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Simulation Model for Grid Based Broadcast Algorithm in Mobile Wireless Ad-Hoc Networks

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Abstract: In this paper we propose a simulation model for the grid-based broadcasting algorithm (GBB) for mobile wireless ad-hoc networks (MANETs). The proposed GBB algorithm [1] is based on a logical 2-dimensional grid view of the geographical region of the MANET. GBB algorithm minimizes the number of rebroadcasts by using gateway nodes for each grid cell. Only gateway nodes are responsible for rebroadcasting the message. In this study we have developed a simulation model based on NS2 simulator to measure the reachability, average end-to- end delay and the number of saved rebroadcast ratio and compare the results with the well-known probabilistic broadcasting algorithm (PROB). The simulation results showed that GBB has improved considerably compared to PROB in terms of the End-to-End delay, the number of saved rebroadcasts and the collision ratio under different traffic and mobility conditions.

Keywords: *Mobile Ad-Hoc Networks; Broadcasting; Position-Based Routing Grid-Based Routing.*

INTRODUCTION

A Mobile Ad Hoc Network (MANET) is a collection of wireless nodes communicating with each other in the absence of any fixed infrastructure. The study of MANETs is a developing area of research. Efforts have been taken for achieving efficient broadcasting in mobile ad hoc networks. Network broadcasting is the process in which one node sends a packet to all other nodes in the network. Various network algorithms are based on broadcasting including: routing, information dissemination and service/resource discovery. Since many systems have stringent end-to-end delay requirements, the design of low-latency and low overhead broadcasting schemes is essential to many practical applications.

A broad category of routing and broadcasting algorithms is the class of position-based algorithms [2-5]. These algorithms make use of the nodes' geographical positions to make routing decisions. Nodes are able to obtain their own geographical positions via Global Positioning System (GPS). This approach has become practical by the rapid development of hardware and software solutions for determining absolute or relative node positions in MANETs [6].

In this paper we propose a simulation model for the Grid-Based algorithm for MANETs called the (GBB) algorithm [1]. In the GBB algorithm, it is assumed each node knows only its position using the GPS system. The GBB algorithm uses a logical grid view of the geographical region and makes use of a new broadcast procedure, which covers all the grid cells of the grid network. The geographical region of the MANET is viewed as a 2-dimensional (2D) grid of cells as shown in Fig. 1. With the help of the broadcast procedure, the initiator of the broadcast message within a given cell broadcasts its message to nodes in neighboring cells (each cell has eight neighbor cells in the 2D grid). This first step is similar to that of other broadcasting algorithms such as those for flooding and probabilistic broadcasting. In the second step of the GBB algorithm, only one node (gateway node) per grid cell rebroadcasts the message. In the flooding algorithm, all the nodes which receive the message will rebroadcast it (broadcast storm problem) or few nodes will rebroadcast the message based on a specified probability to reduce the effect of broadcast storm in the probability based broadcast algorithms. In GBB, the problem of broadcasting to mobile MANET nodes is transformed into a problem of broadcasting to geographically fixed grid cells using only the gateway nodes as forwarders. A packet is forwarded from a node in a grid cell to nodes in neighboring grid cells repeatedly until it reaches all nodes in the 2D grid.

The remainder of the paper is organized as follows: section II presents a summary of related work; section III presents assumptions and notations; section IV presents an overview of the proposed GBB algorithm; section V gives a detailed implementation of GBB algorithm; section VI presents simulation model and some performance results; and section VII concludes the paper.

RELATED WORKS

The idea of treating the geographic area of a MANET as a logical grid of square-shaped cells has been used first in [7] to develop link-state routing, and then in [8] to develop location-aware routing. In [8], one mobile host in each cell (if any) is elected as the leader of the cell. Routing is then performed in a

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cell-by-cell manner through cell leaders. In the GBB algorithm we use a similar idea as in [8], but the difference is that within a cell there might be more than one cell leader (for different forwarding directions) and more importantly we do not have any election to select the leader nodes, which reduces substantially the cost of leader selection. The leader (we call it gateway) selection procedure is described in the next section.

In [9], broadcast algorithms in MANETs were categorized into four families: Simple Flooding, Probability-Based Methods, Area-Based Methods and Neighbor Knowledge Methods. We briefly give an overview of each category.

A. Simple Flooding

In a Simple Flooding [10, 11], one source node broadcasts a packet to all neighbors. Each of its neighbor's nodes rebroadcasts the packet reaches all network nodes. This technique does not solve the broadcast storm problem.

B. Probability Based Methods

Probabilistic Scheme: The Probabilistic scheme [12] is similar to Flooding, except that nodes only rebroadcast with a predetermined probability *p*. The fact that not all the nodes (only *p* percent of the node will rebroadcast) rebroadcast reduces the broadcast storm problem.

We will compare the performance of our GBB algorithm with the performance of this probabilistic scheme.

Counter-Based Scheme: Ni et al [12], the probability of rebroadcast is not fixed. Any receiving node counts the frequency of a reception for a given packet during a period of time RAD. If this frequency number is less than a threshold the packet is rebroadcast otherwise it will be dropped. In a dense area of the network, less nodes would rebroadcast; in sparse areas of the more nodes rebroadcast to improve the delivery ratio.

C. Area Based Methods [12]

This technique supposes that each node knows its own position using a GPS and the initial node or rebroadcast node adds its location to the header of the broadcast message. If the receiving node sees that the packet is sent from a close neighbor, it will not rebroadcast other it will rebroadcast the packet. The advantage of this technique is large area coverage faster.

D. Knowledge Based Methods

The Neighbor Knowledge Method is what Lim and Kim refer to as Flooding with Self Pruning [13]. This algorithm requires that each node has knowledge of its 1-hop or 2-hops neighbors. A node includes its list of known neighbors in the header of each broadcast packet. A node receiving a broadcast packet compares its neighbor list to the sender's neighbor list. If the receiving node would not reach any additional nodes, it refrains from rebroadcasting; otherwise the node rebroadcasts the packet.

For more details about the above methods we refer the reader to the survey paper [9].

Clearly all the presented classes of MANET broadcasting algorithms try to reduce as much as possible the number of rebroadcasts, which will have a positive impact on the performance of the algorithm. Our GBB algorithm covers all the grid cells and uses only one rebroadcast node in each grid cell for forwarding the broadcast message. This new grid-based approach reduces the number of rebroadcasts and thus the overall cost of broadcasting in a MANET.

PRELIMINARIES

We assume a mobile ad-hoc network (MANET) is composed of N mobile wireless devices (nodes) distributed in a given geographical region. We view the geographical region where the nodes are located as a logical $k \times k$ two-dimensional (2D) grid of cells as shown in Fig.1. The length of a side of a grid cell is denoted by *d*. Two grid cells are called neighbors if they have a common side. Therefore each grid cell has 8 neighboring cells except for cells located at the boundaries of the grid which have 2 or 3 neighboring cells each. A path in the 2D-grid is a sequence of neighboring grid cells.

Two MANET nodes are called neighboring nodes if they are located in neighboring cells. The value of *d* is selected depending on the transmission range *r* such that a MANET node located at any position within a grid cell can communicate directly with all its neighboring nodes (located in 8 neighboring grid cells). This requirement is met if *d* satisfies: $r \geq 2d\sqrt{2}$. This can be seen by noticing that the farthest apart points in two adjacent grid cells are two diametrically opposite corners at distances 2*d* along each dimension (See figure 2)

We set *d* to the limit $r/2\sqrt{2}$ in order to minimize the number of broadcasting steps. Each grid cell is identified by a pair of integer grid coordinates (*x*, *y*) as illustrated in Figure 1. Each MANET node has a distinctive node id (IP or MAC address). We assume nodes are able to obtain their own geographical positions through a low-power GPS receiver.

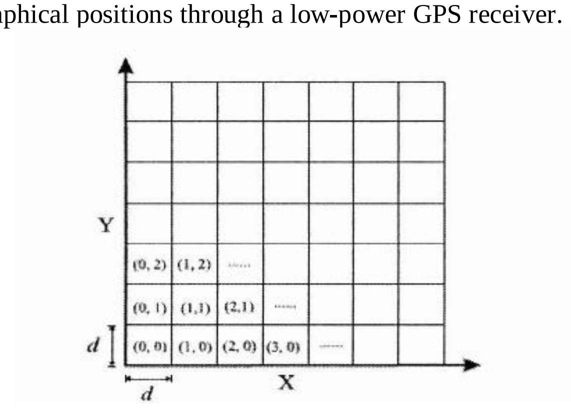

Figure 1. Logical 2D-Grid View of the MANET Area

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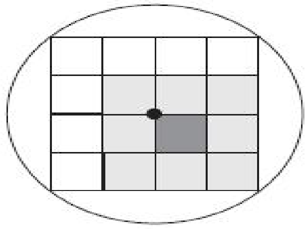

Figure 2. Grid-Cell Neighborhood in the 2D-Grid

OVERVIEW OF THE GBB ALGORITHM

A source node in a given grid cell initiates the broadcast operation then all the nodes located in the eight neighboring grid cells will hear the broadcasted message. The broadcast message consists of a header part and a data part. The header part consists of a sequence number, the source ID, and eight node addresses, each corresponding to the ID of a forwarder node in a specific direction (gateway of a neighboring grid cell). When the broadcasted message is received by a node in one of the eight neighboring grid cells, it will check if its ID is within the gateway nodes list. If the considered node is a gateway node “forwarder” then it will rebroadcast the message to its neighborhoods otherwise the message is consumed but not rebroadcasted. Only the gateway nodes of the grid cells will rebroadcast the message if they see the message for the first time (using the source ID and the sequence number), otherwise the packet is dropped. In GBB only one node per grid cell serves as a rebroadcast node. This solves the broadcast storm problem and reduces the number of messages in the MANET. GBB algorithm has three major phases: Initialization Phase, Forward Phase and Maintenance Phase.

Initialization Phase

In the GBB algorithm each node maintains a list of gateway nodes, one for each of the eight directions. For this purpose, a node located in cell *(x, y)*, stores in an array variable List_of_Gateways the IDs of the eight gateway nodes located in the neighboring grid cells: *(x+1, y), (x-1, y), (x, y+1), (x, y-1), (x+1, y+1), (x+1, y-1), (x-1, y-1), (x-1, y+1).*

In order to initialize the list of gateways for all the nodes, each node sends initially a “HELLO” message to its neighborhood for discovering its gateways in the eight directions. When a node receives a “HELLO” message it replies as a potential gateway node in that direction (the direction is determined based on the relative positions of the sender and receiver). The initiator of the “HELLO” message selects the latest sender of a reply in a specific direction as a gateway for that direction.

Forwarding Phase

At the reception of a broadcast message, if the node is a gateway node (finds in the message header its ID among the list of forwarders), it will rebroadcast the message to the next cells using its gateway information in the direction of that specific cell. If the node is not a gateway node, it consumes the message.

Maintenance Phase

A node continuously updates its list of gateway nodes as it communicates with nodes in neighboring cells. Every time a node receives a message (unicast or broadcast) from a node in a certain direction it sets that node as a potential new gateway node in that direction. This avoids gateway election overheads [8] or cluster heads [14]. To avoid instability in selecting gateways, each node uses a time period TP during which it collects potential gateway node in different directions. When TP expires, the latest potential gateways will be selected for each direction. In the GBB algorithm we assume that unicast routing and more than one broadcast operations can happen at the same time. GBB algorithm collects information about the dynamic neighborhood at almost zero cost (from the traffic) except at the initialization phase at the starting of the algorithm. Other methods such as knowledge based use periodic beacons to collect information about 1-hop and 2-hop neighborhood which will add an extra cost on the broadcasting algorithm.

DETAILS OF THE GBB ALGORITHM

We present in this section a detailed implementation of the proposed broadcasting algorithm. It is based on the coverage of the grid .

As we mentioned earlier, GBB algorithm starts with an initialization phase which consists of “HELLO” messages upon which each node update its list of gateway node in each direction. When a node wants to start a broadcast, it prepares the broadcast packets containing the following information: The source *ID* (as an example IP address); the forwarder node *IDf*, Initially, *IDf= ID0;* the ID of the cell where the initiator node is located (x_0,y_0); ID of the forwarder (x_f,y_f) cell. Initially, $(x_f,y_f)= (x_0,y_0)$; the packet sequence number *Seq* which will be incremented by 1 each time this source node is willing to broadcast a new message; the list of gateway node (forwarders) in the eight directions (see the initialization and the maintenance phase for updating the list of gateways); and the payload (data)

After preparing the packet the source node broadcasts the packet to its neighbors using a limited broadcast operation. Any node with *IDn*, receiving the broadcast packet will check first check if it belongs to the same cell as the initiator or forwarder (from the packet information) then it will not rebroadcast. If the packet has been seen already (from the sequence number of the source) then it will not be rebroadcast. If the node *IDn* is not in the list of gateways (from the packet) then do not rebroadcasts and updates the gateway list of the node *IDn* with respect of the period of time TP. If the node *IDn* sees it’s ID within the list of forwarders (within the packet list of gateway) then it will update the packet list of gateways according to its list of gateway and sets the

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forwarder grid cell its current cell $(x_f,y_f)= (x_n,y_n)$, and rebroadcasts the packet.

```
GBB BROADCAST ALGORITHM
Source node with ID0 located at grid-cell (x0,y0)
1.  Seq=Seq+1   /*increments the sequence number */
2.  Prepare message:
        Message = {<data> , <sourceID>,<Seq>,<(x0,y0)>,   /* Initiator
        <(xf,yf)>,  <IDf>,<List_of_Gateways[8]> }
3.  Broadcast(Message)    /* limited broadcast to the neighborhood */
4.  Any node at cell (xn,yn) with ID = IDn receiving Message:
    if (xn,yn)= Message.(x0,y0) Consume Message   /*do not rebroadcast */
    else if Message.Seq already seen Drop the Packet   /*do not rebroadcast */
    else if IDn not in Message.List_of_Gateways[8]    /*Not a gateway node */
        update_my_gateways((x,y),Message.<x,y>,Message.IDf,
        My_Gateway_List);  /* update the list of forwarder nodes in each
                                direction*/
        Consume Message /*do not rebroadcast */
        else {   /*forwarding node*/
        Message.List_of_Gateways = My_Gateway_List;
        Message.<xf,yf> = (xn, yn);
        Re-broadcast(Message);
        }
```

SIMULATION MODEL AND PERFORMANCE EVALUATION

The NS-2 simulation model consists of two sets of scenario files; topology scenario files and traffic generation pattern files. The topology scenario files define the simulation area and the mobility model of randomly distributed mobile nodes over the simulation time period. On the other hand, the traffic pattern files define the characteristics of data communications, notably, data packet size, packet type, packet transmission rate and the number of traffic flows.

In what follows we study the average end-to-end delay (average time spend to complete one broadcast operation); the number of saved rebroadcast (ratio of nodes that did not rebroadcast); the collision rate (number of collision per second); the average reachability ration (average percentage of nodes that received the broadcast messages) for the three broadcasting algorithm Grid-Based (GBB), probabilistic with probability p=0.6 (PROB 0.6) and the flooding algorithm (flood).

Our typical simulation scenario uses a node speed=1 m/s, number of connections 20, and a pause time= 1 ms. The following table gives a summary of the simulation system parameters.

Simulation Parameters	
CBR sending rate	4 packets per second
Simulation area	1000m x 1000m
Simulation protocols	GBB, PROB 0.6, Flooding
Mobility model	Random waypoint
Number of nodes	100
Nodes speed	1, 2, 4, 6 m/s
Average pause time	Delta =1ms
Number of connections	2, 4, 6, 8
Transmission range	300 meters
Link bandwidth	2 Mbps
Simulation trials	30 times
Simulation time	1000 Seconds

Effect of Offered Load

In this set of simulation experiments we vary the number of connections and study the average end-to-end time, the number of saved rebroadcasts, the collision rate, and the average reachability ratio.

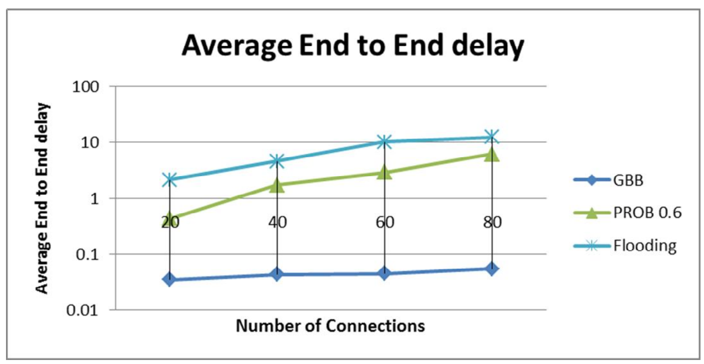

Figure 3. Average End-to-End versus Number of Connections

Figure 3 shows that when the traffic increases the average End-to-End delay of GBB is relatively constant but for the probability based broadcast PROB 0.6 it increases linearly. The average End-to-End delay of GBB is of order 10 time smaller than PROB 0.6 and the flooding.

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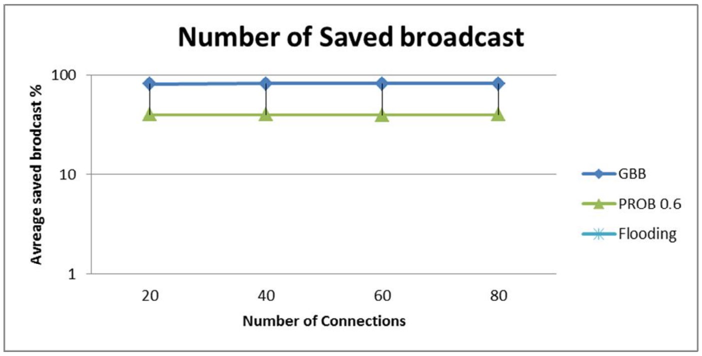

Figure 4. Percentage of Saved Rebrodcasts versus Number of Connections

Figure 4 shows that the number of saved rebroadcast GBB is of order 20% less than PROB 0.6.

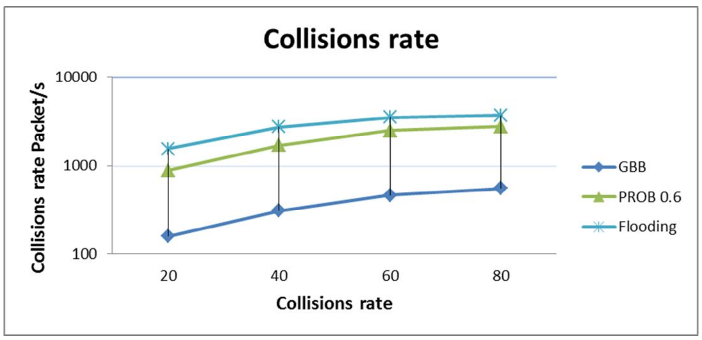

Figure 5. Collision Rate versus Number of Connections

Figure 5 shows that he collision rate GBB is of order 10 time less than PROB 0.6.

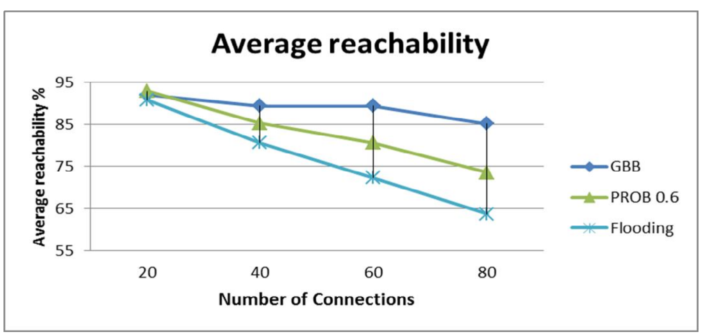

Figure 6. Average Reachability versus Number of Connections

Figure 6 shows that for low mobility speed = 1m/s the average reachability GBB is better than PROB 0.6 and the flooding.

Effect of the Mobility

In this set of simulation experiments we vary the number of mobility and study the average end-to-end time, the number of saved rebroadcasts, the collision rate, and the average reachability ratio.

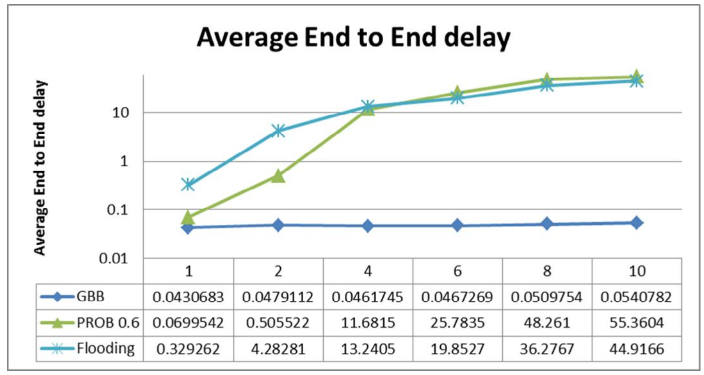

Figure 7. Average End-to-End versus Mobility

Figure 7 shows that when the nodes mobility increases the average End-to-End delay of GBB is still constant but for the probability based broadcast PROB 0.6 and flooding, it increases linearly. The average End-to-End delay of GBB is of order 100 time smaller than PROB 0.6 and the flooding.

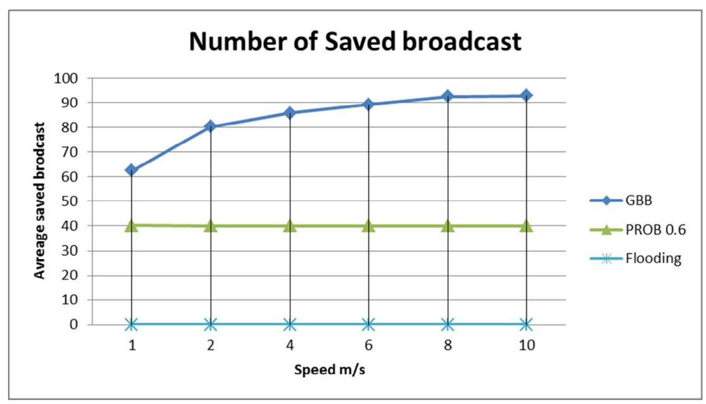

Figure 8. Percentage of Saved Rebroadcasts versus Mobility

Figure 8 shows that the number of saved rebroadcast GBB is of order 40% less than PROB 0.6.

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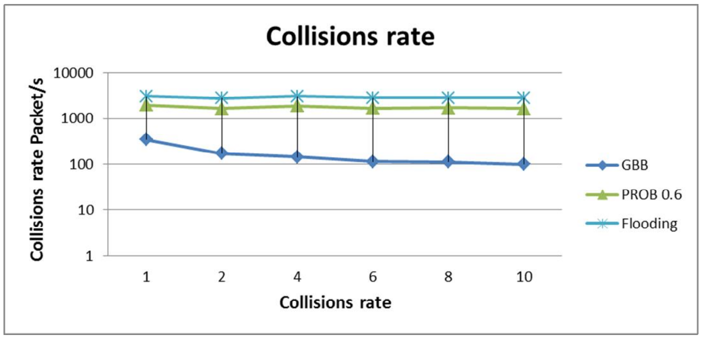

Figure 9. Collision Rate versus Mobility

Figure 9 shows that the mobility does not affect the collision rate of the studied broadcasting algorithms.

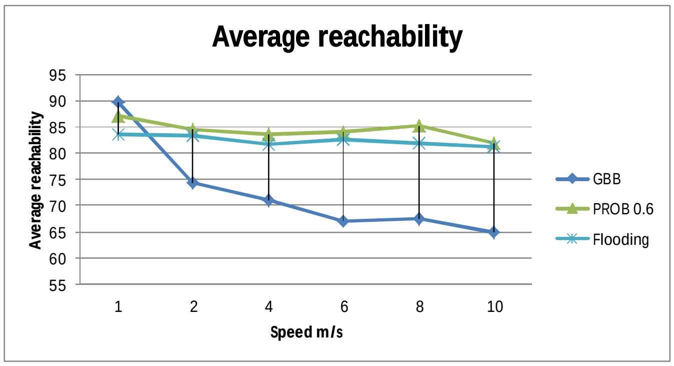

Figure 10. Average Reachability versus Mobility

Figure 10 shows that for moderate to high mobility the average reachability GBB is less than PROB 0.6 and the flooding. The reason is that in our simulation model we perform the Hello phase only one at the beginning and with mobility the gateway table does not reflect the actual situation because of movements of gateways.

CONCLUSION

We have proposed a new broadcasting GBB approach and a simulation model based on Ns2 simulator for mobile ad-hoc networks. GBB views the geographical region as a logical 2-dimensional grid. It uses a limited broadcast operation where only one gateway node in each grid cell rebroadcasts the message. The non-gateway nodes consume the message but do not rebroadcast it. This strategy reduces tremendously the broadcast storm problem. The simulation results showed GBB has improved considerably compared to PROB in terms of the End-to-End delay, the number of saved rebroadcasts and the collision ratio under different traffic and mobility conditions. The shortcoming of GBB (relatively lower reachability ratio) can be addressed by introducing periodic Hello to gather neighboring information more precisely.

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