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Cooperative Diversity-based WBAN Structure with Rotational Precoding

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ABSTRACT: The Wireless Body Area Networks find their use in wide variety of fields starting from medical to sports to the military. However, the main concern for WBANs is their energy efficiency that in turn illustrates the network longevity. This research work is focused towards a cooperative diversity-based wireless body area network (WBAN) by using Alamouti's space-time block code (STBC) with rotational precoding scheme along with Max-Min and Harmonic Mean relay selection procedure. The considered WBAN model is served for healthcare service in order to mitigate the undesired effects of WBAN due to high path loss and fading as well as to keep a low transmit power while meeting to the desired WBAN quality of services. Bit Error Rate (BER) performance is compared to Rayleigh fading environment using ZF and MMSE equalization techniques.

Keywords: Alamouti, BER, MMSE, STBC, WBAN, ZF.

I. INTRODUCTION

Cooperative communication has turned into one of the famous research topics as the solution to the battery life issue and expanding the transmission limit and execution. Cooperative communication is a framework wherever wireless mobiles can together convey their signals, hence attaining a number of substantial developments in communication for multi-path fading channel: enlarged rates for data communication, enhanced clarity and, coherence for voice communications expanded battery life and reduced transmit power [1].

The basic principle of cooperative communication is using other communication devices to relay transmission. Figure 1 shows the data broadcasting from the source node to both the nodes i.e.; receiver node and the relay node. The relay node then forwards the transmission to the end point (destination) node. The source node regards the relay node as a virtual antenna, enabling MIMO systems to be used without having to add a physical antenna.

Wireless channel has a characteristic that the data transmission of each user can be received by all other users and also the base station. In this manner, the data of a partner to the base station is able to receive and re-transmit at a particular mobile, therefore offering support to the respective mobile in light of the fact that the two streams received by means of independent fading paths, the spatial diversity will offer an enhancement in overall reception, regardless of the possibility that we scale the powers (as is required by fairness) so that the general measure of power per data bit in the framework continues as before.

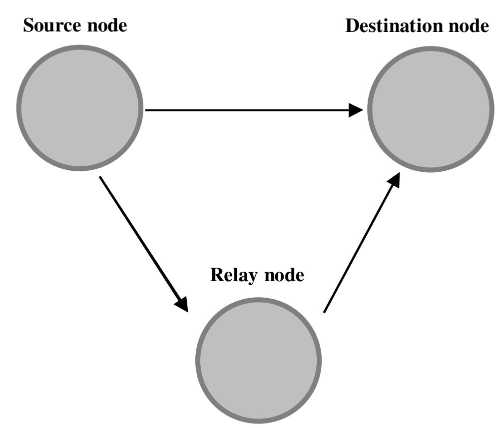

Fig. 1. A basic structure of cooperative communication [1].

A. Wireless Body Area Networks (WBANs)

Health monitoring systems combined with wireless communication create a class of Wireless Sensor Networks (WSNs), known as Wireless Body Area Networks (WBANs). Such networks consist of tiny computing devices, called sensor nodes, along with a central unit called sink. These sensors may be placed in wearable objects such as belts, headsets, wrist watches, etc., or may be attached to or implanted inside the human body to make WBAN.

Initially, the main idea behind WBANs was the provision of remote monitoring of vital signs of patients suffering from chronic diseases such as asthma, heart attack and diabetes. Nowadays, WBANs may also be utilized in sports, military or security applications. Such networks come with a great number of applications such as detection of human body postures, and activities, monitoring of diet and support for other health crisis [2].

WBAN supports both medical and nonmedical applications with diverse application requirements. The nodes in the network can be sensors/actuators or personal devices. For the sake of clarity, the communications for WBAN can be categorized into three parts: intra-body communication, extra-body communication, and inter-body communication. The intra-body communication controls the information handling on the body among sensors/actuators and personal devices; the extra-body communication ensures the connection between a WBAN and other heterogeneous networks and the inter-body communication deals with the information exchange among different WBANs. A typical architecture of WBAN is shown in Fig. 2.

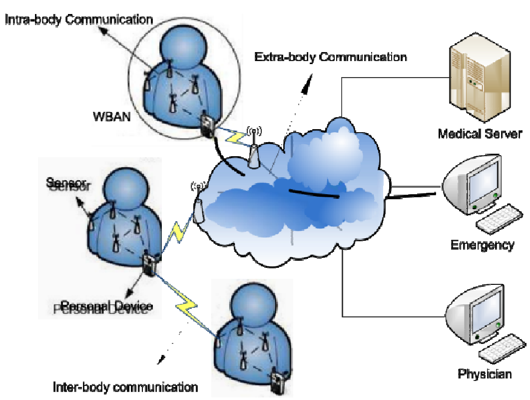

Fig. 2. The Architecture of WBAN [2].

Depending on the applications, the nodes in WBAN may communicate with an on-body coordinator, which can be implemented in a PDA, through intra-body communication; or these nodes may communicate to a gateway through which they are connected to a local or wide area network.

Accordingly, WBAN has medical and nonmedical traffic in the network. The medical traffic includes the data generated from continuous waveform sampling of biomedical signals, monitoring of vital signal information, and low rate remote control of medical devices; while non-medical traffic covers video, audio, and data transfer [3].

II. STATE OF THE ART

The development of WBAN brings a number of research challenges such as interoperability, scalability, reliability, QoS, and energy efficiency to the design of communication protocols. As we mentioned, the energy resources are very constrained in WBAN. Utilizing energy efficient communication protocols to maximize the network lifetime is important for WBAN applications. Reducing transmit power can be a potential approach. Note that, to avoid the negative impact of electromagnetic radiation on the human body, it is critical to keep a low transmit power in WBAN. However, the path loss in WBAN is usually larger than 50 dB [4], causing severe attenuation on wireless signals, and thus without sufficient transmit power the link quality is very likely to be deteriorated. Recently, it is observed that, with 1mW transmit power at 2.4GHz, the on-body (off-body) links of WBAN are intermittently disconnected up to 14.8% (14.9%) of the time when people sleep on the bed [5]. As such, the network topology of WBAN could be frequently partitioned [6]. Further, the data packets in WBAN mostly consist of medical information with the demands of high reliability and low delay. As a result, how to design communication protocols to ensure an end-to-end reliable communication with the least energy consumption becomes a key challenge in WBAN.

Cooperative communications have the advantage of spatial diversity, thus improving both link reliability and energy efficiency [7, 8]. The power consumption with cooperation in the wireless sensor network is studied in [7]. It is shown that, for a large distance separation between the source and destination, cooperative transmission is more energy efficient than direct transmission. The energy efficiency of cooperative communication is further illustrated in the clustered wireless sensor networks in [8], and similar results are revealed. Motivated by these researchers, we are interested in the use of cooperative communications in WBAN and the associated performance in terms of energy efficiency.

Moreover, cooperative diversity techniques, where some relay nodes provide the alternative paths to transmit information from a source to a destination, have also considerably drawn the attention and exploited in wireless networks [9], [10] and wireless body area networks (WBANs) [11]. The relaying paths can provide the better WBAN links when the direct path (from a source to its destination) disappear or is not reliable which always occurs due to high path loss and fading in WBAN. Cooperative communication can enhance the network performance of WBAN extremely, e.g., increasing spectral and energy efficiency, expanding network coverage, and reducing bit error rate etc. Three cooperative transmission protocols, exploited in the relay node, are amplify-and-forward (AF), decode-and forward (DF), and compress-and-forward (CF). AF mode will be exploited in this research because the sensor nodes of a WBAN have the computing time and energy limitations.

In order to employ 2×2-Alamouti's space-time block code (STBC) in practical, a wireless node is needed to have two antennas. On the other hand, if the pre-coding scheme is employed to the STBC, a single antenna of the wireless node can be used and the high gain can still be achieved without loss of transmission rate. The Pre-coding scheme is generally exploited in down-link because a transmitter must know one's own transmit channel state information (CSI). The performance is deteriorated if the received CSI from the receiver is not perfect. However, this event is alleviated possibly as the data symbols are sent by using STBC with rotational pre-coding (STBC-PC) scheme [9].The main objective of this paper is to evaluate the bit error rate (BER) performance of a cooperative diversity-based wireless body area network (WBAN) by using (2×2) Alamouti's space-time block code (STBC) with rotational pre-coding scheme and a relay selection procedure (RSP). Zero Forcing and Minimum Mean Square Error equalizers are used for equalization.

III. PROPOSED METHOD

Figure 3 shows the basic block diagram for the proposed approach. It contains data source, precoding block, decoder and a set of relays. Data source generates a signal which is further precoded and transmitted to different relays. Rest of the process is explained as follows.

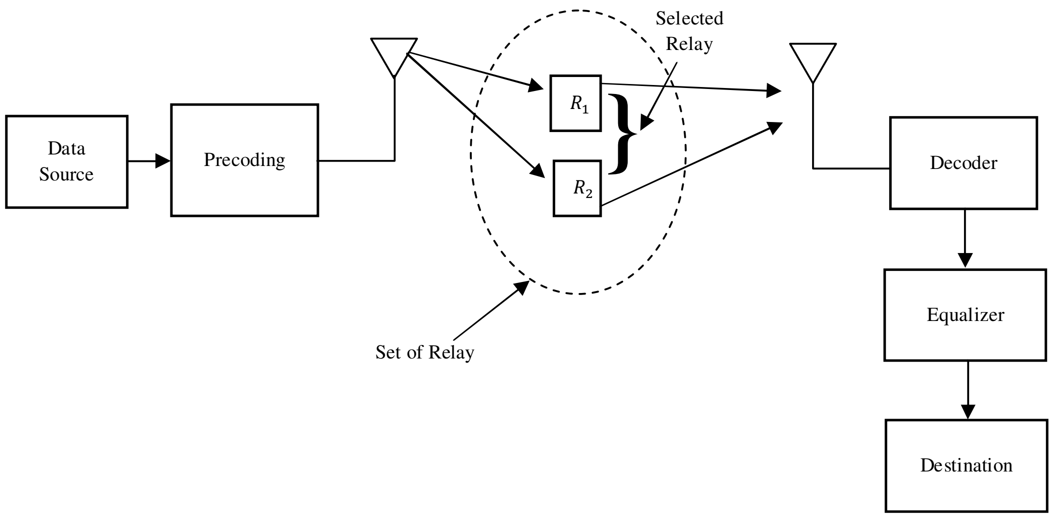

Fig. 3. Block diagram for the proposed method.

A WBAN consists of some sensor nodes as shown in Figure 4, where the sensor nodes transmit their data to a central node.

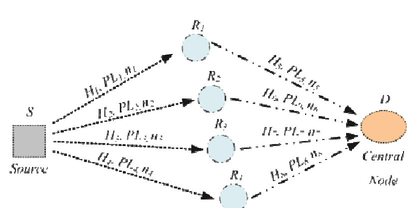

Fig. 4. A WBAN model and propagation channels in WBAN [12].

The symbols for each propagation link in the proposed WBAN model are also shown. A central node is a receiver which acts as a gateway to a computer room or other wireless networks. Each node is placed on the human body and composed of a sensor, electronics module, and a single antenna.

The received signal for a link of any pair of nodes i and j (y_j) is modeled as:

$$y_j = h_{ij}x_i + n_j \qquad (1)$$

A. Rotational Precoding

The main aim of rotational precoding is to direct all the power to the sub-streams along their corresponding Eigen directions of the channel, which can be achieved by the selection of appropriate codeword from the set that minimizes the distance:

$$d(W_k, W_l) = \frac{1}{\sqrt{2}}||W_kW_k^H - W_lW_l^H||_F \qquad (2)$$

Where d is the chordal distance.

B. Relay Selection

The optimal relay selection scheme works on the principle of selecting relay with minimum symbol error rate (SER), while in practice it is hard to analyze. Therefore a suboptimal relay selection scheme which selects relay with minimum SER and which is analyzable is required. Max-min relay selection and Harmonic Mean relay selection schemes work on such principle and they are analyzable as well. Let h_{si}, h_{id} denotes the instantaneous channel condition between source and i^{th} relay, i^{th} relay and destination.

Bletsas *et al.* [13] proposed two formulas to select any relay among a set of relays: under Policy I, the base of the two is chosen, while under Policy II, the consonant means of the two is utilized:

Under Policy I:

$h_i = \min \{|h_{si}|^2 |h_{id}|^2\}$ (3)

Under Policy II:

$$h_i = \frac{2}{\frac{1}{|h_{si}|^2}+\frac{1}{|h_{id}|^2}} = \frac{2|h_{si}|^2|h_{id}|^2}{|h_{si}|^2+|h_{id}|^2} \quad (4)$$

IV. SIMULATION AND RESULTS

The performance of proposed algorithms has been studied by means of MATLAB simulation.

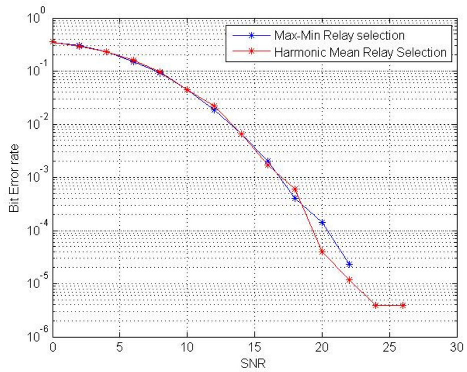

Fig. 5. Comparison of BER performance for Max-Min and Harmonic-Mean relay selection schemes.

Comparison of Bit Error Rate (BER) performance for Max-Min and Harmonic-Mean relay selection schemes is shown in Fig. 5. On observing BER at10^{-4}, it can be seen that Harmonic-Mean achieves this level at 19 dB SNR, while Max-Min at 21 dB. Clearly, Harmonic-Mean shows 2 dB better performance than Max-Min scheme.

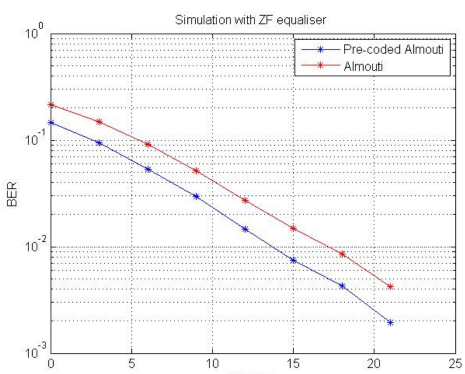

Fig. 6. Comparison of BER performance of Alamouti and Precoded-Alamouti schemes in ZF equalization.

Comparison of Bit Error Rate (BER) performance of Alamouti and Precoded-Alamouti schemes in ZF equalization is shown in Figure 6. On observing BER at10^{-2}, it can be seen that Precoded-Alamouti achieves this level at 14 dB SNR, while Alamouti at 17 dB. Clearly, Precoded-Alamouti shows 3 dB better performance than Alamouti scheme.

Comparison of Bit Error Rate (BER) performance of Alamouti and Precoded-Alamouti schemes in MMSE equalization is shown in Figure 7. On observing BER at10^{-2}, it can be seen that Precoded-Alamouti achieves this level at 14 dB SNR, while Alamouti at 16dB. Clearly, Precoded-Alamouti shows 2 dB better performance than Alamouti scheme.

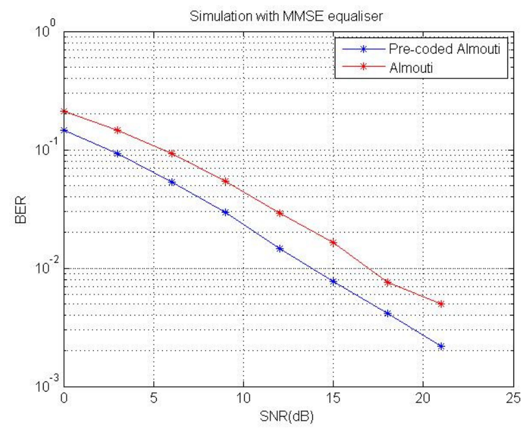

Fig. 7. Comparison of BER performance of Alamouti and Precoded-Alamouti schemes in MMSE equalization.

V. CONCLUSION

Comparison of bit error rate (BER) performance for cooperative diversity-based wireless body area network (WBAN) using Precoded Alamouti's STBC has been presented in this paper. Cooperative Max-Min and Harmonic Mean relay selection schemes have been developed. To evaluate system performance Rayleigh fading scenario has been considered. It can be seen that the Harmonic Mean relay selection scheme outperforms the Max-Min relay selection scheme with 2 dB SNR. Simulation results also show the comparison of BER performance between the Alamouti STBC and Precoded Alamouti for Zero Forcing and MMSE equalization techniques. On observing simulation results it is concluded that Precoded Alamouti STBC gives better performance in case of both equalizers with 3 dB SNR.

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