Wireless Medical Communications Using UWB

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***Abstract*—This paper introduces some of the activities carried out in a medical ICT related ultra wideband (UWB) research at the Centre for Wireless Communications, University of Oulu, Finland. The paper concentrates on the proposed body area network based system architecture for wireless medical communications and gives also a summary on experimental body area network radio channels models. The network architecture under discussion consists of parts that have already been implemented but also parts that require studies in more details before utilization and implementation in operative healthcare network. For detailed communication system design, accurate channel models are also needed. This paper discusses on UWB channel models that are suitable to be used in wireless body area network research.**

Keywords; wireless, body area network, radio channel

I. Introduction

In the last years, two major effects have been recorded in the technological field all around Europe: the penetration of cellular phones, overcoming 100% in many countries, and the access to Internet, reaching an average of 60% of the total populations. These are clear signs on how the knowledge of Information Communication Technology (ICT) is widely spread throughout the population, and how easy is to increase its potentiality by adding new services, fully embedded with the already existing systems.

Wireless communications in itself is a never-ending growing technology: from mobile phones to internet connections, wireless solutions provide reliable means for the transmission of information at reasonable low costs and with a much higher coverage than the traditional means. Wireless transmission could also offer high reliability and security features required by medical applications.

One growing field of research in this direction relates to the ageing of population. On a European perspective this is a common issue over most of the European countries. Moreover, big distances from home to health-care facilities in sparsely populated countries, as well as the lack of resources in both sparsely and dense populated areas bring together the same needs: to increase self-management of chronic conditions and to introduce remote health-care solutions.

Chronic conditions of elderly people are a stunning example; the measurement of vital signs can be done nowadays without the physical presence of a medical staff. Information can be sent directly from home, with a combination of wireless and wired communications, to hospital or health-care institution, and analyzed feedback or medical staff can be sent back to the patient.

People can receive two main benefits in this way:

- Self management: an increased awareness of his/her personal health, by a continuous monitoring of own health parameters.
- Home as a care environment: the possibility of staying longer at home maintaining a normal daily life instead of being at hospital. This can have a positive influence on his/her healing process.

These factors have also an important socio-economic impact. The quality of life is increased and the expenses for healthcare facilities are suppressed, if not even reduced by adopting new wireless technologies in healthcare processes and care.

The use of wireless technologies can be seen as a fast and practical way for finding new means in homecare related issues. Technologies that don't require new cable installations at home, as well as the possibility of monitoring parameters not only in a spatially limited environment but also in outdoor spaces, including mobility, must be exploited in order to create cutting-edge solutions for mid-term market. Self care, self-management and cost effectiveness will be the key factors towards the development of these new technological solutions.

Despite of the slow progress in the utilization of ultra wideband (UWB) technology in commercial applications, and despite of a strong struggle between its different technological solutions, UWB could still be "the" radio interface for several applications. Medical and healthcare related solutions could benefit the low power spectral density that UWB transmission has. Radiated signal power is low enough to be safe for human tissues still providing reasonable communication range and data rate. Extremely wide bandwidth makes it possible also to use UWB signals in applications requiring accurate positioning. These can be either positioning or sensoring applications.

Wireless body area networks (WBAN) form a special network structure to implement a small scale operational environment also for medical purposes. Several vital parameters from a human body could be monitored using small on-body sensors. In addition, implanted in-body sensors could provide important information on internal changes of organs or implanted devices. To communicate from in-body to on-body terminals and then to the backbone infrastructure requires effective wireless solution for WBAN implementation. From radio link point of view, UWB could be the solution.

Ubiquitous, distributed and centralized services related to the patient's problems are the most efficient tools to improve transit speed of a patient at hospital. However, it goes without saying that the process improvement needs to be done without reflection to patients' safety or data security. The advantages of using new technological solutions in medical applications is increasing the effectiveness and reducing costs of the whole public health processes.

Thus the paper describes a concept dedicated for healthcare application it is flexible for other solutions, such as sports, wellbeing, industrial automation, surveillance, storage, etc.

This paper is organized as follows. The second chapter discusses on WBAN network that could be used to monitor human parameters in home, hospital or during transportation. The third chapter discusses on WBAN radio channel models defined for on-body communications by CWC. The last chapter concludes the discussion.

II. WBAN Architecture

The communication architecture designed for medical purposes should be flexible and scalable. The communication needs could be various; starting from transmission of on-body sensor originated data to portable base station or to communication between WBAN and data bases operated by external service provider. All the links at the transmission path could have different quality, physical layer (PHY), etc. requirements. The conceptual overview of the wireless medical communication network discussed in this paper is shown in Figure 1. [1] The interconnections between different sub-networks related to the whole concept are shown in Figure 2.

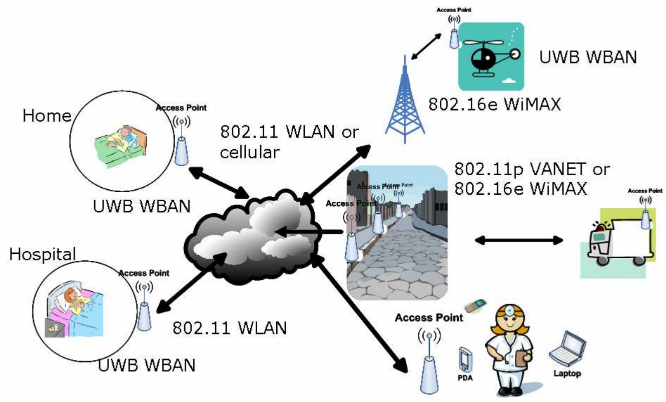

Figure 1. Architecture of a wireless medical communication network.

As Figure 1 shows, the wireless medical communication network could be composed of different set of radio protocols [1]-[3]. One part could utilize short range communication standards, such as UWB, Zigbee or WLAN. The other part creates connections between limited range network to backbone network, dedicated medical networks and data bases. These long haul connections could be implemented using existing cellular phone networks, WiMAX, fixed Internet connection or satellite. There are also dedicated radio standards for vehicular networks, such as IEEE802.11p or mobile WiMAX IEEE802.16e.

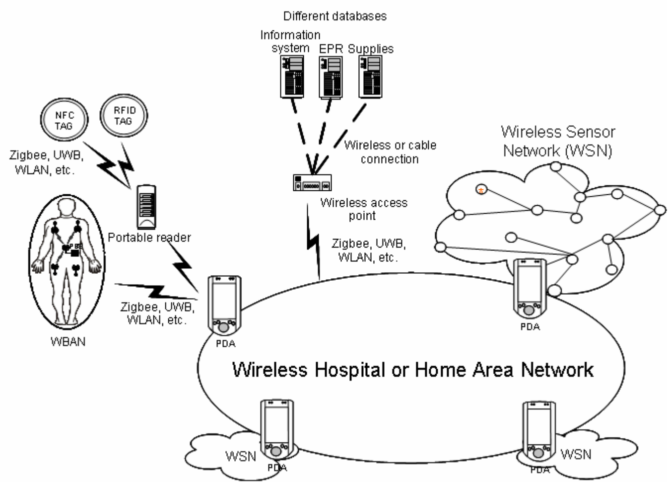

Figure 2. Interconnections between different networks.

As shown in the figures above, the complete wireless communication network could consist of different kinds of sub-networks. The core of the network is a home or a hospital network, depending on the final utilization area. A wearable body area network is then connected to local network, and then routed to the service provider's electronic/patient data bases. This approach makes it possible to create ubiquitous and heterogeneous networks tendering one's services to medical staff, even automatically.

The IEEE802.15.6 task group has been established to develop a communication standard for low power WBAN and medical applications are studied there. This shows that there are global activities towards medical WBAN, and UWB is one possible solution in a wider perspective [4].

A. Utilizing UWB radio technology

Different communication links in the whole system can be built using different radio technologies based on the application specific communication needs. UWB fits well to medical WBAN installations, where low transmission power radio emission is needed to protect human organs. Another advantage is low power consumption that is due to low transmission power, and could then allow long life time for WBAN sensor nodes.

If comparing the two proposed technological UWB proposals, a single band UWB technology [5] utilizing transmission of narrow pulses allows simpler implementation to tiny body nodes than WiMedia [6] based solution. Uncomplicated modulation schemes, such as pulse or burst position modulation [7] techniques can be adopted to low power non-coherent transceivers.

The use of UWB signals in WBAN implies that the transmission is done over a band that most probably is already used by other wireless systems. This requires that possible harmful interference sources need to be identified at a final utilization environment before system design. The design of the UWB receiver should take into account the other electro-magnetic radiation in the vicinity of the transceiver to maximize received signal-to-noise ratio (SNR) and suppress unwanted signal components to prevent front-end saturation.

Considering hospital environments where several electrical and electronic equipments are present, electrical shot noise interference is an UWB type interference source. Interference affects the receiver performance in terms of increasing bit error rate probability.

Integration of several active body area networks in the same environment leads considerably high probability that co-channel interference will be present. As being a code division multiple access (CDMA) type transmission, a single band UWB can tolerate adjacent and co-channel interference well. In a realistic use-case, an UWB body area network applied in a medical application consists of less than dozen of nodes in the same network. However, this could be handled by proper system and user specific spreading code design.

UWB radar techniques have already been investigated for monitoring vital parameters of a patient (i.e. heart rate, respiration rate, lungs, etc.) non-invasively [10]. In a body area network, this data is collected by sensors that are communicating wirelessly with access point placed on the body. Such sensors require two separated units; one unit for sensing and the other for communications purposes. A drastic simplification of this type of sensors could be achieved by signal processing if the signal that propagates through a body (a channel) can provide also such a vital data of interest.

UWB can also be obtained in in-body communications from implanted sensor to access point on a body. Ultra wide bandwidth provides tools to measure the spatial movement or trajectory of an implant after installation. This has a great impact on human healing process because the implant can non-invasively report its conditions.

III. Review to UWB WBAN Radio Channel Models

Medical systems operating in very close vicinity of a human body are one special example of wireless networks that can utilize UWB radio. The goal of the WBAN radio channel measurements to be discussed next was to define accurate channel models for WBAN system design. The collected data are measured in various environments and targeted for numerous applications from which medical ICT is the most interesting one. Summary of the existing WBAN models is given in [8].

All the measurements discussed in this paper were carried out using HP Agilent 8720ES vector network analyzer, thus performing S21-parameter measurement with 0 dBm transmission power.

The radio channel in a WBAN application is affected by several phenomena, such as human or limb position, age and sex. In addition, the environment has impact on the radio wave propagation and interference level. For example, the posture of an arm directly defines if the channel between two body nodes is obstructed or line-of-sight. Only this change in a link causes significant difference to the received signal power. On the other hand, age and sex have impact to fluid concentration or tissue structure inside a body, and therefore to the dielectric behavior. This means that the relative permittivity of a body is changing and for that reason, the radio propagation is different [10].

In addition, implants inside a body have an impact on the radio channel as shown in Figure 3. Metallic components in the implant change the propagation properties, and the measured channel impulse response is dissimilar if compared to non-implanted one. The radio channel measurements carried out in UWB frequency band from 3.1 to 10 GHz expressed these hypotheses. The channel impulse response of a person having a heart implant differs significantly from the responses of non-implanted persons. A similar phenomenon than an implant has on the radio propagation is caused by brassiere. They have also metal in their structure and therefore they are changing body's dielectric properties.

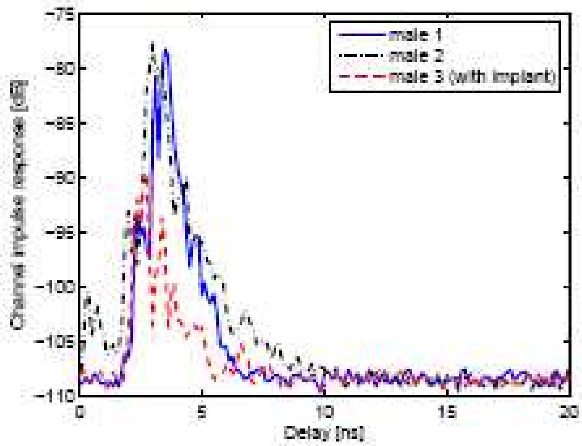

Figure 3. Channel impulse responses of different males. One has a heart implant.

The antenna installation has also great impact on radio wave propagation as shown in Figure 4. The electrical coupling between the antenna and body is changing the antenna's radiation pattern. In addition, the body absorbs part of the emitted signal energy if antenna is attached straight to skin. However, the electrical performance of an antenna can easily be improved using isolating material between the skin and the antenna element.

The example shown in Figure 6 distinguishes the channels during the eating cycle that is shown in Figure 5. The measurements have been carried out for lying person who is eating. As it can be seen, the environment has an impact on the channel behavior; even if the measured network is low power WBAN having nodes in a wrist and a chest.

The previous example pointed also out a difference between the channels measured at hospital and in an anechoic chamber. The results are shown in Figure 6. The out-of-body propagation causes multipath propagation in a similar way than in other communication systems. However, the small transmission power used in WBAN applications reduces the amount of significant multipath components detected at the receiver.

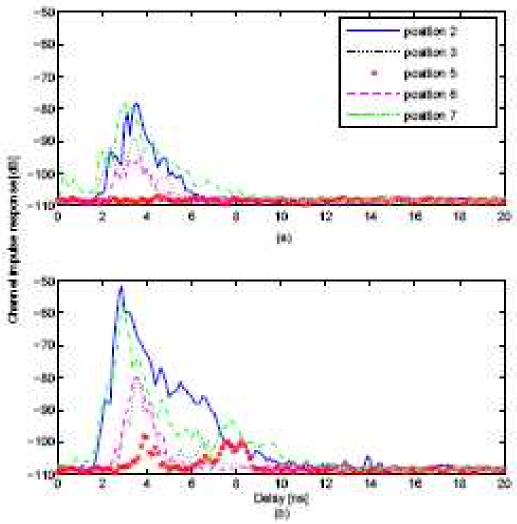

Figure 4. Impact of the sensor position and a dielectric plate on the channel response. On top, the antennas are placed on skin.

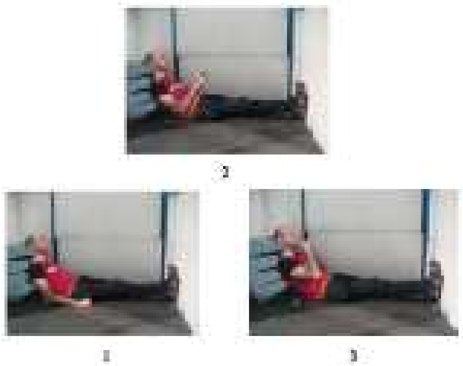

Figure 5. Eating cycle showing different arm positions.

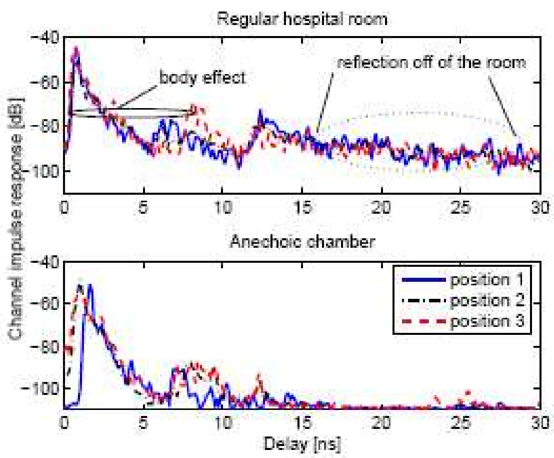

Figure 6. Measured radio channel during eating cycle.

One important finding from the UWB WBAN radio channel measurements is that the signal is not passing through a body. Instead, the signal transmitted from the back to the chest propagates as a surface wave on the body. This means that the first signal component arrives later than the shortest path (thus through body) assumes.

By adopting new technologies in healthcare, independently on the radio standard, the care processes could be green, meaning that the movement from one place to another can be diminished. In a long run, this has a great impact on the care costs.

IV. Summary

This paper summaries the conceptual idea of a medical body area network architecture that is connected to healthcare professionals' information system. Due to the low power spectral density of an UWB transmission, the technology fits nicely to medical and welfare applications. Wireless body area network is one special topology to collect human's vital information and transfer it even automatically to the healthcare professionals. In UWB frequency band, the radio channel in a close proximity of a body has its own impact to the propagating signal. The received signal power depends for example on sex, age, posture and the amount of implants of the person.

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