Efficient Wireless Communication System for Industrial Communications

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Abstract. IEEE 802.15.4 is a global standard designed for the low power consumption, low cost, and low data rate. Thus, this standard is advantageous to implement ubiquitous sensor network (USN). However, researchers do not have been studied to employ cooperative communication in this system. Cooperative relaying system has been shown to help the destination to get the spatial diversity. It is possible to more reliable transmit and to reduce the consumption energy. It is useful for battery powered nodes. Therefore, we propose the IEEE 802.15.4 utilizing cooperative communication system that can efficiently transmit and save energy. We call this system as ZigBee-based cooperative communications.

Keywords: IEEE 802.15.4, Cooperative communication, Diversity

1 Introduction

IEEE 802.15.4 has been studied, which is suitable for short range, low power, and low rate wireless communication system [1]. Therefore, IEEE 802.15.4 is useful for low rate sensor and control devices that must have long battery life [2]-[4]. Zigbee is difficult to communicate over large scale without installing close node. In other words, when Zigbee transmits far node, this system must have relay nodes. Therefore if the node which locates the edge of transmission uses line of sight (LOS) signal and relay nodes' signal, the destination receives more accurate signal such as cooperative communication.

Cooperative relaying system has been also researched for efficient transmission in wireless communication system [5]-[8]. Cooperative relaying system is to share other user's antenna to obtain spatial diversity [9]. The important thing is that cooperative relaying system can also reduce energy consumption for these system that use battery powered nodes [10],[11]. Therefore, if IEEE 802.15.4 utilize cooperative communication, this system can more efficiently transmit for diversity gain. Because IEEE 802.15.4 is a very simple system, we propose simple cooperative relaying system for IEEE 802.15.4. We call this system as ZigBee-based cooperative communications in this paper.

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2 The Overview of Basic Communication System

IEEE 805.15.4 operates within three different frequency bands in the industrial scientific and medical equipment (ISM). Europe uses the band which is between 868.0 and 870MHz. U.S applies 902 to 928 MHz. In this paper, we consider only 2.4 GHz band. The IEEE 802.15.4 is based on direct sequence spread spectrum (DSSS). Each 4-bit symbol is mapped into the 32 chip pseudo noise (PN) sequences in 2.4GHz as shown in [12]. The 2.4 GHz band employs the orthogonal quadrature phase shift keying (OQPSK) with half-sine pulse shaping. This modulation technique is equivalent to minimum shift keying (MSK). Even-indexed chips are modulated onto the in phase (I-phase), likewise odd-indexed chips are modulated onto the quardrature phase (Q-phase).

3 Proposed Cooperative Relaying Scheme

In this section, we represent ZigBee-based cooperative communication. We consider a wireless communication system where the source and relay simultaneously transmit data to the destinatio. The relays help to send the signal with high reliability from source to destination. Conventional cooperative relaying system consists of source, relay and destination. We consider that destination is a master node and that relay and source are slave nodes. To make only simple process, master node only use each two received signals which have the most powerful signal. Proposed system is composed of only one relay and two hops. In this case, line of sight (LOS) signal power is sufficiently transmitted to receiver, so source sends signal to destination through two steps. Destination demodulates signal from the source through two steps and from the relay through one period in the second step. There are several main cooperative signaling methods [13]. In this system, amplify-and-forward (AF) and decode-and-forward (DF) are available for proposed scheme. The received signal of relay and destination at the first time slot is represented as follows:

$$r_R(t) = h_{SR}(t) * s_i(t) + w(t) \tag{1}$$

$$r_{D1}(t) = h_{SD}(t) * s_i(t) + w(t) \tag{2}$$

where $h_{SD}(t)$ and $h_{SR}(t)$ mean the channel between the source and destination, and the channel between source and relay, respectively. $s_i(t)$ is the IEEE 802.15.4's symbol. * means convolution. Lastly, $w(t)$ is additive white guassian noise (AWGN). During the first time slot, $r_{D1}(t)$ and $r_R(t)$ are the received signals at the destination and the relay, respectively. After received the data at the each nodes, destination memorizes the data at first time slot. The relay decodes $r_R(t)$ and re-encodes to $\hat{s}_i(t)$ which is estimated $s_i(t)$. Therefore the second time slot can be written as

$$r_{D2}(t+T_s) = h_{SD}(t+T_s) * s_i(t+T_s) + h_{RD}(t+T_s) * s_i(t+T_s) + w(t+T_s) \tag{3}$$

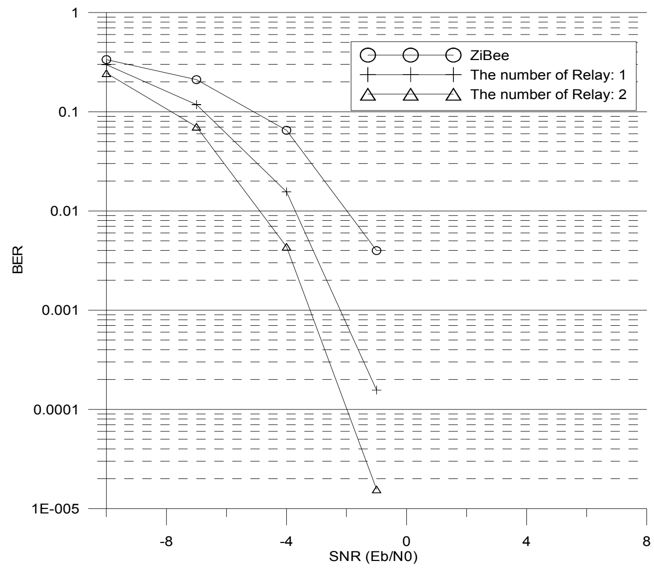

Fig. 1. BER performance comparison of the number of relay based on ZigBee.

where $r_{D2}(t)$ denotes the received signal during the second time slot. $h_{RD}(t)$ represents the channel between the relay and the destination. T_s is symbol duration. Destination uses the signal to demodulate as follows:

$$r_D = r_{D1} + r_{D2}. \tag{4}$$

4 Simulation Results

In this section, we provide performance results for the ZigBee-based cooperative relaying system. Fig. 1 represents the bit error ratio (BER) performance of conventional ZigBee and ZigBee-based cooperative relaying system which has one relay or two relays. Here, we define a term of "signal-to-noise ratio (SNR) gap" which means the difference of SNR between source-to-destination (S-D) channel and source-to-relay (S-R) channel. Fig. 1 denotes the performance when S-R channel's SNR is the same as S-D channel's SNR. When conventional ZigBee SNR is the same as proposed system SNR, the BER performance of proposed system is better than conventional system. In other words, compared with proposed system, conventional system more requires SNR for the same BER performance. It means that proposed system has a quite advantageous condition for using low power.

5 Conclusion

An efficient ZigBee-based cooperative relaying system has been presented in this paper. We have shown that the proposed system can obtain the diversity gain. For this reason, the proposed system can effectively transmit and save energy. We find that when ZigBee-based cooperative relaying system has more relays, BER performance is better than to have less relay.

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