Resource Allocation Scheme for Spectral Efficiency Enhancement of OFDMA WLAN System

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***Abstract* — One of the key challenges in orthogonal frequency division multiple access (OFDMA) wireless local area network (WLAN) systems is an efficient radio resource management which can exploit the channel bandwidth to the maximum extent. The existing medium access control (MAC) protocols for WLANs lack proper utilization of idle or unused sub-channels (SCHs). Moreover, these are applicable to environment with stations (STAs) of homogeneous packet lengths. However, packet lengths are quite heterogeneous in real networks. Therefore, this paper proposes resource allocation scheme based on grouping and fragmentation for improvement of spectral efficiency in real OFDMA WLAN system. We conduct the simulation to evaluate performance of the proposed scheme. The simulation results indicate that the proposed resource allocation scheme increases throughput by almost 10% compared to existing schemes.**

***Keywords* -- OFDMA, resource allocation, fragmentation, heterogeneous packet lengths.**

I. Introduction

With the exponential growth of the number of wireless devices, wireless local area networks (WLANs) will be playing a crucial role in next generation wireless communications. In recent works, orthogonal frequency division multiple access (OFDMA) has become a popular multiple access (MA) scheme due to various aspects [1]. The most important one is that it allows subcarriers to be grouped into sub-channels (SCHs) and assigned to different users. In order to achieve effective WLAN performance, efficient resource allocation is required to utilize the overall resources. Some recent works on OFDMA WLANs have been presented in [2-3]. The work in [4] presents a distributed coordination function (DCF) based protocol where the access point (AP) attempts to reserve the radio resource on behalf of all associated stations (STAs). It proposes a resource allocation algorithm that can be applied to WLANs with stations having heterogeneous packet lengths. The major drawback of [4] is the complexity of the algorithm. Moreover, the algorithm aims to fully exploit multi-user diversity but does not consider unused channel bandwidth. This drawback has been taken care of in [5], where the authors propose a resource allocation algorithm based on grouping to improve the spectral efficiency of the system by reducing radio resource wastage. The system considered in [5] has stations with heterogeneous packet lengths. The algorithm in [5] improves throughput, however the throughput degrades drastically due to presence of idle sub-channel. This happens when for K sub-channels, the number of stations N in Gth group is less than the number of groups, where K is the number of sub-channels and G is the number of groups.

Hence this paper proposes a resource allocation algorithm which implements the concept of fragmentation to overcome the drawback in [5] and improve the spectral efficiency linearly with increasing number of stations. The key objective of our scheme is to address the issue of unused sub-channels. In our system, the AP acts as the central controller and reserves radio resource using the conventional DCF mechanism. The groups are formed as in [5]. When the number of stations in Gth group is less than the number of groups, the AP implements the proposed resource allocation algorithm and allocates the unused segment of sub-channels to the fragments of the packet of required station. This results in better spectral efficiency.

The remainder of this paper is organized as follows. We elaborate our proposed algorithm. Following this the proposed design is analyzed and evaluated. Finally the conclusion of this paper is presented.

II. Proposed Algorithm

A. *System Model*

In the following explanation, we consider a basic service set (BSS) consisting of 1 AP and N stations (STA1 to STAN) and the number of OFDMA sub-channels as K=4 (SCH#1 to SCH#4). However, our proposed algorithm can also be applied for other values of K. We have made certain assumptions for our environment (i) Heterogeneous packet length i.e. each station has a packet length different than others. (ii) Saturation condition i.e. data bursts are always available in the transmission queue of stations. (iii)

Homogeneous data rate i.e. all the stations employ same data rate.

B. Resource Allocation Algorithm

The exchange of control messages takes place in a similar pattern to that in [5]. The AP acts as a master to the associated stations and assigns radio resources. The transmission begins with the exchange of request-to-send (RTS) and clear-to-send (CTS) frames. Following this the AP executes the resource allocation algorithm and transmits the downlink resource allocation information (DL-RAI) to all STAs, in order to notify assigned sub-channel and transmission time. The next step is data transmission by AP on the allocated sub-channels. Then, all the N stations inform the AP about their packet lengths as well as acknowledgements, by transmitting downlink acknowledgements (DL-ACK). From the received DL-ACK frames, the AP uses the packet length information and applies the proposed resource allocation algorithm. This

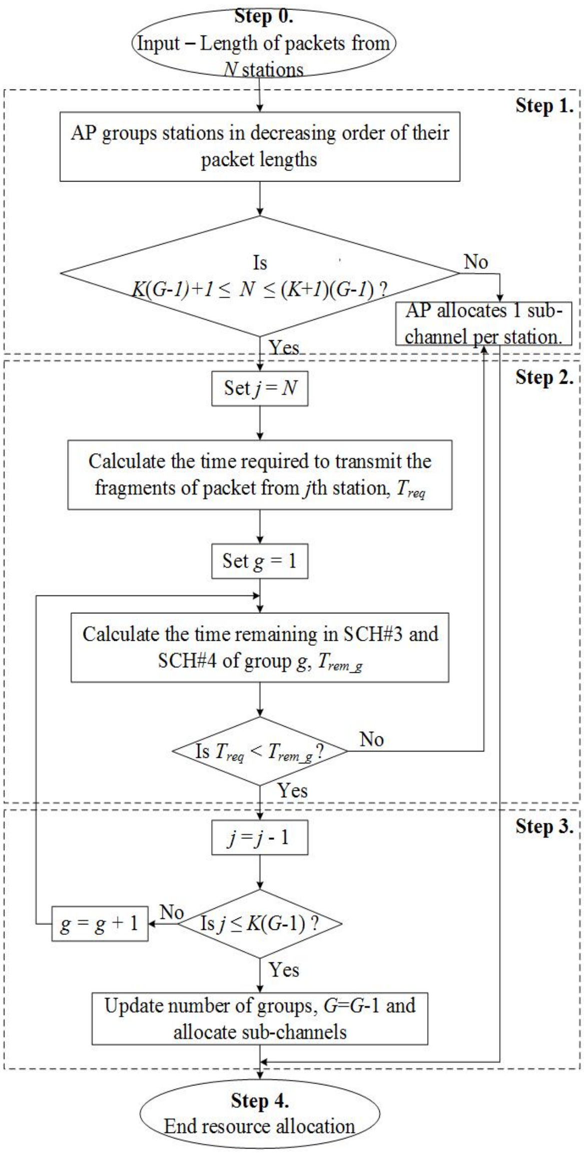

Figure 1. Flowchart of proposed resource allocation algorithm

information is transmitted to all N stations by announcing uplink resource allocation information (UL-RAI). Finally, the AP broadcasts uplink acknowledgement (UL-ACK). Figure 1 illustrates the steps of our proposed resource allocation algorithm.

Step 0. The AP collects packet lengths from all N stations

Step 1. The AP groups stations in decreasing order of packet length. The number of groups, G is given by $\lceil N / K \rceil$. Then the AP checks if the condition, ($K(G$-1)+1 $\leq N \leq$ (K+1)(G-1)) holds. In case it is false, then fragmentation is not applied and the AP allocates 1 sub-channel to each station. However, if the condition is true we proceed to the next step.

Step 2. The AP calculates the duration required to transmit fragments of packet of j^{th} station, where j is index of the stations arranged in descending order of their packet lengths. Initially the value of j is set to N. The required duration, T_{req} is determined by

$$T_{\mathrm{req}} = (L_{Pj} + 2\, H_{mac} + 2\, L_{crc})/R\,, \tag{1}$$

where L_{Pj} is the length of j^{th} packet, H_{mac} is the length of MAC header and L_{crc} is the length of cyclic redundancy check (CRC) in bits. R is the physical data rate.

Next, we need to evaluate the time remaining in g^{th} group, where g is the index of group. We begin with the first group by assigning 1 to g. The duration is given by

$$T_{\mathrm{rem\_g}} = T_{SCH\#K} + T_{SCH\#(K\text{-}1)}\,, \tag{2}$$

where $T_{SCH\#K}$ denotes the time remaining in SCH#K and $T_{SCH\#(K\text{-}1)}$ is the time remaining in SCH#(K-1). In our explanation K=4, hence we have $T_{SCH\#3}$ and $T_{SCH\#4}$.There are two reasons for using the last two sub-channels for fragments (i) To maximize the probability of finding higher remaining time. Since the groups have stations sorted in decreasing order of their packet lengths, the last two stations of the group will be having minimum packet lengths. Hence, when a sub-channel is allocated to the stations sequentially, the last two sub-channels will have maximum idle time, which can be utilized for fragments of other packets. (ii) To keep fragmentation overhead within a limit. Now the AP needs to check if required time is less than the remaining time in g^{th} group. If the condition is false, then the AP just allocates 1 sub-channel to each station. Otherwise, it moves to next step.

Step 3. The AP repeats the previous step for (j-1)th station and (g+1)th group. This continues until ($j \leq K(G$-1)). Then the AP updates the number of groups as G=G-1 and allocates SCH#1, SCH#2 to one station each, SCH#3 and SCH#4 to two stations, where one station can send its packet and another station can transmit fragment of its packet.

Step 4. With this the resource allocation algorithm comes to an end.

In order to explicate our algorithm, we will be citing an example. Let us consider the case where N = 10 and K = 4. Then if [5] is applied there will be three groups as seen in Figure 2.(a). But on application of our proposed algorithm there will be two groups as seen in Figure 2.(b). According to the proposed algorithm, the AP will first group the stations in

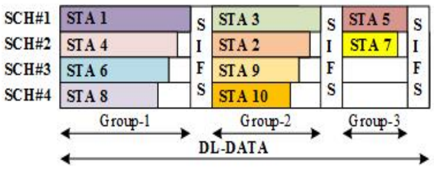

Figure 2.(a) Data transmission without fragmentation

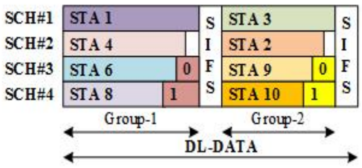

Figure 2.(b) Data transmission with fragmentation

decreasing order of their packet lengths. Then it will check if if $(K(G\text{-}1)+1 \leq N \leq (K+1)(G\text{-}1))$, which is true in our case. Next, the AP calculates the time remaining in SCH#3, SCH#4 and also estimates the time required by the packet along with fragmentation headers. If the remaining time is much higher than the required time, then the AP fragments the packet to *Fg*0, *Fg*1 and allocates SCH#3, SCH#4 to the fragments. The main idea is to reduce resource wastage. Therefore, instead of transmitting packets of 10 stations in three groups, the same can be done in two groups. This implies maximum utilization of channel bandwidth. Figure 2.(b) illustrates the downlink data transmission when our proposed scheme is implemented. We can see that the fragments of packet of STA 5 and STA 7 have been allocated to sub-channels of Group-1 and Group-2 respectively.

III. Performance Evaluation

For performance evaluation, we have used throughput as the metric and compared the results with [4] and [5]. We have assumed that the BSS consists of 1 AP and N stations. The PHY layer specifications are based on that defined in IEEE 802.11ac standard. The lengths of packets generated by stations are uniformly distributed with the range of 200-1500 bytes. The parameters used for evaluation are shown in Table 1, where short interframe space (SIFS) is the SIFS duration and δ is the propagation delay.

Figure 3 shows the throughput performance for increasing number of stations, for a fixed data rate of 65Mbps. Here, the

TABLE I. Parameters for Simulation

Parameter	Value
Bandwidth	20 MHz
Number of SCHs (K)	4
Number of STAs (N)	4-16
Physical Data Rate (R)	65 Mbps
Basic Data Rate (R_b)	7.2 Mbps
Length of MAC header	240 bits
Length of PHY header	120 bits
SIFS	10 µs
δ	1 µs

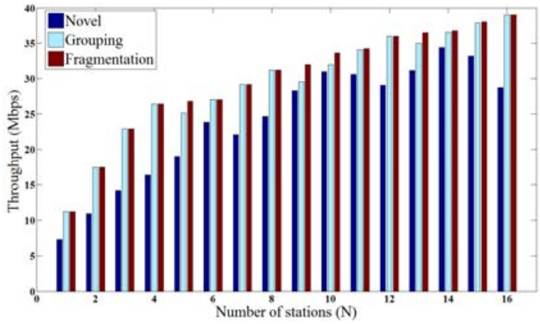

Figure 3. Throughput vs increasing number of stations

throughput is defined as ratio of total data successfully transmitted (uplink and downlink), to the total channel time. From Figure 3, we can deduce that, compared to novel-DCF [4] and grouping algorithm [5] our algorithm achieves the best result. The throughput of novel-DCF decreases with increasing number of stations, due to reduction in the amount of data transmitted. The reason behind this is the complexity of its algorithm. The throughput of grouping algorithm shows best results when $N = 2^n K$, $n \geq 2$. But we can see throughput of our proposed scheme increasing linearly with increasing number of stations. We also see that our proposed algorithm performs better than grouping algorithm when N = 5, 9, 10, 13, 14, 15 by almost 5%. This trend can be justified by the fact that our resource allocation algorithm implements fragmentation and reduces the number of groups. Hence, the spectral efficiency gets better.

To see the effect of increasing PHY data rates on the network, we observed the throughput variation with increasing number of stations and varying PHY data rates. Figure 4 and Figure 5 illustrate the behavior of grouping algorithm and our proposed algorithm at different PHY data rates. From the

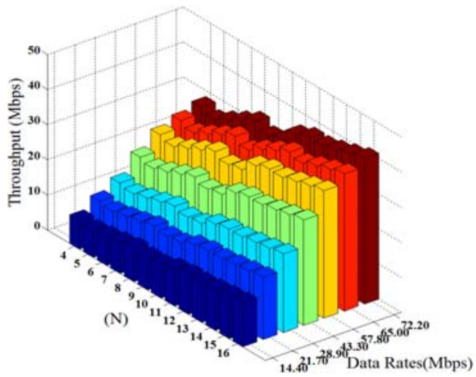

Figure 4. Throughput vs PHY data rates and number of stations (without fragmentation)

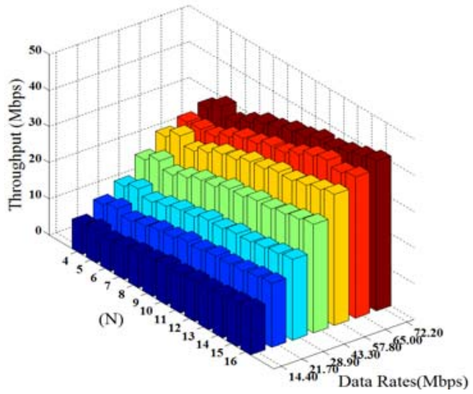

Figure 5. Throughput vs PHY data rates and number of stations (with fragmentation)

results we can conclude that the throughput keeps increasing with increasing data rates. Throughput is highest when data rate is 72.20 Mbps.

IV. CONCLUSION

In this paper, we proposed a resource allocation algorithm, which implements fragmentation and reduces radio resource wastage. The scheme is applicable to WLAN environment in which stations have heterogeneous packet lengths i.e. all stations have data of different lengths in their transmission buffer. From simulation results, we found that the proposed scheme shows enhanced throughput with increasing number of stations compared to existing schemes.

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