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A Novel Channel Access Scheme in the Next Generation WLAN

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Abstract: In order to efficiently utilize wireless channels in Wireless Local Area Network (WLAN), a novel channel access scheme using an alternative primary channel is proposed in this paper. In the next generation Wireless Local Area Network (WLAN), IEEE 802.11ax, since, non-contiguous channels access is allowed, channel efficiency can be enhanced very much. However, there has been no proposal on specific rules and study on performance analysis. In this study, specific protocol to fully utilize non-contiguous channels by designating alternative primary channel is proposed. The performance of the proposed scheme is fully evaluated by mathematical analysis.

Key words: Channel access, efficient transmission, next generation wireless network, wireless local area network, WLAN, primary

INTRODUCTION

With the emergence of communication capable smart devices such as smart phones, tablets and many Internet of Thing (IoT) devices, there has been strong demand for high throughput wireless system using unlicensed band. The most popular wireless system using unlicensed band is IEEE 802.11 based Wireless Local Area Network (WLAN). IEEE 802.11 based WLAN employs a contention based channel access scheme called Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) for efficient channel access in distributed manner. WLAN has made a big progress, since, its emergence due to easy deployment and excellent performance (Ghazala *et al*., 2009; Bongsu *et al*., 2012). Recently, 3GPP has begun the standardization of the unlicensed band system called Licensed Assisted Access (LAA) 3GPP LAA is also employs a contention based channel access to ensure coexistence with WLAN. However, 3GPP LAA is more controlled system for mobiles with both licensed band cellular module, e.g., Long Term Evolution (LTE) and unlicensed band LAA module.

With strong demand for high throughput, IEEE 802 has started the standardization of a new WLAN air interface standard, IEEE 802.11ax, since, May 2014. IEEE 802.11ax is the next generation WLAN after IEEE 802.11ac. The objectives of IEEE 802.11ax are to enhance, its performance at least four times in the average throughput per Station (STA) in a dense deployment scenario while maintaining or improving the power efficiency per STA. In order to provide fair channel access opportunities among stations, the basic access scheme of WLAN is Distributed Coordination Function (DCF). In DCF, stations need to acquire a right to access channel through channel contention. The channel contention is a waiting procedure for stations to wait for available idle channels. That is stations are required to spend some time to transmit their packets. Therefore, as the number stations increases, MAC access delay increases significantly (Bianchi, 2000; Kwak *et al*., 2005).

IEEE 802.11 standard has been developed to achieve high throughput. IEEE 802.11 ac standards supports maximum 160 MHz wideband operation to provide high throughput. Since, basic operation bandwidth of IEEE 802.11 is 20 MHz bandwidth, specific channel expansion rules are required for IEEE 802.11 devices. As shown in Fig. 1a in 802.11 ac, channel utilization pattern is limited to use predetermined 20, 40, 80 and 160 MHz only (in 5 GHz band). In IEEE 802.11ac standard, non-contiguous channel access, as shown in Fig. 1b is not allowed, even in the wide bandwidth of 40, 80 or 160 MHz. The reason for this is that too flexible channel utilization pattern could cause interferences on neighbor Basic Service Set (BSS) devices. Nevertheless, necessity of more efficient channel utilization has been discussed many times during the course of standardization. In order to adopt non-contiguous channel access, extra care needs to be taken in order not to cause complexity, interference and fairness problems.

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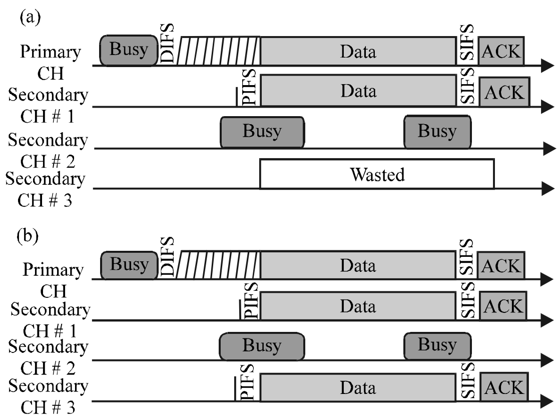

Fig. 1: Two options of wider bandwidth operation based on 802.11 standard; a) Legacy 802.11 wider bandwidth operation (Standardized); b) PIFS sensing based non-contiguous bandwidth operation (Not standardized)

In this study, a novel non-contiguous channel access scheme is proposed in order to provide efficient channel access in distributed manner. In order to investigate the effectiveness and efficiency of the proposed scheme, mathematical analysis is provided. Since, the next generation WLAN standard, IEEE 802.11ax is planning to provide a non-contiguous channel access, the proposed scheme can be a good candidate as a non-contiguous channel access scheme in the IEEE 802.11ax.

MATERIALS AND METHODS

Proposed alternative primary channel scheme: Non-contiguous channel access, transmission is not allowed in IEEE 802.11ac, since, too much degree of freedom in wideband operation requires large and expensive transmitter and receiver circuits. In order to solve such problem, a novel non-contiguous channel access scheme, named Alternative Primary Channel (APCH) scheme is proposed. This is an extended version of the contributions submitted and discussed in IEEE 802.11ax task group (Jinsoo, 2014; Woojin, 2014). The proposed APCH regulates the degree of freedom by expanding channels from a primary channel and an APCH. In addition to the conventional primary channel based wideband expansion, adopting another secondary channel based wideband expansion is able to enhance the spectrum utilization. In the proposed scheme, the secondary channel used for channel expansion is called an APCH. Along with a primary channel, APCH is a basis for channel expansion. APCH based channel expansion is a novel notion for wideband channel expansion. APCH follows the conventional 802.11ac channel expansion rule as a primary channel does. By utilizing the channel

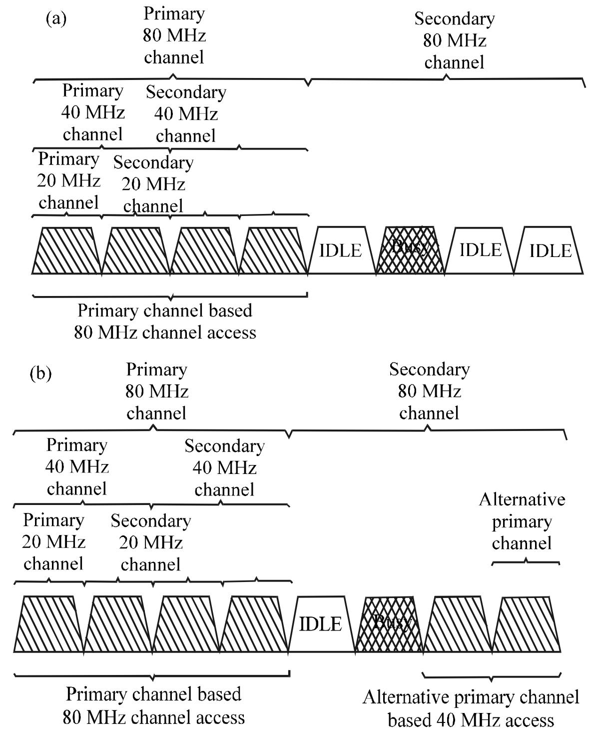

Fig. 2: Channel utilization patterns of APCH and conventional 802.11; a) Channel utilization pattern of conventional 802.11; b) Channel utilization pattern of proposed APCH method

expansion both from a primary channel and an APCH, non-contiguous channel utilization and novel channel use patterns which are not allowed in conventional 802.11ac are newly possible. For example, contiguous 60 MHz bandwidth or non-contiguous 80 MHz bandwidth can be newly utilized which allow significant flexibility enhancement on channel utilization.

Since, the proposed APCH scheme does not require new channel use patterns on primary channel and APCH, modification on frame or preamble format is not required. If an Access Point (AP) and its associated STAs have exchanged their primary and APCH information during the association procedure, APCH scheme could be utilized without format modification. Even though associated STAs are not capable of APCH based channel expansion such STAs can access the channel using only a primary channel. AP is able to support both APCH capable STAs and APCH incapable STAs at the same time. Since, the number of APCH and primary channel limits the number of non-contiguous channels, the complexity of transceivers can be managed. For example, if all 20 MHz channels within 160 MHz are set as a APCH and non-primary channel access, AP could utilize any possible channel pattern in the 160 MHz bandwidth. Figure 2 shows that, additional 40 MHz channel can

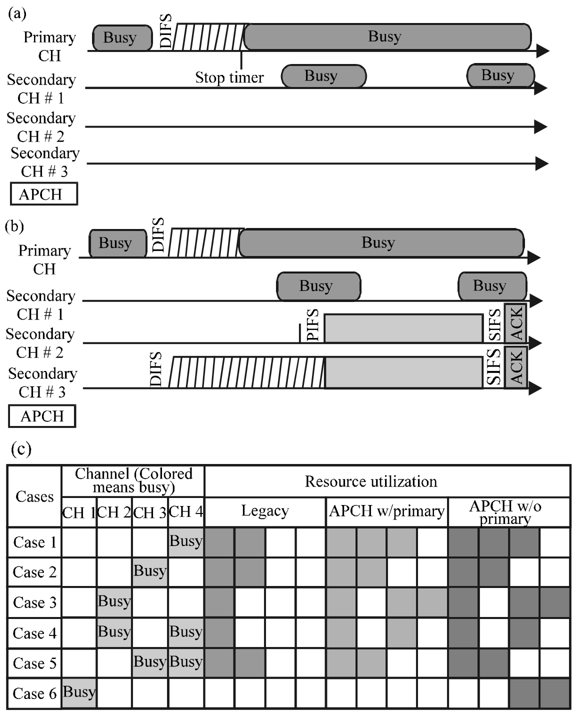

Fig. 3: Wideband operation methods; a) Channel access procedure when channel access without primary channel is not allowed; b) Channel access procedure when channel access without primary channel is allowed; c) Resource utilization patterns among wideband operation methods

utilized by using the proposed APCH scheme. Since, APCH based channel access could be regarded as an existence of an additional AP by OBSS STAs, APCH does not cause severe problems to STAs.

In order to utilize the proposed APCH expansion rule, there are two options to choose. First option is allowing APCH based transmission only with primary channel based transmission, the other option is allowing APCH based transmission without primary channel based transmission. Figure 3 shows examples of channel access procedures and channel utilization for each options of APCH operation and legacy IEEE 802.11ac. As shown in Fig. 3a, first option means that if a primary channel based transmission is not possible due to channel condition, e.g., channel busy, transmission using channels expanded based on APCH is not allowed. Only APCH based transmission is possible as long as primary channel based transmission is possible. Therefore, APCH is a just a new basis of channel expansion in the first option. As shown in Fig. 3b in the second option, APCH is an independent another primary channel. Therefore, even though primary channel is in busy state, transmission using channels expanded from an APCH is allowed. The second option requires some modifications on contention method, especially back-off and channel sensing method.

Figure 3a and b are simple examples for the two options of APCH usage. Figure 3a shows that, a station cannot transmit its data because primary channel is busy. Figure 3b shows although, the channel environment is identical to Fig. 3a, a station does not stop its back-off timer and keeps decreasing the timer based on channel state of its APCH. The back-off operation described above is an example of the proposed APCH back-off procedure. Depending on the purpose and philosophy, specific back-off procedure could vary. Figure 3c shows channel utilization for each options of APCH operation and legacy IEEE 802.11ac. As shown in Fig. 3c, colored blocks in columns mean busy state channels and colored blocks below resource utilization columns mean available channels for each wideband operation methods. As we can see from the Fig. 3c, the proposed scheme shows excellent channel utilization for the selected cases.

RESULTS AND DISCUSSION

Performance analysis: The proposed APCH scheme provides a novel channel expansion rule and channel access procedure. In order to analyze the performance of the proposed scheme, channel utilization of each method needs to be formulated in mathematical equations. In this study, contention on primary channel and APCH is modeled using the identical access probability, p_p. Each secondary channel has busy probability of p_s for Point Coordination Function Inter Frame Spacing (PIFS) duration. Since, the main focus of this study is basic 20 MHz based channel expansion, sub-band (narrower than 20 MHz bandwidth) contention is not considered. Maximum channel bandwidth of 160 MHz is considered as a representative wide bandwidth. As aforementioned, channel expansion rule is identical for both primary channel and APCH. Location of APCH is assumed to be one 20 MHz channel within secondary 80 MHz channel. In order to provide realistic analysis for feasible system, a single APCH case is assumed. Table 1 is the list of parameters used in the analysis of the study. The total bandwidth (W) is decided by the number of 20 MHz channels (N):

$$W = N \times 20 \text{ MHz} \quad (1)$$

Therefore, we need to derive the average value of N for each channel expansion method to analyze the expected bandwidth utilization. For legacy IEEE 802.11ac system case:

Table 1: Analysis parameters

Symbols	Description
N	Number of channels AP utilizes
N_{sec}	Number of secondary channels AP utilizes
W	Bandwidth of downlink transmission
p_s	Busy probability of each secondary channel with PIFS duration
p_p	(Alternative) Primary channel access probability of AP

$$E[N] = P[N = 1]+2\times P[N = 2]+4\times[N = 4]+8\times[N = 8]$$
$$=P_P(-4P_S^7+28P_S^6-84P_S^5+140P_S^4-142P_S^3+90P_S^2-35PS+8) \quad (2)$$

In case of all available channel, all available 20 MHz channels could be utilized. The expected number of available secondary cannels after primary channel access can be expressed with N_{SEC}:

$$N_{SEC} \sim B(7.1-P_S) \quad (3)$$

$$E[N_{SEC}] = (7\text{-}7P_S) \quad (4)$$

$$E[N] = P_P(E[N_{SEC}]+1) = P_P(8\text{-}7P_S) \quad (5)$$

Equation 3, the average number of channel utilization of using all available channel case can be derived easily. In the case of APCH, there are different patterns of channel use. N could be a value of 3 or 5 or 6. Therefore, for APCH case:

$$E[N] = P[N=1]+2\times P[N=2]+3\times P[N=3]+$$
$$4\times[N=4]+5\times P[N=5]+6\times P[N=6]+8\times[N=2] \quad (6)$$

Even if the expected number of available channels with APCH can be obtained with Eq. 6 each probability term has different value depending on the APCH options. For the case of allowing APCH based expansion only with primary channel based transmission, E[N] can be calculated with Eq. 6:

$$E[N] = P_P(2P_S^4\text{-}10P_S^3+19P_S^2\text{-}18P_S+8) \quad (7)$$

For the case of allowing APCH based expansion without primary channel based transmission, E [N] is also obtained similarly:

$$E[N] = (2\text{-}2P_P)P_P\left(\text{-}2P_S^3+6P_S^2\text{-}7P_S+4\right)+P_P^2\left(\text{-}4P_S^3+12P_S^2\text{-}14P_S+8\right) \quad (8)$$

Equation 1, 2, 5, 7 and 8, the average bandwidth can be calculated if P_P and P_S are obtained. Figure 4 shows the average bandwidth of each case over P_P when P_P is 0.7.

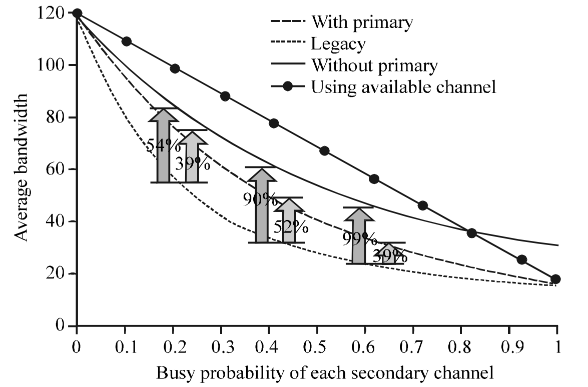

Fig. 4: Performance comparison

Because P_P does a role of pseudo scaling factor in Eq. 2, 5, 7and 8, similar aspect could be observed when different values of P_P are applied.

We can see from Fig. 4, that the proposed APCH scheme always shows superior performance than the legacy case. If all secondary channel is set to be APCH, then it requires primary channel for its wideband transmission. This case is exactly identical to the case of using all available channel with PIFS sensing. As we can observe from Fig. 4, allowing APCH based expansion without primary channel based transmission could enhance the channel utilization dramatically. However, it requires specific back-off procedure and significant modifications on the conventional IEEE 802.11 standards.

Additional improvement methods: With Orthogonal Frequency Division Multiple Access (OFDMA) channel access, wider band channel access operation could be improved more. In DownLink (DL) OFDMA scenario, AP can transmit multiple data to multiple STAs at once. Figure 5 shows how DL-OFDMA reduces the OFDMA channel access delay with contention isolation gain.

In order to compare the access delay of DL-OFDMA with the conventional access delay, it is assumed that AP always allocate 1 STA for each 20 MHz channel bandwidth. In other words if the AP could utilize 40 MHz bandwidth, it means the AP could support 2 STAs at most in a single transmission. From Fig. 5, the following equation can be derived for each cases:

$$E[D]=E[A]+E[T] \quad (9)$$

In order to compare the results of overall wider band operation access delay, IEEE 802.11ac parameters has been utilized to calculate the access delay and specific

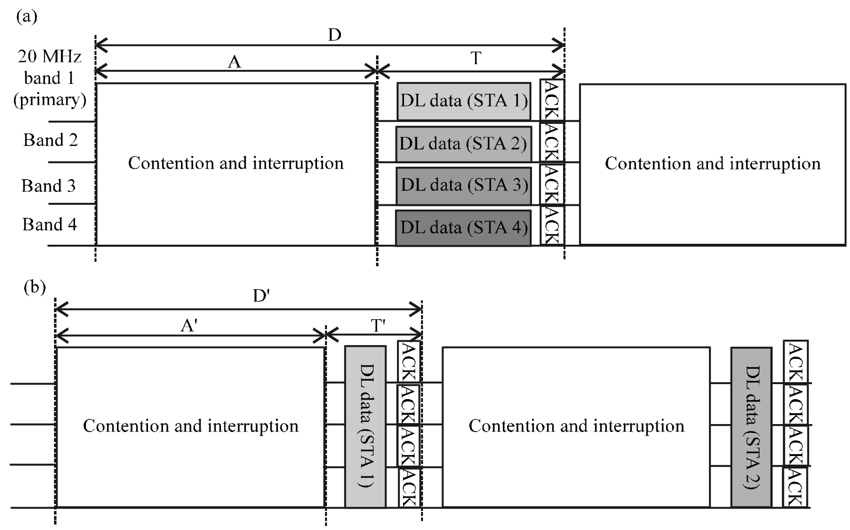

Fig. 5: Channel access delay of DL-OFDMA and conventional DCF; a) Channel access delay of DL-OFDMA; b) Channel access delay of conventional DCF

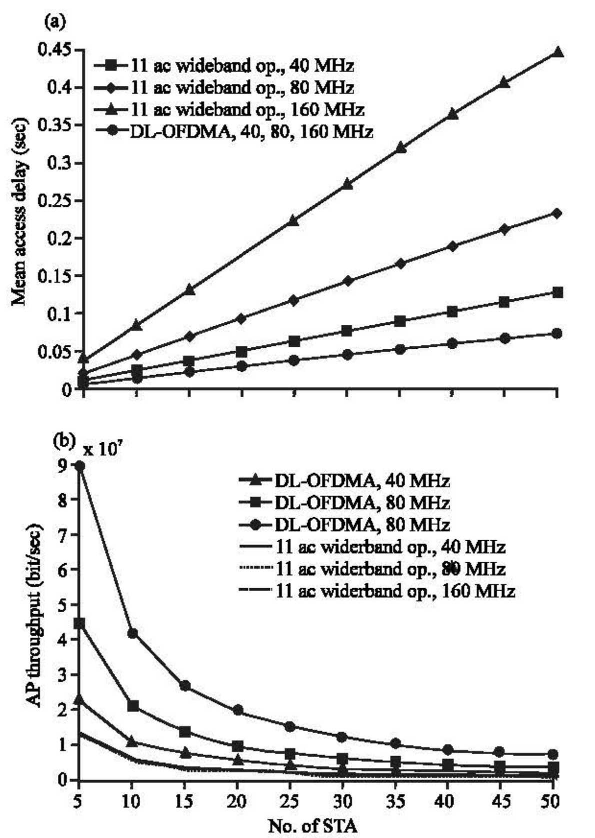

Fig. 6: Performance evaluation of wider band operation of OFDMA and conventional DCF; (BA MCS 8)

parameters are listed in Table 2. From the parameters and equations, the access delay can be obtained as in Fig. 6.

Table 2: Analysis parameters

Parameters	Description
Guard interval	long
Data preamble	11 ac preamble
Maximum retries	10
MCS	MCS8 (Fixed)
CWmin	15
PER	0 (Error free channel)
MSDU length	8000 bytes
Application data size	7964
L4-L3 header size	36 bytes
SIFS	16 usec
DIFS	34 usec

CONCLUSION

In order to efficiently utilize wireless channels in WLAN, a novel channel access scheme using APCH is proposed in this study. As a channel expansion scheme, the proposed APCH based channel access scheme for contention based communication system shows an excellent performance in comparison with the legacy contention based systems. In order to design an efficient channel access scheme, first, channel access inefficiency problem has been investigated. Then, the proposed scheme has been designed to alleviate the inefficiency problem with small implementation overhead. In order to properly evaluate the performance enhancement of the proposed APCH based channel access scheme, mathematical analysis has been provided. The analytical results has corroborated the outstanding performance of the proposed APCH based channel access. Even though the analysis of this study is performed using the parameters of IEEE 802.11, the analysis this study could be easily applied to any other contention based communication system like 3GPP LAA. Since, the next generation WLAN standard, IEEE 802.11ax is planning to provide a non-contiguous channel access, the proposed scheme can be a good candidate as a non-contiguous channel access scheme in the next generation WLAN.

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REFERENCES

Bianchi, G., 2000. Performance analysis of the IEEE 802.11 distributed coordination function. IEEE J. Sel. Areas Commun., 18: 535-547.

Bongsu, R.H.R., N.A. Hamid, A.N.M. Rose and S. Subramaniam, 2012. Enhanced packet scheduling algorithm for multihop wireless LANS. Intl. J. Adv. Sci. Technol., 49: 63-72.

Ghazala, M.M.A., M.F. Zaghloul and M. Zahra, 2009. Performance evaluation of multimedia streams over Wireless Computer Networks (WLANs). Intl. J. Adv. Sci. Technol., 13: 61-74.

Jinsoo, A., 2014. IEEE 802.11-14/1437r1 802.11, Efficient Wider Bandwidth Operation in IEEE 802.11ax. Yonsei University, Seoul, South Korea,.

Kwak, B.J., N.O. Song and L.E. Miller, 2005. Performance analysis of exponential backoff. IEEE. Trans. Netw., 13: 343-355.

Woojin, A., 2014. IEEE 802.11-14/1442r1 802.11, Considerations on Dlofdma Control Mechanism. Yonsei University, Seoul, South Korea,.