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Improved Wi-Fi Backscatter System for Multi-to-Multi Communication

Chang-Bin Ha, Yong-Jun Kim, Dong-Hyun Ha, Hyoung-Kyu Song

***Abstract*—**The conventional Wi-Fi backscatter system can only process one-to-one communication between the Wi-Fi reader and the Wi-Fi tag. For improvement of throughput of the conventional system, this paper proposes the multi-to-multi communication system. In the proposed system, the interference by the multi-to-multi communication is effectively cancelled by the orthogonal multiple access based on the identification code of the tag. Although the overhead is generated by the procedure for the multi-to-multi communication, because the procedure is processed by the Wi-Fi protocol, the overhead is insignificant for the entire communication procedure. From the numerical results, it is confirmed that the proposed system has nearly proportional increased throughput in according to the number of the tag that simultaneously participates in communication.

***Keywords*—**Backscatter, Multi-to-multi communication, Orthogonality, Wi-Fi.

I. Introduction

RECENTLY, internet of things (IoT) technology that connects internet to all things apart from computer is getting a lot of attention [1]. By providing an intelligent interface and communication protocol for things, IoT technology integrates things into network and offers information processing function and response function for request to things. However, due to cost issue, there are two problems for IoT technology. First, all things are not available to use protocol of high cost such as the long term evolution (LTE) and the wireless fidelity (Wi-Fi). Second, all things can't support the required power by the built-in battery for wireless communication.

As a suitable communication protocol for IoT to enable network access to all things, there is the Wi-Fi protocol [2]-[3]. The Wi-Fi access point (AP) is already installed here and there in society and the Wi-Fi can support communication in the coverage of the AP. In addition, as a suitable technology for wireless communication that doesn't use built-in battery among the requirements for realization of IoT, there is the backscatter technology [4]-[5]. The combined system of the Wi-Fi and backscatter is referred to as the Wi-Fi backscatter system [6].

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II. Problem to Be Solved by the Proposed Method with the Conventional Wi-Fi Backscatter System Model

Fig. 1 shows the conventional Wi-Fi backscatter system model and the detailed communication procedure of the Wi-Fi backscatter system was described in [6]. Fig. 2 shows the communication procedure for the conventional Wi-Fi backscatter system.

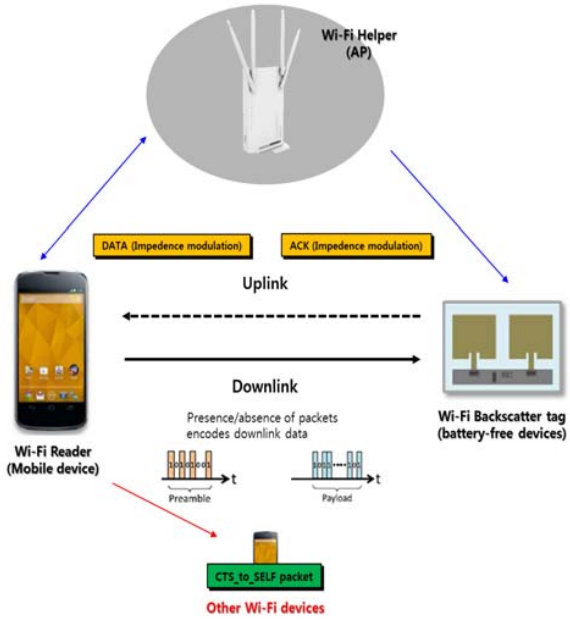

Fig. 1 The conventional Wi-Fi backscatter system model (one-to-one communication)

The conventional Wi-Fi backscatter system has problem for very low throughput. Since the tag doesn't use the Wi-Fi protocol by the cost problem, the reader doesn't Wi-Fi protocol for the communication in the Wi-Fi backscatter system. Instead, the reader uses on-off modulation scheme that determines transmission of the Wi-Fi packet in according to the information of '1' or '0' by unit of transmission period of Wi-Fi packet. The tag detects signal of the reader using receiving energy differences corresponding to '1' or '0' by unit of transmission period of the Wi-Fi packet and transmits respond signal to the reader. However, because the collected power by the ambient radio frequency (RF) signals is limited, the tag does not internally generate a signal and externally transfers the signal to the reader using the impedance modulation to the ambient RF signal from the Wi-Fi AP.

In the next section, the proposed method for solving the

above-mentioned problem of the Wi-Fi backscatter system is described with the proposed system model. In addition, the performance of the improved Wi-Fi backscatter system by the proposed method is analyzed.

TABLE I
EXAMPLE FOR ORTHOGONAL CODE OF THE TAGS

Tag number	CODE			
i (code number)	1	2	…	N
1	1	1	1	1
2	1	1	-1	-1
…	1	-1	1	-1
N	1	-1	-1	1

III. IMPROVED WI-FI BACKSCATTER SYSTEM BY THE PROPOSED METHOD

In contrast to the conventional Wi-Fi backscatter system, the proposed Wi-Fi backscatter system is possible simultaneously communicate with the multiple readers and the multiple tags. Fig. 3 shows the proposed Wi-Fi backscatter system model.

In the proposed Wi-Fi backscatter system model, the tags in the coverage of AP do not have mobility. It is assumed that the tags have identification code that meets orthogonality for each other. In addition, among the readers and the tags in the coverage of AP, the readers and the tags that simultaneously participate in communication are defined as the reader-set and the tag-set, respectively.

Before the substantive communication between the reader and the tag, the Wi-Fi access point (AP) transmits the identification codes of the tags to the reader-set. After transmission for the identification codes, the Wi-Fi AP transmits the assigned time slot for the tags of the tag-set to the reader-set. When the tag transmits response signal to the reader, the time slot specifies the transmission time for each tags. Sequentially, the readers of the reader-set share the request signal by the Wi-Fi AP. Because the Wi-Fi AP and the reader can use the Wi-Fi protocol, the procedure for sharing of the identification code, the time slot, and the request signal is processed by the Wi-Fi protocol.

The reader-set transmits the preamble to the tag-set using the shared identification code. Because the identification code meets the orthogonality for each other, even if the readers of the reader-set simultaneously transmit the identification code, the interference by simultaneous transmission is effectively cancelled by the orthogonality of the code. Table I shows the orthogonal code.

The condition for the code is as,

$$\sum_{i=0}^{N} c_a(i)c_b(i) = 0, \ for\ a \neq b \tag{1}$$

where $\boldsymbol{c}$ is the code for each tag.

The tag-set that recognizes the substantial beginning of communication by the reception of the preamble simultaneously transfers acknowledge (ACK) message using the impedance modulation. The interference by the simultaneous transmission is cancelled by the XOR operation by unit of packet using corresponding code for the tag. The communication for the request signal is processed by the same manner. However, the response signal cannot be simultaneously transmitted from the tags. The reason is that the tag cannot autonomously generate signal. Therefore, the tags sequentially transfer response signal in according to the assigned time slot. Fig. 4 shows the communication procedure for the proposed Wi-Fi backscatter system.

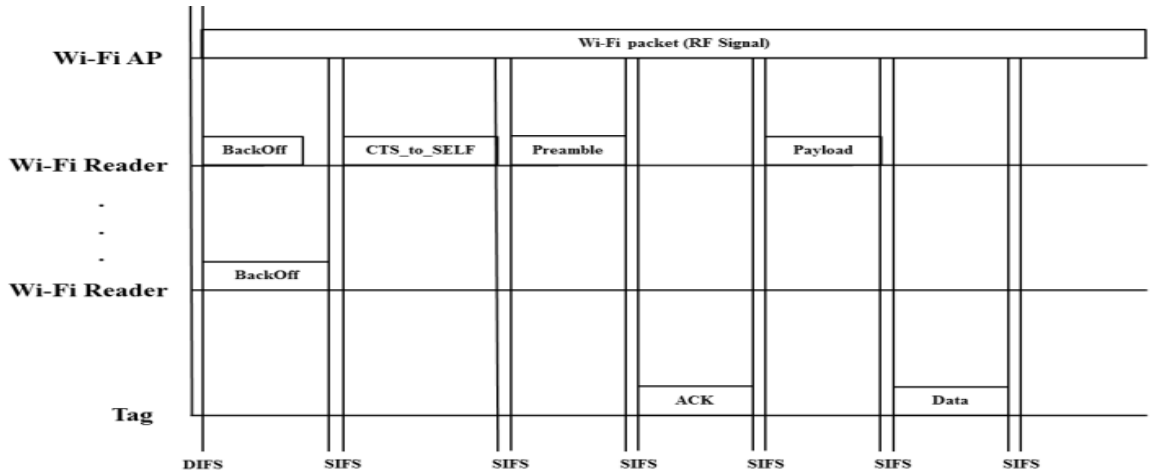

Fig. 2 The communication procedure for the conventional Wi-Fi backscatter system

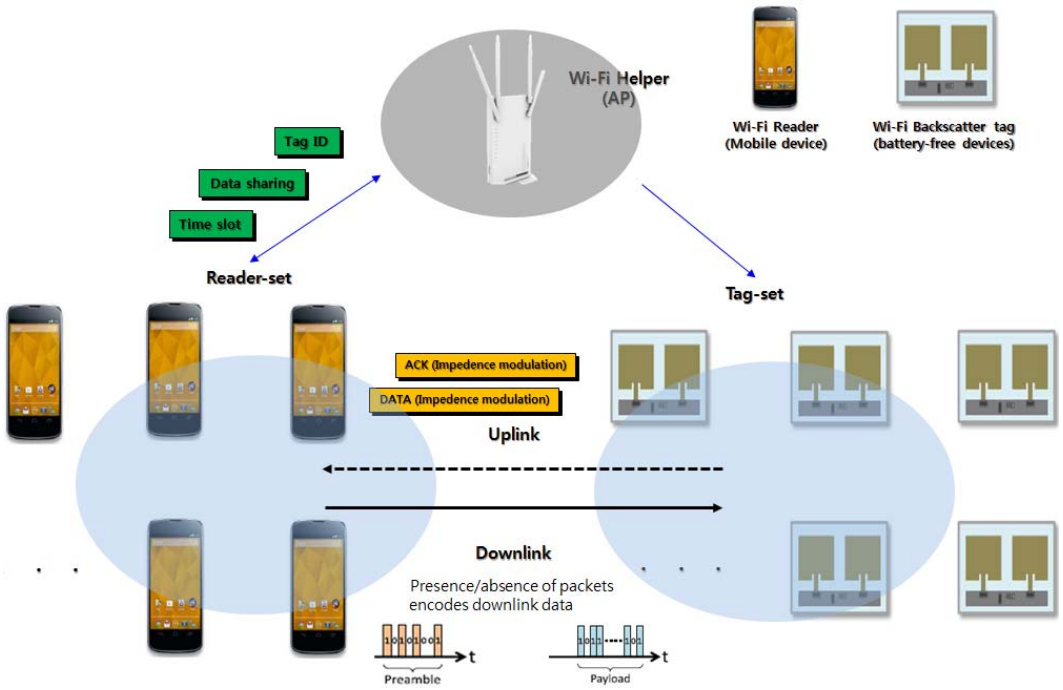

Fig. 3 The proposed Wi-Fi backscatter system model (multi-to-multi communication)

$$Throughput_{conventional} = \left\{ \frac{A}{T_{DIFS} + T_{Channel} + T_{CTS} + (T_{SIFS} \times 6) + T_{preamble} + T_{ACK} + T_{Payload} + (T_{Wi-Fi} \times A)} \right\} \times (1 - BER) \quad (2)$$

$$Throughput_{Proposed} = \left\{ \frac{A}{T_{DIFS} + (T_{Channel} \times N) + (T_{SIFS} \times 12) + T_{ID} + T_{TS} + T_{DS} + T_{preamble} + T_{ACK} + T_{Payload} + (T_{Wi-Fi} \times A) \times N} \right\} \times (1 - BER) \quad (3)$$

TABLE II
PARAMETERS FOR THE SIMULATION

Parameter	Meaning	Value	Unit
T_{DIFS}	DIFS time	34	μsec
T_{SIFS}	SIFS time	16	μsec
$T_{Channel}$	Wi-Fi channel competition time	-	μsec
T_{CTS}	Transmission time of CTS-to-SELF packet	$(12 \times 8)/r_{Wi-Fi}$	μsec
T_{Wi-Fi}	Transmission time of Wi-Fi packet with minimum size	50	μsec
$T_{Preamble}$	Transmission time of preamble	$T_{Wi-Fi} \times 16$	μsec
T_{ACK}	Transmission time of ACK	$T_{Wi-Fi} \times 16$	μsec
$T_{Payload}$	Transmission time of payload	$T_{Wi-Fi} \times 64$	μsec
A	The amount of transmitted response data from tag	-	bits
N	The number of tag = The number of reader	-	-
T_{ID}	Transmission time of packet with tag ID	$(14 \times 8)/r_{Wi-Fi} \times$ N	μsec
T_{TS}	Transmission time of packet with time slot	$(14 \times 8)/r_{Wi-Fi} \times$ N	μsec
T_{DS}	Data sharing time	$64/r_{Wi-Fi} \times$ N	μsec
r_{Wi-Fi}	Data rate of Wi-Fi	54×10^6	bits/s

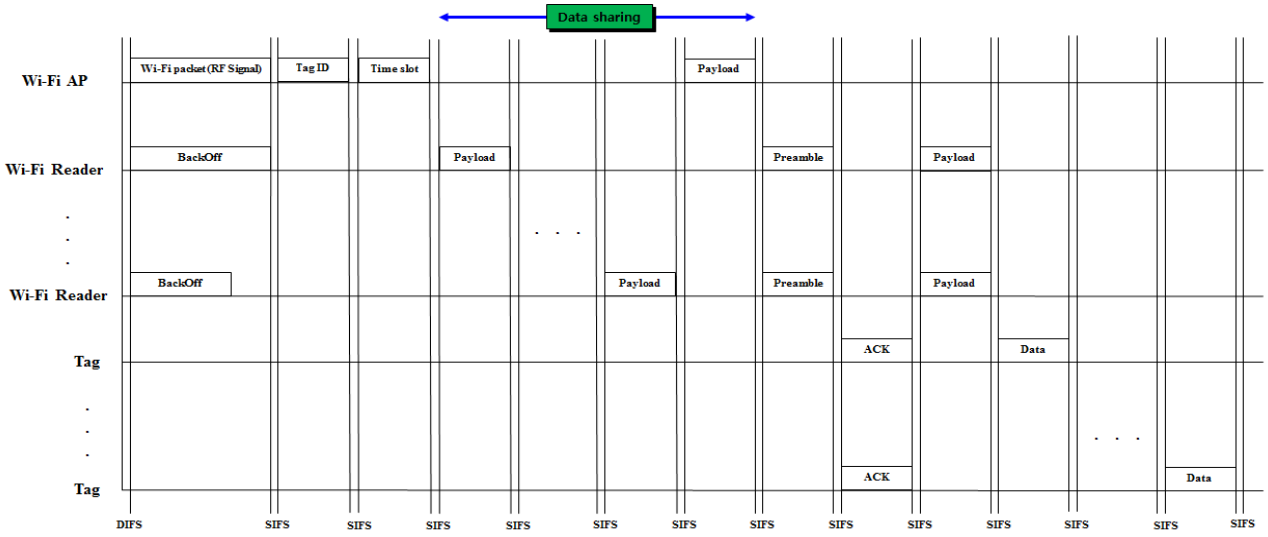

Fig. 4 The communication procedure for the proposed Wi-Fi backscatter system

IV. Performance Evaluation

Fig. 5 shows the throughput of the conventional and proposed Wi-Fi backscatter system in according to the amount of transmitted response signal from the tag-using Table I, (2), and (3). The Wi-Fi protocol for the simulation is IEEE 802.11n [2]. The simulation results show that the throughput is nearly proportionally increased in according to the number of the tag that simultaneously participates in communication. For the proposed multi-to-multi communication, the overhead is generated. However, unlike the substantial data communication, the procedure for the multi-to-multi communication is processed by the Wi-Fi protocol. Therefore, the overhead is insignificant for the entire communication procedure.

V. Conclusion

Among the requirements for the realization of IoT technology, as the system for the battery support problem, the Wi-Fi backscatter system is proposed. However, because the tag doesn't use the Wi-Fi protocol by the cost problem, the Wi-Fi backscatter system has very low throughput. For improvement of throughput of the conventional system, this paper proposes the multi-to-multi communication. For the multi-to multi communication, each tags use the identification code that meets orthogonality for each other. The interference by the multi-to-multi communication is effectively cancelled by the orthogonal multiple accesses based on the orthogonal code of the tag. Because the procedure for the multi-to-multi communication is processed by the Wi-Fi protocol, the throughput for the proposed scheme is nearly proportionally increased in according to the number of antenna.

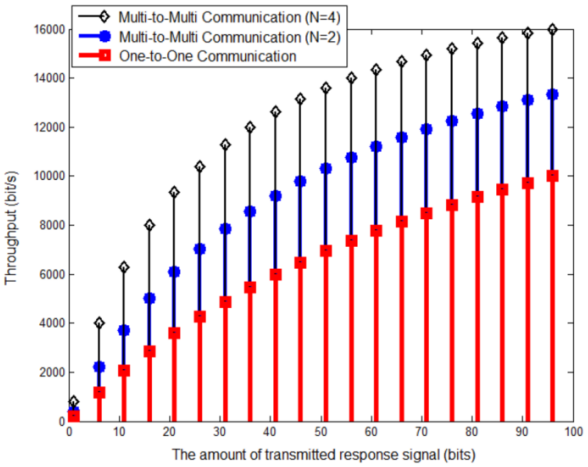

Fig. 5 Throughput of the conventional and proposed system in according to the amount of transmitted data

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