A Versatile Nurse Support System using Bluetooth and FeliCa

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***Abstract*— We have developed a versatile nurse support system. The system adapts different wireless technologies to best suite the applications and yet provides a uniform platform to build a user-friendly environment for visiting nurses, gerontological nurses, and at central hospitals. It is designed to ease the daily work of these nurses by eliminating the needs to manually record medical information into multiple systems and enhancing communication between nurses and doctors.**

I. Introduction

Health care and patient monitoring systems using short-range wireless communication are being actively developed and there are a number of researches that focus on developing new devices in these areas. [1]-[4] Naturally many are proposing new devices with their own protocols, so interoperability is an issue. Interoperability is also an issue on site of medical institutions as well, where medical information is recorded in various formats, depending on the type and scale of the institutions and their policies. It would not be realistic to find a scheme that works for everybody. The system needs to be more flexible, especially in the user-interface, and easily customisable to be acceptable for a variety of users.

The Continua Health Alliance has been promoting Bluetooth Low Energy (and ZigBee) for health care devices. The Continua Design Guidelines, version 1.0, were published in February 2009 and the Bluetooth Health Device Profile was approved in December 2009; there are a few medical devices already on the market. A&D Medical's UA-767PBT-C blood pressure monitor is only an example. We expect more and more medical devices to follow but it would probably take some time before we see them on the market in large, at least in Japan, where new (or even remodelled) medical devices need to be approved by the Ministry of Health, Labour, and Welfare of Japan, a process which tends to be rather lengthy to clear. We suspect it would take even more to see them actually in use in hospitals and other medical institutions, as replacing medical devices is not always easy, financially or politically, or otherwise.

We have developed a small external module that attaches to existing medical devices through a digital interface and turns them into wireless devices while leaving the devices internally intact, thereby bypassing the lengthy approval process. Our system can also integrate seamlessly those devices that *do* have wireless capabilities built in such as Continua certified Bluetooth devices. For gatewaying these medical devices into the WAN, we have chosen notebooks. A similar work using PDAs [5] is interesting, but we find PDAs to be too limiting in its presentation and user-interface capabilities.

In hospitals and nursing homes, it is very common to distribute small devices to many patients at once to effectively shorten measurement time, a typical example being clinical thermometers. There, the main difficulties with short-range wireless systems such as Bluetooth are to figure out whose data the received packet belongs to when more than one device happens to send data to the gateway and where to send it when there is more than one gateway PCs present in the vicinity. RFID smart card systems such as FeliCa are ideal in these cases. It would be a disaster to mix up vital information of one patient with another and that certainly is something we must avoid, and without bothering nurses if possible. FeliCa is a 13.56 MHz RFID smart card system developed by Sony and is widely used in Japan as an electronic settlement system. [6] Its communication range is only a few centimetres at best, so network contention is never an issue. Terumo is very active in standardising protocols based on the FeliCa technology for health care devices, their Medisafe Fit blood glucose monitor being one of the first devices to use the FeliCa Plug embedded module.

The goal of our project is to provide an efficient system to ease the duties of visiting nurses and gerontological nurses as well as nurses and doctors at central hospitals, without affecting the ways they are well accustomed to in their routine work. We have conducted a number of field tests in Goto Island as well as in the City of Nagasaki to understand needs

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of the nurses and doctors, and decided to focus on the following issues:

1. Correctly entering the vital information and other measured values, printouts, photos, and comments, to the medical record system is very time consuming; unnecessary duplications should be eliminated.

2. Sometimes, the visiting nurses (and gerontological nurses, too, to some extent) want advice from doctors while they are still at patient's houses or otherwise away from doctors whether they need to repeat the measurements and/or perform additional tests. If the conditions are *not* as bad as to make phone calls to doctors for immediate alert, they do not have a means to communicate with doctors until they return to their hospitals. Since nurses often visit alone, this responsibility is becoming one of the factors young nurses choose not to work on islands.

3. Audio and visual as well as other analog information such as decubitus or electrocardiogram is much harder to describe in text or verbally over the phone. Some kind of electrical communication system is very much desired.

II. SYSTEM ARCHITECTURE

A. Hardware Architecture

The proposed system is modular in nature. The core system, shown in Fig. 1, consists of a server and one or more gateway notebook PCs on the VPN network over the Internet (Ethernet, 802.11 wireless, and/or i-mode mobile network if necessary) and a number of medical devices, which talk to the gateway PCs via peer-to-peer wireless connection. The medical information collected by these devices is sent to the server through one of the gateways and is shared between the nurses and doctors as soon as it is entered in the database on the server. It is not an electrical "Karte" system *per se*, but connecting it to such a system as well as to a "Rezept" system is foreseen in the near future.

We have chosen Bluetooth as the main wireless technology between the devices and the gateways because the Continua Health Alliance has announced [7] Bluetooth (and Zigbee) as their main target for health care devices so we expect more and more medical devices to appear with Bluetooth connectivity in the near future, and because notebooks that have Bluetooth built in are readily available.

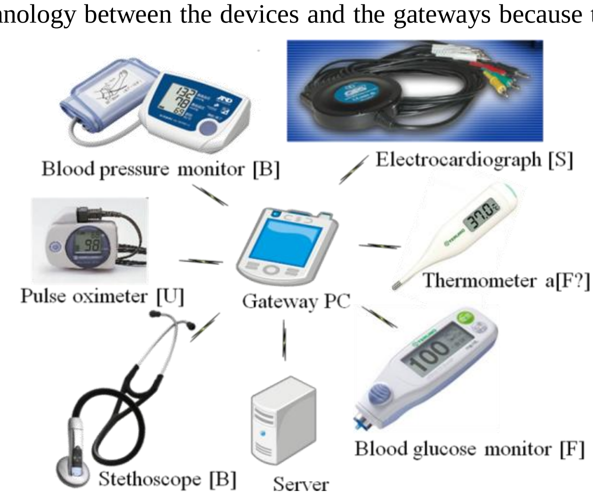

Figure 1. A versatile nurse support system using Bluetooth [B], FeliCa [F], and USB [U] & RS232C [S] over U/B module.

FeliCa is used not only to read in data from medical devices but also to select a patient quickly and to identify the nurse who enters the information as well as to unlock the gateway PC itself. For this purpose any FeliCa card can be used, such as the Nagasaki Smart Card, Edy, and even personal cell phones with Mobile FeliCa chip. A general broadcast message is issued to uniquely identify the owner and the identification number is looked up in the database for authentication.

The key component of the system is the USB-to-Bluetooth (or U/B for short) module we have developed, which converts a normal USB device into a wireless device without physically altering it in any way. Fig. 2 shows the second prototype module. We deliberately decided not to develop new medical devices that talk Bluetooth directly; although building a new device would make it compact and very easy to use, it would take too much time and money to get official approvals from the Ministry of Health, Labour, and Welfare of Japan for even a single device. We therefore decided to use whatever already exists that has a digital interface and attach a small module to it in a general way to make it a wireless device. USB and RS232C are the two serial interfaces that we chose to support with this module. In a way our module enables any wired serial medical devices to become "Continua-like" wireless devices.

The medical devices which we have tried to integrate into our system so far include the following:

- [KONICA MINOLTA] PULSOX 300i pulse oximeter
- [A&D Medical] UA-767PBT-C blood pressure monitor
- [OMRON] HEM-7301-IT blood pressure monitor

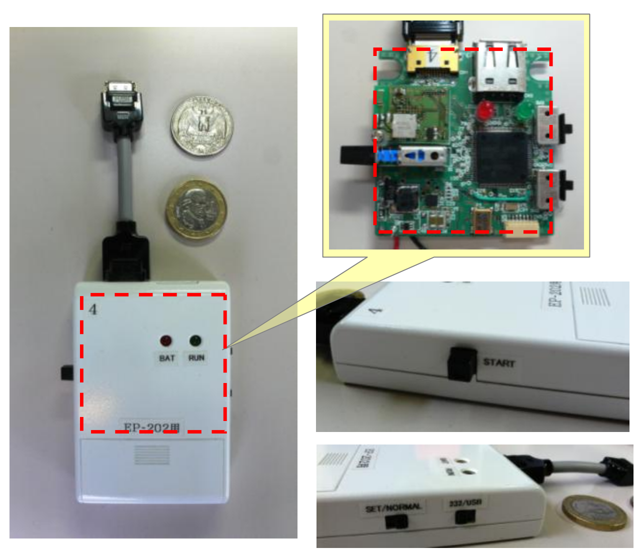

Figure 2. The prototype U/B module.

- [QRS] ECG Card 12-lead electrocardiograph
- [Parama-Tech] EP-202 3-lead electrocardiograph
- [TERUMO] Medisafe Fit blood glucose monitor
- [3M] Littman 3200 electronic stethoscope

Hardwarewise the U/B module is made up of a CYPRESS SL811 USB1.1 host controller, an ADC ZEAL-C01 Bluetooth module, and an NEC UPD78F1165 microcontroller with an RS232C serial port, as shown in Fig. 3. It is driven by two AAA batteries and measures 50 x 60 x 25 mm^3.

Apart from the two small slide switches that select the interface (USB or RS232C) and the running mode (Run or Configure), both of which are normally not to be touched by anyone but experts for initial configuration of the module, and the two LED indicators, the U/B module only has one push button, which initiates the data transfer from the device to the gateway nearby. When data is ready in the medical device, the nurse only needs to push the button once and the next moment the information is transferred from the device to the gateway. We could have removed the button and made everything fully automatic but it was explicitly requested by the nurses during the field tests that they wanted to control when and which data is entered into the system. The module does not have a power switch. It spends most of the time in sleep mode to reduce the current consumptions. One of the LED indicators would start blinking when the batteries are running out.

B. *Software Architecture*

The software within the U/B module is quite simple; it does not try to do much except to transfer data received from one end to the other. The software running in the gateway is therefore responsible for properly initialising the USB devices remotely over the Bluetooth network. It is a user-mode memory resident task running in the background. Since the traffic bypasses the USB device drivers on the gateway, it has to mimic most of its work in the task itself. Dealing with the RS232C devices is usually much simpler, as the communication is more direct in nature. The background task writes all the information received from the U/B module in XML to predefined folders, much like a Continua certified device would.

The application software, named SuiSuiNURSE, runs on the gateway PCs and provides the user interface to the nurses.

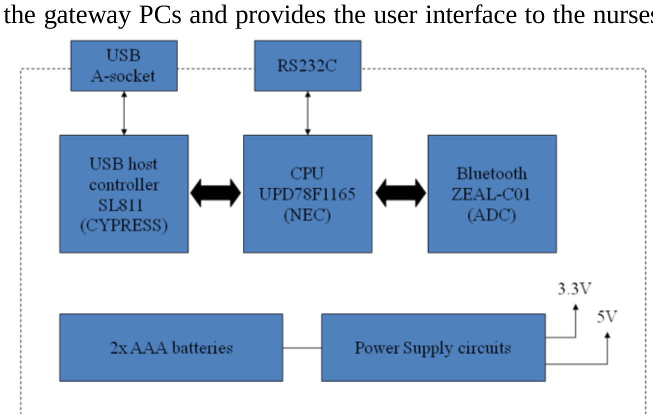

Figure 3. Block diagram of the prototype U/B module.

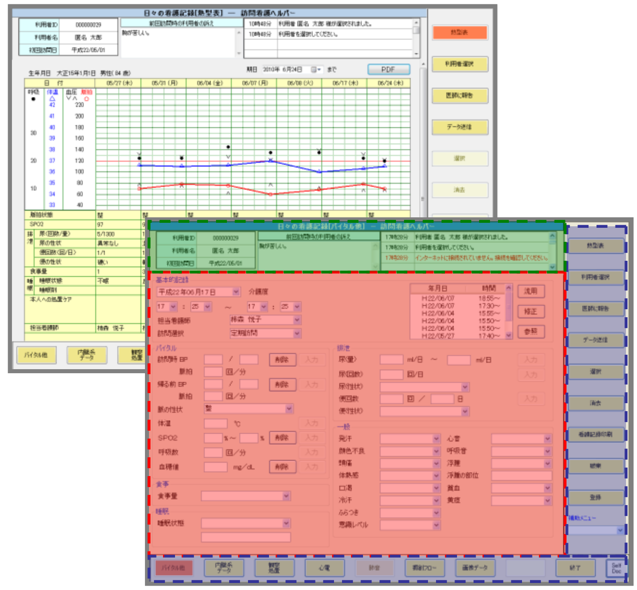

Figure 4. Screen snapshots of SuiSuiNURSE application software (main window in red, message window in green, and buttons in blue).

The screen is divided into multiple sections, as in Fig. 4; each of the software buttons at the bottom and on the right of the screen is associated with a specific task and an independent program runs when the button is activated. The main window in the middle is assigned to the active task and it is free to use it in any way. There is a "manager" process in the background that activates and deactivates these tasks as separate processes. The shared memory pool provides the means to pass information between these tasks in an efficient way. The message window at the top is handled by a "message" process and is mainly used to log activities including error messages if any. A speech synthesiser is embedded in the system and reads out important messages so that nurses can continue to work near the gateway PCs without looking at the screen all the time.

One of the requests from nurses regarding the user-interface and its appearances was to present the measured data in a way that resembles the paper-based system currently in use as much as possible. We therefore customised the layout of the windows, defined a set of programs that are run, and prepared pull-down menus for many comment fields from which nurses can simply choose the appropriate text for the patient. Since the requirements for visiting nurses, gerontological nurses, and nurses at hospitals are somewhat different, we made separate applications for these three types of nurses and added customisations for each site.

III. PERFORMANCE

To evaluate the performance of the prototype U/B module, we have measured its throughputs, latencies, and current consumptions. Preliminary results are presented in this section. The ZEAL-C01 Bluetooth chip used in the prototype has three performance levels that we can configure via its J command: low, standard, and high. The measurements were repeated for all three levels and the results were compared.

The throughput is the rate of data flow that goes through the module. It is entirely limited by the baud rate of the serial communication protocol, for which we use the fixed rate of 155,200 baud, and adding a wireless layer does not show any degradation, even at the low performance level.

The latency is the time spent within the U/B module and was measured by connecting both RS232C and Bluetooth ports to a PC and comparing the time stamps of packets going out into the module through the RS232C port and those coming back out of it via Bluetooth. Fig. 5 shows the distributions of the latency in the three performance levels. Here we see the effect of additional communication buffers, especially for initial packets, which are marked in red. The differences in performance are quite evident as well. The delays may be negligible to a number of devices that deal with single numbers but could potentially pose a problem for others which transfer larger amount of real time data such as stethoscopes and electrocardiographs. The former can safely be operated in the low performance level but for the latter it may be necessary to run in the high performance level.

We have measured the current consumptions of the U/B module with a Fluke 85III digital multimeter. The setup is the similar as in the latency measurements. The results are summarised in Table 1. Assuming we take a 3-sec measurement for 100 times a day, and each time the module enters sleep mode after 30 sec of quiet time, the current consumptions of the U/B module is estimated to be 63 mAh in the standard level and 24 mAh in the low performance level, which means 1000 mAh Ni-MH AAA batteries are expected to last about 16 days and more than 40 days, respectively. Some devices however require bus power through the USB (and sometimes RS232C) port and need to be driven by these batteries, so the lifetime may well be much less.

Feedback from the nurses during the field tests is overwhelming. They loved the wireless devices! Although they liked the idea of using digital devices, wiring them properly into the system (and unwiring them after they are done with them) is something they are not very keen to do every time they need to measure vitals, especially when the data that is transferred electronically is only a number or two. Our system was well received and we received constructive comments in return each time we went to the field.

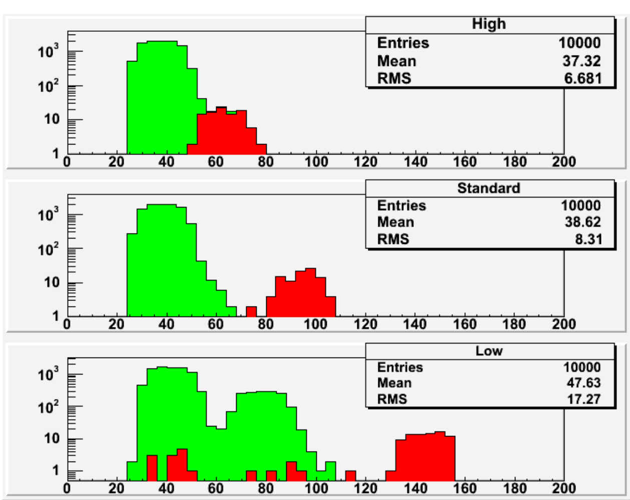

Figure 5. Latencies (msec) through the U/B module in three performance levels; initial packets in red, others in green.

TABLE I. CURRENT CONSUMPTIONS OF THE U/B MODULE IN THREE PERFORMANCE LEVELS.

Mode of Operation	Current (mA)		
	low	standard	high
sleeping	0.13	0.13	0.13
waiting for connection	16	59	90
connection established	53	97	129
during data transfer	92	130	235

IV. SUMMARY

We have developed a nurse support system using Bluetooth and FeliCa technologies. We have built a small external module for legacy serial devices so that they can be used in our system now, together with new wireless devices. Our SuiSuiNURSE is a very flexible application with user-friendly interface that can easily be customised for each site. Field tests have been arranged several times so far, always with very positive feedbacks from the nurses.

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REFERENCES

[1] Roland Bader, *et al.*, “BigNurse: a wireless ad hoc network for patient monitoring,” LOCARE 2006.

[2] Shih-Lun Chen, *et al.*, “A wireless body sensor network system for healthcare monitoring application,” BIOCAS 2007.

[3] Nicolas de Vicq, *et al.*, “Wireless body area network for sleep staging,” BIOCAS 2007.

[4] Bonam Kim, *et al.*, “Design and implementation of a ubiquitous ECG monitoring system Using SIP and the Zigbee network,” FGCN 2007.

[5] Qingfeng Wu, *et al.*, “Development and application of mobile nursing information system based on PDAs,” FITME 2008.

[6] Donghun Yoon, “The treand and user behavior of Japan’s IC-Card system,” WDDC 2009.

[7] Continua Health Alliance, press release, June 8, 2009.