Wireless Communications in Healthcare
Recent and Future Topics

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ABSTRACT
Utilizing information and communications (ICT) technologies for healthcare and medical purposes has obtained a lot of interest and attention during the recent years. All over the world, in Europe, Asia and US, several universities, research institutes and companies have contributed via numerous programs, collaborations, and projects for the topic. This paper gives an collage of the latest interests in the research of field of interest carried out by the Centre for Wireless Communications (CWC), University of Oulu, Finland. We are also summarizing our views of the future development in this very important field. Wireless technology will be one of the key elements when improving safety and effectiveness of healthcare processes in its different application sectors.

Keywords
Wireless sensor network, wireless body area network, channel modeling, behavioural analysis

1. INTRODUCTION
Wireless communication has been shown its usefulness in several application fields. Medical and healthcare sector is not an island which cannot benefit the success of wireless data transmission. On the contrary, a lot of benefits and cost savings are seen. Awareness of information communication technology (ICT) is nowadays widely spread throughout the population. One growing field of research in this direction is related to the ageing of the population. Moreover, big distances from home to healthcare facilities in scarcely populated countries, as well as lack of resources in both scarcely and dense populated areas bring together the same needs: to increase self-management of chronic conditions and to introduce remote healthcare solutions. In this way, people can receive two main benefits: their quality of life is increased and the expenses for healthcare facilities are decreased.

In the previous years, wireless technology is adopted in several consumer and home appliances and the major booster has been cable replacement. Higher and higher data rates are targeted and one key feature has been user-friendliness.

In healthcare and medical sector, the main requirements are reliable, robust, secure and safety communication. There is no room for faults when dealing with the medical information. Another issue is data security. Data should be available only for authorized personnel. Getting rid of data cables give user a freedom to move but it also improves the safety in operations and independent being. All theses should be ensured by demonstrations and test campaigns before new solutions can be taken into real operational use.

Wireless communication opens also a question on possible harm of the transmitted electromagnetic (EM) radiation. Effective radiation power (ERP), and specific absorption rate (SAR) are instruments to analytically evaluate the impact of EM on human body. Even there have been wireless applications available for years the absolute safety limits are not unambiguously defined.

Though there are lots of wireless applications already in use in hospitals and other care units, there are still room for new research and innovations. For example, generic conceptual architecture, related channel models and safety protocols are such themes which need further studies. Also, during the last few years, the standard for wireless body area networks (WBAN) in health and consumer related applications have been prepared by the study group IEEE802.15.6 [1]. At the moment, the IEEE preparation work is at the final stages.

Medical ICT technology based systems and their development requires different players and experts, e.g., end users, hospitals, physicians, economists and engineers. Also differently oriented engineers should be included, i.e., signal processing, data processing, communications and RF experts. The meaning of wireless solutions has increased significantly. CWC plays in its own role in the whole concept: investigation and development of a link within a wireless body area network and a link from WBAN access point to room/home access point. As a whole, the research activities include the following main topics: Channel modeling for wireless body area networks; Performance evaluation of receivers for WBAN medical care applications; System architecture of WBAN sensor network; Prototype development for medical parameters measurements and End-user applications and services. The work carried out at CWC relating to medical ICT sector has been summarized in [2]-[5].

2. GENERAL ARCHITECTURE
The use of wireless technologies can be seen as a fast, practical, and convenient way for finding new means in home-care related procedures. Technologies that do not require installing cables at home, as well as the possibility of monitoring parameters, not only in a closed environment but also in outdoor spaces to improve patient's mobility, must be exploited in order to create cutting-edge solutions for the mid-term markets. Self-care, self-management and cost effectiveness will be the key factors towards the development of these new innovative solutions. A concept that can be effectively used for improving the existing working procedures and distribute the medical information processing have a huge and global market potential.

The overall objective of the general architectural solution is to provide wireless ICT and self-learning solutions in planning and developing a 'wireless hospital' or 'distributed hospital' with cognitive radios and smart components, and is based on the collaboration between hospitals, patients and healthcare services and also service providers in the community, and benefits therefore from the advantages of modern ICT technologies.

The advanced ICT and the self-learning solutions will help population of elderly people independently live at their homes. Moreover, this population has typically one or more chronic diseases such as diabetes, cardiac disease and they use medication. The general "virtual hospital" system will provide monitoring of physiological parameters and also disease management system, adverse drug reaction, early detection of increased risk of falls, depression, sleep deprivation etc. and alarm the human in the loop on a timely basis taking into account long term and short term analysis of behavioral and physiological data. Cognitive evaluation using tests and automated remote behavior monitoring will enable, e.g., early detection of dementia or other diseases.

A smart and self adaptive environment will be enabled via a wireless sensor network, under the control of a home gateway. Information processing can be distributed between the gateway and different sensor nodes (e.g., location, environment, context and patient awareness). The complexity of wearable user sensor devices is kept to a minimum. The target is to facilitate unobtrusive solutions for the user (e.g., smart environment plus miniaturization, ultra low power wearable sensor devices). With the aid of careful planning, the concept itself is adaptable for several different applications.

3. APPLICATIONS

How and how often clinical parameters are collected from human depends on the application. It is possible to aggregate real time or buffered data and then transfer information to distant destination. One type of classification of parameter monitoring is shown in Figure 1.

Independently on the use case, the application and overall wireless system concept need to adapt to various requirements. Applications requiring high data rates can be used occasionally, but most of the time, the transferred data consist of only few status or single value bits. This reflects not only to physical layer design of the protocol stack but also to higher layers of it.

Varying loads requires adaptive medium access to optimally sharing the radio spectrum with other users who also have changing needs. Wireless medical monitoring system cannot be based on the fixed spectrum utilization.

Human care is the most important application in health related context. However, similar approaches than used with humans can be exploited with animals. Added value can be achieved by remotely monitoring grazing cattle or install remote sensor to cow houses etc. A wearable system carried by human is possible to modify for animal use which increase the market potential of the developed system. Even thought the system architecture and algorithms are the same, the final manufacturing and implementation differs.

Another issue in future healthcare trend is to move focus from care to prevention. From cost perspective, touching the medical problem early enough will help to reduce the costs.

Depending on the application, scenario and environment, there can be different kinds of requirements for the quality and amount of payload for wirelessly transmitted signal. The number of sensors needed at one time instant depends on the application and thus simultaneous network usage is varying. This has an impact on cumulative network load. In addition, the amount of preprocessing and coding in a source node or body access point reflects directly on the network traffic and power consumption.

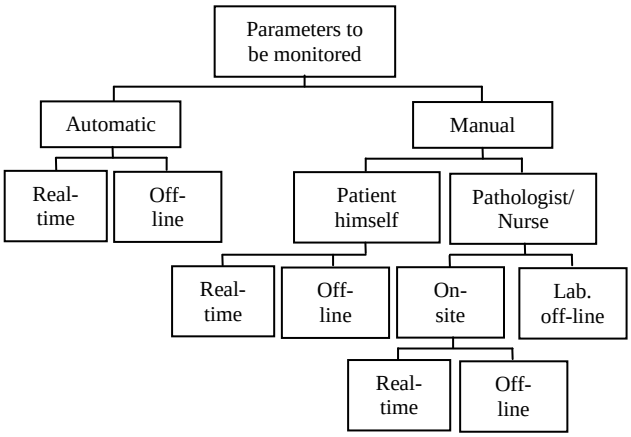

Figure 1. Classification of parameter monitoring.

4. RECEIVERS

The implementation of wireless monitoring systems depends on the final application and end-user environment. This concerns not only wearable gadgets but also surrounding network structure. Furthermore, this has a straight impact on transceiver selection and signal design. Different standardized solutions give a base to select proper signal structure to satisfy the given requirements.

The WBAN system concept study requires information on radio channel propagation characteristics which was the base for our WBAN channel modeling activities. CWC has carried out experimental studies in different environments, including hospital, as referred in [5]-[8].

In the transceiver research, CWC is focusing on UWB receiver investigation using different measured channel models for wireless personal area networks (WPAN) and WBAN, as well as comparison with literature based WBAN channel models. Latest comparative results for have been presented in [9]-[14]. As has been shown, e.g., in [14], the channel model should be selected as realistic as possible because it can cause significant differences in the bit error rate performance of the receivers. The other links (from room access point to data base) can be quite easily based on current well known solutions. Of course, access granting and security offers nice research topics in this as well.

Low complexity in such makes it possible to produce devices having long life time due to their low power consumptions. On the other hand, there is a drawback based on the computational capabilities and lower performance limits. As a result of the receiver research, it is evident that some sort on intelligence and adaptive algorithms should be included to the receiver to select its parameters depending on the situation, e.g., where the WBAN is used.

5. FUTURE TRENDS

Future communication systems are driven by the concept of being connected anywhere at any time, i.e., ubiquitous communication. In addition, recent years have provided us lots of technological solutions to be implemented in different applications. However, the future trend in healthcare is going to two directions: firstly, for smaller particles, and secondly for larger networks of various kinds of networks.

Wireless medical communications by replacing assisting people's work and replacing wired links by wireless connections in a hospital are applying new applications in a healthcare and welfare sector. One example is wireless medical telemetry which is a remote monitoring of a patient's health with the help of radio technology. This gives patients a greater mobility and an increased comfort by freeing them from the need to be connected to medical or hospital equipments that would otherwise be required to monitor their condition. This improves quality of patient care but also the efficiency of hospital administration.

Moreover, wireless medical telemetry also reduces healthcare costs because it permits remote monitoring of several patients simultaneously. The development of this technology will lead to utilization of WBANs, where sensors placed in-the-body (implantable sensors) and on-the-body (wearable sensors) can communicate with the outside world using wireless networks and provide medical information for further studies. The measured physiological information can be forwarded to, e.g., a physician, in real-time. The coming IEEE802.15.6 standard [1] will give a boost for this development. IEEE802.15.6 standard can also give a new boost for utilization of ultra wideband technology in general because UWB is selected the physical layer technology by the standard.

In the first, on we need to think, what nanotechnology can provide for medical and healthcare sector? The future applications are based on extremely small and dedicated gadgets which are circulating e.g., in a blood vessels. Small devices can take samples inside a body without a surgery, operate as a diagnostic device or they can deliver drugs to very specific destination. All these methods are improving the patient's safety and save the patient from a possible surgical procedure. Communication, sensing, measuring, and networking challenges of small and nano-scale wireless sensor networks is interesting, as well as realization of such nano-scale devices. Even though the communication and networking problems are, to some extent, similar to those in current wireless sensor networks, the remarkable smaller node size and limited power resources make the problem also very different in many respects. As a consequence, it is important to obtain knowledge of nano-scale processing and electronics in addition to communication aspects only.

For wireless technology, new applications and tools will provide new challenges. Nanogadgets should be controlled wirelessly or they can provide real time information from inside a body. Taking a small sample of a tissue whose location is preliminary specified, or decision is based on the real time figure, set high demands for positioning accuracy, control signaling and data traffic without speaking the safety margins of EM radiation.

Without going to implementation of this kind of miniaturized device, there are problems for telecommunication engineers too. Antenna design for in-body nano-devices will provide room for new innovative solutions.

The second direction, larger or dense network, direction is due to fact that a lot of WBANS (both in and onbody) have to work in the close vicinity of each other. Other networks, e.g., machine-to-machine (M2M) due to hospital equipment, can be used in the same area. All of there may be connected to the same backbone which can also be wireless. All these lead to dependable wireless networks research taking into account security in different levels (link level and networking level).

When dealing with wireless connections, there can be multiple networks available. This gives pressure for cognitive approach by providing tools to select network type based on the need. There is also a tradeoff between the computational capability, memory amount and such, and power consumption.

6. ACKNOWLEDGMENTS

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