Investigation of Cooperative Transmit Diversity in Narrowband Wearable Wireless Body Area Network at 400-MHz WMTS Band

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1 Introduction
In BAN systems, sensor devices are highly constrained in the power consumption. A cooperative transmit diversity scheme between the nodes of the same BAN is expected to offer high reliability and efficiency at low energy cost at the same time. Moreover, the movement of the body causes an alternation of LOS and Non-LOS links, which can last short or long period along with the body movement pattern [1]. In such situation, cooperative transmit diversity schemes with multiple nodes of which links experience independent fading can offer a good tool for more reliable communications in life-critical BAN applications. This report presents fundamental investigation of the impact of a simple cooperative transmit diversity on wireless BAN system which has been being standardized in IEEE 802.15 T G 6 [2].

2 System Model and Measurement Setup
We assume that half-duplex sensor nodes are attached on body surface as shown in Fig. 1(a), which are chosen based on IEEE model [2]. As shown in Fig. 1(b), a source node transmits a message to the destination (gateway node) and the other sensor nodes which will play parts in relays in second phase. Opportunistically some nodes which can decode the packet retransmit the messages in a decodesend-forward (DF) manner through some orthogonal channels [3]. At destination node, the signal received directly from the source in first phase and those from the relays in second phase are assumed to be combined coherently, so diversity reception can be achieved by using these multiple links of the direct and relay links.

In this report, a narrowband PHY at 444.5-MHz band (allocated for WMTS in Japan) was chosen. BAN medical devices require low power consumption and are mostly used for relatively low rate transmission. Gaussian minimum shift keying (GMSK) which is widely used for such kind of low power communication system was assumed where channel bandwidth and symbol rates were 400 KHz and 230 kbps. However channel coding was not considered. Then, both an implementation less (IL) of 10 dB and a noise figure (NF) of 10 dB were practically included.

A four-channel high speed oscilloscope was used for envelope detection and channel response storage. The measurement was conducted in medium size office environment. We considered two repetitive action scenarios of walking on the spot and standing up / sitting down [1]. The channel responses were captured every 1 msues for about 14 sec. See [4] for the other details about measurement setup.

3 Link Performance Evaluation
In BAN channels, the fading is considered to be quasi-static (referred to block fading); it is rather static during the packet transmission because body movement speed is relatively low compared to other mobile communication systems, and in general, the packet size is small enough for channel coherence time [1]. In this case, the packet error probability (PER) at given SNR ($\gamma$) is expressed by $1 - (1 - P_e(\gamma))^{\frac{N_r}{2}}$, where $N_r$ and $P_e$ denote the number of symbols within a packet (herein, 255) and the symbol error probability of uncoded GMSK ($B_cT_s = 0.25$) with incoherent detection. From the measured channel responses and assumed PHY parameters, the receive SNR were calculated in terms of different transmit powers and then outage probability of PER were calculated as Fig 2. It can be seen that body movement significantly degrades the direct link performance (especially walking scenario) greater than the requirement of 0.05 outage probability at the target PER of 0.1. However, in case of cooperative scheme with direct link and three relay links, it can be seen that the outage was greatly improved because transmit diversity gain could be achieved from independent fading characteristics as well as array gain.

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References