TELKOMNIKA, Vol.10, No.1, March 2012, pp. 165~170
ISSN: 1693-6930
accredited by DGHE (DIKTI), Decree No: 51/Dikti/Kep/2010

Performance Analysis for Bit-Error-Rate of DS-CDMA Sensor Network Systems with Source Coding

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Abstrak

Salah satu teknik terkenal yg digunakan dengan jaringan sensor nirkabel untuk mengakses jaringan adalah memanfaatkan akses jamak pembagian sandi runtun langsung. Jumlah energi yang dikonsumsi dan antar pengguna masih dianggap sebagai masalah utama dengan menggunakan jaringan tersebut. Energi yang dikonsumsi dan interferensi meningkat ketika jumlah pengguna (penerima) meningkat. Penelitian ini dilakukan untuk menyelidiki pengaruh faktor mitigasi melalui analisis penyandian energi minimum yang mengeksploitasi bit redundan untuk menghemat listrik, dengan menggunakan link radio frekuensi dan modulasi on-off-keying. Faktor-faktor ini dianalisis dan dibahas untuk beberapa level galat yang diharapkan dengan memanfaatkan saluran, melalui laju galat bit dan rasio sinyal dan derau pada beberapa pengguna yang berbeda.

Kata kunci: *DS-CDMA, laju galat bit, sensor nirkabel*

Abstract

One of the distinguished techniques used with wireless sensor networks to access the network is utilizing direct sequence-code division multiple access. However, amount of consumed energy and multiple access interference are still considered as the main problems with employing such networks. The consumed energy and interference are rising when number of users (receivers) increases. Therefore, this paper is conducted to investigate mitigating influence these factors through analyzing the minimum energy coding which exploits redundant bits for saving power with employing radio frequency link and on-off-keying modulation. These factors are analyzed and discussed for several levels of expected errors in the utilizing channel, through the bit error rates and amount of signal to noise ratio for different number of users.

Keywords: *bit error rate, DS-CDMA, wireless sensors*

1. Introduction

Recently, wireless sensor network applications are gaining much interest in academia and industry areas. The wireless sensor network technologies have been chosen as one of the most important technologies in the 21th century [1]. Sensor networks consist of hundreds to thousands of tiny sensor nodes that can sense data, process, and communicate with each other nods or data sink [2]. Designing the wireless sensor network is challenging due to high node density, frequent topology changes, limited battery and computing power and requirement of very low cost nodes [3]. Nodes of the sensor networks communicate with each other through wireless media. The multiple access is a serious problem due to high node density, so, the code division multiple access (CDMA) is a promising multiple access scheme for sensor and ad hoc network to its interference averaging properties' [4]. The minimum energy (ME) coding combined with direct sequenceCDMA (DS-CDMA) is proposed to address both power saving and multiple access interference (MAI) problems [5, 6]. ME coding reduces the number of high bit (1 bit) by inserting redundant bits, which results increase in codeword length (bandwidth) with less high bit. Power saving can be achieved by using On-Off-Keying (OOK) because only the high bit is transmitted through the channel. As most of bits in a codeword are zeros the multiple access interference (MAI) is also significantly reduced. Thus, it allows nearby users to co-exist and substantially enhances the bit error rate (BER) performance and specify the (SNR) to number of the receivers (users).

Received December 1st, 2011; Revised January 22th, 2012; Accepted February 15th, 2012

In this paper, influence of the bit error rate on the signal to noise ratio for number of receivers is analyzed. Also, amount of energy for receiving bits is investigated for the SNR and BERs. Then, effect number of users on the probability of received bits is studied. The achieved results indicate that the SNR is dependent on the amount ratio of energy per bit to node density in the used field.

The rest of the paper is outlined as follows. Section 2 includes the model for the system and the achieved results are presented in section 3. Then, the conclusions are drawn to section 4.

2. The System Model

The model for the transmission signal is evolved in this part in order to analyze the system characteristics, represents the general DS-CDMA systems with number of receivers (N). Let the transmitted signal is given by [7, 8]:

$$S_k(t) = \sum_{K=1}^{N} \sqrt{2P_k}\mathrm{m}_k(t-\tau_k).C_k(t-\tau_k)\cos(\omega_c t-\theta_k) \quad (1)$$

Where P_k is the power of the transmitted signal, ω_c is the common carrier angular frequency, θ_k is the phase shift offset, $\mathrm{m}_k(t)$ and $C_k(t)$ are the data and spreading signals for the k_{th} received signal, respectively, and τ_k is a random transmission delay calculated with respect to reference transmitted signal. It is accounting for the lack of synchronization among the users. The data signal and the spreading signal are given as:

$$\mathrm{m}_k(t) = \sum_{i=\infty}^{\infty} \mathrm{m}_i^k \prod(iT_b,(i+1)T_b) \quad (1\text{-a})$$

$$C_k(t) = \sum_{i=\infty}^{\infty} \mathrm{C}_i^k \prod(iT_b,(i+1)T_b) \quad (1\text{-b})$$

where $\prod(t_1,t_2)$ is a unit rectangular pulse on $[t_1,t_2]$.

To keep generality on this interesting case, consider $\tau_k \in [0,T)$ and $\theta_k \in [-\pi,\pi]$ since the analyses are conducted in the time delays module, T, and phase delays module, 2π. Thus the de-spread demodulated signal $S_d(t)$ can be given as:

$$S_d(t)= \sum_{k=2}^{M} m_k(t-T_k)c_1(t)\, c_k(t-T_k)\cos(w_c t+\theta_k)\cos w_c t + m_1(t)\cos^2 w_c t + n(t)\, c_1(t)\cos w_c t \quad (2)$$

With using the ME coding, for coding a data and $C_j^{(K)} \in \{-1,1\}$ with $C_j^{(k)} = C_{j+M}^{(k)}$ getting $P_r\left(m_j^{(k)}=0\right) \gg P_r(m_j^{(k)}=1)$ for all j, k and for some minimum period of the spreading sequence, M.

With taking into account influence of noise in the utilizing channel, we can rewrite Eq. 1 to be as:

$$S_k^{'}(t) = S_k(t) + n(t) \quad (3)$$

where $n(t)$ is a white Gaussian noise with γ, spectral density.

The output of the matched filter, with assuming the received signal is matched to transmitter number 1 at $t = T_b$ is:

$$y = \sqrt{P_1/2}T_b m_0^{(1)} + \sqrt{\frac{P_k}{2}}\mu_1^{(k)}(\tau_k,\theta_k,m_k) + \int_0^{T_b} n(t)c_1(t)cos\omega_c t dt \quad (4)$$

where, $m_k = (m_{-1}^{(k)}, m_0^{(k)})$ (4-a)

and, $\mu_1^{(k)} = \cos(\theta_k).\{m_{-1}^{(k)}.\int_0^{\tau} C_1(t).C_k(t-\tau_k)dt + m_0^{(k)}.\int_{\tau}^{T_b} C_1(t).C_k(t-\tau_k)dt\}$ (4-b)

The output of the correlation receiver for user 1, at t = T_b is= $W_1 + H_1 + \gamma$, where $W_1$is the desired received signal for user number 1, $H_1$is the interference from other users and γ is the AWGN term with variance of $\gamma T_b/2$. In other words, the three terms are:

$$W_1 = \sqrt{P_1/2}T_b m_0(t)$$

$$H_1 = \sum_{k=2}^{k} \sqrt{P_k/2}.\{m_{-1}^{(k)}.\Gamma_{k,1}(\tau_k) + \Gamma_{k+1}(\tau_k)\}cos\theta_k$$

$$\gamma = \int_0^{T_b} n(t)C_1(t)cos\omega_c tdt$$

The $\Gamma_{k,i}(\tau_k)$ and $\Gamma_{k+i}(\tau_k)$ are the continuous – time partial cross correlation function defined as followes:

$$\Gamma_{k,i}(\tau_k) = \int_0^{\tau} C_k(t-\tau)C_i(t)dt$$

$$\Gamma_{k+1}(\tau_k) = \int_{\tau}^{T_b} C_k(t-\tau)C_i(t)dt$$

To evaluate the system performance the signal to noise ratio (SNR) is analyzed. The SNR is a perfect index to evaluate the quality of the received signal. So, to find the (SNR), the signal power of the $m_1(t)$ is computed as

$$P_{d1} = 1/T(\int_0^{T} (\sqrt{P1/2}\ T_b\ m_0^{(1)})^2\ dt = \frac{a_1 P_1}{2} T_b^2 \quad \text{if } m_0^{(1)}(t) \in \{0,1\} \tag{5}$$

Where $a_1$is the percentage of high bits for $m_1(t)$ during the transmission duration of T second. The MAI and AWGN powers can be shown to be

$$P_{n1} = a_1^2\ N_0\ T_b / 4 + \sum_{K=2}^{M} (a_1 a_k\ P_k / 2)\ \sigma^2 \tag{6}$$

So, the SNR in the energy-efficient DS-CDMA system can be found as

$$SNR = P_1\ T_b^2\ /((a_1 N_0 T_b/2) + \sum_{K=2}^{N} a_1\ P_k\ \sigma^2) \tag{7}$$

For analyzing influence error probability of a CDMA receiver several schemes have been presented in the literature over the past couple of years. The approach that first appeared in [7] is followed in this study. And, the MAI is assumed sufficiently well represented by an equivalent Gaussian random process with assuming that the power control for all the transmitters signals arrive at the receiver of transmitter high bit for each transmitter are same, i.e., $a_1 = a_2 = \ldots = a_m$.. For such condition Eq. (7) can be further simplified as

$$SNR_{ME} = (a_1\{\frac{M-1}{3N} + \frac{N_0}{2E_B}\})^{-1} \tag{8}$$

where E_b is energy per bit and N_0 is the node density.

The bit error usually occurs in moving from high bit signal into a lower bit signal or vice versa. The average error probability of reciver1 for transmitting one bit as:

$$P_b = P_0.P_r(y \geq \delta | m_0(t) = 0) + P_1.P_r(y < \delta | m_0(t) = 1) \tag{9}$$

where P_0 is the probability of transmitting "zeros" signals and $P_1$is the probability of transmitting "ones" signals for the first transmitter and δ is the threshold for bit detection. If $m_0(t) = 0$; the output of the integrator can be explained to

$$y_0 = n + \sum_{k=2}^{N} \sqrt{\frac{P_k}{2}} H_i^{(k)}(\tau_k, \theta_k, m_k) \quad (10)$$

If $m_0^{(t)} = 1$, the output of the integrator can be explained to

$$y_1 = y_0 + \sqrt{P_1/2}T_b \quad (11)$$

Let $\delta = \sqrt{P1/2}\, T_b$, we have

$$P_b = P_0^{(1)}.P_r\left(y_0 \geq \sqrt{P_1/2}T_b\right) + P_1^{(1)}.P_r\left(y_0 < \sqrt{P_1/2}T_b\right) \quad (12)$$

As SNR_{ME} approach constant, $\sum_{K=2}^{M}(\alpha_K\, p_k/2)\, \sigma^2_{i(k)} \rightarrow \infty$ as $M \rightarrow \infty$ and $P_0(t) >> P_1(t)$ under these condition, under these condition we can simplify P_b as:

$$P_b = (1 - \alpha 1)\, Q(\sqrt{\mathrm{SNR}}_{ME}) \quad (13)$$

where $Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} e^{u2/2}$ du.

3. Results and Analysis

Figure 1 illustrates variation of the SNR to the number of users (receivers). The SNR increases for different values of the percentage of high bits for $m_1(t)$ during the transmission duration of T second (a_1) when the number of users increases the interference with the users are increased. Thus such behavior leads to increase amount of the MAI power and the SNR decreases.

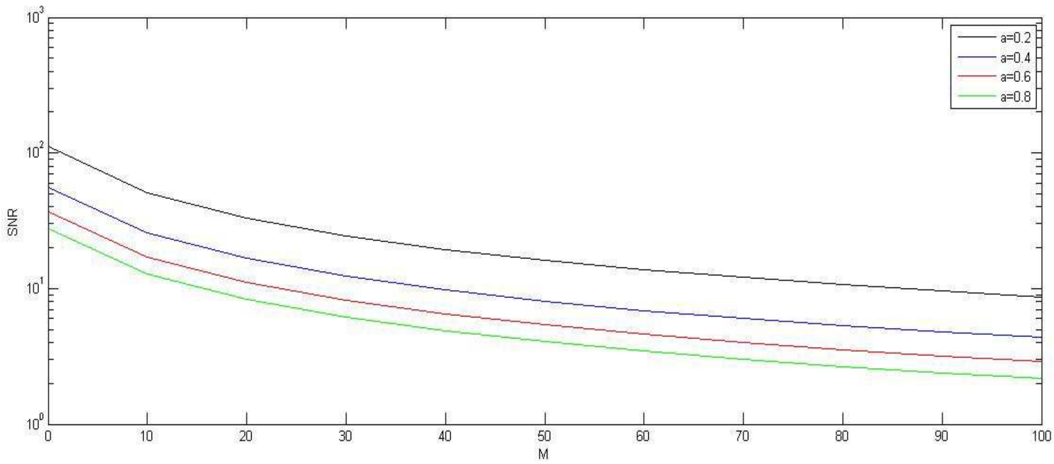

Figure 1. SNR for DS-CDMA energy efficient to the number of users and different values of a_1.

Figure 2 shows that when the E_b/N_0 is increased, the SNR increases linearly at certain values, following that, the SNR become autonomous of E_b/N_0. This can be illustrated as follows, for minimum amount of E_b/N_0 the noise power caused by multiple receivers is trivial. Then, for lower values of E_b/N_0, SNR is associated with E_b/N_0, so the noise power get marginal.

Figure 3 explains variation of the probability of bit error rate to number of users. It is increasing as number of user (M) increases for different levels of α1. The probability reaches to the same value in specific number of users, which leads to the save power in more than specific number of users.

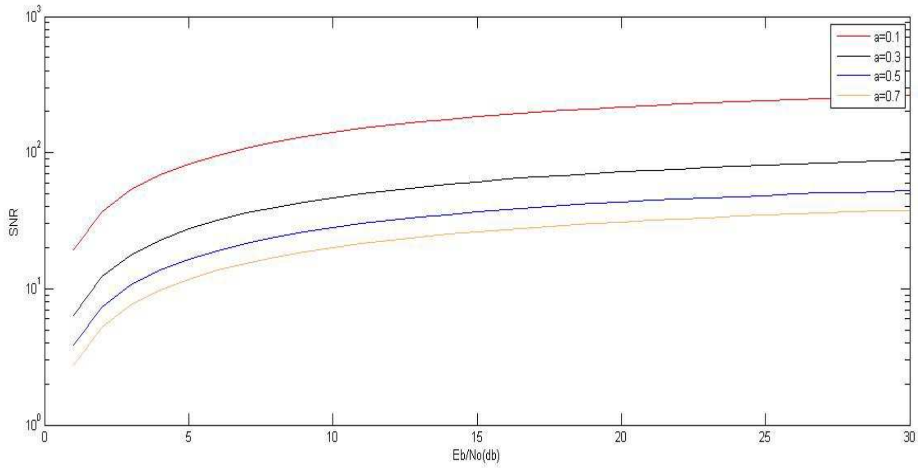

Figure 2. SNR for the ME DS-CDMA system with different E_b/N_0 (dB) using different values of α1, and N = 63.

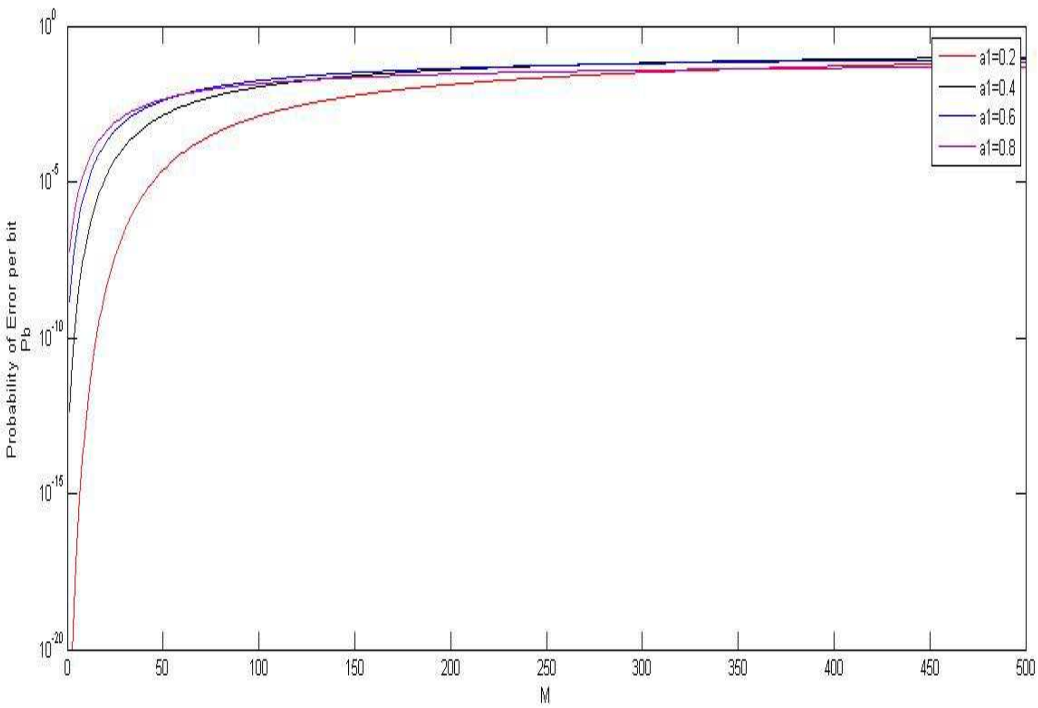

Figure 3. probability of error per bit for different number of users (receivers) with different values of α1.

4. Conclusions

This paper investigated influence using the DS-CDMA with minimum energy (ME) coding for the wireless sensor networks. The achieved results show that the ME DS-CDMA reduce the multiple access interference, save amount of power and improving the system performance; with sending a high bit rate, 1's, the probability of multiple access interference is highly decreases with utilizing the MAI, when a certain probability of multiple channels transmitted signals and identical time are kept. This leads to enhance the total performance of the system. The ME DS-CDMA is important to be chosen for wireless sensor network due to its important role in improving the probability of bit error rate and SNR for saving power with various number of users (receivers).

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