Selected Paper

Delivery of Body Area Network Data Via Ka-band Satellite Links

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1. Introduction

Demand on high quality of medical and healthcare services motivates the research and development (R&D) activities on medical information and communications technology (MICT) [1]. Among various MICT, body area network (BAN) [2] is expected to be able to introduce more efficiency into medical and healthcare and improve the quality of medical treatment and healthcare management. By combining with biosignal sensors, BAN can collect and forward vital biosignal through dependable networks with high security and high reliability for real-time monitoring. It is considered that BAN will play an important role not only for health check and monitoring of patient in hospital but also for healthcare management for elder people at home and fitness assistant, etc.

For applications related to medical treatment or healthcare management, it is desired to have doctors or experts to evaluate the collected BAN data. There are many infrastructures can be used to forward BAN data to a central hospital for evaluation purpose including fiber-based internet, mobile cellular network (MCN), and satellite network. Satellite network has several distinct characteristics in comparison to the others. Firstly, there is less geographical restriction. No matter where a person is, on mountains, on the sea, or in an isolated area, satellite links with identical quality are available. Secondly, satellite links do not need extra infrastructures. Only an earth terminal is required, which can be implemented in small size with state-of-the-art innovation. Thirdly, satellite links support mobility if the earth terminal is equipped with an automatic tracking system.

We describe an experimental system, in which BAN data is forwarded using Ka-band satellite links. In section 2, concept of BAN and a prototype BAN system are introduced. The total experimental system is illustrated in section 3. Finally, a brief summary is given in section 4.

2. Body Area Network

BAN can provide a wide range of applications including medical support, healthcare monitoring, and consumer electronics with increased convenience or comfort. For support of medical and healthcare services, in general manner, a BAN device is a BAN transceiver paring with a biosignal sensor or a set of life sign sensors. The concept of BAN is shown in Fig.1. A BAN consists of a coordinator and several sensor nodes. Coordinator controls network forming, channel allocation, and it is also the sink for all sensor

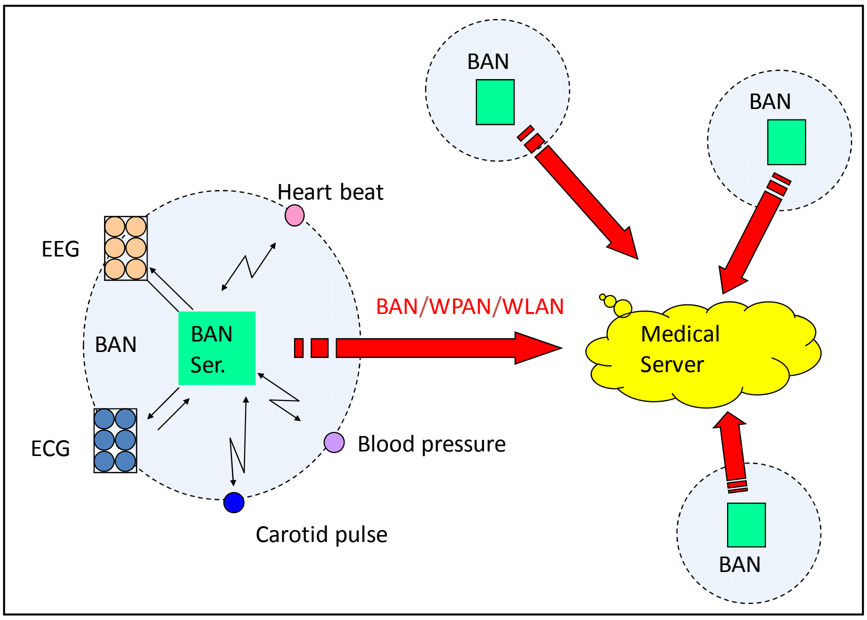

Figure 1 Conceptual block diagram of body area network

nodes. Examples of collectable sensor data include blood pressure, electro encephalo graphy (EEG), electro cardio gram (ECG), carotid pulse, glucose rate, body temperature, etc. A typical application scenario of using these sensor data is real time monitoring of patient state in a hospital. By attaching BAN devices to patients, vital or healthcare data can be automatically collected to the coordinator. From where, BAN data can be further forwarded to a nurse center for patient state monitoring. The benefit of this scenario is that it can reduce the working load of nurses and result in increased efficiency on patient management. Other usage models of using sensor data include at home healthcare, aging people support, physical rehabilitation assistance, etc.

We developed a prototype BAN system using ultra wide-band (UWB) Technology [3]. UWB is selected for the following reasons.

(1) Considering BAN may be widely deployed with persons, the interference level from BAN to other wireless systems must be minimized. Because the power spectrum density (PSD) of UWB is very low (-41.3 dBm/MHz), it naturally produces low interference levels.

(2) The low power emission level of UWB benefits low power consumption, which is a strong requirement for BAN device because they operate with small battery and for long time duration.

(3) The low power emission level is helpful to reduce the specific absorption rate (SAR) to protect human tissues. Because BAN operates in close proximity to body, SAR is an important issue that must be considered in real applications.

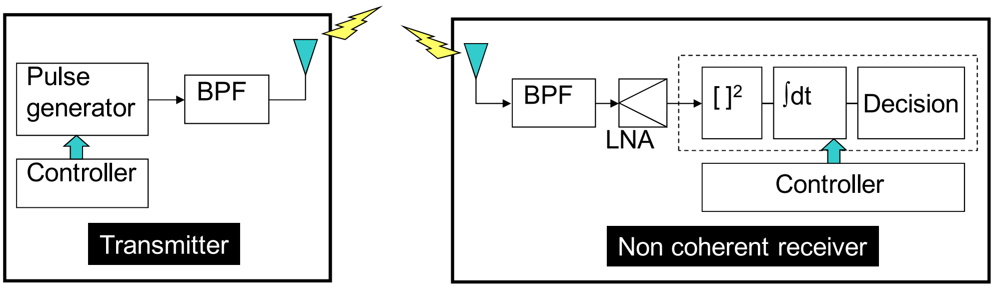

Figure 2 UWB Transceiver structures

Table 1 UWB Specifications

Parameter	**Value**
Center Frequency	4.1 GHz
Bandwidth	1.2 GHz (-10dB)
Data rate	66 kbps
Pulse Shape	Gaussian
Average Power	-45 dBm/MHz
Antenna gain	0 dBi
Modulation	OOK
Demodulation	Energy detection
Pulse repetition frequency	Mean = 21.25MHz

Transceiver structure of the prototype system is shown in Fig. 2. The transceiver operates at a center frequency of 4.1 GHz with a bandwidth of 1.2 GHz. Average emission power density is approximately -45 dBm/MHz. To simplify the implementation, an on-off keying (OOK) modulation is adopted at the transmitter and an energy detector is employed at the receiver. Pulse shape generated by the pulse generator in the transmitter is Gaussian. The sensors implemented with the UWB transceiver are acceleration counter, which can detect three dimensional acceleration changes. Because the sensored data is very limited, the date rate of the transceiver is 66 kbps. However, there is no difficulty to raise the data rate up to a value of 1 Mbps. Specifications of the developed UWB transceiver is summarized in Table 1.

A picture of the prototype BAN is shown in Fig.3. There are three types of devices, BAN coordinator, relay nodes, and sensor nodes. BAN coordinator controls the network and aggregates sensor data. Sensor nodes collect various data and send them to BAN coordinator. A relay node is used to relay data from a sensor node to the BAN coordinator when the sensor node can not directly communicate with the BAN coordinator. Although these three types of devices are assigned with different functions, they are implemented with the same UWB transceiver given in Fig.2. Channel access method of the prototype BAN is designed with TDMA format. Before joining a BAN, a sensor node or a relay node must first send a beacon periodically to request channel allocation. After received the request, the BAN coordinator selects an available time slot for the corresponding node and sends a response with the channel information. Finally, the corresponding node can use the assigned channel in the BAN. A control PC is connected to the BAN coordinator. On one hand, the control PC can intentionally change the networking forming including multi-hop with relay nodes. On the other hand, it is used as a monitor to show the network topology and collected data.

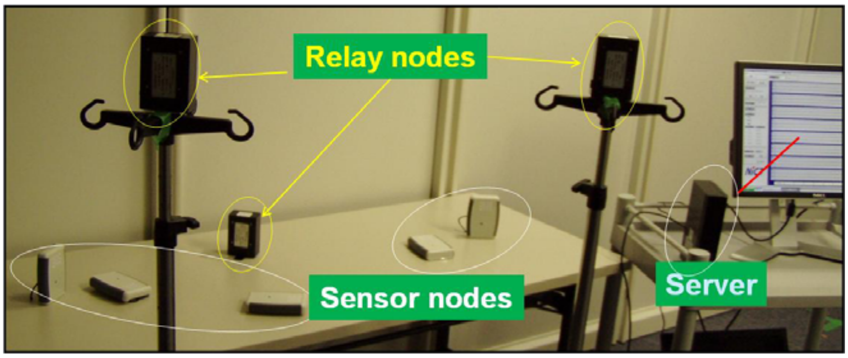

Figure 3 Prototype BAN system

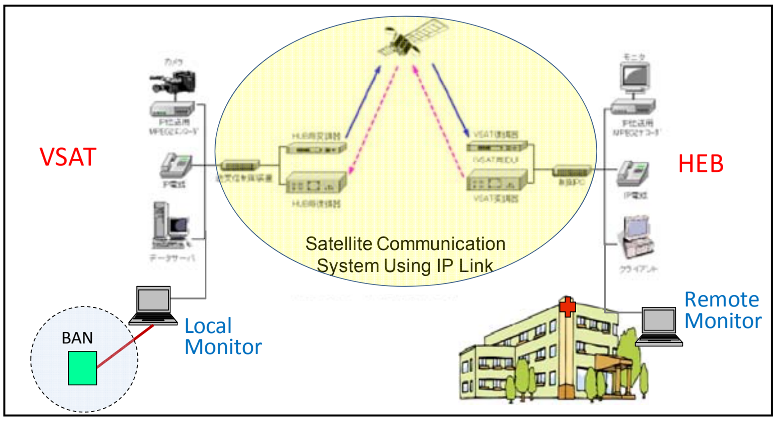

Figure 4 The concept of overall experimental system

3. Forwarding BAN Data Using Ka-band Satellite Link[4]

The concept of overall experimental system is shown in Fig. 4. A hub earth station (HES) and a VSAT station are used in the experiment. Both stations are developed for satellite IP packet transmission. Each station is assigned with an Ethernet address. Therefore, they can connect to a local area network (LAN) directly using a 100BASE-T interface. The advantages of enabling Ethernet connection is that various sources, including IP packets of video, voice, data, etc., can be delivered through LAN infrastructure directly when required. A Ka-band transponder of a commercial satellite, SUPERBIRD, is used in the experiment. The uplink frequency is at 29GHz band and the downlink frequency is at 19 GHz band. The antenna of HES has a diameter of 1.8 m and an output power of 150W, while the antenna of the VSAT has a diameter of 45 cm and an output power of 16W. A picture of the VSAT is shown in Fig. 5. It should be noted that the VSAT antenna is foldable. It is easy for carrying and setting up.

Figure 5 The VSAT used in the experiment

BAN coordinator is connected to a control PC using i-1394 interface. The latter is connected to the VSAT through 100BASE-T interface. The control PC has two functions. On one hand, it performs real-time monitoring of the collected data from sensor nodes. On the other hand, it is added with an additional function of forwarding the BAN data to the remote HES through the Ka-band satellite link. The remote PC is connected to HEC through 100BASE-T interface. The function of the remote PC is to receive BAN data from local PC and show these data with the same format as they do at the local control PC. Besides correct transmission of BAN data, in some medical applications, the relative time delay among the received data is of strong concern. We investigated the relative time delay of BAN data delivery via satellite link. Relative time delay means the variation of time difference between a pair of data packets at remote site related to local site. An example of the measured results is shown in Fig. 6, where No 3, No.5, and No.26 denote three different channel conditions of the satellite link. Throughputs for these three conditions are 605 kbps 519 kbps, 43 kbps, respectively. In fig. 6, it can be seen that the relative delay can be up to 0.1 ms for No. 26 and it varies in a large range. In comparison, the relative time delay and the variation for No.3 and No.5 are very small and stable. Recall that BAN data rate is 66 kbps, it is reasonable to say that throughput has strong effect on relative time delay.

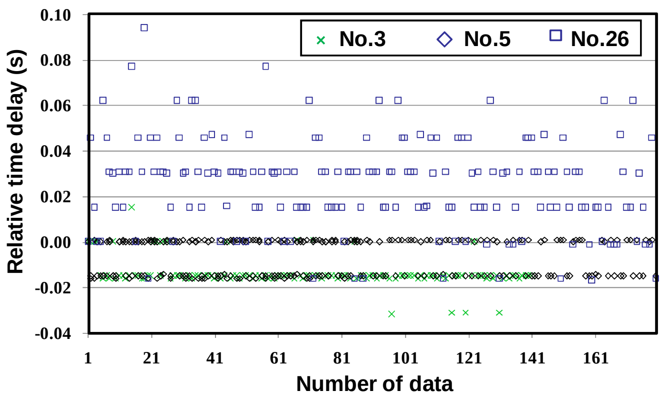

Figure 6 Examples of measured relative transmission delay

4. Summary

An experimental system that combines BAN with satellite communication links to enable BAN data delivery to remote site is described. Prototype BAN system is implemented using impulse UWB technology. Satellite communication links are well known for being able to provide identical services with less geographical restriction compared to other wireless links. The relative delay for BAN data delivery caused by satellite links is investigated. It is shown that link capacity has strong effect on the relative transmission delay.

References

[1] http://www.continuaalliance.org/home

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[3] K. Siwiak and D. McKeown, “Ultra-wideband radio technology, ”John Wiley & Sons, Ltd., 2004.

[4] Huan-Bang Li, Takashi Takahashi, Masahiro Toyoda, Yasuyuki Mori, and Ryuji Kohno, “Wireless Body Area Network Combined with Satellite Communication for Remote Medical and Healthcare Applications,” Journal of Wireless Personal Communications, to be appeared.