IEEE 802.11 Based MAC Improvements for MANET

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ABSTRACT
Broadcasting is one of the essential communication models of MANETs. Many MANET multicast routing protocols rely heavily upon MAC layer's broadcast support. However, the broadcast mechanism of the standard IEEE 802.11 cannot provide reliable broadcasting service. In this paper, we improve the IEEE 802.11 broadcast mechanism's reliability by introducing the new layer of MAC called Dual MAC.

Multihop ad-hoc wireless networks offer great challenges for protocol designers. Stations in such networks are constrained by factors like low power, limited bandwidth, link errors, and collisions. Changes are needed at various levels of the protocol stack, most importantly at the medium access layer (MAC). The medium access mechanism in multihop wireless networks should minimize collisions, and take care of the hidden and exposed node problems. The IEEE 802.11 MAC with Distributed Coordination Function (DCF) does not scale well in such networks. We introduce Point Coordination Function (PCF) in the region of high traffic areas, and discuss its effect on network performance.

To improve network scalability and throughput, we propose the design of a new MAC called Dual MAC. This work discusses architecture and working of the dual MAC in detail.

Keywords

Medium Access Layer, Distributed Coordination function, Point coordinated function.

INTRODUCTION

In recent times, the wireless networks have become very popular. Wireless LANs are being deployed on airports, conferences, etc. People have started using portable laptops to access Internet and other resources using wireless networks while moving. Another area which has generated a lot of interest recently, is wireless ad-hoc networks. An ad-hoc network is formed when two or more stations come together form an independent network. Ad-hoc networks are also termed as infrastructure-less networks since as they do not require any prior infrastructure. Two stations that are within transmission range of each other are called one hop neighbors. Multihop ad-hoc networks are ones in which the stations can talk to stations more than one hop away via intermediate stations. Cooperative ad-hoc networks are formed by several homogeneous wireless stations. All the stations cooperate with each other, i.e., the traffic for the stations that are more than one hop away is routed by the intermediate stations. The intermediate stations are called relaying stations.

The following section describes the common Media Access Control layer used by the 802.11 family of standards. The 802.11 family uses a MAC layer known as CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) NOTE: Classic Ethernet uses CSMA/CD - collision detection). CSMA/CA is, like all Ethernet protocols, peer-to-peer (there is no requirement for a master station).

In CSMA/CA a Wireless node that wants to transmit performs the following sequence:

1. Listen on the desired channel.
2. If channel is idle (no active transmitters) it sends a packet.
3. If channel is busy (an active transmitter) node waits until transmission stops then a further **CONTENTION** period. (The Contention period is a random period after every transmit on every node and statistically allows every node equal access to the media. To allow tx to rx turn around the contention time is **slotted** 50 micro sec for FH and 20 micro sec for DS systems).

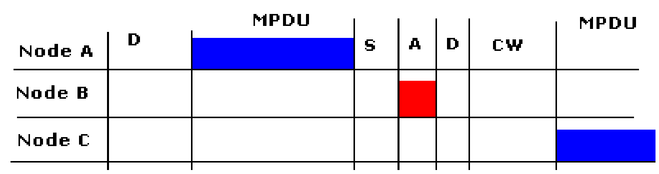


Figure 1

4. If the channel is still idle at the end of the **CONTENTION** period the node transmits its packet otherwise it repeats the process defined in 3 above until it gets a free channel.

Key:
1. D = DCF Inter Frame Space (DIFS)
2. S = Short Inter Frame Space (SIFS)
3. CW = Contention Window
4. MPDU = MAC Protocol Data Unit
5. A = Ack

802 11 also offers a polling mode (known as PCF - Point Co-ordination Function) which is fairly classic polling scheme e.g. 3270 bi-sync!! As with all polling protocols a single master (Base Station) is required.

1. ORIGINAL 802.11 MAC
1.1 DCF
The basic 802.11 MAC layer uses the Distributed Coordination Function (DCF) to share the medium between multiple stations. DCF relies on CSMA/CA and optional 802.11 RTS/CTS to share the medium between stations. This has several limitations:

- If many stations communicate at the same time, many collisions will occur, which will lower the available bandwidth (just like in Ethernet, which uses CSMA/CD)

- There are no Quality of Service (QoS) guarantees. In particular, there is no notion of high or low priority traffic.
- Once a station "wins" access to the medium, it may keep the medium for as long as it chooses. If a station has a low bit rate (1 Mbit/s, for example), then it will take a long time to send its packet, and all other stations will suffer from that.

1.2 PCF

The original 802.11 MAC defines another coordination function called the Point Coordination Function (PCF): this is available only in "infrastructure" mode, where stations are connected to the network through an Access Point (AP). This mode is optional, and only very few APs or Wi-Fi adapters actually implement it. APs send "beacon" frames at regular intervals (usually every 0.1 second). Between these beacon frames, PCF defines two periods: the Contention Free Period (CFP) and the Contention Period (CP). In CP, the DCF is simply used. In CFP, the AP sends Contention Free-Poll (CF-Poll) packets to each station, one at a time, to give them the right to send a packet. The AP is the coordinator. This allows for a better management of the QoS. Unfortunately, the PCF has limited support and a number of limitations (for example, it does not define classes of traffic).

1.3 802.11e MAC protocol Operation

The 802.11e enhances the DCF and the PCF, through a new coordination function: the Hybrid Coordination Function (HCF). Within the HCF, there are two methods of channel access, similar to those defined in the legacy 802.11 MAC: HCF Controlled Channel Access (HCCA) and Enhanced Distributed Channel Access (EDCA). Both EDCA and HCCA define Traffic Categories (TC). For example, emails could be assigned to a low priority class, and Voice over Wireless LAN (VoWLAN) could be assigned to a high priority class.

Standard has been extended to support 2 Mb/s for Frequency Hopping and 5.5 and 11 Mb/s for Direct Sequence (802.11b).

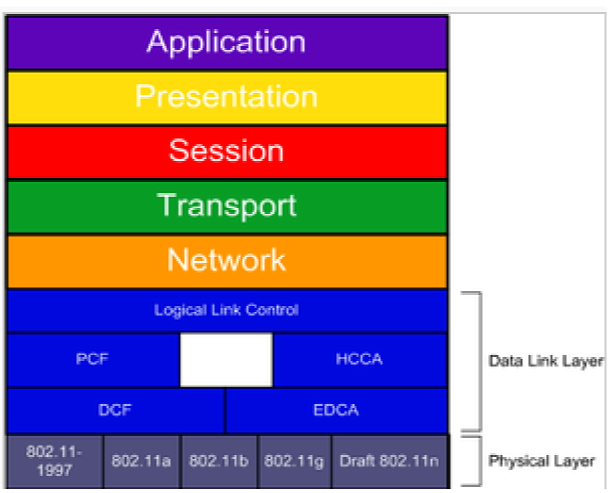
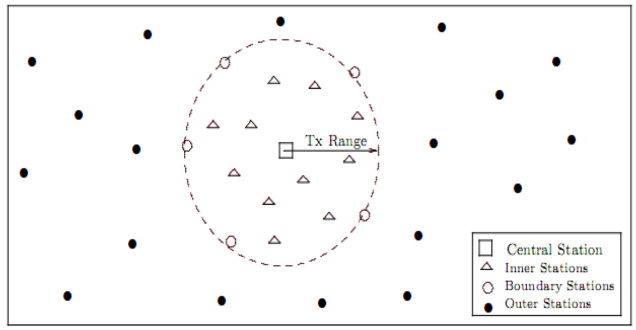


Figure 2 MAC Layer

3. MAC IN IEEE 802.11 IN MULTIHOP SCENARIO

The IEEE 802.11 MAC is designed for wireless LANs. The requirements of multihop ad-hoc networks are more challenging than those of wireless LANs. We will investigate the operation of IEEE 802.11 MAC in centralized multihop ad-hoc networks. The terms station and node are used interchangeably throughout the thesis. Multihop cooperative wireless ad-hoc networks will be simply referred to as multihopnetworks



. **Figure 3: Multihop Scenario**

Consider a multihop centralized scenario, as shown in the figure 4.1. For convenience, the stations inside the network are classified into following categories: Central station is the central controlling station. Most of the traffic in the network is directed towards it. Inner stations are within one hop boundary of the central station. Boundary stations are at one hop boundary of the central station. These stations act as relaying stations for the stations outside the reach of central node. Outer stations are outside the communication range of central node.

3.1 IEEE 802.11 Operations in Multihop Networks

The 802.11 MAC with DCF mode of operation is the simplest choice in multihop ad-hoc networks. The reason for the choice of DCF is that it does not require any prior infrastructure. Two or more stations can come together and form an BSS. This nature of DCF is very suitable for ad-hoc networks as the ad-hoc networks are simply formed by as set of stations coming together. In this section we discuss the operation of 802.11 MAC in multihop networks, especially centralized multihop ad-hoc networks In a centralized multihop network, as shown in Figure 4, the node density in central region is higher than in the outer region. Most of the traffic is directed toward the central node and boundary stations act as relaying stations. Therefore, the traffic near the central station and its one hop neighbors is very high. Since the DCF is a contention based distributed protocol, it performs badly in high load conditions. The poor performance of DCF is due to fact that the collisions increase as more and more stations try to access the medium at the same time. It is well known that the polling

The most suitable choice for the polling MAC would be PCF mode of 802.11, as it is an extension of the DCF mode. Ebert et. all [8] have shown that the PCF mode performs better than DCF when the number of stations in WLAN cell is very high.

Therefore, we make the central node as Point Coordinator (PC), and it polls all the inner and boundary nodes during CFP period. This differs from conventional PCF operation in WLANs where PC resides within AP. The outer stations still perform DCF since the traffic in those regions is not high. The outer stations can send their data in contention period (CP) as all the stations perform DCF during CP. We refer this combination of PCF and DCF as hybrid operation as shown in figure 4.

The hybrid operation seems to be an ideal choice in multihop networks, but it gives rise to following problems:

• The stations that are polled by the Point Coordinator (PC) keep their NAV set during the CFP period, and therefore, can not receive from outer stations. It can also be said that the boundary nodes become exposed to PC.

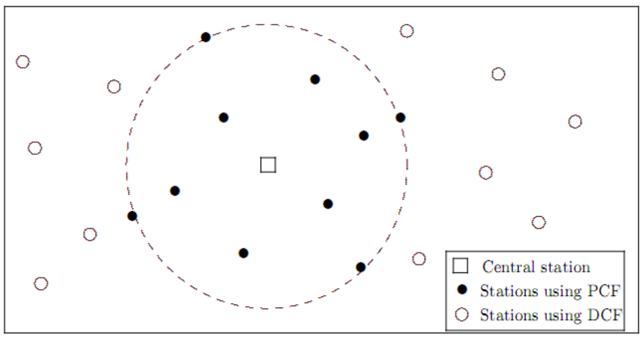


Figure 4 Hybrid PCF-DCF Operations

Outer stations become hidden to PC, and vice versa, as there is no RTS/CTS exchange between PC and its one hop neighbors during CFP period.

3.2 Problem Description

Simple DCF is not suitable for centralized multihop network due to collisions at high traffic. A polling MAC (PCF) is required at the centre of the network to handle high traffic and reduce collision, but it gives rise to hidden and exposed node problems. The solution to both of these problems is provided by introducing dual Nodes at the boundary of the central node.

4. DUAL MAC

Due to these reasons we introduce Dual MAC,

1. The DCF does not work well in high load scenario.

2. In case of hybrid operation, the polling and NAV setting in PCF nodes cause exposed and hidden node problems, thereby decrease the throughput. To improve the throughput, boundary nodes should be able to receive date from outer nodes during the CFP period (NAV is set). For this the MAC should be able to receive even if its NAV is set. Also, transmissions from outer stations should not collide with that of PC at boundary stations. To address above problems, we propose to equip boundary stations with dual MAC.

A dual node is a station which has two independent MACs each communicating on different logical channels. The two MACs are encapsulated inside the dual MAC. The logical channels could be FDMA or CDMA. Consider the boundary stations in Figures 4 and 5 that are equipped with dual MACs. One of the MACs uses the PCF and is termed as PCF MAC. The second MAC uses the DCF and is termed as DCF MAC.

The PCF MAC communicates with the PC, and the DCF MAC communicates with the outer nodes. The exposed and hidden node problems in central region are eliminated as follows:

• Boundary stations use the PCF and the DCF on different channels. Therefore, the transmission of outer node does not collide with that of PC, and vice versa.

• The DCF MAC in the dual node can receive from outer nodes even when the NAV of PCF MAC is set during CFP period, thereby eliminating exposed node problem.

4.1 Architecture of Dual MAC

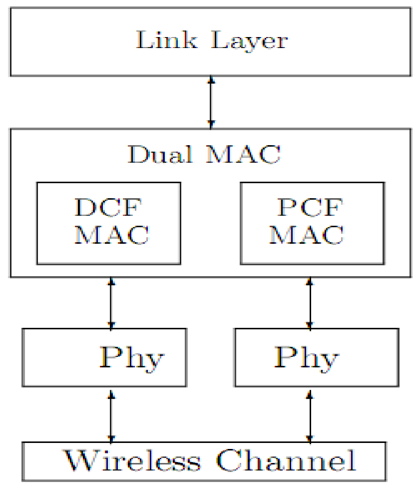


Figure 5: Architecture of Dual Mac

4.2 Operation

A packet arriving from link layer is received by the dual MAC and handed over to the MAC at appropriate frequency. The link layer finds out the MAC address of the next hop destination by using ARP and hands out the packet to the dual MAC layer along with the destination MAC address. In case dual MAC, the dual MAC also needs to know the channel of the destination station. This could be done either by ARP table maintaining information about the channel on which the destination stations is communication, or by maintaining a local list of stations on each channel. The dual MAC figures out the channel of the destination MAC and sends out the packet to the appropriate MAC. The broadcast packets like route discovery packets and ARP packets are sent to both the Macs. On Receiving a packet from layer, the dual MAC simply hands it out to the link layer. The operation of the dual MAC is summarized in figure 6

```
For outgoing packets:
        if ( packet is broadcast ) {
                send packet to both PCF MAC and DCF MAC;
        } else {
                channel = get_destination_MAC_channel();
                if ( channel == DCF_channel )
                        send packet on DCF MAC;
                else
                        send packet on PCF MAC;
        }


For incoming packets:
        hand over the packet to Link Layer;
```

Figure 6 Operation of Dual MAC

5. CONCLUSION

The design of a MAC that meets the demand of a multihop wireless network is great challenge. The restrictions like limited bandwidth, low power, and limited transmission range make this challenge even greater. Further, the hidden and exposed node problem offer even more difficulties by increasing the chance of collision. In this work, we have investigated the usefulness of IEEE 802.11 MAC protocol using the PCF and DCF mechanisms. We find that without modifications, the PCF and DCF are not very useful in multihop networks. The dual MAC was designed to eliminate exposed and hidden node problems in the central region of a centralized multihop network.

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