An Application of Wireless Sensor Networks in Health Care Setting, Part I

Zhibin Gui, Yongxiang Fan

Abstract— This paper and the following papers present an application of wireless sensor networks (WSNs)in health care setting. The application involves building a reliable transmission system to transmit physiological data from ICU gateway to central server wirelessly in hospitals. Due to the length of this project, this paper will include several parts, which are published separately. This paper mainly focuses on background introduction.

Index Terms—Wireless sensor networks, health care, implementation.

I. INTRODUCTION

Wireless networks technology has been consistently improving with time and increasingly finding its way into all aspects of people's daily lives [1]-[42]. Medical application is a key field where Wireless Networking has a promising future. In the healthcare field, access and cost saving are two of the hottest issues these days. Wireless Technologies can contribute towards helping with both of these issues which is in great demand. In wireless sensor networks, transportation technique plays important role [5][14]. This paper will discuss techniques helping sensors to transmit information.

Wireless technology offers tools that can help give caregivers real-time access to accurate patient's information. With all this discussion of wireless applications, healthcare providers such as hospitals, insurance agencies and the government are becoming interested in investing in this area. Cost saving of the whole wireless system is another big topic.

Another hot issue in the wireless networks field is implantable devices. These devices can be implanted on normal day to day wearable. Patients can wear sensors that monitor vital signs and report them in real-time to their doctor. This helps towards the issue of access because now the patient doesn't need to be around the hospital all the time. This improves access and quality of healthcare for patients and saves money for care providers. It increases doctors' and nurses' efficiency, so they can care for more patients than before. Their work is also improved and made easier by having access to accurate data on patients in real-time.

For patients whose health is on the line the benefits are even greater. They have increased access to specialized doctors. They don't have to stick around the hospital any longer. This ease in mobility allows them to do their own work while still under the doctor's care. Safety is another issue that is helped here because the rate of mistakes can significantly be decreased. Also, patients can be picky when making changes in their daily lives when signing up for a treatment. With Wireless Technologies, their healthcare can be less intrusive, for example in the case of wearable sensors. They don't have to show up to the hospital for a blood pressure check. It can be done while they are working through wearing wireless sensors that transmit this information in real-time to their doctors.

As reported earlier, negligent mistakes by doctors and nurses costs hospitals, insurance companies and the government a large sum of money each year. These costs can be reduced by reducing the number of mistakes. Efficient and secure data handling and resource management is another area where wireless networks can help. Deploying huge machines around the hospital can be very expensive and time consuming. With Wireless Technology interfaces can be designed such that access to the machines can be provided from anywhere in the hospital. This allows for rapid and flexible deployment. By increasing the doctors' and nurses' efficiency, hospitals can provide care for more patients and increase their profits.

II. OBJECTIVES AND SCOPE OF THIS PROJECT

The objectives of the project are:

- Build a reliable transmission of physiological data from ICU gateway to central server wirelessly in hospital environments
- Implementation of the transmission system
- Set up a wireless network with the hardware and software provided by Crossbow products
- Performance study of the off-the-shelf protocols and algorithms for TinyOs implementation
- Test and evaluate the performance for each relay-link
- Improve the performance of the wireless protocols and algorithms
- Propose possible methods to extend the usage of the battery energy
- Analyze the relation between massage signal strength and transmission power

This paper and the following papers will firstly describe how to set up a wireless network by using the Crossbow Micaz mote; how to use the software provided by Crossbow Technologies to sending packet to base-station by a fixed time interval. Additionally, it will also explain in detail how to design the transmission protocol to meet project's requirements. Furthermore, the real experimental results and link performance will be deeply analyzed and evaluated. Finally, practical recommendations will be provided.

III. LITERATURE REVIEW

3.1 TinyOS

TinyOS is a free and open source component-based operating system and platform targeting wireless sensor networks (WSN). TinyOS is an embedded operating system written in the nesC programming language as a set of cooperating tasks and processes. It is intended to be incorporated into smartdust. TinyOS started as a collaboration between the University of California, Berkeley in co-operation with Intel Research and Crossbow

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Mr. Zhibin Gui, Xi'an, China.

Technology, and has since grown to be an international consortium, the TinyOS Alliance.

TinyOS applications are written in nesC, a dialect of the C language optimized for the memory limits of sensor networks. Its supplementary tools are mainly in the form of Java and shell script front-ends. Associated libraries and tools, such as the NesC compiler and Atmel AVR binutils toolchains, are mostly written in C.

TinyOs programs are built out of software components, some of which present hardware abstractions. Components are connected to each other using interfaces. TinyOS provides interfaces and components for common abstractions such as packet communication, routing, sensing, actuation and storage.

TinyOs is completely non-blocking: it has one stack. Therefore, all I/O operations that last longer than a few hundred microseconds are asynchronous and have a callback. To enable the native compiler to better optimize across call boundaries, TinyOs uses nesC's features to link these callbacks, called events, statically. While being non-blocking enables TinyOs to maintain high concurrency with one stack, it forces programmers to write complex logic by stitching together many small event handlers. To support larger computations, TinyOs provides tasks, which are similar to a Deferred Procedure Call and interrupt handler bottom halves. A TinyOs component can post a task, which the OS will schedule to run later. Tasks are non-preemptive and run in FIFO order. This simple concurrency model is typically sufficient for I/O centric applications, but its difficulty with CPU-heavy applications has led to the development of a thread library for the OS, named TOSThreads.

TinyOs code is statically linked with program code, and compiled into a small binary, using a custom GNU toolchain. Associated utilities are provided to complete a development platform for working with TinyOs.

2.2 Cygwin

It is free software that provides a Unix-like environment and software tool set to users of any modern version of MS-Windows for x86 CPUs (NT/2000/XP/Vista/7) and (using an older version of Cygwin) some obsolete versions (95/98/ME) as well. Cygwin consists of a Unix system call emulation library, cygwin1.dll, together with a vast set of GNU and other free software applications organized into a large number of optional packages. Among these packages are high-quality compilers and other software development tools, a complete X11 development toolkit, GNU emacs, TeX and LaTeX, OpenSSH (client and server), and much more, including everything needed to compile and use hysioToolkit software under MS-Windows.

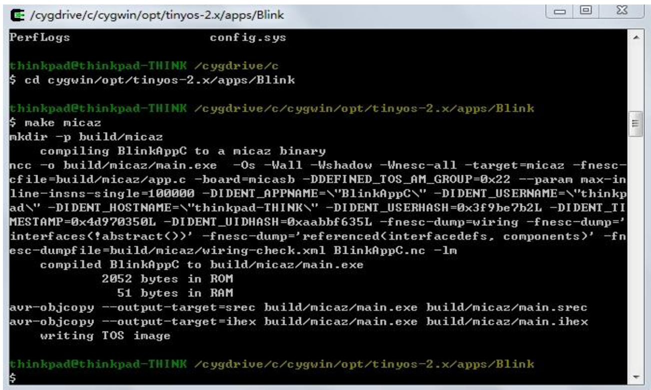

Figure 1 Cygwin User Interface

Basically, the Micaz mote can be programmed and pre-configured by using the cygwin interface under Microsoft environment Analysis of the transmission performance will be based on different transmission power and it basically consists of three methods.

To figure out the best choice for a suitable power in order to save the battery energy, the maximum transmission range will be recorded. The Micaz mote is using the chip CC2420 which power index ranges from 1(Min.) to 31(Max.).

3.3 Micaz

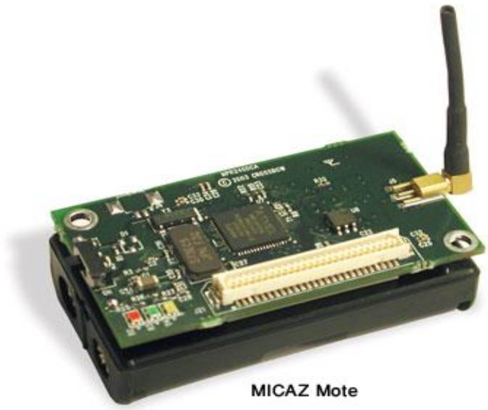

Figure 2. Micaz Mote

The MICAz mote platform is a third generation device used for enabling low-power, wireless sensor netwoeks available in 2.4 GHz and 868/916 MHz. The MICAz Mote offers a 2.4 GHz, IEEE/ZigBee 802. The MICA Mote platforms are fully compatible with the MoteWorks Software Platform and enable users to set up ad-hoc. [2]

As shown below, the rechargeable battery is being used in order to decrease the total size of micaz. Furthermore, the original antenna is replaced with a flat one which looks more professional and practical.

Figure 3. Rechargeable Battery

The original antenna is also replaced with a new In-house designed flat antenna which is more convenient to use. It should be kept parallel with the main body of the mote during the transmission. From the experiment's result, the USB connector of MIB520 board will influence the packet delivery ratio with very high percentage, so a flat cable is designed to solve this problem. The Base Station and MIB520 board will be connected through the flat cable. The basic In-house designed antenna is shown in the following picture.

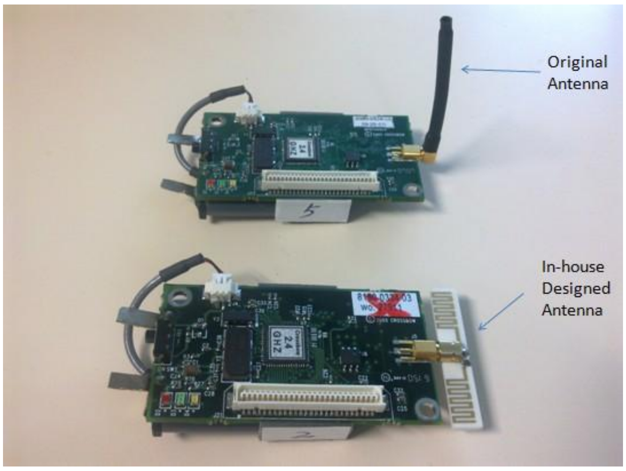

Figure 4. In-house Designed Antenna

3.4 Mib520 Board

The MIB520CA provides USB connectivity to the MICA family of Motes for communication and in-system programming with attached 51 pins. Any MICAz node can be programmed as a base station when mated to the MIB520 USB interface board. In addition to data transfer, the MIB520 can also provide a USB programming interface.

IV. PROTOCOL

4.1 Mote Transmission

Firstly, the simplest way of communication between any two Micaz motes will be introduced and the detailed ideas of the protocol will be discussed.

TinyOS provides a number of interfaces to abstract the underlying communications services and a number of components that provide (implement) these interfaces. All of these interfaces and components use a common message buffer abstraction, called message_t, which is implemented as a nesC struct (similar to a C struct). The message_t abstraction replaces the TinyOS 1.x TOS_Msg abstraction. Unlike TinyOS 1.x, the members of message_t are opaque, and therefore not accessed directly. Rather, message_t is an abstract data type, whose members are read and written using accessor and mutator functions.

For demonstration purpose, two motes are being used to show how they can connect with each other. First of all, tinyos library provides some very useful resource indicating some specific functions. For instance, the user can install two different programs into two micaz mote named base-station and sending-mote separately. And then connect the base-station to PC through Mib520 programming board. The real code is designed and re-built based on the open source code provided by Tinyos Library, it allows user to define the program independently based on the specific requirement.

Basically, there are two separate program working together to fulfill a simple transmission task. First of all, a base station is needed. The base-station will receive packet from other mote which will be saved as file in the host computer. The sending mote will be collecting the information for human body and send it to base-station in a fixed time interval. For this project, the sending mote and base-station will be pre-set to different Micaz mote during the experiment.

4.2 RSSI vs PDR

Each sending mote will send out 2000 packets to base-station with specific RSSI (Radio signal strengthen indication) value. Both of the RSSI value and Node_id (the node number of the mote which is used as a unique id for the mote tell the user where the received packet comes from) is assigned into the packet which can be sent to base-station, the system will help to create a file including these data in one default folder. Then the base-station can read the information by using the following printf command.

“printf("From node is %d \t RssiValue is %d \t seq num %d \t pkt rcv %d \n ",rms->nodeid,rms->RssiValue,rms->seqnum,counter); //rms->Tx);”

The RSSI vs PDR protocol builds and maintains the packet sending interval. The total number of packet can be preset from the code.

To compile the program of micaz mote, basically it needs four files in the source folder: Makefile, Header file, Configuration file and Application file. The transmission power index, channel number and packet sending time interval can be set directly from Makefile.

One of the project goals is to estimate the most efficient transmission power for each specific link, and it can be determined by setting the RSSI (radio signal strength indication) threshold value in order to keep the packet delivery ratio higher than 90 percentages.

For power control protocol, the basic procedures consists three steps. Firstly, the sending mote sends packet to base-station. The packet contains RSSI value, node_id and other useful information. Then, the base-station will transmit these information to the sending mote again which is going to be compared with the standard RSSI threshold value. Finally, the sending mote will adjust its transmission power level based on this information.

V. CONCLUSION

This paper presents an application of WSNs in health care setting. Due to the length of this project, the whole part is divided into several parts. This paper presents background introduction.

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