Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN : 2581 - 611X)
Volume 1- Issue 1, August 2018

RELIABILITY ENHANCEMENT IN MULTIHOP MANET

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Abstract*— A mobile ad-hoc network (MANET) consists of a group of mobile nodes and it enables communications between participating nodes without the burden of any base stations. To increase the capacity of wireless network, multiple transceivers can be used. Multiple transceivers increase the cost of the equipment. So generally for data transmissions, a single transceiver is used in each node. But single transceiver is difficult to implement in multichannel environment. This problem can be solved by Ad-hoc Multichannel Negotiation Protocol (AMNP). For improving reliability, further Reliable Broadcast Algorithm (RBA) is introduced. Simulation analysis in NS-2 based on the combination of AMNP – RBA gives comparatively a better performance.*

Keywords **—** *MANET, Multihop, MAC, Multichannel, AMNP and RBA.*

I. INTRODUCTION

Nowadays there is tremendous increase in usage of mobile laptops and PDA's but we have only limited amount of radio spectrum. Within the available radio spectrum we have to effectively communicate between the nodes. Existing works have dedicated to using multiple channels to increase the capacity of wireless communication by dividing the radio spectrum into number of channels.

Most of the mobile devices are equipped with single transceivers and it operates in single-channel mode hence more amount of bandwidth is wasted. To mitigate this problem, all mobile nodes have to be equipped with multiple transceivers. Enhancement of the present MAC protocol can give better performance on multichannel with single transceiver.

In [1] Jain proposes a CSMA based medium accesses control protocol for multihop wireless network. In which channel selection is based on signal to interference and noise ratio at the receiver. Although this method increases the throughput up to 50% there is delay in performance due to high packet transmission. In [2], Nasipuri propose a new CSMA protocol for ad-hoc networks. In which the CSMA protocol divides the available bandwidth into several channels and selects the channel randomly. It employs "soft channel reservation" that gives preference to the channel that was used for last successful transmission.

In [11] Chen proposes a AMNP protocol that reduces the collision and interruption probabilities, and it uses the same frame format of IEEE 802.11 with some slight modifications but it lacks in reliable broadcast transmission. In [12] Lou proposes RBA (Reliable broadcast Transmission) with selected forward nodes to avoid broadcast storm and reduce broadcast redundancy.

II. PROBLEM STATEMENT

A. Single transceiver constraint

In IEEE 802.11 DCF the MAC protocol is designed for sharing a single channel between the nodes. Nowadays most of the wireless devices are equipped with one half-duplex transceiver to transmit or to

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receive data. The transceiver can operate on multiple channels dynamically but it can either transmit or receive data from one channel at a time. So a node cannot communicate with other nodes when is communicating with another node in another channel concurrently. While using multiple channels IEEE 802.11 DCF will not be suitable because it may dynamically switch channels.

B. Multichannel hidden terminal problem

The node which cannot hear the radio signal from the transmitter node and may disturb the ongoing data transmission is called hidden terminal nodes. Even though IEEE 802.11 provides RTS\CTS handshaking signals, in multichannel environment the nodes still may collide with each other.

C. Broadcast transmission problem

Broadcasting is an important activity in multi hop MANET. Broadcasting a message in single channel is easy, because all the mobile nodes in a network use a single channel so the message can be delivered. But in multichannel environment a node may miss the broadcast frame when is currently transmitting or receiving data from other nodes.

III. AMNP – RBA IMPLEMENTATION

In IEEE 802.11 the sender and the receiver should perform a four way handshaking mechanism: Request-to-send /clear-to-send (RTS/CTS), data, and acknowledgment (ACK) when they have data to transmit in the same channel.

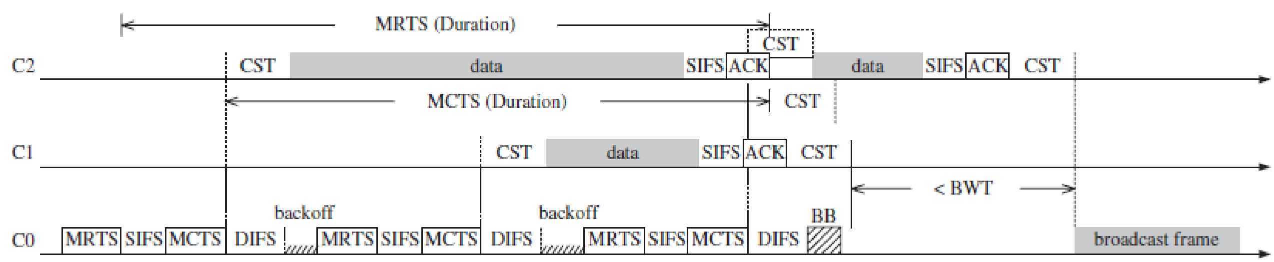

Fig.1 An illustration of AMNP

In fig.1, which *C*0 represents the contention/reservation channel and *C*1 and *C*2 represent the data channels. The identifier BB represents the broadcast beacon, the BWT represents the broadcast waited time and the CST is the channel switching/settling time, respectively.

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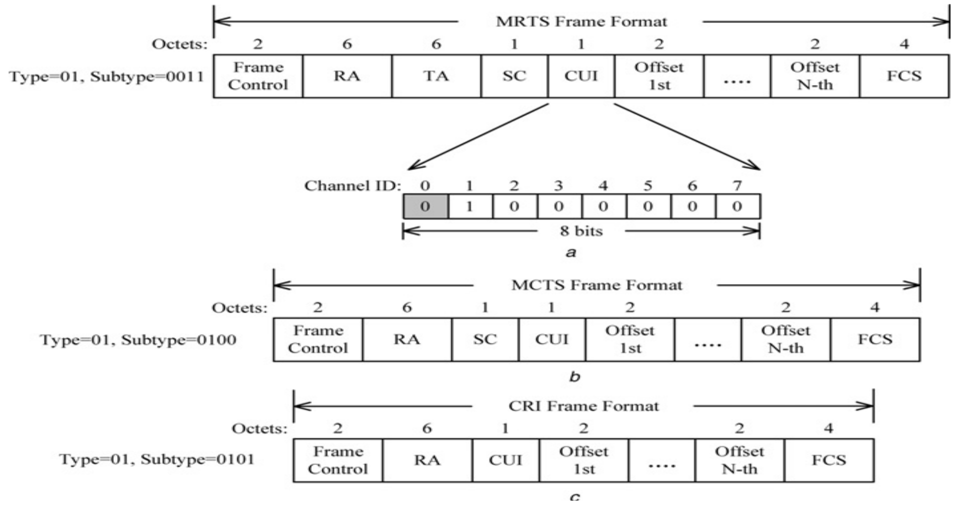

Fig. 2 Frame format of MRTS, MCTS and CRI control frames

If mobile nodes equip with only one transceiver, some nodes will never communicate with each other at the same time. As a result, few data frames will be transmitted in the multichannel environment. If we assign mobile nodes to access channels dynamically, a complicated and distributed channel scheduling mechanism has to be provided for MANETs. It will be more difficult in the MANET.

Instead of employing such complicated scheme, AMNP allocates a dedicated contention or broadcast channel for all mobile nodes to contend. The remaining channels are served as data channels permanently. Fig 1 illustrates the channel usage of AMNP in which channels C_1– C_{n-1} represent data channels, and channel C_0 serves as the dedicated contention channel or broadcast channel. Since there is no stationary node for supporting centralized multichannel control in MANETs, the distributed negotiation protocol, which can provide ad hoc multichannel transmission, is needed. To solve the above-mentioned problems, we employ the concept of IEEE 802.11 RTS/CTS handshaking mechanism to fulfill the multichannel negotiation and transmission mechanism in multi-hop MANETs. We name the RTS/CTS mechanism as MRTS/MCTS in the AMNP. Unlike IEEE 802.11 RTS/CTS mechanism, we need more information to indicate the usage of other data channels.

When two nodes communicate, first a node has to complete a MRTS/MCTS handshaking in the contention channel to acquire the access right of the expected data channel if it has a packet to transmit. The main purpose of the MRTS control frame is to inform its direct receiver and neighbours the preselected data channel to indicate a virtual carrier sensing delay named network allocation vector (NAV) this will prevent the exposed and hidden node problems in the preselected channel. Likewise, the MRTS also carries the newest status information of data channels to notify other mobile nodes within its transmitting range for information updating.

The frame format of MRTS is shown in Fig 2 where the frame control, receiver address, transmitter address and frame check sequence fields are the same as the description in the IEEE 802.11 standard. In order to be compatible with the IEEE 802.11 standard, we use the reserved value Type = 01 and Subtype = 0011 as indicated in the frame control field to represent the MRTS control frame. The original duration field is eliminated since the channel C0 is for contention and broadcast use only. Therefore the

NAV will not be used in C0 when contending for the channel access. The additional fields selected channel (SC), channel usage indication (CUI) and the nth used channel's offset are described as follows. The SC field indicates which channel that the sender prefers to transmit data with the receiver.

The preferred channel (selected) is not compulsory for the receiver depending on the availability of the channel on the receiver's side. The CUI field length is one octet long and the content of CUI indicates the status of the usage in each channel. The bit will be set to 0 if the corresponding data channel is not in use; the bit will be set to 1, if the corresponding data channel is in use.

When a node has received a MRTS frame, it will compare the SC field of the MRTS with its channel status and then check whether it can satisfy the request. If the preselected channel is also available in receiver's side, the receiver will grant the transmission request and reply the MCTS frame back to the sender immediately. Otherwise, the preselected channel cannot be granted to use since the preselected data channel in receiver's side is not free. The receiver then reselects another available channel according to comparing with the status of channel usage of the sender. The reselection rules are as follows:

1) If the sender has another free data channel and the channel is also available in receiver's side. The receiver will select the common available channel to receive data frames.

2) If there is no available free channel in the side of the sender or receiver now, the receiver will compare all data channels of both sender and receiver and then select a common channel which will be earliest released.

Channel information from both sides are taken in order to prevent the hidden node problem. After the checking process, the receiver will reply a MCTS frame back to the sender to make the final decision. The MCTS frame contains the current the usage status of data channels.

Taking Fig. 3 for example, assuming there are 5 mobile nodes in the ad hoc network. Node **c** and **d** are the exposed terminal of node **a** and **b**, and node **e** is the hidden terminal of node **b**. Initially node **e** finishes its backoff count down and then sends an MRTS frame to request the channel 1 for transmitting data. The receiver node **d** approves the request since the channel 1 is also available in side of **d**. After the negotiation of node **d** and **e**, node **a** finishes its backoff count down and sends an MRTS to node **b** to ask channel 1 for transmitting data. Since channel 1 has been reserved by node **d** and **e**, the request could not be accepted. Node **b** compares channel statuses of node **a** with node **b** and then selects an available channel 2 in this example and sends MCTS back to node **a**. After receiving an MCTS from node **b**, node **a** is notified that channel 1 would not be accepted and the agreed channel is channel 2. Node **a** will resend an MRTS to refresh the reservation information (to node **c** in this example).

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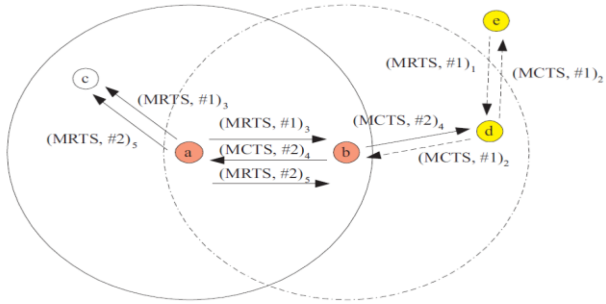

Fig. 3 Transmission of MRTS/MCTS frames to select a channel

D. Broadcast casting in AMNP

The broadcast operation is an important activity in ad-hoc networks. Broadcasting is done to achieve routing information exchanges, address resolution protocol and message advertisement etc. Broadcasting can be done easily when there is a single channel but in multichannel environment, a node may miss the broadcast frame when is currently transmitting or receiving data from other nodes. Here a single transceiver constraint is chosen. To solve this problem, AMNP uses a designated control frame named broadcast beacon (BB) to announce to its neighbouring nodes of an upcoming broadcast transmission.

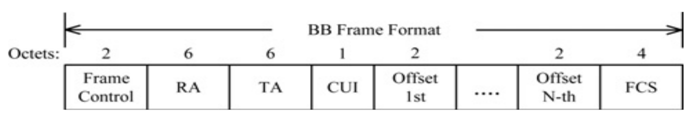

Fig. 4 Frame format of Broadcast Beacon

All nodes which received the BB will stay in the contention channel and wait a broadcast waiting time (BWT) to receive this frame even though it has made a successful reservation. All the scheduled reservations will be delayed a SIFS + BWT + SIFS + broadcast frame length + SIFS period.

Several problems remain by adopting this transmission of the broadcast frame after a SIFS interval. The following four cases are considered as shown in Fig 5, to describe the broadcast problems occurred in the multichannel environment.

Case 1: After finishing the transmission where the sender and the receiver will return to the contention channel during the time period of the beginning of the BB and before the broadcast frame.

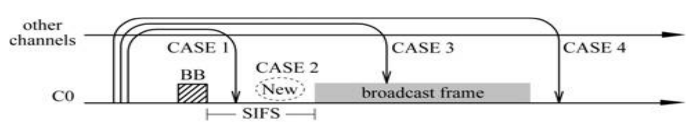

Fig. 5 Broadcast problems in Multichannel environment

Case 3: At a finished transmission where the sender and the receiver will return to the contention channel in the broadcast frame.

Case 4: At a finished transmission where the sender and the receiver will return to the contention channel after the broadcast frame.

In case1 the nodes will receive the broadcast frame because it stays connected in contention channel after the transmission so it receives the broadcast frame. In case 2 it is not sure the nodes will receive the broadcast frame depending upon the physical response time and ready time.

Case 3 and case 4 will definitely miss the broadcast frame, to solve this problem we prefer reliable broadcast algorithm.

E. Reliable broadcast Algorithm

In reliable broadcast algorithm it requires only selected forward nodes among the 1-hop neighbours to send ACKs to confirm their receipt of the packet. Forward nodes are selected in such a way that all senders' 2-hop neighbour nodes are covered. Moreover, no ACK is needed for non-forward 1-hop neighbours, each of which is covered by at least two forward neighbours, one by the sender itself and one by one of the selected forward nodes. The sender waits for the ACKs from all of its forward nodes. If not all ACKs are received, it will resend the packet until the maximum times of retry is reached. If the sender fails to receive all ACKs from the forward nodes, it assumes that the non-replied forward nodes are out of its range and chooses other nodes to take their roles as forward nodes.

The forward nodes are selected based on the following greedy algorithm:

In the sample network shown in Figure 6, *N*(1)={1,2,3,4, 6} and *N*2(1) ={1,2,3,4,5,6,7}. When using the FNSSP, sender node 1 selects nodes 2, 3 and 4 as its forward nodes. Node 3 is selected because there is no node in *N*(1) to cover it.

Algorithm: Forward Node Set Selection Process (FNSSP)

Step 1: The forward node set F is initialized to be empty.

Step 2: Add in F the node that covers the largest number of 2- hop neighbours that are not yet covered by current F. A tie is broken by node ID.

Step 3: Repeat step 2 until all 2-hop neighbours are covered.

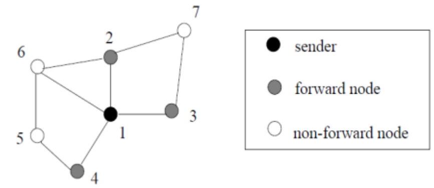

Fig .6 A sample network where the sender 1 uses the FNSSP to select its forward nodes.

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IV. SIMULATION RESULTS

The network is varied from 54 to 108 nodes. The mobility model uses the random waypoint model in a rectangular field. Here each mobile node starts its journey from a random location to a random destination with a randomly chosen speed (uniformly distributed between 0–94 m/s).

Simulation Parameters	Value
Simulation Area	300m*300m
Transmission range	100 m
Transmission rate	2 Mb/sec
SIFS	10µs
DIFS	50µs
MRTS frame length	variable 160 bits
MCTS frame length	112 bits
ACK frame length	112 bits
MAC header length	34 octets
broadcast frame length	128 octets

Table 1. Simulation Configuration Parameter

In all simulation analysis, one contention channel and 11 data channels are considered. Simulation area is 300m x 300m, transmission range is about 100m and transmission rate is about 2Mb/sec.

In Fig 7 When 54 nodes are considered AMNP performs better than IEEE 802.11. When frame arrival rate increases to 20, a significant amount of increase of throughput can be noted.

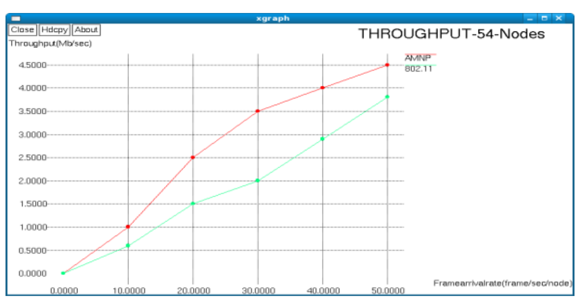

Fig. 7 Comparison of Throughput derived by IEEE 802.11 and AMNP

When 108 nodes are considered AMNP performs better than IEEE 802.11. When frame arrival rate increases to 20, a considerable amount of increase of throughput can be noted when compared to IEEE 802.11.

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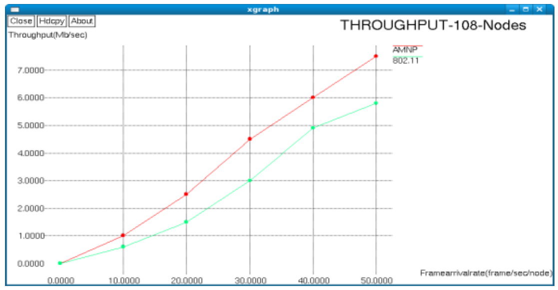

Fig. 8 Comparison of Throughput derived by IEEE 802.11 and AMNP

MAC delay is the sum of MAC operations including back-off countdown, channel negotiation and transmission delay.

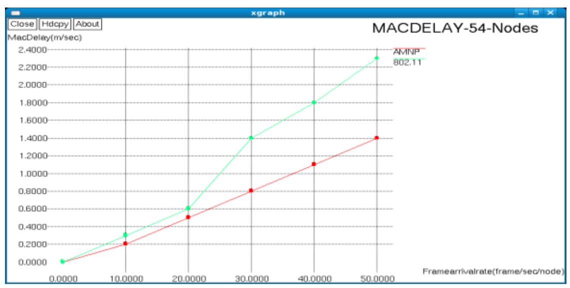

Fig. 9 Comparison of Mac delay derived by IEEE 802.11 and AMNP

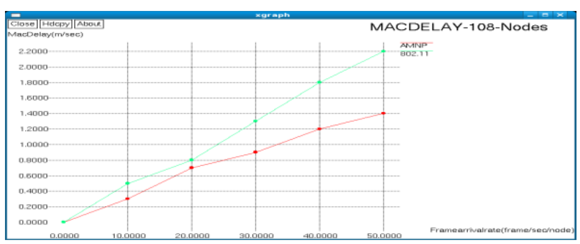

Fig. 10 Comparison of Mac delay derived by IEEE 802.11 and AMNP

The Fig. 9 and Fig. 10 show comparative delay analysis for IEEE 802.11 and AMNP protocol with 54,108 nodes. It is seen that AMNP protocol has lower MAC delay compared to IEEE 802.11 protocol.

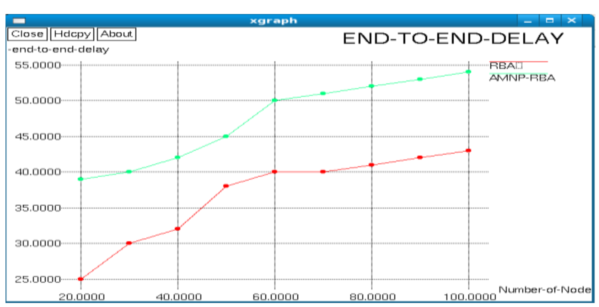

Fig. 11 Comparison of Mac delay derived by RBA and AMNP-RBA

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End - to – End delay is the total delay in the network; AMNP-RBA has higher delay because it is sum of back-off countdown, channel negotiation, transmission delay and the delay in broadcasting.

Broadcast delivery ratio is the ratio of the nodes that received the broadcast packets to the number of the network. AMNP-RBA has lesser BDR compared to RBA because it is used in multichannel environment.

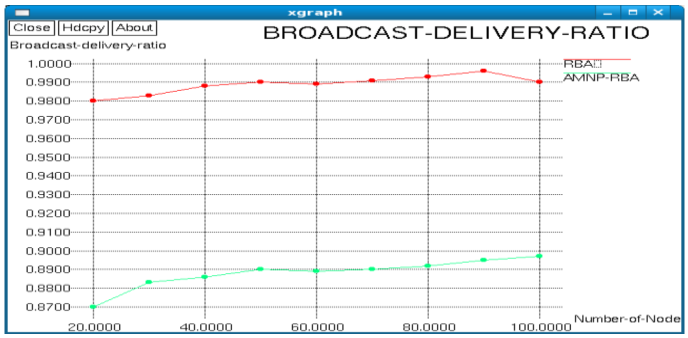

Fig. 12 Comparison of Broadcast delivery ratio derived by RBA and AMNP-RBA

V. CONCLUSION

The multi-hop MANET transmission capacity can be improved by adopting parallel multichannel access schemes. AMNP protocol addresses the problems like multichannel hidden terminal problem and the multichannel broadcast problem. This is due to those mobile nodes that cannot listen to all channels simultaneously. The proposed new MRTS and MCTS handshaking message conquers the multichannel hidden terminal problem. The BB control frame to conquer the multichannel broadcast problem. The performance analysis shows that there is an encouraging result. The parameters are compared for 802.11 and AMNP. It is concluded that the combination of AMNP – RBA gives a reliable broadcast transmission. Because in AMNP case 3 and case 4 are assumed for reliable transfer.

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