Specification of Link Quality Degradation in WLAN based on MCS and Retransmission Flag

Hirotaka Senda* , Osamu Takyu* , Akinori Kamio* , Mai Ohta† and Takeo Fujii‡
* Shinshu University, Japan
E-mail: takyu@shinshu-u.ac.jp Tel/Fax: +81-26-269-5255/+81-26-269-5220
† Fukuoka University, Japan
‡ The University of Electro-Communications, Japan

***Abstract*—Wireless LAN is currently used in various cases such as homes and offices. However, if the carrier sense of each terminal is not detected, a hidden terminal problem appears in which packet collisions occur frequently, and the communication quality deteriorates significantly. In order to overcome the quality deterioration, it is usual to select the low coding rate and low order modulation scheme in the Modulation and Coding Scheme(MCS). However, for quality deterioration caused by packet collisions, there is a report that selecting a high coding rate and high-order modulation scheme shortens the packet length and suppresses the probability of packet collisions. The specifying scheme of causing the communication quality deterioration is necessary for suitable controlling MCS.**

In this paper, we propose a specifying scheme for communication quality deterioration that utilizes header information obtained by packet analysis in wireless LAN. The proposed method enables a third party to evaluate the quality of the wireless LAN by comparing the retransmission flag, which is the header information, with the MCS in each environment. In this research, we report that packet quality can be analyzed by using packet analysis in experimental evaluation, and the factor of quality deterioration according to the decrease in throughput with respect to quality can be determined.

I. Introduction

Wireless LAN is currently used as an infrastructure for connecting to the Internet in homes and offices, and in recent years, it is expected to be applied to control and article management in factories and production sites[1]. When a large number of wireless LANs are deployed, signals between terminals tend to be undetected due to the effect of shielding devices and obstacles. Since a node fails to detect the access from the other node by carrier sensing, packet collision occurs due to simultaneous access, where it is referred to as a hidden node. The throughput deterioration caused by hidden node is serious problem [2].

In wireless LAN, Adaptive Modulation and Coding (AMC) is used to switch the modulation method and coding rate to adapt to the deterioration of reception quality[3]. In AMC for wireless LAN, there is a Modulation and Coding Scheme (MCS), which is a set of modulation scheme and coding rate.In wireless LAN, the MCS is controlled in accordance with the rate of received acknowledgement signals (ACK signals), where it is a rate switching algorithm [4]. In this algorithm, a low MCS is also selected in conjunction with a decrease in the rate of received ACK signals due to the fading loss and the propagation loss. Even when the throughput is reduced, the low MCS is selected similarly. However, when the low MCS is selected, the packet length increases, so that the channel occupying time increases and packet collisions caused by simultaneous access occur. In the hidden node problem, the low MCS causes the additional degradation of throughput performance [7].

In [7], it has been reported that in an environment where packet collisions frequently occur at hidden terminals, high MCS is selected for shortening packets and the frequency of packet collisions is reduced. As a result, it improves throughput performance. In the rate switching algorithm, the low MCS is selected without distinguishing between throughput degradation due to packet collision and throughput due to propagation environment. Therefore, in order to bring out the short packet effect by selecting a high MCS,between the throughputs-deteriorate caused by hidden node problem and that caused by fading and propagation losses. Therefore, the packet shortening for avoiding the packet collision is not available under the rate switching algorithm. It is necessary to specify the cause of throughputs -deterioration.

In this paper, we propose the specification scheme of throughputs-deterioration based on the analysis of packet header. By using the packet capture dongle, it is possible to receive packets propagating in space and analyze the packet header.In the packet header, the information about the retransmission flag and the selected MCS is obtained , where these are directly related to the evaluation of communication quality. We clarify the relationship between the stochastic tendencies of the retransmission flag and the selected MCS and the occasion of the throughput-deteriorates from the experimental evaluation.

The paper is organized as follows.In Section II, we describe wireless LAN communication method. In Section III, we describe a method for identifying communication quality deterioration in a wireless LAN environment. In Section IV, we describe an evaluation experiment using packet analysis software, and in Section V, the results of the experiment performed in Section IV.Finally, Section VI gives a summary of this study.

II. Throughput Degradation of WLAN in Hidden Node Problem

A. Impact of Hidden Node Problem to WLAN

Figure 1 shows the overview of WLAN systems. There are two systems, systems A and B. There are two nodes of systems A and B where the nodes of systems A and B are referred to as node A and node B, respectively. As shown in Fig.1, when node A and node B are in a state where they cannot carry out carrier sense with each other due to an obstacle, even though node A is transmitting to the AP, node B also transmits to the AP, and a packet collision occurs at the AP because node A cannot transmit the channel usage status by carrier sensing. At this time, node A and node B are said to be hidden nodes. When packet transmission fails due to collision, the size of Contestion Window (CW), which is the maximum waiting time for random backoff in wireless LAN, is doubled. As a result, since the transmission waiting time increases, the number of packets that can be transmitted within a certain period of time decreases, and throughput decreases.

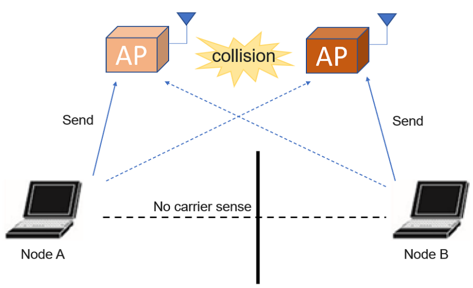

Fig. 1. Hidden node status

B. Impact of Hidden Node Problem to Selection of MCS

Modulation and Coding Scheme (MCS) is an index of combinations of modulation methods and coding rates, and the transmission rate and frame length are determined by each combination. In addition, the dynamic selection of MCS is called rate switching algorithm, which is outside the IEEE802.11 standard and is determined by the implementation of the wireless device development company.For example, we pay attention to the switching algorithm of CISCO [4]. In CISCO, the transmitter calculates the rate of receiving the acknowledgement signal (ACK signal) sent by the receiver, while the rate of receiving the ACK signals is almost equal to the rate of successfully demodulated packets in the receiver. If the rate of receiving the ACK signals becomes smaller, the transmitter decides to downgrade the MCS by one level. When downgrading the MCS but not improving the rate of receiving the ACK signals, the transmitter keeps downgrading the MCS in one by one level. Otherwise, the transmitter upgrades the MCS by one level. In this manner, the rate switching algorithm can exploit the suitable MCS level. Note that the rate switching algorithm keeps changing the MCS even under the steady channel quality .

TABLE I
MCS combination

Index	Transmission rate[Mbit/s]	Frame length[μ sec]	Modulation method	Error correction coding rate
MCS 0	6	125	BPSK	1/2
MCS 1	9	90	BPSK	3/4
MCS 2	12	73	QPSK	1/2
MCS 3	18	55	QPSK	3/4
MCS 4	24	47	16QAM	1/2
MCS 5	36	38	16QAM	3/4
MCS 6	48	34	64QAM	2/3
MCS 7	54	32	64QAM	3/4

In the hidden node state, the frequency of ACK reception within a fixed time decreases, so the rate switching algorithm tends to select a lower MCS. Therefore, the packet becomes long, and packet collisions occur with a high probability in narrow CW transmission control.As a result, the CW increases and the throughput decreases.

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)

III. Proposed Specification of Hidden Node Problem based on Header Analysis

A. Difficulty of Specification between Hidden Node Problem and Fading Loss

In last section, we explain the hidden node problem that causes the degradation of throughput performance. The other term for degrading the throughput performance is a fading loss. In the multipath environment of wireless communication link, the interference between paths causes the reduction of signal power. In addition, the propagation loss also reduces the signal power [5]. When the signal power is under the required Signal to Noise power Ratio(SNR) for demodulation, the demodulation of packet fails. The transmitter downgrades the MCS in accordance with the rate switching algorithm. As a result, the throughput performance is degraded. Both the fading loss and the hidden node terminal cause the reduction of throughput performance. Therefore, these are hardly distinguished by detecting the instantaneously selected MCS or the instantaneous throughput performance.

B. Proposed Specification of Hidden Node Problem

There is a retransmission flag in the packet header of the transport layer [6].In the retransmission of packet, the transmitter set the retransmission flag for informing the packet retransmission to the receiver [8]. If the packets are retransmitted repeatedly, the set of retransmission flag is maintained. When the packet and retransmitted packets are continuously detected, the set sequence of the retransmission flag is detected except for the initial-transmission packet. In this study, the ratio of packets with a retransmission flag of 1 to the total number of detected packets is defined as the retransmission rate. When the number of retransmission packets becomes maximal, the retransmission of data packets is stopped. Therefore, we cannot recognize the demodulate-success of the last retransmitted from the retransmission flag packet because the header of next packet is automatically un-set in the regardless of the demodulate-success or not. The rate of demodulated-success in the receiver can be estimated from the defined retransmission rate if the undetermined of demodulate-success from the last retransmitted packet is accepted.

In addition, the ratio of the selected MCS within a certain observation time normalized by the total number of packets is defined as the MCS selectivity.In this study, we analyze the resend rate and MCS selectivity using packet analysis software from the observation experiment by the actual device, and clarify the possibility of discriminating communication quality deterioration from the difference of MCS selectivity depending on the presence or absence of hidden node state.

IV. Experimental Evaluation

Figure 2 shows the appearance of the measurement environment. STA1 is the measurement node and the state quality of communication with AP1 is evaluated using iperf, which is a network measurement tool. By installing AirPcap, which is a packet analysis dongle, in STA1, packets from STA1 can be received with high signal power, so that errors in packet demodulation and missing packets in capturing can be suppressed. Then, for the environment in which STA1 and AP1 are communicating, STA2 and AP2 are establishing communication as separate systems. In the same as STA1, STA2 also transmits data to AP2 by iperf, and becomes a load system that gives interference to STA2 and AP2. By controlling the traffic volume of the load system, the frequency of packet collisions caused by the hidden node problem is changed. In this evaluation, the throughput of STA2 is defined as the load, and the STA1 single system environment (no load) and the environment where two systems coexist (load) are distinguished.In this experiment, we evaluated two criteria other than throughput: retransmission rate and MCS selectivity.As the STA1 adapter for capturing, Intel(R) Dual Band Wireless-AC 8265 is used.

The layout of each node in this experiment is shown in Figure 3.This arrangement reproduces the environment in which packet collision at [7] occurs.AP1, AP2, and STA2 are placed indoors, and they are taken out of the room with the door in front of STA1 closed.In addition, in order to distinguish and evaluate the factors of quality degradation due to distance attenuation and the factors of packet collision, we created three arrangements of environment 1∼5.In environment 1, communication between STA1 and AP1 only, in environment 2 environment in which another system of STA2 and AP2 is added to communication between STA1 and AP1. Environment 3∼5 is communication only with STA1 and AP1, environment 3 is STA1 in the corridor, environment 4 is STA1 in a separate room, environment 5 is STA1 on the stairs. Environment 2 assumes quality deterioration due to packet collision, and environment 3∼5 assumes quality deterioration

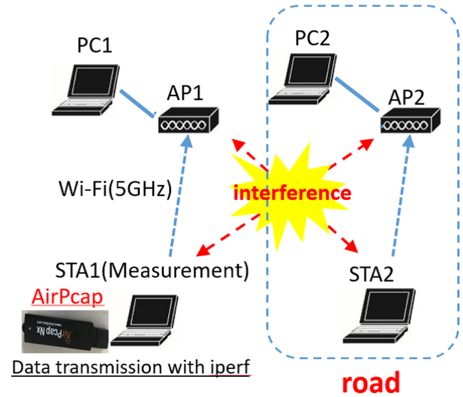

Fig. 2. Measurement environment

due to communication distance attenuation. The experimental specifications are shown in Table III.

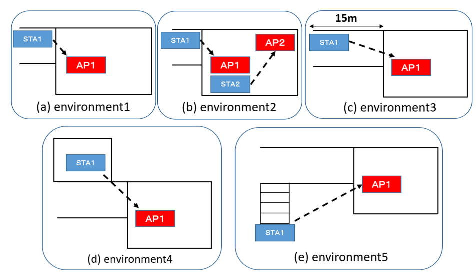

Fig. 3. Arrangement of each node

Fig. 4. Placement of each access point

V. Experimental Result

In this experiment, in order to distinguish between the two quality deteriorations, the throughput is set to the same level in the environment 2∼5, which is the deterioration environment, and evaluated(TableIV). First, Fig.8 and Fig.9 show the average retransmission rate and MCS selection rate, respectively, when the throughput of the first environment

Fig. 5. Placement of STA1 in environment 2 and 3

Fig. 6. Placement of STA1 in environment 4

is unified to about 23 Mbps. Figure 8 shows the average resend rate of each environment. Compared to environment 1, the resend rate increased from environment 2 to environment 5 by about 0.09.The reason for this is that in environment 2, the retransmission rate increases due to packet collisions due to hidden node conditions, and in environments 3, 4, and 5, the packet success rate decreased due to the decrease in received signal power, and the packet length increased due to the selection of low MCS, and the packet collision probability increased. Next, in Fig.9, as in Fig.8, quality is degraded in environment 2∼5, but there is also a difference between the hidden node environment 2 and the path loss environment 3 ∼5. This is because in environment 2, STA and AP are communicating at positions close to each other, so high signal power is ensured and retransmission due to packet collision occurs.Since the ACK notification is irregular, it can be seen that the rate switching algorithm dynamically switches between high MCS and low MCS, and as a result, high MCS and low MCS are selected.

On the other hand, in environment 3∼5, which has a large propagation loss, compared to environment 2, the communication distance is longer and the signal power is lower, so there is a tendency to select a low MCS.Also, although there is a wide range of MCS selection as in environment 2, there is a tendency to select MCS that is lower than environment 2 overall.This shows that the average received power is lower than in environment 2 and that low MCS is selected at a fixed rate as a result of fluctuations in the received power due to multipath fading.

Fig. 7. Placement of STA in environment 5

TABLE III
EXPERIMENTAL PARAMETERS

IEEE802 Protocol	IEEE802.11a
Traffic between STA1 and AP1	Full buffer
Traffic between STA2 and AP2	5 [Mbps]
measurement time	10 [s]
Number of executions	10
L4 protocol	UDP

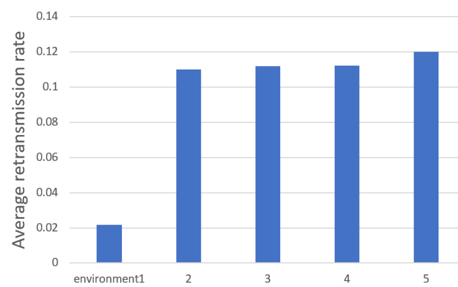

Fig. 8. Average retransmission rate(23Mbps)

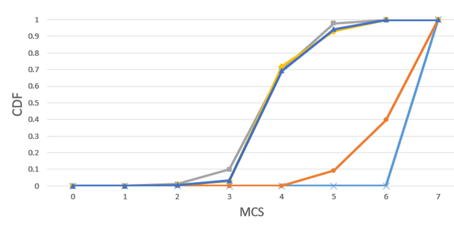

Fig. 9. MCS selection rate(23Mbps)

TABLE IV
THROUGHPUT(I)

environment1	29.1Mbps
environment2	23.1Mbps
environment3	23.0Mbps
environment4	23.2Mbps
environment5	23.2Mbps

TABLE V
THROUGHPUT(II)

environment1	29.1Mbps
environment2	14.1Mbps
environment3	14.3Mbps
environment4	13.9Mbps
environment5	14.5Mbps

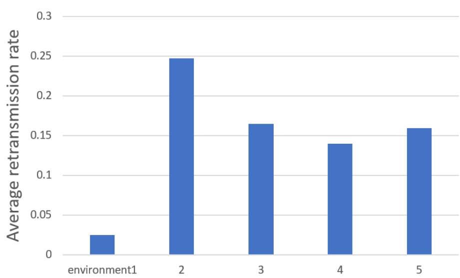

Fig. 10. Average retransmission rate(14Mbps)

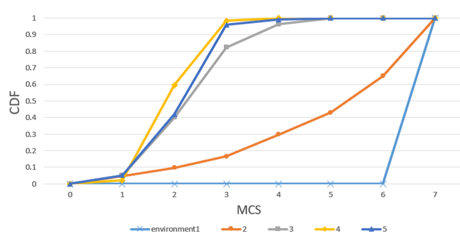

Fig. 11. MCS selection rate(14Mbps)

Next, in order to perform evaluation in another environment, we change the load and unify the throughput of the deteriorated environment to 14 Mbps for evaluation(TableV). The average retransmission rate and MCS selection rate are shown in Fig. 10 and Fig. 11, respectively. According to Fig.10, the quality is deteriorated in environment 2∼5 as in the case of 23 Mbps, it can be seen that the average retransmission rate in environment 2 in the hidden node state is increased by about 0.08 compared to environment 3∼5. Similarly for Figure 11, environment 3∼5 that has lower throughput due to the decrease in received power due to path loss selects MCS that is lower than environment 2 in the hidden node state. Based on the above results, it is possible to judge the presence or absence of throughput deterioration by evaluating the average retransmission rate, and to identify the cause of the deterioration from MCS. In addition, when APs are fixedly arranged, by evaluating the MCS at a specific throughput in advance in a single STA, when a higher MCS is selected during operation of another system than when it is alone, It can be judged that the communication quality is due to the hidden node.

VI. Conclusion

In this paper, we examined a method for identifying communication quality deterioration by packet analysis in a wireless LAN environment.The presence or absence of quality deterioration is determined by the average retransmission rate. Dynamic selection of MCS tends to select a lower MCS set for the distance attenuation than the hidden terminal state. By comparing the MCS when there is a single system and when other systems exist, it is possible to distinguish the factors of quality deterioration.

In this evaluation result, as a method for distinguishing between hidden nodes and propagation loss, a standard was established that the MCS of other systems is improved compared to when the system is operated independently, and if there is a difference in CDF of 0.5 or more for a given MCS, it is judged as a hidden node state. Actually, evaluation of the identification accuracy of the hidden node problem using this criterion is a topic for future study.

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