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A participatory design for a billing system: A South African case study of a community based telephony system

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ABSTRACT
This paper describes the role participatory design can play in developing and implementing an information and communication technology for development project in a rural area. It shows how the process of co-designing an artifact can reflect and shape social development. A case study was conducted in the Mankosi Community in the Eastern Cape with the aim of designing and implementing a billing system for an existing community-owned telephony system, by accommodating the community's requirements. Relevant criteria had to be considered for this telephony system based on voice over Internet Protocol with the possibility of 'break-out' calls to external networks. Different payment modalities were explored that would allow for a transparent method of both collecting money and applying the collected funds to achieve the project's sustainability. A participative methodology with future users and operators of the network—using scenarios and prototypes to illustrate the implementation—informed the design of the billing system. Data was collected by means of unstructured interviews and focus group discussions. Qualitative data was analyzed using a qualitative content analysis tool. The community indicated that a billing system, based on both vouchers and prepaid service, would satisfy their needs.

Categories and Subject Descriptors
D.2.1 [**Software**]: Requirements/Specifications–*Elicitation methods,* D.2.10 [**Software**]: Design – *Methodologies*

General Terms
Management, Design, Economics, Human Factors, Legal Aspects

Keywords
Participatory design, community, telephony, cost

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SAICSIT2014, September 29 - October 01 2014, Centurion, South Africa
Copyright 2014 ACM 978-1-4503-3246-0/14/09…$15.00
http://dx.doi.org/10.1145/2664591.2664618

1. INTRODUCTION
Information and communication technology (ICT) has the potential to bring socio-economic development to rural areas. However, access to ICTs remains a problem in remote areas [5]. This is mainly because telecommunication operators are reluctant to provide services where the income does not warrant the necessary expenditure. Where ICT services are available in rural environments, its usage is limited due to the cost of communication [1]. New technologies such as Wi-Fi and voice over Internet-Protocol (VoIP) have emerged as affordable options and are now being implemented in rural regions of developing countries such as India. To replicate the successful deployment of such ICT systems in rural South Africa is not without its challenges: the socio-political structure of South African rural communities is a challenge, as are the scarcity of resources (such as electricity); limited expert knowledge; and the long-term maintenance of equipment [11]. Due to these implementation challenges, information and communication technologies for development (ICT4D) projects can become costly to operate and this cost often impacts on a projects' sustainability [10].

In a rural community located on the Wild Coast of the Eastern Cape in South Africa—with whom our university has a longstanding relationship—an experimental twelve node wireless mesh network was implemented to allow the local community to communicate affordably and also to determine the acceptability and sustainability of such networks in rural South Africa.

To understand the social environment in which this experimental network was deployed, some background needs to be provided. The Mankosi community consists of twelve villages scattered over a 30 square kilometer area and is governed by a Tribal Authority (TA). The TA is a traditional political institution, which constitutes one headman and twelve sub-headmen (one from each village). In the Mankosi community most people speak only isiXhosa. Their main income is based on pensions and child allowances from the government and remittances from relatives working in towns [11]. Subsistence farming is practiced in Mankosi with the main agricultural activity being cattle farming and the planting of maize and sorghum [8].

Initially the Mankosi mesh network project was intended to provide free voice calls to members of the community with the

idea of later charging a small fee for local calls to assist with the maintenance of the network. Although the community did not use the mesh network's telephones as frequently as expected, the community found the solar panels, that power the node stations, were very useful for charging their mobile phones [12].

In discussions with community members they indicated that they would use the network more if it would be possible to make external calls from the network's telephones or if they could access the Internet via the network. For external calls as well as Internet usage, funding would be required. Thus it was decided that in order to create such a fund, the users of the community telephone network would be asked to pay a small fee to use the system. The research question then became how to do this effectively? What modality of payment would be most suitable for the community and at the same time make the Village Telco (see www.villagetelco.org) sustainable? And furthermore, how should the billing system be designed to address the needs and expectations of the community? Would participatory design be the best approach? It was felt that answers to these questions would provide the means to further the knowledge of the community in terms of technology as well as nurture their trust in the project.

The community together with the stakeholders of the project agreed that the community should define the rates for the use of the phones and should also provide a mechanism for collecting money from end-users. The solar infrastructure that powers the access points of the mesh network was utilized by the community for charging their mobile phones. Thus as a money collection trial, users were asked to pay for this mobile phone recharging service and a mechanism was launched to collect the money from the users. It was explained to the community that by collecting this money the sustainability of the network would be ensured. In the meantime, a business model for the collection of money for the calls in an easy and transparent way had to be found. An automated mechanism was suggested in the form of a billing system that would bill the calls made on the network in a way that would suit the users and the operators that manage the network. It had to be clarified to the community that only calls made to phones external to the network would be paid for and that calls internal to the network would remain completely free.

Billing systems such as the one envisaged for Mankosi have been studied to determine the technical requirements for the proposed billing system. The three billing systems that were considered relevant to this research are:

1. *The Foli Kodjo Gaba's billing system.* Gaba designed a billing system for VoIP services on SWITZERNET™—a network that allows almost free calls to anywhere in the world—as a student project [6]. The billing system used A2Billing open source software to charge Internet calls in a postpaid scenario. The setup used a separate Private Box eXchange: Tripbox, a Private Switched 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).
2. *The Sen et al. system.* This system billed VoIP services made on long distance Wi-Fi links in remote rural areas. Public calling offices (PCO) built in the villages, used a Foreign eXchange Station (FXS) and Foreign eXchange Station boxes (FXO), to bill the calls made inside the Wi-Fi network. A local operator managed these PCOs at each village site. For break-out 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 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 [13].
3. *The Soto et al. model.* was designed 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 USD (the maximum is $4 USD). 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 electricity is cut [15].

A participatory design approach was used to manage the research process of designing a billing system for the Mankosi community [14]. Workshops were organized with the stakeholders of the project in order to come up with the conceptual designs that would answer the business goals and user requirements of the planned system. The novelty of this approach is its sensitivity to the context and its emphasis on the promotion of active participation of the community in ensuring sustainability.

Preliminary findings show that the community members are satisfied with their choice of billing and payment system for the calls. They are now aware of the benefit of such calling facility in their community and are willing to use it if they can make internal as well as external calls from the network.

The rest of this paper will be organized as follows: Section 2 deals with the research approach and the design of the billing system; Section 3 reports on the results; and in Section 4 the results are discussed, conclusions are drawn and suggestions are made for future work.

2. RESEARCH METHODOLOGY

The theoretical perspective that underpins this research is interpretivism and Habermas' theory of critical social science [7]. Habermas in his theory 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 [4]. Participatory design was the method of choice for finding an appropriate design for the proposed Mankosi's billing system.

Participatory design (PD) is defined by Simonsen and Robertson [14] as a process of investigating, understanding, reflecting upon, establishing, developing, and supporting mutual learning between multiple participants in collective "reflection-in action" (see

Figure 1). The participants typically undertake the two principle roles of users and designers where the designers strive to learn the realities of the users' situation while the users strive to articulate their desired aims and learn appropriate technological means to obtain them [14].

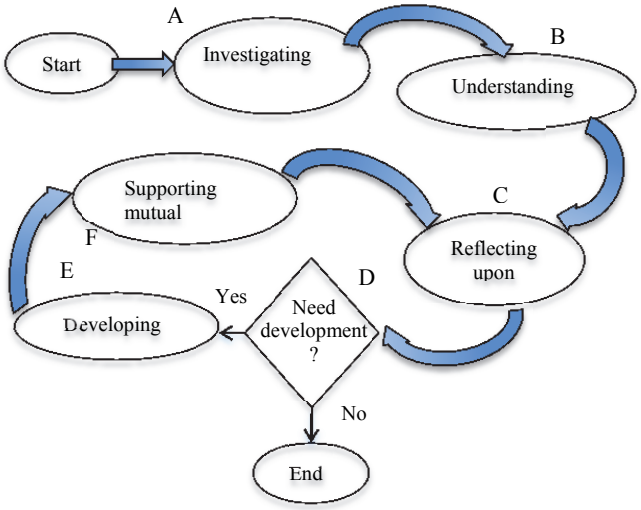

Figure 1: Participatory design (as proposed by Simonson and Robertson)

Muller and Kuhn explained that PD is 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 the needs of the users and that the resultant product is usable [9].

Using PD as research method provided a greater consideration and understanding of the needs of the billing system's future users. To explore, extract, and integrate the needs, perspectives, and affordances of the community, different methods were used. These methods included observation, interviews, surveys, focus groups and also spending extensive times within the community (see A and B in Figure 1).

To demonstrate different billing options and to elicit the users responses and understanding of the system, several scenarios–each with a different modality of payment–were explored during the Reflection stage (C in Figure 1). Some of the scenarios were decided upon as a result of interaction with the literature, for example the scratch cards-idea Others were a result of prepaid practices in the countries where researchers were from, and others were simply suggested by the users according to their needs. The proviso, when choosing a scenario, is that the user should be able to make a call from any of the 11 analogue phone-enabled mesh node stations on the network. In the following section the scenarios considered are described.

2.1 The scenarios considered

Scenario 1: Similar to the Skype application used for Internet calls.

It is a prepaid scenario where the user would have a personal calling account. To top up his/her account, the user will have to purchase credits and the administrator will update the user's credits. The user will have to enter an authentication code every time a call is made.

Scenario 2: Similar to the vouchers purchased for mobile phone airtime in South Africa.

It is a prepaid scenario where vouchers are purchased. The user buys a voucher worth a certain credit-value. Instead of the user having to use an authentication code (as in Scenario 1), the voucher code is used when making a call.

Scenario 3: Prepaid similar to public phone shops

It is a prepaid scenario where the user says for how much he wants to call, pays the service provider, and once the call is terminated, the call is charged and change is returned to the caller if applicable.

Scenario 4: Similar to a public phone booth

In this instance the user can call by adding coins (for the call not to be dropped) or instead of dropping the call, can top-up while calling.

Scenario 5: Similar to an Internet café

It is a post-paid scenario where the user pays after making a call.

2.2 Other aspects that needed consideration

Before deciding on the most suitable payment scheme, the following aspects had to be considered: legal, financial, technical and social aspects of the system.

Legal feasibility: The telephony system would have to be licensed, and a cooperative legal entity registered, with the community as the beneficiary of the entity. Only members of the cooperative (the legal entity) will be allowed to use the network.

Financial feasibility: It required evaluating the economic/financial benefits of the project. For example, if a scenario requires an operator, the operator would need to be remunerated. Some scenarios would only require a call meter. For printing vouchers, a printer, ink and paper would be required. Providing change for cash might also pose a problem.

Technical feasibility: How difficult it is to configure the system also had to be considered.

Social feasibility: The complexity of the money collection system, how to report on the financial status of the system, how user friendly the system is, and how secure it would be, had to be taken into account.

2.3 Prototype design

During the design phase of the billing system (E in Figure 1), several billing applications were explored to determine which one would be the most suitable to be adapted for the Mankosi network. The systems considered were: ASTTP, VBilling, ASTTP, and A2Billing. A2Billing was chosen because it is well documented and well supported online with an active supporting forum. The scenarios informed the design of the payment alternatives implemented by adapting A2Billing to satisfy the community's needs (F in Figure 1).

3. RESULTS

Participative workshops were organized with the stakeholders and the different scenarios were discussed with them. Two iterations of focus group discussions were held with the stakeholders. The stakeholders included the local researchers, operators of the network and community members.

3.1 First iteration

The first iteration of the participatory cycle was to investigate, understand and reflect how to implement a billing system (see A, B and C in Figure 1). This was done by means of focus group discussions and interviews. Random convenience sampling—whereby the research asks randomly any subject who is available to participate in the research study—was used to select participants.

3.1.1 Focus group meeting with local researchers

Consultation meetings were held with a team of local researchers (LRs) consisting of two men and a woman. The LRs lived in the community all their lives and have assisted with the project since its inception. They acted as moderators between the researchers and community members since they are well versed with the needs of the local community [2]. The focus group meetings gave the research team a clear idea of the key issues that needed to be considered during the design process and the implementation of the system.

3.1.2 Focus group with local operators

The so-called local operators (LOs), 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 the persons responsible for collecting the money for the services of the network. Focus group meetings with LOs were held at the Headman's house where the different concepts of the scenarios were discussed. 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.

3.1.3 Interaction with users of the network

In a first iteration of interactions with the community, visits were made to villages in Mankosi to meet with the local users—community members; future users of the system—to become acquainted with them so that when interviewed, they would feel comfortable in the researchers' company and would be able to speak freely. Twenty-five people (four men and twenty-one women) were interviewed. Judgmental sampling—sampling in which the person doing the sampling uses his or her knowledge or experience of the community, to select participants—were used [17]. The number of men and women interviewed were dependent on the availability of respondents at the time of the interviews. Non-structured interviews were conducted, guided by aspects concerning the research. Questions arose during the course of the interviews, based on the interviewee's responses to aspects of the research and allowed for the spontaneous flow of the friendly non-threatening conversation. To avoid creating unrealistic expectations or confusing the interviewees, generic questions were asked that emanated from the scenarios and were familiar to the interviewees since most of them are mobile phone users.

3.1.4 Choice of scenarios

The establishment of what was required was done by means of examples or scenario sketching (see D and E in Figure 1).

While conducting interviews with community members it was found that 96% of people owned a mobile phone, made use of a pre-paid service and knew how to check the balance on their phones. This indicated that most of the users of the Mankosi mesh network would understand how the system functions especially regarding the payment of calls. Although only 4.35% knew how much they were currently paying (per second) for calls most, 81.25%, felt that the mobile costs are prohibitively expensive. The community therefore felt that the network would be an attractive alternative and indicated that they are keen to use it for local calls rather than using their mobile phones. However, they also mentioned that the fact that calls could only be made from call stations, limits the phone's usability. For example if a specific person needs to be contacted, the person may not be at home. If the free call could be made to the person's mobile phone it would be ideal. Most of the people interviewed affirmed that they would use the mesh potato for break-out calls.

During the communicating and reflecting stages (F and C in Figure 1), the feasibility of each scenario was discussed with the stakeholders in terms of its legal, financial, technical and social feasibility and was measured against these defined feasibility aspects. The results of these discussions are depicted in Table 1—where V indicates that the community considered the scenario to be feasible.

Table 1. Summary of the feasibility of the 5 scenarios

	Legal	**Financial**	**Technical**	**Social**
Scenario1: Skype	V	V	V	
Scenario2: Voucher			V	V
Scenario3: Pre-paid			V	V
Scenario4: Phone Booths			V	
Scenario5: Postpaid			V	

It was found that the scenarios that require assistance—other than what the LOs can handle—would not be feasible. Even though, with the initial analyses (see Table 1) it seemed as if Scenario 1 would be the best option, however it would require an assistant to be present all the time which would be impractical, thus the scenarios which were eventually decided upon were Scenarios 2 and 3:

1. The *voucher scenario* was considered to be easy and flexible. Once the voucher was purchased and activated at the station node, where it was bought, it would not need any follow-up by the LOs. Although the users felt that the vouchers could pose a security risk since vouchers could be stolen or lost if not securely kept.
2. Both the LOs and the users felt that the *prepaid scenario* was also feasible since it was possible to call for any amount of money. However if the purchased amounts were too small, the change might pose a problem—most users felt they would forfeit change of less than 50 cents, but would want change of 50 cents or more.

3.2 Prototype implementation

A2Billing together with the input from the Mankosi dwellers was used to implement requirements discussed during focus group and individual interviews. After collecting and defining the user requirements, a model was designed. The architecture of the system consisted of a database server and a web server for the administration of the system (see Figure 2). Provision was made for agents, customers and an online sign-up. A2Billing makes use

of Asterisk to bill and manage VoIP calls. A Linux based server was used to host the system, and connects the mesh potato router to an analogue device phone by means of an Interface Card. An Apache web server and MySQL database was configured as the back-end, to bill and record call duration [16]. After configuring and setting up the billing system, a dial-plan with calling rates was configured. A decision on what to charge for each call is still outstanding. The community in consultation with their Tribal Authority will determine the cost of a call.

Before presenting the community with a prototype of the billing system, it was tested in the laboratory. Laboratory testing of the system involved functionality testing and usability testing.

3.3 Second iteration

During the second iteration of the PD cycle (C, D, E and F of Figure 1), the designed prototype was demonstrated, discussed and tested with the LOs. The LOs made some suggestions about and the system was revised based on their responses.

A workshop was organized and people, interviewed during the first iteration, were invited to test the prototypes. Only five of the ten community members that were invited actually attended and were able to test the prototypes of the two payments scenarios implemented for the billing system. At this meeting, community members advised on adjustments to the billing system based on their choice of the two scenarios.

In a further focus group interaction, a more hands-on approach was followed where the LOs were again able to interact with the prototype implemented according to their scenario suggestions.

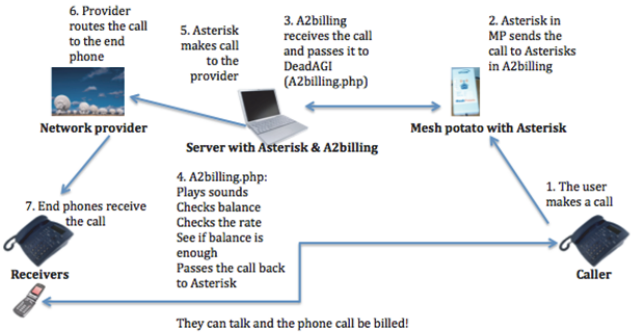

Figure 2: Description of the calling and billing architecture

4. DISCUSSION AND CONCLUSION

Participatory design enabled the researchers to work directly with users and other stakeholders during the design process. The researchers learned about the realities of the users' situation while the users were able to articulate their needs and the needs of their community to the researchers.

The participatory design process had the added advantage that the community now understood the purpose of the network and since they contributed to its design, felt that they owned it and could trust its billing system. A further benefit was that a core group of the participants now were committed to the project and felt that the overall quality of the community's lives could be improved by it and similar projects. The process contributed to the personal development of the participants, it gave the community a voice and sense of power —the ability to change things—and it vastly expanded their vision of what they are capable of doing.

Some aspects of participatory design were difficult to manage. One of the most important difficulties was the considerable time it took to plan and execute meetings and workshops with the community. It had to be planned well in advance in order to get the community together and motivate them to attend the meetings and workshops, which in turn delayed the implementation process. Furthermore the broad involvement of stakeholder participants made it difficult to reach common ground and reach consensus. This was also found by Björgvinsson et al. who said "*... differences and controversies are allowed to exist, dilemmas are raised and possibilities explored...*" [3].

It was found that the current means of communication, using mobile phones, is expensive when considering the average local user's monthly income. The proposed system will 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 that it will generate. The network will in future, provide access to the Internet and will have the capability of handling break-out calls to external networks.

At the time of writing this paper, the prototype of a preferred billing system has been refined and adheres to the needs of the community and can be implemented. Provision has been made for two scenarios in the prototype. The scenarios of choice were: a prepaid system where the caller pays for the call and is refunded the amount which was not used; and a voucher system, where the caller purchases a voucher for a certain amount and can make calls until the amount is depleted.

The most important contribution of this research project however is more than mere technical, it is that the people of the Mankosi community have been empowered – they have contributed to the successful conclusion of this project and have gained transferrable skills that may be of benefit not only for this community but for the larger communal area.

5. ACKNOWLEDGMENTS

We thank Telkom, Cisco, Aria Technologies and THRIP (Technology and Human Resources for Industry Partnership) for their financial support via the Telkom Center of Excellence (CoE). This work is based on the research supported in part by the National Research Foundation of South Africa (Grant specific unique reference number (UID) 75191) and the CONFINE Integrated Project FIRE #288535. Any opinion findings and conclusion or recommendations expressed in this material are those of the authors and therefore the NFR does not accept any liability in this regard.

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