Reconfigurable FPGA Chip Design For Wearable Healthcare System

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Abstract - Smart sensors, which are created by combining sensing materials with integrated circuitry are being considered for several biomedical application such as a Glucoselevel, Temperature, ECG etc. Practical usability of the majority of current wearable body sensor systems for multiple parameter physiological signal acquisition is limited by the multiple physical connections between sensors and the data-acquisition modules. In order to improve the user comfort and enable the use of these types of systems on active mobile subjects, a wireless body sensor system that incorporates multiple sensors on a single node is proposed. The system must be suitable for longer-term monitoring of the subjects, such as continuous wear and autonomous operation up to several days without replacement of the power source. Thus power consumption is a major challenge in these applications.

Keywords - *Sensors, WBSN, Health Care, FPGA Wireless Networking.*

1. Introduction

Recently, the Wireless Body Sensor Network (WBSN) system has been a popular topic for researchers. Typical WBSN applications include the medical and health applications such as vital signs monitoring, fitness and medical care. Such a network consists of a Moderate quantity of low-power, resource-constrained miniature devices (called the sensor nodes) placed in, on or around the body which are usually wirelessly controlled by a portable central control device. Fig. 1 shows some typical applications in WBSN. In these applications, rather than the peer-to-peer self-organized network topologies, the single-hop star network topology and the master-slave protocol are commonly adopted to lower the system complexity and power consumption as well [1], [4]. A typical WBSN is usually composed of a portable device which serves as the master node for central around, or inside the human bodies that act as the slave nodes. Compared to the master node, the slave nodes have more stringent constraints in terms of power consumption and size limitation. And this work mainly focuses on the slave sensor nodes in the WBSNs, control, and a number of miniaturized sensor nodes placed. Typical WBSN slave sensor nodes can be used for biomedical information acquisition, signal pre-processing, data storage, and wireless transmission. This type of slave sensor node is called the sensing node. In addition, the function of sensor nodes can be expanded to medical treatments, such as drug delivery and nerve stimulating [5], and this type of slave sensor node is called the stimulating node. One difference between the two types of nodes is that the functions of a sensing node are usually periodically performed, while the functions of a stimulating node can be either periodical or event driven.

The specifically designed passive RF receiver can harvest energy from the RF signals in the space (transmitted by the master node which is not power critical), and hence, the passive standby mode consumes zero power ideally. The active standby mode can be used for the sensing and stimulating nodes. As a contrast, the passive standby mode can find its perfect use for the stimulating nodes, since the event-driven stimulating nodes can be woken up on demand without any response latency, while consuming zero power.

In-body medical network may require only moderate data rates and low radio ranges, which can be developed with personal area communication standards such as Zigbee/ 802.15.4. The data collection and distribution back-haul requires long-range and high-data rate technologies (Wi Fi) for wide area connectivity and managing data from several hundred sensors. A mobile communication interface is essential for anywhere anytime alarming about emergencies. These diverse wireless platforms cannot operate autonomously for efficient health tracking. This paper provides a practical implementation of the software and hardware solutions required to enable an integrated health monitoring platform.

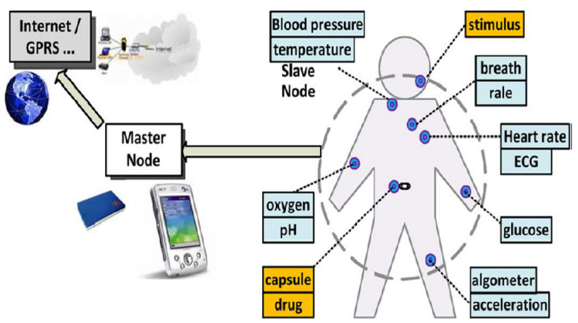

Fig 1. System diagram of typical WBSN applications

2. Wearable Healthcare System Applications

There is a wide range of applications for Wearable Healthcare system in supporting medical and healthcare services. By attaching Wearable devices to patients, vital or healthcare data can be automatically collected, which is then forwarded to a nurse centre for patient state monitoring. The Benefit of this scenario is that it can reduce the working load of nurses and result in increased efficiency on patient management. A reasonable range between these sensors with a receiver carried by the person is set in advance. When the person forgets his belongings and leaves them over the pre-set range, warning signal is generated automatically. Furthermore, in advanced applications, cameras can be attached to a people with visual disability. Pictures taken by cameras are sent to a receiver carried by the people, where they are converted to audio signal to provide guidance to the people. The similar principle can be used for assisting people with speech disability. Here, sensors to catch finger and hand movements are used. The obtained information caught by sensors is converted into speech.

3. Architecture

Wireless Sensor Network (WSN) is becoming a significant enabling technology for a wide variety of applications. The rationale behind the distributed sensor network is for detecting, identifying, localizing, monitoring, and tracking one or more subjects of interest. The BSN node is designed based on the Texas Instrument (TI) MSP430F149 microcontroller. The MSP430 processor is a 16-bit ultra low power RISC processor with 60KB flash memory, 2 KB RAM and 12-bit ADC. The ultra low power processor can operate at minimum of 1.8V, and requires only 3mW at active mode and 15µW at sleep mode, which is much less than the Atmel processor. In addition, it provides a wide range of interconnection functions, such as 12-bit ADCs and serial programming interface. For wireless communication, the ChipconCC2420, is used in the BSN node. The CC2420 has a maximum throughput of 250kpbs with a range of over 50m. In addition, it has a built-in the AES-128 (Advanced Encryption Standard) hardware encryption/decryption and the IEEE 802.15.4 MAC (Medium Access Control) functions. With the built-in buffers and MAC, the CC2420 can act as a coprocessor to handle all the packet communications, and which significantly reduce the computational demands on the microcontroller. Dynamic reprogramming of the BSN node, 512KB of serial flash memory is incorporated in the BSN node. With the 512KB of memory, almost 1.5hour of ECG (100Hz) data can be stored without any compression. By applying the DPCM and LZW in series, ECG data can be compressed down to 11% of its original size, which means that the memory may be able to hold up to 13 hours of ECG data.

Stackable design is adopted in the BSN node, where different sensor boards can be stacked on top of the BSN node. By using the 20-pins connector, various digital and analogue interfaces are provided, which includes two I^2C buses, two UART interfaces, six analogue channels, power and ground signals. In addition to providing sensor interface, the board connector is also used for programming the BSN node where separate a USB programmer is designed for programming the node. In terms of software, the BSN node is designed to run TinyOS by U.C. Berkeley, which is a small, open source and energy efficient sensor board operating system. It provides a set of modular software building blocks, of which designers can choose the components they require. The size of these files is typically as small as 200 bytes and thus the overall size is kept to a minimum. The operating system manages both the hardware and the wireless network—taking sensor measurements, making routing decisions, and controlling power dissipation.

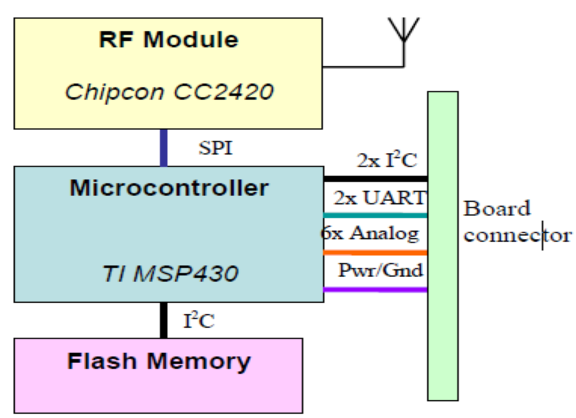

Figure 2.BSN node architecture

By using the ultra-low power TI microcontroller, the BSN node requires only 0.01mA in active mode and

1.3mA when performing computational intensive calculation like a FFT. With a size of 26mm, the BSN node is ideal for developing wireless biosensors. In addition, the stackable design of the BSN node and the available interface channels ease the integration of different sensors with the BSN node. Together with TinyOS, the BSN node can significantly cut the development cycle for wireless biosensor development.

3.1 FPGA Architecture

To establish different operation modes and functionalities we have chosen a FPGA. The FPGAs allow reconfigurable systems which can efficiently implement real-time processing algorithms. Synthesis and reprogramming jobs are made automatically, shortening the time spent on it considerably. We have used a Xilinx Spartan-6. The Spartan-6 family reduces system cost by offering the lowest cost-per-logic of any FPGA family, supporting the lowest-costconfiguration solutions including SPI, parallel flash memories, and the functions integration of many chips into a single FPGA [10].

Filtering algorithms and heart rate computations have been implemented on the FPGA. The R waves of each cardiac cycle are detected, measuring the time between two consecutive waves, thus obtaining the patient's pulse. Should the patient show a value outside the limits for a given number of consecutive cardiac cycles whether by period excess (brady cardia) or defect (tachycardia), this condition is a cause for alarm, and is sent to the mobile device. The R waves in the QRS complex and in the standard derivation used are characterized by their greater amplitude within the complex, rising sharply to a peak and falling away sharply afterwards. Use of amplitude only as an R-wave detection criterion could give rise to many problems since, as already pointed out, the baseline might undergo variations.

One must also use the signal variation criterion, calculating its derivative and detecting the points at which the variation occurs in the derivatives. The presence of the R wave can be associated with the instant at which the derivative passes through zero. This simple procedure make sit possible to detect the R waves with sufficient precision to measure the interval between them, using a suitable timer.Formerly the algorithms have been evaluated; they can be included in the processing layer of the proposed Mixed Signal Reconfigurable FPGA Chip With Wireless Communication For Wearable Healthcare System.

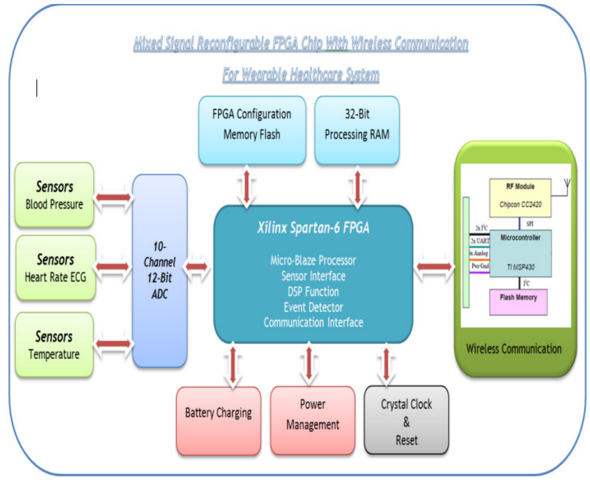

Figure 3. Reconfigurable FPGA Architecture for Wearable Health Care System

4. Multisensor Interfacing

Depending on the application and the operation of the sensor nodes in WBSN, the components of the sensor nodes varies accordingly. There are several sensor nodes, which typically comprises of a wireless transceiver, a processing unit and different types of physiological sensors like electrocardiogram (ECG) sensor, electromyography (EMG) sensor, electroencephalography (EEG) sensor, blood pressure sensor, tilt sensor, breathing sensor, movement sensor, thermometer, etc, deployed on the human being.

In most clinical and research settings, parameters, such as ECG, heart-rate, cardiac vibration, blood oxygen level, blood pressure, respiration, body temperature, body movement, among many others, are commonly obtained through multiple independent bench instruments. When simultaneous and synchronous recording is necessary, a separate signal-acquisition instrument is often utilized to record the multiple signals. The large size and large number of instruments required for multi parameter physiology analysis often renders mobile and continuous monitoring on active subjects impossible. To address this challenge, for multi parameter body activity and vitals monitoring, a small, lightweight, thin, flexible, one piece, wireless multi sensor node is used .

5. Multisensor Interfacing Module Design Challenges

5.1 Energy Efficiency

The total energy consumption of sensor needs to be drastically reduced to allow energy autonomy. The sensing and read-out of the signals may draw a significant part of the power budget in today's sensor nodes in WBAN, especially when the number of signals or channels is increasing. Thus, reducing the power

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required for signal extraction is an important challenge here [4].

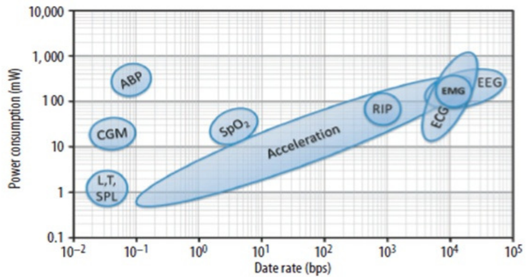

Figure 4. Average power consumption

5.2 Size

To achieve social acceptance, WBSN nodes must be extremely non-invasive, and a WBSN must have fewer and smaller nodes The overall size and weight of sensor nodes should be tailored to the human body.

5.3 Reliability

The acquisition of bio-potential signals, namely ECG, EMG and EOG signals, presents an interesting challenge as the signal amplitudes are in the µV range. Various noise sources, such as electrode offset voltage and interference from power-lines, requires high-performance readout circuit design that is capable of rejecting such aggressors while amplifying the weak bio-potential signals. The signal processing interface between the medical sensor and wireless transceiver is crucial for faithful regeneration of the waveforms at remote end. The voltage measure of physiological condition from medical sensors is typically very small and has to be signal conditioned for wireless transmission. We are developing a medical-signal conditioning interface using Programmable System on Chip (PSoC) that will allow for rapid changes to Component design through software programming.

5.4 Intelligence

The intelligence should be added to sensor signal conditioning and processing so that it is capable of efficiently transferring captured signal data or extracted parameters continuously or on an event-triggered basis. Intelligence could also be introduced by wireless communication.

5.5 Sensor Positioning

For distinguishing motions, an accelerometer/gyroscope array with tens of sensors can be deployed. This raises questions for positioning and noise reduction techniques. Proper positioning reduces the number of accelerometers/gyroscopes needed and the resulting data rate.

6. Network Architecture

The logical architecture of the implemented health monitoring network is shown in figure 4. It comprises three major components:

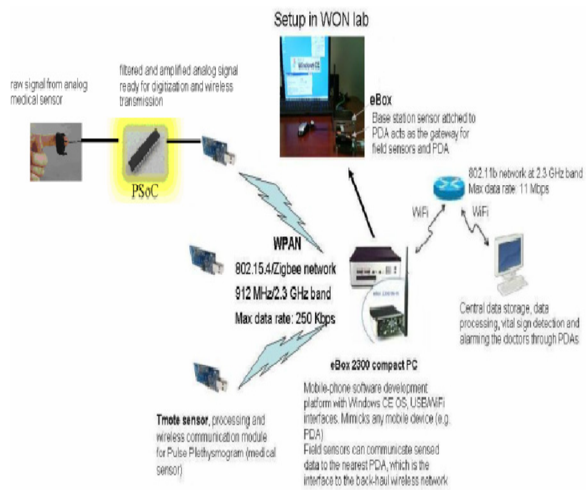

Figure 5: Integrated Health Monitoring Network: Laboratory Prototype

6.1 Data Sensing and Transmission

Module implements the user-end, where certain human physiological condition is sensed periodically, processed and is prepared for telecommunication.

6.2 Data Collection / Storage &Distribution

Module represents the central medical server, which collects and stores all patient information for centralized processing and future retrieval. The server will be interfaced to a back-haul network for wide-area distribution (within and between hospitals).

6.3 Mobile

Component implements the alarming interface, which makes the healthcare providers independent of the need to be logged into server all the time for emergency tracking. The following sections explain each component in detail.

7. Central Data Collection

The health data from the Zigbee sensor network is collected centrally for storage, collaborative processing and future retrieval. The back-haul network represents the collection and distribution location of all patient information. In our network, the medical sensor information is distributed to the back-haul server network through a base-station sensor that is connected through USB port to a PC or PDA or both. eBox 2300

[11] is used as the PDA/smart-phone emulator, which provides Windows Mobile software development environment. Recent advancements in MEMS technology allow for penny-sized motes with efficient computing (upto 400MHz) and transmission capabilities (upto 100m), and thus a motebased wireless interface would not drastically increase the size of in-body medical components. Local processing capabilities will enable local biomedical signal analysis.

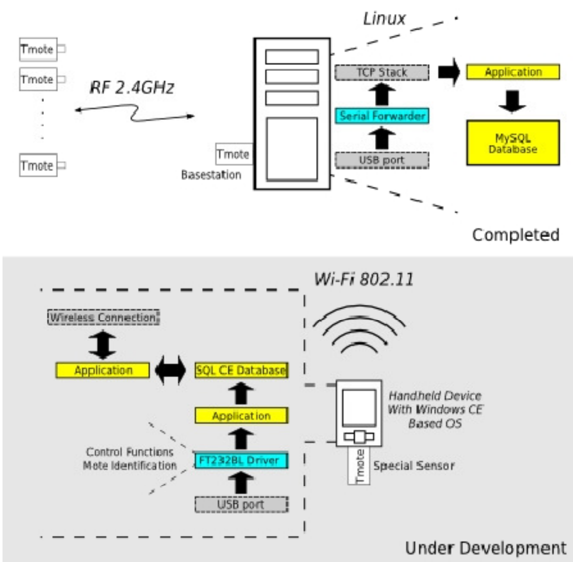

Figure 6.Data Extraction from Sensor Mote to PC/mobile-devices

8. Conclusion

A prototype WBSN system was built to verify the design. The measurement results show that prototype WBSN with the designed ASIC can operate efficiently as expected. In addition to the work-on-demand capability, the special passive standby mode offered by this design shows great advantage in terms of the standby power for the sensor nodes in the WBSN for medical applications. key issues in WSBN / WSN, and the application specific requirements have been discussed. And then sensor node architecture with a hybrid of active / passive RF transceivers is proposed. Adopting the passive RF, the “real-time” demand in the medical care purpose can be satisfied with no extra energy induced in the sensor nodes, solving the problems that trade off occurs between low-power and “real-time” wakeup in WBSN. It is especially suitable for long-term standby stimulus (or drug delivery) sensor node in the medical application. In this paper, we provided a implementation of an Integrated healthcare network that combined the advantages of 802.15.4, 802.11 and mobile technologies for efficient remote health monitoring and alarming. The crucial gap that needs to be filled is the appropriate software interface Development for wireless platform integration. In this work, we developed drivers that enabled seamless information flow across the 802.15.4, 802.11 and mobile platforms. Also, introducing mobile component is crucial for handling Emergency situations. Mobile health monitoring will allow for patients to be monitored without being confined within hospital environments.

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