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A Basic Approach for Full Duplex MAC Design for Asymmetric Uplink and Downlink Traffic

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Abstract: Recent advances in antenna design and interference cancellation techniques make it feasible to transmit and receive data at the same time by using a single carrier frequency, which is known as in-band full-duplex (IBFD) communication. But, along with physical layer technologies, medium access control design is also necessary for a successful IBFD wireless communication. This paper discusses a medium access control (MAC) design for IBFD wireless communications, which supports asymmetric length of traffic for uplink and downlink. This paper discusses a brief description of this FD-MAC for a WLAN that consists of a full-duplex AP, some full-duplex clients and some half-duplex clients.

1 Introduction

Traditional radio transceivers cannot transmit and receive at the same time by using the same band of frequency because of the self-interference (cross-talk) at the receiver end. However, recent technological advancement in antenna design and radio frequency (RF) interference cancellation techniques reduce the self-interference up to a acceptable level by which in-band full-duplex (IBFD) wireless communications is now possible. There are a number of papers that proposed the techniques for the in-band full-duplex wireless communications, which describe the aspects of the physical layer. But along with this, medium access control (MAC) design is also crucial for successful IBFD wireless communication.

On the other hand, traffic asymmetry in terms of uplink and downlink is very common in our practical field of wireless communication. For example, in case of internet uses, much larger amount of data is transmitted in downlink directions as compared to that in uplink directions.

Although some MAC designs have been proposed for the IBFD wireless communication, most of them used the symmetric uplink and downlink data and some other used busy tone, if any transmission (uplink or downlink) ended earlier. For example, a full-duplex MAC (FD-MAC) has been proposed for WiFi networks in [1]. This paper proposed a MAC to mitigate the inter-user interference during full-duplex transmission. However, same length of traffic is used for both uplink and downlink transmission. Another FD-MAC protocol is proposed for WLANs in [2]. In this case, if access point (AP) ends its transmission earlier while receiving from another node, AP sends busy tone. So, during this period of busy tone, the corresponding link is actually idle in terms of data transmission. A cross layer approach for asymmetric traffic is introduced for full-duplex wireless networks in [3]. However, this paper exploits the underlying physical layer characteristics and network layer transmission buffer. So, it did not proposed any MAC protocol. A FD-MAC protocol for decentralized FD networks has been proposed in [4]. Here, the lengths of all packets are considered as fixed lengths.

As the asymmetric data traffic is not discussed significantly in earlier IBFD MAC protocols, we are motivated to design a MAC protocol that supports asymmetric traffic for full-duplex wireless local area network (WLAN). By using the asymmetric data transmission for IBFD wireless communications, the capacity of uplink and downlink will be efficiently utilized.

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2 The FD-MAC for Asymmetric Traffic

2.1 WLAN Structure

The basic structure of a full-duplex WLAN for our FD-MAC is shown in Fig. 1. Here, the AP is Full Duplex capable, some user terminals (UTs) are traditional devices, named as half-duplex clients (HDCs) and some are full-duplex capable which are named as full-duplex clients (FDCs). IBFD communications can be classified in two broad categories, such as bidirectional full duplex (BFD) and relay full duplex (RFD). The BFD communication is performed between AP and any one FDC, when they transmit and receive at the same time. On the other hand, in case of RFD, AP transmits data to one of the clients while receiving data from another client or vice versa.

2.2 Detailed Description of the FD-MAC

The detailed time line of the data transmission are depicted in Fig. 2. Initially, AP will broadcast a frame that

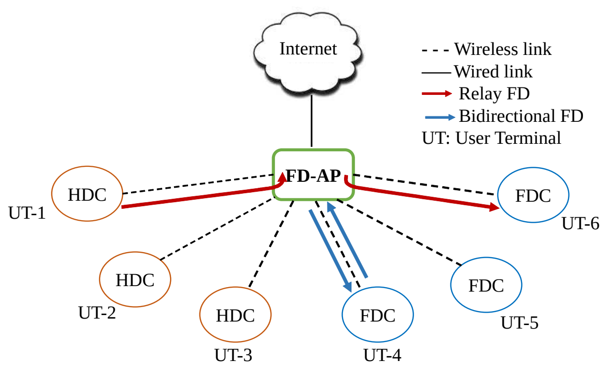

Figure 1: Structure of a full-duplex WLAN.

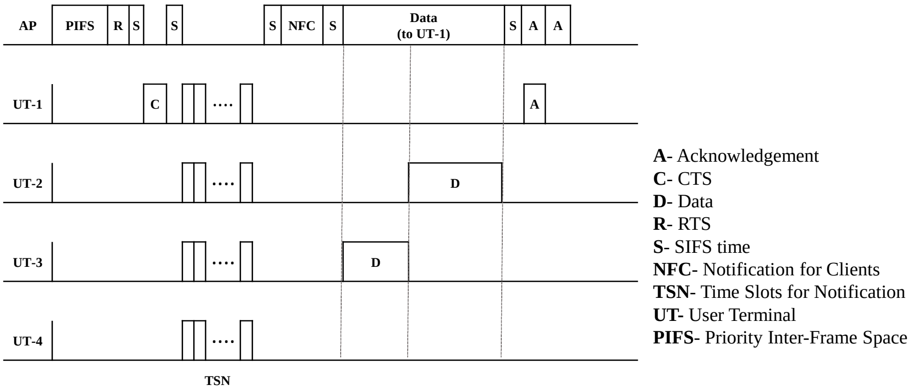

Figure 2: The FD-MAC for asymmetric traffic.

allocate specific time slot to each user terminal. After that, as in Fig. 2, suppose AP has data to send user terminal-1 (UT-1). So AP will send RTS (request to send) to UT-1 after the priority interframe space (PIFS). Then after sending CTS (clear to send) by UT-1, time slots for notification (TSN) starts, where a specific time slot for each UT has been defined earlier. In these time slots UTs send their notifications to the AP, if they have data to send AP. Also UTs checks another condition to eliminate the inter user interference. The condition is that if the UT's received signal strength of earlier CTS (sent by UT-1) is less than a predefined threshold (γ), it can send the notification to AP.

The control frames that are used in this MAC are shown in Fig. 3. Here, the RTS and CTS have the same frame format as IEEE 802.11 standard. TSN mini slot frames have only two bits. These two bits are used by each UT to inform AP whether they have data or not. The UTs also defines the data length by using these two bits. Here, we defined three threshold ($\gamma_1, \gamma_2, \gamma_3$) for traffic length. So, UTs send two bits according to the data length as in Fig. 3. Here, γ_1 = 600 bytes, γ_2 = 1200 bytes and γ_3 = 1800 bytes. If the UT has no data, it will send "00".

After getting all the information from user terminals, AP will send notification for clients (NFC), where AP will select the UTs that can send the data. This selection is performed based on the uplink and downlink data length.

For example, AP has data to send UT-1. So, AP and UT-1 will exchange the RTS and CTS (Fig. 2). Then, after getting all notifications during TSN, suppose AP sends NFC by selecting UT-2 and UT-3, so that they can send data to AP. After SIFS time, AP will send data to UT-1 and UT-3 will send data to AP simultaneously. After finishing the data transmission by UT-3, UT-2 starts to transmit data to AP. At last, after ending the data transmission, acknowledgement (ACK) will be sent as the figure.

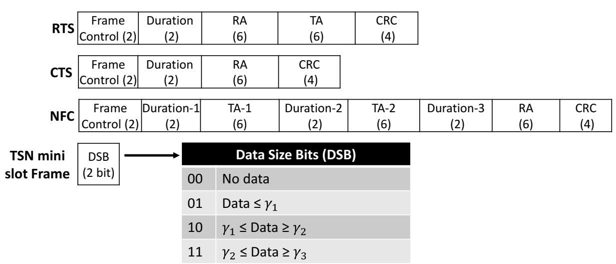

Figure 3: Control Frames (in octet).

3 Conclusion

This paper discusses a full-duplex MAC protocol for a AP based WLAN. This MAC supports asymmetric traffic length for uplink and downlink. So, different user terminals can send data with different length. As a result, the uplink and dowlink capacity can be used efficiently. A fundamental discussion is given in this paper. The simulation for this MAC will be performed in future research work.

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