Telemedicine using VoIP combined with a Store and Forward Approach

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***Abstract*— Rural areas in South Africa have unique conditions such as remoteness and scarcity of reliable public facilities. Information and Communication Technologies (ICTs) introduced into these areas must be suitable for these conditions. Using a user-centred design approach based on Participatory Design and Action Research, we have developed a telemedicine application for a rural village in the Eastern Cape. This paper describes how we determined the requirements and design for the application and why we chose Voice over Internet Protocol (VoIP) combined with a store and forward approach to achieve our telemedicine goals. We present an overview of the methodology we are using, describe the software application we have developed and mention several challenges we have faced to date. Finally we conclude that VoIP and store and forward technologies are appropriate to the South African rural situation.**

***Index Terms*— telemedicine, voip, store and forward**

I. Introduction

There is a growing Digital Divide between developed and developing countries. In Africa, for instance, there are only 1.3 PCs per 100 users [1] and Internet penetration is low. Within developing countries there is also a divide between urban and rural areas. In order to overcome this internal division, access to Information and Communication Technologies (ICTs) must be provided to rural areas [2], [3]. However, introducing ICTs into rural areas brings with it a host of challenges since these areas have unique conditions e.g. remoteness and scarcity of reliable public facilities such as a reliable electricity supply and running water. [4], [5].

In the past, many initiatives attempting to empower communities through the use of ICTs fail. Reasons for failure include not providing suitable content, not addressing real needs and not fostering local buy-in from the community amongst others [6], [7]. The question is can we bridge this gap in these communities and develop locally relevant applications with appropriate technologies? We believe that using a user-centred and participatory approach in the software development process, we can empower rural communities through appropriate ICTs.

With a methodology based on Participatory Design (PD) and Action Research (AR), we have identified and developed an initial prototype tool to enable telemedicine in a rural community in the Eastern Cape province of South Africa. This paper describes how we determined the requirements and design for the application and why we chose Voice over Internet Protocol (VoIP) combined with a store and forward approach to achieve our telemedicine goals. We present an overview of the methodology we are using and describe the software application we have developed. In addition, we present several challenges faced in the South African context when undertaking this kind of project as well as our future plans. Finally we conclude that VoIP and store and forward technologies are appropriate to the South African rural situation.

II. Related Work

There are several examples of initiatives that have succeeded in creating applications for developing countries using user centred design approaches such as the Ore Project in Brazil [8] and the CyberTracker project in South Africa [9].

The user centred methods that we have based our methodology on are PD and AR. PD was developed from Scandinavian approaches for empowering workers in industrial settings by allowing them to influence what technology was introduced into the work environment [10]. It stresses that the most productive ideas arise when there is collaboration from people with diverse backgrounds. It also concentrates on addressing problems that exist and arise from the situation in the workplace rather than from outside [11], [12], [13].

Most PD projects in the past have used a AR methodology [13]. Similar to PD, the AR emphasis is on involving participants/stakeholders in every part of the AR process as they are experts in the local culture, beliefs and practices [14], [15]. Carr and Kemmis describe this method as a spiral of cycles of diagnosing, planning, implementing the plan, observing results and reflecting on the results [16], [10].

AR and PD are applicable because the research focus arises not from the researcher alone but rather from the people and community that an intervention aims to uplift. This overcomes the problem of adapting people to technology instead of vice versa. If we replace a worker with a community member, we can see that this provides a basic framework for conducting research in rural communities. It also means we can more easily identify the kinds of technologies that are appropriate to a particular area in collaboration with community members.

III. Telemedicine in the Eastern Cape

This section presents how we determined the kinds of services that were required in our target community and which technologies were appropriate to fulfil those services.

A. *The Target Area*

We identified the Tsilitwa village in the Eastern Cape province of South Africa as the target community for our research. The village was chosen because of the existing project undertaken there by the Council for Scientific and Industry Research (CSIR). The CSIR together with a consortium implemented a community network in Tsilitwa linking several sites to each other and a neighbouring village using and 802.11b wireless ethernet (Wi-Fi). This network allows phone calls between the sites using Voice over Internet Protocol (VoIP).

The participants in our project include the people responsible for maintenance of this network as well as health care workers in Tsilitwa and Sulenkama, the neighbouring village. The following section presents an overview of the process we are using.

B. *An Inter-Disciplinary Approach*

Our methodology is cyclical, iterative and participatory. We go through cycles of situation analysis, problem identification, planning an action to solve the problem, implementing the plan and finally evaluating the results of the action. The feedback from the evaluation informs the next cycle. In our case, the planning and implementation of the action result in a software prototype. The process is iterative because we go through as many cycles as possible in order to refine the prototype.

The participatory aspect is the involvement of the users of the software system in the software development life cycle. This is achieved through discussion groups, semi-structured interviews and correspondence by cellular telephones. We also rely on input from the CSIR and a Non Government Organisation (NGO) called Bridges.org advises us on best practice in determining what technologies to introduce into the area.

C. *The Process in Action*

In our first field trip, we were introduced to community members by the CSIR and shown the sites linked to the Wi-Fi network. We identified the problem area as being communication for health. A basic telemedicine system was implemented by the CSIR to link the primary health care clinic in Tsilitwa with the nearest hospital, 20 km away. This system allows for telephone calls between the clinic and the hospital using VoIP. In addition, one way video transmission from the clinic to the hospital is possible via a low cost webcam.

Through our discussion groups and interviews with the nurses from the clinic and doctors from the hospital, we found that this system was found to be very useful but problematic. Frequent power failures render it useless for large amounts of time and due to the shortage of staff at the hospital, telemedicine is an additional workload for the doctor who is solely responsible for the entire hospital. It is therefore difficult to schedule times when a telemedicine consultation can occur.

From this diagnosis of the situation, we decided that combining a store and forward approach with VoIP would resolve the communication problems. A store and forward approach would allow patient data to be captured at any time and then sent to the recipient site when a network connection becomes available. To further enhance this system, we decided to introduce laptops since they offer several hours of battery life. This means that data can be captured even during a power failure for as long as the battery lasts. Batteries can then be recharged when the power returns.

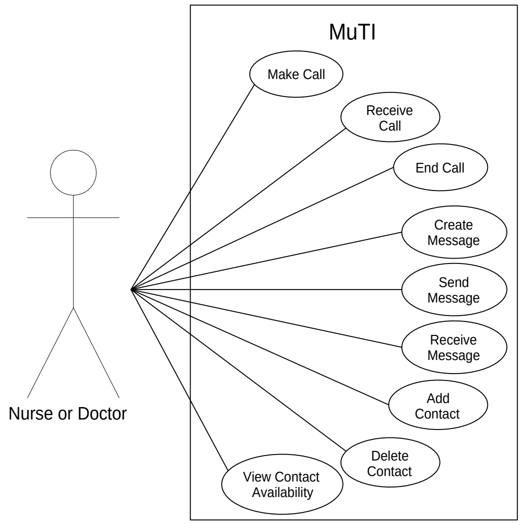

Fig. 1. This use case diagram shows MuTI's basic requirements. These included support for synchronous voice calls and asynchronous sending and receiving of messages. In addition, a contact list was necessary to allow users to see who is available to take calls.

During our second trip, we presented the participants in the project with a paper prototype of the software solution which we were proposing. The paper prototype introduced the concept of store and forward using the analogy of voicemail. Since all the project participants have cellular telephones, they were familiar with this concept. The paper prototype was well received and we proceeded to design and implementation of a functional prototype. The basic requirements for the new telemedicine system are shown in the use case diagram in Figure 1. The software was required to support synchronous voice calls and asynchronous sending of messages between the clinic and the hospital. These messages were to contain text indicating the patients illness and medical history, digital pictures of the patient or particular problem area and voicemail. Voicemail was included to save time on typing and due to the poor quality of the existing video system , digital images were requested due to their higher resolution.

IV. MuTI: Multi-modal Telemedicine Intercommunicator

With these requirements in mind, we designed and implemented an initial prototype tool called MuTI - Multi-modal Telemedicine Intercommunicator. The system was implemented in C# on the Microsoft .NET Platform to allow rapid prototyping.

MuTI is composed of several components as shown in Figure 2. namely *RtcFunctions*, *File Transfer*, *Network Monitor*, *Logs*, *Voice Compressor*, *DirectX*, *Storage*, *Patient Details*, *Contact Details* and *Record Details*. *RtcFunctions* comprises

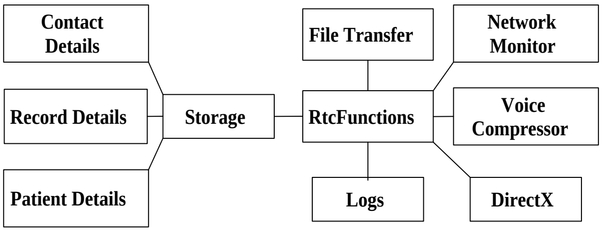

Fig. 2. This diagram shows the major components of MuTI. Each component implements a portion of MuTI's functionality. For an example, File Transfer is responsible for transfer of messages between sites as well as file compression and decompression. The lines indicate associations between components.

the Graphical User Interface (GUI) functionality of MuTI and supports synchronous real time voice calls. It also relies on the other components to carry out database operations and file transfer.

Calls are implemented on a peer to peer basis using Microsoft's Real Time Communications (RTC) API developed for creating VoIP clients based on Session Initiation Protocol (SIP).

The VoIP system in the CSIR telemedicine system relies on a server situated at the school, a site which is often unavailable due to power failures. If the school is offline, the clinic and the hospital are unable to communicate over the VoIP phones. MuTI's peer to peer calls overcome this problem since it only requires the two end points of the call to be functional i.e. the clinic and the hospital.

The *RtcFunctions* component allows a contact list to be maintained similar to those used in instant messenging tools. This list indicates the availability of a contact to take a call and is shown in the main MuTI screen in Figure 3. This enables a nurse or a doctor to determine if the other party is available.

The *Storage* component implements all the store and access functions for an MS Access database. MuTI supports multiple user profiles and stores all information in the database per user. Each user has a number of patients and each patient has a number of records. Records are divided into those that have been created or sent by the user and those that are received from another source. Only file locations are stored in the database. The *Patient Details*, *Contact Details* and *Record Details* components help facilitate access of patient, contact and record data using the *Storage* component.

In the GUI, records that are sent and received are displayed in an Inbox and an Outbox accordingly. The concept of an Inbox and Outbox was familiar since the participants had used email previously when a cellular Internet connection was made available for a short period by the CSIR.

As seen in the records dialogue in Figure 4, each record can contain text, images and a voicemail. Voicemail is captured using Microsoft's *DirectX*. It is compressed using Microsoft's Windows Media Encoding (WME) API in the *Voice Compressor* component resulting in an avi file. When a record is sent, all files for that record are also compressed by the *File Transfer* component before being transferred to another site.

Records are sent immediately if a connection to the other party is available. If no connection is available, the record is flagged to be sent when one becomes available. The network

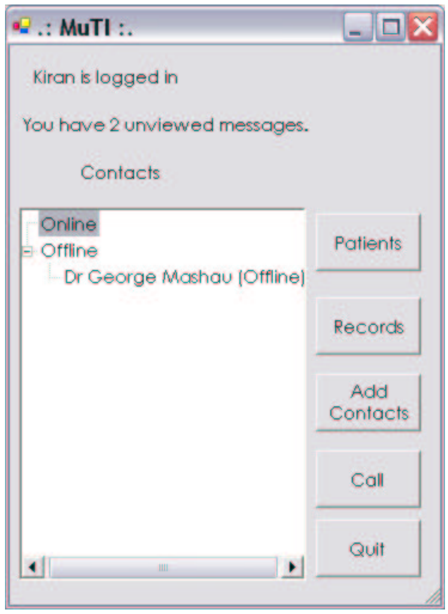

Fig. 3. This screenshot shows the contact list that reflects a person's availability to take calls. Offline means a person is unavailable and online means a person is available. The buttons on the right also reflect the basic functions that MuTI provides. One can manage patients, records or contacts or quit.

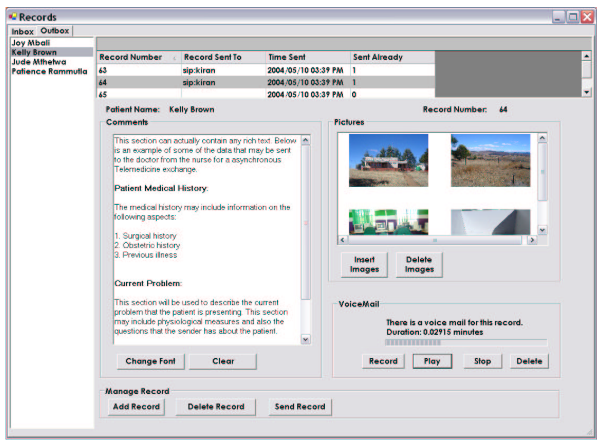

Fig. 4. This screenshot shows the records dialogue where records are displayed per patient in an Inbox and an Outbox. This screenshot shows a dummy record to illustrate that a record can contain text, images and voicemail. Images may also be viewed in a separate image viewer which allows enlargement.

connection is constantly polled by the *Network Monitor* component to determine when to forward queued messages. Events are raised to signal network connection and disconnection. The *Logs* component allows logging of application trace information, debugging data and significant events that occur during execution.

MuTI's main advantage is its multi-modality that combines synchronous VoIP with the asynchronous store and forward of messages. Telemedicine consultations can be conducted synchronously if both parties are available and if the power and network are up. If the power or network is down, or if both parties are unavailable to take part in a synchronous communication, MuTI allows a store and forward approach for the data. Text, voice and images can be captured at any time and they are forwarded when a connection is available. This asynchronous aspect means that an overworked doctor can now process messages at his own convenience and reply when he has time. Digital images in records offer a greater level of detail and voicemail cuts down on typing. The former improves on the poor quality video in the previous telemedicine system and the latter saves time for users with poor typing skills. It is anticipated that the system will also mean cost and time savings for patients since they do not actually have to travel to the hospital to see the doctor, if not necessary. This is particularly significant in Tsilitwa since a large proportion of the patients are unemployed or living on government grants. Also, inter-village travel is erratic and expensive for locals.

On the third cycle of the project, the initial MuTI prototype was demonstrated and tested in Tsilitwa. Before introducing the new system, we gathered baseline data about the previous telemedicine system using questionnaires. We installed the new laptops at the hospital and the clinic and connected these to the Wi-Fi network.

The initial feedback received from interviews with the doctor and nurses in the area was positive. With the previous system, the doctor was constantly interrupted during telemedicine consultations by emergency calls since he is the only doctor at the hospital. He felt that MuTI would allow him to process and reply to messages in his own time and that he could aid more patients through telemedicine. The nurse at the clinic agreed that MuTI would increase the processing of patients and felt that the digital images and text would help the doctor accurately diagnose problems with a patient. Both parties also felt the voice calls with MuTI were of better quality than with the VoIP phones. This implies that a store and forward approach combined with VoIP is suitable for use in a rural area such as the Eastern Cape.

V. Future Work

In the next cycle, we will improve the MuTI interface and instrument the software to gather usage statistics of the system. We will administer questionnaires to the users to assess the usefulness of the new system and gather information on how to improve the system for the following cycle. We are also working to get a satellite internet connection in Tsilitwa.

VI. Challenges In The Rural Context

The project has presented us with many challenges. Due to the number of organizations involved and the large distance that must be travelled to visit the village, scheduling field trips is difficult. Time constraints therefore have to be relaxed and milestones should be flexible during the project duration. Also, merely introducing technology into an area is not sufficient. Along with the software development process, time must be allocated for extensive training of individuals to use the software. In addition measures to ensure sustainability and maintenance of equipment need to be put in place. There are also basic logistical problems. For instance, the hospital has a shortage of doctors and telemedicine merely places an additional burden on the doctor. This issue has to be taken up to government level in order to be resolved. These challenges are important but not impossible to overcome.

VII. Conclusions

To conclude, developing locally relevant applications for rural areas in developing countries like South Africa presents a number of challenges. PD and AR principles and an iterative participatory cyclical process provide a basic framework for introducing ICTs to bridge the technology gap in these communities. We have presented MuTI, which is an example of what can be achieved using this process and incorporates technologies particularly suited to the Eastern Cape area, namely Wi-Fi, VoIP and a store and forward approach. We have also raised several issues associated with this kind of development and feel positive that these projects will inform future research in this area.

Marshini Chetty Marshini completed her BSc and BSc(Hons) in Information Technology at the University of Cape Town (UCT). She will complete her masters degree in the Collaborative Visual Computing Laboratory at UCT later this year. Her interests are bridging the digital divide, computer supported collaborative work and human computer interaction. This project is funded by the Telkom/Siemens/THRIP Centre of Excellence in Broadband Applications and The South African Netherlands Research Programme on Alternatives for Development (SANPAD), the National Research Foundation (NRF) and the International Development Research Centre (IDRC). We thank the Council for Scientific and Industry Research (CSIR) for inviting us to work in Tsilitwa and Bridges.org for their participation.

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