Reliable Broadcasting Using Efficient Forward Node Selection for Mobile Ad-Hoc Networks

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Abstract: *Due to the broadcasting nature of radio transmission, the most fundamental task in MANETs is the broadcast operation. All the current routing protocols depend upon the easier form of broadcasting called flooding which can result in high broadcast redundancy and packet collisions. In this paper, we propose to develop a reliable broadcasting algorithm which is a sender-based algorithm. In this algorithm, the broadcasting nodes select a subset of their neighbors to forward the message using an efficient forward node selection mechanism. The retransmissions of the forwarding nodes are overheard by the sender as the confirmation of their reception of the packet. Moreover, a NACK mechanism is used to provide full reliability for all non forwarding nodes. This algorithm reduces the average retransmission redundancy, avoids both the broadcast storm problem and the ACK implosion problem, recovers the transmission error locally and increases the broadcast delivery ratio. By simulation results, we show that our proposed algorithm achieves good delivery ratio with less forwarding and control overhead.*

Keywords: *Mobile Ad-hoc networks, broadcasting, forward node selection, reliable broadcasting algorithm, sensor.*

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1. Introduction

1.1. Mobile Ad-Hoc Networks

A collection of mobile nodes are comprised into the Mobile Ad-hoc Networks (MANETs). The mobile nodes creates a wireless networks among themselves without using any infrastructure or administrative support dynamically. Ad-hoc wireless networks are self-creating, self-organizing, and self-administering. by communicating among their component mobile nodes they inherit from being exclusive. Therefore, in order to provide the necessary control and administration function, such communications are used for supporting such networks [10]. In earlier days due to such apparent advantages, military, police, and rescue agencies particularly under disorganized or hostile environments, as well as isolated scenes of natural disaster and armed conflict, utilize Ad-hoc networks. The potential applications which are used in other major areas are home, small office networking, in a small area, collaborative computing with laptop computers. Moreover, in all the conventional areas of interest for mobile computing, Ad-hoc networking has clear potential applications [10].

1.2. Broadcasting

A fundamental operation in all kinds of network is broadcasting. It may be used for the following:

- Determining neighbors.
- Collecting global information.
- Naming.
- Addressing.
- Assisting in the multicasting.

In a MANET, in order to propagate routing-related information, several routing protocols have depended on broadcasting [11]. The broadcasting protocols can be classified into four families such as simple flooding, probability based methods, area based methods and neighbor knowledge methods [12].

- Each node should rebroadcast all packets in simple flooding.
- In order to assign a probability to a node to rebroadcast, probability based method use some basic understanding of the network topology.
- Area based methods assumes that nodes have common transmission distances. If the rebroadcast reaches sufficient additional coverage area, then only the node is capable to rebroadcast.
- Through “Hello” packets neighbor knowledge methods maintain state on their neighborhood which is used in the decision to rebroadcast.

1.3. Broadcasting Issues in MANET

The following describes the major issues in designing a localized broadcast protocol while ensuring broadcast coverage [14].

1. Even during the broadcast process, the network topology changes over time.

2. Based on "Hello" intervals, the local 1-hop information is constructed. It is difficult to ensure consistent local or global views among nodes, since the nodes start their intervals asynchronously.
3. When there are mobile nodes, the k-hop collection process information acquires delay even for small k in localized solutions which may not reflect the current network topology. The following issues may occur due to:

   a. *Connectivity Issue*: The virtual network constructed from local views of nodes may not be connected.
   b. *Link Availability Issue*: Its link may not exist in the physical network.
   c. *Consistency Issue*: The global view constructed from collection local views may not be consistent.

Due to the broadcasting nature of radio transmission, the most fundamental task in MANETs is the broadcast operation. Moreover, due to this transmission all the nodes within the sender's transmission range will be affected, when a sender transmits a packet. Therefore, the problems such as exposed terminal problem and hidden terminal problem are created [4].

- *Exposed Terminal Problem*: The exposed terminal problem is created because of interference between one transmission and the other.
- *Hidden Terminal Problem*: If an outgoing transmission collides with an incoming transmission then the hidden terminal problem is created where two incoming transmissions collide with each other.
- *Broadcast Storm Problem*: Some nodes may not receive the broadcast packet because of the frequent contention and transmission collision among the neighboring nodes. This is called as the broadcast storm problem. In MANET, the broadcast storm problem has not been addressed in depth earlier. Most of the existing results depend on Time Division Multiple Access (TDMA) protocol and certain levels of topology information. Flooding is the straight-forward approach to perform broadcast. A host has the responsibility to rebroadcast the message on receiving the broadcast message for the first time. But, this costs n transmissions in a network of n hosts [6].

1.4. Proposed Solution

In this paper, we propose to develop a reliable broadcasting algorithm using the efficient forward node selection mechanism. The broadcasting algorithm is based on the sender-based algorithm. In this algorithm, the broadcasting nodes select a subset of their neighbors to forward the message. The retransmissions of the forwarding nodes are received by the sender as the confirmation of their reception of the packet. Moreover, we use Negative Acknowledgement (NACK) mechanism to provide full reliability for all non forwarding nodes. Therefore, these nodes send an NACK message when the node detects a packet loss during the continuous broadcasting transmissions. Here we are going to examine the approach of applying the NACK mechanism and the effects when the NACK mechanisms are applied. The advantages of the algorithm are:

- It reduces the average retransmission redundancy.
- It avoids both the broadcast storm problem and the ACK implosion problem.
- It recovers the transmission errors locally.
- It increases the broadcast delivery ratio.

2. Related Work

Khabbazian *et al*. [3], have proposed an efficient sender-based broadcasting algorithm based on 1-hop neighbor information that reduces the time complexity of computing forwarding nodes to O(n). Also, they have proposed a simple and highly efficient receiver-based broadcasting algorithm. Using simulation, they have confirmed these results and shown the number of broadcasts in their proposed receiver-based broadcasting algorithm can be even less than one of the best known approximations for the minimum number of required broadcasts.

Pleisch *et al.* [8], have proposed a novel approach for flooding, which relies on proactive compensation packets periodically broadcast by every node. The compensation packets are constructed from dropped data packets, based on techniques borrowed from forward error correction. Since their approach does not rely on proactive neighbor discovery and network overlays it is resilient to mobility. They have evaluated the implementation of Mistral through simulation and compare its performance and overhead to purely probabilistic flooding. Their result shows that Mistral achieves significantly higher node coverage with comparable overhead.

Wu *et al*. [13], have proposed a generic framework for distributed broadcasting in Ad-hoc wireless networks. Their approach is based on selecting a small subset of hosts (also called nodes) to form a forward node set to carry out a broadcast process. Their simulation result shows that new algorithms, which are more efficient than existing ones, can be derived from the generic framework.

Rahman *et al*. [9], have shown how flooding can be adopted as a reliable and efficient routing scheme in Ad-hoc wireless mobile networks. They have discussed a reactive broadcast-based Ad-hoc routing protocol in which flooding exhibits a tendency to converge to a narrow strip of nodes along the shortest path between source and destination. Finally, they pointed out a certain deficiency inherent in the IEEE 802.11 family of collision avoidance schemes and show how to fix it to provide better service to broadcast-based routing schemes represented by their variant of controlled flooding.

Ho *et al*. [1] have proposed cell broadcast, 0-hop broadcast protocol that significantly reduces redundancy without the use of beaconing, while maintaining complete reachability in a high density environment. This technique divides a terrain into cells which assist a node in determining its geographic relationship with a broadcasting node. This geographic relationship can eliminate rebroadcasts not only from nodes close to a broadcasting node but also from a majority of the nodes near the transmission edge of the broadcasting node.

Yassein *et al*. [15], have proposed a dynamic probabilistic approach for broadcasting. They have set the rebroadcast probability of a host according to the host density in its neighbourhood area. When several hosts move toward each other to form a group, their probabilities are set to be lower. When hosts move away from a dense area, their probabilities are kept higher. They have used the information about 1-hop neighbors using short HELLO packet to adjust the probability. If the average number of neighbors is high, which means the host is in a dense area so that it can receive a large amount of rebroadcasts from its neighbors, they decrease the probability of this host. Otherwise, they increase the rebroadcast probability.

Karthikeyan *et al*. [2], have proposed clustering based techniques for mobile Ad-hoc networks which guarantees to deliver the messages from a source node to all the nodes of the network. The nodes are mobile and can move from one place to another. The algorithm adapts itself dynamically to the topology and always gives the least finish time for any particular broadcast. The algorithm focuses on reliable broadcasting. It guarantees to deliver the messages within a bounded time. The algorithm takes into consideration multiple nodes located at the same point. The algorithm tries to fix any delay latencies and message losses. It is collision free and energy efficient.

Pathan *et al*. [7] have proposed Neighbour Aware Multicast Routings Protocol (NAMP), which is a tree based, hybrid multicast routing protocol for Ad-hoc networks. Their routing protocol aims at achieving robustness in the Ad-hoc networks as well as the improvement of the end-to-end delivery of data packets. For route creation, the protocol uses neighboring information and dominant pruning approach. It uses secondary forwarder method for route maintenance. When a source wants to send a data packet, it initializes a FLOOD_REQ packet with data payload attached. This packet is flooded throughout the network based on dominant Pruning method. They first state the dominant pruning approach and then show how it is used in NAMP. Dominant pruning approach extends the range of neighborhood information into two-hop apart nodes. This two-hop neighborhood knowledge can be obtained by exchanging the adjacent node lists with neighbors. In dominant pruning, the sender node selects adjacent nodes that should relay the packet to complete broadcast. The IDs of selected adjacent nodes are recoded in the packet as a forward list. An adjacent node that is requested to relay the packet again determines the forward list. This process is iterated until broadcast is completed.

3. Forward Node Selection

3.1. Overview

When a sender broadcasts a packet, then based on the greedy approach, it selects a subset of 1-hop neighbors as its forwarding nodes to forward the packets.

Node *N1* assigns a weight to each of its neighbor which represents the combination of neighbor's battery lifetime and its distance to *N1*. For a neighbor *h1* of *N1*, the weight can be determined by the following equation:

$$W_{h1} = BL_{h1} + D_{h1} \tag{1}$$

Where BL_{h1} is the battery lifetime of $h1$ and D_{h1} is the distance of *h1* from *N1*. The Forward Node Selection (FNS) algorithm first sorts the nodes by their weights in decreasing order. From this list, the forwarding nodes are selected based on the following two requirements:

1. They cover all the sender's 2-hop neighbors.
2. The sender's 1-hop neighbors are either forwarding nodes or non-forwarding nodes covered by at least two forwarding nodes.

Each forwarding node stores the packet, calculates it's forwarding nodes, and rebroadcasts the packet as a new sender, after receiving a new broadcast packet. The sender eavesdrop the retransmissions of the forwarding nodes as the acknowledgement of receiving the packet. The sender waits for a predefined duration to eavesdrop the rebroadcast from its forwarding nodes. If the sender fails to detect all its forwarding nodes retransmitting during this duration, it assumes that a transmission failure has occurred for this broadcast. The non-forwarding 1-hop neighbors of the sender send a NACK to the sender, when they fail to receive the broadcast packets. The sender then resends the packet until all the forwarding nodes' retransmissions are detected or there is no NACK packet from the non-forwarding nodes. The sender may miss a retransmission from a forwarding node, and therefore resends the packet. When the forwarding node receives a duplicated broadcast packet, it sends an ACK to acknowledge the sender.

3.2. Forwarding Node Set Selection Algorithm

In this algorithm, the node v selects its forwarding node set F from all candidate neighbors X to cover its uncovered 2-hop neighbors Y with a simple greedy algorithm. This Forwarding Node Set Selection (FNSS) algorithm is described below:

Algorithm 1:

1. *Initially, we have*

$$X = NH_1(v)$$
$$= N(v) - \{v\}$$
$$Y = NH_2(v)$$
$$= N_2(v) - N(V)$$
$$F = NULL$$

2. *For each* n *in* X, *find*

$$W_n = BL_n + D_n$$

3. *Let* $Z = Sort(X)$,

where $Sort(X)$ *is the sorted set* X *in decreasing order of* W_n.

4. *Find* n *in* Z *with the maximum effective neighbor degree such that*

$$\deg_e(n) = | N(n) \cap Y |$$
$$F = F \cup \{n\},$$
$$Y = Y - N(n) \text{ and}$$
$$X = X - \{n\}.$$

5. *Repeat steps 2 and 3 until* $Y = NULL$

4. Reliable Broadcasting Algorithm

4.1. Algorithm Structure

Our proposed broadcasting algorithm is a sender based algorithm where each node selects a subset of nodes to forward the message. With the help of the source ID and a sequence number, each message can be identified, where the sequence number is incremented for each message at the source node. The algorithm requests the MAC layer to schedule a broadcast before the timer expires. The scheduled message in the MAC layer is buffered and then it is broadcast with a probability p, which includes an additional delay in broadcasting the message. The MAC layer delay in IEEE 802.11 involves many issues which includes network traffic.

As shown in the proposed algorithm, if the node is selected by the sender and if it has not scheduled the same message before, then each node schedules a broadcast for a received message. A node broadcasts each message once. A broadcast schedule can be set at any time in the algorithm. For example, a message can be dropped after the first reception but scheduled for broadcast the second time. Designing a mechanism for selecting the forwarding nodes is the major design problem in our algorithm.

The entire steps involved in reliable broadcasting algorithm are summarized as follows:

Algorithm 2:

1. Obtain information from the received message M
2. If M *has been scheduled for broadcast or does not contain node's ID then*
2.1. Drop the message
3. Else
3.1. Set a reschedule timer
4. End if
5. If reschedule timer expires, then
5.1. Select the forwarding nodes using Algorithm 1.
5.2. Attach the list of forwarding node to the message
5.3. Schedule a broadcast
6. End If
7. If retransmit duration $< T$, *then*
7.1. If sender hears the rebroadcast from forwarding nodes, then
7.1.1. transmission is successful
7.2. End if
8. Else
8.1. transmission failed
9. End if
10. If sender receives NACK packet from non-forwarding nodes, then
10.1. transmission failed
11. End if
12. If transmission failed, then
12.1. sender resends the packet
13. End if
14. If forwarding node receives duplicate broadcast packet, then
14.1. send ACK to sender
15. End if

4.2. Advantages of Reliable Broadcasting Algorithm

- The broadcast collision and congestion are reduced because only the forwarding nodes transmit the packet. This scheme is used to avoid the broadcast storm problem.
- Sending extra ACK is unnecessary because the retransmissions of the forwarding nodes are also used as the ACK to the sender. This scheme is used to avoid the ACK flooding problem.
- The packet loss can be recovered in a local region because the failure of the overhearing forwarding nodes' relays will activate the sender to retransmit the packet.
- Each non-forwarding nodes can tolerate a single transmission error because it is covered by at least two forwarding neighbors. Therefore, even in a high transmission error rate environment, the chance of receiving the broadcast packet successfully is increased in the non-forwarding nodes.
- The disadvantage of the receiver-initiated approach which needs a longer delay to detect a missed packet does not affect the algorithm.

5. Simulation Results

We use NS2 [5], to simulate our proposed algorithm. In our simulation, the channel capacity of mobile hosts is set to the same value: 2Mbps. We use the Distributed Coordination Function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol. It has the functionality to notify the network layer about link breakage.

In our simulation, 100 mobile nodes move in a 900 meter x 900 meter square region for 100 seconds simulation time. We assume each node moves independently with the same average speed. All nodes have the same transmission range of 250 meters. The simulated traffic is Constant Bit Rate (CBR). Our simulation settings and parameters are summarized in Table 1.

Table 1. Simulation settings.

No. of Nodes	20,40,….100
Area Size	900 X 900
Mac	802.11
Radio Range	250m
Simulation Time	100 sec
Traffic Source	CBR
Packet Size	512
Mobility Model	Random way point
Speed	10,20,…50m/s
Pause Time	10
No. of Sources	4

5.1. Performance Metrics

We evaluate mainly the performance of the following metrics:

- *Average Packet Delivery Ratio*: It is the ratio of the number of packets received successfully and the total number of packets sent.
- *Average Packet Forwarding Ratio*: It is the ratio of the number of packets forwarded successfully and the total number of packets sent.
- *Control Overhead*: The control overhead is defined as the total number of routing control packets received.

In our experiment we compare our proposed Reliable Broadcasting (RB) algorithm with the Sender Based Broadcasting (SBB) algorithm [3].

5.2. Results

5.2.1. Effect of Nodes

In this experiment, we vary the number of nodes as 20, 40, 60, 80 and 100. Figure 1 presents the packet delivery ratio of both the schemes. Because of the reliable broadcasting with retransmission, RB achieves good delivery ratio when compared with the SBB algorithm.

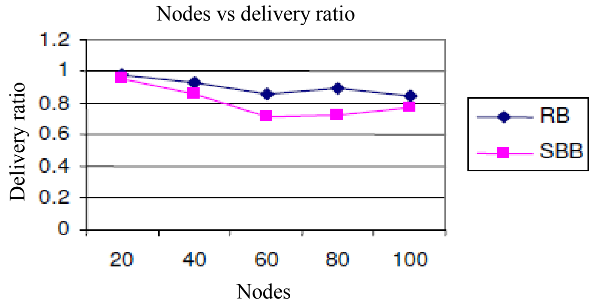

Figure 1. Nodes vs delivery ratio.

Figure 2 shows the results the forwarding ratio when the number of nodes is varied. Clearly our RB algorithm achieves lesser forwarding ratio than the SBB algorithm, since it consists of efficient forward node selection mechanism.

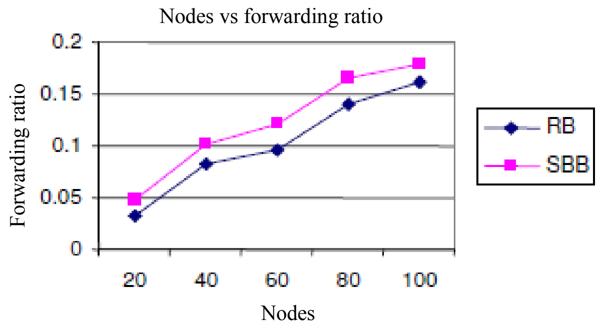

Figure 2. Nodes vs forwarding ratio.

Figure 3 gives the control overhead when the number of nodes is increased. Since the reliable broadcasting does not involve any ACK packets, we can see that RB has less overhead when compared with the SBB algorithm.

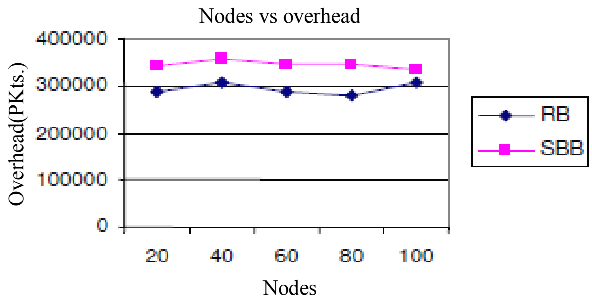

Figure 3. Nodes vs overhead.

5.2.2. Effect of Varying Speed

In this experiment, we vary the node speed as 10, 20, 30, 40 and 50. Figure 4 presents the packet delivery ratio of both the schemes, when the speed is increased. Because of the reliable broadcasting with retransmission, RB achieves good delivery ratio when compared with the SBB algorithm.

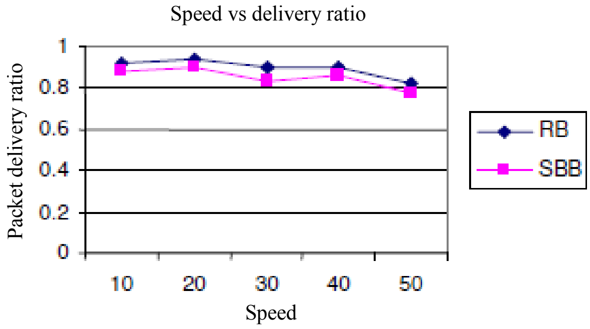

Figure 4. Speed vs delratio.

Figure 5 gives the control overhead when the speed is increased. From the results, we can see that RB algorithm has less overhead than the SBB algorithm, since it does not involve any ACK packets.

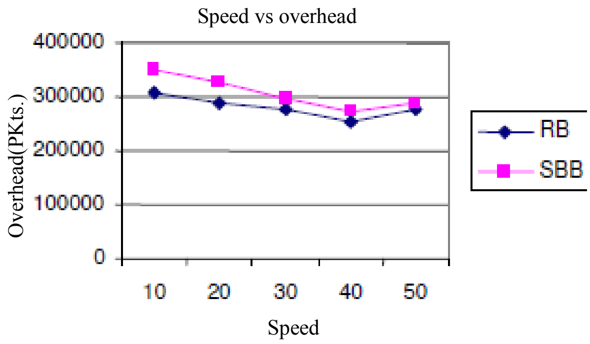

Figure 5. Speed vs overhead.

6. Conclusions

In this paper, we have proposed a reliable broadcasting algorithm using the efficient forward node selection mechanism. Each forwarding node stores the packet, calculates it's forwarding nodes, and rebroadcasts the packet as a new sender, after receiving a new broadcast packet. The sender eavesdrop the retransmissions of the forwarding nodes as the acknowledgement of receiving the packet. The sender waits for a predefined duration to eavesdrop the rebroadcast from its forwarding nodes. If the sender fails to detect all its forwarding nodes retransmitting during this duration, it assumes that a transmission failure has occurred for this broadcast. The non-forwarding 1-hop neighbors of the sender send a NACK to the sender, when they fail to receive the broadcast packets. The sender then resends the packet until all the forwarding nodes, retransmissions are detected or there is no NACK packet from the non-forwarding nodes. The sender may miss a retransmission from a forwarding node, and therefore resends the packet. When the forwarding node receives a duplicated broadcast packet, it sends an ACK to acknowledge the sender. By simulation results, we have shown that our proposed algorithm achieves good delivery ratio with less forwarding and control overhead.

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