ISSN 2320-9984 03 >
9 772320 998015

Volume 1, Issue 3, October 2013 ISSN: 2320-9984 (Online)

International Journal of Modern Engineering & Management Research

Website: www.ijmemr.org

A Scalable MAC Scheme Supporting Multimedia Applications in Wireless Ad-hoc Networks

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Abstract**—***A Mobile Ad-hoc Network (MANET) is a collection of autonomous nodes or terminals which communicate with each other by forming a multi-hop radio network and maintaining connectivity in a decentralized manner. Nodes in ad-hoc networks play both the roles of routers and terminals. Now a day the demand of multimedia applications has increased, because of these increasing demands the requirement and popularity of wireless ad hoc networks the aim of these networks is to provide these heterogeneous services. Along with these requirements some reasons are there which dramatically degrades the performance of these networks. These reasons are Hidden Node, Exposed Node. There is no comprehensive study to completely resolve these problems. In our paper, dual channel based Medium Access Control mechanism is proposed to completely resolve these problems. Multiple data rate environment has used. Our scheme and simulations shows that the proposed scheme can overcome the problems and increases the performance of the network and eliminates the collision probability.*

Key Terms**—** *Wireless Ad Hoc Networks, Medium Access Control, Busy Tone, Hidden and Exposed Nodes.*

1. INTRODUCTION

A wireless ad hoc network is a collection of mobile nodes equipped with wireless transceivers that form an autonomous network without the help of any fixed networking infrastructure. A node can transmit data packets to other nodes who are within its radio coverage range directly, and who are outside the range via multihop store-and-forward relay to extend the range of communication. Such network received considerable attention in recent years in both commercial and military applications due to its attractive properties of building a network on the fly and not requiring any pre-planned infrastructure such as base stations or a central controller. Potential examples of this include in-building wireless networks in malls, hotels and apartment blocks. Together these actors make the study of multihop ad hoc networks very interesting.

In a multi-hop mobile ad-hoc network, mobile nodes cooperate to form a network without using any infrastructure such as access points and base stations. Instead, the mobile

nodes forward packets for each others allowing communication among nodes outside wireless transmission range. Examples of applications for ad-hoc networks range from military operation and emergency disaster relief to community networking and interaction among meeting attendees or students during a lecture. In this ad-hoc networking applications, security is necessary to guard the network from various types of attacks. In ad-hoc networks, adverse nodes can freely join the network, listen to and/or interfere with network traffic, and compromise network nodes leads to various network failures. Since routing protocols are a fundamental tool of network-based computation, at tacks on unsecured routing protocols can disrupt network performance and reliability. Wireless ad hoc networks are collections of nodes equipped with wireless transceivers and communicating exclusively over a common wireless channel. Due to the nature of the wireless channel, each node can only communicate directly with a few other nodes lying in its neighborhood. On the other hand, the traffic requirements of the network are such that distant nodes may need to exchange data. Therefore, the nodes in between such communicating pairs will have to relay the data in a multihop fashion. Medium Access Control (MAC) protocol plays a critical role in determining the throughput of the ad hoc networks. The primary design goal of MAC protocols is to coordinate among multiple nodes to access the channel to achieve high channel utilization. To achieve this goal an efficient MAC protocol is needed to minimize or eliminate the incidence of collisions and maximize spatial reuse at the same time. Hidden terminals are the main cause because of that collision get occurs. A hidden terminal is the one that can neither sense the transmission of a transmitter nor correctly receive the reservation packet from its corresponding receiver. A hidden terminal may interfere with ongoing transmission by sending packet at the same time.

Jurdak [1] give a survey on a set of MAC protocols which have been proposed to improve the performance of ad hoc wireless networks in different aspects. IEEE 802.11 DCF [2] is the most popular MAC protocol used in ad hoc wireless networks. In 802.11 DCF, two carrier sensing functions, physical carrier sensing (PCS) and virtual carrier sensing (VCS) functions, are used to determine the state of the medium. Though 802.11 DCF uses a four-way RTS/CTS/Data/Ack exchange to reduce collisions caused by hidden terminals in the network, but the performance evaluation shows that the throughput of 802.11 DCF may significantly degrade as the number of competing network nodes and number of hops increase, described in [3][4]. Since, 802.11 DCF regards the transmission range and the interference range as the same while in fact interference range varies as the distance between the sender and the receiver changes. The four-way handshake with the VCS only partially solves the hidden terminal problem and does not solve the exposed terminal problem. Hidden and exposed are the reasons to degrade the performance in terms of lesser throughput of the network.

2. BACKGROUND

In order to address hidden and exposed terminal problems many MAC based schemes are proposed in the literature but none of them completely resolves the hidden and exposed terminal problems except DBTMA scheme using RTS/CTS mechanism. However the RTS/CTS method is not more effective to avoid collisions in the region where large number of hidden terminals are there. Some busy tone based approaches are also used to resolve the hidden and exposed terminal problems. Busy Tone Multiple Access (BTMA) scheme is used [4] where there is a base station which broadcast a busy tone signal to let the potential hidden terminals that channel is busy by sensing the channel.

Dual busy Tone Multiple Access (DBTMA) is an extension of BTMA in which a distributed approach is used of sending the busy tones. In this method two out-of-band busy tones are used, transmit busy tone (BTt) and receive busy tone (BTr), to protect the RTS packets and data packets respectively.

This scheme can solve the hidden terminal problem but can not receive the exposed terminal problem.

Xu [15] proposed that the interference range can be modelled as a function of the distances between the sender and receiver nodes. They also investigate how effective is the RTS/CTS handshake in terms of reducing interference.

He [16] introduced the performance of IEEE 802.11 DCF MAC protocol in multihop wireless networks. Here impact of the variable interference range has taken into account.

Cesana [17] proposes a MAC protocol in which information about receiving power and interference levels into CTS packets is inserted. Here, by computing an estimation of the interference increasing due to an estimation of the interference increasing due to an eventual transmission, it increases the spatial reuse. Due to the interference range can exceed the transmission range, not all the node can overhear the CTS package, so the hidden terminal problem can not be resolved.

Choudhury [18] proposes ToneDMAC protocol which encodes the transmitter's node id into the busy tone to alleviate the deafness problem.

Karn [19] proposed a MACA protocol in which Request-To-Send (RTS) and Clear-To-Send (CTS) packets mechanism for the collision avoidance is used. A ready node or sender transmits an RTS packet to request the channel to the receiver. The Receiver replies to the sender by sending a CTS packet. MACA reduces the data packet collision which causes by hidden terminals by using RTS/CTS packets.

Talucci [20] introduced MACA-BI. In this protocol it is defined that in a network with periodic data traffic, the receiver can predict its future reception times.

MACAW protocol has suggested by Bharghavan [21] in which RTS-CTS-DS-DATA-ACK message exchange for a data packet transmission is used. The Data sending (DS) packet was used in this protocol to notify all nodes in the transmitter range that it is using the channel. The ACK packet was used for the acknowledgment.

There was some unfairness problems were there in MACA protocol; in MACAW some new back-off algorithm is introduced to solve the unfairness problems known as MILD algorithm.

3. RELATED STUDY

Many schemes have been proposed in the current literature to reduce severe collisions of DATA packets at the MAC layer. MACA [1] in which Request-To-Send (RTS) and Clear-To-Send (CTS) packets mechanism for the collision avoidance is used. A ready node or sender transmits an RTS packet to request the channel to the receiver. The Receiver replies to the sender by sending a CTS packet. MACA reduces the data packet collision which causes by hidden terminals by using RTS/CTS packets and MACAW [2] proposes the use of RTS and CTS packets for the collision avoidance on the shared channel. MACAW also uses DS packet to advertise the use of the shared channel in which RTS-CTS-DS-DATA -ACK message exchange for a data packet transmission is used. The Data sending (DS) packet was used in this protocol to notify all nodes in the transmitter range that it is using the channel. The ACK packet was used for the acknowledgment. However, both of them solve neither the hidden nor the exposed-terminal problems. The FAMANCS scheme [3] uses long dominating CTS packets which act as a receive busy tone to prevent any competing transmitters in the receiver's range from transmitting. This requires each node hearing the interference to keep quiet for a period of one maximum data packet to guarantee no collision with the ongoing data transmission, which is not efficient especially when the RTS/ CTS negotiation process fails or the DATA packet is very short.

Multi-channel random MAC schemes have also been investigated in the past few

years [4]–[20]. One common approach to avoid collisions between control packets and data packets is to use separate channels for different kinds of packets. The DCA scheme [10] uses two channels; one control channel for RTS/CTS and one or more data channels for DATA/ACK; however, it does not mitigate the hidden terminal problem. Some busy tone based approaches are also used to resolve the hidden and exposed terminal problems. Busy Tone multiple access (BTMA) scheme is used where there is a base station which broadcast a busy tone signal to let the potential hidden terminals that channel is busy by sensing the channel.

Dual busy Tone Multiple Access (DBTMA) is an extension of BTMA in which a distributed approach is used of sending the busy tones. In this method two out-of-band busy tones are used, transmit busy tone (BTt) and receive busy tone (BTr), to protect the RTS packets and data packets respectively. This scheme can solve the hidden terminal problem but can not receive the exposed terminal problem. The dual busy tone multiple access (DBTMA) schemes ([14], [15]) use a transmit busy tone to prevent the exposed terminals from becoming new receiver, a receive busy tone to prevent the hidden terminals from becoming new transmitter, and a separate data channel to avoid collisions between control packets and data packets. However, the DBTMA schemes have no acknowledgements for DATA packets which is needed for unreliable wireless links, and the potential collisions between the acknowledgements and other packets can greatly degrade the performance. PAMAS [16] uses a separate control channel to transmit both RTS/CTS packets and busy tone signals. It gives a solution to the hidden terminal problem and mainly focuses on power savings.

4. SYSTEM MODEL

Consider a scenario of ad hoc wireless network where data and voice traffic are transmitted. There is a communication channel, through which all the nodes send their frames in the network. Any overlap of transmissions at a receiver can cause a collision, and due to this none of the overlapped frames can be correctly received. The successful simultaneous transmissions are possible due to spatial reuse. In this paper, one hop transmissions are taken into consideration.

In this paper we had taken the IEEE 802.11 MAC protocol to describe the problems in this research. These problems not only associated with the IEEE 802,11 MAC but many MAC schemes which uses backoff mechanism also suffers from these same problems. Along with all this we had also taken multiple data rate support of the wireless ad hoc network into consideration. Multiple Data Rates depend upon the bit error ratio of the communication channel.

A. Problem Statement

This section, describes the problems in multi-hop ad-hoc networks when the IEEE 802.11 MAC protocol is deployed. The hidden and exposed node problems are two well known problems.

Here, in this section the hidden and exposed Node problems are defined appropriately

(i) Hidden Node Problem

The hidden and exposed Node problems are two well known problems. For example, in Figure 1, it indicates that the node A is in the transmission range on node B and node C in also in the node B's transmission range. A hidden node problem occurs in this case so it must be important that the transmission range and sensing range should be different.

(ii) Exposed Node Problem

The exposed node problem occurs when a transmitter is in the transmission range of an ongoing transmission and wants to sends data packer to the intended receiver which is not in the transmission range on that ongoing transmission, so the intended transmitter has to wait unnecessarily for that ongoing transmission to be completed, as shown in

Figure 2, where node C is in the transmission range of node B which is the transmitter and node D is in the transmission range of node C, so in this case, node C has to wait until node B completes its transmission, in this node B and node C are exposed to each other.

5. PROPOSED SYSTEM

In this paper, we have proposed a busy tone based protocol in which a busy tone transmitter and busy tone receiver is used. Busy tone transmitter is associated at the receiver side and busy tone receiver associates with the transmitter side.

1. Solution to the Hidden Node Problem

When the receiver node wants to send the data frame, it first senses the carrier f it sense the carrier free, it sends the data or RTS frame to the receiver and simultaneously sends a busy tone to the busy tone transmitter, by sending the busy tone the carrier sensing range of the network increases and due to increased carrier sense all the hidden nodes corresponding to the receiver end postpones there transmission or differs there transmission until the ongoing transmission get finished.

2. Solution to the Exposed Node Problem

To resolve the exposed node problem, a busy tone receiver is associated with the transmitter end, when receiver node gets the data or RTS frame; it sends a busy tone to the busy tone receiver which is associated at the transmitter end. This busy tone works as acknowledgement or CTS. After sending out an RTS (or DATA) frame, the sender senses the BTr channel. The status of a busy channel indicates that the RTS (or DATA) frame has been successfully received by the receiver; otherwise, a collision has occurred. After simulating the network we have analyzed the throughput of the network and we have found that our scheme completely resolves the hidden and exposed terminal problems and the aggregate throughput of our scheme is higher than all the other schemes.

6. PERFORMANCE EVALUATION

A. Simulation Environment

The simulations are done in NCTUns 5.0 simulator. The NCTUns network simulator and emulator (NCTUns) is a high-fidelity and extensible network simulator capable of simulating various devices and protocols used in both wired and wireless networks. It uses a distributed architecture to support remote simulations and concurrent simulations. It uses open system architecture to enable protocol modules to be easily added to the simulator.

Table 1 : Simulation Parameters

Parameters	Value
Data Transmission Range	250 m
Data Interference Range	550m
RTS Threshold Value	300 Bytes
Data Packet Size	1400
Link Bandwidth	11 Mbps
Duration	70
Basic Rate(RTS/CTS) Transmission	2 Mbps

In our proposed scheme, the link bandwidth varies according to the simulation and it varies from 11 Mbps to 5.5 Mbps, 1 Mbps and 2 Mbps.

B. Results and Discussion

We evaluate the performance of the network under various topologies. The system performance is evaluated under some specific topologies firstly as shown in Figure 3. Then, random topologies are simulated for more comprehensive evaluation.

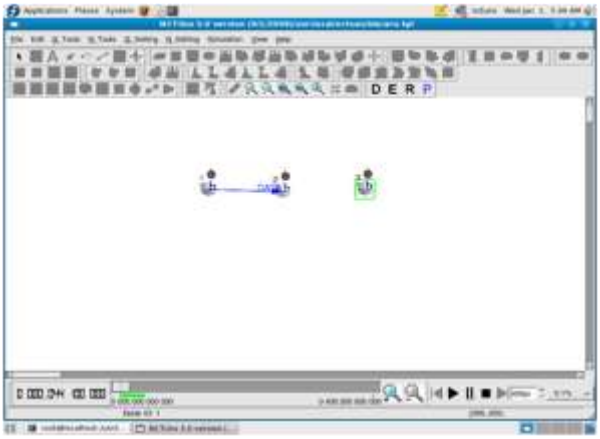

Figure 1 NCTUns Window with 3 Mobile Nodes

Figure 1 describes the hidden terminal problem in which node 1 and node 3 are sending data to node 2. Here, node 1 and node 3 simultaneously sends the data frame to node 2 and this causes the collision at node 2.

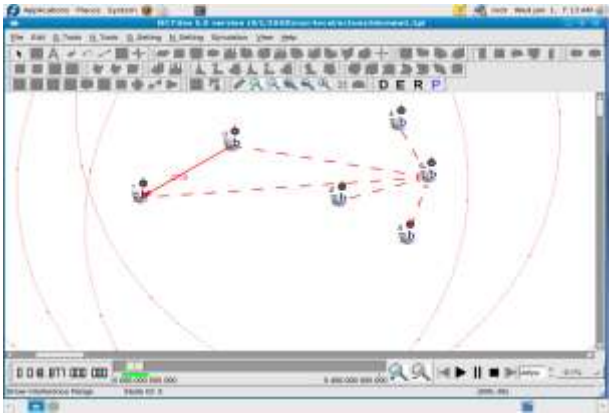

Figure 2. NCTUns Window with 6 mobile Nodes

Figure 2 shows the hidden terminal problem. In our scheme, node 3 waits until the transmission of node 2 get finished. In this way the hidden node problem get resolved in our proposed scheme.

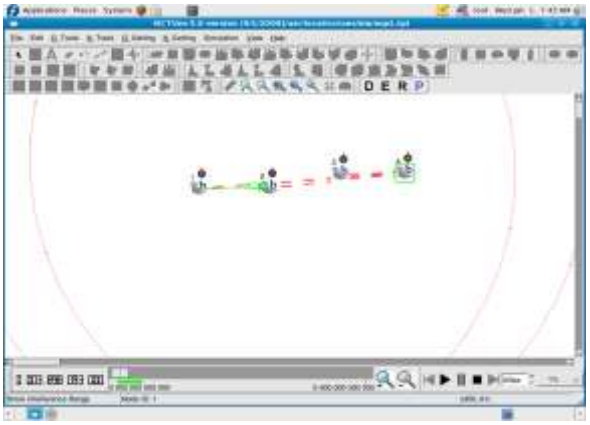

Figure 3. NCTUns Window with 4 mobile Nodes

Figure 4 shows the exposed terminal problem, in our proposed system; nodes can send there data frames without waiting for the completion of the ongoing transmission. Packet drop ratio has been calculated in our scheme by providing packet drop measurement factor to various nodes in NCTUns simulator.

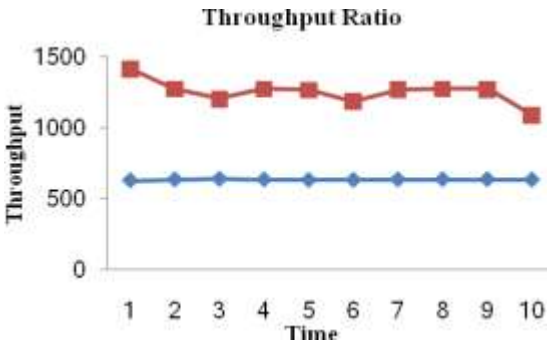

Figure 4 Time vs. Network Throughput

Figure 4, Figure 5 and Figure 6 represents the aggregate throughput of the network. By simulation results it has been shown that in our proposed protocol the overall throughput of the network is increased as compared to the previous schemes. Simulation is done using throughput parameter of NCTUns simulator.

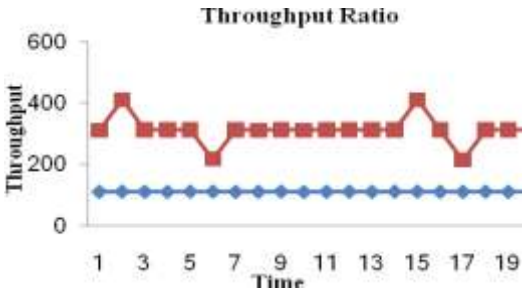

Figure 5 Time vs. Network Throughput

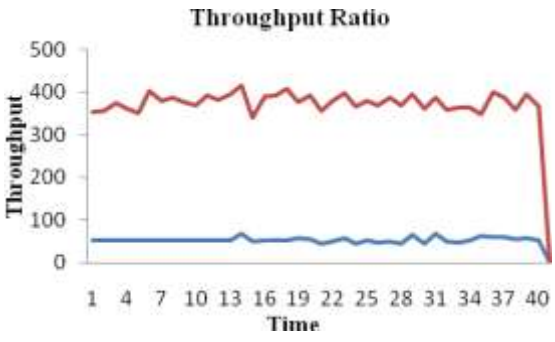

Figure 6 Time vs. Network Throughput

Figure 5 represents the total throughput ratio of our proposed scheme and previous scheme, and Figure 6 represents the time vs. access delay measurement. We have calculated the access delay of the network after simulating the network and we fond in our proposed scheme that the measurement of access delay in our scheme provides the better results. All the calculated results show that our scheme has resolves the hidden and exposed node problem.

7. CONCLUSION

In this paper, we identified the problems that are the main cause of dramatic performance degradation of the IEEE 802.11 MAC in multihop ad hoc networks, namely, the hidden terminal problem, the exposed terminal problem, To mitigate these problems, we proposed a new MAC protocol which uses two channels: one for control packets and the other for DATA packets; a busy tone signal is used to solve the hidden terminal problem. Our scheme reduces the hidden as well as exposed terminal problem and increases the throughput of the network in multiple data rate environment as compare to IEEE 802.11e MAC scheme. Proposed system has some characteristics, these are the use of two out-of-band busy tone and two communication channels, one for control packets and other for data packets and other one is the multiple data rate environment that provides the solution towards the problems. After simulating the network in multiple data rate environment is has concluded that our scheme can fairly addressed the hidden and exposed terminal problems of Wireless Ad hoc network.

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