Analyzing Performance of Counter-Based Broadcasting in Mobile Ad Hoc Networks

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Abstract

Broadcasting is a fundamental service in mobile ad-hoc networks (MANETs). Flooding is used as a broadcast technique for route discovery in MANET. But it can result in high packet collision & redundancy which can degrade the network performance. Such a scenario is referred to as broadcast storm problem. Counter-based broadcasting (CBB) scheme has been proposed to overcome the broadcast storm problem in MANET. Counter-based approaches inhibit a node from broadcasting a packet based on number of copies of the broadcast packet received by the node within a random access delay time. It relies on the threshold value to decide whether or not to forward broadcast packet. In our study, counter-based threshold is dynamically adjusted based on host density in its neighborhood area. Simulation results of this study show the effect of threshold on the performance of proposed counter based flooding scheme.

Keywords: Counter based Broadcasting, CBB, Broadcast Storm Problem

Introduction

Wireless networks are becoming more and more important. People want their mobile and fixed devices to communicate with the hassle of wires. Preferably communication should be established automatically in an ad-hoc fashion. To achieve this, Mobile ad-hoc networks (MANETs) will be an important building block. Mobile ad-hoc networks (MANETs) are special type of wireless networks that comprises of wireless mobile nodes, which communicate with one another without relying on fixed infrastructure or central administration. The main advantage of this is communicating with rest of the world while being mobile. The distributed, wireless and self-configuring nature of MANET make them suitable for a wide variety of applications. These include critical military operations as well as disaster recovery scenario.

Broadcasting is a means of diffusing a message from a given source node to all other nodes in the network. Broadcasting is a fundamental operation in MANETs and a building block for most other network layer protocols. Most existing routing protocols proposed for MANET use flooding as a broadcast technique for route discovery.

One of the earliest broadcasting mechanisms proposed in the literature are simple or blind flooding where each node in the network retransmits a message to its neighbor upon receiving it for the first time. Although, flooding is simple and most commonly used for broadcasting in MANETs; it can result in high packet collision & redundancy which can degrade the network performance. Such a scenario is referred to as broadcast storm problem [1,2,3].

A counter-based method has been suggested in [1,4,5] as a means of reducing redundant broadcasts and alleviating broadcast storm problem. The counter-based method is based on counter c that records the number of times a host has received the same broadcast packet and is maintained by each host for each broadcast packet. When c reaches a certain threshold, the packet is dropped otherwise packet is retransmitted. The counter-based scheme can reduce the number of rebroadcasts, and as a result reduce the chance of contention and collision among neighboring nodes. Counter-based approaches inhibit a node from broadcasting a packet based on number of copies of the broadcast packet received by the node within a random access delay time.

This study introduces an efficient class of Counter-based Flooding scheme that has been proposed to overcome the broadcast storm problem in MANET. It relies on the threshold value to decide whether or not to forward broadcast packet. This is done based on locally available neighborhood information and without requiring any assistance of distance measurements or exact location determination devices. A straightforward method for gathering neighborhood information at a given node involves the periodic exchange of Hello packets between neighbors to construct a one-hop neighbors list at the nodes. The proposed algorithm is a combination of counter-based and knowledge-based methods.

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 proposed Counter-based Flooding scheme. In Section 4, we evaluate our approach and present the simulation results and compares current and proposed work. Section 5 concludes the paper and offers suggestions for future work.

Related Work

One of the earliest broadcasting mechanisms proposed in the literature is simple or blind flooding where each node in the network retransmits a message to its neighbor upon receiving it for the first time. Although, flooding is simple and most commonly used for broadcasting in MANETs; it can result in high packet collision & redundancy which can degrade the network performance. Such a scenario is referred to as broadcast storm problem [1,2,3].

Most sophisticated solutions have been proposed to alleviate the broadcast storm problem associated with blind flooding. Some of solutions inhibits some hosts from forwarding the broadcast packet for the sake of reducing redundancy and hence collision and contention. These solutions include probability-based, counter-based, distance based, area-based, cluster based and neighbor knowledge based schemes. In the probability based scheme [6,7], when receiving a broadcast packet for the first time, a node rebroadcasts the packet with a probability p; when p=1, this scheme reduces to blind flooding. The counter-based scheme [1,4,5] inhibits the rebroadcasts if the packet has already been received for more than a given number of times. In the distance-based scheme [1], a node rebroadcasts the packet only if the distance between the sender and the receiver is larger than a given threshold. An area-based scheme [1] uses pre-acquired location information of neighbors to make broadcasting decision. In neighbor knowledge-based schemes [8], a decision of retransmission of packet is made based on neighborhood information collected using periodic Hello packet exchange. Clustering is another method to select forwarding nodes as addressed in [1]. It groups nodes into clusters. A representative of each cluster is called as cluster head. A node that can communicate with a node in another cluster is called as gateway. Other nodes are called ordinary nodes. Nodes co-operate to elect cluster heads by periodically exchanging information. Cluster head broadcasts all other nodes in the same cluster. To rebroadcast packets to nodes in another cluster, gateway nodes are used. When the broadcast message is heard, if the host is a non-gateway member, the rebroadcast is inhibited and the procedure exits. If the host is either a head or a gateway, any of the probabilistic, counter-based, distance-based, and location-based schemes is used to determine whether to rebroadcast or not.

Broadcasting in MANETs is an active research area. The core problem is how to minimize the number of rebroadcast packets while maintaining reasonable latency and good reachability. Transmitting a large number of rebroadcasts does guarantee high reachability. However, it degrades the network throughput and potentially incurs long broadcast latency. Dispatching fewer rebroadcasts leads to lower bandwidth wastage, higher throughput and lower broadcast latency. However, sending too few rebroadcasts may cause a rebroadcast chain to be broken so that some hosts may never receive the broadcast packet resulting in lower reachability. On the other hand, rebroadcast algorithms may also affect the broadcast latency. For example, a host may dictate a random delay before sending a rebroadcast in order to reduce the chance of collisions. A long delay leads to high broadcast latency. A. Mohammed and M. Khaoua [4] focused on determining the best counter threshold value for counter-based approach. A. Mohammed, revealed in [4] that setting the optimal threshold values can optimize the performance of counter based flooding in terms of saved broadcast and end to end delay. Most counter based schemes assumed a counter threshold value 3 or 4. S.Y. Ni has concluded in [1] that a threshold value 3 or 4 can save many broadcasts in a dense region while achieving a delivery ratio comparable to blind flooding. On the other hand, larger threshold of greater than threshold value 6 will provide less saving of broadcasts in sparse region but behave almost like blind flooding in terms of reachability.

Y.C. Tseng, S.Y. Ni have proposed in [3] schemes to reduce redundant rebroadcasts and differentiate timing of rebroadcasts to alleviate this problem. They have shown that in most cases counter based flooding does not achieve high degree of reachability because each node has the same thresholds value to rebroadcast packets regardless of its surrounding, e.g. number of neighbors. The problem derives from the uniformity of the algorithm; every node has the same thresholds value to rebroadcast a given packet.

Proposed CBB Scheme

The idea of counter based scheme is based on the inverse relation between the expected additional coverage (EAC) and number of duplicate broadcast messages received [1]. A node is prevented from a retransmitting a broadcast packet when the EAC of the nodes rebroadcast is low. The idea of EAC is depicted in Figure 1.

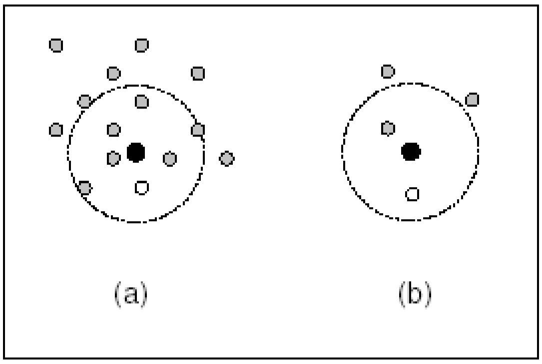

Figure 1: Expected Additional Coverage Example.

The hollow shaped nodes are source nodes that initiate the broadcast transmission and solid black nodes are nodes we use to clarify our ides ; we will refer to them as black-a and black-b. Apparently, the neighborhood density of black-a is higher than black-b. Therefore, the number of duplicate broadcast packets that would be received by black-a is higher as well. Moreover nodes within transmission range of black-a would have been reached by other forwarding nodes. Therefore, the EAC of black-a is lower than the EAC of black-b.

In counter based scheme, when a node receives a flooding packet, it will wait for random assessment delay (RAD). During this period the counter is counting the number of packets. The length of RAD is randomly chosen from uniform distribution between from 0 to Tmax seconds where, Tmax is the maximum delay time. When RAD expires, the counter does not reach threshold k, the node will retransmit the packet.

We have following remarks on existing counter-based broadcasting methods. The topology of MANET is often random and dynamic with varying degree of node density in various regions of the network as shown in Figure 2. The network may contain sparse and dense regions. In dense regions, multiple nodes share similar transmission range. Therefore the thresholds control the frequency of rebroadcasts and thus might save network resources without affecting delivery ratios. Note that in sparse region there is much less shared coverage; thus some nodes will not receive all the broadcast packets unless the threshold parameter is low. Therefore, fixed counter threshold approach suffers from unfair distribution of C since every node is assigned the same value of C regardless of its local topological characteristics. Ideally, the threshold value *c* should be high if a node located in a dense region while relatively low if a node located in a sparse region. If *c* is too high reachability might be poor while if *c* is set too low, many redundant rebroadcasts might be generated. While using small threshold values provides significant broadcast savings. Unfortunately, the reachability will be poor. There exist a tradeoff between reachability and saved broadcast.

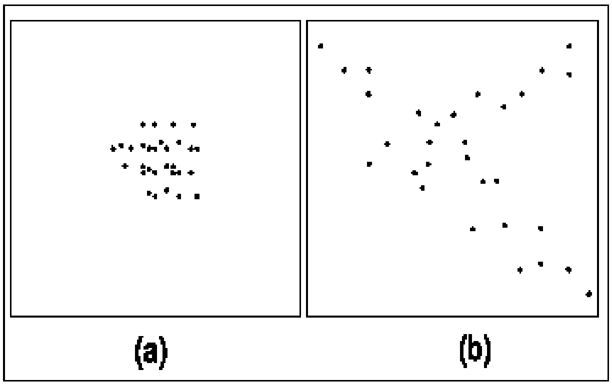

Figure 2: Example of changeable network topology (a) Dense region with 30 nodes (b) Same region with nodes forming several sets of sparse region

In order to achieve both high saved broadcast and high reachability when network topology changes frequently, the threshold should be set low for the nodes located in sparse regions and high for the nodes located in dense regions. The need for dynamic adjustments thus rises. Accordingly, sparse regions need a higher chance to rebroadcast than dense networks. This could be achieved by doing following modifications to fixed counter threshold approach. For dense region, a large threshold value C2 is used. For sparse region, a small threshold value C1 is used.

A high number of neighbors implies that the hosts in dense region, a low number of neighbors imply that the hosts in sparse region. That means we increase the counter-based threshold value if the value of the number of neighbors is too high. Similarly, we decrease the counter based threshold value if the value of number of neighbors is too high.

The proposed algorithm dynamically adjusts the counter based threshold value C at each mobile host according to the value of the local number of neighbors. The value of threshold changes when the host moves to a different neighborhood. A straightforward method for gathering neighborhood information at a given node involves the periodic exchange of Hello packets between neighbors to construct a one-hop neighbors list at the nodes. The proposed algorithm is a combination of counter-based and knowledge-based methods.

On hearing a broadcast packet m at node X for the first time, it does not immediately broadcast the packet. It waits for Random assessment delay (RAD). It finds the degree of X that is the number of neighbors of node X. If the degree of node X is less than the average number of neighbors (that means the current node is located in a sparse network), then the value of counter threshold (C1) is set to low value. If the degree of node X is greater than or equal to the average number of neighbors (that means the current node is located in a dense network), then the value of counter threshold (C2) is set to high value. During RAD, the counter is counting the number of repeated packets received. When the RAD expires, if counter c is less than threshold, the packet is broadcasted. Otherwise the packet is dropped. Additionally the values C1 and C2 are selected in a way that considers the expected additional coverage EAC. That is C2 (dense network threshold) should be in a way larger than C1 (sparse network threshold) in order to redundancy in a dense area.

We present an estimate of average neighbor number as the basis for the selection of threshold as given in Eq. (1). Let A be an area of an ad hoc network, N be the number of mobile nodes in the network and R be the transmutation range. The average number of neighbor's n can be obtained as shown below [6]

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

Equation 1

Performance Evaluation

We evaluate the performance of our proposed algorithm using NS-2 simulator. NS-2 is a discrete event simulator targeted at networking research for wired and wireless networks [9]. This research work suggests and investigates the performance of new counter based flooding algorithms where the threshold values at a node is dynamically adjusted as per the node coverage distribution and movement using one-hop neighborhood information to increase reachability and saved rebroadcast.

Simulation Parameters

The parameters used in the following simulation experiments are listed in Table 1. Each node in the network has a constant transmission range of 250 meter. The MAC layer scheme follows the IEEE 802.11 MAC specification. The simulation is allowed to run for 900 seconds for each simulation scenario. We have used the broadcast mode with no RTS/CTS/ACK mechanisms for all packet transmissions including Hello and DATA packets. The movement pattern of each node follows the random way-point model. Each node moves to a randomly selected destination with a constant speed between 0 and the maximum speed. When it reaches the destination, it stays there for a random period and starts moving to a new destination.

Table 1

Parameter	Value
Network Area	800*800
Transmitter range	250 meter
Simulation Time	900 sec
Channel Bandwidth	2 Mb/sec
Pause time	2 ms
Maximum speed	20 m/sec
Mobility model	Random way point
Number of nodes	20,40,60,80,100, 120

Performance Measures

The performance of flooding algorithm can be measured by a variety of metrics [1,2,3,4]. A commonly used metric is the number of message re-transmissions with respect to the number of nodes in the network. 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 [6].

***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 $(r - t)/r$.

***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.

Performance Analysis

The objective of this work is to present the performance of proposed algorithm using fixed counter based broadcasting algorithm as well as blind flooding algorithm. Our main idea is to reduce the rebroadcasting number. To attain the objective, we vary the density by increasing number of nodes deployed over a fixed area of 800 * 800 m. The number of nodes has been varied from 20 to 120 in steps of 20 nodes with each node moving at a speed 0f 2 m/sec. To reduce traffic load, one node was randomly chosen to initiate the broadcast process at a sending rate of 2 packets per second.

Effect of Threshold

In this section, we evaluate the effect of threshold on the performance of proposed counter based flooding scheme. In this study, we evaluated the performance by changing the dense threshold to higher value over increasing number of nodes. The number of nodes has been varied from 20 to 120 in steps of 20 nodes. Figure 3 and Figure 4 presents the saved Broadcast and Reachability respectively, showing the effect of dense threshold.

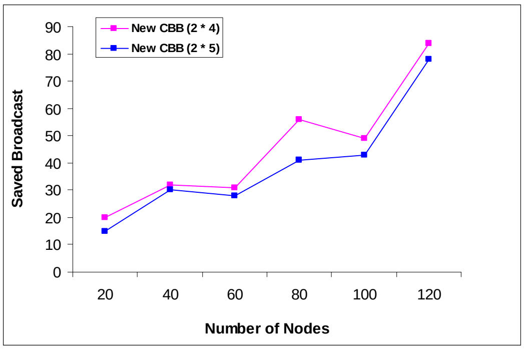

Figure 3: Saved Broadcast showing the effect of Threshold

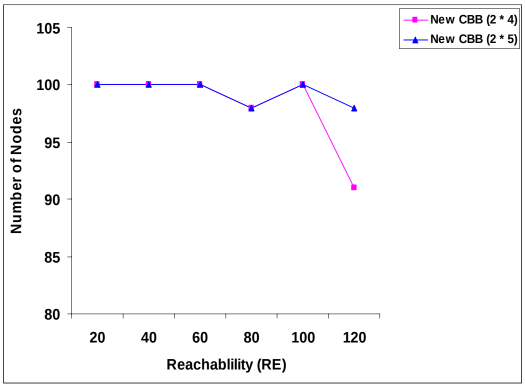

Figure 4: Reachability showing the effect of Threshold

The higher the dense threshold lower be the saved broadcast. But higher threshold value achieves more reachability as compared lower threshold in dense region. Lower the dense threshold higher is the saved broadcast, but results in poor reach-ability in dense region as compared to higher threshold.

Conclusion

The proposed counter based flooding algorithm in mobile ad hoc networks (MANETs) is devised to improve the saved Rebroadcast. The algorithm determines the counter threshold by considering the network density. In order to increase the saved rebroadcasts, the threshold of low density nodes is decreased while that of high density nodes is increased. We also evaluated the effect of threshold on the performance of proposed counter based flooding scheme. Lower the dense threshold higher is the saved broadcast, but results in poor reachability in dense region as compared to higher threshold. The higher dense threshold lower be the saved broadcast. But higher threshold value achieves more reachability as compared lower threshold in dense region. The optimal threshold value has significant effect on the overall performance of the proposed algorithm.

As a continuation of this research, further refining the threshold using more refined levels for nodes density regions, would lead to an improvement in the performance of proposed counter based flooding.

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