Modulation Adjustment Scheme for Asymmetric Data Transmission in In-Band Full Duplex Wireless Communication

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Abstract

The transmission time of uplink data and downlink data are generally different because their average data sizes are different. The uplink and downlink transmission simultaneously occur in in-band full duplex communication where the size difference causes waste of time in transmission. This paper proposes the modulation adjustment scheme to improve packet delivery probability by applying slow but reliable modulation to uplink transmission. As a result, the performance of the proposed modulation adjustment scheme shows improvement in the throughput of uplink transmission.

Keywords: in-band full duplex, asymmetric transmission time, packet error rate.

1. Introduction

Recently, in-band full duplex (IBFD) wireless communication is spotlighted [1]. Since a station can transmit and receive simultaneously, IBFD technique theoretically enables to achieve double capacity.

Generally, uplink (UL, from a station to an access point) data size is smaller than downlink (DL, from an access point to a station) data size. In [2], the authors investigate the average data size of UL and DL in local area wireless network. Their investigation showed that the ratio of UL packet length and DL packet length is 1:3. According to their result, we can assume that UL transmission time is smaller than DL transmission time. When UL transmission time and DL transmission time are different, it is called asymmetric transmission time. In this case, the authors of [3] used busy tone to announce that another station is still in transmission. However, busy tone is a waste of channel resource, because it does not contain any information. Therefore, the ratio of busy tone should be decreased to increase throughput and resource efficiency. In this paper, we propose a novel scheme to improve packet error rate by changing modulation scheme of UL transmission and reduce the ratio of busy tone. The proposed scheme improves packet error rate (PER) and, consequently, throughput.

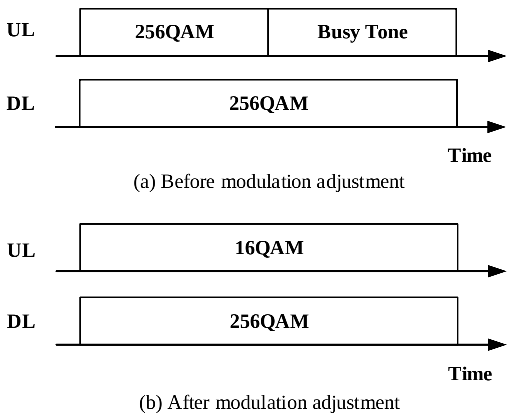

Fig. 1. Example of modulation adjustment

2. Proposed Scheme

First, we assume that energy per bit to noise ratio (E_b/N_0) of UL transmission and DL transmission are same. Therefore, if UL packet length and DL packet length are same, the PER of UL transmission and DL transmission are same. We also consider the case where DL packet length is longer than UL packet length. Fig. 1(a) shows an example of asymmetric transmission time. As we mentioned, since busy tone is a waste of resource, it should be reduced to enhance resource efficiency. To decrease the ratio of busy tone, we propose the change of the modulation of UL transmission.

Let T_{UL} and T_{DL} be transmission time of UL and DL, respectively, which are equal to:

$$T_{UL} = B_{UL} / M_{UL}, \tag{1}$$

$$T_{DL} = B_{DL} / M_{DL}, \tag{2}$$

where B_{UL}, B_{DL} are the packet length of UL and DL, respectively, M_{UL}, M_{DL} are the number of bits per symbol of UL and DL, respectively.

In our proposed scheme, M_{UL} is minimized to satisfy following condition:

$$\frac{B_{UL}}{B_{DL}} \le \frac{M_{UL}}{M_{DL}}, \tag{3}$$

We define the PER of UL transmission and throughput as:

$$PER_{UL} = 1-(1-BER_{UL})^{B_{UL}}, \tag{4}$$

$$Th = \frac{B_{UL}(1-PER_{UL})}{\max(T_{DL}, T_{UL})}, \tag{5}$$

Table 1. Evaluation Environment

Parameter	**Setting**
Downlink packet size	4096 bytes
Uplink packet size	128~4096 bytes
Downlink modulation	256QAM
Uplink modulation	16QAM, 64QAM, 256QAM
Channel model	AWGN channel

Table 2. Transmission rate (Mbps)

Modulation	16QAM	64QAM	256QAM
Transmission rate	60	90	120

where BER_{UL} is the bit error rate of UL transmission.

In our proposed scheme, based on (3), we can change modulation of UL. As the M_{UL} decreases, the BER_{UL} decreases. According to (4), the PER_{UL} also decreases. Although the transmission time of UL increases, the throughput is depending on $\max(T_{DL},T_{UL})$. After modulation adjustment, the transmission time of UL and DL are almost same and the ratio of busy tone decreases, as we can see Fig. 1(b). According to (5), its throughput increases because PER_{UL} decreases.

3. Performance Evaluation

We used performance evaluation parameters as Table 1. We used the fixed parameters for DL transmission while the variable ones for UL transmission. Transmission rate corresponding to each modulation can be seen in Table 2.

Fig. 2 shows that throughput gain depending on the ratio of UL transmission time to DL transmission time. As the ratio of UL transmission time to DL transmission time increases, the effective throughput gain increases. According to (4), the PER of UL transmission increases at the same BER of UL transmission, as packet length of UL increases. However, when the ratio of UL transmission time to DL transmission time is more than 0.75, the gain is 0. According to (3), when the ratio is more than 0.75, our proposed scheme cannot be applied.

Fig. 3 shows that throughput gain depending on PER of DL transmission. This result is evaluated in the ratio of UL transmission time to DL transmission is 1/3. As PER increases, effective throughput gain increases. This is because the original PER of UL and DL are same, and as the DL PER increases, the PER gain of UL increases.

4. Conclusion

In this paper, we proposed the modulation adjustment scheme using asymmetric transmission time information. In IBFD wireless communication, most transmission is UL-DL asymmetric transmission. Therefore, by applying the modulation adjustment scheme, we can increase the throughput of the IBFD wireless communication.

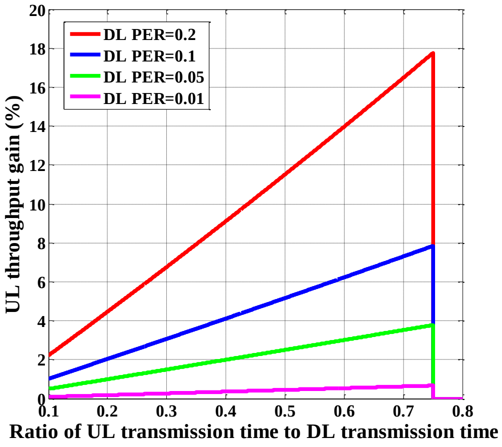

Fig. 2. Effective throughput gain vs. the ratio of UL and DL transmission time

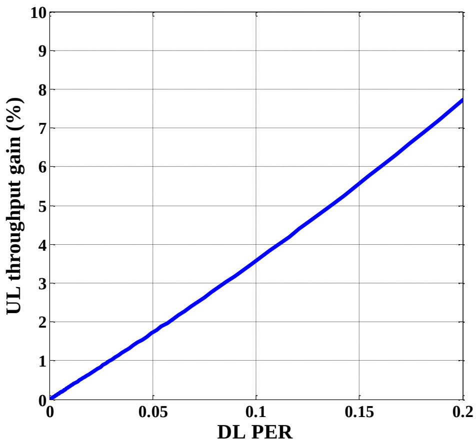

Fig. 3. Effective throughput gain depending on DL PER

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