Performance Evaluation of the Impact between IEEE 802.11ah and Private LoRa using 920 MHz Band*

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***Abstract*—IEEE 802.11ah (11ah) is a wireless LAN standard using the 920 MHz band and is expected to be used in the IoT field as one of the Low Power Wide Areas (LPWAs). Many LPWAs share the 920 MHz band and are characterized by low transmission rates but long-range communication. Therefore, there is a high possibility of contending communication in the real-world environment. In this study, we clarify the characteristics of contending communications between 11ah and LoRa according to evaluating the performance using real devices.**

***Index Terms*—IEEE 802.11ah, Wi-Fi HaLow, Private LoRa**

I. Introduction

The standard for IEEE 802.11ah (after this, we call 11ah) was established in 2016 and approved for use in Japan in September 2022. 11ah is expected to be used in the IoT field as one of the Low Power Wide Areas (LPWAs) because it can provide a wide communication area with low power consumption [1]. 11ah is a narrowband standard based on IEEE 802.11ac [2]. In Japan, 11ah has a communication distance of 1/100 and a maximum throughput of 40 times compared with LoRa (TABLE I). Since many LPWAs have base stations and terminals with the unlicensed 920 MHz (S1G) band, a design that considers the effects of radio interference is necessary [3]. In this study, we measure communications in an environment contending between 11ah and Private LoRa communications and evaluate the impact of performance.

II. Experiment Environment

The purpose of this experiment is to impact the quality of performance by comparing the communication of 11ah only with the contending communication of 11ah and Private LoRa. Fig. 1 shows the experimental topology. 11ahAP and 11ahBR indicate the 11ah access point (AP) and 11ah bridge, respectively. The distance between 11ahBR and LoRa sender is far apart. 11ahAP and 11ahBR connect to a Raspberry Pi 4 via Ethernet. RM92A, the LoRa interface by RFLink Co., connects to a Raspberry Pi 3 Model B+ via serial connection. TABLE II and TABLE III explain transceiver settings for 11ah and LoRa. iperf3 and TShark generate communication flows and capture packets. iperf3 transmits a 1472 Bytes packet with 4 Mb/s UDP in the direction of 11ahBR to 11ahAP. In LoRa,

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TABLE I
Compare with 11ah, 11ac and LoRa

	11ah	11ac	LoRa
Band [Hz]	920 M	2.4 G	920 M
Bandwidth [Hz]	1/2/4 M	20/40/80/160 M	125/250/500 k
Max throughput [b/s]	15 M	6.9 G	37.5 k
Distance [km]	1	0.1	100

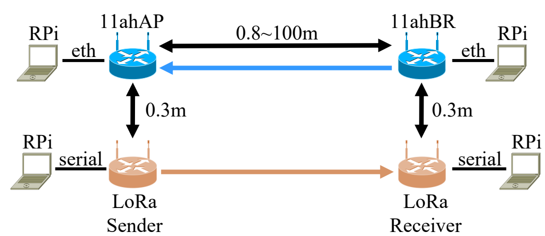

Fig. 1. Experimental Configuration

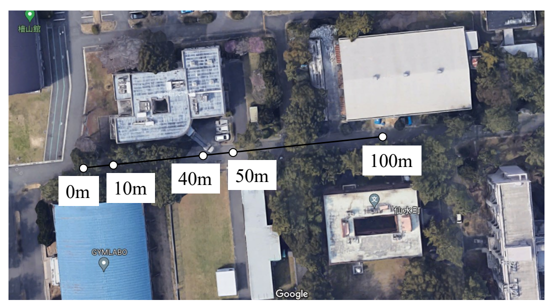

Fig. 2. Experimental Environment

the transmitter sends ten packets at 1 s intervals, and the packet delivery rate is measured. The number of trials is five. This experiment is done repeatedly for five times.

First, we measured the communication distance of 11ah as 0.8 m in an anechoic chamber with no interference from other communication. Second, we measured communications between 11ah and LoRa at distances of 10, 40, 50, and 100 m outdoors as shown in Fig. 2. The distance between the transmitters was set to 0.8 m in an anechoic chamber. In the second experiment, we investigated the impact of changing channels, bandwidth, the number of carrier sense retries, and the payload data size of the transmitted packet of LoRa. Firstly, the LoRa channel focuses on the distance between two communication channels. Secondly, LoRa bandwidth is focusing on the overlap between the 11ah and LoRa bands. Then, the number of carrier sense retries of LoRa focused on the maximum number of carrier sense retries per packet.

TABLE II
11AH SETTINGS

	value
Channel [ch] (Frequency [MHz])	32 (923.0)
Bandwidth [MHz]	1
Tx power [%]	100 (10 dBm)
Frame aggregation	None
Duty window size [s]	120 (Duty cycle:10 %)
Beacom rate [ms]	100

TABLE III
LORA SETTINGS

	value
Channel [ch] (Frequency [MHz])	36 (923.0), 38 (923.4) 41 (924.0), 44 (924.6)
Bandwidth [kHz]	125, 500
Tx power [dBm]	13
Spreading Factor (SF)	11
Coding Rate (CDR)	4/5
Carrier sense times [times]	2, 9
Payload data size [Bytes]	9, 166

Lastly, the payload data size of the transmitted packet of LoRa focused on the transmission time of LoRa by payload data size. The default parameter setting for the channel is 36 ch with the bandwidth set to 125 kHz. The number of carrier sense retries is two, and the payload data size of the transmitted packet is 9 Bytes in LoRa.

III. Experimental Results and Discussion

Fig. 3 shows the results of 11ah communications measured in an anechoic chamber. The experiment of 4 MHz bandwidth was set at 15 Mb/s of Maximum transfer rate and TX rate in iperf3. In these results, the average throughput of 1 MHz bandwidth is approximately 1.6 Mb/s, and 4 MHz bandwidth is approximately 3.1 Mb/s. The average throughput of 1 MHz is approximately half the theoretical value (3.3 Mb/s) because of the overhead of CSMA/CA.

Fig. 4 through Fig. 8 show the results of contending communication measured outdoors. In this subsection, the normalized throughput is calculated based on the throughput of 1 MHz bandwidth in Fig. 3. Fig. 4 shows the results of communication with only 11ah. Each normalized throughput is approximately 100 % regardless of communication distance.

Fig. 5 shows the result of changing the channel of LoRa. When the communication distance is 10 m and the channels used for each other's communication are close, the normalized throughput of 11ah is relatively high while the delivery rate of LoRa is low. This is because the distance between the two communications and the used channels are close, making it easier for LoRa to detect 11ah with carrier sense. Fig. 6 shows the result of changing the bandwidth of LoRa. When the communication distance is 10 m, the normalized throughput of 11ah is high regardless of the bandwidth of LoRa, and the delivery rate of LoRa is low. This is because the proximity of the communication distance and channels makes it easier for LoRa to detect 11ah by carrier sense like the result in Fig. 5. Fig. 7 shows the result of changing the number of carrier senses of LoRa. Regardless of the distance, 11ah cannot communicate when the number of carrier sense times is nine. This is because as the number of carrier sense times of LoRa

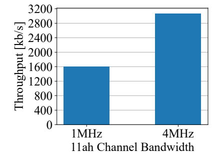

Fig. 3. 11ah throughput in anechoic chamber

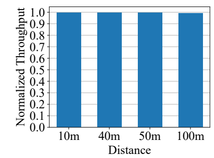

Fig. 4. 11ah throughput in outdoor

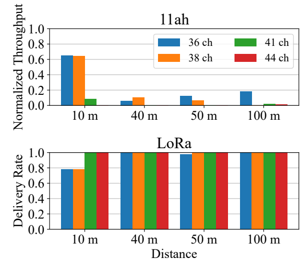

Fig. 5. Channel different

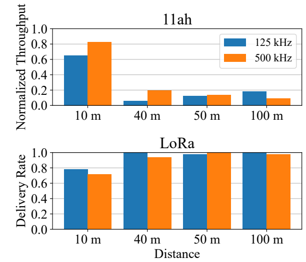

Fig. 6. Bandwidth

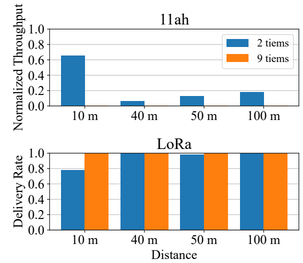

Fig. 7. Carrier sense time

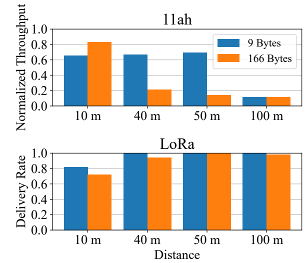

Fig. 8. Payload data size

increases, the probability that LoRa can start transmitting at the carrier sense time of 11ah increases. Fig. 8 shows the result of changing the payload data size of LoRa. When the communication distance is 40 and 50 m and the payload data size of LoRa is 9 Bytes, the normalized throughput of 11ah is high. This is because the smaller packet size of LoRa reduces the occupancy time and increases the time for 11ah to communicate. From the above results, in the contending communication between 11ah and LoRa, changing the payload data size and the number of carrier sense retries of LoRa can improve the fairness of the two communications.

IV. Conclusion

In this study, we evaluated the relationship between the contending communication and LoRa parameter changes. As a result, the number of carrier sense retries and the payload data size of the transmitted packet in LoRa (AirTime) affect the occupancy of 11ah and LoRa communications. Our future work is to propose a fairness improvement method for contending communication between 11ah and LoRa.

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