Implementation of an Advanced and Secure System Using Wireless Medical Devices in Healthcare Settings

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***Abstract*— Computer-based and wireless patient monitoring systems are emerging as a low cost, reliable and accurate way of healthcare delivery. Advanced and secure solutions such as electronic records, mobile systems and cloud computing have been developed for healthcare. Most tele-health solutions send data or video remotely to healthcare providers but very few systems are in place for both vital signs and video connectivity in real-time. We proposed an advanced and efficient telehealth solution focusing on video conferencing (consultation) between patients and medical professionals in addition to wireless vital signs transmission. The selected vital signs include; blood pressure (systolic and diastolic), heart rate, respiratory rate, oxygen saturation, body temperature, spirometry (lung volumes) and blood glucose level.**

I. INTRODUCTION

Patient monitoring systems can simplify solutions to complex data management, thus increase productivity, minimize human error and reduce the overall cost of patient care. In acute (often hospital inpatient) settings where medical professionals are extremely busy a slight distraction or deviation can result in grave consequences. One of the emerging fields in use of information and communication technologies in healthcare is telemedicine, which includes mobile health (m-health), electronic health (e-health) and tele-health. According to the World Health Organization (WHO) telehealth is broadly defined as:

"The delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities" [1].

Telehealth is simply described as the delivery of healthcare when patients and clinicians are separated by distance. The use of advanced technologies in our daily lives such as internet-based social and professional services via computer, laptop, tablets and smartphone theoretically enables researchers to revolutionize the delivery of healthcare in a better and enhanced manner.

Current telehealth care systems implemented in hospital settings have been demonstrated to be efficient and cost effective [2] by providing basic services such as:

- Email: For a low cost, fast and effective medium of communication [3, 4].
- Call and Text Messaging: For making appointments, bookings, reminders and alerts which save time as well as cost. Currently there are a number of mobile phone (SMS) -based projects aimed to improve health care, such as; mobile phone based quit smoking project 'Text2Quit' and 'txt2Stop' [5-8].
- Electronic Health Record (EHR): For providing access, store or transfer of patient's EHR, high resolution images, consultation notes, medical documents and patient's background history [9].
- Physiological Data: A number of studies have been reported which include patients' vital signs transmitted remotely to patient management systems for centralized processing and/or consultation [10].

Remote patient monitoring systems, in particular, play an important role when patient-doctor relationship is conducted at

a distance, and such systems are capable of reducing healthcare costs and enhancing the quality of patient healthcare delivery [2]. Commonly monitored vital signs are: blood pressure (systolic and diastolic) (BP); heart rate (HR); pulse rate (PR); oxygen saturation (SpO2); and body temperature (Temp). This study aims to develop a clinically useful patient monitoring and alarm system. Initially, the proposed system will be installed and implemented at an older adult ward in a hospital setting with the aim of collecting patients' physiological signals (vital signs) wirelessly for early diagnosis and/or intervention. Ultimately, the developed system may be employed as an efficient monitoring system in a broader community setting.

II. Proposed System Model

A. *Medical Devices Connectivity and Data Transmission*

Fig. 1 shows off-the-shelf medical devices and a set-top-box used in this model to achieve high data reliability and accuracy. The system is capable of collecting multiple physiological parameters simultaneously from multiple patients. A brief description of the devices shown in Fig. 1 is given below (numbers 1-8 refer to the medical device shown in Fig. 1);

1. Set-top-box: This runs an application which receives patients' physiological data from different medical devices and transmits the data in real-time over a secure internet connection to a PC or laptop.

2. Blood pressure monitor: Boso-medicus prestige BP monitor is a wireless Bluetooth device which measures BP and pulse rate [11]. It can record the data at user-defined time intervals using a simple user interface feature.

3. Pulse Oximeter: Nonin's Onyx II finger clip oximeter is a wireless Bluetooth device which records oxygen saturation and heart rate continuously [12].

4. Blood glucose meter: Accu-Chek Compact plus blood glucose meter is a wireless infrared connected device which records blood glucose level [13].

5. Ear temperature: Omron's instant ear thermometer is an instant and compact ear temperature measurement device [14].

Figure 1: Medical devices used for the proposed patient monitoring system.

6. Body temperature: G-plus wireless remote body temperature for continues body temperature measurement [15].

7. Spirometer: nSpire's Piko-6 meter is a wireless infrared connected device which measures forced expiratory volume at one and six seconds FEV1/FEV6 [16].

8. Accelerometer: Gulf Coasts Data Concept's accelerometer/Magnetometer Data Logger X8M-3mini [17] is a compact, continues data collection device used for fall detection in the proposed system.

Table I shows the specification of medical devices in terms of device model, size, connectivity and data transmission. These are critical factors to be considered by patients (users) and medical professionals. The medical devices listed in Table 1 were selected for their low cost, accuracy, and most importantly their wireless connectivity features.

TABLE I
MEDICAL DEVICE SPECIFICATION AND THEIR FUNCTIONALITIES

Medical Device	Model	Connectivity/ Transmission
Blood Pressure	Boso-Medicus Prestige BT	Wireless/ BT
Pulse Oximeter	Onyx-II	Wireless/ BT
Blood Glucose	Compact Plus	Wireless/ IR
Ear Temp.	Instant ear thermometer	Wireless
Body Temp.	Wireless body thermometer	Wireless/ BT
Spirometer	Piko-6	Wireless/ IR
Accelerometer	8-XM3-mini	Wireless

Where BT is class-2 Bluetooth, IR is infrared.

B. *Working Model*

The main technological features of the proposed system, VitelMed [11], include real time communication of patients' vital sign and audio/video connectivity with medical professional remotely. The current limitations of telehealth care systems such as low data quality, transmission delay, data collection device's variability and high cost [12] are potentially minimized in the proposed system. The system consists of two components; patients' side and clinicians' side; these are discussed below.

- *Patients' side*

The patient acceptance and user friendliness is considered in the proposed system. Simple and easy-to-use features enable the patient to accept the proposed solution. Below are some of the key features of the VitelMed system:

1. Set-top-box: This can be connected to TV or a screen which runs VitelMed software application. Compact and wireless connectivity via TV gives the user the

advantage of familiar technological and an individually adopted solution.

2. One touch button: Considering the possibilities of an emergency situation, the one touch button gives an instant connectivity to the healthcare professional without any prior process, steps or delay.
3. Medical Devices: The proposed system is fully compatible with more than 20 devices. This reduces the medical devices' dependency. The medical devices (wired and wireless) fully compatible with VitelMed and which are easily available in the market are: heart rate monitors; ECG monitors; blood glucose monitors; vital sign monitors; peak flow meter; blood pressure monitors; weight scales; pulse oximeters and foetal monitors. This gives large scope of patient monitoring, especially for patients with Diabetes mellitus, congestive heart failure, and chronic obstructive pulmonary disease.
4. Video Consultation: A high resolution camera, with pan, tilt and zoom transmits the real-time high quality data. The medical professional can remotely control the patients' side camera which gives them a realistic and face-to-face experience with the patient.

Figure 2. VitelMed solution (patient side); set-top box, camera and remote with one touch button connectivity.

- *Medical Professionals' side*

The medical professionals' component is provided with a software application which can be installed on any personal computer or laptop, with audio/video functionality such as microphone and webcam. The medial professional can have the real-time patients' vial data during the 'video visit' (video-conferencing). The advanced option of audio/video with real-time physiological data and remote control of patient-side's high resolution camera gives the medical professional the experience akin to that of a face-to-face consultation. Easy and simple graphical user interface allows the clinicians a hassle free assessment and treatment. Moreover this will save clinicians' time, work load and patients' time, and cost. Figure 3 shows the consultation between medical professional and patient using the proposed telehealth care solution – VitelMed.

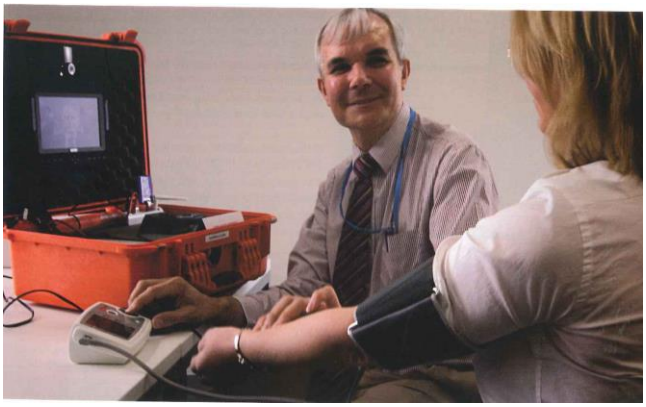

Figure 3. Doctor-Patient consultation using VitelMed solution.

- *Technical Specification of the proposed system*

Some of the advanced technical capabilities which give VitelMed solution a reliable, cutting edge and reliable telehealth care solution are;

- Communication protocols - audio/video with adaptive bandwidth of 16-2048KBps
- Network communications - LAN, WAN, IP addressing (static, DHCP or PPPoE), TCP/IP protocols
- Data ports-two RS-232, four USB, one SD card connector, IR remote control and Bluetooth class 2
- Communication Security-XML based messaging, first key exchange and streaming encryption

III. CONCLUSION

This paper presents an advanced telehealth care solution which specifically focuses on reducing the current limitations of this technology in the areas of interoperability, complexity, high cost and user acceptability. It also addresses the challenges facing the current technology such as reliability, efficiency, data quality and security and privacy. The proposed solution can be implemented at home - as remote and continuous home monitoring or in hospital - as point of care technology with remote access of the patient's physiological data with audio/video connectivity or even in an emergence situation (e.g. ambulance or accident site) as a portable and wireless monitoring device.

The assessment of VitelMed telehealth care solution in real medical environment is underway. A pilot trial of VitelMed solution in an Australia's aged home care is in the final stage of completion with the expectation of positive impact on the Australia's healthcare, especially to the older adult community. Our clinical trial in a New Zealand hospital is also going to commence soon which will give us an immense opportunity to implement this solution in real medical environment with and assess its acceptability to patients (users), nursing staff, junior doctors and specialists.

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