Spatial Clustering Group Based OFDMA Multiple Access Scheme for the Next Generation WLAN (Invited Paper)

Yong Li, Bo Li, Mao Yang(✉), and Zhongjiang Yan

School of Electronics and Information, Northwestern Polytechnical University, Xi'an, China

liyong6@mail.nwpu.edu.cn, {libo.npu,yangmao,zhjyan}@nwpu.edu.cn

Abstract. The next generation wireless local area network (WLAN) needs to significantly promote the area throughput in high dense scenario. OFDMA, considered as the key technology of next generation WLAN, has been adopted by IEEE 802.11ax. However, the existing studies on the OFDMA protocol have the interference extensions problem, i.e. multiple users are located in the dispersive area, and then the geographical interference area is expanded. In this paper, a spatial clustering group based OFDMA multiple access scheme (SCG-OFDMA) is proposed. SCG-OFDMA enables the users in close area to form spatial clustering groups dynamically, then the users in the spatial clustering group access channel and transmit data by OFDMA. It reduces the geographical interference area, and enhances the area throughput. Simulation results show that the area throughput of SCG-OFDMA is higher than OMAX and DCF by 20% and 36% respectively.

Keywords: Wireless local area network · High density scenario Spatial clustering group · MAC · OFDMA

1 Introduction

In recent years, wireless local area network (WLAN) is one of the most important ways to carry wireless network services, through the 802.11 networks (Wi-Fi) or home micro-base station business has occupied 51% of the wireless network business [1]. Wi-Fi needs to support the Internet of Things (IoT) [2]. The next generation of WLAN high-density scenario requires about one user per square meter and the distance between adjacent access point (AP) 5 to 10 m [3]. In this densely crowded WLAN, inefficient channel utilization is a key factor that leads to its poor performance [4]. The next generation of WLAN based IEEE 802.11ax working group was established in 2014, which significantly enhances area throughput and medium access control (MAC) efficiency as one of the key technical goals [5].

In the distributed coordination function (DCF) protocol, only one user is allowed to access and transmit data at the same time, and MAC efficiency is low

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in high-density scenarios [6]. Multi-user parallel access is one of the most important means to improve the efficiency of MAC, in which orthogonal frequency division multiple access (OFDMA) technology has been widely recognized by academia and industry [7–11]. OFDMA technology has been accepted by the IEEE 802.11ax draft [5]. The 802.11ax draft proposed OFDMA protocol based on the trigger frame, and access point by sending a trigger frame to schedule the station (STA) for uplink access and transmission [5]. When the STA received the trigger frame, it sends request to send (RTS) frame for access through the OFDMA way to randomly select a subchannel, and OFDMA is used for access and data transmission. An OFDMA based multiple access protocol OMAX [6] is proposed, and the backoff process of STA is consistent with that of traditional WLAN MAC. When the value of the backoff counter is decremented to zero, the STA randomly selects a subchannel and transmits RTS frame to access, while an OFDMA way is used for access and data transmission. However, there is a common problem of geographical interference area in the existing WLAN MAC protocols based on OFDMA. The STA at the different location initiates access and transmit at the same time, which enlarges the interference range of the transmitter, which affects the access efficiency and the improvement of the area throughput. While in the high density deployment of IoT, the impact of geographical interference becomes greater than its in the low deployment.

In this paper, a Spatial Clustering Group based OFDMA (SCG-OFDMA) scheme is proposed. This scheme could solve the interference diffusion problem with OFDMA access in existed research [6]. The main idea of SCG-OFDMA is that the STA with data transmission request has competed for the right to use, its surrounding stations with data transmission request are triggered by the access criteria to form a spatial aggregation group (SCG). The OFDMA accessing and transmission opportunities of SCG are shared with less overhead. Space utilization may be enhanced significantly by OFDMA access and transmission of SCG. SCG can be IEEE 802.11ax stations or IoT stations.

This paper has three contributions as follows:

- We design SCG-OFDMA scheme based MAC protocol.
- We design two new control frames, Request to Multiple Send (RTMS), Group Clear to Send (GCTS).
- Simulation results show that the area throughput of SCG-OFDMA is higher than OMAX and DCF protocols by 20% and 36%, respectively.

The rest of this paper includes three parts. SCG-OFDMA scheme based MAC protocol is illustrated in Sect. 2. The performance of MACs with SCG-OFDMA, OMAX, and DCF for WLAN are presented in Sect. 3. There is a conclusion of this paper in Sect. 4.

2 Spatial Clustering Group Based OFDMA (SCG-OFDMA) Scheme

The SCG-OFDMA scheme includes requesting SCG period, RTS of SCG collecting period and SCG DATA transmitting period, and works according to the three interdependence stages as described in Fig. 1. We suppose that the channel is divided into multiple subchannels and suppose all stations actively communicate to AP. We assume that the OFDMA technique used in the physical layer and its associated algorithm [10] can sufficiently restrict the frequency selective fading and interference, and the power control and related techniques can control the influence of near-field effects. We assume that OFDMA can be synchronized when the network range is small. The scheme proposed in this paper can calculate and test the received power threshold value according to the parameters of the network system before work, thus ensuring the optimal range of SCG.

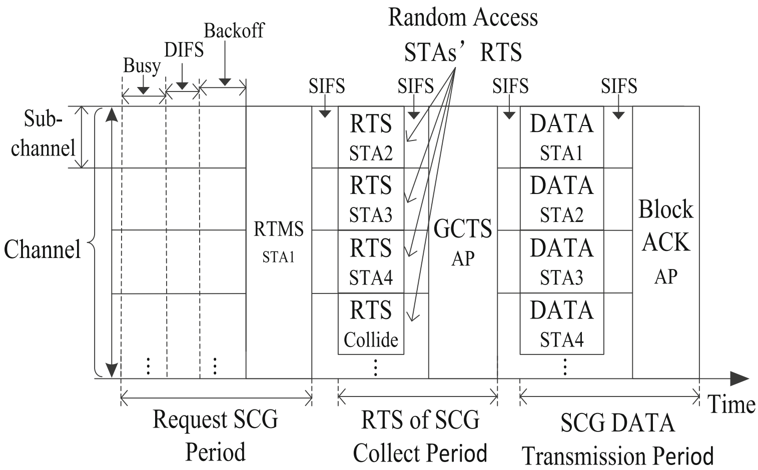

Fig. 1. Procedure of SCG-OFDMA.

2.1 Request SCG Period

The station with the uplink data transmission request senses the entire channel and uses the backoff mode specified in the IEEE 802.11 protocol when the channel is idle. When the value of the backoff counter reduced to zero, the station sends RTMS frame on the entire channel to identify SCG candidate stations and plays a role of timing signal for RTS transmission of SCG candidate stations.

RTMS and GCTS are two new control frames which are designed in detail shown in Fig. 2. Frame control, duration, transmitter address (TA) and frame check sequence (FCS) fields of RTMS are the same as IEEE 802.11 in addition to newly revised type and subtype for Frame Control field. We set type value 01 and set subtype value 0001 to RTMS as shown in Fig. 2a. We design a new field named BSS ID, described in Fig. 2a, which is Basic Set Service Identification (BSS ID) of station. We also design a new field named Rpt, described in Fig. 2a, which is receiver station's referring Received Power Threshold (RPT) value,

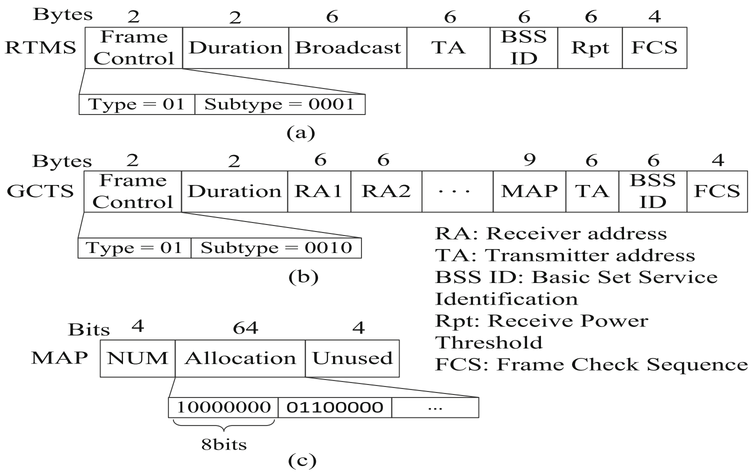

Fig. 2. Control frame structure of SCG-OFDMA.

which is used for comparing to power value of RTMS to be received by receiver station.

Note that station has a right to initiate SCG-OFDMA by sending RTMS through backoff stage like in DCF protocol.

2.2 RTS of SCG Collection Period

Other non-AP station receives RTMS frame, and records cell identification, received power threshold and other information. According to the information carried by the RTMS frame to determine whether access. Access rules are the station itself has uplink data to be sent, the RTMS frame is from the local cell, and the power value of RTMS frame to be received is greater than or equal to the received power threshold. If non-AP station meets the access rules, non-AP randomly selects one subchannel from a list of available subchannels to send Request to Multiple Send (RTS) frame after Short Inter Frame Space (SIFS). Otherwise the RTS frame is not allowed to send.

AP receives the RTMS frame and records carried MAC address, data length and cell identification and other information, and waits for PCF Inter Frame Space (PIFS) duration. In the PIFS duration, once AP receives RTS frame from one of subchannels, AP adopts round robin scheduling algorithm [6], and replies to group clear to send (GCTS) frame after SIFS. If no RTS frame is received, the AP replies to the GCTS frame after the PIFS duration. This means that AP has a right to allocate subchannels for SCG stations which successfully send RTS.

Frame Control, duration, transmitter address (TA) and frame check sequence (FCS) fields of GCTS are the same as IEEE 802.11 in addition to newly revised type and subtype for Frame Control field. We set type value 01 and set subtype value 0010 to GCTS as shown in Fig. 2b. We design a new field named MAP, described in Fig. 2c. MAP is corresponded with Receiver addresses of stations to be scheduled. MAP contains three subfields NUM, allocation and unused [4]. Num includes the number of stations to be scheduled, and allocation indicates subchannel or subchannels to be allocated to each RA of scheduled station in the front sequence. In allocation subfield, a binary string of 64 bits, every 8 bits in the sequence are corresponded with 8 subchannels for one scheduled station in RA subfield. For example, a binary string of subfield 10000000 are associated with subchannel 1 for one scheduled station in RA 1 subfield. However, subchannel 2, subchannel 3, subchannel 4, subchannel 5, subchannel 6, subchannel 7 and subchannel 8 are not allocated for one scheduled station in RA 1 subfield. Similarly, a binary string of subfield 01100000 are associated with subchannel 2 and subchannel 3 for one scheduled station in RA 2 subfield. Thus, subchannel 1, subchannel 4, subchannel 5, subchannel 6, subchannel 7 and subchannel 8 are not allocated for one scheduled station in RA 2 subfield, and so on.

2.3 SCG DATA Transmission Period

STA receives the GCTS frame and transmits the uplink data on the allocated subchannel or subchannels according to the channel allocation information carried into the GCTS frame. AP replies a block acknowledgment (BA) frame after receiving the uplink data using the entire channel.

3 Performance Evaluation

In order to evaluate the performance of MACs with SCG-OFDMA, OMAX, and DCF for WLAN by measuring the impacts of the number of stations which are randomly distributed in 20 m. $*$ 20 m. WLAN, traffic load and data packet size. We adopts area throughput as an evaluation metric of space utilization which is the ratio of throughput to the geographical interference area. Some discrete event driven simulation programs are loaded in NS2 [11] to verify SCG-OFDMA, OMAX, and DCF, respectively. We make use of simulation parameters specified in OMAX [6] as given in Table 1.

Figure 3 depicts the throughput achieved through NS2 simulation versus number of stations changing from 1 to 100 with data packet size of 1500 bytes under the saturated traffic. At saturation traffic, the maximum throughput for SCG-OFDMA is achieved at 20 stations, and decreases slightly afterwards. SCG-OFDMA reflects the high efficiency of OFDMA access and transmission of SCG because SCG and OFDMA are worked when the station number greater than 1. A distributed access protocol DCF works better than OMAX with small number of stations from 1 to 10, but rapidly becomes bad when the number of stations increases as the access collision increases intolerably. In the number of one station, the throughput of DCF is slightly higher than that of SCG-OFDMA and OMAX because the gain caused by OFDMA of SCG-OFDMA and OMAX protocols is smaller than that of overhead for control frame transmission. Another

Table 1. Simulation parameters

Parameters	Value
Channel bandwidth	40 MHz
Number of subchannels	8
Basic rate	6 Mbps
Data rate	135 Mbps
CWmin	15
CWmax	1023
MAC header	32 bytes
PHY header	28 µs
DIFS	34 µs
SIFS	16 µs
PIFS	25 µs
Slot time	9 µs

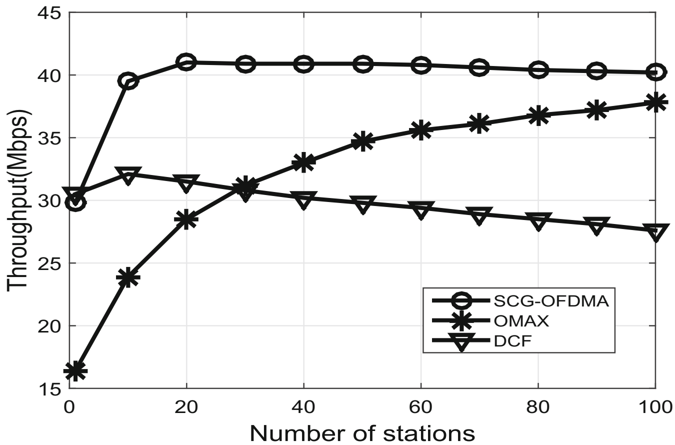

Fig. 3. Saturation throughput with the number of stations.

distributed access protocol OMAX works better than DCF with large number of stations from 30 to 100 because OFDMA is worked. Figure 3 shows that throughput of SCG-OFDMA outperforms the DCF and OMAX over various number of stations from 2 to 100 and that the SCG and OFDMA function as designed.

Figure 4 describes the area throughput achieved through NS2 simulation versus various number of stations from 1 to 100 with data packet length of 1500 bytes within the saturated traffic. At saturation traffic, the maximum area throughput for SCG-OFDMA is obtained at 60 stations, and decreases slightly afterwards. SCG-OFDMA reflects the space utilization high efficiency of OFDMA access and transmission of SCG because SCG and OFDMA is assumed and worked

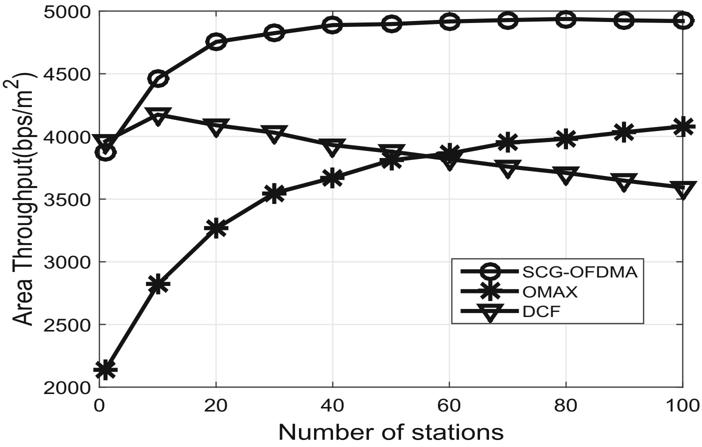

Fig. 4. Saturation area throughput with the number of stations.

when the station number greater than 1. A distributed access protocol DCF works well with small number of stations from 1 to 10, but rapidly becomes bad when the number of stations increases as the access collision increases intolerably. In the number of one station, the area throughput of DCF is slightly higher than that of SCG-OFDMA and OMAX because the gain caused by OFDMA of SCG-OFDMA and OMAX protocols is smaller than that of overhead for control frame transmission. Another distributed access protocol OMAX works better than DCF with the number of stations from 60 to 100 because OFDMA is worked. We observe that area throughput of SCG-OFDMA outperforms the DCF and OMAX over various number of stations from 2 to 100 and that the SCG and OFDMA function as designed. When the number of stations is 100, the area throughput of SCG-OFDMA is higher than OMAX 20% and DCF 36%, respectively. The main reason is that SCG-OFDMA reduces the geographical interference area compared with OMAX and DCF.

4 Conclusion

In this paper, an OFDMA protocol based on spatial aggregation group named SCG-OFDMA is proposed in densely crowded WLANs, which can effectively reduces the geographical interference area compared with the OMAX and DCF proposed in the existed literature, and uplink multiuser demands are taken care of. The simulation results show that the area throughput of SCG-OFDMA is higher than OMAX 20% and DCF 36%, respectively, when the number of stations is 100. For next generation WLAN, it is very important how efficiently area throughput is taken care of to obtain a good performance of MAC to be designed, while SCG-OFDMA works well as intended.

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