al-Humoud, S.O. and Mackenzie, L.M. and Jamaldeen , A. (2008) *Neighbourhood-aware counter-based broadcast scheme for wireless ad hoc networks.* In: IEEE GLOBECOM 2008, 30 Nov - 4 Dec 2008, New Oreans, LA, USA.

Neighbourhood-Aware Counter-Based Broadcast Scheme for Wireless Ad Hoc Networks

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Abstract

Broadcasting is a vital operation in mobile ad hoc networks (MANETs) and it is crucial to enhance its efficiency to ensure successful deployment. Although flooding is ideal for broadcast operations due to its simplicity and high reachability it suffers from high packet collision which can degrade network performance severely. Counter-based broadcast schemes have been introduced to alleviate the limitations of flooding. This study introduces an enhancement to counter-based broadcast by adjusting the threshold value and the Random Assessment Delay (RAD) using minimal neighbourhood information.

Keywords- MANETs, Broadcast, Flooding, Counter-based, Mobility, Density.

1. Introduction

A MANET (Mobile Ad hoc NETwork) is an autonomous system consisting of a set of mobile hosts that are free to move without the need for a wired backbone or a fixed base station. Broadcasting is the process by which one node sends a packet to all other nodes in the network. Broadcasting may be used for discovering neighbours, collecting global information, naming, addressing, and sometimes helping in multicasting [1]. In a MANET in particular, due to node mobility, broadcasting is expected to be performed more recurrently. For example, broadcast service could be used for paging a particular host, sending an alarm signal, and finding a route to a particular host [2]. Moreover, Ad hoc On-Demand Distance Vector Routing (AODV) [3], Dynamic Source Routing (DSR) [4], and Zone Routing Protocol (ZRP) [5], are some examples of routing protocols that rely on broadcasting for route discovery.

Blind flooding is the basic approach to broadcasting where every node in the network forwards the received packet exactly once. Blind flooding is simple and guarantees high reachability, but at the expense of inefficient utilisation of system resources such as channel bandwidth and battery power of mobile nodes. The approach is associated with high redundant transmissions that can cause high channel contention and packet collisions in the network. This phenomenon of blind flooding is referred to in the literature as *broadcast storm problem* [2].

Several methods have been proposed to alleviate the broadcast storm problem associated with blind flooding [2]. However, these methods can be put into two categories. The first category of broadcast schemes is referred to as non-deterministic broadcast schemes. These schemes mitigate the network congestion levels by reducing the number of retransmitting nodes. This is achieved by inhibiting some intermediate nodes from forwarding the received broadcast packets using some local topological characteristic. Examples of the non-deterministic broadcast schemes include counter-based, area-based, distance-based, and probability-based schemes [2].

The second category of broadcast schemes predetermines a set of forwarding nodes based on global topological information of the network. These schemes are referred to as deterministic broadcast schemes. Examples of deterministic broadcast schemes include pruning [6], multipoint relaying [7], node-forwarding [8], neighbour elimination [9], and clustering [10]. In general the nodes using non-deterministic broadcast schemes make instantaneous local decisions about whether to broadcast a packet or not using information derived only from overheard broadcast packets. Consequently non-deterministic schemes incur a small communication overhead and can adapt to changing environments when compared to deterministic schemes [11].

In this study we propose a new efficient counter-based broadcast scheme that aims at reducing the broadcast storm problem without degrading the reachability. Our new broadcast scheme dynamically adjusts the counter threshold at a forwarding node based on its local topological characteristics. Our simulation results reveal that the proposed scheme can achieve better performance in terms of saved

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rebroadcast while providing comparable reachability when compared against the traditional counter-based scheme and the blind flooding based broadcast.

The rest of this paper is organised as follows. Section 2 will be on the related work of the counter-based rebroadcast. Section 3 outlines our proposed adjusted-counter-based scheme. Section 4 presents the simulation results of the proposed algorithm. Finally, section 5 is our future directions and conclusion.

2. Related work

Counter-based broadcasting was initially proposed in [12] as a mechanism to reduce redundant rebroadcast packets and alleviate problems associated with blind flooding. The basic idea of the counter-based scheme is based on the inverse relation between the *expected additional coverage* (EAC) and number of duplicate broadcast packets received [2,12]. A node is prevented from retransmitting a received broadcast packet when the EAC of the node's rebroadcast is low [13].

The counter-based broadcasting scheme works as follows: when receiving a packet for the first time a counter c is initiated to keep track of the number of duplicate packets received and a *random assessment delay* (RAD) timer is also initiated. The RAD is a jitter randomly chosen between 0 and T_{max} seconds, where T_{max} is the maximum time delay. This delay is necessary for two reasons. First, it allows nodes adequate time to receive redundant packets and assess whether to rebroadcast. Second, the randomized scheduling prevents collisions [14]. As soon as the RAD timer expires the counter c is compared against a fixed threshold value C; broadcast is inhibited if $c \geq C$.

An adaptive counter-based scheme was proposed in [1]. The authors have suggested extending the traditional fixed counter threshold scheme to incorporate the number of neighbours at a node. Specifically, the decision to forward the broadcast packet is determined by the function $C(n)$ where n is the number of neighbours of the forwarding node. However, they have stated that the function $C(n)$ is undefined [1]. Other variants of the counter-based broadcast scheme include color-based [15] scheme and the distance-aware counter-based scheme [16].

3. Adjusted Counter-Based Broadcast

Existing counter-based broadcasting schemes use a fixed threshold value to alleviate the shortcomings of pure flooding; however, we have the following remarks on counter-based broadcast schemes with existing fixed threshold value. First, the topology of MANETs is often random and dynamic with varying degree of node density in various regions of the network. 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. Second, there exist a trade-off between reachability and saved rebroadcast. While using small threshold values provides significant broadcast savings, unfortunately, the reachability will degrade sharply in a sparse network. Increasing the value of C will improve the reachability, but, once again, the amount of saving will be sacrificed [1]. Third, according to my knowledge, there is no proposed method that dynamically and autonomously changes the counter threshold value.

Accordingly, sparse networks need a higher chance to rebroadcast than dense networks. This could be achieved by one of two ways or a combination of them. First, altering the threshold value C to adapt to network density where a small threshold value C_2 is used for dense networks (high $\boldsymbol{n}$) and a large threshold value C_1 for sparse networks (low $\boldsymbol{n}$). Second, altering the *Random Assessment Delay* (RAD) where a small RAD is used for dense networks (high $\boldsymbol{n}$) and a large RAD for sparse networks (low $\boldsymbol{n}$). Moreover, a *Random Factor* (RF) is introduced as shown in Equation 1 where x is a random number between zero

$$T_{max} = x / RF \qquad (1)$$

and one.

The adjusted counter-based broadcast algorithm works as follows: when receiving a broadcast packet for the first time a node sets the RAD, which is randomly chosen between 0 and 1 second and initiates the counter to one. Following, the node checks the number of neighbours n against the average number of neighbours avg; if $n < avg$ then the network is considered sparse and $C1$ is selected as the threshold value and RF is set to RF_1 , otherwise the threshold value is set to $C2$ and RF is set to RF_2. Additionally, the values $C1$ and $C2$ are selected in a way that considers the expected additional coverage EAC. That is, $c1$ (sparse network threshold) should be in a way larger than $c2$ (dense network threshold) in order for the node to have a higher chance to rebroadcast in a sparse area whilst the EAC of the sparse network is higher than that of the dense network as we mentioned with an example previously. The same principle applies to RAD, that is, RF_1 is selected to be smaller than RF_2. After selecting the threshold value and during the RAD, the counter is incremented by one for each redundant packet received. When the RAD expires the counter is checked against the threshold value, if the counter is less than or equal to the threshold, the packet is rebroadcast. Otherwise, it is simply dropped.

While blind flooding ensures that every node in the network receives the broadcast packet (i.e. high reachability) at the cost of high communication overhead (i.e. low save rebroadcast), our proposed scheme aims at significantly reducing the communication overhead while still achieving comparable reachability when compared to blind flooding. To achieve this, our broadcast approach utilizes neighbourhood information, i.e. number of neighbours in particular to select the best counter threshold. The *number of surrounding neighbours* (***n***) a node have is known by periodic exchange of HELLO packets among neighbouring nodes.

4. Performance Analysis

We evaluate the performance of our proposed algorithm using the ns-2 network simulator [17]. Ns-2 is a discrete event simulator targeted at networking research for both wired and wireless networks. Moreover, ns2 has been used by most researchers for performance evaluation in MANETs research [14,16,15]. The present study investigates the performance impact of system parameters on the proposed algorithms; notably node mobility and network density. For system parameter under investigation, the counter-threshold values are (2,3), (2,4), (3,4) [18] comparing our scheme to the fixed counter-based threshold value of 2 [14]. The RF (RF_1, RF_2) values are varied over the range (100, 10), (100, 1) and (10, 1) [13]. The results for blind flooding have been added for the sake of completeness

4.1. Simulation parameters

Table 1 shows some of the essential simulation parameters that have been used in the evaluation of our protocols.

Table 1: Simulation parameters

Simulation parameter	Value
Simulator	ns-2 (version 2.33)
Transmission range	250 meters
Simulation Time	100 sec
Packet Rate	2 packets per sec per node

4.2. Performance Measures

Below is the performance metrics used to evaluate the performance of the proposed broadcast approach:

- *Reachability* (RE), defined as *r/e*, where *r* is the number of hosts receiving the broadcast packet and *e* is the number of mobile hosts that are reachable, directly or indirectly, from the source host.
- *Saved Rebroadcast* (SRB), defined as *(r − t)/r*, where *r* is the number of hosts receiving the broadcast packet, and *t* is the number of hosts that actually transmitted the packet.
- *Average latency* (Delay), which is the interval from the time the broadcast, was initiated to the time the last host finished its rebroadcasting.

4.3. Results and Discussion

To analyze the performance of our proposed Adjusted Counter Based approach (ACBase), we divided the results into two parts: first is the impact of nodal mobility, second is the impact density variation. Additionally, in each part we focus on the effect of different pairs of (A) threshold values and (B) RAD values on our algorithm.

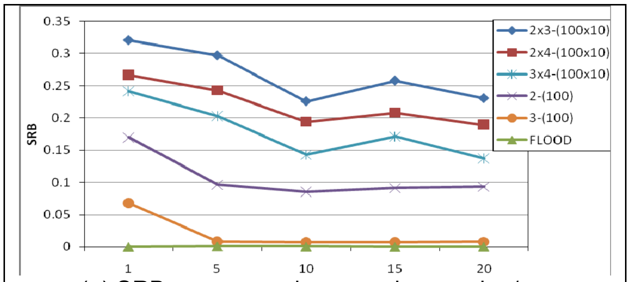
4.3.1. Mobility Impact.

We investigate the effects of mobility on the performance of the proposed algorithms by varying the maximum nodal speed over a range of 1, 5, 10, 15, and 20 m/sec. The number of nodes deployed over the area of 1500m x 500m had been fixed at 50. Ten nodes were randomly selected to initiate the broadcast process. Each node sends 2 packets/ sec. Packet size of 512 byes has been used. Following is the threshold study where the RF values are fixed.

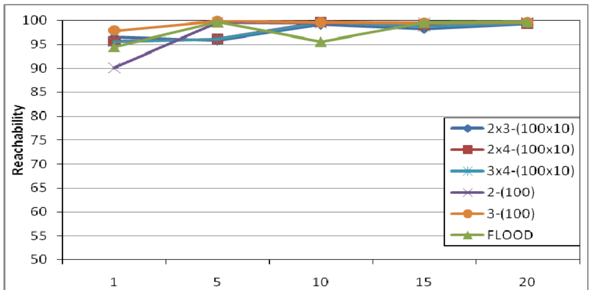
A. Mobility and Threshold study:

Figure1(a) depicts the SRB verses maximum nodal speed. As can be shown in the figure ACBase can achieve high SRB when compared against the counter-based and blind flooding. For example, the SRB of ACBase with thresholds (2x3) is around 33% and that of counter-based is around 17% at low mobility of 1m/sec. At medium to high mobility (i.e. from 10m/sec) the SRB of ACBase is around 25% and that of counter-based is 10%. In addition, the SRB values for ACBase decrease with the increase of the threshold values. For instance, the SRB of ACBase (2x3) is 10% higher than the SRB of ACBase (3x4).

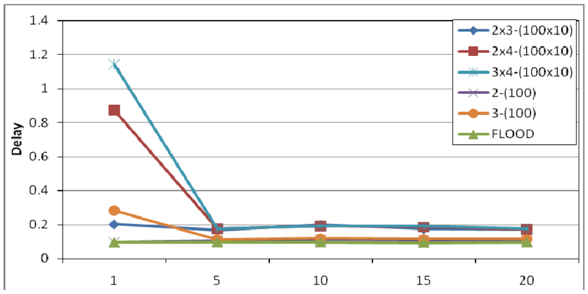
Figure1(b) show reachability versus mobility. All the algorithms present similar trends of reachability for all node speeds. However, reachability is low (i.e. 90 % for the counter-base and 95% for the ACBase) when



(a) SRB versus maximum node speed m/sec



(b) Reachability versus maximum node speed m/sec



(c) Delay versus maximum node speed m/sec

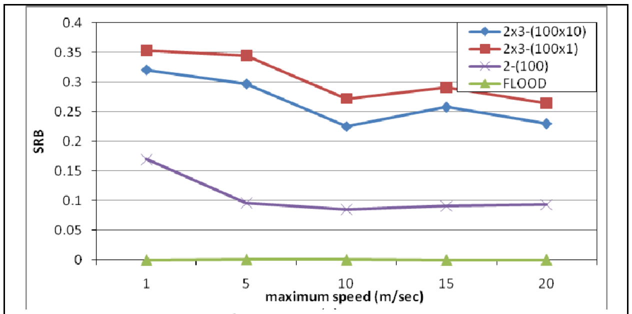
Figure 1: Study of Mobility and threshold value

nodes mobility is low. This is due to poor connectivity in low mobility environments. In a high mobility environment with speed of 20 m/sec, the reachability for all the algorithms is around 100%.

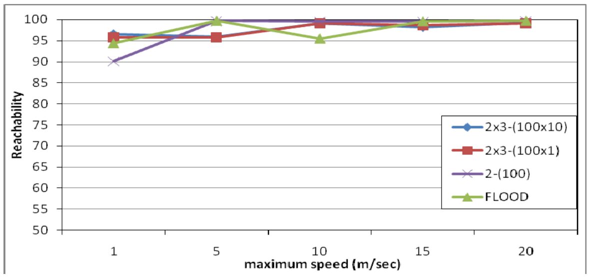
Figure1(c) investigates the effects of mobility and variable threshold values on average latency (delay for short) of the protocols. The figure shows that the ACBase approach is out performed by both counter-based scheme and blind flooding for low mobility scenarios. But the delay for all the protocols remains fairly constant across medium to high mobility.

B. Mobility and RAD Study:

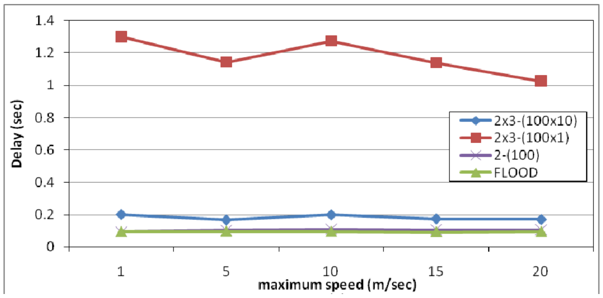
Figure2(a) depicts the SRB versus maximum nodal speed. As can be shown in the figure ACBase can achieve high SRB when compared against the counter-based and blind flooding when the mobility of nodes is increased from low to medium mobility. For example, the ACBace SRB with RFs of (100, 1) is around 35% and that of counter-based is around 17% at low mobility of 1m/sec.



(a) SRB versus node mobility



(b) Reachability versus node mobility



(c) Delay versus node mobility

Figure 1: Study of Mobility and RAD

At medium to high mobility (i.e. from 10m/sec) the SRB of ACBase is around 25% and that of counter-based is 10%. Apparently there exist an inverse relation between SRB and the waiting time factor (RF). That is, SRB increases with the decrease of RF values. For instance, the SRB of ACBase with RFs of (100, 1) is about 3% higher that that of ACBase with RFs of (100, 10).

Figure2(b) show reachability versus mobility. All the algorithms present similar trends of reachability for all node speeds. However, the reachability is low (i.e. between 90 % and 95%) when nodes mobility is low. This is due to poor connectivity in low mobility environments. In a high mobility environment such as 20 m/sec, the reachability for all the algorithms is around 100%.

Figure2(c) investigates the effects of mobility and random delay factor on average latency (delay for short) of the protocols. The figure shows that the

ACBase approach is out performed by both counter-based scheme and blind flooding for mobility scenarios. But the delay for all the protocols remains fairly constant across all mobility. The figure also reveals that the delay incurred by ACBase is worsened when the RFs decreases from (100, 10) to (100, 1).

4.3.2. Density Impact.

This section evaluates the effects of node density on the performance of the proposed protocol. In this study we vary the density by increasing number of nodes deployed over a fixed area of 1500m x 500m. The number of nodes has been varied from 25 to 200 in steps of 25 nodes with each node moving at a speed between 0 and 5 m/sec. To reduce effects of traffic load, one node was randomly selected to initiate the broadcast process at a sending rate of 2 packets/ sec.

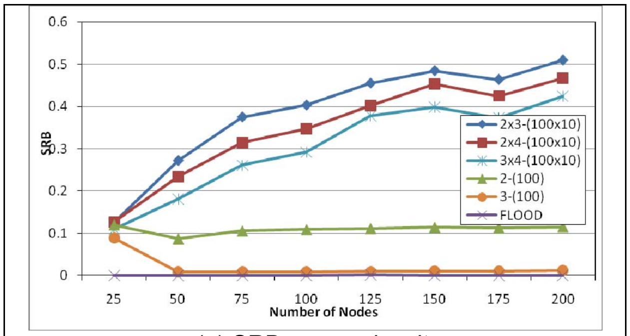
A. Density and Threshold study:

Figure3(a) presents SRB verses network density. The SRB of ACBase increases with increasing density. However, the SRB of counter-based and blind flooding remains almost flatten with increasing node density. This is due to the factor that the counter-base scheme uses fixed counter value and a fixed random factor for all the regions in the network. However, a node using ACBase sets these values low when in dense regions and high when in sparse regions of the network. At low density of 25 nodes, the ACBase and the counter-based scheme achieves similar SRB of around 10%. But at high density of 200 nodes, the ACBase (2x3) achieves superior performance of SRB reaching about 50%.

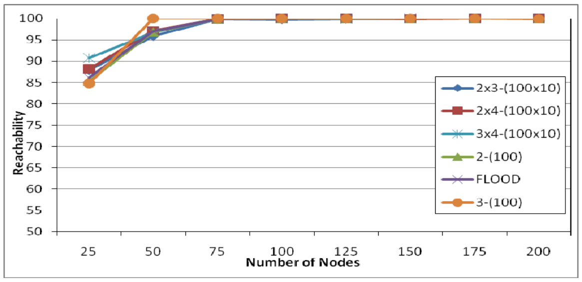
Figure3(b) shows the effects of network density on reachability. All the algorithms present similar trends of reachability with increasing network density. The reachability increases almost linearly from low to medium network density and reaching 100% at high network density. The poor reachability at low network density is due to poor connectivity suffered by sparse networks. In Figure3(c) we present results of the effects of density and threshold values on average latency. ACBase (2x3) achieves comparable performance in terms of delay with the counter-based and blind flooding across high network densities.

B. Density and RAD Study.

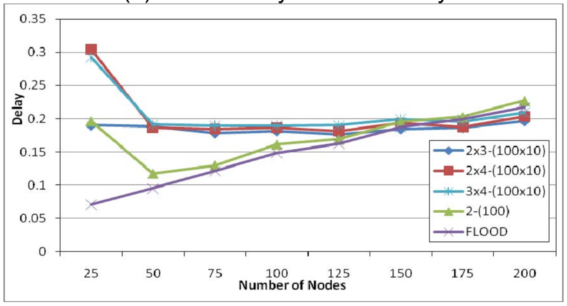
Figure4(a) presents SRB verses network density. The SRB of ACBase increases with increasing density. However, the SRB of counter-based and blind flooding remains almost flatten with increasing node density. This due to the factor that the counter-base scheme uses fixed counter value and fixed random factor for all the regions in the network. However, a node using ACBase set these values low when in dense region and high when in a sparse region of the network.



(a) SRB versus density



(b) Reachability versus density

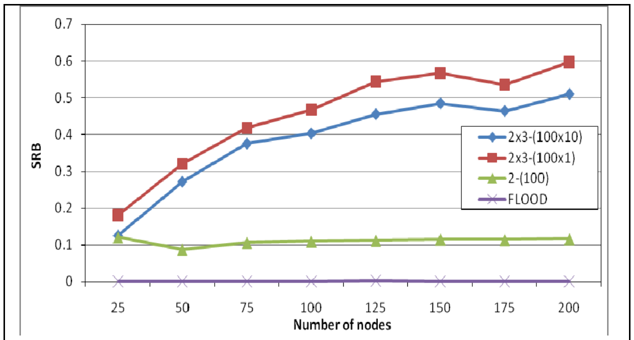


(c) Delay versus density

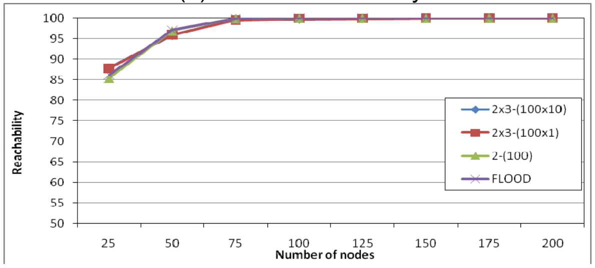
Figure 3: Study of Density and threshold values

At low density of 25 nodes, the ACBase with RFs of (100, 1) and the counter-based scheme achieves similar SRB of around 10%. But at high density of 200 nodes, the ACBase with RFs of (100, 1) achieves superior performance of SRB reaching about 60%.

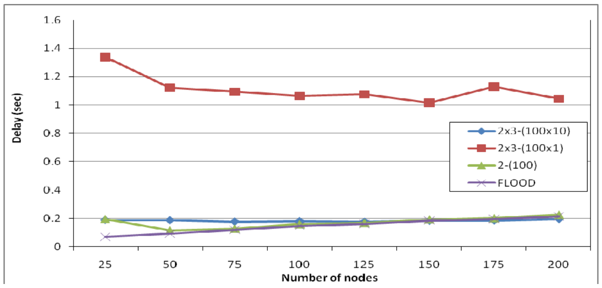
Figure4(b) shows the effects of network density on reachability. All the algorithms present similar trends of reachability with increasing network density. The reachability increases almost linearly from low to medium network density and reaching 100% at high network density. In Figure3(c) we present the effects of density and random factor on average latency. ACBase with RFs of (100, 10) achieves comparable performance in terms of delay with the counter-based and blind flooding across all network densities. However, the delay incurred by ACBase with RFs of (100, 1) is much higher, due to the factor of having high waiting time.



(a) SRB versus density



(b) Reachability versus density



(c) Delay versus density

Figure 4: Study of Density and RAD

5. Conclusion

This paper has analysed the impact of various threshold values on the performance of the proposed Adjusted Counter-Based broadcasting scheme in MANETs. We analysed our algorithm under three different variations: mobility, density, and traffic load. Moreover, the effect of alternative threshold values on SRB, Reachability and delay was investigated. ACBase broadcasting scheme scored a large gain in SRB compared to the fixed counter-based with a similar reachability and a slight loss in delay. As a continuation to this work, we plan to implement a MANET routing protocol that utilizes the new ACBase scheme.

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