Intelligent Mobile Health Monitoring System (IMHMS)

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Abstract

Health monitoring is repeatedly mentioned as one of the main application areas for Pervasive computing. Mobile Health Care is the integration of mobile computing and health monitoring. It is the application of mobile computing technologies for improving communication among patients, physicians, and other health care workers. As mobile devices have become an inseparable part of our life it can integrate health care more seamlessly to our everyday life. It enables the delivery of accurate medical information anytime anywhere by means of mobile devices. Recent technological advances in sensors, low-power integrated circuits, and wireless communications have enabled the design of low-cost, miniature, lightweight and intelligent bio-sensor nodes. These nodes, capable of sensing, processing, and communicating one or more vital signs, can be seamlessly integrated into wireless personal or body area networks for mobile health monitoring. In this paper we present Intelligent Mobile Health Monitoring System (IMHMS), which can provide medical feedback to the patients through mobile devices based on the biomedical and environmental data collected by deployed sensors.

1. Introduction

Pervasive computing is the concept that incorporates computation in our working and living environment in such a way so that the interaction between human and computational devices such as mobile devices or computers becomes extremely natural and the user can get multiple types of data in a totally transparent manner [1]. The potential for pervasive computing is evident in almost every aspect of our lives including the hospital, emergency and critical situations, industry, education, or the hostile battlefield. The use of this technology in the field of health and wellness is known as pervasive health care. Mobile computing describes a new class of mobile computing devices which are becoming omnipresent in everyday life. Handhelds, phones and manifold embedded systems make information access easily available for everyone from anywhere at any time. We termed the integration of mobile computing to pervasive health care as mobile health care. The goal of mobile health care is to provide health care services to anyone at anytime, overcoming the constraints of place, time and character. Mobile health care takes steps to design, develop and evaluate mobile technologies that help citizens participate more closely in their own health care. In many situations people have medical issues which are known to them but are unwilling or unable to reliably go to a physician. Obesity, high blood pressure, irregular heartbeat, or diabetes is examples of such common health problems. In these cases, people are usually advised to periodically visit their doctors for routine medical checkups. But if we can provide them with a smarter and more personalized means through which they can get medical feedback, it will save their valuable time, satisfy their desire for personal control over their own health, and lower the cost of long term medical care.

Various definitions and terminologies are used for bio-sensors depending on the field of applications. Two generalized definitions of biosensor can be found in [2] and [3]. Authors in [2] define it as: "A biosensor is a chemical sensing device in which a biologically derived recognition entity is coupled to a transducer, to allow the quantitative development of some complex biochemical parameter". According to the authors [3]: "A biosensor is an analytical device incorporating a deliberate and intimate combination of a specific biological element (that creates a recognition event) and a physical element (that transduces the recognition event)".The name biosensor signifies that the device is a combination of two parts: bio-element and sensor-element. A specific bio element (say, enzyme) recognizes a specific analyte and the sensor element transduces the change in the bio-molecule into electrical signal. The bio element is very specific to the analyte to which it is sensitive. It does not recognize other analytes. The bio-sensors can have variety of biomedical and industry applications. They are used for Glucose Level Monitoring, ECG Sensing, Pulse Measurement, Blood Pressure Monitoring, Cell morphology monitoring etc. Recently they are used for providing artificial retina to human beings.

A number of bio-sensors that monitor vital signs, environmental sensors (temperature, humidity, and light), and a location sensor can all be integrated into a Wearable Wireless Body/Personal Area Network (WBAN/WPAN). This type of networks consisting of inexpensive, lightweight, and miniature sensors can allow long-term, unobtrusive, ambulatory health monitoring with instantaneous feedback to the user about the current health status and real-time or near real-time updates of the user's medical records. Such a system can be used for mobile or computer supervised rehabilitation for various conditions, and even early detection of medical conditions. When integrated into a broader tele-medical system with patients' medical records, it promises a revolution in medical research through data mining of all gathered information. The large amount of collected physiological data will allow quantitative analysis of various conditions and patterns. Researchers will be able to quantify the contribution of each parameter to a given condition and explore synergy between different parameters, if an adequate number of patients are studied in this manner.

In this paper we present a bio-sensor based mobile health monitoring system named as "Intelligent Mobile Health Monitoring System (IMHMS)" that uses the Wearable Wireless Body/Personal Area Network for collecting data from patients, mining the data, intelligently predicts patient's health status and provides feedback to patients through their mobile devices. The patients will participate in the health care process by their mobile devices and thus can access their health information from anywhere any time. Moreover, so far there is no automated medical server used in any of the work related to mobile health care. To maintain the server a large number of specialist are needed for continuous monitoring. The presence of a large number of specialists is not always possible. Moreover in the third world countries like ours specialist without proper knowledge may provide incorrect prescription. That motivates us to work for an intelligent medical server for mobile health care applications that will aid the specialists in the health care. As a large amount of medical data is handled by the server, the server will perform mine and analyze the data. With the result of mining, analysis and suggestions and information provided by the specialists in the critical scenarios the server can learn to provide feedback automatically. Moreover as time grows the server will trained automatically by mining and analyzing data of all the possible health care scenarios and become a real intelligent one. Our main contribution here is the Intelligent Medical Server which is a novel idea in the field of mobile health care.

The outline of this paper is as follows: We provide the short descriptions of the related works in Section 2. System Architecture of IMHMS is described in Section 3 followed by the characteristics of the IMHMS in Section 4. The impact of IMHMS is given in Section 5. Section 6 presents the evaluation of the system. Our future research direction and concluding remarks are in Section 7.

2. Related Works

All Several health care projects are in full swing in different universities and institutions, with the objective of providing more and more assistance to the elderly. CAST (Center for Aging Services Technologies) [4] is organizing multiple projects including: 1. a safe home that will help debilitated elderly by tracking their activities. 2. a sensor-based bed to track the sleep and weight, which will later be used in detecting diseases. In The Center for Future Health [5], a five-room house has been implanted with several infrared sensors, monitoring devices and bio-sensors. The ultimate goal of the project is to provide a unified solution for the seniors in the home, enabling them to closely participate in disease detection and health management by themselves. A similar type of project named AHRI (Aware Home Research Initiative) [6] is going on at GeorgiaTech University. MobiHealth project [7] [8] [9] is going on to build a system for collecting vital body signals and manipulating those in distant health care institutes. The Terva [12] monitoring system had been introduced to collect data related to health condition like blood pressure, temperature, sleep conditions, weight, etc., over quite a long time. Here data has been collected four times a day (morning, noon, evening and night) and saved in the form a TOD (time-of-day) matrix and analyzed later. The whole system has been housed in a suitcase that includes a laptop, blood pressure monitor and several other monitoring devices. As a result, this system loses its mobility and becomes feasible to be used in a static manner in the home. A feedback-based self monitoring system for managing obesity named Wireless Wellness Monitor [11] [13] has been devised using Bluetooth and Jini network to supports Java dynamic networking. The system consists of measuring devices, a home server as the base station, mobile terminals (e.g. PDA or smart phone) and databases which are connected through the internet. The measuring devices collect data and place that in the home server. Mobile terminals can access information wirelessly from the home server or can collect data from the external databases through the home server. MobiHealth project [11] [12] [13] can monitor crucial health signals through tiny medical sensors and transmit them to health care professionals through highly powerful and cheaply available wireless system. Body Area Network (BAN) has been used in signal monitoring and GPRS and UMTS has been used for transmitting signal on the fly. In [10] researchers have depicted several required characteristics of wearable health care system along with the design, implementation and communication issues of a plug-and-play system but it is not affordable and needs special hardware. [14] Presented WWBAN (Wireless Wearable Body Area Network) which consists of static sensors communicating only with the central control unit. [15] Developed a system named Wellness Assistant (WA), which uses pervasive computing technologies using inexpensive handheld devices such as PDAs, cell phones, and wrist watches with short range wireless capabilities. The WA can be used by people with obesity, diabetes, or high blood pressure, conditions which need constant monitoring. Recently [17] describes various pervasive health care applications and their requirements, required network infrastructures as well as some open issues and challenges. The Centre for Pervasive Health care of Department of Computer Science in University of Aarhus [18] is a dedicated research program to design, develop, and evaluate pervasive computer technologies for clinicians to use in hospitals and for helping citizens to participate closely in taking care of their own health. A large number of works regarding pervasive health care are carried out by them recently.

3. System Architecture

IMHMS collects patient's physiological data through the bio-sensors. The data is aggregated in the sensor network and a summary of the collected data is transmitted to a patient's personal computer or cell phone/PDA. These devices forward data to the medical server for analysis. After the data is analyzed, the medical server provides feedback to the patient's personal computer or cell phone/PDA. The patients can take necessary actions depending on the feedback. The IMHMS contains three components. They are

1. *Wearable Body Sensor Network [WBSN]*
2. *Patients Personal Home Server [PPHS]*
3. *Intelligent Medical Server [IMS]*.

They are described below.

Wearable Body Sensor Network [WBSN]

Wearable Body Sensor Network is formed with the wearable or implantable bio-sensors in patient's body. These sensors collect necessary readings from patient's body. For each organ there will be a group of sensors which will send their readings to the group leader. The group leaders can communicate with each others. They send the aggregated information to the central controller. The central controller is responsible for transmitting patient's data to the personal computer or cell phone/PDA. [16] suggested that for wireless communication inside the human body, the tissue medium acts as a channel through which the information is sent as electromagnetic (EM) radio frequency (RF). So in WBSN, information is transmitted as electromagnetic (EM) radio frequency (RF) waves. The central controller of the WBSN communicates with the Patients Personal Home Server [PPHS] using any of the three wireless protocols: Bluetooth, WLAN (802.11) or ZigBee. Bluetooth can be used for short range distances between the central controller and PPHS. WLAN can be used to support more distance between them. Now days ZigBee introduces itself as a specialized wireless protocol suitable for pervasive and ubiquitous applications. So ZigBee can be used for the communication too.

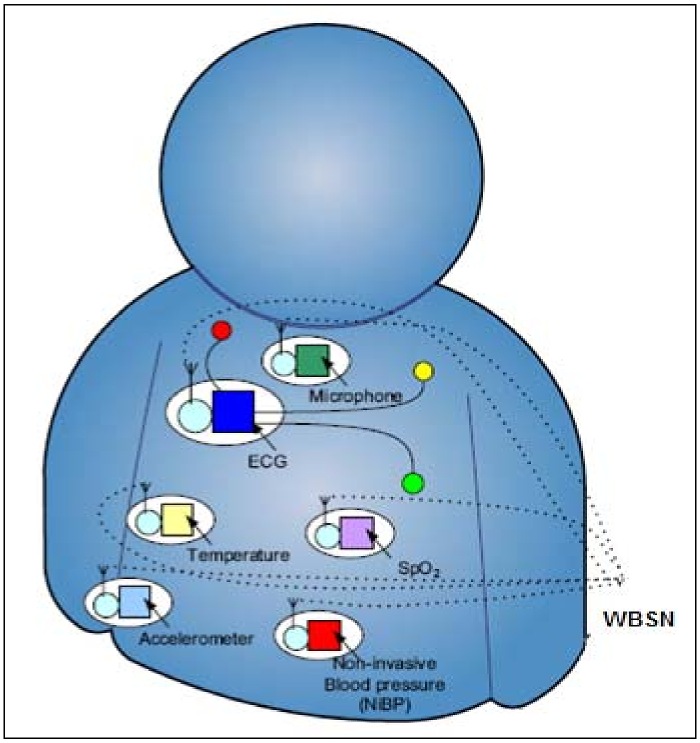


Figure 1: WBSN

Patient's Personal Home Server [PPHS]

The patient's personal home server can be a personal computer or mobile devices such as cell phone/PDA. We suggest mobile devices because it will be more suitable for the users to use their mobile devices for this purpose. PPHS collects information from the central controller of the WBSN. PPHS sends information to the Intelligent Medical Server [IMS].PPHS contains logics in order to determine whether to send the information to the IMS or not. Personal Computer based PPHS communicates with the IMS using Internet. Mobile devices based PPHS communicates with the IMS using GPRS / Edge / SMS. The best way to implement IMS is by Web Service or Servlet based architecture. The IMS will act as the service provider and the patients PPHS will act as the service requester. By providing these types of architecture, a large number of heterogeneous environments can be supported with security. So personal computer or cell phone/PDA can be connected easily to a single IMS without any problem.

Intelligent Medical Server [IMS]

Intelligent Medical Server [IMS] receives data from all the PPHS. It is the backbone of this entire architecture. It is capable of learning patient specific thresholds. It can learn from previous treatment records of a patient. Whenever a doctor or specialist examines a patient, the examination and treatment results are stored in the central database. IMS mines these data by using state-of-the-art data mining techniques such as neural nets, association rules, decision trees depending on the nature and distribution of the data. After processing the information it provides feedback to the PPHS or informs medical authority in critical situations. PPHS displays the feedback to the patients. Medical authority can take necessary measures. The IMS keeps patient specific records. It can infer any trend of diseases for patient, family even locality. IMS can cope with health variations due to seasonal changes, epidemics etc. IMS is controlled and monitored mainly by specialized physicians. But even a patient can help train IMS by providing information specific to him. After mining the database stored in IMS, important information regarding general health of the people can be obtained. It can help the authority to decide health policies. Large numbers of patients will be connected to the IMS using their PPHS. So security of the patients is a major issue here. So RFID can be used in this purpose. Radio-frequency identification (RFID) is an automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags or transponders. An RFID tag is an object that can be applied to or incorporated into a product, animal, or person for the purpose of identification using radio waves. Some tags can be read from several meters away and beyond the line of sight of the reader. So security can be provided by providing RFID tags to each patient.

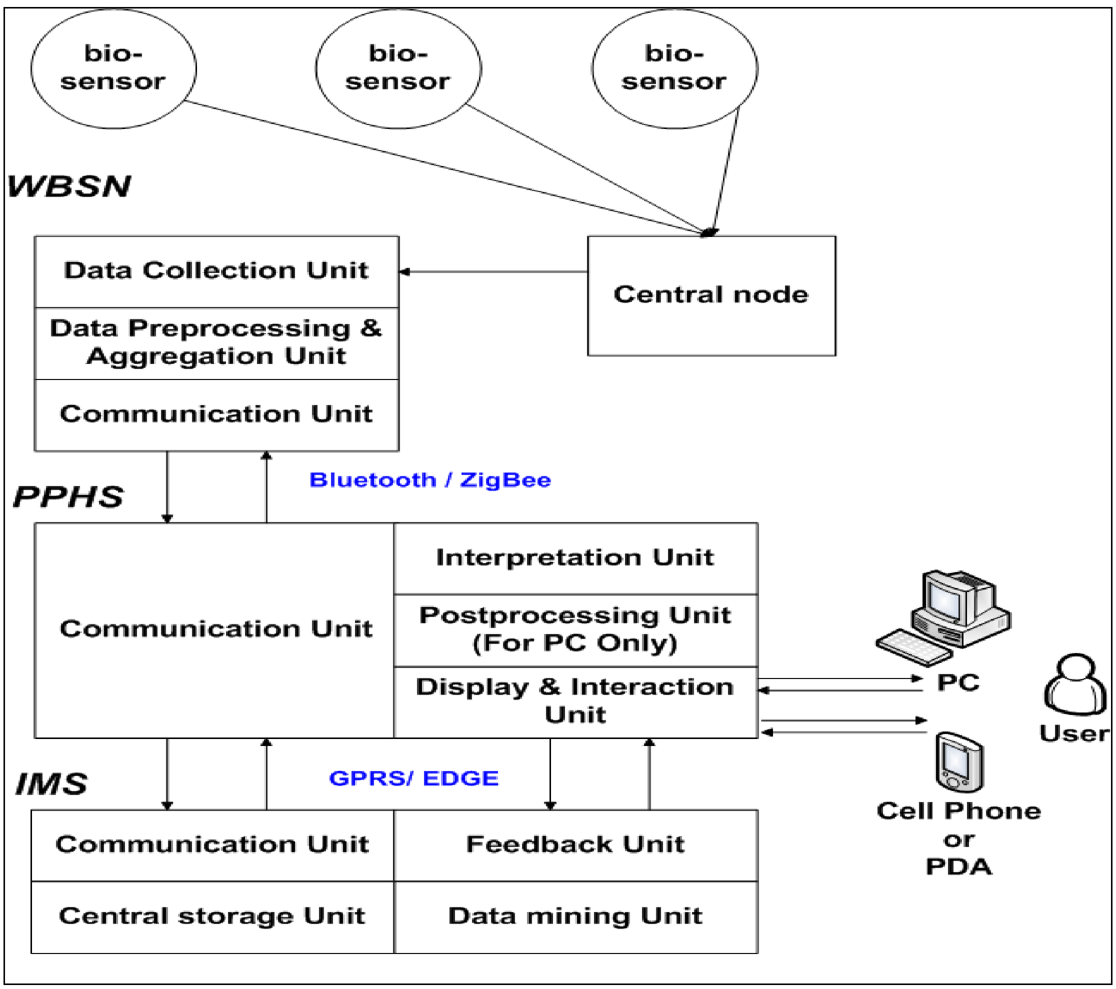


Figure 2: IMHMS System Architecture

Our main contribution is the Intelligent Medical Server (IMS) which is a novel idea. So we are describing it in more details with possible scenarios below.

Scenarios

In intensive care units, there are provisions for continuously monitoring patients. Their heart rates, temperatures etc. are continuously monitored. But in many cases, patients get well and come back to home from hospital. But the disease may return, he may get infected with a new disease, there may be a sudden attack that may cause his death. So in many cases, patients are released from hospital but still they are strongly advised to be under rest and observation for some period of time (from several days to several months). In these cases, IMHMS can be quite handy.

Patients of blood pressure frequently get victimized because of sudden change of pressures. It cannot be foreseen and also a normal person cannot be kept under medical observation of a doctor or a hospital all days of a year. Blood pressures change suddenly and can be life-treating. Using IMHMS, they can get alerts when their blood pressure just starts to become high or low.

Patient's data (temperature, heart rate, glucose level, blood pressure etc.) will be frequently measured and sent to PPHS. Period of sending (say every 3 min) can be set from the patient in the central controller of WBSN. Normally glucose level will be sent after several days or a week. Heart rates can be sent every minute and temperatures can be sent after half an hour etc. But these can be parameterized to ensure that when a patient is normal, not many readings will be sent so that sensors have a longer life-time. But when the patient is ill, readings will be taken frequently and sent to PPHS.

PPHS will have some logic to decide whether the information is worthy of sending to IMS. Say, temperature is in safety range(less than 98F), and then PPHS will not send this info to IMS to save cost for the patient. Again say, glucose level is safe and same as the last several days, then this info also need not be sent. Data must be sent to IMS when there is a change in status (say temperature of the patient goes to 100F from 98F or a patient with severe fever 102F has just got temperature down to 99F). Again if there is a sudden change in blood pressure or glucose level, then this info must be sent to IMS.

IMS learns patient specific threshold. Say the regular body temperature of a patient is 98.2F whereas one person feels feverish if his body temperature is 98.2F. By employing an averaging technique over a relatively long time, IMS can learn these thresholds for patients. However, patients can also give these thresholds as inputs based on directions of their doctors.

Using IMS, one can view his medical history date wise, event wise etc. IMS can perform data mining on a particular patient data to discover important facts. Suppose a person has medium high temperature that starts at evening and lasts till midnight. If this phenomenon continues for several days, IMS will automatically detect this fact and send a message to PPHS saying "You frequently have short-period fever that may be a symptom of a bad disease. Consult doctor immediately".

Using IMS, one can view his medical history date wise, event wise etc. A patient can also enter extra information like he has had chest pain today, or he is frequently vomiting, he has rashes on body etc. in PPHS. In IMS, there will be a set of rules for preliminary prediction of disease. These rules will be pre learnt based on neural network or data mining of existing disease databases that are available over web. Now IMS, with the additional information, will check the rules. If it finds a matching rule, then it will predict the disease and send the message to PPHS.

PPHS can transmit continuous EKG data. Suppose a patient has come back home after cardiac surgery. If the patient has cardiac problems like arrhythmia, then there will be irregular variation of heart signal. This may occur only once or twice a day. But if PPHS transmits continuous EKG data, such variations will be immediately detected and alerts will be issued.

The most important fact about IMS is that it can help stop the spread of diseases. Whenever it finds that several people from same locality over a small period of time are having the same disease, it will predict that the disease is spreading out in that locality so that authority can take immediate action. Say, when some people of the same area report that they are having high fever, pain over body and rashes, IMS will report this which the doctors can interpret that dengue is breaking out in that area and the authority has a chance to take actions at the very first stage so that epidemic can be avoided.

4. Characteristics

The characteristics of IMHMS are described below:

Simplicity

The system architecture of IMHMS is a simple one with no complex system or communication architecture. Though the setup of WBSN is quite sophisticated but to get help from such intelligent health monitoring systems bio-sensors need to implant or wore to the patient's body.

Cost-Effective

IMHMS is cost effective. WBSN setup consists of some low cost bio-sensors. The communication from WBSN is also cheap due to the use of low cost Bluetooth or ZigBee adapters. PPHS setup is cost effective due to use of personal computer of normal configuration or low cost cell phones. IMS will incur some cost due to a large number of patients support. But with respect to the number of patients served by a single IMS this cost is worthy.

Secure

Security is a major issue in IMHMS. Suppose a heart patient's data is manipulated by the malicious attackers. The normal reading can be changed as a serious one and the heart patients can be affected by the faulty result that may even cause him serious heart attack. So without security the IMHMS is not complete. As mentioned in the System Architecture, security in IMHMS is provided by using RFID. Each patient will be provided RFID tags that will be used to uniquely identify the patient. The IMS will maintain patients profile information with the RFID in the central database. So malicious attacks can be blocked using this information because a patient can be easily tracked using RFID. Moreover large volumes of data need to be transmitted between the three components of the IMHMS. So data must be transmitted in encrypted form between the components to protect from security vulnerability.

Flexible communication protocol

The communication protocols of IMHMS are flexible. The WBSN central controller can communicate with the PPHS using any of the three protocols: Bluetooth, WLAN or ZigBee. Moreover the PPHS can be personal computer, cell phone or PDA. In case of computer, it can communicate with the IMS using internet. Cell phones or PDAs can communicate with the IMS using any of the three ways: GPRS / Edge / SMS. So we can see a large number of alternative ways of communication is supported in IMHMS making the communication protocol a real flexible one.

Capability to predict spread of diseases

The intelligent IMS can predict spread of diseases in a specific locality. The IMS contains some strong and efficient data mining algorithms that can be used for this purpose.

Capability to help authority to determine general health policies

The IMS is capable to help authority to determine general health policies. For example, in a specific locality a large number of people (who are the client of IMS) are affected by diseases that occur due to the lack of a specific vitamin, the IMS can track this situation and can generate alert messages for the authority to inform them. Then the authority can determine the health policy by forcing the market to bring and sell foods having the specific vitamin as well make people aware of their vitamin deficiency.

5. Broader Impact

The IMHMS has a broader impact for the developed and developing countries.

Health care through mobile devices with a central medical server is not a new concept for the developed countries. But the medical server used there is mainly for data storage. But the IMS of IMHMS not only stores data but also use it for automated medical feedback. So for developed countries all the existing central storage server can be replaced easily with IMS. So to integrate IMS with the existing health care services, their central medical server's data needs to be migrated to IMS. Then IMS can intelligently support all the existing health care services.

The people of the developing countries extensively use mobile devices but they are not familiar with mobile device based intelligent services. So IMHMS can be very handy for them by providing health care services anywhere anytime through their mobile devices. For developing countries, IMHMS can aid physicians and specialists for better treatment of the patients as their whole medical data and treatment history is stored in IMS. Moreover it is not always possible for the patients to avail the services of special care units like ICU (Intensive Care Unit), CCU (Critical Care Unit) due to limited number of such units and money. So in these cases IMHMS can help the patients by providing continuous health monitoring.

6. Evaluation

To evaluate IMHMS, we have used the following approaches.

1. Implement a prototype of different components of IMHMS

2. Cognitive walkthrough strategy

Prototype Implementation

We are working on building WBSN. This implementation is not complete yet. So we consider the data provided by the bio-sensors as a well structured XML file. A sample XML file is shown in Figure 3 where a patient's Temperature, Glucose-level and Blood-pressure are measured continuously over a period of time.


```
  <?xml version="1.0" encoding="utf-8" ?>
- <Medical>
  - <Data>
      <PatientId>pt1</PatientId>
      <Date>1-8-2008</Date>
      <Time>8:00:00</Time>
      <Temperature>102</Temperature>
      <Glucose-level>80</Glucose-level>
      <Blood-Pressure>100-130</Blood-Pressure>
    </Data>
  - <Data>
      <PatientId>pt1</PatientId>
      <Date>1-8-2008</Date>
      <Time>8:10:00</Time>
      <Temperature>102</Temperature>
      <Glucose-level>75</Glucose-level>
      <Blood-Pressure>110-140</Blood-Pressure>
    </Data>
  - <Data>
      <PatientId>pt1</PatientId>
      <Date>1-8-2008</Date>
      <Time>8:20:00</Time>
      <Temperature>103</Temperature>
      <Glucose-level>85</Glucose-level>
      <Blood-Pressure>90-140</Blood-Pressure>
    </Data>
  </Medical>
```


Figure 3: Patient's Health Data

Two possible implementations are there for PPHS. It can be implemented in personal computer. While implementing for personal computer, the most suitable communication media between WBSN and PPHS is Bluetooth because of its availability and low cost. The personal computer based PPHS implementation required Bluetooth Server setup in the personal computer. The medical data of the patients will be transferred from WBSN to PPHS through the Bluetooth Server. Then the personal computer based PPHS processes the data and send necessary data to the IMS. But we suggest mobile devices for implementing PPHS because it will be more suitable for the users to use their cell phones or PDA in this purpose. The real mobility of the solution can be provided by mobile devices. For mobile device based implementation, we first consider two choices. One is J2ME and the other is Google Android. Android is still in simulator level without any implementation but it is not very far away that it will rule the field of mobile computing. We choose J2ME based custom application so that it can be deployed immediately in a large number of available cell phones or PDA available in the market. The J2ME based PPHS automatically collect patient's data from the WBSN and transfer it to the IMS. It is also responsible for displaying results and feedback from the IMS to any specific patients.

We implemented the skeleton of the IMS. IMS is built with the Java Servlet based architecture. To connect to the IMS, PPHS requires software to be installed. We implemented a J2ME application that processes the XML file of patient's data using KXML which is an open source XML parser. The application connects to the IMS using GPRS or EDGE. It can connect using SMS also if SMS receiving capable application can be developed in the IMS. Our J2ME application connects to the IMS's Web Servlet by GPRS or EDGE. The SMS based portion is not implemented yet. To implement the SMS based portion the IMS must be interfaced with a number of cell phones or PDA in order to receive SMS from the PPHS and send the feedback to the PPHS as SMS.

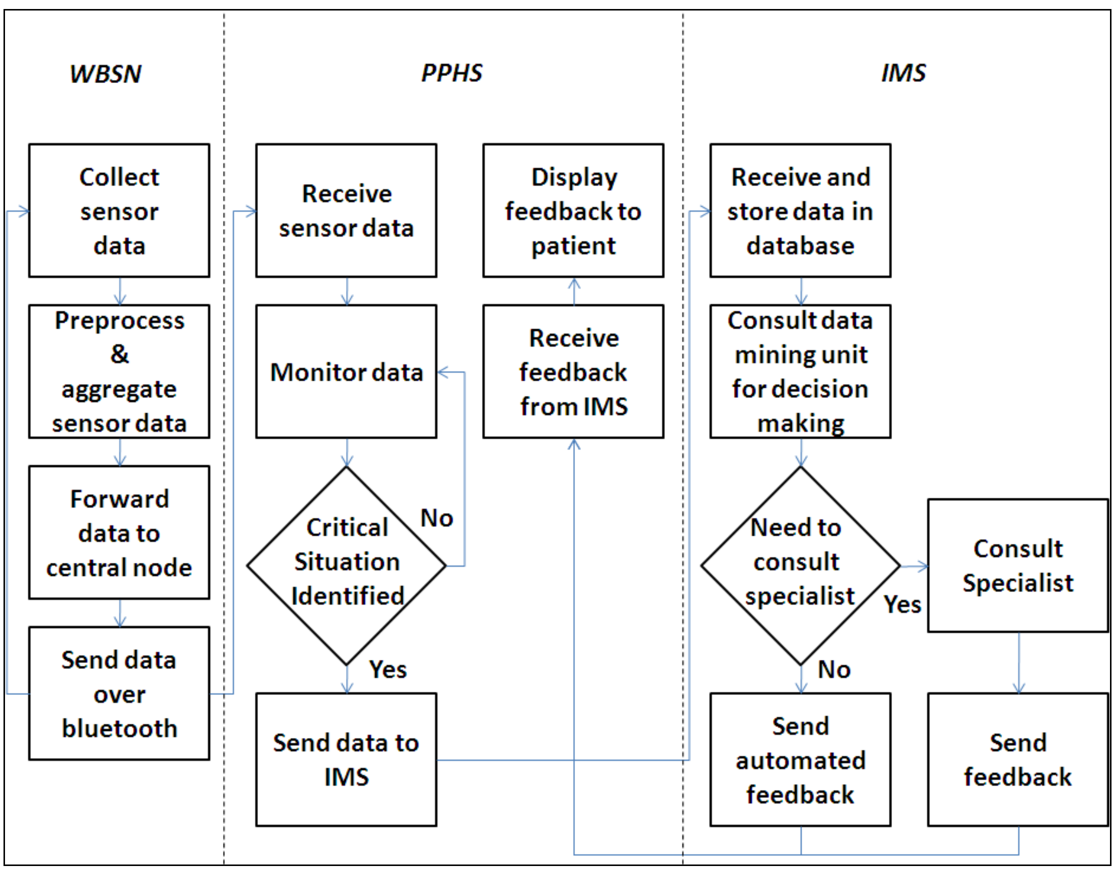


Figure 4: Flow diagram of the implementation

The flow diagram of the implementation is shown in the Figure 4. The WBSN collects patient data and send the data to the PPHS. PPSH receives the data and processed the data to reduce the transmission of unnecessary data to the IMS. The PPHS communicates with the IMS using GPRS or EDGE. The IMS contains a Data Mining Unit, a Feedback Unit and a central database. The database contains the entire patients' profile, continuous health data and a large set of rules for data mining operations. The Data Mining unit processes the data and returns the feedbacks and results to the Feedback Unit. The feedback unit then sends the data to the corresponding PPHS. Moreover the patient's can login to the IMS using authorized patient-id and password to provide information manually and to view the patient's entire history. Some screenshots of these activities are shown in the figure. Figure 5.1 and 5.2 show the interface in IMS for patients profile information and manual health data submission. Figure 5.3 shows one patient's entire medical history with the feedbacks and results stored in the IMS's central database. Figure 5.4 and 5.5 show the automated health data collection of J2ME based PPHS and display of feedbacks provided by IMS based on the collected data.

The interfaces of PPHS and IMS are user friendly. Any people with little or no technical knowledge can use it without any difficulties. The communication architecture of IMHMS is very simple and flexible as we claimed. There is no complexity in communication between the components of IMHMS. So the prototype implementation was quite smooth. The prototype implementation involves a low cost cell phone and a personal computer. The cell phone acts as the PPHS where as the personal computer acts as the IMS. The cell phone communicates with the personal computer using GPRS which is very cheap and available now with every cell phone. So the setup for the evaluation was really cost effective. We are working on providing RFID based security. In the evaluation we encrypted the data using Advanced Encryption Standard (AES). We used Java Cryptography Extension (JCE) for this purpose, which is a framework for encryption, key generation, and key agreement and message authentication code (MAC) algorithms. [19]

Cognitive walkthrough strategy

Cognitive Walkthrough Strategy encompasses one or a group of evaluators who inspect a user interface by going through a set of tasks and assess its understandability and ease of learning. To evaluate our IMHMS, we followed this strategy by collecting valuable feedback and measure the performance of the IMHMS. We have interviewed several people including patients with and without technical knowledge and some undergraduate and graduate students.

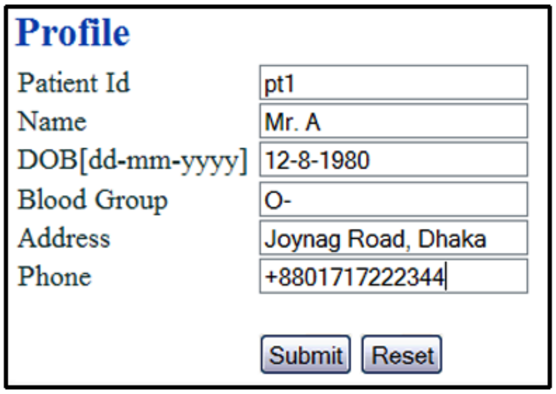


Figure 5.1: Patient's Profile

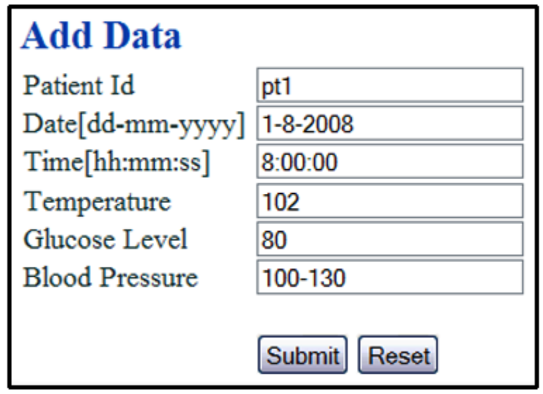
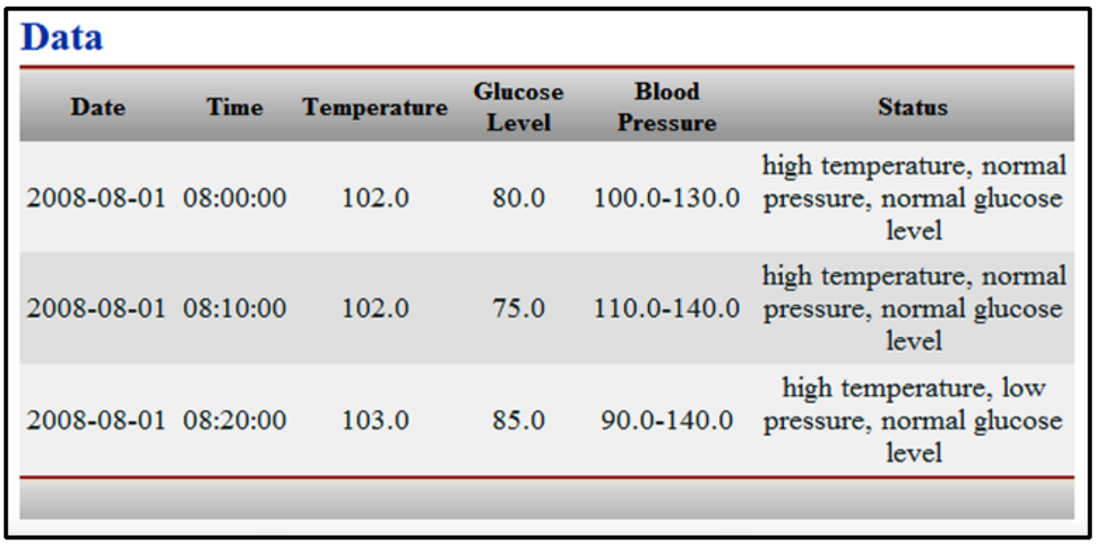


Figure 5.2: Manual Data Submission



Data

Date	Time	Temperature	Glucose Level	Blood Pressure	Status
2008-08-01	08:00:00	102.0	80.0	100.0-130.0	high temperature, normal pressure, normal glucose level
2008-08-01	08:10:00	102.0	75.0	110.0-140.0	high temperature, normal pressure, normal glucose level
2008-08-01	08:20:00	103.0	85.0	90.0-140.0	high temperature, low pressure, normal glucose level

Figure 5.3: View History

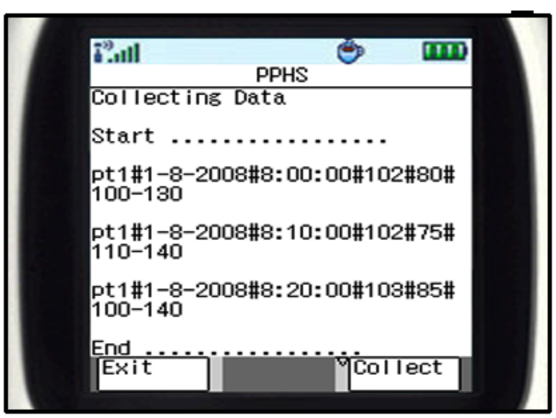


Figure 5.4: Automated Data Collection

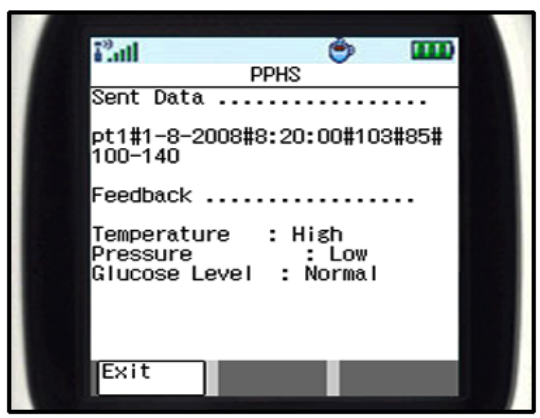


Figure 5.5: Feedback Display

Figure 5: Some screenshots of the implementation

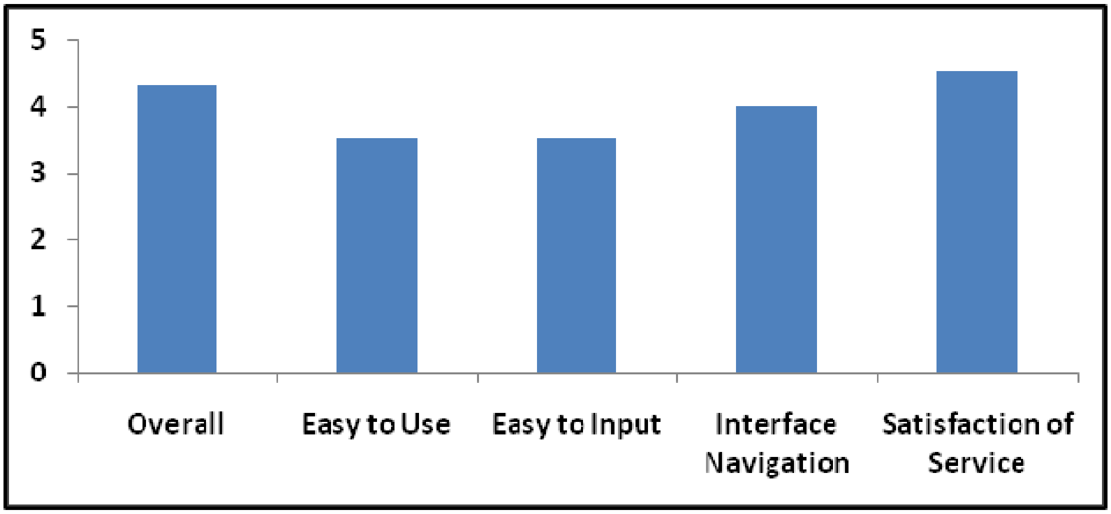


Figure 6: Rating of usability issues by users

7. Future Works and Conclusion

The whole system of mobile health care using biosensor network places forward some future works such as finding the most effective mechanism for ensuring security in bio-sensors considering the severe restrictions of memory and energy, representing the collected data in the most informative manner with minimal storage and user interaction, modeling of data so that the system will not represent all the data but only relevant information thus saving memory. These are the generic works that can be done in future in the sector of mobile health care. For IMHMS our vision is much wider. We think of a system where the patients need not to do any actions at all. With the advancement of sensor technologies it is not far enough when the bio-sensors itself can take necessary actions. A patient needed glucose does not need to take it manually rather the bio-sensors can push the glucose to the patient's body depending on the feedback from the IMS. It seems to be impossible to achieve by everybody. But nothing is impossible. Today we imagine of something and see that it is implemented in the near future. But if we stop imagine and thinking then how impossible can be made possible? This paper demonstrates an intelligent system for mobile health monitoring. Smart sensors offer the promise of significant advances in medical treatment. Networking multiple smart sensors into an application-specific solution to combat disease is a promising approach, which will require research with a different perspective to resolve an array of novel and challenging problems. As wireless networks of sensors are developed for biomedical applications, the knowledge gained from these implementations should be used to facilitate the development of sensor networks for new applications. Expeditious development of implanted smart sensors to remedy medical problems presents clear benefits to individuals as well as society as a whole. There is the obvious benefit to persons with debilitating diseases and their families as these patients gain an enhanced quality of life. Biomedical implants that monitor for cancer will help recovering patients maintain their health. Not only will these individuals personally benefit from their improved health and well-being, but society will also benefit from their increased productivity and societal contributions. Once the technology is refined, medical costs for correcting chronic medical conditions will be reduced. As the world population increases, the demand for such system will only increase. We are implementing the IMHMS to help the individuals as well as the whole humanity. Our goals will be fulfilled if the IMHMS can help a single individual by monitoring his or her health and cautions him to take necessary actions against any upcoming serious diseases.

8. References

[1] A GOOD AGE: Aging and technology. http://ledger.southofboston.com/articles/2004/03/29/life/life02.txt.

[2] Aware Home Homepage-Aware Home Research Institute at Georgia Tech. http://awarehome.imtc.gatech.edu/.

[3] Center For Future Health. http://www.centerforfuturehealth.org.

[4] Centre for Pervasive Healthcare. http://www.pervasivehealthcare.dk/.

[5] Java Cryptography Extension. http://java.sun.com/j2se/1.4.2/docs/guide/security/jce/JCERefGuide.html.

[6] S. I. Ahamed, M. M. Haque, K. Stamm, and A. J. Khan. Wellness assistant: A virtual wellness assistant using pervasive computing. ACM Symposium on Applied Computing (SAC), Seoul, Korea, pages 782-787, March 2007.

[7] D. M. Fraser. Biosensors: Making sense of them. Medical Device Technology, 5(8):38-41, Feb 1994.

[8] S. K. S. Gupta, S. Lalwani, Y. Prakash, E. Elsharawy, and L. Schwiebert. Towards a propagation model for wireless biomedical applications. IEEE International Conference on Communications (ICC), 3:1993-1997, May 2003.

[9] S. P. J. Higson, S. M. Reddy, and P. M. Vadgama. Enzyme and other biosensors: Evolution of a technology. Engineering Science and Education Journal, pages 41-48, Feb 1994.

[10] D. Konstantas, A. van Halteren, R. Bults, K. Wac, I. Widya, N. Dokovsky, G. Koprinkov, V. Jones, and R. Herzog. Mobile patient monitoring: the mobihealth system. Stud Health Technol Inform, 103:307-314, 2004.

[11] I. Korhonen, R. Lappalainen, T. Tuomisto, T. Koobi, V. Pentikainen, M. Tuomisto, and V. Turjanmaa. Terva: wellness monitoring system. Engineering in Medicine and Biology Society, 20th Annual International Conference of the IEEE, 4(29):1988-1991, Oct 1998.

[12] A. Milenkovic, C. Otto, and E. Jovanov. Wireless sensor networks for personal health monitoring: Issues and an implementation. Computer Communications (Special issue: Wireless Sensor Networks: Performance, Reliability, Security, and Beyond), Elsevier, 29(13-14):2521-2533, Oct 2006.

[13] J. Parkka, M. van Gils, T. Tuomisto, R. Lappalainen, and I. Korhonen. Wireless wellness monitor for personal weight management. Information Technology Applications in Biomedicine, IEEE EMBS International Conference, pages 83-88, Nov 2000.

[14] N. Saranummi, I. Korhonen, M. van Gils, and S. Kivisaari. Barriers limiting the diffusion of ict for proactive and pervasive health care. Proceedings of the IX MEDICON, Pula, Croatia, 4(29):1988-1991, Oct 2001.

[15] A. van Halteren, R. Bults, K. Wac, N. Dokovsky, G. Koprinkov, I. Widya, D. Konstantas, V. Jones, and R. Herzog. Wireless body area networks for healthcare: the mobihealth project. Stud Health Technol Inform, 108:181-193, 2004.

[16] A. van Halteren, D. Konstantas, R. Bults, K. Wac, N. Dokovsky, G. Koprinkov, V. Jones, and I. Widya. Mobihealth: ambulant patient monitoring over next generation public wireless networks. Stud Health Technol Inform, 106:107-122, 2004.

[17] U. Varshney. Pervasive healthcare and wireless health monitoring. Jounral on Mobile Networks and Applications (Special Issue on Pervasive Healthcare), Springer, 12(2-3):111-228, June 2007.

[18] M. Weiser. Some computer science problems in ubiquitous computing. Communications of the ACM, 36(7):75-84, July 1993.

[19] J. Yao, R. Schmitz, and S. Warren. A wearable point-of-care system for home use that incorporates plug-and-play and wireless standard. IEEE Trans Inf Technol Biomed, 9(3):363-371, Sep 2005.