Dynamic Band Selection Technique for Dual-band Wireless LAN System

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1. INTRODUCTION
With the enormous growth of computer-based terminals, the demands for indoor network which enable us to transmit and share digital information have been rapidly increased. As a method to form indoor office/home network, wireless LAN (WLAN) systems have taking a great attention, as they provide attractive features such as an ease of network constructions, a flexibility of network reconfigurations, and so on. Among several kinds of WLAN systems, a 2.4GHz-band WLAN system based on IEEE802.11g standard [1] and a 5GHz-band WLAN system based on IEEE802.11a standard [2] attract international attention. However, since the radio frequency bands used to transmit data packets differ, 2.4GHz-band and 5GHz-band WLAN systems cannot communicate each other, and also have quite different characteristics in their performances. For example, 2.4GHz radio frequency band is originally prepared for Industrial, Scientific and Medical (ISM) apparatus such as microwave ovens, and the performance of 2.4GHz-band WLAN system is much degraded by the effect of man-made noise with the coexistence of ISM apparatus. On the contrary, in 5GHz-band WLAN system, because of using the relative high radio frequency band, the effect of both propagation loss and shadowing in 5GHz-band WLAN system becomes large compared with those in 2.4GHz-band WLAN system. As one of the methods to solve the problem about mutually connection between 2.4GHz-band and 5GHz-band WLAN systems, a combo chip compatible with IEEE802.11a/b/g standards is developed and already put in practical use. Access point (AP) or terminals having the combo chip are able to communicate without caring the standards of the other side, and it is expected that the WLAN system corresponding to the dual-band (hereafter, it is called a dual-band WLAN system) spreads widely. However, in conventional dual-band WLAN system, a radio frequency band employed in wireless communication is assigned to a terminal when connecting with network and the terminal only uses this radio frequency band until the terminal disconnects from the network.

In this paper, we propose a dynamic band selection technique for dual-band WLAN systems. In the proposed technique, a radio frequency band employed for the transmission of data packet is changed on packet-by-packet basis according to the channel conditions of 2.4GHz and 5GHz radio frequency band, and then a high throughput performance can be expected by using proposed technique.

2. DYNAMIC BAND SELECTION TECHNIQUE
2.4GHz-band WLAN system based on IEEE802.11g standard and a 5GHz-band WLAN system based on IEEE802.11a standard are major WLAN systems and already widely used. 2.4GHz-band and 5GHz-band WLAN systems have almost the same specifications. In Physical (PHY) layer, both WLAN systems use orthogonal frequency division multiplexing. And also, both WLAN systems support the multiple rate transmission and usually decide the appropriate transmission rate from 6
Mbps up to 54 Mbps according to their channel condition. In Medium Access Control (MAC) layer protocols, both WLAN systems employ a Carrier Sense Multiple Access / Collision Avoidance (CSMA/CA) schemes to avoid collisions of transmitted data packet. However, since 2.4GHz-band WLAN system and 5GHz-band WLAN system employ different radio frequency band, these WLAN systems have quite different characteristics in their performances.

One of the serious disadvantages of 2.4GHz-band WLAN system is the man-made noise emitted from ISM apparatus. 2.4GHz radio frequency band is originally prepared for ISM apparatus, and it is well-known that the periodic high amplitude man-made noise is emitted from ISM apparatus. With the coexistence of ISM apparatus, the man-made noise causes packet errors. And also, at the transmission of data packet, the transmitter erroneously recognizes the high amplitude man-made noise as a carrier signal transmitted from other terminal. In this case, this AP or terminal judges the channel to be a busy state and makes the shift to a stand-by state despite the transmission of data packet is actually possible. Because of these problem caused by man-made noise, the throughput of 2.4GHz-band WLAN system is degraded by the effect of man-made noise.

On the contrary, one of the disadvantages of 5GHz-band WLAN system is propagation loss and shadowing. In general, the influence of both propagation loss and shadowing become large as the radio frequency band to be used becomes high, and then the effect of both propagation loss and shadowing in 5GHz-band WLAN system are much larger than those in 2.4GHz-band WLAN system. As mentioned above, WLAN system usually decides the appropriate transmission rate according to the channel condition. Consequently, in some specific cases, transmission rate of 5GHz-band WLAN system is inferior to that of 2.4GHz-band WLAN system.

As a method to solve these problems in 2.4GHz-band and 5GHz-band WLAN systems and realize a seamless wireless access between 2.4GHz- and 5GHz-bands WLAN systems, we propose a dynamic band selection technique for dual-band WLAN system. In the proposed technique, a radio frequency band employed for the transmission of data packet is dynamically changed on packet-by-packet basis according to the conditions of 2.4GHz-band and 5GHz-band channels. Fig. 1 shows a flowchart for selecting algorithm between 2.4GHz- and 5GHz-bands radio frequency channels. As shown in this figure, a terminal which tries to transmit a data packet performs a carrier sense in order to check the state of both 2.4GHz- and 5GHz-band channels. After that, one of the channels, which is in the idel state during a DIFS (Distributed Inter Frame Space) period, will be used for transmission of a data packet and a back-off is performed to avoid a collision in the channel. A data packet is transmitted after back-off. Of course, there are many methods for selecting a transmitting channel and the algorithm shown in Fig. 1 is not always optimum one. Further discussion about the optimum algorithm for band selection is one of our future works.
3. Performance Evaluation

We evaluate the throughput performance of dual-band WLAN system using proposed dynamic band selection technique and discuss the effectiveness of proposed technique. For comparisons, we also evaluate the conventional 2.4GHz-band and 5GHz-band WLAN systems. In the performance evaluation, we make three environments about 2.4GHz-band and 5GHz-band wireless channels (case1, case 2 and case 3), and these are summarized in Table 1. As noted in this table, in case 1, the distance between an AP and a terminal is assumed to be long. In this case, the propagation loss of 5GHz-band signal is much larger than that of 2.4GHz-band signal, and then the transmission rate of WLAN system using 5GHz radio frequency band is inferior to that using 2.4GHz one. Case 2 and Case 3 assume that the distances between an AP and a terminal are short and long respectively. In both cases, ISM apparatus such as microwave oven is located adjacent to the WLAN system. Therefore, in case 2 and case 3, the performance of 2.4GHz-band WLAN system will be much degraded by the effect of man-made noise. Although a period and duration of high amplitude man-made noise depend on the characteristics of ISM apparatus, in order to simplify the performance evaluation, the period and the duration of high amplitude man-made noise are set to be 20(msec) and 8(msec), respectively.

Fig. 2 shows the throughput performance in case 1. In this figure, throughput of conventional 2.4GHz-band WLAN system is much better than that of conventional 5GHz-band WLAN system. This is a reasonable result, because the distance between AP and a terminal is long, the transmission rate of WLAN system using 5GHz radio frequency band is inferior to that using 2.4GHz one. In addition, since the dual-band WLAN system using proposed dynamic band selection technique always selects the 2.4GHz-band channel and transmits the data packet by using 2.4GHz-band channel, the performance of throughput of dual-band WLAN system using proposed band selection technique is same as that of conventional 2.4GHz-band WLAN system.

Fig. 3 shows the throughput performance in case 2. In this case, because ISM apparatus is located adjacent to the WLAN system and the periodic high amplitude man-made noise are emitted in 2.4GHz-band channel, the conventional 2.4GHz-band WLAN system judges a channel to be a busy state and stands by transmission of data packets. Therefore, as shown in this figure, the throughput of conventional 2.4GHz-band WLAN system is much degraded. On the contrary, the performance of dual-band WLAN system using proposed dynamic band selection technique and conventional 5GHz-band WLAN system achieve good throughput performances.
Finally, Fig. 4 shows the throughput performance in case 3. In this case, because the distance between AP and a terminal is long, the transmission rate of WLAN system using 5GHz radio frequency band is inferior to that using 2.4GHz one. In addition, because ISM apparatus is located adjacent to the WLAN system, the conventional 2.4GHz-band WLAN system judges a channel to be a busy state and stands by transmission of data packets. Consequently, both conventional 2.4GHz-band and 5GHz-band WLAN systems cannot achieve high throughput performances. On the other hand, dual-band WLAN system using proposed dynamic band selection technique uses the 5GHz-band or 2.4GHz-band channels adaptively, and, while the emission of high amplitude man-made noise, dual-band WLAN system using proposed technique transmits the data packets by using 5GHz-band radio frequency channel. On the other hand, while the non-emission of high amplitude man-made noise, dual-band WLAN system using proposed technique transmits the data packet by using 2.4GHz-band radio frequency channel, as it provides the higher rate transmission rate compared with 5GHz-band radio frequency channel. Therefore, throughput of WLAN system using proposed dynamic band selection technique is much better than both conventional 2.4GHz-band and 5GHz-band WLAN systems. From the results shown in these figures, we can conclude that the dual-band WLAN system using proposed dynamic band selection technique improve the performance of WLAN system.

4. CONCLUSIONS
In this paper, in order to improve the performance of 2.4GHz-band and 5GHz-band WLAN systems, we have proposed the dynamic band selection technique for dual-band WLAN system. In the proposed technique, the radio frequency band employed for the transmission of data packet is dynamically changed on packet-by-packet basis. Numerical results conclude that the WLAN system using proposed technique achieves the good performance compared with the conventional WLAN systems.

REFERENCES