

Backscatter Wireless Communication System Using Ambient Wi-Fi Signal in Indoor Propagation Environments

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Abstract

This paper presents a backscatter wireless communication system using power detection of the reflected or absorbed signals in Wi-Fi (802.11a/b/g/n) network. We propose a downlink from Wi-Fi device to the backscatter tag and an uplink from a backscatter tag to Wi-Fi device, in interconnecting with Wi-Fi device and Wi-Fi AP. This system can provide the identification and data of tag on the internet connectivity without requiring extra wireless infrastructure. This uses existing Wi-Fi AP infrastructure. The tag system is possible to be operated without battery because of harvesting and generating power from Wi-Fi signal. Wi-Fi device operates to encode and decode information recognizing the existence of the modulated Wi-Fi packet. This system can be achieved wireless connectivity for ultra-low-power sensor tag and IoT device.

Keywords: Backscatter wireless communication, Wi-Fi, bistatic, ambient RF, tag

1. Introduction

Recently, internet of things (IoT) has emerged as a new market and technology. IoT is related not only to computers and mobile phones connected through the internet but also to the inter-connection between mobile and sensor devices. So, various types of wireless communication and network technologies are applied to devices to send data to each to the internet and to each other without cable [1]. The communication method is decided by selection of appropriate wireless connectivity technology considering network situation of various IoT applications. Key aspects for selection of optimal network connectivity includes the operating range, data rate, power consumption, carrier frequency, cost-effectiveness, and so on. However, it's hard to select the optimal wireless connectivity because of their tradeoffs. For example, Wi-Fi is quite apparent choice for supporting fast data transfer and high quantities of data in indoor environment. However, it requires expansive infrastructure and considerable power. The wireless connectivity technologies for sensor devices are Bluetooth, Zigbee, Z-wave, and RFID. These have to be operated low-power and made inexpensive. The conventional wireless communications for sensor devices exist the

This work was supported by Institute for Information & communications Technology Promotion(IITP) grant funded by the Korea government(MSIP) (No.B0126-15-1076, "Development of non-powered technology combined with ambient RF energy harvesting and Backscatter data transfer").

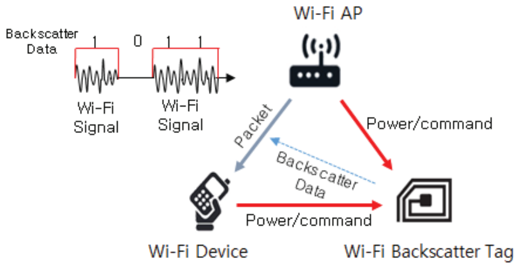

Fig. 1. Architecture of the backscatter communication system using Wi-Fi signal

limitations of power life time and needs an additional infrastructure [2].

We suggest method for ulta-low-power wireless connectivity using an ambient microwave without needing the wireless communication infrastructure.

2. System Architecture

2.1 Backscatter system overview

An RFID connectivity is representative of backscatter communication methods [3]. In conventional RFID system, the RFID reader is a network connected infrastructure device that sends power as well as transfers data to the tag. The RFID reader hardware is absolutely necessary for operating the tag. However, the installation of many RFID readers with antenna needs for communicating data in a variety of places. Because the proposed backscatter communication system using Wi-Fi signal doesn't need a new infrastructure, it doesn't cost for an additional equipment [4].

The backscatter wireless communication system transfers to Wi-Fi device the identification and data of tag using Wi-Fi signal as seen in **Fig. 1**. On the downlink (Wi-Fi device to the tag), the Wi-Fi device transmits the encoded command and power signal. The command for driving response signal of tag is encoded by adjusting length of preamble, header, payload, and SIFS in Wi-Fi packets. On the uplink (tag to the Wi-Fi device), the tag generates data by backscatter modulating the transferred Wi-Fi packet between Wi-Fi device and AP. By altering the tag's antenna impedance load, a Wi-Fi signal with different phase and magnitude is backscattered to the Wi-Fi device. The different modulation states change the CSI and RSSI values, which the

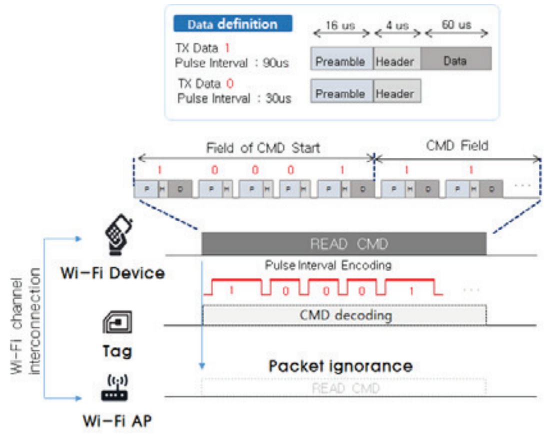

Fig. 2. Downlink sequence (Wi-Fi device → Tag)

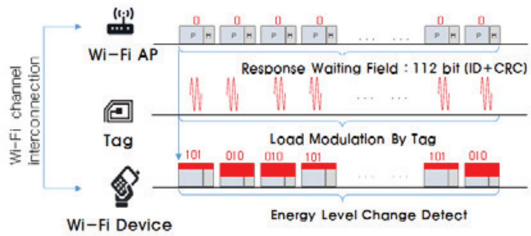

Fig. 3. Uplink sequence (Tag → Wi-Fi device)

Wi-Fi device uses to decode data from the backscatter tag.

This system is able to support a battery-less and a battery-assisted mode. The power of tag is generated or charged from Wi-Fi signal. Power can be maintained by harvesting Wi-Fi signal using a patch antenna attached to a RF-DC converting circuit [5].

2.2 Communication sequence

In downlink sequence, we design the Wi-Fi device encode data using length and presence of Wi-Fi packets. As shown in **Fig. 2**, the encoding mechanism at the Wi-Fi device uses pulse interval encoding (PIE). This is the encoding method based on time duration of data symbols '0' and '1'. Wi-Fi device encodes a '1' bit with increasing payload length of a Wi-Fi packet and a '0' bit with no data. The division between the bits depends on short interframe space (SIFS). Backscatter tag designed low power cannot decode Wi-Fi packet. So instead, for operating low power, tag can design a circuit to detect the energy level of a Wi-Fi packet. Tag decodes request data by tracing energy and voltage level of Wi-Fi packets encoded PIE.

In uplink sequence, the proposed backscatter communication system transfers data of tag by modulating the Wi-Fi channel from interconnected Wi-Fi AP. In order to improve the performance of backscatter modulating, FM0 and miller encoding methods are used to maximize the number of the transitions in the data. Wi-Fi device extracts the modulated Wi-Fi packets through analyzing phase and amplitude of the received channel state information (CSI). For increasing uplink communication data rate, the designed tag uses the multi-level load modulation method.

3. Implementation

3.1 Tag and Wi-Fi Device

The proposed backscatter tag system consists of the components for the communicating and RF energy harvesting. The data communicating block includes the power level detector of Wi-Fi packet and the backscatter load modulator. The power level detector removes the 2.4 GHz carrier frequency, and extracts a data from the envelope of Wi-Fi packet and SIFS. The backscatter load modulator generates the modulation index of backscatter signal through multi-level load array. The RF energy harvesting part obtains power from Wi-Fi signal and supplies the power of the whole tag. This block is composed of an RF energy harvester, a voltage regulator, a power management and a storage element. The RF energy harvester transforms from the ambient Wi-Fi signals to a DC voltage. The tag antenna is designed an array of micro-strip patches, which resonates at 2.4 GHz that can absorb and reflect Wi-Fi signal.

We design Wi-Fi device using Wi-Fi Intel link 5300 card that can plot the CSI. Wi-Fi device consists of CSI analyzer, the backscatter data modem, and Wi-Fi antenna.

3.2 Test

We implement a prototype of tag and Wi-Fi device, and test a bistatic communication system using a commercial Wi-Fi AP. Fig. 4 shows the test environment and CSI values of decoding the backscatter tag data encoded FM0.

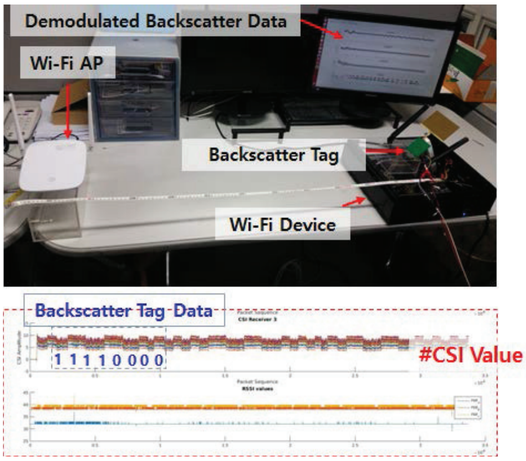

Fig. 4. Backscatter communication system test

4. Conclusions

This paper has presented the backscatter communication system using Wi-Fi signals. We propose backscatter downlink/uplink sequence between tag and Wi-Fi device. And we implement and test the bistatic communication system.

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