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A ZIGBEE SOLUTION FOR TELEMEDICINE APPLICATIONS

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Abstract: The paper addresses several aspects regarding wireless communications in telemedicine applications. Possible solutions and comparisons between different technologies are presented. A ZigBee based implementation case study is commented.

Key words: *telemedicine, wireless technologies, ZigBee, sensor network, wireless body area network.*

I. INTRODUCTION

Telemedicine can be defined as the delivery of health care and sharing of medical knowledge over a distance using telecommunication means.

Nowadays there are several aspects which determine the promotion of advanced technologies for the restructuring medical services, allowing unrestricted access to this type of services, with superior clinic results and lower costs, [1]:

- People are living longer than ever before in history.
- They are better educated and are more comfortable with the use of technology.
- Most people want to remain independent and live in their homes for as long as possible, yet greater numbers of persons are suffering from chronic conditions.
- The health care industry is facing a critical shortage of public resources, as well as nurses and other health care personnel to care for patients.

The advantages of wireless technologies in telemedicine can be exploited in two important directions: for supervising the status of patients in their own homes, especially for the case of elderly patients or those suffering from chronic diseases and for hospitals, in order to increase the efficiency of diagnose or surgery processes, for supervising patient treatments or their rehabilitation.

Nowadays there are several implementation of telemedicine systems which prove the merits of these type of health care systems, [2], [3].

The paper presents a possible solution for monitoring different vital signs using ZigBee based sensor networks. After reviewing the main wireless technologies in Section II, we describe the main parameters of the ZigBee protocol. In Section IV, details of the implementation solution are commented, followed by a brief conclusions and future work section.

II. WIRELESS TECHNOLOGIES

The performances of different communication technologies used for creating wireless networks can vary significantly. The criteria for selecting a specific one are mostly based on historic or availability reasons. For the case of telemedicine application, where a Body Area Network (BAN) must be implemented, usually a compromise has to be made between the requirements for the necessary bandwidth (most frequently less than 10kb/s), the life-time of the battery and the robustness/security of communication.

Figure 1 presents the placement of the main wireless protocols with respect to data rate, complexity and power consumption.

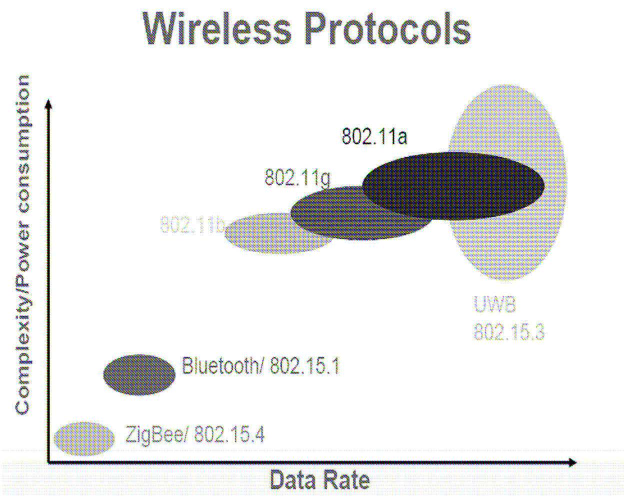

Figure 1. The main wireless protocols

There are now two worldwide open standards candidates for implementing wireless solutions in telemedicine: Bluetooth, [4] and ZigBee, [5]. Basically, each of them support the necessary requirements for BAN implementation.

Bluetooth, [4], is the leader in Personal Area Networking (PAN). It has a relatively complex protocol stack, which requires additional hardware resources to run. Available free protocol stacks are Linux-based, thus

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requiring a system capable of running Linux on the HW-platform. Commercial protocol stacks are available for smaller embedded systems. One of the most used Bluetooth profiles so far has been the RFCOMM profile, which emulates a serial port interface. Hardware modules that provide the user with an RS232 (or RS485) interface while transmitting data wirelessly via Bluetooth are available from several manufacturers. These modules offer simple solution for wireless Bluetooth-based data transfer, which is easy to implement on top of an existing serial port based communication.

ZigBee, [5], was designed to be a low cost alternative to Bluetooth. The physical communication is developed as the IEEE 802.15.4 standard, but ZigBee protocol is less complex than Bluetooth, estimated to be about 10 % of the size of a Bluetooth stack, although it also has 133 simple networking functionality. Transmission speeds are slower, but the range is larger. ZigBee has operating modes for three different frequency bands, from which the 868 MHz and 2,4 GHz bands can be used in Europe.

In Table 1 we present a comparison between the main parameters of the networks build based on ZigBee and Bluetooth technologies respectively.

Table 1. Key features of Bluetooth and ZigBee wireless technologies

Standard / Parameter	**IEEE 802.15.4 ZigBee**	**IEEE 802.15.1 Bluetooth**
Wireless frequency	2.4 GHz/ 868MHz/ 915MHz	2.4 GHz
Data rate	20 kbps up to 250 kbps	1000 kbps
Typical current consumption (Tx mode)	30 mA	50 mA
Battery Life	100–1000 days	1–7 days
Network size	Up to 65536 nodes	Up to 8 nodes
Range	1-100m	10-100m
Stack Size	4 – 32 KB	250 KB
Application	Monitoring & Control	Cable Replacement

A pertinent comparative analysis of the use of the two technologies in telemedicine applications can be found in [7].

III. ZIGBEE TECHNOLOGY

One of the most promising candidates for communication in sensor networks is ZigBee. Because the ZigBee specification was created in an open-consortium, working-group-driven process, it is often argued that ZigBee will succeed in setting the dominating standard at least for the home control applications, which can be an important component of a telemedicine application (personal monitoring combined with position sensing, remote monitoring and control of different medical or household devices, panic-button type systems).

Sensor applications have special requirements, particularly with regard to power consumption. Sensors often have to work for years on a coin cell battery, or on energy harvested from the environment through a solar panel or vibration harvester. Other sensor-specific requirements are governed by factors such as reliability, communication range, the large number of nodes that may need to be supported in a single network, and the need for automatic network organization. In return, a lower data rate is generally acceptable, as most sensors generate fairly small amounts of data, and generally not on a continuous basis.

ZigBee networks are primarily intended for low duty cycle sensor networks (<1%). A new network node may be recognized and associated in about 30 ms. Waking up a sleeping node, accessing a channel and transmitting data takes about 15 ms respectively. ZigBee applications benefit from the ability to quickly attach information, detach, and go to deep sleep. These procedures occur much faster than that using the Bluetooth technology. The structure of a ZigBee network is depicted in Fig. 2.

A ZigBee system consists of several components. The most basic is the device. A device can be a full-function device (FFD) or reduced-function device (RFD).

The FFD can operate in four modes: a personal area network (PAN) coordinator, a router, a gateway or a terminal. A network shall include at least one FFD, operating as the PAN coordinator.

An RFD is intended for applications that are extremely simple and do not need to send large amounts of data. An FFD can talk to RFDs or FFDs, while an RFD can only talk to an FFD.

ZigBee supports three types of topologies: star topology, peer-to-peer topology and cluster tree.

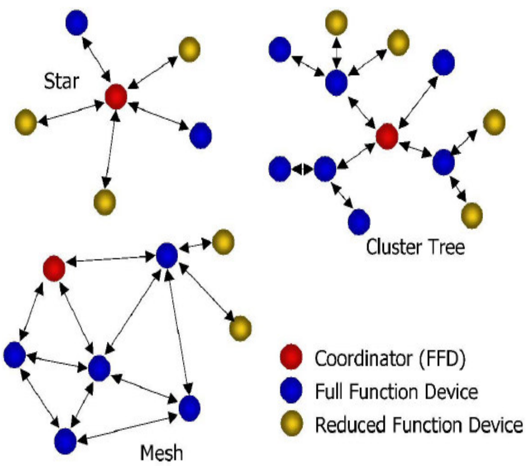

Figure 2. ZigBee network structure

By using ultra low power ZigBee-based wireless networks, it is now possible to create highly reliable and cost effective sense and control networks for a wide range of industrial, manufacturing, healthcare and warehousing operations including environmental and safety regulation.

A standard has been developed for such wireless applications by the IEEE, [6]: "The IEEE 802.15 Task Group 4 is chartered to investigate a low data rate solution with multi-month to multi-year battery life and very low complexity. It is intended to operate in an unlicensed, international frequency band". The scope of the task group is to define the physical layer (PHY) and the media access controller (MAC).

A graphical representation of the areas of responsibility between the IEEE standard, the ZigBee™ Alliance, [5], and the User is presented in Fig. 3.

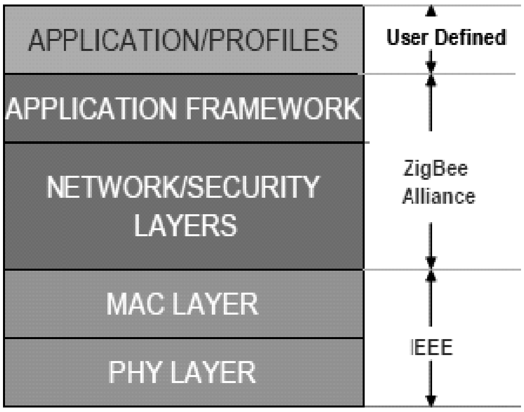

Figure 3. IEEE 802.15.4 Stack

To conclude, recently, [8], ZigBee has been proved to be a key technology for home automation and sensor networks, but also extremely valuable in some healthcare applications. In telemedicine applications, reports showed that for mobile nodes attached to people, ZigBee has the data rates to allow "person down" alarms to be complemented by sophisticated functions ranging from monitoring blood pressure, to breathing or heart rate. Raw data can be transmitted to a central location using a broadband line, or analyzed and stored locally for review on demand. This information can then be used by social services or doctors to monitor when intervention might be required.

More and more manufacturers are interested in integrating both the RF components and the microcontroller, so as to provide support for different complex applications. There has been reported for example, [9], that Freescale's MC13224, besides the necessary RF components, will also pack a 32-bit ARM7 microcontroller running at 26 MHz, two 12-bit analog-to-digital converters, an on-chip IEEE 802.15.4 transceiver, flash memory, RAM, ROM and all necessary RF matching components.

The Platform-in-Package provides what Freescale claims to be the best-in-class RF performance, supporting speeds of 250 kbits/second while requiring just 28 milliamps to transmit, 21 mA to receive and 1 uA during sleep mode. Maximum output power is +5 dBm and receiving sensitivity is -100 dBm.

All these will allow usage of specialized miniaturized system-on-chips for various applications.

IV. ZIGBEE CASE STUDY

Having in view the properties of the ZigBee protocol and its demonstrated adequacy for telemedicine applications, we have investigated the possibility to exploit this specification for the transmission of medical or control signals to a base station using the MCF5213EVB platform from Freescale Semiconductor, [10].

The evaluation board comprises: a transceiver MC 13192, the microcontroller MCF5213, 256 KByte Flash, 32 KByte SRAM, a DMA controller, a DMA, interrupt controller, ADC module, QSPI module , PIT timers, GPIO interface, an 8MHz Quartz, 60 I/O ports, 3 UART ports,3.3V supply.

Freescale ZigBee Family of IC's supports multiple protocol stacks: a ZigBee Compliant BeeStack™ and a Simple MAC (SMAC), IEEE 802.15.4 Compliant PHY/MAC. This allows developers to build solutions that meet the needs of their applications, reducing the time-to-market requirements.

Freescale's SMAC, [9], presented in Fig. 4, is a proven stack that is designed for simple and low cost networks, providing point-to-point and star networks as well as repeaters to extend the range of the network. It requires less then 4K of memory, allowing the use of low cost MCUs.

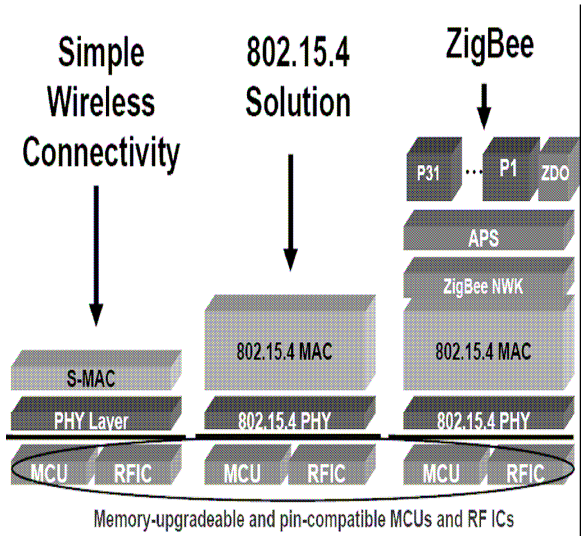

Figure 4. Freescale SMAC stack

The experimental set-up is presented in Fig. 5. We have focused for the beginning on the implementation of two ZigBee nodes: a terminal node – for data acquisition and a gateway node - towards the computer. The terminal (sensor) node software is designed to sample and collect physiological data and to transmit the results wirelessly to the server.

The implementation implied: configuring the microcontroller for data acquisition, commanding the transceiver, transmitting and receiving data using SMAC implementation and transmitting data using the PC serial interface UART0.

The sensor was emulated for experimental tests using a signal generator.

In Fig. 6 we present the flowchart of the implemented node connection procedure.

The application was tested and works for the communication between two nodes and between the gateway node and the computer.

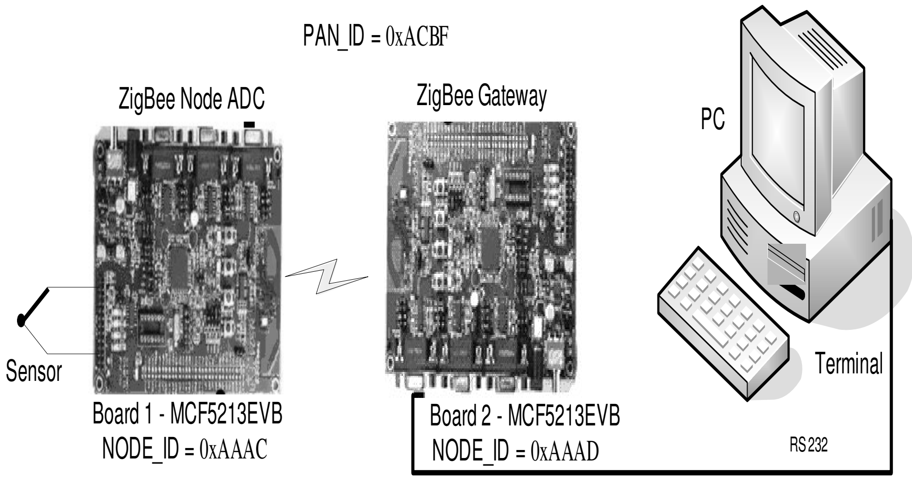

Figure 5. The configuration of the test application.

```
channel scan
if coordinators not found
    association fail
else if no coordinators permit association
      association fail
    else
      select a proper coordinator
      send association request to the coord.
      wait for ACK
       if ACK not received
         association fail
       else
         send data request to the coord.
         wait for ACK
         if ACK not received
             association fail
         else
             wait for association response
             if asso. response not received
                 association fail
            else if association not granted
                 association fail
            else
                  association succeed
```

Figure 6. The flowchart of the node connection procedure

V. CONCLUSIONS AND FUTURE WORK

The successful configuration of the test application proved to provide encouraging results for developing a full functional BAN.

The existing resources for the ZigBee nodes allow further developments, such as: terminal nodes with complex functionality (multichannel acquisition, command and control) and interconnection of several nodes (organizing the net with coordinator node and routing function). We investigate the possibility to implement the full MAC level, as specified in IEEE 802.15.4 and the implementation of high levels of the ZigBee stack.

VI. ACKNOWLEDGEMENTS

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