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# On the Performance of Probabilistic Flooding in Mobile Ad Hoc Networks

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## Abstract

*This paper investigates using extensive simulations the effects of a number of important system parameters in a typical MANETs, including node speed, pause time, traffic load, and node density on the performance of probabilistic flooding. The results reveal that most of these parameters have a critical impact on the reachability and the number of saved rebroadcast messages achieved by probabilistic flooding, prompting the need for dynamically adjusting nodal retransmission probabilities depending on the current state of the network.*

## 1. Introduction

Broadcasting is a fundamental operation in Mobile Ad hoc Networks (MANETs) whereby a source node transmits a message that is to be disseminated to all the nodes in the network. One of the earliest broadcast mechanisms proposed in the literature is simple or "blind" flooding [2] where each node receives and then re-transmits the message to all its neighbours. However, a straightforward flooding of the network 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* [2, 3, 7], and has generated many challenging research issues [2, 3 ,4].

A probabilistic approach to flooding has been suggested in [3, 4] as a means of alleviating the detrimental effects of the broadcast storm problem. In the probabilistic scheme, when receiving a 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 [2, 3] have shown that probabilistic broadcast incurs significantly lower overhead compared to blind flooding while maintaining a high degree of propagation for the broadcast messages. However, when analysing the performance of probabilistic flooding, these studies have not taken into consideration a number of important factors that could greatly impact the performance of a typical MANET. Such factors include node mobility, network density, and injected traffic load.

In an effort to gain a deep understanding and clear insight into the behaviour of probabilistic flooding in a MANET environment, this paper investigates the effects of mobility on the operation and effectiveness of probabilistic flooding. Two important metrics, notably reachability and saved rebroadcasts are used to assess network performance[3]. Moreover, the well-known random waypoint model is used to analyse through extensive simulations the impact of varying node pause times and speeds on the performance of probabilistic flooding. The effects of varying node density, i.e. the number of network nodes per unit area for a given transmission range, and varying the traffic load, i.e. the number of broadcast request injected into the network per second are also studied. The results presented below reveal that node speed, pause time, and density have a critical impact on the reachability achieved by probabilistic flooding, and also have great impact on the saved rebroadcast messages.

The rest of the paper is organised as follows. Section 2 describes the probabilistic flooding method. Section 3 presents performance results and analysis of the behaviour of the probabilistic algorithm. Finally, Section 4 concludes this study.

## 2. Probabilistic Flooding

The simple flooding scheme [3] is a straightforward broadcasting approach that is easy to implement with guaranteed message dissemination. In this scheme, a source broadcasts messages to every neighbour who in turn rebroadcasts received messages to its neighbours and so on. This process continues until all reachable nodes have received and rebroadcast the message once.



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Of course, the naive flooding approach has its obvious shortcoming redundancy and message contention. The probabilistic scheme [3, 6] 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 could 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 messages unless the probability parameter is high.

## 3. Performance Analyses

The network considered for the performance analysis of the rebroadcast probability vs. density has been varied from 25 nodes up 100 placed randomly on $600\times600$ $m^2$, with each node engaging in communication transmitting within 250 meter radius and having bandwidth of 2Mbps. The retransmission probabilities have been varied from 0.1 to 1.0 percent with 0.1 percent increment per trial using ns-2. The random waypoint model has been used to simulate 25 mobility patterns [5, 6]. In this mobility model, nodes that follow a motion-pause recurring mobility state, where 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. It is worth noting that the simulation parameters used in this study have been widely adopted in existing performance evaluation studies of MANETs [2,3].

In this work, we use *rebroadcast savings*, which is a complementary measure as defined below. The other 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.

### 3.1 Effects of Speed and Node Pause Time

The results for saved rebroadcasts achieved by probabilistic flooding are depicted in Fig. 1 for continuous and non-continuous mobility. For each pause time, the maximum node speed has been varied from 1 , 5 , 10, to 20 m/s. As the results show, the node speed has critical impact on the observed saved rebroadcast value since for each probabililty value, as the mean node speed increases the saved rebroadcast increases. Fig. 2 shows the rebroadcast probability against reachability across four different maximum node speeds, and the reachability achieved in the case of continuous mobility. Overall, across the different broadcast probabililties, reachability increases as the mean node speed increases.

### 3.2 Effects of Mobility and Density

Figs. 3 to 6 depict the degree of reachability achieved when the rebroadcast probability is increased. The figures show reachability with four different node densities and four different node speeds. Fig. 3 suggests that reachability using probabilistic flooding for continuous mobility increases with higher density. The trend in the figures also suggests that the reachability increases as the node speed increases.

Reachability improves with higher density and faster nodes for the following reason. As the density of the nodes increases, the number of nodes covering a particular area also increases. As the probability of re-broadcast is fixed for every node, this implies that there are more candidates for transmission in each "coverage "area. Hence, there is a greater chance that a broadcast re-transmission occurs, resulting in increased reachability. Moreover, for a given transmission range, as density increases network connectivity increases. So, a small broadcasting probability, $p$, is sufficient to achieve high reachability. However, a larger $p$ is required if the node distribution is sparse, the amount of reachability increases, proportionally to $p$, as $p$ increases. In addition as node speed increases connectivity increases then the probability of partitioning decreases, leading to a higher degree of reachability.

Figs. 7 to 9 demonstrate the effects of speed and density on the saved rebroadcasts using 16 combinations of node densities and speeds. As can be seen in the figures, the saved rebroadcast increases with higher nodes speeds and densities. The amount of saved rebroadcasts increases as the density of the nodes increases, i.e. as the number of nodes covering a particular area increases. As the probability of the transmission is fixed for every node, this implies that there are more candidates for broadcast re-transmission in each "coverage "area, and consequently, there is a higher chance that a re-transmission occurs, increasing the number of saved rebroadcast messages at the level of each probability. Further note that the saved rebroadcast value decreases as $p$ increases. Moreover, as the node speed increases, network connectivity increases as the probability of partitioning decreases, which in turn results in increased



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saved rebroadcasts.

### 3.3 Effects of Mobility and Traffic Load

Figs. 10 to 13 show reachability results when rebroadcast probability is varied for different mean node speeds and traffic loads. While the node speed has been varied as in the above simulation setups, the load has been varied by increasing the rate of broadcast messages generated at a given source nodes from 1 to 4 broadcast messages per second. Fig. 10 suggests that the achieved reachability for continuous mobility (0 pause time) increases at moderate node speed. Furthermore, the trend in the following four figures suggest that the reachability increases as the node load increases.

Fig. 14 to 17 demonstrate this effect using 16 combinations of node traffic load and speed. As can be observed from the figures, the saved rebroadcast increases with higher nodes speeds and traffic load. The amount of saved rebroadcast increases as the traffic load of the nodes increases, the number of nodes covering a particular area also increases. As the probability of the transmission is fixed for every node this implies that these are more candidates for transmission in each “coverage “area. Hence, there is greater chance that a transmission will occur, thus saved rebroadcast increases at the level each probability. In addition to that, saved rebroadcast decreases as $p$ increases in addition as node speed increases the connectivity increases then the probability of partitioning decreases thus SRB increases.

## 4. Conclusions

This paper has analysed the effects of node speed and pause time on the performance of the probabilistic approach to flooding (or broadcasting) in Mobile Ad hoc Networks (MANETs). Results from extensive ns-2 simulations have revealed that mobility and pause times have a substantial effect on the reachability and saved rebroadcast metrics. The results have shown that for different rebroadcast probabilities, as the node speed increases, reachability and saved rebroadcast increases. Morever, as the pause time increases saved rebroadcast increases. Similar performance trends have been observed when the other important system parameters, notably node density and traffic load, have examined in that they have been found to have a great impact on the degree of reachability and the number of saved rebroadcasts achieved by the probabilistic broadcasting scheme.

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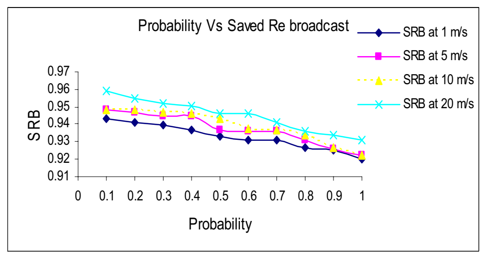


**Fig. 1**: Impact of speed on saved rebroadcast with no pause time and different node speeds 1, 5, 10, and 15 m/s.

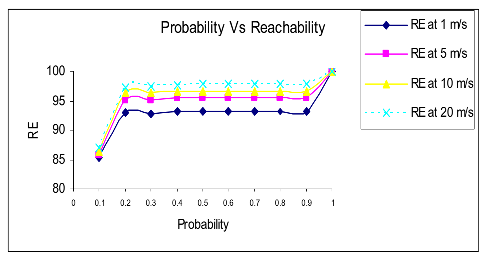


**Fig. 2**: Impact of speed on reachability with no node pause time.

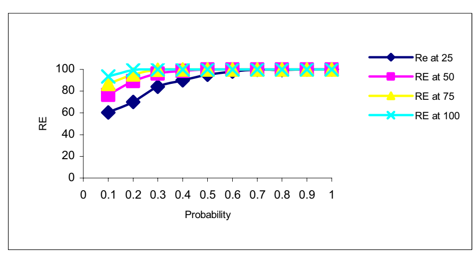


**Fig. 3**: Impact of density on reachability for different network densities with node speed 1 m/s.




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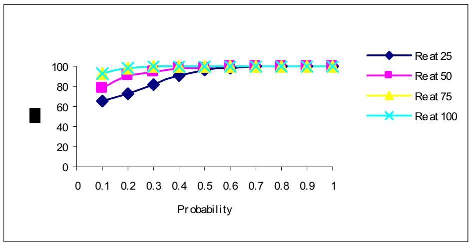


**Fig. 4**: Impact of density on reachability for different network densities with node speed 5 m/s.

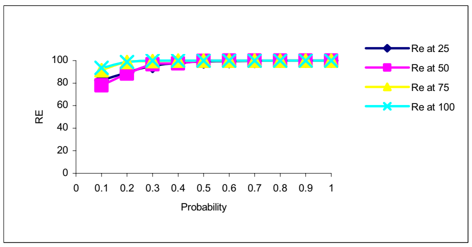


**Fig. 5**: Impact of density on reachability for different network densities with node speed of 10 m/s.

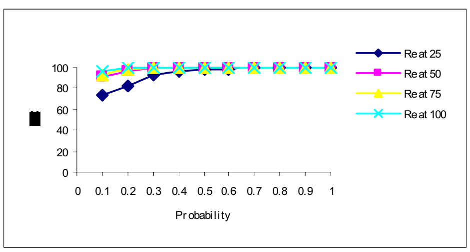


**Fig. 6**: Impact of density on reachability for different network densities with node speed 20 m/s.

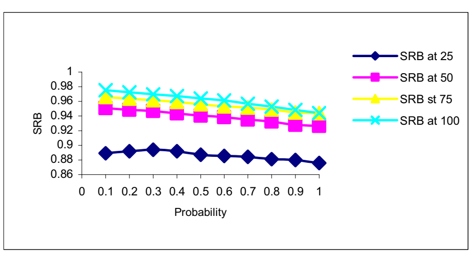


**Fig. 7**: Impact of density on saved rebroadcast for different network densities with node speed 1 m/s.

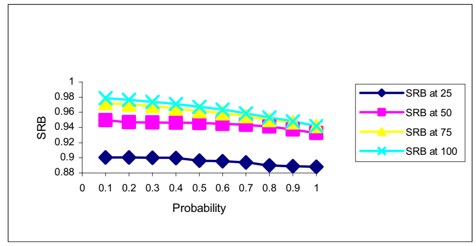


**Fig. 8**: Impact of density in saved rebroadcast for different network densities with node speed 5 m/s

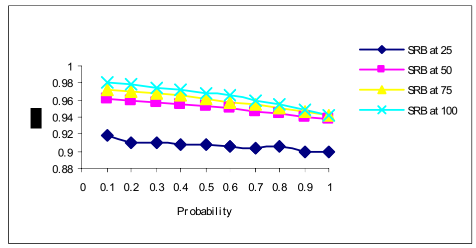


**Fig. 9**: Impact of density on rebroadcast for different node densities with node speed 20 m/s.

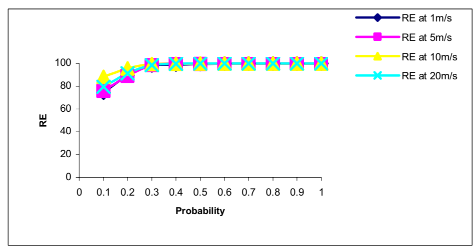


**Fig. 10**: Impact of load on reachability at 1 broadcast/s with different node speed 1, 5, 10, and 20 m/s.

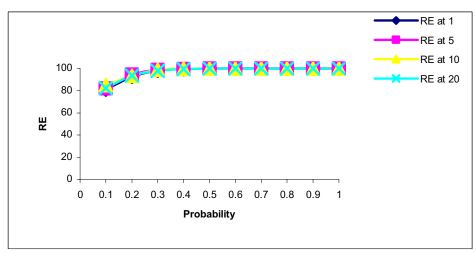


**Fig. 11**: Impact of load on reachability at 2 broadcasts for different node speeds 1, 5, 10, and 20 m/s.

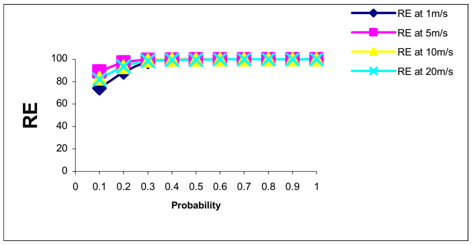


**Fig. 12**: Impact of load on reachability at 3 messages/s for different node speeds 1, 5, 10, and 20 m/s.

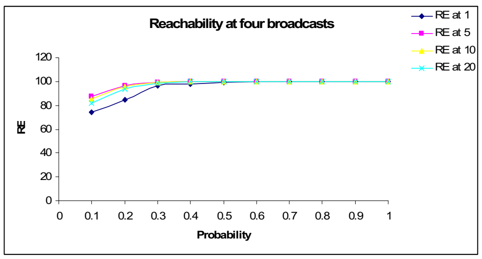


**Fig. 13**: Impact of load in reachability at 4 broadcasts/s for different node speeds 1, 5, 10, and 20 m/s.

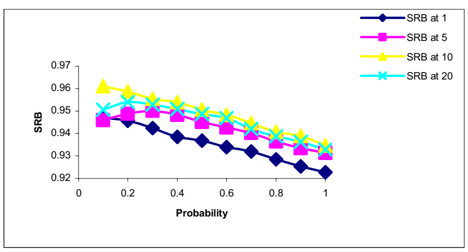


**Fig. 14**: Impact of load on saved rebroadcast at 1 message/s for different node speed 1, 5, 10, and 20 m/s.

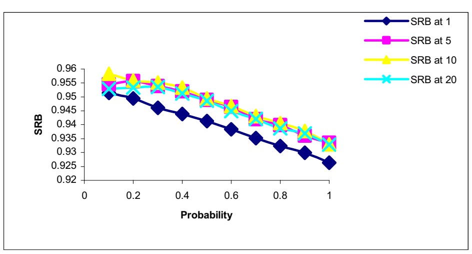


**Fig. 15**: Impact of load on saved rebroadcast at 2 messages/s for different node speeds 1, 5, 10, and 20 m/s.

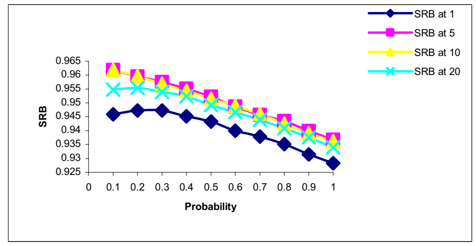


**Fig. 16**: Impact of load on saved rebroadcast at 3 messages/s for different node speeds 1, 5, 10, and 20 m/s.

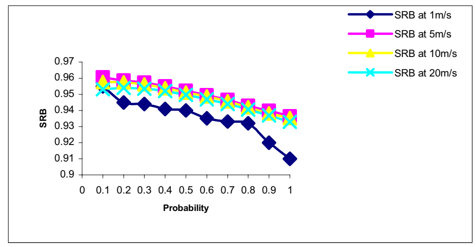


**Fig. 17**: Impact of load on saved rebroadcast at 4 messages/s for different node speeds 1, 5, 10, and 20 m/s.



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