# Co-designing a Billing System for Voice Services in Rural South Africa: Lessons Learned

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## ABSTRACT

Access to information and communication technologies remains unaffordable for many in rural areas despite recent progress in providing voice services to remote communities. The sustainability of alternative technical solutions is a challenge, which can be addressed when local knowledge is taken into account during the design process. This research reflects on the process of co-designing a billing system for voice services provided by a Community Network in rural South Africa. Several payment methods were explored with users and operators of the Community Network, focusing on the legal, financial, technical and social feasibility - as well as constraints - of each method. Those methods that suited the community's needs were implemented and tested with stakeholders. The process revealed factors embedded in the provision of voice services by traditional voice operators in South Africa that prevent economically poor and illiterate users from fully benefiting from voice services. Solutions to these factors were explored with users and were implemented as a billing system. The system is currently being deployed in a rural South African community. Both the problems experienced and solutions proposed may inform similar initiatives.

## Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces; D.2.1 [**Software Engineering**]: Requirements/ Specifications

## General Terms

Economics; Human Factors

## Keywords

Billing system; Participatory Design; rural South Africa; VoIP; Community Networks


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## 1. INTRODUCTION

The rapid uptake of mobile phones by some of the poorest communities in Africa [1], has given access to information and communication technologies (ICTs) to many living on only a few of dollars a day [10]. This has had a positive effect on rural communities, since "*voice applications allow dispersed families to stay in touch, reducing vulnerability and isolation; improve the bargaining power of farmers; eliminate the middleman; and enable the development of nonagricultural economic activities*" [2, p.8]. Despite the increased access to communication provided by mobile network operators in rural areas of developing countries, the model they use presents constraints that limit the development outcomes available to underprivileged areas [25]. Communication remains unaffordable to most inhabitants of rural areas, given the increased cost they incur compared to their urban counterparts [5]. Cost is thus the biggest factor that prevents the poor from accessing ICTs [10].

During the last decade the Computing for Development community has aimed to provide more affordable voice communication options to rural communities. These include Wi-Fi and voice over Internet Protocol (VoIP) services provided in India [21] and Peru [12], and the deployment of Community Cellular Networks in Indonesia [13]. Replicating these successful ICT interventions presents unique challenges due to factors such as culture, language, ethnicity and socioeconomic status [3].

Another major challenge of these projects is to find a source of revenue to financially sustain them [15]. Because VoIP services greatly reduce the costs associated with voice calls [16], they can, in addition to reducing the cost of communication, provide some revenue to maintain the infrastructure by adding a small margin to the fees paid to VoIP upstream providers, which have detailed billing systems for calls made from a given network. Thus, if a similarly detailed system is not deployed at the network end, accounting for this margin becomes difficult. Additionally, if someone abuses the system, the VoIP provider will still claim the cost, even if rural network operators do not collect payment for calls. Many billing systems are available. However, they may not be sensitive to the context in which they are used. Gow and Vasant argue that local participation influences positive payment collection mechanisms in development projects (cited in [8]). This is corroborated by Luk, who highlights the importance of co-designing a business plan with the involvement of financial donors, implementers and beneficiaries (i.e. local communities) (cited in [7]).

This paper presents a participatory design (PD) approach to research the customisation of a billing system for a Community Network in rural South Africa. The value of this approach is its sensitivity to the context and its emphasis on promoting active community participation to ensure the project's sustainability. Additionally, the process revealed factors embedded in the provision of voice services by mobile network operators in South Africa that prevent economically poor and illiterate users from fully benefiting from voice services. Both the factors revealed and solutions proposed may inform similar initiatives.

The paper is organized as follows: Section 2 provides the context of the project. Section 3 considers billing systems used in similar endeavours. Section 4 describes the research approach. Section 5 presents the results, and in Section 6 the results are discussed and conclusions are drawn.

## 2. CONTEXT

In 2012 the authors undertook a feasibility study to determine whether it would be possible to create and implement a low-cost telecommunications network operated by community members in a rural community to reduce high local communication costs. The community in which the case study was conducted, Mankosi, is located on the Wild Coast of the Eastern Cape in South Africa and consists of 12 villages scattered over a 30-square-kilometre area. Families of up to five adults and seven children live in homesteads: clusters of thatched, mud-brick rondavels (See Figure 1), an occasional tin-roofed 2-room dwelling, an animal corral and a garden for subsistence crops. Households survive on $60 to $150 per month, from government grants and payments from family members who temporarily migrate for work. A Tribal Authority - a traditional political institution comprising a Headman and 12 Sub-headmen (one from each village) - governs the community [6]. Most community members speak isiXhosa, 70.2% reported that they could read and 71.6% indicated that they could write isiXhosa easily. This contrasts with the 46.7% and 35.6% of community members who responded that they could read and write English easily, respectively. Additionally, 32.5% of the respondents reported their ability to read English as "Not at all". With regards to the level of schooling, only 13% of the population had matric[1] or a higher level of education[2].

Initially, this telecommunications initiative aimed to provide free intra-network voice calls to members of the community with the idea of later charging a small fee for breakout calls to external phones to assist with the maintenance of the 11-node Community Network. Eventually the income would also be used to finance other community upliftment initiatives. According to a needs assessment survey carried out in April 2012, a faster and higher uptake of the local service was expected [17]. However, data collected in June 2013 showed very limited use of the network [18]. It was found that the Tribal Authority had not informed the community that the communication service was intended for public use, and so community members did not use it. This situation was resolved by conducting several meetings with the community.

[1]Completed secondary schooling.

[2]Results from a stratified random sampling survey conducted in all villages which have not yet been published.

**Figure 1: Village view.**

The population was informed of the service at a general community meeting and at subsequent village meetings in July and August 2013. From these meetings it became clear that the envisioned local call usage would be more sporadic than expected, since calls could not be made to mobile phones.

Given the technical feasibility of providing a service to mobile phones, a socio-economic plan was devised. Based on Bidwell et al.'s experience, to generate revenue to sustain the communications network, the initial design of a wireless station's power supply included two cigarette lighter sockets for the charging of mobile phones [6]. However, once again the Tribal Authority did not inform the community that this service was available. Further community meetings resolved the issue [18], and since then the service has collected more than R9,000 ($900). Part of this money has been used to finance equipment necessary for an Internet connection, which is required to allow calls to mobile phones from the call stations installed throughout the community. The rest of the money has been used to maintain the network.

In parallel, in order to regularise service provision, a not-for-profit cooperative has been established. Community members have mandated the cooperative board to manage the services provided for their benefit. Thus, all the revenue from the service will be reinvested for local development projects decided on by cooperative members. The cooperative board, which includes members from the local Tribal Authority, is responsible for deciding the cost of the services and collecting the revenue for charging mobile phones and making breakout calls to phones in other networks. The questions that arise are: what method of payment for breakout calls would be most suitable for the community and make the network sustainable, and what kind of billing system is needed to address the needs and expectations of the community?

## 3. BILLING SYSTEMS RELATED TO THE RESEARCH

Three billing systems relevant to this research were considered in terms of their technical feasibility in rural areas:

1. The Foli Kodjo Gaba system was designed as a student project. The system billed VoIP services using A2Billing on SWITZERNET$^{TM}$ - a network that al-

lows calls to anywhere in the world at low cost [11]. The billing system used A2Billing open-source software to charge Internet calls in a post-paid scenario.

2. Sen et al.'s system billed VoIP services made on long distance Wi-Fi links in remote rural areas. Public calling offices (PCO) were built in villages to provide the service. For breakout calls to the public switched telephone network (PSTN), an external PCO was required. It had its own billing machine that metered outgoing calls based on the call destination. Once the call was concluded, the billing machine printed the bill and the operator communicated the bill to the operator at the village site, who would then collect the cash from the caller [21]. In this project the community was not involved in the design of the system.

3. Soto et al.'s model was designed to collect revenue for solar electricity delivery in Kenya and Malawi. It is based on a voucher system where users use a voucher code to interact with the server via SMS [23].

Some aspects of these systems informed the design of the billing system presented in this paper: the voucher system of Soto et al. [23] and the billing mechanisms (post-paid system of Gaba [11] and the printed bill of Sen et al. [21]) reported were used in discussions with the users (see Section 4.1).

# 4. METHODOLOGY

The methodology used during the research process was Participatory Design (PD), which involves multiple participants, i.e. both the designers and users of the system, collectively investigating, understanding and reflecting on establishing, developing and supporting a system. The designers learn about the users' situation while the users try to articulate their requirements to the designers [22]. PD "*is thought to result in higher quality of system requirements, higher system quality, a better fit between the system and users, and higher user or customer satisfaction*" (Kaza, cited in [7, p.6]), which leads to the sustainability where PD is taking place [7].

When applying PD to ICT for Development (ICT4D) projects, Dearden and Rizvi recommend that researchers "*recognise participation as going beyond simply engaging people as informants in design. Instead, participation must be framed as an ongoing engagement that supports learning and development of a wide range of knowledge and transferable skills*" [8, p.4]. Bidwell et al., who worked in the same community as we do now, recommend that technical solutions should match local practices and should involve accounting for factors that shape appropriation [5]. In order to apply these recommendations, the authors spent long periods in the community–the lead researcher lived in Mankosi for 15 months–to establish a relationship with community members before embarking on the PD of the system. Additionally, following Bidwell et al.'s example, a team of local researchers (people who were born in the community) acted as moderators between researchers and community members [5]. Being well-versed in the needs and culture of the local community, they were a great help during the design process.

For this project the researchers used a phased PD process (see Figure 2). The investigative phase involved investigating users' needs and discussing the practicality of the various possible systems with the community. In the design phase, the prototype was designed. Finally, in the implementation phase, prototypes were implemented and demonstrated. Throughout the PD process, users formed an integral part of the design team.

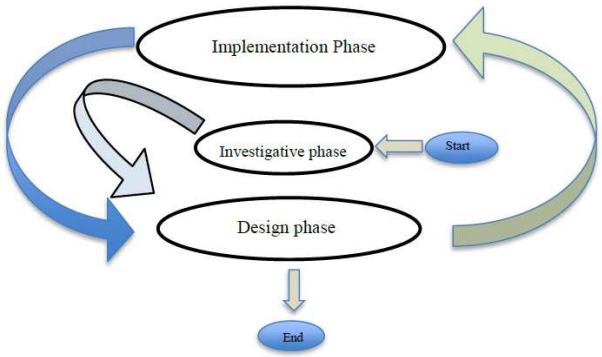


**Figure 2: Phased PD process.**

## 4.1 Investigative Phase

To explore and integrate the needs, perspectives and financial capacities of the community, five scenarios - each with a different payment method - were explored. These scenarios resulted from interacting with users and studying the literature.

- *Scenario 1* was based on a prepaid payment system where each user would have a personal calling account and a password to use as authentication before each call.

- *Scenario 2* was based on a calling-card system. The user purchases a calling card or voucher of a certain value. The code on the voucher is entered before dialling a number.

- *Scenario 3* is similar to a public phone shop and involves a prepaid payment system where the user pays the operator the amount she/he wants to spend when using the system. Once the call is terminated the call is charged and change is returned to the caller if applicable.

- *Scenario 4* is similar to a public phone booth. The user can submit an initial amount, but can add an additional amount to extend the call.

- *Scenario 5* is a post-paid payment system where the user uses the system and the cost is calculated once the call is completed.

In order to allow stakeholders to make an informed decision about each payment scenario, the following feasibility criteria were considered and discussed with them [17]:

- *Legal feasibility*: In South Africa a licence is needed for the deployment of a telecommunications infrastructure. A licence exemption can be obtained if the infrastructure is only used by members of the same organisation. Thus, for the chosen scenario proof should be provided that all network users are members of a

cooperative established to provide the telephone services.

- *Financial feasibility*: The costs of each scenario had to be calculated, e.g. the costs of an operator if one was needed, a call meter, and a printer, ink and paper for the voucher system.
- *Technical feasibility*: The technical challenges 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.

A workshop and interviews were organised with stakeholders (i.e. the local network's operators and its future users) to discuss how the different scenarios would operate and ascertain their preferences about which would best suit their needs in light of the feasibility constraints mentioned above. The basis for choosing a scenario was that the user should be able to make a call from any of the 11 node stations on the network. Furthermore, the interaction between the user, the operator and the billing system preferably had to be done via dual-tone multifrequency signalling (DTMF) using the phone's keypad . Under exceptional circumstances operators should be able to interact with the web interface of the billing system using a laptop.

### 4.1.1 Focus group meeting with local operators

The so-called local operators (LOs), i.e. the owners of the houses where the station nodes are housed, were actively involved in the design of the business model, because they would be responsible for collecting the money for the network services. The focus group meeting with LOs where the payment schemes were discussed was held at the Headman's house.

### 4.1.2 Interaction with users of the network

The researchers visited villages in the community to meet with community members and future users of the system so that when they were interviewed they would feel comfortable in the researchers' company and would be able to speak freely. Twenty-five people (four males and 21 females) from four villages were interviewed using unstructured interviews. Probes were used to start the conversation and further questions that arose during the course of the interviews were based on the interviewees' responses to aspects of the design. To avoid creating unrealistic expectations or confusing the interviewees, the probes emanated from the scenarios and were familiar to the interviewees, since most of them are mobile phone users. Judgemental sampling was used to select interviewees. The number of men and women interviewed was dependent on respondents' availability at the time of the interviews.

## 4.2 Design Phase

The design phase applied the outcomes of the investigative phase using the various scenarios. Only two of the five scenarios were included in the initial prototype. Three billing applications were explored to determine the one most suitable for the network: ASTTP, VBilling, and A2Billing. The

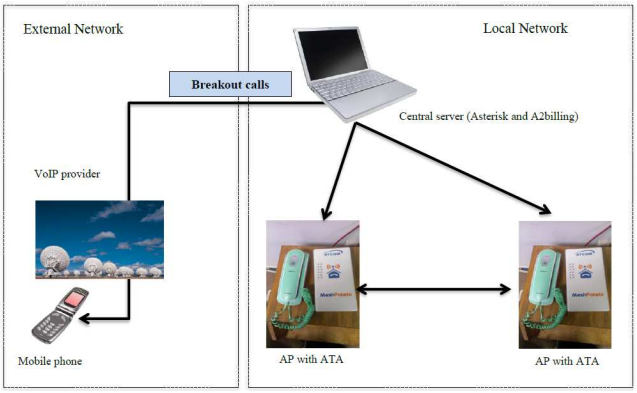


**Figure 3: Description of the hardware of the system.**

A2Billing open-source system was eventually chosen because it is widely used in similar implementations and integrates seamlessly with Asterisk via the Asterisk Gateway Interface (AGI). It is also well documented and supported online by an active forum of users and developers.

A2Billing provides telecoms customer management with flexible inline rating and billing of calls and services in real time [24]. It allows both prepaid and post-paid payment schemes, with the possibility of topping up the latter manually or via vouchers. Additionally, it provides optional built-in interactive messages to inform the user about his/her remaining credit, the rate for a given destination, and the maximum duration of the call for a given credit and destination. Various payment schemes and combinations of audio files using different AGI configuration files per extension dialled can be used. The A2Billing back-end consists of a series of MySQL tables that contain information about customers and interactions with each other during a call.

Before presenting the community with a prototype of the billing system, it was tested in a laboratory off site. This involved functionality and usability testing. The designed prototype was then demonstrated, discussed, refined and tested in workshops with interested members of the community.

Each of the 11 access points in people's houses is a Mesh Potato [20] and contains an Asterisk server that is responsible for routing from an analogue phone attached to it via an analogue telephone adapter (ATA), see Figure 3. For internal calls between analogue phones, calls are routed independently. When the destination of the call is external to the network, the local Asterisk server registers with the central Asterisk server, which is responsible for dealing with the simultaneous calls that may occur in the network and then routes the call via the Internet to a VoIP provider. The VoIP provider routes the call to the final destination which can be a mobile phone or landline anywhere in the world. The central Asterisk server hands the call to A2Billing to start the billing timers in order to bill the call before handing it back to Asterisk for routing to the VoIP provider. During the call A2Billing keeps track of the relevant parameters. For instance, in the case of a prepaid customer, it will automatically hang up the call when the credit reaches zero.

## 4.3 Implementation Phase

### 4.3.1 First iteration

Once the system was designed, two focus group meetings with LOs were held at the Headman's house to test whether the design met with their approval according to their requirements. One of the results was a request that similar workshops should be held in each household to allow other, especially younger, family members to interact with the system. An additional workshop was organised for users interviewed during the investigative phase at which point they were invited to test the prototypes for the billing system. Only five of the ten community members who were invited actually attended.

### 4.3.2 Second iteration

As requested, workshops were held in each of the households that hosts an access point. In total, 40 people attended and participated in these workshops, which included ten of the cooperative board members and younger members of the households.

# 5. RESULTS

## 5.1 Investigative Phase

### 5.1.1 Choice of scenarios

The feasibility of each scenario was analysed and carefully studied. A detailed description of the process is given below.

*Scenario 1* (prepaid individual account) was legally feasible, because users would have to register to obtain their usernames and passwords. Thus, 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 can be done via interactive voice response (IVR) messages. However, socially it was discarded almost from the beginning. 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 IVRs and authentication would be difficult and might 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 too complex.

*Scenario 2* (vouchers) was considered to be simple and flexible by LOs. Once the voucher was purchased and activated at the phone where it was bought, for a specific household's accounting purposes it would not need any follow-up by the LOs. Users were also positive and felt that it would allow them to buy a voucher whenever they had the money. 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 would 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 either written out or printed. This would not be too expensive because there was partnership between the cooperative and a local non-governmental organisation where one of the cooperative board members works. To satisfy the legal requirement, it was decided to keep a register of users in each household. This could be updated at any time; thus if an illiterate person could not update the register, the person's name could always be added later.

*Scenario 3* (prepaid with change and no addition) was the users' choice, because it would allow them to make a call for whatever amount of money they had available. It would require more input from LOs, who would need to have change available and be able to return change to the user. The LOs were concerned about the fact that the system would only register the user's credit and not the change due to them, possibly resulting in their contributing more money than the amount actually collected. They were assured that this would not be the case. They also proposed that if enough revenue is generated by the system, it would be possible to hire someone to do these tasks. To return the necessary change was considered an issue by the researchers. However, most users felt they would forfeit change of up to 50 cents if this was not available. Technically, this scenario required 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 with change and addition) 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 added cost associated with the time necessary to keep the call on hold while the user is topping up (because it is an internal process, the external VoIP provider is not aware of it and will bill the call accordingly). Thus, provided that the cost to establish the call is zero and change is provided, 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 is not ideal, because the conversation would be discontinued, but solves technical issues associated with its full implementation and the additional costs for the user.

*Scenario 5* (post-paid) was unanimously rejected. Both users and LOs felt that it was difficult to know what a call would cost and, once made, the 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.

Thus, only Scenarios 2 and 3 were implemented in the design of the prototype.

### 5.1.2 Additional requirements

During the workshops and interviews carried out to decide on a payment scheme, both users and LOs raised concerns about aspects of the system and asked to have additional requirements included in the final implementation.

The LOs' main concern was that people would be able to make calls to mobile phones without paying. It was emphasised during workshops that the VoIP provider would claim the cost of the call irrespective of whether the LOs had collected the money or not, so they would have to cover the cost if people abused the system or had no money but needed to make an emergency call. They indicated that they wanted the accounting to be correct and clear "*at all times*".

To increase the transparency of the business model, the researchers suggested that an IVR could be implemented to inform users of the total amount collected by the household for a particular period. The LOs opposed this idea and felt that such information should only accessible to them, because it would pose a security risk if everyone knew the amount of money kept in a household at any given time. For transparency they could provide financial statements to the community at their annual cooperative meeting once the money was safely deposited in the bank.

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 a call, and 17.4% both before and after a call. However, only 4.35% knew how much they were currently paying per second for calls. Thus, 92% of 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, once it was explained that this could be done without additional costs to them.

## 5.2 Design Phase

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. Two AGI configurations where created within A2Billing, one for each scenario. Additionally, a test customer account was created and its VoIP credentials introduced in a Mesh Potato for testing. 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 is not complex (see Figure 4). 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. 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 are asked to activate the voucher (introducing the voucher number, but not making a call) before handing it to the user. As described below for Scenario 3, an extension can be used to listen to the cost of the last call made and the remaining credit in the voucher.

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 can 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 (see Figure 5). 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 is then handed to the user to dial the next extension. The maximum duration of the call is read out to the user before he/she can dial the number he/she wants to call. On completion of the call the remaining credit is stored as an internal variable and the credit on the VoIP account is set to zero. To determine the cost of the call, a third extension can be entered, and the cost of the last call made and the change to be received is then read out.

Additional codes for checking the amount to be paid to the VoIP provider for a given month and the money collected for 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. This group's extensions are 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.

## 5.3 Implementation Phase

After testing it with the stakeholders, it became obvious that the implementation of Scenario 3 involved too many steps, and both LOs and users found it too complex. It was therefore redesigned to only use a single extension. Then, after entering the amount the user wants to spend on a call, it is read out to the LO for confirmation. In order to allow for privacy, a period of silence is introduced between the step where the operator confirms the credit and the one where the user can dial a number. Once finished the user can use the same extension and he/she is prompted with the option to either use the remaining credit - which is previously read out together with the cost of the last call - or to ask for the change (see Figure 6).

The LOs requested that the option to enter credit be protected by a PIN code and be reserved for their use only. An existing extension in the Mesh Potato that allows a user to modify the PIN number was adapted so that it is read out in isiXhosa to allow each household to modify the PIN if necessary. This PIN is also used for the other administrative tasks previously described.

Older LOs were satisfied with the messages and the fact that it was possible for them to listen to a message more than once, whereas younger participants were keen to explore ways of speeding up the process. This was satisfied by using the Read() application provided by Asterisk, which plays an audio file while waiting for input from the user. Once the input is completed it moves to the next priority in the dial plan, stopping the audio if necessary and thereby allowing for shorter interactions with the system.

Because these changes were implemented between interactions 1 and 2, it allowed us to get some additional feedback. Although some of the older people testing the system struggled with the new implementation of Scenario 3, others were able to complete it successfully. They stated that "*it was A,B,C*", as a way of explaining that they just needed to fol-

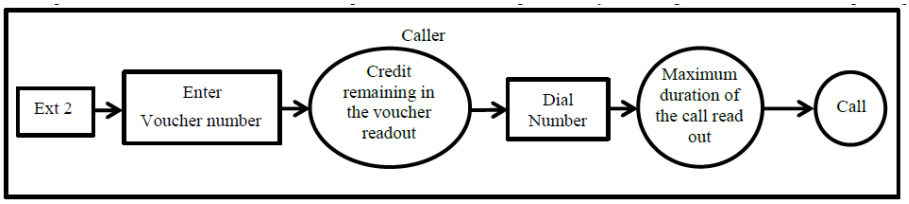


**Figure 4: Scenario 2.**

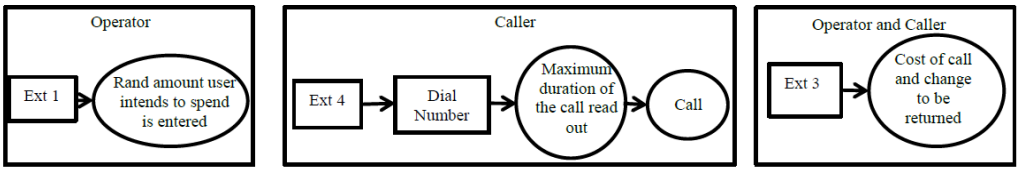


**Figure 5: Scenario 3.**

low the prompts. Those who struggled mentioned positively that they were not required to remember the procedure, because it was repeated every time, so they would improve with practice. In some workshops some participants, especially younger ones, refused to engage with the testing process because they thought the audio files played were in English and they did not want to show in public that they could not interact with them.

The slower pace of older operators also highlighted the need to increase the timeouts allowed for A2Billing to enter the voucher number or the number to dial. The billing system automatically hangs up the call if a given time elapses, resulting in confusion because users did not understand what they had done wrong. Other source of confusion came from either not entering all the numbers of a voucher or destination number, or entering them incorrectly. Some struggled to identify the representation of a given number on the keypad.

Rather than the design of the billing system, the billing process was the main concern for both users and LOs. The former were worried that the informative messages would add to the total cost of a call. It was demonstrated to them that this was not the case. The LOs were concerned that the money collected might not match the amounts billed. When it was explained that this could only happen due to human error, the issue became who should be the person(s) in the house responsible for knowing the PIN. In households where several candidates were available, those who were considered more trustworthy and knowledgeable were appointed. This was also linked to demands for employment, especially from the youth. The cooperative agreed to accede to these demands if the system generated enough revenue.

## 6. DISCUSSION AND CONCLUSION

The aim of co-designing this billing system was to fulfil both the needs expressed by the community to be able to call mobile phones through a Community Network and the requirement to be able to do so sustainably.

Although four sustainability criteria were considered (legal, financial, technical and social), only those payment scenarios that aligned with local practices and thus were socially feasible were implemented. Communication amongst local people is still mostly oral, so the billing system attempted to replicate oral communication by using IVRs. IVRs are considered to be a limited form of communication, since they do not capture the extra linguistic features of the orality of the Xhosa culture [4]. This may explain why some participants struggle to follow audio prompts, although challenges with IVR have been documented in other scenarios [14]. Nevertheless, the use of local voices emulating the flow of a conversation (and the functionality for repeating messages) has been reported as being very valuable by future users of the system. Even those who consider themselves less literate could interact easily with both billing system scenarios.

This contrasts strongly with the methods used by local mobile network operators (MNOs), who use English for IVR messages. It became apparent during the design of the billing system that this practice is experienced negatively by the mostly isiXhosa users. Another method of interacting with local MNOs is by means of unstructured supplementary service data, which requires users to understand written English. The pricing system of South African MNOs [9], is a further obstacle, which contributes to the lack of awareness of the cost of their services manifested by rural users. It is expected that providing exact information about costs will address this situation.

Additionally, it is further felt that the payment methods implemented for the billing system would target other challenges experienced by users while using the services provided by the MNOs. Specifically, Scenario 3 targets those users who find difficult gathering the money necessary to purchase top-up vouchers. Unlike the rest of groceries and household items that can be purchased in the community, top-up vouchers are one of the few items that can not be purchased with the credit line that local shops allow clients based on their monthly government grants. Scenario 2 allows users to purchase vouchers that will not expire before the purchased amount has been used. Furthermore, providing the user with the maximum time to call (once the destination and the maximum credit are known) has been also found to help the economically poor to make more informed decisions to plan their conversations. These options, together with the cheaper voice services provided by the cooperative, are expected to improve access to voice services in rural ar-

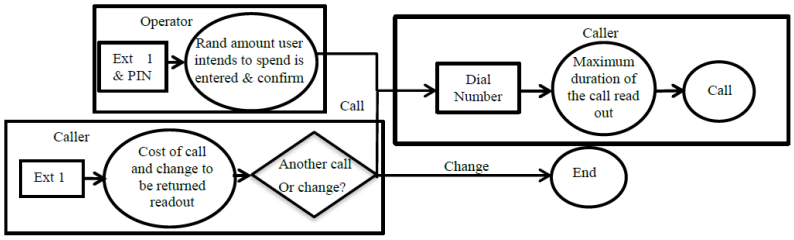


**Figure 6: Scenario 3 revised.**

eas. These findings are of wider application than to network infrastructures similar to the ones described here - VoIP-oriented wireless mesh - because they could inform other efforts to provide affordable voice services through bottom-up Community Cellular Networks [13]. After being adapted to their corresponding localities, similar solutions to those presented here could be easily incorporated into their VoIP servers.

Despite the benefits of using oral communication, some sort of written support mechanism could improve the user experience. The inability to see the numbers dialled led to many mistakes during testing. Also, users have to carry a charged mobile phone with them to access the numbers they want to call, because very few people can remember them. Thus, in similar initiatives an analogue phone with a screen would be worth exploring in the future. It may contain numbers in memory as well, although this needs to be considered carefully because it may cause some privacy concerns. Alternatively, this could be solved by the likely arrival of Wi-Fi enabled phones in the mid-term, because the network infrastructure deployed offers the possibility of using the system designed to make calls from SIP clients installed on them [20]. If this is the case, Scenario 2 (vouchers) could be used with Wi-Fi enabled phones, whereas Scenario 3 (prepaid) presents more difficulties, particularly in terms of people abusing the system. A solution would be to implement individual accounts, as in Scenario 1. Although this idea was originally rejected, it may become more acceptable with time as users become better acquainted with personal accounts while using the Internet.

In addition, the design process served to corroborate older people's perceptions that younger people were more technologically literate and so were important for the success of technologically driven initiatives [19]. Young participants' ability to understand the payment scenarios more quickly and their desire to minimise the time required for introducing the credit bought by the user confirmed this perception. The process also revealed the lack of employment opportunities among the youth in the area. If uptake of the voice services is high, the cooperative could offer jobs to some of them.

During the design process, users and LOs showed different degrees of involvement, particularly during the testing of the prototype. While only some potential users attended the workshop [3], LOs were very involved in the second workshop. This could be explained by the different type of relationship established with each group and their level of understanding [8]. While we met at least monthly with the LOs, we interacted with users for the first time only during the investigative phase. Equally, LOs had been taking strategic decisions about the project for more than two years, while users were much less involved and may not have developed the confidence needed to contribute more extensively.

The long-term engagement with the community, especially the LOs, provided researchers a better understanding of their practices. This allowed researchers to propose leaving the phones with zero credit when they were idle to prevent abuse of the system and introducing the double-checking mechanism for both credit and change. Neither solution was requested by either users or LOs. Thus, although in the strict sense of participation in the system design, users and LOs did not provide all the requirements that the final system included, this process supports Harris's belief that "*through community involvement comes understanding, and with understanding comes public support and commitment*" (Harris et al. cited [7, p.9]). LOs' commitment during the testing of the system is also expected to increase their sense of ownership of an externally initiated project and to lead eventually to full local management of the network and its services.

When consensus could not be reached, the opinions of LOs weighed more than those of users, since LOs had a better understanding of the system due to their extensive involvement in the process. This confirms findings suggesting that the involvement of influential people in the community creates space for social acceptance [7]. We believe the system is now acceptable to the local community, since most of their recommendations were implemented in the final system and that, in the words of a Local Researcher who was present in all the stages of the co-design process, "*people see this as a good thing that will help them with their life styles and the money they use in their phones. They wish it to happen now*". The system incorporates their oral culture and is sensitive to their literacy level, their financial situation, the economy of the community, and community members' trust in the structures already in place. Thus, most of the local factors that shape appropriation and uptake were considered, factors that "*would not have emerged without co-generating methods and interpreting data with community members*" [5, p.117].

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## 8. REFERENCES


[1] J. Aker and I. Mbiti. Mobile Phones and Economic Development in Africa. *Journal of Economic Perspectives*, 24(3):207–232, 2010.

[2] M. Andrianaivo and K. Kpodar. ICT, Financial Inclusion, and Growth: Evidence from African Countries. Technical report, International Monetary Fund, Apr 2011.

[3] Y. Anokwa, T. Smyth, D. Ramachandran, J. Sherwani, Y. Schwartzman, R. Luk, M. Ho, N. Moraveji, and B. DeRenzi. Stories from the field: Reflections on HCI4D experiences. *Information Technologies & International Development*, 5(4):101–116, 2009.

[4] N. Bidwell and M. Siya. Situating Asynchronous Voice in Rural Africa. In *Proceedings of Human-Computer Interaction - INTERACT 2013*, pages 36–53. Springer Berlin Heidelberg, Sep 2013.

[5] N. J. Bidwell, M. Lalma, G. Marsden, B. Dlutu, S. Ntlangano, A. Manjingolo, W. D. Tucker, M. Jones, R. Robinson, E. Vartianen, and I. Klanpanos. Please call ME.N.U.4EVER: Designing for 'Callback' in Rural Africa. In *IWIPS'11 (10th Intl. Workshop on Internationalisation of Products and Systems)*, pages 117–138, 2011.

[6] N. J. Bidwell, M. Siya, G. Marsden, W. D. Tucker, M. Tshemese, N.Gaven, S. Ntlangano, K. A. Eglinton, and S. Robinson. Walking and the Social Life of Solar Charging in Rural Africa. *ACM Transactions on Computer-Human Interaction*, 20(4), 2013.

[7] S. David, A. Sabiescu, and L. Cantoni. Co-design with communities. A reflection on the literature. In *Proceedings of the 7th International Development Informatics Association Conference (IDIA)*, pages 152–166, Nov 2013.

[8] A. Dearden and H. Rizvi. Participatory IT design and participatory development: a comparative review. In *Proc. of the Tenth Anniversary Conference on Participatory Design 2008*, pages 81–91. Inidiana University, Oct 2008.

[9] E. Calandro and A. Gillwald and C, Stork. Africa Prepaid Mobile Price Index 2012: South Africa. *Research ICT Africa Policy Brief*, 1:207–232, 2012.

[10] L. Elder, R. Samarajiva, A. Gillwald, and H. Galperin. *Information Lives of the Poor. Fighting poverty with technology.* IDRC, Ottawa, Canada, 2013.

[11] F. Gaba. Projet de Semestre: SIP Billing. Technical report, Swizernet, Jun 2007.

[12] H. Galperin and F. Bar. The microtelco opportunity: evidence from Latin America. *Information Technologies & International Development*, 3(2):73–86, 2006.

[13] K. Heimerl, S. Hasan, K. Ali, E. Brewer, and T. Parikh. Local, sustainable, small-scale cellular networks. In *Proceedings of the 6th International Conference on Information and Communications Technologies and Development: Full Papers*, volume 1, pages 2–12. ACM, Dec 2013.

[14] Z. Koradia, P. Aggarwal, A. Seth, and G. Luthra. Gurgaon idol. In *Proceedings of the 3rd ACM Symposium on Computing for Development - ACM DEV '13*, Bangalore, India, Jan. 2013. ACM Press.

[15] C. Pade, B. Mallinson, and D. Sewry. An exploration of the categories associated with ICT project sustainability in rural areas of developing countries: A case study of the Dwesa project. In *Proc. of the 2006 Annual Research Conference of the South African institute of Computer Scientists and Information Technologists*, pages 100–106. SAICSIT, Oct 2006.

[16] F. Proenza. The road to broadband development in developing countries is through competition driven by wireless and internet telephony. *Information Technologies & International Development*, 3(2):21–39, 2006.

[17] C. Rey-Moreno, Z. Roro, M. Siya, J. Simo-Reigadas, N. Bidwell, and W. Tucker. Towards a Sustainable Business Model for Rural Telephony. In *Proc. of the III International Workshop on Research on ICT for Human Development*, 2012.

[18] C. Rey-Moreno, Z. Roro, W. Tucker, and M. Siya. Community-based solar power revenue alternative to improve sustainability of a rural wireless mesh network. In *Proceedings of the 6th International Conference on Information and Communications Technologies and Development: Notes*, volume 2, pages 132–135. ACM, Dec 2013.

[19] C. Rey-Moreno, Z. Roro, W. Tucker, M. Siya, N. Bidwell, and J. Simo-Reigadas. Experiences, challenges and lessons from rolling out a rural WiFi mesh network. In *3rd ACM Symposium on Computing for Development*. ACM, Mar 2013.

[20] C. Rey-Moreno, W. Tucker, and J. Simo-Reigadas. Optimisation of SlotTime for a single-radio Mid-Range Multi-hop Wireless Mesh Network. In *Proceedings of the Southern Africa Telecommunication Networks and Applications Conference 2014*. SATNAC, Sep 2014.

[21] S. Sen, S. Kole, and B. Raman. Rural telephony: A socio-economic case study. In *International Conference on Information and Communication Technologies and Development 2006*, pages 301–309. IEEE, May 2006.

[22] J. Simonsen and T. Robertson. *Routledge International Handbook of Particpatory Design.* Routledge, New York, United States of America, 2013.

[23] D. Soto, M. Basinger, S. Rodriguez-Sanchez, E. Adkins, R. Menon, N. Owczarek, I. Willig, and V. Modi. A Prepaid Architecture for Solar Electricity Delivery in Rural Areas. In *Proceedings of the 5th International Conference on Information and Communications Technologies and Development*, pages 130–138. ACM, Mar 2012.

[24] Star2billing S.L. A2Billing, 2012 (accessed August 3, 2014). http://www.asterisk2billing.org/.

[25] R. Westerveld. Inverse Telecommunications: The Future for Rural Areas in Developing Countries? In T. M. Egyedi and D. C. Mehos, editors, *Inverse Infrastructures: Disrupting Networks from Below*, pages 187–207. Edward Elgar Publishing Ltd, 2012.