Recognition and Countermeasure to Hidden Terminal Problem by Packet Analysis in Wireless LAN

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***Abstract*—A carrier sense multiple access with collision avoidance (CSMA/CA) is an access protocol of wireless LAN (WLAN). When the carrier sensing is missed, the WLAN systems simultaneously access the channel and then packet collision occurs. It is a hidden terminal problem. In this paper, the recognition of the hidden terminal problem is performed by packet analysis. For suppressing the packet collision under the hidden terminal problem, the proposed countermeasure uses the modulation and coding set with high order modulation and low coding rate. Since the length of the packet is shorten, the probability of packet collision is reduced and thus the throughput and delay performances are improved.**

I. Introduction

Recently, an internet of things assisted by a wireless local area network (WLAN) is expected for enhancing the productivity of factory and farmer [2]. In the application of WLAN for industry, a lot of access points (APs) and stations (STAs) are excessive concentration. As a result, the frequency spectrum division for sharing the wireless resources among APs and STAs is requited. Ii is achieved by a multiple access scheme. In WLAN, a carrier sense multiple access with collision avoidance (CSMA/CA) is used because it is suitable for the distributed wireless scheme. In the CSMA/CA, before accessing the channel, the wireless terminal detects the signal by carrier sensing. The carrier sensing is used for confirming the access from the other terminal. If the wireless terminal recognizes no-access to the channel, it access the channel. For avoiding the simultaneous access among the wireless terminals, the random waiting period is set for spreading the access timing among them, where it is referred to as the random back off. However, the miss detection of carrier sensing occurs because the power of detected signal by carrier sensing becomes small due to fading and shadow effect [5]. As a result, the multiple wireless terminals access to the channel, simultaneously and then the packet collision occurs. It is a hidden node terminal problems [6]

This paper analyses the impact of hidden node terminal problem by packet capture in experimental evaluation. From the evaluation, there are three reasons for reducing the throughput and enlarging the delay in the hidden node terminal problem. The first one is a retransmission of packet. In WLAN, the maximal waiting period for deciding random back off is extended every re-transmission, where it is referred to as exponential back off. The second one is adaptive modulation and coding scheme. In WLAN, lower modulation and coding scheme (MCS) is selected as lower quality of communication link becomes. The third one is the extension of packet length. The longer packet have more opportunities to collide the access among the other wireless terminals. As a result, the packet collision more frequently occurs. From the packet analysis, not only the number of retransmission packets but also the number of continuous retransmission packets are increased, where the continuous retransmission packets are that the same data packets are retransmitted, repeatedly. In WLAN, the header of packets includes a retransmission flag for distinguishing between the initial data packet or not [1]. A retransmission rate and a continuous retransmission rate are analyzed by packet capturing based on retransmission flag. We confirm that these depends on the occurrence of hidden node terminal. Therefore, the retransmission rate and continuous retransmission rate are available for recognizing the occurrence of hidden node terminal. For recovering the hidden node terminal problem, we consider the MCS control by the command sent by the AP to the STA. Since the packet length becomes shorter, not only the information data per time becomes larger but also the occurrence probability of packet collision becomes smaller. It is referred to as the short packet effect. Even though the adaptive modulation and coding makes the lower MCS selected in STA, AP centralizes the MCS control of the STA. In experimental evaluation, when the STA uses the adaptive modulation and coding, it selects the lower MCS than the MCS ordered by AP in certain time period but it changes the MCS to that ordered by AP every sending the indicating command of MCS selection. As a result, the short packet effect is effective and thus the throughput performance is improved.

II. Hidden Node Terminal Problem in Wireless LAN

In WLAN, a carrier sense multiple access with collision avoidance (CSMA/CA) is selected as the multiple access scheme. In CSMA/CA, the constant waiting time before access is set for priority control, where it is referred to as inter frame space (IFS). In addition, the random waiting time before access is set for avoiding the simultaneous access, where it is referred to as random back off. During the waiting time, the carrier sensing is effect for detecting the channel access from the other wireless terminal. If the carrier sensing does not detect any access as well as IFS and random back off are finished, the wireless access is started.

The detected signal power by carrier sensing becomes smaller due to the fading or the shadowing effect. Although the other wireless terminal accesses to the channel, the carrier sensing cannot detect any signal and thus decides no wireless access, where it is referred to miss detection. The wireless terminal whose access cannot be detected owing to the miss detection is hidden node. If the hidden node exists, some wireless terminals access to the channel, simultaneously, the packet error caused by the packet collision occurs. In WLAN, for compensating the packet error, the packet retransmission of the same packet is performed. The packet retransmission are repeated until the certain number of retransmission packets or the recovering of packet error. Every packet retransmission, the maximal range of random back off twice becomes larger, where it is referred to as the exponential back off. This is because as the maximal range of random back off becomes larger, the avoidance of packet collision is more effective. If the hidden node terminal is assumed, the required time difference of access timing between two wireless terminals is at least larger than the packet length. For the more effective of avoiding the packet collision, the larger maximal rang of random back off is required and thus the required retransmissions becomes larger.

In addition, the modulation and coding set (MCS) is adaptively changed in accordance with the quality of wireless communications. In low quality, the low MCS is selected for avoiding the packet error. Since the packet length with lower MCS is larger, the throughput performance is degraded. When the one frame of Ethernet is 1500 byte, Table I shows the relationship between the length of a packet and each MCS.

In WLAN, the adaptive modulation and coding is referred to as rate switching algorithm. The rate switching algorithm is out of standard in IEEE 802.11. Therefore, it is originally arranged by the product company of WLAN. The configuration of rate switching algorithm is hardly opened but the tendency of selecting lower MCS under the lower quality of wireless channel is satisfied. If the hidden node terminal exists, the terminal recognize the low quality of wireless channel because the more retransmission packets are transmitted. The lower MCS is selected and then the length of packet becomes longer. Since the required random back off for avoiding the packet collision is at least one packet, it becomes larger because of longer packet length caused by selecting low MCS by rate switching algorithm.

TABLE I
FRAME LENGTH FOR MCS SELECTION

Index	Transmission rate[Mbit/s]	Frame length[μ sec]
0	6	2072
1	9	1388
2	12	1048
3	18	704
4	24	536
5	36	364
6	48	280
7	54	248

From the above explanation, when the hidden node problem occurs, the packet retransmission and the exponential back off are effect for avoiding the packet collision in WLAN. In addition, the rate switching algorithm is also effect for compensating the low channel quality. Therefore, the required random back off becomes larger. As a result, the number of successfully transmitted packets per certain time duration becomes smaller. The throughput performance is degraded.

III. Recognition of Hidden Node in WLAN

We consider the packet header analysis by packet capturing for recognizing the hidden node terminal.

A. Detection of Hidden Node based on Retransmission Flag

After the data packet is rejected by the receiver, the retransmission flag is changed from 0 to 1 in the header of the retransmission packet. In this paper, the rate of the number of data packets with the retransmission flag of "1'' divided by the total number of packets is a retransmission rate. In addition, the data packets with the retransmission flag of "1 '' as well as the same data is defined as the continuous retransmission packets. Under hidden node terminal, the retransmission rate and the number of continuous retransmission packets are commonly increased. Therefore, the retransmission rate and the continuous retransmission packets analyzed by packet capture are available for detecting the hidden node terminal.

IV. Countermeasure to Hidden Node Terminal Problem

Under hidden node terminal problem, the large random back off is selected by the function of exponential back off. In addition, the lower MCS is selected by the function of rate switching algorithm. As the packet becomes larger, the required length of random back off becomes larger. As a result, the throughput performance is significantly degraded.

If the higher MCS is maintained even under the hidden node terminal, the short packet is maintained. As a result, the required length of random back off is smaller and the data rate becomes larger. Therefore, the high throughput performance is expected. We pay attention to the command of MCS selection with access point (AP). When the AP sends the command indicating the suitable MCS to the station of WLAN (STA), STA selects the MCS ordered by the AP even under the rate switching algorithm. If the AP recognizes the hidden node terminal, it can order the MCS to the STA by the command. As a result, the effect of short packet is effective. However, the MCS becomes lower because the rate switching

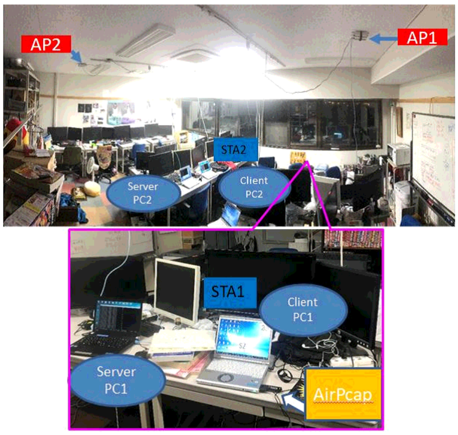

Fig. 1. Experimental drawing

TABLE II
ACCESS POINT DETAILS

Model Number	Aironet3500, LAN-WAGE/AP
Company	Cisco, Logitec
IEEE 802.11 Protocol	IEEE 802.11a
Center Frequency	5.22GHz (W52 44ch)

algorithm is effective after the certain time duration. Since the AP periodically sends the command to the STA, the MCS is modified to the higher MCS but the MCS becomes lower after the certain time duration. Although the STA cannot select the higher MCS, constantly, the higher MCS is selected for the larger time duration. As a result, the effect of short packet can be derived and then the throughput put performance is improved.

V. EXPERIMENTAL RESULTS

A. Experimental Environment

Figure 1 shows the overview of experimental environment. Table II shows the detail of the AP used in this evaluation. The adapter of "STA 1 '' is Intel(R) Dual Band Wireless-AC 8265.

Figure 2 shows the image of experimental evaluation for analyzing the hidden node terminal problems. Figure 3 shows the location of each STA. A server is connected to AP by Ethernet cable and This AP is located on the top of roof. The traffic between AP1 and STA1 and AP2 and STA2 can be controlled by iperf. The network interface card of WLAN for packet capturing is connected to STA1, where the driver of packet capturing is referred to as AirPcap. AirPcap monitors the wireless communication between AP1 and STA1. We consider the data upload from STA to AP. The evaluation period is 10 seconds. The user datagram protocol (UDP) is used. The traffic load between AP2 and STA2 is from 0 to 54 Mbit/sct.

For evaluating the effect of countermeasure to the hidden node terminal problem, the experimental evaluation of the constant MCS controlled by AP is performed. In accordance with Figure 3(c) , the length between AP and STA is so small

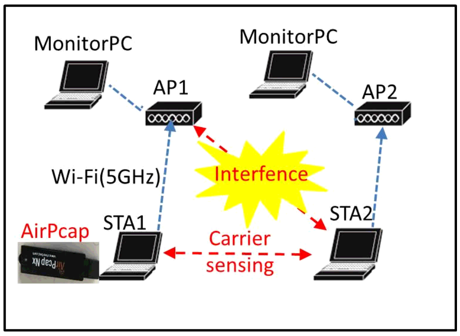

Fig. 2. Experimental image

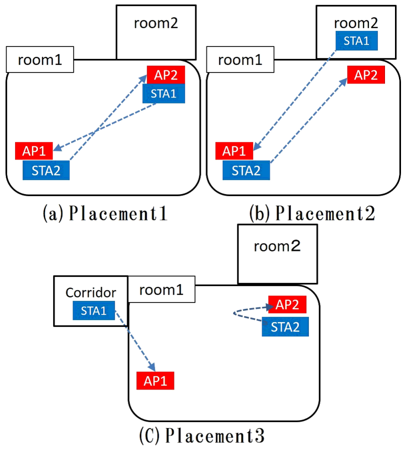

Fig. 3. STA location

that the highest MCS can be selected but the lower MCS is automatically selected by the rate switching algorithm under hidden node terminal problem. In proposed countermeasure, the MCS supporting 54 Mbit/sec is selected by the command from the AP.

B. Performance of Analyzing Hidden Node Terminal Problems by Packet Capture

Figures 4 and 5 shows the performance of retransmission rate and MCS selection, respectively. Figure 6 and Table III show the histogram of continuous retransmission number and cumulative distribution of it. From these figures, the retransmission rate and the continuous retransmission in Position 2 and 3 are larger than those in position 1. It is obvious the STA 1 and 2 in position 2 and 3 are hidden node. In Figure 6, in 2 continuous retransmissions, the cumulative distribution function (CDF) in position 1 is 1.0 but those in position 2 and 3 are smaller than 1.0. If the continuous retransmission is larger than or equal to two, the wireless terminals are considered as the hidden nodes.

C. Evaluation Results of Countermeasure to Hidden Node Terminal Problems

Figures 7 and 8 show the histogram of MCS in the constant MCS of 54 Mbps and the variable MCS controlled by rate

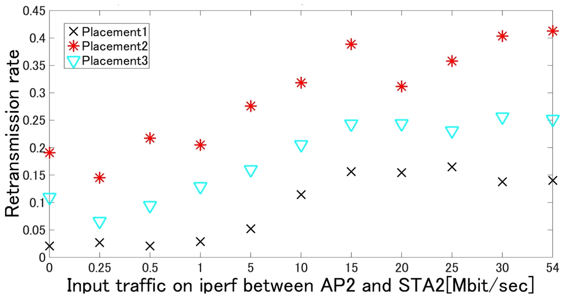

Fig. 4. Retransmission rate of STA1

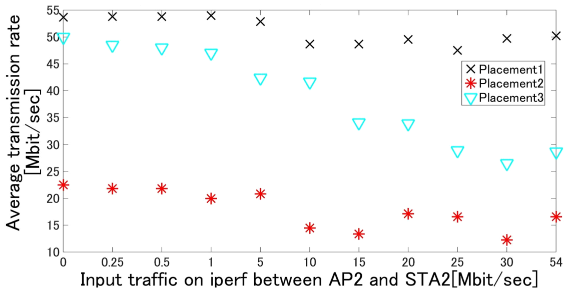

Fig. 5. MCS of STA1

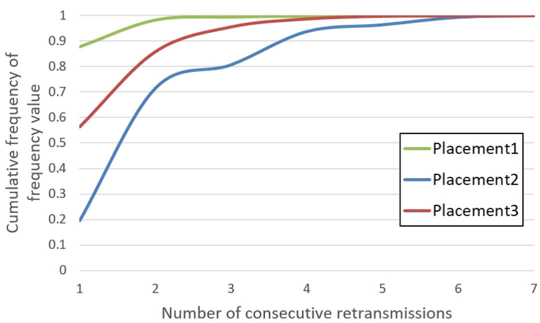

Fig. 6. Number of consecutive retransmissions of STA1

TABLE III
FREQUENCY VALUE OF CONTINUOUS RETRANSMISSION NUMBER OF STA1

	Number of consecutive retransmissions						
	1	2	3	4	5	6	7
Placement1	0.877	0.106	0.012	0.004	0.002	0	0
Placement2	0.195	0.520	0.092	0.131	0.027	0.027	0.006
Placement3	0.564	0.293	0.097	0.031	0.010	0.002	0.001

Number of STA1's MCS	AP2's Input traffic[Mbit/sec] 0	1	3	5	7	10	15	Full buffer
6 [Mbit/sec]	0.000	0.001	0.001	0.002	0.005	0.006	0.015	0.015
9 [Mbit/sec]	0	0	0	0	0	0	0	0
12 [Mbit/sec]	0	0	0	0	0	0	0	0
18 [Mbit/sec]	0	0	0	0	0	0	0	0
24 [Mbit/sec]	0.004	0.011	0.016	0.022	0.029	0.058	0.143	0.176
36 [Mbit/sec]	0	0	0	0	0	0	0	0
48 [Mbit/sec]	0	0	0	0	0	0	0	0
54 [Mbit/sec]	0.996	0.989	0.982	0.975	0.966	0.937	0.841	0.808
Total number of packets	23046	20411	20017	17572	16437	13711	9347	8483

Fig. 7. MCS frequency value of STA1(Fix MCS at 54Mbit/s)

Number of STA1's MCS	AP2's Input traffic[Mbit/sec] 0	1	3	5	7	10	15	Full buffer
6 [Mbit/sec]	0	0	0	0	0	0.001	0.001	0.001
9 [Mbit/sec]	0	0	0	0	0	0.002	0.002	0.006
12 [Mbit/sec]	0	0.001	0	0.001	0.001	0.015	0.007	0.035
18 [Mbit/sec]	0	0.001	0	0.002	0.005	0.019	0.076	0.020
24 [Mbit/sec]	0	0.008	0.007	0.035	0.049	0.075	0.069	0.157
36 [Mbit/sec]	0	0.357	0.244	0.135	0.174	0.435	0.752	0.757
48 [Mbit/sec]	0.005	0.362	0.225	0.216	0.193	0.265	0.071	0.024
54 [Mbit/sec]	0.995	0.271	0.523	0.610	0.578	0.189	0.022	0.000
Total number of packets	21385	23079	21183	19391	17533	15318	8509	9181

Fig. 8. MCS frequency value of STA1(Dynamic selection of MCS)

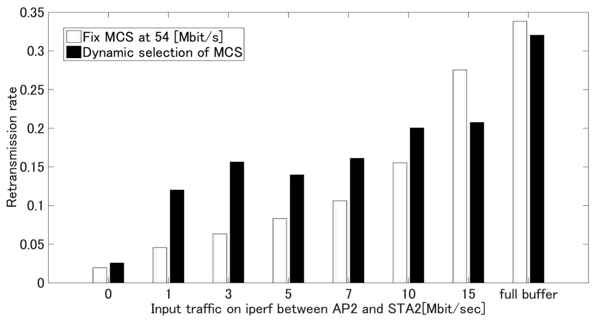

Fig. 9. Retransmission rate of STA1

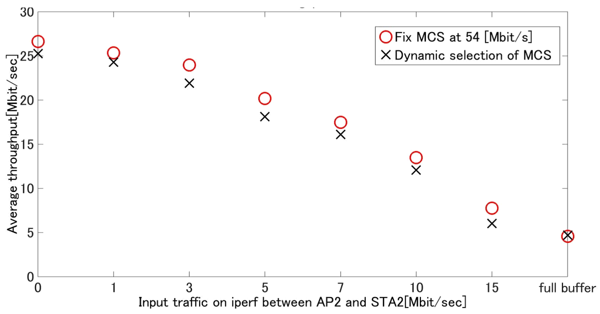

Fig. 10. Average throughput of STA1

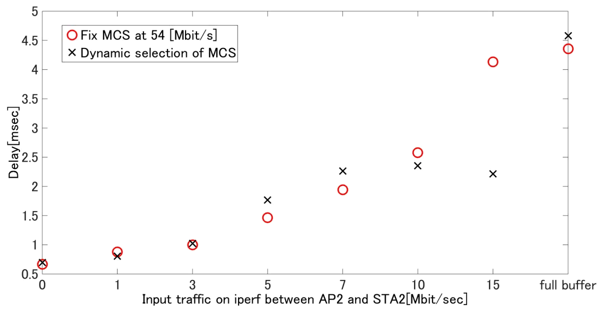

Fig. 11. Delay of STA1

switching algorithm, respectively. From Figure 7, even though the MCS of 54 Mbps is requested by the command from AP, the STA selects the lower MCS for the certain frequent than 54 Mbps. As we explained, the rate switching algorithm is not stopped and thus the STA periodically select the lower MCS because of recognizing the lower quality of wireless channel degraded by packet collision. In addition, the constant MCS and the variable one commonly reduce the total data packets. This is because the length of maximal random back off becomes larger, the waiting time for packet transmission becomes larger, and thus the transmitted data packets are reduced.

Figures 9, 10 and 11 shows the performances of retransmission rate, average throughput, and delay, respectively.

From figures 10 and 11, as the traffic load of STA2 are from 5Mbps to 7Mbps, the throughput of the constant MCS is 2Mbps larger than that of the variable MCS and the delay of the former is 0.25msec smaller than that of the latter. From these results, we confirm the advantage of the short packet effect under the hidden node terminal problems. However, as the traffic load of STA2 is larger than 7Mbps, the obvious improvement of the throughput and the delay are not confirmed. The traffic load of STA is so large that the packet collision frequently occurs. Although the packet length is shorten, the packet collision cannot be avoided.

VI. Conclusions

This paper analyzes the hidden node terminal of wireless local area network by packet capturing. The retransmission rate and the continuous retransmissions derived by the retransmission flag of the packet header are available for recognizing the hidden node terminal. The countermeasure to the hidden node terminal is the shortening of packet by the command specification of modulation and coding set by the access point. From the experimental evaluation, the countermeasure to the hidden node terminal is effective for improving the throughput and the delay performances owing to the reduction of packet collision.

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