Performance Evaluation of Flooding in MANETs in the Presence of Multi-Broadcast Traffic

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Abstract

Broadcasting has many important uses and several Mobile Ad hoc Networks (MANETs) protocols assume the availability of an underlying broadcast service. Applications, which make use of broadcasting, include LAN emulation, paging a particular node, However, broadcasting induces what is known as the "broadcast storm problem" which causes severe degradation in network performance, due to excessive redundant retransmission, collision, and contention. Although probabilistic flooding has been one of the earliest suggested approaches to broadcasting. There has not been so far any attempt to analyse its performance behaviour in MANETs. This paper investigates using extensive ns-2 simulations the effects of a number of important parameters in a MANET, including node speed, pause time and, traffic load, on the performance of probabilistic flooding. The results reveal that while these parameters have a critical impact on the reachability achieved by probabilistic flooding, they have relatively a lower effects on the number of saved rebroadcast packets.

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 [1]. These include critical military operations, rescue and law enforcement missions as well as and disaster recovery scenarios [1]. 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 neighbour using narrow beam directional antennas or separate frequencies for each node [5]. A number of MANET routing protocols such as Dynamic Source Routing (DSR), Ad Hoc on Demand Distance Vector (AODV) , Zone Routing Protocol (ZRP) and Location Aided Routing (LAR)) use broadcasting or one of its derivatives to establish routes[5]. 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 [3]. 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* [3, 7] and has generated many challenging research issues. A number of researchers have identified this problem by showing how serious it is through analyses and simulations [3, 7].

A probabilistic approach to flooding has been suggested in [3, 6, 8, 9] 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 [3, 7, 8] have shown that probabilistic broadcasts incur significantly lower overhead compared to blind flooding while maintaining a high degree of propagation for the broadcast messages. However, these studies have not taken into consideration the impact of important factors in a MANET including node mobility, and injected traffic load to assess the performance of probabilistic flooding. In an effort to gain a deeper understanding and gain a clearer insight environment , this paper investigate the effects of

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mobility on the operation and effectiveness of probabilistic flooding, two important flooding metrics, namely reachability and saved rebroadcasts. In particular, using the popular random waypoint model we analyse through extensive simulations the impact of varying the node pause time and speed on the performance of probabilistic flooding [4]. The effects of varying traffic load, i.e. the number of broadcast request injected into the network per second. The results reveal that while node speed, pause time, and traffic load have a critical impact on the reachability achieved by probabilistic flooding, they have relatively a lower impact on the saved rebroadcast packets.

The rest of the paper is organised as follows. Section 2 gives an overview of the previous on broadcasting in MANETs. Section 3 present the performance results and analyse the behaviour of broadcasting flooding. Finally, Section 4 concludes by a recount of the obtained results and 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 [3, 7] that is characterised by high redundant packet retransmissions, network bandwidth contention and collision. Ni et al [3, 7] have studied the flooding protocol analytically and experimentally. Their obtained results have indicated that rebroadcast could provide at most 61% additional coverage and only 41% additional coverage in average over that already covered by the previous. Therefore, rebroadcasts are very costly and should be used with caution. The authors in [5] 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 [3] 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 [5].

The cluster-based scheme divides the MANET into a number of clusters or sub-sets of mobile nodes. 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.

The simple flooding scheme [3, 8] 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 shortcoming redundancy and message contention.

The probabilistic scheme [8, 9] 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.

Previous studies [3, 8] have only considered the performance of probabilistic flooding as a function of the network density. This study investigates the effects of the node speed, pause time, traffic load, on the performance behaviour of the probabilistic approach to flooding in MANETs considering a wide range of mobility scenarios using the popular random waypoint model [4].

3. Performance Evaluation

We have used the ns-2 packet level simulator (v.2.27) [2] to conduct extensive experiments to evaluate the performance of probabilistic flooding. The network considered for the performance analysis of the rebroadcast probability vs. traffic load varies from 1 broadcast per second up to 4 broadcast per second with 50 nodes on 600×600 m^2, with each node engaging in communication transmitting within 250 meter radius and having bandwidth of 2Mbps. The random waypoint

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model is used to simulate 25 mobility patterns with retransmission probabilities ranging from 0.1 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 [4]. 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.

Table 1: Summary of the parameters used in the simulation experiments.

Parameter	Value
Transmitter range	250m
Bandwidth	2Mbps
Simulation time	900 seconds
Pause time	0,20,40 seconds
Packet size	512 bytes
Number of nodes	50
Maximum speed	1,5,10 and 20 m/s
Interface queue length	50 packets

The performance of broadcast protocols can be measured by a variety of metrics [3, 5, 7]. A commonly used metric is the number of message re-transmissions with respect to the number of nodes in the network [8]. In this work, we use saved *rebroadcast*, which is a complementary measure as 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 [3].

Saved ReBroadcasts (SRB): Let r be the number of nodes that received the broadcast message and let and t be the number of nodes that actually transmitted the message. The saved rebroadcast is then defined by *(r – t)/r [3].*

Reachability (RE): Reachability is defined by 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 [3].

Figures 1-6 depict reachability percentages shown for increasing the rebroadcast probability. The figures show reachability with four different mean node speed and four different node traffic loads. Figure 1 suggests that achieved reachability using probabilistic flooding for continuous mobility (0 pause time) increases with medium speed. Furthermore, the trend in the following four figures suggest that the reachability increases as the node load increases.

The reachability is getting better with higher load traffic and faster nodes the rational is as follows. As the 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 reachability increases. In addition to that, for given transmission range, as load increases the connectivity of the network increases then a small probability p is sufficient to achieve high reachability. but larger p is needed if the node distribution is sparse , the amount of reachability (RE) increases , proportionally to p , as p increases in addition as node speed increases the connectivity increases then the probability of partitioning decreases thus reachability increase.

The remaining simulation results give indication on the effect of speed and traffic load of the save rebroadcast. Figures 7 through 8, 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 saving (SRB) 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 (SRB) increases at the level each probability. In addition to that, (SRB) decreases as p increases in addition as node speed increases the connectivity increases then the probability of partitioning decreases thus (SRB) increases.

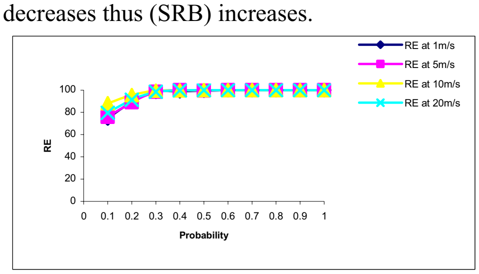

Figure 1 : The impact of load on reachability at one broadcast/ second for different node speed

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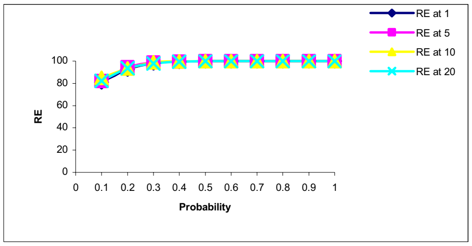

Figure 2: The impact of traffic load on reachability at two broadcasts/ second for different node speed.

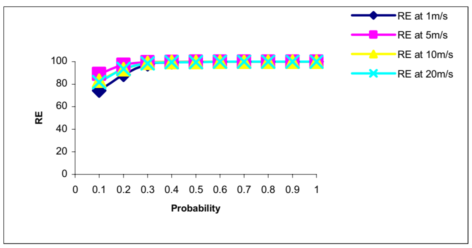

Figure 3: The impact of traffic load on reachability at three broadcasts/second for different node speeds.

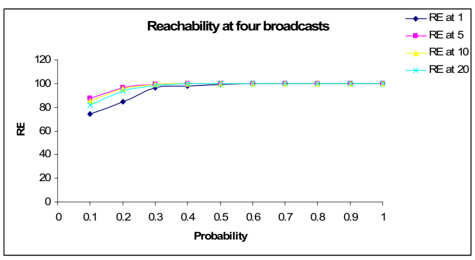

Figure 4: The impact of traffic load in reachability at four broadcasts/second for different node speeds.

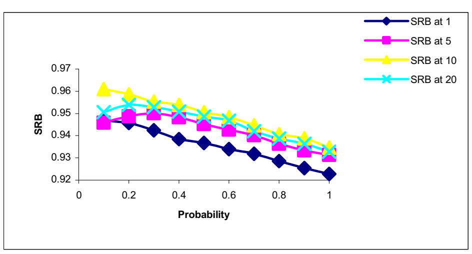

Figure 5: The impact of traffic load on saved rebroadcast at one broadcast/ second for different node speed

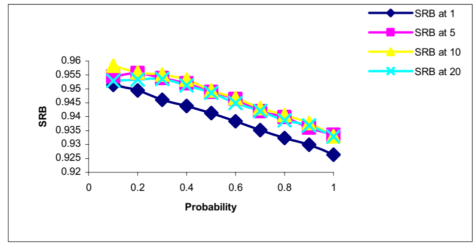

Figure 6: The impact of traffic load on saved rebroadcast at 2 broadcasts/second for different node speeds.

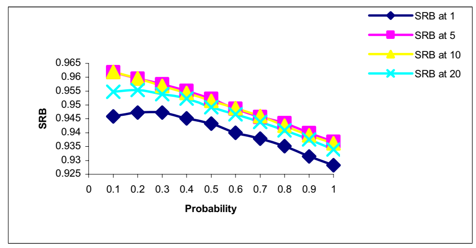

Figure 7: The impact of traffic load on saved rebroadcast at three broadcast/ second for different node speed.

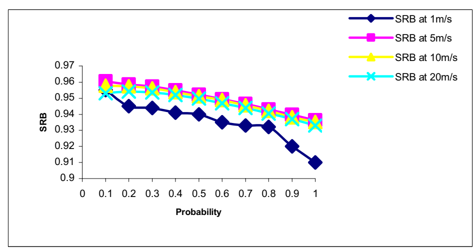

Figure 8: The impact of traffic load on saved rebroadcast at four broadcasts/second for different node speeds.

4. Conclusions

This paper has studied the effects of traffic load on reachability and saved rebroadcast ratios of Mobile Ad hoc Networks. In this study, we have used the random waypoint model applied to the probabilistic flooding approach. Through simulation, we have shown that there is a substantial effect of traffic load and mobility on the reachability and saved rebroadcast ratios. This prompts the need of a dynamically probability adjustment strategy for the probabilistic flooding approach. Another potential area of possible improvement includes investigating the effect of nodes' transmission ranges on the rebroadcast probability.

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