UNDERSTANDING THE FACTORS THAT INFLUENCE TRUST IN E-SERVICES: A CASE STUDY OF A WIRELESS MESH NETWORK IMPLEMENTATION IN MANKOSI, SOUTH AFRICA

by

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ABSTRACT

This thesis deals with the design of a business model for rural telephony based on a wireless mesh network for a rural community, the Mankosi community, located in the Eastern Cape Province of South Africa. Its aim is to understand the social, economic and technical issues that are involved in the adoption of information and communication technologies for development and how they relates to trust in e-services.

Externally funded projects tend to be expensive and are often unsustainable once the external funding ceases. The cost of a mesh network (once implemented) is almost negligible, apart from its maintenance. The pillars of the project are sustainability and community ownership, and the aim was to design the wireless mesh network, provide telephony service to the community and use solar power to charge mobile phones. The community leaders of Mankosi indicated that they do not want the service to be completely free, but would charge a small fee for each call in order to generate the funds needed for the maintenance of the system. In order to do so, a prototype billing system was configured and adapted to the needs and expectations of the community.

The principles and steps of soft systems methodology were used to manage the research process of this case study. This methodology was a powerful tool to carry out the research and address the research problem in a participative way with the stakeholders. The participatory design process used in the design phase of the project had the added advantage that the community understood the purpose of the network, and since they contributed to its design, they felt that they owned it and could trust its billing system. A further benefit was that a core group of participants were committed to the project and felt that the overall quality of community members' lives would be improved by it and similar projects. The process contributed to the personal development of the participants by giving the community a voice and sense of power – the ability to change things – and it vastly expanded community members' vision of what they are capable of.

It was found that the current means of communication, i.e. using mobile phones, is expensive for local users in relation to their average income. The proposed billing system – designed with the help of the community – will be trusted by the community and provide Mankosi with a low-cost communication system by making use of the existing experimental mesh network. The community will be able to sustain their network with the income generated. The network will in future provide access to the Internet and will be able to handle breakout calls to external networks.

Keywords: billing system, case study, community, money collection, sustainability, transparency, tribal authority, trust, wireless mesh network.

DECLARATION

I, Marie Josée Ufitamahoro, declare that "*Understanding the factors that influence trust in e-services: A case study of a wireless mesh network implementation in Mankosi, South Africa*" is my own work, that it has not been submitted for any degree or examination at any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Full name: Marie Josée Ufitamahoro

Signed:

Date: 27 February 2015

EDITOR'S CERTIFICATE

23 November 2014

To Whom It May Concern

This is to confirm:

1. That I am a professional copy-editor;

2. That I have copy-edited the thesis 'Understanding the factors that influence trust in e-services: A case study of a wireless mesh network implementation in Mankosi, South Africa' by Marie Josée Ufitamahoro;

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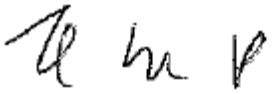

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2014 Rey-Moreno, C., Ufitamahoro, M. J., Venter, I. M., and Tucker, W. D. (2014, December) Co-designing a Billing System for Voice Services in Rural South Africa: Lessons Learned. In Proceedings of the 5th Annual Symposium on Computing for Development (DEV-5). ACM (in press)

2013 Ufitamahoro, M. J., Venter, I. M., Tucker, W. D., & Rey-Moreno, C. (2013, December). Unmasking Community Trust Issues in Rural Field Work. In Proceedings of the 4th Annual Symposium on Computing for Development (Article 23). ACM.

GLOSSARY

BANG (Bridging Application and Network Gaps) group: Research group that conducts applied research into information and communication technology for development (ICT4D)

E-services (Electronic services): Services that are automatically delivered with the use of information communication technologies (ICTs) over the Internet or other electronic networks

ICT4D (Information and Communications Technologies for Development): Technology applied for socio-economic development to improve income, health, security or any other aspect of human development (Heeks, 2008)

IP (Internet protocol): A protocol for communication that is used to transfer packets of data across a network.

LOs (Local operators): The owners of the houses where the station nodes are housed (Ufitamahoro, Venter, Rey-Moreno, & Tucker, 2014)

LRs (Local researchers): A team of two men and one female born and leaving in the community and assisting in the project as moderators between the researchers and community members (Ufitamahoro, Venter, Rey-Moreno, & Tucker, 2014).

Mesh network: A type of networking topology where each node acts not only as a host, but also as a relay for other nodes by forwarding packets in order to propagate the data in the network (Akyildiz, Wang, & Wang, 2005)

MCA (Mankosi Community Association): Group of community members in charge of the management of community funds (Rey-Moreno, 2012)

MP (Mesh potato): A communication device that combines an access point and an analog telephony adapter. It is used to provide low-cost telephony and Internet access in remote areas (Village Telco, 2011)

MT (Mankosi Trust): Legally recognised institution created for the collection of money and manipulating it for the good of the whole community (Rey-Moreno, 2012)

MySQL (My Structure Query Language): An open source database management system (Oracle Corporation, 2014)

NGO (Non-Governmental Organisation): An association that operates independently of government to deliver resources or serves some social or political purpose to develop projects or to promote a cause (Rouse, 2010)

PD (Participatory design): A method used in research methodology with the goal of working directly with stakeholders in the design process (Muller & Kuhn, 1993).

PSTN (Public Switched Telephone Network): The international telephone system based on copper wires carrying analog voice data. Telephone service carried by PSTN is often called "plain old telephone service" (POTS) (Roos, 2014)

TA (Tribal authority): A traditional political institution inherited patrilineally (Rey-Moreno, Roro, Masbulele, Javier, Bidwell, & Tucker, 2012)

Trust: A psychological state in which consumers of a service believe in the integrity and competence of the service and its supplier (Zhu, Lee, & O'Neal, 2011)

UWC (University of the Western Cape): The University attended by the candidate

VoIP (Voice over Internet Protocol): A communication protocol where the voice messaging application is transported over the Internet (Teliqo)

VT (Village Telco): Initiative that builds low-cost and easy-to-use community telephone networks (Village Telco, 2011)

Wi-Fi (Wireless Fidelity): A technology that allows electronic devices to exchange data wirelessly over a network (Kioskea.net, 2014)

Chapter 1

PROBLEM STATEMENT AND ANALYSIS

This chapter presents the background information that contextualises the research undertaken for this project. The research problem is clarified and refined with reference to the related literature. The research approach is also specified and the research methodology is introduced.

Sketching the background

Information communication technology for development (ICT4D) is a powerful tool that is transforming the global economy and enhancing rural development, particularly in developing countries (Mandioma, 2007). When ICTs are appropriately adapted they can improve the livelihoods of poor communities by increasing their income opportunities, thereby improving their chances of escaping from persistent poverty (Gunasekera, 2008). Weber and Kaufmann (2011) argue that where telecommunication services reduce isolation, they result in increased business activities and improved social interaction by providing easy access to new knowledge.

In rural areas of developing countries people are socially excluded because the transport infrastructure is usually limited. Consequently, most rural people have limited opportunity to access new technologies and to learn about relevant applications from others, which poses an obstacle to development (Memeburn, 2010).

If some form of inexpensive communication infrastructure could be deployed it could address the isolation of rural communities. According to Heeks (2008), wireless technology has become the delivery mode of choice to provide connectivity to remote communities in developing countries. During the 1980s and 1990s the focus was on land-based transmission systems; however, the installation of landlines is costly and thus new ways of service delivery were explored. Wireless Fidelity (Wi-Fi)-based systems and Worldwide Interoperability for Microwave Access (WiMax) systems are innovative methods to provide affordable communication to rural areas (Heeks, 2008). The creation of the Village Telco, a communication technology designed to address communication problems in remote areas, brought the mesh potato – a device that merges analog phones with wireless communication (Village Telco, 2011).

To keep costs low, the mesh potato runs on open source software and has been developed so that it is easy to install and uses very little energy, thus it is recommended for areas where electricity supply is limited (Rowe, 2009).

A mesh potato Wi-Fi system has the ability to connect users on a network efficiently, is flexible and requires little configuration. Its installation allows neighbourhoods to be connected and has the potential to increase the economic activity of people in remote areas of Africa (Memeburn, 2010). These advantages of mesh potato technology make it the technology of choice for use in rural areas such as Mankosi.

Mankosi is an impoverished rural community located on the so-called "Wild Coast" of South Africa. It is located in Nyandeni Municipality in the Eastern Cape Province of South Africa and comprises 12 villages. The community is mostly isiXhosa speaking. Its members' main income is based on land use and animal farming. Almost all households receive additional income from family members who work in other areas and income from government in the form of pensions or child allowances. Mankosi is governed by a tribal authority (TA), a traditional political institution inherited patrilineally. It is very different from the democratic and modern legislative and political institutions that exist in urbanised areas of South Africa. One headman and 12 sub-headmen (one from each village) make up the TA and approve decisions about projects in the community (Rey-Moreno, 2012).

In rural areas such as Mankosi, ICT4D projects face many challenges, mostly due to the scarcity of resources (such as electricity and expert knowledge). These challenges make the projects costly to operate and often impacts on their sustainability. (Pade, Mallinson, & Sewry, 2006). The failure of the projects can also be ascribed the developers misconception of concerns of the technologically "disadvantaged" users and their need for services. Failure to develop a sense of user security and trust could arise as an obstacle to the successful service delivery of an ICT4D implementation (Kaisara & Shaun, 2009).

Many innovative ICT4D projects in rural areas have failed and were not entirely adopted and used by the communities for which they were designed (Mpofu & Muyingi, 2008). Issues related to trust might have been the reason for these projects' failure.

Context and motivation

To understand the factors that influence trust in e-services, this project will pose the following question: "How should an e-payment system for voice services on a rural Village Telco be designed and implemented to gain the trust of the community?"

The ICT revolution will bypass rural areas in developing countries if nothing is done to get these communities connected (Siochrú & Girard, 2005). Access to telecommunications remains a problem in remote areas where telecommunication operators cannot or will not operate, and even where services are available, e.g. cellular communications, access is limited due to their excessive costs relative to the personal income of most of the rural inhabitants. Electronic services could offer a solution for many of the challenges experienced by rural dwellers, such as the long distances inhabitants have to travel to access banking and government services.

This research effort was motivated by the emergence of new communication technologies that are particularly suited to these rural communities, especially when such technologies can be deployed as a community-owned network. An inverse deployment of the infrastructure is attractive because of its low level of initial investment and scalability. It is technically relatively simple to install, its cost is low, and the fact that it is based on open standards makes it adaptable to both voice and data services. To conclude: combining the latest wireless networking technology and open source telephony software in a Village Telco can create the potential for a community to possess its own phone system (Village Telco, 2011).

Research approach

The main problem that drives this investigation is the need to understand what dynamics build trust in a service and to explore the role that trust could play in stimulating the adaptability, usability and sustainability of a communication network owned by a community, in this instance the Mankosi community.

The research question is: How should an e-payment system for voice services on a rural Village Telco be designed to gain the trust of the community?

This question can be unpacked into the following sub-research questions:

- What are the needs and expectation of the community in terms of communication services?
- What modality of payment would be suitable for the community, but will also make the Village Telco sustainable?
- How should the payment system be designed or developed to address the needs and expectations of the community?
- How should the system be built and managed so that it is trusted by the community?

Aims and objectives of the study

The primary objective of the study is to understand trust issues associated with the use of e-services and to explore the specific role of ICTs in local economic development.

The study has the following specific objectives:

- To analyse the layers of trust in a billing system by the community, the TA and all entities involved in its design; and
- To involve the community in the evaluation of different possible billing scenarios demonstrated with a built prototype.

Approach and methodology

To answer the above questions, various strategies were adopted. Soft systems methodology was used to manage the research process, which entailed several methods. These included document analysis (articles, journals and reports), a pilot study, the use of qualitative methods (such as interviews and observation) and surveys (which were analysed quantitatively).

Ethics and permissions

Ethics clearance was sought and given by the Faculty of Natural Science Research Committee to the umbrella project that deals with the design implementation and evaluation of a rural wireless network for the Mankosi community (Reference 13/06/31). The participants in the research were invited to participate in the research with the insurance that all information provided would be treated as confidential and that they may withdraw at any stage (see Appendix A)

Roadmap

In this chapter the background of the research was discussed, the motivation for choosing the topic was explained and the research questions were outlined. The methodology used during the research was briefly discussed. In Chapter 2 the literature will be reviewed in terms of the research questions and the key concepts as defined in Chapter 1. In Chapter 3 the research design and methodology will be discussed. This includes the methods adopted to collect information from the Mankosi community and the programming tools used to build and test the e-payment system. Chapter 4 gives the results, including the system testing results. Chapter 5 provides an analysis of the results and demonstrates the extent to which the resulting system answers the research questions posed; it concludes with recommendations based on the results.

Chapter 2

LITERATURE REVIEW

In the previous chapter the background to the study was sketched. In this chapter the literature that is pertinent to this research as well as the basic terms and concepts that the study is built on are defined. The review focuses on the influence that "trust" has on the acceptance and usage of ICT4D.

Research location and context

MANKOSI COMMUNITY

The Mankosi community forms part of a ward, one of 31 wards constituting Nyandeni Municipality, Eastern Cape Province, South Africa. A ward is the smallest administrative division of the municipality, and a warden (a political administrator elected democratically by the ward's population) governs it. Nyandeni Municipality has a population of over 320,000 people, of whom most (99.6%) speak isiXhosa (Rey-Moreno, Tucker, Bidwell, Roro, Masbulele, & Javier, 2013).

Residents often use the word "community" such as in "Mankosi community", to describe those living within a specific location. Communities are governed by local TAs. The TA is a traditional political institution that is inherited patrilineally and runs parallel to the normal legislative and political institutions. A headman and 12 sub-headmen (one from each village) govern the Mankosi community, each of whose homesteads is also a site for administration. Sometimes a community can belong to two different wards simultaneously as a ward is a governmental division and a community is not. In each community, land is organised according to the community's traditional culture. This is the way it has been done for many generations.

The Mankosi community is composed of approximately 580 households, according to data collected directly in the field (Rey-Moreno, 2012). The villages in Mankosi are geographically spread across 30 km of scattered hills and the infrastructure is limited, e.g. very few roads connect the villages, and these roads are not easily accessible, because their condition is often bad. People in Mankosi commute by walking, which makes coordinating villages socially and administratively difficult. Umthata, 70 km away, is the closest city to Mankosi, and to reach it can take 1.5 hours in a high-clearance vehicle or up to four hours using local transport driving on dirt roads over hilly terrain and across river passes.

Figure 1: Mankosi community setting

To communicate with each other, the people living in Mankosi either walk to other community members or use mobile phones, which are expensive, especially when considering the income of the community (Reitmaier, Bidwell, & Marsden, 2012). As stated by Bidwell (2011), the community needs a communication system that consumes less airtime or which is free, since currently community members spend approximately R60 per month each on local communications, because most calls are made to people in the community.

STAKEHOLDERS

The tribal authority

The TA plays an important role in the community, e.g. it is approached to solve the community's local problems. The chief of the TA controls several communities, the headman controls a particular community, and the sub-headmen each control a village in the community.

If the problem is easy to solve, the sub-headman of the relevant village deals with it locally, if not, it is scaled to the *isibongas* (who are the intermediaries between the headman and the sub-headman and act if the headman is not available), then to the headman, and finally, if still unresolved, it is dealt with by the chief. If he cannot solve the problem, it is brought to the Official Court. In this social structure the sub-headmen are appointed (by the headman), and both the headman and the chief are born into their positions. The sub-headman in most cases is chosen from members of the extended family of the headman.

When he is busy with official duties, the headman is normally accompanied by *isibongas* who also work for the ward councillor, so they bridge the gap between the official and traditional administrations, and they attend both's meetings when possible. The ward councillor plays a central role in the communication process between the communities he represents and the council. He reports regularly to the community through ward meetings. He assists the community in identifying needs and prioritising areas of development, which feed into the municipality's planning processes. Apart from the *isibongas*, the headman normally relies on the advice of somebody from his clan or somebody that has worked with the previous headman (Bidwell et al., 2011; Rey-Moreno, 2012).

Transcape

Transcape is a non-governmental organisation (NGO) based in Mdumbi (one of the 12 villages in the Mankosi community) that has been involved with the community since 2000. It runs many active projects, some of which are an HIV (human immunodeficiency virus) programme, an education centre, a home-based care programme, and an Eco-Homestead programme. They are currently planning two further projects in the area, i.e. building a clinic and an eco-village (including a restaurant and spa).

Mankosi Trust

The Mankosi Trust (MT) is a legally recognised institution created to manage and invest money collected for goods that belong to the community (like sand to build bricks) to the benefit of the community (not only the people making a business out of it); it also collects and uses funds for the benefit of the community (Rey-Moreno, 2012). However, due to trust issues in the community, the MT has been suspended.

Mankosi Community Association

With the approval of the community and the TA, a grassroots organisation called the Mankosi Community Association (MCA) was formed to manage the collection of money for goods that belong to the community and use the money for community projects.

One of the projects initiated by the MCA and assisted by Transcape was the building of a clinic. Members of MCA (trained in accounting by Transcape) are tasked to keep the TA and the whole community informed about activities in the community. The MCA plays a significant role in prioritising the needs of the community.

The local researchers

The local researchers (LRs) are a team of three people (two men and a woman) who were born and have lived in the community all their life and have assisted with the project since its inception. They acted as moderators between the researchers and community members, since they were well versed in the needs of the community. Because they were familiar with the needs and culture of the local community they were a great help, because they could not only translate the language, but also explain the culture and traditions of the community.

Local operators

Local operators (LOs) are the owners of the houses where the station nodes are housed. They consisted mostly of male family heads. When they were not available, one member of the family could be sent to represent them in community meetings and focus group meetings presided over by the headman. These people were actively involved in the design of the business model, because they are responsible for collecting the money for the network services.

The research team

The research team from the University of the Western Cape (UWC) was made up of the researcher (myself) and a fellow researcher, Carlos Rey-Moreno from the Department of Signal Theory and Communications at University Rey Juan Carlos, Spain, who is a member of an exchange programme at UWC. His research focuses on how ICTs are being accessed and used in Mankosi and aims to measure how the introduction of a cheaper mechanism to communicate among the villages will affect the lifestyles and livelihoods of the community's people and households. My research is aligned with Rey-Moreno's in that there is a need to understand the factors that influence trust in the services delivered on the network and design a system to enable and manage its sustainability (i.e. a billing system). The two projects fall under an umbrella project coordinated by the Bridging Application and Network Gaps (BANG) research group at UWC.

Characteristics of successful ICT deployments

In order to understand rural communities and build successful systems in rural areas of developing countries, there is a need to consider the characteristics of successful ICT developments in similar communities. The main aim of this thesis is to gain an understanding of the social environment of rural users and to take this into consideration when building technical systems for such communities.

Bridges.org (2012) described 12 characteristics of successful ICT applications in developing countries: trust, appropriate technology, physical access, affordability, capacity, relevant content, integration, socio-cultural factors, the legal and regulatory framework, the local economic environment, the macro-economic environment, and the political will to implement such applications. In the following section the first three of these characteristics (which are the most pertinent to my research) are discussed.

TRUST

Although the financial side of a project is one of the many factors that affect its sustainability, to improve the chances that it will survive after the initial launch, trust issues are a primary aspect that needs to be taken into account.

What is trust?

Much research has been conducted on the subject of trust, but a concise and universally accepted definition of the concept remains unavailable. Hence, the term "trust" is used in distinct and not always compatible ways, depending on the context and the field in which it is studied.

From Sabatini's (2009) point of view, "trust", derived from the German word *trost,* means comfort, implying instinctive, unquestioning belief in and reliance on something. Luhmann (1988, p. 99) describes trust as a means to reduce social complexity. To highlight the necessity of trust, he says that "*Trust is mostly irrational and used to deal with situations where there is a deficit of information or knowledge*". In their study Hébert et al. (2006) emphasise that "*Trust arises in conditions where rationality governs human behaviour, but it is characteristic only for those situations with a considerable risk and a clear orientation towards the future, for which predictions based on trust rather than on information are made*" (Pande, 2010, p. 15).

Influential definitions consider trust as a general attitude or expectation about other people and the social system of which they form a part (Sabatini, 2009). According to Blind et al. (2007), trust is a complex interpersonal and organisational construct that occurs when the parties holding certain favourable perceptions of each other allow this relationship to reach its expected outcomes, although it is closely linked to risk and expectations.

Trust is used as a substitute for risk, but it also creates a risk for the trustee. As Baier (1986) states, trust involves the belief that others will look after our interests without taking advantage of or harming us. Therefore, trust would involve personal vulnerability caused by uncertainty about the future behaviour of other people that may be trustworthy or not (Bouckaert, G., & Van de Walle, S., 2003).

In political institutions, trust is related to be the way citizens assess the current policy achievements of public institutions (Van de Walle & Bouckaert, 2003). Citizens will manifest their intention to trust and support institutions only when they are satisfied with the output of these institutions. As Levi et al. state "*Trust … reflects evaluations of whether or not political authorities and institutions are performing in accordance with normative expectations held by the public. Citizen expectations of how government should operate include, among other criteria, that it be fair, equitable, honest, efficient, and responsive to society's needs. In brief, an expression of trust in government (or synonymously political confidence and support) is a summary judgement that the system is responsive and will do what is right even in the absence of constant scrutiny"* (Levi, Margaret, & Stoker, 2000).

Satisfaction with the delivery of public services determines performance from a different perceptive. People may be satisfied with the existence of a particular service or the availability of certain services that meet their needs. At the same time, they may also be satisfied with information about services; the accessibility and friendliness of the service providers they meet; the competence of service personnel; the fairness, effectiveness and efficiency of the services; or other factors (Christensen & Laegreid, 2005). The above analysis therefore shows that trust is the result of performance.

On the other hand, some scholars have realised that trust is the *cause* of performance. A good example is given by the findings of the Canadian Centre for Management, which realised that general attitudes towards government affect perceptions of service quality (Van de Walle & Bouckaert, 2003). Similarly, Bouckaert et al. (2003) maintains that "*the survey data on relationship between evaluations of government performance and political support is incapable of establishing the direction of interconnection. It is uncertain whether citizens give negative responses to questions on government performance because they do not trust the government or if they loose faith in government because they evaluate the economic performance as poor*" (Bouckaert, G., & Van de Walle, S., 2003, p. 93).

Based on these scholars' points of view, one should clearly state whether trust would be dealt with as a dependent or independent variable when doing research, for the simple reason that trust could be both a cause and an effect. For this research, trust will be indicated to the occurrence of the people to perceive themselves in the design of the system and the willing to use the system.

THE APPROPRIATE TECHNOLOGY

As stated by Heeks (2008), the adoption and diffusion of new technology is regarded as a trusting process, with "the tendency to trust" related to the perceived quality and value. When the details of new technology become unclear, ambiguous or imprecise, and when the information is inaccessible or unreliable people feels insecure, rending the technology unusable (Zhu, Lee, & O'Neal, 2011).

The introduction of new services implies a good understanding and knowledge sharing of the new technology that is to be adopted and used. To ensure that the expected performance will be achieved, technological challenges must be excluded. We need to ask: "What is the appropriate technology according to local conditions, and how do people want to put technology to use?" or, in short, "What are the needs of the community in terms of ICT services?"

ICT4 Dis one of the channels that suit the flow of information, especially in remote areas. Just as in developed countries, the acceptance and adoption of the mobile phone, computer and Internet in developing countries shows the level of confidence that people have in technology use, and this has been a defining factor in the design and widespread acceptance of ICT in such countries (Donner & Camilo, 2008). The way in which people are willing to use technology can be significantly limited when technology users do not feel confident about what happens "behind the screen". The adoption of e-government and e-commerce applications especially demonstrated this, but this lack of confidence also affects the motivation to become e-literate in general (Bester, 2010). This is why a study of the socio-cultural needs surrounding a project is the first step toward an effective and appropriate solution for a properly functioning project.

When it comes to environmental, cultural and economic conditions, appropriate technology would be the most suitable type available that would meet the objectives of a project in a feasible and sustainable way (Townsend, Sathiaseelan, Fairhurst, & Chigona, 2013). With the aim being to use the appropriate ICT and have appropriate support for its use, Townsend et al. (2013) find that the need to bridge the digital divide is no longer an issue, hence the focus has shifted to the design and implementation of programmes that have the potential to close the information and knowledge gap between developing and developed nations. Most of these programmes were successful in the developed world; however, it has become increasingly clear that the successes experienced so far do not necessarily translate well to the context of developing nations.

Many reasons explain why ICT projects fail in developing countries. Heeks (2003) suspects that failure might be caused by the selection of inappropriate hardware and software. Not only computer hardware and software, but also methods and techniques for the design and implementation of information technology are without exception invented in the developed countries (mainly Europe and North America). Van Reijswoud (2009) emphasizes that the contextual and cultural elements of these developed countries are deep-seated in their design such that these elements limit the transferability of the technology to other, different, environments. Townsend et al. (2013) express the view that using relatively simple ICTs combined with traditional approaches could be effective, and might overcome technological barriers in developing countries, especially in rural areas. Such

barriers include limited access to communications capability (e.g. access to broadband, the Internet and cellular phone networks), the cost of such facilities and their maintenance, and sometimes deficits in the learners' and instructors' training in ICT and lack of support for remote sites. A study by Kozma and Robert (2005) demonstrates that the evaluation of ICT projects often reveals underutilization of the resources, because the newly introduced ICT is not properly integrated into the local context and that such underutilization is a result of non-local ownership by the receiving communities and the community's lack of understanding of the approach being used. Moreover, the actual impact is affected by the technical (hardware and software) problems resulting from the hostile conditions in which the ICT was introduced (Gichoya, 2005). Vaughan (2006) points out that high rates of hardware breakdown combined with low levels of locally available technical problem-solving skills have led to underutilized and even abandoned projects.

Based on the above discussion, community satisfaction with the ICT services delivered, community participation in decision-making processes and transparency in financial matters will serve as the indicators of performance.

PHYSICAL ACCESS

The remoteness of communities

Rural areas potentially suffer economic and social disadvantages due to problems of distance and remoteness (Townsend, Sathiaseelan, Fairhurst, & Chigona, 2013). ICTs, and in particular broadband, could benefit such areas by connecting communities, businesses and services. Yet, ironically, the technological landscape amplifies the rural isolation, with rural communities facing problems both in terms of physical access to technologies and the willingness or ability of residents to adopt them.

The significance of ICT in the rural development process is highlighted by the emerging importance of information and knowledge as key strategic resources for social and economic development (Meyer , Estrin , Bhaumik, & Peng , 2008). ICTs can act as supportive tools in this process to create interconnectivities between rural communities and more developed regions (Heeks, 2003). However, their implementation and sustainability in rural regions are limited (Buré, 2007). Developing better and more appropriate mechanisms and initiatives for the design and implementation of ICT projects in rural areas remains the best option.

Design and implementation of billing systems

Because one of the target of this research is to present and further develop guidelines for ICT project management in rural areas, specific measures that identify the people, environments, technologies, systems, and requirements for ICTs to support rural development activities effectively, specially in rural South Africa, are explored. One of these measures is a method for making payments that suits the community and sustains the Villages Telco through the community's own initiative.

What is a Village Telco?

A Village Telco is an initiative that builds low-cost and easy-to-use community telephone networks. In our case, the network consists of a network of 11 station nodes of mesh potatoes connected wirelessly and spread throughout the community. The mesh potatoes are small devices (See Figure 2) used for voice communications over the wireless medium, but that also support data. The device consists of an 802.11bg router with a single Foreign eXchange Services (FXS) port and one 10/100Mbit Ethernet port.

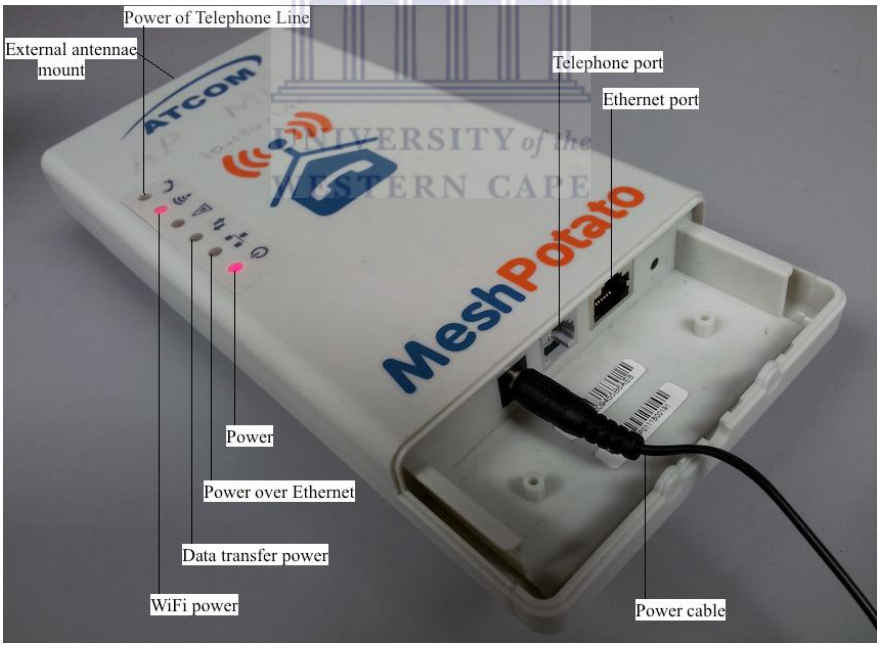

Figure 2: The mesh potato device

Adjacent mesh potatoes automatically form a peer-to-peer network and relay telephone calls without any need for mobile phone or landline towers (Village Telco, 2011). Open source telephony software and wireless mesh networking technologies are used to deliver an affordable wireless telephone communication system.

Many Village Telcos have been installed around the world and small deployments of 5–15 mesh potatoes are now growing to larger deployments of 50–200. For example, a small network that was started in the mountainous region of José Soto in Puerto Rico with 83 mesh potatoes is now being extended to provide services to the central Puerto Rican region (Village Telco, 2011). A Village Telco project is deployed in Kranshoek – a popular holiday destination in the Eastern Cape Province of South Africa – and is combined with wireless nodes to create the Kransmesh. In a Bo-kaap street in the heart of Cape Town a Village Telco has been deployed in a largely Muslim community with strong social bonds that links everyone in the street (Song, Bo-kaap Village Telco, 2012).

Billing of e-services

Billing systems that track and verify computing resources usage have been developed and studied by several researchers. After using open source software to build a Voice over Internet Protocol (VoIP), Yang et al. (2006) developed a billing system for its administrative functions. The billing system was based on Free RADIUS (Remote Authentication Dial in User Service) software compatible with the MySQL database and the CISCO PSTN gateway (Yang, Yu, Chen, & Chen, 2006).

Harshini & Venkata Krishna (2013) also designed THEMIS, a billing system for a cloud-computing environment.

Both of these billing services are used for a post-paid service, which is not suitable for customers with low incomes. Prepaid services may be the more appropriate for such customers. The A2Billing platform ensures a quick and low-cost entry for VoIP users (A2Billing, 2012). Combined with Asterisks, which is an open source PBX for communication servers, they form an engine to ensure that users can make calls within their credit limit. The engine forms a telecommunication platform and with Soft-Switch provides a wide range of communication services using VoIP with real-time billing that rates and invoices calls using a payment gateway (A2Billing, 2012).

As a school project, Gaba (2007) designed a billing system for VoIP services on SWITZERNET™. On a network that allows almost free calls, a billing system using A2Billing open source software was designed to charge Internet calls in a post-paid scenario (Gaba, 2007). The setup used a separate Private Box eXchange: Tripbox, a Private Switch Telephone Network (PSTN) through a Basic Rate Interface (BRI) on a Cisco router connected with an Integrated Service Digital Network (ISDN) on a local area network (LAN). However, the system was designed in the lab without consulting local users.

Another billing system was designed by Sen et al. (2006) to bill VoIP services made on long-distance Wi-Fi links in remote rural areas. Public calling offices (PCOs) were built in the villages. Using a Foreign eXchange Station (FXS) and Foreign eXchange Station boxes (FXO), the calls were billed on the Wi-Fi network using local operators managing the PCOs at each village site. For breakout calls to the PSTN, an external PCO was required, with its own billing machine that metered outgoing calls based on the call destination. Whenever a caller at the village site wanted to make a call to a PSTN phone, the number of the VoIP phone at the PCO end had to be dialed and an operator there would manually make the PSTN call on behalf of the caller. A line was then given to the caller at the village station, using a two-line phone. Once the call was concluded, the billing machine at the commercial PCO would print the bill and the operator would communicate the bill to the operator at the village site, who would then collect the cash from the caller. When cashing up at the end of the day, the two operators would exchange the revenue collected and compare their takings for the day.

Soto et al. (2012) designed a billing system for solar electricity delivery in Kenya and Malawi. Customers buy an electricity voucher card from a local vendor which, when scratched, reveals a voucher code. Scratch cards can be bought for very small amounts, as low as $1 (the maximum is $4). With the voucher code the user can interact with the server by sending an SMS to the central server for validation.

Once validated, the central server sends a message to the local meter instructing it to add the scratch card's credit amount to the customer's account. The consumer can then access electricity until the credit is exhausted, at which time the electricity supply is cut.

Summary

This chapter discussed the literature on the usage of ICTs in developing countries, especially in South Africa. The literature was discussed in terms of the key concepts involved and the research questions. To gain an understanding of the social environment of rural technology users, three of the most relevant characteristics of successful ICT deployments, according to Bridges.org (2012), were explored in this literature review, namely trust, appropriate technology and physical access. The following chapter will cover the research approach, design, methodology and methods used.

Chapter 3

RESEARCH DESIGN AND METHODOLOGY

Having dealt with the literature review in the previous chapter, the methodology used in order to attain the prescribed objectives of the research will be explained in this chapter. The focus of the chapter is therefore on the research design, the methodologies and methods adopted, data collection methods, and the data analysis tools used. The programming tools that were used to build the system and the testing techniques that were adopted are also clarified.

Research question

As highlighted in the previous chapter, trust issues influences the adaptability of ICT projects in rural areas. The main research question is: "How should an e-payment system for voice services on a rural Village Telco be designed to gain the trust of the community?" This research question needs to address two aspects: the first is how such a system should be built, i.e. what modality of payment would be suitable and affordable for the community and would make the network sustainable. The second aspect is an understanding of the social space of the users the system is built for, how to give them support and how to encourage them to use the system. The key issue is whether the technical solution (the system built) would provide the required transparency that would allow it to be trusted by its users.

Research approach

To answer the research questions, the choice of methodologies and methods to be employed is fundamental. Crotty (1998) sketched four key questions to guide the research process: "*What methods to use? What methodology governs the choice and the use of these methods? What theoretical perspective lies behind the methodology in question? What epistemology informs this theoretical perspective?"* (Crotty, 1998, p. 2).

In line with these four questions, four basic elements depict the research process: methods, methodology, theoretical perspective and epistemology. According to Crotty (1998),

"*methods are techniques or procedures used to gather and analyse data related to the research question or hypothesis; methodology is the strategy, plan of action, process or design lying behind the choice and the use of particular methods and linking the choice and use of methods to the desired outcomes; and the theoretical perspective is the philosophical stance that informs the methodology and provides the context for the process. Finally, epistemology is the theory of*

knowledge embedded in the theoretical perspective and thus in the methodology?" (Crotty, 1998, p. 3) Figure 3 shows how these four stages are related to one another.

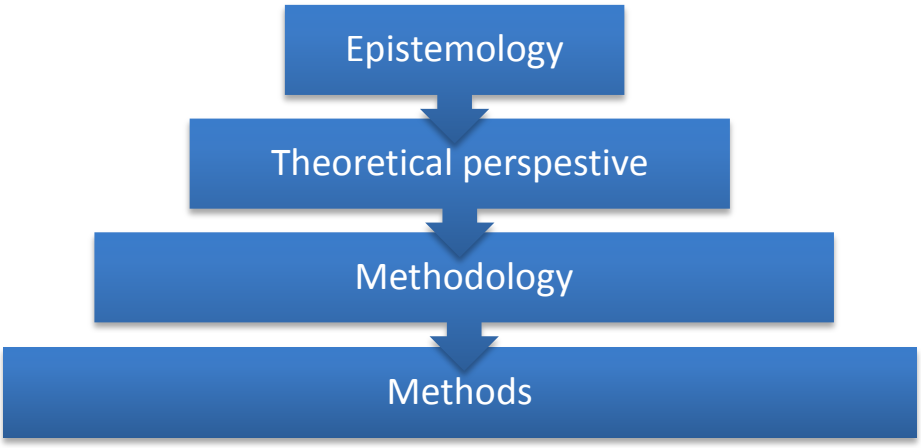

Figure 3: Four basic elements of research (Crotty, 1998, p. 4)

EPISTEMOLOGY

Epistemology is the theory of knowledge. It is an attempt to explain how we know what we know. The epistemological stance underlying this research is constructionism**.** It assumes that "*the social world is constantly being constructed through group interactions, and thus social reality can be understood via the perspectives of social actors enmeshed in meaning-making activities" (Crotty, 1998, p. 8)*

THEORETICAL PERSPECTIVE

A theoretical perspective is a general framework that describes the philosophical stance that lies behind a chosen methodology (Crotty, 1998). It provides a context for the process and grounds its logic and criteria in terms of how we see the world. The theoretical perspective for this research is interpretivism and Habermas's theory of critical social science (Habermas, 1972). Habermas opposes the claim that science offers an objective and neutral account of reality and embraces the idea that critical social science will reveal underlying causal mechanisms to those whom they affect (Carr & Kemmis, 1983).

METHODOLOGY

Methodology refers to an action plan or a strategy to choose methods that will be used in the research (Crotty, 1998). For this research, soft system thinking (Checkland & Scholes, 1999) was used as a sense-making process while caring out participatory action research, because there is no "easy solution for the problem" (Stan, 2008).

Soft systems methodology

SSM is a problem-solving approach developed by Peter Checkland and his colleagues at Lancaster University to shape interventions encountered in problematic situations where there are no straightforward or easy solutions to the problem (Stan, 2008). Kline (1995) explained SSM as a cyclical process where each cycle is made up of four steps (see Figure 4):

- Understand the real-world situation of concern (stage A in Figure 4). The key task is the development of a rich picture of the problematic situation by mapping the problem setting.
- Building relevant systems of purposeful activities (stage B in Figure 4). This is based on the researcher's explicit worldview and is designed to develop conceptual models of what activity could address the problem. A critical element of this is the development of root definitions for the activity models using the structure defined by the questions: What needs to be done? How can we do it? And why? These three questions provide focus to the brainstorming task.
- Comparison of the models with the perceived real-world situation (stage C in Figure 4). This is the critical element of the methodology where thinking in the concrete and abstract worlds meet. This stage forms the reality test of the thinking that has gone before, where the actors of transformation and the users/owners evaluate the new environment and examine the possible solutions.
- Action needed to improve the situation (D in Figure 4): an action plan is built on the now-extended view of the problem area and potential activities to improve it.

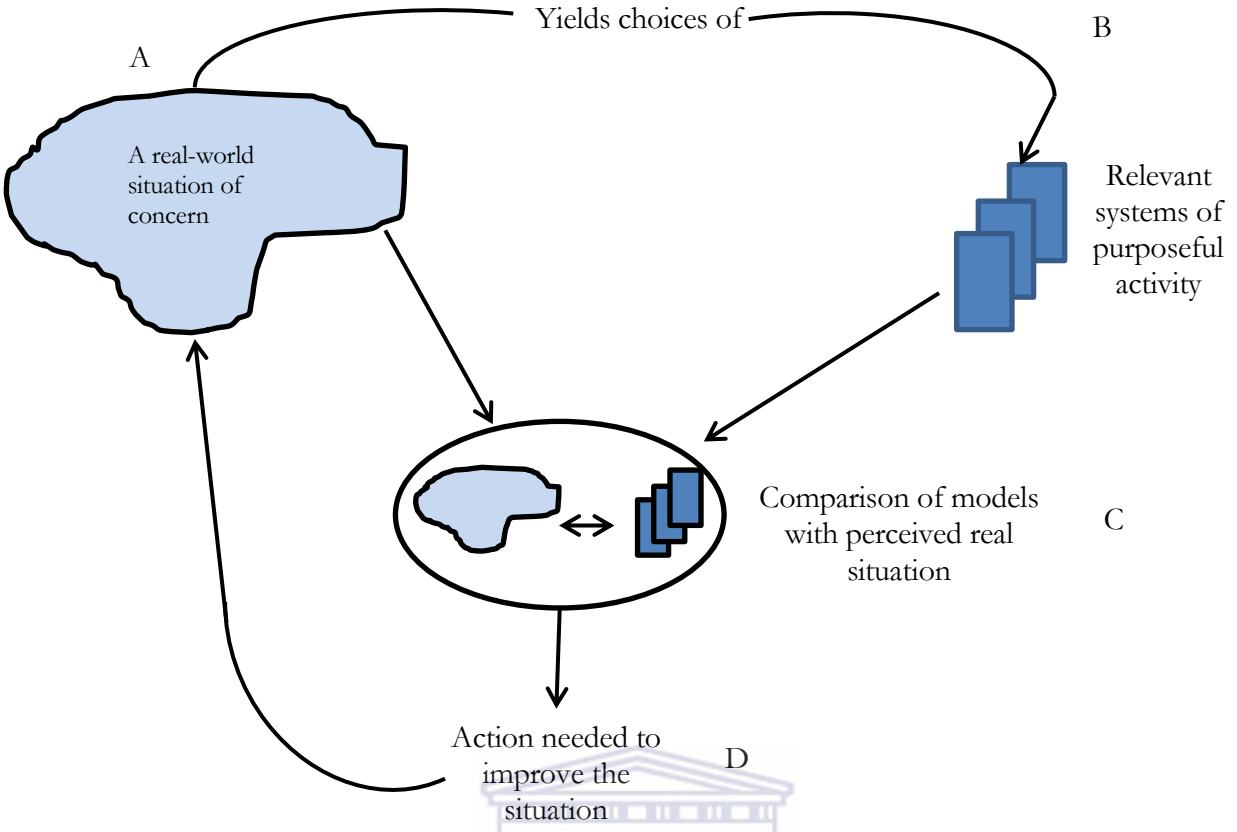

Figure 4: The basic shape of SSM (Checkland & Scholes, 1999, p. 7)

METHODS

Methods are the different tools used in the process of gathering data. For this research both quantitative and qualitative methods were used. These included a pilot study, surveys, observation, participatory design, interviews/focus groups and content analysis. Random convenience sampling was used to choose stakeholders to speak to in personal interviews and focus groups.

Pilot study

To gather user needs and requirements, a pilot study was conducted using surveys and observation. A pilot study is a standard scientific tool that allows researchers to conduct a preliminary analysis before embarking on a mature study. It gives the scientist the opportunity to improve the quality and efficiency of the study (Van Teijlingen & Hundley , 2001).

A pilot study is normally small in comparison with the main experiment and therefore provides only limited information on the sources and magnitude of variation of response measures. It can, however, reveal deficiencies in the design of a proposed experiment or procedure, and these can then be addressed before time and resources are expended on a larger-scale study (NC3Rs, 2006).

Survey

A survey is a data collection tool used to gather information about individuals from a sample of entities for the purposes of constructing quantitatives descriptors of attributes of a larger population of which the entities are members (Groves, et al., 2013). In this research a survey was used to identify the level of use of ICTs in the community, and especially the use of mobile phones and the need for a cheap communications service in the community. After data was gathered, an in-depth analysis followed to improve and develop the theoretical framework of the research.

Observation

Observation is used to gather data by watching behaviour and events or noting physical characteristics in their natural setting (ERT, 2008). Through observation it is possible to ascertain whether what people say they do and what they do in reality tally. Observations can be overt (when everyone knows they are being observed) or covert (when no one knows they are being observed and the observer is concealed). People are more likely to behave naturally if they do not know that they are being observed, and this has proved to be a benefit of covert observation. On the other hand, overt observations are also needed to overcome ethical problems related to concealing the observation process. In the present study, observation was used to build rapport with informants, to provide a better platform to later cross-check information and possible differences between what people do and what they say they do, to familiarise ourselves with the activities of the community, to gather data on how users interacted with their peers in the community, and to gain new insights or discover things that people may not wish to reveal in interviews, or may be not asked about in surveys and may not have thought of mentioning. Different types of tools such as field notes, photos/pictures and audio recordings were taken to facilitate the observation process.

Participatory design

A participatory design (PD) approach was used to design and configure the prototype. Muller and Kuhn (1993) explain that PD constitutes a rich diversity of theories, practices, analyses, and actions, with the goal of working directly with users and other stakeholders in the design process to help ensure that the result meets users' needs and that the resultant product is usable. PD is defined by Simonsen & Robertson (2013) as "*a process of investigating, understanding, reflecting upon, establishing, developing, and supporting mutual learning between multiple participants in collective 'reflection-in action'*" (Simonsen & Robertson, 2013, p. 53). In this research PD was used to explore, extract, and integrate the needs, perspectives, and available income of the community and actively involve all stakeholders in the design and decision-making processes.

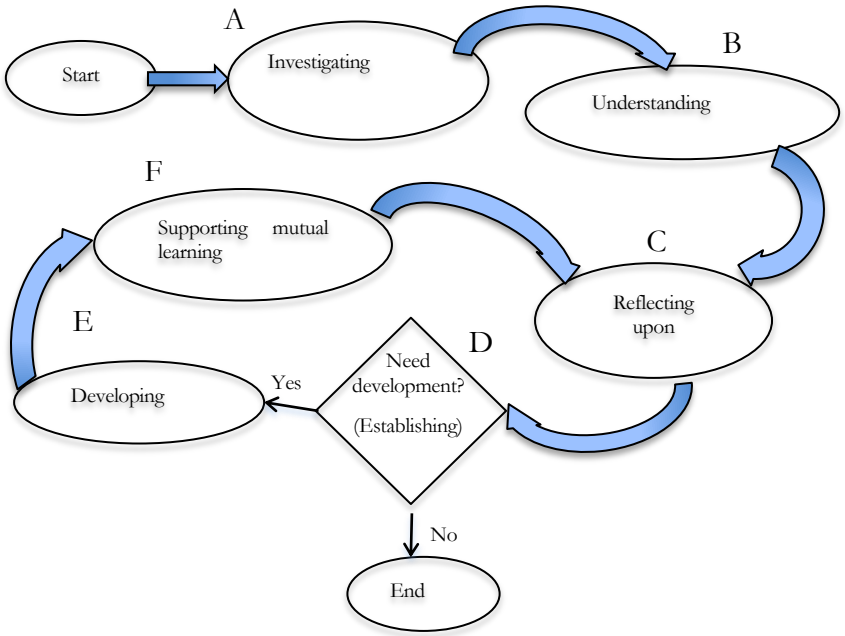

Figure 5: Participatory design, as proposed by Simonsen & Robertson (2013)

Interviews

Unstructured interviews and discussions with community members were conducted. Non-structured or unstructured interviews are interviews in which questions are not prearranged in advance, allowing for spontaneity and for questions to develop during the course of interview. Questions are thus based on the interviewee's responses and interviews proceed like a friendly, non-threatening conversation (Yan & Wildemuth, 2009).

Focus groups

Krueger and Casey (2009, p. 10) define a focus group as "*a qualitative data collection method in which one or two researchers and several participants meet as a group to discuss a given research topic*". To ensure that all the data are gathered properly, the sessions are normally tape recorded and sometimes videotaped. One researcher (the moderator) leads the discussion by asking participants to respond to open-ended questions, i.e. questions that require an in-depth response rather than a single phrase or simple "yes" or "no" answer. "*Focus group meeting are effective for accessing a broad range of views on a specific topic, as opposed to achieving group consensus*" affirm Krueger and Casey (2009, p. 10).

Content analysis

Qualitative research deals with non-statistical methods of inquiry and analysis of social phenomena. It draws on an inductive process in which themes and categories emerge through analysis of data collected by such techniques as interviews, observations, videotapes, and case studies.

McRoy (2013, p. 1) states that: "*Qualitative research uses detailed descriptions from the perspective of the research participants themselves as a means of examining specific issues and problems under study*".

The qualitative data collected was analysed using a content analysis tool, Qualitative Content Analyser (QCA) developed by Andy Bytheway (2013). It is a tool that matches the essential features of commercially available packages of qualitative analysers and was made available to research students at no cost (Bytheway, 2013). Qualitative data are grouped in chunks, summarised and categorised. Codes are used to indicate the unit of meaning that associates a chunk of text with a category.

Random convenience sampling

Convenience sampling and judgemental sampling were used to select participants. In convenience sampling the researcher asks any subject who is available to participate in the research study (Explorable Psychology Experiments, 2009). Random sampling means that each and every person has the same probability of being selected, whereas judgemental sampling means that the person doing the sampling uses his/her knowledge or experience to select the participants (Westfall, 2009).

The figure below summarises the methods used based on the methodology approach of Crotty (1998).

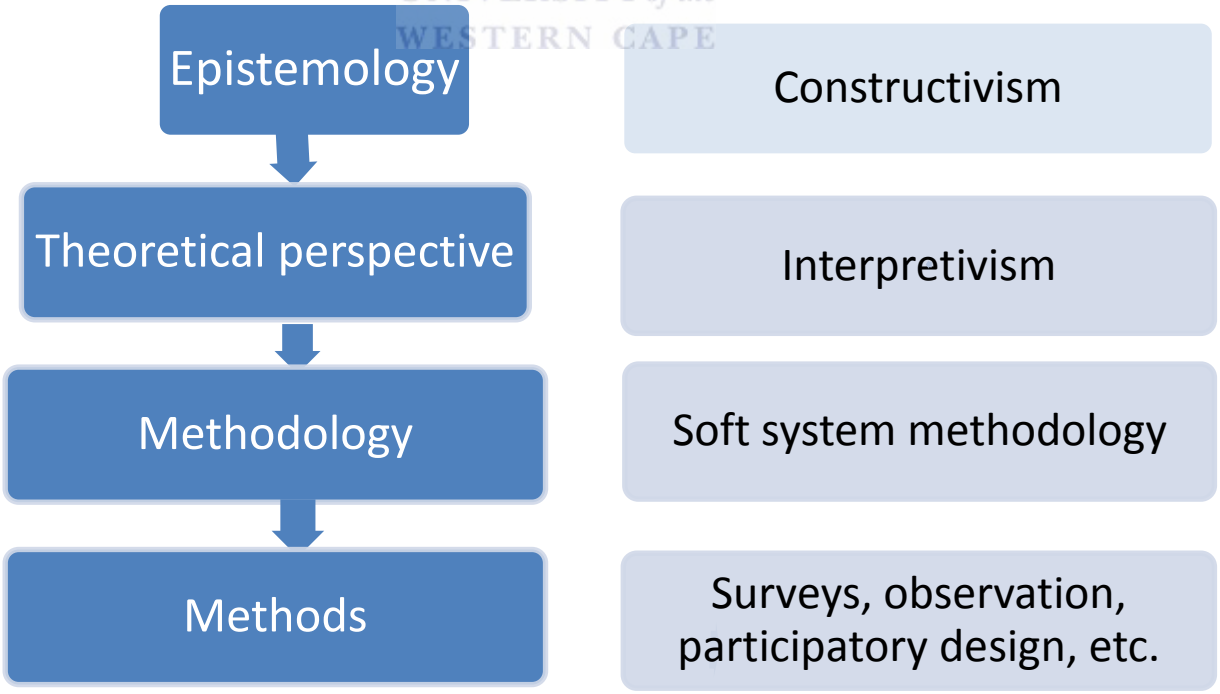

Figure 6: Based on the methodology approach of Crotty (1998)

RESEARCH DESIGN

SSM was used to manage the research process. This methodology assisted with the logical progression of the study and the interpretation of results. Four complete cycles of SSM were used during the study.

Cycle 1: The pilot study

To establish a research focus to which the research would refer over the period of study, a pilot study was conducted. The researcher investigated the object of the study in depth by means of a literature review to establish what related research had been previously conducted. The literature review and definition of the purpose of the study guided the study design. Secondary data from a survey done in Mankosi community (Rey-Moreno, Roro, Masbulele, Javier, Bidwell, & Tucker, 2012) led to refined, pertinent research questions. The definition of the question determined the methods of analysis that would be used in the study. The researcher determined what analysis techniques to use with the data to answer the research questions and what type of evidence to gather.

Cycle 2: Observation on site

Not all qualitative data collection approaches require direct interaction with people. According to Hancock (1998, p. 15): " *Observation is a technique that can be used when data collected through other means can be of limited value or is difficult to validate*". For example, in interviews participants may be asked about how they behave in certain situations, but there is no guarantee that they actually do what they say they do. The observation technique was used to address this issue. Ethnographic research was conducted in Mankosi in July 2013 to explore the perceptions of people and their culture through interactions and observations in naturally occurring settings. During the visit on site, the researcher determined what approaches and which data-gathering instruments would be used to answer the research question. The researcher observed how the inhabitants of Mankosi live and work, how they generate income, what their level of literacy is, their ICT usability, and mostly their interaction in the community. Information from this investigation defined user requirements. Some data were also collected during this phase.

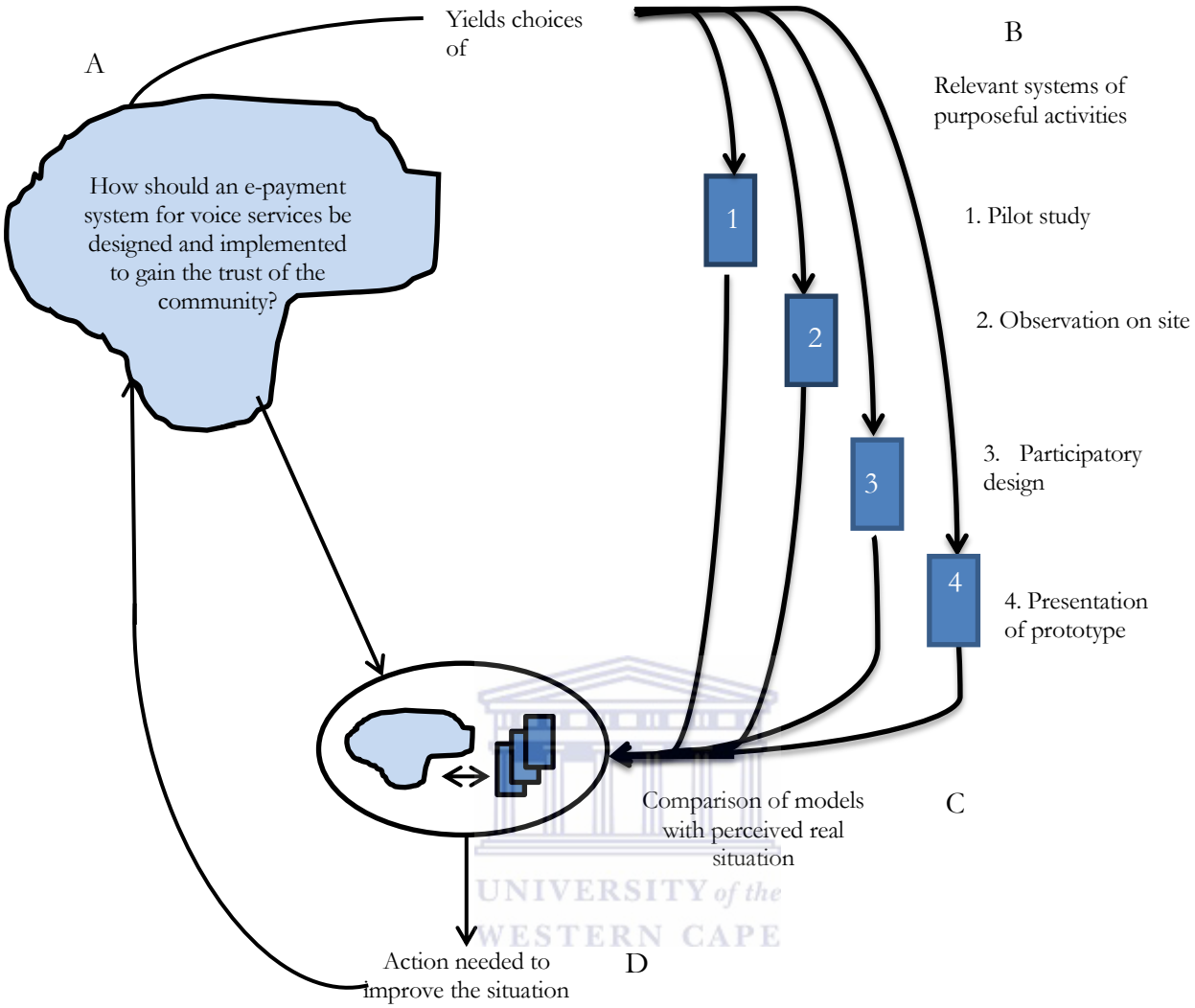

Figure 7: The principle of SSM applied to the research

The data were analysed and the results presented as tables and graphs. The qualitative data that were collected were analysed using the QCA tool, while Microsoft Excel and SPSS (Statistical Package for the Social Sciences) were used to analyse the quantitative data. To determine if the data were legitimate and consistent, more than one method of capturing data was used and the results were triangulated in order to strengthen the research findings and conclusions.

Cycle 3: Participative design of the prototype

During the design phase of the billing system participative workshops were organised with stakeholders and the various scenarios were designed with the stakeholders. Focus groups were used at this stage because they generated a large amount of information over a relatively short period of time and acted as an enabling tool for the design. Group dynamics stimulated conversation and reactions.

Two iterations of the participative design cycle were made with stakeholders, i.e. the local researchers (LRs), the local operators (LOs) of the network and community members.

The LRs are a team of three people who were born and live in the community and have assisted with the project since its inception. They acted as moderators between the researchers and community members since they are familiar with the needs of the local community, whereas the LOs are the owners of the houses where the station nodes are housed. They were actively involved in the design of the business model, because they are responsible for collecting the money for the network services. In this research, focus groups were typically one method among many that were used to establish a well-grounded understanding of the subject of discussion for the three categories of stakeholders. In order to design a comprehensive focus group a preparation meeting was held between the researcher and LRs to explore the subject under discussion.

The first iteration of the participative design cycle was used to investigate, understand and reflect on how to implement a billing system (see stages A, B and C in Figure 5). This was done by means of focus group discussions and interviews. Focus group meetings with LOs were then held at the headman's house. Different payment scenarios had been explored, sketched and studied. The feasibility of each of the scenarios was discussed with the stakeholders in terms of its legal, financial, technical and social feasibility and was measured against these defined feasibility criteria. After collecting and defining the user requirements, a model was designed. A2Billing and the input from the community were used to implement requirements that were identified during focus groups and individual interviews.

Cycle 4: Presentation of the prototype

Before presenting the community with a prototype model of the billing system, it was tested in the laboratory. The model assisted with understanding the system structure, activities and sequence of activities required to build the prototype. Laboratory testing of the system involved functionality and usability testing. Throughout the design phase the researcher ensured that the study was properly constructed to ensure construct validity, internal validity, external validity and reliability. Construct validity requires the researcher to use the correct measures for the concepts being studied. Internal validity demonstrates that certain conditions lead to other conditions and requires the use of multiple pieces of evidence from multiple sources to expose convergent lines of inquiry. External validity reflects whether or not findings are generalisable beyond the immediate case study. Reliability refers to the stability, accuracy and precision of measurement (Soy, 1997).

The designed prototype was then first demonstrated, discussed and tested in the workshops held with community members, then with the LOs for testing purposes. The test involved functionality, usability and trustworthy. Information from the testing process helped to improve the prototype and it was retested with community members and revised until the users were entirely satisfied.

Summary

This chapter outlined the approach and methodology adopted in this research. SSM was found to be useful to manage the research. Both qualitative and quantitative methods were used, i.e. content analysis, observation, interviews, focus groups, surveys and the quantitative analysis of the findings. The design of the prototype – using participatory design – was also illustrated. The next chapter will focus on the results of the requirement identification process and those obtained during prototype testing.

Chapter 4

RESULTS PRESENTATION

In the previous chapter the research approach and design were discussed. In this chapter the results of the surveys will be presented, as well as the outcomes of the proof-of-concept prototype testing process in the Mankosi community. The research process entailed several cycles of analysis, evaluation of findings, changes and interventions until the results were within the required parameters. SSM (Checkland & Scholes, 1999) was used to manage the research process.

The focus of this chapter centres on the research question for this study, which is: "How should an e-payment system for voice services on a rural Village Telco be designed to gain the trust of the community?" and is contextualised in terms of the Mankosi community.

SSM methodology uses four steps:

1. Strategies are developed to identify the problem.
2. Different methods are used to solve the problem.
3. The existing problem is compared with the proposed solution to see if they match.
4. If the solution does not solve the existing problem satisfactorily, the cycle is repeated until a satisfactory solution is found.

Cycle 1: The pilot study

During the first cycle of SSM a pilot study (see Figure 8) was conducted and data about the geographic area, population, administration and local organisation, and wireless network being implemented were collected.

A DETAILED DESCRIPTION OF THE PRELIMINARY INVESTIGATION

A preliminary investigation was carried out to collect information about the community and to identify user requirements for the network's billing system. This was done by means of document analysis and a survey.

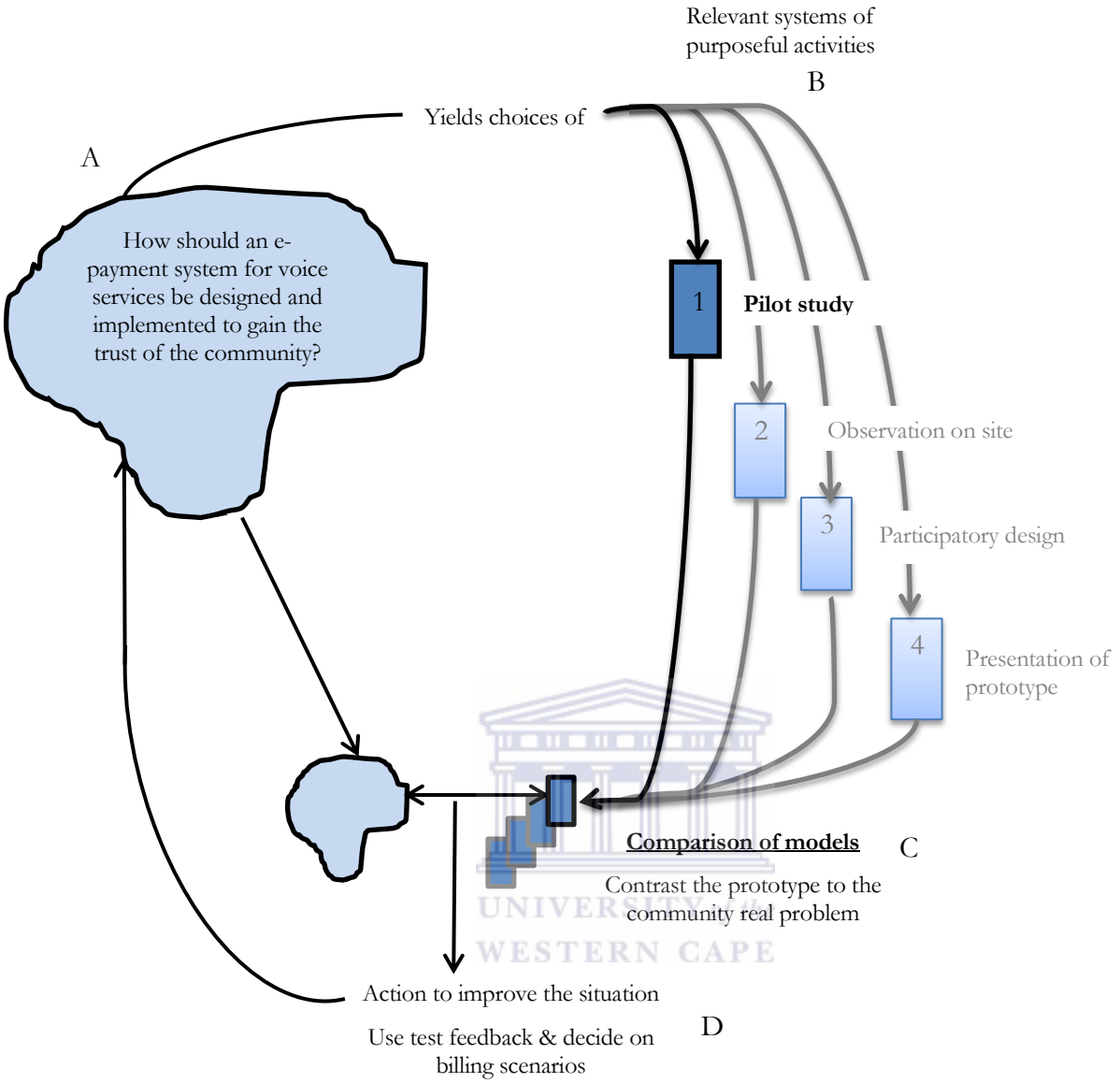

Figure 8: Cycle 1: The pilot study

Document analysis

A wide range of written materials were studied. These were particularly useful in trying to understand the culture of the community and its organisation, since the researcher is not South African and only arrived in South Africa a few months before starting on this study. The documentation studied included magazines, articles related to the community, a documentary movie of the Mankosi community, meeting reports and other researchers' field notes.

The literature revealed that a specific management and authority hierarchy exist in the community, which is governed by the TA (see Figure 9).

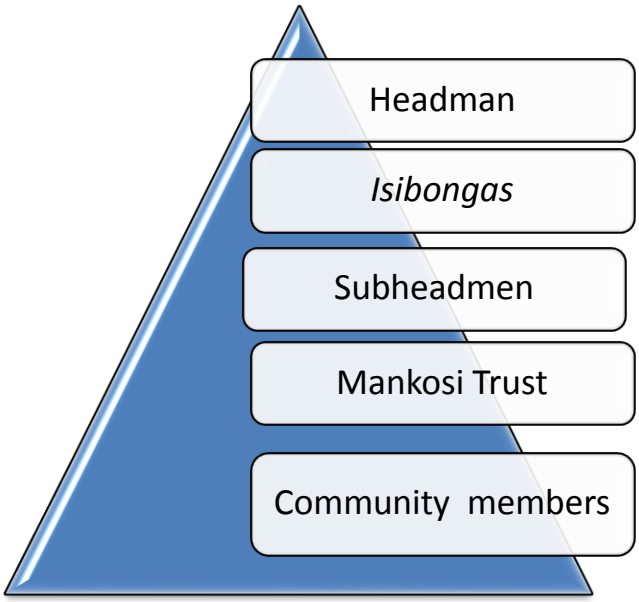

Figure 9: Tribal authority hierarchy

A particular protocol is followed in the community administratively: for a new project to be introduced into the community it is first presented to the headman (who also heads the TA). If he judges the project to be beneficial to the community, he calls a meeting of his advisors. The advisors are *isibongas*,[1] sub-headmen and influential people in the community. If the advisors agree, permission to work in or with the community is granted.

Survey

An initial survey was conducted in the community. The survey comprised a set of questions that were added to a larger survey conducted by a peer researcher (see Appendix B). These questions were aimed at determining the user environment, i.e. the nature of the social and economic life of the community. Door-to-door visits were paid to members of the community and short interview sessions were held with each household. The survey identified issues related to trust, confidence and accounting in the community. Among the 178 community members interviewed, 167 said that they were aware of the Mankosi Trust. The Mankosi Trust managed the community's property, and 93% of community members knew that a new trust had been established. Only 27% indicated that they trusted the management of the two entities. The reasons cited were that the managers did not to report to the community on how the money collected was used or spent. Furthermore, the community indicated that some misuse of community money had been exposed.

[1] *Isibongas* are tasked by the headmen to resolve problems and/or inform the community of decisions.

The interviews revealed that of the 250 people aged 15 to 93 years randomly sampled, 50% were between 15 to 24 years of age, 16% were aged 25 to 34 years, 11% were aged 35 to 44 years and the rest (33%) were older than 44 years of age.

The inhabitants live in 580 households. Households accommodate families of up to five adults and seven children. The community comprises 12 villages spread over 30 km^2, and most inhabitants are subsistence farmers, most of whom do not have access to domestic electricity or water. Men are more likely to temporarily migrate to towns and mines to work, so more women and children live in Mankosi than men.

Households survive on R660 to R1,660 ($60 to $150) per month. Their incomes come from government grants and payments from family members who are working in the cities. Most members of the community are functionally illiterate.[2] Only 13% of the population had completed 12 years of schooling (matric) or more.

Most community members speak isiXhosa. Of the respondents who reported that they could speak isiXhosa (70.2%), 46.7% indicated that they could read English and 35.6% indicated that they could read and write English. However, 32.5% of the respondents reported that they could not read English at all.

There are only a few local businesses and these are largely focused on obtaining products from the nearest city to resell locally at a much higher price, e.g. selling a minimal mobile top-up voucher with a 50% markup.

The information about communication in the community gathered during the survey showed that to communicate, inhabitants favour voice calls, but they keep them short because such calls are very expensive when compared to inhabitants' monthly incomes.

Most people (older than 15) in the community own a cellphone. This can probably be ascribed to the fact that access to mobile networks is available even in these remote areas. Mobile phone users charge their phones infrequently and conserve their phone's batteries' energy by switching them off. While most young people have attractive (expensive) cell phones, the adult population uses basic mobile phones (with basic features like voice and SMS functionality)

The major use of cell phones in the community is to call community members living in the same community and family members that have migrated to towns or cities, or to make emergency calls.

[2] The term "functionally illiterate" means that although a person may be able to read and write a few words of a spoken language like English, they do not do so well enough to deal with the requirements of everyday life (Kiyaga & Moores, 2003) basically "meaning that they cannot read a simple set of instructions to use an appliance or fill in a form" (Lind, 1992).

RESULTS OF CYCLE 1

It seems that the majority of people in the community (including its older members) are knowledgeable about mobile phones and are able to make calls. They know about the available ICT features of cell phones, but do not use these features (such as taking photos) due to a perception that they would be expensive and use up the available airtime. The telecommunication initiative launched in Mankosi was aimed to provide free intra-network voice calls to members of the community. However, the community asked if it would be possible to use the network for external calls (breakout calls), i.e. for calling mobile phones and landlines and even accessing the Internet. If money could be collected for breakout calls it could be used to assist with the maintenance and sustainability of the network. Eventually the income could also be used to finance other projects for the benefit of the community. A transparent means of collecting money was thus needed.

Further interview findings regarding community members' access to Internet services are that access to Internet is possible with the introduction of smartphones.[3] However, the interviews showed that most community members do not own smartphones. This might be due to the fact that smartphone use is tied to factors such as age and income, as stated by Zickuhr (2013, p. 24): "*older people as well as people with less education and those with less income tend to adopt technology more slowly*", and in rural areas like Mankosi there is a higher concentration of poor and older people .

It is difficult to access the Internet in rural areas; however, cyber cafés do exist in small towns and thus the Internet is accessible through these. While most community members do not use the Internet, those who do have to go to a cyber café that provides Internet services by travelling to the small towns in the vicinity of the community – the closest town is 30 km away.

Cycle 2: Observation on site

A field trip in July 2013 was aimed at observing the community in a normal setting (see Figure 1). The observation technique used was to build a relationship with the information providers in order to provide a better platform to crosscheck information and possible differences between what people do and what they say they do. It helped to obtain a better understanding of the community's context and allowed the researcher to gain new insights into the lives of community members. Information that people may not have wished to reveal during interviews came to the fore and aspects that may not have been part of the surveys were observed.

[3] A smartphone is a mobile phone with a complete operating system that allows for computing capability and provides better connectivity than a basic mobile phone (http://www.phonescoop.com/glossary/term.php?gid=131).

The process allowed the researcher to gather rich data about the future users of the system. The research team attended several MCA management committee meetings and village meetings as observers in order to collect these data.

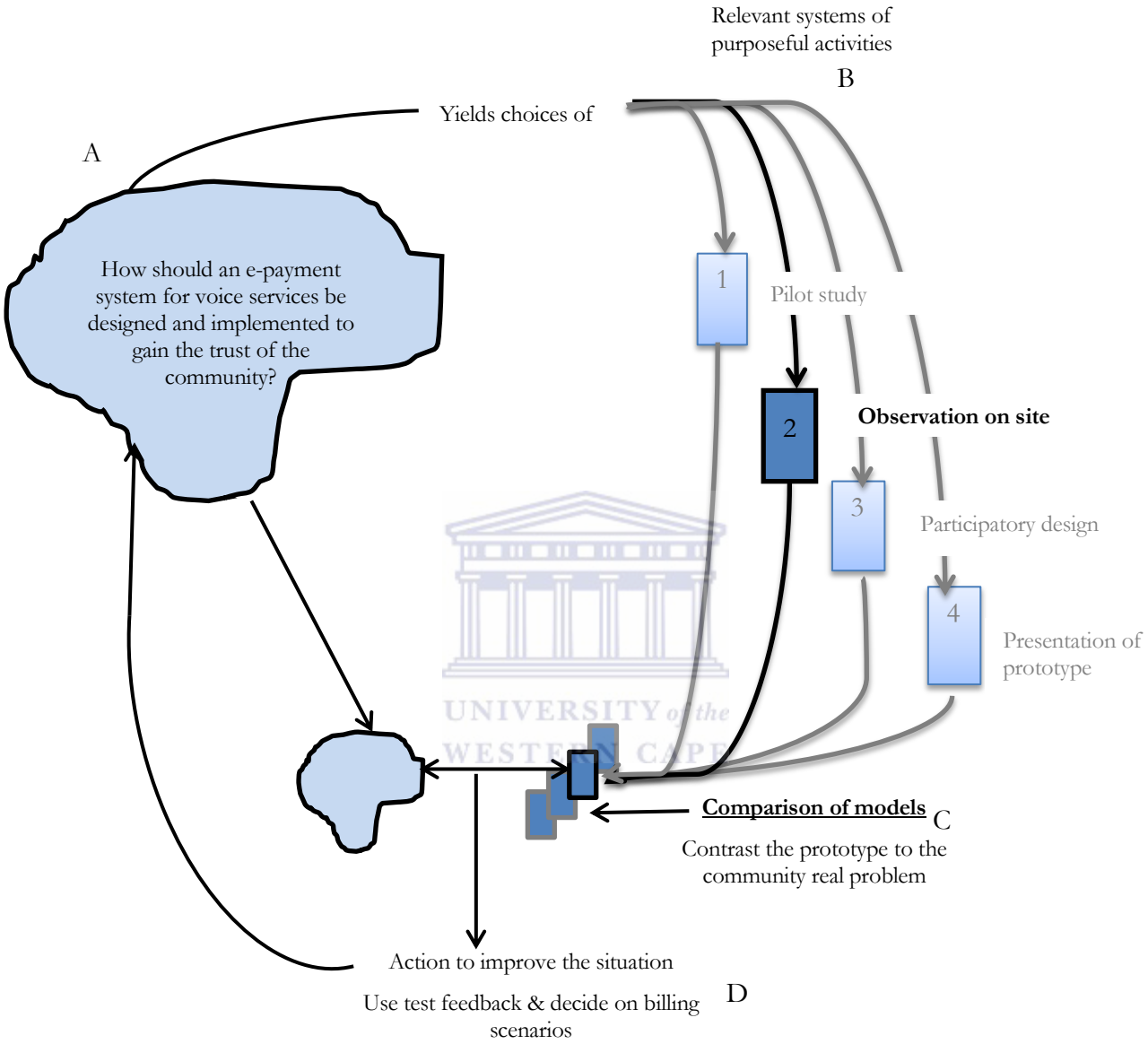

Figure 10: Cycle 2: Observation on site

TECHNIQUES EMPLOYED FOR COLLECTING DATA THROUGH OBSERVATION

To facilitate the observation technique field notes, audio recordings and photos/pictures were taken (see Figure 11) at community meetings and/or during interactions with community members.

Figure 11: Community meeting in Nkumandeni village

Written descriptions

When problems occur in the community or when new information becomes available that needs to be imparted to community members, meetings that anyone in the community can attend are called. The researcher observed the community members in these meetings and recorded their interaction by taking notes on what was observed. The limitation of this method is similar to trying to write down interview data as it occurs. Firstly, there is a risk that the researcher will miss out on some observations because she is writing about the last thing she noticed. Secondly, the researcher may find her attention focusing on a particular event or feature because it appears to be particularly interesting or relevant and as a result miss other aspects which are equally or even more important, but are not recognised or acknowledged at the time.

Audio recording

Audio recordings were thus used because they freed the observer from the task of taking notes at the time and allowed information to be reviewed later. Community members had to give their consent and thus knew that they would be recorded. The disadvantage was that, since the participants were conscious of the audio recorder, it may have influenced their behaviour. Some were not comfortable with this method of recording; however, when the audio recorder was placed in a specific place (rather than being carried around) community members were more at ease with being recorded.

This meant that only discussions held in the vicinity of the device could be recorded. For this reason a mobile phone, a device that community members are more familiar with, was used and was more accepted by the community. It also did not impact on community members' behaviour while they were interacting with one another.

Photographs

According to Hancock (1998, p. 13), photographs "*are a good way of collecting observable data of phenomena which can be captured in a single shot or series of shots*". Photographs of the participants were captured with their permission. These photographic "artefacts" (objects which inform us about the phenomenon under study because of their significance to the phenomena) thus formed part of the record of the research.

RESULTS OF CYCLE 2

The observations on site revealed that there are trust issues within the community. Community members do not trust their local authorities such as the TA, because, for example, they sold the communally owned sand to external consumers without informing the community or sharing the income with the community, and similar committed transgressions. Furthermore, community members do not trust the management committee (elected to manage community property and income) since they think that money had been embezzled, mainly because the process was not transparent. Community members and the authorities were also distrustful of the research team, because they felt that its members may have had hidden agendas.

Although the needs assessment carried out during the previous survey predicted a rapid and high uptake of the telephony services on the network, it was found that the community did not in fact use these services. However, the network's solar power generators were used to charge mobile phones for a small fee. It was only discovered later that the TA had not informed community members that the communication service was intended for their own and public use. Several meetings (a general community meeting and village meetings) were subsequently held to explain to the community how the communication service functions and how the community can use it.

The community decided that a not-for-profit cooperative, in parallel with the MCA, had to be established to manage the services provided by the network. The revenue generated by the telephony services could then be used for local developmental projects decided by the cooperative members or reinvested for future use.

The calling system should allow the users to call for small monetary amounts, such as a few South African cents (the South African monetary unit is a rand, where R1 = $0.09 at the time of writing), to make the service more accessible to community members.

A billing system needed to be developed. It would have to have an interactive voice response (IVR) in isiXhosa to facilitate a better interaction with the users of the system, because some community members do not speak English.

The operators of the network wished to have access to resources (such as the tablets that were used in a previous project within the community) and remuneration (Reitmaier, Bidwell, Siya, Marsden, & Tucker, 2012). They were told that tablets were not necessary for this project, but that the project will benefit them by, for example, providing lighting in the houses that host the solar panels that power each node of the network.

Cycle 3: Participatory design

In order to develop a system that meets its users' requirements, the researcher had to rely on information provided by the future users of the service (see Figure 12). The process of eliciting requirements was complex because users could often not properly articulate their needs. The three primary objectives of this method were aimed at:

1. Studying users' characteristics in order to develop a user-friendly system;
2. Allowing users to voice their opinions and concerns about the proposed system; and
3. Taking users onboard as partners with the developers (researchers) in the design process of the system by using participatory design.

The researchers spent some time in the community to establish a relationship with its members. Before embarking on the design phase of the system the needs and culture of the local community were studied (this was done in Cycle 1 and 2 of the research).

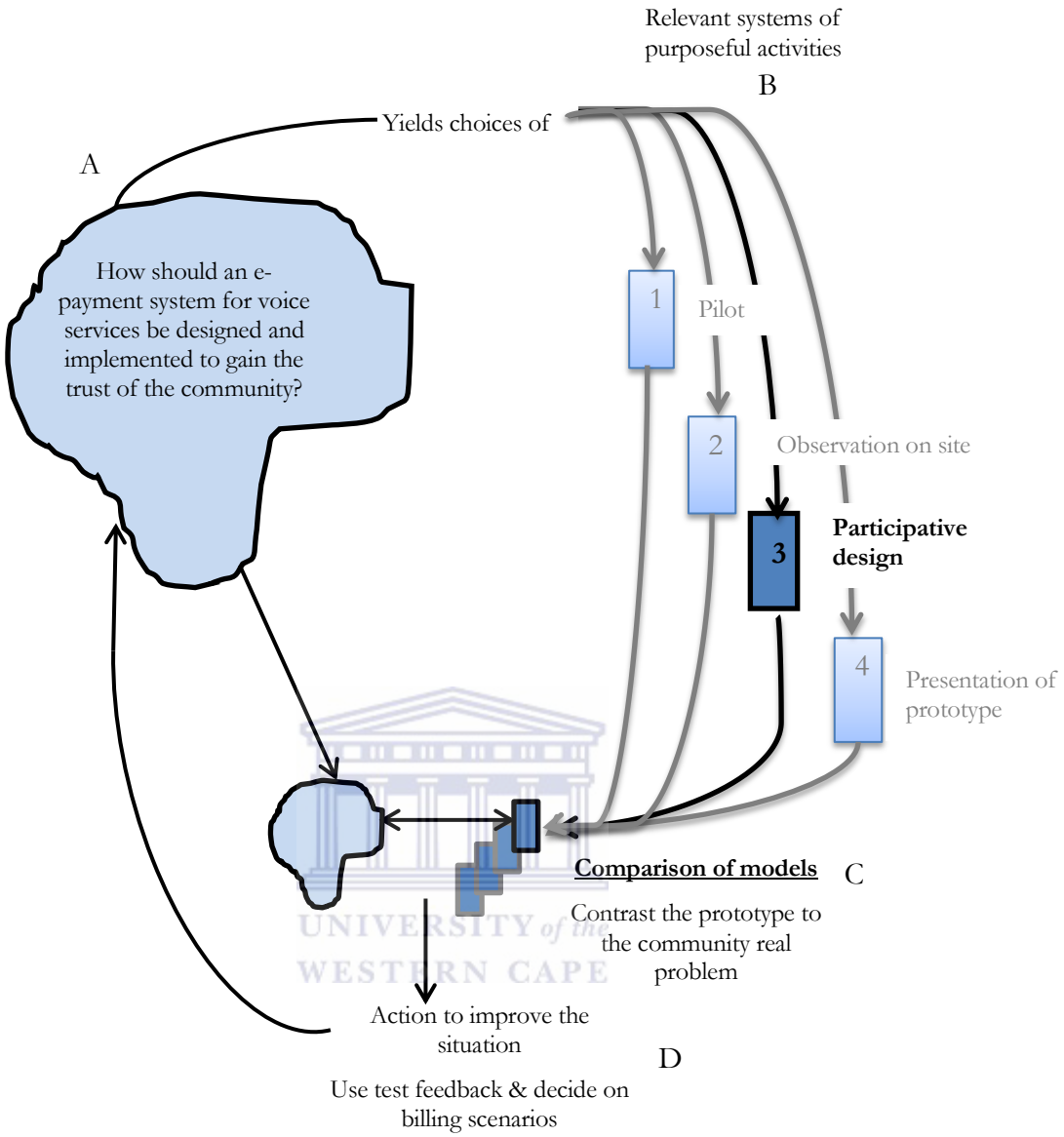

Figure 12: Cycle 3: Participatory design

During the participatory design phase, multiple participants (i.e. both the designers and users of the system) were involved with the design of the system. It was very important for the researchers to learn about users' situation so that when users articulated their requirements, the researchers would understand what they meant. The design process consisted of a sequence of collectively investigating, understanding and reflecting on possible solutions for the system (stages A, B and C in Figure 13). Once the system was being designed, the designers and users had to establish what needed further development, develop that aspect, and support mutual understanding and learning about the system (stages C, D, E and F of Figure 13, which will be discussed in Cycle 4).

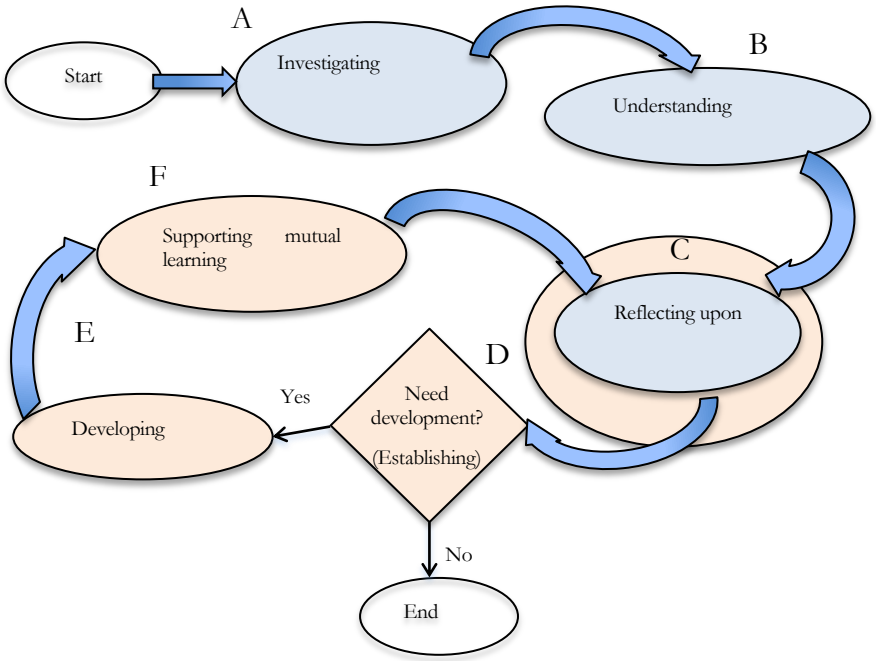

Figure 13: Participatory design in action

TECHNIQUES EMPLOYED FOR DESIGNING THE PROTOTYPE

To investigate, understand and reflect on how to implement a billing system (see stages A, B and C in Figure 13), interviews and discussions about the system were conducted with community members, while focus group discussions were held with LRs and LOs.

Interviews with community members

Interviews were used to collect information that could inform the design of the prototype so that it would address the community's needs. Semi-structured interviews were conducted, guided by key aspects of the research (see Appendix C). Twenty-five people (four men and 21 women) were interviewed. Random convenience sampling - as defined above – was used to select participants. Probes were used to start the conversation (see Appendix C) and during the course of the interviews further questions were posed based on the interviewees' responses to aspects of the research. This allowed for the spontaneous flow of discussion and a friendly (non-threatening) conversation. Since most of the interviewees were mobile phone users, they understood the questions. Quantitative data collected during the interviews were recorded in a spread sheet and analysed using Microsoft Excel and SPSS.

The number of men and women interviewed was dependent on the availability of respondents at the time of the interviews (see Figure 14).

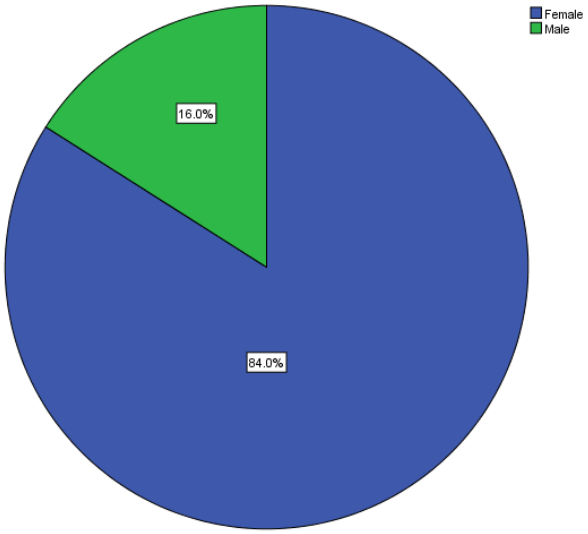

Figure 14: Gender of respondents

Most of the community members interviewed were aged between 13 and 65 years (See Figure 15). Among the 25 people interviewed, only two did not own a mobile phone; they indicated that they borrowed their neighbour's or friends' phones when they wished to make a telephone call.

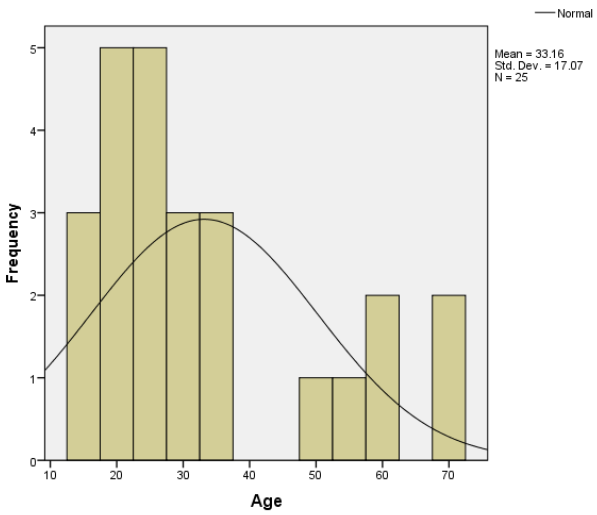

Figure 15: Graph of the age of interviewees

Among those interviewed, 96% did not know that the analog phones that were installed in certain huts of the community would allow them to use the network and that they would in future be able to make calls to mobile phones on other networks (breakout calls). When they were informed of this, they indicated that they would be very keen to use this service.

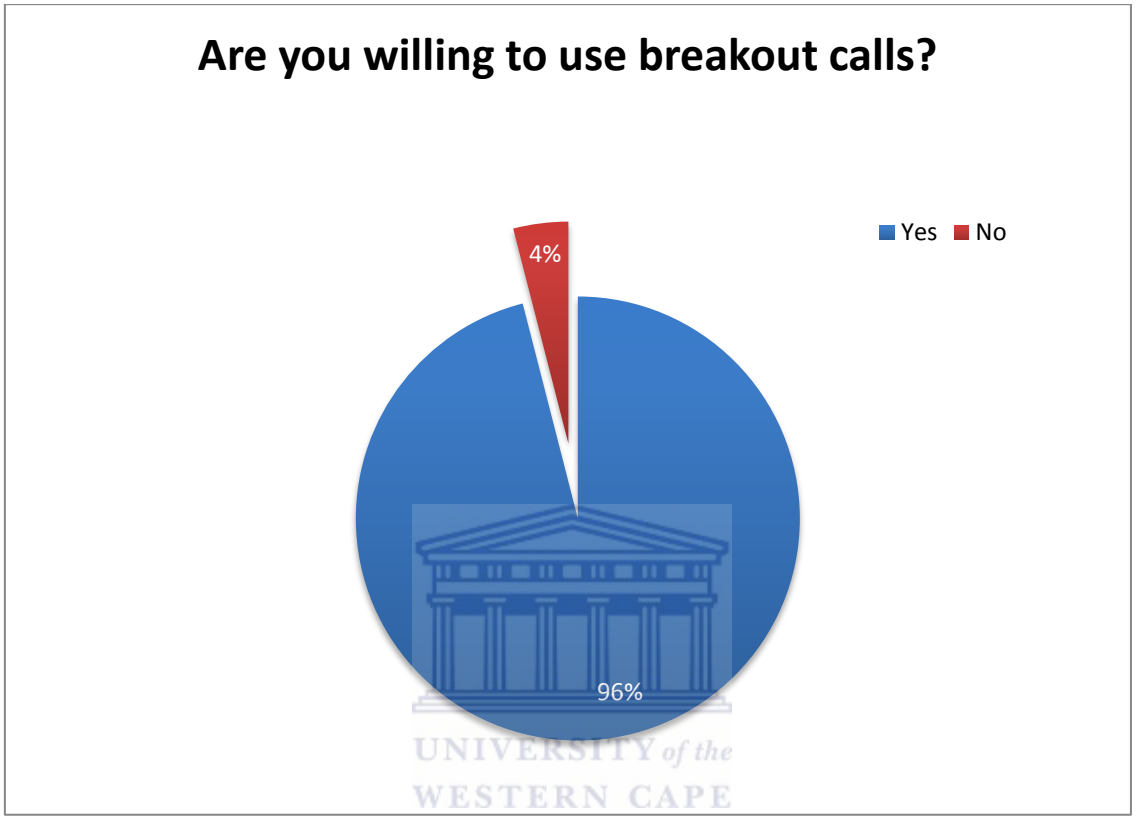

Figure 16: Willingness to use the breakout call service

While conducting interviews with future users it was found that most users who owned a mobile phone (96%) knew how to check their balances. Of the users who checked their balances, 43.5% checked them before making a call, 39.1% after making a call, and 17.4% both before and after making a call. However, only 4.35% knew how much they were currently paying per second for calls. Most (92%) of the respondents felt they wanted to know the duration of the call at the start of the conversation, arguing that it would allow them to plan the conversation accordingly. A further 66.7% felt that they would not mind being informed of the duration of the call, provided the message prior to the start of the conversation was not too long. It was explained to them that this would not incur additional costs.

Focus group meeting with local researchers

Consultation meetings were held with LRs who live in the community and were thus familiar with the culture of the community. The focus group meetings gave the researchers a clear idea of the key issues that needed to be considered during the design process and the implementation of the system. The conversations and interaction were conducted in both English and isiXhosa so that all the LRs, some of whom were not fluent in English, could follow the discussion.

Focus group with local operators

Focus group meetings with LOs were held at the headman's house to explore and integrate the needs, perspectives and financial capacities of the community. It was decided to use scenarios to explain the different financial and usage models to LOs. The LOs were enthusiastic about the project and its potential and understood that their involvement with the project was paramount to its sustainability and success, because they would be responsible for collecting the money for the services of the network. They identified stories that could exemplify the scenarios, respectied and listened to everyone's opinion, and engaged in spirited discussions without being disagreeable. They were given enough time to thoroughly discuss the issues involved – meetings could take up to three to four hours – and all questions posed by them were answered.

Five scenarios resulted from interacting with users and studying the literature. Each one represented a different payment method:

- **Scenario 1** was based on a prepaid payment system where in order to use the network, each user would have a personal calling account and a password for authentication before each use.
- **Scenario 2** was based on a calling-card system. For this scenario, the user would purchase a calling cards or vouchers of a certain value. To make a call, the code on the voucher would be entered before dialling the number.
- **Scenario 3** was similar to a public phone shop and involves a prepaid payment system. To use the system, the user would pay the operator the amount she/he wants to spend and make a call. Once the call is terminated, it would be charged and change would be returned to the caller, if applicable.
- **Scenario 4** was similar to a public phone booth. To make a call, the user could submit an initial amount, but could add an additional amount to extend the call.

- **Scenario 5** was a post-paid payment system. The user would use the system and the cost would then be calculated once the call is completed and payment would be made afterwards.

In order to allow stakeholders to make an informed decision about each payment scenario, the following feasibility criteria were considered and discussed with them:

- **Legal feasibility:** According to South African legislation, a licence is needed to deploy telecommunication infrastructure. A licence exemption can be obtained, but only if members of the same organisation use the infrastructure. For this reason, proof would have to be provided that members of a cooperative established to provide the telephone services use the network.

- **Financial feasibility:** The costs of each scenario had to be calculated to ensure that the income would cover all the expenses. Additional expense could be sometimes be needed, e.g. the first scenario would need an operator to create users' accounts and/or assist them with account authentication; a printer, ink and paper would be needed for the voucher system; a call meter would be needed for scenarios 3 and 4, etc.

- **Technical feasibility:** The technical challenges that would be faced when implementing, operating and maintaining each scenario had to be considered.

- **Social feasibility:** The complexity of the money collection system, whether local inhabitants understood the call-making process and the system's sensitivity to local practices had to be considered for each scenario.

When all five scenarios and been explained to and understood by everyone, the feasibility of each scenario was analysed. A detailed description of the process is given below.

Scenario 1 (prepaid individual account as in Skype): This was legally feasible, because users would have to register to obtain their usernames and passwords, so it would have been easy to satisfy the legal requirements. Technically it would have required an in-depth tweaking of A2Billing, because it was not designed for the communal use of phones, but it was still technically feasible. Economically, it did not entail initial additional costs, because account creation and authentication could be done via IVR messages.

However, socially it was discarded almost from the beginning because it was considered that in the likely event that the operator in the house is elderly, the process of creating an account or even making a call using IVR and authentication would be difficult and would take too long. Additionally, community members foresaw problems with people remembering their account details. Although a per-household register of user accounts could be populated in each household's register, the process was considered to be too complex.

Scenario 2 (vouchers) was considered by the LOs to be simple and flexible. Once the voucher was purchased and activated at the phone where it was bought, for a particular household's accounting purposes it would not need any follow-up by the LOs. Users were also positive and felt that it would work. However, some of them felt that the vouchers could pose a security risk since they could be stolen or the voucher code could be misused. They were also concerned that the voucher could expire, like airtime, but they were assured that this would not happen. Several suggestions were made as to how to keep the vouchers and their codes secure. Vouchers would need to be generated centrally and would need to be either written or printed out. This would not be too expensive, because there was partnership between the cooperative and Transcape – the local NGO that works closely with the community. To satisfy the legal requirements, it was decided to keep a register of users in each household. The register could be updated every time the network was used.

Scenario 3 (prepaid with change and no addition) was the users' choice, because it would allow them to make a call for any small amount of money that they had available. It would, however, require LOs to have a float available to return change to users and a system to record the change given. They also proposed that if enough revenue is generated by the system, it would be desirable to hire someone to carry out this administration. The ability to return the exact change was considered to be an issue by the researchers. However, most users felt they would forfeit change of up to 50 cents if change was not available. Technically, this scenario would require minor tweaking of A2Billing and legally the solution proposed by the cooperative board was similar to the one described in Scenario 2.

Scenario 4 (prepaid, plus an additional payment to lengthen the call) was presented after Scenario 3 and covered the issue of someone wanting to continue a conversation once their credit was finished. A2Billing provides the option of in-line top-up.

However, it would entail some added cost associated with the time necessary to keep the call on hold while the user is topping up. This would be necessary because topping up would be an internal process/arrangement and the external VoIP provider would bill the call according to the call's length. Thus, provided that the cost to establish the call would be zero and change was available, the LOs proposed that the user could continue the conversation by making a new call to the same destination, as is the case for Scenario 3. This would not be ideal, because the conversation would be discontinued and then continued in the next call, but it would solve the technical issues associated with its full implementation and the additional costs for the user.

Scenario 5 (post-paid), although considered to be technically feasible, was unanimously rejected. Both users and LOs felt that it was difficult to know what a call would cost and, once it was made, users might not have enough money with them to pay for the call and it would be difficult to enforce payment. Therefore, the scenario was not considered further, although it would not have entailed additional requirements in terms of its legal, technical and economic feasibility.

Table 1: Summary of the feasibility of the five scenarios

	Legal	**Financial**	**Technical**	**Social**
Scenario 1: Skype	V	V	V	
Scenario 2: voucher			V	V
Scenario 3: prepaid			V	V
Scenario 4: phone booths			V	
Scenario 5: post-paid			V	

The outcome of these discussions can be seen in Table 1, which indicates that the Skype scenario (Scenario 1) is the most feasible, followed by Scenario 2 (voucher) and Scenario 3 (prepaid). Even though Scenario 1 seemed to be most feasible, it was socially not accepted and thus rejected. Only Scenarios 2 and 3 were therefore considered for implementation.

RESULTS OF CYCLE 3

Prototype design

After collecting and defining the system requirements during the investigative phase, a model was designed and a prototype based on Scenarios 2 and 3 was implemented (see Figures 19 and 20) Two Asterisk Gateway Interface (AGI) configurations where created in A2Billing, one for each scenario. Additionally, a test customer account was created and its VoIP credentials introduced in a mesh potato for testing.

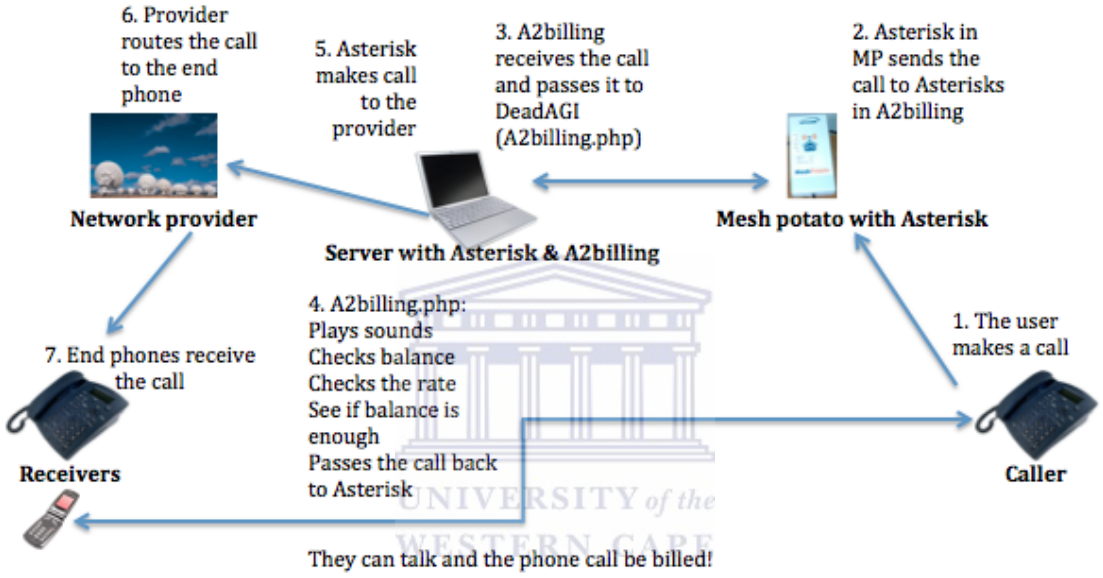

Figure 17: Description of the calling and billing architecture

Rates provided by the VoIP provider for the different destinations were included in the system. To prevent abuse, the main assumption was that VoIP accounts would only reflect a positive credit during the calling process and zero once a call was completed.

Scenario 2 was not complex. Its AGI configuration file was edited to play an audio clip asking the user for the voucher number once a given extension was dialled. After the voucher number is introduced successfully, the credit on the voucher is read out and the user is then prompted to enter the number he/she wants to call. The maximum duration of the call is read out to the user before the call is processed. A2Billing deals with vouchers in the standard way, i.e. once the call is completed the credit in the voucher remains associated with the VoIP account setup in the Asterisk server where the voucher was loaded, so that the voucher is zero after the call. This procedure was modified in order to transfer the remaining credit back onto the voucher.

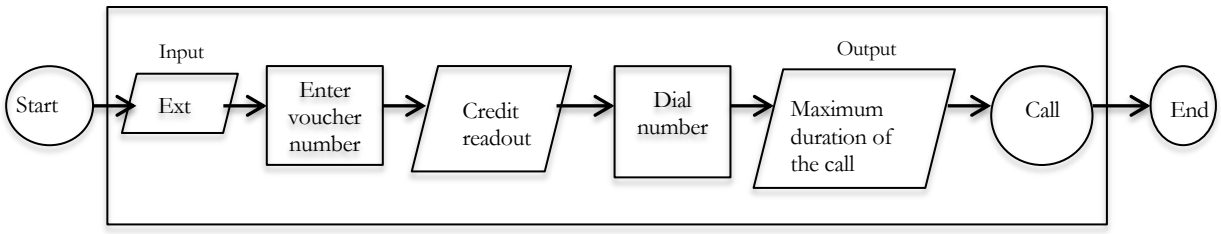

Figure 18: Schematic representation of Scenario 2

For money collection purposes, the initial credit of the voucher is associated with the VoIP account where the voucher was purchased. From then on every call made from the voucher is registered as having no cost. For this to be possible, LOs would be asked to activate the voucher (introducing the voucher number, but not making a call) before handing it to the user.

For **Scenario 3**, an extension would be used to listen to the cost of the last call made and what the remaining credit in the voucher is. Although users did not specifically require the functionality of being prompted with the credit before making a call, it was introduced as a mechanism to foster trust in both the system and the LOs.

The extension to determine the remaining credit on a voucher could be used as often as necessary by the LO or the user to check the remaining amount available on a voucher. For Scenario 3 three extensions had to be entered consecutively. The first extension, used by the LO, was implemented to enter the amount the user intends to spend for the call, which is read back to the LO to confirm that the amount has been entered correctly. The phone would then be handed to the user to dial the next extension. The maximum duration of the call would be read out to the user before he/she would be able to dial the number he/she wants to call. On completion of the call the remaining credit would be stored as an internal variable and the credit on the VoIP account would be set to zero. To determine the cost of the call, a third extension could be entered, and the cost of the last call made and the change to be received would then be read out.

Additional codes for checking the amount to be paid to the VoIP provider for a given month and the money collected over a specific period were also created. For this to be possible an extra extension was created for guiding the user to enter the collection period using DTMF signalling. These extensions will be referred to as administrative extensions. The prompts for all the extensions were recorded in isiXhosa and included in the central Asterisk server (where A2Billing is hosted) and the Asterisk servers in the access points.

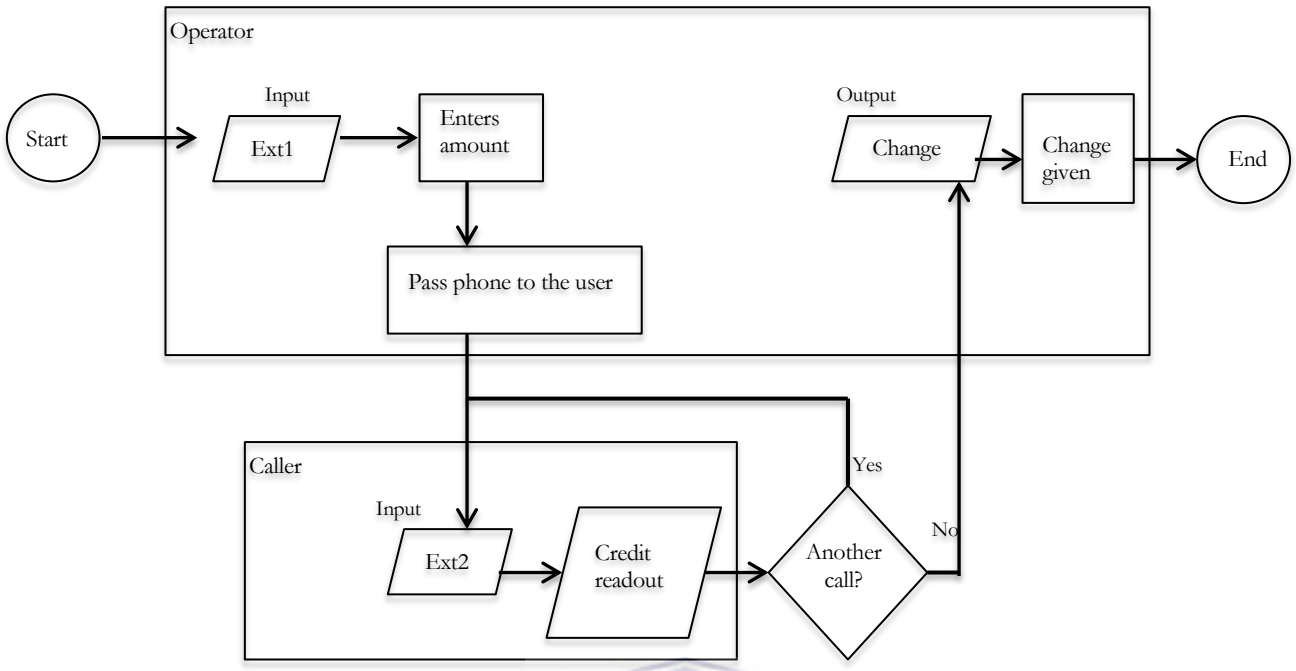

Figure 19: Schematic representation of Scenario 3

A2Billing platform

The A2Billing platform is a fully featured prepaid and post-paid calling-card platform built and designed on LAMP (Linux, Apache, MySQL and PHP). The telephony interface is supplied by Asterisk, while the open source telephony toolkit is designed by Digium. The A2Billing platform has many features that are only found in high-end calling-card platforms costing many thousands of dollars (A2Billing, 2012).

A2Billing sits at the top of Asterisk to bill and manage VoIP calls. It includes a server running Linux as operating system to host the system, a line Interface Cards (an analog phone device) to connect to the Time Division Multiplexing (TDM) network, Apache for the web server and MySQL for the back-end database (A2Billing, 2012). A2Billing takes advantage of the Asterisk Manager Interface (AMI) (see Figure 20) and AGI to deal with the call logic (Village Telco, 2011).

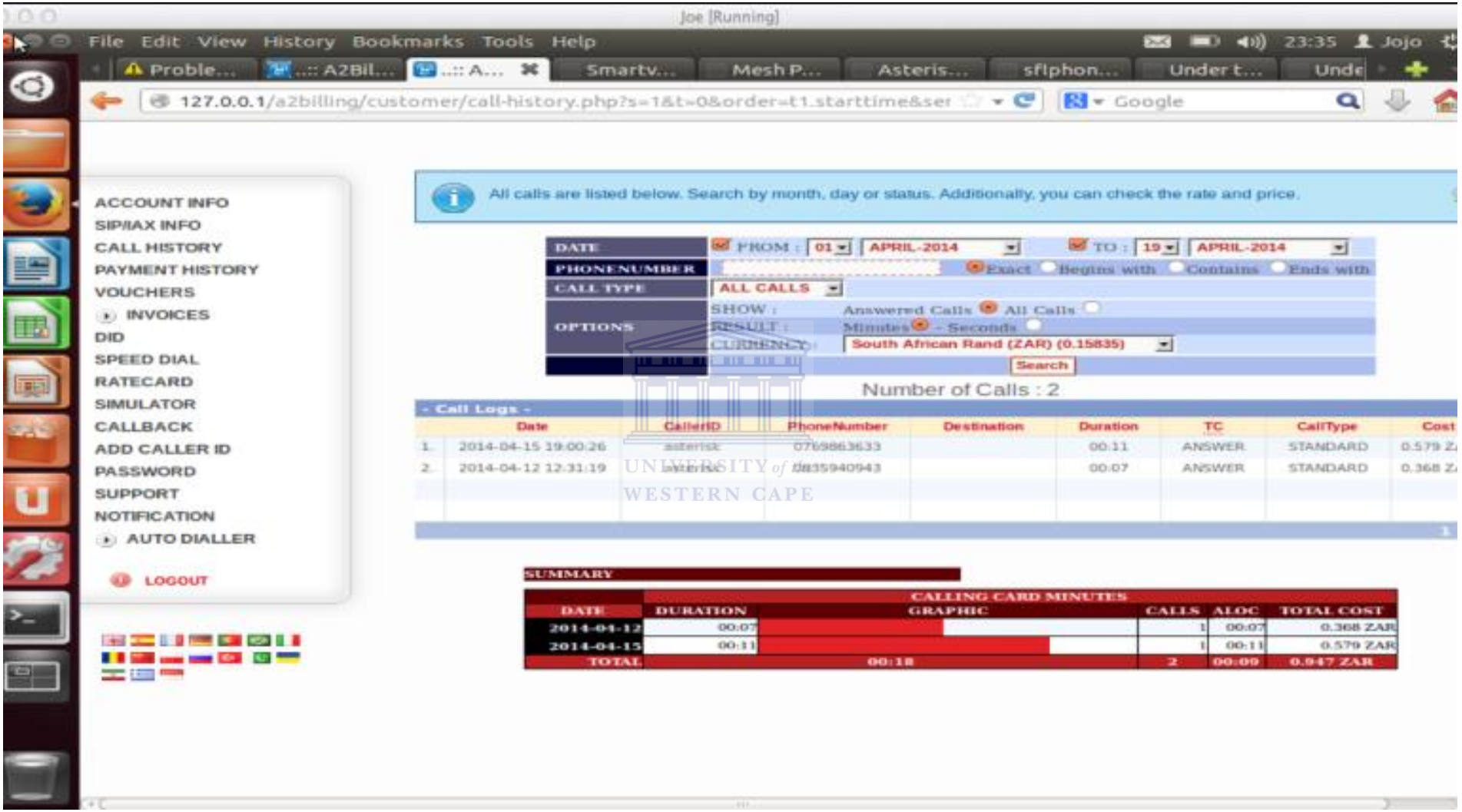

Figure 20: Screen shoot of the A2Billing-user interface

For a detailed description of the A2Billing system, see Appendix D.

Cycle 4: Presentation of the prototype

After the design phase, the system was presented to the stakeholders for testing. This was done during the second iteration of the PD cycle (stages C, D, E and F in Figure 13). The designed prototype was demonstrated, discussed and evaluated with the LOs in focus groups where a more hands-on approach was used. Participants were able to interact with the prototype implemented according to their suggestions for each scenario. This was done in two workshops: the first with the people interviewed and the second in focus group meetings with the LOs.

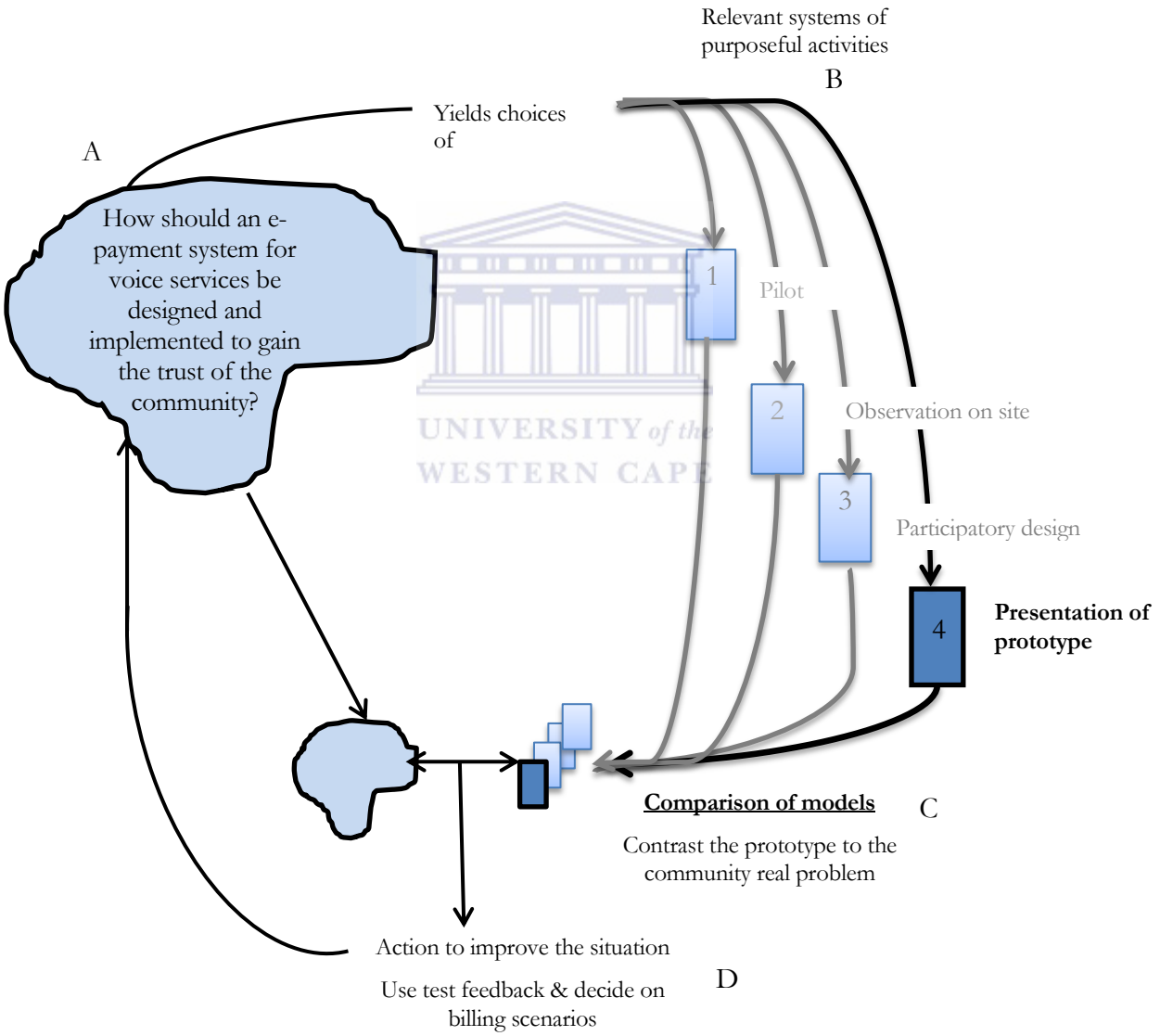

Figure 21: Cycle 3: Presentation of the prototype

DETAIL DESCRIPTION OF PRESENTATION OF THE PROTOTYPE

A workshop was organised and some of the community members who had previously been interviewed were invited to test the prototypes (see Figure 22). Of the 25 community members interviewed, 10 were chosen (using judgemental sampling according to availability and closeness to the place where the workshop was held) to test the system. However, only five of the ten community members that were invited attended the workshop and were able to test the prototypes of the two payments scenarios. At this workshop, community members gave advice on adjustments to the billing system based on their choice of the two scenarios.

Figure 22: Presentation of the prototypes

RESULTS OF CYCLE 4

The presentation of the prototypes revealed the following:

- Communication among community members is mostly oral. That is why the billing system attempted to reproduce oral communication by allowing users to interact with the system orally using IVRs. The IVRs were customised in the local language, isiXhosa, which presented some limitations, since it does not capture some extra-linguistic features of oral expressions. This may be the reason why some participants struggled to follow audio prompts.
- The use of local voices emulating the flow of conversation and the currently available amount of money to make a call was reported to be very useful by the users of the system because they allowed the users to plan and control their conversations.

Even those who were less literate could easily interact with both the billing system and the scenarios.

- Scenario 3 was reported to be very useful for users who find it difficult to assemble enough money to purchase top-up vouchers. Unlike groceries, which can be purchased at local shops and paid for later after the receipt of monthly government grants, vouchers would have to be paid in cash.
- Scenario 2 was reported to be useful because it allowed users to purchase vouchers that would provide the user with the maximum time to call and would not expire before the purchased amount was used. This scenario was therefore found to be economically useful to people with lower incomes and allowed them to make informed decisions about their conversations.
- Although oral communication is privileged in the prototypes, the inability to see the users' dialled number led to many mistakes. The users furthermore had to use their mobile phones to access the phone numbers they wanted to call. Phone numbers therefore need to be accessible through the system. However, this needs to be considered carefully in order to preserve the privacy of users and may eventually be possible if mobile phones can be used on the system.
- The youngsters who participated in the testing understood the various payment scenarios and requested that the IVR be minimised to save time, i.e. so that when they know the codes they can enter them without having to listen to the IVR message. However, their request was turned down, because the system had to accommodate everyone in the community.
- The process once again revealed the lack of employment opportunities for the youth in the community. If the uptake of this network is successful and everyone uses it, it should create job opportunities.

Summary

In this chapter the design of a billing system that would be accepted and trusted by the users was discussed, the techniques used to test the system were explained, and the results obtained were discussed. Four cycles of the SSM methodology was used to manage the research, and the results in terms of each cycle were presented. In the next chapter the lessons learned will be discussed, while future work and recommendations for similar projects will also be presented.

Chapter 5

DISCUSSION AND FINDINGS

This chapter presents the discussion and conclusions of the thesis addressing the research question.

The research question revisited

To recapitulate, the research question that was posed in Chapter 1 is: "How should an e-payment system for voice services on a rural Village Telco be designed to gain the trust of the community?" This research question was addressed from three perspectives: social, economic and technical each addressing an aspect of the sub-questions namely:

- What are the needs and expectation of the community in terms of communication services? How should the system be built and managed so that it is trusted by the community? (Social)
- What modality of payment would be suitable for the community, but will also make the Village Telco sustainable? (Economic)
- How should the payment system be designed or developed to address the needs and expectations of the community? (Technical)

THE SOCIAL PERSPECTIVE

The social perspective was aimed at understanding how the users of a system should be supported to understand, trust, adopt and use it. The researcher discovered that in rural environments of a developing country, such as Mankosi, a monitoring process to understand the social issues of the community is important and affects the usage of the system designed for the community. Furthermore, it is difficult to design a system attuned to the community without including community members in the design process. Participatory design was used to involve the community and also to understand what users expect from the designed system. Awareness of community members' levels of literacy was important in order to integrate all users into the project. This was found to be very important for the successful uptake of the system. Support mechanisms and adaptations were thus applied throughout the research cycles.

ECONOMIC PERSPECTIVE

In terms of economic perspective, although the overall focus of the project was to provide the community with the ability to communicate easily through an affordable calling system, the solar system that powers the calling nodes also generates revenue that was considered in the business model. The solar panel system that powers the calling nodes in the community was over-dimensioned to allow users to charge their mobile phones at a lower cost than existing alternatives – a charge of R3 instead of the R5 charged by local shops. At the time of writing the revenue generated was being used to sustain the network. The mesh network therefore enables lower cost alternatives that provide access to voice services in the area.

TECHNICAL PERSPECTIVE

In terms of the technical perspective, the thesis aimed to understand how a technical system could be built to resolve a specific social issue. It was found that engagement with the users of the system and an understanding of the social environment of the users are important and affect the technical requirements of the system. The requirements evolved during the design process and the system had to be adjusted continuously to suit the evolving requirements of the community. The methodology used (SSM) allowed for the design to be refined over several requirement collection and design cycles. It was discovered that this approach allowed for both an understanding of the technical requirements and the involvement of users in their social environment to shape thinking about how a technical system should be built so as to be accepted by its users.

UNIFYING SOCIAL, ECONOMIC AND TECHNICAL PERSPECTIVES

SSM, with its cyclical process, allowed changes to be made to the design in each cycle based on the findings of a previous cycle. The findings were based on the observations of the social space of the users. The findings highlighted how the technical system should be built, but also how the users would need support to use such a system. The on-going evaluation allowed the changes required in each SSM cycle to be tracked. This understanding provided a framework for moving closer to the envisaged outcome of the project. The changes that were made to the technical system were thus based on the understanding of the social space of users in the community. The social and technical perspectives are therefore interwoven, in the sense that if the social perspective was not understood, the resulting technical system would result in it not being fit for use in the social environment of the users. Thus it was found that the technical system should be built to reflect and respond to users' social circumstances.

Findings, challenges and lesson learned

The researcher spent time in the community and studied the literature of projects that were conducted in a similar context. The recommendations and guidelines are drawn from this experience and emerge from the findings of the research. The limitations and lessons learned will be also be highlighted.

FINDINGS

The aim of this project was to design and implement a trustworthy payment system for voice services delivered on the Mankosi community communication network. With a participatory design methodology, a billing system was a co-designed with the Mankosi community. The billing system fulfilled both the needs expressed by the community – to be able to call mobile phones through the community network – and the requirement to be able to sustain the network by generating funds that could also be used for other projects to benefit the community. The sustainability criteria were considered (legal, financial, technical and social) and only the payment scenario that aligned with local practices was implemented, thus satisfying users' social requirements and encouraging their trust in the system.

The cheaper voice services provided by this Village Telco and the options provided by the modality of payment implemented in the billing system are expected to improve access to voice services in remote areas especially in developing countries. These findings are of wider application than those similar to a network infrastructure described in Heimerl, Hasan, Ali, Brewer, & Parikh (2013). However, they provide a better solution by providing affordable voice services through a bottom-up community cellular network.

During this research it was found that the pricing system of South African mobile network operators that use English for IVR messages was practically unknown to users, especially the less literate. It became apparent during the design phase of the billing system that isiXhosa-speaking users are unaware of the costs of mobile services, which impacts on the usability of the system. For the Mankosi network, customising the IVR in isiXhosa eliminated this language challenge. We believe that the system is now accepted and trusted by the local community, because most of the requirements and their recommendations were implemented in the final system. This was confirmed by the LRs, who indicated that they were satisfied with the system because they were involved in its planning and design. They felt that the system integrates their oral culture and is sensitive to users' literacy levels, their financial situation and the economy of the community.

The design and implementation of the system were made transparent to the users. Furthermore, the fact that the system reports on the calls made and the money collected makes the administration transparent to users and thus increases the community's trust in the system.

CHALLENGES

During the design process, users and LOs showed different degrees of involvement, particularly during the testing of the prototype. While only some community members attended the workshop (Ufitamahoro, Venter, Rey-Moreno, & Tucker, 2014), LOs were very involved in all the design workshops. Consequently, when consensus could not be reached, the opinions of LOs weighed more heavily than those of users, since LOs had a better understanding of the system and had more responsibilities regarding the management of the network. We hope that this did not affect the users in any way.

The local culture posed limitations such as that the female voice was not heard – the male voice was prominent during interactions. This is mainly because in general community meetings women had to sit separately from the men and thus they could not talk and contribute freely, as the culture requires of women to be subservient. The researcher (a woman) also experienced some dfficulties in this regard while conducting interviews. The users' language also posed a limitation: all communication required an interpreter, which made communication laborious.

LESSONS LEARNED

When conducting research in a community, it is very important to assess the needs and requirements of end users, because they differ according to the context of the system. The system being developed should be trusted, and most importantly, used by the target community. It would be difficult and sometimes even impossible for users to accept and adopt a system for which a proper needs assessment was not done. On the other hand, expectations in terms of the aims of the research need to be managed carefully, to distinguish between research and providing a solution. It is very important to make clear from the beginning that users should not have unrealistic expectations in terms of solutions.

This is because research is not about providing a solution, but is rather a process of learning how a solution could be provided in light of the present situation. The solution cannot therefore be fully guaranteed.

For the project to obtain support and suit the target area, it is important to engage community members who live in the area, as they have a better understanding of the community's needs. Even if community members tend to be more open and more trustful of people they know, a long-term engagement with users is beneficial in that it provides the researcher with a better understanding of community practices. This supports Wells & White (1988, p. 63) belief that "*through community involvement comes understanding, and with understanding comes public support and commitment"*. The involvement of users increases their sense of ownership of an externally initiated project and leads eventually to adoption and usage of the project's services.

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APPENDICES

APPENDIX A

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26/05/2014

Appendix A: Consent form for participants in the survey

This form is provided only in English because participants will have this form translated an interpreter.

I, _____, fully cognize the "Understanding the factors that influence trust in e-services: A study of a mesh network implementation in Mankosi, South Africa" project and agree to participate. I understand that I can withdraw from the study at any time, and any information collected pertaining my contribution will be destroyed at once. I also understand that all information that I provide will be kept confidential, and that my identity will not be revealed in any publication resulting from the research unless I choose to give permission. I acknowledge that all information attained in this study or test will be stored on a computer that has a password that is only known by the researcher. Furthermore, all recorded interview media and transcripts will be destroyed after the project is completed. I am also free to withdraw from the project at any time.

I understand that an interpreter will be used for this trial and the information he/she translates will be kept confidential and not repeated.

Signature..... Date.....

For further information, please do not hesitate to contact:

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Name:.....Signature:.....

APPENDIX B

Questionnaire to evaluate the use of information technologies in South Africa

Dear Participant,

Thank you for volunteering to complete this questionnaire. The data collected will be used for a survey study on the access and usage of information technologies in South Africa. Your participation will be highly appreciated.

MODULE D: HOUSEHOLD ROSTER: HOUSEHOLD ATTRIBUTES (TO BE COMPLETED FOR EACH HOUSEHOLD MEMBER BY HEAD OF THE HOUSEHOLD OR SOMEONE THAT MANAGES THE HOUSEHOLD)									
Q1.	HOUSEHOLD MEMBER		1	2	3	4	5	6	7
Q2.	FIRST NAME								
Q3.	GENDER	[0] male [1] female							
Q4.	AGE (YEARS)								
Q5.	MARITAL STATUS	[1] married [2] single [3] widowed [4] divorced [5] other [6] NA							
Q6.	HIGHEST LEVEL OF SCHOOLING COMPLETED	[1] none [2] primary [3] secondary [4] tertiary: diploma/certificate [5] tertiary: BSc/BA [6] tertiary: Masters [7] tertiary: PhD							
Q7.	MAIN ACTIVITY DURING LAST 6 MONTHS?	[1] below school age [2] student / pupil [3] unpaid housework (housewife e.g.) [4] retired [5] unemployed [6] disabled [7] employed [8] self-employed							
Q8.	MONTHLY INCOME IN TERMS OF SALARY OR WAGE?								

MODULE D: HOUSEHOLD ROSTER: HOUSEHOLD ATTRIBUTES (TO BE COMPLETED FOR EACH HOUSEHOLD MEMBER BY HEAD OF THE HOUSEHOLD OR SOMEONE THAT MANAGES THE HOUSEHOLD)									
Q9.	MONTHLY INCOME IN TERMS OF SELF EMPLOYMENT (PROFIT) AND PROPERTY INCOME OR INCOME FROM AGRICULTURAL PRODUCE AND FARMING?								
Q10	MONTHLY INCOME IN TERMS OF PENSION, TRANSFER INCOME & SCHOLARSHIPS?								
Q11	OWNING A MOBILE PHONE	[0] no [1] yes [2] don't know							

MODULE E: EXPECTATIONS			
E.1	DID YOU KNOW ABOUT THIS PROJECT?	[0] no [1] yes	
E.2	HOW DID YOU LEARN ABOUT IT?		
E.3	WHO DO YOU THINK WOULD USE THE SYSTEM?		
E.4	IF PRICE OF CALLS AMONG PUBLIC PHONES WERE HALF OF THE PRICE THAN THE CALLS FROM YOUR MOBILE PHONE, HOW OFTEN WOULD YOU USE A PUBLIC TELEPHONE IF ONE WAS WITHIN 5 MINUTE WALKING DISTANCE FROM YOUR HOME?	[1] More than once a day [2] Every day or almost [3] At least once a week [4] At least once a month [5] Less than once a month [6] Never	
E.5	IF PRICE OF CALLS AMONG PUBLIC PHONES WERE HALF OF THE PRICE THAN THE CALLS FROM YOUR MOBILE PHONE, HOW OFTEN WOULD YOU USE A PUBLIC TELEPHONE IF ONE WAS WITHIN 30 MINUTE WALKING DISTANCE FROM YOUR HOME?	[1] More than once a day [2] Every day or almost [3] At least once a week [4] At least once a month [5] Less than once a month [6] Never	
E.6	IF PRICE OF CALLS AMONG PUBLIC PHONES WERE HALF OF THE PRICE THAN THE CALLS FROM YOUR MOBILE PHONE, WOULD YOU RECEIVE MORE CALLS, IF A PUBLIC PHONE WAS WITHIN 5 MINUTES WALKING DISTANCE FROM YOUR HOME?	[1]Yes [0]No	
E.7	DO YOU KNOW ABOUT THE MANKOSI COMMUNITY ASSOCIATION?	[0] no [1] yes	
E.8	DO YOU TRUST THEM MANAGING THE MONEY OF THE COMMUNITY GOODS (SAND)?	[0] no [1] yes [2] don't know	
E.9	DO YOU KNOW ABOUT THE MANKOSI TRUST?	[0] no [1] yes	
E.10	DO YOU TRUST THEM MANAGING THE MONEY OF THE COMMUNITY GOODS?	[0] no [1] yes [2] don't know	
E.11	HAVE YOU EVER PERSONALLY USED TABLETS (TABILOTS) AFTER WORKSHOPS?	[0] no [1] yes [2] don't know	IF NO, JUMP TO E.13
E.12	DO YOU THINK USING THEM HAS INFLUENCED YOUR PERCEPTION OF TECHNOLOGIES?	[0] no [1] yes [2] don't know	
DO YOU THINK THAT PRESENCE OF A CHEAPER MECHANISM IN THE COMMUNITY TO COMMUNICATE AMONG VILLAGES WOULD IMPROVE: [1] DECREASED [2] THE SAME [3] INCREASED			
E.13	CONTACT FAMILY		

MODULE D: HOUSEHOLD ROSTER: HOUSEHOLD ATTRIBUTES (TO BE COMPLETED FOR EACH HOUSEHOLD MEMBER BY HEAD OF THE HOUSEHOLD OR SOMEONE THAT MANAGES THE HOUSEHOLD)		
E.14	CONTACT WITH WORK COLLEAGUES	
E.15	CONTACT WITH FRIENDS	
E.16	CONTACT WITH MEMBERS FROM LOCAL INSTITUTIONS	
E.17	THE COMMUNICATION WITHIN THE TRIBAL AUTHORITY (HEADMAN, ADVISERS AND SUBHEADMEN)	
E.18	THE COMMUNICATION BETWEEN THE TRIBAL AUTHORITY AND OTHER COMMUNITY GROUPS IN THE COMMUNITY (MANKOSI COMMUNITY ASSOCIATION, MANKOSI TRUST, TRANSCAPE, ETC)	
E.19	THE COMMUNICATION BETWEEN THE TRIBAL AUTHORITY AND THE COMMUNITY	
E.20	THE COMMUNICATION WITHIN OTHER GROUPS IN MANKOSI (CHURCH GROUPS, MANKOSI COMMUNITY ASSOCIATION, TRANSCAPE, MANKOSI TRUST)	

APPENDIX C

Probes for the interviews

1) What is your name?
2) How old are you?
3) What is your gender?
4) Did you know before this introduction that you could be able to call mobile phones using the phones in the community?
5) Do you think that you will use it?
6) Do you have a mobile phone? Which service provider?
7) Do you know how much you pay (per minute or per second)?
8) Do you know how to check your balance?
9) How often do you check it? Before making a call? After making a call? Always?
10) How interested will you be if you could hear your balance:
11) Always before making call?
12) After every call you make?
13) Would like to know for how long you can call with that balance?
14) Wouldn't a message (or too much information) before every call take too long?
15) Now much airtime do you often buy (for how much?) Do you think that is too expensive for you?
16) How interested will you be to have vouchers of R2? R1?
17) What if the number of the voucher was open (numbers printed on a piece of paper, not something to scratch), would you trust it?
18) What if you have to introduce that code every time before making the call? Would you be interested?
19) Did it happen to you that you wanted to call and were not able to because you were not able to buy airtime? Why? (Because you did not have money? Because it was late in the night? Because it was far from the place to buy airtime? Because it was raining?)

20) Imagine that you could pay after making the call. Would you be interested?

21) If yes, what would happen if you don't have enough money to pay for the call?

22) Imagine that you go buy bread or paraffin or something else in a spaza shop and the change is less than 5 cents. Will you forgive that change (in other words, will you agree not to receive it)? How about less than 10 cents? What would you suggest if there is no change, especially small change? (I want to know how much change you would forgive in the store or what you would suggest if there is no change.)

23) It was agreed that the money collected after charging the phone will be used for maintenance and if possible to start other projects beneficial to the community. Do you trust that this will be done? Why or why not?

APPENDIX D

A2Billing installation and configuration

INSTALLING A2BILLING

For the installation of A2Billing, the following guide was used:

https://github.com/Star2Billing/a2billing/blob/master/INSTALL.rst

PRE-REQUIRED SOFTWARE PACKAGES

A2Billing requires the packages of a LAMP (PHP5) installation. To install the necessary packages, run the following commands:

apt-get install libapache2-mod-php5 php5 php5-common apt-get install php5-cli php5-mysql mysql-server apache2 php5-gd apt-get install openssh-server subversion

A2Billing also requires the MCrypt module for PHP5:

apt-get install php5-mcrypt

Asterisk is also needed:

apt-get install asterisk

Extra software is needed to support text-to-speech IVR monitoring:

The new monitoring feature requires text-to-speech (TTS) support; the default TTS engine is Cepstral http://www.cepstral.com/ although A2Billing can also support Festival.

Install Cepstral (default path: /opt/swift) and make a symbolic link: - ln -s /opt/swift/bin/swift /usr/bin/swift

Make sure that the dynamic libraries are linked, create a file called cepstral.conf under /etc/ld.so.conf.d/ including the path : /opt/swift/lib

Always configure the voice registration.

INSTALLATION

Installing A2Billing requires a minimum of 12 steps:

1. Download and unpack source code
2. Set up the database
3. Edit a2billing.conf file and set up the database parameters
4. Fix permissions and folders

5. Install the web-based graphical user interfaces (Customer and Admin)
6. Place the AGI files
7. Prepare your dial plan
8. Configure recurring services
9. Callback daemon
10. Enable monitoring
11. Enable monitoring (only for IVR monitoring)
12. Enable card locking (only for card PIN locking)

Step 1: Download and unpack source code

Create an A2Billing folder under /usr/local/src:

mkdir /usr/local/src/a2billing

Unpack the code.

Download the code from the SVN repository, run:

svn co --username guest --password guest http://svn.a2billing.net/svn/asterisk2billing/tags/1-current /usr/local/src/a2billing/

At the end of this step you should have an A2Billing tree structure that should look like this:

/usr/local/src/a2billing/

Files:

AGI

CHANGELOG

COPYING

CallBack

Cronjobs: Recurrent services run via crontab

DataBase: Database Schema/DB Installation

FEATURES_LIST

a2billing.conf: Main Configuration file

Addons: Sounds and other addons

Admin: Admin UI

Agent: Agent UI

Customer: Customer UI

Webservice

Step 2: Prepare thedatabase

Let's now create a MySQL database (mya2billing) for the billing software. The file a2billing-createdb-user.sql includes a script that creates the database with the correct access control users and permissions:

cd /usr/local/src/a2billing mysql -u root -p < DataBase/mysql-5.x/a2billing-createdb-user.sql

The script with create a database, username and password with the following default values:

Database name is: mya2billing

Database user is: a2billinguser

User password is: a2billing

After creating the database structure, we create a set of tables and insert some initial basic configuration data:

cd DataBase/mysql-5.x/ ./install-db.sh

Checkpoint 1: Check that the database (my2billing) and that (97) tables have been created.

mysql -u root -p mya2billing mysql>show tables mysql>exit

Step 3: Edit the a2billing.conf configuration file

The A2Billing configuration file (a2billing.conf) contains the basic information to connect to the a2billing database. Copy or make a symbolic link from /usr/local/src/a2billing/a2billing.conf to /etc/a2billing.conf

a2billing.conf -> /usr/local/src/a2billing/a2billing.conf

Option 1:

cp /usr/local/src/a2billing/a2billing.conf /etc/

Option 2:

ln -s /usr/local/src/a2billing/a2billing.conf /etc/a2billing.conf

Open the file with your favourite text editor (vi is used in this example). If you are new to Linux, we recommend that you use the text editor Gedit.

vi /etc/a2billing.conf

The only parameter that you need to change here is the database connection information; an example follows:

[database] hostname = localhost port = 3306 user = a2billinguser password = a2billing dbname = mya2billing dbtype = mysql

Step 4: Fix permissions, files and folders

In this step, the Asterisk file permissions will be tweaked to fit the A2Billing software. A number of additional files and folders that A2Billing needs and does not come with the default installation will be created.

SIP and IAX

First we will set a few file permissions (chmod, chown) and create (touch) the SIP and IAX configuration files for Asterisk:

chmod 777 /etc/asterisk touch /etc/asterisk/additional_a2billing_iax.conf touch /etc/asterisk/additional_a2billing_sip.conf echo \#include additional_a2billing_sip.conf >> /etc/asterisk/sip.conf echo \#include additional_a2billing_iax.conf >> /etc/asterisk/iax.conf chown -Rf www-data /etc/asterisk/additional_a2billing_iax.conf chown -Rf www-data /etc/asterisk/additional_a2billing_sip.conf

Sound files

Run the sounds installation script available in the addons folder (IMPORTANT: the script assumes that Asterisk sounds are under /usr/share/asterisk/sounds/):

/usr/local/src/a2billing/addons/install_a2b_sounds_deb.sh chown -R asterisk:asterisk /usr/share/asterisk/sounds/

Configure Asterisk Manager

Configure the Asterisk Manager by editing the manager.conf file.

vi /etc/asterisk/manager.conf

Notice that the default values are used (myasterisk, mycode) in this section. The configuration should look like this:

[general] enabled = yes port = 5038 bindaddr = 0.0.0.0 [myasterisk] secret=mycode read=system,call,log,verbose,command,agent,user
write=system,call,log,verbose,command,agent,user

Step 6: Install the AGI components

Copy or create a symbolic link of the entire content of the AGI directory into the Asterisk agi-bin directory:

mkdir /usr/share/asterisk/agi-bin chown asterisk:asterisk /usr/share/asterisk/agi-bin

Option 1:

cd /usr/local/src/a2billing/AGI cp a2billing.php /usr/share/asterisk/agi-bin/ cp a2billing-monitoring.php /usr/share/asterisk/agi-bin/ cp -Rf ../common/lib /usr/share/asterisk/agi-bin/

Option 2:

ln -s /usr/local/src/a2billing/AGI/a2billing.php /usr/share/asterisk/agi-bin/a2billing.php ln -s /usr/local/src/a2billing/AGI/lib /usr/share/asterisk/agi-bin/lib

Make sure the scripts are executable:

chmod +x /usr/share/asterisk/agi-bin/a2billing.php

If you are going to run the monitoring AGI script:

chmod +x /usr/share/asterisk/agi-bin/a2billing_monitoring.php

Step 5: Install web-based graphical interfaces

In this step, the three graphical interfaces of A2Billing will be installed: the Administration (admin), Agent (agent) and Customer (customer) interface. As in previous steps you can copy the folders of make symbolic links.

Place the directories "admin" and "customer" into your webserver document root.

Create an A2Billing folder in your web root folder:

mkdir /var/www/a2billing chown www-data:www-data /var/www/a2billing

Create folder directory for monitoring scripts:

mkdir -p /var/lib/a2billing/script

Create folder directory for Cronts PID:

mkdir -p /var/run/a2billing

Option 1:

cp -rf /usr/local/src/a2billing/admin /var/www/a2billing cp -rf /usr/local/src/a2billing/agent /var/www/a2billing cp -rf /usr/local/src/a2billing/customer /var/www/a2billing cp -rf /usr/local/src/a2billing/common /var/www/a2billing

Option 2:

ln -s /usr/local/src/a2billing/admin /var/www/a2billing/admin ln -s /usr/local/src/a2billing/agent /var/www/a2billing/agent ln -s /usr/local/src/a2billing/customer /var/www/a2billing/customer ln -s /usr/local/src/a2billing/common /var/www/a2billing/common

Fix the permissions of the templates_c folder in each UI:

chmod 755 /usr/local/src/a2billing/admin/templates_c chmod 755 /usr/local/src/a2billing/customer/templates_c chmod 755 /usr/local/src/a2billing/agent/templates_c chown -Rf www-data:www-data /usr/local/src/a2billing/admin/templates_c chown -Rf www-data:www-data /usr/local/src/a2billing/customer/templates_c chown -Rf www-data:www-data /usr/local/src/a2billing/agent/templates_c

Checkpoint 2: Direct a browser to the administrative web interface (http://<ip-addr>/a2billing/admin) and login as administrator. Default passwords are:

user: root

pass: changepassword

Step 7: Create a dialling plan for A2Billing

The extensions.conf is the Asterisk dialling plan. Calls that interact with the billing software need to be handled inside one or many A2Billing-related contexts.

The calls that reach the context are processed using the a2billing.php AGI script. The a2billing.php script can be invoked in many different modes (standard, did, voucher, callback, etc). In the example we create two different contexts, the first context [a2billing] handles all the calls from VoIP clients. When a call arrives, any extension number _X. (2 digits or more) reaches the script a2billing.php.

The second context [did], will be used to route inward calls back to the users. Calls to the clients (DID) are handled inside the [did] context. The script a2billing.php in "did" mode is responsible for routing the call back to users.

Edit extension.conf:

vi /etc/asterisk/extensions.conf

and the following contexts:

[a2billing] include => a2billing_callingcard include => a2billing_monitoring include => a2billing_voucher [a2billing_callingcard] ; CallingCard application exten => _X.,1,NoOp(A2Billing Start) exten => _X.,n,DeadAgi(a2billing.php|1) exten => _X.,n,Hangup [a2billing_voucher] exten => _X.,1,Answer(1) exten => _X.,n,DeadAgi(a2billing.php|1|voucher) ;exten => _X.,n,AGI(a2billing.php|1|voucher44) ; will add 44 in front of the callerID for the CID authentication exten => _X.,n,Hangup [a2billing_did] exten => _X.,1,DeadAgi(a2billing.php|1|did) exten => _X.,2,Hangup

Note that newer versions of Asterisk use a comma (,) instead of a pipe (|) to separate the AGI arguments.

Step 8: Configure recurring services

Recurring services are handled via /etc/crontab

You can add the following cron jobs to your /etc/crontab or create a file with the jobs in /var/spool/cron/a2billing

Update the currency table:

0 6 * * * php /usr/local/src/a2billing/Cronjobs/currencies_update_yahoo.php

Manage the monthly services subscription:

0 6 1 * * php /usr/local/src/a2billing/Cronjobs/a2billing_subscription_fee.php

To check the account of each user and send an email if the balance is less than the user has, choose:

0 * * * * php /usr/local/src/a2billing/Cronjobs/a2billing_notify_account.php

This script will browse all the DIDs that are reserved and check if the customer needs to pay for it. It will bill them or warn them via email to find out if they want to pay in order to keep their DIDs:

0 2 * * * php /usr/local/src/a2billing/Cronjobs/a2billing_bill_diduse.php

This script will take care of the recurring service.

0 12 * * * php /usr/local/src/a2billing/Cronjobs/a2billing_batch_process.php

Generate invoices at 6 am every day:

0 6 * * * php /usr/local/src/a2billing/Cronjobs/a2billing_batch_billing.php

Proceed to the autodialer:

* / 5 * * * * php /usr/local/src/a2billing/Cronjobs/a2billing_batch_autodialer.php

Manage alarms:

0 * * * * php /usr/local/src/a2billing/Cronjobs/a2billing_alarm.php

Step 9: Callback daemon (only for callbacks)

The callback daemon is responsible of reading from the database the pool of calls stored for call back and trigger those calls periodically.

The daemon is written in Python. Install the python-setuptools and use easy_install to install the callback_daemon:

apt-get install python-setuptools python-mysqldb python-psycopg2 python-sqlalchemy cd /usr/local/src/a2billing/CallBack easy_install callback-daemon-py/dist/callback_daemon-1.0.prod_r1527-py2.5.egg

Install the init.d startup script:

cd /usr/local/src/a2billing/CallBack/callback-daemon-py/callback_daemon/

For Debian:

cp a2b-callback-daemon.debian /etc/init.d/a2b-callback-daemon

For RedHat:

cp a2b-callback-daemon.rc /etc/init.d/a2b-callback-daemon chmod +x /etc/init.d/a2b-callback-daemon

Make sure the daemon starts:

For Debian:

update-rc.d a2b-callback-daemon defaults 40 60

If you need to remove the daemon in the future run:

update-rc.d -f a2b-callback-daemon remove

For RedHat:

chkconfig --add a2b-callback-daemon service a2b-callback-daemon start chkconfig a2b-callback-daemon on

Step 10: Enable monitoring

General system monitoring via IVR is available from version 1.7, the new AGI a2billing_monitoring.php provides access to an IVR where monitoring tasks can be configured via the new Monitoring Menu under Maintenance.

SQL queries can be performed and shell scripts can be invoked. Place your scripts under /var/lib/a2billing/script/

Step 11: Security features via IVR (Monitor account and locking calling card)

Two new IVR menus are now available via the main a2billing.php AGI. The menus needs to be enabled setting the variables in the agi-conf menu (GUI system settings)

Locking Options IVR menu ivr_enable_locking_option = true (default: false)

Monitoring your Calling Card IVR menu ivr_enable_account_information = true (default: false)

In some steps minor modifications were included:

1. The link in the svn command does not work; I downloaded manually /usr/local/src/ instead

$ cd /usr/local/src

$ sudo wget https://github.com/Star2Billing/a2billing/archive/master.tar.gz

$ sudo tar -zxvf master.tar.gz

Caution: remember that from now all the commands which contain A2Billing in the path need to be substituted by: a2billing-master

2. . In *step 2,* I had to use mysqladmin because there is nowhere to find the default password for the root user at mysql (other issues with mysql passwords are provided with a solution here: http://www.powerpbx.org/content/a2billing-install-guide-v2)

$ sudo mysqladmin -u root password mya2billing

3. When installing the databases (./install-db.sh) answer the following:

Enter Database Name: mya2billing

Enter Hostname: localhost

Enter UserName: root

Enter Password: {mysql-root-password...not a2billing db password}

4. In Step 2, copying the sounds give an error, because in the version it contains the relative path so you need to execute while being in /usr/local/src/a2billing-master/addons/sounds so:

$ cd /usr/local/src/a2billing-master/addons/sounds

$ ./install_a2b_sounds_deb.sh

5. In Step 2 I prefer the option of using a symbolic link and I added the following:

$ ln -s /usr/local/src/a2billing-master/AGI/a2billing_monitoring.php /usr/share/asterisk/agi-bin/a2billing_monitoring.php

Additionally I gave Asterisk ownership of the two symbolic links:

$ chown -Rf asterisk:asterisk /usr/share/asterisk/agi-bin/a2billing.php

$ chown -Rf asterisk:asterisk /usr/share/asterisk/agi-bin/a2billing_monitoring.php

After having configured extensions.conf and the cronjobs, some additional tasks can be done:

6. Creating the log files and given Asterisk ownership of them:

$ mkdir -p /var/log/a2billing

$ touch /var/log/a2billing/cront_a2b_alarm.log

$ touch /var/log/a2billing/cront_a2b_autorefill.log

$ touch /var/log/a2billing/cront_a2b_batch_process.log

$ touch /var/log/a2billing/cront_a2b_archive_data.log

$ touch /var/log/a2billing/cront_a2b_bill_diduse.log

$ touch /var/log/a2billing/cront_a2b_subscription_fee.log

$ touch /var/log/a2billing/cront_a2b_currency_update.log

$ touch /var/log/a2billing/cront_a2b_invoice.log

$ touch /var/log/a2billing/cront_a2b_check_account.log

$ touch /var/log/a2billing/a2billing_paypal.log

$ touch /var/log/a2billing/a2billing_epayment.log

$ touch /var/log/a2billing/a2billing_api_ecommerce_request.log

$ touch /var/log/a2billing/a2billing_api_callback_request.log

$ touch /var/log/a2billing/a2billing_api_card.log

$ touch /var/log/a2billing/a2billing_agi.log

$ chown -R asterisk:asterisk /var/log/a2billing

7. Add some rotation to the logs:

$ cd /etc/logrotate.d

$ nano -w a2billing

Include the following:

/var/log/a2billing/*.log {

weekly

missingok

rotate 4

sharedscripts

postrotate

endscript

}

8. Enable SSL using the default certificate for admin:

$ sudo ln -s /etc/apache2/sites-available/default-ssl /etc/apache2/sites-enabled/000-default-ssl

$ sudo a2enmod rewrite

$ sudo service apache2 restart

Install Asterisk RealTime

That was the first phase of installation and configuration of Asterisk and A2Billing. Now let's configure Asterisk to communicate with A2Billing in real time.

1. Install the package that allows Asterisk to communicate with the Mysql server

$ sudo apt-get install asterisk-mysql

2. If everything went fine check that cdr_addon_mysql.so module is loaded.

CLI> module show like mysql

Module	Description	Use Count
res_config_mysql.so	MySQL RealTime Configuration Driver	0

cdr_addon_mysql.so MySQL CDR Backend 0

app_addon_sql_mysql.so Simple Mysql Interface 0

3 modules loaded*

CLI>

3. Configure /etc/asterisk/res_config_mysql.conf (under [general]) with the same data as that included in /etc/a2billing (dbname, dbuser, dbpass, dbport and dbhostname in /etc/asterisk/res_config_mysql.conf must match with the values in, dbname, user, password, port and hostname in /etc/a2billing)

[mya2billing]

dbhost = localhost

dbname = a2billing

dbuser = a2billinguser

dbpass = mya2billing

dbport = 3306

dbsock = /var/run/mysqld/mysqld.sock

The value in dbsock must match the socket value in /etc/mysql/my.cnf (depends on the distro) you can additionally check that the socket exists with ls, in my case:

$ ls -al /var/run/mysqld/mysqld.sock)

4. Then you need to add in /etc/asterisk/extconfig.conf the mapping under setting:

(The second parameter in each line must be consistent with the context in res_config_mysql.conf. In this case **general** in both, but it could have been any other.)

[settings]

sipusers => mysql,general,cc_sip_buddies

sippeers => mysql,general,cc_sip_buddies

iaxusers => mysql,general,cc_iax_buddies

iaxpeers => mysql,general,cc_iax_buddies

5. Restart Asterisk

$ sudo service asterisk restart

6. Step 4 can be confirmed by checking that these mappings are present in Asterisk:

CLI> core show config mappings

Config Engine: curl

Config Engine: sqlite

Config Engine: mysql

===> sippeers (db=general, table=cc_sip_buddies)

===> sipusers (db=general, table=cc_sip_buddies)

===> iaxusers (db=general, table=cc_iax_buddies)

===> iaxpeers (db=general, table=cc_iax_buddies)

7. And if everything has gone well, RealTime is also already up.

CLI> realtime mysql status

General connected to mya2billing@localhost, port 3306 with username a2billinguser for 19 seconds.

8. Once you have introduced users in A2Billing, you can see their info by using:

CLI> realtime load sipusers name XXXXXXX

9. If you want the peers registered via Asterisk RealTime when using "sip show peers", you need to include the following option within the [general] context in /etc/asterisk/sip.conf: rtcachefriends=yes

Configuring A2Billing

First steps

The first thing is to set up some global variables. It is important to do this at the very beginning as it may create problems later on.

1. Go to: System Setting – Global List

2. In the options above set "Select Group" as "Global"

3. Edit the following (clicking on the pencil):

Base Currency: zar (to enter a valid one, follow this: http://sysadminman.net/blog/2012/setting-a2billing-base-currency-4532)

Server GMT: GMT+02:00

Base Country: ZAF (http://en.wikipedia.org/wiki/ISO_3166-1)

Asterisk Version: 1_8 (or the one you are using)

It is now important to follow the steps in http://sysadminman.net/blog/2012/setting-a2billing-base-currency-4532 (Billing – Currency List – Update – Click Here to Update Now), so when we check the currency we have entered in Global Settings, the exchange rate is 1.000000.

You need also to modify the Asterisk version in agi-conf:

1. Go to: System Setting – Global List.

2. In the options above set "Select Group" as "agi-conf1".

3. Edit the following (clicking on the pencil):

Asterisk Version: 1_8 (or the one you are using)

Set up the rates

1. PROVIDERS – Providers - Add Provider (Optional)

2. PROVIDERS – Trunk

Delete any existing Trunk

Add Trunk

Provider (the one created)

Add/Remove prefix, in case you need to remove any code preliminary code required by Asterisk to route here or to add any prefix that is required for assigning this call to a given rate (see below):

Provider Tech: SIP

Provider IP: enter the context in extensions.conf that will route the calls to the provider.

Maximum Connections: This can be used to provide some sort of security.

3. RATES – RateCard – AddRateCard

RateCard: The card must be associated to a RateCard.

Make sure that the Start Date and Expiry Date exist.

DNID can be used to assign this RateCard when a specific number is entered.

CallerID can be used to assign this RateCard when the CallerID is a specific one.

4. RATES – Rate – AddRate

Dial Prefix: This is the most important parameter, it has to exist a rate to match the number dialled to pass through A2Billing. If your provider charges you different prices to different destinations you will have to create different rates.

Destination Prefix: This is just a label for the CDRs.

Set the Buying and Selling rates and related parameters accordingly for your case.

Make sure that the start and expiry dates exist.

Trunk: The rate must be associated to a trunk.

Note: you can import Rates from a csv file; see Importing Rates section.

5. RATES – Call Plan – Add Call Plan

A call plan is a collection of RateCards. You need to create one.

Once the call plan is created you need to edit it to attach RateCards to it. So, click on edit the Call Plan, select the RateCards you want to Add and click on the Add button. Do not forget to Confirm Data.

6. CUSTOMER – Add

The UserName given is a random number generated by A2Billing for security reasons and cannot be modified.

Apart from the personal info, important to include one Call Plan (the user must used at least one of the Call Plans created). It is also important to consider the Simultaneous Access Parameter. In my case I have set it to individual for security reasons because I am not expecting multiconferencing in this scenario.

If the previous steps where done correctly, you can use the Rate Simulator to see how much a given customer would be billed for a given call. Or, more precisely, for how long he/she can talk for with a given amount of credit.

Configuration of Asterisk in A2billing Server

A2Billing interacts with the configuration files in Asterisk in order to route the calls properly. The most important interaction is in the definition of the trunk, where you specify the technology and its name. In the SIP/IAX configuration file the there needs to be a context with the same name, which contains the information about how that channel is going to be used.

If an Outbound Trunk is defined to use SIP for a trunk called trunk_out, as in the screenshot, then the following needs to appear in sip.conf.

[trunk_out]

Define the operation of the trunk, including the credentials from the VOIP provider:

Type = peer

host = XXXXXXXX

username = XXXXXX

secret = XXXXXXX

auth = XXXXXXX

context = default

dtmfmode = rfc2833

disallow = all

allow = gsm

insecure = invite

qualify = yes

nat = yes

If the Asterisk clients making the calls are behind a NAT, including nat=yes and qualify=yes when defining the trunk helps the calls to go through.

Configuration on the mesh potato

1. In the A2Billing server go to CUSTOMERS – VoIP Settings

In this screen you can see the credentials that need to be configured in the A2Billing clients: a) ACCOUNTCODE and b) SECRET

2. In the mesh potato open /etc/asterisk/sip.conf

Add the following to the [general] context:

register=> ACCOUNTCODE:SECRET@a2billingIP

For instance, for the screenshot above you need to include:

register=> 6613813819:96819rdpagzy5fylk0eo@10.130.1.1

Additionally include the following context:

[trunk-villagetelco]

username = 6613813819

type = friend

secret = 96819rdpagzy5fylk0eo

host = 10.130.1.1

context = default

disallow = all

allow = gsm

trustrpid = yes

sendrpid = yes

canreinvite = no

insecure = very

permit = 10.130.1.1

3. In the mesh potato open /etc/asterisk/extensions.conf

;;C-O-N-F A2Billing /you will communicate with A2billing by entering 0000

exten => 0000.,1,Dial(SIP/trunk-villagetelco/${EXTEN})

4. Go to the web interface of the MP, go to Advanced, and within the Asterisk configuration tick the option "Enable NAT", save and reboot the router. Alternatively you can go to /etc/config/secn and edit option 'enablenat' '' to option 'enablenat' 'checked', and reboot your router.

5. At this point, your MP is ready to make outbound calls to the destinations specified in the Rates above. In order to make them real, the configuration of the Asterisk in A2Billing needs to be enabled to route the calls to your provider properly.

Adding incoming calls via A2Billing

In the A2Billing web interface you go to INBOUND DID:

1. Add a new DID with the number given by the provider and configure the parameters as you wish.

2. Add a Destination SIP/4000@10.130.1.252 and link to a given customer and to the newly created DID. Then, make sure that every is 'yes'and validated.

In the MP

I had to include this on the trunk in sip.conf (nothing on extensions.conf because that extension was already there):

context = default ; in the context in extensions.conf where the extension 4000 is defined

nat = yes

localnet = 10.130.1.0/255.255.255.0

externip = 0.0.0.0

In A2Billing

In extensions.conf I added this to the [default] context:

exten => 0354798081,1,Goto(a2billing-did,${EXTEN},1)

exten => 0354798081,n,HangUp()

and created the following context for A2Billing to handle the call:

[a2billing-did]

exten => _X.,1,deadAGI(a2billing.php,1,did)

exten => _X.,2,Hangup

In sip.conf I have added this to the [trunk_out] trunk:

allow=gsm

Importing rates

Create a text file (which will save with .csv extension)

In each line we include the following 8 fields:

1. Prefix

2. Destination (tag)

3. Selling rate

4. Selling rate minimum duration

5. Selling rate billing block

6. Buying rate

7. Buying rate minimum duration

8. Buying rate billing block

Example:

0606;Vodacom;0.5;0;0;0.399;0;0

Once completed (and saved) you send it to the A2Billing server:

```
scp rates.csv linaro@10.130.1.1:/home/linaro/
```

Then in A2Billing web interface go to Rates Import and import, making sure you follow the order given above.