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Body Area Network: Analysis and Application Areas

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Abstract:- The communication standard 802.15.6 was published at the beginning of the year 2012. This standard is also known under the acronym WBAN by the first letters of the description "Wireless Body Area Network." This paper is devoted to this new communication standard that is primary designed to create applications in the medical field. The paper analyzes assumptions and limitations of this communication standard which have to be met for the medicine applications. It also analyzes restricted frequency band and application possibilities. Finally, the communication system BodyCom is compared with the HBC standard.

Keywords:- BAN, IEEE 802.15.6, application areas, BodyCom, communication channel

I. INTRODUCTION

Problems of measuring various parameters which characterize the state of the human body have relatively long history in the medicine area. At the present, we can meet the increasingly sophisticated methods for measuring and processing data characterizing the health of the monitored patients. There are two basic directions of the measurement and diagnostic systems in the medicine area:

- Powerful, diagnostic equipment (computer scanning devices using magnetic resonance imaging, ultrasonic tomography, etc.).
- Relatively simple measuring systems, which can continuously monitor selected parameters characterizing the patient's state of health with data pre-processing possibility and mutual communication. These systems allow remote monitoring of patients without activities limiting, evaluate critical situations and inform the doctor in the remote monitoring center.

In the case of using more energy-efficient sensors located on the body or clothing of the monitored person it is possible to obtain a lot of information about the activities, vital signs and the patient's condition. Based on this information it is possible to detect the health risks, trends and diagnosis, which depend on the measurement variables only indirectly. Sensors placed on the patient's body are creating a network of sensors - BSN (Body Sensor Network). If we expand BSN for other devices (pacemakers, implants and wearable audio-video equipment) we get a new group of devices. If these devices can communicate with each other they create a network known as Body Area Network (BAN). BAN is a network for short range wireless communication in close proximity of, or inside a user's body. The basic BAN applications can include:

- Physiological and vital signals monitoring: Blood pressure sensor, heart rate monitor, cardiac arrhythmia, motion sensor, temperature sensor, respiratory monitor, saturation of oxygen, breathing monitor, electrocardiogram, electro encephalography, electromyography, Ph value, glucose sensor etc.
- Stimulators: Cortical stimulator, deep brain stimulator, neuro stimulator, wireless capsule for drug delivery, brain-computer interface etc.
- Remote control of medical devices: Pacemaker, insulin pump, hearing aids, cochlear implant, implantable cardioverter defibrillator, retina implants, actuators etc.
- Fitness Monitoring: heart rate, speed motion, respiration monitor, temperature etc.
- Entertainment applications: Audio (ear set, microphone, player), video (camera sensor), cellular phone etc.
- Disability and Elderly people assistance: Muscle tension sensing and stimulation, fall detection, foot sensor for steps monitoring, breathing sensor, temperature sensor, movement sensor etc.
- Other applications: Industrial automatization, authorizing access systems etc.

For the information transmission in close proximity of the human body it is possible to use radio communication or a user's body as a communication channel, while it is assumed capacitive or galvanic coupling between the transmitter and receiver (transceiver 1 – user's body – transceiver 2). This is the base principle in the human body communication (HBC) area.

In order to unify the rules of communication in the BAN a working group TG6 was established in March 2007. This working group was charged with developing a communication standard design for the medical field applications. The work was completed in 2012 by defining medium access control (MAC) and physical (PHY) layer communication standard which is often known as Wireless Body Area Network (WBAN). The communication system has to respect some specific restrictions related to the target application area. These must include following in particular:

- Specific Absorption Rate (SAR):
  - 1,6 W/kg averaged over 1 gram of actual tissue.
  - 0,08 W/kg average value calculated for the whole body.
- Restrictions for the broadcasting bands:
  - 25 μW maximum radiated power in the frequency bands for communication with implants and other regulatory authority directions.
- Restrictions for energy consumption:
  - Small size batteries and the maximum operating time etc.
- Requirements for transfer rate:
  - 10 Kb/s to 10 Mb/s depending on the application.

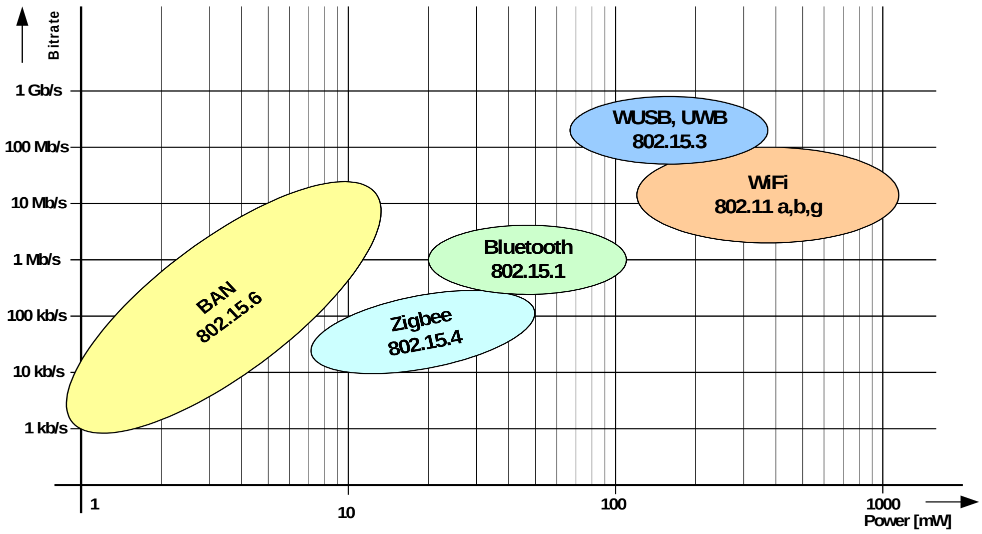

Fig. 1: Comparison of current RF communication standards

The work on the communication standard 802.15.6 is successfully completed now and it is on the manufacturers of semiconductor devices to support the standard by appropriate semiconductor devices portfolio and allow the development of new applications. The Figure 1 illustrates a comparison of the current communication systems for wireless personal area network WPAN in terms of average power and bit rate.

II. STANDARD IEEE 802.15.6

As part of the IEEE 802.15, the working group TG6 has developed communication standard oriented for communication between the energy-saving devices which operate close to or inside the human body. Note that this communication standard is not exclusively intended to support medicine applications, but it can be used for consumer electronics, sport, entertainment, creation of new applications in social networks, and many others, now still unknown applications.

The standard supports two basic communication network topologies in particular. These are the star network topology with one skip and extended star network topology allowing two skips.

The communication standard 802.15.6 defines only the two lowest layers of the wireless communication system (Fig. 2.). It is the physical layer and the transmission medium access control layer.

The standard supports three different physical layers - narrowband NB-PHY layer, ultra wide-band UWB PHY layer and the communication within the human body HBC-PHY. Physical layers are designed for different applications, based on their specific requirements.

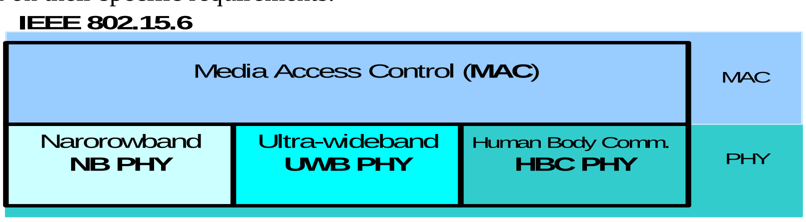

Fig. 2: Physical layers defined by standard 802.15.6

Narrowband NB-PHY layer can use the following frequency bands:

- 402 to 405 MHz MICS – reserved band for communication between and with implants,
- 420 to 450 MHz telemetry – Japan,
- 863 to 870 MHz ISM Europe band,
- 902 to 928 MHz ISM USA band,
- 950 to 958 MHz ISM Japan band,
- 2360 – 2400 MHz MBAN – medical body area network band,
- 2400 – 2483,5 MHz ISM worldwide band.

Narrowband NB PHY layer supports data rates from 100 kb/s up to 1 Mb/s. It features low power consumption up to 10 mW. Note that the same frequency bands are used by other narrowband communication systems (802.11 b, g, n, 802.15.1 and 802.15.4).

The ultra wide-band UWB-PHY layer uses a frequency band in the range from 3 GHz up to 10 GHz. Within this frequency range there are defined 11 transmission channels, three in the lower frequency range from 3 to 5 GHz and eight in the upper frequency range from 6 to 10 GHz. Within each physical channel there are four logical transmission channels defined. Transmission speed range is from 395 kb/s up to 12 636 Mb/s.

HBC-PHY layer uses the following reserved frequency bands:

- 18,375 – 23,625 MHz USA, Japan, Korea,
- 28,0 – 36,0 MHz USA, Japan, Korea,
- 14,0 – 18,0 MHz Europe,
- 25,0 – 29,0 MHz Europe.

Transmission systems are using capacitive binding to the human body. This solution is pointing at wired communications solutions more than at RF transmission systems. For the data transfer only two channels with the center frequency fc = 21 MHz and fc = 32 MHz are reserved. Transmission rate for the first channel is in the range from 164 up to 1312.5 kb/s, and from 250 up to 2000 kb/s for second channel. Fig. 3 illustrates the using of the appropriate bands.

The transmission channel access control layer (MAC) defines how the individual nodes of the communication network can access the transmission medium. Transmission channel is divided into superframes. Each superframe has the same length and is bounded by "Beacon" period defined by the network coordinator. The network can operate in one of the following three modes:

- The "Beacon" mode with "Beacon" period and superframe boundaries.
- The "Non-beacon" mode with superframes.
- The "Non-beacon" mode without limits.

The following mechanisms are used to control the access to the transmission medium:

- Random access using CSMA/CA, or time-division multiplexing using the ALOHA procedure,
- Improvised unplanned approach based on query/broadcast,
- The planned approach, which plan the time slots allocation in one or more incoming superframes.

All these work and transmission channel access control mechanisms are described in detail in the 802.15.6 standard.

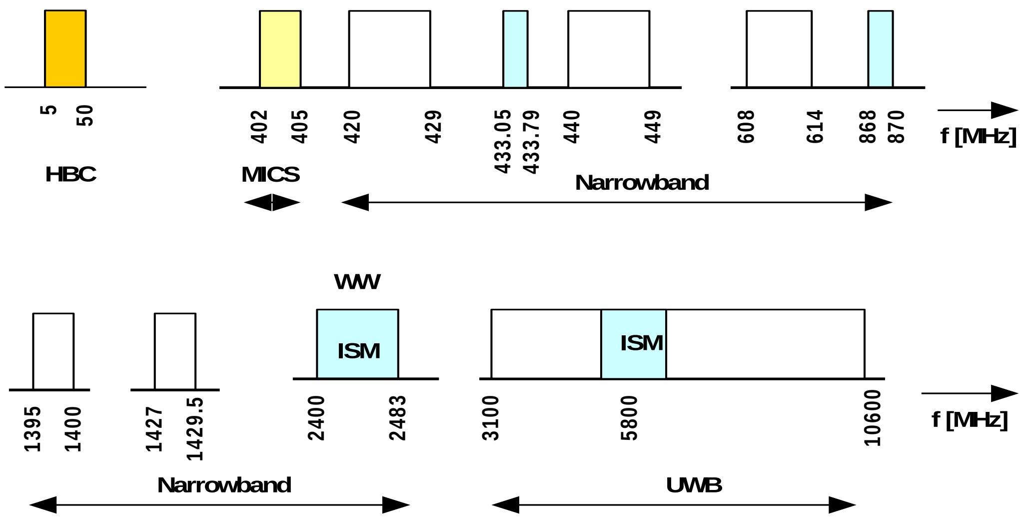

Fig. 3: WBAN frequency bands

III. BODYCOM

Traditional short range wireless data transmission systems rely on the typical frequency like 434 MHz, 868 MHz or 2,4 GHz. They provide comfort and convenience of wireless control for its owner, but these systems are vulnerable and may pose a potential security threat to the user. These threats may mean increase of the design costs and can reduce operator comfort.

Precisely for these situations is determined by BodyCom system, which aims to overcome these threats and utilizes the user's body as an ideal medium for the transmission of data. The principle of the system is simple and lays in proximity or contact of the user with the basic unit on one end of communication channel and for example a mobile phone on the other end. Data is transmitted using capacitive coupling between the base station and the mobile unit, while the transmission uses a simple amplitude modulation (ASK) and an agreed data format. Because the data is coupled through the user, there are no RF transmission security issues. As the mobile unit must be in close proximity to the body, abuse of such a system is considerably more difficult.

BodyCom is a new system from Microchip [6] for control and data signal transmission over the short distances. BodyCom technology uses the human body as the communication channel. The result is an intuitive, easy and secure communication system to connect two compatible devices. BodyCom system principle is not new, it has been known for many years. It uses the fact that there is a capacitive coupling and the transfer of energy between the devices placed a few centimeters away from the body and the body itself. The system interconnection can be created by proximity or direct contact of the body with the device. Basic block schematic of the communication system is depicted in the fig. 4.

The main features of BodyCom include:

- Very low power consumption, especially for mobile units,
- Fast response times,
- Stable and robust communication with the faults detection,
- Limited scope (range of a few centimeters), so the identification is possible only with the owner of the mobile unit,
- The simple design and low manufacturing cost.

Human body when used as a communication channel causes different attenuation of the various signal transmission frequencies. Therefore, it is useful to use two frequencies in practice. Low-frequency signals are attenuated more than higher frequency signals, so the mobile device uses a higher frequency that need lower power output. The main reason is that the mobile unit is usually only powered by batteries and its consumption is one of the priorities. While the base unit is usually supplied by the network and the communication can deliver more power.

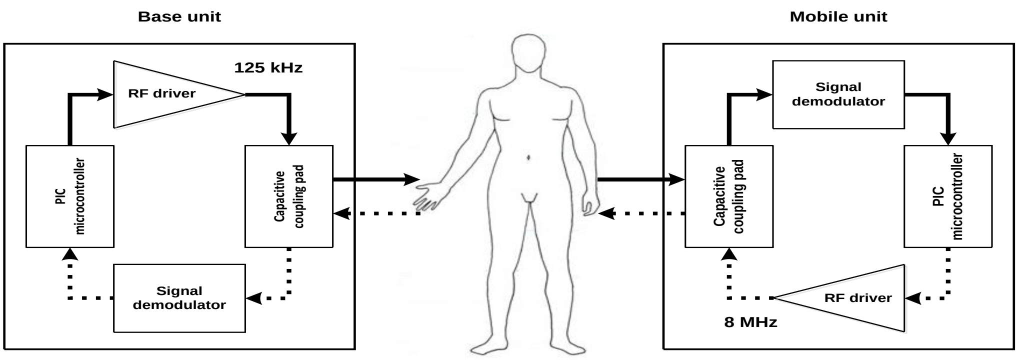

Fig. 4: The basic block schematic of the BodyCom system

Another limitation for the communication frequency choice is based on consumption of the mobile unit in the receiving mode. Typical components that are commonly available for the receiver circuits offer low power consumption only when operating in a frequency range from about 60 to 400 kHz. For transmitting is recommended to use the frequency range 6 to 13 MHz, where can be found the optimal relationship between the consumption of energy and transmitting power in a given frequency range.

In example presented in fig. 4 is used signal with frequency 125 kHz for the data transmission between PC and the mobile unit. To transfer data between the mobile unit and the base station is used signal with frequency 8 MHz. The mobile unit power consumption according to [7] is:

- 3 µA – waiting for a signal,
- 160 µA – receiving the signal,
- 1.3 mA – decoding data,
- 17 mA – transmitting of the answer.

It is obvious, that the BodyCom solution is not direct implementation of the HBC physical layer. Although they are using the same working principle, the frequencies are different. So it is on the user's decision whether he uses existing solution or will wait for the devices which fulfill the 802.15.6 standard requirements.

IV. CONCLUSIONS

Progress in communication technologies allow to realize low power short range wireless communication systems WBAN. WBAN systems stimulate the development of new exciting applications not only in medicine area, but also in many other areas. Today, it is possible to assume that the applications of WBAN will probably have a great influence on the life of every individual.

It is necessary to count with this reality and to prepare for the expected applications expansion, not only technically but also in terms of legal, social and economic impact. Technological progress is neither possible nor practical to stop but it must be streamlined to provide benefits for all interested. It is necessary to find a compromise between the negative effects of developed applications and their benefits.

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