Characterization On-Body Communication Dynamic Channel for Wireless Body Area Networks

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Abstract:-

The development and optimization of wireless system that detected for providing services for human require a comprehensive knowledge and accurate modeling for real and efficient using for radio channels. However, many core service applications for human are existing close to the human body which effected on nature of such wireless channels to be dynamic with its characteristics. Influences of the human body on the antennas and propagation channels have been deeply investigated in mobile communications, the wireless body area network (WBAN)for the mobile communication systems in operating frequency bands, communication ranges and environments and device size and on-body positions. These differences may change the channel characteristics and, hence, require new investigations of the WBAN channel. Therefore, this paper presents analyses forthe dynamic on-body area channelbased on real-time measurements of the time domain channel impulse response (CIR) at frequencies near the 800MHZ- and 3-GHz industrial, scientific, and medical (ISM) bands.

Introduction:

Wireless Body Area Networks (WBAN) offer many promising new applications in the area of remote health monitoring. An important element in the development of a WBAN is the characterization of the physical layer of the network, including an estimation of the delay spread and the path loss between two nodes on the body [1]. In hospitals patients and other medical facilities have various levels of mobility, e.g., walking, wheel chairing, eating, etc. There is also growing evidence that for most medical conditions having patients move or walk, as much as they can tolerate, will improve their health. With keeping this in mind, notonly static wireless body area network (WBAN) radio channels usually investigated, but also dynamic scenarios due to the effect of body motion must be considered [2]. The channel models for on-body WBANs have been initially developed by IEEE 802.15 task group 4a [3] as a spin-off of the channel models for energy efficient wireless personal area network (WPAN).According to the locations of the devices, body wireless communication systems (BWCS) can be classified into three categories: off-body, on-body and in-body communication systems [4]. This paper focuses on the dynamic channel characterization for on-body systems. The scopes and interconnection of the WPAN/WBAN and off/on/in body BWCS are summarized as Figure (1)

Frequency Allocation for Body and Personal Area Networks:

Wireless communications systems operate in unlicensed portions of the spectrum. However, the allocation of unlicensed frequencies is not the same in every country. Table1 lists the frequency bands allocated for WBANs and WPANs

1- Medical Implanted Communication Service (MICS).

2- Industrial Scientific and Medical (ISM).

3- Wireless Medical Telemetry Services (WMTS).

4- Ultra Wide - Band (UWB).

The Commission set aside the 402-405 MHz band because the signal propagation characteristics in the band are particularly well suited for implantable applications due to signal propagation characteristics in the human body [5], the relative dearth of other users in the band, and the ability to stake out the band internationally. The MICS uses of this band is secondary to the primary users of this spectrum – Meteorological Aids Service (Medaids), the Meteorological Satellite Services, and the Earth Satellite Service [4]. Table I, lists the Unlicensed frequencies available for WBANs and WPANs.

The idea of a WBAN was initiated for medical purposes, in order to keep continuous records of patients' health at all times. Sensors are placed around the human body to measure specified parameters and signals in the body (e.g. blood pressure, ECG, sugar level, temperature, etc). As an extension to these sensors, base units can be deployed on or close to the human body to collect information or relay command signals to the various sensors in order to perform a desired operation. Figure 1 presents an illustration of WBAN applied in medical care services. Body area network kscan be applied to many fields; some of its applications include [5] and [6]:

- Wearable audio - the central device is the headset, applying stereo audio and microphone, with connected devices including (but not limited to): cellular phone, MP3 player, PDA, CD audio player[7].
- Assistance to emergency services, such as police, paramedics and fire fighters.
- Military applications, including soldier location tracking, image and video transmission and instant decentralized communications.
- Augmented reality to support production and maintenance.
- Access/identification systems by identification of individual peripheral devices.
- Navigation support in the car or while walking with reliable and efficient communication with existing technologies, such as GPS.
- Bio - Sensors for athletes' performance monitoring and enhancement to improve outcomes in major events

Mobile communication devices will have an important role, because they will allow data transmission between PANs and/or BANs with the outside world, such as the mainframe that keeps the information, the doctor responsible for a certain patient or even to call an emergency team. The system used to communicate depends on the specific implementation, and it can be a WLAN or cellular one (e.g., GSM or UMTS). This device would be the central point to which all terminals would connect, managing them. Figure2 depicts one possible case scenario of all these internetwork connections, where BAN is used for fitness monitoring

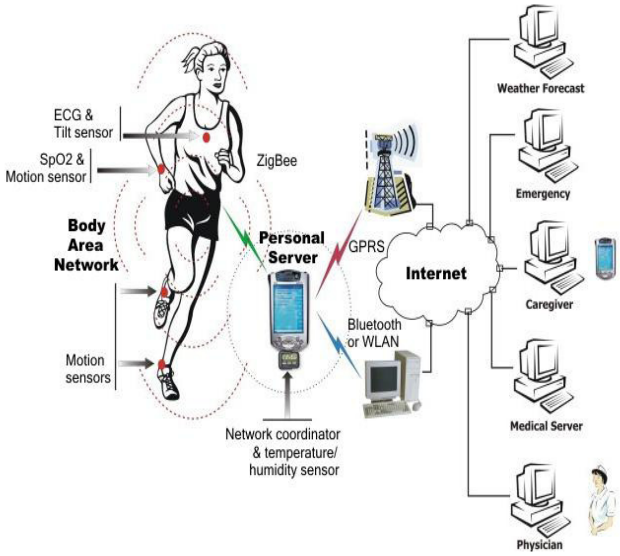


Figure (2) WBAN applied in medical care services

Wireless communication systems, i.e., systems transmitting information via electromagnetic(radio) or acoustic (sound) waves, have become ubiquitous [7]. In many of these systems, the transmitter or the receiver is mobile.Even if both link ends are static, scatterers i.e., objects that reflect, scatter, or diffract the propagating waves may move with significant velocities.These situations give rise to time variations of the wireless channel due to the Doppler effect. Non-ideal local oscillators are another source of temporal channel variations, even in the case of wire line channels. Because of their practical relevance, linear time-varying (LTV) channels have attracted considerable interest in the fields of signal processing, communications, propagation, information theory, and mathematics. Sources of data traffic in a WBAN are mostly medical sensors and actuators that, depending on the physiological duty cycle, communicate key data to a BCU (Basic Command Unit), or sink.

Table I: Unlicensed frequencies available for WBANs and WPANs [5]

Name	Band [MHz]	Max Tx Power	Comments
MICS	402.0-405.0	-16	Worldwide
ISM	433.1-434.8	+7.85	Europe
ISM	868.0-868.6	+11.85	Europe
ISM	902.8-928.0	+36	w/ spreading Not inEurope
ISM	2400.0-2483.5	+36	w/ spreading Worldwide
ISM	5725.0-5875.0	+36	w/ spreading Worldwide
WMTS	608.0-614.0	+10.8	US only
WMTS	1395.0-1400.0	+22.2	US only
WMTS	1427.0-1432.0	+22.2	US only
UWB	100.0-960.0		US only
UWB	3100.0-10600.0		US only

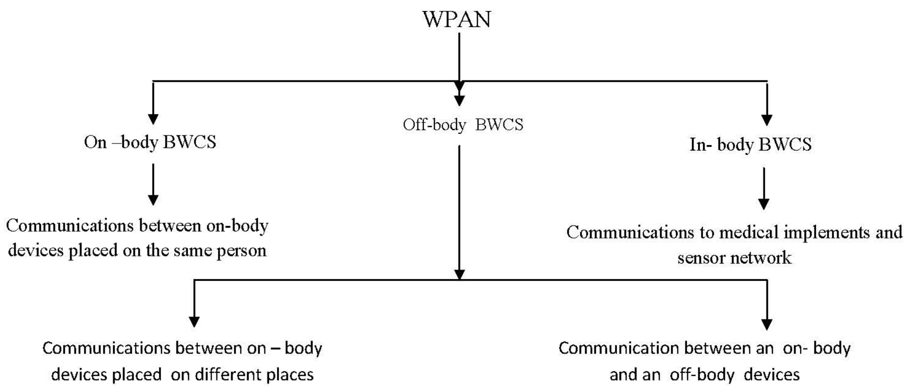


Figure (1) The scopes and interconnection of the WPAN/WBAN and off/on/in body BWCS

The nodes that communicate data around the human body mostly transmit at low data rate with fixed packets size. Most nodes transmit periodically at a regular sampling frequency [8].

Propagation along the torso

The radio link can be represented as three distinct blocks, namely, the transmitting antenna (with transfer function $H_{Tx}(\omega)$), the radio channel (with transfer function $H_{Ch}(\omega)$), and the receiving antenna (with transfer function $H_{Rx}(\omega)$. Therefore, the receiving signal $S_{Rx}(\omega)$ may be defined as [9]:

$$S_{Rx}(\omega) = S_{Tx}(\omega)H_{Tx}(\omega)H_{Ch}(\omega)H_{Rx}(\omega)$$

where $S_{Tx}(\omega)$ is the input signal. The path gain, which is given by the ratio for the received to the transmitted power is achieved by adopting the Friis transmission formula [9].

$$PG = \frac{p_r}{p_t} = (1 - |\Gamma_t(\omega)|^2)(1 - |\Gamma_r(\omega)|^2)G_r(\omega)G_t(\omega)\left|\hat{P}_t(\omega).\hat{P}_r(\omega)\right|^2\left(\frac{\lambda}{4\pi d}\right)^2$$

Where:

G_t is the peak gain of transmitting antenna;

Gr is the peak gain of receiving antenna;

Pt is the average input power of transmitting antenna;

Pr is the average output power of receiving antenna;

$\Gamma_t$is the return loss at the input of transmitting antenna;

$\Gamma_r$is the return loss at the output of receiving antenna;

$\left|\hat{P}_t(\omega).\hat{P}_r(\omega)\right|^2$is the polarization matching factor between T_X and the output at Rx;

λ is the wavelength at the operating frequency;

d is the distance between transmitting and receiving antennas;

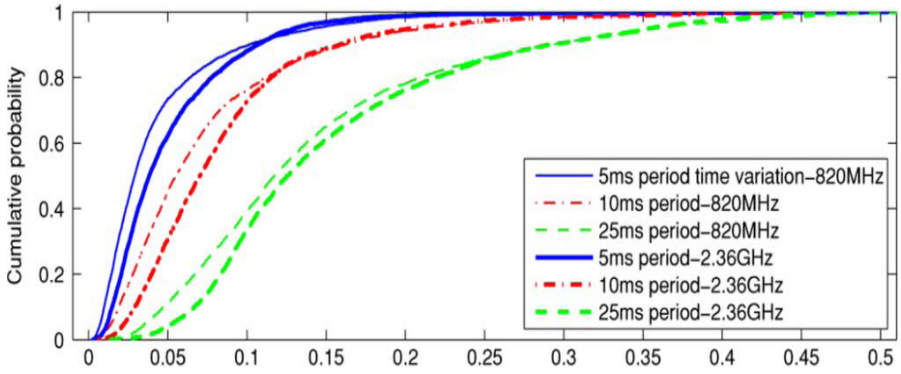
A WBAN node could use significant amount of energy if there are many retransmissions. To minimize the number of retransmissions a WBAN node should select its transmission power in such a way so that a receiver can receive a packet with a sufficient SNR to decode the packet correctly.

Results and discussions

Considering the channel models for on-body WBANs which is initially developed by IEEE 802.15 task group 4a [10] as a spin-off of the channel models for energy efficient wireless personal area network (WPAN). In Nov. 2007, IEEE wireless body area networks TG6 was established in order to develop communication standard optimized for low power devices and operation both in-body and on-body. The work presented by E. Reusens [9] stated that the wireless on-body channel measurements were made using two wearable antennas (one transmit, Tx, one receive, Rx) strapped to the body of a 181.5-cm/78-kg male test subject in an indoor office environment.

The *autocorrelation* function is generally used to analyze fading channel variation [10] and [11]. The *channel coherence time* is considered to be the period over which the correlation coefficients are suitably large; the channel is stable within this coherence time. The autocorrelation approach is not suited to characterizing the dynamic WBAN channel .

In dynamic WBAN channels, a repeated channel impulse response (CIR) may be observed due to regular movements such as movement of an arm and/or a leg. Autocorrelation analysis will fail to detect the feature of time variation in this case. Figure 2 shows the empirical cumulative distribution function (cdf). The cumulative probability is presented for different values of frequency: from 800MHZ to 3GHZ. The MATLAB



Channel variation factor

Figure (2)cumulative distribution function (cdf) of channel for walking

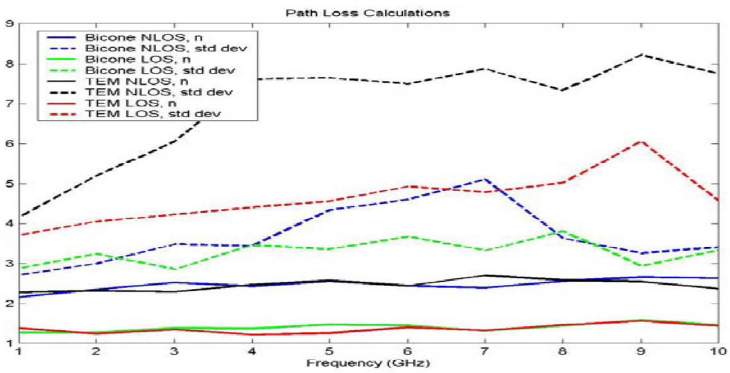


Fig (3) Path Loss Exponent and Standard Deviation for Different Frequencies

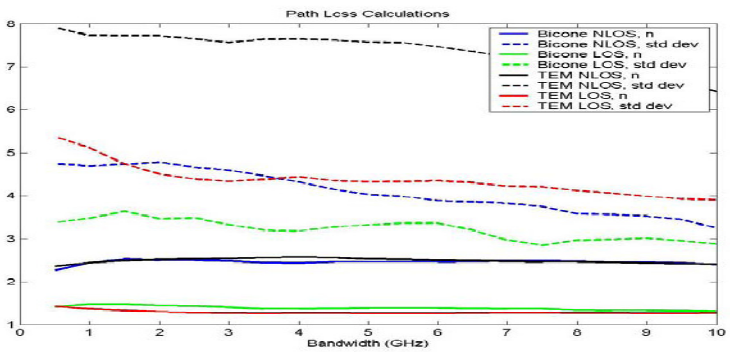


Fig (4) Path Loss Exponent and Standard Deviation Calculations for Different Bandwidths

In this figure, path loss variation- for 10 different bins from 1 GHz to 10 GHz - is computed in 1 GHz increments. The path loss exponents and standard deviations are given for both non-line-of-sight (NLOS) and line-of-sight (LOS) environments,the characteristics of on-body WBAN channels including body motions are altered time-variantly since the link distance changes when arm moves, body will block the LOS link due to the misalignment of the transmit (Tx) and receive (Rx) antennas. Dynamic features of path fading process, which is important for system designs, are taken into account. In practice, only a subset of total resolved multipath components is important and is used for designing a UWB receiver.

Conclusions

Time variation calculation of path gain provide vital information for on-body communications system design, such as outage rates and channel variation rates. An on-body propagation channel can noticeably vary with the posture of the body (variability is most severe when two antennas are mounted on different parts of the body moving in respect to each other).Power efficient wireless sensor design can be achieved by a combined understanding of antennas, radio channel modeling as well as the transceiver design.The relations between path loss and different frequencies and different bandwith show a slight increase in the path loss exponent with increasing frequency, however it is possible that see some frequency dependency with distance.

الخلاصة:

مميزات قنوات الاتصال المتحركة الموجودة على الجسم ضمن مساحة الشبكات اللاسلكية

إن التطور الحاصل في أنظمة الاتصالات اللاسلكية وإمكانية الحصول على أمثلية في التصميم ضمن نطاق قنوات الاتصال اللاسلكي أصبح من الأمور التي تتطلب من الإنسان معرفه شامله ودقيقه للنماذج الحقيقية المستخدمة ضمن قنوات الراديو حيث انه الكثير من التطبيقات الحديثة تكون المستخدمة بالقرب من الجسم البشري. ان خواص الجسم البشري المختلفة المتعلقة بالتوصيلية والمقاومية ودرجة الحرارة... الخ بالتأكيد سوف يكون لها تأثير على الهوائيات المنتشرة ضمن التصميم للموديل للقنوات المتحركة على ذلك الجسم. ان الشبكات اللاسلكية المستخدمة ضمن مساحة تطبيقات الجسم البشري تستخدم حزمه معينه من الترددات وأيضا" تتحدد بحجم معين للهوائي المستخدم إضافة إلى موقع ذلك الهوائي على الجسم. هذه الفروقات هي التي تحكم مميزات القناة. في هذا البحث تمت معالجة بعض الخصائص لقناة متحركة مصممه على جسم بشري ذو المميزات الآتية: ذكر, طول =١٨١ cm والوزن = ٧٨ kgm عند الترددات التي تتراوح من ٨٠٠ MHz الى الترددات ٣ GHz .

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