A MediNet for staying connected in a Mobile Healthcare System

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Abstract - A mobile healthcare system is a network includes a collection of number of components that includes patients and their health-care providers. In this system it is important that the patient to remain connected at all times even if one of the communication components fails. In this paper we discuss the design of the MediNet system and shows how it faultlessly handles connectivity issues between patients and their mobile phones, between the healthcare meters and mobile phones, and between mobile phones and web server components. The overall goal behind our design strategies is to continue providing a high level of service to the patient in the face of communication problems leading to improved acceptability and trust of the system by patients.

I. INTRODUCTION

A. The MediNet

Mobile Health or simply **mHealth** is a recent term for medical and health-care practice supported by mobile devices, such as mobile phones, patient monitoring devices, PDAs, and other wireless devices. It involves the use of mobile devices to collect community and clinical health data, delivery of healthcare information to practitioners, researchers, and patients, real-time monitoring of patient vital signs, and the direct provision of healthcare. The main objective of the system is to network the healthcare resources in the Caribbean region with the aim of providing personalized healthcare services to a wider population regardless of economic status or location.

Figure 1 illustrates the four main components of the MediNet system: the healthcare meters interface, the patient interface, a set of web services, and an online portal for healthcare providers and caregivers.

The healthcare meters interface is responsible for the transfer of the patient's physiological signs from the respective meter to the phone. A heuristic usability evaluation was conducted to select appropriate health-care meters for MediNet. Based on the evaluation, two meters were chosen for the pilot study: the OneTouch Ultra 2 glucometer with the Polytel Glucose Meter Accessory (for diabetes) and the A and D UA-767PBT blood pressure meter (for cardiovascular disease). Both meters offer Bluetooth connectivity and similar protocol APIs.

The patient interface is a mobile application. It provides an easy-to-use interface for users to take their blood glucose and blood pressure readings as well as view historic readings in either tabular or graphical formats. The web services component consists of a set of web services and other communication protocols which authenticate users as well as transfer a patient's data from the mobile phone to a remote server. Finally, the online web portal enables healthcare providers and caregivers to remotely monitor the health of their patients.

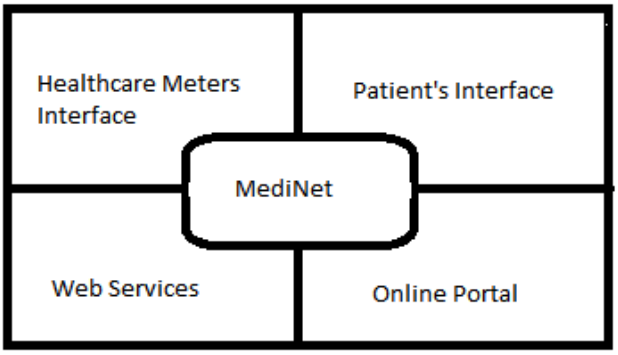

Figure 1: Components of MediNet

B. Mobile Network Environment Challenges

There are numerous challenges that surround the design and development of a healthcare system based on mobile telephony. Mobile networks or wireless networks on a whole are characterized by lack of connectivity, limited bandwidth, dropped packets, and security issues.

Mobile applications that depend on network services may experience some form of disruption when there is a lack of connectivity. This disruption may occur at anytime and represents a burden to the user. Research has shown that users like the feeling of "always being on" and may get unmotivated if interruptions happen too frequently. The effects are even more pronounced if disruptions occur when the user is performing a key task such as receiving feedback from a healthcare provider. Mobile healthcare applications must take this into consideration and ensure that fail-safe procedures are in place so that the burden to the user is reduced or in the best case, the user is not even made aware of the disruption.

Limited bandwidth is another challenge. The more users on a mobile network, the higher the probability that services may be denied. Mobile phones are becoming more and more intelligent with expandable storage. Therefore whenever possible, developers should use the local phone to perform some of the processing given the nature of the task.

Dropped packets occur during transmission when some interruption takes place. In a mobile healthcare application, lost packets can mean the difference between life and death. Mechanisms should be put in

place to ensure that any data sent has actually been received. This can be done by means of an acknowledgement or by using an alternative procedure such as calling the healthcare provider directly using the mobile phone.

Security is a major concern in any healthcare system and in the mobile context it is no different. In the case of patients sending private or sensitive data to a remote server, it is important to guard this data against eavesdroppers or external parties who can use the information against the person. To address this issue some systems have used a patient id instead of the patient's name on all records so as not to associate the information with the identity of someone.

II. LOGICAL CONNECTIONS IN A MEDINET

A. *Mobile Phone Limitations*

One of the major challenges faced when designing an application for a mobile phone is addressing the constraints that are inherent in the small device, namely: limited screen size, limited input methods, and the presence of distractions from the external environment.

B. *Mobile Phone Choice*

The age group of the target users (40 years and older), it was important to select a mobile phone that met their special needs: impaired vision, limited mobile usage and not too technologically inclined. These needs indicated that the most appropriate phone would be one with a fairly large viewing screen to enable the use of large fonts or graphics and a good-sized keypad or input area for hassle-free navigation.

C. *Patient Interface Application Design*

In designing the patient interface, the User-centered Design model was employed. The first stage was the use of paper prototypes which sketched the main screens of the proposed system.

The design of the patient interface was also influenced by the objective of keeping things simple and making the interaction with the system as seamless as possible. Therefore if an interruption is experienced when performing tasks due to some connectivity issue, the execution of the application should continue to flow by providing the user with alternatives.

A key feature of the patient interface is that it maintains a local data store on the mobile phone. This local store was implemented for fail-safe reasons allowing the user to interact with the application even in the absence of a connection to the web server. Therefore, even if server connection is lost, the user can still connect to the patient interface and use it as normal. The local store holds encrypted information on the user, meters used and the readings taken.

When designing the application for the phone, the memory size of the phone was taken into consideration. A maximum of 100 readings for each user is kept on the phone. These readings represent the 100 latest readings the user has record. This limit was set to ensure the application does not take up too many memory resources and hence avoid slowing tasks down. It is also not necessary to store more than 100 because the patient may not need to access such a long history on the go and in the case they did, all the readings are still available through the online portal.

Every time the phone is able to establish a GPRS or Wi-Fi connection to the Internet, the readings are securely transferred to the server and the local store is updated to indicate that the readings were success-fully transferred.

III. PATIENT AND MOBILE PHONE CONNECTION

A. *Using the features of Mobile Phone*

Using the mobile phone in a healthcare system provides many affordances. Firstly, there are the features of the phone itself. Patients are able to make or receive calls from their healthcare provider and caregiver. The patients can also receive SMS reminders about taking their measurements and medication as well as send SMSs if necessary. The mobile phones that are available today also offer the capability of browsing the Internet and sending email. Patients can therefore be referred to healthcare resources online.

One of the main reasons for using the mobile phone as a platform for healthcare delivery is the fact that the phone has become such an integral part of a person's everyday life. It is considered a personal item and as such, services can be tailored to each user. The objective of the MediNet patient interface is to integrate the processes of measurement taking and recording as a part of the user's everyday mobile usage; not to be seen as a separate application but instead as one of the core features of the phone.

B. *Using Patient Interface Application*

The patient interface in the MediNet system was designed to exploit the storage and processing capabilities of the smart phone. When the patient logs onto the system the first time, server authentication is required. This authentication takes place on a remote server. The patient enters his login credentials which are sent securely through a web service call to a remote server. Once his credentials are successfully authenticated, the patient is granted access to the application and any subsequent login event will occur locally using the data store on the mobile phone. This feature enables the patient to access the application securely at any time, even though no connection to the server is available. Hence the patient stays connected

to the patient interface. The authentication is possible locally because the patient's login credentials are encrypted and stored in the user data section of the local store. If the patient chooses, he can change his password at any time. However, this password change has to be authenticated through a web service call.

Once the patient has successfully logged on, the main menu is presented, as shown in Figure 2. The main menu contains six options, Get Readings, Edit User Data, View Log Book, View Tip, Get Help, and Exit.

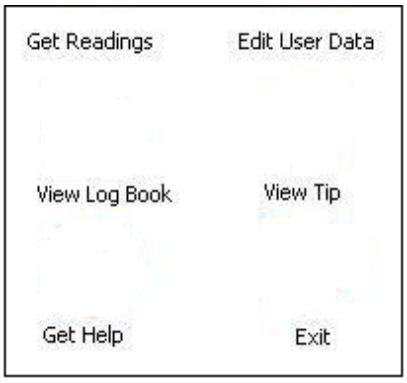

Figure 2: Patient Interface Main Menu

The **Get Readings** feature allows the user to enter the readings from the blood sugar or blood pressure meter. The user has two choices for transmission: automatic or manual.

As mentioned earlier, the automatic transmission uses Bluetooth to transfer the values from the meter to the phone. If the user is unable to establish a Bluetooth connection or if the user prefers, manual entry is also possible whereby the user enters the values into the application. The manual entry also allows users who own meters other than the ones supported to enter readings from their respective meters.

The **Edit User Data** option enables the user to update their profile including changing their password. The system also keeps a log or history of readings. This feature is available through the **View Log Book** option. The user is offered two views of their history: a tabular or a graph view. The tabular view provides the user with a history of all their readings including contextual data surrounding the readings such as time of day, activity level and stress level. The graph view facilitates the identification of trends such as increases, decreases or no change.

A preliminary analysis of users' interactions with the application indicates that for some users, the **View Log Book** feature is used immediately after a reading has been entered. This suggests that the feature is being used to verify that the reading has in fact been entered correctly into the system. Furthermore, the user has a sense of assurance knowing that his readings are always available for reviewing. This comes in handy when an abnormal event occurs. Lastly, the history of readings at a glance may also assure the user that he is managing his disease satisfactorily.

The **View Tip** feature provides the patient with personalized feedback based on the current reading as well as his history of readings. The patient is congratulated when the readings are within a specified acceptable range. If there is some abnormal event or the reading is outside the acceptable range, the healthcare provider and caregiver are notified.

The **Get Help** feature provides assistance to the patient on the use of the mobile application and the **Exit** feature closes the application.

IV. CONNECTION BETWEEN PATIENT, HEALTHCARE METER, AND MOBILE PHONE

The MediNet client interface enables a patient to transfer her readings to the mobile phone automatically via Bluetooth or manually via a data entry screen in the application.

In order to use the Bluetooth meters currently supported by MediNet, the patient must choose the **Get Readings** option from the Main Menu. After taking her reading, the patient then chooses the option to get the reading automatically via Bluetooth. After a few seconds, the reading is transferred via Bluetooth to the mobile phone. At this point, the application on the mobile phone presents a data entry form prompting the patient to enter additional data. This form is the same as the form used for the manual entry of readings except that the reading fields are automatically populated with the data obtained from the measuring device.

V. CONNECTION BETWEEN PATIENT'S PHONE AND REMOTE SERVER

After the patient chooses to save her reading on the mobile phone, the reading must be saved to local storage. It must also be transmitted over the Internet and saved on the database server. This is the connection which is most prone to failures in MediNet and generally, in any mo-bile healthcare system. Two data storage protocols were implemented in MediNet to deal with different kinds of network failures in a simple way. Indeed, the protocols were implemented in such a manner that the patient is completely unaware of the data transfers taking place. This section describes the client and server data storage protocols implemented in MediNet. It also describes a messaging feature that was implemented to encourage patients to take their readings regularly.

A. Client Protocol

The following algorithm describes the protocol for storing readings both locally and on the remote database server. The reading is first saved locally and then an attempt is made to transfer the reading to the remove server. If this is unsuccessful, an attempt will

be made to send the reading when the next reading is taken. The procedure is threaded so the patient can continue using the client application while it is being executed. Thus, the patient has no idea of the data transfer processes taking place.

```
procedure saveReading (Reading reading)
    { saveLocally (reading)
     reading.transferred = false
    Let S = {All readings, r, from local storage,
    where r.transferred = false}
insert reading in S
    try {
        result = saveRemotely (userid, password,
        S)
        if result = true then
           for all readi r, in S
              r.transferred = true then
           end  for
    end if
  }
    catch (TimeoutException te) {}
}
```

The client protocol facilitates several important scenarios that are likely to be encountered in a mHealth system. If mobile network ser-vices become unavailable because of disruption in services or because the patient has moved out of an area where communication is unavailable, the data will be transferred when the network services become available. Other scenarios are possible such as the patient's failing to pay his bill on time and being disconnected from the mobile network or the patient travelling to another country where it is difficult or costly to make remote Internet connections. In all cases, the local storage on the mobile phone keeps the patient connected to their readings all the time.

B. Server Protocol

The following algorithm describes the protocol implemented by the remote server to save readings sent by the client application. Because of the nature of network failures, it is possible that a reading was successfully saved to the database but the client application was not made aware of this. Thus, the **transferred** attribute for that reading would be **false** and the client will make another attempt to send the reading when subsequent readings are taken. Consequently, the server protocol ensures that the reading is not already in the database before inserting "new" readings to prevent duplicates. Also, any problems encountered by the web service when processing the readings will result in a **false** message being returned to the client application so it will send the reading/s again at the next opportunity when the connection is re-established.

```
procedure saveRemotely (userid, password, S):boolean
  {  try {
     result = authenticate (userid, password)
     if result = false then
        return false
     end if
     for each reading, r, in S
          result =  search(r, database)
        if result = = false then
          insert(r, database)
        end if
     end for
     return true
    }
catch(dataReceivedException dre) {
return false
  }
}
```

C. SMS Reminders to Take Readings

In addition to the client and server data storage protocols, MediNet also implements a feature to remind patients to take their readings. This is especially important during the initial months of using a mobile healthcare system since its helps in the change management process (Sultan et al, 2009). The system presently gives daily reminders to patients. However, future versions of MediNet will personalize the reminders based on historic usage patterns, patient preferences, and other factors.

VI. CONNECTION BETWEEN PATIENT'S HEALTH CARE GIVERS AND PROVIDERS

The components of MediNet described so far keeps the patient connected to the physical components of the system, namely the healthcare meters, mobile phone, and Internet servers. MediNet provides additional features that keep the patient connected to her healthcare providers and caregivers. One such feature is the Web portal.

The Web portal is an application that can be used by the patient's healthcare providers and other authorized individuals to view the patient's information. Data is displayed in various formats such as graphical and tabular views of readings. Thus, a patient's doctor can monitor a patient remotely and can contact the patient if the need arises. The Web portal can also be used by authorized persons (e.g., relatives and caregivers) to monitor the health of a patient and provide advice and support as necessary from a distance.

MediNet also provides a **View Tip** feature where a patient can ask for feedback based on his current readings. This feedback is generated by the patient interface and is based on generally accepted guidelines for the self-management of diabetes and blood pressure problems. In the case of two successive readings being out of range, MediNet sends a text message to the patient's healthcare providers and other pre-assigned individuals such as an emergency contact.

VII. CONCLUSION

This paper identified the need for a mobile healthcare system to continue to provide a high level of service to its users in the face of communication failures. It described the design strategies used in MediNet to ensure that patients continue to use the system despite failures that may occur when transferring data between healthcare devices and mobile phones and between mobile phones and web server components. The intention is to keep the patient feeling connected at all times leading to improved acceptability and trust of the system by patients.

The MediNet system is also being extended to include other healthcare meters such as pulse oximeters and scales. Future field tests are likely to include other countries of the Caribbean. The ultimate aim is to provide a system which connects patients and their healthcare providers and caregivers in a seamless manner.

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