DEVELOPING LOCALLY RELEVANT APPLICATIONS FOR RURAL SOUTH AFRICA: A TELEMEDICINE EXAMPLE

A DISSERTATION
SUBMITTED TO THE DEPARTMENT OF COMPUTER SCIENCE,
FACULTY OF SCIENCE
AT THE UNIVERSITY OF CAPE TOWN
IN FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE

By
Marshini Chetty
December 2005

Supervised by
Edwin Blake and co-supervised by William Tucker

© Copyright 2005
by
Marshini Chetty

Acknowledgements

This research project presented many challenges, being the first of its kind in the Department of Computer Science at the University of Cape Town and relatively new for similar departments across the country. Without the support of my colleagues, friends and family, completion of this dissertation would not have been possible. I would therefore like to express my heartfelt thanks to the following people:

- My supervisor: Edwin Blake for his guidance and sagacious advice throughout the project.
- Bill Tucker, my co-supervisor and co-researcher for administering the project and for being a jovial travelling companion on all our field trips; your impeccable taste in music has helped me discover lots of mellifluous tunes.
- Xolisa Vuza, a co-researcher who helped provide us with insight into the community views, helped with software installation, training and testing; and who made another great travelling buddy supplying us with information on the local culture and traditions of the Eastern Cape.
- Chris Morris of the Council for Scientific and Industry Research (CSIR), who invited us to work on the Tsilitwa-Sulenkama project.
- The Tsilitwa community members who worked with us and the Cuban doctor working at Nessie Knight Hospital in Sulenkama at the time of the project.
- Matthew Tagg, for all his support, encouragement and love and for putting up with me during all the stressful periods of this degree.
- My wonderful family: Segeree Chetty, my mother for her aid during times of need; Unita Chetty and Kuben Naidu, my sister and her husband who helped me through times of stress and fed me for much of my degree; Rudashan Chetty, Rulisha Chetty and Vanashree Chetty; my brother and sisters who supported me throughout the two years; Riya Naidu and Keeran Naidu, my niece and nephew, who provided me many hours of entertainment and joy.

- My great friends: Ben Tobler and Oksana Ryndina for keeping me company during coffee breaks and providing me with wise words of advice; Simon Lukell and Nico de Wet for treating me like a member of their own research group; Cara Winterbottom, Sarah Brown and Ilda Ladeira, the three ladies who suffered through the pains of research alongside me; Gerard Petersen, my best friend; Barry Steyn and Yumna Omar, two good friends; Chad Botha who made me laugh and Richard Schroder who kept me up to date with Voice over IP news.
- The South African Netherlands Policy Alternatives for Development (SANPAD), Telkom's Centre of Excellence (CoE) and the National Research Foundation (NRF) for funding equipment, travel and study expenses.
- Finally, thanks to Bridges.org for their advice and guidance throughout the project.

Abstract

Within developing countries, there is a digital divide between rural and urban areas. In order to overcome this division, we need to provide locally relevant Information and Communication Technology (ICT) services to these areas. Traditional software development methodologies are not suitable for developing software for rural and underserviced areas because they cannot take into account the unique requirements and complexities of such areas.

We set out to find the most appropriate way to engineer suitable software applications for rural communities. We developed a methodological framework for creating software applications for a rural community. We critically examined the restrictions that current South African telecommunications legislation places on software development for underserviced areas.

Our socially aware computing framework for creating software applications uses principles from Action Research and Participatory Design as well as best practice guidelines; it helps us address all issues affecting the project success. The validity of our framework was demonstrated by using it to create Multi-modal Telemedicine Intercommunicator (MuTI). MuTI is a prototype system for remote health consultation for a rural community. It allowed for synchronous and asynchronous communications between a clinic in one village and a hospital in the neighbouring village, nearly 20 kilometers away, in the Eastern Cape province of South Africa. It used Voice over Internet Protocol (VoIP) combined with a store and forward approach for communication. MuTI was tested over a Wireless Fidelity (WiFi) network for several months.

Our socially aware framework proved to be appropriate for developing locally relevant applications for rural areas in South Africa. We found that MuTI was an improvement on the previous telemedicine solution in the target community. Using the approach also led to several insights into best practice for ICT development projects. We also found that VoIP and WiFi are relevant technologies for rural regions and that further telecommunication liberalisation in South Africa is required in order to spur technological developments in rural and underserviced areas.

Contents

List of Acronymns

3G

Third generation wireless

API

Application Programming Interface

AR

Action Research

CAPs

Community Access Points are centres in areas lacking adequate telecommunications infrastructure. These centres may contain faxes, telephones, computers and may offer internet access. They offer these paid services to the surrounding communities and are used in places where access at an individual level is not yet feasible.

CAR

Critical Action Research

Codec

Coding and Decoding algorithm for sampling and compressing voice

CSIR

The South African Council for Scientific and Industry Research — a national semi-private research organisation.

DECT

Digitally Enhanced Cordless Technology

DGP

Digital Gangetic Plains project

DoH

Department of Health

EC

Eastern Cape Province of South Africa

ECGs

Electrocardiograms

FTP

File Transfer Protocol

GHz

Gigahertz

GPRS

General Packet Radio Service

GUI

Graphical User Interface

ICASA

The Independent Communications Authority of South Africa regulates the telecommunications and broadcasting sectors in South Africa. Its duties include making policies and regulations and issuing licences to providers of telecommunications and broadcasting service providers.

ICTs

Information and Communication Technologies are tools which can be used to empower people primarily through providing them with access to information.

IETF

Internet Engineers Task Force

IP

Internet Protocol

ISM band

Industrial Scientific and Medical band

ISPA

Internet Service Providers Association

ISPs

Internet Service Providers

ITU

International Telecommunication Union

Kbps

Kilobytes per second

LAN

Local area network

MAC

Media Access Control

Mb

Megabytes

Mbps

Megabits per second

MPCC

A Multipurpose Community Centre is an extension of a Community Access Point (see CAP). It offers public services above basic communications services such as government services and postal services. The premise behind this is that multipurpose centres will have a better chance of success particularly in terms of sustainability. This is because more organisations will offer services at one point and each organisation offers support to the centre.

MuTI

Multi-modal Telemedicine Intercommunicator

NGOs

Non-Government Organizations

PAR

Participatory Action Research

PCs

Personal Computer

PD

Participatory Design

PDAs

Personal Digital Assistants

PSTN

Public Switched Telephone Network

RA/RI

Real Access/Real Impact Framework

RAM

Random Access Memory

RTC

Real Time Communications

RTP

Real-Time Transport Protocol

SDLC

Software development life cycle

SIP

Session Initiation Protocol

SMME

Small medium and micro enterprises

SMS

Short Message Service

SNO

The Second National Operator will compete with Telkom, the incumbent telecommunications operator in South Africa, to offer fixed line telecommunications services. The SNO was supposed to be licensed and operational from 2002 but the process of selection has been lengthy and subject to many disputes. At the time of writing, an entity meeting the criteria for an SNO was identified and the licensing procedure was expected to be completed by the end of 2005.

TB

Tuberculosis

UCT

University of Cape Town

UDP

User Datagram Protocol

UNITRA

University of the Transkei

UPS

Uniterrupted Power Supply

USA

The Universal Service Agency of South Africa was created by Telecommunications Act of 1996, *as amended*, and the Telecommunications Amendment Bill of 2001. It is the agency responsible for providing universal service and universal access: infrastructure and facilities to provide telecommunications to people in underserviced areas. To achieve these goals, it manages and uses the Universal Service Fund — a fund which comprises of monies which the fixed line and mobile telecommunications operators in South Africa must provide by law.

USAL

The Under Serviced Area Licence are licences for regions where less than 5 percent of the population have access to affordable telephony. 27 areas have been identified for USAL licences with the aim of awarding one USAL per area. These licences are for small businesses only and allow the licensee to set up telecommunications operations in the designated area using whatever technologies are necessary.

UTP

Unshielded Twisted Pair

UWC

University of Western Cape

VANs

Value Added Network

VoIP

Voice over Internet Protocol

VSAT

Very Small Aperture Terminal

Webcam

Web Camera

WiFi

Wireless Fidelity or 802.11b

WME

Windows Media Encoding

List of Figures

List of Tables

Chapter 1

Introduction

Information technology is not a magic formula that is going to solve all our problems. But it is a powerful force that can and must be harnessed to our global mission of peace and development.

Kofi Annan, Secretary General, United Nations [3]

There is a growing digital divide within developing countries between urban and rural areas. This division refers to the disparity between those with access to Information and Communication Technologies (ICTs) and those without access; ICTs being technologies for the provision of information, for example, the internet. We know that access to information empowers individuals and allows for improved health care delivery, education and government services. Thus, it is important that this widening gap be reduced to ensure that more people are empowered by gaining improved access to information.

In this dissertation, we investigated appropriate methodologies to engineer suitable ICT applications in a bottom up manner for rural communities in South Africa. By borrowing from existing user centred methodologies and lessons learned from past ICT development initiatives, we augmented a standard software development life cycle to form a socially aware computing framework. This augmentation integrated an understanding of the social context of software into the software engineering process. It also added a research constituent to the software engineering process so that we could learn both from the application developed and the process itself.

In addition, we tested the methodological framework we developed by using it to create an ICT application for a rural community in South Africa. Finally, from our experiences in South Africa, we formulated opinions about the restrictions which telecommunications legislation places on software development and general ICT use for underserviced areas in our country. In the following section, we discuss the motivation behind our research.

1.1 Motivation

In Africa, there are only 1.3 Personal Computers (PCs) per 100 users and internet penetration is low [56]. In South Africa, the situation seems slightly better with a total of 7.26 PCs per 100 users and 7.1 internet users per 100 people [55]. However, these figures are deceptive since most of the PC and internet users are concentrated in the cities. In South African rural areas, there is a distinct lack of ICT infrastructure and many people in these areas do not even have access to a telephone although mobile phones are gaining ground increasingly.

Kofi Annan aptly enunciates the simple truth that merely providing access to ICTs is not a panacea for poverty in rural areas. However, if ICTs are used appropriately to provide useful services in these areas, they can contribute to development and growth in rural and isolated regions [19, 71]. It is no easy task to use ICTs in rural parts of South Africa since these areas have unique conditions. For an example, rural areas are often remote and lack reliable public facilities such as a reliable power supply and telephone lines [39, 73]. Also, in the past, many initiatives around the world attempting to empower communities through the use of ICTs failed. Reasons for failure include not providing suitable content for ICT applications, not addressing real needs or not fostering local buy-in from the target community [32, 40]. The question is can we bridge this gap in rural communities and develop locally relevant applications with appropriate content?

As computer scientists we are used to a positivist way of thinking and our traditional software engineering methodologies are not up to meeting the challenge of development for underserviced areas. Loosely defined, positivism is the belief that knowledge is produced through direct observation and experience which can be objectively verified by empirical methods [5]. In computer science, this would amount to doing research to test and prove or disprove that our theories are correct. However, most standard software engineering models do not have an inherent research component and are focused solely on application development and delivery. For instance, one of the most common methods of software development is the waterfall model [87]. This is a straightforward top down approach where one takes a software specification, creates a design, implements the design and tests it in an iterative fashion.

From previous failed ICT projects, we know that top down approaches do not work in rural areas as the applications developed in this manner are not rooted in the needs of the people. We therefore require a modified software engineering methodology to help us create applications which have locally suitable content. This method should work in a bottom up manner to allow us to develop applications which are borne out of community requirements. Thus, we need to augment traditional approaches so that we can research appropriate ICT applications for rural communities as well as produce ICT applications for these communities, while learning from the process.

Additionally, developing locally relevant software for rural areas is not possible without a supportive legislative environment. In South Africa, certain technologies are restricted for use by telecommunications operators only or other qualified and licensed service providers. This limits the technologies one can utilise in a rural software application as well as for telecommunications and network infrastructure in underserviced areas. Thus, we need technology neutral legislation which encourages telecommunications growth and development in underserviced areas and which allows software developers to provide relevant applications with whatever means or ICTs are necessary. The following section outlines our main aims in this research.

1.2 Objectives

The precise aims of our research were threefold:

1. We wanted to compose a suitable process that would enable us to develop locally relevant software applications for rural and underserviced areas in South Africa. For this, we aimed to use principles from existing user centred methodologies, lessons learned from past ICT development initiatives and the traditional waterfall model of software development.

2. Next, we aimed to develop an application for a rural community in South Africa using the framework we formulated in order to refine and learn from this process and show the validity of the approach. The focus was to develop an application grounded in community needs using our bottom up process; beginning with low fidelity prototypes, moving to software prototypes and refining these until suitable functionality was incorporated into a full system.

3. Finally, we wanted to determine the relationship between the telecommunications legislative environment in South Africa and software applications for rural and underserviced areas. We anticipated that often legislation unnecessarily restricts the applications one can develop in these areas.

In the following section, we describe the method used in the project in order to achieve the project objectives.

1.3 Method: Socially Aware Computing Framework

In order to fulfill our aims, we augmented the normal software development life cycle. We found traditional software development processes lacked an awareness of the social context of the software. Moreover, we felt that these approaches tended to be top down approaches. In other words, usually, as computer scientists, we are given a software specification and are asked to develop it. This approach will not work in rural areas if we wish to address actual community needs. Instead, a bottom up approach is needed which is grounded in the requirements of the target community.

To address these holes in traditional models of software development and to adapt it for use in South African rural areas, we searched for existing user centred methodologies. We used principles of Action Research (AR) and Participatory Design (PD) to develop a framework for the project process. AR is a methodology geared towards solving a problem for a target group of people by involving them in the process and using their expertise in their area of work [7]. It aims to empower groups by creating relevant solutions for their problems and benefits both participants and researchers in the process. AR provided us with the steps we needed to follow for software engineering a locally relevant application. It described the overall process we could use to approach a target community and guidelines on how to work with that community in order to discover a problem area and provide a solution for this problem.

PD evolved from attempts to empower workers in industrial settings [31]. Contemporary PD specifies a set of techniques to increase user involvement in the software development life cycle. This is done to increase the chance that software solutions are appropriate for the people they serve. We used PD to give us guidelines on the techniques we could use to ensure that the software prototypes we develop addressed user needs. These included discussion groups and paper prototyping amongst others.

Additionally, we used principles from previous ICT for development projects in the form of the Real Access/Real Impact (RA/RI) framework to ensure we followed best practice throughout the project [23]. The RA/RI principles are guidelines that were formulated from an examination of ICT development initiatives around the globe. Incorporating RA/RI into our process helped ensure that we did not neglect any aspect of the project that could affect its success. With all these existing methodologies and guides in mind, we composed a cyclical approach for developing software applications in rural and underserviced areas in South Africa. This enabled us to follow a flexible process to develop software prototypes and work with a rural community by adding a social and research aspect to the software development life cycle.

We used our socially aware framework to develop and test an application for a rural community in the Eastern Cape (EC) province of South Africa. The contextual software solution we arrived at was a communication system for health for the region in which our target community fell. Our telemedicine solution is called Multi-modal Telemedicine Intercommunicator (MuTI) and it allowed two forms of communication between a clinic in one village and a hospital in a neighbouring village, nearly 20 kilometers away: synchronous and asynchronous [30].

For synchronous communication, MuTI used Voice over Internet Protocol (VoIP), a communication protocol to allow telephone calls over packet based networks [86]. For asynchronous communications, MuTI used a store and forward approach for messages [82] where MuTI messages are stored locally and forwarded when a connection to the target site is available. Messages in MuTI consisted of text, images and voice messages. MuTI was run over a Wireless Fidelity (WiFi) or 802.11b network; 802.11b being a standard for wireless networking [36].

During our research, we evaluated MuTI, reflected on our socially aware computing process and formulated comments in [29] on how legislation affects the ICTs one can use in rural areas in South Africa. The next section outlines the scope and limitations of the project.

1.4 Scope and Limitations

This masters project was run for a one year period from the time the target community was identified. Our focus was on providing a software prototype with the correct functionality as opposed to developing a fully sustainable application. We must emphasise that this masters project was not a telemedicine project, i.e, we did not *set out* to undertake a telemedicine project. It is only as a result of using our socially aware computing process that we discovered the solution application for our target community was a communication prototype for health care, which was an aspect of a telemedicine.

Finally, we restricted our choices of software engineering methodologies to the waterfall model and our user-centred methodologies to AR and PD alone which served our purposes aptly. Narrowing the scope of the project to these three approaches was necessary in order to carry out the research within the specified time period. We now provide a summary of the organisation of this dissertation as well as chapter by chapter outlines.

1.5 Organisation of this Dissertation

This section describes the organisation of this dissertation. We discuss the reasons for not following a conventional dissertation format and provide a chapter by chapter outline for the readers convenience.

1.5.1 Outline

Due to the methodology used in this research project, which follows the cycles of an Action Research approach, it is not appropriate to present this work as a conventional computer science dissertation. Instead, as suggested by Dick [38], the work in this dissertation is presented around our main contributions — those being the development of the MuTI system, the use of the socially aware computing framework and the compilation of comments on telecommunications policy in South Africa. This is the most apposite and standard way to present this type of research.

We discuss the background information first in Chapter 2 and then we describe the socially aware computing methodology in detail in Chapter 3. Thereafter, we split the cycles of the process we followed into two chapters: Chapter 4 explains how we developed MuTI and Chapter 5 explains how we adapted MuTI through subsequent cycles of the socially aware computing process. Each cycle is presented stage by stage.

In Chapter 6, we discuss the overall results of the MuTI project, in terms of the findings about MuTI, the socially aware computing process and how telecommunications policies affect the technologies one can use in rural areas in South Africa. Finally, in the last chapter, Chapter 7, we discuss the conclusions of the project and make suggestions for future work. Please note that following the table of contents of this dissertation, a list of acronyms has been provided as a reference for the reader. Also, the author has endeavoured, where appropriate, to explain terms which may be unfamiliar to the reader within the body of the dissertation. The following section provides chapter outlines.

1.5.2 Chapter Summaries

This section provides a chapter by chapter summary of the dissertation:

Chapter 2 describes background information on previous ICT development initiatives and the digital divide. We justify the need for locally relevant applications in technology development projects. The unique conditions of rural areas are mentioned and examples of ICT development projects and more specifically, telemedicine projects, around the world are given. Next, we provide examples of ICT development projects in South Africa. We then summarise several factors affecting the success of an ICT development project. Thereafter, we discuss how the way forward in terms of how we can use ICTs in rural areas in South Africa. We describe relevant user centred methodologies which can help gear the software development life cycle towards developing software for underserviced areas. In addition, we discuss relevant technologies for rural regions, such as VoIP and WiFi, and how telecommunications legislation affects the use of these technologies in South Africa.

Chapter 3 details existing methodologies which we used to augment the software development life cycle. We discuss Action Research and Participatory Design and how they were synthesised into a socially aware computing framework for use in rural and underserviced areas. We also describe related projects and their findings using these methodologies. Additionally, we describe the Real Access/Real Impact framework - guidelines we used to ensure we followed best practice in our research. Next, we discuss in detail the steps in the socially aware framework which is a combination of the waterfall model of software development, principles from AR and PD as well as RA/RI . We also detail the methods used for data collection during the project and the measures we took to overcome the limitations of the methodologies used.

Chapter 4 mainly deals with the software prototype developed for the project which we called MuTI. We begin by describing the project setting and the Eastern Cape province where the project took place. A synopsis of the major events in the project is provided next. We then describe how we used our socially aware computing framework, step by step, for the first two cycles of the project. This includes details of how we first met our target community, to how we formulated the ideas for the software solution and finally, to how this culminated in the MuTI prototype. The last three project cycles are covered in *Chapter 5.*

Chapter 5 primarily discusses how we adapted the MuTI prototype to the target community through a further three project cycles. We detail the revisions we made to MuTI and the results of these changes. The chapter ends with a description of how the project eventually terminated.

Chapter 6 discusses the final outcomes of the project. First, we describe the results pertaining to a previous telemedicine solution in the target community. Next, we discuss the evaluation of the MuTI prototype. This involves a triangulated view of the data from interviews, trace files and researcher observations. We also discuss general results regarding telemedicine. Next, we present the lessons learnt from using our socially aware framework to develop a locally relevant software application for a rural village. Finally, we provide our comments on how telecommunications policies affect the technologies one can use in rural and underserviced areas.

Chapter 7 summarises how we achieved our original aims. We then discuss the contributions related to telemedicine, best practice for ICT development projects in developing countries and telecommunications legislation pertaining to rural areas in South Africa in more detail. Next, we provide suggestions for future work and conclude with final remarks.

The following chapter describes the background information for the project.

Chapter 2

Overcoming the Digital Divide In South Africa

Chapter 1 introduced the problems associated with developing locally tailored software solutions for rural and underserviced areas. It also outlined the project aims, contributions and summarised the research process used. In this chapter, we provide background information on development efforts being undertaken to utilize Information and Communications Technologies (ICTs) for poverty alleviation. Moreover, we provide evidence which indicates a need for locally relevant applications in these initiatives. First, we discuss the digital divide and present the role of ICTs for uplifting underserviced communities worldwide.

We then briefly describe the unique conditions of rural areas before giving examples of ICT development initiatives around the globe and more specifically, of telemedicine applications around the world. Next, we illustrate through examples how development initiatives in South Africa have attempted to use ICTs for empowering isolated communities and how often the approach used in these initiatives leads to failure of the project. From a review of several global studies, we outline the factors that most often affect the success of a ICT development project.

Finally, we outline the way forward in terms of how ICTs can be used for the purpose of uplifting disadvantaged communities. In particular, we suggest an approach for using ICTs as tools for poverty alleviation, we mention which technologies are relevant for rural areas and finally, we comment on how the regulatory environment should support the use of ICTs in these communities.

2.1 Digital Divides And Developing Countries

The digital divide is defined as the gap between the information-haves and information-have-nots. This means that there is a division between people with access to ICTs and those without this type of access. ICTs are defined by the World Bank as "hardware, software, networks, media for collection, storage, the processing, transmission and the presentation of information (voice, data, text, images)" [49]. They are tools which can be used to empower people primarily through providing them with access to information.

To illustrate this point, consider a rural farmer with a cellular telephone or cellphone[1] that allows him to access market information about crops that he wishes to sell. This information allows him to price his goods according to market trends and ensure that he maximizes the return on his goods as shown in Figure 1. He could be considered at an advantage to the farmer without this information or the technologies to receive such information. This latter farmer has to rely on traders for his market information and cannot check prices against prevailing market trends. He is unable to make calculated decisions on which markets to supply in order to sell his crops at a profitable margin [85].

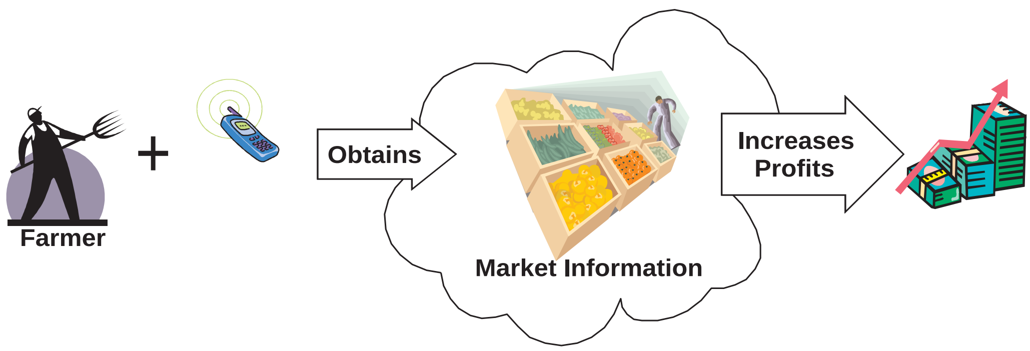


Figure 1: One application of ICTs is to enable rural farmers to gain access to market information through use of devices such as cellular telephones. They can then utilise this information to decide when and where to sell their crops as well as how to price the goods in order to turn a profit.

The digital divide exists between developed and developing countries who are far behind in terms of infrastructure and resources. This essentially excludes them from the global technological exchange of information. Within developing countries, there is also a divide between urban and rural areas and it is on this divide that we shall focus. To overcome this internal division, access to ICTs must be provided to isolated rural areas and underserviced urban areas [19, 71]. The next

[1] A cellular telephone or cellphone is the term commonly used to refer to a mobile phone in South Africa.

section describes the role ICTs can play in poverty alleviation.

2.2 The Role Of ICTs in Poverty Alleviation

The World Bank group and the Canadian International Development Research Centre (IDRC) suggest that ICTs can be used to fight poverty and to foster sustainable development [49, 59, 94]. ICTs provide fast access to and enable the distribution of information. They also offer new ways to do business. Some cited uses of ICTs are: improving market efficiency, improving social and economic inclusion, especially for people in remote areas and improving political involvement. ICTs can also be used for education and health [12, 97].

Navas-Sabater *et al.* [71] elaborate by stating that ICTs promote the integration of isolated communities into the global economy and they promote the delivery of better public services. In effect, they give a voice to the poor by allowing these communities to influence the decisions of policy makers. Through ICTs, the economically deprived have the opportunity to participate in the government's decision making process.

According to the IDRC [59, 94], changes perceived by users of ICTs in underserviced areas include perceptions that ICTs contribute to better sanitary conditions, better educational conditions, higher outcome and employment generation. However, this is only the case if ICTs are tailored to suit the needs of the target people. More importantly, we recall from Chapter 1 that ICTs are not an all in one solution for poverty but can play a role as tools for national development.

In rural areas, using ICTs for poverty alleviation is made more difficult by unique conditions that prevail in these areas. The following section outlines several of these conditions and describes how these affect the use of ICTs in these areas.

2.2.1 ICTs and Rural Areas

In rural areas, introducing ICTs for poverty alleviation is affected by the general circumstances of these regions. For instance, these regions are plagued by paucity or absence of public facilities such as a reliable electricity supply, access roads and water facilities as shown in Figure 2 [39, 73].

There is also a scarcity of technical personnel in these areas which has implications for maintenance and repair of technical problems that arise from equipment placed in these areas. In addition, these kinds of areas may have difficult topological conditions and this makes wired infrastructure both costly and sometimes infeasible. Moreover, the climatic conditions prevalent in rural regions

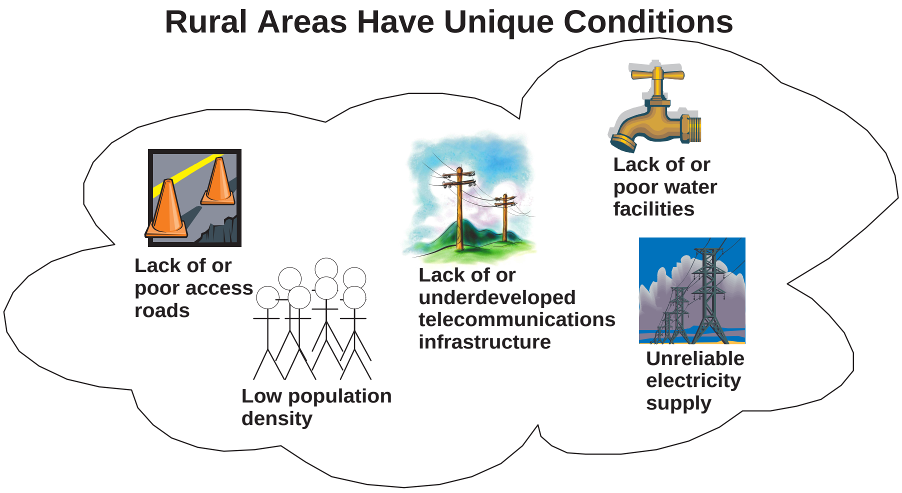


Figure 2: Rural areas have conditions which make it difficult to use ICTs for poverty alleviation. For an example, they have poor access roads, unreliable electricity supplies, a lack of adequate telecommunications infrastructure, usually no running water and a low population density overall.

may place demands on the equipment installed in these areas. For an example, the constant tripping and restoration of the electricity supply can damage computer equipment although this may be reduced by use of a Uninterrupted Power Supply (UPS) device; essentially a backup power supply.

Furthermore, rural areas have a low per capita income level and a low level of economic activity as well as a low population density. Communication in these areas is crucial but often there are very few telephones in these areas leading to a high calling rate per telephone. There is also a need to have a basic level of literacy and training in order for ICTs to be successful in these areas. Most importantly, relevant content is critical to the success of any rural application. Possible areas for software technology to uplift rural communities could be multimedia applications, telemedicine applications, education and government applications as well as e-commerce applications.

In South Africa, one of the poorest provinces is the Eastern Cape which still has many rural and underdeveloped areas. Most of the conditions described above are true of this province and, for these reasons, it is in this province that the project at hand takes place. Generally, the consensus is that ICTs can be used in innovative ways to include and empower marginalised communities. The following section discusses how ICTs have been used in real development initiatives around the globe for this purpose.

2.2.2 Examples of Development Initiatives Using ICTs in Developing Countries

There have been many development initiatives using ICTs in underserviced areas[2]. The first example of an ICT development initiative we present was undertaken in India. In fact, India has many development projects using technology to advance the state of poverty ridden areas. In Gujarat, many milk collection centres have become computerised. Traditionally, the quantity and quality of milk was measured manually and the delays this caused meant farmers could only collect payments after 10 days from delivery. With the computerisation of this process, farmers are assured that their produce is valued correctly and they are able to receive payment immediately. Further examples of improving government service delivery, health care delivery and microfinance provision to rural areas in India are discussed in [26, 27].

Another development initiative showing the potential of ICTs was undertaken by Satellife in Ghana, Kenya and Uganda [20]. This project provided health care workers with Personal Digital Assistants (PDAs) or handheld computers in order to carry out field surveys. In addition, medical reference material from textbooks was loaded onto the PDAs in order to provide health care workers with easy access to this information. The project was successful in reducing the time to conduct field surveys via use of the PDAs and improving the entire survey handling process.

At the beginning of this chapter, an example of how ICTs can be used to provide market related information to farmers was given. This concept has been put into practice in the Philippines via a website called B2BPriceNow.com [9, 65]. This website provides market prices and trade prices for farmers, fishermen and agricultural small and medium enterprises. The impact of the project is yet to be measured.

These case studies illustrate the variety of initiatives being undertaken worldwide. From the studies reviewed, it is evident that although ICTs are seen as one tool for empowering underserviced communities, there is no general strategy across the board on how to utilize them successfully in economically deprived areas. Moreover, most of the case studies do not include any method of evaluation or monitoring so it is hard to gauge the true success of the projects.

This section has illustrated how ICTs have been used in case studies around the globe. In the next section, we describe several development cases involving telemedicine to illustrate how telemedicine initiatives have been undertaken around the globe. Note again, that the project we

[2]Due to the large volume of information available, the reader is referred to the following websites for further case studies on ICT development around the globe: www.bridges.org, www.iicd.org, www.globalknowledge.org and www.sustainableicts.org. This section presents only a few examples to show the diversity of the initiatives being undertaken worldwide.

undertook was not primarily a telemedicine project but that through our dealings with a rural community, we found that a telemedicine application was necessary to improve communication for health care. Thus, the following background material is necessary for the reader.

Telemedicine Case Studies

Huston and Huston [53] define telemedicine as the use of telecommunications technologies and interactive multimedia to provide medical information and services over a large distance. Telemedicine can be used for remote diagnosis and treatment of patients, real time consultations, and continuing medical education for health care professionals. Applications and technologies used in telemedicine vary. Tulu *et al.* [95] applied their taxonomy of telemedicine to a number of telemedicine projects and describe instances of telemedicine using videoconferencing, audioconferencing, data exchange, store and forward technologies and web based systems. Infrastructure for telemedicine also varies from satellite connections, wireless connections to fixed lines. Generally, most telemedicine applications use either synchronous/real-time communication or asynchronous/store and forward communication and not both.

We describe three applications to illustrate how telemedicine has been used both outside of Africa and in Africa. Chau and Hu [28] describe a teleconsultation program implemented in Hong Kong for neurosurgeons. This program allowed transfer of images from physicians at general hospitals to neurosurgeons at specialised or tertiary hospitals. Physicians would transfer patient data from the general hospital to the tertiary hospital and then notify the on-duty neurosurgeon at the tertiary hospital by phone of the incoming message. On the phone, the physician would brief the surgeon on the patient case and provide the relevant clinical information. After the neurosurgeon examined the images, he/she would then discuss the assessment and recommendation with the attending physician, again via telephone.

The system has been used increasingly, now up to 3 times daily, and the surgeons felt that hands-on experience was the best way to learn the technology. With increased usage, they were also able to suggest improvements for the system, which went through several phases of development. The evolution of the system illustrates how a prototype system can help identify the functionality required of system and then be later replaced by an industrial strength program with the same functionality.

In Africa, similar telemedicine systems have been deployed with success. In Mozambique, a telemedicine project linked up the central hospitals of Beira and Maputo for low cost teleradiology [67]. The system consisted of 2 Personal Computers (PCs) equipped with radiological film digitizers.

It allowed for annotation of images, verbal descriptions of a patient's case and scanning of patient records. Doctors at Beira hospital used the system to send patient data to Maputo for a primary or secondary diagnosis.

Another telemedicine project was undertaken in Senegal [67]. This project linked the Lille Regional University hospital to the European Institute of Telemedicine in Toulouse. It used videoconferencing for distance training and remote diagnosis. For patient data exchange, a store and forward approach was used. These projects illustrate only a minor portion of the telemedicine applications being utilised worldwide.

These case studies illustrate how technology can be used for telemedicine in the developing world context. In all three cases, information is transmitted between two sites in order to assist with diagnosis, consultations and training. Information can include but is not restricted to images, text and verbal messages. In our project, we discovered that a simple telemedicine solution which also required the transmission of information between two sites was required. This will be discussed in greater detail in Chapters 4 and 5. Next, we discuss how ICTs have been used for development in South Africa.

2.3 ICT Development Strategies In South Africa

In South Africa, there is a low overall penetration in terms of the internet and computer usage. Most of this penetration is concentrated in urban areas. Previous research into development using technologies in underserviced areas in South Africa has been largely dominated by international development organizations such as the IDRC, the World Bank, telecommunications operators and non-government organizations (NGOs). Comparatively, little research has been undertaken in this area by computer scientists from universities around South Africa.

There are two main ICT development strategies being utilized in South Africa to achieve universal access obligations in underserviced areas; universal access referring to access to basic telecommunications such as telephones and information services. The first is to deploy public telephones and the second is to build Community Access Points (CAPs) or telecentres around the country in the areas that lack basic telecommunications. We focus on the second strategy here. Community access is being used because at this stage, it is not feasible to have access on an individual basis. This is because of lack of infrastructure and also, particularly in rural areas, there is a lack of sufficient funds to support access on an individual basis given the poverty levels.

According to Stavrou *et al.* [91], CAPs are centres which are available to all members of the community in which they are situated. These centres act as resource and communication nodes and should be seen as tools and not ends. They provide access to ICTs and offer ICT services to people that live in very isolated or underserved areas. Stavrou *et al.* report that the telecentres in South Africa, deployed by: the Universal Service Agency of South Africa[3] (USA), the national organisation responsible for using contributions from South Africa's telecommunications providers to achieve universal service obligations; MTN (one of the cellular operators in South Africa) and Telkom (the incumbent telecommunications operator in South Africa) have had many problems with sustainability and most have failed. This is due to a number of factors that include a poor business model, bad management and lack of locally relevant content that fails to attract potential customers.

In South Africa, one of the more successful telecentres is the Gaseleka telecentre [10]. It is primarily an information centre and is equipped with telephones, email, printing and internet facilities. Surprisingly, most of the centre's revenue is not from the internet usage. In fact, the usage of internet facilities has been very low at this centre and this is because of the lack of relevant local content.

There are several other examples of ICT enabled development initiatives in the urban developing areas in South Africa. One initiative was conducted at the Tygerberg Children's Hospital in the Western Cape province [22]. This initiative attempted to provide specialist support to outlying district hospitals. It utilises a provincial network which connects all district hospitals to Tygerberg hospital for email. Doctors at district hospitals can email electrocardiograms (ECGs) and x-rays to Tygerberg hospital. Here, one person scans all incoming queries and directs them to the relevant specialists at Tygerberg. Responses are then sent by the specialist to the sender in order to provide remote advice and consultation.

Another example is the Soweto Digital Village [64]. This is a telecentre in a previously disadvantaged township in Johnannesburg. It provides computer literacy training for surrounding communities, schools, students and local entrepreneurs. The centre has been quite successful and high profile, being opened by Bill Gates in 1997.

One other ICT initiative in South Africa has used Short Message Service (SMS) technology in order to help patients undergoing treatment for Tuberculosis (TB) comply with their medication schedules [21]. SMS technology allows users of cellular networks to exchange alphanumeric messages of up to 160 characters in length [81]. It is widely used in South Africa as a text based method of communication since it is less expensive than making a call on a cellular phone. SMS can also be

[3] www.usa.org.za

used to send text messages from a PC to a cellular phone and can be used to send many people the same text message at once. Since there is a high incidence of TB in South Africa, measures have to be taken to help people who have contracted the disease to overcome it. For a patient to combat TB, s/he needs to follow a strict drug regime. Failure to follow the drug taking schedule aggravates the TB condition and makes the TB virus increasingly drug resistant. A company, The Compliance Service working with the city of Cape Town, sends SMSs to patients to alert them to take their medication. The initiative impact has not yet been evaluated.

It appears that more ICT development work has been undertaken in South African urban areas. Moreover, it seems that provision of community access in the form of telecentres around has largely not been successful. The question to answer now is what are the factors that make a successful ICT development initiative and how can we ensure that we as computer scientists develop relevant software applications for underserviced areas. The following section describes the factors that help make an ICT project successful and Section 2.5 suggests how to address some of these factors to ensure a successful project.

2.4 Factors Affecting The Success of an ICT Development Project

From an examination of case studies and reports of ICT development initiatives around the globe [9, 49, 73], the following themes emerge:

1. *Local content is the key* — Applications for underserviced areas need local content if they are to successfully address user needs; be seen as beneficial by the communities in which they reside and to be utilized successfully [8, 42, 94]. The tagline here is that ICTs will not attract potential users unless they find them useful [32, 40]. Ernberg argues that the demand for ICTs will increase as an iterative process [41]. As various user groups learn to use tools and discover what they can do with them, they will realise how the tools can benefit them. Thus he stresses that it is important to create content that meets the needs of various user groups and to adapt existing information to the conditions of people in rural and remote areas.

2. *Training is a necessity* — ICTS are tools not ends. If one is introducing new technologies into an area, sufficient training should be provided so that people are able to use these technologies successfully and for their benefit [42, 94]. In 2003, we visited a telecentre in Tombo in the Eastern Cape set up by the USA of SA. The centre, shown in Figure 3, had been built in 1999

but, at the time of our visit, none of the surrounding community had ever used the centres computers.

Figure 3: Tombo Telecentre in 2003 - The computers at this centre had yet to be used by the surrounding community even though the centre was built in 1999. Factors hampering usage of the computers included the fact that no training was provided to the show people how to use the computers and that no attempt was made to provide relevant content.

Reasons for this included the fact that no training had been provided and that the local people did not see the benefit of using the technology. A local organisation was due to start teaching basic computer literacy in the centre soon after our visit in order to overcome these problems. This case illustrates the points that local content creation and training are prerequisites for the success of any community oriented development initiative in South Africa.

3. *Participation helps foster trust, usage and makes it easier to create context relevant applications.* — Introducing technologies that are necessary to address a community problem is most often accepted when participatory approaches are used. Also, participatory approaches usually ensure that the applications developed are locally relevant because it enhances sensitivity of the projects to the social environment [9, 42, 94].

4. *Bottom-up approaches are far more likely to succeed than top-down approaches* — Bottom-up approaches are far more successful than top down approaches as they are grounded in the realities of the community situation. This is especially the case in South Africa, where past

failures in telecentres have proved that a top-down approach to development does not work [91]. Additionally, Bridges.org reviewed a number of development initiatives from around the globe and found most failed projects used a top down approach which is not grounded in the needs, interests and participation of the local residents. [19].

5. *The local and macro economic and legislative environment should support ICT development initiative [8]* — According to Bridges.org [19], there also needs to be political will in the government to do what is needed to integrate the technology into society.

6. *Successful projects often make use of a local champion* — This champion is an individual in the local community that coordinates other community members and spearheads part of the project [19].

7. *Evaluation and monitoring should be built into each project as a means of assessing impact [9]* — If no measures are put in place to evaluate the impact of a project, it is hard to determine whether the project has been a success or not. This makes it difficult to alter the initiative to better suit the local conditions and to learn from project successes or failures.

8. *Keep it simple - often the simpler technological solutions are the most effective* — An anecdotal case is mentioned by the Global Knowledge Partnership [80], which illustrates this point. Here, a sophisticated and complicated telemedicine system introduced into a hospital had limited success whereas a basic communication system was used to its full potential. It is important therefore to provide systems that enable local facilities to communicate in a simple and efficient manner [9].

In this dissertation, we attempted to create a socially aware methodology that would have these factors intrinsically built into it. This is discussed in Chapter 3. The following section outlines how the factors above can be dealt to increase the likelihood of success in an ICT development initiative in South Africa.

2.5 The Way Forward

There is a definite opportunity for South African computer scientists to contribute to the alleviation of the digital divide within our own country. To meet the challenges discussed earlier of using ICTs in locally relevant ways and in ways which integrate the factors discussed in Section 2.4, we discuss three strategies. The first is to utilise a more socially aware software development process that will enable us to develop applications for underserviced areas in South Africa. The second is to uncover technologies which are best suited to rural areas, given their unique conditions. The third is to muster the support of the legislation at the government level in order to sustain these development projects. The following sections discuss each of these issues in greater detail.

2.5.1 User Centred Methodologies

It is evident that when developing software for rural areas in South Africa, local content is the key to the success of the application. To develop relevant applications we need to consider social aspects of computing and to understand the needs of the target communities. Yet, traditional computer science methods do not, by nature, produce research results. For instance, usually in software development, one is given a specification which one develops and tests before delivering the result to a client. There is no need in this approach to produce results about the process or the application developed; the process is merely a means to an end. In rural areas, the process needs to accommodate user needs and local conditions. Firstly, in the rural case, one would not necessarily have a specification to begin with and secondly, rural community members might not be able to express their needs in technical terms. Thus, conventional software development methods alone will not address the kinds of issues arising in rural areas. In order to address these issues, user involvement in the software development life cycle needs to be increased and a process to discover user needs requirements must be incorporated in the methodology.

At present, according to Carroll *et al.* [25], most software development methodologies only call for user involvement after the initial concept and possibly when a prototype implementation already exists. This is illustrated in one of the software development life cycles commonly used in software engineering, the waterfall model as shown in Figure 4.

This has five stages consisting of requirements definition, system and software design, implementation and unit testing, integration and system testing and operation and maintenance [87]. This iterative process only involves the client or user during the first stage and thereafter there is little user involvement before product delivery. This kind of process is typical of the extent of user involvement throughout a standard product oriented software development life cycle.

Another process with a larger degree of user involvement is evolutionary prototyping [87]. Here, the stages of specification, development and validation are interleaved. A prototype is developed first and this is then exposed to the client or user for comment. The prototype is then refined until it meets the clients requirements. Again, user involvement is minimal and the developer has most of the control in determining the type of software system developed.

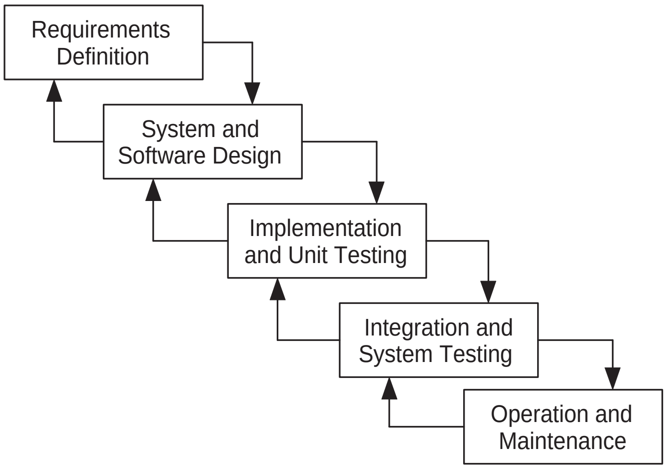


Figure 4: The Waterfall Model - This process has five stages with iteration between the stages. They consist of defining the user requirements in stage one, designing the entire system and software in stage two and implementing the system in stage three with the appropriate technologies and platforms. Stage four entails testing each module comprising the system as well as the entire system itself. The final stage is when the software is installed at the client or user premises and requires operation and maintenance of the product.

These examples illustrate the fact that in computer science, there is no social aspect to computing in many software development approaches in practice today. If we were to use a standard software engineering approach in rural areas, this is analogous to a top down approach which we saw in Sections 2.3 and 2.4 does not often succeed. Therefore, we need to augment our software engineering process in order to meet the challenges of developing useful applications for remote and rural areas. To do this we require participatory methodologies centred on user needs and we also need to learn from past projects in order to use best practices in our own research. This is discussed further in Chapter 3.

2.5.2 Technologies Relevant to Rural Areas

For rural areas, we should also consider technologies which are suited to their unique conditions as described in Section 2.2.1. Two relevant technologies are Voice over Internet Protocol (VoIP) and Wireless Fidelity (WiFi). In addition, the concept of store and forward is pertinent to rural situations in South Africa.

Voice over Internet Protocol

VoIP refers to a range of protocols designed to send voice over packet switched networks, traditionally the domain of internet traffic. Voice is sampled, digitized and broken down into packets before being sent to its destination [2, 46, 52, 86, 96, 99]. This is achieved by a signalling protocol for call setup and teardown as well as a transport protocol for transmitting the voice packets. The two most common signalling protocols are the International Telecommunication Union's (ITU) H.323 standard and the Internet Engineers Task Force's (IETF) Session Initiation Protocol (SIP). The transport protocol used in both implementations is Real-Time Transport Protocol (RTP) which has been optimised for the transmission of realtime data. RTP operates on User Datagram Protocol (UDP), a connectionless protocol used on the internet.

VoIP offers several advantages over the Public Switched Telephone Network (PSTN). It makes more efficient use of bandwidth by only transmitting when there is useful data to be sent. For an example, it does not transmit data during the pauses occurring in natural speech. VoIP also obviates the need for a separate data and voice network. In other words, users can use the same line for browsing the internet and phone calls. Moreover, the coding and decoding algorithms or codecs used to digitise the voice, generally work at lower rates than the PSTN. For instance, one codec produces voice at a rate of 11.8kbps as opposed to the unvarying 64kbps rate produced by a call on the PSTN.

In addition, in the PSTN, each call requires a dedicated end to end virtual channel for the duration of the call. Using VoIP, packets in a call can take different paths to their destination, which can bypass link failures and save bandwidth. Since the intelligence in the network is provided by smart terminals, adding more features to a VoIP network is easier than adding features to the PSTN network. Overall, this means that a VoIP network is generally cheaper to set up than traditional telephone networks. Additionally, VoIP allows for presence information to be displayed to users indicating the availability of a callee to take a call. This shows where a contact is *online* and able to receive calls or *offline* and unable to take calls. It can be used to enable efficient call centres, click to dial on web pages and multimedia sessions with audio and video.

However, VoIP does suffer from several disadvantages. Unlike the PSTN, where the quality of service is very high, voice quality using VoIP varies with the codecs used. Factors such as latency, packet loss and jitter may also degrade the overall voice quality. The differences between VoIP and the PSTN have been summarised in Table 1.

Proenza [83] states that VoIP opens up opportunities for networking and access to information in such a way that these services can now be made available to low income groups. He feels that VoIP is a useful technology but faces obstacles such as legislation and latency. Additionally, he suggests that VoIP can be used in conjunction with traditional technologies to broadcast information to

Feature	**PSTN**	**VoIP**
Bit Rate	64 Kbps	Varies with codec used
Bandwidth	Dedicated channel required	Dynamically allocated
Silence Compression	No	Yes
Additional Features	Costly to add	Easily added
Quality of Service	99.9 %	Varies
Network Type	Circuit Switched	Packet Switched
Disadvantages	Need separate data and phone network Uses more bandwidth	Jitter Delay, packet loss Cannot assure quality

Table 1: Table showing the major differences between the PSTN and VoIP networks. Here a 'codec' is an encoding and decoding algorithm for digitising voice.

wide areas. For these reasons, it is clear that VoIP may be a useful technology to use in rural contexts in South Africa.

Wireless Fidelity

WiFi stands for wireless fidelity, which is the popular name for the IEEE 802.11b standard [57,89,90,98]. It is the protocol behind "hot-spots", areas where wireless internet access is provided to the public. Essentially, the protocol defines how devices can connect to each other (*ad hoc* mode) or to a central access point in order to access another network (infrastructure mode); both wirelessly. 802.11b has a maximum channel bit rate of 11 Mbps (shared) and operates in the Industrial, Scientific and Medical (ISM) band at 2.4 GHz. This band is considered licence-exempt by the ITU and many American and European countries follow this recommendation. The WiFi protocol describes 2 layers of communication, a physical layer and a Media Access Control (MAC) layer. The physical layer defines how the data is encoded and transmitted and the MAC layer specifies how devices can use the transmission medium in an orderly and efficient manner. In the 802.11 standard, there are 3 ways to transmit data: frequency hopping spectrum; digital sequence spectrum and infrared.

WiFi is a short range protocol providing coverage of up to 100 metres [61]. Multiple hops or repeaters can be used to spread this coverage over a wider area (up to 20 kilometres) but the further one is from the main access point in terms of hops, the more one experiences reduction in signal strength and data rates [11, 36]. Another restriction on WiFi is that to connect sites that are far apart is that a clear line of site must exist from one site to the other. If no such line of sight exists, repeaters may have to be used to connect areas up by configuring the network so that each site can 'see' either a repeater or the final site.

More recent wireless standards include 802.11g, 802.11a and 806.11. The first two standards improve on security flaws in the WiFi standard and have a higher data rate of 54 Mbps. The third standard refers to WiMax, which defines a wider range point to point wireless protocol. WiFi can be used to provide hot-spots in rural areas. Combined with VoIP for voice services, one could quickly provide basic telephony services and other applications over a large area, especially in areas where laying down cables may be expensive and subject to cable theft. Thus, WiFi is definitely pertinent to South African rural areas.

Store and Forward Approaches

Another apt concept for South African rural areas is that of store and forward applications. The concept for these applications is borrowed from networks where store and forward technology is the basis of many ubiquitous applications such as email. According to Petersen and Davie [82], packet-switched networks are usually called store and forward networks . They describe the concept as when each node in the network first receives a complete packet over a link, then stores this packet in its memory before forwarding the packet to the next node in the network. Store and forward applications are an extension of this concept. They are applications capable of creating and storing data at a site and then transmitting or forwarding that data when appropriate. Data may be stored at many nodes along the way and then forwarded to the destination. Store and forward applications allow for asynchronous modes of communication and this is pertinent for situations where connectivity is sporadic.

The store and forward concept is illustrated by another project by Satellife, an organisation mentioned earlier in Section 2.3. In this project, health facilities communicate by sending each other images and textual descriptions of patient problems via email [20]. This asynchronous communication allows for advice in diagnosing patient problems and provides specialist support for health workers that are in remote areas. The store and forward paradigm may therefore be useful in rural areas where conditions could mean than connectivity is occasional.

These are some of the technologies which are relevant to the South African rural situation. The following section illustrates how the regulatory and legislative environment can either hamper or encourage the use of these kinds of technologies for ICT development.

2.5.3 Supportive Regulatory and Legislative Environment

This section describes telecommunications policies in South Africa on VoIP and WiFi. We then present trends in global telecommunication policies regarding these technologies before drawing conclusions regarding how policies affect underserviced areas. We need to ensure that we support rural access to technologies by policy [8]. In particular, the regulatory and telecommunications framework should stimulate and encourage developments in these areas as suggested by Best and Maclay [12].

This is emphasised by Hanrahan [51] who states that effective telecommunication regulation is important to meet South Africa's economic and social goals. He stresses that policy legislation and regulation should be technology-neutral. Legal concentration should focus on protecting user interests and should describe the services the networks should provide as opposed to how they implement them. This makes for robust policy since the technologies to provide a particular service can change during the lifetime of a policy.

Until recently, legislation in South Africa restricted the use of both VoIP and WiFi. According to the Telecommunications Act of 1996, *as amended* [76], and the Telecommunications Amendment Bill of 2001 [77], VoIP could only be provided by Telkom (the incumbent telecommunications operator in South Africa), the Second National Operator (SNO) (which is not yet licensed or operational [100]) and the Under Serviced Area Licensees (USALs) [75]. USALs are licences designed for small, medium and micro enterprises (SMMEs) and are geared to achieve connectivity in areas where less than 5 percent of the population have access to a telephone. The initial call for USAL applications was released in December 2002. Yet, at the end of 2004, only 4 out of 27 USALs had been granted; none of which were operational at the time of writing this dissertation [74]. This is due to the high entry costs associated with setting up an infrastructure in the areas covered by the USAL and the fact that these USALs were only recently granted in late 2004, leaving little time to set up operations before this dissertation was written.

In September 2004, the Minister of Communications announced that from 1 February 2005, use of VoIP by specified bodies other than Telkom, the SNO and the USALs would be permitted [79]. In terms of these ministerial determinations, Value Added Networks (VANS), the term used to include Internet Service Providers (ISPs), were given the power to carry voice using any protocol and VoIP was deemed legal for use by the general public. ISPs are organisations which provide internet access and related services to corporations and individuals. For this service, ISPs charge a monthly or annual fee and provide the user with software and access codes to access the internet.

In the initial announcement, VANS were also told that they would be allowed to use telecommunications facilities other than those provided by Telkom. The ministerial determinations conflict with the Telecommunications Act of 1996, *as amended*, which states that only licensed telecommunications operators are allowed to provide telecommunications infrastructure. Thus, according to

Gillwald and Esselaar [44], in order for these determinations to come into effect legally, a new licensing regime for VANS needs to be provided, which will also cover the use of voice over any protocol. The Independent Communications Authority of South Africa (ICASA), the South African telecommunications regulatory body, must also define interconnection and numbering rules for VoIP use before the determinations declared in September 2004 come into effect legally.

Already, several concerns have been raised over the new proposed VANS licence by the Internet Service Providers Association (ISPA). Specifically, the proposed new VANS licence does not outline the definition of a VANS clearly and the license fee has increased significantly without justification [102].

Thus, even though liberalisation for VoIP is in the pipeline, it may be several months before it is implemented in practice. In rural areas, the ramifications of VoIP being legalised may not be immediately felt either. USALs were always allowed to use VoIP but now other organisations may experience cost savings by making use of this technology. For these smaller players, however, VoIP will have no benefits in isolated and remote areas *unless* it can be used in conjunction with wireless technologies. These technologies can more easily connect up areas in the harsh conditions associated with rural areas in South Africa than wired alternatives.

Yet, using WiFi with VoIP is not an option since its usage is still constrained by South African law. WiFi can be used for hot-spots within the confines of the same premises or buildings but once it crosses beyond the border of the premises it becomes a local access telecommunication service. This means connecting wireless local area networks (LANs) between premises is illegal unless the provider has a telecommunications service licence [78]. Similarly, in rural areas, communities can not be linked up or linked to public networks legally and this effectively rules out WiFi as a last mile solution for these areas except for provision by telecommunications operators until the legislation becomes more permissive.

In terms of WiFi regulation, ICASA has largely focused on opportunities for the private sector, by allowing WiFi to be legal for wireless LANs within the confines of one's own premises. This benefits businesses because it allows them to have wireless infrastructures within a premises. However, even in this case the legislation is still very restrictive. For instance, hot-spots require a VANS licence and the VANS licensee is bound to using Telkom's facilities for the wireless link between the hot-spot and the user. For rural areas, this means one could set up local hot-spots for WiFi within buildings but that connecting up hot-spots would be illegal. This hampers the infrastructure that one could use to provide services to remoter regions.

Unless these existing restrictions on the provision of VoIP and wireless technologies are removed, achieving the goals of universal access will be more difficult. In essence, the regulatory environment should support the use of suitable technologies in underserviced areas instead of obstructing them in this manner.

Global Telecommunications Policies

We now examine where South Africa fits into the global context in terms of telecommunications legislation on VoIP and WiFi. In addition, we provide several examples of how VoIP and WiFi can be applied to rural settings. VoIP is legal in most developed countries such as the United States of America, Canada, the United Kingdom and in much of Europe. However, according to Cohen and Southwood [33], most countries in Africa still restrict competition in both fixed line and mobile markets and VoIP usage is usually limited. In fact, Mauritius and Nigeria are two of the only countries in Africa to have legalised the use of VoIP and WiFi.

For these countries, Cohen and Southwood argue, the long term benefits these technologies will bring, offsets the short term losses in revenue by the incumbent telecommunications operators. However, other countries in Africa are slowly waking up to the usefulness of VoIP and its potential for lowering costs for network providers and consumers. Algeria has experimented by allowing ISPs to utilise VoIP for PC to phone traffic and Kenya is investigating using VoIP services in cybercafes. Thus South Africa is not unique in realising the potential of liberalising VoIP.

In terms of WiFi legislation globally, the ISM bands including 2.4 GHz and 5 GHz are licence exempt in the United States of America and much of Europe [72]. In fact, 96 percent of developed countries have licence-exempt wireless while only 41 percent of all developing countries worldwide allow unlicensed use of internet devices and/or spectrum [54]. However, in Africa, wireless spectrums are largely restricted. For use of these bands, Neto *et al.* [72] have drawn up several categories into which each African country falls. In parts of Africa such as Rwanda, Lesotho and Tunisia, the bands are considered unlicensed with no registration. Other countries like Kenya and Ethopia consider the bands unlicensed but require registration for use.

In some cases, the unlicensed bands are still restricted in terms of the amount of power the wireless points are allowed to operate and signal range is limited. In other parts of Africa, like South Africa and Botswana, a licence is required for these bands, conditional upon payment of licence fees and fulfilling criteria specific to that countries regulations. In the last category of licensing of wireless technologies in Africa, use of the ISM bands is simply barred as in Zimbabwe. Even though licensing regimes differ across the continent, it was found that 37 percent of all African countries are using wireless technologies for providing backhaul connectivity in rural areas [72]. Backhaul connectivity refers to connecting links up to the main network backbone.

Thus VoIP and WiFi in general are more restricted in Africa than in Europe and America. In most cases, this is because Africa has more countries with state owned incumbent telecommunications operators and there is reluctance to cut into the revenue streams of these monopolies [33].

Examples of Using VoIP and WiFi to achieve Rural Connectivity

However, there are many examples around the globe illustrating how wireless technologies combined with VoIP can help to provide connectivity in rural and remote regions. For instance, Best [11] describes a village area network which provides services and capabilities that enhance the economic development of rural communities. One particular village area network was implemented in the rural community of Behechio in the Dominican Republic in March 2001. This area is home to some 7000 people and comprises one of the least developed communities in the country. The village area network covers an area of one square kilometer and took a mere 3 days to install. It makes use of radio antennaes and routers operating on the 802.11b standard at 11Mbps.

The village area network extends the facilities of the Multipurpose Community Centre (MPCC) to the rest of the village and via mobile and fixed wireless devices and services. In addition, the MPCC has a satellite or Very Small Aperture Terminal (VSAT) internet connection. It also runs a VoIP telephone service accessed by IP phones in village. VoIP services have also been tested on hand held devices. This illustrates how innovative solutions can be developed for rural communities using a variety of technologies including VoIP.

Another example of using wireless technologies to connect up rural areas is discussed by [13]. They describe the Digital Gangetic Plains (DGP) project in India which has investigated the use of 802.11 as a long distance access technology. Their aim was to find a solution that provides both rapid and low cost deployment of voice and data communications services in rural areas. Using 802.11 links, the DGP has built a multi-hop testbed spanning up to 80 kilometers on the longest link. They conclude that using wireless links to provide voice and data services in rural areas is cost effective and speedily deployed.

Zhang and Wolff [107] also argue that WiFi is a cost effective way for providing broadband access to sparsely populated rural areas. In the United States, they modelled a network from realistic demographics based on information from an American rural area called Gallatin County and concluded that providing wireless internet access to rural areas can be cost effective. The model is more limited when applied to rural areas in developing countries where subscribers often cannot afford to pay individual subscription costs. However, if the subscription costs are shared by a group or paid by an organisation and access is provided for community centres, schools and businesses, this model does indicate that WiFi is a viable last mile solution for rural areas in developing countries. Combined with VoIP, it can be a cost effective solution for providing value added services as well as telephony.

From these examples and global telecommunications trends, it is clear that while much of the developed world is already reaping the benefits of both VoIP and WiFi, South Africa is falling behind. The desire to protect telecommunications monopolies by delaying liberalisation, typical of African countries, only widens the digital divide between the developed and the developing world. By following the example of the developed world, it seems that South Africa should follow suite in not only liberalising VoIP but also wireless technologies. Moreover, as the case studies above illustrate, the combination of VoIP and wireless technologies can help provide connectivity to rural areas efficiently and at low cost.

2.6 Concluding Remarks

In conclusion, the digital divide is a vast and ever-growing phenomenon and both globally as well as in South Africa efforts are underway to overcome internal divisions. In order to do this effectively, we require a method for developing software applications that meet the needs of target communities. Additionally, we require support in terms of the legislative and regulatory environment. In particular, use of relevant technologies for underserviced areas should be encouraged by the government. These technologies include VoIP, WiFi and store and forward applications. The following chapter describes participatory user-centred approaches that we have used to augment the traditional waterfall model of software development. We also discuss how we used best practices in the process we developed and provide a step by step breakdown of the resulting socially aware computing framework we used in this project.

Chapter 3

A Framework for Socially Aware Computing

In Chapter 2 we provided background information for why we need locally relevant applications in rural and underserviced areas. This chapter details the methodology which we used during the course of this project. It is essentially a modified, socially engaged software development life cycle with a large research component aimed at producing applications relevant to rural communities in developing countries. Firstly, we discuss the background principles on which the project methodology is based. This includes a description of Action Research (AR) and Participatory Design (PD) and of related work undertaken using these methodologies.

This is followed by an explanation of why these methodologies are suited to the problem of using Information and Communication Technologies (ICTs) in rural areas to address development issues. We also discuss the Real Access/Real Impact (RA/RI) framework in Section 3.2; a set of best practice guidelines developed from studying past ICT projects around the globe. This framework helps ensure that we consider all aspects affecting the success of our project and we discuss why this is an important facet for our methodology. Finally, we detail the synthesis of these approaches as used in the project — including a step by step breakdown of the methodology.

3.1 Socially Aware Methodologies

In order to develop novel applications for rural areas in developing countries, a user-centred approach is required. The reason for this is that methodologies previously used in providing ICTs to underserviced areas have mostly not succeeded. Also, the traditional computer scientist notions of software development are focused solely on the development and delivery of a software application. There is no research component to standard software development techniques. This has been discussed in Chapter 2. If we are to research appropriate software solutions for rural areas, we need to add a research component to the software development life cycle. This component will also allow us to take into account the social context of software when developing apposite software solutions for underserviced areas. We therefore require a more applied and socially aware approach if we are to overcome the failures which plagued ICT development initiatives in the past. By 'socially aware', we mean an approach that does not merely take into account the technologies necessary to produce software solutions for rural areas.

A socially aware approach should be cognizant of the broader picture into which the software and suitable technologies fit into, for example, whether the solution is cost effective or sustainable. In addition, it should consider what people need and utilise the expertise of users in their work environment so that appropriate solutions can be developed in collaboration with these users. Furthermore, it should consider how the software fits into people's daily routines and ensure that the local environment supports use of the technological solutions created. Ideally, it should not just be a process to develop apposite software solutions for underserviced regions. It should also empower all the participants involved in the project in some way. In other words, we want a process which not only produces a software solution, as in software engineering, but also produces research results.

Two user-centred methodologies that could form the backbone of a socially engaged software development life cycle are Action Research and Participatory Design. These methodologies were selected for their relevance to the problem at hand and from reviewing related work as described in Section 3.1.4 where both methodologies were found to be useful in increasing the chances of producing relevant solutions for a target community. These methodologies are described below along with a summary of their respective advantages and disadvantages. A short section follows on related projects which utilised these methodologies.

In Section 3.2, we discuss the RA/RI framework which we included in our user-centred approach to enable us to follow best practices from previous ICT development projects. This was required so that our methodology encompassed the issues raised in Section 2.4. These issues included the fact that most successful ICT initiatives in underserviced areas make use of a local champion, provide relevant content in their initiatives and keep their solutions simple.

3.1.1 Action Research

Kurt Lewin [62] wrote *"research that produces nothing but books will not suffice"* . This epitomizes the methodology that Lewin developed in 1946 which he called AR and which is appropriate for our socially aware computing framework as will be explained later in this chapter. According to Lewin, AR is research leading to social action. It is a methodology to link technology, the work process and the worker [34]. For Lewin, merely providing people with technology is not sufficient unless it can benefit them in their daily lives.

AR provides a structured way to involve people in the process of providing them with a new solution to an immediate problem in their environment and by doing so, produce a solution that is highly relevant [6,7,60] . This involvement improves the lives of the participants in the project and enhances their awareness of their own strengths and weaknesses [5]. It is an iterative and cyclical process which may include phases such as problem diagnosis, action intervention and reflexive learning as shown in Figure 5. [4]. The research aspect of the method is captured by the reflection where one looks back over the process, draws conclusions and learns how best to alter the process for future cycles.

Figure 5: The basic Action Research process is cyclical and iterative with stages of identifying a problem, taking appropriate action and then reflecting on the outcomes and learning from one cycle to inform the following cycle.

The domain of AR is usually the workplace [7,34] or a community where a social practice needs to be reformed [5, 6, 50, 58, 92]. The cornerstones of AR are that it is performed collaboratively and that participants or stakeholders are seen as experts in local culture, beliefs and practices [4–6, 24, 50, 58, 62, 92].

Critical Action Research (CAR) is a form of AR. Carr and Kemmis [24] explain that CAR has a strong emphasis on the empowerment of groups or communities. It involves an outside researcher concentrating on a community's problems and helping to facilitate a change in the community through facilitating action. This action is done in collaboration with the community members. CAR is also seen as emancipating communities or groups from old practices and ways of behaving.

There are many criticisms of AR, one being that the direct involvement in the research by the researcher means the researcher is unable to remain impartial [7]. This view is supported by Cunha and Figueiredo [37] who go on to mention that since AR works on a unique local situation, the interventions used cannot be repeated to confirm the results or to try out different alternatives. Another drawback of AR, suggested by Kock *et al.* [60], is that it may be difficult to procure access to a site where the researcher can act as an agent of change if the researcher does not already have close ties with at least one organisation. In addition, AR projects are more lengthy and time-consuming than other approaches.

AR is therefore often dismissed as research that is not generalisable and not repeatable [6, 7, 34, 37, 58, 92]. However, the drawbacks of AR can be minimised in the following ways. For instance, Baskerville and WoodHarper [7] as well as Winter [106] suggest the use of multiple methods of data collection to ensure data verification. They also suggest using an external unbiased observer or *monitor* to evaluate AR research for validity. To increase validity, Avison *et al.* [4] advise that the approach used in an AR project needs to be explicitly defined in terms of a research aim, theory and method. They also propose that the entire process be thoroughly documented and recommend that the evaluation phases be well planned.

The criticism of AR not being repeatable is a moot point. It is clear that AR interventions must be situation specific if they are to solve locally relevant problems and therefore, by definition, cannot be repeatable. However, although AR produces results that may not be repeatable, they are of value to the communities that they serve. The fact that AR is not generalisable is also debatable. It seems fair to assume that AR results about particular work and community environments may be extrapolated to other similar environments. If the above measures are taken to minimize the drawbacks of AR, its basic cyclical stages can be used as a framework for working to introduce ICTs to a rural community and to document the research results.

3.1.2 Participatory Design

Another methodology or set of techniques that is appropriate for the research we undertook is PD which is similar to AR. According to Clement and Van Den Besselaar [31], PD was born out of Scandinavian approaches to empowering workers in industrial settings by allowing them to influence what technology was introduced into the work environment. It has evolved into a more general approach to encompass all users of technology in the workplace and it emphasizes that they should be respected regardless of their status in the workplace or their level of technical expertise.

Like in AR, every participant is viewed as an expert in what they do and workers are seen as a source for innovation. PD is similar to AR in that it has two main goals: to involve the people affected by a software or information system within a project development team and to improve the lives of these participants [17, 69]. PD, unlike AR, specifies a range of methods and techniques to facilitate participation in the design and implementation of software and information systems but does not specify an overall process that one should follow to achieve ones goals.

A PD approach emphasizes that the most productive ideas arise when there is collaboration from people with diverse backgrounds [25, 69, 70]. This is because participation of users in the software development life cycle improves the final product by helping to design context appropriate goals and to plan suitable prototypes [14, 25, 32, 48, 88]. PD also stresses the need to understand organizations in their own territory and suggests that to do this it is important to spend time in workplace under study. As in AR, it also aims to address problems that exist and arise from the situation rather from outside [47].

Additionally, PD can lead to a sense of shared ownership of the technology by the users and software developers which may help with the eventual acceptance of and buy-in to the technology [47,69,88,104]. Many PD projects in the past have used an AR methodology according to Clement and Van Den Besselaar [31]. This means they used the cyclical stages of AR, alternating between practical work in the field to effect changes in the workplace, collecting data on those changes and reflecting on those changes to decide how to proceed. AR in this case was felt to increase participation in design by overcoming two barriers to effective participation. These barriers were the lack of access to relevant information and a lack of appreciation about the expertise of workers about the own environments.

Using AR, one is not *only* concerned with producing results of interest to those beyond the immediate project site like conventional research. In fact, with AR one focuses on improving the lives of all the participants in a project whether these be practical or political changes. AR and PD seem to complement each other in that AR defines a cyclical step by step process which one

PD Technique Name	Description
Future Workshops	Sessions with users and designers to identify problems of work and alternatives from the perspective of the user
Studies of Work or Ethnography	Studies of the workplace that may reveal work practices that require support
Low Fidelity Mock-ups	Cardboard and paper prototypes designed with users to show how work might be done in the future
Prototyping	Iterative design of prototype systems that give users a chance to experience what a new system may be like and to modify that system while its in a prototype phase. These prototypes can be low technology prototypes, storyboarding or software prototypes
Scenario Construction	Constructing scenarios of what work might be like using alternative to existing practices

Table 2: This table shows several examples of techniques that have been associated with Participatory Design (PD).

can follow and PD defines a set of techniques and methods to increase user participation in the design of software and information systems. Both methodologies therefore provide excellent guiding principles for ICT development in underserviced areas.

However, there are several problems associated with PD [31]. For instance, often funding for PD projects comes with the researchers. This means that they control the availability of resources, particularly equipment. Thus equipment is generally only available for the duration of a project, following which it is removed from the project site. Another problem with PD is that participation in the process by users does not foster self sustaining practices by itself. To ensure sustainability, further measures beyond this process need to be taken. Again, if procedures are put in place to reduce the disadvantages of PD, it also provides several solid principles which can be used to introduce ICTs to rural communities. The following section highlights the differences and similarities between AR and PD.

3.1.3 Comparing Action Research and Participatory Design

AR and PD are comparable, being similar in certain fundamental concepts such as empowering project participants and being different pragmatically. AR specifies a loose process for how to produce relevant solutions for a community, either in the workplace or elsewhere.

Contemporary PD, on the other hand, focuses more on how to involve the user or workers in the software design process. It is usually used for developing solutions for work situations and does not specify a particular process for design. Instead, it sets out tools and techniques such as participatory workshops and paper prototyping to increase user participation in design. Several PD techniques are shown in Table 2; the list being compiled from the work by Crabtree [35] and Muller *et al.* [70]. Both methodologies are geared towards developing locally relevant solutions for the communities that they involve. Additionally, both are concerned not only with solving a particular problem for a community but also with improving the lives of all participants in some manner. Thus, we use AR for the process framework and PD for methods to increase user participation in the socially aware software design and implementation process. The following section describes several projects which have used AR and PD methodologies and their experiences with these methods.

3.1.4 Related Work

Several projects exist which have used either an AR or PD approach. One project with goals similar to our own project, involving handheld devices and CAR, was undertaken by Blake [15] and Blake *et al.* [16]. Here, a field computer system was developed to gather complex data on animal behaviour that is observed by expert animal trackers. The system was designed to empower semi-literate trackers using a CAR approach. The trackers were consulted on every stage of the development of the system and their input was incorporated into subsequent designs. Empowerment was seen as affording the trackers greater recognition and rewards for their expert knowledge on animal behaviour through use of the field computer system to disseminate their information. The resultant application has become a successful product called CyberTracker that is used in four African National Parks.

Another related project was undertaken using Participatory Action Research (PAR) in Borneo, Malaysia and is described in [66]. PAR is merely AR with a strong emphasis on participation throughout the research process. Here, PAR was used to stimulate rural development in a remote and isolated community in the arenas of health, education, commerce and agriculture. To do this, community access to information and learning resources was provided in the form of a telecentre, equipped with 4 Personal Computers (PCs), 2 printers and a Very Small Aperture Terminal (VSAT) or satellite internet connection. This project found that PAR is a suitable methodology for developing useful information systems that are based on the needs of a community and also to demonstrate the value of ICTs in general to communities in developing countries.

Most related work using PD has been conducted in Western contexts but a few projects have been conducted in developing countries. One example using PD was undertaken in Kwa-Zulu

Natal province of South Africa and used this approach to improve child health related information collection in a rural remote area [84]. A participatory approach was found to be key to dealing with community settings. Another project implemented a computerised health information system in Cuba using PD and AR [18].

All these projects have advocated using participatory approaches in developing countries. This is because these approaches lead to increased community buy-in for the project and can help develop locally relevant solutions to community problems. In addition, these approaches utilise the expertise of both the researcher and community participants to develop effective solutions for community problems.

Furthermore, these approaches are more centred in the needs of the community as they are bottom up processes. Top down approaches on the other hand tend to implement solutions that may not address community problems as they are distanced from the community and their requirements. Again, this suggests that AR and PD are good guiding methodologies for developing a socially aware computing process for software development in rural areas. Next, we discuss how we can learn from past ICT development projects around the globe and use best practice guidelines in our own research.

3.2 The Real Access/Real Impact Framework

It is not sufficient to utilize a user-centred participatory approach if we want to ensure project success in terms of developing software with apposite content for rural and underserved communities. In Section 2.4, we found that there are many factors that affect the success of at ICT development project which may not be addressed by participatory methodologies or the traditional software development life cycle alone. These include factors such as finding a local champion for a project, ensuring that the local and macro environments support the technologies used and providing training for project participants. If we are to learn from past project failures, we need to integrate best practices extracted from previous ICT development projects into our socially aware software development approach.

To do this, we utilise the RA/RI framework developed by Bridges.org [23]. Bridges.org[1] is a non-government organisation (NGO) that evaluates ICT development projects and lobbies governments to form telecommunications policies that support development in underserviced areas. They developed the RA/RI framework to be a holistic integrated strategy that forms a basis for analysis,

[1] www.bridges.org

Real Access Criteria	8 Habits of Highly Effective ICT Initiatives
Physical access to technology	Do a needs assessment
Appropriateness of technology	Implement and disseminate best practice
Affordability	Ensure ownership, get local buy-in, find a champion
Human capacity and training	Set concrete goals and take small achievable steps
Locally relevant content	Critically evaluate efforts, report back, adapt as needed
Integration into daily routines	Address key external challenges
Socio-cultural factors	Make it sustainable
Trust in technology	Involve traditionally excluded groups
Local economic environment	
Macro economic environment	
Legal and regulatory framework	
Political will and public support	

Table 3: This table shows the main principles forming the Real Access part of the Real Access/Real Impact framework. See Appendix A.2 for more detail.

measurement and implementation of development initiatives from the ground up to policy level. The RA/RI framework sets out 12 real access criteria designed to measure the impact of a project's success in providing access to technology. Additionally, RA/RI sets out 8 guidelines or habits for project management based on Bridges.org experience with ICT development projects around the globe. The category names of the 12 real access criteria and 8 habits of highly effective ICT projects forming RA/RI are shown in Table 3. Expanded versions of these categories with defining questions can be viewed in Appendix A.2, in A.2.1 for real access and A.2.2 for the 8 habits.

Essentially, the RA/RI framework allows one to broaden the focus of an ICT development project so that the technologies used are not the central focal point. It forces one to consider all the issues, including the technical ones, affecting the uptake of a new technology or software artifact in an underserviced setting. Since the framework was borne out of evaluations of previous ICT initiatives around the globe, it provides one with all-encompassing questions to ask oneself when undertaking a new ICT development project. These factors may otherwise be overlooked utilizing solely user-centred participatory methodologies or the traditional waterfall model of software development where the focus is either on reforming social practices or developing a software artifact alone.

An example of a factor that RA/RI encourages one to contemplate is how much a community trusts a particular technology. For instance, if people are used to cellular phones, they grow to trust cellular technology. If they wish to place a call, they trust that the underlying technology is reliable and will allow them to do so. If one is introducing a new technology, it is important to ask whether people will feel the same level of trust in the new technology. Moreover, measures should be taken to foster trust so that users will eventually accept the technology and perceive it as reliable and secure.

Another factor which may not be obvious without looking at the RA/RI guidelines but which is important for the sustainability of a project, is the issue of affordability. This refers to the fact that new technologies and equipment should be affordable in that they should be easily maintained or if equipment fails, it should be possible to replace it at relatively low cost. Also, affordability refers to the fact that new technological services should be charged at rates that surrounding communities can afford given their disposable incomes.

The RA/RI therefore provides useful best practice guidelines which can be integrated into a user-centred participatory approach combined with a traditional software development life cycle in order to develop relevant software applications for rural and underserviced areas. The following section discusses how we synthesised principles from AR, PD and RA/RI to provide us with a socially aware methodology for our research.

3.3 A Socially Engaged Software Development Life Cycle

As seen in Section 2.5.1, the traditional waterfall model or software development life cycle (SDLC) is mainly concerned with implementing a software specification. There is no research component inherent in this cycle. Yet, if we are to produce relevant software applications in a bottom up fashion for rural areas, we need to do research in order to identify the correct functionality required of a software system. In addition, a research component in this process allows us to broaden the focus of a traditional software development life cycle so that issues external to the software that affect its use are addressed.

For example, we need to ensure that the software is integrated in the daily routines of the users. Moreover, adding a research constituent to conventional software development allows us to consolidate and disseminate the lessons learnt from using this process in rural and remote regions. We added a research component to the SDLC by synthesising the straightforward waterfall model of software development with principles from PD, AR and RA/RI.

These methodologies helped shape the software development process into a socially aware approach for several reasons. They aim to maximise empowerment of community participants in a project as well as providing solutions for a community problem. Additionally, they result in mutual learning and development for all the participants [25]. Furthermore, the research question is co-defined by the researchers and the participants and users are seen as experts in work practices [17, 88] which can aid in achieving community buy-in and context appropriate interventions. Moreover, from Section 3.1.4, it is evident that these methodologies may be used with success in rural environments in developing countries.

From PD, we borrowed techniques for evolving user interfaces and prototypes to user needs. These included discussion groups, paper and software prototyping which will help us to increase community participation in our software development approach. From AR, we borrowed the process for interacting with a community in order to solve a particular problem. This defined a cyclical approach for working with a community to empower them in some manner using technology if necessary. We matched each AR phase to the appropriate stage of the waterfall model of software development.

Note here that we chose to utilise the standard waterfall model of software development and not other software development methodologies because the waterfall model stages can be easily integrated with the cyclical stages of AR. This is illustrated in Figure 6. At each stage, we used the apposite PD techniques to facilitate user participation in the software development process. AR essentially bridges the gap between positivism or empirical verifiable research, defined earlier in Section 1.1, and standard software development which is focused on producing software applications. It provides both a process for conducting positivistic research and its end goal is to produce a contextually relevant intervention, in our case a software application, for a target community.

More precisely, our approach is a customized version of the AR process described by Susman and Evered [93], with PD and RA/RI principles combined with a standard waterfall model of software development. All these modifications are aimed at maximising user involvement throughout the SDLC in order to produce a relevant technological solution to a community problem.

Our process was participatory since we involved the target community in the entire software development process. This was achieved through discussion groups, semi-structured interviews and consultation by cellular telephones and Short Message Service (SMS) which was explained in Section 2.3. However, this aspect alone was not sufficient to have a truly socially aware methodology. To ensure that we were always mindful of the wider context of a software solution and to help us ask the right questions at the right times, we needed to learn from past ICT development projects. To do this, we employed best practices learnt from successful ICT development initiatives. To integrate this into our socially aware process, we used the RA/RI framework in each project phase

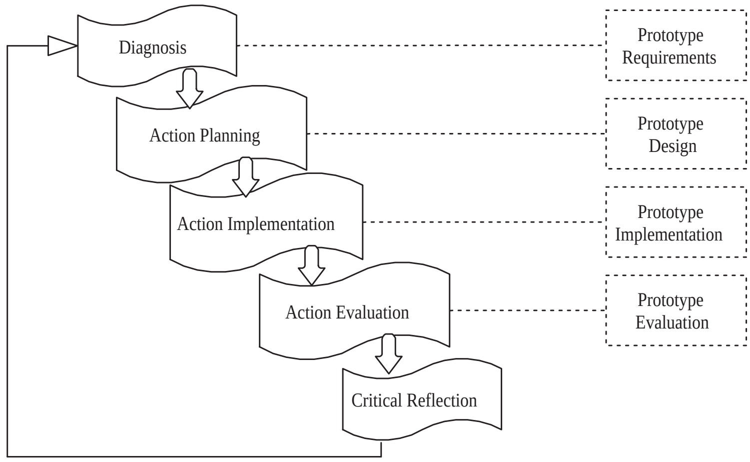


Figure 6: The methodological process is cyclical and iterative, involving stages where we analyse the circumstances of the target community, identify a problem to work on, plan an intervention, implement an intervention and evaluate the outcomes. Finally, after each cycle, we reflect on the results of that cycle in order to correctly plan for the next cycle. The dotted boxes indicate stages of the process where we gather the requirements and design for prototype applications as well as the points at which implementation and evaluation of a prototype occurs.

to identify issues which may not have been technical in nature but which had to be considered in order to ensure the highest opportunity for project success.

When we identified issues to resolve, we held workshops amongst ourselves to discuss how to best address these issues and we made action plans that can be implemented during the regular project cycles. The RA/RI principles therefore ensured that we addressed issues that did not arise from software development but affected the use of the software systems we developed — for example, project sustainability and training. In particular, in our research, we placed a special emphasis on the RA/RI principles regarding the local and macro environment surrounding a project. These principles stress that the local and macro environment into which a software solution fits should be supportive of the technologies used within that solution. We were more attentive to these factors in the RA/RI so that we could extract the ramifications of restrictive telecommunications policies with respect to developing software for underserviced areas. Recall from Chapter 1, that this was one of the aims of this dissertation and therefore this proviso was made to achieve this aim by integrating questions about telecommunications into the socially aware methodology which we used.

In the following sections, we describe different facets of our methodology and provide a step by step breakdown of the cyclical process we used in the project. In the remainder of this dissertation, the term *community* will be used to refer to a collection or group of people of similar cultural background living in a rural setting. This community may be governed by traditional tribal councils and may have a community leader. Next, we describe two constructs we used to help facilitate the socially aware process in rural and underserviced areas.

3.3.1 Allies and Show and Tell

To facilitate interaction with the target community, we identified the need for an *ally*. This is an individual trusted by the community that can act as an interpreter between the researchers and the community members. A similar concept of a *informant* is mentioned by Millen [68]. These informants are people with access to a broad range of people and activities who can reduce observation time by telling the researcher where and when to find certain people and activities. Informants can also be fringe members of a group who are allowed to move freely within that group. They can provide interpretation of events based on their experiences with the group.

Allies differ from informants in that they need not necessarily be part of the community or the research team. *Allies* can also be access points to external organisations. Williams and Begg [105] also describe a similar notion of a *translator* that helps translate between users and engineers. This is because the user does not possess the technical expertise to express her needs in the language of the engineers. Similarly, the engineer may not easily grasp the conditions of the user and her environment. Effective translation is necessary for participatory design and translators can provide translation between the design group and outside groups. *Allies* play a similar role by interacting with the researchers and the community or the researchers and their own organisations.

We used *allies* to leapfrog the relationship building phase between the researcher and the community. For instance, an *ally* may have already built up a rapport with the community and if the researchers are introduced to the community by this *ally*, it becomes easier for the community to accept the researchers. In addition, we utilised the expert knowledge of these types of *allies* to help design solutions for community problems. These *allies* have acquired an extensive knowledge about the community and are familiar with the community situation, thus can provide valuable input into the process of designing software solutions for the community. *Allies* are also invaluable for interacting with organisations. They provide a single access point to the knowledge and services of that organisation and can facilitate further relationship building with the rest of the organisation. We have used *allies* throughout the project.

Another problem that we needed to deal with occurs frequently in underserviced areas. Community members in a rural situation may not be able to express their needs in terms of technology, since they are unfamiliar with it and lack technical expertise. Compounding this problem in many rural situations, is the fact that the researchers and the community members may speak different first languages. Even within the community, different languages may be spoken. This makes it very difficult to be sure that the developers and the community members understand each other.

To overcome this problem, as mentioned by [14,17,103], users need to learn about the capabilities and limitations of technological solutions from the software developers and in turn, developers will gain the opportunity to learn about the application domain from the users. In order to implement this suggestion, we used a *show and tell approach*. We were able to show and tell community members what is possible with technology by demonstrating paper and functional prototypes to the community members. This use of paper prototypes is adapted from PD, where usually paper prototypes are used for collaborative design with users and developers. This ensuresd that our ideas regarding different software solutions were successfully conveyed to community members and we also gathered feedback from the evaluation of these prototypes. In the next section, we describe the step by step breakdown of the socially aware methodology. We also describe our evaluation techniques and how we documented our entire methodological process.

3.3.2 The Different Stages

There are several stages making up our socially aware framework which is both cyclical and iterative. As mentioned earlier, the stages are adapted from the model proposed by Susman and Evered [93]. Several key differences are that we were attempting to provide a software solution to a community problem as opposed to reforming a social or organisational practice in a work environment. Also, we employed PD techniques of prototyping and discussion groups, *allies*, *show and tell* tactics and attempted to address all issues associated with ICT development in underserviced areas by following the guidelines set out by the RA/RI framework. This ensures that the project lends itself both to providing a solution for a community as well as contributing to knowledge about these kinds of endeavours. At each stage, the community was involved in the process by providing us with information about the general situation in the community.

Community involvement also occurred through discussion groups about software solutions for community problems and by evaluating prototypes that we developed. Furthermore, the community was also involved through participating in workshops, by filling out questionnaires and through interviews. At each phase of our process, we used the RA/RI guidelines to identify the most important issues affecting the project at that phase. We used 5 stages per each cycle of the project, namely *Diagnosis, Action Planning, Action Implementation, Action Evaluation* and *Critical Reflection* as shown in Figure 6.

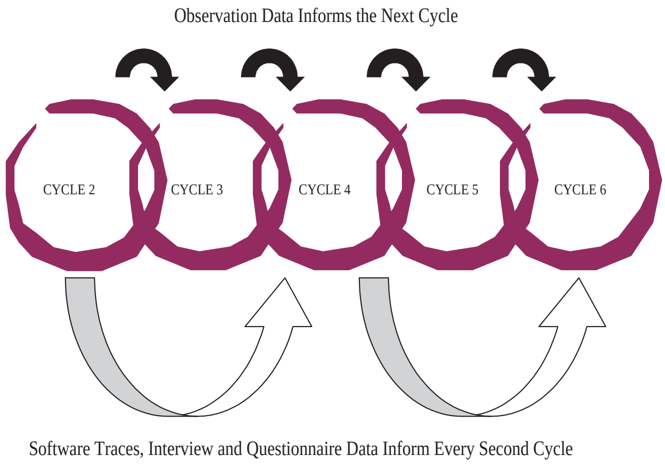


Figure 7: If we install a prototype in Cycle 2, observations made during demonstration and training sessions are used to inform the design of the prototype for the following cycle. It is only in the Cycle 3, when we return to install a new prototype that we are able to gather software traces, interview and questionnaire data about the usage of prototype from Cycle 2. This information is therefore only used to inform the prototype design for Cycle 4. Thus the second set of evaluation data skips one cycle before making any impact on the prototype design.

At any stage, the software we developed was a clear embodiment of the common understanding between the researcher and the community. We documented the entire process using notes, semi-structured interviews, questionnaires and audio records as suggested by [5,58,93]. Additionally, the different versions of the software prototypes we developed acted as documents of the changes that were undertaken throughout the cycles. By comparing each prototype version to the one before or after it, it was easy to extract the alterations that were required at each stage. Also, contiguous versions, show how the software evolved in response to user needs in subsequent iterations of the entire process. Thus documentation occurred at every phase of the process in some form. The focus was on qualitative results as opposed to empirical experimental data [7]. However, we also collected quantitative statistics by instrumenting our software to record usage data. We used triangulation or multiple sources of data to enhance validity and reliability as suggested by Babbie and Mouton [5]. The next sections describe each stage of one cycle in detail.

1. *Diagnosis:* In this stage, we assessed the present circumstances of target community. Next, we identified a problem area requiring a technological solution and gathered or refined existing requirements for a prototype application. The principal methods used in this phase to gather data were semi-structured interviews and discussion groups [104]. Data was documented in

field notes, and/or audio tapes and prototypes [5, 58, 93].

2. *Action Planning:* We designed prototypes in this phase. There was a focus here on rapid prototyping so that cycles could occur frequently. This allowed for the software to quickly approximate what is required of it. Note, in the initial cycles, several paper prototypes may be created before the move to a software implementation. As proposed by Bjerknes [14], prototypes were developed in an incremental way — first starting with the basic requirements and then slowly refining designs as the requirements became more clear.

3. *Action Implementation:* In this phase, we implemented the prototype. This was either a paper or a software prototype. Paper prototypes were used for *show and tell* discussions to help explain technical concepts to community members. Software prototypes were used when we were confident that we had collaboratively identified sufficient functionality to implement a software system. All prototypes were implemented remotely at the researchers laboratories and were only deployed when ready for evaluation. Once a prototype was deployed, it remained at the user site for a period of 2 or 3 months. As suggested by Gronbaek *et al.* [48], this relatively short period of evaluation allowed for rapid prototyping and frequent iteration .

   Weinberg *et al.* [103] suggest that traces to capture user selections should be placed in applications that need to capture these selections. This provides the researcher with a more complete and detailed set of data about the usage of the software. In the software prototypes we developed, we used this suggestion by instrumenting the software to document all user actions. This information was logged to a database and trace files so that it could be easily queried. In addition, this data was compared against data gathered from interviews and questionnaires with users in order to form an accurate picture of software usage.

4. *Action Evaluation:* During this phase, we conducted field trials to see if the prototype was appropriate for the problem. Data collection methods used here included observations, semi-structured interviews and questionnaires [103]. Observations and interviews were documented in field notes and most interviews were also audio taped and later transcribed for analysis. We also collected trace files and database logs which recorded user activity on the software prototypes.

   Three types of evaluation data were taken during each evaluation phase. Observations of participants made by the researchers during demonstration and training sessions gave us data about the most current prototype version being installed. On the other hand, interviews and questionnaires with the users and the software measures gave us data about the previous cycle's prototype. Similarly, trace files and database logs showed how the user had actually used the software over the evaluation period so this data only fed back into the process one cycle later. This is illustrated in Figure 7.

During our field trips, we also held a debriefing session with all the researchers at the close of each day to mull over the events of the day. This helped each researcher to gain different perspectives on a day's events and to solidify overall impressions of what transpired with respect to training, testing and the growing relationship with the community. This information was helpful for fleshing out notes that were recorded during the day when the trip agenda was being carried out as well as for compiling an evaluation report for the field trip. An evaluation report was compiled after each evaluation phase. This document formed part of the analysis of the cycle for the stage described next.

5. *Critical Reflection:* In the last stage of each cycle, we reflected on the entire cycle. This involved reflecting on how well goals were achieved and whether the overall goal of the project should be modified. We also reflected on the feedback from the evaluation to decide if our prototypes were addressing user needs and to identify possible revisions to improve performance. As Bjerknes [14] proposes, not all of the user suggested revisions for the prototype were implemented since users may not always see the consequences of their proposals which may be obvious to developers. This limited the process to some degree and this is discussed in the following section. At the end of each cycle, a document was prepared including details about field trips and salient issues which would affect the next cycle. The aim of this reflection stage was to inform the next cycle in the process in terms of goals.

We now describe the strengths and limitations of this framework.

3.3.3 Strengths and Limitations

The socially aware computing approach had strengths and limitations. One of the strengths was that it is a holistic approach which was mutually beneficial for the target community and the researchers. The community involvement empowered individuals since they exercised a proportion of control in how the software was developed. Also, through their contributions, they were able to see how the software was going to benefit them. This means the software was more likely to be used. The researchers benefited by learning which technologies and services were appropriate for rural areas and how to develop these kind of applications.

Another advantage of the approach, was that using the RA/RI helped broaden the focus of the process so that we did not solely concentrate on software development. In fact, we attempted to address other factors that affected the use of the software in order to increase the likelihood of sustainability and of creating a useful product as well as empowering community members in the process. The augmented software development process also allowed us as researchers to extract and disseminate the lessons learnt from using this process in rural areas so that others may learn from our experiences.

However, every process has certain limitations and the socially aware computing framework is no exception. For instance, the process was limited somewhat by the staggered collection of trace files and database data as illustrated in Figure 7. This delayed the feedback of user activities into the software adaptation process. In future uses of this process, this may be overcome by using remote monitoring of events. This would be possible if a project site had internet connectivity. Trace files and database data could be easily retrieved or automatically sent to the developers periodically. This would mean this information would feed into the software development process as soon as it becomes available.

Another limitation of the process was selective implementation of user suggestions in software prototypes, due to time constraints or the researchers decisions based on what she felt was necessary. This means that useful features may have been left out even if user data suggested they should be put in. Conversely, features that were not strictly useful may have been introduced by the researcher which may not have been useful to end users. Another danger in this process, was that user suggestions in workshops, questionnaires and interviews did not always reflect what their real needs were in daily work practices. This means that the software prototypes may not always have correctly addressed work issues with relevant features.

A further limitation of using this process, is that because the development took place remotely, there was limited times for interacting with the target community as this was done solely on field trips, by phone and SMS defined in Section 2.3. This made maintaining a relationship with a community more difficult particularly since field trips were short. One way to overcome this is to extend field trips to several weeks or months, if practical. This would strengthen ties between the researchers and the community and allow prototypes to be tested and altered on site. However, even with these limitations, we believe involvement of the user was still beneficial and led to the design of a relevant software system.

To minimise the limitations, we chose qualitative methods, such as questionnaires, interviews and field notes, to evaluate whether our software system made the impact that it was designed to make. According to Spinuzzi [88], qualitative field methods are good for investigating the relationship between technology, work, and workers. Furthermore, in order to improve the validity, reliability, objectivity and generalizability of our approach, we took following measures, most of which are suggested by [5, 37]. We used the observations and aid of more than one researcher and used triangulation or multiple sources of data to increase the accuracy of our evaluation data.

Additionally, we describe the entire project in sufficient detail in this dissertation in order to increase transferability. Transferability, according to Mouton and Babbie [5], is the extent to which the findings can be applied in other contexts. Describing the project setting in detail allows the reader to establish if the contexts of other projects are similar enough that the same kind of results should hold. Also, we placed a great emphasis on establishing a rapport and trusting relationship with all the participants in an attempt to avoid error and increase validity. In all, our focus was more on the methodological process as opposed to merely the outcomes of the process as suggested in [5].

In addition, we contracted an external monitor to evaluate our project and provide us with guidance on best practice in ICT development initiatives. The monitor we solicited was Bridges.org [19] who also provided us with the RA/RI framework. Bridges.org advised us on how to align our project goals with community needs. This was accomplished through discussion workshops with Bridges.org where we presented our work to them, discussed salient issues and then received feedback several weeks later in an evaluation report. In this way, we were advised of problem issues that Bridges.org identified as well as where our research was working well. The RA/RI principles as applied to our project are discussed in Section 4.2.

Bridges.org also accompanied us on a project field trip to gain an accurate picture of the ground level situation and the problems that we encountered. Bridges.org therefore played the role of the unbiased observer and adviser. All these measures were taken to minimise the drawbacks of using a largely qualitative process for software development. This concludes the description of the methodology used in the project. The next chapter describes the project setting and the first few cycles of the project using the socially aware framework. We also describe how we created the first software prototype for our target community. The last three cycles of the project are described in Chapter 5.

Chapter 4

Multi-Modal Telemedicine Intercommunicator

Our project went through five cycles of the socially aware computing framework discussed in Chapter 3 which culminated in a communication prototype for telemedicine. In this chapter, we describe the project setting and the South African province in which we worked. We then provide an overview of the project in terms of the major events that occurred in each project cycle. Also, we summarise how the Real Access/Real Impact (RA/RI) framework was applied during the project.

In the remainder of the chapter, we discuss the first two cycles of the project in detail. The remaining three project cycles are discussed in Chapter 5. The first cycle focuses on how we discovered our target community's needs and the requirements for a software prototype. The second cycle describes how we designed and implemented a telemedicine software prototype, called Multi-modal Telemedicine Intercommunicator (MuTI) for the project area. Each cycle is described according to the stages outlined in Section 3.3.2, beginning with *Diagnosis* and ending with *Critical Reflection*.

4.1 The Project Setting

The project was undertaken in the Eastern Cape (EC) province, where approximately, 14.4 percent of South African's live according to the South African Census 2001[1]. Census 2001 found that the EC is a fairly poor province and has a high unemployment rate of 54.6 percent. In addition, a large number of people still live in rudimentary dwellings in this province and in general the

[1] http://www.statssa.gov.za/SpecialProjects/Census2001/Census2001.htm

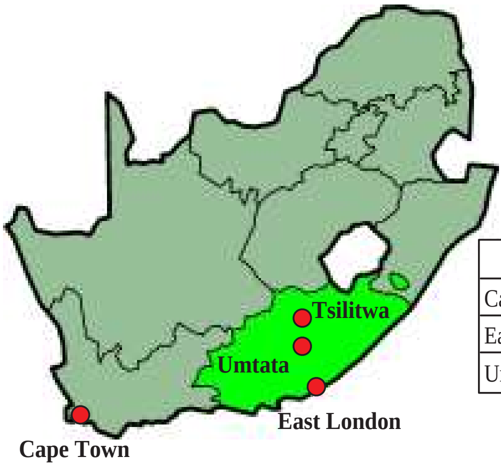
telecommunications infrastructure in the remoter regions of the province is poor. In fact, across the entire province, only 29 percent of the population have a telephone in their place of dwelling or possess a cellular phone [1]. Given the rolling hills and uneven terrain in the province, fixed line phone services are more difficult to set up, particularly in rural and isolated communities. This is because these wired networks require the laying of cables which can be expensive and time consuming in these areas, especially in places where it is difficult to lay cables, such as over large hills [63].

Additionally, the remoter areas in the EC have a low population density so they are not an attractive market for fixed line telephony. Most of these isolated regions fall into the category where less than 5 percent of the population have access to telephony and are classified as areas where the Underserviced Area Licensees (USALs) can operate as mentioned in Section 2.5.3. From our experiences in the area, we feel that categorising these areas as regions where less than 5 percent of the population have telephone access is misleading. In fact, many of these rural areas have full cellular coverage by two of the cellular operators; MTN and Vodacom. During the project, we discovered it was not uncommon for people in these areas to have prepaid contracts[2]. Also, several businesses have developed as a result of the cellular coverage. For instance, there are shops where one can pay a small fee to have one's phone charged. This is a necessary service as many people do not have access to electricity in these regions. Thus it may be more appropriate to classify these areas as regions where less than 5 percent of the population have access to *affordable* telephony given than cellular phones and cellular call charges are expensive.

We worked in Tsilitwa village which is approximately two hours away from Umtata, both of which are shown on the map in Figure 8. Umtata was the capital of the former Transkei, a homeland reserved for blacks which was created by the apartheid government. Umtata and Tsilitwa now form part of the EC province, an amalgamation of several former black homelands and South African land. The former homelands are amongst the poorest parts of South Africa.

Tsilitwa is atypical in that it is an area that has undergone a fair amount of development. For example in 2004, a new clinic and school were built in the village. This development is mainly due to the charismatic community leader who has lobbied government to improve the village and the publicity which a previous technology development project has afforded the village. On the other hand, Tsilitwa is typical in that it has a fairly large population living in mainly mud hut dwellings spread over a large distance. Figure 9 shows the type of housing found all over the area.

[2]This type of cellphone contract allows you to purchase different windows of airtime to receive calls. To make calls, one buys credit which enables one to call at a set call charge until all the credit is depleted. This allows people to spend according to their needs and has made cellphones more accessible to all income groups.



Distance Chart	Kilometres
Cape Town-East London	1050
East London- Umtata	215
Umtata -Tsilitwa	+-80

Figure 8: Map showing the Eastern Cape province with the approximate location of Tsilitwa village in proximity to Umtata. East London and Cape Town, two major South African cities, are shown as reference points. [4]

Figure 9: Mud huts are the most common type of dwelling in the rural village of Tsilitwa as well as the neighbouring village of Sulenkama.

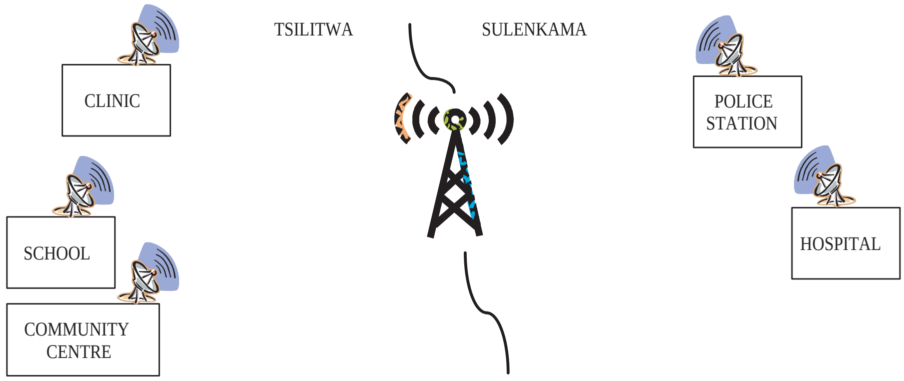


Figure 10: This is the schematic of the WiFi network connecting several facilities in two neighbouring villages: Tsilitwa and Sulenkama. Each facility has an antenna and there is also a repeater site between the two villages due to the line of sight obstruction presented by an intermediate hill. Each facility has a VoIP phone and a Personal Computer connected to the network.

Previous attempts had been made by Telkom, the incumbent telecommunications operator in South Africa, to set up public phones using Digitally Enhanced Cordless Technology (DECT) in the Tsilitwa area but these have not been successful for a number of reasons. Phones are often vandalised or stolen and the power supply to these phones is often unreliable. The poor access roads to the rural regions also makes maintenance difficult. Also, DECT only offers 70kbps and although this is dedicated bandwidth, it is not adequate to provide Voice over Internet Protocol (VoIP) applications or a broadband value added service.

Our project built on a previous undertaking in Tsilitwa village by the Council for Scientific and Industry Research (CSIR), a national semi-private research organisation. The CSIR built a wireless network connecting up several structures in Tsilitwa village with the neighboring village of Sulenkama, nearly 20 kilometers away. To our knowledge, this network was built without the permission of the Independent Communications Authority of South Africa (ICASA), the telecommunications regulator, even though it violated laws governing the use of 802.11b as described in Section 2.5.3. The Wireless Fidelity (WiFi) network connects five facilities together, the school, community centre and clinic in Tsilitwa and the police station and hospital in Sulenkama. A schematic of the network is shown in Figure 10.

Each facility has an antenna and there is a repeater site in the middle of the two villages to overcome the obstruction presented by an intermediate hill. Recall from Section 2.5.2, WiFi requires line of sight between two sites. The network in Tsilitwa has been operational from late 2002. The CSIR provided each site with a Voice over Internet Protocol (VoIP) phone and a Personal Computer (PC), both of which were connected to the network. We were invited by the CSIR to use their network as a testbed for developing locally relevant software applications for Tsilitwa.

As suggested by Denzin and Lincoln [58], our project included a mixed group of participants: researchers from the University of Cape Town's (UCT) Computer Science Department and from the University of Western Cape's (UWC) Computer Science Department as well as community members in Tsilitwa village. The project members included: Mr William Tucker, a lecturer from UWC who was involved in leading discussion groups, conducting interviews and project adminstration throughout the project; Mr Xolisa Vuza, originally from the Eastern Cape area and a masters student from UWC who was involved in building up relationships with community members, helping with software installation and training in the latter stages of the project (2004 only) and Miss Marshini Chetty, the author of this dissertation and a masters student from UCT who was responsible for software development and installation, preparing questionnaires and interview materials, training materials, project documentation and conducting training. The next section summarises the major events that occurred during each project cycle and illustrates how we applied the RA/RI principles, described in Chapter 3, as part of the socially aware computing framework throughout the project.

4.2 Summary of Major Events of the Project

As mentioned previously, we went through five cycles of the socially aware computing framework which was discussed in Chapter 3. Table 4 provides a synopsis of the entire project with a description of the major events that occurred during each project cycle. It also identifies the field visits and when they occurred in the project timeline as well as the allies that we used at each phase of the project. The allies included one of the network administrators trained by the CSIR, the head nurse of Tsilitwa clinic, the community leader of Tsilitwa, the district manager from the Department of Health (DoH) in the region and one of our researchers, Mr Vuza, originally from the Eastern Cape.

Through our DoH ally, we lobbied the DoH to sustain the telemedicine project we began. Mr Vuza was our ally in that he was the only researcher in our group with a similar cultural background to the community members and who spoke the same language. We also identify a special type of ally we used; the local champion. According to the RA/RI framework, the local champion is an individual in a position of authority who is respected by community members that sets an example

Cycle No	Field Visit No	Allies	Main Events
1st	1 (Aug 03)	CSIR project leader	Met community members Assessed what infrastructure was present Conducted needs assessment Discovered problems with network and power affecting the telemedicine system
	2 (Dec 03)	Network admin*	Paper prototype show and tell demo
2nd	3 (April 04)	Network admin Nurse* DoH	Met DoH and secured permission for project Provided training for doctor and nurse Tested and installed 1st MuTI prototype Training in battery life preservation Network assessment by Mr Pearson (Researcher)
3rd	4 (June 04)	Network admin Nurse* Community leader Mr Vuza (Researcher) DoH	Trained doctor and nurse Tested and installed 2nd MuTI prototype Invited to work in Tsilitwa by community leader
4th	5 (Sept 04)	Network admin Nurse* Community leader Mr Vuza	Installed and tested 3rd MuTI prototype Provided digital camera and training in usage of camera Implemented first part of exit stratgey
5th	6 (Oct 04)	Network admin Nurse* Community leader Mr Vuza	Removed all equipment and software Implemented second part of exit strategy Gathered final results

Table 4: This table shows the field visits, the major allies and the main events for each project cycle. The asterisk (*) represents the ally fulfilling the role of the local champion and DoH is an abbreviation for the Department of Health.

as a technology user [23]. This individual is therefore key in helping foster buy-in from other community members and by doing so, driving the project forward.

Our local champion was initially one of the network administrators trained by the CSIR, also a schoolteacher at the Tsilitwa school. He helped us foster relationships with the nurse at Tsilitwa clinic and to arrange meetings with community members. During the second project cycle, there was a shift in champions to the head nurse of Tsilitwa clinic. The head nurse had a good relationship with the community leader of Tsilitwa and most importantly, she bought into the technology. We believe that she convinced the community leader that our project would aid health care in the area. Consequently, we were accepted by the community leader and given free reign to work in Tsilitwa. This was an achievement since the CSIR had previously experienced difficulties in dealing with this community leader in their own project and felt that without his acceptance, any project in the area would probably not succeed.

As shown in Table 4, the project ran from August 2003 to October 2004. Table 5 describes the steps we took to meet each Real Access criterion and Table 6 describes how we used the 8 habits of highly effective Information and Communication Technology (ICT) enabled development initiatives in the project.

Real Access Criteria	
Criteria Name	**Usage During the Project**
Physical access to technology	Unreliable electricity supply, project used laptops to overcome power problems Used VoIP over WiFi network as the infrastructure was already available Project aimed to demonstrate need for change in legislation in favour of VoIP and WiFi
Appropriateness of technology	Secure environment for equipment and use in hospital and clinic Laptops could run for 5-6 hours on battery and extra batteries were supplied

Continued on next page. . .

Real Access Criteria	
Criteria Name	**Usage During the Project**
Affordability of technology and technology use	Project roll out depended on DoH buying into project and sustaining it In real system, there may be licence costs for using WiFi and VoIP depending on who ultimate service provider is Cost savings for patients by cutting out unnecessary travel ICT policy at the time inflated connectivity costs as only certain service providers could provide WiFi and VoIP
Human capacity and training	Training provided by researchers but long-term this would not be suitable Users understood the benefits of the technology Local technical support available for network (2 network administrators trained by CSIR) MuTI support provided by remote UCT researchers, not ideal for long-term
Locally relevant content, applications and services	MuTI used English medium, language used by health care workers in the province due to different backgrounds (Xhosa and Spanish, for example) Worked with health care workers who were literate
Integration into daily routines	Users interviewed at beginning of project to ensure integration of technology into daily routines Store and forward used in MuTI to enable use despite power problems and to accommodate doctors busy schedule Users were interested in using MuTI from onset

Continued on next page...

Real Access Criteria	
Criteria Name	**Usage During the Project**
Socio-cultural factors	Local community leader sanctioned project Difficulties in adapting software interface due to general reluctance to criticize, could be related to culture, may view criticism as sign of disrespect
Trust in technology	Users familiar with email and cellular technology so had confidence in using new technology Security beyond scope of project
Local economic environment	Project may be scaled up if the future MuTI pilot is successful and this could spur further developments
Macro-economic environment	Policy restricted use of VoIP and WiFi Disparities in wealth in country, project region very poor
Legal and regulatory environment	Legislation barring VoIP and WiFi during the project Project highlighted uses of VoIP and WiFi in a rural setting
Political will and public support	Both VoIP WiFi not supported politically during the project VoIP now supported since February 2005 WiFi still restricted

Table 5: This table summarises the main Real Access criteria used throughout the project

8 Habits of Highly Effective ICT Initiatives	
Habit Name	**Usage During the Project**
Do some homework, conduct needs assessment	Needs assessment conducted in first project cycle as part of first *Diagnosis* phase Held discussion groups, interviews with and administered questionnaires to local community members Attended telemedicine workshop in Umtata to learn about telemedicine in Eastern Cape Visited other clinics and hospitals in Eastern Cape to compare situations and get a general idea of how health care operates in the province Attended workshops with CSIR to find out about other development initiatives being undertaken in South Africa and in Africa
Implement and disseminate best practice	Used socially aware framework to ensure we followed best practice
Ensure ownership, local buy-in, find a champion	Identified local champion - the head nurse of Tsilitwa, she helped facilitate buy-in from community leader who in turn, helped facilitate buy-in from other community members
Set concrete goals and take small achievable steps	Milestones set at each *Diagnosis* phase Re-evaluated at each *Critical Reflection* phase of socially aware framework
Critically evaluate efforts, report back, adapt as needed	Reflection at end of each project cycle Reported back to users at each field visit and had regular contact by phone and SMS

Continued on next page...

8 Habits of Highly Effective ICT Initiatives	
Habit Name	**Usage During the Project**
Address key external challenges	Personal safety was an issue since the Tsilitwa -Sulenkama region has history of violence (shootings,hijacking etc) Dealt with this by not staying overnight in Tsilitwa unless necessary
Make it sustainable	Lobbied DoH to see benefits of MuTI They had power to make MuTI sustainable by incorporating telemedicine as part of their provincial strategy for improving healthcare
Involve groups that are traditionally excluded	Project in impoverished area of Eastern Cape and involving rural and isolated communities

Table 6: This table summarises the main project management skills from the Real Access/Real Impact criteria used throughout the project

The RA/RI helped us to widen our focus so that the project was aware of all factors that may have affected the project success and we attempted to address each criterion of RA/RI as best as we could. Each of the project cycles will be discussed in more detail in Sections 4.3 and 4.4 in this chapter and in Chapter 5. The following section describes the first project cycle in detail. Section 4.4 covers the second project cycle.

4.3 Discovering The Community Needs

This section describes the first cycle of the project with emphasis on how we discovered the community needs.

Figure 11: Tsilitwa clinic

4.3.1 Diagnosis

On the first cycle of the project, we visited Tsilitwa in August 2003 to discover the community needs. Our main ally at this point was the leader of the previous project in Tsilitwa headed by the CSIR. He had already built up a trusted relationship with Tsilitwa community and it is through him that we were introduced to the community members who had been most prominent in the previous project. The community was initially suspicious of our intentions but since they were familiar with our ally, the CSIR project leader, they began to show more trust in us as the first trip progressed.

This constituted our first *Diagnosis* stage where we attempted to assess the current conditions of the Tsilitwa project as well as identify a problem area which we could contribute to. The guiding questions used in the needs assessment can be found in Appendix A.1.1. We met the head nurse of the Tsilitwa clinic (shown in Figure 11), the two community members responsible for maintaining the CSIR WiFi network and the current doctor working at the Nessie Knight hospital in the neighbouring village of Sulenkama.

The network maintenance staff included a schoolteacher from the school in Tsilitwa and the manager of the Vodacom phone container in Tsilitwa. The Vodacom phone shops are mobile shipping containers with about 5-10 cellular phones for general use by the public at reasonable call rates. They are common in the Eastern Cape. The network maintenance staff had been contracted and trained by the CSIR to manage the WiFi network. The main doctor was on leave at this stage but we met his companion who was due to return to Cuba in the next month. Both doctors were Cubans on a 3 year contract for the Eastern Cape which had been negotiated with the South African DoH.

We held a discussion group at the hospital with all the community members we met. At this meeting, we explained that we were undertaking a research project to help build applications for the community. Through this meeting and several informal discussions, we realised that the health care staff were experiencing difficulties with the telemedicine system which was set up by the CSIR. Before we elaborate, we first describe the telemedicine system placed in Tsilitwa and Sulenkama by the CSIR.

The CSIR telemedicine system was designed to aid communication for health in the Tsilitwa area. The system relied on a web camera (webcam) which was set up at the Tsilitwa clinic. This camera contained a web server and was viewable from the hospital by surfing to its web address. The CSIR implemented a protocol whereby the head nurse at the clinic could set up a telemedicine appointment with the doctor at the hospital. During this appointment, she could converse with the doctor using the VoIP phones present in both locations and manoeuver the camera to show the doctor a patient. From this consultation, it was possible for the nurse to determine if the patient needed to be referred to the hospital for treatment or whether the patient could be treated at the clinic.

This system improved the previous protocol for referrals whereby the nurse at the clinic would give patients hand written referrals. The patient would then travel to the hospital and return to the clinic with a hand written response from the doctor, if necessary. This system was not very reliable since often patients never travelled to the hospital or never returned to the clinic even if they did travel to the hospital. In the new system, teleconsultation between the nurse and doctor allowed the nurse at the clinic to decide if a patient needed to be referred to the hospital. At the same time, the doctor could then expect to see the patient at the hospital and inform the nurse when an examination was performed, as a follow-up.

The telemedicine system was designed to obviate the need for patients to travel to the hospital unnecessarily. Since there are no reliable fixed phone lines or DECT phones in the area, the system provided a valuable communication service. The only alternative would be to use handwritten referrals or cellphones for communication. Since the DoH does not pay for cellular calls, this solution was not practical or cost effective for the nurses at Tsilitwa clinic or the doctor at Nessie Knight Hospital in Sulenkama. Also, given the poverty in the surrounding areas, saving a patient the cost and travel time to the hospital is a significant improvement in patient care. Additionally, as there was only one medical doctor working at Nessie Knight Hospital at most times, patients had to wait in queues for up to several hours before they received treatment. Eliminating the wait and travel time for patients that do not require advanced treatment, reduces the number of patients at the hospital and ensures health care service delivery at the earliest point of contact, i.e., the clinic.

Through the discussion groups and interviews, we discovered that this CSIR telemedicine system had only been operational since November 2003. Also, the system was problematic for several reasons. One of the main problems was that frequent power failures caused network failure and consequently rendered the telemedicine system unavailable. This meant that often the webcam and VoIP phones were not working and therefore scheduled telemedicine consultations could not occur. Also, in this system it was only possible to have synchronous communication, i.e., where the caller and the callee were both available to take part in a telephone call. This was not always practical as the nurse and the doctor both had busy schedules. At this stage, it became evident that we could improve the telemedicine solution in order to make it more robust and better suited to the local conditions.

4.3.2 Action Planning and Implementation

To utilise the knowledge of our allies to the maximum, following our first field trip, in the *Action Planning* phase of the first project cycle, we attended several workshops and meetings with the CSIR which included the network administrator (and schoolteacher) from Tsilitwa village, who we by this stage viewed as an ally and the current local champion for the project. Additionally, we consulted with our external monitor, Bridges.org. Since both the CSIR and Bridges.org were familiar with ICT for development projects, we felt they would be able to assist us in designing with a solution for the telemedicine problem. We also attended a telemedicine workshop held at the University of the Transkei (UNITRA) in Umtata to learn more about telemedicine in the EC area. Working with these organisations and the community members of Tsilitwa, we decided that combining a store and forward approach with VoIP would improve communication for health in the area.

Fraser and McGrath [43] advocate an email and store and forward approach to telemedicine in isolated areas. They argue that although it may not allow real time interaction, it provides critical specialist support in the management of difficult cases. This approach is also economical and the only challenge in implementing these kind of applications is connectivity. Since connectivity was not an issue for our project, we felt using a store and forward approach was appropriate for the area.

A store and forward approach would allow messages to be sent between the hospital and the clinic while VoIP would allow for phone calls between two sites similar to the previous telemedicine system. Messages would contain text, still images and voicemail. Messages could be created and stored at any time and then forwarded if the power and network were available. To deal with the poor power supply, we decided the system would be run on laptops which could provide several hours of battery power when a power failure and subsequent network failure occurs. We developed a very basic paper prototype illustrating these concepts and visited Tsilitwa again in December 2003 for our *Action Implementation* phase of the first project cycle.

We used a *show and tell* approach during a discussion group with project participants. Our aim was to gather the community's feedback on the paper prototype and our proposed solution for telemedicine. The network maintenance members were also present at this discussion group. During the discussion, we explained our solution for telemedicine which used VoIP and a store and forward approach using the paper prototype as a visual aid. We used the analogy of voicemail to describe the store and forward component. Since all of the participants had cellular phones, they were familiar with this concept and easily grasped the concepts of the proposed solution.

We also explained that the system would overcome power problems that rendered the previous system unavailable. This was because the nurse could still create messages during a power failure if the system was run on laptops. These messages would then be saved and sent when the power resumed and the network was restored. Overall, the paper prototype was very well received. Both the nurse and the doctor were positive that the new system would be an improvement on the old system because it would also allow asynchronous communications.

4.3.3 Evaluation and Critical Reflections

In the *Action Evaluation stage* of the first project cycle, we analysed comments and notes from the field trip to confirm whether we were proposing a viable solution for the network and power problems plaguing the telemedicine system. At this stage, we found that the doctor's main problem with the previous telemedicine system was scheduling appointments with the nurse. Given his busy schedule, it was very difficult for him to guarantee an interruption free hour dedicated to a telemedicine consultation. He welcomed the new solution feeling positive about its impact on the patients in the area. The nurse was also pleased with the proposed solution. She supported the addition of messages in the new system. In particular, she favoured digital pictures over the webcam video as she felt these pictures were of superior quality. In fact, with high resolution pictures, she felt that there was no need for video, which due to manoeuvering, poor video quality and lag, was not practical in many telemedicine consultations. She was also excited at the prospect of using voice messages since nurses at the clinic are often not computer literate and therefore have poor typing skills.

In the *Critical Reflection* phase of this first cycle, we decided that we had successfully identified a problem area to work on using our bottom up approach. Since the paper prototype was well received, we felt it was time to proceed to implementation of a software prototype. At the end of the first project cycle, we also identified that our main ally and local champion in the community at this stage was one of the network adminstration staff, the schoolteacher. He was key in helping to arrange and facilitate meetings and to help us build a relationship with other community members. All the details of the first project cycle and our reflections were documented in a report.

4.4 The First MuTI prototype

After reflecting on the first project cycle, we re-evaluated the situation in Tsilitwa in order to plan our goals for the second cycle of the project. We decided that since the paper prototype was well received, it was time to implement a concrete software prototype to test our ideas. For this cycle, our goal was to design and implement a telemedicine prototype based on the requirements we gathered from the second field visit. The action plan for the second project cycle corresponded to the requirements definition for and the design of a software prototype. Section 4.4.1 details the requirements for the prototype and describes the basic design for this prototype. The implementation of the prototype is discussed in Section 4.4.2.

4.4.1 Prototype Requirements and Design

From the field trips carried out in the first project cycle, several requirements became apparent for a telemedicine software prototype. In general terms, there was a need for improved communication between Tsilitwa clinic and the Nessie Knight Hospital in Sulenkama. A number of factors affected this communication. For instance, there were no reliable phone lines in the area at the time of the project and the electricity supply to both the clinic and hospital was erratic. Additionally, the previous telemedicine system was being underutilised due to power and network problems

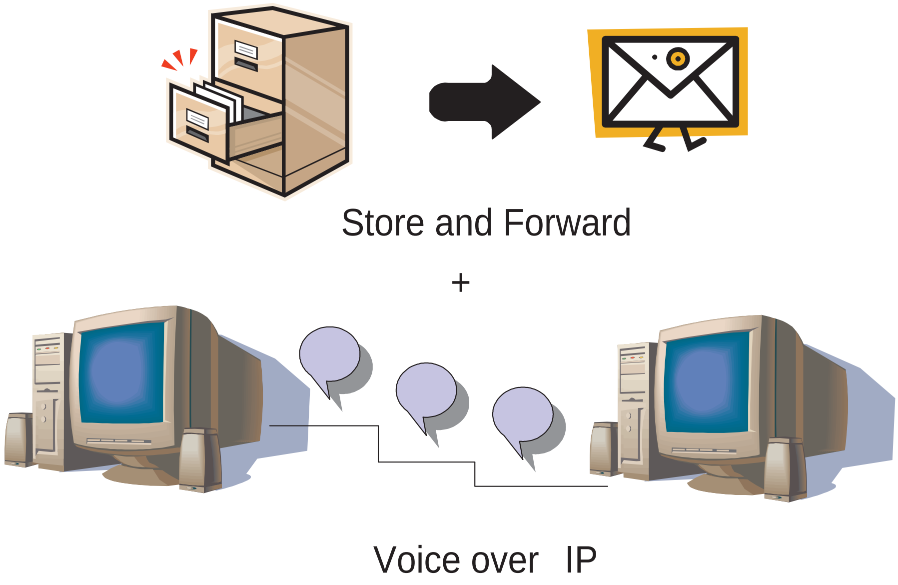


Figure 12: MuTI required two main components: a store and forward component and a VoIP component. Each of these components in turn have several components to enable them to carry out the functionality required from them.

rendering it unavailable for large periods. Also, since the old system only offered synchronous communications, it was difficult to fit in using the system because of personnel shortages leading to busy work schedules.

To improve the telemedicine solution, a more versatile tool was required: one which allowed multiple modes of communication; both asynchronous and synchronous in order to deal with these unreliable points and allow at least asynchronous communication if no synchronous communication was possible. The basic components for the new telemedicine system are shown in Figure 12: a store and forward component for asynchronous message passing and a VoIP component for synchronous voice calls.

Watts and Monk [101] analysed telemedicine tasks and concluded that voice and pictures are essential for most of these tasks . Our prototype was therefore in keeping with general telemedicine trends. The software had to support synchronous voice calls and asynchronous message passing between the clinic and the hospital. These would enable most of the required telemedicine tasks to be carried out. These messages had to contain text indicating a patient's illness and medical history, digital pictures of the patient or particular problem area and a voice message which we shall refer to from now on as voicemail. Voicemail was included to save time on typing and due

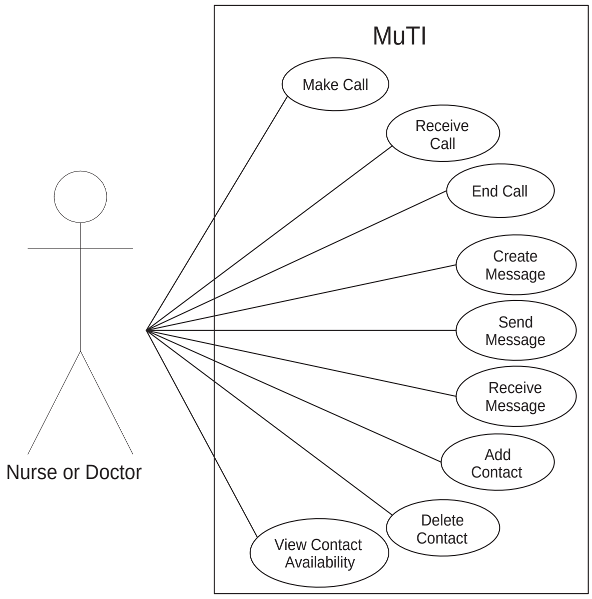


Figure 13: This use case diagram shows MuTI's requirements. These included support for making and receiving voice calls and sending and receiving of messages. In addition, a contact list was necessary to allow users to see who is available to take calls. Thus, the ability to add and delete contacts was necessary as was the ability to view the availability or 'presence' information of a contact.

to the poor quality of the existing video system, digital images were requested due to their higher resolution.

The system also had to support a contact list showing a contact's availability or *presence* i.e. whether a contact is *online* and able to take a call or *offline* and unable to receive a call [86]. These requirements are shown in the use case diagram in Figure 13. The store and forward component is responsible for the creation, storage and forwarding of patient files and records. The VoIP component handles call initiation and maintains the information necessary to display presence information on the contact list. The participants in the project were familiar with the use of email since the CSIR had made email available for a short period using the cellular network for a dial up connection. Thus, the basic Graphical User Interface (GUI) designed for the prototype followed similar conventions to an email client.

Since the concentration in the project was on rapid prototyping, only a minimal design using use cases and class diagrams for the static structure of the system was undertaken. Furthermore, work on security issues such as channel encryption and the GUI were lower priority than fine tuning the basic functionality required of the prototype. However, in the first prototype, a log in and password dialogue were provided to allow restricted access to patient data.

The prototype is similar to other telemedicine applications, as described in Section 2.2.2, in that it uses a store and forward paradigm. On the other hand, it is atypical since it is multi-modal, i.e., it provides for both asynchronous and synchronous communication. Also, it uses a contact list to display a person's availability to receive messages or engage in a call, a feature usually associated with instant messaging tools. After, designing the prototype, we proceeded to implementation as described in the next section.

4.4.2 Prototype Implementation

The initial prototype tool was called Multi-modal Telemedicine Intercommunicator[5] (MuTI) and was implemented in C# on the Microsoft .NET Platform to allow rapid prototyping. MuTI initially supported the use of multiple user profiles to allow users of the tool to store their details and messages separately. Users were required to create an account for themselves upon their first use of the system. Each account was associated with a user name and password and after the first log in, users merely had to click on their user name and type in their password to access the system. Each user had a contact list which was updated regularly to reflect each contact's availability status. Clicking on a contact's name, brings up a context menu from which one can choose to delete, call or view a contact's details.

MuTI is composed of several components as shown in Figure 14. namely *RtcFunctions*, *FileTransfer*, *NetworkMonitor*, *Logs*, *VoiceCompressor*, *VoiceRecorder*, *Storage*, *PatientDetails*, *ContactDetails* and *RecordDetails*. *RtcFunctions* comprises the 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) Application Programming Interface (API) developed for creating VoIP clients based on Session Initiation Protocol (SIP).

The VoIP system in the previous telemedicine system, an off-the-shelf solution used by the CSIR, relied on a H.323 server situated at the school. This site was often unavailable due to power failures and if the school was offline, the clinic and the hospital were unable to communicate over the VoIP phones because the server was down. MuTI's peer to peer calls overcame this problem since it only required the two end points of the call to be functional, i.e., the clinic and the hospital.

The *RtcFunctions* component also allows a contact list to be maintained similar to those used

[5] This is a play on the Zulu word '*umuthi*' meaning traditional medicine. Zulu is one of the eleven official languages of South Africa. (www.websters-online-dictionary.org/definition/Zulu-english/um/umuthi.html)

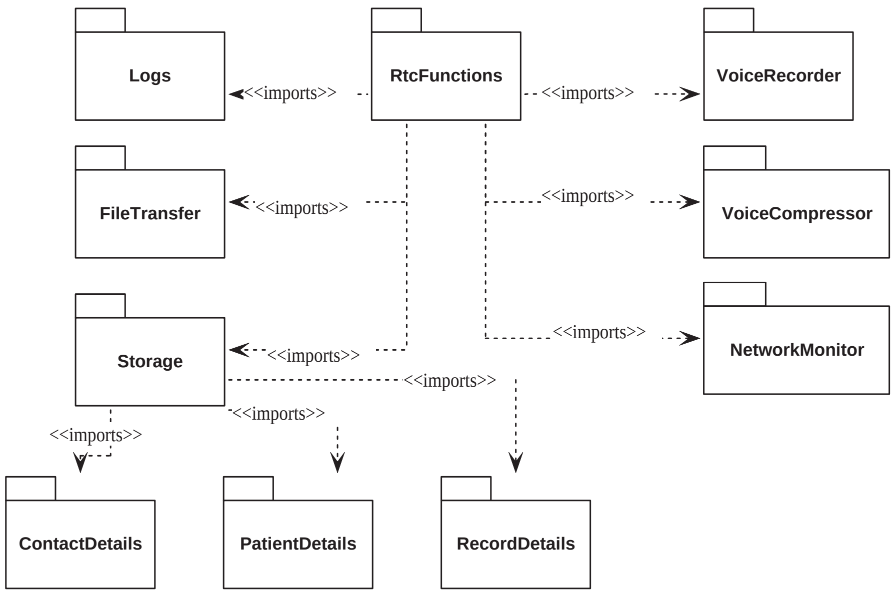


Figure 14: This package diagram shows the major components of MuTI. Each package implements a portion of MuTI's functionality. For an example, FileTransfer is responsible for transfer of messages between sites as well as file compression and decompression. The lines indicate associations between packages and RTC stands for Real Time Communications.

in instant messaging tools. This list indicates the availability of a contact to take a call and is shown in the main MuTI screen in Figure 15. This enables a nurse or a doctor to determine if the other party is available to take a call.

The *Storage* component implements all the store and access functions for an Microsoft Access database. MuTI initially supported multiple user profiles and stored all information in the database per user. Each user had a number of patients and each patient had a number of records. Records were divided into those that were created or sent by the user and those that were 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. As mentioned earlier, the concept of an Inbox and Outbox was familiar since the participants had used email previously when a dial up internet connection was made available for a short period by the CSIR.

As seen in the records dialogue in Figure 16, each record can contain text, images and a voicemail. Voicemail is captured by the *VoiceRecorder* using Microsoft's DirectX. It is compressed using Microsoft's Windows Media Encoding (WME) API in the *VoiceCompressor* component. When a record is sent, all files for that record are also compressed by the *FileTransfer* component before being transferred to another site where they are decompressed. Images can be enlarged or shrunk in a separate image viewer dialogue, shown in Figure 17, which is implemented in the *RtcFunctions* component.

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 connection is constantly polled by the *NetworkMonitor* 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 was formally tested at the researchers laboratory to ensure that each component was functioning correctly. These tests were conducted between two laptops connected with a cross cable, each with its own headset — the laptops being identical to the ones which were to be deployed for field trials. A comprehensive test of each MuTI feature was performed by the developer. For an example, MuTI was installed on each laptop, and logging in functionality was tested. A contact was then added to each machine to point to the other testing machine. Calls were made from each

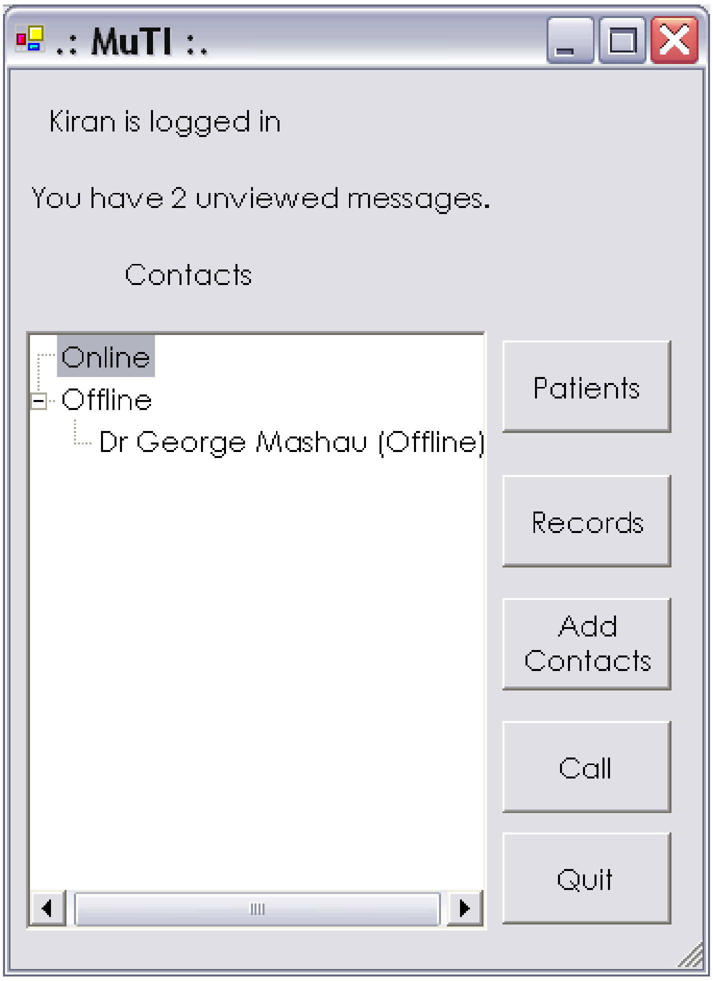


Figure 15: This screenshot shows the initial MuTI prototype's main screen. The contact list reflects a person's availability to take calls. Offline indicates a person is unavailable and online indicates a person is available. The buttons on the right show the basic functions that MuTI initially provided. One could manage patients and records, add contacts, call contacts or quit.

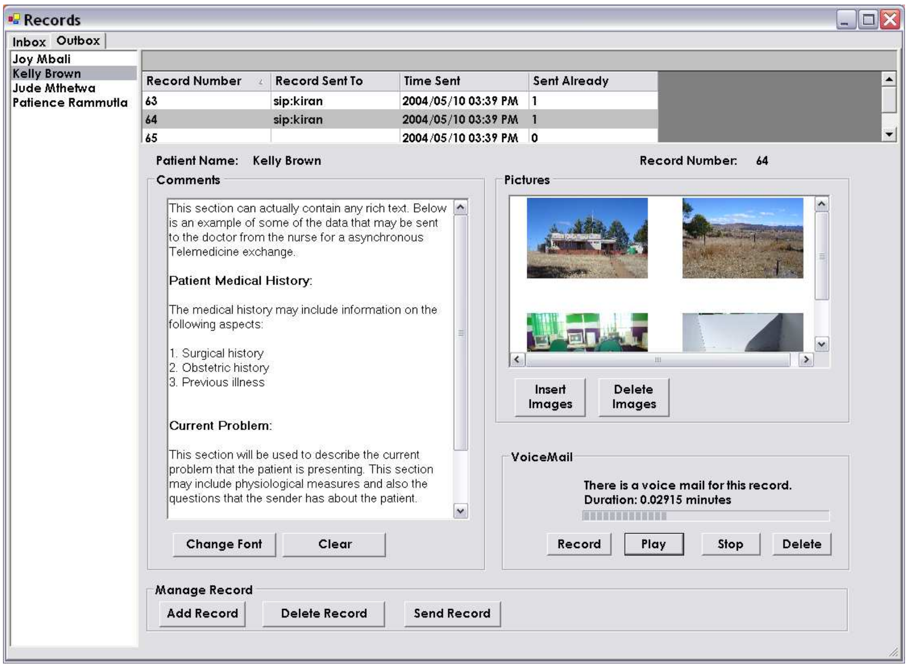


Figure 16: This screenshot shows the records dialogue where records are displayed per patient in an Inbox and an Outbox. This screenshot shows a dummy record to illustrate that a record can contain text, images and voicemail. Images may also be viewed in a separate image viewer which allows enlargement.

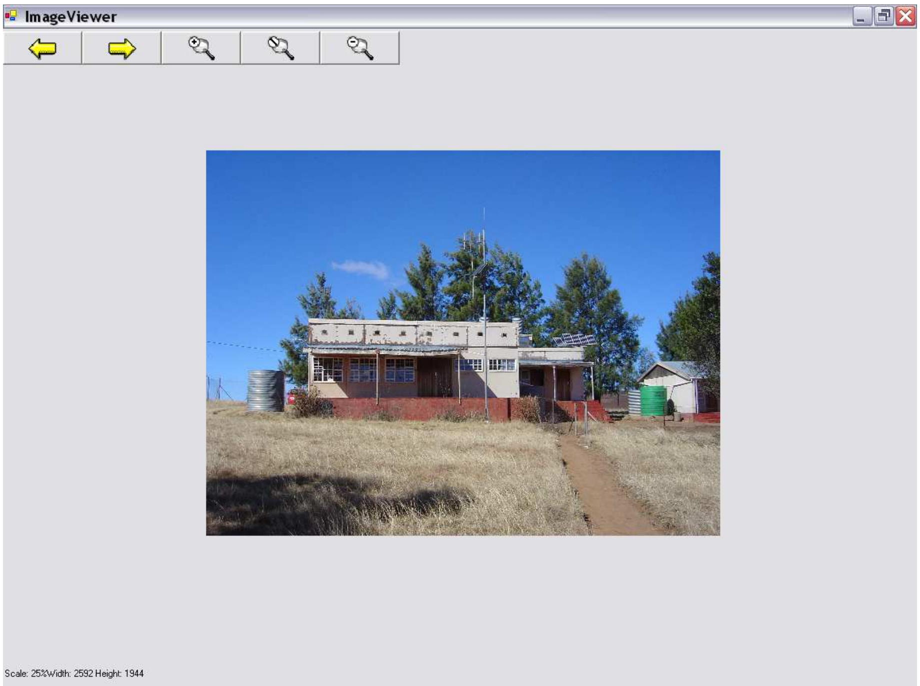


Figure 17: This screenshot shows the image viewer dialogue in MuTI which allows users to enlarge or shrink images that are contained in patient records.

machine to the other to test voice clarity and messages were sent between the two machines. In addition, messages were created when the laptops were not connected and then a connection was established to test the functionality of the store and forward component. The entire testing process was repeated in implementation phases in subsequent cycles after any change was made to the MuTI prototype. Testing usually occurred over 1-2 weeks. When the prototype was thoroughly tested and functioning correctly, it was considered ready for deployment.

MuTI's main advantage is its multi-modality that combines synchronous VoIP with the asynchronous storage and forwarding of messages. The contact list allows the user to determine if the person s/he wishes to contact is available. 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 improved on the poor quality video in the previous telemedicine system and the latter saved time for users with poor typing skills.

It was anticipated at this stage that the system would lead to cost and time savings for patients since they would not have to travel to the hospital to see the doctor, if not necessary. This was 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. The following section describes how we evaluated MuTI.

4.4.3 The First MuTI Trials

In order to evaluate the action implemented for the second project cycle, i.e., MuTI, we arranged a field visit. The purpose of this visit was to introduce the first version of MuTI to the project participants. In terms of equipment, we provided two Dell Inspiron 5150 laptops on which to run MuTI, one for the clinic and one for the hospital. The machines had Intel Pentium 4 processors (3.06 GHz), 512 Mb RAM and Microsoft Windows XP Professional Operating Systems. Headsets were also provided so that participants could make VoIP calls with MuTI. Furthermore, we provided spare battery packs for each laptop so that in the event of a power failure, additional battery power was available and patient data could still be captured.

During this trip, as part of the evaluation of this software prototype, a discussion group was held with the participants. Also, a questionnaire was administered to gather baseline data and a demonstration of MuTI was arranged. In addition, training was provided for the users and MuTI was tested across the WiFi network from the clinic to the hospital.

To increase validity of the results, data triangulation was employed, i.e., multiple sources of data were compared for accuracy. Additional data gathering techniques employed were mainly qualitative including interviews and observations from ethnography which were recorded in field notes. Also, the software prototype was instrumented to gather quantitative statistics to indicate usage of MuTI. The following sections describe the project participants, the discussion groups held, the baseline questionnaire administered as well as the demonstration, training and testing sessions for this project cycle.

Participants

The project participants consisted of two health care professionals, a Xhosa-speaking South African nurse from Tsilitwa primary health care clinic and a Spanish-speaking Cuban doctor from Nessie Knight Hospital in Sulenkama. The nurse had some prior experience with computers from using the previous telemedicine system. She was classified as a novice computer user. The doctor, on the other hand, had used computers extensively and was familiar with email and the internet. He was classified as an average computer user. The nurse had worked at Tsilitwa for several years and the doctor, at the time, was completing his three year contract at the hospital.

The doctor was the sole doctor at the hospital at the time of the project, responsible for 200 beds, treating on average 100 out-patients per day. The other two participants in this experiment were the two network maintenance staff from Tsilitwa who were trained by the CSIR to maintain the wireless network. Both had been trained in basic network management. The network administrators only took part in the discussion group whereas the nurse and the doctor also participated in the demonstration, training and testing sessions using MuTI. Next, we describe the discussion group we held with the participants.

Discussion Group

We held a discussion group with the nurse, the doctor and the two network maintenance staff. This group was contained by researchers through focus on a set agenda. The group was given an outline of the purpose behind our work, i.e., that the work was being undertaken for research reasons. We also clarified our relationship with the CSIR and highlighted our role as trying to improve the old telemedicine system. The cyclical nature of the overall research process was emphasised and we explained our future plans for revisions and follow-ups.

This was necessary particularly for the doctor at the hospital since we had not met him previously. The doctor we met at the previous visit had since returned to Cuba. We also gave all the participants a typed one page project summary to augment the talk. To end the first part of the meeting, we discussed the ethical considerations for the study. This included mentioning that we would not be collecting personal data and only statistics. Attendees were formally asked if they wish to participate in the study and we stressed that this was on a voluntary basis. We also informed all attendees that participants could opt to withdraw from the study at any point. After the explanations, we handed out consent forms for all the participants to sign as a contract of goodwill between the researchers and the community members. The next part of the discussion group was dedicated to talking about the MuTI tool. We provided an overview of the purpose of the tool and its capabilities and prompted attendees for feedback. In the following section, we describe the baseline questionnaire we administered.

Questionnaire and Clarification Interview

We administered a questionnaire during the second project cycle to determine baseline data and usage of the previous telemedicine system developed by the CSIR. This included questions on how often the system was used in the past, what it was used for and also how it could be improved. The questionnaire can be viewed in Appendix A.1.2. Afterwards, an interview was held to clarify responses to the questionnaires and annotations were made on the response sheets. Only the doctor and the nurse completed the questionnaire as they had used the previous telemedicine system whereas the maintenance staff were only involved in the network administration. We now give a brief description of the demonstration that took place in this evaluation phase.

Demonstration

A demonstration was set up using two laptops connected with a cross cable in the hospital meeting room. Here, the principal researcher demonstrated how to send a MuTI message and make calls using MuTI to another party using MuTI. All the functions of MuTI were shown to the doctor and the nurse and we observed their responses. Scenarios of use demonstrated included how to log in to MuTI, how to call another MuTI user, how to create a record and how to send a record to another MuTI user. Once we had demonstrated MuTI, we made arrangements to train both the nurse and the doctor individually in how to use MuTI. This is described in detail below.

Figure 18: This picture shows one of the training sessions with the nurse. In the foreground from left to right: Mr Vuza (Researcher), Mr Tucker (Researcher), Tsilitwa Clinic Head Nurse and Miss Chetty (Researcher). In the background, from left to right, Network Administrator and Tsilitwa Schoolteacher, Network Administrator and Vodacom Phoneshop Manager (bending over) and a Tsilitwa schoolchild.

Training the nurse

The nurse was trained at the school, as seen in Figure 18, since the clinic did not have power on the morning that the training was scheduled. Again, two laptops were set up and connected via a cross cable. On each laptop, MuTI was set up with a pre-created account, the “Hospital” account for the hospital machine with a simple password and the “Clinic” account on the clinic machine also with a simple password. For each account, a contact was added - the contact being the name of the other machine. For an example, the “Hospital” account had the contact with the name “Clinic” and with the address being clinic laptop’s Internet Protocol (IP) address and vice versa. Training for the nurse took approximately one and half to two hours. She was walked through the system by the principal researcher and shown the following items:

- Logging in
- Adding a patient

- Adding a record to the Outbox
- Recording a voicemail for an Outbox record
- Listening to the recorded voicemail for an Outbox record
- Adding text to an Outbox record
- Adding images to an Outbox record
- Sending an Outbox record to another participant
- Viewing a record received in the Inbox
- Viewing an image in an Inbox record
- Listening to a voicemail in an Inbox record
- Reading the text of an Inbox record
- Calling another participant

In addition, a rudimentary user guide was provided to augment the training. The nurse was also trained in basic battery life preservation so that the laptops power resources would be used efficiently, particularly during power failures. During the training session, detailed observations were recorded in field notes about how the nurse used the system and questions were asked at each task to gather feedback about the system.

Training the doctor

Training for the doctor had the same format as the session described above and took place at the hospital. Here, the training lasted about forty five minutes. The doctor was walked through the same tasks as the nurse as described above as well as battery life preservation and observations about how he used MuTI were recorded in field notes. The researchers also asked questions about the tasks as the doctor performed them to gather feedback about MuTI. As a final part of the installation and evaluation phase, we tested MuTI across the WiFi network in Tsilitwa and Sulenkama.

Testing across the network

Before we tested MuTI across the WiFi network, we installed the laptops at the clinic and the hospital sites. Headsets were provided as the laptops did not have built in microphones and both a microphone and speakers were required for MuTI VoIP calls. Moreover, using headsets, one experiences less feedback echo. This occurs when the caller's voice which is emitted from the speakers is picked up by the microphone and fed back into the system, obscuring clarity. Each laptop was connected via an Unshielded Twisted Pair (UTP) cable to a switch. The switch was then connected to the main hub for the wireless network. Both the IP addresses for the clinic and hospital laptop were statically configured so that they would not change in case of a power failure. If this were not done, the server may have assigned each laptop a different IP address following a power failure and this would have adversely affected the correct performance of MuTI.

Once the hardware was installed, MuTI was started at both ends of the network, i.e., on the clinic side and the hospital side. Since extensive testing had been performed during the training sessions, minimal testing occurred after setup. The CSIR VoIP phone at the clinic was used to inform the doctor at the hospital that the testing session was ready to proceed. The nurse then called the doctor at the hospital using MuTI. This call was made successfully. The doctor then reciprocated by making a call to the clinic, also using MuTI. We did not feel it was necessary at this stage to re-test the sending of records across the wireless network. As far as we knew at this stage, MuTI was working correctly, as proved in the training and demonstration sessions. Section 4.4.4 describes the results that we gathered from this evaluation phase.

4.4.4 Results and Data Analysis

The data collected from observations of the doctor, the nurse and the other participants, the questionnaire data and the network assessment yielded the following results.

Questionnaire and Interview Data

From the baseline questionnaire and clarifying interviews, we gathered the following information about the previous telemedicine system set up by the CSIR. This information was to serve as baseline data for our study to enable us to compare our own experiences with MuTI to the previous telemedicine solution. We discovered, firstly, that the previous telemedicine system had been functioning since late November 2003. Consultations were arranged via the VoIP phones and initially the doctor and the nurse arranged to use the system twice a week. This arrangement failed because the doctor was too busy to commit to a formal schedule. This was due to the shortage of personnel at the hospital, the doctor at the time being the only doctor serving the entire hospital. Telemedicine consultations were then arranged to take place once a week. This did not improve the situation because the system not working most of the time. During these periods, patients were referred to the hospital as usual with hand written referrals. The webcam was generally more reliable than the VoIP phones since the VoIP phones were dependent on a server situated at the school, which was often unavailable due to power and network failures.

Telemedicine consultations, when they did occur, usually lasted for approximately 50 minutes. During a consultation, the doctor never interacted directly with the patient. This was because there was no speaker phone so only one person could talk to the other at a time. This was compounded by language differences. In fact, the doctor admitted that even at the hospital he did not communicate directly with the patient due to language differences. A nurse was always required as an interpreter. Consultations were usually arranged for patients that fell into a category of non-primary health care as well as for dermatology cases.

The doctor stated that a telemedicine consultation usually takes about 2-3 times longer than if the patient came to him at the hospital. This is because of the nature of telemedicine. At the hospital with the patient in front of him, a doctor can quickly examine the patient himself. Via telemedicine, he has to instruct the nurse through the phone, then she has to align the camera correctly and then he has to ask her to adjust it as necessary. The nurse then has to examine the patient and pass the information along to the doctor. This means this kind of consultation requires more time. Additionally, the doctor mentioned that the quality of the video system in the previous telemedicine system was very poor and that if the patient was too close to the camera or too far away, the image became blurred. Moreover, the staggered video images were not ideal. The nurse also did not like the quality of the video in the previous telemedicine system. In addition, she was unhappy about power failures rendering the system unavailable and mentioned that there were occasional technical problems with the computer itself.

Despite these issues, both the doctor and the nurse liked the telemedicine concept and indicated that they would like to see the current system improved. Even though the system made more work for the doctor, he saw it as beneficial to the patients who save on time and costs of travelling to the hospital. In the doctors opinion, 2-way video was not a priority. This would probably only benefit the patient but not add much more to the consultation. His opinion at this stage was influenced by the inferior quality of the current video system. Thus, still images with a higher resolution were requested by both the nurse and the doctor. Additionally, both of them indicated that they would like to use the computers for internet access and email if that were possible. Furthermore, the nurse indicated that she would like to store documents on the PC such as the minutes of meetings. For the telemedicine consultation, she also indicated that she would like to send the doctor a patient's medical history. We did not gather any further data from the baseline questionnaire administered in this cycle. Next, we present the data we recorded from observing participants in the demonstration, training and testing sessions.

Observations

From observing the participants during the demonstrations, training and testing sessions, we discovered the following revisions needed to be made to MuTI. Firstly, several interface improvements that would enhance MuTI became clear. For instance, we noticed that the differentiation between offline and online states could be enhanced with the use of colour. Another observation made was that most feedback messages were presented to the user using pop-up message boxes. These message boxes turned out to be overwhelming to the user. Instead of these pop-up dialogues, we surmised that in future the use of on-screen notifications would be more appropriate for user feedback. Observations also revealed that the text on the 'Recording' button for recording voicemail did not change to indicate that the user should click on it to stop recording a voicemail. This confused users when recording a voice mail since they were unsure of which button to click to stop recording. We also discovered that the call button on the main menu was not being utilized at this stage and that it should be removed to simplify the interface.

During the observations, several suggestions arose from both the participants in the project and the researchers. The doctor expressed a need for a "Reply to" function to be added to MuTI. He also expressed a need for printing images. A further suggestion was to improve the general interface by putting all the actions in a tool or menu bar instead of having a button per an action. We also noted a suggestion to make a global Inbox for all MuTI records since the system, at the time, displayed records in an individual Inbox for each patient so that all messages for a specific patient were in one view. Lastly, one of the researchers also suggested adding the ability to send video clips. All these suggestions were documented so that the researchers could decide which features and changes were required in MuTI. We now briefly describe the network assessment we conducted in the second project cycle.

Network Assessment

During the third field trip, we were accompanied by Dr Murray Pearson from the University of Waikaito who has done extensive research in implementing WiFi networks for rural areas in New Zealand[6]. He provided us with a detailed assessment of the CSIR WiFi network. We found that the Uninterrupted Power Supplies (UPS) in the network were not functioning properly and were making resetting the network difficult. Also, the network was not deemed to be running at optimal efficiency. Additionally, the architecture of the network was found to contain too many points of

[6] www.crc.net.nz

failure. For instance, as mentioned previously, for the VoIP phones provided by the CSIR, the H.323 server was located at the school. This meant that if the school link was not functioning, then no other points on the network could utilise the voice phones. After our field trip, we alerted the CSIR to the inefficiencies in the network and considered how these findings affected our project. In Section 4.4.5 we describe how we dealt with factors external to developing the MuTI software in the second project cycle.

4.4.5 Factors External to Software Development

As seen in Chapter 2, ICT development projects should take into account how the development fits into the local and macro environment, socially, culturally and economically. In order to address this component of the project, we held a workshop with our external monitor, Bridges.org, before the third field trip in the second project cycle. The purpose of this was to gather feedback on how well the project addressed real world needs. The project was evaluated according to the criteria defined in the 8 habits of highly effective ICT-enabled development initiatives and the real access criteria [23]. Prior to the workshop, a detailed questionnaire designed to assess these criteria was completed by the researchers.

At the workshop, feedback on the questionnaire was provided. Bridges.org found that our project was addressing RA/RI very well. For instance, the use of laptops to overcome the unreliable power supply was seen as a positive step. Also, the fact that we had identified a local champion and that our users had bought into the technology was highlighted as a good example of best practice. However, they suggested that we think about long terms plans with respect to software and hardware support. During the project, support was provided by the researchers. In the long term, Bridges.org suggested that the Department of Health could be responsible for this if they could be convinced of the worth of the telemedicine service. Bridges.org also suggested that we encourage the head nurse to train other nurses in the clinic so that skills are not lost if there is a staff turnover. Finally, they encouraged us to make contact with the Tsilitwa community leader to secure his support for the project.

This workshop allowed us to re-align our goals for the evaluation phase of the second cycle with real access. We arranged a meeting with the DoH to bring up the issue of sustainability and to secure permission to work with both the head nurse in Tsilitwa as well as the doctor in Sulenkama. In addition, we planned to encourage the head nurse to train other nurses and to meet the community leader of Tsilitwa when the opportunity to do so presented itself.

As a result of our actions to address the issues raised by Bridges.org, we were granted permission to install and test MuTI after meeting with the district manager of Health for the Tsilitwa/Sulenkama area. This meeting also allowed us to showcase the MuTI project to make the DoH aware of MuTI as a telemedicine solution for the Eastern Cape and to inform them about the problems we uncovered with respect to health care from our research such as the shortage of personnel in outlying areas. These are the main external issues we addressed in the second project cycle. We now detail the reflections we formulated after the *Action Evaluation* phase in this project cycle.

4.4.6 Critical Reflections

The second project cycle was perceived as successful. We accomplished our goals of developing a software prototype, installing it in the field, training participants to use it and testing it. Additionally, based on the results of the evaluation of MuTI in the second project cycle, we came up with the following reflections.

Infrastructure and Equipment

Regarding the wireless infrastructure in Tsilitwa and Sulenkama, the network assessment showed that the WiFi network could optimised which would enable it to handle more applications. However, at this point, we were the sole users of the bandwidth so the VoIP calls had no discernible latency. The network inefficiency did slow down the transfer of messages from the clinic to the hospital and vice versa but again this posed no serious problems at this stage. We decided here that the network was sufficient for our purposes and disseminated our findings to the CSIR for their future reference in the event that they altered the network infrastructure.

With respect to the equipment we chose to use, we felt in future it may be more appropriate to use laptops with wireless headsets. This would cut down on the number of wires which coupled with the wires from the keyboard, the mouse and other devices proved to be cumbersome. In our third visit, we also discovered that the digital camera provided by the CSIR was not working. The ramifications of this were that images of patients could not be captured, and therefore no images could be transmitted in MuTI patient records at this time. We informed the CSIR of the problem with the digital camera and they resolved to fix it in one of their upcoming field visits.

Software

The first version of MuTI with its multi-modality was very well received by the participants who felt the system could improve communication for health, in theory. However, we discovered that although the main goal of MuTI was to minimize the work for the doctor, it actually placed more of a burden on him. This was due to the fact that he was the sole doctor at the Nessie Knight Hospital at the time of the project. From his suggestions, it seemed that future projects could connect more clinics and hospitals together which would expand the base of doctors available and spread out the workload between multiple doctors. For this to work, internet connectivity is a necessity. This connectivity would also allow the doctor and nurse to keep up to date with the latest medical information and, particularly in the case of the foreign doctor, to feel less isolated. In our project, it was unlikely that we would secure this kind of connectivity in the short time period in which the project was meant to run. We therefore decided to concentrate on refining the existing MuTI prototype without concern for expansion using the internet.

From the observations we made of the participants during the demonstration, training and testing sessions, we found that the following improvements were necessary for MuTI. Foremost, several bugs were discovered in the system. For instance, the file transfer component was not functioning efficiently and certain error recovery mechanisms were not deemed to be working correctly. Moreover, we found that changes to the interface were required. For example, certain buttons needed to be labelled better as participants seemed to confuse functions. Also, feedback to the user was often provided in pop-up dialogs which disturbed the flow of events needed to complete a task, such as sending a MuTI record. Also, we found we needed to streamline MuTI to take out unnecessary functions, which we observed were never used, such as the option to call a contact by typing in their address. Lastly, we decided that we needed to add more logging capabilities to MuTI to accurately record how a participant used the system. At this stage, minimal logging was in place to record when users logged into MuTI, created and sent messages and made calls but specific details were not logged such as the time of a call.

Socially Aware Computing

We found that the RA/RI questions as applied to this project cycle, led us to the decision that we should bring the shortage of doctors to the attention of the DoH on our next field trip. This was because this shortage affected the usage of the software, as if the doctor was busy, there was nobody to answer the nurses queries.

Allies and Local Champion

Lastly, we reflected at this stage, that a new local champion had emerged from our growing relationship with the community. This champion was the head nurse of the Tsilitwa clinic and one of the primary participants in the project. The previous champion was the schoolteacher who was also one of the network administrators, but he was not directly involved in health care so he could not fulfill the role of local champion indefinitely. The new champion, the head nurse, seemed to grasp the potential benefits of MuTI for health care in the area and she, of her own volition, spread this message to the community leader with whom she had a strong relationship. This was crucial for us since we had been forewarned by Bridges.org that without the community leader's sanction, the project would not succeed. Our new local champion therefore was key in helping us achieve buy-in from the target community.

At this stage, the schoolteacher still remained a strong ally, helping us to arrange meetings and continuing to maintain the wireless network. Another ally was introduced at this point, Mr Vuza, one of the researchers that joined our team, who was originally from the Eastern Cape. Mr Vuza provided us with a whole new perspective into community issues and politics, being easily accepted into the community and seen as less of an outsider than the other researchers who could not speak the local language. Another new ally also emerged in the DoH in the form of the district manager of Health. This district manager was key in us securing future funding for the project and in convincing the DoH to make MuTI part of its provincial telemedicine strategy if it proved to be a success. This would ensure MuTI would be sustainable. At this stage, we decided we would hold future meetings with the DoH to pursue this cause and bring the shortage of personnel in the hospital, mentioned earlier, to their attention. These were the main reflections on the second project cycle. The next chapter details how we refined the MuTI prototype to more clearly embody user needs. We describe three more iterations of the socially aware framework and discuss how the project terminated.

Chapter 5

Adapting MuTI to The Users

The previous chapter detailed how we developed and evaluated our software prototype, Multi-modal Telemedicine Intercommunicator (MuTI), in the first two project cycles. This chapter describes last three cycles of the project which involved refining the MuTI prototype. Section 5.1 describes the third project cycle where we first began revising the initial MuTI prototype. The following section describes the fourth project cycle where we altered the MuTI prototype for a second time. Finally, in Section 5.3, we describe how the project drew to a close.

5.1 Refining MuTI

This section describes the third project cycle where our *Diagnosis* was to improve the performance of the MuTI system and to refine the prototype to more closely match the user needs. The revisions for MuTI and goals for this cycle were based on the reflections from the previous project cycle described in Chapter 4. We decided to gather feedback on the revisions and continue to refine MuTI in a cyclical manner. Our intention was to only stop revisions once the functionality of MuTI was considered to be a complete embodiment of user requirements. In practice, we had to stop revising MuTI earlier than planned but this will be discussed in Sections 5.2 and 5.3.

In order to achieve the goals described above, the *Action Planning* phase of the third project cycle concentrated on adapting MuTI to the users. First, MuTI revisions were identified, categorised and prioritized based on the reflections from the second cycle. Next, we implemented these changes to MuTI in the *Action Implementation* phase. Lastly, in order to evaluate the new version of MuTI, a field trip was arranged for the *Action Evaluation* phase.

5.1.1 MuTI Improvements

The following improvements were made to the initial MuTI prototype based on the reflections and results received from the first MuTI trials. Three main areas for revision were identified based on the reflections in Section 4.4.6 — bug fixes, interface enhancements and lastly, detailed logging. Bug fixes entailed changes required to improve software performance. Interface enhancements were any changes required to alter the user interface. Lastly, detailed logging was added to supplement our knowledge of how the software was being used.

By collecting usage statistics in the software, we were able to determine how the users actually used the system as opposed to how they think they used it. In addition, a clearer picture of system usage enabled us to determine how best to revise the system for future cycles. Due to time constraints and selective revising, not all of the suggested changes gathered from the first field trials were included in the second version of MuTI. The revisions made are discussed below.

Bug Fixes

All the bugs we discovered from observing participants in demonstration, training and testing sessions in the second cycle were fixed. The file transfer component was rewritten to increase efficiency and the handling of calls was improved. In general, error recovery was improved for the entire program in order to increase overall robustness.

Interface Enhancements

Minor interface enhancements were undertaken including better labelling of buttons, removal of pop up dialog boxes and adding a notification icon displaying when new records are received. The option to call a contact by entering an address (entered from the main MuTI screen) was removed as it was deemed unnecessary. As requested by the nurse, a medical history section was added to the details stored for each patient. This history is sent with all records for a specific patient. An example of the medical history sent is shown in Figure 19.

Detailed logging

Detailed logging functionality was added to MuTI to improve the measures made by the software. Information is logged to the local database and to trace files. The following data is recorded:

- Start and finish time when a call is made and the callee address.

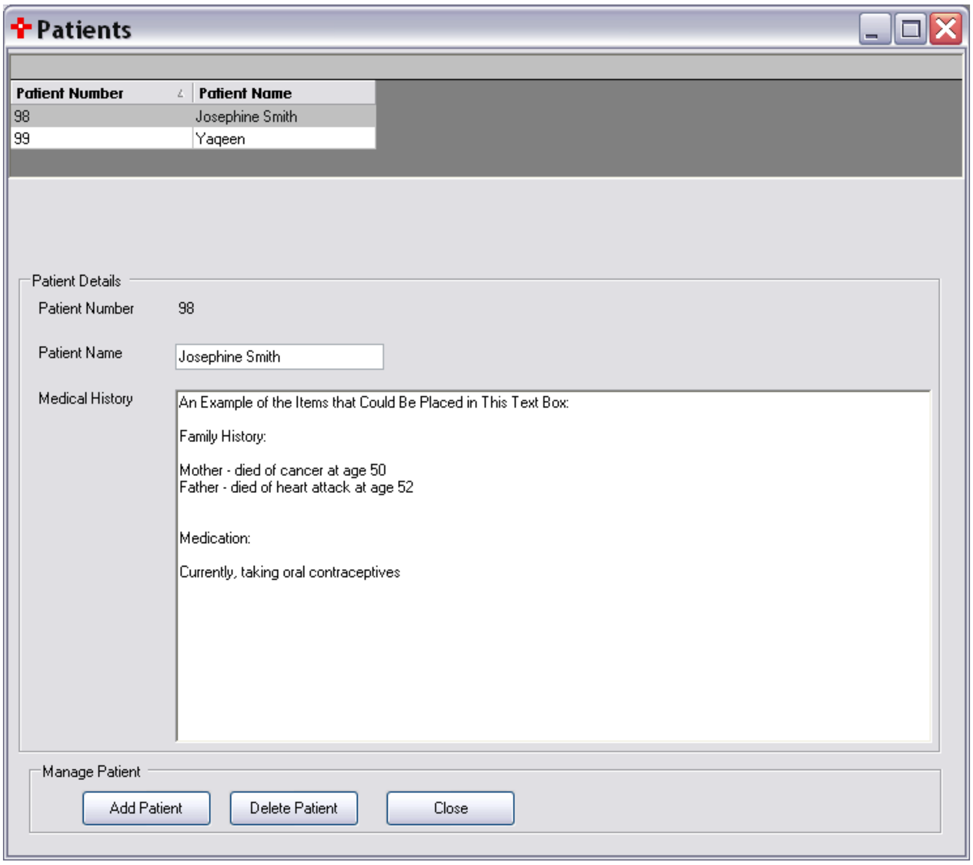


Figure 19: Screenshot of the patient dialogue showing an example of the type of information that can be included in the Medical History field.

- Start and finish time when a call is received and the caller address.
- Creation time for records in Outbox and whether the record was created when MuTI was in an offline or online state i.e. whether there is a network connection at that point in time
- Time that a record is sent to a recipient and the recipient address. Also logs type of data included in a record, i.e. whether images, text and/or voicemail are included.
- Logs whether a record is sent successfully.
- Logs time a record is received and the sender's address. Also logs the type of data that received records contain i.e. images, text and/or voicemail.
- Logs all exceptions.
- Logs when the network connection is lost or regained
- Logs the progress of a call from setup to termination

- Trace files log redundant data to compliment information that is logged to database.

After the above revisions were made to MuTI, it was extensively tested in the laboratory to ensure correct performance. Once the testing for MuTI was complete, training material was prepared. In addition, a user manual for MuTI was created with accompanying screenshots to provide assistance to the users. That concluded the *Action Implementation* phase of the third project cycle. In the *Action Evaluation* phase, we tested the second version of MuTI in the field as described below.

5.1.2 Evaluating the Second MuTI Prototype

In order to evaluate the revisions made in MuTI, we undertook another field trip to Tsilitwa in the *Action Evaluation* phase of the third project cycle. Here, we demonstrated the new version of MuTI to the participants in the project. We also re-trained these participants to use the updated version and finally conducted another testing session to ascertain whether the new version of MuTI was functioning correctly across the network from the clinic to the hospital. We used semi-structured interviews, field notes and observations to gather feedback about the second MuTI version and collected trace files as well as database data about the first version of MuTI installed in the previous project cycle. The sections below describe the participants in the evaluation phase, the data gathering methods used and then the results using these methods.

Participants

The participants were two health care professionals working in Tsilitwa and Sulenkama respectively as described in Section 4.4.3. Next, we describe the interviews we conducted in this project cycle.

Semi-structured interviews

A single semi-structured interview was held with both the participants present. The MuTI Evaluation Questionnaire upon which the interviews were based can be viewed in Appendix A.1.3. The interviews were recorded using a Sony digital audio recorder. All participants were made aware that the personal interviews would be recorded and transcribed. The interview was conducted in the meeting room of the Nessie Knight Hospital in Sulenkama. The use of this room was limited to the sole use of the researcher and the participants for the time taken to conduct and conclude the full interview. Both the researcher and participants gave clarification when comments or questions were unclear to the other party. We now move on to describe the demonstration and training sessions in the evaluation phase of this project cycle.

Demonstration and Training

Each participant took part in a demonstration and training session lasting about one hour and a half. During this session, the new version of MuTI was demonstrated to show different scenarios of usage, repeating much of what was done in the previous project cycle. Two laptops were connected using a cross cable, one to mimic use at the hospital and the other to mimic use at the clinic. The setup for the demonstration has been explained in Section 4.4.3. After an initial demonstration, each participant was then walked through usage of the system by one of the two researchers present. The researchers's role here was merely to instruct the participant on how to perform a function and then to observe the participant undertaking the action themselves. Help and clarification was provided on request from the participants. During this training session, participants performed the same tasks as in the training session of the previous visit as depicted in Section 4.4.3.

Participants were also shown how the system performs when the network connection is broken. This was simulated by disconnecting the machines from one another by removing one of the laptop's cross cable connection. The re-connection was then simulated by reconnecting the cable. This was done to show the nurse and the doctor how to create records and how these records are sent when a connection becomes available.

Testing across the network

After the demonstration and training sessions were complete in the third project cycle, the laptops were re-installed at the hospital and clinic sites respectively. The purpose of this was to ensure that the system was working correctly across the network and that communication between the clinic and the hospital was possible using MuTI. Also, several bug fixes for MuTI were applied to each laptop's version of the software. For the testing session, MuTI was first set up to run at each of the two sites.

Once this was done, each version of MuTI was configured with an account and a contact denoting the other site, as described previously in Section 4.4.3. On the clinic end, one researcher and the nurse were present and at the hospital end, two researchers and the doctor were present. Once the system was installed, the previous telemedicine VoIP phone was used to inform the clinic side of the test that the hospital was ready to being the testing session.

MuTI was started at both ends and the participants were instructed to try out using the system. At the clinic side, the first thing the nurse did was view the message that was sent by the doctor earlier on that day. Note here that this message was sent of the doctors own accord to test out the system. The nurse viewed the message in the Inbox and listened to the voicemail that the doctor had sent. The second thing the nurse did was call the doctor using MuTI. She called the doctor several times, each time with him answering the call. The last time she called towards the end of the experiment, the call was not answered so she received a rejection message. The doctor performed the following tasks: calling the nurse, answering a call from the nurse, sending the nurse a record and viewing a received record. This concluded the testing session. In the following section, we describe the type of trace data we collected during the third project cycle.

Trace Files and Database Data

The first version of MuTI was instrumented to log events to a trace file and to log minimal statistics to the database. On the field trip for the third cycle, the trace files and the Microsoft Access database were inspected to see how the system had been used. The next section reveals the results of the third cycle's *Action Evaluation* phase.

5.1.3 Results and Data Analysis

The data gathered was analysed to determine the results of the actions undertaken for the third project cycle. We were able to gather feedback on the first MuTI prototype from the log files and first impressions of the second version of MuTI. First, we discuss the results from the interview. Next, we describe the observations made by the researchers during the demonstration, training and testing sessions. Lastly, we describe the results from the quantitative software measures recorded in trace files and the database logs.

Interview Data

The audio taped interview, described in Section 5.1.2, was transcribed verbatim by the researcher. The transcription revealed the following themes. It became evident that the main problems hampering use of MuTI were not directly linked to the software implementation. For instance, the first version of MuTI was rarely used due to lack of time by the doctor. This is aptly illustrated by his reply when asked about using the MuTI system in general:

Doctor: *To work the system, I don't have time...to see the whole hospital, to attend the hospital,* *the patients in the wards. There are 200 beds, private ward, OPD [Out Patients Department]...almost 100 patients daily, emergencies during the day, theatre. I am only one.*

He indicated that even if the system was working one hundred percent of the time, he still would not use it due to lack of time. For instance, when there is an incoming call on the CSIR system, the nurses at the hospital always notify him. However, he is mostly unable to answer the phone during the day as he is preoccupied with other activities. This is compounded by the fact that he may also be some distance away from the computer room where both the CSIR VoIP phones and MuTI are located. He suggested that if there were more doctors at the hospital then the system would be used more because the doctors could have a rotating schedule to share the responsibilities of the telemedicine system.

Both the doctor and the nurse also claimed that they had not used the CSIR system since our April visit, since the network was not working. We also noted here that the CSIR webcam was now out of order and that the digital camera had not been fixed since our previous visit.

However, both participants remained positive about the advantages of MuTI even though they had not made an effort to use the system in practice. They still indicated that it will be an improvement on the previous system as shown in the two excerpts below:

Researcher: *Do you think you would be able to service more clients than the previous system [using MuTI]?*
Nurse: *Ja, I think we will because with the previous system, you know, if I don't get the doctor, I don't get the doctor. And it is closed. With this one, there is that possibility of leaving a message at the doctor so I think maybe it is better.*
Doctor: *It's out of the question, its going to be better that system. No doubt about that.*

Researcher: *What about specifically the features of MuTI compared to the features of the older, the original system?*
Doctor: *It's advanced alot, in comparison to the old system. It's advanced alot because it can receive the records for the patient - I don't have to be present in front of the computer. I can receive remote messages with the system. And I will be able to attend the computer in my free time.*

The basic functionality of the system was found to be sufficient to allow a diagnosis as shown from the interview:

Researcher: *Besides the voicemail, the comments and the images, is there other information you would like to include in the message that goes to the doctor?*
Nurse: *I should think that is enough.*
Researcher: *Is there any extra stuff you would want to send to her [refers to the Nurse]?*
Doctor: *What I said that previous time, it's enough to make a diagnosis. It's never going to be perfect but to see a patient in front of me [but] this information I can work with.*

From the interviews we also discovered that both participants preferred using the headset as opposed to the CSIR VoIP phones as they allow one to type, talk and listen at the same time. Also, as already indicated in the second project cycle, they did not see an immediate value in adding video conferencing but concurred that this was because they had not experienced high quality video conferencing. In addition, we discovered in this project cycle that the power problems are better in winter when there are no strong winds or rain. This was supported by the fact that neither the nurse nor the doctor had the need to use the spare batteries for the laptops. Lastly, the interview revealed that the doctor would be leaving Sulenkama in October to return to Cuba. To our knowledge, the Department of Health (DoH) did not have a replacement doctor to take over from him and it was not certain when another doctor would be appointed to the Nessie Knight Hospital. Next, we describe the results we gathered from our observations of participants during the demonstration, training and testing sessions.

Observations

The following ideas for revising MuTI arose from observations of the doctor and nurse using MuTI during the demonstration, training and testing sessions. We felt that the log in screen should be removed as it is not necessary to support multiple user profiles at this stage. Moreover, we found that feedback on when there are new messages in the Inbox needed to be improved. An idea for future work which we identified would be to add Short Message Service (SMS) (defined previously in Section 2.3) notification to recipients of messages to make them aware that new MuTI messages have arrived for them. We also decided that when a call is not answered, voicemail should be provided.

In general, as noted in the second project cycle as well, we found that the interface needs to be improved by removing the buttons and replacing them with a toolbar and adding icons as well as tooltips. Lastly and most importantly, we realised that received records should display both the time that the record was sent at as well as the time the record was received at. This would allow participants to gauge the delay between when the message was sent and when it was received. These are the major ideas for revision that arose from the observations. Below, we describe the data we collected from the trace files and database data which gave us insights into the first MuTI prototype. Recall from Section 3.3.2, that the trace data only feeds back into the project cycles, one cycle late.

Trace Files and Database Data

The trace files indicated that the usage of MuTI was almost nil as shown in the graph in Figure 20. In a 2 month period, the doctor had only used MuTI on 3 days, 6 times on one particular day. The nurse had used MuTI more often, on 8 days in total and only about once on each of these days. By 'use' in this case, we mean that both participants opened up and logged onto MuTI but did not use MuTI to perform any tasks.

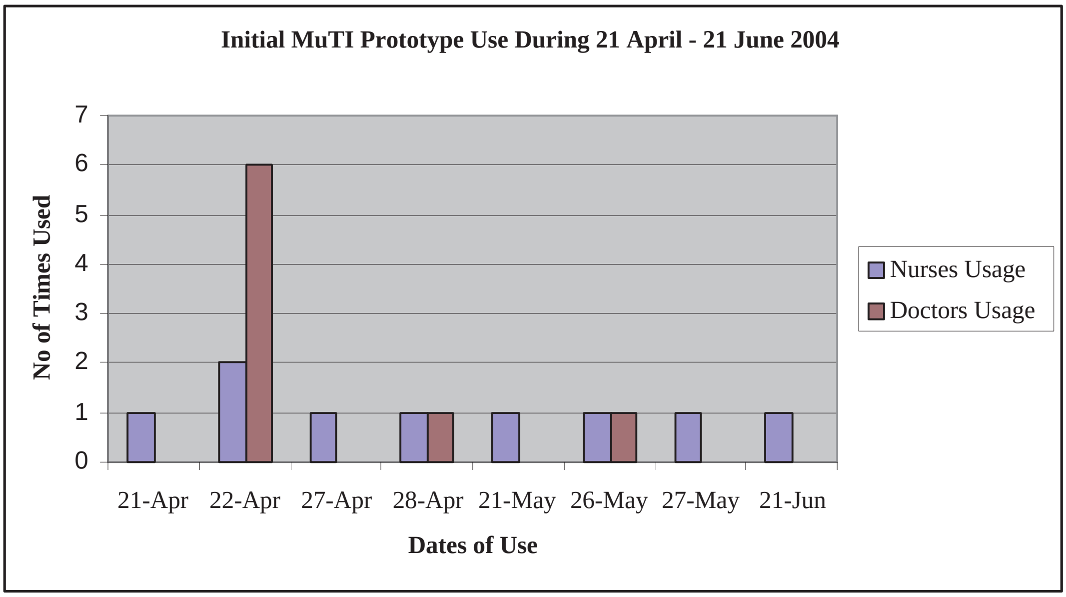


Figure 20: Graph showing the number of times MuTI was used in the two month period following the first installation. Overall usage was extremely low, with the nurse using the system only nine times in total and the doctor using it eight times. There were only 3 days when a synchronous communication could occur.

Inspection of the databases at the clinic and the hospital revealed that no MuTI records had been created or sent by either party. Additionally, no calls were placed by either participant. The fact that the participants took the time to open MuTI was positive in that it indicated that they did have an interest in the system. From the logs, it was evident that a synchronous communication was only possible on three days of this evaluation period, i.e., both participants only had MuTI open on the same day three times. In all, it was disappointing to see that they had not actually communicated with MuTI during the evaluation period. This also showed us that the participants opinions about MuTI gathered from the interviews were not based on practical use of the system. We now discuss how we worked with our external allies in the third project cycle.

5.1.4 Working With Our External Allies

A subsidiary goal of the third cycle was to once again engage allies that were not directly involved in the main project. Therefore, during this project cycle's field visit, several meetings were held with our external allies. We met again with the district manager for the DoH for Tsilitwa-Sulenkama district. On this occasion, we demonstrated MuTI to the DoH and informed them of our progress. Additionally, we participated in a larger meeting with the DoH, the CSIR, the Tsilitwa community leader and nurses at the Tsilitwa clinic.

The aim of this meeting was to encourage DoH support of the staff at the clinic and the hospital to use MuTI and to show them how MuTI may be useful for telemedicine in the Eastern Cape (EC). A further action we undertook here, not part of our original plans, was to introduce ourselves to the community leader and lastly, to meet with the CSIR to update them on our work. As discussed in Section 4.4.5, as part of re-aligning the project with RA/RI, we seized the opportunity to meet with the community leader to gain his support for the MuTI project. Bridges.org had suggested that without the community leaders support, the project would have a smaller chance of success. The results of these meetings are presented in the following section along with the reflections made about the third project cycle.

5.1.5 Critical Reflections

Based on the results received from the evaluation of the actions for the third project cycle, the following conclusions were drawn.

Infrastructure and Equipment

Regarding infrastructure and equipment, the wireless network was found to be failing quite frequently. The Uninterrupted Power Supplies (UPSs) were still faulty and often the network had to be reset manually, as we found in the previous project cycle as well. This may have influenced our results as it appeared the network was not functioning for the full evaluation period. At this stage, the digital camera was still out of order and it seemed that there were no plans to fix it. We therefore decided that we should provide the nurse with a new camera so that we could test whether the inclusion of images in MuTI records was useful to the participants.

Software

With respect to MuTI, there were many factors preventing the use of MuTI that had little to do with the software. This included the doctors busy schedule and frequent network failures. This may be why the data collected revealed there was no activity on MuTI by either of the participants during the evaluation period. We did, however, discover many improvements that could be made to enhance MuTI from the results of the demonstration, training, testing sessions, interviews, field notes and observations we made during the third project cycle's field visit. For example, we realised that there was no need for the logging in screen or multiple user profiles in MuTI at this stage as there were only two participants and this slowed down their activities. Also, we found that it was necessary to include the sent time for MuTI records so that participants could tell how long the period was between when a message was sent and when it was received. We decided to resolve these issues in the next project cycle.

Socially Aware Computing

With respect to reflections on our socially aware computing approach, several drawbacks were revealed. We found that although the participants were enthusiastic during the interviews about the system, they did not actually use the system. Thus, we realised that much more support and encouragement was required from the researchers to help the participants try MuTI properly. We decided that in future cycles, we would increase SMS (defined in Section 2.3) and phone contact and attempt to decrease the time periods between field visits. Already, during the field visit in this project cycle, with a little extra encouragement, the doctor sent the nurse a MuTI message of his own accord — a positive outcome.

Allies and Local Champion

Our reflections regarding engaging our allies, external and internal, revealed that we made a major breakthrough with the Tsilitwa community leader. We were extended an open invitation to continue our work in Tsilitwa by the community leader, indicating that we were not viewed as a threat to the community. We suspected that this was largely due to our local champion, the head nurse of Tsilitwa. Based on this, we surmised that the relationship we were building with the community in general was strengthening and that we were addressing the RA/RI issues appropriately. Also, we deduced that the head nurse was still convinced that MuTI could improve communication for health in the area. At this stage, we found that she was still reluctant to train other nurses to use MuTI but we decided at this stage that we would not press this issue. Recall from Section 4.4.5, Bridges.org had encouraged us to train more nurses how to use MuTI so that in the event of staff turnover, skills would not be lost.

From our meetings with the other key players the DoH and the CSIR, we were less successful. We were not able to persuade the DoH to appoint more doctors to Nessie Knight Hospital. However, they did realise that staff needs to be increased at the clinic. Moreover, we were still not certain at this point if we had secured support for MuTI from the DoH. Recall that soliciting the DoH was important in order to make the project sustainable although this was not a major focus of this project. In all, we remained positive after the third cycle of the project and prepared to continue improving MuTI for the fourth cycle as described in the following section.

5.2 Final Revisions to MuTI

The goal of the fourth cycle was to further revise MuTI according to user needs and to once again evaluate the revised version. However, we were informed at this stage that we would no longer be able to work in Tsilitwa. This was due to a conflict of research interests between the CSIR and ourselves. The CSIR felt they wanted another opportunity to improve on their telemedicine system without our system interfering with their results. Consequently, we were to terminate the project sooner than planned in October 2004.

We planned an exit strategy to inform the community members of this early termination. This was particularly important since we were also asked to remove all our equipment and MuTI from the premises of both the hospital and the clinic. Our *Diagnosis* was to revise MuTI one final time and to evaluate the final version over a one month period before terminating the project. The exit plan was to inform the community that we were leaving the Tsilitwa project and to collect final sets of data spread over two field trips. We decided that utilising two trips to end off the project would lessen the impact of this abrupt departure. As in the previous cycle, we planned and implemented changes to MuTI in the *Action Planning* and *Action Implementation* phases of this cycle. We also undertook a field trip to introduce the second revised MuTI prototype, evaluate the community response and begin implementing our exit strategy to terminate the project.

5.2.1 MuTI Revisions

From the reflections made in the third cycle, we identified several more revisions for MuTI. First, we had to simplify MuTI by removing the support for multiple user profiles. Since we only had two target users at this stage, removing the logging in screen and implementing a default user profile became more appropriate for the test sites. This revision was also in line with the principle from Section 2.4 of keeping things simple. Even with our fairly simple prototype, it seemed that further simplification was required. We also discovered from observations that the creation and sent time should be displayed for all patient records. In this way, the doctor and nurse could tell how long ago a message had been sent as opposed to when it was received. Finally, we added an icon to indicate if a voicemail was included in a patient record and we improved the labelling of the recording buttons to eliminate confusion about how to stop recording a voicemail. In the following section we describe how we evaluated this third version of MuTI.

5.2.2 Evaluating the Third MuTI Prototype

In the fourth project cycle's field trip in September 2004, for data collection purposes, we once again conducted interviews with the nurse and the doctor. In addition, we purchased a digital camera for the nurse to use since the previous camera was not working. We provided training for the nurse showing her how to take pictures, how to download them to the laptop and send them using MuTI. We also installed and tested the latest version of MuTI and collected the statistics of MuTI usage from the previous cycle. The results of our data gathering techniques are discussed next.

5.2.3 Results and Data Analysis

We re-tested basic communications using MuTI in the fourth project cycle but since there were no major changes there was no need for another demonstration or training session during this visit. The results from this stage were positive. Participants used MuTI for both synchronous and asynchronous communication for the first time. The support we provided since the previous cycle seemed to have influenced the participants and encouraged them to use MuTI. Next, we describe the data we collected from the interviews we conducted as well as from the trace files and database logs.

Interview Data

The following information was gathered from the interviews. The views of the nurse were very similar to the doctors so only excerpts from the nurses interview have been provided to illustrate the users views. We found that the nurse and the doctor had set up a weekly meeting time for telemedicine consultations. In addition, we discovered that the nurse was pleased that we had brought a replacement camera and was excited about using it to send images with MuTI. Using MuTI, the nurse estimated that about 4 patients could be helped during the weekly consultation. She felt that using the old system she could help approximately the same amount of patients. However, with the old system, only a direct communication was possible whereas MuTI had the additional feature of allowing her to leave messages and receive a response at a later stage. This is illustrated by her words:

Researcher: *When you use MuTI, how many patients per week is the doctor able to help with?*
Nurse: *Four.*

Researcher: *Are you able to help more patients with MuTI than with the other system?*
Nurse: *I think it's the same.*

Nurse: *But with MuTI you are able to leave...to send a message and get a response.*

The nurse told us that the doctor only called her with MuTI during the weekly consultation but arranged times on other days to leave messages. MuTI records were sent about 3-4 times a week. If a message was sent to the doctor when he was busy then he usually responded the following day. The nurse was appreciative of this quick response time given the doctors busy schedule.

Researcher: *And when you send a record with MuTI, how long is it before you receive a reply?*
Nurse: *No maybe if I didn't get the doctor then the next day he responds.*

We also discovered that when the nurse sent a record, she usually includes a voicemail with the following information:

Researcher: *When you send a record with MuTI, do you usually send a voicemail?*
Nurse: *Yes.*
Researcher: *If you send a voicemail, what information do you usually include in the voicemail?*
Nurse: *I include the problem with the client, the problem that the client is presenting.*

The nurse clearly preferred voicemail over typing. It was interesting to note that the voicemails sent back and forth either contained patient data or merely messages to rearrange meeting times. Overall, the nurse was content with the information she could send in a MuTI record and felt no other information was necessary for a record. Additionally, she found it helpful to be able to see if the doctor was available or not using the presence information. The doctor mentioned that the video camera forming part of the CSIR system had not been working since April. He changed the view he expressed in the previous project cycle saying that he now felt that video might be useful but with the poor quality and delays in the present system, it was not of a high enough quality. He felt that with the previous system he was able to help more patients but this was because at that time there were 2 doctors at the hospital. This meant he had had more time to use the CSIR system.

The doctor also enjoyed the fact that MuTI was run on the laptop since it was portable. He had used MuTI in his office and on several occasions had also used MuTI at home. Another interesting discovery was that the power problems were not as severe as we had originally assumed. In fact, the spare batteries provided for the laptop in both the clinic and the hospital had never been used to date.

Additionally, the doctor told us that he mostly used the call feature in MuTI during this evaluation period but he did feel that MuTI was also useful because it allows you to store and send messages in your own time. Finally, the doctor once again suggested to improve MuTI, one could link up more hospitals so that more doctors could share the burden of answering and responding to records.

Trace Files And Database Data

The trace files indicated that both the hospital and clinic had actually used MuTI during the period from June to September. 'Use' in this context meant they had created and viewed, sent or received records. In addition, it means they had placed calls to each other even if these calls were not always answered. In fact, the clinic showed activity on MuTI on 31 occasions and the hospital showed activity on MuTI on 13 occasions. This was positive in that we could now confirm the opinions expressed in the interview data since this time the participants had actually gained practical experience with MuTI. Next, we mention several bugs in MuTI that came to light in the fourth project cycle.

Bug Discoveries

From the interview data, we discovered that the following high level changes to MuTI were required. The custom peer to peer file transfer system was still performing inefficiently and this indicated that it should be replaced with a standard service such as File Transfer Protocol (FTP) to make file transfers more efficient. Also, the doctor pointed out that the interface for the image viewer was problematic since the buttons to change the image size disappear if you scroll to the far right and bottom of the screen. This again indicated he had actually used the system in this project cycle. Due to the premature termination of the project, we were unable to make these changes to MuTI. In the section that follows, we discuss how we implemented the first part of our exit strategy.

Implementing the Exit Strategy

In the fourth project cycle's field trip, we implemented part one of our exit strategy. This meant we informed all the participants of the impending project termination and why the project was going to finish earlier than planned. The nurse did not respond well to the news. In particular, she was distressed that we were planning to remove the equipment we provided and with it, MuTI. Moreover, she felt that such a decision lay in the hands of the community and that the research conflicts between our project and the CSIR's project was not a community concern. In her opinion, MuTI was a superior solution to the old telemedicine system and she was reluctant to relinquish use of a system which she felt might improve health care service delivery in the area.

The community leader was not displeased with us as we expected, given that he had in the past been obstinate in dealing with the CSIR. In fact, he was only unhappy that the CSIR had not discussed the research conflicts with him so that he could have influenced our decision. However, in all, he supported our decision to leave. The doctor was the most understanding about our reasons for terminating the project. This could be because he was due to return to Cuba in October 2004, the date set for the project termination. Part two of the exit strategy was implemented in the final project cycle. This entailed removing the equipment from the hospital and clinic sites and wrapping up the relationship with the community. The reflections we made from this fourth project cycle are described next.

5.2.4 Critical Reflections

From the fourth project cycle, no major reflections were made regarding the network infrastructure or equipment. We did, however, make the following critical reflections regarding MuTI, the socially aware computing framework and our allies. In general, we found that MuTI had been used in the period from June to September. The additional support and encouragement we provided to participants since the previous cycle seemed to have a positive influence on the participants. Even so, the results may have been negatively affected by the network which was unavailable for a large portion of the evaluation period. In fact, when we arrived for the September field trip the network was down and the Uninterrupted Power Supply (UPS) devices had to be reset.

During the period of evaluation from June to September, one synchronous voice call was made between the clinic and the hospital. Also, several MuTI records were sent back and forth between the two sites. In most cases, we found that the doctor preferred to have a synchronous voice communication if that were possible. For him, asynchronous communication was a last resort and useful only if a synchronous voice teleconsultation could not be arranged. One of the main decisions we made here regarding MuTI was that, due to the pending project termination, we would not revise MuTI further. We also planned to allow for one final month long evaluation period to see how the digital camera was used before implementing part two of the exit strategy; i.e., removing all the project equipment which included laptops, headsets, spare batteries, switches, a digital camera and cables.

With respect to our methodological process, we confirmed the value of triangulation of data at this stage. We found that the log files showing what the participants had actually done, differed by a large margin from what they perceived they had done in the interviews. Lastly, regarding our allies, we felt ,given the fact the network seemed to be quite unreliable, there was a definite need for a reliable ally that is always present in the field to deal with minor problems and ensure that the project runs smoothly. This is in agreement with the principles described in Section 2.4.

In our project, we initially solicited one of the network maintenance staff to fulfill the role of the local ally. This was because he was involved in the CSIR project and had a detailed knowledge of how the network functioned. Furthermore, he attended many of the workshops held with the CSIR. This meant that he could function as an ally and provide us with community feedback on ideas discussed at these workshops which were held in Pretoria, the capital of South Africa.

However, as the project progressed, this ally became more despondent about the project as the CSIR did not remunerate him for his maintenance work as they had initially promised. Also, as he was not directly involved in health care, he may not have been the ideal choice for a local ally. By the time of the fourth project cycle, he did not feel motivated enough to inform us about the frequent network failures. We decided, at the time, that since the project was due to terminate, we would not engage any other local allies to take over the schoolteachers role. With these ideas in mind, we began planning our last field trip in the sixth and final project cycle as described in the following section.

5.3 Project Termination

The *Diagnosis*, *Action Planning* and *Action Implementation* phases of the final cycle mainly revolved around planning how to extricate ourselves from Tsilitwa with minimal consequence to the community. This was not an easy task as the project was terminating abruptly. We did not plan or implement any changes to MuTI in this last cycle. Instead, we focused on strategies to inform the community of our departure and to remove our equipment from the project sites. We planned a final field trip to collect all the remaining data for the project and to implement the project closure.

During the sixth and final project cycle, we conducted our last interviews with the nurse and the doctor. These were informal and not audio-taped. We also removed all equipment and MuTI from Tsilitwa. As part of our plan, we ensured that both the nurse and doctor were provided with copies of all important data and ensured that any sensitive material was destroyed. Additionally, we held a final meeting with all the community participants - including the network maintenance staff and the nurse. Once again, we explained the different research agendas and the need to separate to a new site.

The nurse finally accepted our decision to move to a new site although she reiterated that MuTI worked better than the old system. She also felt that we had not adequately clarified the ownership of the laptops at the onset of the project. The doctor was happy that he had participated in the project as his final contribution to the community before he returned to Cuba. In all, the project ended on a positive note even though the community was reluctant to see the project end, they were understanding but sad to see MuTI removed. In the following section, we describe the results gathered from the last project cycle.

5.3.1 Results

No major data from observations were collected in the final cycle and the interviews were very short and informal, yielding no additional data. The following section describes the results gathered from an analysis of the trace files and database data for the period between September and October.

Trace Files and Database Data

From the trace files, we discovered that MuTI usage for last period between September and October was extremely low. The nurse had created about 20 patient records but had only sent 3 to the doctor. The doctor, on the other hand, created only 2 records and sent none to the clinic, not even responses to the records received. Several call attempts were made from the clinic and the hospital but none of these were successful. Here, 'call attempt' means a call that was placed but not necessarily answered by the callee. It is assumed that in each of these cases, the callee was unavailable to take the call because they were too busy. The results were positive in that they indicated that the participants still made an effort to use MuTI in the last evaluation period, even though use declined from the previous project cycle.

5.3.2 Critical Reflections

Again, from the last project cycle, we did not draw any major inferences about the network infrastructure. On the equipment front, we did find that, as expected due to the short period of time the system was used, the digital camera we provided in the fourth project cycle was not utilized at all. Pictures were taken of patients but none were sent to the doctor. We assumed that the nurse had practiced taking pictures but did not have a chance to send them to the doctor. Regarding the software, we found that MuTI usage for the last cycle declined sharply from the previous evaluation period. This period was not a good period for MuTI usage for several reasons. Firstly, for 2 weeks of the month from the September visit to the October visit, the network was not working. Secondly, the nurse took 2 weeks of bereavement leave. Also, the doctor was busiest during this period since he was preparing to return to Cuba. These factors coupled with the fact that we had already informed both parties that the project was terminating led to poor results. Thus system usage sharply declined during this time.

Despite the problems, the project ended on a positive note. With respect to the socially aware framework, we make the following reflections. Eventually, the nurse and doctor accepted the fact that the MuTI project was coming to a close. They were reluctant to let us take the software and equipment because they felt MuTI offered a better solution to the previous telemedicine system. Also, the nurse felt we had not clarified the fact that all equipment would be removed at the close of the project. We decided that in future projects, we would have to ensure that all participants understood the principles of research and that ownership issues were clear at the onset. All participants were pleased to hear we would attempt to remain in the Eastern Cape continuing our work with MuTI and communication for health care. Again, we found that a local champion is key to project success, not only in helping to bring about community buy-in to the project but also in terms of driving the project forward. Our local champion at this time, the head nurse, was away for 2 weeks during the evaluation period and that brought the project largely to a standstill, until she returned.

Additionally, we found that cultural factors seem to play a part in the iterative cycles for software revisions. At all stages, during all interviews and discussions, both the Xhosa nurse and the Cuban doctor seemed reluctant to criticize the MuTI interface. This was not helpful in revising the user interface. Also, they generally exaggerated how much they used MuTI as proved by comparing what they said in the interviews with data from the trace files. However, in all, we felt that MuTI was an appropriate telemedicine tool for Tsilitwa and the remoter rural areas in the Eastern Cape with similar conditions.

At the end of the final cycle, we derived no new major reflections about our allies. Chapter 6 discusses the overall results gathered during the entire research project. This includes results regarding usage of MuTI, use of our socially aware framework and how telecommunications policies affect the applications one develops for rural and underserviced areas.

Chapter 6

Discussion of Results

The previous chapter discussed how we refined the Multi-Modal Telemedicine Intercommunicator (MuTI) prototype in the last three project cycles as well as how the project was terminated. This chapter describes the final outcomes of the project. First, in Section 6.1, we describe findings regarding the previous telemedicine system implemented in the target area, in order to place the findings about MuTI in context. Next in Section 6.2, we discuss how MuTI performed. In particular, we describe the final results collected from the trace files and database logs as well as the interviews conducted with the project participants and observations made by the researchers. We also discuss the overall findings about telemedicine for the Eastern Cape. In Section 6.3, we discuss our results with respect to the socially aware computing framework. Section 6.4 draws out our observations about how telecommunications policies affect the technologies one can use in rural and underserviced areas. Finally, we end the chapter with concluding remarks in Section 6.5.

6.1 Findings about the previous telemedicine system implemented prior to the MuTI project

To place our findings in context and to provide a base case for comparison, we first discuss the findings regarding the previous telemedicine system used in Tsilitwa and Sulenkama; the Council for Scientific and Industry Research (CSIR) system which was described in Section 4.1. From the baseline questionnaire administered in the beginning of the project, we found that the CSIR telemedicine system had been working from November 2003. We also discovered that there was a definite need for telemedicine in the area in order to aid with the referral system, whereby patients that cannot be treated at the Tsilitwa clinic are referred to the Nessie Knight Hospital in Sulenkama.

Essentially, patients are referred if they present a problem that is beyond the knowledge of the nurses at the clinic or if they are afflicted with a serious injury, trauma or illness that requires hospital care. The nurse told us that she referred patients to the hospital on a daily basis and this was confirmed by the doctor. Both participants indicated that they would like to use the telemedicine system throughout the week as seen by the doctor's response:

Question: *How many times would you like to use the telemedicine system?*
Doctor's Response: *At least 3 times daily according to the perennial shortage of doctors at NKH [Nessie Knight Hospital].*

Participants claimed they used the CSIR telemedicine system two to three times weekly but that the network often failed for long periods of time. Since no trace data was available on the actual system usage, we could not verify this claim. However, from our experience with the MuTI project, we feel that it is unlikely that the system was used this frequently in reality.

The nurse and the doctor also specified that the CSIR telemedicine system could be improved. Problem areas they identified included the fact that the video was not clear, that there was a shortage of personnel to operate the system and that technical and power problems rendered the system unavailable fairly often. Moreover, the doctor found that the web camera was not ideal in the CSIR telemedicine system as it required a fair amount of manual maneuvering by the nurse during a telemedicine consultation. This was exacerbated by the fact that the CSIR Voice over IP (VoIP) phone is a separate device. Thus the doctor had to issue instructions over the phone, wait for the nurse to adjust the camera to point at the patient before going back to the phone for further instructions and advice.

However, both participants did indicate that telemedicine provided a valuable service. Here, it seemed that the participants were influenced by the promises of telemedicine to improve health care delivery in cases where a direct service is not available. However, the full benefits of telemedicine were never realised in practice since neither of the participants used the CSIR system frequently enough to discern the effects on the surrounding community.

Similarly, as we will discuss in the following sections, MuTI was praised as being a good telemedicine solution for the area by both participants but was never used frequently enough in practice to discern the full benefits of telemedicine. In the case of MuTI, this was because the participants had busy schedules due to the personnel shortages at both the clinic and the hospital so they had little time to use the system. The nurse described her feelings about the CSIR telemedicine system clearly as seen below:

Question: *What do you like about the existing telemedicine system?*
Nurse's Response: *It is cost effective and ensures service delivery as the patients don't have to go to the hospital to follow long queues.*

Overall, the CSIR system seen as useful with room for improvements. In the next section, we discuss the results pertaining to the MuTI project. MuTI was developed to overcome power failures and scheduling issues which rendered the CSIR telemedicine system unavailable for large periods.

6.2 Multi-modal Telemedicine Intercommunicator Evaluation

We collected several types of data to evaluate MuTI: statistics of usage recorded in trace files and database logs; data from semi-structured interviews and data from observations and field notes. This section presents our results regarding MuTI and discusses a triangulated view of the data.

6.2.1 Overall Use of MuTI

The graph in Figure 21 shows the overall usage pattern for MuTI from the time it was first installed in April 2004 until the project termination in October 2004. In general, the nurse at the clinic used MuTI more often than the doctor at the hospital. This may be due to the fact that the doctor was the sole doctor responsible for Nessie Knight Hospital during the trial period. This left little time for him to participate in the project, whether for asynchronous message passing or synchronous calls. As mentioned earlier in this dissertation, this means that to have a successful telemedicine system, one might require multiple doctors and even multiple nurses to operate the system.

Additionally, the low usage of MuTI indicates that when telemedicine occurs on a voluntary basis as in our project, it has a lower priority relative to paid work duties. This means new telemedicine systems may have a lower chance of success if there is insufficient motivation to use these systems. To increase the chance that a new system is properly adopted, suitable remuneration should be provided for health care professionals for using telemedicine services and telemedicine should be integrated into the job description for these professionals. The fact that one will be compensated for telemedicine services rendered provides motivation for staff to utilise a new system. This may be more reliable than relying solely on each individual's personal motivations to use a particular system, for instance, because they wish to help others or gain new skills, as in the case of the MuTI project.

From the graph in Figure 21, it is evident that the nurse at the clinic had more time to use MuTI since the clinic used MuTI more often than the hospital overall. This may be attributed to the fact

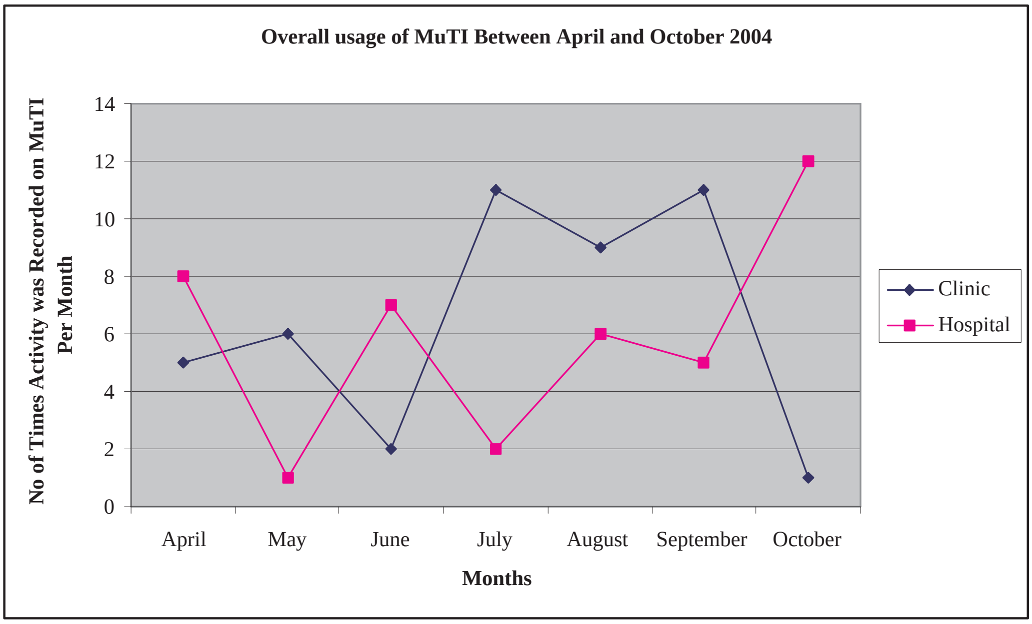


Figure 21: This graph shows the number of times MuTI was used per month for any activity by the clinic and the hospital during the project. Here, 'use' of MuTI here was defined as opening up MuTI, using MuTI to place or receive a call or using MuTI to view, create or send a MuTI record. From the graph it is clear that both the clinic and the hospital used MuTI very infrequently, from as low as just once in a month to around 12 times a month. At the clinic, the highest period of usage was during June and September whereas at the hospital, the highest period of usage was between September and October. Towards the end, usage at the clinic declined. This was most likely due to the head nurse taking a 2 week bereavement leave and being demotivated after hearing the project was due to terminate.

that there were several nurses at Tsilitwa clinic. This meant that the head nurse was free to use MuTI on occasion while the other nurses tended to patients. The fact that MuTI was used by the clinic indicates that the nurse had a high degree of personal motivation to utilise telemedicine since all use of MuTI was voluntary in our project. From the interviews, we found that this motivation stemmed from her desire to contribute to her community by ensuring the delivery of a good health care service. The nurse was also happy to participate in the project because it afforded her a sense of importance i.e. that her opinions were highly valued.

Towards the end of the trial period, the clinic usage of MuTI declined sharply. This can be attributed to the fact that the head nurse had taken a two week period of leave during the last evaluation period. Since none of the other nurses were trained to use MuTI, the system was left unused. Thus, although the doctor used MuTI the most during September and October, the nurse would not have been available to participate in synchronous or asynchronous communication for most of the last project evaluation period.

Other factors that may have affected the usage towards the end was the fact that the network was not running for a substantial period between September and October. Also, the fact that we had informed participants that the project was due to end in October may have caused demotivation and again, led to lower usage. Overall, we felt we had gathered sufficient data to make reflections on MuTI. Next, we discuss the results we obtained regarding the different components of MuTI, beginning with the synchronous aspects or Voice over Internet Protocol (VoIP) calls and covering the asynchronous aspects in Section 6.2.3.

6.2.2 Synchronous Aspects of MuTI — Calls

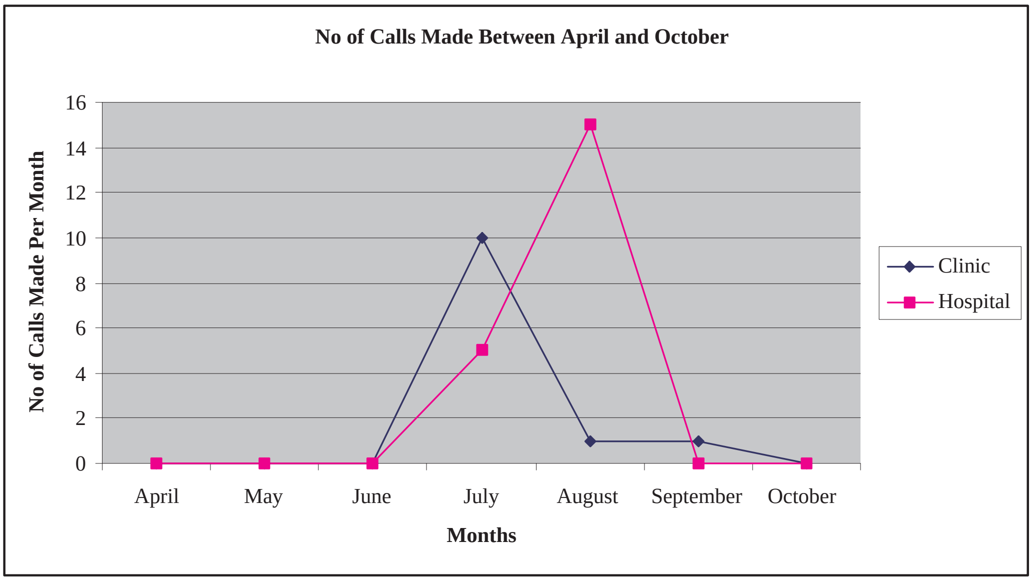


Figure 22: The graph shows the number of call attempts made per month by the clinic and the hospital during the project. A “call attempt” is any call that was placed to another party but which may not have been answered by the other party. It is clear that the doctor at the hospital was very eager to use this feature of MuTI by the high amount of calls he placed to the clinic between June and September. Similarly at the clinic, most call attempts were made during June and September. From the graph it is clear that the call feature was desirable as both parties attempted to place many calls, with the hospital placing a total of 16 calls in August alone and the clinic placing a high of 10 calls in July.

The synchronous aspect of MuTI, i.e. the voice calls enabled via VoIP, was used mainly between June and September as seen in Figure 22. Both the clinic and the hospital made a number of call attempts during this period. In fact, the clinic made a total of 12 call attempts and the hospital made a total of 20 call attempts. By 'call attempt', we mean a call that was made but which was never answered by the callee. In fact, from an examination of the log files, it was evident that only one synchronous communication occurred during April and October. This occurred on 14 July during what is presumed to be a pre-arranged telemedicine consultation between the doctor and the nurse.

The clinic placed two calls to the hospital on this day and the hospital placed one call to the clinic on the same day. All the calls here were answered by the callee and at least 2 minutes of connection time was recorded. This shows that a synchronous telemedicine consultation is possible using MuTI and that the doctor and the nurse were sufficiently motivated to use MuTI for this purpose on at least one occasion. The short duration of the call indicates that the consultation may have been cut short or the participants may have switched to using the CSIR VoIP phones, the latter point will be elaborated on later in Section 6.2.4.

In all, the total number of call attempts made indicate that voice calls are an essential part of MuTI which both participants were eager to use. These results also indicate that a synchronous voice communication may be preferable to an asynchronous communication. This may be because it is often easier to communicate information verbally, if both parties speak the same language. Synchronous communications would only work if there are sufficient personnel in both the hospital and the clinic — meaning less frantic work schedules and more time to schedule synchronous appointments — and if the network is reliable. If the network and power in this project were not problematic at all and if there were no personnel shortages, we feel that this aspect of MuTI may have been utilised more extensively.

In comparison to the feelings expressed about the CSIR telemedicine system, MuTI was seen as a positive step to improve telemedicine in the Tsilitwa-Sulenkama area. The interview data confirmed the trace data about the MuTI VoIP component as we discovered that both participants liked the idea of the synchronous aspect of MuTI. Both the doctor and the nurse claimed the call feature in MuTI enabled them to call each other if they had the time to have a synchronous telemedicine consultation.

In the logs, we found only one day where a full synchronous communication occurred using MuTI. However, the data we collected still suggested that the synchronous aspect of MuTI was valuable, since many attempts to call each other were made even though almost none of the calls made were answered by the callee. Therefore, telemedicine systems should aim to provide a synchronous avenue of communication if possible. In the following section, we discuss the results we obtained with respect to the store and forward component of MuTI, i.e., the asynchronous aspect or exchanging of MuTI records.

6.2.3 Asynchronous Aspects of MuTI — Patient Records

With the asynchronous aspect of MuTI, i.e., creating patient records with text, voicemail and images, the results were positive. During the evaluation period, the clinic created a total of 35 records and the hospital created a total of 11 records, as seen in Figure 23. Out of the records created, only about half were actually sent to the other party in the project as seen in Figure 24. This may be because records were created to edit later or to send at a later stage. From the trace files and the database, it was evident that almost all of these patient records contained a voicemail and only a small proportion contained textual information. This again indicates that conveying information verbally was found to be quicker and easier than typing.

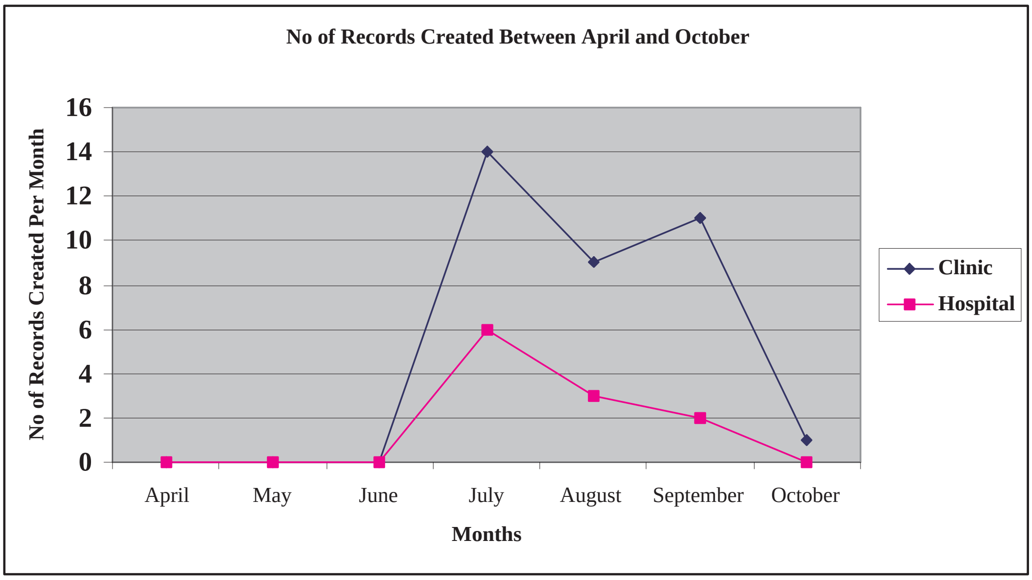


Figure 23: This graph shows the number of records created per month by the clinic and the hospital during the project. From the graph, it is clear that both the clinic and the hospital created records mainly during the June to September period before the decline in October. Also, we can see that the clinic was more proactive in creating records than the hospital.

Unfortunately, the trace results regarding the inclusion of images in records are minimal and

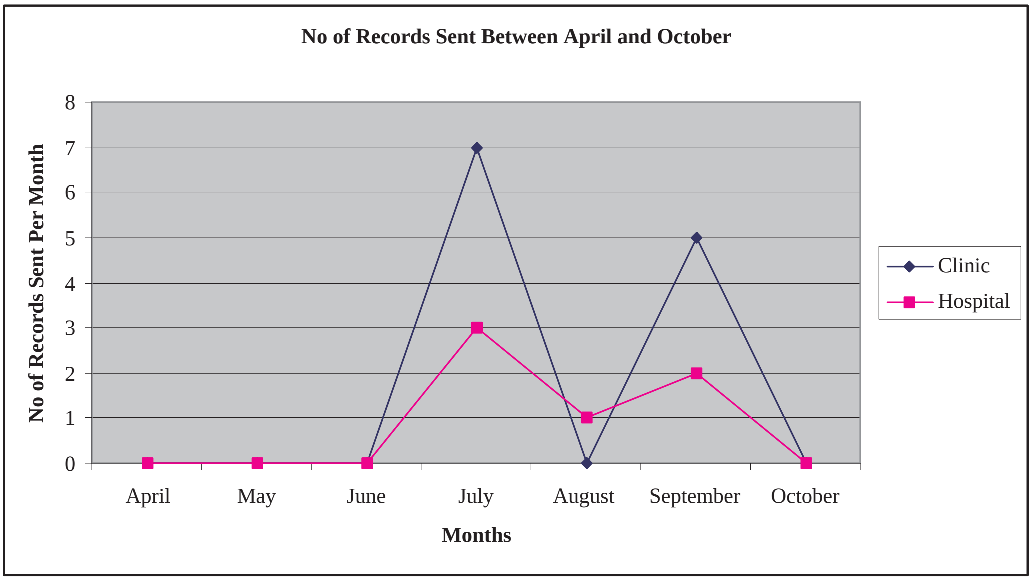


Figure 24: This graph shows the number of records sent per month by the clinic and the hospital during the project. There is a large disparity between the number of records that were created by each party (seen in Figure 23) and the number of records actually sent off to the other party. For instance, the clinic only sent a total of 11 records and the hospital sent off a total of 6 records. However, the clinic created well over 7 records and the hospital created over 6 records. This may have been due to the participants experimenting with creating records in order to become familiar with making a record. It may also be attributed to the fact that records may have been created as a electronic backup and not for referral purposes. Other factors affecting the number of records sent might have been network and power failures where parties did not attempt to send records because the system showed the other party as 'offline'.

inconclusive. The clinic only had a working digital camera between September and October and during this one month period, the nurse participating in the project was away for two weeks. Additionally, the network was not functioning for large portions of the last one month evaluation period. We do know that the nurse did take several pictures of patient ailments between September and October when she was provided with a digital camera. However, she did not attach or send any of these pictures to the doctor.

In the interviews, both participants indicated that they would prefer high quality still images over low resolution video. This suggests that it may not be necessary for telemedicine systems to offer video conferencing since high resolution still images and voice alone may be sufficient to convey the data required for remote teleconsultation. Overall, the interviews confirmed that the asynchronous aspect of MuTI was helpful as illustrated by the nurse's response to the question below:

Researcher: *So you don't use it [MuTI] when he's offline?*
Nurse: *I do use it when he's offline. I've been sending him text messages, voice messages, he also could send them.*

This response indicates that presence information is a useful feature for telemedicine tools because it helps users identify opportunities to have a synchronous communication or when an asynchronous communication should rather be used. In the interviews, the doctor explicitly stated that he found the store and forward aspect of MuTI very useful, but only wanted to use this facility if a synchronous voice communication was not possible at all. This assertion was supported by the trace data which showed the doctor had placed many calls to the clinic but had created and sent few MuTI records. In addition, the doctor felt that if more clinics and hospitals were linked up with MuTI, the store and forward side would work more efficiently as more doctors would be able to respond to queries, as mentioned several times previously in this dissertation.

The doctor described how he found the store and forward part of MuTI useful through an anecdotal experience. Here, he described one instance where he had responded to a message from the nurse with a treatment for a patient. Later that same day, he recalled an extra piece of information that needed to be included in the treatment and was able to send off another record with this amendment which he saw as very convenient. In particular in the interviews, participants stated that voicemail was definitely a time saving aspect to MuTI since it meant that no typing was required in a patient record. This confirmed the trace data findings where we tabulated that most MuTI records contained voicemail and no textual information. This is aptly described by the nurse:

Nurse: *Talking is much faster than typing.*

The participants indicated that the voicemails they sent each other either contained information about patients or information regarding the telemedicine consultation times. This shows that voicemails may be useful for telemedicine as well as general coordination activities and even social communications. The doctor also indicated that he preferred MuTI over the previous telemedicine system because it requires less manoeuvering. Using the headset, one can talk and type at the same time. The doctor admitted that some manoeuvering of the digital camera was still required but that it was significantly less than with the webcam of the CSIR telemedicine system. This indicates that telemedicine systems should strive to utilise as few devices as possible in order to achieve their aims. Furthermore, it is therefore important to consider the effects of each additional device on a telemedicine consultation in terms of how much manual manipulation is required and whether this is easy or difficult to manage in the context of a particular consultation. With the MuTI system, the main additional devices were the digital camera and the headset. In future systems, a high resolution web camera may be easier to manipulate than an altogether separate digital camera.

Overall, the data we collected from the trace files and database indicated a low use of MuTI throughout the entire project. This was deemed to be a fairly accurate representation of system usage since it was a record of user activities. However, we found the interview, questionnaire and observational data painted a more positive picture of MuTI, being based more on the participants opinions than practical experiences. The quote below summarises the views of the nurse:

Researcher: *What do you like about MuTI?*
Nurse: *Um...I think MuTI..it is convenient. When the doctor is not there I am able to leave messages, sending message via voicemail and get a response back and MuTI also you can use images and I am very happy now that you have brought a camera.*

In practice, both participants used the system infrequently. However, in the interviews both participants showed a high level of personal motivation to use the telemedicine system since they wished to contribute to the surrounding communities. This suggests personal motivation alone is not sufficient to have a working telemedicine service. In the MuTI project, time constraints due to personnel shortages and an unreliable network led to low system usage even though participants wanted to provide the telemedicine service to their patients. In the doctor's opinion, telemedicine will always be less efficient and slower than examining and treating patients directly. However, he felt the benefits of telemedicine outweighed the slow nature of this form of health care delivery. For him, telemedicine meant that one was able to provide a service to patients and save them time and money. This indicates that there needs to be sufficient nurses and doctors to operate a telemedicine service assuming the network connectivity is reliable.

That summarises the information gathered from the data collected throughout the project. Overall, from the participants responses, we found that MuTI was an improvement on the previous telemedicine system because it allowed both synchronous and asynchronous communications whereas the previous system allowed synchronous communication only. The asynchronous communication was found to be helpful since the nurse and doctor both had busy schedules making synchronous communications difficult to arrange. The following section discusses several factors that may have led to a low usage of MuTI.

6.2.4 Factors Affecting Results

Several factors may have affected our overall results regarding MuTI. For instance, the head nurse participating in the project was reluctant to train any other nurses from Tsilitwa clinic to use MuTI. This was because the CSIR project drew publicity in the past, and at these times she was the only nurse that knew how to operate the telemedicine systems. As a result, she was the one called to participate in television and newspaper interviews. We surmise that she became reluctant to share the spotlight and assured herself the sole glory for telemedicine by limiting the participation of other nurses in the project.

If she was less affected by the attention she received for telemedicine, we feel she would have allowed the other clinic nurses to undergo training. This impaired the usefulness of the system since the system could only be operated by the head nurse and if she was not available, it could not be used. If more nurses used the system, it may have sped up health care delivery to patients requiring telemedicine services and MuTI usage may have been higher.

Moreover, the overall results may have been affected by a poor network. We did not have a mechanism in place to monitor the network uptime as this was not part of our infrastructure. From Dr Murray Pearson's evaluation of the Wireless Fidelity (WiFi) network and our personal experiences of the network having to be reset during most of our field trips, we must conclude that the network was fairly unreliable. Again, this may have led to a lower usage of MuTI than if the network was functioning for one hundred percent of the evaluation period.

Another factor mentioned earlier which may have affected the use of MuTI was the fact that the doctors and nurses were not getting paid for their time. Although we had permission from the Department of Health (DoH) to train and interview the doctor and the nurse, we never negotiated a specific time period for which the participants could use MuTI. Thus, all MuTI use was purely voluntary and unpaid. Results may have differed if suitable remuneration was provided for telemedicine consultations by the DoH and if there was a specific time set aside for telemedicine as part of a nurse or doctors working contract. Also, if there were more doctors and nurses to operate MuTI, usage may have been higher.

More specifically, the results concerning calls may have been affected by the fact that the CSIR VoIP phones were also available to the participants during the April to October period. Thus, we cannot rule out the fact that participants may have used the CSIR VoIP phones to call each other during telemedicine consultations. Since these phones were not part of MuTI, we did not log any calls made using them. These are the main factors which may have interfered with our evaluation of MuTI. Next, we draw out the findings about telemedicine based on the results we have discussed.

6.2.5 Findings about Telemedicine

In general, the data collected showed that MuTI was an improvement on the previous telemedicine system. In particular, the asynchronous aspect of MuTI which allows records to be sent to another party was found to be a useful function since it meant the doctors and nurses had the option of asynchronous communication. This fitted in with their busy daily schedules more appropriately than adhering to a synchronous teleconsultation. Specifically, the ability to record and send a voicemail in a MuTI record and the presence information allowing one to detect the availability of a contact were found to be valuable features.

This suggests that telemedicine systems for rural areas with sporadic power supplies, unreliable networks and personnel shortages should be multi-modal. This allows asynchronous communication to be used when synchronous communications are not possible. Also, presence information can be used to decide which form of communication to use. Additionally, to cut down on training and the need for typing skills, voicemail could be used in asynchronous messages to convey information.

No conclusive evidence could be deduced about the usefulness of images in MuTI records since a camera was only provided to the nurse for a one month period and she was away for half of this time. However, both the doctor and the nurse indicated the inclusion of high resolution digital images in MuTI records was an essential feature. Therefore, telemedicine systems may not require video conferencing facilities since high quality still images and voice messages are suitable substitutes and preferable to low quality video. In fact, the interview data suggests that video conferencing does not seem to provide any additional value to a telemedicine system.

From both the trace data and the interviews, MuTI was deemed to be a locally relevant software application for the Tsilitwa-Sulenkama area. The socially aware computing framework helped us identify a workable telemedicine system for the target area. Moreover, we found that telemedicine is a good concept in theory but that in order for it to work well, there needs to be extensive training for the health care professionals involved as well as support (technical and motivational) in order for the service to work properly.

Most importantly, there should be sufficient time in a health care professionals schedule to use a telemedicine service, especially if this service is over and above normal duties. If the personnel shortages cannot be overcome, linking up more rural clinics and hospitals with a central system may provide the additional manpower to improve system usage. From our travels to other parts of the Eastern Cape and visiting clinics and doctors around the area, we feel that linking up more clinics and hospitals with WiFi, VoIP and a MuTI system would provide a useful telemedicine service in the Eastern Cape. The system could be used for remote consultations, diagnosis, support and continuing medical education. In addition, it may make working in the more remote regions more attractive as doctors will not feel as isolated if they have access to a communication system of some kind.

Finally regarding telemedicine, we found that participants felt empowered and motivated to use the MuTI system and felt valued because we treated them as experts in their domain. Furthermore, participants seemed to enjoy the project because they could see their input as having an impact on the project. Next, we discuss our findings related to the socially aware computing framework.

6.3 The Socially Aware Computing Framework Findings

Our socially aware computing framework provided a well structured process to follow in order to develop a software solution for our target community. It enabled us to create a working relevant telemedicine solution for health care communication in the Tsilitwa-Sulenkama area. Working within this framework has led to several significant insights regarding developing software for rural areas using the framework, the overall process for an Information and Communication Technology (ICT) development project as well as issues related to evaluating one's work in these types of projects. In the following sections, we discuss these insights in turn. Section 6.3.1 discuss software related results, Section 6.3.2 discusses methodological related results and finally, Section 6.3.3 discusses results related to evaluation.

6.3.1 Software Related Issues

We made the following observations about software related issues for ICT development projects:

1. *Training, participation, local content do affect project success.* We confirmed what projects in the past had found, as discussed in Section 2.4, that training, participation and local content do affect the success of a project. We found that by training the participants, we were empowering them and motivating them to use MuTI. Also, from the participants involvement in planning and evaluation phases, we were able to foster buy-in for MuTI. This meant that with only a little extra encouragement, participants were using MuTI on a voluntary basis. Also, we found from the data we gathered about the CSIR telemedicine system that adapting a system to local conditions is critical for the success of a system. It was because the CSIR system did not allow multiple modes of communication and the frequent power failures that the system was underutilised. We were able to address the local conditions more appropriately

by adding just the store and forward feature. This was tailored for working in an environment with sporadic connectivity where personnel shortages made synchronous communications near impossible. We also retained much of the functionality of the original CSIR telemedicine system in MuTI. Locally determined content is therefore crucial for a application to have a chance of success in a rural area.

2. *Keeping it simple works.* We also discovered the principle of keeping it simple works, another factor we discussed in Section 2.4. Even though our initial prototype was very simple, we had to simplify it further by removing logging in functionality and support for multiple user profiles. Eventually we made a default user since this was appropriate to the situation at the time. The principle of keeping things simple applies to any application developed for rural areas. We suggest therefore that applications be developed in an incremental fashion, beginning with the most basic functionality required.

   Also, we found that participants struggled with the CSIR system because it required manually manoeuvering the webcam as well as talking on a separate VoIP phone. With MuTI, the digital camera was separate to the laptop used but participants were able to talk and type at the same time using the headset. This suggests that devices should be kept as simple as possible and that operation of several devices should be avoided where possible.

3. *Having more than one software developer may improve rapid prototyping.* Due to the rapid cycles that we undertook in the project, the prototyping process was quite short with frequent iterations. To improve this process, more than one software developer is needed so that the system can be divided into manageable chunks which can be developed in succession. We also confirmed that participation of users or community members in the software development life cycle helps one identify requirements and design issues for software quickly and easily.

4. *It is important to support and encourage project participants even if support is provided from a distance.* The project experienced problems beyond the control of the researchers. For instance, MuTI was not used in some instances because of the shortage of staff at the Nessie Knight Hospital. As mentioned earlier, we brought this to the attention of the DoH but we were unsuccessful in securing a commitment to relieve the problem. Moreover, we found that even if the participants in the project are eager to use a new software system, they may not use it. This was revealed by the results we gathered in the first evaluation period where MuTI was not used for communication at all. To overcome this, participants should be provided with a great deal of support and encouragement throughout the project. This is

because a new system places a burden on the participants as they have to learn how to use the software and how to integrate it into their daily schedules. In addition, if there is a large time period between field visits and if field visits are short, participants may lose motivation if not supported. Remote support can be established through phone contact and even Short Message Service (SMS) - which was defined in Section 2.3.

In summary, we found that for a software solution to be successful in a rural area, one needs to provide adequate training and support for the users. Also, participatory approaches can help ensure that the software content is tailored to the local needs of the community for which the software is developed. Software solutions should be kept at simple as possible to start with, in terms of functionality and for telemedicine, the number of devices required for the service to work should be kept to a minimum. With respect to developing software prototypes using a socially aware computing approach, having more than one software developer will speed up the development process. Next, we discuss results related to the overall process used for an ICT development project in rural areas.

6.3.2 Methodological Issues

Several issues became apparent with respect to undertaking an ICT development project in rural and underserviced regions. These are enumerated below:

1. *Finding a target community to work with may be difficult.* Foremost, it was very difficult to find a community to work with for this project. Unless one already has a project site in mind, one should allow for time to discover a community. In this project, the author spent approximately six months looking for a community to work with in order to test our socially aware computing approach. This period consisted of meeting with different organisations doing development work in South Africa to find potential allies, searching the internet for community projects and contacting field experts by phone or in person. Many of these leads led nowhere and it was difficult to remain motivated. However, we had a breakthrough when we discovered the CSIR project in Tsilitwa and we were able to form a relationship with the CSIR that allowed us to undertake this project.

2. *The Real Analysis/Real Impact framework helps one broaden the focus of the project and identify key issues external to the software development process that are important in rural areas.* Overall, we found that within the socially aware computing framework, the RA/RI

guidelines developed by Bridges.org were very helpful. For instance, software development in a socially aware manner without RA/RI is not sufficient to ensure its success since Participatory Design (PD) and Action Research (AR) alone do not deal explicitly with factors beyond developing software and the people using the software. Factors such as training participants and ensuring that the use of the software is integrated in their daily routines are essential. Using RA/RI principles throughout our process, we were able to bring these factors to light and address them. In the case of training and integration, we provided extensive training sessions and negotiated with the DoH to allow the doctors and the nurses to use MuTI for the research project on a voluntary basis. All these factors need to be considered when undertaking a software engineering project in a rural and underserviced area in South Africa and similar situations.

3. *A project needs to be sustainable to succeed and this factor should be addressed from the project onset.* Measures should be put at the onset of a project to ensure sustainability. In our project, sustainability was an issue since the laptops on which MuTI ran were quite expensive[1]. Since the villages were remote, if laptops or personal computers broke down, procuring replacement parts would not have been trivial and maintenance would be costly. We were fortunate that we experienced no equipment problems during the project. If we had secured the support of the DoH, they would have paid the costs of equipment and provided remuneration for telemedicine services. We did lobby the DoH to make MuTI part of their telemedicine strategy in the Eastern Cape (EC). However, since the project terminated earlier than expected we were not able to evaluate the outcome of this aspect of the project.

4. *Local buy-in from a community makes things easier for researchers and project participants.* When undertaking this kind of project, we found that it is essential to have local buy in from the community. At the onset of the project, we were warned that the community leader was seen as intransigent and that he may not accept our presence in Tsilitwa. Fortunately, with the help of our local champion, the head nurse, we gained acceptance by the community leader. This is because the head nurse had a strong relationship with the community leader. Moreover, she grasped the benefits of using a system like MuTI and was able to filter her views to the community leader. The community leader consequently granted us free reign to work on telemedicine in Tsilitwa. His acceptance made it easier for the rest of the community to accept our presence during the project. It also helped the project participants, for example

[1]Note again, that creating a sustainable application was not a goal of this project.

the nurse and the network maintenance staff, to feel at ease working with us and encouraged them to collaborate with us. This point also highlights the importance of having a local champion who can drive the project forward, another factor discussed previously in Section 2.4.

5. *The research agenda should be clarified with the target community at the project onset to avoid misunderstandings and serve as a contract of goodwill between the researchers and community members.* We discovered that it is important to clarify one's research agenda at the onset of the project and clearly explain this to the target community. This explanation should cover how and when the researchers will undertake field visits as well as precise ownership of equipment provided. In effect, this explanation becomes a verbal contract of conduct for the researchers and community members, laying out what can be expected from each party. In our case, due to the abrupt project termination, we experienced difficulties in explaining why we were removing the project equipment. The clinic nurse felt that we had not clarified ownership of the equipment and she was under the false perception that we were donating the laptops and headsets to the clinic. At the project onset, we did explain that we were not implementing a sustainable solution for Tsilitwa and that the DoH was needed to make the project sustainable. In retrospect, we should have also explicitly stated when equipment would be removed and how this paradigm fits in with a research agenda.

6. *A local ally can help facilitate political and social relationships with community members, help arrange meetings and monitor the project in the field.* From our experiences, we also confirmed that it is essential to have a local ally in the community. This person can then facilitate meetings with other project participants and monitor the project progress, for suitable remuneration if necessary. In this way, if there are problems with the software systems, network or socio-political issues, the ally can bring them to the attention of the researchers. For us, due to the long periods between field visits (up to 2 months) and the distance between the researchers base and the project site, we were unable to pick up major issues until the field trips due to limited communication options. An ally acting as a monitor is therefore essential for keeping track of what is occurring in the field. In our case, our local ally was one of the network maintenance staff who helped to arrange meetings, took part in discussion groups and workshops. He was invaluable to the success of the project. However, towards the end of the project, he became despondent as he did not receive payment for his work as negotiated with the CSIR. Choosing an appropriate and reliable local ally is therefore essential.

7. *It helps if one of the researchers comes from a similar background as the target community and can take the role of an ally.* One of the difficulties we encountered working in Tsilitwa was the language differences between the researchers and the community participants. This meant we often missed out on subtleties in body language and conversations made in Xhosa during group meetings. In this case, it is useful if at least one of the researchers is an ally with a similar background culture or language to the local community. This will enable him/her to provide insights to the researchers that would not otherwise be picked up by those seen as outsiders. Our research team were fortunate in that one of our members was this type of ally. He came from a similar background as the community participants in terms of culture and language. With his aid, we were able to interact with the community on a deeper level and we were able to extract community views on MuTI and our presence more easily.

8. *Coordinating field visits with a large number of organisations is made more difficult if the target site is a large distance from the researchers base and milestones therefore have to be flexible.* In the MuTI project, coordinating field visits was time-consuming. This was caused by the large distance between the project site and the researchers base. This meant all field visits had to allow for travel time. Furthermore, due to the number of organisations and participants involved in the project, for example, Bridges.org, CSIR, University of Cape Town (UCT), University of Western Cape (UWC) and the community participants, coordinating field visits was not trivial. This meant that milestones and time constraints had to be flexible in our project. This may not be ideal if a project must be completed in a fairly short time frame. It might be easier to work on a project closer to the researchers base and to plan field trips well in advance to cut down expenses.

9. *A bottom up cyclical approach may be apposite for areas similar to the rural regions in the Eastern Cape.* We feel that our bottom up socially aware approach is appropriate for developing locally relevant software applications for areas similar to Tsilitwa and Sulenkama. In addition, a cyclical approach works well for refining software prototypes and adapting the software to user requirements.

To summarise, using a socially aware computing methodology, we found that it may be difficult and time-consuming to find a target community initially if the project is started without a clear focus or community in mind. However, once a target community is identified, this bottom up approach can help identify real community needs to develop working solutions for rural areas.

The RA/RI framework in the approach helps one address issues not directly related to software development but which affect project success.

When working with a rural community, one should clarify one's research agenda at the start of the project outlining the expectations of the researchers and the community and an exit strategy. One should also make provisions for ensuring project sustainability from the project onset. With a proper plan in place, it will be easier to secure community buy-in for a project and this is critical for project success.

Another factor that may help with identifying project requirements and gaining buy-in is the use of appropriate allies. Local allies in the community can monitor project progress in the field and provide technical and motivational support to users. They can also inform the researchers of problems as soon as they occur. For the research team, having an ally with a similar background or language to the target community as part of the team can also help facilitate relationship building with the target community.

Lastly, if there are multiple organisations involved in an ICT development project, arranging field trips and meetings may be time-consuming and difficult to co-ordinate. This means that undertaking these type of projects for degree purposes requires the use of multiple researchers and a flexible time schedule. In the following section, we discuss the insights we gained relating to evaluation mechanisms for ICT development projects for rural areas.

6.3.3 Evaluation Issues

Evaluation is crucial for checking whether an ICT development project has been successful or not and we found that the following issues are important when deciding how to evaluate one's project:

1. *Triangulation of data helps create an accurate picture of software usage and evaluation is key.* Triangulation of data, or collecting and comparing multiple sources of data, is crucial. We found that often in the interviews the participants believed that they had used the system more than they actually did. Without the trace files and database logs, we would not have detected this discrepancy. Thus multiple sources of data should be collected to ensure accuracy of results. Also, without the evaluation data we gathered there would be no way for us to ascertain whether MuTI was an apposite solution for the target area. Thus it is critical to have evaluation mechanisms built into any software engineering process for rural areas.

2. *An external monitor helps highlight strengths and weaknesses in ones project approach.* For the MuTI project, it was beneficial to have Bridges.org as an external monitor. They were

able to guide us throughout the project and inform us when we strayed from the principles of RA/RI. Through workshops and feedback provided in bi-annual reports, Bridges.org's role as an unbiased observer helped ensure that we not only addressed software issues but issues related to the bigger picture. One of the weaknesses identified in our project was that we did not place sufficient emphasis on how to make the project sustainable. We attempted to address this deficit by lobbying the DoH to make MuTI part of its national telemedicine strategy, although achieving sustainability was beyond the scope of the project as mentioned in Section 1.4. The precise application of RA/RI to the MuTI project was shown in Section 4.2.

3. *Cultural factors may affect participants responses in interviews.* We found that cultural factors may play a part in refining the prototypes. For instance, both participants in our project generally did not criticise the MuTI interface in interviews and always leaned towards the positive in all their suggestions. This may be attributed to the nurse being from the Xhosa culture and the doctor being from the Cuban culture — both of which can exhibit a general reluctance to criticise as this is seen as a sign of disrespect. In rural areas, one therefore needs to be aware of any cultural factors that may have an impact on the project, whether negatively or positively.

There were the three main insights we had regarding evaluation using the socially aware computing framework or in general ICT development projects. First, using multiple sources of evaluation data is the only way to build an accurate picture of system usage and to identify what is working and what is not. Also, external monitors can help provide an unbiased opinion on the project progress and can help identify problem areas in the project. Finally, when evaluating user interfaces, one should be aware that cultural factors may affect user responses in interviews. In the following section, we discuss why VoIP and WiFi may be useful technologies for rural and underserviced areas in South Africa. We also discuss how current telecommunications legislation hampers the provision of telephony and value added services in these areas by restricting the use of wireless technologies.

6.4 Telecommunications Policy and Underserviced Areas

Telecommunications policies affect the technologies that one can use in rural and underserviced areas. In this section, we discuss our views emerging from the project on the relationship between policies and software development in these areas. In our view, there should be no licences required for VoIP and WiFi in the traditional licence-exempt bands in rural and underserviced areas. This section presents our justification for this opinion.

1. *Fixed line telecommunications may not be appropriate for the rural regions in the Eastern Cape.* From the MuTI case study [30], it became evident that fixed line communications infrastructure may not be the right solution for the rural areas in the EC due to the difficulties in laying cables in isolated areas with poor or no access roads which hampers system maintenance. A better solution might be to utilise a combination of wireless access and VoIP solutions since this would be cost effective and would allow villages to be connected quickly and easily. Wireless access would be used as the last mile technology connecting up rural villages to each other and to the backbone network. The cost of this type of access would then depend on the wireless service provider, the cost of connecting the network to the backbone network and the cost of setting up the wireless infrastructure. Note, exact costing information for installing a wireless network in a rural area and connecting this up to the backbone public switched telephone network is beyond the scope of this dissertation[2].

   In the proposed solution, VoIP would be utilised over the wireless network to provide voice services. Until the technologies are improved, using VoIP would only make sense for relatively few subscribers. This is because WiFi shares bandwidth amongst users and the quality of service for VoIP calls may deteriorate with a congested network. In the MuTI project, the CSIR VoIP phones and the MuTI VoIP calls were functioning well over the WiFi network. This illustrates that a working telephone service can be provided to rural villages without the need for extensive cabling, utilising WiFi and VoIP. The network set up by the CSIR presented almost no running costs and it was provided free of charge to the villages in the project since it was part of a research initiative. In a commercial situation, this would obviously be different.

   WiFi may be more appropriate than fixed line services for the last mile in rural areas for several reasons. First, as mentioned in Liew *et al.* [63], in rural areas with a sparse population, using wireless networks can be less expensive than a wired alternative which requires cabling. Also, wireless networks are easier to install in areas where it is difficult to lay cables, for example,

[2]Personal Communication with William Tucker (btucker@cs.uct.ac.za): Setting up a rural WiFi network costs approximately $730 per each site in the network. This cost includes the cost of a waterproof antenna enclosure, an antenna, a router board, radio cards, batteries and either a battery charger or a solar panel. Only router sites require router cards and sites with solar panels may be slightly more expensive. This cost excludes the once off cost of purchasing power tools, cabling and mounting hardware — all of which are reusable. Minimal additional cost may also be incurred for consumables such a cable ties and power wires as well as providing power to sites without solar panels. This information was gathered during an extension of the MuTI project into another area of the Eastern Cape in May 2005.

over large hills, roads and valleys. Additionally, installing a wireless network can be less time consuming than installing a wired alternative where laying cables can take substantial amounts of time.

Moreover, at present, most of the rural areas in the Eastern Cape do not have any wired line telephones even though Telkom, the incumbent telecommunications operator, had a mandate to provide a telephony service to these areas. The reason for this might be that these rural areas do not have the economic activity or buying power to justify rolling out wired lines, i.e., these areas are not seen as profitable. However, there was a wide usage of the cellular network in the villages described in the case study which indicates that people in these areas, despite having a low disposable income, are willing to spend money on telephony. Thus, there is a market in these areas for telephony and for cheaper alternative forms of telephony to the cellular network.

Some may argue that with the limited range and line of sight restrictions of WiFi, wireless networks may not be appropriate for rural areas. These restrictions can be overcome. In the MuTI project, Tsilitwa village and Sulenkama village are separated by a large hill so there is no line of sight between the Tsilitwa clinic and the hospital in Sulenkama. The obstruction presented by the intermediate hill was overcome using a repeater site which was installed on the top of the hill. The repeater site also helped extend the somewhat short range of WiFi to connect the two villages which are approximately 20 kilometers apart.

Another point against using WiFi is that the spectrum is limited and interference may be a problem. In rural areas, interference is unlikely to be a major problem as there are no competing signals in these areas at present and it is only as more service providers build up wireless networks that are overlapping, that this aspect of using WiFi will become apparent. For the short term, therefore, interference is less of an issue than in urban areas. If one wished to provide value added services to rural and isolated regions which used WiFi as a last mile technology, one could use a Very Small Aperture Terminal (VSAT) or satellite internet connection. This would extend the range of services available to the people living in these areas. This kind of network also lends itself to many other applications for schools and government amongst others.

These suggestions are supported and advocated by Cohen and Southwood [33] as well as Gillwald and Kane [45] who feel that VoIP can be combined with WiFi or other wireless technologies to provide last mile solutions for remoter locations. Furthermore, they recommend that WiFi and VSAT should be opened up to further this cause.

Best [72] and Neto *et al.* [11] also propose that the unlicensed spectrum and low cost wireless technologies that operate in these bands could benefit developing countries with underdeveloped telecommunications and internet infrastructures. They propose that licence exempt regulations provide an environment for entrepreneurship which will lead to a reduction in barriers to entry for network service providers.This will help to achieve more widespread internet access. Setting up wireless LANS is cost effective since equipment using these protocols is now widely available commercially and relatively inexpensive. They also require little technical expertise to install. If there are no licence fees, this makes it even easier to quickly establish wireless data networks without having to depend on telecommunications operators for the use of their services.

Small enterprises could then easily become internet service providers and voice service providers in their local communities. Collections of these local operators could then connect to larger internet and basic service providers. This will enhance competition in these areas which ultimately benefits consumers who can then choose from a variety of connection options for their telephony and internet needs. This will help to achieve rural connectivity and universal access. It will also spur development, which in turn will create employment and further development.

The Wireless Internet Institute *et al.* [54] concur and suggest that wireless internet technologies can enable deployment of low cost broadband internet infrastructure and last mile solutions. Using wireless, it is possible to leapfrog traditional infrastructures to the latest most advanced technologies. The Wireless Internet Institute *et al.* [54] feel that the demand for connectivity and applications will drive further development in underserved areas. This is elaborated on in the next point.

2. *Applications and services drive development and dictate which technologies are relevant for remote and isolated regions and basic telephony alone is not sufficient to empower these regions.* Using our methodology, it has become apparent that applications drive development and dictate which technologies should be used to supply local demands. Basic telephony alone is not sufficient for bridging the digital divide in underserviced areas. The provisions of value added services such as internet access is also necessary if universal access goals are to be met.

   An example of how applications drive development is illustrated in the following anecdote mentioned earlier in this dissertation. During the case study, the authors discovered that in many of the so-called underserviced areas in the Eastern Cape such as Tsilitwa and Sulenkama, there is widespread cellular coverage. A substantial amount of people in these areas have prepaid phone packages and cellular phones. Since the electricity supply in these regions is sporadic and many households do not have electricity, many small businesses have developed around the cellular industry. Specifically, shops have sprung where one can pay a small fee to have one's cellular phone recharged. This example shows how where there is a need, businesses and development follows. It is therefore imperative that the needs and services required in rural and remote regions be fully assessed before deciding what technologies are appropriate to fulfill those needs.

Aside from the telemedicine application described in the case study, people in these regions could benefit from applications to improve the delivery of social services, interaction with government and information provisions services. Thus technologies should be used in these areas according on the services and applications required. Also, free reign should be given over the combination of technologies one can use for achieving connectivity and value added services in these areas.

3. *If wireless technologies are opened up and combined with VoIP for voice services, they can be used by organisations other than Under Serviced Areas Licensees (USALs) to increase development quickly.* Another reason why wireless technologies should be opened up is that it will benefit the USALs. At present, USALs have to compete with MTN and Vodacom, who due to universal service obligations already have a large market and widespread coverage of remote areas, attracting people with prepaid packages. Also, USALs are for small businesses only which means it is expensive to set up operations in these areas, as they do not have access to large amounts of capital and traditional telephony infrastructure is costly. Wireless last mile solutions could be combined with VoIP to lower the entrance costs for USALs.

   However, USALs may not be the answer for deploying telecommunications in underserviced areas. At the time of writing, no USAL was operational due to the drawn out application process for USALs and the fact that only 4 USALs have been awarded and only as recently as late 2004. Furthermore, Gillwald and Esselaar [44] point out how the ministerial determinations announced in 2004 [79], while good for industry and the general public, have weakened the business case for USALs in several ways. First, the determinations allow VANS and private telecommunications networks to self-provide their infrastructure. This means USALs can no longer count on bringing in revenue from offering alternative telecommunications infrastructure to VANS and mobile operators in underserviced areas.

Second, the determinations stated that the Department of Communications will allow anyone to apply for licences to provide pay phones. Again, pay phones in rural areas have a high calling rate per phone since there are not many communication options in these areas. Allowing anyone to provide pay phones cuts down an advantage USALs may have had to provide these kind of services in rural and remote regions. Third, the determinations state that all schools must receive a 50 percent discount for internet access. Again, this removes a potential revenue stream for USALs in remote regions. Fourth, USALs were part of the original triad allowed to use VoIP (SNO, USALs, Telkom) — this advantage has been removed.

Allowing any company to be a telecommunications service provider using WiFi, VoIP and other technologies without having to apply for licences may be a better solution. This would spur competition and development and allow companies to quickly set up operations without having to deal with cumbersome and expensive licensing procedures. It would also enable the provision of telephony and value added services at affordable rates.

4. *Wireless solutions are less susceptible to vandalism in rural areas.* We can use wireless solutions coupled with VoIP for voice services in rural areas because they are less exposed to acts of vandalism and there is no risk of cable theft and network loss. In fact, during the MuTI project, we found that the Digitally Enhanced Cordless Technology (DECT) phones in the Tsilitwa and Sulenkama area were often unavailable due to vandalism and cable theft.

5. *Wireless solutions with VoIP for voice services may provide a cheaper model for poorer areas than newer technologies such as 3G and GPRS.* In the South African case, give the extent of the coverage of cellular networks in rural areas, one might argue that we should utilise cellular technologies, such as third generation wireless (3G) or and General Packet Radio Service (GPRS), to provide value added services as opposed to WiFi. Using 3G, one can access multimedia content and internet services from one's cell phone [61]. Similarly, GPRS also enables internet connectivity through a cellphone at a data rate of up to 114kps [61]. However, the low population density of rural areas and the fact that rural populations generally have a lower disposable income, make the pricing schemes for these technologies too costly for these areas.

   Bhagwat *et al.* [13] support this statement, claiming that cellular services are value-priced for markets where users are willing to pay a high price. In rural areas, this type of pricing is not apt. Furthermore, at present, only the mobile operators in South Africa are licensed to provide 3G and GPRS. Again, this means there is less scope for competition amongst the service providers and thus, the end users may not be provided with prices that are suited to the rural environment.

If WiFi is opened up to allow anyone to use the Industrial Scientific Medical (ISM) bands in rural areas and combined with VoIP for voice services, communities could be quickly connected by service providers other than a monopolistic USAL. This would allow for explosive development instead of perpetuating the monopoly model which has not yet resulted in providing proper telecommunications services in underserviced areas.

Summarising the above points, we found that fixed line infrastructure may not be the appropriate way to address universal access at this stage in rural development in South Africa. We also found that VoIP and WiFi can provide an inexpensive replicable way to connect up rural villages and provide both services as well as basic telephony. Services could be related to education, government or health and could either be sponsored by the relevant government departments or be charged for at affordable rates. A proper business model with exact costing was beyond the scope of this dissertation. WiFi would be less susceptible to cable theft and vandalism and the VoIP-WiFi model may prove to be a cheaper way to provide telephony and value added services than GPRS and 3G technologies. The next section concludes the chapter.

6.5 Concluding Remarks

To summarise our results, we were able to devise an approach based on existing methodologies for developing applications for rural areas in South Africa. We used Action Research, Participatory Design and best practice from previous ICT development initiatives in the Real Access/Real Impact framework. We showed the feasibility of the socially aware framework by developing MuTI: a communication tool for health in the target area in the Eastern Cape province of South Africa.

The data we gathered about MuTI showed that MuTI was found to be useful by both of our project participants and an improvement on the previous telemedicine system created by the CSIR because it allowed multiple modes of communication. Asynchronous communication was found to be helpful since the participants often could not arrange synchronous communications due to their busy schedules. Although overall usage of MuTI was low, both participants made a number of call attempts and sent a number of records to each other. They also found the presence information and the inclusion of voicemail in MuTI records to be helpful.

Using the methodology we synthesised also led to insights regarding undertaking ICT development projects as computer scientists in a developing country. Finally, we found that WiFi and VoIP are two technologies that may be useful for providing telephony and value added services in the Eastern Cape and that further telecommunication liberalisation is required in South Africa if we are to uplift rural and underserviced communities with technology. In the next and final chapter, we describe the overall conclusions of the project.

Chapter 7

Conclusions

Chapter 6 discussed the final results of the MuTI project. This chapter presents the main conclusions that emerged from our research. We present a summary of how we achieved our original aims in Section 7.1, discuss our overall contributions in Section 7.2 and suggest possibilities for future work in this research area in Section 7.3.

7.1 Achievement of Original Aims

Before we describe what we achieved in the MuTI project, we revisit the original aims of our research:

- We wanted to devise a methodology from existing methodologies and learn how to develop locally relevant software applications for rural areas in South Africa.
- In addition, we wanted to approach a rural community and use the framework we developed to build, refine and test an application built in a bottom up manner to solve a problem for our target community. From this process, we aimed to learn about the validity of our methodology.
- Lastly, we wanted to derive comments on how telecommunications policies should enable the provision of telephony and value added services in underserviced regions with whatever technologies are necessary, based on our experiences during the research process.

To address these aims, we first devised a socially aware computing framework geared towards developing context appropriate software for rural areas. We synthesised this approach from existing user-centred methodologies, namely Action Research (AR) and Participatory Design (PD) as well as best practice principles from previous Information and Communication Technology (ICT) development projects — the Real Access/Real Impact (RA/RI) framework. Next, we tested this approach by using it to create a software application for a rural village in the Eastern Cape province of South Africa.

The approach helped us identify community needs and we created a communication tool for telemedicine for the target community called Multi-modal Telemedicine Intercommunicator (MuTI). This tool proved to be an improvement on the previous telemedicine tool used in the target village because it allowed both asynchronous and synchronous modes of communication. This was useful since the network connectivity was unreliable and both participants were often too busy to engage in synchronous communications.

We demonstrated that the socially aware computing framework was a valid approach for developing applications for rural areas by creating a working software application with functionality appropriate for the target community. Additionally, we learnt that needs drive development and dictate which technologies should be used to fulfill those needs. Also, telecommunications legislation in the country currently restricts the applications one can develop in rural areas. In all, we achieved all three of our original aims. In the next section, we discuss our contributions in more detail.

7.2 Overall Contributions

From this research, we reached several overall conclusions about working with ICTs for development. Many of the points below are more thoroughly discussed in the preceding chapter, Chapter 6. In Section 7.2.1, we discuss the contributions made regarding telemedicine. Next, in Section 7.2.2, we discuss the contributions made regarding best practices for ICT development projects in developing countries. Finally we outline our contributions pertaining to telecommunications policy in South Africa regarding rural and underserviced areas in Section 7.2.3.

7.2.1 Contributions Regarding Telemedicine

We made the following observations about telemedicine based on our results on MuTI.

Multi-modal telemedicine systems may be more suited to rural areas

Our results indicate that multi-modal telemedicine solutions will work best in rural areas where connectivity is sporadic and personnel shortages mean that staff have busy schedules. Multi-modal in this instance refers to software applications which offer multiple modes of communication in terms of different types of media and whether the communication is real-time or not. In these cases, asynchronous communications prove to be useful. When opportunities do arise for synchronous communications, multi-modal systems allow personnel to take advantage of them. Also, presence information can be used to determine which form of communication to use. Telemedicine systems for rural regions should also make use of voicemail messages where possible. This reduces the need for typing skills since information can be spoken instead of typed.

Without support, training and adequate motivation, telemedicine may not work well in practice

Telemedicine is a good concept and relevant for rural and underserviced regions. However, if implemented without proper support, training and motivation for the health care professionals involved, it might not work well in practice. For instance, we found throughout the project that both the doctor and nurse bought into the idea of telemedicine as a useful service. Yet, in practice we found the system was underutilised even though in the interviews we found that both participants were highly motivated to use MuTI. This may have been due to factors such as poor network conditions and more importantly, busy schedules due to personnel shortages.

We argue that if the telemedicine service was properly integrated into the job descriptions of both the doctor and the nurse and if they were suitably remunerated for their work, the system would have been used more often. In this case, telemedicine would not be viewed as an additional burden, as described by the doctor in our project, but merely another aspect of one's job. This may make telemedicine systems easier to accept and provide motivation for health care professionals to use these systems.

Another important discovery we made is that telemedicine systems for rural areas should initially be as simple as possible if they are to be accepted. With MuTI, even though we made the system as simple as possible, we found that it was still an effort for the participants to use. This was because all use of MuTI in our project was on a purely voluntary basis. As a result, we had to refine MuTI and remove features to simplify it even though the initial system was fairly uncomplicated. Also, separate devices for a telemedicine system should be avoided where possible and integration of all functions using minimal devices is preferable.

Since health care professionals in these areas may not be familiar with complicated technologies, it makes sense to first introduce simple solutions before building up to full blown systems. If these systems are integrated into the job descriptions of these health care workers, a clear protocol for use should also be developed. This would also make the system easier to use. From our results about MuTI, discussed in Section 6.2, we conclude that MuTI did meet the user expectations of the system, since they were eventually motivated to try out the system and expressed that the system was an improvement on the problems that caused the previous CSIR system to be underutilised.

Overall, we found that in rural areas in South Africa, until health care services improve, telemedicine provides one mechanism to improve the current service offered. In an ideal world, however, we feel that the ultimate goal for these areas should be to provide a service where telemedicine is not required or is only required in extreme cases. This is because telemedicine is by nature a slower means of delivering a health care service and is by nature not as pragmatic as having a patient examined directly by a physician.

Contributions Summary

In summary, we found that multi-modal telemedicine solutions may be appropriate for rural regions in South Africa where connectivity is sporadic and personnel shortages make synchronous communications difficult. Also, for a telemedicine service to work, the health care professionals using the telemedicine software need to be supported technically, given adequate training and most importantly, require sufficient motivation to use the system. Suitable compensation for using the telemedicine service may provide motivation. Also, mapping out work processes and integrating telemedicine into a health care professionals work life may ease the burden of learning a new system and finding time to use it. Keeping systems simple will also help users learn to use it faster. Next, we discuss the observations we made regarding best practice for ICT development projects working with rural communities.

7.2.2 Contributions Regarding Methodologies for Working with Rural Communities

From using the socially aware computing framework in a rural village, we had several insights regarding best practice for ICT development initiatives in developing countries. These are outlined in this section.

Evaluation is imperative in ICT development initiatives

Many ICT development initiatives have no mechanism for evaluation integrated into their methodologies. Without any means of evaluation, it is impossible to learn what is working and what is not working in an intervention. Furthermore, one not only requires adequate evaluation mechanisms but also multiple methods of assessment for increased accuracy. For instance, through our evaluation we saw that MuTI was used infrequently. In addition, we were able to detect a discrepancy between what participants claimed in their interviews and how they actually used MuTI in practice. Without multiple methods of evaluation, the data may have been misleading.

One caveat regarding evaluation is that cultural factors may affect the data collected. In our project both the Cuban doctor and the Xhosa nurse seemed reluctant to criticise MuTI. This means that evaluating user interfaces, for instance, may be difficult. Also, one should be aware that in interviews when questioned about interfaces and the software functionality, users may paint a picture than is more positive than the reality in practice.

Regarding evaluation mechanisms, we found that logging everything we could was useful. Field notes and recorded observations were invaluable for reflection phases and for compiling detailed field trip reports. Observations made during training and demonstration sessions were especially useful for detecting bugs in the software interface. Additionally, general observations and field notes helped us to gain an idea about the community's attitudes towards both the researchers and the software.

Also, audio recording interviews for transcription was found to be more helpful than written questionnaires. This is because there may be a time lapse between when the data is recorded and when it is analysed and audio data helps recreate the interview more clearly than reviewing a written questionnaire. In addition, having an external monitor for one's initiative can provide valuable insights into the project and help to evaluate the impact of a project. Bridges.org was our external monitor and they helped us identify strengths and weaknesses in our project as an unbiased observer.

In all, evaluation is imperative if we are to learn from ICT development initiatives and disseminate lessons learned. We suggest that any ICT development initiative should have clear mechanisms for evaluation in place as well as avenues for disseminating the lessons learned.

A contract of goodwill is necessary between researchers and target communities

When working with a rural community of particular culture, it is best if one has a contract of good will between the researchers and the community. This means at the onset of the project one needs to:

- clarify ones aims and agenda

- clarify the communities aims, expectations and agenda
- have a well defined exit strategy. Although we knew the project was only meant to run for a short period, we did not realise the importance of an exit strategy until the project was abruptly terminated.

Furthermore, we suggest that multiple researchers need to involved in this type of community-oriented project in order for a project to succeed. This is because the scope of these projects is very wide and there are a myriad of different facets which need to be attended to in any one ICT development project. In other words, one cannot undertake research of this scope individually especially if the research is undertaken as part of a masters or PhD degree.

However, if working in a team, different parts of the project can be tackled by different team members and the project as a whole can move forward more easily. For an example, multiple software developers could be responsible for implementing different parts of any software system developed as part of a project. This would enable each developer to fully focus on one area of the software and enable quick iterations of software development for a high quality system.

We also suggest that if one is conducting an ICT development project with a rural community that one should roughly plan one's trips and milestones. This helps one keep on track towards the overall goal of the project and on a timeline, particularly if the research is undertaken for degree purposes. Regarding the relationship with one's target community, we suggest that one should spend as much time in the field as is pragmatically possible. This is because the more contact one has with a community, the stronger one's relationship becomes.

Furthermore, we found that although most of the time spent in the field will be work related, it is equally important to socialise with the community when possible. Casual socialising whether in between or after work activities, helps strengthen the researchers relationship with the community and can help with being accepted by the community.

For most projects, it is not practical to spend all one's research time doing field work. It is important however that even when one is not in the field, that one should remotely support the participants in the project. We found that we could keep our project participants motivated through phone and SMS (defined in Section 2.3) contact when we were not in the field. In addition, we feel that ICT development projects will benefit from appointing a local ally in the field devoted solely to monitoring the project and providing hands-on support for participants, for suitable remuneration if necessary.

Community needs drive development in rural areas and dictate which technologies should be used in these regions

Instead of the top down approach of deciding that computers are useful and literally "dropping off" computer kits deemed useful for rural and underserviced communities, one should first try and identify the real needs of these communities. From there, one can identify services to fulfil these needs and then discern which technologies are appropriate for these services and consequently, these areas. A corollary to this bottom up approach is that telecommunications legislation should encourage ICT development in these areas instead of hindering it by making technology neutral policies. For example, we found that one service in the areas we worked in would be to provide internet connectivity for doctors working in isolated rural hospitals.

South African doctors refuse to work in these areas because of the isolation. If a service was provided whereby these doctors could be connected to the outside world for communication purposes, i.e., where they would have at least email connectivity, these doctors would feel less isolated. This would mean even if they work in areas far away from their home towns they will still be able to stay in touch with family and friends. This would make these areas more attractive as places to work since doctors need not have to worry about loneliness. As a result, local doctors may not be adverse to these rural positions and the need for foreign doctors might decrease.

Socially aware computing is a useful process for rural and underserviced areas

The socially aware computing process provided a structured way to conduct this ICT project in a rural area and to work with a rural community. The waterfall model of software development helped us develop the MuTI software and PD provided us with techniques, such as discussion groups, to involve our target community in the software development process. AR helped bring these approaches together and provided a framework for us to structure the overall project; providing a cyclical method to refine the software as well as a way to build up a relationship with our target community. Also, the RA/RI framework helped us consider all factors not directly related to the software or the people using the software and enabled us to think about the bigger picture into which the project fitted. We would therefore recommend using socially aware computing for similar type projects.

We also made several observations about the socially aware computing process in general. First, we noticed a trend in the Action Research cycles. We found that at the start of a cycle, one usually has a general idea of the goal for that cycle but that by the end of that cycle, the goal is clearer and more concrete. Also, at the end of a cycle, the overall goal of the entire process becomes clearer. In addition, the software specifications evolve as each cycle progresses and it is towards the end of a cycle that one discovers what works and what does not - both in terms of the software and in terms of working with people. Another important trend that became evident is that in the first few cycles, patterns are set.

For example, for our field visits, we developed a set agenda for detailing the activities for each day of the trip and the milestones for that field visit. In subsequent cycles, we then merely had to follow this pattern or agenda by just updating the activities needed for the next field visit. By the third cycle, planning the agenda for field trips was easy. In fact in general, the later cycles in the project progress more smoothly since one has preliminary results and the experience of several cycles behind oneself. It thus becomes easier to set ones goals, pick up on what is needed in a cycle and to direct the cycles clearly towards the overall project objective.

Also, we found that providing training and using a participatory approach benefited the project participants. The training sessions helped the users to grow from the project by allowing them to gain more experience with computers and to become familiar with MuTI. The participatory nature of the socially aware computing approach benefited each of the participants individually. For instance, both the doctor and the nurse seemed more confident in interviews conducted later in the project since they felt that their opinion was valued and this increased their self esteem.

More importantly, particularly in the case of the nurse, the participants felt like they were contributing to the surrounding community and improving health care in the area. Again, this empowerment of the participants is a direct consequence of using a socially aware computing approach. Therefore, we feel we achieved our objective of formulating a process for software development in rural and underserviced areas and recommend the socially aware computing process for ICT development initiatives similar to the MuTI project.

Contributions Summary

To summarise, we found that the only way to assess the impact of an ICT development project and find out what has worked and what has not is through stringent evaluation. Multiple forms of evaluation give one an accurate picture of how a project is performing and specific techniques used depend on the type of project. We found that recording everything we could from trace data about software usage, observations, interviews and general field notes was important in evaluating our project. In particular, audio recording interviews was helpful since often there was a large time lapse between the interview and the time the data was analysed. Audio recordings helped retain more of the information about the interview than a handwritten questionnaire. For evaluating user interfaces with interviews, cultural factors such as a general reluctance to criticise may affect results.

Also, we found when working with a target community that it is imperative to define a contract or research agenda between the researchers and the community. This outlines what is expected of both the researchers and community. In these projects, multiple researchers are necessary to deal with the complexities of the project. Overall, the socially aware computing framework was useful in providing a working telemedicine solution for our target community and we feel it can be used in other rural contexts for developing context appropriate software solutions. Most importantly, we learned that community needs drive development and applications to fulfil those needs should be identified before identifying the technologies required to build those applications. The next section discusses the conclusions we drew about telecommunications policy in South Africa and its effect on rural and underserviced regions.

7.2.3 Contributions Regarding Telecommunications Policy

From the MuTI project, we drew the following conclusions about telecommunications technologies and policies in South Africa and their relation to rural regions.

VoIP and WiFi are useful technologies for rural areas

VoIP and WiFi proved to be useful technologies for rural areas. In our project, the WiFi network allowed us to quickly deploy a telemedicine service to two rural communities and VoIP allowed us to provide voice calls between these two villages. Although, the cost of using these technologies is beyond the scope of this project, we feel they can be useful for providing information and communication services to rural and underserviced areas in South Africa.

Under Serviced Area Licensees (USALs) may not be right model for underserviced areas

Telecommunications liberalisation in South Africa has a long way to go before it opens up real opportunities for development in rural and underserviced areas. In particular, we presented our arguments for the combination of VoIP for voice services and WiFi as a last mile solution for providing telephony and value added services in isolated regions. We also argued that these areas should allow any service provider, not just USALs or telecommunications operators, to operate wireless technologies in the Industrial, Scientific and Medical (ISM) bands or licence-exempt bands so that more service providers can provide a telecommunications service in these areas without having to follow cumbersome licensing procedures.

More importantly, this would also allow service providers to use whatever technologies are necessary to provide locally relevant services. USALs are just perpetuating the current model in South Africa since they are mini-monopolies and this may not be the best model for rural areas. This is particularly true since the business case for USALs has been weakened by the ministerial determinations announced in 2004 as discussed in Section 6.4.

Contributions Summary

To summarise the points above, we found that VoIP and WiFi can provide a replicable model for connecting up rural villages to each other and possibly a backbone network. Also, we found that USALs may not be the best way to provide universal access to underserviced regions. Next, we suggest possibilities for future work in this research area.

7.3 Future Work

There is scope for future work in this field of research. The socially aware computing framework could be further refined as apposite for rural and isolated areas other than the Eastern Cape. Limitations of the process could be addressed in future scenarios of use. For instance, in the evaluation phases of the process, measures could be put in the test sites to enable remote monitoring, if internet connectivity is available. This would help the researchers to always be cognizant of the field situation so that they can take appropriate action in trouble cases sooner rather than later. It would also mean data from trace files and database data would feed into the software development process as soon as it becomes available.

Methods to reduce the limitation caused by not always implementing all user suggestions and the fact that user suggestions in workshops, questionnaires and interviews may not always truly reflect what they need in daily work practices could be investigated.

Also, to better adapt MuTI and integrate it into the work lives of the users, mapping out the information flows and work processes for health care between a rural clinic and a hospital with ethnographic techniques may be helpful. This would help identify how MuTI can fit into a normal work schedule instead of leaving it to the user to decide how to integrate the telemedicine and system use into their daily routines.

Another area for future work would be to do a comparative study of the cost of different last mile technologies for rural areas in South Africa. For instance, a long term study could be undertaken on the costs of providing a wireless access network for the last mile in isolated rural areas. The costs could also be compared to the cellular network costs since many of the rural areas in South Africa already have cellular coverage. Next, we make suggestions for how to improve the MuTI software.

7.3.1 Improvements to the MuTI Software

The MuTI prototype could be improved and tested in other environments similar to the Eastern Cape. Revisions that were suggested by participants but which were not implemented during the project due to time constraints could be introduced. For an example, the Graphical User Interface (GUI) could be improved significantly. MuTI could also be adapted for Personal Digital Assistants (PDAs) or cellphones. Short Message Service (SMS), defined in Section 2.3, could be included to inform participants when a MuTI patient record has arrived. Another additional feature would be implementing video conferencing with a proper quality of service and high image quality. One could also cut down the wires used in the system by using cordless headsets.

Furthermore, MuTI could be expanded to facilitate communication between multiple clinics and hospitals. At each site, either one person could be solely responsible for telemedicine or multiple people could do the work in shifts. Internet connectivity could also be provided to link up international sites using MuTI. Another area for future work would be to see how MuTI can be altered now that VoIP is legal. An analysis of this change could be performed to see if VoIP alone will help make MuTI and other applications in underserviced areas a success. The scope for changing the MuTI prototype is therefore endless but all suggestions and changes should always be centred in community needs. At the time of writing, plans were being formulated to move the MuTI project to another area in the Eastern Cape with similar conditions. Many of the suggestions made here will be tested at his new site. The section below concludes this chapter.

7.4 Final Remarks

In all, the MuTI project helped us comment on both the methods we use to develop software for rural and underserviced areas and to develop an application that we believe is beneficial to health care in the Eastern Cape. Although the MuTI results have limited generalizability because of the small number of project participants and the specific application tailored to our target community, we believe that reflections about the process we used and on South African telecommunications policies are transferable to situations with similar conditions and circumstances.

Appendix A

A.1 Questionnaires Used During the Project

A.1.1 Needs Assessment Guidelines for Primary Diagnosis Phase of Project

1. What **equipment** is currently available?

   (a) What are the specifications of the computers in use?

   (b) Are they running Windows or Linux?

   (c) Processor speed?

   (d) Disk space?

      i. How is memory used?

   (e) RAM?

   (f) CD ROM?

   (g) Are there any peripheral devices like printers, faxes?

   (h) What is the wireless connection like?

      i. What software is it using?

   (i) Who provided the equipment?

   (j) What happens when the equipment breaks?

   (k) Is there fixed telephone line access?

   (l) Is there any Internet access?

   (m) Is there a reliable electricity supply?

2. What **applications** are currently in use?

(a) Who developed these applications?
(b) What do these applications do?
(c) Who uses the applications the most and which applications are preferred?
(d) Which is the most popular application or service offered?
(e) Do they use local content?
(f) Do they use local languages?
(g) How much does the use of an application cost?

3. Regarding the **community:**
   (a) Who is the community made up of?
      i. What age groups?
      ii. Who are the users?
      iii. Which gender uses the services/applications more?
      iv. What is the level of literacy in general?
      v. What is the level of schooling?
      vi. How much do they earn/can they afford?
      vii. Do they have any idea how technology can benefit them?
      viii. What is the level of computer literacy?
   (b) What are the needs of the community?
      i. What services does the community lack?
      ii. What could be improved using a multimedia tool?
      iii. Are there any particular needs for agricultural support?
      iv. Are there any particular medical needs?
      v. Are there any particular needs for small business support?

A.1.2 Baseline Questionnaire

Please fill out the following questionnaire to help us understand more about the present Telemedicine system in Tsilitwa. You do not have to provide any personal details but please circle your current profession:
Profession: Nurse / Doctor
Please fill out the sections for your profession only.
Nurses – Sections A, C and D
Doctors – Sections B, C and D
Section A - Questions for the nurses at Health Care Clinic, Tsilitwa:

1. On average, how many times a week do you need to refer patients to the doctor at Nessie Knight Hospital?

   ----
2. On average, how many times a week would you like to use the Telemedicine system to communicate with the doctor (even though you might not be doing so at present)?

   ----
3. On average, how many times a week do you use your cellphone to call the doctor?

   ----
4. How many times a week do you use the existing Telemedicine system to communicate with the doctor?

   ----
5. On average, when you do use the system, how many patients per week is the doctor able to help with the present Telemedicine system?

6. For what kinds of illnesses or ailments do you need to consult with the doctor?

7. What happens when you get the advice from the doctor?

8. What kind of information about a patient do you need to exchange with the doctor?

9. What else do you use the computer for and what else would you like to use the computer for?

Section B - Questions for the doctor at Nessie Knight Hospital, Sulenkama:

1. On average, how many times a week do you see patients referred from the nurses at the clinic in Tsilitwa?

2. On average, how many times a week would you like to use the system to communicate with the nurses at the clinic in Tsilitwa (even though you might not be doing so at present)?

----

3. On average, how many times a week do you use your cellphone to call the nurses at the clinic in Tsilitwa?

   ----

4. How many times a week do you use the existing Telemedicine system to communicate with the nurses at Tsilitwa?

   ----

5. On average, when you do use the system, how many patients per week are you able to help with the present Telemedicine system?

   ----

6. What else do you use the computer for and what else would you like to use the computer for?

Section C - Questions for both nurses and doctors:

1. When using the voice phone, what is the response lag when talking?

   ----

2. When using the webcam, what is the response lag like when viewing video?

   ----

3. When using the digital camera, how long does it take to send pictures?

4. On average, how many times a week is there a power failure?

5. When there is a power failure, how long does it usually last for?

6. When the power comes back up, how long does it usually take for the network to work?

7. How do you know when the network is working again?

8. How do you schedule the time when you talk with doctor using the existing Telemedicine system?

9. What do you like about the existing Telemedicine system?

10. What do you dislike about the existing Telemedicine system?

----

11. What would you like to change about the existing Telemedicine system?

Section D – Any other comments you would like to make can be filled out in this area.

Thank you for your participation

A.1.3 MuTI Evaluation Questionnaire

Please fill out the following questionnaire to help us understand more about how you use MuTI in Sulenkama and Tsilitwa. You do not have to provide any personal details but please circle your current profession:
Profession: Nurse / Doctor
Date: ____________________
Please fill out the all sections.
Section A – Main Questions about MuTI
Section B – Additional Comments can be made here
Section A – Main Questions about MuTI:

1. How many times a week do you use MuTI to communicate with the doctor/nurse?
   ____
   ____
   ____

2. How do you arrange the times when you will talk to each other using MuTI?
   ____
   ____
   ____

3. How do you arrange with patients when they should come in so that they can be present when you speak to the doctor?
   ____
   ____
   ____

4. Do you prefer speaking using the headset or the telephone of the previous system? Please explain why you prefer this option.
   ____
   ____
   ____

5. Do you prefer to send the doctor video footage of the patient or to send pictures of the patient? Please explain why you prefer this option.

----

6. For the nurse: When you do use MuTI, how many patients per week is the doctor able to help with?

   ----

7. For the doctor: When you do use MuTI, how many patients per week are you able to help with?

   ----

8. For the both: Are you able to help more patients with MuTI than with the previous system? Please explain why.

   ----

9. How many times a week do you call the doctor using MuTI?

   ----

10. When you add patients in MuTI, do you usually also type in their medical history?

    ----

11. How many times a week do you send the doctor/nurse records using MuTI?

    ----

12. When you send a record with MuTI, how long is it before you receive a reply?

    ----

13. When you send a record with MuTI:

    (a) Do you usually send a voicemail? If you send a voicemail, what information do you usually include in the voicemail?

    (b) Do you usually type in comments for the record? If you do type in comments, what information do you include in the comments?

        ----

14. Do you usually insert images in the record? If you do insert pictures, what are these pictures usually of? How long does it take you to insert pictures into a record (including the time to take the picture, transfer it from the camera and include it in the record)?

    ----

15. Is there any other information you would like to include in a record?

    ----

16. Is it helpful to see when the doctor/nurse is available or not?

    ----

17. Is it helpful to run MuTI on the laptop? Do you use the laptop when the power goes down and how long do the batteries usually last for?

    ----

18. When do you use MuTI and where? Are you usually connected to the network during this time? E.g. at work, connected to the network

    ----

    ----

19. What do you like about MuTI?

    ----

20. What do you dislike about MuTI?

    ----

21. What would you like to change about MuTI?

Section B – Any other comments you would like to make can be filled out in this area.

Thank you for your participation

A.2 Real Access/Real Impact framework

A.2.1 Real Access Criteria

Real Access Criteria	
Criteria Name	**Questions Associated with Criteria**
Physical access to technology	Is technology available and physically accessible to the people and organisations? What technology is available? What factors affect physical access to technology in general? What factors affect physical access to technology in project context/policy context? What can be done to ensure technology is available and physically accessible to people?
Appropriateness of technology	Is the technology appropriate to the local needs and conditions of the community? How do people need and want to put the technology to use? What can the project do to ensure the technology is appropriate to the local needs and conditions of the community? Can we modify technologies that work well in developed countries to be more suitable for developing countries? Have all the existing technology options been assessed and has the most appropriate solution been selected?
Affordability of technology	Are the technologies and services affordable for local people to obtain, access or use? What does 'affordable' mean in context of project? Are measures being taken for long term sustainability?

Continued on next page...

Real Access Criteria	
Criteria Name	**Questions Associated with Criteria**
Human capacity and training	Do people have training and skills necessary to use the technology effectively? Do they understand how to use the technology? Can they see the benefits of using the technology? Does the project provide training on how to use the technology?
Locally relevant content, applications and services	Are there locally relevant content applications and services enabled by technology that people can access? Is content provided in local languages relevant to the target community?
Integration into daily routines	Is technology use an additional burden to the lives and work of people involved? How can the technology be adapted to fit into peoples daily routines?
Socio-cultural factors	Are people limited in their use of technology because of their gender, race, disability, age or other socio-cultural factors? What other socio-cultural factors affect the project?
Trust in technology	Do people have confidence in technology use? Do they understand the implications of the technologies they use? How do the target users feel about privacy, security and crime as related to technology use? How can the project overcome these issues?
Local economic environment	What is the condition of the local economic environment? What impact will the project have on the local economy? Can the local economy sustain the technology use?

Continued on next page. . .

Real Access Criteria	
Criteria Name	**Questions Associated with Criteria**
Macro-economic environment	Does the macro-economic environment in the country affect the technology use? How do policy issues like deregulation, taxation, trade, investment or labour affect the use of the technology in the project?
Legal and regulatory environment	Do the country's laws and regulations affect the use of technology and how? Does the legal and regulatory framework promote or hinder technology use? What can the project do to help ensure that laws and regulations promote, and do not hinder, technology use?
Political will and public support	Do people support the use of technology in their community? Does the government have the will to drive change to promote technology use? How can the project help to stir up political will and public support?

Table 7: This table illustrates the type of questions associated with each Real Access criterion in the Real Access/Real Impact framework. (All questions extracted from [23].)

A.2.2 8 Habits of Highly Effective ICT-Enabled Development Initiatives

8 Habits of Highly Effective ICT Initiatives	
Habit Name	**Questions Associated with Habit**
Do some homework, conduct needs assessment	What kind of homework can be done to gain a full understanding of the lessons learned by previous efforts of this kind? What kind of assessment will paint a picture of the needs of the community or target group? Is the initiative looking at concrete needs of people and target community? Is the initiative built around the real needs of an identified group?
Implement and disseminate best practice	What does 'best practice' mean for this particular initiative? Does the initiative draw on best practice in the field? What concrete steps have been taken to build on best practice ? What can this initiative do to contribute to best practice in the field? Does this initiative share experiences and lessons learned to contribute to body of knowledge in the field?

Continued on next page. . .

8 Habits of Highly Effective ICT Initiatives	
Habit Name	**Questions Associated with Habit**
Ensure ownership, local buy-in, find a champion	What can project do to ensure local buy-in for the project or policy? What are the characteristics for an appropriate local champion? Has local champion been identified and engaged? Does initiative connect effectively with community that it serves? Do local participants feel a sense of ownership? Were local participants involved in project planning?
Set concrete goals and take small achievable steps	What are the concrete and realistic goals for the project? Does the project set concrete and realistic goals for the ICT use? Does the initiative have a structured methodology based on small achievable steps?
Critically evaluate efforts, report back, adapt as needed	Does the initiative evaluate its efforts, see what is working and what is not and learn from its mistakes? Does it adapt its methodologies as appropriate? Does it report back to the community it serves as well as funders and supported to explain how and what it is doing to help the community?
Address key external challenges	What are the key external challenges that could affect ICT use? Does the initiative identify and understand external challenges that it faces? Does the ICT initiative take practical, proactive steps to overcome obstacles?

Continued on next page...

8 Habits of Highly Effective ICT Initiatives	
Habit Name	**Questions Associated with Habit**
Make it sustainable	What is needed to make the ICT initiative sustainable? Does the initiative work to make its efforts economically and socially sustainable over short and long term?
Involve groups that are traditionally excluded	Does the project involve groups that are traditionally excluded because of social or cultural reasons?

Table 8: This table illustrates the type of questions associated with each habit of the 8 habits of highly effective ICT-enabled development initiatives. The 8 habits are part of the Real Access/Real Impact framework. (All questions extracted from [23].)

Bibliography

[1] Statistics South Africa. SA Census 2001. Available: http://www.statssa.gov.za/SpecialProjects/Census2001/Census2001.htm.

[2] S.R. Ahuja and R. Ensor. VoIP: What Is It Good For? *Queue*, 2(6):48–55, 2004.

[3] K. Annan. Kofi Annan's IT Challenge to Silicon Valley. Available: http://news.com.com/2010-1069-964507.html?tag=lh, 5 November 2002.

[4] D.E. Avison, F. Lau, M.D. Myers, and P.A. Nielsen. Action Research. *Communications of the ACM*, 42(1):94–97, 1999.

[5] E.R. Babbie and J. Mouton. *The Practice of Social Research*. Oxford University Press, Cape Town, South Africa, 2001.

[6] R.L. Baskerville. Investigating Information Systems with Action Research. *Communications of the AIS*, 2(3es):4, 1999.

[7] R.L. Baskerville and A.T. Wood-Harper. A Critical Perspective on Action Research as a Method for Information Systems Research. *Journal of Information Technology*, 11:235–246, 1996.

[8] S. Batchelor, P. Norrish, N. Scott, and M. Webb. R8067 Sustainable ICT Case Studies. Gamos Ltd and Big World, January 2003. Available: http://www.sustainableicts.org/execsumm.htm.

[9] S. Batchelor and S. Sugden. An Analysis of infoDev Case Studies: Lessons Learned. Gamos Ltd and Big World, October 2003. Available: http://www.sustainableicts.org/execsumm.htm.

[10] P. Benjamin. The Gaseleka Telecenter, Northern Province, South Africa. *Perspectives on Distance Education: Telecentres - Case Studies and Key Issues*, pages 75–84, 2001. C. Latchen and D. Walker (Eds).

[11] M. Best. The Wireless Revolution and Universal Access. Trends in Telecommunications Reform 2003, Geneva, Switzerland: International Telecommunications Union, 2003. (Chapter 7).

[12] M. L. Best and C. M. Maclay. Community Internet Access in Rural Areas: Solving the Economic Sustainability Puzzle. *The Global Information Technology Report 2001-2002: Readiness for the Networked World*, 2002. G. Kirkman, J. Sachs, K. Schwab and P. Corneilus (Eds).

[13] P. Bhagwat, B. Raman, and D. Sanghi. Turning 802.11 Inside-Out. *SIGCOMM Comput. Commun. Rev.*, 34(1):33–38, 2004.

[14] G. Bjerknes. Some PD Advice. *Communications of the ACM*, 36(6):39, 1993.

[15] E. H. Blake. Extended Abstract: A Field Computer For Animal Trackers. In *CHI '02: CHI '02 extended abstracts on Human factors in computing systems*, pages 532–533. ACM Press, 2002.

[16] E. H. Blake, L. Steventon, J. Edge, and A. Foster. A field computer for animal trackers. In *In Proceedings CHI-SA 2001, South African Human-Computer Interaction Conference, University of Pretoria*, 2001. Available: http://www.chi-sa.org.za/CHI-SA2001/chisa2001New.htm.

[17] J.L. Blomberg and A. Henderson. Reflections on Participatory Design: Lessons from the Trillium Experience. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems*, pages 353–360. ACM Press, 1990.

[18] J. Braa, O.H. Titlestad, and J. Saebo. Participatory Health Information Systems Development in Cuba: the Challenge of Addressing Multiple Levels in a Centralized Setting. In *Proceedings of the Eighth Conference on Participatory design*, pages 53–64. ACM Press, 2004.

[19] Bridges.org. Spanning The Digital Divide, Understanding And Tackling The Issues, May 2001. Available: http://www.bridges.org/spanning/pdf/spanning_the_digital_divide.pdf.

[20] Bridges.org. Satellife PDA Project 2002 - Testing The Use of Handheld Computers for Healthcare in Ghana, Uganda and Kenya. Available: http://www.bridges.org/satellife/index.html, February 2003.

[21] Bridges.org. The Compliance Service uses SMS Technology for TB Treatment. Available: http://www.bridges.org/iicd_casestudies/compliance/index.html, January 2003.

[22] Bridges.org. Tygerberg Children's Hospital and Rotary Telemedicine Project. Available: http://www.bridges.org/iicd_casestudies/tygerberg_telemedicine/index.html, April 2003.

[23] Bridges.org. The real Access/Real Impact Framework for Improving The Way ICT Is Used In Developmen. Available: http://www.bridges.org/real_access/RealAccess_overview_bridges_03Aug04ii.pdf, August 2004.

[24] W. Carr and S. Kemmis. *Becoming Critical - Education, Knowledge and Action Research*. The Falmer Press London and Philadelphia, 1991.

[25] J.M. Carroll, G. Chin, M.B. Rosson, and D.C. Neale. The Development of Cooperation: Five Years of Participatory Design in the Virtual School. In *Proceedings of the conference on Designing Interactive Systems*, pages 239–251. ACM Press, 2000.

[26] S. Cecchini. Tapping ICTs to Reduce Poverty in Rural India. *IEEE Technology and Society Magazine*, pages 20–27, 2003.

[27] S. Cecchini and G. Prennushi. Using Information and Communications Technology to Reduce Poverty in India. PREM Note No. 70: World Bank, June 2002.

[28] P. Y. K. Chau and P. Hu. Technology Implementation For Telemedicine Programs. *Commun. ACM*, 47(2):87–92, 2004.

[29] M. Chetty, E. Blake, and E. McPhie. VoIP Deregulation in South Africa: Implications for Underserviced Areas. *Telecommunications Policy*, 2006. Elsevier Science Ltd.

[30] M. Chetty, W. Tucker, and E. Blake. Developing Locally Relevant Software Applications For Rural Areas: A South African Example. In *SAICSIT '04: Proceedings of the 2004 Annual Research Conference of the South African Institute of Computer Scientists and Information Technologists on IT Research in Developing Countries*, pages 239–243. South

African Institute for Computer Scientists and Information Technologists, 2004. Available: http://portal.acm.org.

[31] A. Clement and P. Van den Besselaar. A Retrospective Look at PD Projects. *Communications of the ACM*, 36(6):29–37, 1993.

[32] D. Cogburn. HCI In The So-Called Developing World: What's In It For Everyone. *Interactions*, 10(2):80–87, 2003.

[33] T. Cohen and R. Southwood. An Overview of VoIP Regulation in Africa: Policy Responses and Proposals. Commonwealth Telecommunications Organisation (CTO), June 2004. Available: http://www.cto.int/index.php?dir=06&sd=11&id=138.

[34] R.W. Collins. CSCW: An Opportunity For Action Research. *Proceedings of Conference on Organizational Computing Systems ACM Press New York, NY, USA*, pages 162 – 167, 1995.

[35] A. Crabtree. Ethnography in Participatory Design. In *In Proceedings of the 1998 Participatory Design Conference*, pages 93–105, 1998.

[36] B. Crow, I. Widjaja, J.G. Kim, and P.T. Sakai. IEEE 802.11 Wireless Local Area Networks. *IEEE Communications*, 35(9):116–126, September 1997.

[37] P.R. Cunha and A.D. Figueiredo. Action Research and Critical Rationalism: a Virtuous Marriage. *in Proc. of the The Xth European Conference on Information Systems, European Conference on Information Systems, Gdansk, Poland*, June 2002.

[38] B. Dick. Approaching an action ressearh thesis: an overview. Resource Papers in Action Research, 1997. Available: http://www.scu.edu.au/schools/gcm/ar/arp/phd.html.

[39] S. Dray and D. Siegel. Learning From Latin America: Methodological Lessons From Emerging Markets. *Proceedings of The Contextual Invention*, pages 9–18, 2003.

[40] S.M. Dray, D.A. Siegel, and P. Kotze. Indra's Net: HCI In The Developing World. *Interactions*, 10(2):28–37, 2003.

[41] J. Ernberg. Universal Access for Rural Development from Action to Strategies. First International Conference on Rural Telecommunications, Washington, 1998. Available: http://www.itu/ITU-D/univ_acess/telecentres/papers/NTCA_johan.html.

[42] F. Etta and S. Parvyn-Wamahiu, editors. *Information and Communication Technologies for Development in Africa: Opportunities and Challenges for Community Development*, volume 2. CODESRIA and IDRC, 2003.

[43] H.S.F. Fraser and St. J.D. McGrath. Information Technology and Telemedicine in Sub-Saharan Africa. *BMJ*, 321:465–466, 2000.

[44] A. Gillwald and S. Esselaar. South African 2004 ICT Sector Performance Review. LINK Centre Public Policy Research Paper No 7, LINK Centre, University of the Witwatersrand, December 2004. Available: http://link.wits.ac.za/papers/tspr2004.pdf.

[45] A. Gillwald and S. Kane. South African Telecommunications Sector Performance Review. LINK Centre, University of the Witwatersrand, 2003. http://link.wits.ac.za/papers/tspr2003.pdf.

[46] B. Goode. Voice over Internet Protocol (VoIP). *Proceedings of the IEEE*, 90(9):1495– 1517, September 2002.

[47] J. Greenbaum. PD A Personal Statement. *Communications of the ACM*, 36(6):47, 1993.

[48] K. Gronbaek, J. Grudin, S. Bodker, and L. Bannon. Achieving Cooperative System Design - Shifting From Product To Process Focus. *Participatory Design: Perspectives of Systems Design.*, Hillsdale, NJ: Lawrence Erlbaum Associates:79–98, 1993. In Namioka, A. and Schuler, D. (Eds.).

[49] The World Bank Group. *ICTs and MDGS - A World Bank Group Perspective*. World Bank, 2003. Available: http://info.worldbank.org/ict/assets/docs/mdg_Complete.pdf.

[50] S. Grundy and S. Kemmis. Educational Action Research in Australia - The State of the Art (An Overview). *Action Research - Justified Optimism or Wishful Thinking*, 1984. W. Flanagan, C. Breen and M. Walker (Eds).

[51] H. E. Hanrahan. Abstraction of Services and Network Technologies to Support Robust Telecommunications Legislation and Regulation. In *Proceedings of the South African Telecommunications Networks and Applications Conference*, September 2002. Available: http://www.ee.wits.ac.za/comms/output/satnac02/hanrahan1.pdf.

[52] M. Hassan, A. Nayandoro, and M. Atiquzzaman. Internet Telephony: Services, Technical Challenges, and Products. *IEEE Communications Magazine*, 38(4):96–103, 2000. Available: http://citeseer.nj.nec.com/hassan00internet.html.

[53] T.L. Huston and J.L. Huston. Is Telemedicine a Practical Reality? *Commun. ACM*, 43(6):91–95, 2000.

[54] Wireless Internet Institute, editor. *The Wireless Internet Opportunity for Developing Countries*. Wireless Internet Institute (W2i), UN ICT Task Force and infoDev Program of the World Bank, 2003. Available: http://www.w2i.org/pages/wificonf0603/wiofdc_book.html.

[55] International Telecommunications Union. Africa, ICT Indicators. Available:http://www.itu.int/ITU-D/ict/statistics/at_glance/Internet03.pdf, 2003.

[56] International Telecommunications Union. Internet Indicators: Hosts, Users and Number of PCs. Available: http://www.itu.int/ITU-D/ict/statistics/at_glance/af_ictindicators.html, 2003.

[57] S. Kapp. 802.11: Leaving the Wire Behind. *IEEE Internet Computing*, 6:82–85, Jan 2002.

[58] S. Kemmis and R. McTaggart. Participatory Action Research. *Handbook of Qualitative Research*, pages 567–606, 2000. N.K. Denzin and Y.S. Lincoln (Eds).

[59] C. Kenny and C. Qiang. Information and Communication Technologies and Broad-Based Development. The World Bank, December 2003. Available: http://info.worldbank.org/ict/WSIS/docs/comp_ICTBroad.pdf.

[60] N. Kock, D. Avison, R. Baskerville, M. Myers, and T. Wood-Harper. IS Action Research: Can We Serve Two Masters? (panel session). In *Proceeding of the 20th International Conference on Information Systems*, pages 582–585. Association for Information Systems, 1999.

[61] J. F. Kurose and K. W. Ross. *Computer Networking - a top down approach featuring the internet*, chapter Wireless and Mobile Networks, pages 503–563. Pearson Education Inc and Addison Wesley, 3rd edition, 2005.

[62] K. Lewin. *Resolving Social Conflicts: Selected Papers On Group Dynamics.* New York: Harper & Row, first edition, 1948.

[63] J. Liew, A. W. Yeo, K. A. Hamid, and A. Othman. Implementation of Wireless Networks in Rural Areas. In H. M. Khalid, M. G. Helander, and A. W. Yeo, editors, *Work with Computing Systems*, pages 282–285. Kuala Lumpur: Damai Sciences, 2004.

[64] Gamos Ltd and Big World. Digital Village, Soweto, South Africa. Available: http://www.sustainableicts.org/DIGVILL.htm, 2003.

[65] Gamos Ltd and Big World. E-commerce for Farmers Hands-On Training. Available: http://www.sustainableicts.org/infodev/B2B.pdf, 2003.

[66] S. Marshall, W. Taylor, and X. Yu, editors. *Closing the Digital Divide - Transforming Regional Economies and Communities with Information Technology*, chapter Information and Communication Technologies for Rural Development in Asia: Methodologies for Systems Design and Evaluation. Greenwood Publishing Group, Westport, USA, 2003.

[67] V. W. A. Mbarika and C. Okoli. Telemedicine in Sub-Saharan Africa: A Proposed Delphi Study. In *HICSS '03: Proceedings of the 36th Hawaii International Conference on System Sciences*, page 172a. IEEE Computer Society, 2003.

[68] D.R. Millen. Rapid Ethnography: Time Deepening Strategies for HCI Field Research. In *Proceedings of the Conference on Designing Interactive Systems*, pages 280–286. ACM Press, 2000.

[69] M.J. Muller, J.L. Blomberg, K.A. Carter, E.A. Dykstra, K.H. Madsen, and J. Greenbaum. Participatory Design in Britain and North America: Responses to the Scandinavian Challenge. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 389–392. ACM Press, 1991.

[70] M.J. Muller, D.M. Wildman, and E. White. A Taxonomy Of PD Practice: A Brief Practitioner's Guide. *Communications of the ACM*, 36(4):26–28, June 1993.

[71] J. Navas-Sabater, A. Dymond, and N. Juntunen. *Telecommunications And Information Services For The Poor: Towards A Strategy For Universal Access*. International Bank for Reconstruction and Development World Bank, Washington DC, 2002. Available: http://www-wds.worldbank.org/servlet/WDS_IBank_Servlet?pcont=details&eid=000094946_02041804225061.

[72] I. Neto, M. Best, and S. Gillett. License-Exempt Wireless Policy: Results of an African Survey. *ITS 15th Biennial Conference, Berlin Germany*, September 2004. http://itc.mit.edu/itel/docs/2004/ITS_paper_neto_best_gillett.pdf.

[73] Final Report of ITU-D Focus Group 7. New Technologies For Rural Applications. International Telecommunications Union, 2000. http://www.itu.int/ITU-D/fg7/pdf/FG_7-e.pdf.

[74] Independent Communications Authority of South Africa. Media release - icasa to issue four under-serviced area licences (usals). ICASA, 2004. Available: http://www.icasa.org.za/.

[75] Republic of South Africa. Notice 3458 of 2002. Government Gazette. Available: http://www.icasa.org.za/.

[76] Republic of South Africa. Telecommunications Act, No 103 of 1996. Government Gazette, November 1996. Available: http://www.info.gov.za/gazette/acts/1996/a103-96.htm.

[77] Republic of South Africa. Telecommunications Amendment Bill, No 65 of 2001. Government Gazette, August 2001. Available: http://www.info.gov.za/gazette/bills/2001/b65-01.pdf.

[78] Republic of South Africa. Notice 2610 of 2003. Government Gazette, October 2003. Available: http://www.info.gov.za/gazette/notices/2003/25594.pdf.

[79] Republic of South Africa. Policy Announcement by the Minister of Communications, Dr Ivy Matsepe-Casaburri. Department of Communications, September 2004. Available: http://www.doc.gov.za/Press_Stmnt_02Sep_2004.htm.

[80] Global Knowledge Partnership. *GKP Recommendations on Issues of Bridging the Digital Divide*. Malaysia, February 2004. Available: http://www.globalknowledge.org/gkps_portal/index.cfm?menuid$\bar{1}$49&parentid% =179.

[81] C. Peersman, S. Cvetkovic, P. Griffiths, and H. Spear. The Global System for Mobile Communications Short Message Service. *IEEE Personal Communications*, 7(3):15–23, 2000.

[82] L. L. Petersen and B. S. Davie. *Computer Networks - A Systems Approach*. Morgan Kaufmann Publishers, 2000.

[83] F.J. Proenza. Telecentre Sustainability. Internet Publication: Bridging the Rural Knowledge Gap: Infomation Systems for Improved Livelihoods, December 2001. Available: http://www.fao.org/waicent/faoinfo/agricult/ags/AGSP/topics.html.

[84] S.K. Puri, E. Byrne, J.L. Nhampossa, and Z.B. Quraishi. Contextuality of Participation in IS Design: A Developing Country Perspective. In *Proceedings of the Eighth Conference on Participatory design*, pages 42–52. ACM Press, 2004.

[85] A. Sheperd. Bringing Market Infomation to Farmers. Internet Publication: Bridging the Rural Knowledge Gap: Infomation Systems for Improved Livelihoods, December 2001. Available: http://www.fao.org/waicent/faoinfo/agricult/ags/AGSP/topics.html.

[86] P. Sherburne and C. Fitzgerald. You Don't Know Jack About VoIP. *Queue*, 2(6):30–38, 2004.

[87] I. Sommerville. *Software Engineering*. Addison Wesley, fifth edition, 1998.

[88] C. Spinuzzi. Investigating the Technology-Work Relationship: A Critical Comparison of Three Qualitative Field Methods. In *Proceedings of IEEE Professional Communication Society International Professional Communication Conference and Proceedings of the 18th Annual ACM International Conference on Computer Documentation*, pages 419–432. IEEE Educational Activities Department, 2000.

[89] W. Stallings. IEEE 802.11: Moving Closer to Practical Wireless LANs. *IT Professional*, 3(3):17–23, 2001.

[90] W. Stallings. IEEE 802.11: Wireless LANs from a to n. *IT Professional*, 6(5):32–37, Sept/Oct 2004.

[91] A. Stavrou, P. Benjamin, P. Burton, and C. McCarthy. Telecentre 2000 Report. Available: http://www.communitysa.org.za/, 2000.

[92] E.T. Stringer. *Action Research: A Handbook For Practitioners*. Sage Publications USA, 1997.

[93] G.I. Susman and R.D. Evered. An assessment of the Scientific Merits of Action Research. *Administrative Science Quarterly*, 23:582–603, 1978.

[94] R.M. Thioune, editor. *Information and Communication Technologies for Development in Africa: Opportunities and Challenges for Community Development*, volume 1. CODESRIA and IDRC, 2003.

[95] B. Tulu, S. Chatterjee, and S. Laxminarayan. A Taxonomy of Telemedicine Efforts with Respect to Applications, Infrastructure, Delivery Tools, Type of Setting and Purpose. In *HICSS '05: Proceedings of the 38th Annual Hawaii International Conference on System Sciences (HICSS'05) - Track 6*, page 147.2. IEEE Computer Society, 2005.

[96] International Telecommunications Union. IP Telephony. ITU Internet Reports, 2001. Available: http://www.itu.int/osg/spu/wtpf/wtpf2001/.

[97] International Telecommunications Union. *World Telecommunication Development Report: Access Indicators for the Information Society.* ITU, Geneva, Switzerland, December 2003. Available: http://www.itu.int/ITU-D/ict/publications/wtdr_03/.

[98] U. Varshney. The Status and Future of 802.11-based WLANs. *IEEE Computer*, 36:102–105, June 2003.

[99] U. Varshney, A. Snow, M. McGivern, and C. Howard. Voice over IP. *Communications of the ACM*, 45(1):89–96, 2002.

[100] P. Vecchiatto. June SNO licence expected, Tata takes stake. ITWeb, 11 February 2005. Available: http://www.itweb.co.za/.

[101] L. Watts and A. Monk. Telemedical Consultation: Task Characteristics. In *CHI '97: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 534–535. ACM Press, 1997.

[102] R. Weidemann. Telkom, IS clash over VANS licences. ITWeb, 24 January 2005. Available: http://www.itweb.co.za/sections/telecoms/2005/0501241210.asp.

[103] J.B. Weinberg and M.L. Stephen. Participatory Design in a Human-Computer Interaction Course: Teaching Ethnography Methods to Computer Scientists. In *Proceedings of the 33rd SIGCSE Technical Symposium on Computer Science Education*, pages 237–241. ACM Press, 2002.

[104] A. Williams. Assessing Prototypes' Role in Design. In *Proceedings of the 20th Annual International Conference on Computer Documentation*, pages 248–257. ACM Press, 2002.

[105] M.G. Williams and V. Begg. Translation Between Software Designers and Users. *Commun. ACM*, 36(6):102–103, 1993.

[106] R. Winter. Some Principles and Procedures for the Conduct of Action Research. *New Directions in Action Research*, 1996. O. Zuber-Skeritt (Ed).

[107] M. Zhang and R. Wolff. Crossing the Digital Divide: Cost Effective Broadband Wireless Access for Rural and Remote Areas. *IEEE Communications*, 42(2):99 – 105, February 2004.