Social and Technical Issues of IP-Based Multi-Modal Semi-Synchronous Communication: Rural Telehealth Communication in South Africa

by

Xolisa Vuza

Supervised by: Mr. William D. Tucker

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Abstract

Most rural areas of developing countries are faced with problems like shortage of doctors in hospitals, illiteracy and poor power supply. Because of these issues, Information and Communication Technology (ICT) is often seen as a useful solution for these areas. Unfortunately, the social environment is often ignored. This leads to inappropriate systems being developed for these areas. The aims of this thesis are firstly, to learn how a communication system can be built for a rural telehealth environment in a developing country like South Africa, secondly to learn how users can be supported to use such a system. The thesis argues that the social environment, in which the users work, is important in understanding how the technical system can be built. The thesis adopts an Action Research approach in which prototypes are introduced in each cycle based on an understanding of the social space of the users, and the use of the technical system from the previous cycles. The thesis takes into consideration data collected from the ethnographic observations, semi-structured interviews and automated system usage to develop and enhance the prototypes in each cycle. Data triangulation is performed on this data to understand how a prototype can be changed and enhanced for the next cycle to better fit into the social space of the users. The thesis also uses the Outcome Mapping methodology to evaluate the progress made in terms of the required outcomes from the users and other stakeholders. The thesis reports on research activity that extends similar work done in the rural Eastern Cape of South Africa. Videoconferencing, video messaging and Instant Messaging have been added to the MuTI system to produce a new system called MuTI Version 2. The thesis discovers that an understanding of the social environment of the users is helpful when developing a technical system. The thesis also finds that the social space of the users is affected due to the way the technical system is built. The thesis posits that the social environment in which the users live and work should be taken into consideration when developing ICT applications for rural areas of developing countries. The thesis suggests that an understanding of the social space of the users, when developing a technical system for them, is likely to lead to an appropriate technical system for the users. Lastly the thesis contributes guidelines and recommendations concerning how to develop communication systems for rural areas of developing countries.

Declaration

I declare that *Social and Technical Issues of IP-Based Multi-Modal Semi-Synchronous Communication: Rural Telehealth Communication in South Africa* is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by completed references.

Full name .....

Date .....

Signed .....

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Glossary

ASYNC	Asynchronous
CB	Citizens Band
CPE	Customer Premises Equipment
CSIR	Council for Scientific and Industrial Research
DoH	Department of Health
FTP	File Transfer Protocol
ICT	Information Communication Technology
IP	Internet Protocol
IM	Instant Messaging
IT	Information Technology
LAN	Local Area Network
MuTI	Multimodal Telemedicine Intercommunicator
MuTIv1	MuTI version 1
MuTIv2	MuTI version 2
NGO	Non Governmental Organisation
OM	Outcome Mapping
P2P	Peer-Peer
PBX	Private Branch Exchange
PC	Personal Computer
PDA	Personal Digital Assistant
PoE	Power over Ethernet
PSTN	Public Switched Telephone Network
RTP	Real Time Transport Protocol
RTCP	Real Time Transport Control Protocol
RTC SDK	Real Time Client Software Development Kit
SDK	Software Development Kit
SDLC	Software Development Life Cycle
SIP	Session Initiation Protocol

SQL	Structured Query Language
SYNC	Sychronous
UPS	Uninterruptible Power Supply
VoIP	Voice over Internet Protocol
WiFi	Wireless Fidelity

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Chapter 1

Background and Introduction

This chapter presents the background related to this thesis. Firstly, the motivation for this thesis is presented. The aim and the significance of this thesis follows based on the motivation. A brief history of the target area is described with specific focus on its economic status and way of living. Two systems, developed before the current system in this thesis, are discussed with a view to highlight the transition from these systems to the current system that was developed in this thesis. To highlight the transition, the first system developed by the Council for Scientific and Industrial Research Council, is discussed in terms of how it works and some of the problems that resulted to the first version of Multimodal Telemedicine Intercommunicator (MuTI) system. A brief description of how the first version of the MuTI system functions is provided. A transition to the system built in this thesis, the second version of the MuTI system, is discussed with some background on how it came to exist. Lastly, the thesis structure and outline is detailed in this chapter.

1.1 Motivation

The main motivation for this thesis emanates from the failure of many Information and Communication Technology (ICT) systems previously developed for developing coutries. Related research presented in the following chapter highlights some of the reasons for the failure of these systems. One of the reasons is that Western strategies are inappropriately applied in providing these ICT systems for the developing world [74]. For example, systems are developed in laboratories and deployed in target areas without much training and support for the users of these systems [18] [1]. These systems may not be addressing the real needs of the target areas in which they are deployed. The reason being that the social characteristics of these target areas are totally ignored when developing these ICT systems [16] [54]. Some of the social characteristics are high rates of illiteracy in the people the systems are developed for, poor bandwidth, unreliable power supplies and shortage of staff [43] [30] [50] [72]. While the target areas are characterised by shortage of staff and high rates of illiteracy, users of these systems continue not to be part of the development process. For example, they do not

contribute to the development of the systems themselves [10]. The thesis posits that the users know best about their problems and working processes, and building an ICT system needs an understanding of these processes within the social environment. The thesis furthermore posits that an understanding of the social environment, and the process of obtaining the understanding, have beneficial impact on the software development process. The thesis chronicles work done, on site, in a rural community in South Africa.

1.2 The Target Area

The target area is situated in Libode in the Eastern Cape province of South Africa. The Libode district is situated in a former homeland, then known as Transkei. During the apartheid years, the South African government set aside certain regions as homelands for various African ethnicities. The Transkei was selected as the homeland of the Xhosa people. The Transkei was then given self- government in 1963 and full independence in 1976. The capital of Transkei was then established at Umtata. As with other homelands, the driving force behind Transkeian independence had been South Africa's apartheid regime, which wanted to deprive large sections of its black population of its citizenship of South Africa. Transkei depended on South Africa economically as well as politically. In 1985 the country had a population of 2,539,000, of whom 128,000 lived as migrant workers in South Africa [77. When the apartheid policy was abolished in 1994, Transkei was combined with other homelands into South Africa and today forms part of the Eastern Cape Province [77]. 86% of the population of the Eastern Cape Province consists of isiXhosa speakers [77]. Figure 1.1 shows a detailed map of the Eastern Cape Province.

The Eastern Cape is currently divided into seven districts. Each district consists of several municipalities. Libode belongs to the Nyandeni Municipality which belongs to the Oliver Tambo District. The Oliver Tambo District covers most of the former Transkei. The district includes the Wild Coast and Pondoland. Pondoland is one of the most fertile areas of South Africa, with warm temperatures, frost-free conditions and good soils. The district covers an area of 15,535 square kilometres [29]. Other major towns in the district are Mqanduli, Port St Johns, Qumbu, Lusikisiki, Flagstaff and Bizana. Oliver Tambo District has the second highest population estimated at 1,504,411 [29]. This is mainly a rural district and has a high population

density for a mostly rural district. As a result of the Apartheid regime, the population has an African majority of 99%, with very few coloured or white inhabitants [29].

Figure 1.1 : **The Map of the Eastern Cape**: This map shows the target area in which this project is located. The Libode district is circled in this map. The map also shows the area in which the first prototype of the MuTI system was deployed and tested.

Figure 1.2: **The village huts and the dirt road**: This photo shows the type of informal housing that is very common in the target area. Most people still live in rondavels and the roads are all dirt roads.

The main challenge facing the Oliver Tambo District is to develop and increase the economy and create employment. The unemployment rate is very high at 77% [29]. Social services and infrastructure require massive improvement. 99% of the houses are still informal, reflecting traditional unserviced sites [29]. Only 9% of households have portable water on site and 49% have a flush toilet, reflecting major social backlogs. Many schools and clinics require upgrading or rebuilding. Rural access roads also require upgrading in most areas [29]. Figure 1.2 shows the traditional mud and thatch houses still used in the area together with the dirt roads that are very common.

1.3 The original CSIR tele-health System

The Council for Scientific and Industrial Research (CSIR) built a tele-health system that runs over a WiFi network between two villages, Tsilitwa and Sulenkama, in the Oliver Tambo District of the Eastern Cape [19]. The CSIR system allows two users to communicate using Voice over Internet Protocol (VoIP) phones. The system also supports synchronous communication by means of one way video. This system was primarily set up to help with the referrals between a clinic in Tsilitwa and a hospital in Sulenkama.

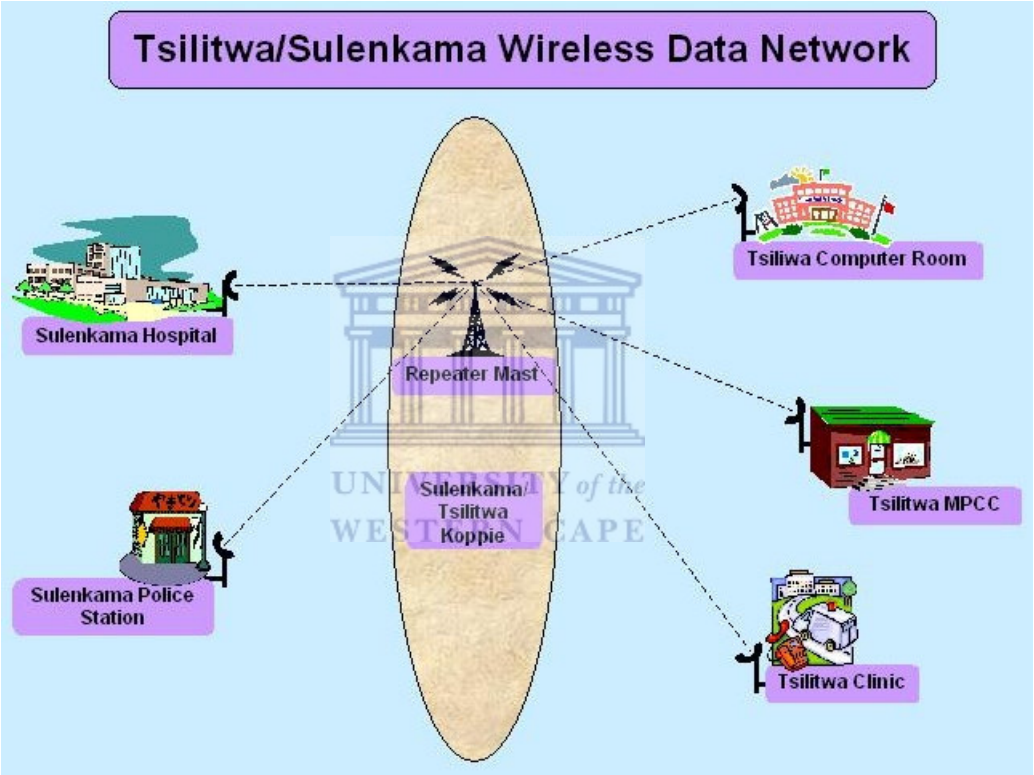


Figure 1.3: **CSIR network diagram**: This diagram shows the architecture of the network built by the CSIR. In this diagram, five sites are connected to the network. The Tsilitwa computer room is actually the school where a server runs a VoIP Private Branch Exchange (PBX) [19].

The referral process starts when a nurse calls the doctor with a case. They can talk over VoIP and the doctor may ask the nurse to show the patient on a low end webcam if he/she needs to see the patient. The doctor then surfs to the camera through a browser on a Personal Computer (PC) to see the patient. The doctor will then make a diagnosis for the nurse based on the streaming video of the patient. Figure 1.3 shows the architecture of the wireless network built by the CSIR.

At one point, the nurse could also send images of the patient to the doctor via email when it was available. At the time of this research project, e-mail was no longer functioning. After a number of visits, it was found that the system had not been effective and was therefore not used. This was due to a number of reasons:

Problem 1 The VoIP server running the PBX software was at the school and the power bill was not paid for, which led to the server being down.

Problem 2 Power surges led to Uninterruptible Power Supply (UPS) backup not functioning properly at the relay tower. This caused the network link to be down. It had to be reset to work again.

Problem 3 The system was also not resilient to either the doctor or nurse not being available to answer a call.

Problem 4 There was only one doctor at the hospital who was overworked and could not attend to the real-time system referrals even if the system were functioning.

Problem 5 Poor quality one way video from the webcam created frustration on the doctor's side.

Problem 6 No e-mail meant nurses could not send pictures to the doctors.

Problem 7 The digital camera, that should have been used to capture pictures to be e-mailed to the doctor, was broken.

The CSIR system was, however, easy to use for the nurses and the doctors because there was only a telephone handset to pick up and dial when a call needed to be made.

The wireless network functioned if the support personnel made an effort to maintain it, which often was not the case.

1.4 The MuTI version 1 System

Multimodal Telemedicine Intercommunicator version 1 (MuTIv1) was developed by Chetty *et al.* based on the visits made to the Tsilitwa/Sulenkama site and discussions with the CSIR team [23]. The visits and discussions enabled an understanding of the problems with the CSIR system, and how these problems could be solved (see section 1.3). Problems 1 and 3 led to the development of a store and forward approach to allow the nurse or doctor to be able to record messages which would be sent later if the network is down or the other party could not answer the call. Laptops were introduced so that messages could be recorded locally even if the power

is down since laptops can run on batteries. Another solution to specifically overcome problem 1 was to develop a peer to peer (P2P) system based on the Session Initiation Protocol (SIP) instead of the client-server architecture the CSIR had. A new digital camera was introduced to overcome problems 4 and 6. The images, together with voicemail and text, were then introduced in a store and forward fashion. The MuTI system had voice support in P2P fashion. The system also supported store and forward sending of images, text and voice. Table 1.1 details how the MuTI system works. Table 1.2 shows the modalities supported by the MuTIv1 system compared to the CSIR system and the Multimodal Telemedicine Intercommunicator version 2 system (MuTIv2).

Table 1.1: **Working Scenarios of MuTI version 1 system:** This table shows the working scenarios of the MuTI version 1 system in different situations

Power/Network	Doctor/Nurse	MuTI version 1 Mode
Up	Available	Sync & Async
Up	Not Available	Async
Down	Not Available	Async
Down	Available	Async

1.5 MuTI Version 2 Evolution

The MuTIv2 system is an extension to the MuTIv1 system based on the requirements that came out of Action Research cycles conducted first at the Tsilitwa/Site and later at the target area. The MuTIv2 system uses the same functionality and components as the MuTIv1 system. Synchronous and asynchronous video were added to MuTIv1 to overcome problem 5 of the CSIR system. Synchronous text messaging was also added as a modality to MuTIv1 to round off all the modalities. This means that when the doctor and the nurse are available, they can videoconference and send each other video clips, audio clips, text and images, using the current MuTIv2 system. Furthermore enhancements and changes in MuTIv1 have been introduced in a cyclical manner and the details are discussed in Chapters 4 and 5 where the development process of the MuTIv2 system is detailed. When the power/network is down or the doctor is busy, the system can be used in store and forward mode in any or all of the modalities. The main differences in the system evolution from the CSIR system to MuTIv2 are shown in Table 1.2.

Table 1.2: **Differences in modalities supported by the CSIR, MuTIv1 and MuTIv2 systems:** This table shows the differences in the modalities supported by the CSIR system, the MuTIv1 system and the MuTIv2 system. The table also shows the modes in which the modalities operate for each system.

	Text	Image	Voice	Video
CSIR				
Sync	No	No	Yes	Yes (one way)
Async	No	No	No	No
MuTIv1				
Sync	No	No	Yes	No
Async	Yes	Yes	Yes	No
MuTIv2				
Sync	Yes	No	Yes	Yes (two way)
Async	Yes	Yes	Yes	Yes

1.6 Research Aim and Significance

Based on some of the problems already discussed, the thesis aims to suggest how to build an appropriate ICT system for a rural area of a developing country. The research aims to build a communication system, by understanding the social environment of the users and building the system based on the understanding of that particular social environment. The thesis applies methodologies that allow an understanding of the social environment by making use of a cyclical process in which reflection and adaptation occur in each cycle based on the previous cycle. Lastly, the thesis aims to document the lessons learned from building such a system in the target environment and offer suggestions for building successful ICT systems for similar areas.

1.7 Thesis Outline

In **Chapter 2**, the Literature Review, related work is critically discussed in terms of how it connects to the research. In this chapter, locally relevant software applications, needs assessments for developing ICT applications developing countries and user involvement in

developing these applications are discussed. The chapter deals with work related to multimodal semi-synchronous communication by looking at the benefits of such system and the methodologies used to build such systems. The chapter closes by showing the current status of the related research in building ICT applications for developing countries as well as what the problems are.

In **Chapter 3**, Research Design and Methodology, the methodology used in this thesis is given and explained. Action Research, ethnography, data triangulation and Outcome Mapping are defined and the use of these methodologies in this thesis is justified. It is described how each of these methodologies has been used in this thesis.

In **Chapter 4**, Data Collection, data that has been collected by the proposed methodologies is outlined. Action Research, ethnography and Outcome Mapping have been used to collect data. The qualitative and quantitative data collected by each of these methods is detailed in this chapter. The quantitative data is automated system usage data, which gives an understanding of how much the system was used, as well as which features were used the most. The qualitative data provide insight into the social environment as well as insight into the progress of the thesis in terms of the required outcomes from the stakeholders.

In **Chapter 5**, System Design, the technical design and development of the system tested in this thesis is given. The system was developed based on the requirements that came from the Action Research cycles listed and discussed in Chapter 4. The chapter differentiates between MuTI version 1 and MuTI version 2 and details what the additions and enhancements are. The chapter explains in detail the development process of the MuTI version 2 system by providing schematic diagrams and algorithms for the functional modules of the system.

In **Chapter 6**, Data Analysis and Discussion, the process of data triangulation is applied on the collected data to draw an understanding of what really happened in terms of the required outcomes in the target area of this thesis. The data triangulation process is conducted for the nurses, doctors and the Department of Health. Patterns are then drawn based on the qualitative and quantitative data that have been triangulated. Lastly, the chapter engages in a discussion of the relationship between the technical system and the social environment based on the data collected in chapter 4.

In **Chapter 7**, Conclusion and Future Work, conclusions are drawn based on the data triangulation and discussions given in chapter 6. The chapter attempts to provide an answer to the research question for this thesis. The chapter then provides recommendations and guidelines for building ICT applications for rural areas of developing countries. Lastly, the chapter outlines possible future work based on the findings of this thesis.

Chapter 2

Literature Review

The focus of the research is on Internet Protocol-based multimodal semi-synchronous communication. A health communication environment has been chosen as the specific focus for this research. The main aim is to learn how to provide communication, with Internet Protocol, in a remote rural area of a developing country, specifically South Africa. In many cases, appropriate strategies and methods used to build such systems are not adopted. Problems in these areas, like the shortage of doctors in the hospitals [43] [30], low bandwidth and poor power supply [50] are widely acknowledged. This thesis shows that Action Research [7], together with Participatory Design [55] and ethnographic observations [53], can give insight into the problems and issues, both in terms of what the users would like the system to be and how they would like to use the system.

The chapter starts by looking at the potential that Information Communication Technology (ICT) has in improving the lives of people in developing countries. The author then examines what are believed to be contributing factors in developing successful, locally relevant ICT applications. Specific examples of some teleconsultation applications, that run over the Internet Protocol, as well as a critical view of the strategies and methodologies used is discussed. Most importantly the author looks at, and discusses, the results and lessons learned from providing these systems. The chapter then concludes by showing how the related work fits within this thesis in general, and suggests the approach followed within this thesis.

2.1 ICT for Development

ICT has been hailed by many as the solution to address poverty and bring about development in developing countries [2] [11] [21] [63]. This is because of the potential that ICT offers in helping people in different aspects of their lives. Some of these aspects can be access to health, education and government services [42]. ICT can be used by government to speed up the delivery of these services in these areas of life. Whilst this is true, there are a number of obstacles that need to be addressed in the developing world. These problems can be: inadequate

physical infrastructure; insufficient access by the majority of the population to hardware and connectivity; and a lack of skills for using ICT [20]. Chandrasekhar and Gosh state that ICT has a great potential in improving health in developing countries [20]. This is because ICT can serve as an instrument, since it can be used by doctors in developing countries to communicate and learn from other doctors in the developing world. This in turn will have a great impact on the way these doctors do their work, which in turn will impact on the way they treat their patients. This is furthermore echoed by Kenny when he says that a significant percentage of health workers, about 54% in Uganda and 20% in Kenya, have taken part in radio-backed training courses to improve their skills [40]. Kenny's work suggests that there has been an improvement in knowledge, attitudes and practices amongst these workers. Kenny further highlights that there is a big role that can be played by ICT among the poorest of the poor, especially with respect to natural disasters and powerlessness [40]. While it is clear that ICT has this great potential, the question is how can we make sure that we harness the power of ICT?

Kenny mentions that while ICT has a big benefit, without appropriate content, ICT will be irrelevant for the poor in the developing countries [40]. Annam feels that in order to address the question of what ICT can do for the poor,

we do need to start by facilitating need oriented programs that pay adequate attention to the social and structural influences that affect both access as well as impact [5].

On the other hand there are other indirect benefits that ICT can have for people. For example, corruption is one of the biggest problems in developing countries. Every day on television and in newspapers, corrupt government officials who use services for their own benefit as well as their families and friends, are mentioned and spoken about. An important view mentioned by Akbar suggests that despite the big potential that ICT has in making the lives of the people in developing countries better, policy and program efforts need to support and link work in all the services that are needed to make people's lives better [4]. Heeks mentions that ICT does have a big role to play in combating corruption [35]. In Cameroon, government employees have access to personal government rocedures in which they are involved. For example, if the personal clerk delays a service in the hope of getting a bribe, that delay is easily detected and that prevents corruption from happening [35].

2.2 Locally Relevant ICT Applications

This thesis offers that in order to understand and build successful systems in rural areas of developing countries, there is a need to take into consideration the characteristics of successful ICT for development applications. To recap, the main aim of this thesis is to gain an understanding of how the social environment of the users helps in building a technical system. Bridges.org looked at and described 12 characteristics of successful ICT applications [12]. In this section, four characteristics of successful ICT applications, as described by bridges.org are discussed. The characteristics described are most pertinent to the aim of this thesis.

2.2.1 Needs Assessment

Much research emphasizes the importance of doing grassroots research such as community needs assessment, because this gives a clear insight into different situations of different countries and therefore will lead to the provision of appropriate content [61] [16] [58] [6] [18]. Roman and Colle furthermore suggest that more research needs to be done to learn how to provide locally relevant ICT applications [61]. Irawan and Soegojoko's development of appropriate telemedicine in Indonesia is work dedicated to providing an appropriate system to improve the management information system for community healthcare [38]. The most interesting point in Irawan and Soegojoko's work is that the first step is really about identifying what the problem is. This thesis agrees that one cannot solve the problem if one does not know what the exact problem is. It is furthermore expounded in this thesis that the most difficult part is identifying the problem and clearly understanding it. This is where the focus should be first. It is only then that one can propose a solution.

2.2.2 Relevant Content

Chetty *et al.* investigated what needs to be done to provide applications that reflect the environment or applications with respect to appropriate content [23]. Chetty *et al.* suggest that Action Research and Participatory Design methodologies provide a framework and insight into developing information systems for bridging the digital divide. Work done by Soriyan *et al.* is also an attempt in trying to provide a methodology for developing information systems, specifically for health, in Africa [67]. Soriyan *et al.* stress that locally developed information systems in Africa are also subject to the availability of appropriate methods and procedures.

Soriyan *et al.* have developed a methodology for information systems development in Africa. The procedure followed by Soriyan *et al.* involved looking at the methodologies that are available in developing these information systems, analysis of the special requirements in Africa, as well as a survey of the existing problems among software companies in Nigeria. This thesis affirms that in order to learn, there is a need to look at the mistakes that have been done by other people previously and start working from these experiences.

Winschiers and Paterson feel that there are ICT systems developed in Europe, and that Africa has to invest in these systems in order to bridge the widening gap [78]. Winschiers and Paterson feel that these systems are, however, inappropriate for Africa because they have not been evaluated in Africa. This therefore leads to a growing stockpile of unused software and hardware. Winschiers and Paterson furthermore suggest that for African countries to benefit from ICT, local ICT development has to be practiced. This work suggests that although most ICT developers usually claim to involve the user, they still keep a clear line between what the users want and what they want in terms of interpretation and implementation of the system. The same view is shared by this thesis because the users are the ones who will use the system at the end of the day. They have to be involved in every stage of the process. Talyarkhan's work is an attempt to provide a relevant framework for developing ICT projects in development projects [73]. Talyarkhan's work confirms common criticism that ICT projects often fail to work in a participatory way with end users. This lack of working in a participatory way leads to projects not being able to achieve local ownership, which is a key to the success factor for these projects or initiatives [73]. Talyarkhan also stresses that ICT for development initiatives are most of the time too global and that global content is often pushed onto the local level. Winschiers and Paterson share the same view with regard to the globalization of information systems [78]. Thus, in summary, locally relevant content is a prime component of successful ICT for development projects for developing countries.

2.2.3 Community and User Involvement

Cecchini and Scott suggest that successful ICT projects are characterized by local ownership and community involvement [16]. This view is further highlighted by Hawkins when he says that the key to successful information systems projects is community involvement and sharing of ideas [33]. Byrne's work involved developing an information system for health in the Uthukela District in South Africa [14]. Byrne's work was carried out in conjunction with everyone affected by the information system. The whole purpose of Byrne's work was to get insight into the problems the target community had, let them express their needs as well as exchange ideas and principles. Byrne's work followed a holistic approach in developing the health communication information system because she believed that users and stakeholders knew best about their environment and that listening to them would help him obtain a better understanding of the requirements in developing the health information system [14]. Batchelor *et al.* also feel that involving target groups in project design and monitoring, enables projects to better meet their needs. Batchelor *et al.* also conducted a number of evaluations in order to have an insight into critical success factors, as well as failure factors, in the development of ICT systems for developing countries [8]. Quraishy executed an evaluation on a health information system for Indian districts [60]. Quraishy's work involved a project in which ICT was used to store and transfer patient data to speed up the process of making decisions at district level. The decisions were concerned about what was needed in terms of patient care at local levels of the district. One of the success factors in this project was a participatory and prototyping approach where the design and development process involved the user. User feedback was also effectively taken into account in this project. One of the recommendations emerging from Quraishy's work was to follow a participatory, prototyping approach because it was felt that health information systems work better when feedback from all the stakeholders is taken into account, at all levels, during all phases to improve quality and ownership of the system. Bhatnagar also performed further evaluations on ICT applications in Asia [10]. The most important issue that emerges from the evaluations done by Bhatnagar is the issue of user or stakeholder involvement in these initiatives. Bhatnagar's work further suggests that appropriate technology has to be fostered in rural areas by involving target communities. The first step is to conduct a needs assessment in these projects because these projects need to encourage grassroots and local ownership [58] [18]. Training is also seen as a critical factor from this work and this observation is also shared by [1]. Bhatnagar's work finally views lack of participation by the users in these initiatives, as a big stumbling block and suggests that

greater sharing of information and communication amongst all the people involved in these initiatives is another critical factor.

2.2.4 Socio-Cultural Factors

Too many ICT initiatives that have been undertaken in developing countries have failed. Heeks *et al.* suggest that one reason for this failure is because more emphasis is given to technical issues and social issues are totally ignored while developing these systems[34]. This in turn leads to inappropriate content being provided to the users. Heeks *et al.* suggests that many follow the European approach in developing ICT applications for developing countries. It is proposed in Heeks *et al.*'s work that this approach does not work properly because of the differences in situations between these two different worlds. The approach in this thesis is aligned with this sentiment. There is a need to devise or follow methodologies that are appropriate to developing the systems for developing country contexts. This thesis attempts to take into account the social issues or situation in which the users live and work.

Tacchi *et al.* also feel that social aspects are part of the package when working on ICT projects [70]. Similarly, Chetley stresses that learning lessons from previous attempts is the key to developing successful ICT initiatives [22]. Chetley's work furthermore agrees with work done by Heeks *et al.* in that more emphasis is normally given to the technology aspects, while less emphasis is placed on the communication aspects, such as what exactly must form part of the communication, when developing systems [34]. It is furthermore highlighted, in Chetley's work, that communication amongst the stakeholders, and not the technology, should be the key concern while developing these systems. Chetley's work has similarity with work done by Cecchini and Scott together with Moshapo and Hanrahan. The belief is that local ownership, participation and content improve the relevance of ICT projects [16] [54]. It is furthermore suggested in Chetley's work that successful ICT initiatives are those that take into account the social needs rather than the technology pushers. Byrne also evaluated a project called Participatory Design of a community-Based Child Information System in South Africa [15]. One of the recommendations from this work is to adopt a participatory approach in which the community members participate in the development of the health information system. Another recommendation is to adopt a flexible approach because of the complexity of social situations.

In this project, availability of the community members depends on the weather, harvesting times and other everyday chores. It is therefore important to liaise with the community members to find suitable times to discuss issues pertaining to developing an information system.

Pleasant *et al.*, including Chau and Hu, feel that once these systems have been developed, a local champion should be allocated. This is someone who is going to look after the systems and report all the problems with the system while it is being used. This makes it easier to know when there are problems or an upgrade is required in the system [58][18]. LittleJohns *et al.* evaluated a hospital information system in Limpompo province in South Africa. The evaluation provided a number of reasons why this system failed. Amongst others it was because of failure to take into consideration the social and professional cultures of healthcare organizations and also recognize that the education of users and the staff is essential [48]. Another very important factor which caused the failure was the failure of the system developers to look for and learn lessons from previous projects. Training was another key factor. It is mentioned that provincial workers understood to some extent how the system operated while the workers at local level did not have any training with regard to how to use the system.

This point is furthermore emphasized by Adderley's work in that even if beautiful systems are developed, it will only be a waste of resources if the users are not trained in how to use these systems [1]. Thanasankit and Corbitt clearly state that it is very important to take into consideration the differences between the cultures and situations of different countries in order for systems developers to be able to successfully develop information systems for these countries. It is important that they understand each culture [74]. Applying Western styles of thinking may cause a misinterpretation of what the users really need. This will therefore result in unused systems or cancellation of projects and waste of resources like time and money [74].

2.3 Examples of Tele-health Systems

2.3.1 Benefits of Tele-health Systems

Mea and Beltrami focused their research on the use of multimedia electronic mail for exchanging multimedia cases. Results from this study suggest that e-mail could be used for

tele-consultation [51]. They stated that this type of communication is cheaper as real time communication systems are a little more expensive compared to non real time communication systems. Another benefit, stated by Mea and Beltrami, is that most of the time doctors are attending to patients and have no time to attend to real time systems. More research could be done to compare these two communication modes to see which modes are preferred before drawing conclusions. Sewakambo and Riccio discuss the evaluation of Satellife handheld computer project [65]. Their work is an investigation into whether Personal Digital Assistants (PDAs) are appropriate devices in collecting as well as disseminating medically relevant data. A data collection system that runs in a PDA was built to collect health related data. The other points of investigation were to find out whether these devices are usable, cost effective and whether they also have a good power supply. The research was implemented in three different countries or under three different conditions to evaluate whether it would be useful in each environment. The results show large saving in cost when compared to the traditional paper-based methods. What is also very interesting are the lessons learned during this process which highlight that the content must be locally relevant to have the greatest impact. It is also highlighted that the power supply of the devices used in these areas must be appropriate to the situation [65].

Chronaki *et al.*'s work clearly show the benefits of tele-consultation in patient care [25]. In this work, a web-based tele-consultation service, to support remote screening of patients with suspected heart problems, was developed. In this system, a digital electrocardiogram is transmitted along with relevant clinical data from a clinic to a shared folder in the hospital to be accessed by a doctor. Results from this study show that there are many other benefits in using tele-consultation. For example, it is mentioned in Chronaki *et al.*'s work that frequent use of a tele-consultation system yields a good idea of the frequency of patient illnesses. The other benefit mentioned in Chronaki *et al.*'s work is that when a patient is referred, the doctor also receives information about that patient prior to the patient's arrival. The results also show that a lot of unnecessary visits by patients can be avoided by using the tele-consultation system. Also very interesting is that the doctor can tell the nurses about how to handle the patient when bringing that patient to the hospital. It is concluded in the study that tele-consultation can contribute significantly to the quality of health care more especially in rural areas. The results from Jong *et al.*'s evaluation of a store and forward telemedicine application showed that this application is clinically useful and is associated with a decrease in

health care costs [39]. The results also showed that the nurse in the remote community felt more confident in treating the patient and also provided a higher quality of care to the patient because of the help she got from the doctor which in turn increased her skill. What is also interesting is that the results showed that the system allowed the doctor himself to make more informed decisions regarding patients. Furthermore, out of 32 patients who responded to a patient satisfaction questionnaire, 84.4% believed that their care was much better while 15.6% said it made no difference. There was also a cost savings of about 20 877 canadian dollars in patient transportation and the patients themselves could save 8008 canadian dollars per year in transport [39].

Worth and Stern also developed a store and forward tele-consultation system. Significant cost savings emerged from the evaluation completed on the teleconsultation system to identify what the benefits could be. These cost savings came from the reduced frequency in transporting patients that did not really need to be sent to hospital [79]. Further research conducted by Stahl *et al.* state that there are a number of reasons why store and forward communication could be preferred over real time communication. One of the reasons is the ability of store and forward to transmit high quality images in low bandwidth [68]. Stahl *et al.*'s work suggests that real time tele-consultation in the systems could be used after the data about a patient has been transmitted to the remote site for communication on a personal level instead of only communication about the patient. Barnard and Goldyne's work discusses an evaluation of store and forward to determine the level of diagnostic accuracy and concordance among dermatologists when evaluating digital images of skin disease [9]. This study shows that asynchronous communication serves the purpose the same way as synchronous communication would serve in a health environment.

Chang *et al.* also built and evaluated a tele-consultation system [17]. Results from the evaluation shows that teleconsultation systems are more effective than traditional consultation and supervision [27]. More benefits of a teleconsultation system are also shown in this study. It is mentioned that the system can also be used for training while the system saves a lot of money in transportation [39]. Givens *et al.*'s work involved developing an internet based Tele-Audiometry system for the assessment of hearing [32]. The results from this study specifically show that there is no significant difference in diagnosis when the doctor is there and when the doctor is not. Lau *et al.*'s work involved building and testing an asynchronous web-based home telemedicine system [46]. The advantages of asynchronous versus synchronous systems

are stated in this work. Also stated in this work is the advantage of web based systems because one would be able to access them again anytime, anywhere as long as one has internet access. Once more asynchronous communication is stated as having more advantage compared to synchronous because of its non-urgent characteristics. While this may be true, the thesis notes the case that there may be a need to provide flexibility for different situations and scenarios by trying to provide both synchronous as well as asynchronous communication. What happens when urgency is required? Facing these situations includes acknowledging the fact that people do not all have computers at home and there is no Internet access in most places in the developing world.

2.3.2 IP-Based Multi-Modal Store and Forward Tele-health Systems

Jong *et al.* evaluated the effect of a store and forward system with a mix of text, pictures, audio and video between the remote community of Black Tickle in northern Canada and a small regional hospital in Goose Bay, Labrador [39]. Even though this system was developed for a developed country like Canada, it is very interesting to note the combination of different modalities for tele-consultation. The data, in this system, is transmitted via microwave with a bandwidth equivalent to ordinary copper wire. Lau *et al.* developed a web based home telemedicine system for orthopedics [45]. This system uploads readings taken from a patient at home and requires no movement at all of the patient. The doctor can access this information and reply by surfing the web server. This solution can work in developed countries where people have Internet access at their homes. In developing countries, however, there are fewer computers in households because people simply cannot afford to buy these computers or Internet access. On one hand, seeing a health specialist like the nurse, in person, increases the level of trust in what one gets from him/her as a patient. On the other hand, web based systems are remarkable because they are accessible anywhere, anytime as long as there is a computer connected to the Internet. Unfortunately in the developing world, this is not the case. Winschiers and Paterson emphasize that there is a need to develop systems that are appropriate to the situations and environments the systems are built for [78].

Kuntalp and Orkun also developed a simple and low-cost internet-based teleconsultation system that could be used in rural areas of developing areas [44]. This system allows medical experts to access patient data remotely by using the Internet. The system has client-server architecture. The interface to the systems is web-based and based on PHP. This system

supports storing of images, text, audio and video by using MySQL database. While the system is good for tele-consultation, the problem is that Internet access is still needed for one to be able to use the system. As previously mentioned, this is still a dream in most developing countries.

Geissbuhler *et al.* studied and evaluated the potential and the risks of an internet-based teleconsultation network in the developing countries of Western Africa [31]. The main aims of this study were to develop and use Internet-based connections between the national and regional healthcare institutions, implement basic services such as e-mail and a medical web portal, and train users, implement a low-bandwidth, Internet-based distance learning system and lastly to evaluate the feasibility of distance collaboration for both medical education and teleconsultation. Results of the evaluation of the system built by Geissbuhler *et al.* showed that physicians showed immense interest in the system due to its ease of use. Potential obstacles for use in the developing countries are lack of Internet access and personal computers since both are needed to use the system.

Tadler's work involved developing a cost effective telemedicine kit for use in developing countries [72]. A low-cost telemedicine kit of approximately 8000 US dollars was developed to address the needs for sustainable telemedicine solutions for the local delivery of healthcare and efficient access to medical expertise when needed. The telemedecine kit, developed by Tadler, consisted of a durable case that houses a portable computer, a digital stethoscope and a digital imaging system. The kit allows a health practitioner in a remote area to capture patient data in the form of audio, video and images in a asynchronous fashion and forward them via the internet to a doctor for diagnosis. The network infrastructure was based on a 802.11b wireless metropolitan network and also on the public telephone network to reach regional hospitals. The e-mail and web services were hosted on Linux-based servers, and protected from the instability of electric power supplies by three dozen truck batteries. It is very interesting to note that there are problems with power in most of developing countries. The fact that this problem was not ignored in this study is very encouraging. The system supports sending of images by using e-mail and also supports chatting by means of Instant Messaging. Evaluation of the network and the system showed that the biggest problem was the instability of the basic infrastructure, in particular the electricity. The evaluation also showed that asynchronous communication tools like e-mail are efficient and can be used productively. Finally, the evaluation revealed that there is a need to develop local content management skills to translate global knowledge into

local realities. A multimedia story telling service developed for socially isolated seniors with speech or language impairments by Davies *et al.* supports creating stories using images, video clips and sound clips [26]. These clips and images are then retrieved later by the user during interaction with the other user.

2.3.3 Development Methodology

Jong *et al.*'s work involved evaluating the effect of a store and forward system with a mix of text, pictures, audio and video between the remote community of Black Tickle in northern Canada and a small regional hospital in Goose Bay, Labrador involved training. A significant success of this pilot project was the training [39]. The training was built into the study design in that the staff, that is the nurses and the doctors, were to be trained in the use of telemedicine equipment before the project continued. This is the same issue mentioned by Bhatnagar when he said training is also the key [10]. Davies *et al.* used ethnography techniques together with participatory design to develop a Personal Digital Assistant (PDA) application to facilitate communication between people who have aphasia. Davies *et al.*'s development of this PDA communication application was carried out by spending time with the user and trying to understand how he communicates and a participatory prototyping approach was followed in the study to develop the communication application [26]. The most interesting point in this study is that no assumptions were made about the communication aspects of a patient with aphasia. Davies *et al.* interacted with a person who had aphasia while developing the system to get more insight into other issues they might have previously taken for granted. The research emphasised social issues.

Martinez *et al.* did research on providing low cost synchronous and asynchronous communication means in the rural areas of a developing country [50]. The research basically followed four steps of action. The first step involved research into the communication needs of rural health personnel in developing countries. The second step was to design a system according to the conditions in these areas. The conditions could be poor bandwidth and power supply, for example. The third step was to design the system suited to the needs of the users and deploy these systems through pilot projects. Lastly this work performed an evaluation of the impact of these systems on health services. Pilot projects in 39 different sites were done by this study. The results of this study showed that only with participative implementation programs, using solutions derived from the needs and constraints of the target communities and

not technology driven, is it possible to achieve the global acceptance of all users involved in the system [34].

2.4 Summary

In this chapter, work related to developing ICT for development applications for developing countries was discussed. The role of ICT for development applications in the developing countries was highlighted. The characteristics and applications of some of the characteristics of successful ICT for development applications have been discussed with the main focus on those that are pertinent to this thesis. The main issue that came out of the discussion of ICT for development applications is that they do hold great promise in resolving some of the problems faced by the developing countries. This will, however, occur when appropriate strategies for developing these applications have been adopted. The chapter then discussed examples of systems specific to the context of this thesis, multi- modal semi-synchronous tele-health communication systems. Some of the strategies used in developing these systems as well as the lessons learned while developing these systems were mentioned. The conclusion drawn is that most of the developed applications do not have some of the characteristics of successful ICT applications for developing countries. In developed countries, the key focus seemed to be more on the technical issues more rather than the social issues. There was also very little integration of various modalities in both synchronous and asynchronous mode. This thesis applies methodologies that help in understanding both the social and technical issues related to the target environment. In terms of the technical system itself, the thesis experiments with a similar mix of modalities in both synchronous and asynchronous modes while keeping in mind some of the lessons learned from the literature described in this chapter. In the following chapter, the methodology used to gain an understanding of the social and technical issues related to the target environment will be described.

Chapter 3

Approach and Research Methodology

In chapter 2, the emphasis was placed on discussing the literature regarding Information and Communication Technology for development potential for solving some of the problems in developing countries. Some tele-health systems developed for the developing country context were also discussed in terms of the technical aspects and methodology used in building these systems. This chapter presents the research methodology that is used to approach the research question in this thesis. A clear definition and justification of the methodologies are also given in this chapter. Furthermore the research question for this thesis is stated, broken down and discussed in this chapter.

3.1 Research Question

This thesis is aimed at answering one main research question. The research question is explicitly stated as follows: ***Is an IP-based multi-modal semi-synchronous communication system applicable in rural tele-health in a developing country context?*** This research question must be addressed from two main perspectives. The first perspective addresses how such a system can be built. The second perspective addresses how to understand the social space of the users the system is built for, and how to give support and encourage the users to use such a system. The research question is thus subdivided into two questions. One question aims to find out whether the technical system built is applicable to the target environment. The other question is aimed at investigating the methods used to engage the community.

In order to answer these research questions, a multi-modal semi-synchronous system was built and tested in the target environment with an Action Research cyclical process. Each cycle is an introduction of changes and enhancements in the prototype to satisfy requirements gathered from the previous cycle. System usage data is collected by observing the system usage, system logs and informal interviews. As the technical system is built, the proposed methodologies are

applied in a cyclical process. The methodologies applied contend with understanding the working environment and social space of the users to understand the applicability of the proposed technical solution. This leads to requirements gathering for the technical system itself. It was initially thought that the requirements gathering process would be enabled by the Participatory Design methodology as described by Muller and Kuhn [55] but it was found that an interpretation of the requirements is best done as the requirements emerge from the Action Research cycles. This is mainly due to the limited time spent with the users during each Action Research cycle because participants perform their own duties while visited. When the system was built, an evaluation of whether the system helps or not was performed using the proposed methodologies. The social environment in which the users work informs how the prototype must change because it has to fit in with their work processes to enable the users to use the system.

3.2 Social Methodologies

3.2.1 Ethnography

Ethnography is a methodology that allows researchers to see what is happening in the target areas of their research by spending time with the users and observing the way they live and work. Myers mentions that ethnography allows a researcher to have a deep understanding of the people, the organization, and the broader context within which they work [56]. Tacchi *et al.* describe ethnography as literally meaning to represent a culture and is traditionally based on long term engagement in the field of study or site [70].

Davies *et al.* used ethnography while developing a Personal Digital Assistant to support communication amongst people with aphasia [26]. The major advantage mentioned in using ethnography is that it does not only offer an opportunity to gain insight into the working environment of the target groups but also allows an improved understanding of the social environment of the target groups. The only disadvantage is that this methodology requires more time in the field. Ethnography is often chosen because it allows the researchers to be within the social space of the users or stakeholders [56] [53]. This is important in this thesis because a deeper understanding of the way the users work is needed. This knowledge or information provides a very deep understanding of what the users say and what they actually do because it is really important to have a clear understanding of what is going on in the target

environment. Furthermore it is easier to see where the technical solution can fit in the social space of the users and also provides room for knowing how the system can be changed during the Action Research cycles.

3.2.2 Action Research

Action Research is described by Smith, as well as Buskerville, as a research process that has the five steps of action [66] [13]. The first step involves identifying a general idea/problem. The second step involves the planning of action to be taken as a result of the identified idea/problem. The third step is taking action. The fourth step is an evaluation of the actions taken. The final step involves critical reflection and leads to the next cycle. Susman clearly describes the Action Research steps as shown in Figure 3.1 [69].

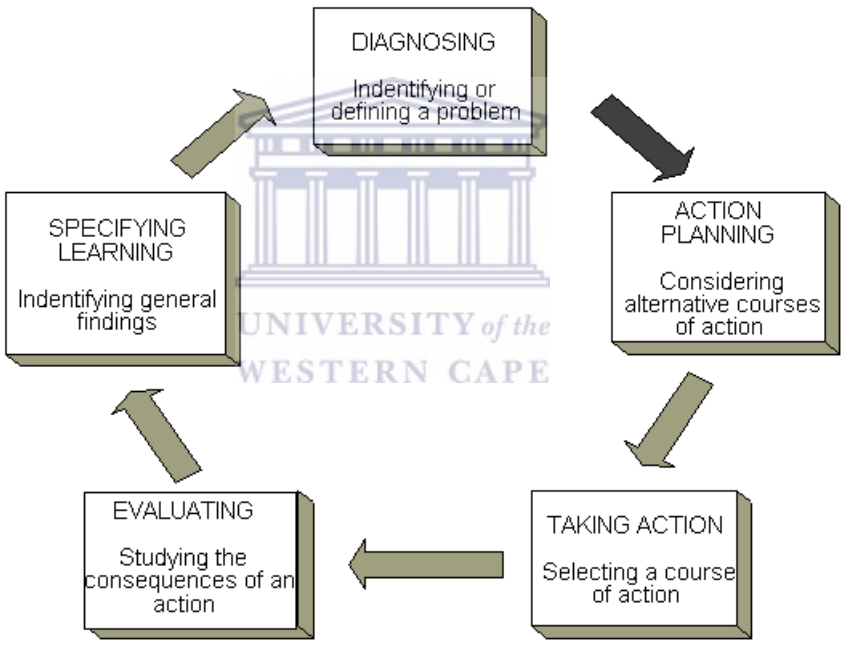


Figure 3.1: **Action Research Steps:** This figure illustrates and defines what actually happens in the steps in the action research methodology. These steps are presented in a circular form to represent the relationships between them [69]

Avison *et al.* said that "To make academic research relevant, researchers should try out their theories with practitioners in real situations and real organizations" [7]. Lewin also said that "Research that produces nothing but books will not suffice" [47]. MacIsaac clearly states that Action Research is used in real situations, rather than in contrived, experimental studies, since its primary focus is on solving real problems [49]. Mostly, though, in accordance with its principles, it is chosen when circumstances require flexibility, the involvement of the people in the research, or change must take place quickly or holistically

[49]. MacIsaac furthermore states that it is often the case that those who apply this approach are practitioners who wish to improve understanding of their practice, social change activists trying to mount an action campaign, or more likely, academics who have been invited into an organization or any other domain by decision makers aware of a problem requiring action research, but lacking the requisite methodological knowledge to deal with it. Heeren *et al.* adopted a collaborative Action Research approach in developing a videoconferencing system for medical consultation on cancer patients [36]. One of the advantages of the Action Research approach adopted by Heeren *et al.* is that it allowed them to collaborate and be more flexible with their target group. The only disadvantage mentioned is that the use of Action Research is very time consuming.

The situation of this thesis is also a real-world environment with real problems rather that an in-lab experiment. The thesis aims to understand the social space of the users in their environment and how a technical system can be built based on the social space of the users themselves. Action research is therefore most appropriate for this thesis. Secondly, the thesis indirectly tries to make academic research relevant by tackling a real problem with real people in a real world [7].

3.3 Technical System Development Methodology

3.3.1 Waterfall Model

Pfleeger and Lawrence describe the waterfall model as a software development process model in which the stages are depicted as cascading from one another as shown in Figure 3.2 [57]. In this model, each step is directly dependent on the previous step. This means that the process cannot continue until the previous step is ready and satisfactory. Pfleeger and Lawrence discuss two of the problems with the waterfall model. The first problem is that the waterfall model does not discuss the way code is developed except for a very well understood problem where the software is usually developed with a great deal of iteration [57]. The second problem is that this model tends to treat software as a problem-solving process. Pfleeger and Lawrence state that software is a creation process and not a manufacturing process [57]. The waterfall model does not allow the creation of software to happen effectively as it says nothing about back-and-forth activities that lead to the development of a software product [57].

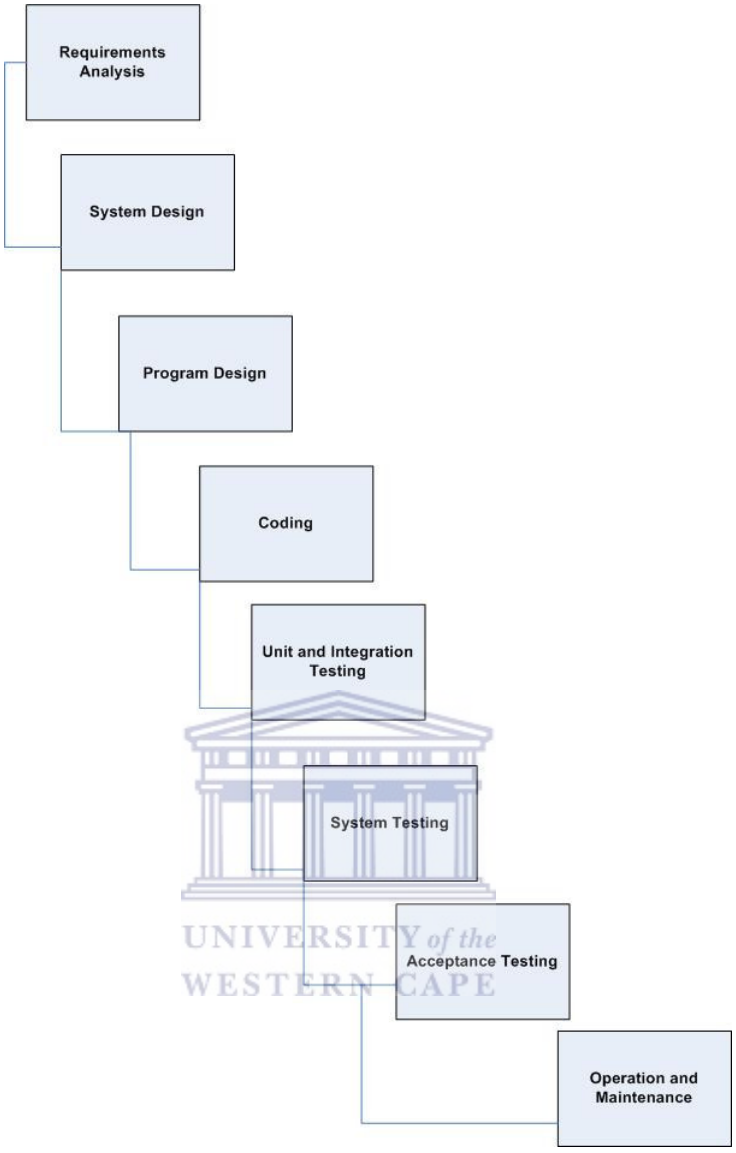


Figure 3.2: **The Waterfall Model:** This figure shows the steps involved in the waterfall model. Each step in the model leads to the following step and all the steps are Interconnected [57].

3.3.2 Exploratory Prototyping

Exploratory prototyping is a model where the requirements for the technical system are first collected and analysed. After the process of requirements analysis is done, a design and building of the prototype based on the analysis of the requirements is completed. After building of the prototype, it is the tested to determine whether the prototype captures all the requirements as needed. The prototype is then evaluated to determine whether it meets the

requirements. If the prototype meets the requirements it is then deployed otherwise it is evaluated further [37]. Figure 3.3 shows the process of exploratory prototyping.

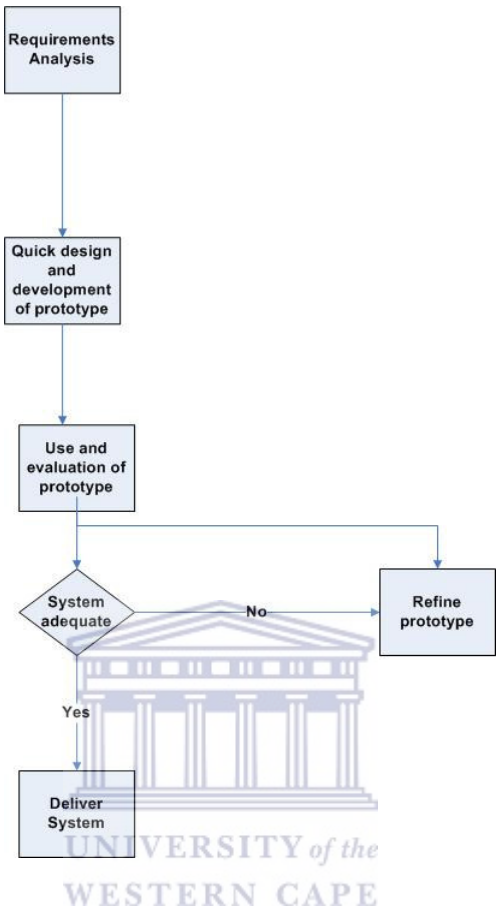


Figure 3.3: **The exploratory prototyping model:** This figure shows the steps involved in the exploratory prototyping model. In this model, requirements are collected and a prototype is designed and built based on the requirements. If the prototype meets the requirements, it is deployed, otherwise it is further refined until it meets the requirements.

3.3.3 Integration with Action Research

The technical system development methodology, adopted in this thesis, is a prototyping approach situated within Action Research cycles. In each Action Research cycle, the software development life cycle process (shown in subsections 3.3.1 and 3.3.2) is performed in which requirements are collected, a system is built and tested. The development process then continues based on the requirements that come out of the system usage, interviews and ethnographic observations performed in each cycle. This leads to a new prototype and new actions for each cycle, and also a reflection on the process. A holistic approach is taken when developing the system as one reflects on whether there will be new features needed in the system, or whether the technical system will fit into the social environment of the users. The

beauty of this approach is that it offers flexibility for change as Action Research cycles need to be performed to get an understanding of the social environment and the way the technical prototypes are used. These are the major sources that drive the requirements in the technical system prototype for the next cycle. The process is time consuming. The other difficulty with this approach is that it is difficult to say when the cycles will end. The prototype could be appropriate in the third or even tenth cycle depending on how well one understands the social environment of the user. The main point is that this approach is sensitive to the social environment of the users while developing the technical system.

3.4 Data Collection

3.4.1 Outcome Mapping

Outcome Mapping (OM) is described by Earl *et al.* as a methodology that can be used to collect data as well as evaluate projects [28]. The way OM is used depends on the needs of a particular project. OM consists of *boundary partners*. Boundary partners are the people whose behavioural changes the research aims to monitor. This behavior is monitored by making use of different levels of monitoring known as *progress markers* [28]. The progress markers are divided into three categories in OM as follows:

- "Expect to see" outlines the issues that one expects the boundary partners to do or ways in which one expects them to behave.
- "Like to see" outlines key points that one would also like to see the boundary partners to do.
- "Love to see" outlines the things that one does not really mind if they do not happen within the time-frame but would be excellent if they did actually happen.

OM consists of three stages. The first stage is known as *Intentional design*, in which the research must identify the vision to which it wants to contribute, identify the boundary partners it wishes to work with, identify the changes it seeks from the boundary partners and also explain how it plans to contribute to the change process. The second stage, *Outcome Performance and Monitoring* allows for the ongoing monitoring of the boundary partners towards the achievement of the outcome being sought. The last stage, *Evaluation Planning* helps in identifying evaluation priorities and plans [28].

Earl *et al.* also mention that Outcome Mapping is not concerned with impact and provides a suitable means of documenting small changes whether positive or negative [28]. Outcome Mapping has mainly been used for two reasons in this thesis. The first reason is that it is important to document all the changes that happen as a result of the actions taken and avoid only looking for impact rather than changes. This is because these changes are important (to document) as they show whether one is going in the correct direction or not in terms of achieving the desired result. These changes that are documented will help in getting closer to the solution in terms of both the methods and the technical solution that are provided. The second reason is that it is important to evaluate the actions that are taken by documenting the effect that they have on the users or stakeholders. Outcome Mapping allows far easily documenting all this information in journals and makes it easy to see whether there is progress or not in each Action Research cycle.

3.4.2 Automated Data Collection

The automated data collection happens when the system is used by the users. The data collected in this method provides an understanding of when the system was started, the features used by the users in the system as well as the features that were not used by the users in the system. Automated data collection allows collection of data that one would otherwise not have been able to collect whilst the system being was used. This data is important as it gives an idea and helps in the mapping performed between what the users of the system say they did and what actually happened. This data also gives an idea of the important events and logs that occur when the system is in use. The data is helpful when there are bugs in the systems as it helps in giving an idea of what the users did when the bug occurred. This makes debugging less difficult.

3.4.3 Semi-Structured Interviews

Semi-structured interviews offer an understanding of both the social and technical issues in the target environment because one is able to follow a certain structure of the interview while being able to ask more questions within the context of an interview. The semi-structured interviews follow an outline defined by a questionnaire in Appendix A. Semi-structured interviews provide an understanding from the users themselves, of how many times they used the system, when they used the system, the modes of communication they prefer as well as the actual

modalities they use when communicating. The interviews also help in asking the users what they like about the system in terms of the features currently available in the system. Lastly the questionnaires also allow the users to provide input on how they think the system can be improved as well any other features they would like removed or added in the technical system. The semi-structured interviews are recorded with their permission. This data is then transcribed and presented as text to highlight and support claims in this thesis.

3.4.4 Ethnographic Observations

Ethnographic observations allow a better understanding of the social environment, how the users use the system and the features they find easy or difficult to use in the system because one is able to spend time with the users in their working and living environment while observing the way the execute their tasks. During the observations, questions were also asked of the users to provide clarity on how they work. During ethnographic observation, notes were taken based on the observations. The notes taken helped to record the Outcome Mapping journals and document reflection for the next Action Research cycle.

3.4.5 Data Triangulation

While the methodologies given were explicitly used as data collection or evaluation methodologies, the data collected from these methodologies informs how to better understand the social space of the users. Secondly this data also informed how the technical system could be built and enhanced throughout the Action Research cycles and also how the system can be used. For example, Outcome Mapping was used as an evaluation methodology in this thesis but the data collected from Outcome Mapping informed whether there was a need to change the technical system or a need to change actions to be more involved in the social space of the users. All the methodologies used formed part of understanding both the social environment and the technical aspects/use of the system. This relationship is shown in Figure 3.4.

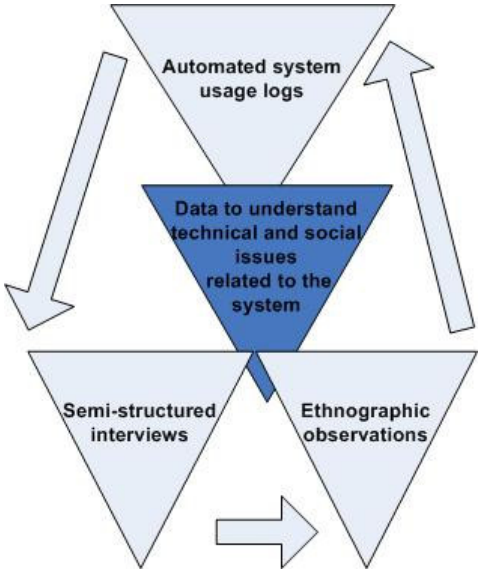


Figure 3.4: **Data Triangulation Diagram:** This figure illustrates how data is triangulated to come up with conclusions. Different sources of data are shown in this figure. The system logs, semi-structured interviews and ethnographic observations are triangulated to get an understanding of what is really happening in terms of how the system is used.

The data collected in this thesis is collected by means of different forms in order to get an understanding of both the social and the technical issues related to the system and its usage in the target environment. The data collection methods used are system logs, ethnographic observations, semi-structured interviews. The data collected in system logs give an insight into whether the system was used or not, what features in the system were used and which ones were not used, how many times the system was used and also whether the system helped in any way. The data collected by means of semi-structured interviews allow an understanding of how the users feel about the technical system and the way it is integrated into their social environment, as well as what they think could be improved or changed in the technical system and actions to better meet their social environment. The data collected by means of ethnographic observations provides an understanding of whether the system is really helpful or used, and also allows one to see the features the users use most. These observations also allow an understanding of what else the system is used for. This data is then triangulated to draw a better understanding of the environment since different sources are used. The use of the data triangulation process is shown in Figure 3.4.

Data triangulation is used for several different reasons in this thesis. The first reason is to compare what the users say during the interviews to what actually happens during the Action Research cycles in terms of system usage. Secondly, the ethnography applied is very limited

because of the limited time spent with the users. A process of rapid ethnography as described by Millen is applied when a visit to the field is made [53]. The data triangulation process will therefore allow a broader understanding of both the social and technical aspects of the research question.

3.5 Summary

In this chapter the research question is stated and defined. The research question is aimed at learning how a technical system can be built for a rural telehealth environment in a developing country like South Africa. This research question is split into two sub research questions dealing with how such a system can be built and how the users can be supported to use such a system. Action Research cycles are used during which ethnographic observations, semi-structured interviews, and system usage logs are collected within the context of Outcome Mapping. This data is then triangulated to get an understanding of how the technical system can be enhanced and improved as well as how the users can be supported to use such a system. A clear definition of how each methodology works, and why it was chosen for this thesis is also provided. These methodologies have been applied in the field-work of this thesis and the following chapter defines how these methodologies have been applied in the field-work. The data collected by these methodologies are also presented in the next chapter and the technical system that was built in concert with the Action Research cycles is described in Chapter 5.

Chapter 4

Data collection

In the previous chapter, data collection and evaluation methodologies were presented. The data collection methods used were ethnographic observations, system usage logs and semi-structured interviews. In this chapter, the activities performed and the data collected during the Action Research cycles using these methods, are provided and discussed. This data is presented in the form of Action Research cycles. The automated system usage data is not presented in the Action Research cycles as the system data collection only took place in cycles 5 to 7. This was the time when the system was operational. Outcome Mapping journals are also presented in this chapter to depict outcome monitoring and evaluation of the boundary partners. The journals present a picture of the progress in each cycle in terms of the outcome challenges that were required from each boundary partner. Different sources of data collection are used in the Outcome Mapping journals presented for each boundary partner during each Action Research cycle to perform an evaluation on the partners. The resulting technical system development is discussed in Chapter 5.

4.1 Outcome Mapping Intentional Design

Outcome Mapping was used as both an evaluation and a data collection methodology. The three steps of Outcome Mapping are Intentional Design, Outcome Performance and Monitoring and Evaluation Planning. These steps were applied in this thesis during the data collection and evaluation process on the boundary partners (4.1.3) during the Action Research cycles. The data collected, using Outcome Mapping is presented in the Outcome Mapping Journals later in this chapter. The vision, mission, the boundary partners, and their outcome challenges are stated and listed. To recap, the vision is what the project would like to achieve. The mission consists of the steps or procedures necessary to get to the vision. Boundary partners are those individuals, groups or organization interacted with directly, and with whom the project anticipates opportunities for influence [28].

4.1.1 Vision

In the remote rural hospital and clinic in South Africa, Canzibe Hospital and Lwandile Clinic, nurses and doctors will be able to use a wireless Internet Protocol-based communication system to conduct patient referrals, request ambulance services, order supplies and generally keep in contact with one another. This will enable nurses to learn how to treat a wide range of problems locally, it will prevent unnecessary travel by sick patients (to the hospital) and simultaneously it will lessen the workload for the doctor(s) at the hospital. Community leaders and both regional and provincial Department of Health groups recognize the value of the system and support its development and maintenance.

4.1.2 Mission

In support of the vision, the programme uses an Action Research and Ethnography approach to learn how to develop an appropriate technical system and also to learn how to support the stakeholders to participate in the system's design and deployment. The technical system will cope with the frequent power outages in the remote rural areas and will also cope with the severe scheduling demands experienced by the doctors and nurses using the system. Attention to the human computer interface with a user-centered development approach will enable an individual to learn how to develop a usable and sustainable system that fits into the social context of its usage. In addition to targeting doctors and nurses, the programme will also target community leaders and government agencies involved with the target communities it will support.

4.1.3 Boundary Partners

The boundary partners for this thesis are grouped into the Clinic Nurses, Hospital Doctors and the Department of Health (DoH) - District and Provincial Levels. The outcome challenges and progress markers, for each boundary partner, are stated below. Boundary partners are addressed in terms of groups, e.g. hospital doctors and clinic nurses. This is because the outcome challenge and the progress markers are the same for all of the people in each specified group. The DoH provincial boundary partner is located far away from the project site as well as the hospitals where all the meetings were held. In order to get to the hospital, the DoH boundary partner needed to drive for at least four hours. The DoH district boundary partner is

also located away from the hospital and they had to drive a few hours to attend the meetings during the research visits. The only contact with the DoH district boundary partner is through the use of telephone and fax as they have no e-mail. The hospital doctors boundary partner lives in the hospital but all the members are from foreign countries and had different motivations for working in South Africa. The nurses are South Africans, some of them live in the nearby villages and some live in villages far away. The nurses go home at the end of the month. Sometimes they go home over some of the weekends. Some of the nurses felt intimidated and felt that the way in which they work was being watched. Lastly some of the nurses did not take the research seriously and thought that the research was just a game because of their social and educational background.

Clinic Nurses

Outcome Challenge

The programme intends that nurses use the system to request advice from a remote doctor before directing a patient to the hospital. The request may be for treatment and/or diagnosis information. Depending on the availability of a doctor, at the other end, the request may or may not be immediately answered. If delayed, the nurse still places the request, and will have to make a plan as to how to get the information back to the patient, for example via another patient that lives nearby. It is expected that the number of hospital referrals from the target clinic should decrease over time as the nurse becomes more adept at handling a wider range of medical problems. It is also expected that the doctors and nurses develop a form of semi-personal contact via interaction over the system.

Progress Markers

The progress markers chosen for the Clinic Nurses were chosen based on the participation of a nurse since they were the users of the system. There are two main aims of these progress markers. First, the aim is to monitor whether the nurses are keen on the technical system itself as well as the issues surrounding its usage. This is monitored by using progress markers that are directly linked to system support and suggestions on the technical system. Secondly, the progress markers chosen for the Clinic Nurses also enable an understanding of whether the sisters are taking ownership of the system by finding more uses for it themselves. The progress markers are listed as follows:

Expect to see

• Meet with the research team when visiting the Eastern Cape

• Fill out questionnaires and participate in interview

• Initiate enquiries to the doctors on the system for patient referral advice

• Use the system during allocated hours for synchronous calls

Like to see

• Help generate a policy for the semi-synchronous use of the system

• Provide helpful suggestions to improve the software

• Let the technical support know when something is wrong

• Point out deficiencies/problems with the software

• Use the system after hours or when free

• Keep track of the patient referrals, for example whether they actually went to the hospital or not

• Use the system in store-and-forward mode

• Use the system to schedule in-service training

Love to see

• Convince their Department of Health superiors to expand the system to other clinics and hospitals

• Establish regular personal communication with the doctors and other nurses on the system

• Find innovative uses for the system beyond patient referrals

Hospital Doctors

Outcome Challenge

The programme intends that doctors allocate time to use the system to respond to the nurses' referral requests. A doctor's schedule is typically so heavy at a rural hospital that participation in a research project such as this actually takes away from patient time. By taking the time to use the system, a doctor responds to a nurse's request by informing the nurse how to handle a case locally or by asking her to refer the patient to the hospital. The doctor may require additional information from the nurse, such as physiological measurement, a picture or a video. Hence, depending on the case, the communication can be a once off reply, or some form of patient discussion. It is expected that the number of hospital referrals from the target clinic should decrease over time as the nurse becomes more adept at handling a wider range of medical problems. It is also expected that the doctors and nurses develop a form of personal contact via interaction over the system.

Progress Markers

The progress markers chosen for the doctors were very similar to those chosen for the Clinic Nurses for two reasons. The first reason is that the doctors are at the same level of interaction with the system that is they are end users. Secondly, the doctors need to be monitored to find out whether they are taking ownership of the system.

Expect to see

• Meet with research team when visiting the Eastern Cape

• Fill out questionnaires and participate in interview

• Respond to the nurses' enquiries on the system

• Use the system during allocated hours for synchronous calls

Like to see

• Help generate a policy for the semi-synchronous use of the system

• Provide helpful suggestions to improve the software

• Let the maintenance support know when something is wrong

• Point out deficiencies/problems with the software

• Use the system after hours or when free

• Use the system to initiate contact with the nurses to follow up on a patient or to see how things are going in general

• Use the system in store-and-forward mode

• Keep track of the patient referrals from the clinic

Love to see

• Find innovative uses for the system beyond patient referrals

• Use the system for personal communication with other doctors and nurses

• Convince their DoH superiors to expand the system to include more clinics and hospitals

Department of Health - District and Provincial Levels

Outcome Challenge

The programme intends that members of the regional and provincial Department of Health (DoH) take an active interest in the proceedings of the programme, keeping in touch with the research team on a regular basis. They support the programme and if it is successful, they devise mechanisms to support further development and maintenance of the programme. On a regional basis, this means the direct support of the Information Officer to help train nurses and

doctors on PCs, allocation of maintenance resources and personnel, and managerial authorization for the doctors to dedicate time for using the system would be necessary. At the provincial level, it means support for this research to continue as a possible alternative to work into their overall IT strategy for the province.

Progress Markers

The research needs support from the Department of Health to support and sustain the use of the system since they are the managers in the environment in which the system is deployed. The progress markers are chosen to allow monitoring of their interest in the project. It is hoped that if the system proves helpful, the Department of Health can adopt the system and provide all the necessary support to expand the system as well as sustain the system. The progress markers are as follows.

Expect to see

• agree to meet with research team when visiting the Eastern Cape

• respond to voice mail, faxes and email

• authorize and ask the doctors and nurses to participate in the research

• offer some feedback on the system

Like to see

• offer critical feedback on the system itself

• offer critical feedback on the use of the system

• train the nurses at Lwandile clinic

• allocate someone for technical assistance and maintenance

• help identify the types of statistics they would like the system to collect

• use the system to communicate with the clinics and hospitals

• initiate contact with us concerning the system

Love to see

• put together a training and maintenance programme for clinics

• help organize a roll out plan to expand the programme

• allocate funds on their budget for the training and maintenance

4.2 Action Research Cycles

In this section, the Action Research cycles performed for this thesis are described. The main aim of each Action Research cycle is explained, as well as the key findings in each Action Research cycle. Each cycle consisted of data collection processes for the system requirements as well as an understanding of the social environment to understand whether the built system fits and how it can be made to fit in better.

4.2.1 Action Research Cycle 1

This cycle involved requirements gathering from the Tsilitwa/Sulenkama site. During this cycle a number of visits were made to the original site to elicit user requirements for the new MuTI version 2 system by performing ethnographic observations and informal interviews. Because the MuTI version 1 (MuTIv1) system was already installed and being tested by Chetty et al. [23], the main issue was to find more requirements for extending and enhancing the MuTI system. MuTIv1 was providing voice in real-time as well as voice, images and text in store and forward modes. As previously discussed in chapter 1, this site had a system installed by the Council for Scientific and Research council (CSIR) that supported synchronous voice and one way video from the clinic to the hospital. The users felt that the quality of this video was not good and it was difficult to do anything with the poor video that came from the web camera. It was suggested that an addition of video in both real-time and non-realtime mode to the MuTIv1 system was needed. The following requirements came up during this cycle.

Requirement 1 Addition of video in synchronous and asynchronous functionality.
Requirement 2 Addition of Instant Messaging to round off the modalities.

While the implementation of requirement 1 was taking place, the CSIR team and this project team felt that similar research was being done in one site and therefore confusing the two research teams. It was decided that the research could be moved to another site and comparisons could be made on the findings between the CSIR site and the site where this project is located.

4.2.2 Action Research Cycle 2

This cycle was concerned with finding a new site in which this project would continue. At this stage a visit was made to the target area to find a potential site and the boundary partners with whom this project was to work with. The main issue at this point was to create relationships with the possible boundary partners. The site was chosen based on word of mouth during a social visit made by one member of the project team. It was known at this point in time that there was a hospital serving clinics. The name of this hospital was Canzibe hospital. However, the project still had to decide on which clinic it would focus. During this visit, a meeting was held with three doctors, the local hospital superintendent and the matron. An explanation of the research was made. It was discovered that there was another communication system installed by missionaries who lived in the area. This communication was based on Citizens Band (CB) radio and proved very helpful when it was operational. However, it had not been operational since the year 1999 because it had not been maintained.

It was evident that a communication system was needed and a discussion of the clinics that surrounded the hospital ensued. A site survey was performed to see how the network could be built, including the line of site for wireless connectivity. Clinics were evaluated according to the different criteria like power, distance from the hospital and the number of staff that worked in the clinic. Lwandile Clinic was chosen because it was very far from the hospital and had solar power, as well as adequate staff to use the system when installed. The next step was to really engage the boundary partners to form solid working relationships and trust, as well as explain the purpose of the project to the boundary partners.

4.2.3 Action Research Cycle 3

First, the purpose of this Action Research cycle was again to meet the boundary partners and confirm mutual interest and participation. Secondly, this cycle was concerned with building relationships with the boundary partners as well as engaging them so that they can offer support. During this cycle a meeting was held with the doctors at the hospital to find out if they could find any further uses of the MuTI system as well as find out how they could benefit from the system. Furthermore, a demonstration of the then current MuTI version 2 system was done to provide an idea to the boundary partners about what the project aimed to achieve.

The doctors mentioned that some of the nurses at the clinics were not qualified enough to actually decide and see what the problem was with the patient. The doctors also mentioned that sometimes they received referrals that were really unnecessary and these referrals could easily be taken care of at the clinic and that, with the system, could be solved. Another meeting was also held with another boundary partner, the Department of Health, at district level. A detailed explanation of the aims of the thesis was done together with a demonstration of the system. The deputy district manager mentioned that the previous system, based on CB radio, was very helpful when it was there. CB radio provided excellent communication, not only between the clinics and the hospital, but also amongst the clinics themselves. The deputy district manager furthermore mentioned that a system like MuTI would definitely help in providing the communication between these areas. It emerged from this meeting that the system could also be used to motivate for wheelchairs for patients to the government by recording a video of a patient and sending it to the provincial Department of Health. A quick site survey of Lwandile Clinic was also performed during this cycle. The cycle ended with a visit to the village headman of the village where the clinic was located. An explanation, in a local language, about the aims of this project was presented to the village headman of Lwandile village as he did not understand English. Permission was asked from the headman to use his house to install equipment for the required network because his house was on top of the hill and within the line of sight to a tower. It was also safer to install equipment at his place as it was safer than installing it in a place where there were no people or proper security.

4.2.4 Action Research Cycle 4

This action research cycle was about understanding the social environment, more specifically the working environment of the users. The cycle was also about meeting with the boundary partners, who were not met in the previous cycle to explain the project and create more relationships. Ethnographic observations and informal interviews were used at both the clinic and the hospital to get a better understanding of the social space of the users. This subsection describes the ethnographic observations that were performed together with the meetings held with the boundary partners, as well as the key findings in both the hospital and the clinic.

Observing the process of referrals

The process of observing the existing communication, between the clinic and the hospital was essential to understand how a communication system could be used and incorporated into the whole social space of the users. The observations were conducted at both the clinic and the hospital to understand how the patients were referred as well as how the decision-making occurs in terms of when a patient has to be referred. The main purpose was to find a link to how the new MuTI version could be used and enhanced in both the clinic and the hospital.

Observing at the Clinic

During observation, three nurses were present and patient attendance was high. The chance of seeing some referrals was high because of the high number of patients who came to the clinic on this day. Before the observation, informal interviews with the sisters were performed to understand how the CB system worked and how it helped when it was operational.

The doctor is available once every month at the clinic to take care of extreme cases. Luckily the doctor was available when the observations were made. When patients entered, their details were recorded onto a piece of paper by the nurse. They were then asked to leave a sample of their saliva or blood for a test in the lab at the hospital. The blood and saliva samples of the patients are taken once a month and a doctor transports them to the hospital for a test. The patients then have to wait until the results are back from the lab. When the results are ready from from the lab test, they are written on a piece of paper and transfered back to the clinic, usually with the doctor. A patient with an eye problem came in and was given first aid and told that he must go to the hospital if the first aid did not work. Another patient entered and wanted

medicine as she had severe ear and stomach pains. This patient had already left her samples for testing but she complained that the results were taking too long to come back. It was also learned that referrals also happened amongst the clinics mostly when medicine was not available and patients could get medicine at one of the clinics.

Requirement 3 Use MuTI to send back test results to the clinic.
Requirement 4 Use MuTI to communicate between clinics.

There are many delays in getting the results back to the clinic after the test has been completed as they have to wait for the doctor to come to the clinic and the doctor only comes once every month. This means that the doctor fetches the samples and must return with the results. The turn around time for this process is at least a month. It appears that it would also be easy on the hospital side to send the result using MuTI as the results would get back immediately and patients would get treated as soon as possible. It also seemed that some of the cases could be treated at the clinic if the nurse could have some communication with the hospital to get help from the doctor. Lastly, it seemed that a referral process amongst the clinics could also work if there was a way to know whether another clinic had medicine or not before the patient was sent.

Observing at the Hospital

The referrals at the hospital are put into three categories. The three categories are: referrals from the clinic; reviews, for example patients seen by the doctor and asked to come back after three days; and all the other categories. It was also evident that there were many delays in the queue before the patients could see the doctor as there were many patients. The patient waits approximately two to three hours before they see the doctor, but emergencies are handled first. Cases that are not serious are sent to the gateway clinic within the hospital. The procedure is as follows:

- patients get their information logged and pay the required fee.
- Next, nurses screen and discuss how the patient has been taking the medicine.
- After this the patients get grouped by the nurses according to the doctors they have to see.
- Finally, they meet the doctors.

The main concern here is that once there are a lot of patients, it becomes a problem as some patients leave without getting the doctor's help. Maybe if some of the patients could get help

remotely from their clinics, the queues would be much smaller. This cycle ended by meeting the Department of Health, provincial level boundary partners. During this meeting the purpose of the project was explained, that the project was an investigation process and not a solution. The intent was to manage expectations as regarding a finished product. Secondly, future collaboration and sustainability issues were discussed.

4.2.5 Action Research Cycle 5

This cycle was concerned with building the wireless network and installing the software described in the next chapter. The network was built in about a week. Upon completing the network, the first prototype of the MuTIv2 system was tested over the network and seemed to run smoothly, although some bugs were noted during the test. The technical support technician was also trained on the MuTIv2 system so that he could provide training to the users between the visits. During the training, suggestions came from the technical support technician on how the interface could be improved. The requirements are listed below. The nurses had been receiving computer literacy training since the previous cycle. The nurses were trained during this cycle for the first time in using the MuTI version 2 system. Ethnographic observation was made on how they performed on the system based on the computer literacy they had been receiving. More requirements on how the system could be enhanced came out of this cycle based on the training given to the technical support person and the nurses. The technical support person was instrumental in providing feedback on how the interface could be improved and enhanced. Most of the requirements were suggestions that came from him based on time spent with the users during the computer literacy training. The requirements and suggestions that came out of this cycle, from the technical support technician, were as follows:

Requirement 5 Fix the Videoconferencing window on the user interface so that a local preview of the video is what the remote user sees.

Requirement 6 Use the real name of the user in instant messaging instead of using ”Local user” and ”Remote User”.

Requirement 7 The call status window must be placed at the bottom of the main interface.

Requirement 8 Disable the send button in the instant messaging interface when there is no session connected.

Requirement 9 The asynchronous module needs to be fixed as it is not working properly.

Requirement 10 When a new message comes in, the database needs to be refreshed to show the message in the messages list for the user.

The training with the nurses started by explaining how the system works, the components of the system as well as how the system could help the nurses. The nurses seemed to understand how the system could really help them. The first step in the training was an explanation of presence and what it meant for a person to be "available" and "not available" in terms of how they could use the system. If the contact's presence shows available, it is possible to make a real-time call. If the other person is not available, a non-realtime module of the system can be used to leave a message. The sisters were then asked to perform instant messaging and observations were made while they did so. The key observations here were that the nurses were very slow in typing and confusion would happen as one would panic and send messages before the other one replied. This caused confusion as it was not clear who sent the message and when during the conversation. A new requirement was suggested as follows:

Requirement 11: To play a beep when a new instant message comes in to alert the other user that they have a new message. To show the user name of the person who sent the message and show the time when the message was received.

4.2.6 Action Research Cycle 6

This cycle was concerned with bringing in a new prototype based on the requirements collected in the previous cycle as well as having more discussion and demonstrations about the system. The point was to encourage the doctors and nurses to use the system. A meeting involved three doctors from the hospital and two nurses from the clinic as well as the technical support team. A demonstration of the system became very problematic. The non-realtime component was not working consistently as required because sometimes messages were sent and received properly, but most of the time the messages never arrived at the destination. Even if they got to the destination, they would often be invalid files. A decision was made, after trying to fix the bugs in the field, that a new requirement was needed based on the problems.

Requirement 12 A redesign of the whole File Transfer Protocol transport module.

4.2.7 Action Research Cycle 7

A re-design of the File Transfer Protocol transport was made based on the problem that was discovered during the previous cycle. The purpose of this cycle was to install the new prototype, provide training on the new prototype and have a group discussion about the system

usage with the technical support team, the doctors and the nurses together with the Department of Health at both district and provincial levels. Unfortunately, the Department of Health staff were unable to attend the meeting because of work commitments. The first day started with an interview with one of the doctors as he was leaving the next day. This doctor is the only doctor who had interaction with the system as it was installed in the room where he was practicing. A questionnaire was given to the doctor fill in about the system usage and informal discussions were conducted with him around system usage.

The doctor felt that it was a bit difficult for him to use the system as the nurses were not initiating contact. In his view, they were the ones that would need help from the hospital doctors. The following extract from the semi-structured interview stresses the doctor's feeling that the nurses did not start the contact.

Researcher*: What would you like to change about MuTI?*

Doctor: *I would like the nurses to initiate contact more often.*

This meant that if the nurses did not ask for help from the doctor, the doctor would also not use the system. The doctor felt that it would be easy for him if he could have the system at home, so that he could view the messages later in his own spare time as he was very busy most of the time. The doctor felt that another reason for the nurses not initiating contact with him was that they felt that it was not really part of their job description to use the system and the system might be making more work for them. It seemed as if MuTI was providing a solution that the users never really asked for. The next step was to show a new technical support member how the system works, as well as train the nurses more in how to use the system. The training focused on using the non-real time component of the system as it was the most complicated for the nurses. During observation, while training and when the nurses were using the system, it was discovered that the nurses were still struggling to use the system. What was interesting was that when reminded about where to click, they found it easy to continue. Another point observed was that the nurses lacked the confidence to use the system. For example, they would ask whether they were doing the right thing every time when they were actually doing the correct thing. The following extracts from the semi-structured interview show that the nurses still needed more training to build this confidence. The extracts are taken from two nurses, nurse 1 and nurse 2 interviewed about system usage.

Researcher: *Well then, do you have any other comments or anything that you would like to add or change related to the system or anything that we can do for you to support you guys to use the system?*

Nurse1: *We do not have time ..... enough time to train .....so if we can have enough staff in our side to .... so that we can be able to train so that we cannot be short staffed like we are doing now.*

Researcher: *So, are you able to help more people now compared to when there was no communication between the clinic and the hospital?*

Nurse2: *Yes, I prefer this MuTI system because now, time again, there are no transports here and now we are using MuTI, you can just contact the doctor, I thinks it will be much easier once we have been trained, it will be much easier to communicate with the doctors there at Canzibe.*

Another major problem for the nurses was that if the doctor's presence status showed "offline", the nurses did not think there was anything else they could do with the system because the doctor was not online. However it is important to note that a message can be sent whether the status of the doctor is "offline'' or not as this message will be sent when that user's status becomes "online". It is also very interesting to note that the nurses say they like the system but they do not use it.

Researcher: *Can I just get an understanding of the reasons why you have not used the system yet?*

Nurse 1*: Umhh Maybe...It is because I'm used to using old methods of doing things here in the clinic or the computer in the clinic shows hospital not available ..... or I think maybe the patient from the clinic ....umh snake bite or dog bite and that patient is supposed to go to the hospital and then I call the doctor*

In the extract above, one of the nurses mentioned that for her it was very difficult to shift from the way she was used to when working. For example, if there was a problem at the clinic, she did not think that she could use the system to call the hospital or send a message. This meant that it was difficult for her to include the system in her daily routine and this resulted in her not using the system as expected. A further discussion about the system usage and issues surrounding the system usage was held at the hospital. Two doctors attended the meeting with one nurse and two technical support and training personnel. The purpose of this meeting was to try and understand why the system was not being used, how the system could be made easier to

use and how the system could be integrated into the daily routines. The following user requirements all came from the meeting held during this cycle.

Requirement 13 When a user makes a call, if the recipient does not answer, the system should automatically change to asynchronous mode and leave a message. The same thing should happen when a user tries to make a call to someone who is "off-line". They should still be able to leave a message, too, if they want to.

Requirement 14 All three real-time modalities must be able to run concurrently for example one can use Instant Messaging at the same time during VoIP. This means the users can switch between and use different modalities
of their own accord.

Requirement 15 The log facility requires: a) trace/log levels and b) controls on the size of logs (so that they don't grow out of control).

Requirement 16 Ability to record the subject of a call and message. A dialog comes up for the doctor to choose the category of the call/message. The list should be easily defined by the user. This is to provide DoH with categorized usage statistics.

Requirement 17 Dr. wants to be able to call from the clinic (or the hospital)
to the hospital in Umtata to book a bed. Also the nurse ought to be able to book a bed and also to request emergency service. But this request must go through a doctor at the hospital. This requires a PSTN gateway. This feature needs to be restricted so that people can't make a call any time they want. Requirement 18 Automate the picture/camera process so that sister just has to connect the camera and the software will copy and delete the photos off the camera, and eject the USB device, leaving it ready for the next attachment.

4.3 Outcome Mapping Journals

The research presented in this thesis consisted of seven cycles. Most of these cycles were concerned with collecting the user requirements for the MuTI version 2 system as well as creating relationships with the boundary partners and developing prototypes for this thesis. The application of Outcome Mapping data collection was initiated in Action Research cycle 3. The boundary partners and progress markers for this thesis are listed at the beginning of this chapter. The Outcome Mapping methodology on the boundary partners is performed from Action Research cycle 3 to Action Research cycle 7 of this thesis. Key observations are presented for each boundary partners during these cycles. This section presents the data

collected from outcome mapping monitoring and evaluation process for each of the boundary partners listed.

4.3.1 The Department of Health - Provincial and District Levels

Action Research Cycle 3

Description of change: This cycle was the first contact with the Department of Health (DoH) at district level. There seemed to be a lot of interest in the communication system hen described and demonstrated to the DoH. Possible use of the system also came from the DoH, that is use of the video component of the system to motivate for wheelchairs for patients. An exchange of the contact addresses and fax numbers, as well as an explanation of the previous installed system also showed immense interest in a communication system by the DoH. The research team was also welcomed to work in the target area.

Contributing Factors and Actors: A thorough explanation of the research, as well as how a communication system like MuTI version 2 can be used, was one contributing factor. The other factor was that the demonstration of the prototype itself, to the DoH staff, also allowed them to think about possible uses of the system based on how they saw it functioning.

Sources of Evidence: The meeting held with the DoH at district level staff.

Unanticipated Change: No Unanticipated changes were observed as the goal was to introduce the research to the DoH as well as ask for permission to work in the district. Lessons/Required **Programme Changes/Reactions**: More future contact is needed as well as informing the DoH with all the progress of the research. The DoH needs to be invited to participate in meetings in which issues surrounding the system use can be discussed.

Action Research Cycle 4

Description of change: The DoH, at provincial level, was very keen on helping and supporting the project so that it could succeed. The DoH was willing to provide support for the project to be allowed by the independent Communications Authority of South Africa since a wireless network was needed and is still illegal in South Africa. The DoH mentioned their future plans for their telemedicine projects and brainstorming of future collaborations were done. The information officer of the DoH, at district level, volunteered to help in providing material for training to help out with the computer literacy training for the nurses.

Contributing Factors and Actors: The thesis aims to learn from the mistakes done in the past as well as the lessons that arose during the thesis. The DoH has had no success in getting the nurses and doctors to use the systems installed. Since the thesis is about finding some of the problems and how ICT for development systems can be made to work in the future, the department of health sees this is going to be invaluable in the future. The DoH can relate to the application and scope of the technical system being investigated and built.

Sources of Evidence: The first source is the meeting held with the DoH head of the telemedicine unit and his deputy in East London, South Africa. Another source is the meeting held with the DoH at the hospital to discuss how the system can be sustained.

Unanticipated Change: There seems to be a lot of interest in providing various communication systems. The DoH is keen on providing their own communication system in the province. The deputy head of the telemedicine unit is keen on building applications for his dentistry practice.

Lessons/Required Programme Changes/Reactions: More meetings need to be held to provide ongoing feedback with the DoH. The meetings should also clear the expectations in terms of what the research aims to achieve as well as the support needed from the DoH.

Action Research Cycle 5

Description of change: The DoH, provincial and district levels, attended a meeting at the hospital. They drove a long distance to attend the meeting. This was an indication of the DoH's interest in being involved in the project.

Contributing Factors and Actors: The calls and continued progress feedback to all the stakeholders, to keep them in the loop and let them know what is happening with the research, were the key contributing factor as it showed seriousness from the researchers.

Sources of Evidence: The meeting held with the DoH, at the hospital, was the main source of evidence. The calls made to the technical support team were also another source of evidence.

Unanticipated Change: The information officer from the DoH still has not attended and helped with the training of the nurses as promised in the previous meeting. Lessons/Required **Programme Changes/Reactions**: Relationships are very important in developing Information Communication projects as the projects are not just about a technical system but they are also about how such a system can be used and sustained. This level of help requires help from administrators. Secondly, it is important to also be ready for issues not to happen as planned and expected.

Action Research Cycle 6

Description of change: The DoH, provincial and district levels, were invited to another meeting to continue engaging with them and keeping them in the loop in terms of what the research is currently doing. They confirmed that they would attend the meeting but they did not attend the meeting.

Contributing Factors and Actors: The schedules might have been tight for the DoH staff. The distances that they also had to travel may have been a problem for them to attend the meeting every time.

Sources of Evidence: The meeting that was supposed to be held with the all the boundary partners did not happen as planned as one of the boundary partners, the DoH, did not attend the meeting.

Unanticipated Change: The DoH's not being able to attend the meeting was an unanticipated change as they managed to attend the previous meetings.

Lessons/Required Programme Changes/Reactions: The major lesson learned was that it is important to have a backup plan for meetings as well as planned activities as they might not take place according to the way they were planned.

Action Research Cycle 7

Description of change: The DoH, district level, is invited for a meeting to discuss more issues surrounding the system usage, how the system can be used to help them collect the statistics they need for their health care programme monitoring. Despite the invitations having been made early and confirmed, the DoH did not attend the meeting.

Contributing Factors and Actors: The scheduling of meetings might have been a contributing factor from the DoH as they had to attend to other tasks during the time they scheduled for the project meetings.

Sources of Evidence: The previous meetings held with the DoH at the hospital and their offices

Unanticipated Change: There is no unanticipated change as the DoH did not manage to attend the previous meeting scheduled with them.

Lessons/Required Programme Changes/Reactions: The lessons learned is that it is important to be flexible as events do not always work as expected. Backup plans for visits are necessary as you can never really know what will happen until the last day. A backup plan will allow the research to continue if the other plan fails.

4.3.2 The Clinic Nurses

Action Research Cycle 3

Description of change: The nurses were very welcoming and happy to explain to us the way they work. The nurses were also happy to explain how they see a communication system helping in terms of the problems they are facing. Furthermore the nurses cannot wait to see the actual system in place between the hospital and the clinic.

Contributing Factors and Actors: The previous system prototype demonstrations between two laptops in the clinic, using a crossover cable, have helped the nurses see how the system works. The nurses were also interested in the idea of them having contact with a computer and learning how to use a computer as they had never used one before and were also computer illiterate.

Sources of Evidence: The meeting and the demonstration of the system to the nurses at the clinic is the main source of evidence for these observations.

Unanticipated Change: At this point there is no unanticipated change.

Lessons/Required Programme Changes/Reactions: More contact and system demonstrations with the nurses are needed as this will help them think about how the system can help them. This might be helpful in motivating the nurses when the training begins and furthermore build more trust between the researchers and the nurses for working together.

Action Research Cycle 4

Description of change: Nurses were more welcoming and allowed to be observed when working with the patients. This observation, on its own, is major in terms of the vision of the thesis. Nurses are furthermore tolerant to the questions asked about their work. Contributing **Factors and Actors**: The approach of respect, to both the patients and the nurses, creates trust between the nurses and the research team and the nurses are more willing to open their doors for the research to continue.

Sources of Evidence: The ethnographic observation performed at the clinic is the main source of evidence.

Unanticipated Change: One of the nurses is retiring and there will be a shortage of staff, however she is still interested in the system and is willing to participate in the training but unfortunately will be unable to use the system when retired.

Lessons/Required Programme Changes/Reactions: The lessons learned here is that when working in a real environment, things look good at a certain point but change also happens unexpectedly. On of the nurses was retiring which meant that there would be less staff and even more difficulty in using the system as the clinic would be understaffed.

Action Research Cycle 5

Description of change: The nurses have improved in terms of using the computer. They are able to start up a computer, install the mouse and the headset required to use the MuTI system. The typing and clicking is still difficult though. Even though one of the nurses has retired, she is still interested in learning how to use a computer and the MuTI system.

Contributing Factors and Actors: The computer literacy training, provided by the technical support team, had been the main driving force behind the nurses learning how to use a computer.

Sources of Evidence: The main source of evidence was the time spent by the research team at the clinic and the observations performed while the training on the MuTI system occured. The conversations with the technical support team were the other source of evidence as they spent more time training the nurses in computer literacy.

Unanticipated Change: There was no unanticipated change at this point in time.

Lessons/Required Programme Changes/Reactions: The lessons learned are that more training on how the system is used is still very needed to the nurses as they are still very slow in using the computer itself. The technical system was anticipated to be a bit difficult to use as usability was not a major focus. The user interface needs to be made easier to use for the nurses.

Action Research Cycle 6

Description of change: The nurses and the doctors availed themselves for the meeting held at the hospital to discuss issues surrounding system usage. This was a major change as it was the first time the nurses came for a meeting at the hospital.

Contributing Factors and Actors: The contributing factors are trust and a realisation that for them to use the system more often, they needed to engage with the doctors and discuss possible time slots to use the system together as they both needed to make time to use the system.

Sources of Evidence: The meeting with the doctors and the nurses at the hospital. **Unanticipated Change**: The asynchronous component of the system was very problematic because of a bug in the File Transfer Protocol (FTP) transport, however the synchronous component was still working fine. There was still very little evidence of system usage in the synchronous component of the system as it was expected that it would have been used by the nurses at this point in time. The nurses were also not available on the Monday which was scheduled for a meeting with them at the clinic

Lessons/Required Programme Changes/Reactions: Sometimes, one may bring the best technology, but it can end up not being used. More training and hand holding is still needed to build the confidence of the nurses in using the system. The nurses themselves need to try and use the system when they have time. Lastly it is always good to expect the unexpected because for example a meeting was set up at the clinic for Monday and the clinic was closed on this Monday.

Action Research Cycle 7

Description of change: One of the nurses has used the system to reply to a message sent by the doctor to ask is she needed anything from the hospital. The other nurse however still has not used the system because she is finding it difficult for her to switch from the way she had previously done her own work. The system seems to be more of a burden to her. The other nurse has managed to reply to the doctor when asked about what she needs from the hospital.

Contributing Factors and Actors: The continued training given by the training team is slowly building the confidence of the nurses to at least reply if they received a request from the hospital.

Sources of Evidence: The system usage statistics, trace logs and semi-structured interviews are the main sources of finding out what has happened with the system in terms of usage.

Unanticipated Change: The system is still not being used by the nurses. The only system use picked up is during the training day, which is on Thursday.

Lessons/Required Programme Changes/Reactions: The reaction was that more training is still needed, more especially on the asynchronous component of the system since it was not functional because of the bug in the previous cycle. The other conclusion was that the system interface needed to be made much more userfriendly for the nurses to use the system.

4.3.3 The Hospital Doctors

Action Research Cycle 3

Description of change: The doctors were welcoming and very excited about the research. The doctors saw how the system could be of help to them in avoiding unnecessary referrals from the clinic.

Contributing Factors and Actors: The research is about community upliftment and some of the doctors are really keen on uplifting the community. They came to the target environment mainly for that purpose of helping the community.

Sources of Evidence: The main source of evidence was a meeting held with the doctors at the hospital to find out how they saw the system being used when installed in the target area.

Unanticipated Change: There was no unanticipated change in this cycle.

Lessons/Required Programme Changes/Reactions: More meetings need to be held together with the doctors and the nurses to create relationships amongst them to make it easy to ask for help.

Action Research Cycle 4

Description of change: The doctors are very welcoming and willing to engage socially and have allowed the use of their houses by the research teams when available and needed.

Contributing Factors and Actors: The doctors trust and believe that the research aim is to find solutions for the community. Social conversations have also helped in building trust as well.

Sources of Evidence: The fact that the research team lived in one of the doctor's house, during this research cycle, was a main source of evidence to show that doctors are willing to engage socially and help where they can.

Unanticipated Change: One of the doctors is not available and the others will be really busy and unable to really attend to us.

Lessons/Required Programme Changes/Reactions: Relationships are the key and again it is important to expect the unexpected as the team is unable to meet the doctors during this cycle.

Action Research Cycle 5

Description of change: There is no major change. The network itself is installed and the system is tested from the doctor's room. There is still one doctor available to talk to and he is extremely busy.

Contributing Factors and Actors: One of the doctors went home on vacation and therefore made it difficult for the doctor to attend to us as expected since he is busy.

Sources of Evidence: The visit made to the hospital is the main source of evidence. Talking to other doctors about their social environment is also another source of evidence.

Unanticipated Change: There is no unanticipated change at this point during the research.

Lessons/Required Programme Changes/Reactions: It is going to be extremely difficult for the doctor to attend to the system when he is alone in the hospital. Other doctors may need to help with using the system. More meetings need to be conducted on how the scheduling of system use can be done are needed with the doctors themselves.

Action Research Cycle 6

Description of change: There is no change except that there is still very little usage of the system from the hospital. This however is making some sense as the doctor would attend to the nurses referrals or requests if there are any.

Contributing Factors and Actors: There has not been requests coming from the clinic to the doctors to ask for help with the patients using the system and there is nothing the doctors can do when this is the case. The doctors are really busy and the system is installed and locked in one of the doctor's rooms.

Sources of Evidence: The meeting held with the doctors, the nurses and the technical support team in the hospital.

Unanticipated Change: There is still very little system usage. The doctors are expected to have at least used the system or tried to initiate contact with the nurses. One of the doctors mentioned that she has never used the system because she is too busy most of the time.

Lessons/Required Programme Changes/Reactions: The system needs to be able to be moved around the hospital while it is still connected to the network. There is a need to provide access points to extend the network in the hospital to provide mobility for the users so that they are not confined in just one room all the time.

Action Research Cycle 7

Description of change: One of the doctors had initiated an Instant Messaging contact with the nurse to ask if she needed anything from the hospital. The doctor felt that the system was difficult to use as it was. The doctors suggested a system that falls into voicemail if the other person is not available to take the call for all the modalities. Finally, they suggest a system that can connect to the telephone systems that they already have in place.

Contributing Factors and Actors: The contributing factors are the previous meetings held and the way in which the doctors know the nurses.

Sources of Evidence: The meeting held with the doctors, the technical support team and one nurse, at the hospital, is the main source of evidence.

Unanticipated Change: Some of the doctors felt that only the synchronous component would be useful to them and they do not really need the asynchronous component of the system.

Lessons/Required Programme Changes/Reactions: The system needs to be re-designed as a whole according to the new requirements suggested by the technical support team and the doctors during the meeting at the hospital. The nurse in attendance was however very quiet as she did not have much interaction with the system. A method to get some suggestions about the system from the nurses needs to be devised.

4.4 Automated Data Collection

This section presents the quantitative use of the MuTI version 2 system from June to September, 2005 when it was installed in the target area. Data is presented to find an understanding of how much the system was used in the target area. Secondly, the data is presented to get an understanding of the features the nurses and doctors preferred while using the system.

4.4.1 Asynchronous Usage

In terms of the asynchronous use of the system, most of the messages were sent on Thursdays from both the hospital and the clinic. In Table 4.1, the maximum average of messages sent to the clinic was 8.00 registered in the month of September and the minimum is 0.00 registered in July. The average on other days was 0.00 during all the months when the system was installed. This average was not very surprising as the doctors at the hospital do not normally send asynchronous messages. The messages are normally sent from the clinic first, as the nurses

would ask for help from the doctor using any of the modalities supported by the system. The high average of 8.00 in September can also be attributed to the testing of the system performed during the Action Research cycle 7. In Table 4.2, the asynchronous messages sent from the clinic to the hospital are presented. In this table, a maximum average of 6.00 was registered in the month of September from the clinic. The average use on the other days is 0.00 during all the other months. A minimum average of 5.00 was also registered in June, immediately after the system was installed in the target area. This seemed to drop however, in July and August. This could have been caused by a bug in the FTP transport threading in the asynchronous module of the system (see next chapter).

Table 4.1: **Average asynchronous messages made at the hospital**: This table shows the average number of messages made on Thursdays, in each month, at the hospital as well as the average number of messages made on the other days of the week for all the months when the MuTI version 2 system was used.

Month	Average/Thursday	Average/Other days
June	5.00	0.00
July	0.00	0.00
August	1.00	0.00
September	8.00	0.00

Table 4.2: **Average asynchronous calls made at the clinic**: This table shows the average number of messages made on Thursdays, in each month, at the clinic as well as the average number of messages made on the other days of the week for all the months when the MuTI version 2 system was used.

Month	Average/Thursday	Average/Other days
June	5.00	0.00
July	3.0	0.50
August	3.50	0.00
September	6.00	0.00

4.4.2 Synchronous Usage

Figure 4.2 shows a steady increase followed by a drop in synchronous call initiation. Figure 4.2 further shows more use between June and July in the hospital compared to the clinic. This can be attributed to the fact that the doctors at the hospital are more computer literate than the nurses at the clinic and therefore have more confidence in starting up the system and making a call. The use at the clinic however, happened during the training days most of the time. The training, in how to use the system, was provided on every Thursdays at the clinic. More average use was found at the clinic on Thursday. However, there were a few synchronous

calls made during the other days in each month. At the hospital however, there were a number of calls made on other days, for example, on Wednesdays and Thursdays in each month.

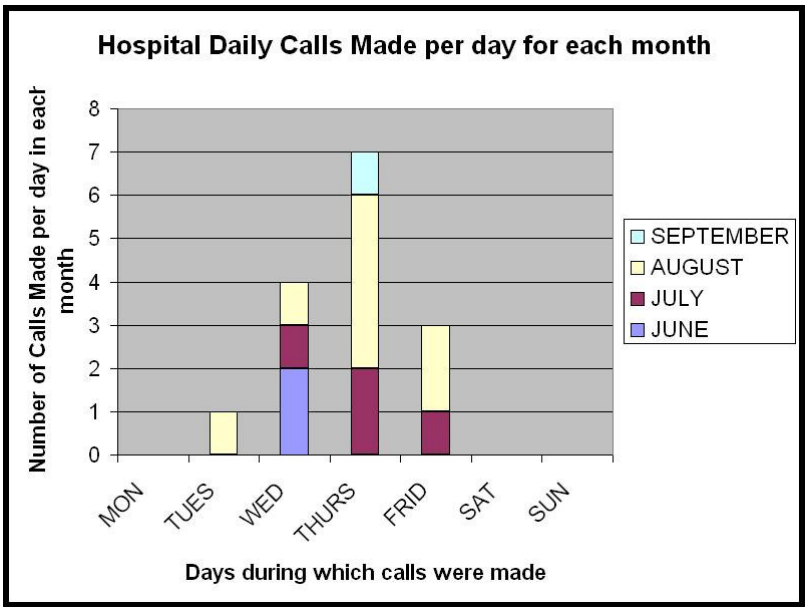


Figure 4.1: **Hospital synchronous calls made per day in each month**: This diagram shows that most of the synchronous calls made at the hospital took place on Thursdays most of the time, in all the months, when the system was installed. However, Wednesdays seemed to be popular for making calls as well.

Table 4.3: **Average synchronous calls made at the hospital**: This table shows the average number of calls made during the training day in each month at the hospital as well as the average number of calls made on the other days of the week for all the months when the MuTI version 2 system was used.

Month	Average/Thursday	Average/Other days	Difference
June	3.00	2.00	1.00
July	2.0	2.50	0.50
August	6.25	2.00	4.25
September	13.00	0.00	13.00

Again by looking at Figure 4.1 Thursdays seem to be the days when most of the calls were made in each month from the hospital. This could be due to the fact that during the training at the clinic, which happened on Thurdays, two-way communication occurs between the clinic and the hospital. Calls were made from the hospital as a result because the hospital normally makes calls based on the trigger made from the clinic. There were a few instances, however, when calls were made from the hospital beforehand.

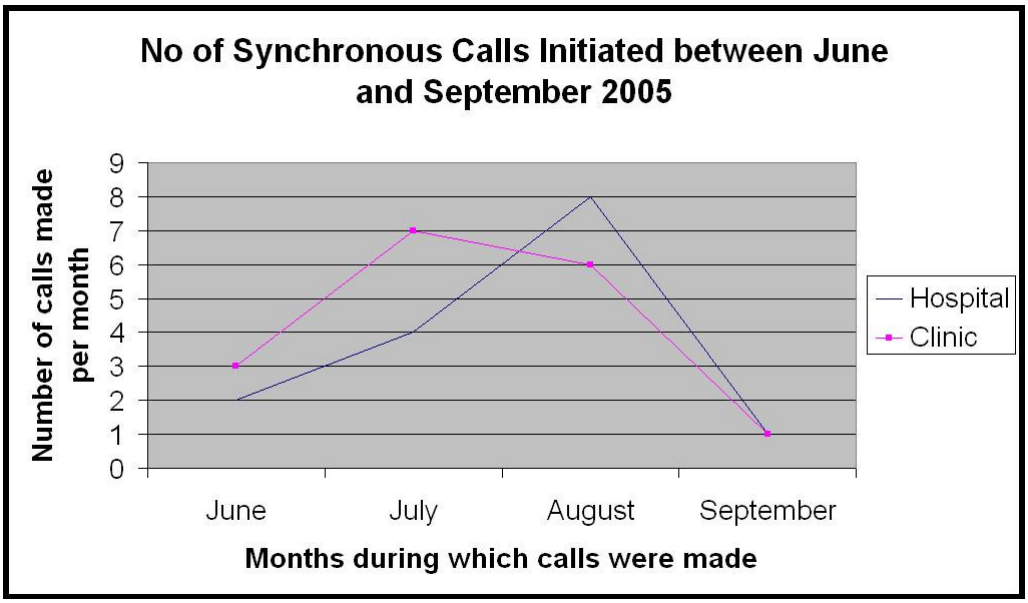


Figure 4.2: **Monthly synchronous call initiation in both the hospital and the clinic**: This diagram shows the call initiation in the clinic and the hospital. The use is shown on a monthly basis and the diagram shows how many synchronous calls were initiated in each month from June to September 2005.

Table 4.4: **Average synchronous calls made at the clinic**: This table shows the average number of calls made on Thursdays in each month at the clinic as well as the average number of calls made on the other days of the week for all the months when the MuTI version 2 system was used.

Month	Average/Thursday	Average/Other days	Difference
June	17.00	4.00	13.00
July	3.275	4.50	-1.225
August	5.33	1.500	3.83
September	20.00	0.00	20.00

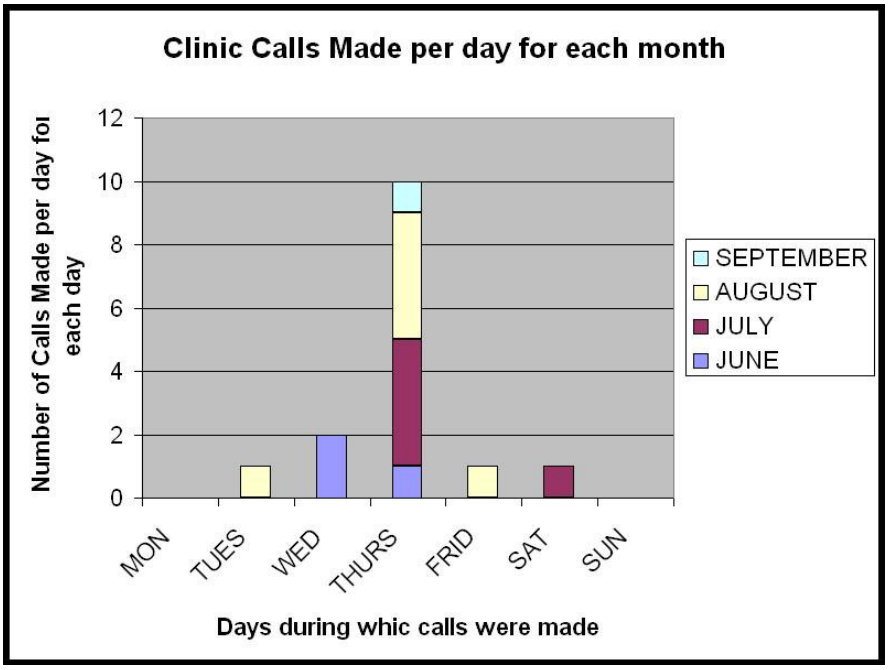


Figure 4.3: **Clinic synchronous calls initiated per day in each month**: This diagram shows that most of the synchronous calls made at the clinic took place on Thursdays most of the time, in all the months, when the system was installed.

4.3 Synchronous Modality Preferences

In terms of the modality preferences of the users at the hospital, voice calls seemed to be the most popular modality used at the hospital followed by videoconferencing. In Figure 4.4, voice calls seemed to be the steady option of use for the doctor at the hospital across all the months when the system was installed. The following extract from the interview with the doctor also supports the findings presented in Figure 4.4.

Researcher: *When you do call, do you use voice, videoconferencing or instant messaging? Please explain your choice.*

Doctor: *Yes. I use voice more often because it is more useful but I would prefer whatever is more convenient.*

The preference in call types at the clinic is, however, different from the hospital, as shown in Figure 4.5. At the clinic, Instant Messaging seemed to be the most popular choice when making synchronous calls. This can be attributed to the fact that the first training on the system was provided on Instant Messaging and therefore the nurses might have felt more confident in using Instant Messaging compared to other modes of communication.

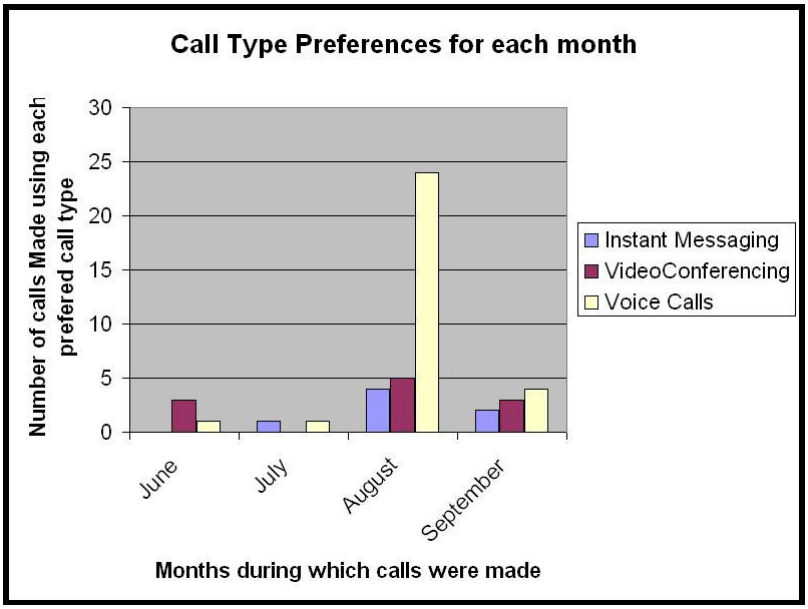


Figure 4.4: **Hospital synchronous call preferences**: This diagram shows that the doctors prefer using voice calls compared to any other mode of communication.

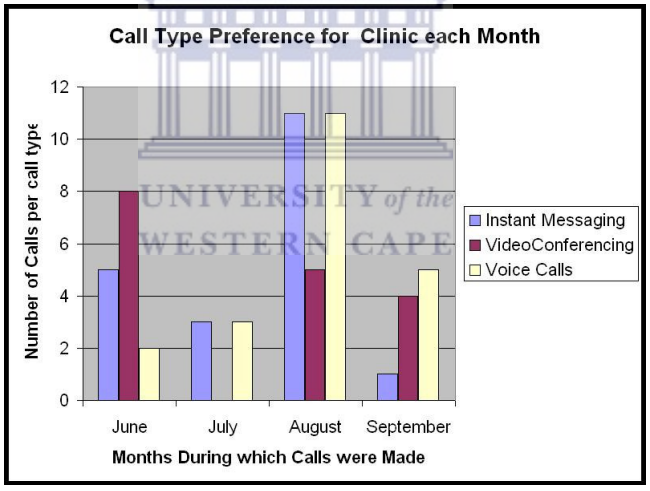


Figure 4.5: **Clinic synchronous call preferences**: This diagram shows that the nurses pretty much use all the modalities in real-time communication. Instant Messaging seems to be the steady choice of communication in all the months though.

4.5 Summary

Action Research cycles have been applied in this thesis to collect user requirements for developing the prototypes as well as perform ethnographic observations to see how the prototypes have been used. Automated System logs and semi-structured interviews were mainly used to understand how the system was used, how many times it was used as, well as whether the system itself can be improved and changed throughout the cycles. The Outcome Mapping methodology was applied on the boundary partners provided in chapter 4, to evaluate the target progress markers for this thesis based on the data collected using these different methods. The applied Action Research cycles have been instrumental in collecting the requirements for enhancing the technical system as well as understanding the social space of the users. The Outcome Mapping journals have been presented for each boundary partner during the Action Research cycles which were conducted. The system usage data presented is then divided and presented according to the use of both the synchronous and asynchronous modules of the system. Moreover, the call preferences of the users are also presented in terms of what the users said during the semi-structured interviews and what the system logged to perform data triangulation. The next chapter, focuses on how the system was built and enhanced based on the requirements from the Action Research cycles using the different sources of data collection.

Chapter 5

System Design

A multi-modal semi-synchronous system, MuTI version 2 (MuTIv2), that supports voice, text, video and images has been built based on the previous system, MuTI version 1 (MuTIv1) [23]. A description of the MuTIv2 system is provided and this chapter follows on the requirements that evolved out of the research cycles presented in Chapter 4. The features and the high level design strategy for the MuTIv2 system are discussed in detail. The differences between MuTIv1 and MuTIv2 systems in terms of functionality are discussed. Lastly, the chapter discusses the design of the functional modules of the MuTIv2 system.

5.1 Services supported by MuTIv2

The system allows a nurse in a rural clinic to make a synchronous call using voice, video as well as text, to a doctor in a rural hospital if the doctor is available to take the call at that time. The system also allows the nurse or doctor to send a message that contains any combination of images, text, voicemail and video clips in a store and forward fashion. On the receiving end, the system stores the messages in the local database and the user can view the images, read the text message and also play the video clip and voicemail when there is time to do so. As shown in the previous chapter, the user requirements for the MuTIv2 system were driven by the Action Research cycles. These requirements were also driven by the use of prototypes and the need to modify the prototypes to meet the requirements as they arose during the Action Research cycles. The training and use of the prototypes in the field, have been the driving force to identify enhancements of the features and the interface of the prototypes. These requirements then drove changes in the prototypes introduced in each cycle. In the previous chapter, these requirements are listed as they evolved from the Action Research cycles. The results are summarised in table 5.1

Table 5.1: **Summary of the requirements from Action Research cycles**: This table summarises the requirements that came from Action Research cycles in Chapter 4. The requirements are stated together with the cycle they came out from.

	Requirement
Cycle 1	Addition of Sync/Async Video
Cycle 1	Addition of Instant Messaging
Cycle 4	Use MuTI to send back test results
Cycle 4	Use MuTI to communicate between clinics
Cycle 5	Fix Videoconferencing Window
Cycle 5	Use real name in instant messaging chat window
Cycle 5	Put Call Status window at the bottom
Cycle 5	Disable Send when not connected
Cycle 5	Fix Asynchronous Module
Cycle 5	Refresh Database when new message comes in
Cycle 5	Play beep when new message comes in
Cycle 6	Redesign the whole FTP transport
Cycle 7	System should go into voicemail if user does not answer
Cycle 7	Voice, Videoconferencing and IM should run concurrently
Cycle 7	A user may send messages to one or more users at the same time
Cycle 7	Monitor logs so that they do not grow big
Cycle 7	Ability to track call subject and message
Cycle 7	Be able to call from system to PSTN telephone
Cycle 7	Automate camera process for nurses

5.2 Deployment of the MuTIv2 system

The MuTIv2 system is deployed in a 8011.2b wireless network between a clinic and a hospital in the rural Eastern Cape. The network based on the CRC Net model [76] was built from scratch and is shown in Figure 5.1 but all the materials used to build the network were purchased locally. Laptops are used in the deployment of the MuTIv2 system to support the possibility of a power outage so that the system can still be used in store and forward mode when the power fails.

Figure 5.1: **The network diagram**: This diagram shows the structure of the network on which the MuTIv2 system runs. The network has two main sites and two relay points between the sites because of the long distances and lack of line of sight between the two main sites.

Site 1: Hospital

On this site, a router is installed to route the packets to Relay Site 1: Eskom Tower. A hospital antenna has direct line of sight to the tower. A 96aH battery powers the router. The battery is charged from the mains power on site. Power over Ethernet (PoE) is used to power the router from the battery. A static route to Site 2: Clinic, has been configured in the router at this site. The Customer Premises Equipment (CPE) on this site consists of a waterproof 16 db flat panel enclosure with a small biscuit Personal Computer (PC) running a Linux kernel. The biscuit PC has an RJ-45 to connect to the Local Area Network (LAN) as well as an 802.11bg mini-PCI radio card for the wireless link to the relay at the tower. The MuTIv2 system is also installed on this site on a laptop.

Relay Site 1: Eskom Tower

This relay site is situated on top of a hill and was chosen for several reasons. Firstly, it has line of sight to Site 1: Hospital as well as Relay Site 2: Headman house. Secondly this site has a reliable power supply to charge the battery. Thirdly, this site is safe because it is in a locked compound as equipment can get vandalised in this area. Lastly, it is always best practice to use resources already in place. The tower was already there and permission was asked from the owners to use it. This site has the same CPE Equipment as Site 1: Hospital but the biscuit PC has two radio cards. A 24 db antenna grid is used to push the signal to Relay Site 2: (Village Headman) because of the 15 km distance between the two relay sites. The router is powered by a charged battery, just as at the hospital. PoE powers the router via a shielded cable so as to run one cable up the tower to the CPE.

Relay Site 2: Village Headman

This site charges the battery with a solar panel. This site has line of sight with Relay Site 1: Eskom Tower and Site 2: Clinic. This site has the same CPE and antenna setup as Relay Site 1: Eskom Tower.

Site 2: Clinic

Site 2: Clinic had an existing solar power supply and this supply is used to power the router by using a PoE injector. The CPE setup is similar to Site 1: Hospital. The MuTIv2 system is installed in a laptop at this site.

5.3 Development of the MuTIv2 system

The development alternatives for the MuTIv2 system were: to build a new system from scratch, adapt the current MuTIv1 system or use all the current tools and languages used in the MuTIv1 system to build a new system. The decision taken, at first, was to produce a new system that had the required features, but it was realised that this would take a while. It therefore made more sense to adapt the current MuTIv1 system and add, as well as enhance, the features as required. Secondly, a prototype would be produced as quickly as possible to deploy in the site rather than taking a long time to build a new one. This enabled the project to continue with the Action Research cycles without a long lead in period. The MuTIv1 system already had support for both synchronous and asynchronous communication in text and voice.

Tables 5.2 and 5.3 highlight the differences in the features that MuTIv1 and MuTIv2 support as well as the enhancements done on the MuTIv1 system. In the previous chapter, requirements were identified as they came out of Action Research cycles. The requirements from Action Research cycles 1 to 6 have been implemented, as well as the changes and improvements in the features and bug fixes that came from the technical support team. Most of the requirements that came from Action Research cycle 7 require major changes in the MuTIv2 system and will be implemented in future work.

Table 5.2: **MuTIv1 versus MuTIv2 synchronous features**: This table shows the main additions done on the synchronous module of the MuTIv1 system to get the MuTIv2 system.

Synchronous	MuTIv1	MuTIv2
Text	NO	ADDITION
Voice	YES	NO CHANGE
Video	NO	ADDITION

Table 5.3: **MuTIv1 versus MuTIv2 asynchronous features**: This table shows the main additions done on the asynchronous module of the MuTIv1 system to get the MuTIv2 system.

Asynchronous	MuTIv1	MuTIv2
Text	YES	NO CHANGE
Voice	YES	NO CHANGE
Video	NO	ADDITION
Images	YES	NO CHANGE

5.4 The new MuTIv2 system Modules

MuTI consists of three main modules: The modules are the synchronous communication module, the asynchronous module and the logging module. The overall structure of these modules is the same as in the previous MuTIv1 system but have extended functionality. The synchronous module deals with all the aspects of real-time or synchronous communication. The asynchronous module deals with non real-time communication. The logging module is used by both the synchronous and asynchronous modules to read and write data during system use. Figure 5.2 provides a clear view of the system module structure.

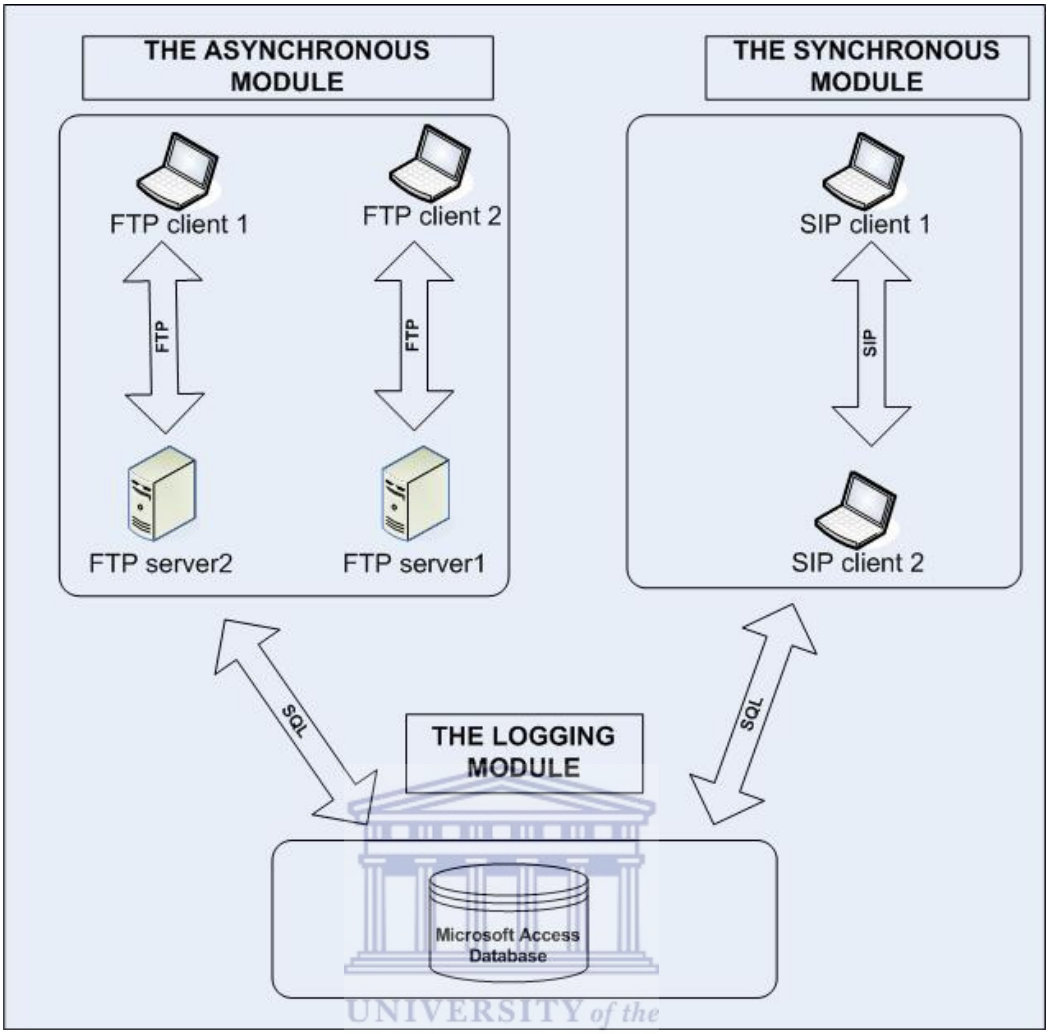


Figure 5.2: **Main Functional Modules of the MuTIv2 system**: This diagram shows the three independent system modules. The synchronous module is based on a peer to peer structure where each client communicates directly with the other. The asynchronous module, however, is based on a client-server architecture where each end- point can be both a client and a server depending on the direction of the transport. Both modules write to and read from the database in the logging module.

5.4.1 The Synchronous Module

The Synchronous module, as shown in Figure 5.2, is based on a peer to peer architecture. This means that there is no middle party in the synchronous communication. When the user sets up a call, the call is made directly to the other user. Depending on the availability of the other user to accept the call, a call is either accepted or rejected by the remote user. A session is established when the remote user accepts the call. If the user is not available to accept the call, the call is automatically rejected by the system and the user can continue until the call is accepted. This module uses SIP [64] to set up calls and Real-Time Transport Control Protocol (RTCP) and Real Time Transport Protocol (RTP) to transport media across to the remote user.

This module was implemented using Microsoft's Real Time client Software Development Kit (RTC SDK) [75]. MuTIv2 added video conferencing as well as instant messaging.

5.4.2 Asynchronous Communication Module

As shown in Figure 5.2, this module is based on a client-server architecture and uses passive File Transfer Protocol(FTP) [59], where a server and a client open two ports for data and FTP message communication. The client connects to the server listening at a given port, in the case of the MuTIv2 system, 8090. When this new connection comes in, a new thread is spawned by the server to handle that client while it gets ready to process requests from other clients. This is done so that the server is always ready for new connections while the connected clients are busy sending data and FTP messages to the server through their given ports. Figure 5.5 shows the scenario for an upload process. The main function of this module is to enable recording, sending and receiving as well as playback of the asynchronous messages in the MuTIv2 system. This module was adapted from the initial MuTIv1 system.

5.4.3 Logging Module

The logging module enables the logging of important events and data about system usage. This module is also used by the system to store all data needed by the system for example the users of the system. The module uses the Structured Query Language (SQL) to store and retrieve data in a Microsoft Access database. The data logged by the module is the data used by the system when it is being started as well as the automated collection of usage data needed for this thesis. The data needed by the system, includes the names and the addresses of the contacts. It also includes the names of the patients used by the system to group the messages that are sent and received. The usage data such as the data needed for this thesis was also logged into tables. For example, whenever there is an activity such as sending a message or making a synchronous call, all this information was logged to the database to track what has happened with the system.

5.5 The Enhancement Process

The enhancements required on the MuTIv1 system to get the MuTIv2 system were the addition of video in both synchronous and asynchronous fashion in the MuTIv1 system, the addition of synchronous text messaging in the MuTIv1 system, a redesign of the message transport system to make it efficient in the asynchronous module of the system, the improvement of the Human Computer Interface as well as the logging to support data collection required.

Figure 5.3: **The MuTIv1 system main interface**: this diagram shows the main interface of the MuTIv1 system. In this diagram all the options for using the MuTIv1 system are shown to the user when the system starts up.

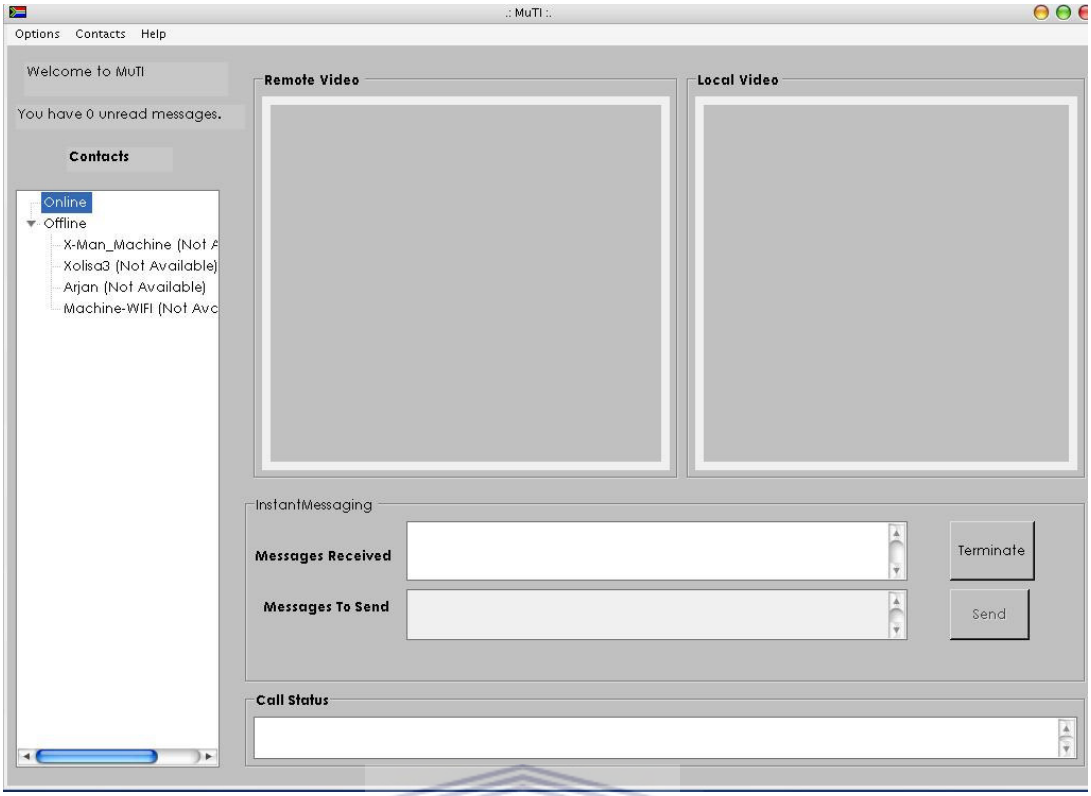


Figure 5.4: **The MuTIv2 system main interface**: this diagram shows the main interface of the MuTIv2 system. Most of this interface is occupied by videoconferencing and instant messaging. The options that were available in the MuTIv1 system are grouped under options in the menu of this interface.

5.5.1 Addition of Synchronous video

The addition of synchronous video is requirement 1 and evolved out of Action Research cycle 1. The idea of adding video as a synchronous modality to the MuTIv1 system was to allow the user to choose whether to use videoconferencing or just audio when placing a call. The MuTIv1 system had support for synchronous audio support by using Microsoft's Realtime Client SDK (RTC SDK) described in [75]. It would then be easy to leave the audio support as is and then have additional support for videoconferencing. The problem, however, was that videoconferencing is a combination of both audio and video at the same time. The added video stream would therefore have to correspond with the current audio stream already supported in the MuTIv1 system when a videoconferencing call is made by the user.

The RTC SDK currently allows implementation of the following types of calls and sessions.

1. Personal Computer (PC) - PC session: In this session voice, video, whiteboard and application sharing are supported
2. PC-Phone Session: This session allows a PC in an Internet Protocol (IP) network to call a phone in a Public Switched Telephone Network (PSTN) via a SIP gateway.
3. Phone-Phone session: This session allows initialising the client running in a PC as a phone and calling another client running in an IP network.
4. Instant Messaging session: This session supports instant messaging and does not use any streaming resources.

If a session of type PC-PC is created, the RTC SDK automatically initialises all the media from the hardware. This means that if the user has capabilities for video and audio, then both audio and video streams are initialised and sent across the network when a call is made. This made it easy to add synchronous video to the MuTIv1 system because all that was essential was to handle the incoming and outgoing video streams and render the streams to the user interface. A set of events to check when the media has started coming in or going out are implemented in the RTC SDK. These events were then used to check whether there was incoming or outgoing audio and video and then show the video on the user interface. The audio is rendered to the default device connected that is speaker or headphone.

While this method worked well for videoconferencing, it posed a problem when the user did not want to see the video. This requires a method to separate a voice stream and video stream and only send and receive the required stream, in this case, the audio stream. This is because the RTC SDK automatically starts both streams when a webcam is connected to the PC. The solution was to give the user a choice in the menu for making a voice call or a video call. In the case of a video call, everything would be fine as all the streams would be sent and handled. For voice call, however, the video stream would have to be blocked from sending. Fortunately, with the RTC SDK, it is possible to separate one stream from another and block it. To have a voice call then would mean just blocking the video stream from sending when the user chooses to make a voice call.

5.5.2 Addition of Asynchronous Video

This requirement was also part of requirement 1 and came out of Action Research cycle 1. Video was added as an option to the asynchronous message system provided by the MuTIv1 system. The motive here was to allow the user to record and playback a video clip and send it to the other user. Microsoft's DirectX SDK [41] was used for video recording and playback. Because video can become really big, the recorded video should be com- pressed to send over the network. On the receiving end the video is then decompressed to accommodate its original form and quality. Windows Media SDK [52] was used for compressing and decompressing the video in the MuTIv2 system.

5.5.3 Addition of Instant Messaging

This requirement was requirement 2 and came out of Action Research cycle 1. Instant Messaging does not use the streaming resources and is handled in a different manner by the RTC SDK. This means that if the user is already in a voice or video call, it would not be possible to initiate instant messaging. If the user wanted to continue the voice or video call and also have instant messaging, two things would have to happen.

1. The voice or video call would have to end and an instant messaging (IM) call would have to be placed to allow the system to allocate only the resources needed for IM.
2. Another way would be using multi-threading where one thread handles a certain type of call, for example a separate thread to take care of voice and video calls, and another one to handle instant messaging and run them parallel to each other.

Option 2 posed a problem because there is only one port used to listen for client connections and therefore a re-design of the way the RTC SDK works would be needed to accommodate this option. Option 1 was simple and straight forward as the user would either choose IM as a session from the beginning or end the voice or video call if they wanted to make a call of type IM.

An option for making an instant messaging call was added to the user menu for making calls. When this is chosen, a session of type IM is created by using the RTC SDK and the user can perform instant messaging with the other user as all the resources and listeners for instant

messages will be allocated. The user can then start sending and receiving instant messages without a problem. This call would have to be terminated if the user wants to go back to videoconferencing or audio call to allow the RTC SDK to initialise streaming resources.

5.5.4 Enhancement of the FTP transport

This was requirement 7 and came out of Action Research cycle 5 and 6. The MuTIv1 system's functionality in terms of sending the asynchronous messages became unreliable after a while. The problem was the connection logic in the server and the client. It was discovered that the server was receiving incorrect FTP instructions during the incorrect time, for example the server would sometimes tell the client that it has received the whole file while it had not received the file correctly. This would therefore result in the client quitting without uploading the whole file in the remote server and corrupt files being received by the remote server. It was discovered that these problems were mainly caused by the parallel threads running wild. These threads confused the logic of the system as they would be running at a time when they were not needed to. This meant that procedures were executed unnecessarily in the system.

The FTP Server

The FTP server listens for requests from remote clients that want to upload files. When a client uploads a file, the server receives the file in its own socket and writes this file into a local file that has the same filename and path as the file being uploaded. When the whole file has been received and written, the server then unzips this file into a local directory and stores the properties of received data into the database as a received record. This is done so that when this data has to be viewed, it is easier to locate it by looking in the database.

The FTP Client

When the user sends a message to a remote machine, the client initiates a connection to the server. The server then accepts the connection and talks to the FTP client until the upload is completed. The FTP client initiates the following functions in the asynchronous module of the system.

1. Initiate a connection to remote server

2. Ask the server if the client can upload file
3. If server says yes, upload the file by writing to the remote server socket until all the data is written
4. Wait for the server to say it has read all the data from the socket
5. Quit the server connection.

A detailed view of the steps that occur in the file transfer process is shown in Figure 5.5

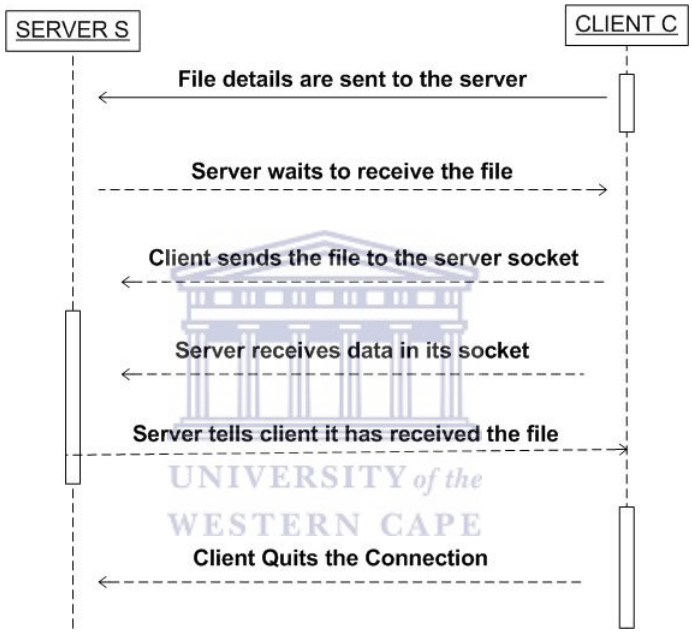


Figure 5.5: **The Sequence diagram for the upload process:** The client first sends all the details about the file to the FTP server. The client writes all the bytes to the server socket. The server tells the client that it has now received the whole file when it has read and written the whole file size. The client then quits the connection.

A redesign of the logic was achieved and modifications were completed on the asynchronous module of the MuTIv1 system to accommodate the redesign of the asynchronous module for the new MuTIv2 system. The redesign is shown in the form of a flowchart in Figure 5.6.

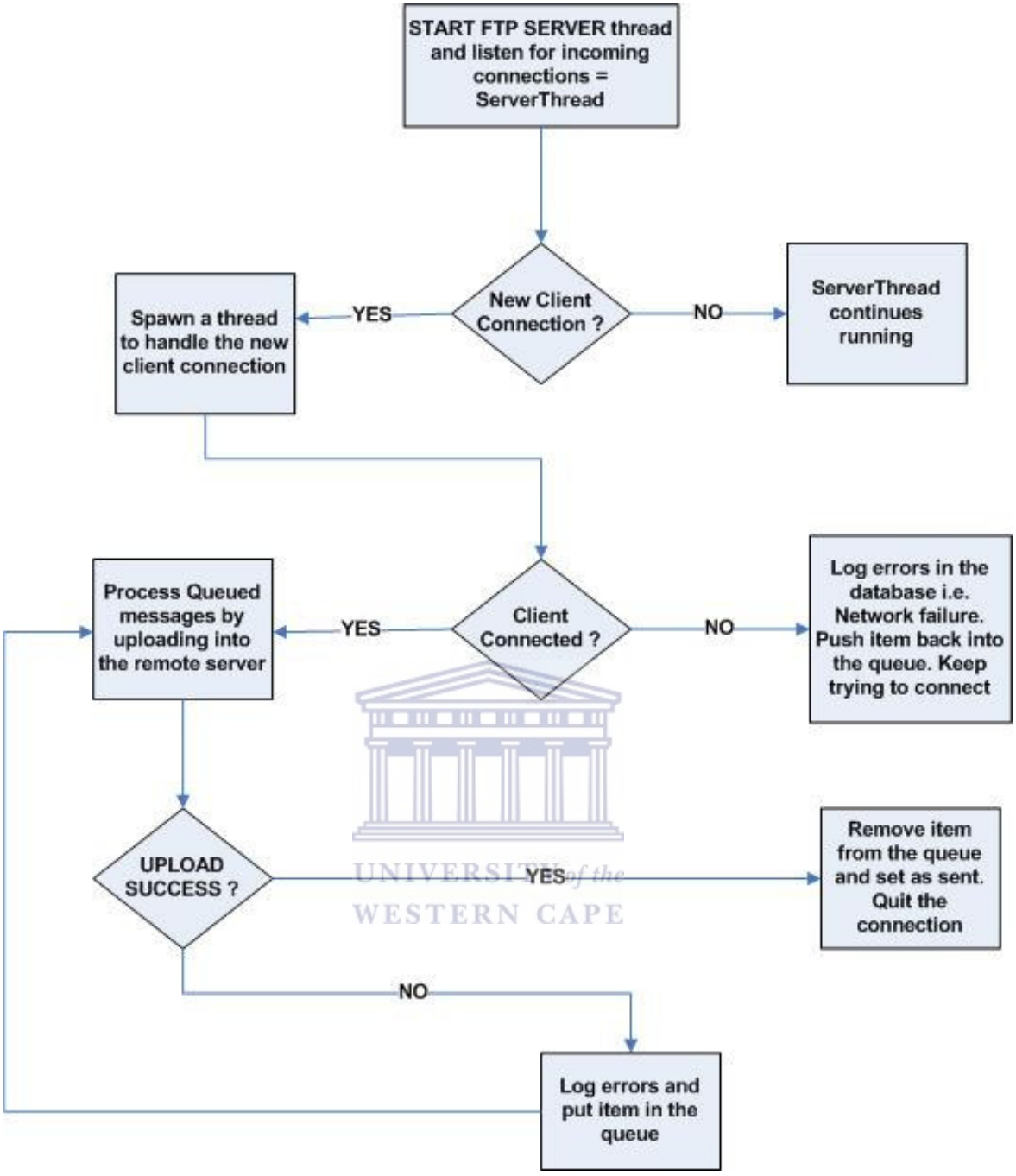


Figure 5.6: **The Asynchronous Module Re-design**: This diagram shows the steps that happen during the FTP process between the server and the client in the new MuTIv2 system.

5.5.5 Enhancement of the Human Computer Interface

The requirements implemented here came out of Action Research cycle 5 and are requirements 3, 4, 5, 6, 8 and 9. The Action Research cycles conducted enabled an understanding of the features that can be changed and improved in the user interface to try and make the system easier to use. The system was found to be very difficult to use because of the difficult user interface. Changes have been incorporated into the interface for the asynchronous module of the system to make the system easier to use for the users. In the requirements from the Action Research cycles section, suggestions were provided with regard to how the interface can be changed and improved and this section shows the changes made on the human computer interface.

A major improvement on the human computer interface of the system was the use of icons in the buttons as shown in Figure 5.7. This change was made because it was difficult for the users to see which button they should click when using the system. A concept of a tape recorder was used where the buttons are similar for each functionality, for example a pause, play and record button similar to that of the radios the users had at home. Secondly, the user is alerted when a new message arrives by showing a message box stating the patient the message belongs to and a refreshment of the interface is performed when the user clicks the refresh button of the system as shown in Figure 5.9. This change was introduced because it became difficult for the users to have to search on the whole system for a new message. It would then be easy for them to look for a message if they knew who the message concerns as they would just click on the name in which the message belongs and read the message. On the instant messaging interface, the user names are shown for messages together with the times the messages are received. Sound is also played when the new message arrives to let the user know that there is a new message that came in. The human computer interface of instant messaging is shown in Figure 5.8. This change was introduced because of confusion that occured when new instant messages came, as it was difficult to see who sent the message and when the message was sent.

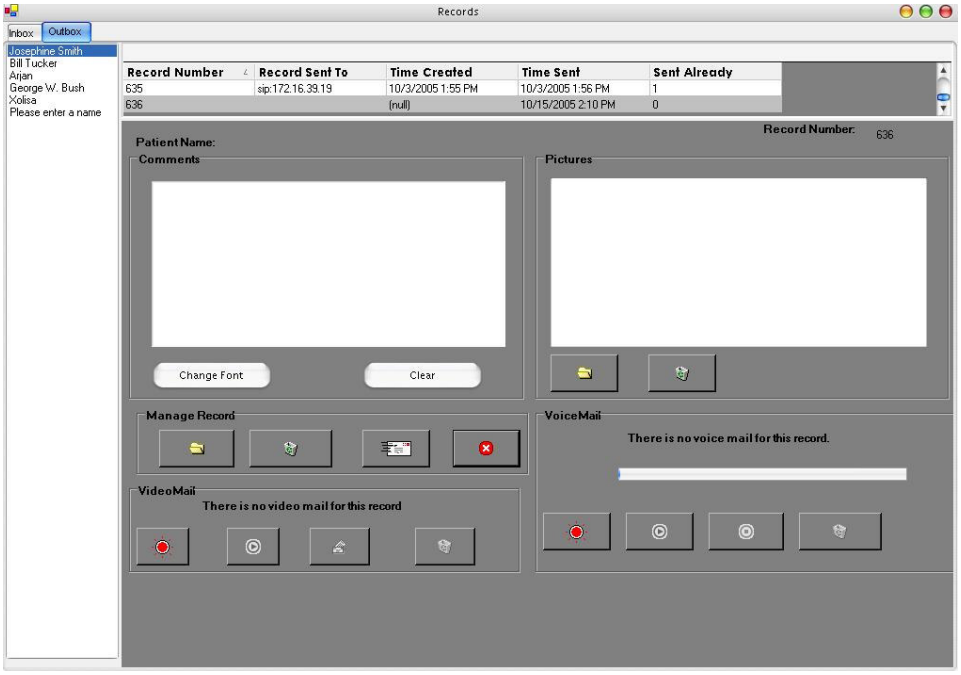


Figure 5.7: **The outbox messaging interface**: This diagram shows the work done on the human computer interface of the MuTIv2 system to incorporate some of the require- ments from the Action Research cycles. The major change here is the use of icons instead of text in the buttons to lead the users.

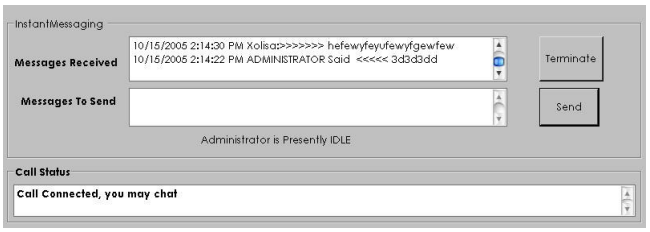


Figure 5.8: **The instant messaging interface**: This diagram shows the work done on the human computer interface of the instant messaging interface. The interface was improved according to the requirements collected during the action research cycles.

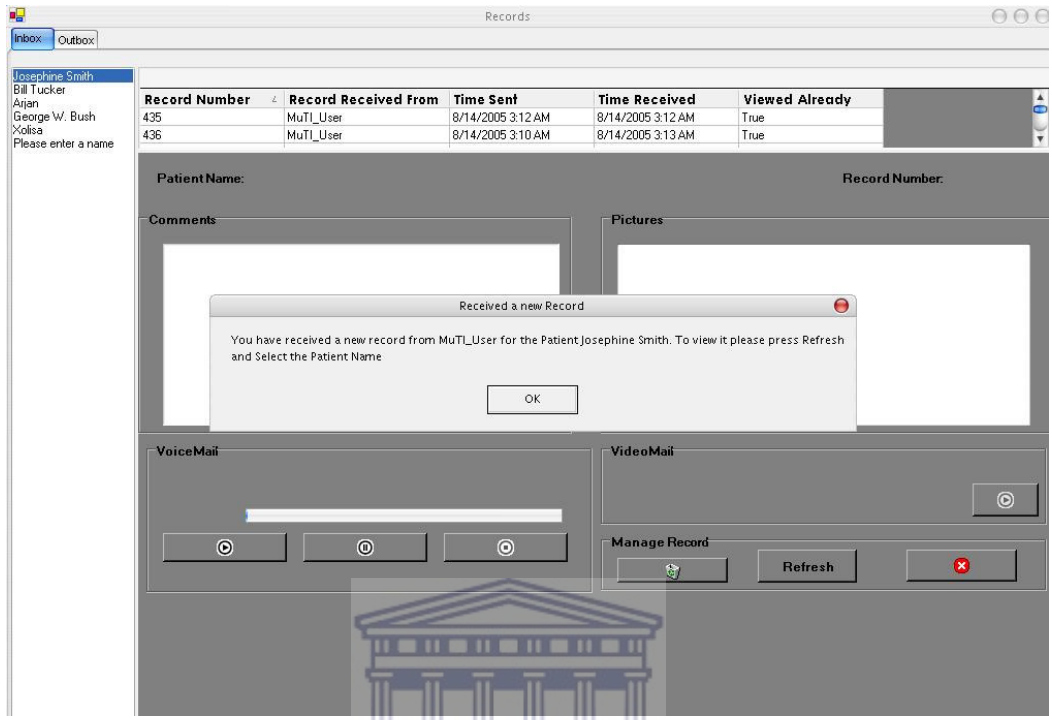


Figure 5.9: **The outbox messaging interface with new message arrival**: This diagram shows that the user is alerted when a new message comes in unlike before in the MuTIv1 system where one had to hunt for the new message.

5.5.6 Enhancement of Logging Functionality

This requirement came naturally out of Action Research cycles because an activity needed to be logged everytime new features were added on the system. The logging module enables the logging of important events and data during the system use. The messages are logged into the database using Structured Query Language. A creation of the new tables and functions to enable the logging of the data needed was achieved on the logging module. The change made was an introduction of tables for video messages, sent and received tables in the database to keep track of how many messages were sent and received. A table to keep track of the types of synchronous calls the users were making was also introduced. Text files were used to log instant messaging conversation. These data were all needed for this thesis as presented in the previous chapter.

5.6 High Level Design

The high level design of the MuTIv2 system is shown in Figure 5.10. The enhancement over MuTIv1 is the addition of the required classes for the new functionality needed. Figure 5.10 is a Unified Modeling Diagram of the main classes projects. These are the classes that are invoked when the system starts and they invoke other classes when the system is being used by the users. The main class, in the diagram, is MainDialog and this is the class that loads the main user interface. The other classes in the diagram are invoked during the user interaction with the system. It is important to note that all these classes are linked to DbFunctions as all of them use the functions in this class to talk to the database for logging whatever events are happening during the system usage.

5.6.1 MainDialog

The MainDialog class is the main class of MuTIv2 system. This class loads up the user interface when the user starts the system. This class provides a main point of interaction with the system for the user. It is in this class where the user can make choices in using the system. Depending on the choices made by the user, one or more classes as shown in Figure 5.10 is (are) invoked. This class has been enhanced from the previous MuTIv1 system to accommodate the new requirements. In this class, changes have been made to support videoconferencing and instant messaging as well as call status. To see these changes, compare Figure 5.3 and Figure 5.4.

5.6.2 RtcSession

RtcSession is the driving force behind the synchronous module of the system. This is the class that enables the user to make a real-time call with voice, videoconferencing or instant messaging. The modifications in this class from the previous MuTIv1 system by Chetty *et al.* [23] is the additional support for videoconferencing and instant messaging.

5.6.3 RecordsDialog

RecordsDialog is the main interface for asynchronous use of the system. In this class, the users can decide what they want to do in terms of asynchronous use of the system. Furthermore this class allows recording, playback, viewing and sending of asynchronous messages. The enhancement in this class is the addition of video message support as well as some changes in the user interface as a result of this addition.

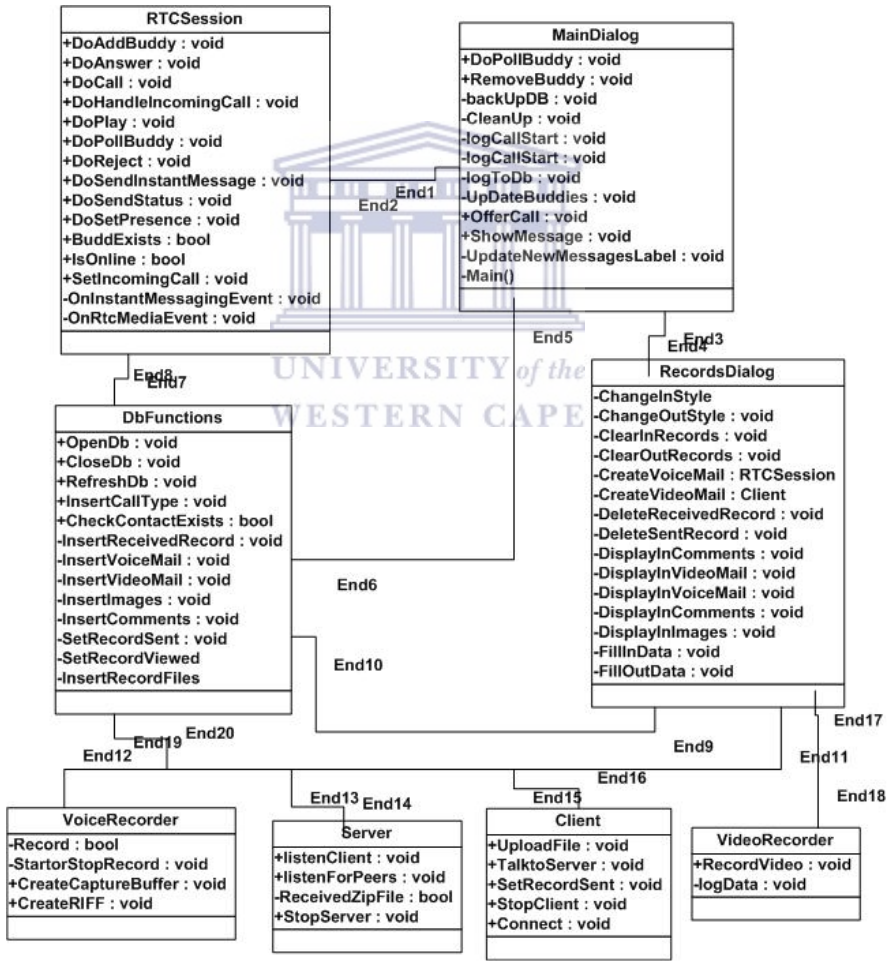


Figure 5.10: **The High Level Design of the main classes:** In this diagram, the MainDialog class, which is the main class of the system, makes use of other classes depending on user execution.

5.6.4 DbFunctions

DbFunctions is the class that is used by the system to talk to the database. This class is used by the system to store information about records, contacts, patients as well as logging. It can be argued that this is the most important class in the system. The system cannot function without it because it loads information from the database, when it starts, so that it can map and create relationships between patient data, records and contacts.

5.6.5 VideoRecorder

The VideoRecorder class allows the user to be able to record video clips as messages to be sent later. This class has been added to the Recorder project of the MuTIv1 system.

5.6.6 Server

The Server class is used in the asynchronous module of the system. This class is called in the MainDialog class to prepare to accept new connections that need to send FTP messages.

5.6.7 Client

The Client class is called in the MainDialog class, as well as the RecordsDialog class, to facilitate sending messages such as voicemail, videomail and images to the remote user.

5.7 Summary

In this chapter has discussed the system design for the MuTIv2 system was discussed. The synchronous and asynchronous modules of the system were discussed and their components introduced together with their purposes and functions. A redesign of the asynchronous module was also discussed. The design of the MuTIv1 system is enhanced to cater for the requirements as they evolved from the Action Research cycles and feedback from the users. The features added to the MuTIv1 system are videoconferencing, Instant Messaging and Video Messaging. The features that were enhanced are the FTP transport threading methods, the logging of the messages and data, as well as the Human Computer Interface. Feedback from the users and technical support have driven the enhancements of these features, in the system, through the continuous feedback during the Action Research cycles, as well as the Ethnographic observations performed during the research. The next chapter presents the analysis on the findings during the use of the system designed and developed in this thesis.

Chapter 6

Data Analysis and Discussion

In Chapters 4 and 5, it was described how the data was collected, and a system was built using the proposed methodologies from Chapter 3. The methodologies were applied in a cyclical manner. In each cycle a new prototype was introduced, as a reflection based on the data collected from a previous cycle. This data, collected during the previous cycles, enabled an understanding of social space of the users as well as how the system can fit within their social space. The data also enabled an understanding of how the users use the prototypes, which led to required changes and enhancements on the prototypes introduced in each cycle. In terms of support for use of the system, it was always important to evaluate the progress in terms of the stakeholders or role players in the technical use of the system, since social support is required for the technical system to be tested and used. Outcome Mapping methodology has enabled an ongoing evaluation through the use of progress markers for all the project partners. This whole process occured within the context of Action Research cycles.

6.1 Outcome Mapping Analysis

The data presented in this thesis is both qualitative and quantitative. The qualitative data was collected by using semi-structured interviews as well as ethnographic observations during the Action Research cycles. The quantitative data were automatically collected by the system as it was being used. This data was triangulated to find patterns to answer the research questions. This section therefore discusses the patterns that came out of the different data collection methods within the context of Outcome Mapping. Outcome Mapping journals were used to keep track of the changes in the boundary partners' behaviour throughout the Action Research cycles.

6.1.1 Department of Health Behavioural Analysis

The main pattern seen, in the monitoring of the Department of Health (DoH) boundary partner is that at the start of the Action Research cycles, there seemed to be immense interest in the project, however, this that tapered off towards the end of the project. During Action Research cycles 3 to 5, the DoH showed immense interest in the project. During these cycles, the visits and meetings, scheduled with the DoH boundary partner, were successful. The success means that there was tremendous input from the DoH boundary partner in terms of how the project could be made successful for sustainability. More uses for the system were brainstormed so that the DoH can help in making the project sustainable. Some of the suggestions included collecting the usage statistics that could help in showing whether the system was helpful or not. The DoH also promised to help in providing material for training and even be physically available to offer training to the nurses. However, this promise was not fulfilled by the DoH. The meetings scheduled for visits in Action Research cycles 6 to 7 to further discuss what exact statistics were needed, were also not attended by the DoH boundary partner. The promises made by the DoH, district level, were never really fulfilled. Lastly, there seemed to be wonderful ideas about moving forward but the actions were opposing the ideas. If one says the statistics can help in showing whether the system helps or not, one also needs to be able to help in saying exactly what statistics are needed. The follow up action on their part did not occur.

6.1.2 Doctors Behavioural Analysis

If one looks at the doctors, there seemed to be constant excitement about the project throughout the Action Research cycles. This excitement could have been caused by the fact that the doctors were all foreign and they came to these villages to help in uplifting the community. It seemed as if anything that was aimed at uplifting the community was excellent for the doctors. The doctors were busy most of the time, but they managed to attend the meetings when requested even if it meant they had to leave before the meeting had ended. In terms of actual interest in the system, there seemed to be divisions amongst the doctors because some of them seemed to rate patient care high

and never had much contact with the technical system. One of the doctors had immense interest in the technology and the technical system itself. The system was installed in his room and this could have made it easy for him to play around with the system, when he had a moment to do so. For example, this interest was shown by him initiating an Instant Message call to the nurses and asking them if they needed anything from the hospital. In terms of preferences, the doctors mentioned that they prefer using the synchronous call options in the system more than using the asynchronous options. This could have been caused by two reasons. One reason is that the doctors did not really have to send asynchronous messages to the nurses as they were not referring patients to the nurses. Secondly, the synchronous component of the system is easier to use than the asynchronous component. In terms of call options, the doctors mentioned that they preferred voice in making synchronous calls. The system logs also agree with what the doctors said. Data triangulation confirms that the main pattern for the doctors is that what they say is what they really did.

6.1.3 Nurses Behavioural Analysis

The nurses seemed to behave differently from the doctors. There seemed to be a tendency of doing things because they were asked to do them, rather than self motivated. There seemed to be a tendency to say things that were only positive during the interviews. If one asked whether they found the system useful, they would say the system was very helpful even when they did not actually use it. Some of the nurses seemed to be worried when told that there would be a visit or a meeting with the doctors and the DoH. It seemed as if there was something to hide from the superiors. One of the nurses was also worried that their conversations would be heard when using the system and that their superiors could "snoop" on them. In terms of the technical system and its usage, the interviews revealed that the nurses still needed more training in how to use the system. This made more sense as the nurses had just begun to use the system. The interview feed back showed that the nurses realised how the system would help them as one of them mentioned explicitly that she could see how the technical system would help her. The important aspect to note here is that nurses could be saying what they think the

researchers wanted to hear when it comes to using the technical system. One of the nurses mentioned that she initiated a call to the doctor to ask for medicine and that she used MuTI to call when there was a problem. The system logs, however, showed that the call was initiated from the hospital as the doctor said. The system logs showed furthermore that most calls were made during training days. An interesting thing to note here is that the nurse replied to that call and the required medicine was brought for her as she requested. This seemed to agree with the doctor's feeling that the nurses did not initiate contact when they had a problem, that is there was no way the doctor could have known that the nurse needed help if he did not call her. To summarise, the main pattern for the nurses was that they lack confidence and feel that they are being monitored and evaluated, they furthermore appeared to tell what they think the researchers wanted to hear.

6.2 Discussion

This section provides a discussion of the social and technical issues. The significance of both these issues in terms of building a technical system is also discussed. The section then provides a discussion of how the technical issues affect the development of the technical system and vice versa.

6.2.1 Social Issues

Action Research has been used in this thesis in the form of cycles in which each cycle contained reflection based on what happened during the previous cycle. Three main issues were taken into consideration, during the data collection of each Action Research cycle:

- Firstly, to try and map how the technical system could be further enhanced and changed, an endeavour to understand the social space of the users and the way they work was taken into consideration.

- Secondly, the understanding of whether the technical system was being used or not, and also whether it was difficult to use, was taken into consideration during each Action Research cycle.
- Lastly, Outcome Mapping progress markers were used to perform an evaluation of whether action required, to support the use of the technical system by the users, was taken into consideration during each Action Research cycle. The technical system features have been built and enhanced, based on the observations and requirements, which came from the three main issues in each Action Research cycle. The same applies to the technical system overall because observations and data sometimes revealed that the technical system was not integrating well into the social space of the users. This led to the technical system itself not used.

6.2.2 Technical Issues

The technical system, built in this thesis, is a system that works in real-time and non realtime. This is to try and help with the social problem of the doctors and nurses not having time to use the system because of the high number of the patients they see. The system was built with the hope that when there was time, the real-time component could be used by the nurses and doctors and the non-realtime component could be used when there was no time to use the system. Moreover, the findings also showed that building a technical system is more than time-scheduling for the user. For example, one of the nurses mentioned that it was difficult for her to adopt the system and include it in her daily schedule. This is important to know and track using the progress markers given in the Outcome Mapping journals. Understanding an issue of not being able to include the system in a daily schedule might mean two things:

- The first thing could be that the nurse needs more support on the system in terms of training.
- Secondly, perhaps the technical system needs to be changed and improved to be in line with the work processes the nurse is used to. To be able to understand how the technical system can be made more in line with the work processes of the

nurses, a social understanding of the way the nurse works is important as it provides a picture of how the system can be improved and changed.

6.2.3 Combining Social and Technical Issues

The understanding of the social environment leads to a change in the technical system as well as a review of the actions previously taken to build the system and support the users. This leads to a new prototype being developed and a next set of planned actions for the next Action Research cycle. The social space of the users is therefore deemed important to understand how the prototypes can be changed and enhanced during each Action Research cycle. An evaluation of the built technical system is important as it affects the social environment of the users it is built for. A more balanced approach, in terms of understanding the technical system as well as the social space, is therefore needed. Action Research cycles are important to achieve this balance since in each cycle new prototypes are introduced, based on the understanding of the social space from the previous cycle. An evaluation of the progress is enabled by Outcome Mapping. This evaluation allows an understanding of whether a change, in the technical system prototypes and the way the support is given, is needed during each Action Research cycle. The issue here is that it is not very easy to understand the requirements for building a technical system and supporting the users in one cycle, as the social space is also not always what it seems to be from an outsider's point of view. This is why a cyclical process and ongoing evaluations are needed to try and adapt the technical system into the social space. The relationship between the social space of the users, the methodology used and the technical system is shown in Figure 6.1.

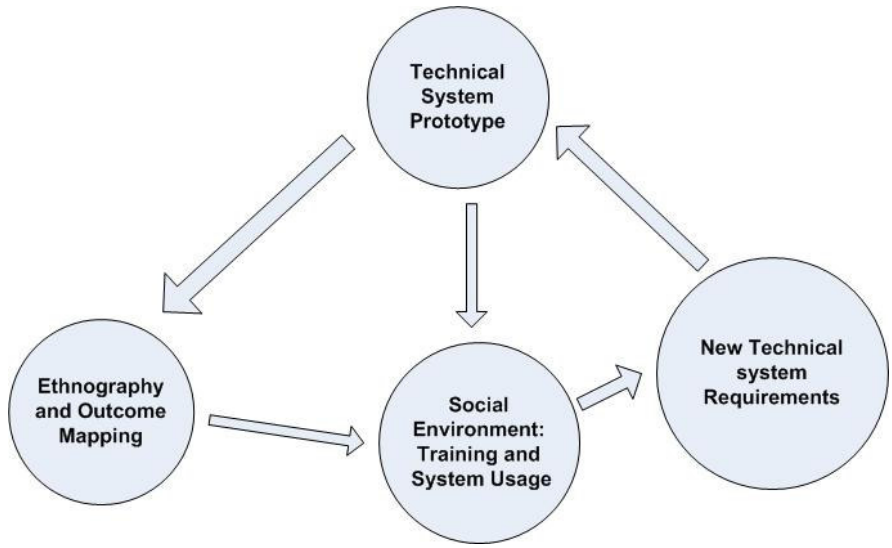


Figure 6.1: **The relationship between the technical system and the social environment of the users**: This diagram represents and Action Research cycle. In this cycle, the relationship between the methodology used in understanding the social environment, which leads to an understanding of technical requirements, is shown.

6.3 Summary

This discussion has shown how the technical understanding of the social space of the users affects the development of a technical system. The relationship between the social space of the users and the technical system has been discussed in terms of the methodologies that have been used in this thesis. Action Research allows a cyclical process to occur in which new changes are brought in each cycle, based on the findings of a previous cycle. The findings are based on the observations of the social space of the users and how the technical system can be built and enhanced, including how the users can be supported to use such a system. The ongoing evaluation is also enabled by Outcome Mapping through the use of progress markers. Progress markers track whether the changes being sought happened in each Action Research cycle to get closer to the outcomes being sought. The changes to be made can be on the technical system or the way the social space of the users is understood. The next chapter presents conclusions and future work based on the discussion provided in this chapter.

Chapter 7

Conclusion and Future Work

This Chapter presents the conclusions and future work for this thesis. In this Chapter, the research questions the thesis aimed to address are answered. In terms of building a technical system, an Action Research prototyping approach together with an understanding of the social space of the users are suggested. In terms of support for the users, training and an understanding of the progress of the users, in terms of what the users need, are suggested. Outcome Mapping is regarded as a valuable tool to accomplish this as it allows an understanding of the progress in terms of the behavior observed in the users. The thesis also suggests that an evaluation of progress in the managers and colleagues must take place within the context of the social working environment of the users. A list of recommendations are provided to address these topics. Lastly, the chapter provides some directions for future work. The thesis suggests a continuation of the Action Research cycles by taking the requirements that were not implemented in the last Action Research cycle of this thesis and implementing these requirements, while keeping in mind the lessons learned and recommendations stated. The limitations of this thesis are that it was executed in only two sites. Similar patterns were found in Chetty et al.'s work [23]. While this is true in this particular case, conclusions drawn in this thesis may not be true for developing an ICT system for all developing countries, however, one can certainly apply the principles of the lessons learned and the recommendations and guidelines provided in this thesis.

7.1 Research Question Resolution

In chapter 3, the research question the thesis aims to answer was presented. To recap, the research question was stated as follows: **Is an IP-based multi-modal semi-synchronous communication system applicable in rural tele-health in a developing country context**. This research question has been addressed from two perspectives (the technical as well as the social perspectives) as stated in chapter 3.

7.1.1 The Technical Perspective

In the technical perspective, the thesis aimed to understand how such a technical system could be built. In terms of this perspective, it has been found that an engagement with the users of the system and an understanding of the social environment of the users are important in understanding the technical requirements of a technical system to be built. The requirements, however, do not evolve just once, as the system needs to be adjusted to suit the users concerned. The researcher discovered that the traditional approach of the Software Development Life Cycle (SDLC) where requirements come once would make it difficult for the users to contribute their requirements and adjust to the system being built. The traditional SDLC approach would also make it difficult to adapt the system into the social environment of the users. The researcher discovered that the prototyping approach, in the form of Action Research cycles, is helpful in collecting these requirements and adjusting the technical system to the new requirements as they evolved. It was discovered that this approach does not only allow for an understanding of the technical requirements, but the social environment which helps in thinking about how the technical system can be built.

7.1.2 The Social Perspective

The social perspective was aimed at understanding how the users of such a system could be supported to use such a system. The researcher discovered that a monitoring process, to understand the issues in the social environment of the users, is crucial in supporting the users to use a system in a rural environment of a developing country. This is because sometimes what one hears is not what one sees. Users need to be constantly trained because of the high rate of illiteracy in the rural areas of developing countries. The researcher also discovered that it is sometimes difficult to attain what the users really need by only asking them. A way of mapping what they do and what they say is also important in order to understand a way forward. In this thesis, Outcome Mapping was used to get an understanding of what is happening in terms of what is expected of the users. This measurement was found to be important as it gave an idea of whether more support mechanisms and adaptations were needed throughout the research cycles.

7.1.3 Unifying the Technical and Social Perspectives

Action Research allows a cyclical process to occur in which new changes are brought in each cycle, based on the findings of a previous cycle. The findings are based on the observations of the social space of the users. The findings highlight how the technical system can be built and enhanced as well as how the users can be supported to use such a system. The ongoing evaluation, enabled by using Outcome Mapping progress markers, allows the tracking of the changes being sought in each action research cycle. This understanding then provides an idea of what could be changed in the next Action Research cycle to get closer to the outcomes being sought. The changes are then made on the technical system itself based on the understanding of the social space of the users. The social and technical perspectives affect each other, in the sense that if the social perspective is not understood, the resulting technical system could result in it not being able to fit well in the social environment of the users. The same issue occurs with the technical system being developed because if it is not in line with the social environment of the users, then it has a potential to create a difficult social environment for the users it

is developed for. The technical system being built should reflect the social environment of the users.

7.2 Lessons Learned and Recommendations

The recommendations and guidelines drawn from this study were drawn from the experiences the project team had during the time spent in the two sites. The first site is where Chetty et al. [23] tested the MuTI system and the second site is where this research was executed. It is important to note that while these two sites were not similar in terms of the user base and the background, the approach followed in terms of research, is almost similar. The recommendations emerge from the successes of the research, mistakes made and the lessons learned.

7.2.1 Lessons Learned

• Needs assessment is very important when conducting research in order to learn how to provide ICT systems for developing countries. This is important because of the characteristics of these areas. If a system is developed without proper needs assessment, it may be difficult for such a system to get accepted and supported. The system being developed should be a system that has the potential of being used and helpful in the target community.

• In terms of project support, it is important to engage people, who live in the area, as they have a better understanding of the needs of the community and who to contact when more information is needed. The other issue here is that it is easy for communities to develop trust with someone they know. This makes it easy for the communities to accept projects.

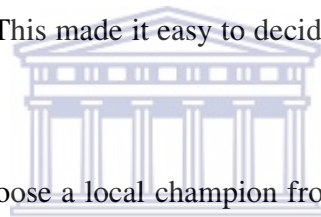
• Leaders of the community are vital in the facilitation of the projects because when new equipment has to be installed, it is always important to get permission from the local leaders as they will let the community know about projects that are taking place in their areas. This could also help in ensuring the safety of the equipment.

• In terms of support, management has to be involved as they have the power to make decisions that could be helpful in the success of projects. For example, if one needs to use a building for a meeting, management needs to be consulted for permission to use such a building.

• Working with external groups is also important as they can prove useful when help is needed.

7.2.2 Successes

• The project managed to engage the stakeholders important for the project to con- tinue. Meetings were held with the stakeholders to brainstorm ideas about where to go when there are problems. This made it easy to decide on who to ask when there was a problem.



• The project managed to choose a local champion from the start. This was vital as the local champion proved to be the point of contact when the project team was not on site.

• The project goals and purpose were also clarified from onset. This helped in managing expectations from the community and the stakeholders.

• In terms of levels of treatment, the project did not choose one person as a point of focus. The stakeholders were all treated with the same level of trust and respect. This is very important as it does not provide an idea that some people are more contributing than others. In reality, this would be the case but the project team need not provide this idea to the stakeholders.

• The project team also put in an effort to spend more time with the users and training was the major component of the project. The training did not only happen when the project team was on site, but it also happened when the project team was away. This helped in getting contact with the users to create relationships as it took time to formulate solid relationships.

• Lessons learned from the site where Chetty et al. [23] [24] performed research, were kept in mind during this thesis to not repeat the same mistakes.

7.2.3 Mistakes

• The clinic, in which the system developed in this thesis was tested, was chosen purely on word of mouth and what seemed to be, that there was enough staff to use the system once installed. This proved problematic later as this did not turn out to be the case. The nurses were not always at work as anticipated.

• A solution was thought of before the target area was seen. It is important to note that the actual solution was implemented together with the user, but the actual concept of a solution was brought in from a previous site where Chetty et al. [23] performed research.

• There was also very little input from the users about what the solution should look like. This could, perhaps have been caused by the fact that a solution was thought of for them, instead of discussing the solution with them.

7.2.4 Recommendations

• Ethnographic observations needs to be performed in the target area even before the building of the application is thought of. In the case of this thesis, a site was chosen based on the interpretations of the target area. The literature review, discussed in chapter 2, showed that it is important to develop applications based on the needs in the target areas. In the case of this thesis, a need for a communication system was seen during the visits made. It seems that the needs assessment is not enough.

• More endeavor needs to be made for fitting the technical system with the work processes of the users as much as possible.

• Sometimes the work ethics do not seem to be what they are and make it difficult for things to happen as planned as sometime there will not be staff available to work with.

• It is helpful to have a local or someone who understands the local language of the target area to enable communication between the villagers and the research team. This helps in easily building trust between the research team and the community.

• A local champion was shown, in the literature review, to be the key in the ICT for development projects. This is very important as the research team cannot always be on site. However, in the case of this project, the champion was not an end-user. The champion belonged to a Non Governmental Organisation (NGO). NGO's tend to be externally motivated and move to the target area to make a concerted effort to realize change. Someone who can train and support the users, while the research team is away, is needed. It is important to have someone who can send bug reports between the visits to keep the flow of work.

• While the local champion does not have to speak the same language as the users, training a local to help is always very helpful. The users tend to connect and understand things much faster and better if they are explained in their home language. Therefore the NGO motivates local support on the ground.

• Expectations, in terms of the aims of the research, need to be carefully managed. It is very difficult for most people to distinguish between research and providing a solution. This needs to be made clear from the beginning as expectations, in terms of output, will be really high. This is because research is not about providing a solution but a process of learning, how a solution can be provided, which means that an immediate solution is not guaranteed.

• A plan for an exit strategy, in case the hypothesis fails, is also important as research equipment may have to be taken away. Taking away research equipment has proven to be difficult in the previous site where Chetty et al. tested the first version of the MuTI

system [23]. The users tend to take ownership of the equipment and makes it difficult when the equipment must be taken away.

• In terms of getting information a systematic way of speaking to the right people is always helpful for support during the research. The reason for this is that when one works with organizations, there is management at all levels. An understanding of who to speak to is important as it helps to do tasks quickly. Relationships need to be encouraged and fostered at all levels. Relationships are very important as they build trust and enable a working understanding between the research team and the all the other external stakeholders involved.

• Lastly , if the research is a partnership between two or more teams, it is important to define goals, approaches and contributions early in order to avoid confusions in terms of contributions expected from each research team.

7.3 Future Work

During the Action Research cycles, the requirements were collected to build the technical system discussed in this thesis. The requirements, from the last Action Research cycle, were not implemented in the technical system discussed in this thesis. Most of these requirements concerned trying to fit the technical system more to the work processes of the users. For example:

Requirement 3 Use MuTI to send back test results to the clinic.

Requirement 4 Use MuTI to communicate between clinics.

Requirement 13 When a user makes a call, if the recipient does not answer, the system should automatically fall over to leaving a message.

Requirement 14 Concurrently run all three synchronous modalities.

Requirement 15 The log facility requires: a) trace/log levels and b) controls on the size that logs can grow to (so that they don't grow out of control).

Requirement 16 Ability to record the subject of a call and message.

Requirement 17 Allow breaking to the PSTN gateway. This feature needs to be restricted so that people can't make a call any time they want.

Requirement 18 Automate the picture/camera process so that sister just has to connect the camera and the software will copy and delete the photos off the camera, and eject the USB device, leaving it ready for the next attachment.

An implementation of these requirements will allow further understanding of whether more use will prevail in the technical system when it is further tested. A Participatory Design approach as described by Muller and Kuhn [55] is suggested, in which prototypes are discussed in detail with the users before they are developed to create an understanding of usability and functionality in the technical system being built. This will happen when the users are more technically adept.

In Future work it is suggested to run the developed system on mobile devices to allow mobility for the users so that they can take requests while on the go. It is also suggested to expand the communication system to other clinics to have a broader understanding of what is really happening in terms of system usage and requirements, as this will allow comparison of patterns that occur from the different clinics.

The recommendations given in this thesis need to be taken into consideration when implementing the new requirements of the technical system. This is important as it will allow the research not to repeat the mistakes already made. This approach will also focus the research into providing more recommendations from new lessons that will be learned.

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Appendix A

MuTI Questionnaire

Please fill out the following questionnaire to help us understand more about how you use MuTI in Lwandile and Canzibe. 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 to send the doctor video footage of the patient or to send pictures of the patient? Please explain why you prefer this option.

_____
_____
_____

5.

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

_____
_____
_____
_____

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

_____
_____
_____
_____

c. For the both: Are you able to help more patients with MuTI than previously when the system was not there? Please explain why.

_____
_____
_____
_____

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

_____
_____
_____
_____

7. When you do call, do you use voice, videoconferencing or instant messaging? Please explain your choice

_____
_____
_____
_____

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

_____
_____
_____
_____

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

_____
_____
_____
_____

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

_____
_____
_____
_____

11. When you send a record with MuTI:
    a. Do you usually send a voicemail or video clip? If you send any of these, what information do you usually include?

_____
_____
_____
_____

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

_____
_____
_____
_____

    c. 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)?

_____
_____
_____
_____

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

_____
_____
_____
_____

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

_____
_____
_____
_____

12. 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?

_____
_____
_____
_____

13. What do you like about MuTI?

_____
_____
_____
_____

14. What do you dislike about MuTI?

_____
_____
_____
_____

15. What would you like to change about MuTI?

_____
_____
_____
_____

16. What else do you think MuTI could be used for other than referrals?

_____
_____
_____

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

_____
_____
_____
_____

Thank you for your participation