M-1-1 Cooperative Protocol Based on OSOC-SS to Improve Bandwidth Utilization in USN

Hyung-Yun Kong · Yun-Kyeong Hwang

Abstract

A bandwidth and power efficient high speed ubiquitous sensor network(USN) for realizing a ubiquitous society is a great challenge for researcher community. In this paper we incorporate a cooperative transmission protocol within a special type of multi-code modulation to meet these requirements. Multi-code(Mc) modulation has been developed for high-speed data transmission over wireless channels. We proposed a new class of orthogonal codes for multi-code modulation which is an orthogonal subset of orthogonal codes(OSOC)[1]. Our proposed OSOC structure allows us to use only one relay to cooperate M nodes that effectively reduces the bandwidth and power requirement. This protocol is similar to spread-spectrum(SS) technique that can reduce both broad and narrow band jamming.

Key words : USN, Cooperative Transmission, OSOC, Broad Interference.

Ⅰ. Introduction

The coming ubiquitous sensor networks(USN) collect information from established sensors for the purpose of control. The sensor networks are drawing a lot of attention as a method for realizing a ubiquitous society. The future USNs are expected to meet a drastically increasing demand of information, communication and various data such as voice, data, image, video and etc, which can be accessed anywhere at anytime. It collects environmental information to realize a variety of functions through a countless number of compact wireless nodes that are located everywhere. In order to development of multimedia sensors, high data rate transmission system is required in USN which is bandwidth limited. In wireless communications, signal fading due to multi-path propagation is serious problem which can be mitigated using transmit diversity by deploying multiple antennas at transmitter[2]. However, a constraint on node size which requires each sensor node to be equipped with single-antenna makes it impossible. A feasible solution is to take full advantage of idle sensor nodes, namely relays, in the vicinity of the transmitting node to relay the original signal to its destination. This is benefits from enables nodes to use each other's antennas to obtain an effective form of spatial diversity without physical antenna arrays[3]. Additionally, a constraint on node size which requires each sensor node to be equipped with single-antenna makes such a solution very appropriate in wireless sensor networks scenario. The ways how idle sensor nodes process the signals received from a desired node are known as cooperative protocols.

Orthogonal subset of orthogonal code(OSOC) spread spectrum(SS) modulation is a flexible scheme to obtain a multi-rate transmission[1]. OSOC supports high data rate in CDMA system uses similar construction of matrix as our proposal but application is different. OSOC multi-code system increase data rate and number of user in CDMA system[1]. In proposed protocol each sensor nodes have own OSOC to access destination and relay at the same time therefore only one relay can cooperate a group of sensor nodes. M sensor nodes multiply their data with M OSOCs and transmit towards a single relay and destination. Relay performs a summation operation on received data from M nodes and multiply with an orthogonal code(OC) before transmitting them towards destination. OSOCs are also orthogonal with OC therefore destination can recover M users' data forwarded by a single relay.

Summation of OSOCs at the relay can increase throughput of sensor nodes but also increases PAPR(Peak-to-Average Power Ratio) in proportion to the number of OSOCs. We proposed a mapping technique at relay to reduce PAPR that is serious problem to design hardwares. Moreover, SS communications are currently under development for wireless mobile communication applications due to their utilization of channel bandwidth, the relative insensitivity to multipath interference, and the potential for improved privacy. Furthermore, the proposed cooperative transmission with OSOC will proved a very high flexibility in adjusting data-rate along with

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Department of Electrical Engineering, University of Ulsan, Ulsan, Korea.

parameters related to QoS[4],[5].

The rest of this paper is organized as follows. Section 2 discusses the proposed protocol. Then signal analysis is presented in section 3. The simulation results are reported in section 4. Finally, the paper is end with the conclusion in section 5.

Ⅱ. Proposed Protocol

2-1 Orthogonal Subset of Orthogonal Code(OSOC) with Method to Reduce PAPR

Orthogonal subset of orthogonal code(OSOC) developed in [1] is a multi-code modulation technique. OSOC can be simply designed as shown in Fig. 1, where OSOCs is obtained from OSOCG(OSOC Group) of size $L \times L$ where L is length of OSOC. For example, consider a 8×8 Walsh-Hadamard(WH) matrix in Fig. 1, there are two feasible OSOCGs with the sizes 2×2 and 4×4. Also, OCs are constructed by using $N \times N$ WH matrix[5],[6], technique which is used in mobile communication system like CDMA(Code Division Multiplexing Access). We apply this system to sensor networks with felicity. The duration of OC and OSOC is related by $N_{TC}=L_{TOSOC}$, where T_C and T_{OSOC} represent the duration time of OC and OSOC, respectively.

Sensor nodes can not transmit and receive signal at the same time to mitigate implementation complexity since considerable attenuation over wireless channels and insufficient electrical isolation between transmit and receive circuitry make a sensor node's transmitted signal dominate the signals of other sensor nodes at its receiver input. Towards this end, we adopt code division multiplexing(CDM) for channel access in this paper. M sensor nodes multiply the data of each sensor node with its own OSOC sequence. OSOC sequence helps to transmit simultaneously M data to relay and destination from M sensor nodes. The output signal of the Mth sensor node is given by

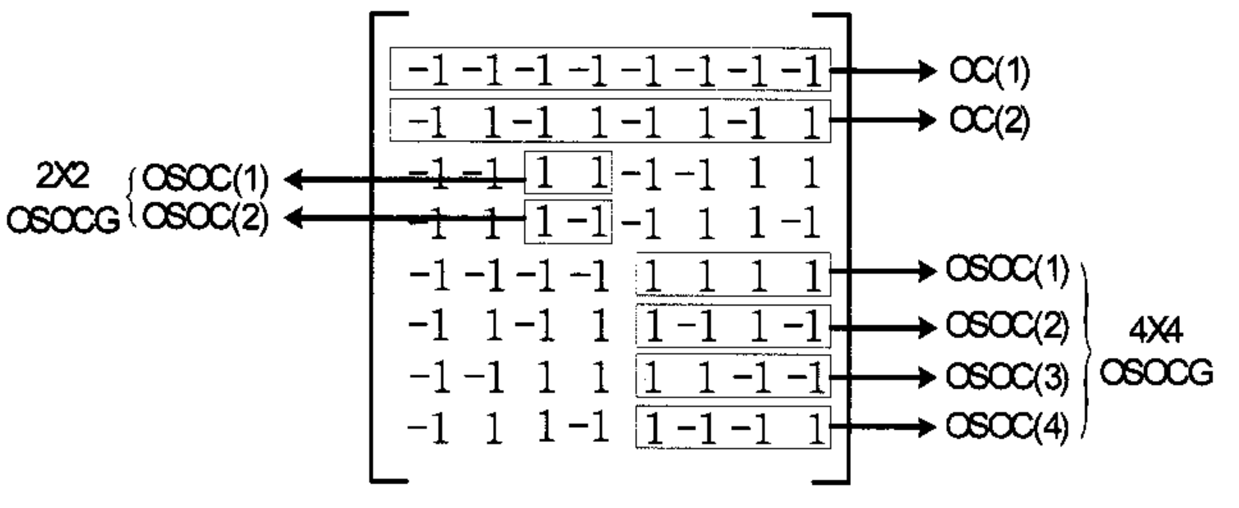

Fig. 1. Example of WH matrix for OCs and OSOCs (filled areas are the OSOCGs for any WH matrix with size $N \times N$).

$$S_m(t) = a_m OSOC_m(t) \tag{1}$$

where a_m is the BPSK modulated data-symbol, $OSOC_m$ is OSOC for M-th sensor node.

The signals received at relay through independence carrier

$$y_{SRm} = \alpha_{SR_m}\sqrt{P_{S_m}}\, S_m + n_R \tag{2}$$

At the relay, the combined data is given by

$$S_{RD1}(t) = \sum_{m=1}^{M} y_{SRm} \tag{3}$$

The peak power of signal S_{RD1} can be up to M2, where M is number of sensor node i.e., number of OSOC.

High PAPR of proposed system only happens after the summation of OSOCs. Therefore, a $(M+1)$PSK mapping block should be inserted after added part by OSOCG at the relay as in Fig. 2 and a $(M+1)$PSK de-mapping block between OCs and OSOCs at the destination (see Fig. 3). The function of mapping block is to map the PAM signal $S_{RD1}(t)$ at the output of OSOC-spread part into the $(M+1)$PSK signal constellation $S_{RD2}(t)$ related by the expression

$$S_{RD2}(t) = e^{j\pi S_{SD1}(t)/(M+1)} \tag{4}$$

Next, the signal S_{RD2} continues to be spread by OC to generate the following waveform.

$$S_{RD}(t) = S_{RD2}(t) OC(t) = S_{RD}(n) p(t - nT_c), \tag{5}$$

where $S_{RD}(n)=S_{RD2}(nT_c)OC(nT_c)$ and $p(t)$ is a unit- amplitude rectangular pulse with duration T_c.

The demodulation is easily performed by schematic diagram in Fig. 3 as

$$a'_m = \frac{1}{NT_c}\int_0^{NT_c} y_{RD}r(t)\, OC(t)\, OSOC_m(t)\, dt \tag{6}$$

in which $y_{RD}(t)$ is input signal of demodulator and a'_m is the recovered symbol of a_m.

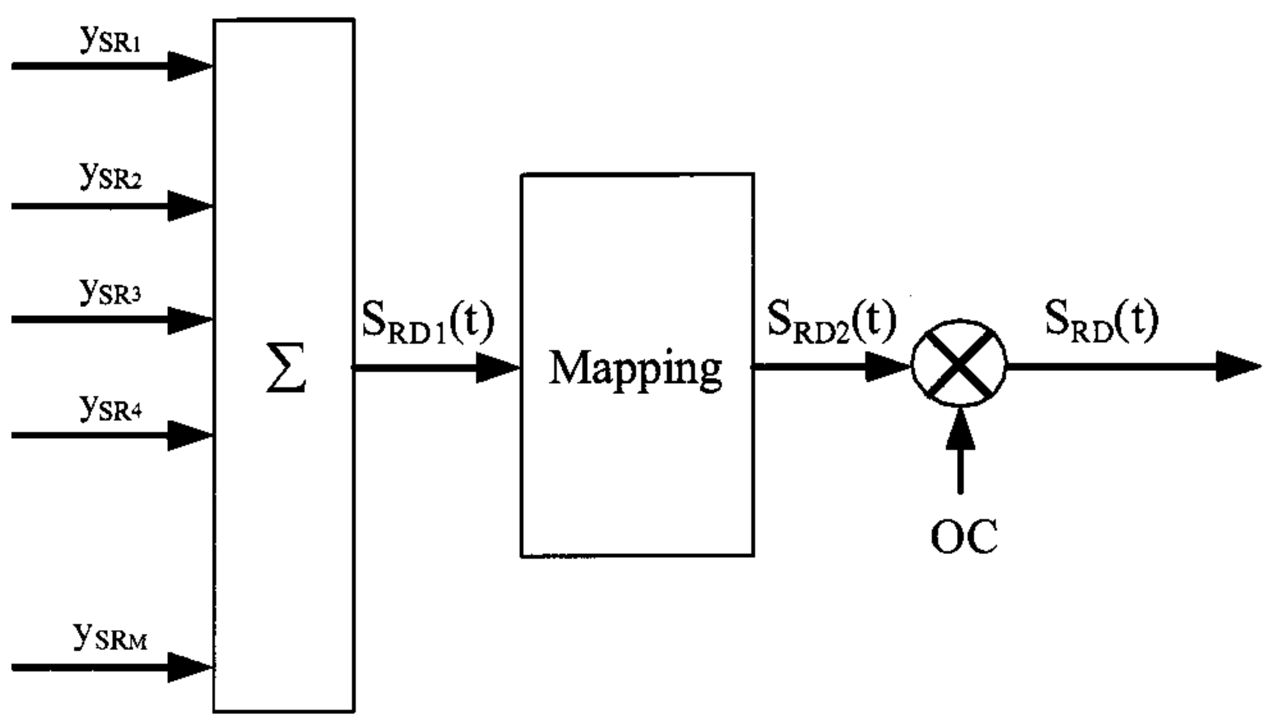

Fig. 2. Block diagram of a relay.

Fig. 4 illustrates the mapping mechanism for OSOCGs of size 8×8 (M=8, L=8) and 6×8 (M=6, L=8) adopted from 16×16-size WH matrix. This mapping scheme always guarantees PAPR '1', the output of OSOC-SS-Mapping modulator at a relay, regardless of the number of OSOCs.

2-2 M-1-1 Cooperative Protocol

Cooperative transmission protocol is an extension of the multi-hop protocol where the receiver combines the data from the desired source node and all its relays instead of only from the last relay as for the multi-hop protocol. A wide variety of cooperative transmission protocols were proposed and bring many simultaneous advantages such as diversity gain, coverage extension, energy saving, etc. In these protocols users transmit their information and due to the broadcast nature of wireless transmission destination and a group of relay received this transmission. Relays then forward this received information to achieve spatial diversity at destination. Depending on the forwarding strategy at relay cooperative communication protocols can classified as three major categories: amplify-forward(AF), decode-forward (DF) and coded cooperation(CC). DF appears to be a proper choice for cooperation in WSNs because it demonstrates the lowest complexity(each receiver only needs CSI of the channel it is listening).

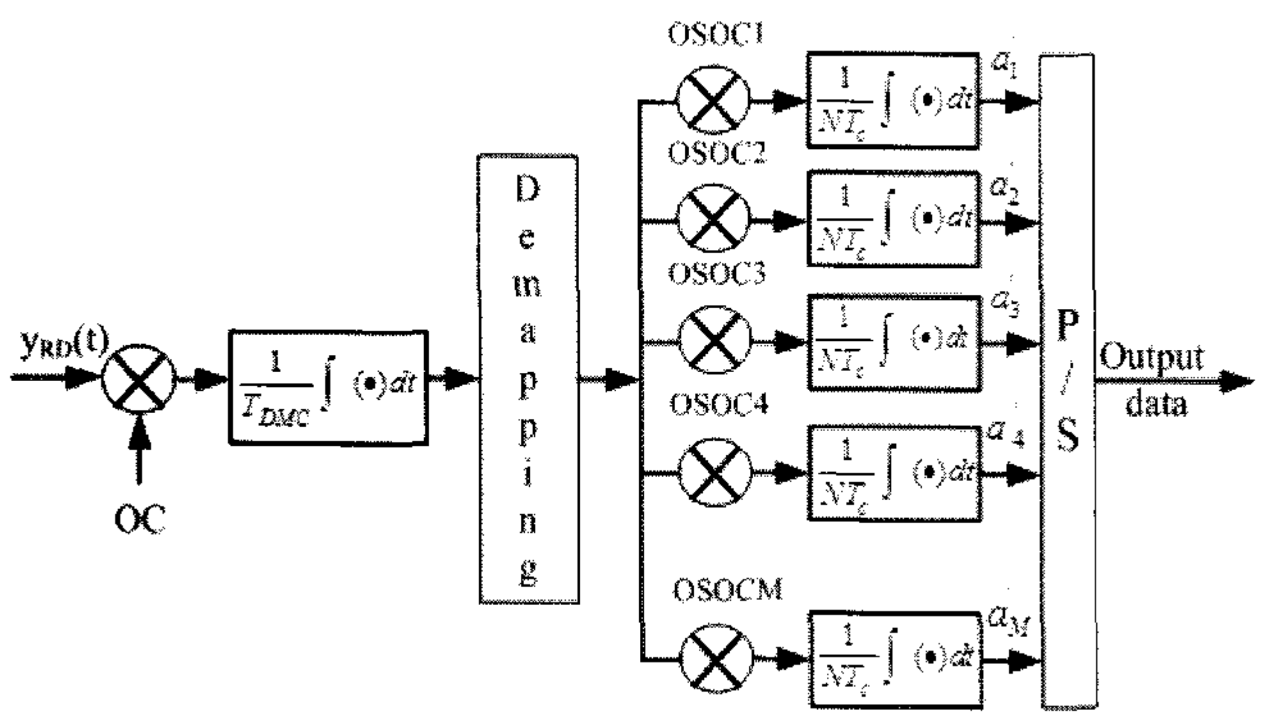

Fig. 3. Block diagram of a destination.

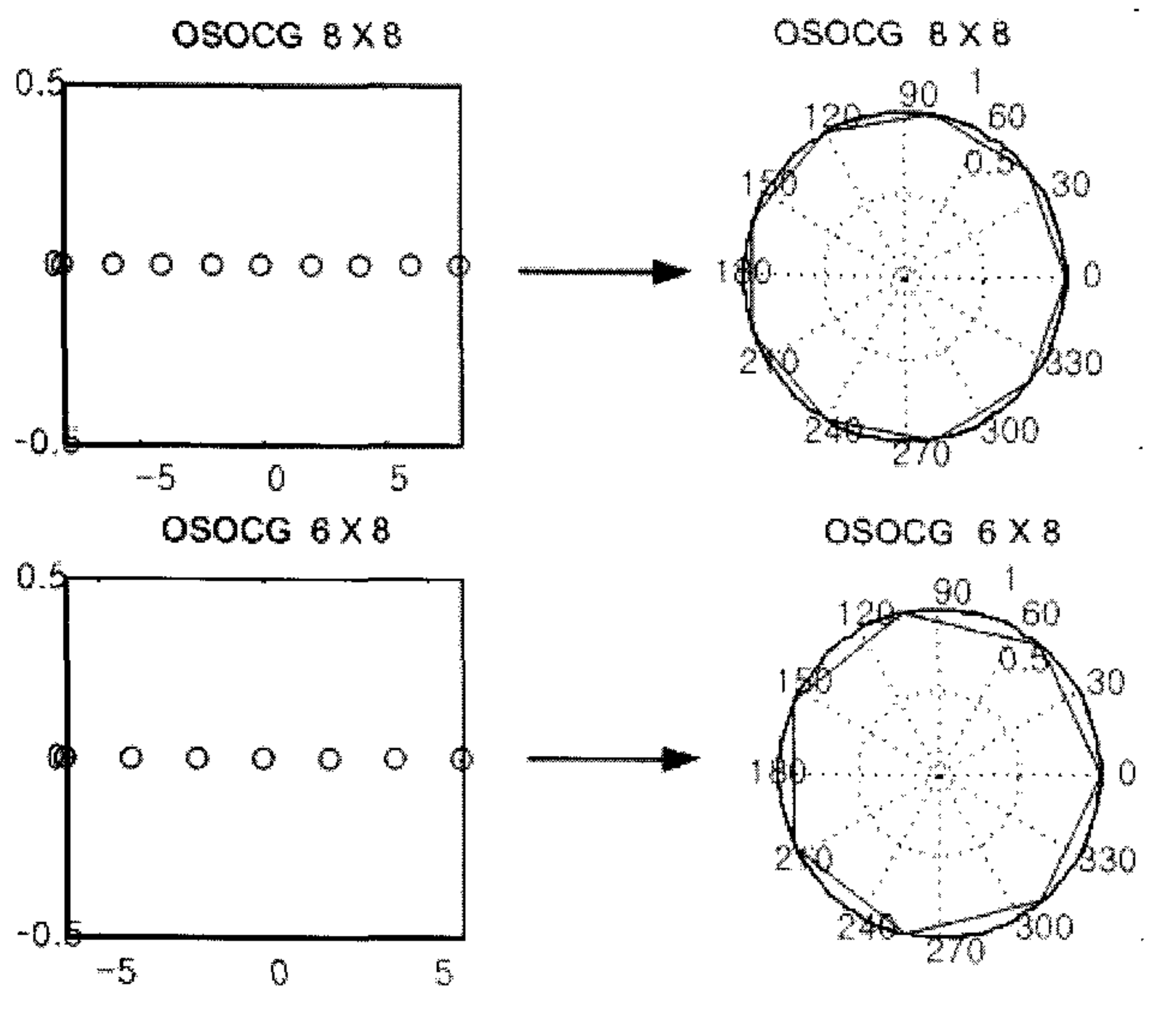

Fig. 4. Mapping technique for OSOCG 8x8 and OSOCG 6x8.

In the conventional DF, a direct transmission time-slot is divided into two phases. Sensor node uses the first phase to broadcast data to destination as well as to relay. After decoding the received signal, relay forwards the resulting signal to destination. Then the destination combines the signals received in two phases based on MRC (Maximum Ratio Combining) to make a final decision on the original data. In our proposal, information is transmitted from M sensor nodes to a destination with the assistance of a single relay as shown in Fig. 5. Proposed protocol offers the similar diversity order as conventional DF with same power and much less bandwidth. M sensor nodes transmit each data to both destination and relay using own OSOC at the same time.

In proposed protocol, a time-slot is divided into two phases. The first phase is for sending information from M sensor Nodes to both destination and relay using OSOC. Destination detects each users information by multiplying with corresponding OSOC and save to combine after second phase. Relay collects the transmitted signals from M sensor nodes. After sum up these data multiply with OC then retransmit data to destination in the secondphase. Because OSOC is orthogonal with OC, destination can detect each user data as explained in previous section. Thus, destination receives two copy of signals from each node and combine this two copy using MRC. It is straightforward to realize that the proposed protocol becomes the conventional one when only one sending node is available.

However, proposed protocol offers the same diversity order as conventional cooperative transmission with same power and much less bandwidth. One relay assists M sensor nodes using OSOC technique, so we can transmit M nodes's information at the same time.

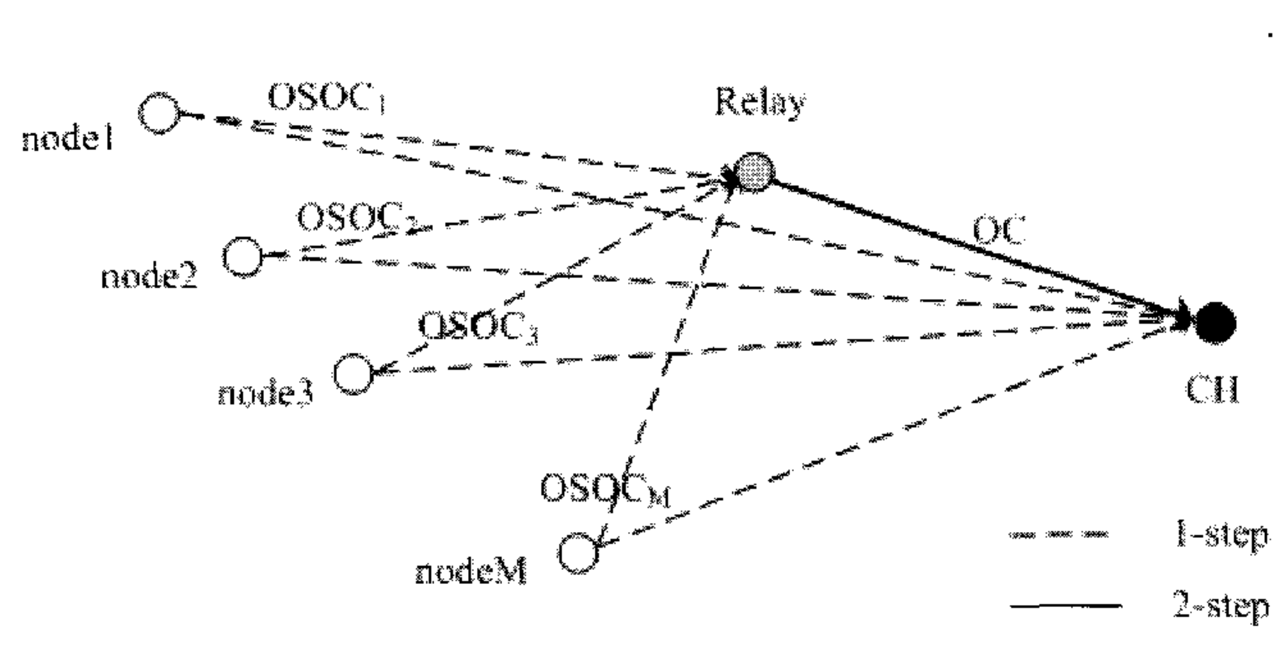

Fig. 5. The proposed protocol.

Ⅲ. Signal Analysis

In proposed protocol utilizes an M-1-1 scheme: M sending nodes, 1 relay and 1 destination. For ease of exposition, we denote the transmitting source node as SN, their relay(or partner node)as R and destination as D.

The signals received at R and D through independence carrier in the first phase are equation (2) and

$$y_{S_mD}=\alpha_{S_mD}\sqrt{P_{S_m}}S_m+n_{S_mD} \tag{7}$$

where S_m same as equation (1) and P_{S_m} the average transmit power of S_m.

R is shown in Fig. 2. After summation the received signals from M SNs, the signal is mapped and multiplied with OC. Then R retransmits this signal to D in second time-slot.

D receive the signal transmitted from R

$$y_{RD}=\alpha_{RD}\sqrt{P_R}S_{RD}+n_{RD} \tag{8}$$

where, S_{RD} as equation (4).

Now, the destination combines the received signals from S given by (7) and from its partner in (8) to recover the original data bits. A simple maximal ratio combining technique is used for combining as

$$r_m=\frac{\alpha^*_{S_mD}}{\sigma_{S_mD}}y_{S_mD}+\frac{\alpha^*_{R_mD}}{\sigma_{R_mD}}y_{R_mD} \tag{9}$$

where y_{R_mD} de-spreading signal using block which is multiply with OC, σ_{i_mD} is variance of AWGN at node i(S and R). This combining yields spatial diversity gain since under good S-R channel conditions the partner forwards the data from M sources. After de-mapping and dispreading with OSOC the series of r_m, we can recover the received data of $a'm$ which is copy of am.

So, we affirm that conventional cooperative transmission and proposed protocol achieve the same diversity order 2. In addition, proposed protocol can reduce the bandwidth.

Since there are M sending nodes, the total power of the system must be MPT. If SNs transmit with the equal powers, then the following equation must be satisfied for a fair comparison among the examined protocols.

Therefore, complying with this energy constraint requires as

$$P_{S_m}=P_T/2 \tag{10}$$

$$P_R=P_{S_m}\times M=(P_T/2)\times M \tag{11}$$

where P_T is the average transmit power of S in case of direct transmission.

Ⅳ. Simulation Result

In this section, we investigate the performances of three transmission protocols: direct transmission(DT), Multi-hop transmission(MH) and Proposed Cooperative transmission(CT). The flat fading channel is usually assumed for most spatial diversity systems in which path gains $a_{i,j}$ from transmit antenna i to receive antenna j are modeled as samples of independent complex Gaussian random variables with zero-mean and are constant during two-chip durations[7].

With mapping technique we can reduce the PAPR which can be increase stability of system. Table 1 show the PAPR values before and after using mapping technique for different number of sensor nodes.

Fig. 6 we compare the performance of proposed system where we change the number of sensor nodes co-operated by a single relay. Here, M is the order of SNs and number of OSOC, L is the length of OSOC. At the target BER of 10-1, the 4-1-1 protocol outperforms the other conventional protocols. It can save the time to sending data from 4-SN and increase the utilization of bandwidth using OSOC. And all of our proposed protocols

Table 1. PAPR performance of mapping technique.

Number of sensor nodes (Number of OSOC)	PAPR values		
	Before mapping		After mapping
4	3.0	→	0
6	3.5	→	0
8	3.8	→	0

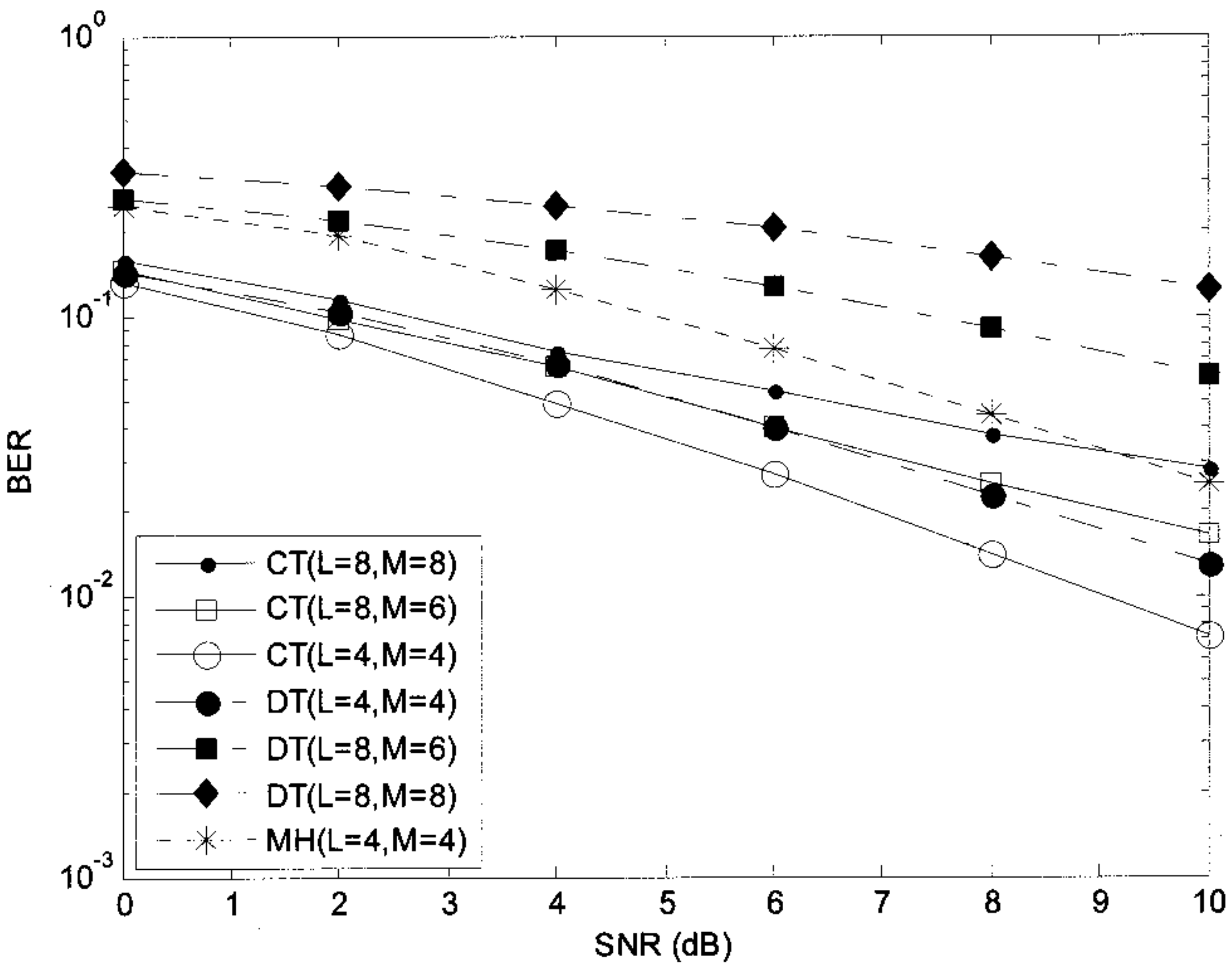

Fig. 6. BER performance of the direct transmission and proposed protocol using OSOC-SS.

are better than direct transmission case. With the same SNR, BER of system will decrease when order of M increase from 4 to 8 because the bandwidth of each node diminishes when number of nodes M increased in fixed total bandwidth.

In the first simulation result, the best protocol is chosen by comparing their performances. In this simulation, this protocol will be verified under different channel conditions. For fair comparison, the transmit power of each protocol is equal. There are two kinds of channel. One is flat fading added AWGN the other is flat fading added AWGN and jamming. We consider two kind of jamming for simulation: broad band jamming (BBJ) and narrow band jamming(NBJ). Fig. 7 show the BER performance under BBJ. Propose protocol is better than directtransmission and we can overcome broad jamming problem using spread spectrum technique. In our simulation we change the size of the spreading code (16, 32 and 64) and found that our proposed system performs well against jamming as we increase the size i.e. 64-ss system is stronger than 32-ss and 16-ss system against jamming.

Narrow band Jamming is considered as pulse interference. The worst-case pulse interference which we considered occur when

$$\alpha^* = \begin{cases} \frac{0.71}{\epsilon_b/J_0}, & (\epsilon_b/J_0 \geq 0.71) \\ 1, & (\epsilon_b/J_0 < 0.71) \end{cases} \quad (12)$$

In Fig. 8 proposed system can overcome the pulse interference. We found some interesting result for this case, as the performance of our proposal significantly reduce the narrow band jamming effect in comparison with direct transmission. We also found the similar result as broadband jamming case when we change the

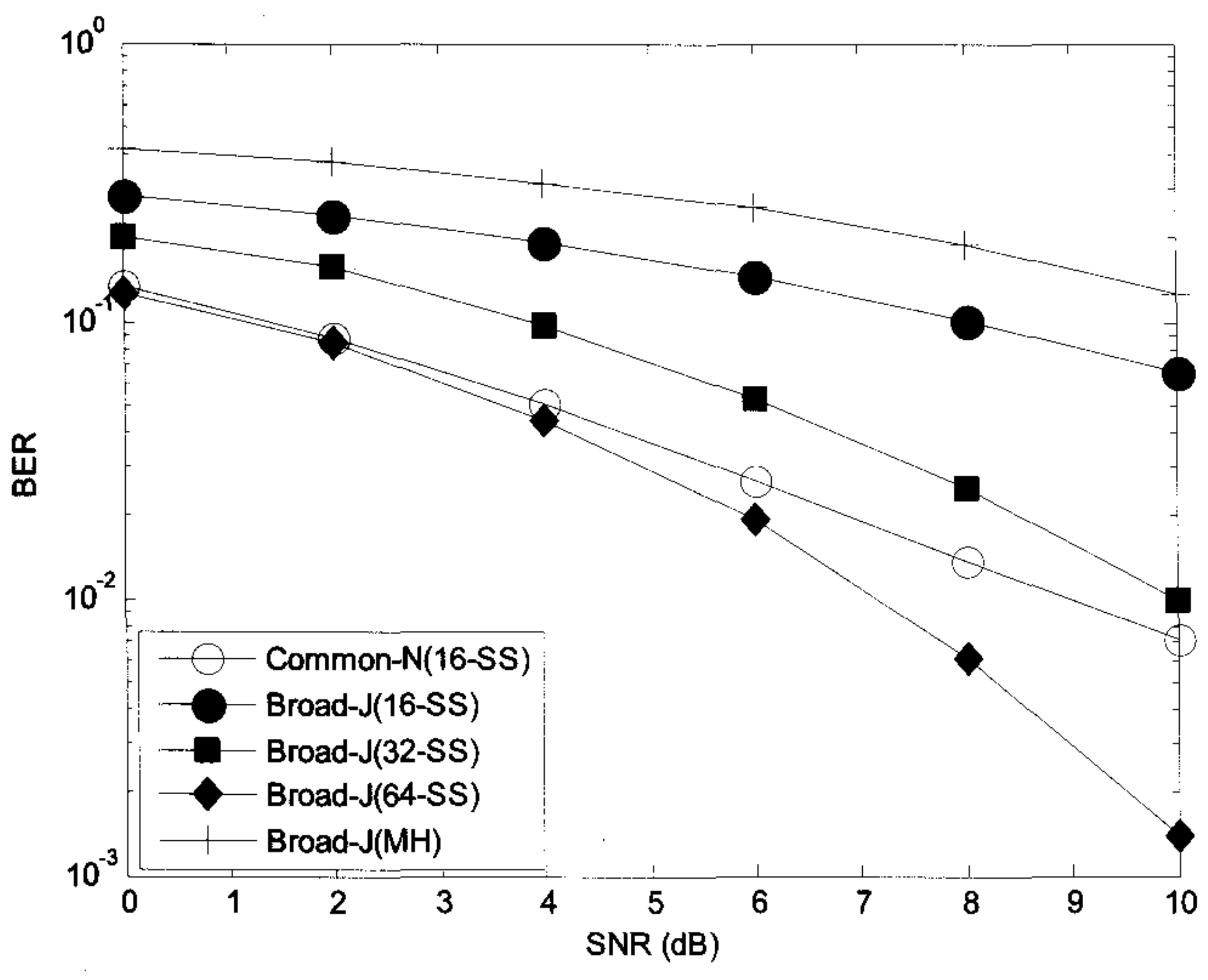

Fig. 7. BER performance of the broadband jamming case.

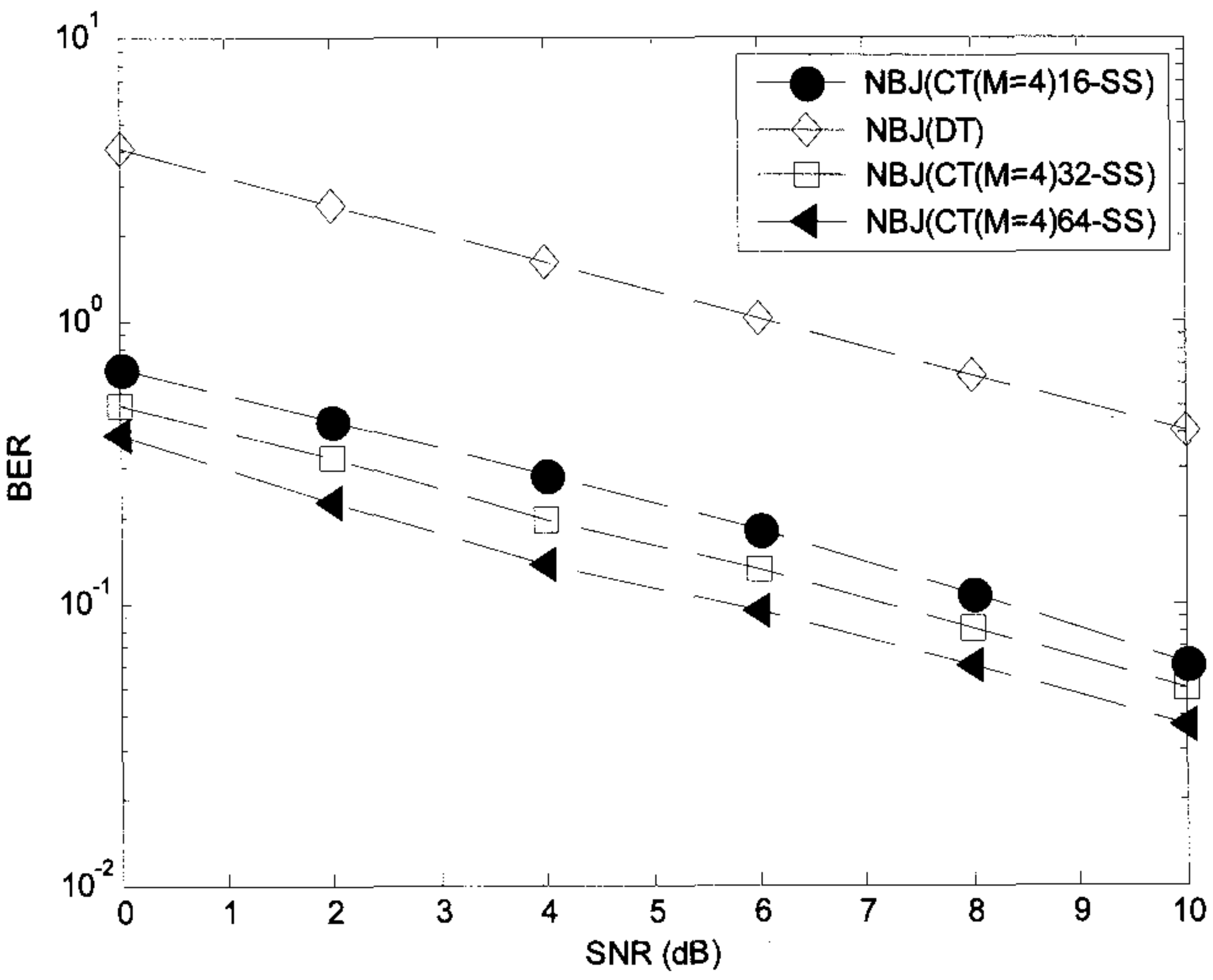

Fig. 8. BER performance of the pulse interference on proposed system.

size of spreading code. As we increases the SS size the system performance is also improves by reducing the narrow band jamming effect.

V. Conclusion

The proposed cooperative transmission protocol allows an idle node to help other sensor nodes for data transmission to a destination. We proposed a new modulation technique that used a mapped OSOC with many advantages such as low PAPR, high performance and flexibility in altering modulation levels as well as very low implementation complexity. Moreover, spread spectrum technique using OSOC and OC can overcome various interference effects which are core problem in USN where many nodes scatter in wide area. The simulation results showed the proposed protocol significantly increases the channel utilization efficiency and power efficiency without requiring additional implementation complexity for sensor nodes. Our proposal also efficiently combats against narrow and broad band jamming as we increase the size of spreading code.

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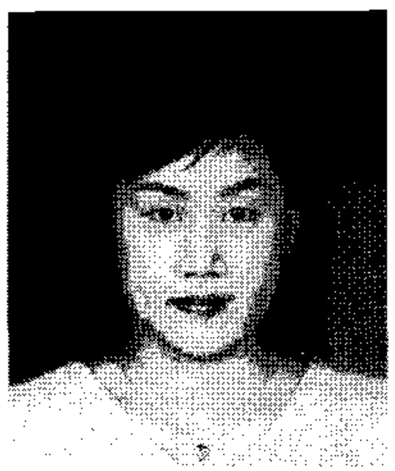
Hyung-Yun Kong

received the M.S. and Ph.D. degrees from electrical engineering from Ploytechnic University, Brooklyn, New York, USA, in 1991 and 1996. And he received the B.S. in electrical engineering from New York Institute of Technology, New York, in 1989. Since 1996, he was with LG electronics Co., Ltd., in the multimedia research lab developing PCS mobile phone systems, and from 1997 the LG chairman's office planning future satellite communication systems. Currently he is in Associate Professor in electrical engineering at University of Ulsan, Korea. He performs in several government projects supported by ITRC, Korean Science and Engineering Foundation(KOSEF), etc. His research area includes high data rate modulation, channel coding, detection and estimation, cooperative communications, and sensor networks. He is a member of IEEK, KICS, KIPS, and IEICE.

Yun-Kyeong Hwang



received the M.S. degree from electrical engineering from University of Ulsan, Korea in 2008. And he received the B.S. in electrical engineering from University of Ulsan, Ulsan, in 2005. His research area includes waveform codes, multi codes, sensor network, and cooperative communication system. He is a member of KIEES, and KIPS.