Ad Hoc Wireless Networks: Architectures and Protocols: Ch. 8.6, Tree-Based Multicast Routing Protocols

C. Siva Ram Murthy, B. S. Manoj
Antti E. J. Hyvärinen

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Abstract

Ad Hoc Wireless Networks are an interesting and developing area in networking. A typical scenario in a wireless, mobile network is the need for a set of participants to communicate information to other participants. Practical examples of such multicast communication include information transmitted in search and rescue missions, military campaigns and many others. Depending on the scenario, mobility, the physical environment and available communication hardware, such environments pose a variety of challenges to the protocols applied for the communication. A widely used family of protocols is the Tree-Based Multicast Routing protocols. This summary describes certain criteria against which such protocols can be measured, describes two types of multicast tree, and aims at presenting a representative set of existing tree-based multicast routing protocols from the literature

1 Basics

Mobile Ad hoc Wireless Networks (MANETs) comprise a challenging and practically interesting field. Applications include search and rescue mission coordination, military campaigns and law enforcement, where setting up the infrastructure is impractical. Many civilian applications, such as classroom and conference communication profits from ad hoc building of infrastructure also.

Requirements for such environments vary depending on the application, but usually includes certain Quality of Service requirements. This is especially true for military and multimedia applications. However, almost all MANETs have in common that group communication is in more central role than point-to-point communication. As a result, the research on multicast protocols in MANETs has recently become a lively field and several protocols have been proposed with diverse properties fitting different application needs (see, for example, [6]).

In multicast, the aim is to concurrently send the same message from one source to several destination. Traditional multicast protocols are designed for use in fixed networks. However, such protocols do not in general perform well in mobile networks, where the proximity of communicating nodes changes dynamically with time. As a result, multicast protocols for MANETs have been proposed.

For robust communication, the mesh-based multicasting [4, 1] enables the use of several distinct routes between a pair of source and a receiver. As a consequence of the redundancy, bandwidth is wasted due to duplicate sending of data packets, resulting in wasted resources. In tree-based multicasting, such as [9, 7, 2, 3, 10], only a single path exists between the source and the receiver. Such an efficient organization of the communicating nodes results in closer to optimum resource usage. However, the node mobility results in the need for restructuring more often the tree topology, resulting in great overhead. A thorough comparison between mesh-based and tree-based multicast protocols is available in [5].

Multicasting can be seen as a single node, called the *source*, sending data to zero or more *receivers*. Constructing such an environment can be initialized by either source-initiated or receiver-initiated method. In the case of multicast trees, the tree can be source-tree multicasting, in which each source has its own tree, or shared-tree multicasting, where a single tree is shared by multiple sources (see Fig. 1). Source-tree multicasting has the advantage of having an even distribution of network traffic among the links, but is not efficient memory-wise, since the nodes might need to maintain large routing tables. Shared-tree multicasting is efficient in case of multiple sources, but might overload certain links making the network slow [6].

Due to the mobility of the nodes, the design of MANETs must include not only the construction and routing of the tree, but also maintaining the tree in dynamic situations. Two extremes have been introduced — the soft state, and the hard state approach. In soft state, the liveness of links and members of the multicast group is periodically polled by *beacons*, making the maintenance *proactive*. In hard state, link statuses are only refreshed in case of failures, resulting in a *reactive* maintenance scheme. Naturally, also hybrid methods exist.

The next section of the summary describes certain representative examples of tree-based multicast protocols in MANETs, and the final section draws certain conclusions of the protocols.

2 Tree-Based Routing Protocols: Examples

2.1 Multicast Routing Protocol Based on Zone Routing

Multicast Zone Routing Protocol (MZRP) [10] associates a zone with every node. Inside the zone, the node knows the topology and can do routing individually. However, the communication directed to nodes outside the zone is done by letting the nodes residing on the border of the zone perform the routing. The source initiates construction of the shared multicast tree in two phases, first constructing the zone and then propagating the tree to other zones. Zone tree is constructed by issuing a TREE-CREATE to all nodes in the zone, to which the nodes willing to join the multicast tree will reply with a TREE-CREATE-ACK. The routing towards nodes outside the zone is done by the source s issuing a TREE-PROPAGATE to all nodes. A node n_b residing on the border of a different zone will have access to communication from node s in the original zone, and a new TREE-CREATE will be issued by n_b in its respective zone, leading to a further connection.

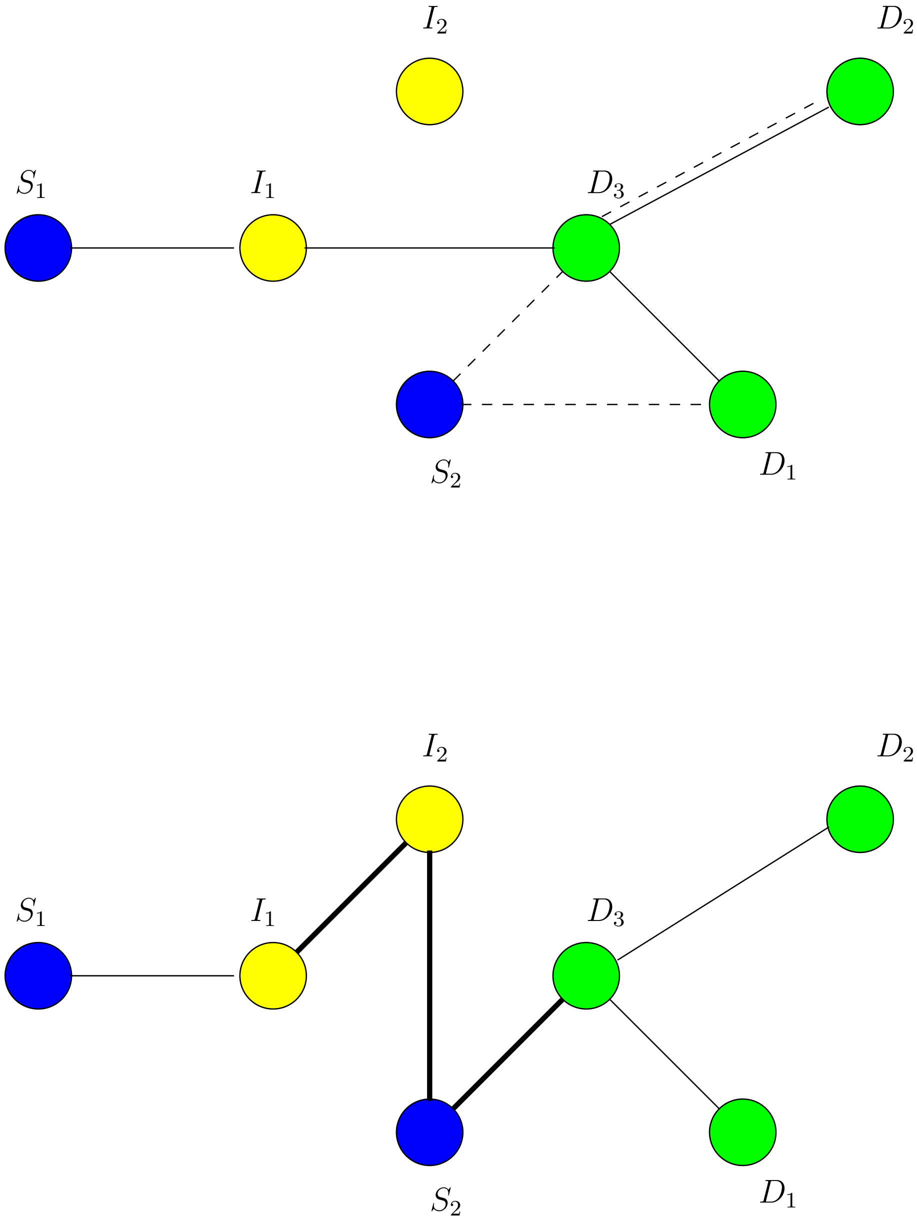

Figure 1: Source-tree based (top) and Shared-tree based (bottom) multicasting

Source maintains the tree in a proactive way by periodically sending a TREE-REFRESH message. If a node in the tree does not receive TREE-REFRESH after a timeout, it removes the stale multicast entry. If a receiver R becomes disconnected from the multicast tree due to a failure in an intermediate node I, R sends a *tree-join* -message to its zone. After connecting the zone, R issues a *join-propagate*, which is handled by the border nodes.

2.2 Multicast Core-Extraction Distributed Ad-Hoc Routing

Multicast Core-Extraction Distributed Ad-Hoc Routing Algorithm (MCEDAR), based on the CEDAR algorithm [8], aims at combining the strengths of mesh-based multicast to tree-based multicasting. It assumes an underlying mesh of core nodes which form a minimum dominating set for all the nodes in the network. The dominating set is constructed by a distributed algorithm with no state information on nodes, and is in practice an approximation of the actual minimum dominating set. Resulting multicast tree is a source-tree with a robust forwarding infrastructure called *mgraph*, the set of core nodes. Each core node has complete knowledge on their neighborhood within three-hop radius, and due to the dominating set, this neighborhood includes at least one other core node. Multicast is based on reliable unicast between the nodes.

A new node n joins the group by initiating a *JoinReq* to its dominator. Each *JoinReq* contains an identity number which is decreased by each hop to avoid forming of routing loops. When the *JoinReq* reaches a tree-node n_t, a *JoinAck* is sent by n_t containing the identity of n_t. The new node n accepts multiple *JoinAck*s depending on the *robustness factor*. The robustness factor corresponds directly to the maximum possible number of redundant links a node is willing to maintain. The node n might become a forwarding node, if there are downstream nodes below it.

The protocol maintains the qualities of the links. Good quality is propagated more seldom than bad quality, leading to more stable link status information.

2.3 Differential Destination Multicast Routing

In Differential Destination Multicast Routing (DDM) [3], the routing information in messages is (partially) maintained in the headers of the data packets. This leads to a memory-efficient routing protocol, with the side effect of possibly higher overhead in each data packet.

The source node manages the multicast group membership, possibly using some authentication mechanism. Destination nodes join the source by unicast messages, and source piggy-backs queries periodically to refresh its list of destinations.

Each node independently decides to operate in stateless mode or soft-state mode. Stateless nodes require the route of the packet to be coded in the data headers. This reduces the need for complicated routing, but creates a high overhead in large networks. In soft-state mode, every node has the option of caching the routing information. As a result, the protocol needs not to list all destinations in every data packet. Only when the routes change, upstream nodes send a *difference* to the destinations, hence the name. This has been shown to significantly reduce the overhead of the stateless mode.

2.4 Weight-Based Multicast

In Weight-Based Multicast (WBM) [2], a destination R joining the multicast tree aims at minimizing the cost of the route to the source S by considering not only the distance from R to S, but also the number of new intermediate nodes required to build the route.

A destination wishing to join the multicast floods the network with *JoinReq* having a certain time-to-live. Each node residing in the multicast tree responds with their respective distance from the source, which is increased by each hop to the node R. The joining node R will collect several of these responses corresponding to alternate routes to the source, and then find the minimal value for the cost function

$$Q = (1 - joinWeight) \times (n_h - 1) + joinWeight \times (n_h + n_s).$$

In the function, n_h is the hop distance from joining node to tree node, n_s is the hop distance from tree node to the source, and $joinWeight$ is a constant between zero and one, depending on the cost characteristics of the network.

Efficient maintenance of the tree is performed by predicting link failures. All neighboring nodes N listen the communication in *promiscuous mode*, where the communication between two nodes is heard by these third parties. If a node R submits a packet piggy-backed with a *TriggerHandoff*, the neighbor N has information about the multicast tree and the distance from the tree is less from N than the from the upstream node of R, the node N sends a *HandoffConf* to the node R requesting the handoff. After receiving possibly several *HandoffConf*s from neighbors, node R selects the best according to the closeness to the tree. In case the handoff fails, R needs to re-initiate the joining as described previously.

2.5 Preferred Link-Based Multicast Protocol

Preferred Link Based Multicast Protocol [7] is a receiver-initiated protocol with a separate local routing maintained in a *Neighbor-Neighbor Table* (NNT) and a *Connect Table* (CT). The NNT contains every neighbor of the node up to two steps, whereas CT contains information about the multicast tree. The information in NNT is used for quick recovery from broken links.

Each node periodically transmits a beacon which is used in other nodes to update NNT. Thus, a node willing to join the multicast will be aware of any tree nodes in its neighborhood, and no flooding is required for a node to join the tree in case the neighborhood contains a tree node. Otherwise, the neighborhood not containing any tree nodes are checked by PLBA [7] algorithm for *eligibility* for forwarding data to the tree. All nodes in the neighborhood will hear the flooding, but only those which are marked eligible in the flood packet will forward the message. This results possibly in several good quality responses from nodes connected to the tree, from which the joining node may choose the most prominent.

2.6 Ad-Hoc Multicast Routing Protocol

Ad-Hoc Multicast Routing Protocol [9] is based on logical, dynamically changing core of nodes. The protocol will use the logical core nodes for routing. Each core will construct a virtual IP tunnel above the underlying network.

A node willing to join the network will declare itself as a core node in a single-node network. Nearby cores will notice this by multiple tree creation messages. This will initiate a distributed core-selection algorithm which yields a single core to the segment. Due to link failures and node movement, the network will eventually be split into several partitions. In a partition without a core node, one of the nodes will after a random time period declare itself as a core and start expanding the network again.

3 Conclusions

Multicasting is possibly the most important requirement for any MANET. This summary discusses six different tree-based multicast protocols for MANET. The protocols vary from source-initiated to destination-initiated, stateless to soft-state to hard-state, source-tree based to shared-tree based, and should give a fairly representative discussion on different types of protocols. Although the summary also mentions certain mesh-based protocols, these are not as extensively covered.

Most routing protocols utilize the local state information for local routing and delegate routing to far distances to further nodes or the nodes belonging to the multicast tree.

Most results on the performance of the protocols are achieved by simulation, and it is unclear how the protocols will be usable in actual MANET environments.

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