Advanced Wireless Cooperation mechanisms for Interference Mitigation in the 2.4 GHz ISM Band

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Abstract—**We propose a new cooperation mechanism, denoted by cooperative channel segmentation (CCS), between IEEE 802.11 WLANs and Bluetooth based WPANs, which operate in the 2.4 GHz ISM band. The CCS avoids false detection of WLAN carrier sense, which usually happens when WLAN and Bluetooth antenna are nearly deployed. In CCS, WLAN and Bluetooth system share the mutual interference channel information and devices operation channels between Bluetooth and WLAN. We evaluated the performance of CCS by simulation, and the simulation result showed that the performance of CCS is better than legacy cooperation mechanisms.**

Keywords-component; Bluetooth, coexistence, interference mitigation, WLAN

I. INTRODUCTION

As the variety of portable device applications has been increasing, portable devices such as smart phones, tablets and netbooks carry two or more kinds of wireless network interfaces. Most commonly used wireless network interfaces in such devices are Bluetooth and IEEE802.11 (WLANs), and they are sometimes used simultaneously in mutually complementary use cases. For example, some cellular phones carry Bluetooth and WLAN interfaces, and Bluetooth is used for hands-free call while WLAN is used for internet connection access point. Bluetooth and WLAN, however, use the same 2.4 GHz ISM frequency band, and this causes radio interference each other if they are used simultaneously. Because portable devices are usually small, Bluetooth and WLAN antenna in the devices are nearly deployed. This enhances the interference.

Bluetooth devices have a function to avoid such interference. The function is called advanced frequency hopping (AFH). When a Bluetooth device detects interference on Bluetooth operation channels, it disables the Bluetooth channels where the interference is happened. On the other hand, some WLAN devices have a function to detect other 2.4 GHz devices and defer transmission when channel is used by other devices. As the mutually complementary use cases of Bluetooth and WLAN became popular, it was found that these interference avoidance functions do not work effectively. In some former investigations [1][2][3], methods to improve the efficiency of the interference avoidance were proposed. These former investigations, however, cannot avoid a kind of interference: 1) false detection of WLAN carrier sense because their interference avoidance mechanisms consider only the channel condition of Bluetooth, 2) "Transmit-Receive" collisions which one radio is transmitting and the other is receiving because their interference avoidance mechanisms control transmission timing between Bluetooth and WLAN. In this paper, we propose a new cooperation mechanism which effectively avoids false detection WLAN carrier sense by considering pre-shared information of mutual interference channels. The remainder of this paper is organized as follows: Section 2 presents the proposed advanced coexistence mechanisms, and Section 3 shows the effectiveness of proposed protocols via computerized simulation. Finally, Section 4 gives concluding remarks and directions for future research.

II. ADVANCED WIRELESS COOPERATION MECHENISMS

In this section, we present the proposed advanced wireless cooperation mechanisms based on frequency domain multiplexing which mitigate interference between Bluetooth and WLAN technologies. The proposed algorithm can apply when Bluetooth and WLAN are able to exchange information on the same device. The algorithm, denoted by cooperative channel segmentation (CCS), shares the mutual interference channel information and divides operation channels between Bluetooth and WLAN. This scheme enhances the current AFH mechanisms to avoid frequency overlap channels between Bluetooth and WLAN in consideration of mutual interferences and the carrier sense detection of WLAN. Figure 1 shows the overall structure of CCS mechanisms. In a Bluetooth, legacy AFH mechanism is processed in the baseband module automatically based on channel conditions. The CCS block checks the current AFH channel map periodically using Bluetooth host controller interface (HCI) commands. In a WLAN, WLAN driver indicates the current WLAN channel information to the CCS block when WLAN STA associates with WLAN AP, WLAN AP starts operation, and WLAN AP/STAs changes the operation channel using Dynamic Frequency Selection (DFS). The CCS block multiplies the current AFH channel map from Bluetooth by the current WLAN channel, and makes the new AFH channel map in consideration of the adjacent channel interference of Bluetooth and WLAN. Thus, the new AFH channel map is considered of Bluetooth channel condition and the carrier sense detection of WLAN. Finally, the CCS block set new AFH channel map to Bluetooth module through Bluetooth HCI commands.

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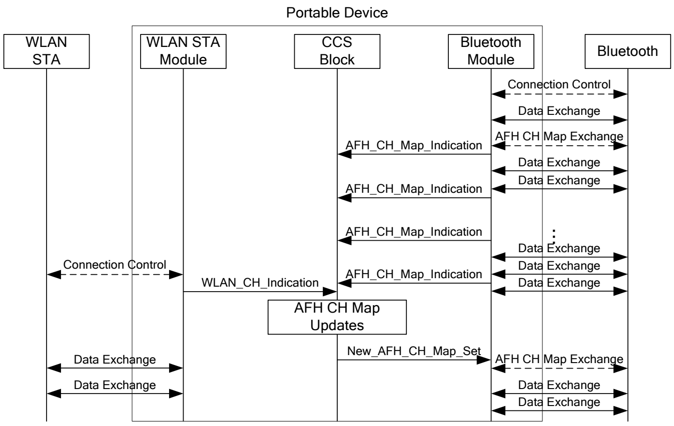

Figure 1. Overall structure of the proposed CCS mechanism

TABLE I. SIMULATION PARAMETERS

WLAN (IEEE802.11g)	- Operational Channel : 7 ch (fc =2442MHz) - Data/ACK Transmission Rate: 54Mbps, 24Mbps - Transmission power : 10dBm/20MHz - Noise figure : 101dBm (114dBm/MHz) - Traffic: 1500 byte of UDP constant data (full buffer)
Bluetooth (version 2.1)	- Transmission pattern : eSCO for voice - Transmission power : 0dBm/MHz - Noise figure : 101dBm
Location (x, y) [m]	- Bluetooth Master (0, 0) / Slave (0, 0) - WLAN AP/STA (0, 0) - Channel Model: Rayleigh Fading

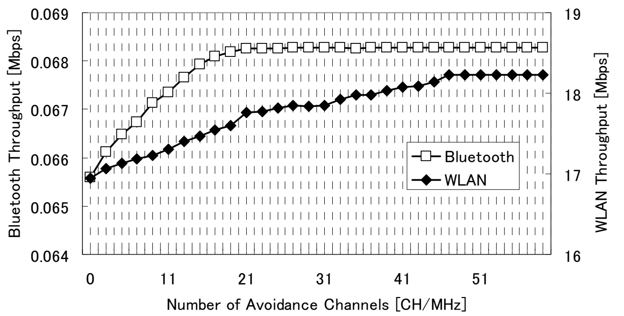

Figure 2. Throughput performance according to the avoidance channel between Bluetooth (eSCO) and WLAN in Fading condition

III. SIMULATION RESULTS

The performances of proposed CCS mechanism as the function of Bluetooth avoidance channel were evaluated by computer simulation. Table 1 lists the Bluetooth and WLAN parameters for simulations. Figure 2 shows the throughput performances according to the avoidance channel between Bluetooth and WLAN. The horizontal axis is the number of avoidance channel between Bluetooth and WLAN from the center of WLAN channel. The number of avoidance channel 0 means full use of Bluetooth channels. The number of avoidance channel 19 means Bluetooth uses 60 channels except from 2433 MHz to 2451 MHz (19 Bluetooth channels). The right vertical axis is the throughput performances of WLAN. The left vertical axis is the throughput performances of Bluetooth.

As shown in Figure 2, the throughputs of Bluetooth and WLAN are seriously degraded because of packet collision and restraint of WLAN transmission where the number of avoidance channel is lower than 19 Bluetooth channels. The throughput of Bluetooth achieves the theoretical value of 0.068 Mbit/ sec where the number of avoidance channel is over 21 Bluetooth channels. In this case, the throughput degradation of WLAN is restriction to transmit WLAN frames due to carrier sense detection of Bluetooth frame in adjacent channels. And, the throughput degradation of WLAN according to the packet collision between Bluetooth and WLAN is negligible where the number of avoidance channel is over 21 Bluetooth channels. It is also confirmed that the throughput of WLAN is degraded where the avoidance channel of 22 is selected in the typical legacy AFH scheme. In addition Bluetooth achieves theoretical value; the throughput of WLAN also achieves the theoretical value of 18.2 Mbit/sec where the number of avoidance channel is over 45 Bluetooth channels. The CCS multiplies the current AFH channel map from Bluetooth by the current WLAN channel in consideration of the avoidance channel of 45, and makes the new AFH channel map. From the summary of simulation results as above, the proposed CCS mechanisms achieves mutual interference avoidance between Bluetooth and WLAN, and guarantee mutual communication qualities where the avoidance channel of over 45 is selected in this situation.

IV. CONCLUSION

In this paper, the problem of mutual interference between Bluetooth and WLAN operating in the 2.4 GHz SIM bands was addressed. The previous approaches improve Bluetooth performance, but the existed devices such as WLAN remains interference because only the channel condition of Bluetooth is considered. Hence Bluetooth and WLAN are set up in close, WLAN transmission is controlled because WLAN detects Bluetooth by the carrier sense in adjacent channel. We propose CCS based on frequency domain multiplexing techniques, which mitigate interference between two technologies. The protocol sequence to make the new AFH channel map in consideration of Bluetooth and WLAN communication qualities are also addressed. The optimal number of avoidance channel is evaluated in computerized simulations. The proposed CCS mechanisms achieves mutual interference avoidance between Bluetooth and WLAN, and guarantee mutual communication qualities where the avoidance channel of over 45 is selected in this situation. Results show that through the proposed CCS mechanisms the interference between WLAN and Bluetooth can be reduced and the throughput of the two systems is significantly improved from legacy AFH and IEEE802.15.2 schemes. Implementation of CCS on the prototype device is in progress.

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