HEALTH ALERTS: INTERACTION PROTOCOLS IN REMOTE HEALTH CARE MONITORING

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ABSTRACT

Remote health care monitoring is a promising technology to make health care more efficient and cost-effective. A crucial aspect of remote health care monitoring is interaction protocols that govern how alert and information messages are delivered to patients and health care professionals. Proper interaction protocols are essential in ensuring that not only the right messages are delivered to the right receiver in a timely manner but also that the intended actions are understood and carried out and any entailed exceptions are taken care of. In this paper, we discuss various issues in designing interaction protocols for remote health care monitoring. We also present a prototype implementation of an interaction protocol. A simple case study is shown to illustrate how the prototype works in a real-life scenario.

KEYWORDS

Remote health care monitoring, interaction protocol, alert and notification

1. INTRODUCTION

In order to meet the unprecedented challenges posed by the rapidly ageing world population, it is essential to find ways to make health care more efficient and cost-effective. Currently, one of the more promising approaches to accomplish this is remote health care monitoring. Through this approach, patients can have the privacy and comfort of their own home while their health status is monitored by an array of health sensors. If the sensors detect some conditions that need the attention of a health care professional, one will be automatically alerted by the system. While remote monitoring reduces traditional face-to-face interaction to a certain extent, different modes of interaction arise. For example, the right healthcare professional needs to be notified about the patient's conditions in a timely manner. In the other direction, the patient also needs to be notified about medical advices and necessary actions to be carried out. Should some exceptional situations arise, appropriate actions must be carried out. All these interactions must be properly defined and designed beforehand in the interaction protocols of the system.

The complexity and diversity of possible scenarios make designing proper interaction protocols a challenge. First, there should be a mechanism to identify the current scenario and its severity so that appropriate messages can be generated. Next, the correct receivers of the messages need to be identified. It is important to send messages to the right people to ensure the patient's safety and privacy. We also want to limit the number of receivers so as not to overwhelm the health care professionals with messages. Similarly, the number of messages to the patients and the delivery channel need to be carefully considered to ensure that they are received and acted upon. To ensure the patient's safety, robust mechanisms to ensure that the messages are delivered to the receivers and acted upon must be built into the system. For example, if the primary device of a health care professional does not respond to a message, the system should try a different device and/or a different health care professional. Or if the patient does not acknowledge an urgent message, it will be sent to the designated carer.

In this paper, we address the issues of user interaction within a remote health care monitoring framework. Our work in this paper is built upon the remote health care monitoring framework that we proposed earlier. We explore the different ways in which the appropriate messages can be transmitted to the appropriate receivers using the appropriate communication devices and channels. The design ensures that the message is received by the right person and the necessary actions are carried out. We also present a prototype to

illustrate the concepts and issues being discussed and a simple case study to show how it works in a real-life scenario.

The remainder of this paper is organized as follows. Section 2 discusses the related work. Section 3 presents the components of health care interaction. Section 4 discusses about the interaction protocol. Section 5 presents the implementation of the prototype using a case study as an example. Section 6 concludes the paper with a discussion on future work.

2. RELATED WORKS

Alerts and notifications are an example of user interaction that is used to notify relevant personnel in the health care system of some conditions that need attention. The features of alerts are vital because health care is sometimes a time-critical process where the patient's health and safety are at stake. The idea of alerting and reminding using computer technology has evolved since early 1970 (CJ., 1976, HR et al., 1972). Still, the proposed alert and reminder systems have yet to reach a mature standard. The standardization issue among the systems is one of the major obstacles (Silverman et al., 1998). Often, an alert and reminder system is specific to a certain institution and it is not possible to be deployed to other places without modification. In addition, the system logics are hardcoded, making it difficult to maintain and modify.

In health care application, a web-based reminder and list of things to do that are related to a patient is proposed in (Silverman et al., 1998). However, the architecture is limited to web-based applications only. Mobility is a serious concern in health care. Since the occupational nature of a clinician involves moving around in many different places, a solution with a mobility support is highly demanded. For these reasons, current research in health care monitoring adopts mobile technology in order to provide mobility features. In 2002, ReNAP was proposed to provide clinicians with a notification of laboratory result (Poon et al., 2002). The result was sent to the clinician's pager so further actions can be taken. With recent advances in mobile computing technology, methods for sending alerts and reminders have become more versatile, sophisticated and complex. The alerts and reminders can be delivered to the intended user using several different mediums; phone, mobile phone, short messaging service (SMS), e-mail and fax. Quite a number of research works include the alerts and notification features in their health care system designs. (Anliker et al., 2004, Jovanov et al., 2005, L. Yuan-Hsiang, 2004, Lee et al., 2007, Ren-Guey et al., 2005, Ren-Guey et al., 2007). Furthermore, there are also notification products that are available commercially, for example, Red Alert Emergency Notification System (AMTELCO). The system notifies the users when a critical incident occurs. When there is an emergency situation, the operator will use the system to send messages to the intended users. However, the system has no mechanism to check on whether the intended user has actually received the notification.

In the above research work, alerts are sent to warn the patients and their carers so that appropriate actions can be taken in a timely manner in critical circumstances. Assistive health messages are not intended to warn the patient but to inform them about their current condition on a regular basis. For instance, after receiving cardiac congestive failure (CCF) treatment in the hospital, Patient John Doe has recovered from his health's complications. However, he needs to monitor his activities, and lifestyle to avoid recurring attacks. As a result, the patient always feels uncertain to perform his daily activities, afraid that those activities will lead him to another attack. This situation will restrict the patients from having their preferred lifestyle and might lead to boredom and stress. In this scenario, there is a need for a mechanism to give the patients some assurance about their current health condition from time to time. In addition, patients also would feel contented if they could be supplied with assistive advices that they can follow as guidelines such as lists of do's and don'ts with regard to their current condition. Our framework sends not only alerts on a critical condition but also assistive health messages in non-critical condition to the intended person. With the reassurance about their health condition and assistive advices, the patients will feel more confident to do their daily work and worry less about their health. Consequently, this will promote better quality of life to the patients. To our knowledge, there is currently no health care alert system that handles alerts in non-critical condition as described in the above scenario.

3. HEALTH CARE INTERACTION COMPONENTS

For our purposes, health care interaction is defined as the transfer of messages within a health care monitoring environment between two parties, which are the server and the client. In order for the message transfer to occur, an interaction protocol is needed. The purpose of this protocol is to govern the message transfer across the network to ensure that it is received and acted upon by the appropriate receivers/users of the system. As shown in Figure 1, health care interaction comprises of several components: sender, message, medium, channel, device and receiver. In this section, we will discuss each of these components.

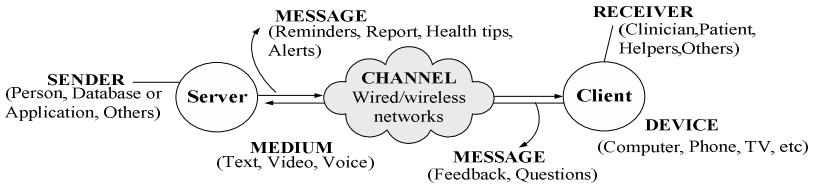

Figure 1. The components of health care interactions

3.1 The Sender

The sender could be users of the system, the database system or some other applications within the system. The users of the system can start the interaction by sending requests to the system or interacting with other parties. Interaction between patient and health care professionals is an example. The database system and application are responsible for monitoring the physiological parameters of the patient and identifying if there is any condition that needs attention from the users of the system and then initiates the interaction.

3.2 The Message

A message carries health-related information for the receiver and can belong to any of the following groups:

- **Alerts and notifications:** This message is automatically sent to the user when certain health conditions in the monitored patient are detected.
- **Reminders:** The message is sent to remind the user about important details that they should be aware of, for instance, a message to remind about the patient's appointment date, test date or regular checkup date. In addition, the reminder message can be extended to remind about certain actions such as consumption of medicine, doing exercise etc.
- **Health information or health tips:** This category of message is to help the patients obtain some knowledge on how to improve their health. For example, what foods are good for consumption and how much exercises they should do depending on their type of diseases. In general, this is a day-to-day health message/tip tailored to their conditions.
- **Reports and summary of patient:** This category is to report and summarize the patient's condition. This message is sent to the health professional upon demand. It can also be configured to be sent automatically at daily, weekly or monthly intervals according to the patient's conditions.

Health messages could be either scheduled or unscheduled. Scheduled message is preconfigured to be sent to the users, at certain date and time. Unscheduled message is the result of health parameter monitoring. When the value of a parameter exceeds a certain threshold, alert messages will be sent to the health care professionals for follow-up actions.

3.3 The Receiver

In general, there are three target groups of receivers: patient, health professional and non health professional. Patient is the person whom health parameters are being self-monitored. The second group is individuals who treat the patient directly or person who are capable of giving a treatment to the patient. These include

midwives, general practitioner (GP), clinician or specialist. People in non-health professional group are usually those who are related to the patient, for instance, the spouse or partner, relatives, and friends of the patients.

3.4 The Medium, Channel and Devices

In our system, medium refers to the form **how the message is convey**, such as text, voice or video messages. Channel refers to the network channels used to transmit the message, which can be wired or wireless channels. And device refers to the end device used to receive and display the message, such as mobile phone, TV, PC.

4. INTERACTION PROTOCOL

4.1 Discussion of Protocol Issues

The following are important issues that need to be considered in developing an interaction protocol for remote health care monitoring.

4.1.1 Generating the Right Message

Generating the right message as dictated by the patient's condition is the first crucial task in the interaction process since the doctors only have the messages to assess the patient's condition. In order to do that, the system must first ensure that it gathers sufficient and correct information about the patient. Next, the patient's condition must be mapped to the right message category. Finally, the content of the message itself must be generated such that it captures all the essential information and yet is concise and easy to understand.

4.1.2 Selecting the Right Recipient

Selecting the right recipient is the next important task in the interaction process. First, the recipient must have the knowledge to interpret the message and the authority to carry out necessary actions. Without either of these, the message may be disregarded, which can potentially be disastrous in an emergency situation. Or it may be misinterpreted, causing anxiety on the patient and his/her relatives. Selecting the right recipient is also important for privacy reasons. In order to do this, it is important to group the recipients into separate categories and have a robust mechanism to map message types to those categories.

4.1.3 Availability of Communication Channel to reach the Intended Recipient

Unlike the above two issues, this issue is not completely under the control of the health care monitoring system. Therefore, the system designer can only implement measures to mitigate potential outage. Those measures may be broadly classified as adding redundancy or escalation. We will briefly discuss each below.

Adding redundancy means having as many available communication channels to the recipients as reasonable so that another one may be used should the primary channel fails. Common mediums include phone call, text messaging, or email. Each of them has its own advantages and limitations. Phone call has the advantage of being fast and direct, but it is intrusive, hence, it should only be used in urgent situations. Text messaging or email is less intrusive but there is no guarantee when they will be read by the recipient. They are therefore better suited for delivering informational messages that are not time critical. In an urgent situation, several communication channels may be utilized at once to increase the chance of reaching the recipient. Some mediums may also be catered for special-need recipients such as video calls for deaf people. In a time-critical situation, if the recipient cannot be contacted, the message should be escalated to another recipient to handle it. Therefore, the system should always have a list of secondary recipients available for that purpose.

4.1.4 Reliability and Accuracy of the Transmission

We adopt the concept of three-way handshakes to ensure the reliability and accuracy of the transmission. Based on the three-way handshake concept, three steps are required in making the connection or termination of each transaction: request; acknowledgement of request; and confirmation of acknowledgment. Similarly, in general, there will be three steps involved in completing a communication process between the system and the patient.

4.1.5 Understanding of the Message Content

This relates to the ability of the recipient to understand the message and what actions are required. This issue is touched upon above when we discuss generating the right message and selecting the right recipient. It basically means that the message should be written clearly enough to be understood and the recipient should have adequate knowledge to interpret the message content. Apart from that, there should also be a mechanism for the recipient to ask for clarification when necessary regarding the message. Clarification may take the form of additional information or more detailed procedures.

4.1.6 Acknowledgement of Actions that have been carried out

Another important aspect is to ensure that certain action is performed by the receiver within the time required. As this is remote health care monitoring, the patient is not communicating face to face with the health care professionals. This means that the patients are able to do as they want whether or not to perform the requested action. So, there should be a mechanism to monitor whether or not they are actually performing the required actions. With that, the receiver should give some response and feedback after they have completed performing the action. On the other hand, an acknowledgement of the actions can also be in the form of an input from the patients, for instance, when the action is required to measure some attributes of the patients such as weight and diet profile.

4.2 Protocol

4.2.1 Mapping Patient Condition and Message

In order to automate message generation and recipient selection, we classify the patient condition into several groups. ‘Condition’ here refers to the current values of monitored physiological parameters and whether they are within normal range or not. In general, we categorize the condition into three main groups; Normal, High and Low. Each High and Low group is divided to subgroups namely; Mild, Moderate, Severe and Very Severe. These groups are important to identify the severity of the patient’s condition. That leads to the message type being generated and the recipient groups being contacted. For example, during normal and mild condition, the message is sent to the patient only. However, if the condition becomes worse, the message is also sent to the health professionals and the patient’s carer.

4.2.2 Message Format

The general format of alert messages consists of three items: a destination address, the message’s title and the message’s content. The destination address is where the message will be sent to. It contains information such as mobile number, email address, pager number, etc. Message title resembles the summary of the content, which could be ALERT, REMINDER, INFO & TIPS or REPORT. This is important to capture the receiver attentions upon receiving the message. The content of the message is dependent on the message type. This is summarized in Table 1.

Information (I) in message content row represents the information about the message. Action (A) describes the necessary steps that the receiver should take upon receiving the message while Response (R) indicates whether the system waits for a response from the receiver.

Table 1. Content for each type of message

Message content / Message Type	Information (I)	Action(A)	Response (R)
Alert	√	√	√
Reminder	√	√	
Health information and tips	√		
Report or Summary	√		

4.2.3 Interaction

Figure 2 shows the general flow chart of the operation involved in the prototype. It is programmed to receive the measured physiological parameters from the patients, do some simple analysis and send the results to the authorized users of the system. The prototype is preconfigured with a default value. For example, threshold value of systolic blood pressure between 90 and 140mmHg is considered normal. However, in certain cases, the value might need to be altered to suit with a particular monitored person. The configuration is done by the users of the system according to their roles. For example, a patient can reconfigure their preference of device to receive the message and person who will be their helper. On the other hand, the clinician can input messages to the system that will be sent to the patient, and edit the threshold value for each of monitored parameters.

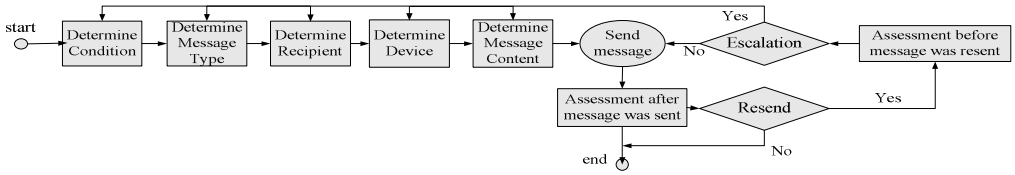

Figure 2. General flowchart of the prototype operation

There are several procedures that need to be checked before a message is sent out. This is important as to ensure correct message to the correct receiver through appropriate device. Once an event arises, the system determines the condition of the patient and then decides the type of message to be sent and identifies the target recipient of the message. After that, the destination device is determined. Only then the message content is formulated. The format of each generated message is different, depending on the receiver and the device that is used to send the alerts and notification. When the message is sent to the receiver, there will be an assessment by the system based on content of the message and feedback from the receiver. If the content contains I only, the transaction is complete once the sender receives the acknowledgement that the message has successfully arrived at the receiver. If no ACK is received, the transmission is assumed to be erroneous and the message is resent. The process will be repeated for thrice. However, if the content contains I and A only, the system waits for the action to be carried out and marks the transaction as complete after it receives an acknowledgement of the completed action. On the other hand, if the content contains I, A and R, the system anticipates for a response message from the receiver. This response message carries not just an acknowledgement but additional information as required in the original message such as how the patient feels at the moment or manual readings of some health parameters. If there is no response from the receiver for a message with R, the transaction is considered as unsuccessful and the message will be resent.

Finally, if a time-critical message cannot be delivered to any of the recipients, either primary or secondary, or if acknowledgement of a time-critical action is not received, the system will inform a stand-by user for appropriate measures. This is the ultimate failsafe mechanism to ensure that the safety of patients.

4.3 Snapshoot of the Prototype

The following are the prototype that we build for implementing the interaction protocol. The interface of the system is built to accommodate the screens of PDAs and smart phones. Pre-configuration can be done before a monitoring process is started. For instance, in condition page as shown in Figure 3(b), the target group of receivers for a particular patient is determined. The group can be changed at any time when necessary. The preference of device to receive the message can be configured as in Figure(c). However, if there is any

problem such as network problem, the system will switch to other devices or recipients. Figure 3(d) displays the recipient list of the patient and Figure 3(e) is a form whereby a new message can be added to the message bank in the system.

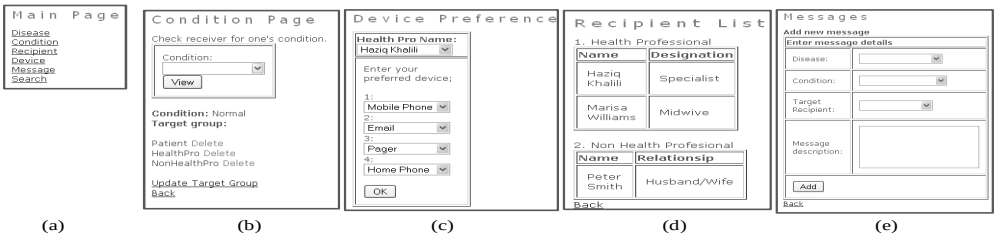

Figure 3. Snapshot of the prototype

5. THE EXAMPLE

In this section, we show a simple case study to demonstrate the working of the prototype. Hanna Edwards is a 26-years-old woman having her first baby. She is 13 weeks pregnant and attends the antenatal clinic for her first pregnancy visit. She weighs 78 kg and has a blood pressure of 120/60mm Hg. Her physical examination is normal and she has no history of medical complications. During the first visit, her urine and blood tests are all within normal ranges. When she comes for the regular antenatal visit at 24 weeks of pregnancy, she has a blood pressure of 140/90 mm Hg. However, as before, all tests show no abnormalities. Hanna requires additional follow-up as her blood pressure is elevated and she is showing signs of hypertension in pregnancy. Over the rest of her pregnancy, she will require continuous monitoring of her blood pressure, as well as her urine (for evidence of protein) and some of her blood tests (especially tests that assess liver and blood clotting function) during her regular checkups. During the monitoring, target groups of the patient are determined. Possible list of target group of Hanna is grouped into four different groups which are Hanna herself, the midwife, the specialist and her partner or relatives. For testing purposes, we put the range of blood pressure value as the condition category by referring to Chobanian et al. (2004). Details configuration is shown in Table 2.

Table 2. Configuration for Hanna's case

Condition	**Systolic/Diastolic**	**Receiver**			
		Hanna	***Midwife***	***Specialist***	***Partner***
Normal	90-139/60-89	√	-	-	-
High-Mild	140-159/90-99	√	√	-	-
High-Moderate	160-179/100-109	√	√	-	√
High-Severe	180-209/110-119	-	√	√	√
High-Very Severe	210-230/120-135	-	√	√	√
Low-Mild	70-89/50-59	√	√	-	-
Low-Moderate	60-69/45-49	√	√	-	√
Low-Severe	50-59/35-44	-	√	√	√
Low-Very Severe	Not Applicable				

For testing, we simulated the reading of about 200 physiological data points of systolic and diastolic blood pressure which is generated every 15 minutes. These readings represent the blood pressure in our experiment. The data is shown in the graphs in Figure 4. As can be seen, the blood pressure reading of the patient fluctuates over the monitored time, falls into three categories which are Low-Mild, Normal and High-Mild. When then BP values are in Low-Mild and High-Mild categories, alerts and notifications messages are sent to Hanna and her midwife while during Normal condition, the messages are sent to Hanna only.

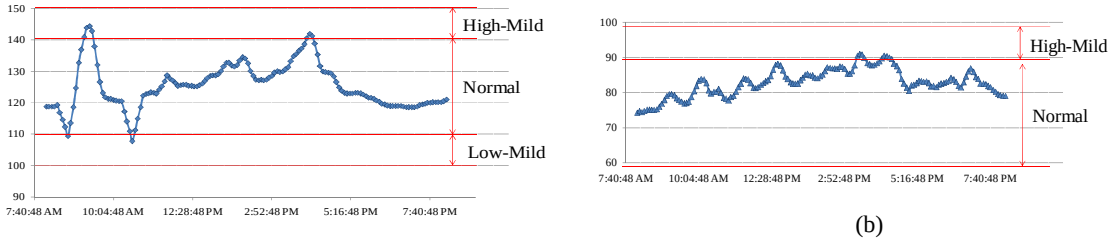

Figure 4. The blood pressure reading (systolic in (a) and diastolic in (b)) for the testing

6. CONCLUSION AND FUTURE WORKS

Interaction protocols are very important for the proper operation of a remote health care monitoring system. In this paper, we have discussed various issues involving designing interaction protocols. A prototype together with a simple case study has also been presented to illustrate its operations in a real-life scenario.

There remain several issues worthy for further investigation in this area. Ambiguity is an interesting issue in sending alerts and notification. Before an alert or a notification message is sent to the users, the system needs to make sure that the message can be understood by the intended receivers. Wrong interpretation of a message can be catastrophic. The user might take inappropriate actions that lead to worsening of the patient's condition. It is an interesting research to gather information about the clarity of the message and perception and understanding of the users towards the wording of the message. Location awareness is another interesting research area. Complex mechanisms are needed for detecting the location of the patients, and what devices are the most appropriate to alert them. Testing for larger set of setting is planned to get the better perspectives and view from the users in clinical setting and at home.

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