batteries, routing protocols must limit the amount of control information that is passed between nodes. The majority of applications are in the areas where rapid deployment and dynamic reconfiguration are necessary and the wire line network is not available.Theseincludemilitarybattlefields,emergencysearchandrescuesites,classrooms,andconventions where participants share information dynamically using their mobile devices. These applications lend themselves well to multicast operation. In addition, within a wireless medium, it is even more crucial to reduce the transmission overhead and power consumption. Transient loops may form during reconfiguration of distribution structure (e.g., tree) as a result of mobility. Therefore, reconfiguration scheme should be kept simple to maintain low channel overhead. As we can see, providing an efficient multicasting over MANET faces many challenges including dynamic group membership and constant update of delivery path due to node movement. In the next sections, we cover the major protocols proposed so far and compare them under different criteria.

Multicast Routing Protocols:

We can classify the protocols into four categories based on how route to the members of the group is created:

- Tree-BasedApproaches
- Meshed-BasedApproaches
- StatelessMulticast
- HybridApproaches.

1. Tree-BasedApproaches

Most of the schemes for providing multicast in wired network are either source-based or shared tree- based. Different researchers have tried to extend the idea of tree-based approach to provide multicast in a MANET environment. Due to simplicity and innate properties of tree structures, many characteristics can be identified such as: a packet traverses each hop and node in a tree at most once, very simple routing decisions at each node, and the number of copies of a packet is minimized, tree structure built presenting shortest paths amongst nodes, and a loop-free data distribution structure. On the other hand, there are many issues that must be addressed in tree-based approaches. As mentioned earlier, trees provide a unique path between any two nodes. Therefore, having even one link failure could mean reconfiguration of the entire tree structure and could be a major drawback. In addition, multiple packets generated by different sources will require some consideration when utilizing multicast trees such that efficient routing can be established and maintained. Thus, it is common to consider the use of either a shared tree or establish a separate tree per each source (i.e., separate source trees). As highlighted in [Garcia-Luna-Aceves 1999a], each approach has to deal with own individual issues. For separate source trees, each router(ornodeincaseofMANETs)involvedinmultipleroutergroupsmustmaintainalistofpertinentinformation for each group in which it is involved. Such management per router is inefficient and not scalable. On the other hand, for shared trees, there is a potential that packets may not only not traverse shorter paths, but in fact may be routed on paths with much longer distances than the shortest paths. While any scheme has positive and negative sides, the simple structured coupled with ease of approach has made multicast trees the primary method for realizing multicasting on the Internet. Due to this fact, tree-based approaches for ad hoc networks have been investigated and we will study them in the followingsections.

2. Mesh-BasedApproaches:

In contrast to the tree-based approach, mesh-based multicast protocols may have multiple paths between any source and receiver pairs. Existing studies show that tree-based protocols are not necessarily the best suited for multicast in a MANET environment if the network topology changes frequently. In such an environment, mesh-based protocols seem to outperform tree-based proposals due to availability of alternative paths, which allow multicast data grams to be delivered to the receivers even if links fail.

The disadvantage of a mesh is the increase in data-forwarding overhead. The redundant forwarding consumes more bandwidth in the bandwidth constrained ad hoc networks. Moreover, the probability of Collision s is higher when a larger number of packets are generated. Therefore, one common problem mesh-based protocols have to consider is how to minimize the data-forwarding overhead caused by flooding. As we shall see, different protocols attack this issue in different ways through the use of forwarding groups, cores, and so on. This section gives an overview of the mesh-based approaches that support multicasting MANETs.

3. StatelessApproaches:

Tree-based and mesh-based approaches have an overhead of creating and maintaining the delivery tree/mesh with time. In a MANET environment, frequent movement of MHs considerably increases the overhead in maintaining the delivery tree/mesh. To minimize the effect of such a problem, stateless multicast is proposed wherein a source explicitly mentions the list of destinations in the packet header. Stateless multicast approaches focus on small group multicast and assumes the underlying routing protocol to take care of forwarding the packet to the respective destinations based on the addresses contained in the header. In this section we present the main stateless multicast routing protocols proposed for use inMANETs.

Differential Destination Multicast

Differential Destination Multicast (DDM) protocol [Ji2001] is meant for small-multicast groupsoperating in dynamic networks of any size. Unlike other MANET routing protocols, DDM lets source to control multicast group membership. The source encodes multicast receiver addresses in multicast data packets using a special DDM Data Header. This variable length destination list is placed in the packet headers, resulting in packets being self-routed towards the destinations using the underlying unicast routing protocol. It eliminates maintaining per-session multicast forwarding states at intermediate nodes and thus is easily scalable with respect to the number of sessions. DDM supports two kinds of operating modes: "stateless" and "soft state". In stateless mode, the nodes along the data forwarding paths need not maintain multicast forwarding states. An intermediate node receiving a DDM packet only needs to look at the header to decide how to forward the packet. In the "soft-state" mode, based on in-band routing information, each node along the forwarding path remembers the destinations to which the packet has been forwarded last time and its next hop information. By caching this routing information at each node, the protocol does not need to list the entire destination in future datapackets.

In case changes occur in the underlying unicast routing, an upstream node only needs to inform its downstream nodes about the differences in the destination forwarding since the last packet; hence the name "Differential Destination Multicast". At each node, there is one Forwarding Set (FS) for each multicast session, which records to which destinations this node forwards data. The nodes also maintain a Direction Set (DS) to record the particular next hop to which multicast destination data are forwarded. At the source node, FS contains the same set of nodes as the multicast Member List (ML). In the intermediate nodes, the FS is the union of several subsets based on the data stream received from upstream neighbors. Associated with each set FS_k, there is a sequence number SEQ(FS_k) which is used to record the last DDM Block Sequence Number seen in a received DDM data packet from an upstream neighbor k. It helps to detect loss of data packet containing the forwarding set updates. At a given node, FS also needs to be partitioned into subsets according to the next hops for different destination mechanism defined by the DSR unicast protocol to flood the data packets in the network. Although this is derived from DSR, it can be implemented as a stand-alone protocol. In fact, it does not rely on unicast routing to operate. If DSR has already been implemented on the network, minor modifications are required to enable this protocol. This multicast and broadcast protocol utilizes controlled flooding to distribute data in the network and does not require establishment of a state in the network for data delivery. It is not intended as a general purpose multicast protocol. Its applicability is mainly in environments characterized by very high mobility or by a relatively small number of nodes. In the former case, protocols relying on the establishment of multicast state perform inadequately because they are unable to track the rapid changes in topology. In the latter case, the overhead of keeping multicast state exceeds the overhead offlooding.

DSR Simple Multicast and Broadcast Protocol

The DSR Simple Multicast and Broadcast protocol (DSR-MB) [Jetcheva2001b] is designed toprovide multicast and broadcast functionality in ad hoc networks. It utilizes the Route Discovery .

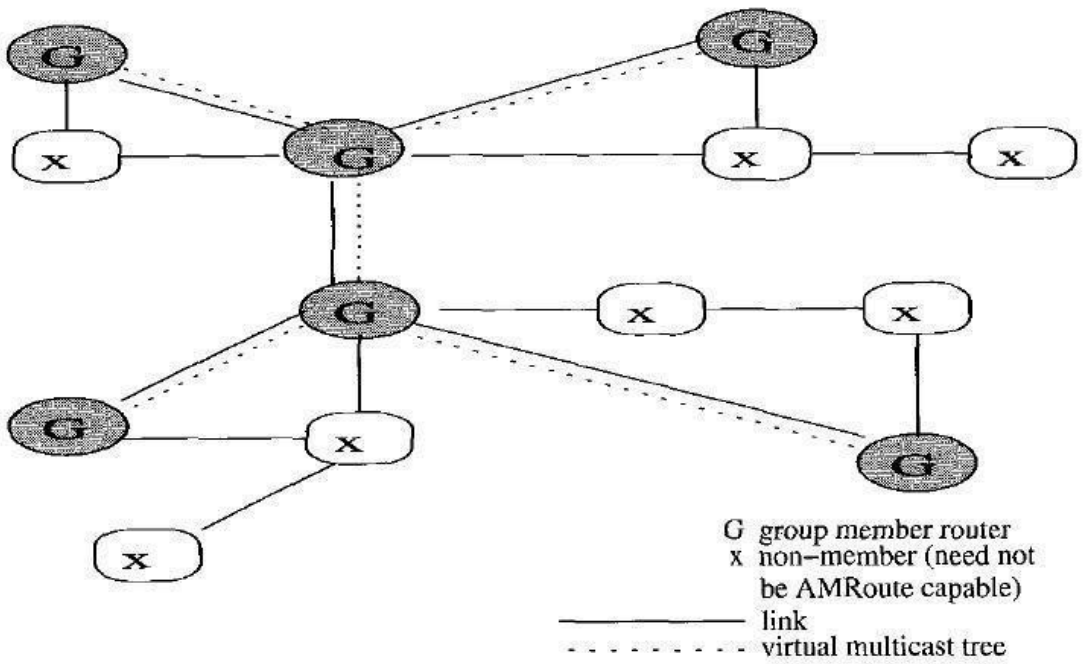
Hybrid Approaches

The protocols to provide multicast in ad hoc networks discussed so far, either address efficiency or robustness but not both simultaneously. The tree-based approaches provide high data forwarding efficiency at the expense of low robustness, whereas mesh-based approaches lead to better robustness (link failure may not trigger a reconfiguration) at the expense of higher forwarding overhead and increased network load. Thus, there is a possibility that a hybrid multicasting solution may achieve better performance by combining the advantages of both tree and meshed-based approaches. In this section, we explore the different hybrid approaches to enable ad hocmulticasting.

The Ad hoc Multicast Routing Protocol (AMRoute) [Bommaiahl998] creates a bi-directional, shared tree by using only group senders and receivers as tree nodes for data distribution. The protocol has two main components: mesh creation and tree setup The mesh creation identifies and designates certain nodes as logical cores and these are responsible for initiating the signaling operation and maintaining the multicast tree to the rest of the group members. A non core node only responds to messages from the core nodes and serves as a passive agent. The selection of logical core in AMRoute is dynamic and can migrate to any other member node, depending on the network dynamics and the group membership. AMRoute does not address network dynamics and assumes the underlying unicast protocol to take care of it. To create a mesh, each member begins by identifying itself as a core and broadcasts JOIN_REQ packets with increasing TTL to discover other members. When a core receives JOIN_REQ from a core in a different mesh for the same group, it replies with a JOIN_ACK. A new bi-directional tunnel is created between the two cores and one of them is selected as core after the mesh merger. Once the mesh has been established, the core initiates the tree creation process. The core sends out periodic TREE_CREATE messages along all links incident on its mesh. Using unicast tunnels, the TREE_CREATE messages are sent only to the group members. Group members receiving non-duplicate TREE_CREATE message forwards it to all mesh links except the incoming one, and marks the incoming and outgoing links as a tree links. If a link is not going to be used as part of the tree, the TREE_CREATE is discarded and TREE_CREATENAK is sent back to incoming links. A member node, which wants to leave a group, can do so by sending a JOESLNAK message to its neighboring nodes. AMRoute employs the virtual mesh links to establish the multicast tree, which helps in keeping the multicast delivery tree the same even with the change of network topology as long as routes between core nodes and tree members exist via mesh links. The main disadvantage of this protocol is that it may have temporary loops and may create nonoptimal trees in case ofmobility.

Multicast Core-Extraction Distributed Ad Hoc Routing

The Multicast Core-Extraction Distributed Ad hoc Routing (MCEDAR) [Sinhal999] is a multicast extension to the CEDAR architecture. The main idea of MCEDAR is to provide the efficiency of the tree-based forwarding protocols and robustness of mesh-based protocols by combining these two approaches. It is worth pointing out that a source-based forwarding tree is created on a mesh. As such, this ensures that the infrastructure is robust and data forwarding occurs at minimum height trees. MCEDAR decouples the control infrastructure from the actual data forwarding in order to reduce the control overhead.



3.10 – AMRoute virtual multicast tree [Taken from IEEE Publication Cordeiro2003]

Mobility-Based Hybrid Multicast Routing

The Mobility-based Hybrid Multicast Routing (MHMR) protocol [An2001] is built on top of the mobility-based clustering infrastructure. In order to deal with the issues of scalability and stability, the structure is hierarchical in nature. The mobility and positioning information is provided via a GPS for each node. For a group of nodes, a cluster-head is chosen to manage and monitor the nodes in a cluster. A mesh structure is built based on all the current clusters. Thus, MHMR achieves high stability. This is followed by a tree structure built based on the mesh to ensure that the multicasting group achieves maximal efficiency. MHMR also provides a combination of proactive and reactive concepts which enable low route acquisition delay of proactive schemes while achieving low overhead of reactive methods. It isinteresting to note that cores are employed in both AMRoute and MCEDAR, as well as in many tree and mesh multicast algorithms. The use of cores has been shown to lower the control overhead. The use of cluster-heads has been proposed in MHMR. This has been shown to be a reasonable approach since dividing the nodes in an ad hoc network into clusters seems to be a promising method in taking careof highly dynamic nodes. Hybrid methods can reveal themselves to be attractive as they can provide protocols that can address further robustness and efficiency. Though hybrid protocols have not been as deeply investigated as tree and mesh protocols, they are under development and recent results indicate its promising future.

Geocasting

We now turn our attention to the problem of geocasting over MANETs. As we have mentioned earlier, geocasting is a variant of the conventional multicasting problem and distinguishes itself by specifying hosts as group members within a specified geographical region. In geocasting, the nodes eligible to receive packets are implicitly specified by a physical region and membership changes as mobile nodes move in or out of the geocastregion.

Flooding	Mesh	Yes	No	No	No
AMRoute	Hybrid	No	Yes	Yes	Yes
AMRIS	Tree	Yes	No	Yes	Yes
MAODV	Tree	Yes	Yes	Yes	Yes
LAM	Tree	Yes	Yes	No	No
LGT-Based	Tree	Yes	No	Yes	No
ODMRP	Mesh	Yes	No	Yes	Yes
CAMP	Mesh	Yes	Yes	Yes	No
DDM	Stateless Tree	Yes	No	Yes	No
FGMP-RA	Mesh	Yes	Yes	Yes	Yes
FGMP-SA	Mesh	Yes	No	Yes	Yes
MCEDAR	Hybrid	Yes	Yes	Yes	Yes

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Geocast Routing Protocols

In this section, we discuss the main geocast routing protocols proposed for use in MANETs. We start with data-transmission oriented protocols, followed by the route creation orientedapproaches.

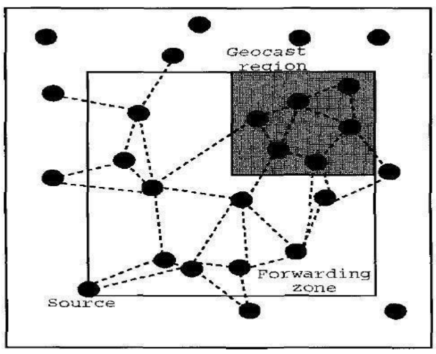
Data-Transmission Oriented

Data-transmission oriented geocast protocols use flooding or a variant of flooding to forward

3.4.1.1.1 Location-Based Multicast

The Location-Based Multicast (LBM) protocol [Kol999] extends the LAR unicast routing algorithm for geocasting. As we have seen, LAR is an approach to utilize location information to improve the performance (i.e., higher data packet delivery ratio and lower overhead) of a unicast routing protocol in a MANET. Similarly, the goal of LBM is to decrease delivery overhead of geocast packets by reducing the forwarding space for geocast packets, while maintaining accuracy of data delivery. The LBM algorithm is based upon a flooding approach. LBM is essentially identical to flooding data packets, with the modification that a node determines whether to forward a geocast packet further via one of twoschemes.

• **LBM Scheme 1:** When a node receives a geocast packet, it forwards the packet to its neighbors if it is within *& forwarding zone;* otherwise, it discards the packet. Thus, how to define the forwarding zone becomes the key point of this scheme. Figure 3.11 shows one example of a forwarding zone Boleng2001]. In Figure 3.11, the size of the forwarding zone is dependent on (i) the size of the geocast region and (ii) the location of the sender. In a BOX Forwarding Zone, the smallest rectangle that covers both the source node and the geocast region defines the forwarding zone. All the nodes in the forwarding zone forward data packets to their neighbors. Other kinds of forwarding zones are possible, such as the CONE Forwarding Zone [Boleng2001]. A parameter <5is discussed in [Kol999] to provide additional control on the size of the forwarding zone. When. *S* is positive, the forwarding zone is extended in both positive and negative X and Y directions by <5.(ie., each side increases by 2*S*).



. BOX forwarding zone

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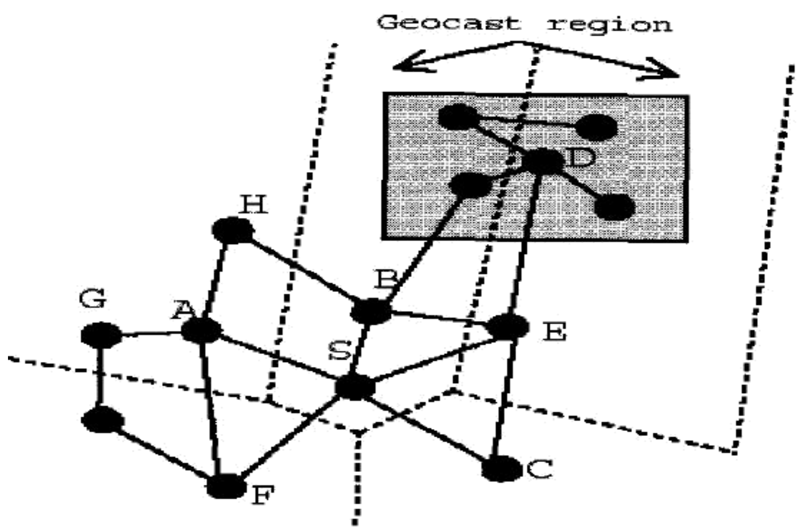
LBM Scheme 2: Unlike scheme 1, in which a geocast packet is forwarded based on the forwarding zone, scheme 2 does not have a forwarding zone explicitly. Instead, whether a geocast packet should be forwarded is based on the position of the sender node at the transmission of the packet and the position of the geocast region. That is, for some parameter *8*, node B forwards a geocast packet from node A(originated at node S), if node B is "at least. *S* closer" to the center of the geocast region *(Xc, Yc)* than node A. In other words, *DISTA* > *DISTB*+ *S*. We define *(Xc, Yc)* as the location of the geometrical center of the geocast region, and for anynodeZ, *DISTz*denotes the distance of node Z from *(Xc, Yc)*. In Figure 3.12 [Kol999], node B will forward a geocast packet transmitted by node A since *DISTA* > *DISTB* and. *d*= 0. Node K will, however, discard a geocast packet transmitted by node B, since node K is not closer to *(Xc, Yc)* than node B. In brief, this protocol ensures that every packet transmission sends the packet closer to the destination. As for the performance, the accuracy (i.e., ratio of the number of geocast group members that actually receive the geocast packets to the number of group members that were supposed to receive the packets) of both LBM schemes is comparable with that of flooding geocast packets throughout the network. However, the number of geocast packets transmitted (a measure of the overhead) is consistently lower for LBM than simpleflooding.

Voronoi Diagram Based Geocasting

The goal of the Voronoi Diagram based Geocasting (VDG) protocol [Stojmenovicl999] is to enhance the success rate and decrease the hop count and flooding rate of LBM. It is observed that the forwarding zone defined in LMB may be a partitioned network between the source node and the geocast region, although there exists a path between the source and the destination.

In VDG, the definition of the forwarding zone of LBM has been modified. The neighbors of node A that are located within the forwarding zone in VDG are exactly those neighbors that are closest in the irectionofthedestination.Thisdefinitionofaforwardingzonenotonlyresolvestheproblemofhaving no nodes inside the forwarding zone, but also precisely determines the expansion of the forwarding zone. This forwarding zone can be implemented with a *Voronoi diagram* for a set of nodes in a given node's neighborhood of a MANET. A Voronoi diagram of *n* distinct points (i.e., *n* neighbors) in a plane is a partition of the plane into *n* Voronoi regions, which, when associated with node A, consists of all the points in the plane that are the closest to A. In other words, the *Voronoi diagram model* is a model where every point is assigned to a Voronoi region. The subdivision induced by this model is called the

Voronoi diagram of the set of nodes [Berg]. For example, in Fig, five neighbors of source node S (A, B, C, Eand F) carve up the plane into five Voronoi regions. The region associated with node A, consists of nodes G and H, since these two nodes are closer to node A than to any other node. The geocast region is the rectangle with the center D. In Figure 3.14, the Voronoi regions of nodes B and E intersect the geocast region; thus, only nodes B and E will forward geocast packets from node S. Although there are not any simulations of the VDG algorithm, it is believed that VDG reduces the flooding rates of LBM Scheme 1, as fewer packets should be transmitted. On the other hand, VDG may offer little improvement over LBM Scheme 2, as the end result of the two protocols appears to besimilar.



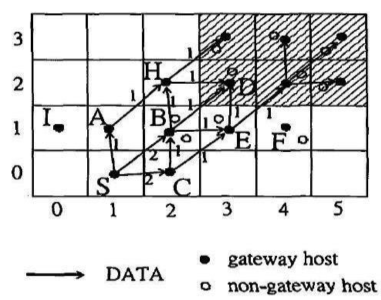
Example of a Voronoi diagram and the request zone

GEOGRID

Based on the unicast protocol GRID [Liao2001], the GeoGRID protocol [Liao2000] uses location information, which defines the forwarding zone and elects a special host (i.e, *gateway)* in each grid area responsible for forwarding the geocast packets. It is argued in [Liao2000] that the forwarding zone in LBM incurs unnecessary packet transmissions, and a tree-based solution is prohibitive in terms of control overhead. GeoGRID partitions the geographic area of the MANET into two-dimensional (2D) logical grids. Each grid is a square of size *d X d* (there are trade-offs in choosing a good value of *d*, as discussed in [Liao2000].) In GeoGRID, a gateway node is elected within each grid. The forwarding zone is defined by the location of the source and the geocast region. The main difference between GeoGRID, LBM and VDG is the following: in GeoGRID, instead of every node in a forwarding zone transmitting data, only gateway nodes take this responsibility. There are two schemes on how to send geocast packets inGeoGRID:

*Flooding-Based GeoGRID*and *Ticket-Based GeoGRID*. In Flooding-Based GeoGRID, only gateways in every grid within the forwarding zone rebroadcast the received geocast packets. Thus, gateway election becomes the key point of this protocol. In Ticket-Based GeoGRID, the geocast packets are still forwarded by gateway nodes, but not all the gateways in the forwarding zone forward every geocast packet. A total of $m + n$ tickets are created by the source if the geocast region is a rectangle of m X n grids. The source evenly distributes the $m + n$ tickets to the neighboring gateway nodes in the forwarding zone that are closer to the geocast region than the source. A gateway node that receives X ticketsfollowsthesameprocedureastheonedefinedforthesource.ConsidertheexampleinFigure3.15where node S begins with five (2+3) tickets. Node S may distribute two tickets to its neighboring nodes A and B, and one ticket to its neighbor node C, which are closer to the geocast region than node S. It is not mentioned in [Liao2000], however, why node C is given fewer tickets than nodes A and B. We believe the philosophy is that each ticket is responsible for carrying one copy of the geocast packet to the geocast region. Hence, if a node is sent a geocast packet that it has seen before, it does not discard it. For example, if node C decides to give its ticket to node B in Figure 3.15, (i.e., node B receives a geocast packet from node C), node B will rebroadcast the packet. In other words, node B will transmit the geocast packet (at least) two times.

Both the Flooding-Based GeoGRID and the Ticket-Based GeoGRID protocols need an efficient solution for the gateway election. Once this node is elected, it remains the gateway until it moves out of the grid. One problem of this selection process is when another potential gateway roams closer to the physical center of the grid than the currently assigned gateway and cannot be elected as the gateway until the current gateway leaves the grid. To eliminate this possibility, multiple gateways could be



A geocast example for the Ticket-Based GeoGRID protocol allowed to reside in a grid temporally. In this situation, if a gateway hears a packet from another gateway at a location closer to the physical center of its grid, it silently turns itself into a non-gateway node and does not forward any further geocast packets. However, if the grid size is small, or the mobility of the node is low, this problem may not be severe. Another effective way of gateway election is via theconceptof Node Weight [Basagnil999]. For example, we could assign the weight of a node as being inversely proportional to its speed. Flooding-Based GeoGRID and Ticket-Based GeoGRID have obvious advantages over LBM Scheme 1 and LBM Scheme 2, especially in dense networks. The two GeoGRID protocols should offer both higher accuracy and lower delivery cost than LBM and VDG due to the reduced number of transmitted packets.

GeoTORA

The goal of the GeoTORA protocol [Ko2000] is to reduce the overhead of transmitting geocast packets via flooding techniques, while maintaining high accuracy. The unicast routing protocol TORA is used by GeoTORA to transmit geocast packets to a geocast region. As TORA is a distributed routing protocol based on a "link reversal" algorithm, it provides multiple routes to a destination. Despite dynamic link failures, TORA attempts to maintain a destination-oriented directed acyclic graph such that each node can reach the destination. In GeoTORA, a source node essentially performs an *anycast*to any geocast group member (i.e, any node in the geocast region) via TORA. When a node in the geocast region receives the geocast packet, it floods the packet such that the flooding is limited to the geocast region. The accuracy of GeoTORA is high, but not as high as pure flooding or LBM. One reason is only one node in the geocast region receives the geocast packet and if that node is partitioned from other nodes in the geocast region, the accuracyreduces.

Mesh-Based Geocast Routing Protocol

The Mesh-based Geocast Routing (MGR) protocol [Boleng2001] uses a mesh for geocasting in an ad hoc environment in order to provide redundant paths between the source and the group members. Since the group members in a geocast region are in close proximity to each other, it is less costly to provide redundant paths from a source to a geocast region than to provide the redundant paths from a source to a multicast group of nodes that may not be in close proximity of each other. Instead of flooding geocast packets, the MGR Protocol tries to create redundant routes via control packets. First, the protocol floods JOIN-DEMAND packets in a forwarding zone. A JOIN-DEMAND packet is forwarded in the network until it reaches a node in the geocast region. This node unicasts a JOIN-TABLE packet back to the source by following the reverse route of the JOIN-DEMAND packet. Thus, the nodes on the edge of the geocast region become a part of the mesh. Once the first JOINTABLE packet is received by the source, data packets can be sent to the nodes in the geocast region. Figure shows an example of geocast communication via amesh