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Wireless Healthcare Monitoring System for Home

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***Abstract*—**A healthcare monitoring system is presented in this paper. This system is based on ultra-low power sensor nodes and a personal server, which is based on hardware and software extensions to a Personal Digital Assistant (PDA)/Smartphone. The sensor node collects data from the body of a patient and sends it to the personal server where the data is processed, displayed and made ready to be sent to a healthcare network, if necessary. The personal server consists of a compact low power receiver module and equipped with a Smartphone software. The receiver module takes less than 30 × 30 mm board size and consumes approximately 25 mA in active mode.

***Keywords*—**healthcare monitoring, sensor node, personal server, wireless.

I. Introduction

POPULATIONS of industrialized nations of the world are ageing at a rapid rate. This has a profound implication on the healthcare systems of these nations. A large number of the elderly citizens will be spending their lives in the confines of their home, suffering from chronic illnesses that need continuous monitoring [1].

An effective system for home-based monitoring the health status of such patients will go a long way in relieving the load on the healthcare system, by reducing the number of outpatient visits to hospitals. It will also avoid a great deal of trouble for the elderly patients and their caregivers. Our work aims to create such a health monitoring system through the development and use of advanced microelectronic components.

This paper presents the system design of the wireless electrocardiogram (WECG) system and focuses more on the personal server hardware and software design. Section II describes overview of the wireless healthcare monitoring system, which consists of a sensor node and a personal server. The design and implementation of the personal server is then given in detail in Section III. Section IV gives both the hardware and software development and results. This is followed by a conclusion in Section V.

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II. Overview of WECG System

We propose a wireless health monitoring system for home usage as shown in the diagram below. Wireless sensor nodes collect vital health parameters from the body of the patient. The data from the sensor nodes is sent to a personal server – which is worn by/kept close to the patient. The data from the personal server can be examined by a doctor for further diagnosis. The data can also be sent to a home server from where it can be transferred to a healthcare network through a public telephone network or through the Internet. The scheme of this wireless healthcare monitoring system is illustrated in **Fig. 1**. The detail implementation is depicted in **Fig. 2**.

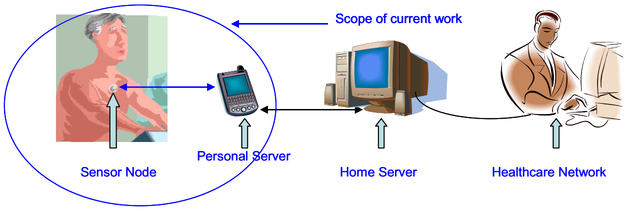

Fig. 1 Scheme of the wireless healthcare monitoring system

The technical approach chosen to implement the proposed health monitoring system is as follows:

- Design & Develop Analog, Digital & Radio Frequency Integrated Circuits, optimized for ultra-low power applications
- Use these key components to develop ultra-low power Wireless Sensor nodes (WSN) which are used to collect vital body parameters from a patient's body
    - Data from the WSN will be transmitted to a Personal Server (PDA with hardware & software extensions). This will be a short-range link (< 5 m), which facilitates conserving power in the WSN.
    - The data from the Personal Server can be transferred to the external world through conventional links, for further analysis.

Briefly, the WECG system consists of

1. A micro-power wireless sensor node to acquire the bio-signal from biosensors, encode and modulate it via ultra low-power ASK transmitter.

2. A personal server to acquire the wireless bio-signal streamed out from the sensor node.
3. GUI software to view and log the acquired bio-signal

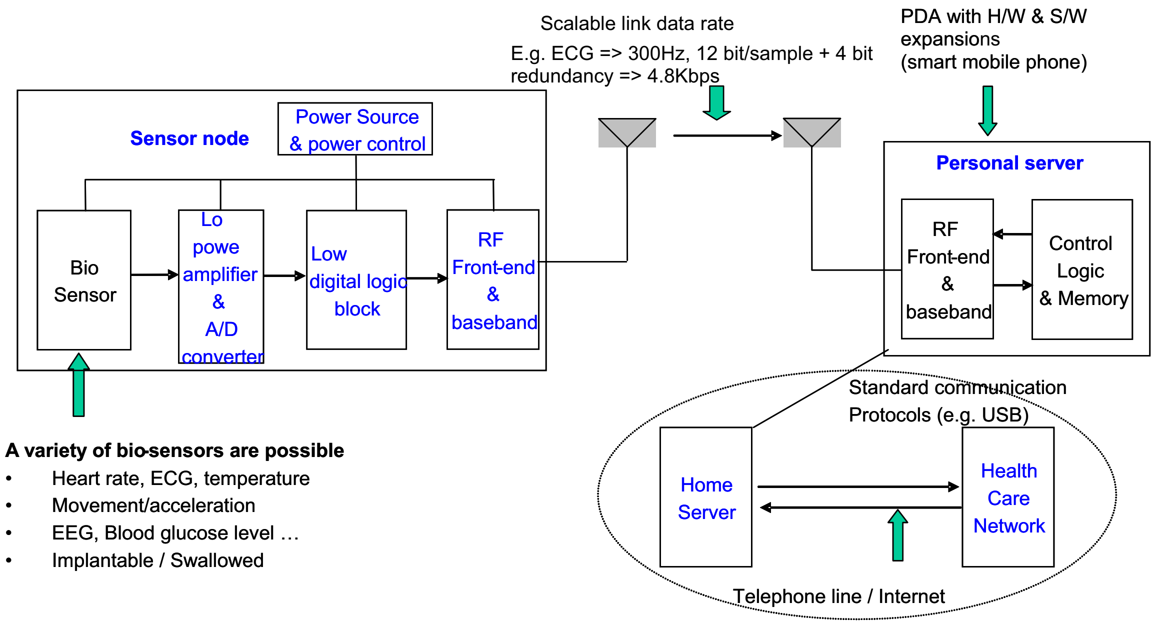

Fig. 2 Block diagram of the wireless healthcare monitoring system

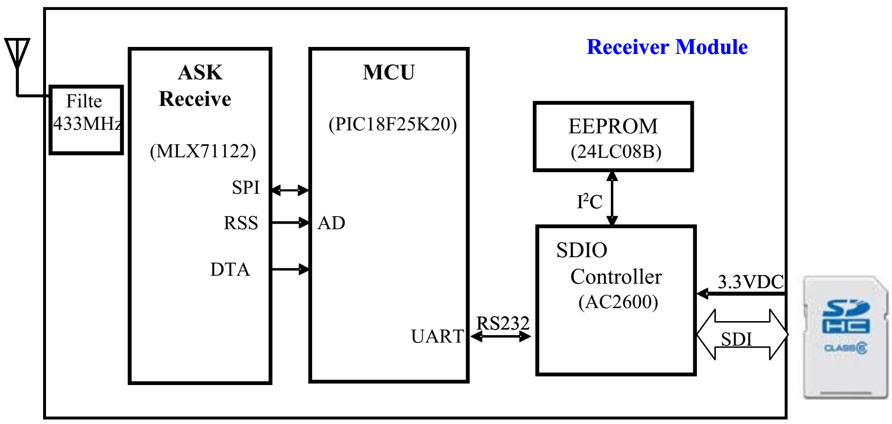

Fig. 3 Block diagram of the receiver module implementation

III. Personal Server

The personal server is built around a Window Mobile Smartphone and a Secure Digital Input Output (SDIO) wireless receiver module. The wireless module is connected to the Smartphone via microSD slot that is commonly found on today's mobile phones.

A. Receiver Module

The receiver module provides the necessary control to select the desired Amplitude Shift Keying (ASK) frequency, convert the received Manchester [2] encoded signal into valid data, and transmit the data and Received Signal Strength Indicator (RSSI) signal to the Smartphone software via SDIO interface.

The front end of the receiver module consists of a double-superhet ASK receiver, Melexis MLX71122, that can support data rate up to 100 kbps and cover frequency ranges 300 to 930 MHz with channel raster as low as 10 kHz. Its RF dynamic range ranges -10 dBm and -112 dBm. Despite of this wide flexibility, in our application we fixed the channel of the receiver at the 433 MHz-ISM band and configure its data filter to accept channel data rate of 9600 bps.

The configuration of the receiver front-end is Serial

Peripheral Interface (SPI) programmable by the Microcontroller Unit (MCU), MicroChip PIC18F25K20. The RSSI is sampled through the MCU's built-in Analog-to-Digital Converter (ADC), and the received data (DTAO) is passed as digital input. The MCU communicates with the mobile software residing on the Smartphone through the Universal Asynchronous Receiver/Transmitter (UART) to SDIO controller, the Arasan AC2600 chip. The Electrical Erasable Programmable Read-Only Memory (EEPROM) provides the configuration and initialization settings for the UART to SDIO controller.

The PIC18F25K20 runs on its internal oscillator of 16 MHz, with 4 x PLL enabled, giving 16 MIPS. SPI and UART modules are used. SPI is configured at 1 MHz and UART is configured at 115200 bps by default. RSSI from the RF receiver is sampled through a built-in ADC channel and the received Manchester encoded data is received through a digital input pin.

The firmware running on the MCU is also responsible for the bit and frame synchronization of the received data stream, and handles exceptions like parity error and synchronization error. A resynchronization algorithm has also been in-cooperated in the firmware to improve the reliability of the wireless link. After proper synchronization, the original bio-data is then decoded and extracted out from the data stream and supplied the sampled bio-data to the Smartphone via SDIO interface for display and logging.

To ease the design of bit and frame synchronization of the receiver, the transmission framing is actually following the concept of UART framing, with predefined length of start and stop bits. The transmitted data stream is Manchester encoded to ensure equal transitions of '1's and '0's.

Each frame contains 16 bits of formatted serial data: with 4 bits reserved for synchronization and error checking, leaving only 12 bits for carrying useful bio-data. The framing rate follows the ECG sampling rate, which is 300Hz per second, and resulted in serial data rate of 9600bps after Manchester encoding.

The AC2600 provides the bridge between the MCU and the Smartphone. The MCU is connected to the AC2600 via UART, and the Smartphone is connected to the AC2600 via SDIO. A 14.7456 MHz oscillator is required to generate the required baud-rate for UART. The EEPROM provides the configuration and initialization settings for the AC2600 at power up.

B. Smartphone Software

The purpose of the Smartphone software is to provide data logging and viewing, and to relay the acquired data to remote server via mobile network.

The overall architecture of the application software is shown in **Fig. 4**. The features include start / stop / pause / resume acquisition ECG signals, requesting remote device identity (ID), requesting current state, requesting current baud rate and setting baud rate.

The functions of the software include:

- wrapping the user-initiated communication protocol
- reading/writing through the RS232 serial port
- handling the received data packet from the receiver module
- suppressing the 50 Hz interference, which human body is prone to couple it from near-by domestic power lines, by using a digital notch filter
- analyzing the signals to extract the critical data
- processing to display the finalized received signals
- monitoring and controlling the receiver module

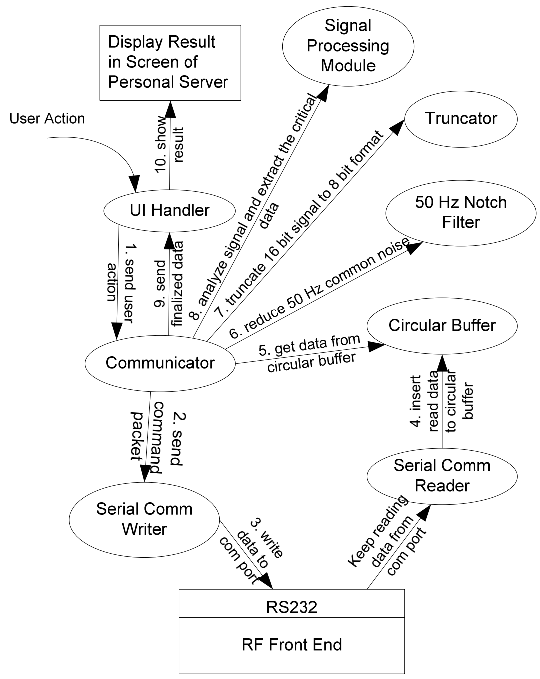

Fig. 4 Block diagram of the Smartphone software implementation

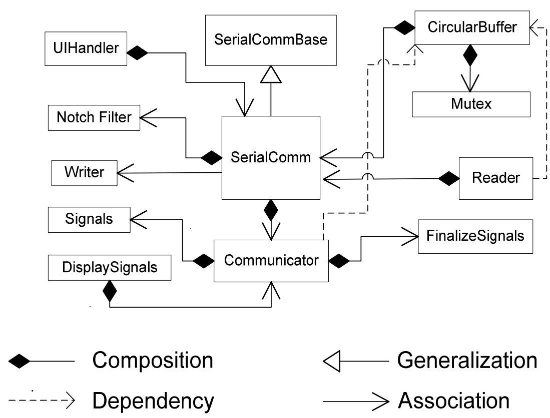

Fig. 5 Class diagram of the Smartphone software implementation

The overview of class diagram of the Smartphone software is as shown in **Fig. 5**.

The purpose and detail functions of each class are:

UIHandler	*to handle all the user interface actions and events*
SerialCommBase	*to control the fundamental serial communication operations*
SerialComm	*to manage the associated serial communication operations which are specific to WECG*
Communicator	*the hub class of WECG. All the communication between UIHandler and reader are gone through it*
Notch Filter	*to reduce the 50 Hz interference noise*
Circular Buffer	*data structure that uses a single fixed size buffer as if it were connected to end-to-end*
Mutex	*to avoid the simultaneous use of common resource such as circular buffer*
Reader	*to handle keep reading data from RS232 port*
Signals	*data structure that store the signal data receiving from com port and after passing through the notch filter*
DisplaySignals	*data structure for displaying the finalized data on screen*
FinalizeSignals	*for truncation of 16 bit format to 8-bit format*

IV. Development and Results

The prototype of the personal server including the receiver module and Smartphone software were developed and tested. The photograph of the receiver module is shown in **Fig. 6**. The receiver module is inserted into a PDA phone, which has a size limit of 30 × 30 mm. The screen shot of the Smartphone software Graphic User Interface (GUI) is also depicted in **Fig. 7**.

The receiver module consumes approximately 25 mA during active mode and consumes less than 1 mA during stand-by mode. This current is about 50% of a typical Bluetooth handset consumption. The consumption of the micro-sensor node is estimated to be around 3 mA. A supply voltage of 3.3 V was being used during the testing of receiver module.

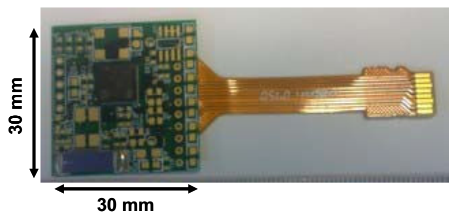

Fig. 6 Photograph of the receiver module

V. Conclusion

A Wireless ECG monitoring system for use in a home setting, for the monitoring of chronically ill patients is introduced in this paper. The system design and hardware/software design for one of the key components of the system were presented. Further work is in progress to link up the proposed system with a health care network through the internet.

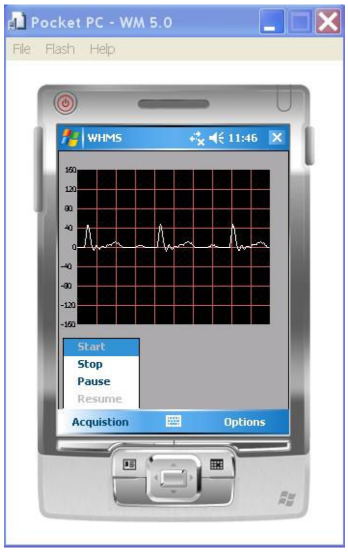

Fig. 7 Screen shot of the Smartphone software

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