Multicast Routing Considering Reliability And Network Load In Wireless Ad-Hoc Network

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Abstract

Several multicast protocols have been newly proposed to perform multicast in wireless ad hoc networks. Tree based multicasting is fragile and requires frequent control to maintain multicast tree. Mesh based multicasting is reliable but increases network load by flooding through mesh.

In this paper, we propose a hybrid structure of tree and mesh for multicasting in wireless ad hoc network. We assume that the system can predict the connection holding time between each upstream and downstream node by using the location and mobility information provided by GPS (Global Positioning System). The proposed scheme is more reliable than tree based scheme and reduces network load.

1. Introduction

A mobile ad-hoc network is a multi-hop wireless network in which mobile hosts communicate over a shared, limited radio channel. In general cellular networks, there are a number of centralized entities, such as BS (Base Station), MSC (Mobile Switching Center), HLR (Home Location Registry) and so on. These centralized entities perform the function of coordination. But a mobile ad-hoc network is characterized by the lack of a wired backbone or centralized entities.

Nodes in this network move arbitrarily, thus network topology changes frequently and unpredictably. Moreover, bandwidth and battery power are limited. These constraints, in combination with the dynamic network topology make routing and multicasting in ad hoc networks extremely challenging.

In an ad hoc network environment, mobile nodes work in groups to carry out a given task. Thus, multicast plays an important role in ad hoc networks [3]. Multicast protocols in the existing fixed networks (e.g. Distance Vector Multicast Routing Protocol (DVMRP) [4], Multicast Open Shortest Path First (MOSPF) [5], Core Based Trees (CBT) [6], and Protocol Independent Multicast (PIM) [7]) are not directly applicable for ad hoc networks because multicast trees are fragile and must be reconfigured as network topology changes.

Several multicast protocols have been newly proposed to perform multicast in wireless ad hoc networks. Adhoc Multicast Routing (AMRoute) [8] is a tree based multicast protocol. It creates a bi-directional shared multicast tree using unicast tunnels to provide connections between multicast group members. On-Demand Multicast Routing Protocol (ODMRP) [9] creates a mesh of nodes (the "forwarding group") which forward multicast packets via flooding (within the mesh), thus providing path redundancy. Tree based multicasting is fragile and requires frequent control to maintain multicast tree. Mesh based multicasting is reliable but increases network load by flooding through mesh.

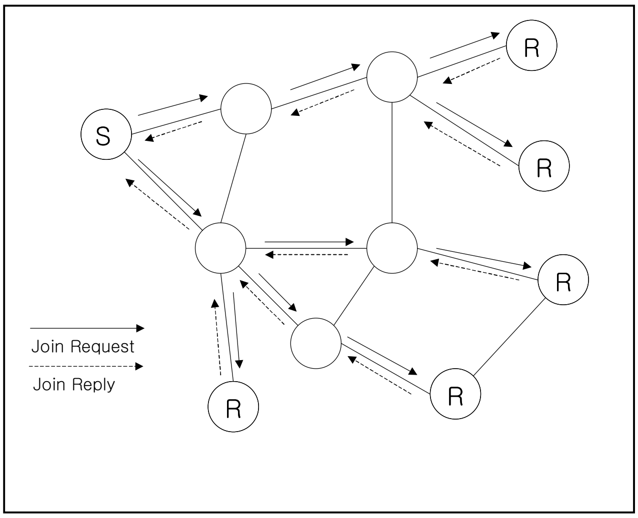

Figure 1. On-demand process for multicast group management

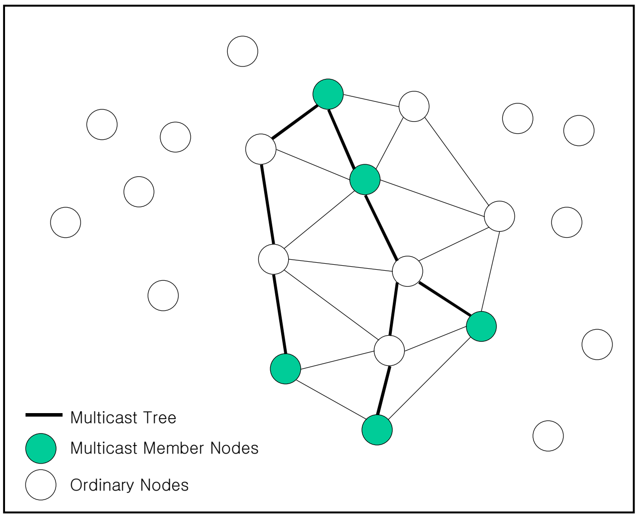

Figure 2. Multicast tree by tree based scheme

Thus, in this paper, we propose a hybrid structure of tree and mesh for multicasting in wireless ad hoc network. We assume that the system can predict the link holding time between each upstream and downstream node by using the location and mobility parameters provided by GPS (Global Positioning System) [11]. Then we can determine which link on the multicast tree is more fragile. This information is used to construct our hybrid structure.

The remainder of this paper is organized as follows. In Section 2 existing multicast routing schemes are examined and a hybrid structure is proposed. Section 3 follows with simulation results and concluding remarks are made in Section 4.

2. Hybrid Multicast Routing Scheme

2.1. Tree and Mesh Based Schemes

In this section, we focus on the on-demand multicast routing protocol. In general, on-demand multicast protocol consists of a query phase and a reply phase as in Figure 1.

To manage the multicast group and update the routes, multicast source periodically broadcasts JOIN REQUEST packet through the network. When a mobile receives a JOIN REQUEST, it stores the upstream mobile id in its routing table and rebroadcasts the packet. When a multicast receiver receives the JOIN REQUEST packet, it sends JOIN REPLY packet to the multicast source.

Tree based protocol constructs the multicast tree as in Figure 2. Tree based multicasting is fragile and requires frequent control to maintain multicast tree. But the number of nodes to forward multicast packet is smaller than mesh based multicasting. Thus network load is relatively low.

Figure 3 shows an example of a mesh which mesh based protocol constructs. The mesh is a set of nodes which is in charge of forwarding multicast packets. All nodes inside mesh forward multicast data packets. The mesh provides richer connectivity among multicast members compared with trees.

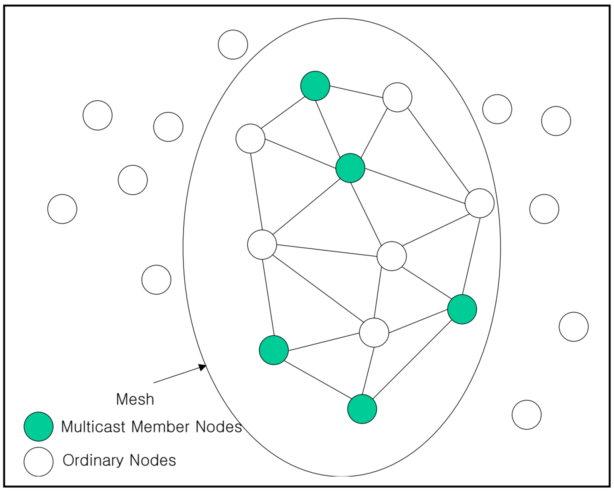

Figure 3. Multicast mesh by mesh based scheme

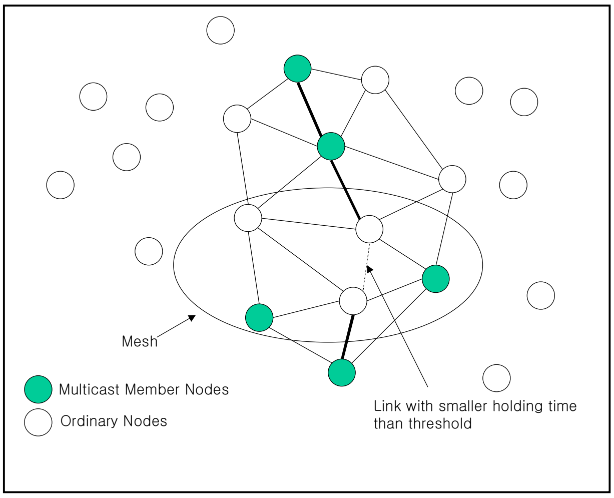

Figure 4. An example of hybrid structure

Hence, unlike trees, meshes do not require frequent reconfigurations. However, the number of nodes to forward multicast packet is lager than tree-based multicasting. Thus network load is relatively high.

2.2. Link Holding Time Prediction Method

By assuming a free-space where the received signal strength of a mobile solely depends on its distance to other mobile, the link holding time between two mobiles can be determined with mobility parameters such as speed, direction, and transmission range [11].

If we know the mobility parameters of two nodes (such as speed, direction, transmission range) by using GPS, we can determine the link holding time two nodes will stay connected. Assume two nodes i and j are within the transmission range r of each other. Let (x_i, y_i) be the coordinate of mobile host i and (x_j, y_j) be that of mobile host j. Also let v_i and v_j be the speeds, and θ_i and θ_j ($0 \le \theta_i, \theta_j \le 2\pi$) be the moving directions of i and j, respectively.

Then D_t, the amount of time that they will remain connected satisfies the following equation

$$D_t = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2}$$

where

a = $v_i cos\theta_i$ - $v_j cos\theta_j$,

b = $x_i - x_j$

c = $v_i sin\theta_i$ - $v_j sin\theta_j$, and

d = $y_i - y_j$.

By using information field of JOIN REQUEST and JOIN REPLY packets, the system can utilize the information to predict the link holding time. Hence the system can predict the link holding time between each upstream and downstream node.

2.3. Hybrid Multicast Routing Scheme

By using above prediction method, the system can determine which link on the multicast tree is more fragile.

In our proposed scheme, by defining α, a threshold of connection holding time, a least delay multicast tree through the network can be constructed by selecting links whose connection holding time is longer than α. Then, we construct the mesh between two end nodes of the selected link having smaller holding time than α. Figure 4 shows an example of hybrid structure.

JOIN REQUEST includes threshold, α in the information field. Thus all nodes that receive the JOIN

REQUEST recognize the threshold, α of the corresponding multicast group.

In hybrid scheme, the multicast packet is delivered through the tree and flooded in the mesh to support reliable forwarding. The proposed scheme is more reliable than tree based scheme. It also reduces network load compared to the mesh based scheme. As α increases, multicasting becomes more reliable and network load becomes higher.

3. Simulation Results

In this section, we analyze the performance of the proposed scheme with simulation. Test is performed with network consisting of 50 mobile nodes, whose initial positions are chosen from a uniform random distribution over an area of 100m by 100m. All nodes move at a constant speed, v, with an initial direction, θ, which is uniformly distributed over 0 and 2π. Direction is measured as an angle relative to the x-axis.

The simulation of the proposed scheme is based on the assumption that the network topology remains constant over the duration of a route discovery. We also assume that any packet can be received, error-free, within a radius of transmission range r.

In Figure 5, tree based scheme and hybrid scheme have a smaller number of hops for multicasting than mesh based scheme. It indicates tree based and hybrid scheme reduce the network load rather than mesh based scheme.

Figure 6 shows that the packet delivery ratio of proposed scheme is similar to the mesh based scheme as the mobile speed increases. The hybrid structure results in 20-30% better packet delivery than the tree based structure.

According to simulation results, we can conclude that hybrid scheme is very robust and has better performance than other schemes.

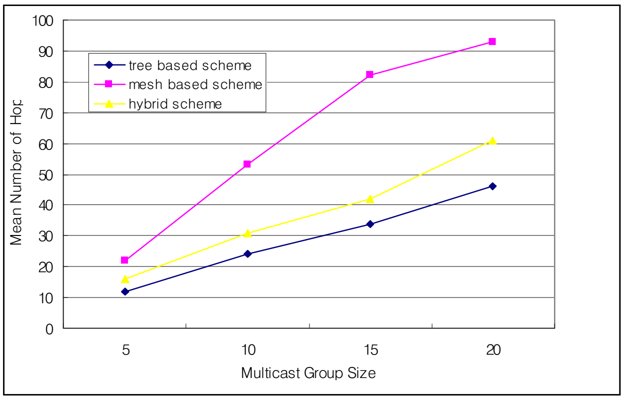

Figure 5. Mean number of hops vs. Number of multicast group size

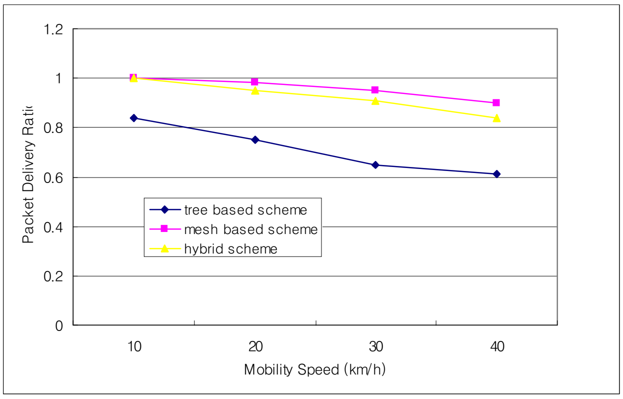

Figure 6. Packet delivery ratio vs. Mobility Speed

4. Conclusion

In this paper, we propose a hybrid structure of tree and mesh for multicasting in wireless ad-hoc network.

To construct a hybrid structure, we define a threshold of connection holding time. A least delay multicast tree through the network is constructed by selecting links whose connection holding time is longer than the threshold. Then we construct a mesh by including two end nodes of each selected link having smaller holding time than the threshold. Multicast packets are delivered through the hybrid structure.

We evaluate the performance of the proposed scheme by using simulations. Simulation results show that the proposed scheme outperforms the tree based multicasting and the mesh based multicasting. As α increases, multicasting becomes more reliable and network load becomes higher.

In the future, more research is needed to support QoS based multicast.

References

[1] Internet Engineering Task Force (IETF) Mobile Ad Hoc Networks (MANET) Working Group Charter. http://www.ietf.org/charters.html/manet-charter.html

[2] J. Jubin and J. D. Tornow, “The DARPA Packet Radio Network Protocols,” *Proceedings of the IEEE*, vol. 75, no. 1, Jan. 1987, pp. 21-32.

[3] S. H. Bae, S. J. Lee, W. Su, and M. Gerla, “The Design, Implementation, and Performance Evaluation of the On-Demand Multicast Routing Protocol in Multihop Wireless Networks,” *IEEE Network*, Jan. 2000, pp. 70-77.

[4] S. E. Deering and D. R. Cheriton, “Multicast Routing in Datagram Internetworks and Extended LANs,” *ACM Trans. Comp. Sys.*, vol. 8, no. 2, May 1990, pp 85-110.

[5] J. May, “Multicast Routing Extensions for OSPF,” *Commun. ACM*, vol. 37, no. 8, Aug. 1994, pp. 61-66, 114.

[6] T. Ballardie, P. Francis, and J. Crowcroft, “Core Based Trees (CBT) – An Architecture for Scalable Inter-Domain Multicast Routing,” *Proc. ACM SIGCOMM ’93, San Francisco, CA*, Oct. 1993, pp. 85-95.

[7] S. Deering et al., “The PIM Architecture for Wide-Area Multicast Routing Protocol,” *IEEE/ACM Trans. Net.*, vol. 4, no. 2, Apr. 1996, pp. 153-162.

[8] E. Bommaiah, M. Liu, A. McAuley, and R. Talpade, “AMRoute: Ad-hoc Multicast Routing Protocol,” Internet-draft, draft-talpade-manet-amroute-00.txt, Aug. 1998, Work in progress.

[9] S. J. Lee, M. Gerla, and C. C. Chiang, “On-Demand Multicast Routing,” *Proc. IEEE WCNC ’99, New Orleans, LA*, Sept. 1999, pp. 1298-1302.

[10] T. S. Rapparport, *Wirless Communications: Principles and Practice, Prentice Hall*, Upper Saddle River, NJ, Oct. 1995.

[11] W. Su and M. Gerla, “Ipv6 Flow Handoff in Ad Hoc Wireless Networks Using Mobility Prediction,” *GLOBECOM*, 1999, pp. 271-275.