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Orthogonal Frequency Division Multiple Access (OFDMA) Based MAC Protocols Survey for the Next Generation WLAN

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Abstract

The proliferation of wireless communications systems poses new challenges in terms of coexistence between heterogeneous devices operating within the same frequency bands. In fact, in case of high-density concentration of wireless devices, like indoor environments, the network performance is typically limited by the mutual interference among the devices themselves, such as for wireless local area networks (WLANs). It is proved that the throughput is very low comparing to the PHY peak rate, and the media access control (MAC) efficiency is very low in the current WLANs specification, especially in dense deployment scenarios. Therefore, to achieve high MAC efficiency the IEEE Standards Association Standards Board (IEEE-SA) approves IEEE 802.11ax in March 2014, to draw up a brand new amendment for the next generation WLAN.

Keywords—Survey, Next Generation WLANs, IEEE 802.11ax, MAC, OFDMA

Introduction

We use Wireless local area networks (WLANs) communicate with each other and to know the world in our daily lives. IEEE 802.11n published in 2009 adopts OFDM and 4X4 multiple input multiple output (MIMO) and achieves 600Mbps in two 20MHz channels (total 40MHz) and recently IEEE 802.11ac published in 2013 leverages OFDM and 8X8 MIMO and achieves 6.9Gbps in eight 20MHz channels (total 160MHz) .Despite the almost exponentially increase of the PHY peak rate, in the dense deployment scenarios which is regarded as one of the unique characteristics of the next generation WLAN. Current WLAN MAC protocol is a typical single user channel access and single user data transmission protocol. For WLANs (wireless local area networks), the transmissions are typically organized on a packet basis, so that each node occupies the medium for a time interval that is much shorter than the transmission period. However, in the dense deployment scenarios of the next generation WLAN, the MAC efficiency of this single access single transmission protocol will deteriorate to almost 33%-40%.Thus the current MAC protocol will be no longer suitable.

For instance, in order to achieve high MAC efficiency the OFDMA based centralized MAC protocol is adopted for channel access and data transmission in LTE and Wi-Max. With OFDMA technology, the whole channel is divided into several sub-channels, and several subcarriers comprise one sub-channel. Thus, OFDMA enable multiuser channel access and multiuser data transmission since different nodes could use different sub-channels simultaneously.

The main novel contributions of this work are as follows:

(i) Throughput analysis of the Control Layer Medium Access (CL-MA) when applied to a standard WLAN traffic layer under conditions of saturated traffic.

(ii) Comparison, in terms of throughput performance, among the proposed access scheme, the standard WLAN MAC, and the main scheme based on a signaling channel.

(iii) Study of the role of the fundamental system parameters, like bandwidth, processing gain, and time slots in the design of the CL.

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OFDMA is considered as one of the most promising technologies for the next generation WLAN. There are total four advantages of introducing OFDMA into the next generation WLAN MAC protocol, i.e., multiuser access and transmission, QoS guaranteed scheduling, multiuser diversity and low signaling overhead.

Multiuser access and transmission

Due to the orthogonal feature of OFDM, the multiuser interference can be eliminated and thus multiple nodes can access channel simultaneously and transmit data concurrently.

QoS guaranteed scheduling

The QoS of the different categories of traffic can be guaranteed. The time-frequency resource block (RB) could be fine-grained using OFDMA, hence various scheduling algorithm may be employed in access point (AP) to guarantee the QoS of the traffics.

Multiuser diversity

The throughput of WLANs can be further improved by taking advantage of multiuser diversity in frequency domain. Since multiple users can access the channel simultaneously and the RBs can be scheduled, each user can be allocated with only high channel gain RBs.

Low signaling overhead

The signaling overhead of the OFDMA can be largely decreased. Since some control signaling could be aggregated into one frame using OFDMA, the same frame space time can be shared by many nodes.

Survey on OFDMA Based MAC Protocol

The research on OFDMA based MAC protocols design is classified into total four categories, based on two domains, i.e., sponsor node (AP or STAs) and channel access type (OFDM or OFDMA). These four categories are introduced respectively.

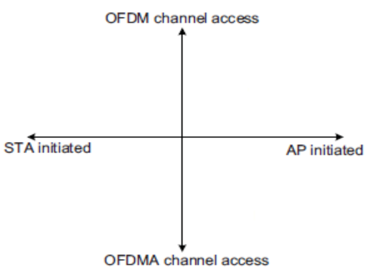

Figure 1: Four categories of OFDMA based MAC protocol

STAs Initiated Channel Access with OFDM

Based on Request to Send (RTS) and Clear to Send (CTS) mechanism in IEEE 802.11, proposed an OFDMA MAC protocol using channel state information (CSI) measurement. STAs contend for the channel resource as in current WLANs, and once AP receives a RTS frame from STAs, AP sends ask for request (AFR) to allocate resource to the STA sending the RTS frame based on the CSI capturing from RTS frame and to ask for new channel access request from other STAs.

STAs Initiated Channel Access with OFDMA

The basic idea of time-frequency two domain back-off procedure is that STAs could monitor all the sub-channels in WLAN, and adjust the back off rate according to idle sub-channel number. There are total two STAs and two sub-channels in WLAN.

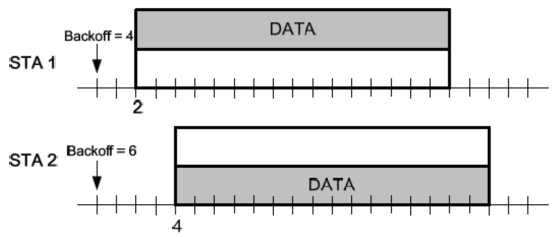

Figure 2: Time-frequency two domain backoff process.

The total process of MAC protocol consists of transmission opportunity request (TR) phase and scheduled data transmission (ST) phase. In TR phase, each STA runs one CSMA/CA procedure on every sub-channel, thus STAs should monitor all the sub-channels in WLAN. The back-off counters decrease one when corresponding sub-channel has been idle for a minimum time slot. Once any back-off counter reaches zero in TR phase, STAs could send channel access request frame. In the ST phase, AP sends scheduling frame to schedule channel resource allocation, and all the sub-channels are assigned to just one STA at the same time like OFDM operation.

AP Initiated Channel Access with OFDM

AP occupies the channel resource for TXOP duration following CSMA/CA in IEEE 802.11. AP asks the STAs to reply CTS frames to provide service information in the RTS frame. After receiving all the CTS frames of STAs, AP sends DL-ARBI (downlink assigned resource block information) and UL-ARBI (uplink assigned resource block information) to announce scheduling information, and STAs send or receive data frame according to the scheduling information. At the end of downlink or uplink data transmission, STAs send ACK frames one by one, while AP sends just one UL-ACK frame.

AP Initiated Channel Access with OFDMA

The uplink transmission and downlink transmission are all controlled by AP. When AP has data packets for STAs, AP sends downlink data transmission scheduling information to STAs on different sub-channels. Once STAs receive the downlink scheduling information, STAs replay ACK frame on the corresponding sub-channel. After receiving ACK frame of STAs, AP transmits downlink data and wait for STAs' ACK frames. For the uplink data transmission, AP send uplink polling frame to ask for uplink request frame (ULR) of STAs.Then STAs send ULR in their own sub-channel according to the information in uplink poll frame. After collecting the uplink request of STAs, AP sends scheduling frame to allocate channel resource to STAs. Once receive the scheduling frame, STAs send data frames on the allocated sub-channel.

Framework for Protocol Design

To satisfy the requirements of the next generation WLAN, a framework of OFDMA based multiuser MAC protocol is proposed, which consists of 3-parts:

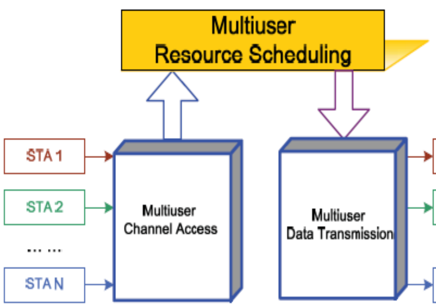

Figure 3: Framework of OFDMA based multiuser MAC protocol

Multiuser channel access

A number of STAs could access channel simultaneously by using OFDMA to decrease collision probability and thus improve the channel access efficiency.

Multiuser resource scheduling

After the collection of channel access requests, service information and channel state information, AP need to schedule the channel resource to all the STAs which access channel successfully.

Multiuser data transmission

All the scheduled STAs can transmit data several times within a TXOP, and for each data transmission there could be a group of STAs share the transmission time simultaneously. A group of STAs could transmit data at the same time by using OFDMA and/or multiuser multi-input and multi-output (MU-MIMO).

With the frame work in mind, the surveyed OFDMA based MAC protocol is compared in total ten design issues as shown in TABLE I.

Table I. Comparison of OFDMA Based Mac Protocol

Item	1	2	3	4	5
Multiuser Access		*	*	*	*
Multiuser Transmission	*	*	*	*	
Multiuser Diversity	*		*		
Non sub-channel monitor	*				
CSI Measurement	*				
AP Scheduling	*		*	*	*
Downlink Transmission		*	*	*	
QoS Guaranteeing					
Simple Signaling Exchange	*	*	*	*	*
Compatibility	*				

Conclusion & Future Work

The existing OFDMA based multiuser MAC Protocols are surveyed and categorized into four categories. Moreover, the framework of OFDMA based MAC protocol for the next generation WLANs including multiuser channel access, multiuser resource scheduling and multiuser data transmission is proposed. Based on this framework, the MAC protocols surveyed in this paper are compared according to ten design issues. In the future, we will dedicate ourselves to propose an suitable OFDMA based multiuser MAC protocol for the next generation WLAN according to the requirements of IEEE 802.11ax and the framework proposed in this paper. Interactive and high-definition video applications are predicted to dominate future Internet usage. Two examples of applications that require throughputs of several GBPS are high-definition multi-party video conferences in business environments, which can help avoid unnecessary travel and meetings, and virtual reality entertainment applications at home, which include culture, films and games. Additionally, web surfing is moving further towards a multimedia experience, where rich text, images, audio and video content interact. Furthermore, file storage, management and synchronization in the cloud are becoming the standard in terms of content management and generation. Those applications are bandwidth-demanding and require both reliability and limited delay.

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