Improving the Performance of Broadcasting in Ad Hoc Wireless Networks

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Abstract

Broadcasting is an often seen operation in wireless network environment. In an ad hoc wireless network, because of the mobility of each host, it is not an easy job for every mobile host to receive the broadcast message. Applications such as current time synchronization, paging, finding the route to particular destination, etc., all need to broadcast frequently. A simple broadcasting strategy is flooding. However, flooding leads to many redundant broadcasts and makes poor utilization of bandwidth. In this paper, we try to improve the performance of broadcasting in an ad hoc wireless network. We propose several methods to reduce the redundancy of rebroadcasting the same message and increase the reachability.

1. Introduction

Currently the wireless networks are very popular around the whole world. The environments for the wireless networks will be more mature in the future. Everyone can have a portable device and transfer messages to each other at any time and place.

Although the development of the wireless networks is very impressive, it still cannot satisfy all the users' requirements. For example, the bandwidth is not enough for multimedia applications. However, it has an important advantage over the wired networks. The wired networks may not be deployable in the required time frame, such as in a natural disaster or in battlefields. During 921 Taiwan Earthquake in 1999, the fixed base stations around the earthquake area are all damaged. The transmission of messages between disaster areas is broken down. The disruption in communication hindered the rescue effort and broadened the scope of damages. Similarly, if we can be informed of a car accident in the road ahead, we can have a detour to avoid the possible traffic jam. To communicate in this kind of situation, an ad hoc wireless network is a good candidate. An ad hoc wireless network is a collection of wireless mobile hosts forming a temporary network without the aid of any centralized administration or standard support services [1]. It is a multi-hop wireless network in which mobile hosts communicate over a shared, scarce wireless channel [2]. Each host in the ad hoc wireless network is responsible for transferring, receiving, and if necessary, routing the messages.

The ad hoc wireless network lacks a wired backbone to maintain routes as hosts move, turn off, or turn on. We can only communicate through sending the route request message to find the path to the destination host. Since routes change quickly not only because end nodes move but also because intermediate nodes move, ad-hoc routing algorithms must react quickly to topology changes. The routing algorithm for an ad hoc network must also have low message overhead to avoid wasting the limited bandwidth [3].

If we want to find a route to a particular host or to page a particular host, broadcasting is an important operation. The traditional method of broadcasting is flooding. It is always very costly and results in serious redundancy. The difficulty to do broadcasting operation in ad hoc wireless networks is caused by its intrinsic property such as lack of central controller, mobility of users, lack of bandwidth, and so on. Assume that mobile hosts share a common channel to transfer messages and there is no collision detection action taken. Due to the mobility of hosts, broadcasting is very expensive and difficult to achieve full coverage.

Define the reachability as the percentage of total nodes that can receive the message. The most reliable method for broadcasting is flooding and its reachability is usually one hundred percent. However, it has many problems. The main problem is messages redundancies. This will waste the limited bandwidth in the wireless environment. Since the radio propagation is omnidirectional and the hosts are within different distance with respect to one another, many rebroadcasts are considered to be redundant and heavy contention could exist between hosts.

Another kind of broadcast scheduling in ad hoc wireless network relies on TDMA (Time Division Multiple Access) and a part of network topology information. It is interesting in how to schedule the use of time slots to avoid collision between hosts. The goal is to assign a contention-free time slot to each radio station.

To save bandwidth, the number of the rebroadcasts needs to be limited. There are several schemes [4] to improve the result of flooding, probabilistic, counter-based, distance-based, location-based, and cluster-based. Our scheme is similar to the location-based scheme. We refine it to get better control

0-7695-1153-8/01 $10.00 © 2001 IEEE

of broadcasting in ad hoc wireless networks.

Sun et al. studied the method of GPS-based message broadcasting for inter-vehicle communication (IVC) [5]. It can be regarded as a type of ad hoc network, although significantly different. The hosts in traditional ad hoc networks move slower than those in IVC. This implies that the links between vehicles can be unstable in the road. They classify the vehicles into different types and distinguish the links between them to avoid link failure. The purpose is to reduce the number of rebroadcasts of the nodes. However, they focus on the improvement of bandwidth utilization with slight sacrifice of reachability.

In this paper, we study the broadcast problem in ad hoc wireless networks. If the density of the hosts in the networks is high, flooding the message between hosts will have enormous redundancy and waste limited bandwidth. If the number of unnecessary rebroadcastings can be reduced, we can save scarce bandwidth. Since flooding in an ad hoc network is not a good choice, we provide a better method to solve the broadcast communication problem between the mobile hosts.

We present four algorithms to determine whether a message has to be rebroadcast after a host received it. It combines the idea of the location-based transferring scheme and the broadcasting for inter-vehicle communications. Each host also uses GPS system to collect the position and time information. Also assume each host knows its moving velocity and moving direction. These data will help each host to know the location, direction and velocity of the neighbors. It uses the information to predict the movement of the neighbors and to decide whether to rebroadcast or not. The advantage is that we do not have to broadcast a location message periodically or build a table of topologies for the whole network. We can save the bandwidth and reduce the number of rebroadcasts to achieve an efficient broadcast in ad hoc wireless networks. The goal of efficient broadcasting is to reduce the number of rebroadcasts and maintain a certain level of reachability for most applications in ad hoc wireless networks.

The remainder of this paper is organized as follows. Preliminary material is described in Section 2. Our algorithms are described in Section 3. Simulation results are presented in Section 4 and conclusions are drawn in Section 5.

2. Previous Schemes

here are many methods to solve the rebroadcast problem in ad hoc wireless networks. We discuss several of them in the following [4].

Probabilistic scheme: If a host receives a message for the first time, it will rebroadcast the message with a probability *P*. When *P*=1, the scheme is equivalent to flooding. The scheme is suitable for dense networks. If we want to make the reachability performance in a sparse network better, we have to increase the value of probability. The number of rebroadcast will increase and the redundancy problem will get worse.

Counter-based scheme: When the medium is busy and the queued messages are many, there is a chance that the host has received the same message many times before the host really starts rebroadcasting the message. The host keeps track of the number of times the same message is received. If it is larger than a threshold, the rebroadcast is inhibited. Experimental results [4] show the average delay is less than the probabilistic scheme. The reachability is also better than the probabilistic scheme.

Distance-based scheme: It is similar to counter-based, but it uses the distance to be the stop criterion. A host checks the distance of the nearest host that transferred the same message. If this distance is smaller than a threshold ***D***, the rebroadcast transmission is cancelled. Its reachability is higher than the counter-based scheme but the average delay is worse.

Location-based scheme: It uses the GPS (Global Positioning System) to get precise location of each node. The location information was also used to facilitate the route discovery process in ad hoc wireless networks [14]. The host gets the location information of hosts that sends the messages and uses it to determine whether the host rebroadcasts the message or not. The main obstacle of this scheme is the cost of computing, which is related to calculating many intersection among several circles.

Cluster-based scheme: This approach is based on graph modeling. It assumed a host must periodically send packets to advertise its presence. Each host has a unique ID and can determine which connection to other host it wants. All hosts in the ad hoc network are classified into many clusters. Each cluster has many hosts as members. Each member can communicate to other members and communicate to other hosts in different clusters through a host called gateway. The advantage of this scheme is that there is no need for non-gateway member to rebroadcast the message. The reachability is not good, but the average delay is the smallest.

In this paper, we want to reduce the number of rebroadcasts such that the limited bandwidth is used more efficiently and the level of reachability is good.

3 Proposed Algorithm

3.1 Basic Ideas

If we know the speed and direction of movements of our neighbors, it is easy to determine whether to rebroadcast a received message or not.

Assume that the transmission range (i.e., the range that the radio wave of a host can reach and be correctly deciphered) of each host is the same. In Fig. 1, the circles *Ca* and *Cb* denote the transmission range of host *a* and host *b*. If a message *m* is sent from host *a* to host *b*, define the extra coverage area ***ECA:b(m)*** of *m* by *b* to be the shaded area in Fig. 2. Further assume that host *b* has *x* neighbors. Among the *x* neighbors, *y* of them ($y \leqq x$) lie in ***ECA:b(m)***. Define the exposure ratio ***ER:b(m)*** to be *y*/*x*. We can use the extra coverage area of *m* by *b* and the exposure ratio to determine whether *b* should rebroadcast message *m* or not. If the extra coverage area or the exposure ratio is large, probably we should rebroadcast. Otherwise, it may not be worth it.

3.2 Data Structure

After receiving a message, a host must decide whether to rebroadcast or not. A message includes the data itself, sender's ID, current *x* and *y* coordinates, direction and speed of movement, and current time. Assume the location and time information is obtained from the global positional system. The received neighbor information is stored into the following neighbor table.

In this table, **nodeID** is the neighbor's ID, ***x*** is the value of neighbor's *x* coordinate, ***y*** is the value of neighbor's *y* coordinate, ***speed*** and ***direction*** are the moving speed and direction of nodeID, ***time*** is the time when this message was sent. Assume that each host has different velocity and direction of movement.

3.3 Algorithms

We describe four algorithms in this section. All algorithms begin by sending a request message to announce its existence to all neighbors (hosts that can hear this message). Neighbors do not rebroadcast this request message. The first method, *Location*, is that when a host *N* wants to rebroadcast a message *M*, it checks that if the *ECA:N(M)* is larger than threshold Threshold_ECA. *Ratio* method is that when a host *N* wants to rebroadcast a message *M*, it checks if *ER:N(M)* is larger than threshold Threshold_ER. *Location_or_Ratio* method rebroadcasts if either one of the conditions holds, i.e., either *ECA:N(M)>Threshold_ECA* or *ER:N(M)>Threshold_ER*. *Ratio_and_Request* will announce one's identity when there are no activities. Each node has a **quiet_time** timer. If a host does not receive any message during a quiet_time, it will send a request message such that other hosts can learn its existence.

Algorithm Location_Broadcast_Handling

```
/* Assume the ID of this node is N */
Send a request message to announce one's existence to
all neighbors. /* The content should include one's ID,
current x and y coordinates, direction and speed of
movement, and current time. */
While (True) {
   Wait_for_event(&event);
   Switch (event) {
     Case (want to broadcast a new message);
          Send this message out; /* Besides the
          message itself, the content should include
          one's ID, current x and y coordinates,
          direction and speed of movement, and
          current time. */
     Case (a message M arrived);
          Calculate ECA:N(M);
          If (ECA:N(M)>Threshold_ECA) {
             Send M out along with one's ID, current
             x and y coordinates, direction and speed
             of movement, and current time; }
       Default; Break;} /* end of switch */
   } /* end of while */
```

Algorithm Ratio_Broadcast_Handling

```
/* Assume the ID of this node is N */
Send a request message to announce one's existence to
all neighbors. /* The content should include one's ID,
current x and y coordinates, direction and speed of
movement, and current time. */
While (True) {
   Wait_for_event(&event);
   Switch (event) {
     Case (want to broadcast a new message);
          Send this message out; /* Besides the
          message itself, the content should include
          one's ID, current x and y coordinates,
          direction and speed of movement, and
          current time. */
     Case (a message M arrived);
          Calculate ER:N(M);
          If (ER:N(M)>Threshold_ER) {
             Send M out along with one's ID, current
             x and y coordinates, direction and speed
             of movement, and current time; }
       Default; Break;} /* end of switch */
   } /* end of while */
```

Algorithm Location_or_Ratio_Broadcast_Handling

```
/* Assume the ID of this node is N */
Send a request message to announce one's existence to
all neighbors. /* The content should include one's ID,
current x and y coordinates, direction and speed of
movement, and current time. */
While (True) {
   Wait_for_event(&event);
   Switch (event) {
     Case (want to broadcast a new message);
          Send this message out; /* Besides the
          message itself, the content should include
          one's ID, current x and y coordinates,
          direction and speed of movement, and
          current time. */
     Case (a message M arrived);
          Calculate ECA:N(M);
```

```
            Calculate ER:N(M);
            If (ECA:N(M)>Threshold_ECA) or
(ER:N(M)>Threshold_ER) {
                Send M out along with one's ID, current
                x and y coordinates, direction and speed
                of movement, and current time; }
        Default; Break;} /* end of switch */
    } /* end of while */
```

Algorithm Ratio_and_Request_Broadcast_Handling

```
/* Assume the ID of this node is N */
Send a request message to announce one's existence to
all neighbors. /* The content should include one's ID,
current x and y coordinates, direction and speed of
movement, and current time. */
While (True) {
    Wait_for_event(&event);
    Switch (event) {
      Case (quiet_time times out);
            Send a request message out;
      Case (want to broadcast a new message);
            Send this message out; /* Besides the
            message itself, the content should include
            one's ID, current x and y coordinates,
            direction and speed of movement, and
            current time. */
      Case (a message M arrived);
            Calculate ER:N(M);
            If (ER:N(M)>Threshold_ER) {
                Send M out along with one's ID, current
                x and y coordinates, direction and speed
                of movement, and current time; }
        Default; Break;} /* end of switch */
    } /* end of while */
```

4. Simulation Results

We have developed a simulator using Java language. Assume the transmission range, transmission rate and the numbers of nodes are fixed. We wish to observe the performance and phenomenon between these different broadcasting methods. Our simulation environment is described below. There are 100 hosts in the network, the transmission range is 200 coordinate units, and there are two source hosts for broadcasting. The exposure ratio threshold (***ER***) is 0.3 and the threshold of ***EAC*** is $0.2\pi r^2$, where r is the transmission range (200 coordinate units). There are two cases of host movements. One is fixed velocity and random fixed moving direction. The other is varying velocity and moving direction.

First assuming fixed velocity and random fixed moving direction, we change the size of map to see the effects with four methods. In Fig. 2, we can see that the reachability is decreased when the map size becomes larger. (The density becomes smaller.)

The *location* method and the *location_or_ratio* method have better reachability than *ratio* and *ratio and request*. When the map size becomes larger, we find the *location_or_ratio* method is the best choice.

We then see the results of reducing the number of rebroadcasts of four methods. In Fig. 3, the legend of the y-axis (reduced broadcast) is equal to (the number of rebroadcasts by flooding minus the number of rebroadcasts by the method)/(the number of rebroadcasts by flooding). Intuitively, the value is the larger the better. However, a value of 1.0 means that it does not rebroadcast at all (A possible reason is that the hosts are sparsely placed). It will seriously affect the reachability, as demonstrated in the *ratio* method.

5 Conclusions

Broadcast is a useful and common operation in wireless networks. Flooding may be the simplest to implement. However, it also leads to serious redundancies and waste. In this paper, we provide four methods that have good reachability and reasonable redundancies in rebroadcasting for ad hoc wireless networks. In the future, we hope that we can integrate schemes to develop a good method with good reachability and small number of rebroadcasts.

Acknowledgements

This research is partially supported by ROC NSC under contract number 89-2213-E-259-015 and 89-2219-E-259-005.

References

[1] David B Johnson, Routing in Ad Hoc Network of Mobile Hosts. *Mobile Computing Systems and Applications,* Workshop on, 1995 , Page(s): 158 –163.

[2] Sivakumar, R., Das, B., and Bharghavan, V., The Clade Vertebrata: Spines and Routing in Ad Hoc Networks, *Third IEEE Symposium on Computers and Communications,* 1998, Page(s): 599 –605.

[3] Das, B., and Bharghavan, V., Routing in ad-hoc networks using minimum connected dominating sets, *IEEE International Conference on Communications*, 1997. Montreal, Volume: 1, Page(s): 376 -380, 1997.

[4] Sze-Yao Ni, Yu-Chee Tseng, Yuh-Shyan Chen, and Jang-Ping Sheu, The Broadcast Storm Problem in a Mobile Ad Hoc Network, ACM Wireless Networks (to appear), also in MobiCom' 99, Seattle, Washington, USA.

[5] Min-Te Sun, Wuchi Feng, and Ten H Lai, GPS-Based Message Broadcasting for Inter-vehicle Communication, Technical report, Department of Computer and Information Science, The Ohio State University, Columbus, OH 43210, USA.

[6] National Science Foundation, Research priorities in wireless and ad hoc communications and networking: Report of a workshop held March

24-26, 1997, Airline House, Virginia.

[7] Broch, J., Maltz, D.A., and Johnson, D.B. Supporting hierarchy and heterogeneous interfaces in multi-hop wireless ad hoc networks, *Architectures, Algorithms, and Networks, 1999. (I-SPAN '99). Proceedings*, Fourth International Symposium on, Page(s): 370 –375, 1999.

[8] Basagni, S., Chlamtac, I., and Syrotiuk, V.R., Dynamic source routing for ad hoc networks using the global positioning system, *Wireless Communications and Networking Conference*, 1999. IEEE, Page(s): 301 –305, vol.1, 1999.

[9] Pearlman, M.R. and Haas, Z.J., Determining the optimal configuration for the zone routing protocol, *IEEE Journal on Selected Areas in Communications*, Volume: 17 Page(s): 1395 –1414 8 , Aug. 1999.

[10] Radhakrishnan, S., Racherla, G., Sekharan, C.N., Rao, N.S.V., and Batsell, S.G, DST-A routing protocol for ad hoc networks using distributed spanning trees. *Wireless Communications and Networking Conference,* 1999. WCNC. 1999 IEEE , Page(s): 1543 -1547 vol.3, 1999.

[11] Young-Bae Ko amd Nitin H. Vaidya, Using Location Information to Improve Routing in Ad Hoc Network (A brief note), Department of Computer Science, Texas A&M University, College Station, TX 77843-3112. Technical Report 97-013 1997/12/11.

[12] I.F.Akyildiz, S.M. Joseph, and Y.B. Lin, "Movement-based location update and selective paging for PCS networks," *IEEE/ACM Transactions on Networking*, vol. 4, no. 4, pp. 94-104,1996.

[13] D.Johnson and D.A.Maltz, "Dynamic source routing in ad hoc wireless networks," in *Mobile Computing* (T.Imielinski and H. Kouth, eds.), Kluwere Academic Poblishers, 1994.

[14] S.Basagni, I. Chlamtac, V. R. Syrotiuk, and B. A. Woodward, "A distance routing effect algorithm for mobility (DREAM)," In Proc. *IEEE/ACM Intl. Conf. On Mobile Computing and Networking MOBICOM*, pages 76-84, 1998.

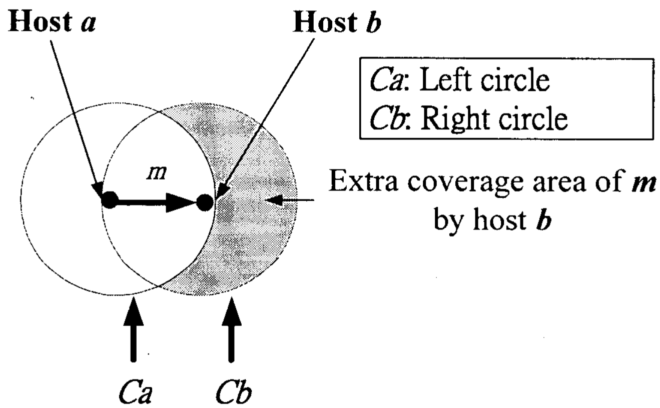

Fig. 1 The extra coverage area.

Table 1. Neighbor Table

nodeID	*x*	*y*	*speed*	direction	*time*

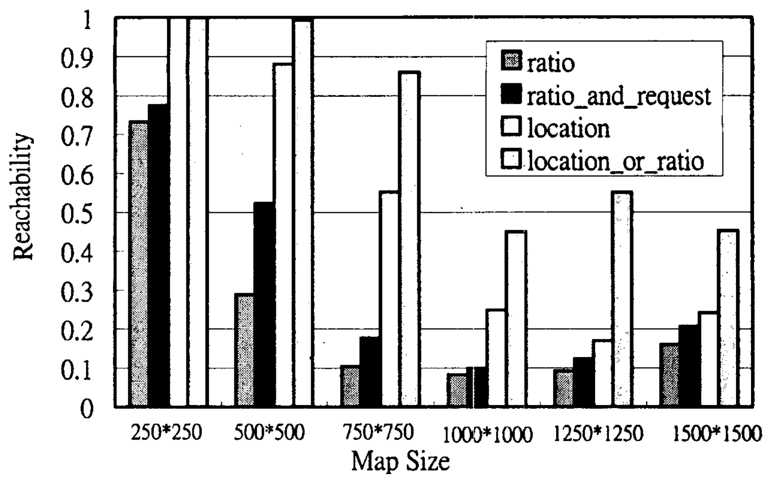

Fig. 2: Comparison of reachability between four methods

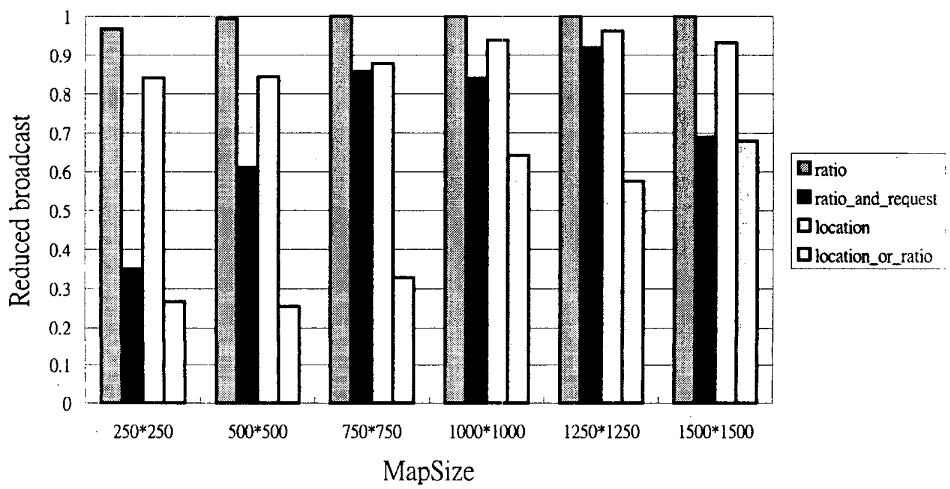

Fig. 3: Comparison of reduced rebroadcasts between four methods