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Distance Based Dynamic Probabilistic Broadcasting in Ad Hoc Wireless Networks

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ABSTRACT

Broadcasting is fundamental and effective data dissemination mechanism for route discovery, address resolution, and many other network services in mobile ad hoc networks. Although many approaches for broadcasting have been proposed to minimize the number of retransmissions, none of them guarantee the best-suited bounds of retransmissions. Appropriate use of probabilistic method can lower the chance of contention and collision among neighboring nodes, so that it reduces the number of rebroadcasts. In this paper, we propose a probabilistic approach that dynamically adjusts the rebroadcasting probability according to the distance between the sender and the receiver. While the rebroadcast probabilities of a mobile node close to sender will be set lower, the rebroadcast probabilities of a mobile node far away from sender will be set to higher, The rebroadcast probability of a node will be set according to the distance from sender. We evaluate the performance of proposed approach by comparing it with flooding as well as a fixed probabilistic broadcast approach. Simulation results showed that the performance of proposed scheme outperforms by about 70% than flooding scheme and outperforms by about 20% than fixed probabilistic scheme.

Keywords: MANET, Ad Hoc Network, broadcasting, probabilistic broadcasting

1. INTRODUCTION

As the results of advances in wireless communication technologies, portable computers with wireless interfaces can communicate among themselves. It is argued that future wireless network will be converged to be more easily reconfigurable situations such as *Mobile Ad hoc network* (MANET). MANET is a special type of wireless mobile network in which mobile hosts can communicate with no aid of any established infrastructure and deployed for many applications such as battlefield, disaster relief and rescue, and so on. Broad- casting is to transmit a message from a source to all the other nodes in the network. It is widely used to resolve many network layer problems. In a MANET in particular, due to host mobility, broadcastings can be applied to many areas, such as paging a particular host, sending an alarm signal, and finding a route to a particular host, etc. Several ad hoc network protocols assume that the broadcasting service is available. For instance, AODV (Ad Hoc On-demand Distance Vector Routing) protocol adopts broadcasting mechanism as a route request in MANET.[1,2]

Many approaches[3-12] are proposed for broadcasting in a MANET. But none of them have been considered as the optimal method for the broadcasting. The simplest one is flooding. Even though flooding is very simple and reliable approach, it produces a high overhead in the network such as contention, collision, and redundant broadcasts. More sophisticated solutions such as probability based, counter based, distance based, location based, and neighbor knowledge based approaches

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have been proposed to overcome the drawbacks of flooding. Probability-based approach is another simple one. It depends upon pre-defined fixed probability to determine whether it rebroadcast the packets or not. One problem of the probabilistic approach is how to set the rebroadcast probability. It is demonstrated that the optimal rebroadcast probability is around 0.65. Intuitively, this value does not seem globally optimal regardless of neighbors' distance or density. For example, the mobile hosts close to sender will have more neighbors whose coverage areas significantly overlap. So, the rebroadcast probability of a node in MANET should be set dynamically according to its circumstances.[4-7]

In this paper, we propose a dynamic probabilistic approach that is based on the distance between sender and receiver to rebroadcast the received packet. The rebroadcast probability of a node is dynamically adjusted by the distance between sender and receiver. If mobile nodes are located in the area close to sender, which means the sender's neighbors have low additional coverage and they can receive a large amount of rebroadcasts from their neighbors, their rebroadcast probabilities will be set lower. On the contrary, if mobile nodes are located in the area far from sender, which means their additional coverage will be larger than the nodes close to sender, their rebroadcast probabilities will be set to higher. We set the rebroadcast probability of a node according to the distance of sender. The distance between sender and receiver can be estimated by signal strength or global positional system (GPS). We compare our approach with simple flooding approach and the general probabilistic approach under various network conditions through simulations. Simulation results show that our approach can improve the average performance of broadcasting in various network scenarios. In particular, they are independent of the number of network nodes and the maximum degree of nodes in the network. Our approach is simple and can be easily implemented in MANET.

The rest of this paper is organized as follows: In Section 2, we introduce the background and related work of broadcasting in MANET. In Section 3, we describe our dynamic probabilistic approach, highlighting the difference in our approach from other similar approaches. We evaluate the approach and present the simulation results in Section 4. Section 5 contains conclusions and directions for future work.

2. RELATED WORK

One of the earliest broadcast mechanisms proposed in the literature is flooding, where every node in the network retransmits a message to its neighbors after receiving it. Although flooding is extremely simple and easy to implement, it can be very costly and can lead to serious problem, named as *broadcast storm problem*, which is characterized by redundant packet retransmission, network bandwidth contention and collision. Ni *et al.* study the flooding protocol analytically and experimentally and show that a rebroadcast can provide only 61% additional coverage and only 41% additional coverage in average over that already covered by the previous transmission. So, rebroadcasts are very costly and should be used with caution.[4,5]

B. Williams and T. Camp classified the broadcasting techniques into four groups and compared their performances: Simple flooding, Probability based, Area based and Neighbor Knowledge scheme. In flooding scheme, every node in the network retransmits the message to its neighbors after receiving it. Probability based scheme is a very simple way of reducing rebroadcasts. Each node rebroadcasts with a predefined probability p, where p=1 activates blind flooding. In Area Based scheme, a node determines whether it rebroadcast a packet or not by calculating its additional coverage area. Although Area based scheme works quite well, it doesn't know if there are any nodes existing in the calculated coverage area. So, some nodes may not receive broadcasting packets. Neighbor

Knowledge scheme maintains neighbor node information to decide whether it or the neighboring nodes have to rebroadcast or not. To use Neighbor Knowledge methods, each node has to explicitly exchange neighborhood information among mobile hosts using periodic Hello packets. The length of the period affects the performance of this scheme: If it is set to short then it could cause collision or contention while setting it too long would degrade its ability to cope with mobility.[5]

Self-pruning is an effective method in reducing broadcast redundancy. Unlike flooding, in self-pruning based broadcast protocols such as [6,7], each node collects neighborhood topology information (i.e., static information) via exchanging "Hello" messages and extracts broadcast history information (i.e., dynamic information) from incoming broadcast packets. Each node decides its role in a specific broadcasting: it becomes either a forwarding node or a non-forwarding node. A node forwards the broadcast packet if the node is forwarding node, where as a node is self-pruned and does nothing if the node is non-forwarding node. Collectively, forward nodes, including the source node, form a Connected Dominating Set (CDS) and ensure the coverage. A set of nodes is a dominating set if every node in the network is either in the set or a neighbor of a node in the set. If the decision is made based on only static information, the corresponding protocol is a static protocol; otherwise, it is a dynamic protocol. Both static and dynamic protocols are localized methods, that is, the decision made on each node does not rely on global network information or any network infrastructures. Although self-pruning does not provide a constant approximation ratio to the optimal solution, it exhibits better average efficiency than pure probabilistic broadcast algorithms.

Although the goal of all the above protocols is to minimize the number of retransmissions, none of them guarantee the best-suited bounds of retransmissions. In general, Neighbor knowledge methods perform better than Area based methods; while Area based methods perform better than Probability based methods. This is due to the complexity and increased overhead of the complex schemes. Our approach combines the advantages of probabilistic and area-based approach, and it has higher throughput, better reachability, and lower latency compared with general probabilistic or area-based approach. Moreover, it is simple enough for easy implementation. We describe the details of our approach in Section 3.

3. DISTANCE BASED DYNAMIC PROBABILISTIC BROADCASTING

In this section we describe our protocol in detail. Probability based methods such as [4,5], and [9] use certain predefined rebroadcast probability p ($0 < p \leq 1$) to decide whether to rebroadcast or not. The biggest problem with these schemes is determining the suitable probability. We propose dynamic probabilistic broadcasting according to the distance between sender and receiver.

3.1. Shadow Effect

As described previous section, the goal of our protocol is to achieve the high reachability of broadcasting and the reduction of rebroadcast. The rebroadcast probabilities P of all mobile nodes are fixed as same value in general probabilistic approach[4, 5, 9]. However, the same threshold value, Pc, in general probabilistic approaches can't reflect the situation of MANETs which topologies are frequently changed. For example, how much sparse or dense a MANET is, or how far from or closer to the sender the rebroadcast nodes which receive the rebroadcast packets are. If these circumstances are not taken into consideration, the value of P might be set too small or large value, and after all, the reachability will be poor or so many rebroadcast packets will be generated. So, the rebroadcast probabilities P need to be adjusted by the circumstances of the node.

We allow each node to choose different probability according to its distance from sender. The distance from node to sender can be calculated from sender's transmission power level or GPS (Global Positioning System). In short, with our protocol, each node examines how far it is from sender and determines its retransmission probability. It is better for the node that is further from sender to have high retransmission probability than to have low probability. It means that a node that is geographically further from sender may potentially act as a relay node for a node that is closer to sender. When a node receives a flooded packet, it refers to its distance from sender to determine its rebroadcast probability. As explained above, if a node is outer node, the node assumes that it has much coverage area, and if a node is inner node, the node assumes that it has small coverage area.

Our scheme is based on the shadowing effect. While the nodes located in the area far away from sender node will act as relays with high retransmission probability, the nodes close to sender node will be shadowed from relays with low retransmission probability. Fig. 1 shows this shadowing effect. For example, in Fig. 1, most of node *N1*'s coverage area will be covered by node *N2*'s coverage area. So, node *N1* can be shadowed from rebroadcasting as relay node. This shadowing effect will reduce the number of rebroadcast packets.

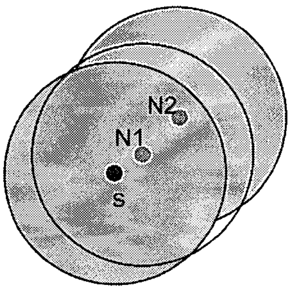

Fig. 1. Shadow effect.

3.2. Distance based Probabilistic Broadcasting

As the coverage area is proportional to the distances from sender, the rebroadcast probability of a node should be considered according to its coverage area. Dynamic probabilistic rebroadcast scheme uses its coverage area to determine its rebroadcast probability.

We propose simple equations defining the relationship between the coverage area and rebroadcast probability to acquire good output. When a node, *d* in Fig. 2, receives a broadcast packet from node *s*, its relative distance can be obtained by comparing the signal strength with maximum signal strength or by using GPS. Then the node *d* has to determine its own rebroadcast probability *P* whether it retransmits the packet or not. Fig. 2 shows how to get the rebroadcast probability that is proportional to the distance from sender. Let *R* be the communication range of a node s, and *C* be the covering area of the node s. *C* can be obtained by the equation: $C = \pi R^2 \cdot C'$ is sub area of *C* with radius *R'*. We can get the rebroadcast probability (*P*) as follows.

$$P = \mu \frac{C'}{C} \qquad (1)$$

where, μ is a sensitivity parameter to control the rebroadcast probability.

Ni *et al.* analyzed the additional coverage of each rebroadcast after receiving *n* copies of the same packet in [4] and [7]. They show, for $n = 1$, the maximum additional coverage is 61% of the original area, and the average additional coverage is 41%. The value decreases dramatically as *n* increases, which means the more copies a node receives, the higher chance that its neighbors have already obtained the same packet, and the more likely that a rebroadcast will be redundant. They showed that many rebroadcasts could be saved when *n* is 3 or 4. So, we define the sensitivity parameter μ as follows: if *n* is less than 4, then 2 is assigned to μ, else 1 is assigned to μ. This approach gives a good approximation in the general distribution of mobile node.

Our distance based probabilistic broadcasting algorithm is depicted in Fig. 3. Each node has a broadcast table (BT), where identifiers are recorded for each broadcast already received. This table is extended with an improvement: for each new entry in BT, a list of the neighbors from the neighbor table (NT) of the receiver is added. Our algorithm is a combination of probabilistic and area-based approaches. It dynamically adjusts the rebroadcast probability P at each mobile host according to the coverage area of a node.

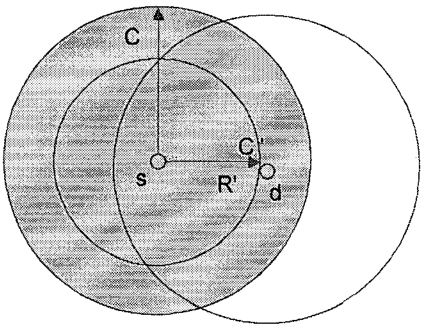

Fig. 2. Model to get rebroadcast probability.

```
Broadcast (P)
Upon receiving a broadcast packet p at node d from node s:
Get the Broadcast ID bid from the packet p
If p is received for the first time
   Then
   Get the coverage areas of C and C'
        If n (count of same packet) < 4
             Then μ = 2
             Else μ = 1
        End If
   Calculate the rebroadcast probability P of packet p
   Rebroadcast p with probability P
   Create an entry BTbid in the Broadcast Table with an expiration
   time.
   Create a list Lbid with all node IDs in the neighbor table.
   Add packet ID to the received packet lis.
End If
```

Fig. 3. Distance based probabilistic broadcasting algorithm,

3.3. Neighbors Confirm

An important problem is how to minimize the number of rebroadcast packets while retransmission latency and packets reachability are maintained appropriately. Even though the large number of rebroadcasts guarantees high reachability, it causes high network bandwidth wastage and so many packets collisions. On the other hand, the small number of rebroadcasts results in low reachability, because it cause rebroadcast chain broken so that some hosts may not receive the broadcast packets.

However, the probabilistic approached presented above may cancel a non-redundant packets retransmission. Fig. 4 shows the bad scattering of mobile node in MANET. In the case of node distribution, early die-out of rebroadcast may happen. When a non-redundant retransmission is dropped in first few steps, the number of unreachable nodes increases fast hop by hop.

To prevent from early die-out of rebroadcast, neighbors confirm scheme is applied. The neighbors confirm scheme is to get high reachability to the last nodes by second retransmission of a packet. For example, N1 in Fig. 4 is located so close to sender that it would have low probability and would not rebroadcast packets. If N1 doesn't send broadcast packet, N6 can't receive it. To avoid the early die-out of rebroadcast, N1 have to wait a given amount of time t, and check if all the neigh

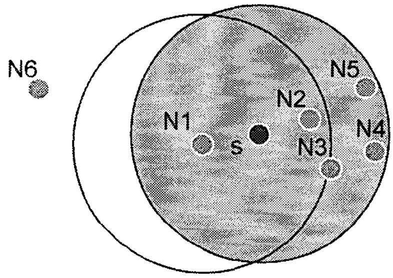

Fig. 4. Bad distribution may cause early die-out of rebroadcast.

bors have received the broadcast packet. If N6 didn't receive the broadcast packet, N1 have to rebroadcast it.

Each node that forwards the broadcast packet includes the list of its neighbors. The receiver can identify which nodes have been covered by checking the neighbor list of the transmitter and comparing with its own neighbor list. Neighbors confirm algorithm is depicted in Fig. 5. Neighbors confirm algorithm is performed by the nodes that do not broadcast a packet according to distance based probabilistic broadcasting algorithm. After a given amount of time *t*, a node checks the list associated with the broadcast entry in BT. If it is not empty, it rebroadcast the broadcast packet.

4. PERFORMANCE EVALUATION

We evaluate the performance of our algorithm by comparing with a simple flooding algorithm and a probabilistic algorithm with fixed rebroadcast probability[4,5].

4.1 Analytic Model

In this section, we analyze our scheme using mathematical method. In flooding[5,7], a mobile node rebroadcasts all routing request packets that are received for the first time. Therefore, there is *N-1* possible rebroadcasts at each node, where *N* is the total number of neighbor nodes. In general probabilistic approach[4,9], each node decides

```
Neighbors_Confirm()
FOR EACH id included in the broadcast packet
   If node id is included in Lbid
      Remove id from Lbid
   End If
End for
If Lbid  is not empty
   Rebroadcast broadcast packet
End if
```

Fig. 5. Neighbors confirm algorithm.

to rebroadcast or not according to a fixed probability *P*. Since their decisions are independent, the total number of rebroadcasts is *P*(N-1)* on average.

In our approach, the rebroadcast probability is dynamically set according to the distance from sender. The probability is set to high for the mobile node that is far from the sender, where as the probability is set to low for the mobile node that is close to the sender. Let *A* be the area of an ad hoc network, *N* be the number of mobile hosts in the network, and *R* be the communication range. Let *a* be the fraction of the area of a mobile host can cover to the whole network area.

$$\alpha = \frac{\pi R^2}{A} \tag{2}$$

The average number of neighbor $N_{neighbor}$ can be obtained by the formula (3).

$$N_{neighbor} = (N-1)\alpha \tag{3}$$

Let p_i be the probability that a mobile host has *i* neighbors, then we can obtain p_i by formula (4).

$$p_i = \binom{N-1}{i} \alpha^{i} (1-\alpha)^{N-1-i} \tag{4}$$

So, the total number of forwarding, N_{FW}, can be calculated by formula (5):

$$N_{FW} = \sum_{i=1}^{N-1} N_{neighbor} P_i p_i \tag{5}$$

where, P_i is forwarding probability for a mobile node *i*.

Each node can obtain its neighbor information by exchanging neighbor number and neighbor list in HELLO message. Another type of control message is routing messages, including route request and route reply. We ignore the route reply messages in this analysis for simplicity. Assume that the data rate is *d* packets per second, and the unavailable route probability is δ. If total simulation time is *T*, the number of route request messages (N_{RQ}) can be obtained by formula (6).

$$N_{RQ} = Td\delta \qquad (6)$$

Then, the total number of forwarded route request messages (N_{FR}) in our protocol can be obtained by formula (7).

$$N_{FR} = N_{FW} N_{RQ} \qquad (7)$$

The main purpose of this paper is to get better performance. Goodput is a key performance metrics. Assume that the data packet size is k bytes, while the control packet size is k_c bytes. Let N_{FR} be the total number of forwarding route request. A rough estimate of theoretical goodput G can be obtained by formula (8).

$$G = \sum_{i=1}^{N-1} \frac{kd}{\frac{kd}{1-p_i} + \frac{N_{FR}k_c}{p_i}} \qquad (8)$$

4.2 Simulation

The objective of this paper is to reduce the rebroadcast number of relay, therefore reduce the network traffic and finally the throughput can be improved. For our simulations we modified Ad hoc network simulator Glomosim[12]. All simulations were performed in a simulation area of 2000m x 2000m, and the number of nodes was varied from 100 to 1000. The radio frequency at the physical layer is 2.4 GHz of the ISM band and the moving speed of mobile node is 20m/sec. The raw network bandwidth is 2Mbps and the MAC layer protocol is IEEE 802.11[4]. Other simulation parameters are shown in Table 1.

Table 1. Simulation parameters

Simulation Parameter	Value
Simulator	GloMoSim (v2.03)
Network Range	1000m ×1000m
Transmission Range	250m
Number of Mobile Nodes	10 - 100
Bandwidth	2Mbps
Traffic Type	CBR (Constant Bit Rate)
Packet Rate	10 packets per second
Packet Size	512 bytes
Simulation Time	900s
Number of Trials	100

We used five kinds of measures to evaluate our scheme, which is rebroadcast number of relay, reachability, collision, broadcast latency and throughput. The number of relay is the number of rebroadcast packets, i.e. rebroadcast number of relay. In flooding, there is *N-1* possible rebroadcasts, where N is the total number of nodes. In our approach, the rebroadcast probability is dynamically set according to the distance from sender. Fig. 6 shows the relationship between the numbers of relay for a network with 10-50 connections of source-destination pairs. In Fig. 6, the saving of relay ranges from 50% to 80% than flooding and from 15% to 30% than generic probabilistic broadcasting. This indicates that our approach substantially reduce the number of rebroadcasts than flooding or generic probabilistic broadcasting.

Flooding approach guarantees that all nodes can receive the broadcast packets, while as some packets would be dropped in probabilistic approach. This means that some broadcast packets may not reach some mobile node. *Reachability* is the mean ratio of recipient nodes to the total number of nodes in the entire network. So, reachability can be derived from the percentage of mobile hosts receiving the broadcast message directly or indirectly divided by the total number of mobile hosts. Fig. 7 shows that there is no significant difference among

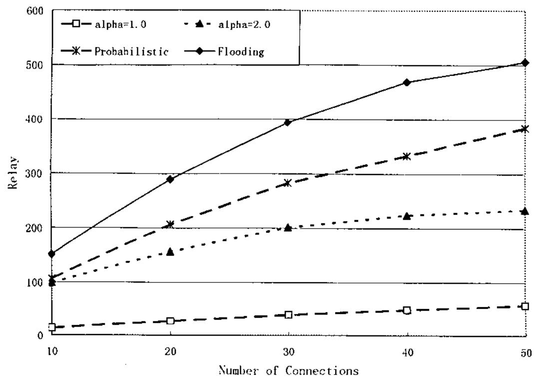

Fig. 6. Number of Relay.

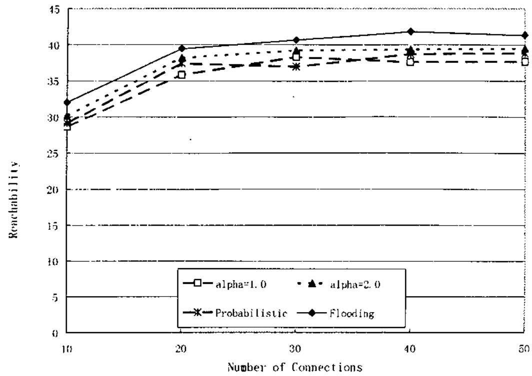

Fig. 7. Reachability.

the reachability of the three approaches. This indicates that our approach can achieve high throughput without sacrificing reachability.

Collision is the number of collision packet that mobile nodes rebroadcast. Consider the scenario where several neighbor nodes hear a broadcast from node x. After hearing broadcast message, they (i.e. neighbor nodes of x) all try to start rebroadcasting at around the same time. Flooding scheme causes enormous collisions. Most broadcast methods obviously aim to reduce the collision. Fig. 8 shows the simulation result for collision. In Fig. 8, we can see that our scheme can reduce the collision packets more than 60 % compared with flooding. Reducing the collision regardless of the reachability would be meaningless, since it would be omitting the original concept of broadcasting. The results show our scheme has good performance without sacrificing high reachability.

Broadcast latency is the traveling time of broadcast packet that starts the sender and reach the last node. For the simulation of the delay, the start times are recorded when source node send broadcast packets as well as the end times are recorded when the broadcast packet reaches the last node. The broadcast delay is defined as the time difference between these two values. Fig. 9 shows the simulation result of delay. In Fig. 9, our scheme shows more delay time than flooding. Our mechanism use neighbors confirm scheme to get high

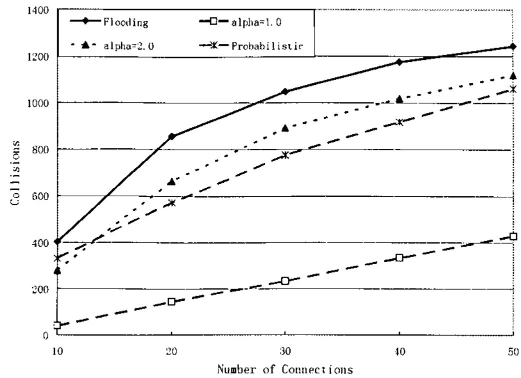

Fig. 8. Collision.

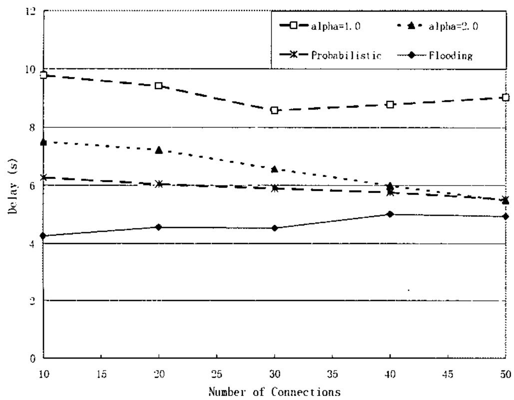

Fig. 9. Delay.

reachability. Neighbors confirm is conducted by the node that doesn't rebroadcast after some random intervals. It is analyzed that these intervals cause the overall delay of broadcast packets in our scheme. To reduce the overall delay of broadcast packets is our further research.

It is important to evaluate the overall throughput of a protocol. We define throughput as the amount of broadcast data (bits) transmitted during a second in MANET. To evaluate the throughput of our scheme, we measured how many data (bits) are transmitted per second. Fig. 10 shows the simulation result of throughput. From our results, we observe that the throughput of our scheme outperforms flooding more than about 70% and outperforms generic probabilistic scheme by 10%-40%.

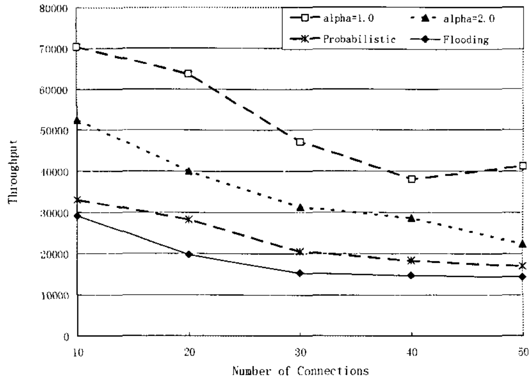

Fig. 10. Throughput.

It is analyzed that these good throughput is the results of decreased rebroadcast node and reduced collision packets in our scheme. Even though the transmission delay of our scheme is larger than flooding, which was described in Fig. 9, our scheme outperforms the deficiency of delay in the aspect of overall throughput.

5. CONCLUSION

An important problem in data broadcasting is how to minimize the number of rebroadcast packets while good retransmission latency and packets reachability are maintained. Even though the large number of rebroadcasts guarantees high reachability, it causes high network bandwidth wastage and so many packets collisions. On the other hand, the small number of rebroadcasts results in low reachability, because it cause rebroadcast chain broken so that some hosts may not receive the broadcast packets.

In this paper we introduced a dynamic probabilistic broadcasting approach with coverage area and neighbors confirm for mobile ad hoc networks. Our scheme combines the probabilistic approach with the distance-based approach. A mobile host can dynamically adjust the value of the rebroadcast probability according to its additional coverage in its neighborhood. Additional coverage is estimated by the distance from sender. Our scheme combines also neighbors confirm concept to prevent early die-out of rebroadcast.

Our simulation results show this approach will generate fewer rebroadcasts than the fixed value probabilistic approach. It also incurs lower broadcast latency than the area-based approach. We plan to build an analytic model for the dynamic probabilistic approach in order to facilitate the exploration for the optimal adaptation strategy. On the base of the analytic model, we can obtain the proper value for using our scheme and predict the network performance for using our approach in a MANET.

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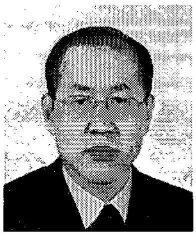

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