Copyright ⓒ 2012 KSII

Multi-Modal Sensing M2M Healthcare Service in WSN

Wan-Young Chung[1]
[1] Department of Electronic Engineering, Pukyong National University
Busan 608-737, Korea
[e-mail: wychung@pknu.ac.kr]
*Corresponding author: Wan-Young Chung

Received October 28, 2011; revised January 9, 2012; accepted February 4, 2012; published April 25, 2012

Abstract

A multi-modal sensing M2M healthcare monitoring system for the continuous monitoring of patients under their natural physiological states or elderly persons with chronic diseases is summarized. The system is designed for homecare or the monitoring of the elderly who live in country side or small rest home without enough support from caregivers or doctors, instead of patient monitoring in big hospital environment. Further insights into the natural cause and progression of diseases are afforded by context-aware sensing, which includes the use of accelerometers to monitor patient activities, or by location-aware indoor tracking based on ultrasonic and RF sensing. Moreover, indoor location tracking provides information about the location of patients in their physical environment and helps the caregiver in the provision of appropriate support.

Keywords: WSN, routing protocol, healthcare, multi-hop communication

This research was finantially supported by the Ministry of Education, Science Technology (MEST) and National Research Foundation of Korea (NRF) through the Human Resourse Training Project for Regional Innovation.

http://dx.doi.org/10.3837/tiis.2012.04.008

1. Introduction

Population aging has become one of the most significant demographic processes of modern times. Decreasing fertility along with lengthening life expectancy has reshaped the age structure of the population in most regions of the world by shifting relative weight from younger to older groups. In much of the world, populations are aging at an extremely rapid pace. The elderly population, that is, those aged 65 years and over, currently comprises around 10 percent of the world's population, and this figure is projected to increase to 22 percent by the year 2050 [1]. Together with a concomitant socio-economic transition, this demographic shift has been forcing policy makers to prepare for the challenges of a rapidly aging society.

Providing patients with convenient health facilities at a low cost has always been a great challenge for health service providers. Moreover, the fast changing life style of the modern world and the problem of aging society pose an urgent need to modernize such facilities. This involves devising cheaper and smarter ways of providing healthcare to sufferers of age-related diseases. In addition, emphasis has to be paid on providing health monitoring in out-of-hospital conditions for elderly people and patients who require regular supervision, particularly in remote areas. Future trends in national healthcare services are expected to include shorter hospital stays and better community care.

This paper presents a M2M healthcare monitoring system for the continuous monitoring of patients under their natural physiological states or elderly persons with chronic diseases. Especially our system is designed for homecare or the monitoring of the elderly who live in country side or small rest home without enough support from caregivers or doctors, instead of patient monitoring in big hospital environment. Further insights into the natural cause and progression of diseases are afforded by context-aware sensing, which includes the use of accelerometers to monitor patient activities, or by location-aware indoor tracking based on ultrasonic and RF sensing. Moreover, indoor location tracking provides information about the location of patients in their physical environment and helps the caregiver in the provision of appropriate support.

Recent advances in Wi-Fi, WSN, cellular and wireless network technologies enable envisaging novel M2M healthcare systems [2][3][4][5] that simplify the monitoring and treatment of patients, although much of the research effort in the area only regards the use of such technology in the context of personal and local area networks. Among many network technologies for M2M service, WSN technology plays a key role in enabling communication capabilities everywhere. It will improve the quality of life of patients, provide early detection for certain ailments and improve doctor-patient efficiency. Consequently, it will serve to reduce the health-related budget burden that governments in aging societies face. Nonetheless, WSNs also pose several challenges to M2M healthcare applications.

They comprise numerous energy and resource-constrained devices, which have to be self-configuring, self-monitoring, self-healing and robust in often unpredictable environments with noise, signal loss and failures [6][7][8]. In addition, the devices can be mobile, such as emergency devices, or fixed, such as temperature sensors, etc. Some of the main characteristics of a networked sensor are: (1) small physical size, (2) low power consumption, (3) limited processing power, (4) short-range communication capability and (5) small storage capacity.

As healthcare applications commonly handle several types of waveform data, the application of wireless sensor network technology to ubiquitous healthcare is rather more demanding than its application to other real-time systems monitoring such factors as temperature, humidity, acoustics, light and pollution [9][10].

2. Multi-Modal Sensing M2M Healthcare System

As depicted in **Fig. 1**, our MSUS system consists of four major components: (1) sensor nodes for health monitoring, activity monitoring and patient tracking, (2) a cellular phone functioning as a local processing unit or a monitoring tool, (3) a central server and (4) a terminal PC or PDA [11]. This system has several features and capabilities that are present in already existing u-healthcare systems. However, unlike other healthcare systems, MSUS was developed mainly for elderly persons or patients with chronic diseases living at home. It measures patient activities, defined as sleeping, working, running and falling, together with indoor tracking signals. This context information helps to provide further insight into the natural cause and progression of the patient's condition and enhances the accuracy of early symptom detection. For example, when monitoring arrhythmic heart disease, the underlying cause of altered ECG signals can be attributed to a number of factors other than an intrinsic cardiac condition, including physical and mental stress.

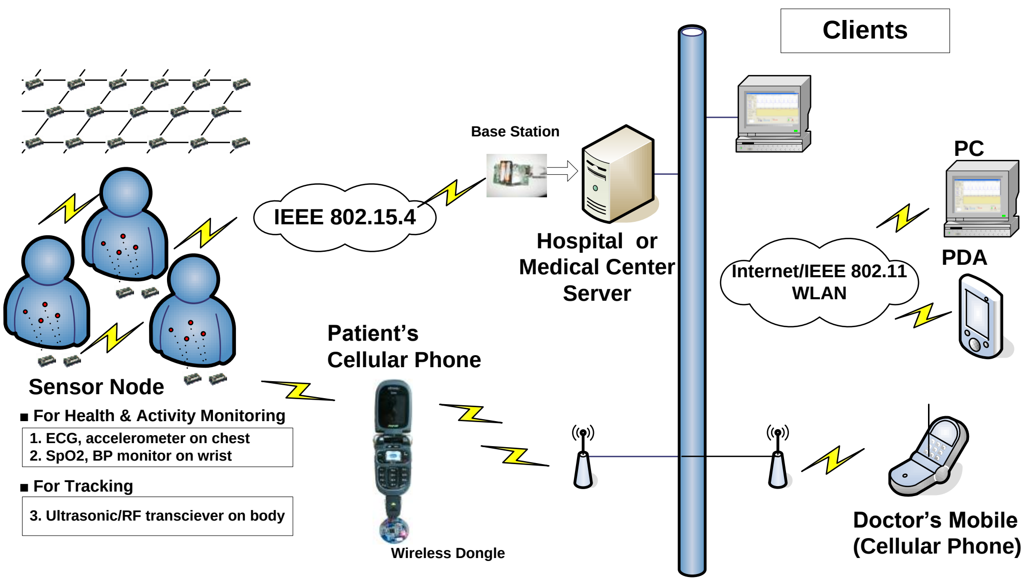


Fig. 1. System architecture of the Multi-Modal Sensing u-Healthcare System (MSUS).

MSUS employs wearable physiological biosensors, such as ECG, SpO2 and blood pressure sensors, which are used in conjunction with other context awareness sensors, such as accelerometer sensors. Moreover, ultrasonic/RF transceivers can also be fitted together with sensor nodes to characterize the patient's activity and position.

3. Design Issues and Challenges in Wireless Healthcare

In ubiquitous healthcare applications, the most significant limitations of wireless networks are the slow data transfer rate and lack of a single connectivity standard that enables devices to communicate with one another and to exchange data [6]. Other limitations include wireless devices, which are still in their infancy stages and therefore slower in speed than desktop computers, high initial costs involved in setting up wireless systems and lack of real-time connectivity due to device mobility.

In order to achieve efficiency gains in the healthcare setting, three major issues in wireless development need to be addressed:

1. Appropriate development methodology must be developed to enable proper integration of new solutions with existing wireless solutions.
2. Data access, communication and synchronization issues between mobile devices and existing databases must be resolved.
3. Suitable user interfaces must be designed in order to capture and access data accurately and timely.

While many prototypes of healthcare solutions have been found to be successful, they have also suffered from limitations with regard to code, integration with existing applications, user interfaces and data transmission [12]. To allow flexibility, code is often written as generic as possible and parameters are kept as variables. During real-time testing, some of these parameters have caused run time errors, as the compiled code has not been able to resolve certain data types prior to the run. This has created the necessity to re-visit the code and examine every instance of the run in order to fix the problem. Also integration with existing applications has caused concern, as the healthcare industry lacks uniform standards.

Different types of healthcare sensors require different sampling rates and reliability requirements. Linear, or waveform-independent, healthcare data, such as body temperature, blood pressure and oxygen content, require a lower sampling rate and lower reliability than waveform-like, that is, waveform dependent data, such as ECG or EKG. Since waveform-like data do not need continuous data transfer, data transfer can be initiated only when desired by the monitoring side or in periods of finite duration. On the other hand, in critical and emergency situations, waveform-like data require long-term data transfer. As a result, data-centric approaches are better for waveform-like data, where a query or command from the base-station initiates data transfer. Linear data can use either the data-centric approach or the event-driven approach, where data are transferred when an event is sensed. It is generally observed that linear data change gradually without any periodic sequences. So, sometimes only a change in amplitude is required to detect an abnormal event. Consequently, a threshold limit can be set to limit the amount of data transferred, and data transfer is initiated only if the value of sampled data exceeds the threshold. For waveform-like data, any packet loss can be a serious problem, as it may lead to loss of useful information or may give a false impression of abnormality. Unlike typical wireless sensor environments, where many sensors are used to sense the same event simultaneously, each sensor in a healthcare application senses a different event. This characteristic has the practical consequence that the query model for a healthcare system can be simpler in design that that for an industrial system.

4. Experiment and Results

4.1 Wearable Shirts

A wearable wireless node for the ubiquitous monitoring of ECG, activity and SpO_2 measurement module as a wearable system for healthcare monitoring was fabricated. This system is capable of obtaining physiological data from a wearable wireless sensor node and transfers it wirelessly to a base-station connected to a server PC in an ad-hoc network using IEEE 802.15.4.

The developed wearable IFUS (Integrated Fusion Sensor) node containing a conductive fabric electrode (8 cm in width) for ECG measurement and a tri-axial accelerometer sensor (MMA7260Q, Freescale) for measuring acceleration. **Fig. 2** shows the developed sensor board, which integrates a wireless sensor node, an ECG and accelerometer sensor in an IFUS-1 node (a) and a SpO2 interface in an IFUS-2 node (b). The wearable IFUS-1 node has a double-layer structure with a wireless sensor node on the top layer and ECG and accelerometer sensor boards on the bottom layer. The IFUS-1 node has one ECG channel with a gain of 300 (24.8db). With a measurement resolution of 12 bits, the sampling frequency of the A/D converter varies between 0.05–123 Hz. Placed firmly on the chest, the bottom layer of the node, containing the accelerometer sensor, is connected to the body by conductive fabric electrodes. Wirelessly connected to the base-station using an IEEE 802.15.4-based radio protocol, the IFUS-1 node measures ECG and accelerometer signals, and transmits them with a sampling rate (fs) of 200 Hz. These ECG signals are later processed using MATLAB 7.4.0 (R2007a). Accelerometer (ACC) signals are used as reference for the adaptive filtering of ECG signals.

Fig. 3 shows a wearable shirt with an integrated IFUS-1 node and ECG/accelerometer sensors.

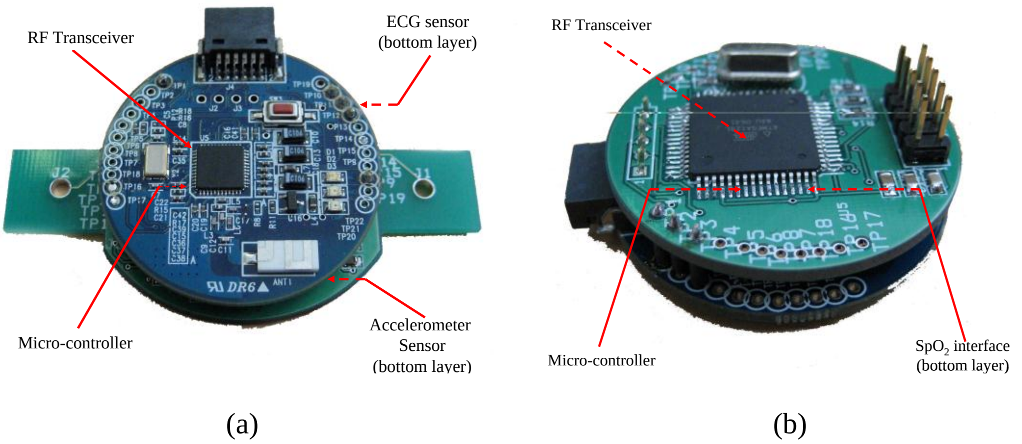


Fig. 2. Wearable IFUS-1 and IFUS-2 nodes with ECG and accelerometer sensor (a) SpO2 sensor (b).

The idea of an SpO_2 monitoring system is to place unobtrusive sensors on a person's body to form a wireless network that provides interoperability layers which enable portable sensors to access body signals and route these signals to a monitoring PC. This section describes the architecture of the SpO_2 monitoring system, which comprises measurements, communications and a monitoring system. In addition, the section provides a brief introduction to the hardware devices used in the system and explains the functionality of the applied communication methods in detail.

Fig. 3. Wearable shirts with IFUS-1 node and ECG/accelerometer sensors.

The healthcare monitoring system can utilizes a portable sensor to measure SpO_2 values. Built using a Nonin OEM (original equipment manufacturing) pulse oximeter module (Nonin Inc., USA), the sensor measures 53 mm × 20 mm × 15 mm. Its optical components include a red LED, an infrared LED and a photodiode for light transmittance measurement. SpO_2 values can be obtained by calculating the ratio of the two lights, depending on the absorption of light. 5-byte photoplethysmographic (PPG) data sampled at 75 Hz and SpO_2 values are acquired at one second intervals.

The SpO_2 sensor device contains three parts: sensor, cabling and pulse oximeter monitoring. The sensor part includes a probe with two LEDs as light sources and a photodiode for photon detection on the wrist. Cabling connects the probe to the SpO_2 module and sends signals received from the body to the device. The module's main processing component is the pulse oximeter monitor. It includes signal processing, LED control, calculation and display. Thus, almost all functionality required to obtain SpO_2 values is managed in this part. To enable communication, the sensor is designed to be attached to an IFUS-1 node.

Fig. 4 presents the portable SpO_2 sensing system, which is designed to be compatible with homecare systems and comfortable to wear. Its main function is to collect body signals wirelessly from the sensor and then forward the data to the base-station via a wireless sensor network.

To manage patient information effectively, a home-care management program had to be developed to enable patients/users and doctors to monitor/modify/update relevant personal details and health information. After receiving ECG, acceleration and SpO2 wave data in server, than the data is modified by MATLAB functions which are filtering, amplification and compensation. **Fig. 5** shows complemented waves.

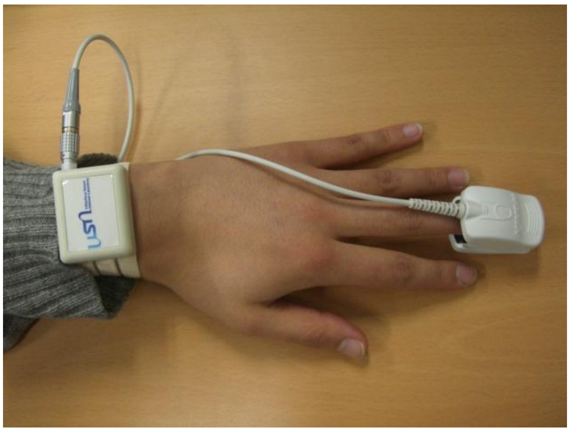


Fig. 4. Portable SpO_2 sensing system.

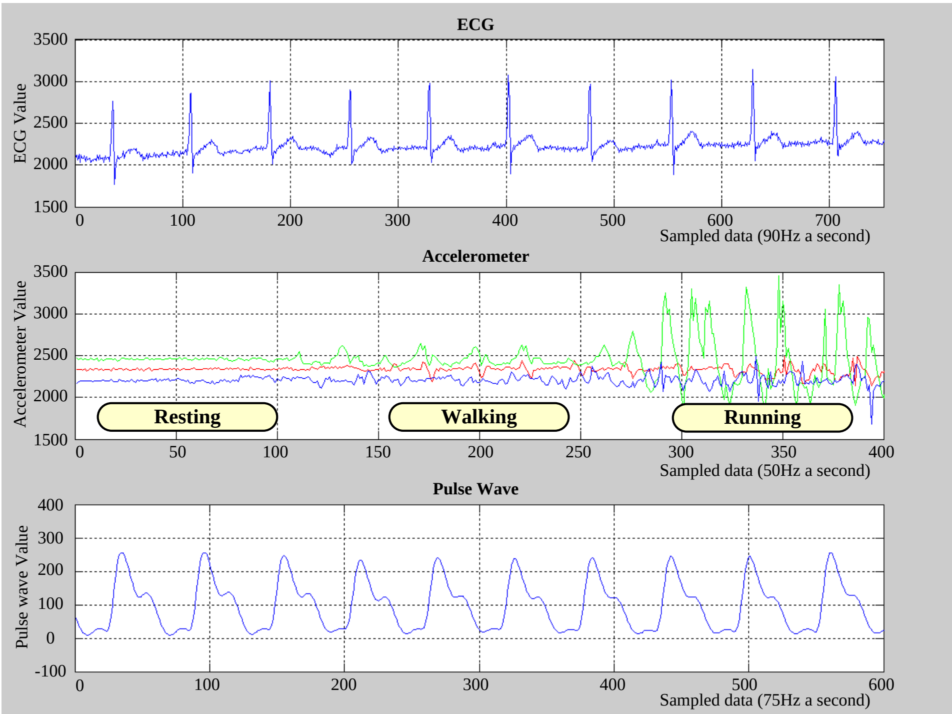


Fig. 5. The GUI of integrated waveforms of EVG, acceleration and SpO_2 signals.

4.2 Indoor Location Tracking

The system aims at helping to evaluate the health status and monitor the activities of elderly persons or chronic patients in the home environment [13][14][15]. A location-aware application provides information about the daily activities of elderly persons at home or hospital to caregivers. To locate an object, active, ceiling-mounted reference beacons are placed throughout a building. By periodically publishing location information using RF and ultrasonic signals, these beacons allow a location-aware application running on mobile or static nodes to determine its physical location. Once a passive listener carried by the person being tracked receives the information, it infers its location from the set of reference beacons it hears. This information from sensor nodes is then forwarded to a base-station, where further computation is performed to determine the current position of the listener and several applications are enabled for context awareness.

In this system, a combination of RF and ultrasonic hardware is used to enable a listener to determine its distance to beacons, of which the nearest can be identified. Measuring the one-way propagation time of ultrasonic signals emitted by a beacon involves taking advantage of the fact that the speed of light (=3 × 108 m/sec) is greater than that of ultrasonic signals (speed of sound) in air. In each transmission, the beacon sends information about the space over RF concurrently with an ultrasonic pulse. When the listener hears the RF signal, it uses the first few bits as training information and turns on its ultrasonic receiver. It then listens for the ultrasonic pulse, which usually arrives a short time later, because it travels at a slower speed than the RF signal. The listener uses the time difference of arrival (TDOA) [16] between the receipt of the first bit of RF information and the ultrasonic signal to determine the distance to the beacon. The distance between a listener and the beacons can be determined by multiplying the speed of sound with the TDOA. Because the speed of the sound varies with

temperature, the effect of temperature is also considered in distance determination. The location of the static listener is determined by a triangulation algorithm as follows. Consider a listener located at (*x, y, z*) in the beacon coordinate system and assume that the listener can measure the distance to n beacons *b1, b2….bn*. Let *di* be the measured distance between *bi* and the listener. Beacon *bi* has the coordinates (*xi*, *yi*, *zi*). The true distance between the listener and *bi* is given by *di* − *€i*, where *€i* is the measurement error. If n = 3 and the distance measurement errors are not too large, a reasonable estimate of the listener's position can be obtained by solving three simultaneous equations:

$$d_i^2 = (x_0 - x_i)^2 + (y_0 - y_i)^2 + (z_0 - z_i)^2 \qquad for \quad i = 1,2,3$$

Two possible solutions are calculated for these three equations. In the first one, the listener is located above the plane containing the three beacons, and in the other, the listener is placed below this plane. Because the beacons are deployed on the ceiling, we can assume that the listener is always located below the plane containing the beacons. When $n \geq 4$, the following non-linear optimization is used to compute the listener's coordinates. We assign some initial coordinates (x_0, y_0, z_0) to the listener. For each beacon *bi*, residual $e(i)$ is defined as follows

$$e(i) = \sqrt{((x_0 - x_i)^2 + (y_0 - y_i)^2 + (z_0 - z_i)^2) - d_i}$$

The sum squared error *Ess* is defined as

$$E_{ss} = \sum_{n}^{i=1} e(i)^2$$

The optimization problem is to find the listener coordinates (x_0, y_0, z_0) that minimize *Ess*. As the number of beacons giving location information to the listener increases, the accuracy of localization becomes higher. When the listener is mobile, distances to multiple beacons are received at different instances of time, with the listener in different positions. However, it is still possible to compute a representative position for the listener on the basis of these distance samples. Moreover, the same technique can be used for mobile users, the only difference being that the error now has two components: measurement error and error caused by the listener being at different positions when the different distance samples are obtained. However, these errors can be reduced by using the Kalman filter approach [17], which also considers the effect of temperature on the velocity of sound.

For an experimental evaluation of the developed system, its location determination capability was tested by deploying beacons on the ceiling and measuring the obtained coordinate and space information at the base-station. Testing was carried out by installing beacons in a home in two different arrangements. By processing the data obtained from the listener, we can track the movements of the user over short (minutes or seconds) or long time periods (hours and days). Each type of moving path provides important cues for understanding what is going on. Recognition of short-time activities can be used to determine the current status of the user, while long-term activities can be regarded as routines, from which deviations can be measured.

To determine measurement accuracy and track the moving path of the user, sensor nodes were placed as shown in **Fig. 6**. Since the previous experiments indicated that the user spent most of his time in the living room and the bedroom, sensor nodes were deployed there. Here the main focus is to visualize the user's travel path, using the same sensor arrangement as before. The accuracy of the location in the form of user space is dependent on many variable parameters such as the deployed topology of the beacons that are attached to the ceiling of a building, and the interference avoidance and detection algorithms. Achieving a position estimation accuracy between 7~15 cm, the developed system is very efficient compared to other approaches such as radar, active bat and active Badge, whose tracking accuracy is several meters [18]. The path travelled shows the movement of the person inside the experimental test bed. **Fig. 7**, on the other hand, displays the distances travelled per hour and enables us to estimate the activity of the person at the time of observation. This type of activity information can be very useful for remote monitoring. For better visualization and understanding, we have tried to plot the experimental test bed on the plot by measuring its length and width. Measurement accuracy and the path observed are mapped on this plot, as shown in the figures. These results provide information for the experimental evaluation of this system and for the various application scenarios that can be developed using the system.

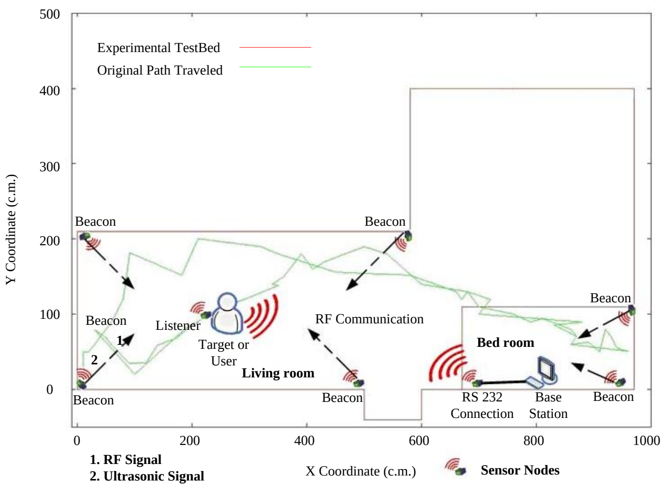


Fig. 6. Deployment of sensor nodes for evaluation of moving paths in traditional home environment.

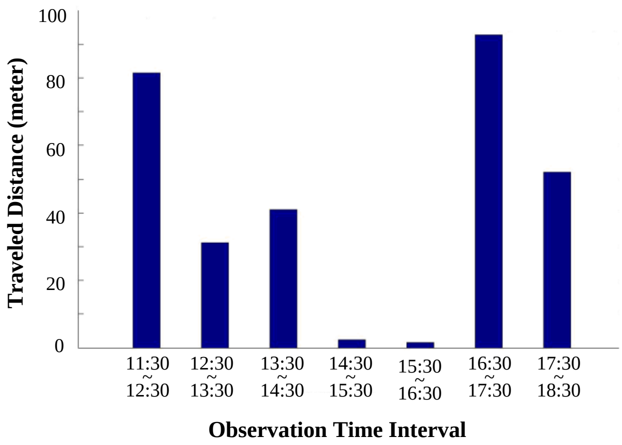


Fig. 7. Activity monitoring based on distance information.

4.3 Personal Mobile Healthcare Diagnosis System

The developed system utilizes mobile computing technology in a merged infrastructure consisting of IEEE802.15.4 networks and CDMA networks. It employs IEEE802.15.4-enabled medical devices to empower caregivers to access vital information and provide quality patient care in a cost-effective manner.

The major communication protocols in this system are the IEEE 802.15.4 wireless network protocol and the CDMA network protocol. The third part of the system, i.e., healthcare management, includes a web server, used to handle received data and to respond to requests to and from cellular phones, and a server monitoring program [19][20], which provides real-time monitoring, analyzes the acquired data and formulates a diagnosis in case of abnormal data. However, due to the memory limitations of cellular phones and the cost of data communication, a simple ECG diagnosis algorithm is constructed, permitting the mobile application to continuously analyze the signals it receives. It only forwards unknown or suspicious signals.

Medical sensors, a fixed base-station and a wireless dongle prototype are the three main hardware devices in our system. Built on the IEEE 802.15.4 standard, these devices are compatible with each other and capable of providing interoperability. **Fig. 8** presents the sensor node and the wireless dongle prototype, measuring 4 × 4 × 0.2 cm3, based on the hardware specifications shown in **Table 1**.

The MSP430F1611 microcontroller (MCU) by Texas Instruments is a 16-bit ultra-low power MCU with 48kBytes Program Flash, 256Bytes data Flash and 10kBytes RAM. Providing a low-supply-voltage range from 1.8V to 3.6 V, it enables sensor nodes to continue data acquisition and transmission by only consuming 330 A at 1 MHz in the active mode, 1.1 A in the standby mode and 0.2 A in the off mode (RAM Retention). Other features include 12-bit ADC, Dual DAC, 2 USARTs, I2C, HW, MULT and DMA to allow the wireless dongle prototype to collect, store, process and transmit digital ADC output received from the sensor interface using the serial port interface (RS232) through SPI/UART or I2C. The developed wireless dongle prototype is pluggable to cellular phones and acts as an intermediary device (base-station) for data acquisition from IEEE802.15.4-enabled medical devices and interacts with CDMA networks to relay the data to the server.

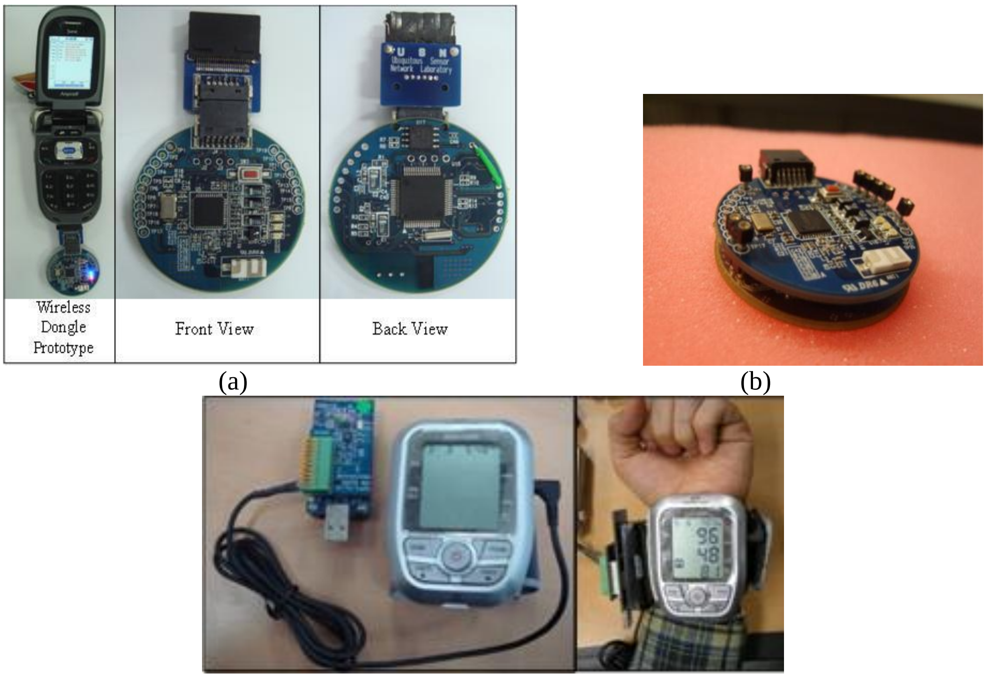
Table 1. Hardware specifications

MCU	MSP430F1611
RF transceiver	CC2420
Bandwidth	2.4 GHz
RF range	≈ 100 m
Power	2.5 ~4.0 V (battery or cellular phone)

To extend the range of the developed healthcare solution from the hospital to outside environments, where CDMA networks are available, the system integrates wireless sensor networks with CDMA networks. The original IEEE 802.11 standard offered a radio networking scheme with data rates of 1 or 2 Mbit/s, while the IEEE 802.11b standard introduced higher-speed operation (up to 11 Mbit/s), with the slower rates being employed as an automatic fall-back in the event of poor reception. However, there are many wireless networking application that do not require the speed and complexity of the IEEE 802.11, so the IEEE 802.15.4 specification for a 'Low-rate Wireless Personal Area Network' (LR-WAN) was created to operate in the 868/915 MHz or 2.4GHz bands. An ad-hoc network is a peer-to peer system, where each node can transmit and direct communication between nodes on the network.

Access points which act as gateways allow transparent communication between wired and wireless nodes, thus enabling the existing network software to be used on a wireless sensor network with no changes. During a wireless network assessment, the developed IEEE 802.15.4-enabled medical devices can perform a quick scan to detect any wireless devices operating in the vicinity, to discover access points (APs) in the area and to determine the path for routing the vital information between CDMA and IEEE802.15.4 networks. The purpose of installing the monitoring program on the server is to directly monitor and interpret the data received from the medical devices in the network. This arrangement helps to reduce the burden of medical caregivers, as it reduces the need to measure vital parameters individually.

To continue the provision of care even outside the hospital, the system employs a cellular network to establish a link between doctors and patients regardless of their physical location. Cellular networks based on the TCP/IP protocol enable mobile users to connect to the internet. A web server was developed to upload data received from IEEE802.15.4 devices to a cellular network and then to the server. However, continuous transmission of data over a cellular network is costly and imposes a heavy burden on network traffic. Most current cell phone models have the capability to support mobile applications, which require high resolution and large memory resources. As a result, we have developed a mobile monitoring application that includes a simple ECG diagnosis algorithm for the local monitoring of vital parameters on a cellular phone and only transmits abnormal or unknown data to the monitoring program on the server for further analysis.



(c)

Fig. 8. Cellular phone with a wireless dongle (a), sensor node together with ECG interface board (b) and wrist blood pressure monitor with wireless sensor node (c).

Our system uses the Samsung Anycall SCH-V670 cell phone. The mobile application, developed for our system using the J2ME platform, provides such functions as remote access to medical information, updating and requesting health records, as well as local monitoring of vital parameters. **Fig. 9** presents a flow chart of the developed mobile healthcare application. Using the application, users can trigger the wireless dongle to measure and aggregate vital parameters and to continuously monitor and analyze ECG signals until any abnormalities are detected. Abnormal data are then relayed to the monitoring program on the server for a more detailed analysis. The ECG diagnosis module consists of two submodules: QRS detection and status decision rule. This module is responsible for visualizing data and displaying measurement results. In addition to providing a user-friendly interface for viewing ECG waveforms, it has the capacity to monitor ECG waves by detecting QRS complexes and determining the normality of vital signs. On detecting abnormal signs, the module transmits the data to the monitoring program on the server for further evaluation.

Fig. 10 shows a snapshot of the ECG monitoring screen, together with additional information such as status, suspected disease, RR interval peak, RR interval time, QRS interval time and ECG value (a). Also shown is a blood pressure monitoring screen together with a summary report screen, showing systolic and diastolic blood pressure as well as pulse and status information after a measurement (b). Patients can save their blood pressure records on their own cellular phones for tracking and monitoring purposes. This feature enables them to retrieve and view their past medical history anytime, and may also serve to remind them of their health condition. As a result, patients have a clear picture of their own health status, and preventive action can be taken earlier on the basis of the information provided by this monitoring program.

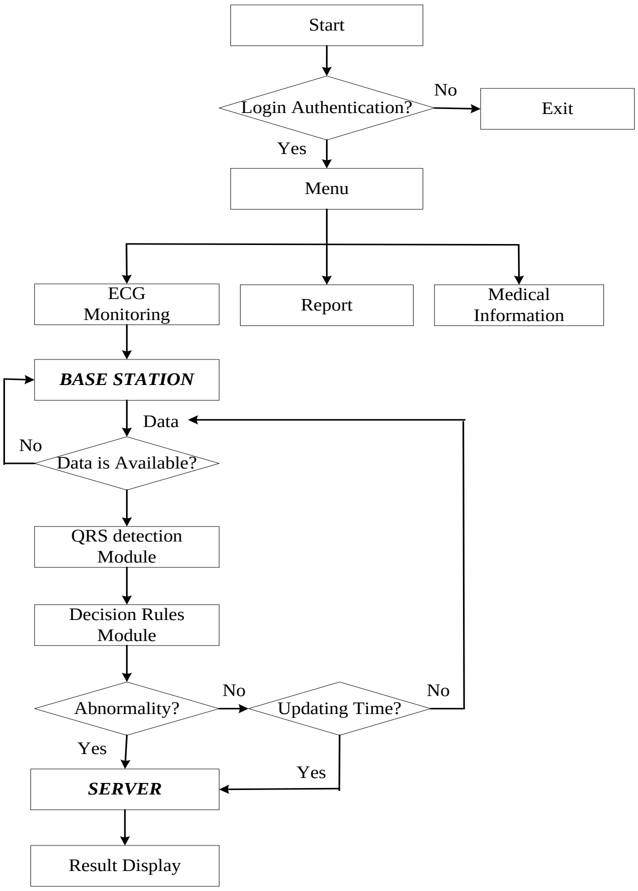
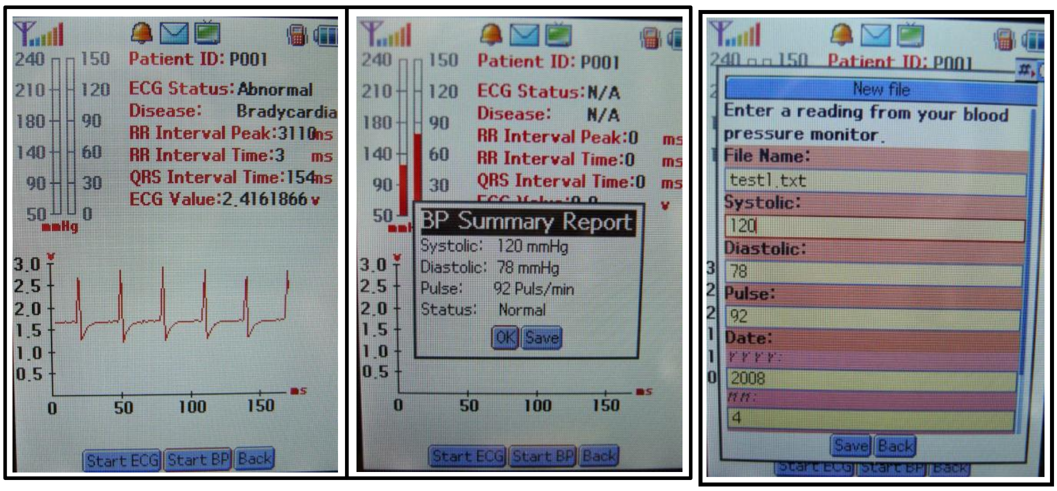


Fig. 9. Flow chart for the developed mobile healthcare application.



(a) (b) (c)

Fig. 10. Screen capture of the ECG and blood pressure diagnosis program on a cellular phone (a, b), and medical records saved locally on a cellular phone (c).

5. Conclusion

Healthcare applications typically deal with several types of waveform data, thus the use of wireless sensor network technology to M2M-healthcare is much more demanding than the use of WSNs for other real-time monitoring tasks, including temperature, humidity, acoustics, light and pollution measurements. This study summarizes the research around the “Multi-modal Sensing u-healthcare System (MSUS) project”, which has been mainly carried out by Pukyong National University, Korea. MSUS employs wearable physiological biosensors, such as ECG, SpO_2 and body temperature sensors, in conjunction with other context-awareness sensors, such as accelerometer sensors and ultrasonic/RF transceivers, to recognize the activity and position of the users.

Compared to other well known previous healthcare projects, our research has several distinctive characteristics:

1. Our system is fully based on the wireless sensor network environment, that is, users’ health parameters, including ECG and body temperature, and context-awareness information, such as activity and position as well as tracking data, are acquired in wireless sensor network both at home and in the hospital environment.
2. Special characteristics of healthcare data, including waveform data from sensors, were considered when the system architecture was designed. Also the effect of packet size and routing update time on the reliability of wireless data transfer has been carefully researched.
3. Context-aware information, such as user activity, location and tracking, is also collected to enhance the reliability of health parameter analysis.
4. Waveform health parameters may place a heavy burden on wireless communication between sensor nodes. To reduce wireless traffic between sensor nodes and the gateway node, ECG analysis on sensor nodes is proposed, together with query architecture.
5. Two communication technologies, the 802.15.4 wireless sensor network and CDMA cellular network, are used to gather medical data from sensors on a patient’s body to a server PC at the hospital. Choice of network technology depends on whether the sensor is within or outside the wireless sensor network area.

Integrating these different approaches, which reflect the special characteristics of M2M-healthcare applications, the developed MSUS system offers very good performance. The design and performance of wireless sensor networks always depend on application requirements, hardware and software limitations. Keeping these considerations in mind, we attempted to develop a healthcare system for the hospital and home environment. Future efforts include the M2M healthcare optimization which reflects the upcomming communication and device standards and practical field testing in the home and hospital environment. Results obtained from these tests can then be used in further design to improve the performance of the M2M-healthcare system.

References

[1] Report of an expert group meeting population aging and development, “Social, health and gender issues with a focus on the poor in old age 29–31,” 2001.

[2] N. Nakajima, “Short-range wireless network and wearable bio-sensors for healthcare applications,” in *Proc. of the 3rd International Symposium on Applied Sciences in Biomedical and*

Communication Technologies,2009. Article (CrossRef Link)
[3] Guang-Zhong Yang (ed), *Body Sensor Networks*. Springer-Verlag London Limited, 2006.
[4] M. Chen, S. Gonzalez, Q. Zhang, M. Li and V. Leung, "A 2G-RFID based E-healthcare System", *IEEE Wireless Communications Magazine*, vol.17, no.1, pp.37-43, Feb.2010. Article (CrossRef Link)
[5] M. Chen, "Towards Smart City: M2M Communications with Software Agent Intelligence", *Multimedia Tools and Applications*, 2012. Article (CrossRef Link)
[6] Min Chen, Sergio Gonzalez, Athanasios Vasilakos, Huasong Cao and Victor C. M. Leung, "Body area networks: A survey", *Mobile Networks & Applications*, vol.16, no.2, pp.171-193, 2010. Article (CrossRef Link)
[7] Chunxiao Chigan and Vikram Oberoi, "Providing QoS in ubiquitous telemedicine networks", in *Proc. of the Fourth Annual IEEE International Conference on Pervasive Computing and Communications Workshop*, Mar. 2006. Article (CrossRef Link)
[8] J-M Lee, J-H Lee and T-M Chung, "Experimental QoS test of medical data over wired and wireless networks", in *Proc. of ICACT 2008* , pp.142–146, 2008. Article (CrossRef Link)
[9] Rune Fensli, Einar Gunnarson and Torstein, "A wearable ECG-recording system for continuous Arrhythmia monitoring in a wireless tele-home-care situation", in *Proc. of 18th International Symposium on Computer-Based Medical Systems*, pp.407-412, 2005. Article (CrossRef Link)
[10] Chulsung Park, P.H. Chou, Y. Bai, R. Matthews and A. Hibbs, "An ultra-wearable, wireless, low power ECG monitoring system", in *Proc. of Biomedical Circuits and Systems Conference*, pp.241–244, 2006. Article (CrossRef Link)
[11] Wan-Young Chung, "Ubiquitous healthcare system based on a wireless sensor network, doctor of science in techology" thesis, University of Oulu,2009.
[12] R. Gururajan and T. Vuori, "Experience in wireless application development in a healthcare setting", Web Center, Edith Cowan University, pp.1–7, 2003.
[13] T. Gao, D. Greenspan, M. Welsh, RR Juang and A Alm, "Vital signs monitoring and patient tracking over a wireless network", in *Proc. of the 2005 IEEE Engineering in Medicine and Biology*, pp.102–105, 2005. Article (CrossRef Link)
[14] L. Nagl, R. Schmitz, S. Warren, T. S. Hildreth, H. Erickson and D. Andresen, "Wearable sensor system for wireless sensor system for wireless state-of-health determination in cattle", in *Proc. of 3rd Joint EMBS-BMES Conference*, 2003. Article (CrossRef Link)
[15] S. Pandey and P. Agrawal, "A survey on localization techniques for wireless networks", *Journal of the Chinese Institute of Engineerings*, vol.29, no.7, pp.1125–1148, 2006. Article (CrossRef Link)
[16] J. Hightower and G. Borriello, "location systems for ubiquitous computing", *Computer*, vol.34, pp.57–66, 2001. Article (CrossRef Link)
[17] RE Kalman, "A new approach to linear filtering and prediction problems", *Trans. ASME*, vol.82, pp.35–45, 1960. Article (CrossRef Link)
[18] Nissanka Bodhi Priyantha, "The cricket indoor location system", *Ph.D. thesis*, MIT, 2005.
[19] Dae-Seok Lee, B. Sachin, R. Myllylä and W.-Y. Chung, "A wireless ECG monitoring system for continuous event detection and analysis", in *Journal of Technical Digest of International Meeting on Chemical Sensors*, pp.185-186, 2006.
[20] B. Sachin, G. Walia, R. Myllylä and W.-Y. Chung, "Query based ECG monitoring and analyzing system via wireless sensor network", in *Proc. of 2nd international conference on WCSN*, India, pp.146–153, 2006.

Wan-Young Chung is a Professor at Department of Electronic Engineering in Pukyong National University, Busan, Korea from September, 2008. He earned B.S. and M.S. degrees in Electronic Engineering from Kyungpook National University, Daegu, Korea in 1987 and 1989 respectively and Ph.D. degree in Sensor Engineering form Kyushu University, Fukuoka, Japan in 1998. From 1993 to 1999, he was an assistant professor in Semyung University. From 1999 to 2008 he was an associate professor in Dongseo University. His areas of interest include Ubiquitous Healthcare, Wireless sensor Network and Embedded Systems.