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Improvement to Efficient Counter-based Broadcast Scheme through Random Assessment Delay Adaptation for MANETs

Aminu Mohammed[1], Mohamed Ould-Khaoua[2], and Lewis M. Mackenzie[1]
[1]Department of Computing Science, University of Glasgow, Glasgow, G12 8RZ, U.K
[2]Department of Electrical & Computer Engineering, Sultan Qaboos University, AL-Khodh 123, Muscat, Oman
[1]*[maminuus, lewis] @dcs.gla.ac.uk;* [2]*mok@squ.edu.om*

Abstract

Flooding, the process in which each node retransmits every uniquely received packet exactly once is the simplest and most commonly used mechanism for broadcasting in mobile ad hoc networks (MANETs). Despite its simplicity, it can result in high redundant retransmission, contention and collision, a phenomenon collectively referred to as broadcast storm problem. To mitigate this problem, several broadcast schemes have been proposed which are commonly divided into two categories; deterministic schemes and probabilistic schemes. Probabilistic methods are quite promising because they can reduce the number of redundant rebroadcast without any control overhead. In this paper, we investigate the performance of our earlier proposed efficient counter-based broadcast scheme by adapting its random assessment delay (RAD) mechanism to network congestion. Simulation results revealed that this simple adaptation achieves superior performance in terms of saved rebroadcast, end-to-end delay and reachability.

1. Introduction

Mobile Ad hoc Networks (MANETs) are wireless networks formed by an autonomous system of mobile nodes that are connected via wireless links without using an existing network infrastructure or centralized administration. The nodes are free to move randomly and act as end points as well as routers to forward packets in a multi-hop environment where all nodes may not be within the transmission range of the source. Scenarios that might benefit from MANETs technology includes rescue/emergency operations in natural or environmental disaster areas, military operations, mobile conference, and home networking [1].

Broadcasting is a means of diffusing a message from source node to all other nodes in the network. It is a fundamental operation in MANETs and is extensively used in route discovery, address resolution, and many other network services in a number of routing protocols [2]. For example, ad hoc on demand distance vector (AODV)[3], dynamic source routing (DSR)[4], zone routing protocol (ZRP)[5], and location aided routing (LAR)[6] use broadcasting or its derivative to establish routes. Other routing protocols, such as the temporally-ordered routing algorithm (TORA) [7], use broadcasting to transmit an error packet for invalid routes.

These protocols typically assume a simplistic form of broadcasting called flooding, in which each mobile node retransmits every unique received packet exactly once. Despite its simplicity, it can result in high redundant retransmission, contention and collision, a phenomenon collectively referred to as the *broadcast storm problem*, which can greatly increase the network communication overhead [8]. To mitigate this problem, several broadcast schemes have been proposed [4-6]. These schemes are commonly divided into two categories; *deterministic schemes* and *probabilistic schemes*. Deterministic schemes use network topological information to build a virtual backbone that covers all the nodes in the network. In order to build a virtual backbone, nodes exchange information, typically about their immediate or two hop neighbours. However, they incur a large overhead in terms of time and message complexity for building and maintaining the backbone, especially in the presence of mobility.

Probabilistic schemes, in disparity, rebuild a backbone from scratch during each broadcast. Nodes make instantaneous local decisions about whether to broadcast a message or not using information derived only from overheard broadcast messages. Consequently these schemes incur a smaller overhead and demonstrate superior adaptability in changing environments when compared to deterministic schemes [6]. However, these schemes have poor reachability as a trade-off against overhead.

Several probabilistic schemes have been proposed in the past [8, 9]. These include probability-based,

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counter-based, location-based, distance-based and hybrid-based schemes [8-12]. In probability-based scheme, a mobile node rebroadcasts a message according to certain probability while in counter-based schemes messages are rebroadcast only when the number of copies of the message received at a node is less than a threshold value. On the other hand location-based and distance-based schemes exploit position information or distance information between nodes to reduce the number of redundant retransmissions. However, nodes need to be equipped with a Global Positioning System (GPS) or a Received Signal Strength Indicator (RSSI) which incur more cost. Recently, hybrid schemes [13, 14] are proposed which combines the advantages of pure probabilistic and counter-based schemes to yield a significant performance improvement.

In this paper, we investigate the effect of adapting RAD value to network congestion on the performance of our scheme [13], called *Efficient Counter-based Broadcast Scheme* (ECS). To adapt ECS's RAD to congestion levels each node keeps track of the number of packets received per second. We compare this scheme against simple flooding, ECS and counter-based scheme. Simulation results reveal that this simple modification can achieve better performance in various network situations.

The rest of the paper is organized as follows: In Section 2, we introduce the related work on probabilistic and counter-based broadcasting. The description of our scheme and its RAD adaptation is presented in Section 3. We evaluate the performance of the scheme and present the simulation results in Section 4. Finally, concluding remarks are presented in Section 5.

2. Related work

This section sheds some light on the research work related to probabilistic and counter-based broadcasting schemes.

Ni *et al* [8] proposed a probability-based scheme to reduced redundant rebroadcast by differentiating the timing of rebroadcast to avoid collision. The scheme is similar to flooding, except that nodes only rebroadcast with a predetermined probability P. Each mobile node is assigned the same forwarding probability regardless of its local topological information. In the same work, counter-based scheme is proposed after analysing the additional coverage of each rebroadcast when receiving n copies of the same packet.

Cartigny and Simplot [12] have proposed an adaptive probabilistic scheme. The probability p for a node to rebroadcast a packet is determined by the local node density and a fixed value k for the efficiency parameter to achieve the reachability of the broadcast. However, the critical question thus becomes how to optimally select k, since k is independent of the network topology.

In Ni *et al.* follow-on work [9], the authors have described an adaptive counter-based scheme in which each node dynamically adjust its threshold value C based on its number of neighbors. Specifically, they extend the fixed threshold C to a function $C(n)$, where n is the number of neighbors of the node. In this approach there should be a neighbor discovery mechanism to estimate the current value of n. This can be achieved through periodic exchange of 'HELLO' packets among mobile nodes.

Zhang and Agrawal [10] have described a dynamic probabilistic broadcast scheme which is a combination of the probabilistic and counter-based approaches. The scheme is implemented for route discovery process using AODV as base routing protocol. The rebroadcast probability P is dynamically adjusted according to the value of the local packet counter at each mobile node. Therefore, the value of P changes when the node moves to a different neighborhood. To suppress the effect of using packet counter as density estimates, two constant values d and d_1 are used to increment or decrement the rebroadcast probability. However, the critical question is how to determine the optimal value of the constants d and d_1.

In recent work, Alieza et al [15] proposed a color-based broadcast scheme in which every broadcast message has a color-field, with a rebroadcast condition to be satisfied after expiration of the timer similar to counter-based scheme. A node rebroadcast a message with a new color assigned to its color-field if the number of colors of broadcast messages overheard is less than a color threshold μ.

Recently, in [14] an efficient counter-based scheme was proposed which combines the merits of probability-based and counter-based algorithms using a rebroadcast probability value of around 0.65 as proposed in [8, 11] to yield a better performance in terms of saved-rebroadcast, end-to-end delay and reachability. Furthermore, in follow-on work [13], they showed that a better rebroadcast probability value was around 0.5, which achieve better performance than their earlier scheme.

In this paper, we evaluate the performance of our counter-based scheme [13] by adapting the RAD value to network congestion. An overview of our scheme together with the RAD adaptation is presented in the next section.

3. Efficient counter-based broadcast scheme (ECS)

In this section, we present the efficient counter-based scheme (ECS) that mitigate the broadcast storm problem associated with flooding. The use of ECS for broadcasting enables mobile nodes to makes localized rebroadcast decisions on whether or not to rebroadcast a message based on both counter threshold and forwarding probability values. Essentially, this adaptation provides a more efficient broadcast solution in sparse and dense networks.

In ECS, a node upon reception of a previously unseen packet initiates a counter *c* that will record the number of times a node receives the same packet. Such a counter is maintained by each node for each broadcast packet. After waiting for a random assessment delay (RAD, which is randomly chosen between 0 and T_{max} seconds), if *c* reaches a predefined threshold *C*, we inhibit the node from this packet rebroadcast. Otherwise, if *c* is less than the predefined threshold, *C,* the packet is rebroadcast with a probability $P = 0.5$ as against automatically rebroadcasting the message in counter-based scheme. The use of a rebroadcast probability stem from the fact that packet counter value does not necessarily correspond to the exact number of neighbours of a node, since some of its neighbours may have suppressed their rebroadcast according to their local rebroadcast probability. For more details refer to [13].

3.1. RAD Adaptation

Essentially, selection of appropriate RAD time can play a vital role in the performance of any broadcast scheme. In original counter-based scheme [8], each node is assigned a fixed constant value T_{max} which is used to determine RAD value at random. Thus, node does not utilize any network information such as congestion or number of neighbors in determining this value. Clearly, higher RAD value is effective in increasing the delivery ratio in a congested network while lower RAD values are needed in non congested network. Adapting RAD in this way maximizes delivery ratio and minimizes end-to-end delay.

We realize that congestion can be obtained by increasing the packet size or increasing the packet generation rate or both. We choose to fixed the packet size but varied the packet generation rate because we anticipated that broadcast packets, as control type packets, to be generally small in size [11]. Therefore to adapt ECS's RAD Tmax to congestion levels, each node keeps track of the number packets received per second. Table 1 provides average packet reception rate for our scheme given various packet origination rates.

Table I. Average Packet Reception Rate for different Origination Rate

Packet Origination Rate	Reception Rate (Pkt/sec)
10	51
20	102
30	147
40	191
60	287
70	321
80	367

Our simple adaptation called *adaptive ECS* is as follows: if the node is receiving more than 200 packets per second on average (which roughly correlates to a broadcast packet origination rate of 50 packets per second), the node uses a RAD T_{max} time of 0.05 seconds. Otherwise, the node uses a RAD T_{max} time of 0.01 seconds.

4. Performance analysis

In order to verify the effect of the RAD adaptation, we perform simulation using ns-2 packet level simulator (v.2.29) [16]. We provide a side by side implementation with ECS, counter-based, and flooding, and compare the results against those obtained from the three approaches. The performance analysis is based on the assumptions widely used in literature [4, 17].

1. Nodes are identical
2. All nodes participate fully in the protocol of the network. In particular each participating node should be willing to forward packets to other nodes in the network.
3. Links are bidirectional and no selfishness in the network.
4. Mobile nodes operate in flat squared simulation area.
5. The transmission range is fixed at 250m in all nodes to approximately simulate networks with a multi-hop networks.

4.1. Simulation parameters and metrics

The radio propagation model used in this study is the ns-2 default, which uses characteristic similar to a commercial radio interface, Lucent's WaveLAN card with a 2Mbps bit rate [18]. The distributed coordination function (DCF) of the IEEE 802.11 protocol [19] is utilized as MAC layer protocol while random waypoint model [20] is used as the mobility model. In a random waypoint mobility model, each node at the beginning of the simulation remains stationary for a pause time seconds, then chooses a random destination and starts moving towards it with a randomly selected speed from a uniform distribution [0, max-speed]. After the node reaches its destination, it again stops for a pause-time interval and chooses a new destination and speed. This cycle repeats until the simulation terminates. Because it takes time for the random way point model to reach a stable distribution of mobile nodes [21], the modified random waypoint mobility model [20] used take care of this node distribution problem. The simulation is allowed to run for 900 seconds for each simulation scenario. Other simulation parameters that have been used in our experiment are shown in Table II.

Table II. Simulation Parameters

Simulation Parameter	Value
Simulator	NS-2 (v.2.29)
Transmission range	250 meters
Bandwidth	2 Mbps
Interface queue length	50
Packet size	512 byte
Traffic type	CBR
Packet rate	10-80 packets/sec
Topology size	1000 x 1000 m^2
Number of nodes	20, 40, …, 100
Number of trials	30
Simulation time	900 sec
Maximum speed	3 m/s

Each data point represents an average of 30 different randomly generated mobility models with 95% confidence interval. We evaluate the broadcast schemes using the following performance metrics:

- Reachabilty (RE) – This is the percentage of nodes that received the broadcast message to the total number of nodes in the network[22].
- Saved Rebroadcast (SRB) – This is defined as $(r - t)/r$, where r and t are the number of nodes that received the broadcast message and the number of nodes that transmitted the message respectively[22].
- End-to-end delay - is the average time difference between the time a data packet is sent by the source node and the time it is successfully received by the destination node.

4.2. Simulation results

Extensive simulation experiments have been carried out to compare the performance of the adaptive ECS against ECS, flooding and counter-based schemes using two different set of network conditions. First we evaluated the impact of density on the performance of the schemes. First, we evaluated the impact of density by varying the number of nodes within the network area from 20 - 100 nodes using traffic rate of 10 packets/second and 3m/s node speed.

We assess the impact of network density on the performance of the different broadcast schemes by varying the number of nodes from 20 to 100 deployed randomly on a fixed area of 1000 x 1000 m^2.

Figure 1 demonstrates the effects of density on the saved rebroadcasts achieved by the four broadcast schemes. The figure shows that adaptive-ECS has superior saved rebroadcast performance than ECS in sparse networks and comparable performance in dense network. This might be due to increase in the number node covered within the network. In sparse network most of the schemes saved less rebroadcast as a result of less connectivity within the network.

Figure 2 depicts the degree of reachability of the different broadcast schemes. The figure shows the reachability achieved by the schemes as the node densities increases. The result shows that reachability increases when network density increases regardless of which scheme is used. The flooding and counter-based algorithms have the best performance. Adaptive-ECS has a better reachability performance than ECS.

Figure 3 depicts the effects of density on end-to-end delay as network density increases. It shows that the delay is largely affected by network density and thus, increases with increase in density. Adaptive-ECS has least end-to-end delay as a result of the RAD adaptation which insures that low RAD values are utilize when network is not congested while high RAD are used when network is congested.

In Figure 4 we present the effect of density on number of retransmission node which is a complementary metric to saved rebroadcast. The figure depicts that number of retransmission nodes increases with increasing density. However, unlike saved rebroadcast the less the number of retransmitting nodes the better for the algorithm in terms of performance because few nodes rebroadcast and therefore higher saved rebroadcast and less collision and contention in the network. Adaptive-ECS and ES have almost the same number of retransmission nodes.

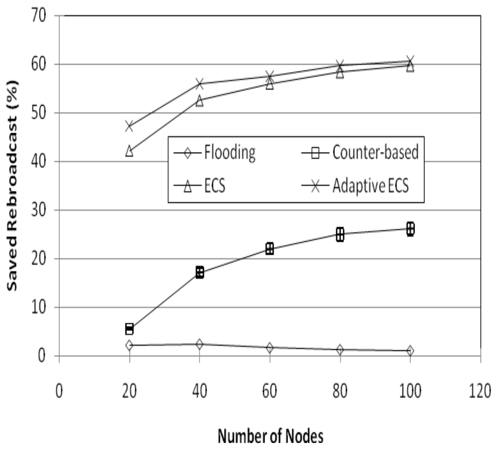

Figure 1. Impact of density on saved rebroadcast using 3 m/s node speed and 10 packet/second traffic rates.

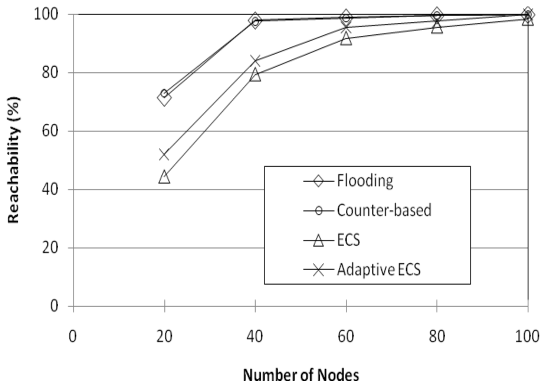

Figure 2. Impact of density on reachability using 3 m/s node speed and 10 packet/second traffic rate.

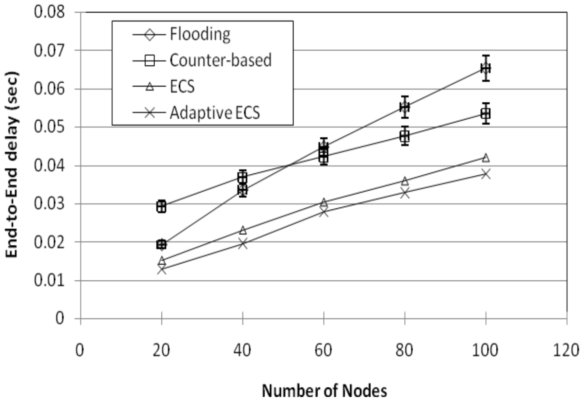

Figure 3. Impact of density on end-to-end delay using 3 m/s node speed and 10 packets/second traffic rate.

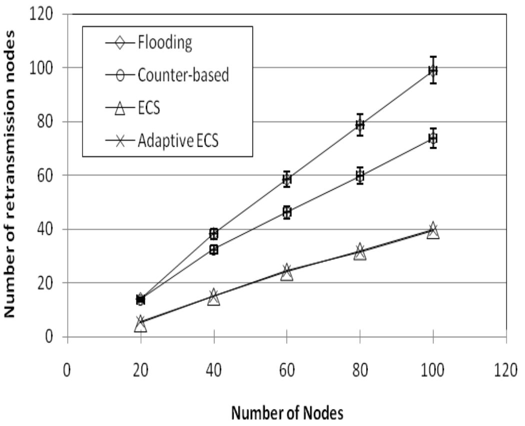

Figure 4. Impact of density on number retransmission nodes using 3 m/s node speed and 10 packets/second traffic rate.

5. Conclusions

In this paper, the efficient counter-based scheme (ECS) was focused on as broadcast scheme for mobile ad hoc networks that mitigate the broadcast storm problem associated with flooding. A simple RAD (random assessment delay) adaptation to network congestion has been proposed to improve the original RAD used by both counter-based scheme and ECS. Simulation results revealed that this simple adaptation minimizes end-to-end delay and maximizes delivery ratio. Thus, achieving superior performance in terms of saved rebroadcast, end-to-end delay and reachability.

There are a couple of areas for future work involving our improvement to ECS. One area in which we see the potential for even further improvement is to make the adaptation of he RAD value to other network parameters like number of neighbours, node speed and transmission range. Another area of future work is to investigate further the effect of this adaptation on increasing network congestion and mobility.

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