Efficient Data Transmission Technique for Ubiquitous Healthcare Systems

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Abstract. In this paper, we propose a efficient data transmission algorithm of UWB (ultra wideband) signals, and analyze performance of UWB signal detection probability using digital watermarking sequence for ubiquitous healthcare (u-healthcare) applications. The digital watermarking is employed to enhance security of bionic data. Because the power level of the UWB signals can be sufficiently low than other signals, there are no harmful effects on human body. In the proposed sperad spectrum watermarking system, Kasami sequence is chosen as a spreading sequence due to its good correlation property. The performance of proposed scheme is analyzed in terms of detection probability. The results of the paper can be applied to design of various u- healthcare systems.

Keywords: UWB Signal, digital watermarking, u-healthcare system, WBAN

1 Introduction

One of the promising solutions to this is UWB (ultra wideband) system. The power level of the UWB signals can be sufficiently lowered than other signals, so that there are no harmful effects on the human body [1-5]. In the u-healthcare system based on WBAN (wireless body area network), the UWB signals are very efficient with its low power level. In the WBAN, there are a lot of sensors on the body to detect and manage bionic signals. For efficient implementation of the WBAN, there is a critical problem on how exactly detect a desirable signal among the various sensors' signals. A server of the WBAN collects the sensors' singals, and then informs state of body of a hospital or a doctor. Under these conditions, it is very important to accurately detect each sensor's signal without miss detection.

In this paper, we propose a novel transmission algorithm of UWB signals based on digital watermarking for the WBAN. The proposed algorithm employs digital watermarking sequence which spreads signal for watermarking capability. The primary advantage of watermarking comes from the fact that digital watermarking make the system more robust and secure in noisy and interference environments. The proposed algorithm is expected to have the following adventageous features: First, the proposed algorithm can achieve high detection probability, especially at low SNR (signal-to-noise-ratio). Second, the digital watermarking sequence level can be controlled according to its target applications. And third, the proposed algorithm can simultaneously transmit a simple addtional information with transmission of UWB signals through spreading and despreading property. As a digital watermarking sequence, Kasami sequence is employed owing to its good correlation property. Signal detection probability is derived for various system parameters in WBAN applications.

The rest of this paper is organized as follows: In Section 2, WBAN channel model is introduced for analysis and simulation of the proposed scheme. In Section 3, the proposed system model is analyzed and its system block diagram is suggested. In Section 4, signal detection probability is derived and simulation results are presented for various system parameters, respectively. In Section 5, application fields of proposed algorithm is suggested. Finally, In Section 6, some conclusions are drawn.

2 WBAN Channel Model

There are three choices for a location of communication equipments: in-body, on-body, and off-body. In addition, there are three modes according to transmission speed: low, moderate and high speed [6]. CM 1 is a channel model inside a body, and its response is determined by internal organ or blood vessels. Also, CM 2 and CM 3 are channel models between in-body and on-body, respectively, and their responses are affected by skin, muscle and fat. Usually, the CM 3 has a longer distance than the CM 2. Fianlly, CM 4 is a channel model between on-body and external terminal. The distance between external devices is typically considered to be a maximum of 5 m.

In the WBAN channel, the complex channel impulse response $h^i(t)$ for the *i-th* device is given by [7]

$$h^i(t) = \sum_{l=0}^{L-1} \alpha_l^i \delta\left(t - \tau_l^i\right), \tag{1}$$

where L is the number of total arrival paths modeled as Poisson random variables with a mean value of 400, l is the *l-th* arrival path of the signal and α_l^i is the magnitude of the *l-th* path, which can be expressed as

$$\left|\alpha_l^i\right| = \Omega_0 \exp\left(-\frac{\tau_l^i}{\Gamma} - F_k\left[1 - \delta(l)\right]\right)\beta. \tag{2}$$

In (2), Ω_0 is the path loss, Γ is an exponential decay factor, β is a log-normal random variable with zero mean and variance σ^2, and τ_l^i is the path arrival time that is modeled as a

Poisson random process with an arrival rate of $\lambda = 1/0.50125ns$. Also, in (2), F_k denotes effect of K-factor in NLOS (non-line-of-sight) environments and can be calculated as

$$F_k = \frac{\Delta k \ln 10}{10}, \tag{3}$$

where Δk is the difference between magnitude of the first impulse response and average value of impulse responses.

3 Proposed System Model

It is assumed that each device and access point can support TH-PAM UWB standard of IEEE 802.15.3a.
The transmitted signal $s(t)$ can be described as below

$$s(t) = \sum_{i=-\infty}^{\infty} \sqrt{E_{RX}}\, p_0 (t - iT_s - c_i T_c), \tag{4}$$

$$\sqrt{E_{RX}} = \sqrt{E_{TX}} + \sqrt{E_{Wat}}. \tag{5}$$

where E_{RX} is power of received signal, E_{TX} is power of transmitted signal, E_{Wat} is power of digital watermarking sequence. $p_0(t)$ is normalized pulse signal, T_s is symbol duration, T_c is time duration and c_i is the i-*th* time-hopping code.

Fig. 1 shows the block diagram of the proposed algorithm with digital watermarking sequence for UWB signals of the WBAN. The input data is regarded as bionic data from each on-body sensors. Each on-body sensor data is spread by direct sequence generator. And then, spread data is modulated by pulse amplitude modulation (PAM) modulator.

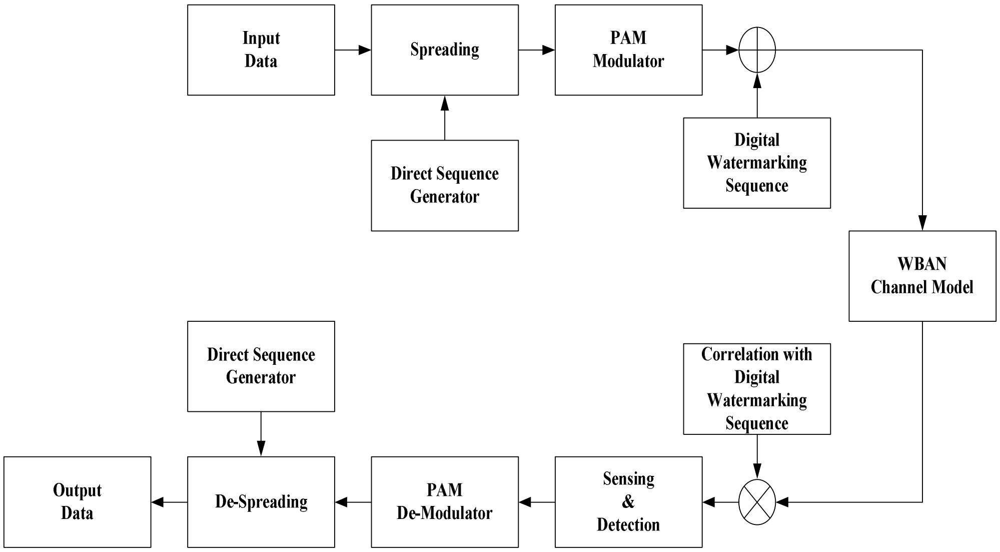

Fig.1. Block diagram of the proposed algorithm.

Finally, digital watermarking sequence is added up to the modulated data. At this block, digital watermarking sequence has the power level about -5dB ~ -20dB compared with power level of transmitted PAM data. In general, the watermarking sequence should have good autocorrelation property, therefore, we employs Kasami sequence.

At the receiver, a log-likelihood function of received signals is given by

$$L(S) = \ln p(r(n)), \tag{6}$$

where $r(n)$ is received signal and $p(r(n))$ denotes probability density function (PDF) of $r(n)$.

From (6), we obtain maximum likelihood (ML) estimation of S given by

$$\begin{aligned}\hat{S} &= \arg\left\{\max_S L(S)\right\}, \\ &= \arg\left\{\max_S \sum_{n=0}^{i-1} \ln\left(p\left(r\left(n\right)\right)\right)\right\}, \\ &= \arg\left\{\max_S \sum_{n=0}^{2i-1} r\left(n\right) w\left(\tau - n\right)\right\},\end{aligned} \tag{7}$$

where $w(n)$ is watermarking sequence added up to the transmitter signal. ML estimation finds the maximum output value of the correlator from correlation between the received signal and the watermarking sequence.

4 Simulation Results

In this section, simulation results of the proposed system are presented for the varying system parameters. The performance is evaluated in terms of detection probability P_D .

In the simulation, we compare the detection probabilities with various FA probabilities in the specific digital watermarking sequence level. Digital watermarking sequence levels considered in this paper include -5dB, -10dB, -15dB and -20dB. As a digital watermarking sequence, Kasami sequence is applied for enhanced detection performance. Also, we employ UWB time hopping-PAM (TH-PAM) signal in the on-body sensor.

To assess detection probabilities, FA probabilities are found to be as 6.4%, 8.5% and 9.5%. Finally, in the simulation results, we assume that the channel estimation is perfect.

Fig. 2 shows detection probabilities vs. SNR for the proposed algorithm with various FA probabilities when the digital watermarking level is -20dB. In Fig. 3, X-axis represents SNR from -25dB and 0dB and Y-axis represents signal detection probability from 0% and 100% range. As shown in Fig. 2, detection probabilities are getting higher with FA probability. Also, because the power level of the digital watermarking sequence is very lower than the power level of on-body sensor's signal, the detection probability is between 55% ~ 60% at the SNR of -10dB.

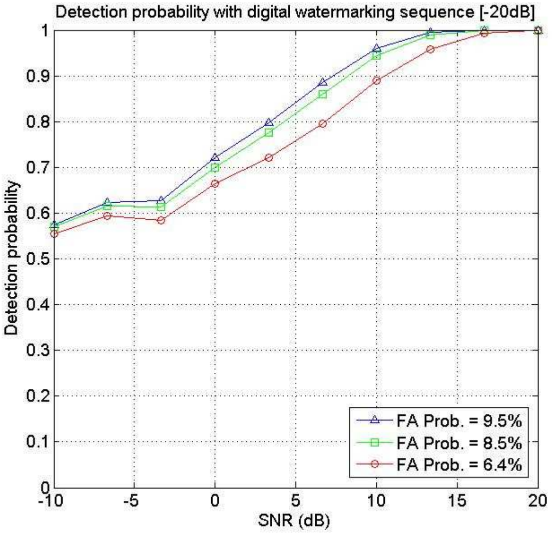

Fig. 2. Detection probabilities vs. SNR performance with various FA probabilities. (Watermarking sequence level is -20dB)

Fig. 3 presents the detection probabilities vs. SNR for the proposed algorithm with various FA probabilities when the digital watermarking level is -15dB. The detection probabilities for an overall SNR are improved by change of digital watermarking sequence level compared with the results of -20dB.

Fig. 4 shows the BER performance with various digital watermarking sequence levels. As shown in Fig. 4, BER performance of without watermarking is almost same as the BER with -20dB, -15dB and -10dB digital watermarking levels. Because -5dB watermarking level may affect the on-body sensor's data, a BER of -5dB is higher than other watermarking level. Therefore, the watermarking sequence level is cautiously chosen to avoid degradation of BER performance. From the results of this paper, it is confirmed that there is a trade-off relationship between detection probabilities and BER performance. So, it should be paid special attention to choice of digital watermarking sequence levels [8].

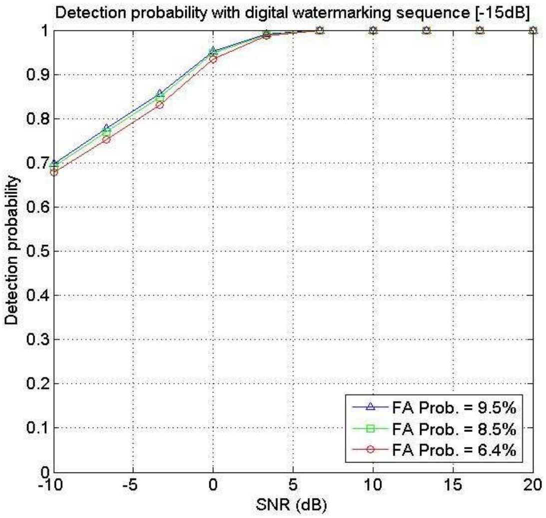

Fig. 3. Detection probabilities vs. SNR performance with various FA probabilities. (Watermarking sequence level is -15dB)

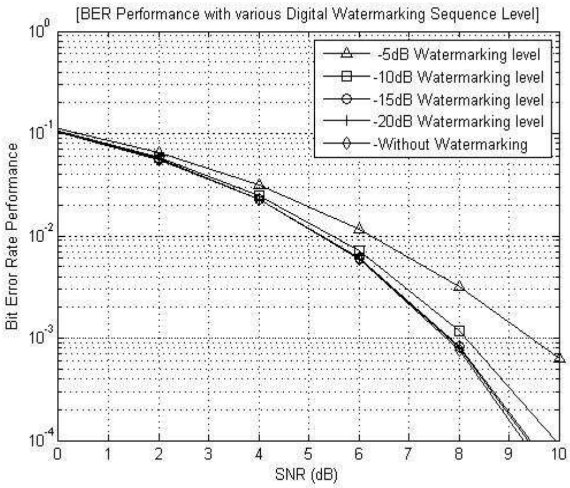

Fig. 4. BER performance with various digital watermarking sequence level (-5dB, -10dB, -15dB, -20dB, and without watermarking)

5 Application for U-Healthcare Systems

Moreover, the proposed algorithm can be applicable to the medical ICT (Information and communication technology) using WBAN, as shown in Fig. 5. Main application examples are ECG, pacemaker and wireless capsule endoscope. The ECG is a device which records contraction of heart according to stream of times while the pacemaker is a device which makes patient’s heart working normally, and it is inserted inside human muscle. The wireless capsule endoscope is usually a tablet-sized capsule, and if a man swallows the capsule, it sends the moving capture data of internal organ to the external sensor. In the aspect of medical applications above mentioned, a main issue is whether the medical system can coexist with other RF systems. This issue can be solved by the proposed algorithm where the WBAN based on UWB can effectively operate with the very low power spectral density. Therefore, algorithm and results of this paper are appropriate for medical ICT.

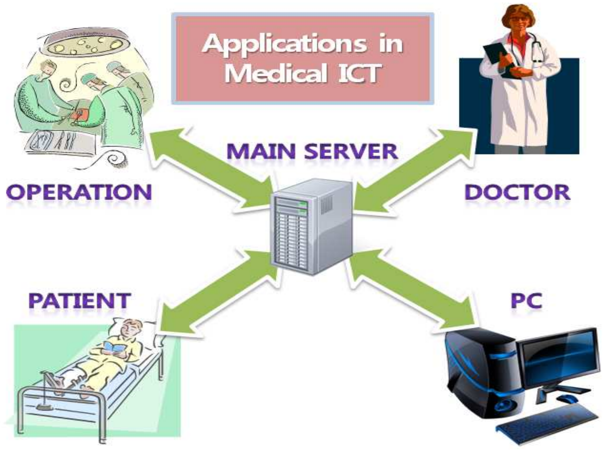

Fig. 5. Application fields of proposed algorithm based on WBAN.

6 Conclusions

In this paper, we proposed the novel transmission algorithm of UWB signals with digital watermarking sequence, and we analyzed and simulated performance of UWB signal detection probabilities for WBAN applications. . From the simulation results, it is confirmed that detection probability over 90% can be achieved in the overall range of SNR for the WBAN channel model at the SNR of 0dB. Also, from trade-off relationship between detection probability and BER performance, it is very important to properly choose digital watermarking level for various WBAN applications. By employing digital watermarking, we can make the proposed WBAN system more robust and secure while maintaining system performance. The results of this paper can be applied to the various WBAN application fields such as healthcare system, living assistance of an elder and blind person, and entertainment services as well as other wireless consumer electronics in various home network applications.

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