

# Improving the Performance of Probabilistic Flooding in MANETs

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## Abstract

*Broadcasting in mobile ad hoc networks has traditionally been based on flooding, which swamps the network with large number of rebroadcast packets in order to reach all network nodes. The appropriate use of probabilistic broadcasting can reduce the number of packet transmission, effectively alleviating the problem of contention. In particular, a good probabilistic broadcast protocol can achieve higher saved rebroadcast and higher reachability. This paper presents a new probabilistic approach that dynamically adjusts the rebroadcasting probability as per the node distribution and node movement. This is done based on locally available information and without requiring any assistance of distance measurements or exact location determination devices. We evaluate the performance of our approach by comparing it with simple flooding as well as a fixed probabilistic approach. The results show that the new algorithm exhibits superior performance in terms of both the reachability and saved rebroadcasts.*

## 1. Introduction

Mobile Ad hoc Networks (MANETs) consist of a set of wireless mobile nodes, which communicate with one another without relying on any pre-existing infrastructure in the network. The distributed, wireless, and self-configuring nature of MANETs make them suitable for a wide variety of applications [2]. These include critical military operations, rescue and law enforcement missions as well as disaster recovery scenarios [1, 2]. Other applications of MANETs are in data acquisition in hostile territories, virtual classrooms, and temporary local area networks.

Broadcasting is a fundamental operation in MANETs whereby a source node transmits a message that is to be disseminated to all the nodes in the network. In the one-to-all model, transmission by each node can reach all nodes that are within its transmission radius, while in the one-to-one model, each transmission is directed toward only one neighbor using narrow beam directional antennas or separate frequencies for each node [8]. Broadcasting has been studied in the literature mainly for the one-to-all model, and most of this study is devoted to

this model. The one-to-many model can also be considered, where fixed or variable angular beam antennas can be used to reach several neighbors at once [6].

Broadcasting has many important uses and several ad hoc network protocols assume the availability of an underlying broadcast service [7, 8]. Applications, which make use of broadcasting, include LAN emulation, paging a particular node, or sending an alarm signal thereby establishing unicast routes in proactive protocols [8]. It can also be used for route discovery in reactive protocols. For instance, a number of MANET routing protocols such as Dynamic Source Routing (DSR), Ad Hoc on Demand Distance Vector (AODV), Zone Routing Protocol (ZRP) ) [11], and Location Aided Routing (LAR), use broadcasting or one of its derivatives to establish routes. Broadcasting also serves as the last resort for other group communication operations such as multicast.

One of the earliest broadcast mechanisms proposed in the literature is simple or “blind” flooding [6] where each node receives and then re-transmits the message to all its neighbours. The only ‘optimisation’ applied to this technique is that nodes remember broadcast messages received and do not act if they receive repeated copies of the same message [11]. However, a straightforward flooding broadcast is usually costly and results in serious redundancy and collisions in the network; such a scenario has often been referred to as the broadcast storm problem [5, 6, 7], and has generated many challenging research issues [5]. A number of researchers have identified this problem by showing how serious it is through analyses and simulations [6].

A probabilistic approach to flooding has been suggested in [8, 9, 10] as a means of reducing redundant rebroadcasts and alleviating the broadcast storm problem. In the probabilistic scheme, when receiving a broadcast message for the first time, a node rebroadcasts the message with a pre-determined probability  $p$ ; every node has the same probability to rebroadcast the message. When the probability is 100%, this scheme reduces to

simple flooding. The studies of [5] have shown that probabilistic broadcasts incur significantly lower overhead compared to blind flooding while maintaining a high degree of propagation for the broadcast messages.

This paper focuses on probabilistic broadcast. One problem of the probabilistic approach is how to set the rebroadcast probability. Current approaches assume a fixed probability. It is demonstrated [7] that the optimal rebroadcast probability is around 0.7. Intuitively, this value is not likely to be globally optimal. For example, in a denser area, each mobile host has more neighbors whose coverage areas significantly overlap. Rebroadcast packets from hosts in a close neighborhood will reach the same subset of hosts many times. To reduce such redundancy, the rebroadcast probability in these areas should be set lower. On the contrary, the probability should be set higher in sparser areas so that a broadcast packet can reach all hosts in the MANET. In this paper, we propose a dynamic probabilistic approach for broadcasting. We set the rebroadcast probability of a host according to the host density in its neighbourhood area. When several hosts move toward each other to form a group, their probabilities are set to be lower. When hosts move away from a dense area, their probabilities are kept higher. We use the information about one-hop neighbors using short HELLO packet to adjust the probability. If the average number of neighbors is high, which means the host is in a dense area so that it can receive a large amount of rebroadcasts from its neighbors, we decrease the probability of this host. Otherwise, we increase the rebroadcast probability. We compare this approach with both the simple flooding approach and the fixed probabilistic approach. Simulation results show this simple adaptation can improve the average performance of broadcasting in various network scenarios.

The rest of this paper is organized as follows: In Section 2, we introduce the related work of broadcasting in MANETs. In Section 3, we describe our dynamic probabilistic approach, highlighting the difference in our approach from other similar approaches, and analyzing the strength and weakness of our approach. In Section 4, we evaluate our approach and present the simulation results. In Section 5, we conclude the paper and offer suggestions for future work.

## 2. Related Work

One of the earliest broadcast mechanisms is flooding, where every node in the network retransmits a message to its neighbours upon receiving it for the first time. Although flooding is very simple and easy to implement, it can be very costly and may lead to a serious problem, often known as the broadcast storm problem [5, 6, 7] that is characterized by high redundant packet retransmissions, network contention and collision. Ni et

al. [4] have studied the flooding protocol analytically and experimentally. Their obtained results have indicated that rebroadcasts could provide at most 61% additional coverage and only 41% additional coverage on average over that already covered by previous transmissions. Therefore, rebroadcasts are very costly and should be used with caution. The authors in [6] have also classified broadcasting schemes into five categories to reduce redundancy, contention, and collision. These categories are probabilistic, counter-based, distance-based, location-based and cluster-based. A brief description for each of these categories is provided in the sequel.

In the probabilistic scheme, a mobile node rebroadcasts packets according to a certain probability. In the counter-based scheme, a node determines whether to rebroadcast a packet or not by counting how many identical packets, it has received during a random delay. The counter-based scheme assumes that the expected additional coverage is so small that rebroadcast would be ineffective when the number of recipient broadcasting packets exceed a certain threshold value.

The distance-based scheme uses the relative distance between a mobile node and previous sender to make a decision as to whether to rebroadcast a packet or not. In the location-based scheme, the additional coverage concept [5] is used to decide whether to rebroadcast a packet. Additional coverage is acquired by the locations of broadcasting nodes using the geographical information of a MANET [4].

The cluster-based scheme divides the MANET into a number of clusters or sub-sets of mobile nodes [1, 2]. Each cluster has one cluster head and several gateways. Cluster head is a representative of the cluster whose rebroadcast can cover all hosts in that cluster. Only gateways can communicate with other clusters and have responsibilities to propagate the broadcast message to other clusters.

An alternative classification for broadcasting techniques in MANETs could also be found in [6]. In this study, Williams et al [6] have classified the broadcasting techniques into the following four categories: simple flooding, probability-based, area-based, and neighbour knowledge scheme. In the flooding scheme, every node retransmits its neighbours as a response to every newly received packet. The probability-based scheme is a simple way of controlling message floods. Each node rebroadcasts with a predefined probability  $p$  [8]. Obviously when  $p=1$  this scheme resembles simple (blind) flooding. In the area based scheme, a node determines whether to rebroadcast a packet or not by calculating and using its additional coverage area [3].

The neighbour knowledge scheme [6] maintains

neighbour node information to decide who should rebroadcast. To use the neighbour knowledge method, each node has to explicitly exchange neighbourhood information among mobile hosts using periodic “hello” packets. The length of the period affects the performance of this scheme. Short periods could cause collision or contention while long periods may degrade the protocol’s ability to cope with mobility.

Cartigny and Simplot [9] have described a probabilistic scheme but the probability  $p$  of a node retransmitting a message is computed from the local density  $n$  (i.e. the number of neighbours) and a fixed value  $k$  for the efficiency parameter to achieve the reachability of the broadcast. The previous model of [9] has the disadvantage of being locally uniform. Indeed, each node of a given area receives a broadcast and determines the probability according to a constant efficiency parameter to achieve the reachability and from the local density [9].

Zhang and Dharma [10] have described dynamic probabilistic scheme. They use a combination of probabilistic and counter-based approaches. The value of a packet counter does not necessarily correspond to the exact number of neighbors from the current host, since some of its neighbours may have suppressed their rebroadcasts according to their local rebroadcast probability. On the other hand, the decision to rebroadcast is made after a random delay. However in our algorithm the decision to rebroadcast is made immediately after receiving a packet without any delay. Therefore the broadcast latency of our algorithm is lower than that of the dynamic probabilistic scheme [10].

### 3. Probabilistic Flooding

The simple flooding scheme [4] is a straightforward broadcasting approach that is easy to implement with guaranteed message dissemination. In this scheme, a source broadcasts packets to every neighbour who in turn rebroadcasts received packets to its neighbours and so on. This process continues until all reachable nodes have received and rebroadcast the packet once. Of course, this approach has its obvious shortcomings of redundancy and message contention.

The probabilistic scheme [5, 8] is one of the alternative approaches that aim at reducing redundancy through rebroadcast timing control in an attempt to alleviate the broadcast storm problem. In this scheme, when receiving a broadcast message for the first time, a node rebroadcasts the message with a pre-determined probability  $p$  so that every node has the same probability to rebroadcast the message, regardless of its number of neighbours. In dense networks, multiple nodes share similar transmission range. Therefore, these probabilities

control the frequency of rebroadcasts and thus might save network resources without affecting delivery ratios. It should be noticed that in sparse networks there is much less shared coverage; thus some nodes will not receive all the broadcast packets unless the probability parameter is high. So if the rebroadcast probability  $p$  is set to a far small value, the reachability will be poor. On the other hand, if  $p$  is set far large, many redundant rebroadcasts will be generated. In order to achieve both high saved rebroadcast and high reachability in MANETs where network topology changes frequently, the rebroadcast probability at every host must be dynamically adjusted.

The rebroadcast probability should be set high at the hosts in sparser areas and low at the hosts in denser areas. Our simple method for density estimation requires mobile hosts to periodically exchange HELLO messages between neighbours to construct a 1-hop neighbour list at each host. A high a number of neighbours implies that the hosts in denser areas, a low number of neighbors imply that the host is in sparser areas. We increase the broadcast probability if the value of the number of neighbours is too low (or similarly if the current node is located in a sparse neighbourhood), which indirectly causes the probability at neighbouring hosts to be incremented. Similarly, we decrease the rebroadcast probabilities if the value of number of neighbours is too high.

This kind of adaptation causes a dynamic stability between rebroadcast probabilities number of neighbours values among neighbouring hosts. Intuitively, the probabilities at the stability states should lead to optimal solutions. We adopt a simple adaptation algorithm. A brief outline of the adjusted probabilistic flooding algorithm is presented in Figure 1 and operates as follows. On hearing a broadcast message  $m$  at node  $X$ , the node rebroadcast a message according to a high probability if the message is received for the first time, and the number of neighbours of node  $X$  is less than average number of neighbours typical of its surrounding environment. Hence, if node  $X$  has a low degree (in terms of the number of neighbours), retransmission should be likely. Otherwise, if  $X$  has a high degree its rebroadcast probability is set low. The adjusted rebroadcast probability for probabilistic broadcasting algorithm for each node is presented below:

#### The Adjusted Probabilistic Flooding Algorithm

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##### Protocol receiving ()

*On hearing a broadcast packet  $m$  at node  $X$   
Get the Broadcast ID from the message;  $\bar{n}$  average  
number of neighbor (threshold value);*

Get degree  $n$  of a node  $X$  (number of neighbors of node  $X$ );

If packet  $m$  received for the first time then

If  $n < \bar{n}$  then

Node  $X$  has a low degree: the high rebroadcast probability  $p = p_1$ ;

Else  $n \geq \bar{n}$

Node  $X$  has a high degree: the low rebroadcast probability  $p = P_2$ ;

End if

End if

Generate a random number  $RN$  over  $[0, 1]$ .

If  $RN \leq p$  rebroadcast the received message; otherwise, drop it

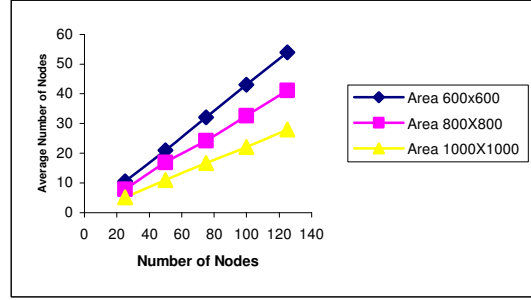
**Figure 1:** An outline of the adjusted probabilistic flooding algorithm.

Our algorithm is a combination of probabilistic and knowledge-based approaches. It dynamically adjusts the re-broadcast probability  $p$  at each mobile host according to the value of the local number of neighbours. The value of  $p$  changes when the host moves to a different neighbourhood. In a sparser area, the rebroadcast probability is larger and in denser area, the probability is lower. Compared with the probabilistic approach where  $p$  is fixed, our algorithm achieves higher saved rebroadcast. On the other hand, the decision to rebroadcast is made immediately after receiving a packet in our algorithm without any delay.

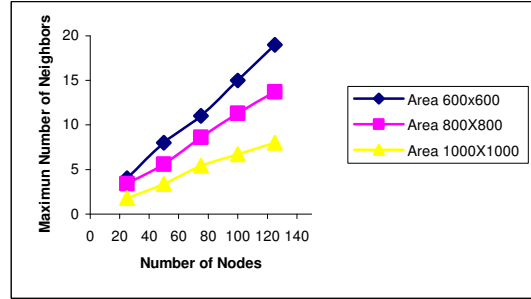
We present the analysis of average neighbour number to provide the basis for the selection of the value of  $p$ . Let  $A$  be the area of an ad hoc network,  $N$  be the number of mobile hosts in the network, and  $R$  be the transmutation range. The average number of neighbour  $\bar{n}$  can be obtained by the following formula:

$$\bar{n} = (N - 1)0.8 \frac{\pi r^2}{A} \quad (1)$$

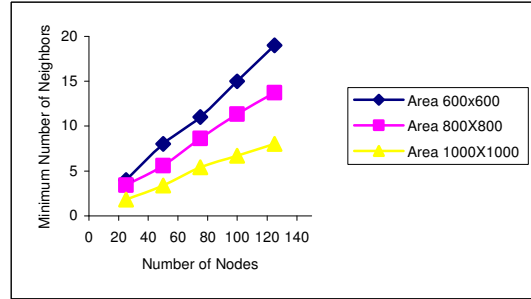
Figures 2-4 show the minimum, average and maximum number of neighbours for different node number with the network area of 600 m × 600 m, 800 m × 800 m, and 1000 m × 1000 m, respectively. The higher is the maximum number of neighbours, the denser the network is. Lower the minimum number of neighbours is sparser the network is. From the minimum, average and maximum number of neighbours, we can estimate the value of rebroadcast probability.



**Figure 2:** Average number of neighbors vs. number of nodes.



**Figure 3:** Maximum number of neighbors vs. number of nodes.



**Figure 4:** Minimum number of neighbors vs. number of nodes.

#### 4. Performance Evaluation

We have used the ns-2 packet level simulator (v.2.27) [3] to conduct extensive experiments to evaluate the performance of probabilistic flooding. The network considered for the performance analysis of the rebroadcast probability vs. density varies from 25 nodes up to 100 placed randomly on 600×600 m<sup>2</sup>, with each node engaging in communication transmitting within 250 meter radius and having bandwidth of 2Mbps. The random waypoint model is used to simulate 25 mobility patterns with retransmission probabilities ranging from 0.5 to 1.0

percent with 0.1 percent increment per trial. In short, the random waypoint model considers nodes that follow a motion-pause recurring mobility state. Each node at the beginning of the simulation remains stationary for pause time seconds, then chooses a random destination and starts moving towards it with speed selected from a uniform distribution (0, max\_speed]. After the node reaches that destination, it again stands still for a pause time interval (pause\_time) and picks up a new destination and speed. This cycle repeats until the simulation terminates. The maximum speeds (max\_speed) of 1, 5, 10, 20 meter/second and pause times of 0 seconds are considered for the purposes of this study. The simulation parameters are summarised in Table 1 below.

**Table 1: Te parameters used in the simulation.**

Parameter	Value
Transmitter range	250 meter
Bandwidth	2Mbit
Interface queue length	50 packets
Simulation time	900 seconds
Pause time	0
Packet size	512 bytes
Topology size	600x600 meter <sup>2</sup>
Number of node	25,50,75,100
Maximum speed	1,5,10 20 meter/seconds

The performance of broadcast protocols can be measured by a variety of metrics [1,4,5,6,7] A commonly used metric is the number of message re-transmissions with respect to the number of nodes in the network [6]. In this work, we use *rebroadcast savings*, which is a complementary measure and is precisely defined below. The next important metric is *reachability*, which is defined in terms of the ratio of nodes that received the broadcast message out of all the nodes in the network. The formal definitions of these two metrics are given as follows [4, 7].

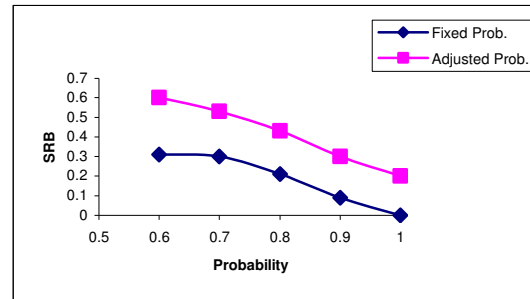
**Saved ReBroadcasts (SRB):** Let  $r$  be the number of nodes that received the broadcast message and let  $t$  be the number of nodes that actually transmitted the message. The saved rebroadcast is then defined by  $(r - t)/r$ .

**Reachability (RE):** is the percentage of nodes that received the broadcast message to the total number of nodes in the network. For useful information, the total number of nodes should include those nodes that are part of a connected component in the network. For disconnected networks this measure should be applied to each of the components separately.

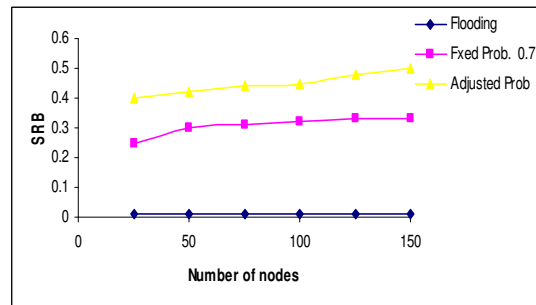
We have compared the saved broadcast (SRB) in fixed probability and our algorithm Adjusted Probabilistic. Figure 5 shows the our algorithm can significantly reduce

the number of saved rebroadcast (SRB) with rebroadcast probabilities ranging from 0.5 to 1.0 percent with 0.1 percent increment per trial for a network with 50 nodes and maximum speed 20 m/s and 0 pause time.

Figure 6 shows the saved rebroadcast (SRB) of the fixed probabilistic and our Algorithm Adjusted Probabilistic. The SRB of our algorithm Adjusted Probabilistic is 40% in low-density networks (25 nodes) and 50% in high-density networks (150 nodes). The SRB of the fixed probabilistic scheme with the probability assigned to 0.7 in any density of network is around 30%. Finally, we can see that our algorithm performs the best in various network densities.



**Figure 5: The SRB vs. the rebroadcast probability with node speed 10m/s.**



**Figure 6: SRB of three broadcast schemes against network density with node speed 10m/s.**

Figure 7 shows that reachability increases when network density increases, regardless of what kind of the algorithms is used. The flooding algorithm has the best performance in reachability, reaching nearly 1. The performance of adjusted probabilistic algorithm shows that the reachability is above 95% in any density of the network. In all network densities, the reachability of our Algorithm performs better than the probabilistic scheme with the probability assigned to 0.7. In higher density networks, i.e., 120 hosts and above, the reachability of our approach and flooding are very close. The reachability is close to 100%.

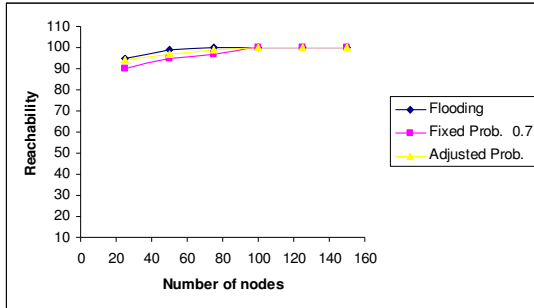


Figure 7: The reachability of three broadcast algorithms.

## 5. Conclusions

This paper has proposed a probabilistic flooding algorithm in mobile ad hoc networks (MANETs) to improve the saved Rebroadcast. The algorithm determines the rebroadcast probability by considering the network density. In order to increase the saved rebroadcasts, the rebroadcast probability of low density nodes is increased while that of high density nodes is decreased. Compared with the simple flooding and fixed probabilistic flooding, our simulation results have shown that our adjusted probabilistic flooding algorithm can improve the saved broadcast up to 50% without scanting reachability, even under conditions of high mobility and density.

As a continuation of this research in the future, we plan firstly to combine our algorithm with a counter-based approach and note if a combined performance improvement is feasible. Secondly, we aim to propose a highly adjusted probabilistic flooding algorithm approach in order to facilitate the exploration of the optimal adaptation strategy. Thirdly, we will build an analytic model for our dynamic probabilistic approach in order to facilitate the exploration of the optimal adaptation strategy. Finally, we will study the effects of modifying the nodes' transmission range with regard to the rebroadcast probability and examine if through regulating the nodes' transmission radius it is possible to maximize saved rebroadcasts whilst maintaining a low number of retransmissions.

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