Enable Pervasive Healthcare through Continuous Remote Health Monitoring

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***Abstract*—In this article, we introduce a novel Remote Health Monitoring (RHM) system to enable high-quality pervasive healthcare services to users with low delivery delay and reduced costs. We define the RHM architecture and summarize the design considerations. We then present a promising commercialized solution, ViiCare, with system infrastructures and supporting techniques. We also discuss future research challenges for implementing RHM systems.**

I. Introduction

Ever advancing science and technology are gradually changing our way of living and prolonging our life span while we enjoy the amenities of modern society. Since the start of this century, the proportion of seniors in the world has been increasing more rapidly than any other age group. According to [1], the overall median age in the world rose from 23.9 in 1950 to 26.8 in 2000, and is predicated to reach 37.8 in 2050. Many countries in Asia and Europe face an even worse situation soon, where the largest age group will be 65+ and the average age will be approximately 50 [2]. A rise in global aging demands an increased focus on preparing a pervasive healthcare system capable of caring for seniors, and improving their health, well-being and independence in their later life.

The health issues related to the aging population are complex. One of the most serious health risks among seniors over 65 is falling, which is the leading cause of death for this age group. Among those who survive a fall, many will suffer hip fractures. Even with timely and successful surgery, 40% of those hospitalized for hip fracture cannot return to independent living, and 20% will die within a year [3]. If an inventive detection apparatus and compatible reporting system was developed and used, almost 80% of the falls could be quickly determined and medical services would be provided directly to the injured seniors. The sooner they are helped, the less likely they will suffer long-term disabilities.

Chronic medical conditions place millions more seniors at risk. Cardiovascular disease, arthritis, diabetes, diminished hearing and eyesight, Parkinsons, etc. all leave seniors vulnerable to helplessness at home. Medical reports [4] indicate that 133 million people live with chronic medical conditions. That number is projected to increase by more than 1% per year by 2030, resulting in an estimated chronically ill population of 171 million. According to the American Heart Association, chronic heart failure alone costs the US economy over 33.7 billion dollars a year, of which $16 billion is attributed to re-hospitalization, while 42% of the re-hospitalizations were preventable by adequate patient monitoring, instruction and education outside hospital [5].

Recent advances in computing technologies including body sensors and wireless communications have revealed the possibility of providing Remote Health Monitoring (RHM) to patients at high risk of falls and with chronic diseases. The body sensors deployed in, on, or around the human body are able to measure the fundamental health parameters in a situation where large-sized and standard medical examination equipments are not available; the pervasive use of mobile phones and the ubiquity of WiFi connection enable medical informatics to overcome the time and location barriers. RHM systems offer long-term, real-time individualized medical measures and continuous health data collection. They provide a unique opportunity to shift healthcare tasks from a traditional clinical environment to a pervasive user-centered setting. They allow users to reduce healthcare expenses through more efficient use of clinical resources and earlier detection of medical conditions, which in turn drastically trims government health budget. By fully utilizing advanced biomedical sensing technologies and wireless communications, RHM systems indeed hold the promise to provide an effective solution to the rising healthcare crisis.

In this article, we envision a three-tier RHM architecture and discuss the system design considerations. Among many existing in-market RHM products, ViiCare (invented by Care In Motion (CIM), www.cim120.com.cn) complies with our proposed system architecture and has potential in being widely adopted and deployed. The article concludes with a discussion concerning open research problems for implementing future RHM systems and providing some preliminary solutions.

II. Remote Health Monitoring (RHM)

We envision a typical RHM system with an architecture of three tiers or domains: body area domain, communication and networking domain and service domain, as illustrated in Fig. 1. The following section explains in detail on the components and

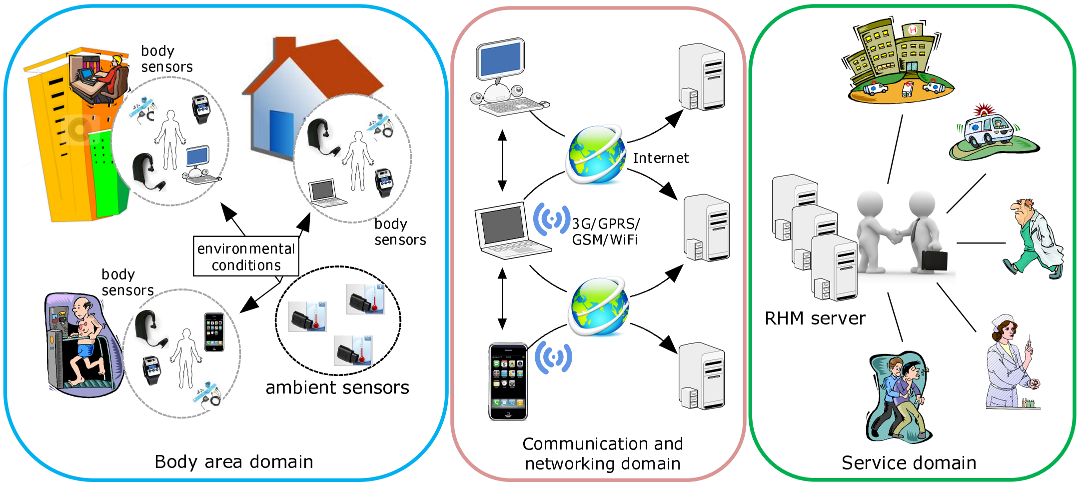

Fig. 1. RHM Architecture. Users are wearing monitoring sensors which send data to the personal server (e.g., a mobile phone). Then, through any wireless connections, the data are streamed through an internet gateway and the RHM servers, to a remote medical doctor's site for real-time diagnosis, to a medical database for record keeping, or to the corresponding emergency contacts for emergency services.

the functional role of each domain as well as the interaction among them.

The body area domain is defined by a number of *wireless body area networks* (WBANs), each corresponding to a user. A WBAN is composed of a few sensors and a gateway. The sensors are classified into two groups: *body sensors* and *ambient sensors*. The body sensors are the essential parts of the WBAN. They are placed in, on, or around a user's body for continuous monitoring of the user's physiological conditions such as heart rate and body temperature. The ambient sensors are optional. They are deployed in the surroundings of a user and monitor the environmental conditions of the user's body such as air temperature, humidity, and brightness. As the user moves, the ambient sensor set may change. The data provided by the ambient sensors are important. When, coupled with users' physiological conditions measured by the body sensors, they provide valuable supplementary information for medical diagnosis and treatment. All the sensors including body sensors and ambient sensors interconnect through multi-hop wireless links and transmit sensory data to the gateway, which can be any pre-defined portable device such as mobile phone or PDA held by the user. The gateway combines various types of sensory data, and report them through the communication and networking domain to an online RHM server in the service domain, and when necessary, to nearby handset holders too.

The major functionality of the communication and networking domain is to bridge the body area domain and the service domain. Advanced wireless communications technologies, such as Cellular 3G, WiFi, and WiMAX, link WBAN gateways to the Internet and enables efficient mutual data communication between the WBANs in the body area domain and an online RHM server in the service domain. With the online server as a data sink, health-related information can be easily accessed by users themselves or authorized parties whenever they have connection to the Internet. This domain also serves as a platform of local information dissemination. WBAN gateways and nearby handheld devices spontaneously form a mobile ad hoc network (MANET) in emergency situations like falls and stroke. The users use this network to distribute calls for help in the vicinity of their corresponding users, in the hope that there are nearby healthcare workers who are able to provide immediate medical care. Clearly, the ad hoc networking function would save precious lives in the case where the healthcare professional dispatched by the RHM server in the service domain is too far from the emergency location and cannot arrive in time. However, this functionality should be activated according to customized configuration, in order to respect user privacy concern.

In the service domain, a trusted authority maintains an online RHM server that is responsible for receiving, recording and analyzing user health-related information. This server is a virtual component. It can be realized by multiple physical servers that are not necessarily located at the same place. If the RHM server identifies that a user is experiencing health deterioration, it will recommend a healthcare specialist to the user through the communication and networking domain; if it detects that a user is in an emergency, it will trigger an immediate procedure (e.g., informing the emergency contact and/or healthcare center, or dispatching a healthcare worker directly) to save the user's life. By automatic cross-patient analysis, the server learns an accurate and comprehensive picture about the effects (including healing effect and side effect) of the medical treatments taken by the monitored patients. The server is therefore able to present valuable feedback to new patients who are taking the same medicine or treatment. Depending on need, it may also periodically advise governmental health agencies about the overall health conditions in the monitored region so that an appropriate number of local healthcare resources can be maintained. Other value-added services may be implemented in this domain too, such as, the ability to respond to user questions about system setup and maintenance, health news and product information dissemination, etc.

III. Design Considerations

The design of RHM systems embodies many research issues. The issues must be resolved in order for RHM systems to realize the anticipated functionalities and eventually be widely adopted and distributed. We classify these issues as *operational concerns* and *technical concerns*, and summarize the key RHM system design considerations under this classification.

A. Operational concerns

Worker-friendly: RHM systems usually require direct involvement of healthcare workers, but there are insufficient incentives for healthcare workers to adopt the emerging RHM technologies. Workers may complain about not being familiar with reading electronic records, not getting paid for reviewing RHM data, not being able to validate data or not having effective tools to interact with remotely-monitored users. Therefore, RHM systems must be easy to use by current healthcare workers and provide necessary tools for them to carry out their healthcare duties.

User-friendly: Existing RHM systems are often designed for one-time physical examination rather than long-term monitoring. They have to be initialized each time when used, and their initialization involves setting up multiple system parameters, a demanding process that usually cannot be finished by a novice. In addition, the key components of these systems are normally large in size, weighty and not comfortable or convenient to wear. Patients are inclined to reject the devices initially. Hence, operability and comfort (non-disturbance) are important factors for RHM systems to be accepted by users.

Automation: RHM systems often require users to take their own measurements and send them to the data center. Thus, a user with a chronic disease such as congestive heart failure (CHF) or Alzheimer must be able to comply with the routines and protocols specific to particular RHM devices. Users may have difficulty remembering or mastering sophisticated routines and protocols due to health problems and changing proficiency. Therefore, minimal user involvement and maximal automation during health monitoring are necessary.

B. Technical concerns

Reliability: Sensors are capability-limited weak devices. They may produce false information in response to environmental and hardware dynamics. Wireless communication channels are error-prone due to interference and path fading, and multi-hop routing paths are not stable because of body mobility. Inaccurate information and faulty/delayed information transmission can be misleading, resulting in inaccurate diagnosis, unnecessary monetary cost, and even loss of lives. There is no doubt that the realization of an RHM system requires reliable sensing and communication.

Efficiency: The major components of an RHM system are WBANs with limited power supply. The algorithms embedded in WBAN nodes must be highly efficient so as to enable long-term monitoring and continuous data collection. As these nodes are operating in, on, or around the human body, they must minimize the generation of electromagnetic radiation, by reducing power usage (for computing and transmission), in order not to cause damage to human tissue. Indeed, energy

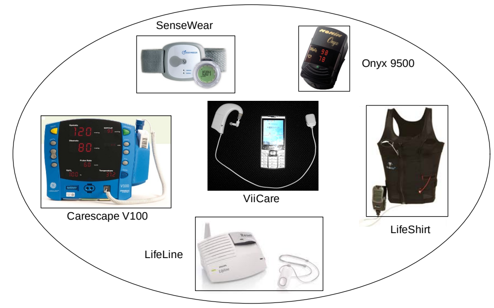

Fig. 2. RHM products

efficiency is a critical factor to transform RHM systems from laboratory prototypes to real-life applications.

Security and Privacy: The pervasive use of wireless techniques and the dynamic (varying and potentially unknown ambient sensor sets) of WBANs make it easy for malicious adversaries to launch security attacks which include compromising or paralyzing body sensors and WBAN gateways. As RHM systems are designed to assist in medical treatment, security vulnerabilities render the entire system unreliable, eventually putting user lives at risk. Health-related information is highly privacy-sensitive [7]; users will not allow unauthorized access to their personal data.

IV. ViiCare – A Promising Solution

While RHM technologies are incomplete, there are already many RHM products available in the market. Table I presents a comparison of popular RHM products. Carescape, Onyx, SenseWear, LifeShirt, Lifeline, and ViiCare are respectively the products of General Electric, Nonin, BodyMedia, VivoMetrics, Philips and CIM. Among these products, ViiCare is distinctive for its user-friendly industrial design, integrated sensing, rich functionalities and advanced system architecture.

Figure 2 shows the physical design of ViiCare compared to other RHM products. ViiCare's competing systems rely on separate sensors for only a few health measures and are characterized by bulky and weighty designs that discourage users from wearing them for long-term monitoring. In contrast, ViiCare uses a single sensing device, coupled with advanced biological analysis techniques, to provide an impressive "all-in-one" feature, i.e., measuring a wide range of physiological conditions. As shown in Fig. 3, it is small, lightweight, and can be conveniently worn on the pinna of the ear (the earlobe) without much disturbance to users' daily activities.

ViiCare complies with our proposed RHM system architecture, in that it allows long term storage and ubiquitous access to health-related data and flexible emergency handling. Other products are merely uncommunicative terminal devices (thus in a 1-tier structure) and do not have these functionalities. In Tab. I, Lifeline and ViiCare are marked to have a 2.5-tier structure because they partially implement the communication and network domain: they do not support ad hoc networking among local communication devices for emergency information dissemination and nearby first-aid lookup.

ViiCare consists of three main components: i) a ViiCare sensing device, ii) a mobile phone (gateway) that are connected through Bluetooth in the body area domain, and iii) a ViiCare

TABLE I
COMPARISON OF IN-MARKET RHM PRODUCTS

Products		Carescape	Onyx	SenseWear	LifeShirt	Lifeline	ViiCare
Design	System architecture	1-tier	1-tier	1-tier	1-tier	2.5-tier	2.5-tier
	Physical dimension	large	small	small	large	small	small
	Wearable (vs. portable)		✓	✓	✓	✓	✓
	Automatic (vs. manual)			✓	✓	✓	✓
	Real-time (vs. post proc.)	✓		✓	✓	✓	✓
	Work in motion (vs. at home)		✓	✓	✓	✓	✓
	Continuous monitoring			✓	✓	✓	✓
	Integrated biomedical sensing						✓
Sensing capabilities	Heart Rate	✓	✓		✓		✓
	Blood Pressure	✓			✓		✓
	Body Temperature	✓		✓	✓		✓
	Respiration Rate/Pulse				✓		✓
	SpO2/Peak Flow	✓	✓				✓
	Activity/energy			✓	✓		✓
	Sleep Quality			✓			✓
	Location/Environment/Posture				✓	✓	✓
Functionalities	Automatic Emergency Warning				✓	✓	✓
	Long-term Health Trend			✓			✓
	CHF/Arrhythmia	✓	✓	✓			✓
	COPD/Asthma	✓					✓
	Hypertension	✓					✓
	Sleep Apnea				✓		✓
	Fall Detection				✓	✓	✓
	Medication/life style						✓

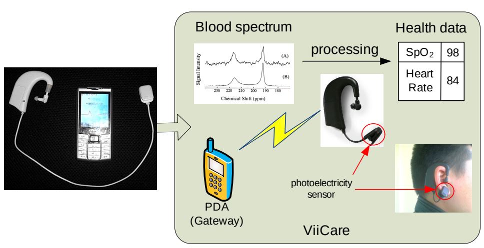

Fig. 3. Wearable device – ViiCare

server in the service domain. These components are connected through wireless technologies and the Internet. In the next section, we explain these components individually. Although the development of ViiCare is currently incomplete with respect to our proposed system architecture and envisioned functionalities, it can be readily extended to completion as a promising RHM solution.

A. Body area domain

In this domain, each WBAN is composed of a single ViiCare device and a mobile phone. The ViiCare is a wearable multi-function sensing device. As shown in Fig. 3, it can be clamped onto a user's ear. It senses the user's blood spectrum by a photoelectricity sensor located on the clamp. The sensor is attached to the earlobe for two reasons. First, this body part is relatively static when the user is moving; second, the blood spectrum detected via the earlobe is stable and accurate because the distance between earlobe and heart is constant or varies only slightly. Based on variation of the strength of the photoelectricity measured, an intelligent Digital Signal Processor embedded in the ViiCare device extracts multiple health parameters from the detected analog signal of blood spectrum. This integrated sensing technique distinguishes ViiCare from other RHM products that measure different physiological conditions with different types of sensors. With other seamlessly-embedded sensors, the ViiCare device also detects the user's motion, environmental temperature, etc.

Both the ViiCare device and the mobile phone are equipped with Bluetooth technology, enabling mutual data communication. In real time, the ViiCare device transmits its sensory data to the mobile phone. To save energy, it does not send the raw data but the data difference. The mobile phone is programmed with alarming and reporting algorithms. The alarming algorithm considers a user's adaptive body posture and cognitive injured body region so as to detect falls. Since different people have different living habits, the manifestations of postures differ as well. The alarming algorithm adaptively analyzes the detected parameters and determines the level of injury to provide relevant data to medical personnel for rescue and treatment. Through the reporting algorithm, the mobile phone sends the detected falls and other sensory data received from the ViiCare device to the service domain.

Currently the ViiCare device can communicate with the mobile phone through a single wireless link. In this case, more sensing devices may be placed on the human body and included into the body domain for measuring more health parameters. If so, multi-hop routing algorithms need to be embedded in these devices to report their sensory data to the mobile phone. This extension is straightforward.

User: Mr Zhong 24-hour 7-day 30-day View Curve Health Data

Data Item	Current Data	Evaluation	Reference	Abnormality
Heart Rate	82 beats / min		60 ~ 120	Statistic
SpO2	98%		93 ~100	Statistic
Body Temperature				Statistic
Environment Temperature	24°C		-50 ~ 50	Statistic
Test Item 1	26%			Statistic
Test Item 2	42%			Statistic
Anoxic Index	Normal		Normal ~ Seriously Anoxic	Statistic
Abnormal Heart Beat	Normal		Normal ~ Pulse Stopped	Statistic
Cardiopulmonary Index			Normal ~ Bad	Statistic
Sleep Quality Index			0 ~ 100	Statistic
Respiration Stop Style				Statistic
Respiration Stop Level				Statistic
Respiration Rate	22 times / min		8 ~ 30	Statistic
Activity Style	Slightly Active		Stationary ~ Strongly Active	Statistic
Activity Intensity	6%		0 ~ 200	Statistic
Fall Detection Index	Normal		Normal ~ Seriously Fallen	Statistic
Test Item 3	80			Statistic
Test Item 4	82			Statistic
Comprehensive Health Index	100%		60 ~ 100	Statistic

(Sample time: 2008 -8-28 18:10:34)

Fig. 4. Dynamic list of instant medical conditions

B. Communication and networking domain

ViiCare relies on mobile telecommunication network technology to transfer data between the body area domain and the service domain. However, it currently does not support ad hoc networking among local communication devices. Thus, ViiCare users will not be able to disseminate their emergency calls to nearby people for immediate first aid. Hence, we consider that the ViiCare system has a 2.5-tier, rather than 3-tier, structure. Nevertheless, the extension to a full 3-tier structure can be extended by allowing ad hoc networking [14] to the mobile phone (WBAN gateway).

C. Service domain

The service domain contains a ViiCare server that is implemented by various high-performance workstations with large storage and powerful communication devices. These workstations not only receive and store users' electronic health records but also offer a secure web service and emergency call center functions. Users and healthcare professionals may access the ViiCare server through the web service anywhere, anytime. After logging onto the server, device users are allowed to read their own data, while healthcare professionals can read only the data authorized by those users. A user may obtain two data health reports. One is a dynamic list of instant medical conditions (Fig. 4). It displays multiple health parameters such as heart rate, blood pressure, SpO2, together with the reference standards in real-time. Even without much medical knowledge, users can be aware of their own health status by simply comparing the data with the reference values. The other report is a long-term medical condition graph, as shown

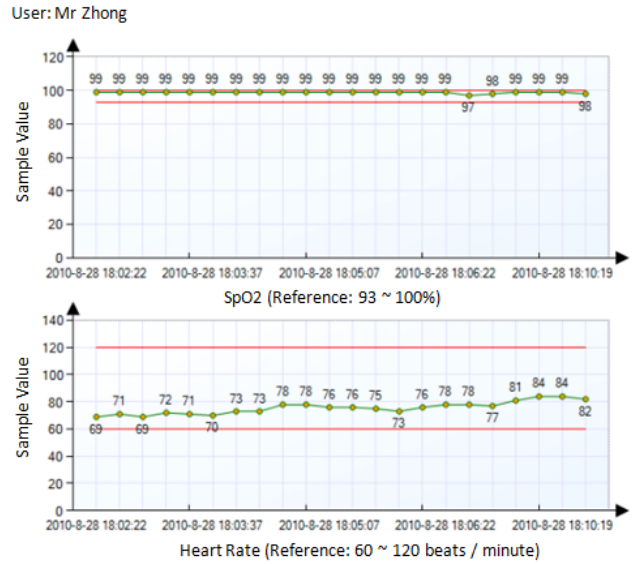

Fig. 5. Long-term medical conditions

in Fig. 5, which indicates the variation tendency of users' medical conditions. Under doctors' supervision, users can change their living and eating habits to regulate the parameters before further deterioration. Using the web as a communication platform and being assisted by long-term medical records, online consultation and diagnosis becomes possible. Additionally, the call center informs users' emergency contacts about their health conditions by automatic text messaging or phone calls in pre-defined priority situations. It also answers users' questions regarding system setup and maintenance.

V. Research Challenges

There are many research challenges for implementing RHM systems, most of which, like efficient routing in mobile ad hoc networks and data secure storage, are critical but common in other types of systems. Below we pinpoint unique research challenges specific to RHM systems.

A. Device Advancement

Advances in nanotechnology and micromechanical devices, combined with the emerging demand for advanced RHM systems, are driving the development of new and more effective sensors. Novel sensor specializations for environmental condition monitoring, physiological monitoring, interacting with various objects, and physical exercising are desired. For example, diabetics need to conduct blood test everyday (using a needle) in order to continuously monitor and control their blood sugar levels. Their blood has to be sampled frequently resulting in uncomfortable pain to diabetics. Many biomedical researchers and RHM companies (e.g., CIM) are dedicated to developing a smart sensor that is able to measure the blood sugar without incurring physiological pain. Such development requires great research efforts and large monetary investments.

Small size, light weight and integrated-function are desirable characteristics for sensor design. The sensor design of

ViiCare complies with these requirements and thus provides user comfort. To develop smaller-sized, lighter-weighted and to have more integrated sensing functions are possible but challenging. Moreover, battery design needs to be advanced along the sensor development. The battery issues include user safety, low-cost, low-radiation, and environmental friendly. A new type of battery using zinc-air fuel is introduced in [8], for example. Continuous research efforts are needed in order to make the prototype technologies practical.

B. Communications

To achieve energy-efficient communications is critical to RHM systems. A memory unit integrated into a wearable device can be used to store sensory data locally when a proper communication channel cannot be established with the gateway. With a memory unit integrated, an adaptive scheduling scheme becomes possible, prolonging the WBAN lifetime by enabling dynamic sleep-time based on traffic priority, user mobility, and surrounding interferences. In [9], an adaptive listen and sleep mechanism is proposed to reduce energy consumption. The mechanism builds a tree structure among body sensors to guarantee collision free access to the wireless medium and to route data towards the WBAN gateway. In [10], energy management mechanism is examined and a dynamic power control scheme that performs adaptive body posture inference for optimal power assignments is presented. In [11,15], body posture information is utilized to assist an individual body sensor in choosing direct-relay, single-relay, or multi-relay communication. These techniques (adaptive listen and sleep, dynamic power control, and cooperative relay) can be adopted to improve energy efficiency. Since the heterogeneous traffic from sensors is considered in current research, designing an energy-efficient protocol to schedule the traffic with different transmission rates, priority levels and delay bounds is a challenging.

C. Security and Privacy

Reliable RHM systems must ensure that the availability of health data in electronic form adheres to the same levels of privacy and disclosure policy as applicable to present-day paper-based patient records, which are accessible only from the secured medical offices. Instead of storing health data locally, the recent advancement of Cloud computing allows RHM systems to store all or selective health data at the cloud storage and ensures availability with reduced capital and operational expenditures. In cloud design, data is stored on multiple third party servers where the storage can be accessed on demand. Migrating health data into the cloud offers enormous convenience to healthcare service providers because they do not have to worry about the complexities of direct hardware management. Nevertheless, user privacy preservation and proper access control of health data are growing concerns due to the direct human involvement. Contextual patient-centric access policy may be adopted. The policy would classify the roles of users and assign privacy levels to user's health data based on data-sensitivity. [12] presents potential solutions to implement patient self-controlled access policy. Different access privileges are assigned to data requesters based on their roles including different attribute sets to these groups of data requesters. Only the authorized users would be able to have secure access to the encrypted health data. Further research is needed to determine how to modify the access policy of encrypted health data. For a large volume of stored health data, simply repeating the encryption with updated access policy is inefficient. A re-encryption algorithm enabling users to easily modify the self-controllable access policies with slight computational overhead is highly desired.

RHM systems can provide fast emergency services and real-time access of health data to the users who are in emergency situations. Future RHM systems should be integrated with local first-aid searching services. This type of service better assists users in a remote location where the central emergency medical services (EMS) cannot be delivered effectively. In practice, International Medical Health Organization (IMHO) allows users to directly transmit the emergency data to a remote hospital via wireless channels so that the hospital could find a physician near to the emergency location to provide emergency care. In this case, user privacy concerns must be reconsidered; users might be required to provide certain unauthorized private information for the patient to receive fast and high-quality EMS. [13] proposes a decentralized emergency response system with a privacy-preserving emergency call scheme (PEC), where user's security and privacy requirements are both attained. PEC guarantees the fastest emergency services, user self-control and fine-grained access of health data, and resistance to malicious attacks such as identity theft attack, emergency forgery attack. Before implementing PEC into RHM systems, many practical issues have to be determined. First, RHM systems need to confirm user self-defined emergency conditions and the emergency measures in advance. Users will be charged for corresponding services. Second, RHM systems must be appropriately decisive to read the collected health data, i.e., to differentiate the signals of a life-threatening situation from those of a normal variation due to the constant change of activities. Otherwise, such a proactive local first-aid searching service triggered by inaccurate decision will cause great amount of labor and medical resource in vain.

VI. Conclusion

In this article, we have introduced a new Remote Health Monitoring (RHM) system which provides pervasive and continuous healthcare to users. We have envisioned an RHM architecture with three domains, body area domain, communication and networking domain, and service domain. For each domain, we have identified and investigated certain operational and research concerns for implementation. We have also surveyed the RHM products in the market and compared their characteristics. Among these products, ViiCare has been demonstrated as the product most suitable currently for the proposed RHM architecture. Finally, we have determined several outstanding research challenges related to the advancement of device, communications and issues of security and privacy.

ACKNOWLEDGEMENT

This research has been supported by a research grant from the Natural Science and Engineering Research Council (NSERC), and Care In Motion, Canada.

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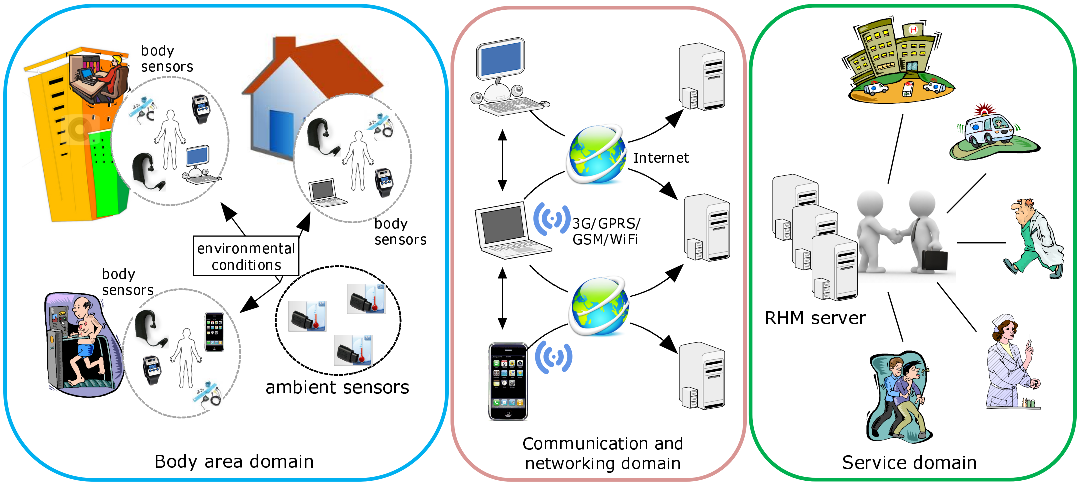

body sensors
body sensors
environmental conditions
body sensors
ambient sensors
Body area domain
Internet
3G/GPRS/ GSM/WiFi
Communication and networking domain
RHM server
Service domain

Figure 1

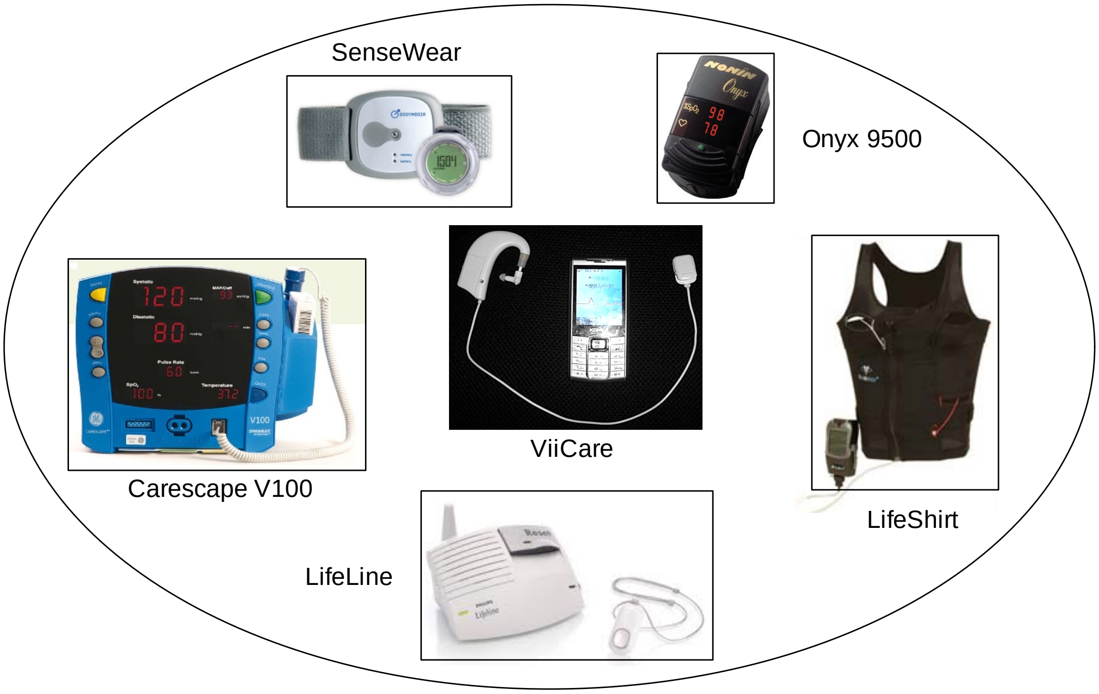
SenseWear
Onyx 9500
Carescape V100
ViiCare
LifeShirt
LifeLine

Figure 2

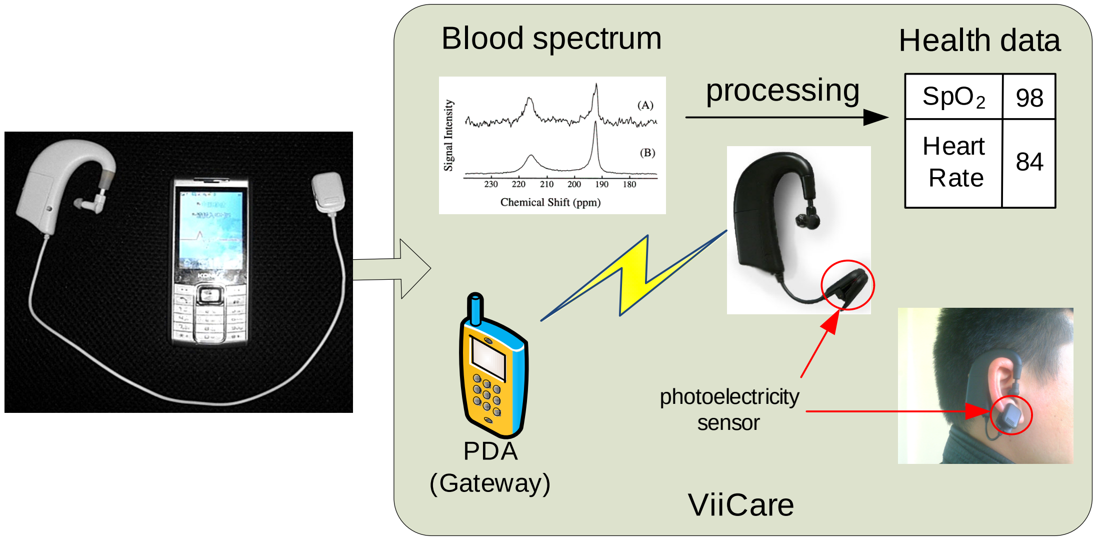
Blood spectrum
Signal Intensity
(A)
(B)
230 220 210 200 190 180
Chemical Shift (ppm)
processing
Health data
SpO2 | 98
Heart Rate | 84
PDA (Gateway)
photoelectricity sensor
ViiCare

Figure 3

User: Mr Zhong 24-hour 7-day 30-day View Curve Health Data

Data Item	Current Data	Evaluation	Reference	Abnormality
Heart Rate	82 beats / min		60 ~ 120	Statistic
SpO2	98%		93 ~100	Statistic
Body Temperature				Statistic
Environment Temperature	24°C		-50 ~ 50	Statistic
Test Item 1	26%			Statistic
Test Item 2	42%			Statistic
Anoxic Index	Normal		Normal ~ Seriously Anoxic	Statistic
Abnormal Heart Beat	Normal		Normal ~ Pulse Stopped	Statistic
Cardiopulmonary Index			Normal ~ Bad	Statistic
Sleep Quality Index			0 ~ 100	Statistic
Respiration Stop Style				Statistic
Respiration Stop Level				Statistic
Respiration Rate	22 times / min		8 ~ 30	Statistic
Activity Style	Slightly Active		Stationary ~ Strongly Active	Statistic
Activity Intensity	6%		0 ~ 200	Statistic
Fall Detection Index	Normal		Normal ~ Seriously Fallen	Statistic
Test Item 3	80			Statistic
Test Item 4	82			Statistic
Comprehensive Health Index	100%		60 ~ 100	Statistic

(Sample time: 2008 -8-28 18:10:34)

Figure 4

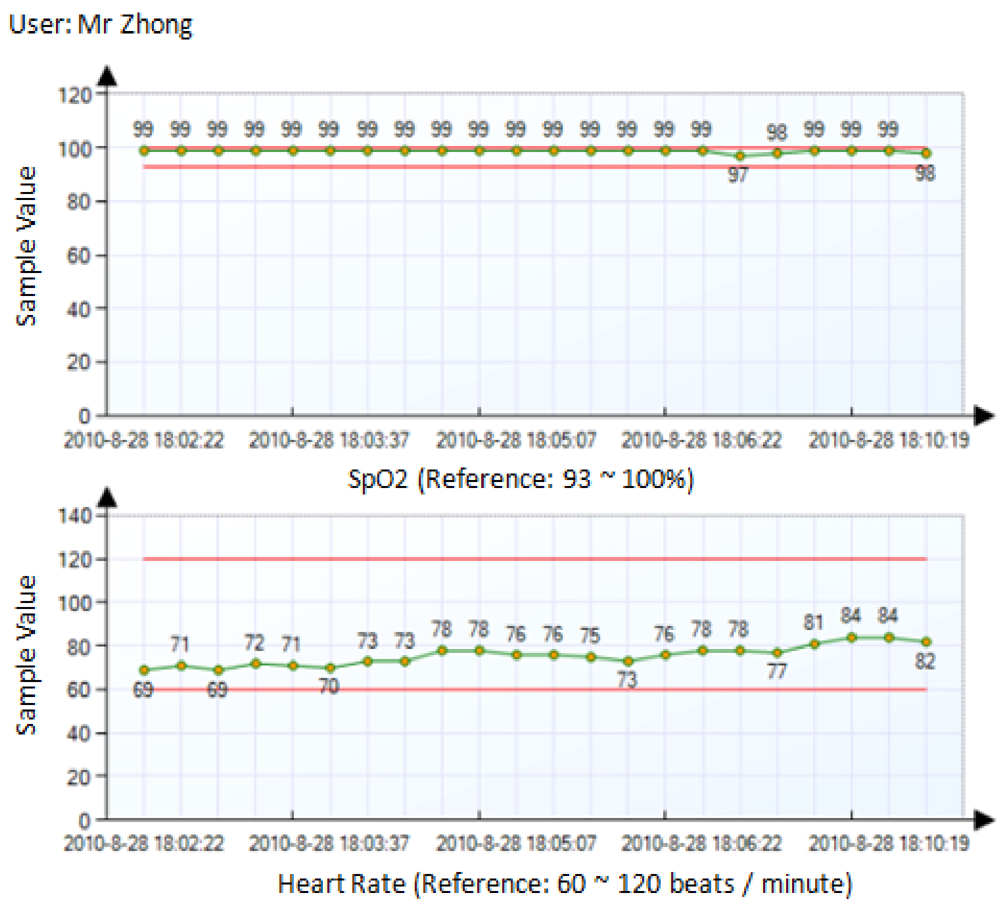
User: Mr Zhong
Sample Value
120
100
80
60
40
20
0
99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 98 99 99 99
97
98
2010-8-28 18:02:22
2010-8-28 18:03:37
2010-8-28 18:05:07
2010-8-28 18:06:22
2010-8-28 18:10:19
SpO2 (Reference: 93 ~ 100%)
Sample Value
140
120
100
80
60
40
20
0
71 72 71 73 73 78 78 76 76 75 76 78 78 81 84 84
69 69 70 73 77 82
2010-8-28 18:02:22
2010-8-28 18:03:37
2010-8-28 18:05:07
2010-8-28 18:06:22
2010-8-28 18:10:19
Heart Rate (Reference: 60 ~ 120 beats / minute)

Figure 5