Vikas Sejwar/ International Journal of Engineering Research and Applications (IJERA)
ISSN: 2248-9622 www.ijera.com
Vol. 2, Issue 1, Jan-Feb 2012, pp. 007-011

Simulation study for Mobile Ad hoc Networks Using DMAC Protocol

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Abstract

This paper addresses the issue of deafness problem in Mobile Ad Hoc Networks (MANETs) using directional antennas. Directional antennas are beneficial for wireless ad hoc networks consisting of a collection of wireless hosts. A suitable Medium Access Control (MAC) protocol must be designed to best utilize directional antennas. Deafness is caused when two nodes are in ongoing transmission and a third node (Deaf Node) wants to communicate with one of that node. But it get no response because transmission of two nodes are in process. Though directional antennas offer better spatial reuse, but this problem can have a serious impact on network performance. A New DMAC (Directional Medium Access Control) protocol uses flags in DNAV (Directional Network Allocation Vector) tables to maintain information regarding the transmission between the nodes in the network and their neighbor's location. Two performance matrices have been used to show the impact of New DMAC algorithm on Deafness problem using simulator. These are RTS Failure Ratio and RTS Re-transmission due to timeout.

KEY WORDS*: Ad hoc networks; Medium Access Control Protocol; Directional Antennas; Deafness; Deaf node*

1. Introduction

An Ad Hoc network is a self organizing and adaptive collection of devices connected with wireless links. An Ad Hoc network does not need any centralized controls and established infrastructure. Various MAC protocols have been developed for wireless Ad Hoc networks. A paper "The medium access control protocol for wireless Ad Hoc network: A Survey" by Sunil Kumar, Vineet S. Raghavan and Jing Ding [1] describes the classification and summary of various MAC protocols for Ad Hoc networks. The ease of deployment without the existing infrastructure makes ad hoc networks an attractive choice for situations such as military operations [2], disaster recovery [3], wireless mesh networks [4], wireless sensor networks [5], and so forth.

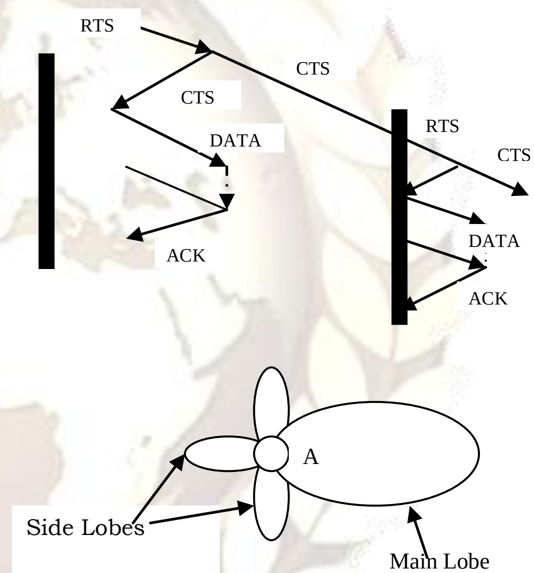
This work is motivated by the observation that nodes in ad hoc networks are typically assumed to be equipped with *omni directional antennas*. However, with the rapid advance of antenna technology in recent years [6,], it also becomes possible to use *directional antennas* [7] or *smart antennas* [8] to improve the capacity of ad hoc networks [9]. Using directional antennas may offer several interesting advantages for ad hoc networks. For example, routing performance can be improved by using a directional antenna [10]. To best utilize directional antennas, a suitable Medium Access Control (MAC) protocol must be used. Previous MAC protocols, such as the IEEE 802.11 standard [11], do not benefit when using directional antennas with changeable beam patterns, because these protocols have been designed to exploit omni directional antennas or directional antenna with a single fixed pattern. ***Directional antennas*** can concentrate radio signal energy in a particular direction, instead of radiating it in all directions like their omni-directional counterpart. So the transmission on a directional antenna can potentially cause much lesser interference, thereby giving a significant capacity advantage in multi-hop wireless networks. Though directional antennas offer many benefits such as better spatial reuse, increased coverage and better link reliability, they also present new problem called ***Deafness***. Deafness occurs when the transmitter fails to communicate to its intended receiver, because the receiver's antenna is oriented in a different direction. The rest of the paper is organized as follows. Firstly it discusses the existing work in the directional MAC layer protocols in Section 2. Section 3 outlines the brief description DMAC protocol. Section 4 thoroughly describes deafness phenomenon in directional antenna. Section 5 discusses the proposed enhancements. Then simulation results shown in Section 6. Finally, this paper is concluded in Section 7 highlighting some open problems and future research.

2. Related Work

Majority of the research using directional antenna were focused on single hop networks and cellular networks [16] in the past. Recently, many researchers have started to use directional antenna for multi-hop ad hoc or mesh networks [12],[13]. Various proposed protocols are similar to IEEE 802.11, carefully adapted to use over directional antennas. I present a brief overview of IEEE 802.11, followed by a discussion of the existing protocols for directional medium access control. Previous proposal on the use of directional antenna in multi-hop networks [15], Nasipuri et al. have proposed to send the RTS and CTS packets omni-directionally so that the transmitter and receiver can locate themselves, and then send the DATA and ACK packet directionally. This solves the deafness problem but results in poor spatial reuse. Ko et al. have proposed that the nodes send directional RTS while the CTS is sent omni-directionally [14]. They assume that the transmitter knows the location of the receiver. Directional RTS leads to deafness around the neighborhood of the sender. In a similar work, Roy Choudhary et al. have proposed the DMAC (directional MAC) protocol that performs all MAC layer operations in directional mode [11]. This combined with the DVCS mechanism achieves maximum spatial reuse, but it suffers from both deafness and directional hidden terminal problems. In [16], Gossain et al. have identified the problems mentioned earlier and proposed modifications to existing directional MAC protocols to address the deafness problem. Their approach addresses the deafness scenario but not the hidden terminal problem. In [16], Cordiero et al. have proposed an optimization to the circular DMAC protocol to solve deafness and hidden terminal problem due to asymmetry in gain between directional and omni-directional antennas.

3. Directional MAC (D-MAC) Scheme

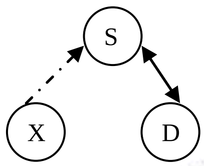
The Directional MAC (D-MAC) scheme [16] is similar to IEEE 802.11 in many ways. The DMAC scheme also sends an ACK immediately after the DATA, as in IEEE 802.11—however, in D-MAC scheme, the ACKs are sent using a directional antenna, instead of an omni directional antenna. In IEEE 802.11, if a node X is aware of an on-going transmission between some other two nodes (due to the receipt of RTS or CTS from those nodes), node X will not participate in a transfer itself—that is, X will not send a RTS, or send reply to a RTS from another node, while the transfer between other two nodes is in progress. The D-MAC protocol apply a similar logic, but on a per-antenna basis. In brief, if antenna T at node X has received a RTS or CTS related to an on-going transfer between two other nodes, then node X will not transmit anything using antenna T until that other transfer is completed. Antenna T would be said to be 'blocked' for the duration of that transfer—the duration of the transfer is included in each RTS and CTS frames (as in IEEE 802.11), therefore, each node can determine when a blocked antenna should become unblocked. The key point to note about is that, when using directional antennas, while one directional antenna at some node may be blocked (as defined above), other directional antennas at the same node may not be blocked, allowing transmission using the unblocked antennas. This property results in performance improvement when using directional antennas. Omni directional transmission of a frame in DMAC scheme requires the use of all the directional antennas. Therefore, an omni directional transmission can be performed if and only if none of the directional antennas are blocked.



Example of Directional MAC protocol

4. Deafness Problem

This section will focus various scenarios in which deafness problem would occur. In general, deafness is caused when the transmitter repeatedly tries to send RTS to a destination but the destination does not reply with a CTS. In Figure below, if node **S** is transmitting to node **D**, it sends a directional RTS to Node **D**. Node **D** then sends a directional CTS. Node **X** is not aware of this transmission. If it initiates a transmission to node **S**, node **S** will not respond as it is transmitting data directionally to node **D**. This causes node **X** to back off unnecessarily resulting in poor channel utilization. Here, deafness arises because node **S** has its beam oriented in a different direction and node **X** assumes that the RTS packet is lost due to congestion. Node **X** cannot initiate a transmission to node **S** immediately when the transmission between node **S** and node **D** is over, because it has to wait for the entire back off interval. The directional MAC protocols that send RTS or CTS in a directional manner (DRTS/DCTS) suffer from this problem.



Deafness Problem

5. New D-MAC Protocol

D-MAC protocol utilizes a directional antenna for sending the RTS frames in a particular direction, whereas CTS frames are transmitted in all directions.

In a D-MAC protocol to improve network performance, a DRTS frame is transmitted in the direction of the intended receiver prior to the transmission of the actual data frames. Using DRTS only, instead of omni directional RTS (ORTS), may increase the probability of control packet collisions in some cases. To overcome the probability of collisions between control frames which lead to deafness problem the paper proposes a NEW D-MAC protocol. This protocol minimizes the deafness and hidden node drawbacks of directional antennas in MAC layer. A flag is used in DNAV table which takes care of the ongoing transmission between various nodes in the network, as well as their neighboring nodes location also. Now the RTS frames are send in the two different types i.e. DRTS\ORTS. Suppose any node say **G** has to transfer data then it has to follow below cited algorithm:

I. If none of the directional antennas at node **G** are blocked and the flag value is null then node **G** will send ORTS,
II. If any of the directional antennas at node **G** are blocked, then it will check the value in DNAV table consist of flag in which the information regarding the ongoing transmission between the neighboring nodes is available,
III. Node **G** will wait for processing transmission, after that again it will sends DRTS.

The DMAC protocol [16] is used as a baseline for performance comparison. In DMAC, all the MAC layer operations are done in a directional manner. It is aimed towards maximum spatial reuse but it suffers from all the problems mentioned in Section 4. The various parameters are used to optimize the network performance and to improve the overall throughput. The factor that is to be calculated for the optimization of New DMAC protocol is RTS failure ratio since both the deafness problem occurs due to RTS packet dropout by the nodes.

Failure Ratio = 1- (NCTS/NRTS)

Where:

NCTS = No. of CTS successfully received
NRTS= No. of RTS sent

These parameter are helpful in the performance evaluation of the protocol because deafness of node depends upon the RTS not received due to beam formed towards another node.

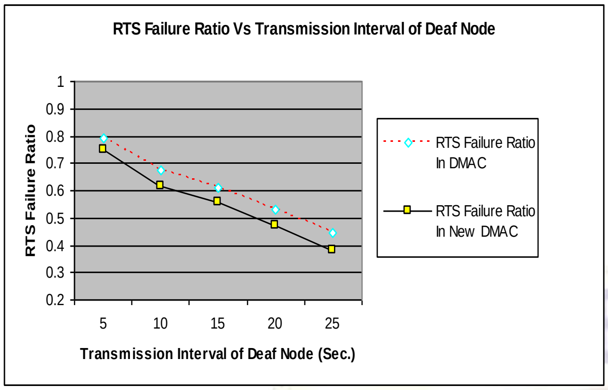
6. Results

A. Simulation Environment

In this dissertation work all the simulation work is done in QualNet wireless network simulator version 4.0. Simulation time was taken 50 seconds and it remains fixed throughout all simulation work. All the scenarios have been designed in 300m x 300m area. Mobility model used is Random Way Point (RWP). In this model a mobile node is initially placed in a random location in the simulation area. Two nodes are communicated in whole simulation and other nodes, called Deaf nodes[17] try to communicate with this two nodes.

Wireless network which we have used have following values for different parameter**:** Channel frequency: 2.4 GHz, MAC Protocol: MAC802.11, Directional Antenna Mode: Enable, Directional Antenna Model: Switched Beam, Antenna Beam Pattern: 4

B. Simulation Result



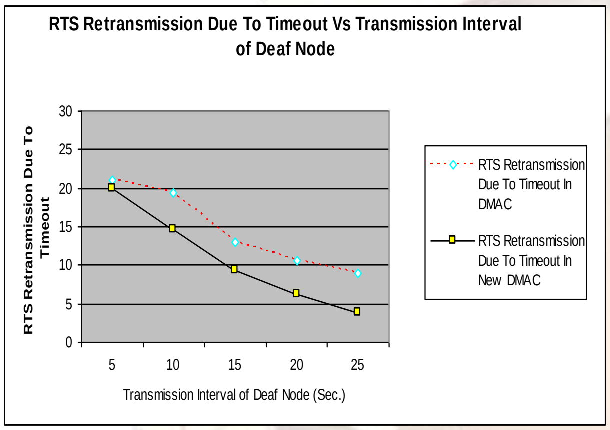


Fig 1. Comparison of RTS Failure Ratio and RTS Re-transmission Due to Timeout for the New DMAC Protocol using different values of the transmission interval of Deaf Nodes.

By looking at figure 1 we can easily say that the RTS Failure Ratio decreases in both the protocols as the transmission interval of deaf nodes increases. RTS Failure Ratio is highest in case of interval is lowest i.e. 5 seconds, it means that in this case deaf nodes wait only 5 second for transmit RTS to communicating nodes. When the interval of transmit RTS increases, the RTS Failure Ratio decreases in both protocol, but in New DMAC it is low then DMAC.

The RTS re-transmission due to timeout decreases in both the case as the transmission interval increases from 5 to 25 second. In case of New DMAC protocol, the no of RTS sent by the deaf nodes decreases when the waiting time to access channel or sending control frames is increases because in New DMAC protocol there is a flag value which force the deaf nodes to increase its waiting time up to the flag value in DNAV of communicating nodes becomes 0. the DMAC protocol does not have flag value in DNAV of the nodes, that's why the RTS re-transmission due to timeout is higher as comparatively in New DMAC protocol.

7. Conclusion

This paper have focused deafness & hidden node problems that may affect the performance of MAC protocols for adhoc networks using directional antennas. The proposed New DMAC protocol very well handles the above problems. The conventional DMAC protocol repeatedly transmits RTS/CTS without having exact location and time duration for which the node has to wait. A New DMAC protocol provides certain rules for handling DRTS/ORTS transmission. New DMAC protocol helps in the improvement of the following criterion:

- Deafness of Nodes
- Neighbor Discovery
- Power Management

New DMAC protocol improves overall network performance and provides effective handling of the network traffic. It should be noted that Adhoc network is a dynamically changing scenario therefore the final performance depends on network topologies, and flow patterns in the network.

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