An Overview of ICT Innovation for Developmental Projects in Marginalised Rural Areas

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Abstract: In recent years, assistance from developed countries to developing countries has intensified. Information and Communication Technologies (ICTs) have also been widely deployed in developmental programmes, leading to the creation of a new field – ICT for development. This paper reviews a number of projects that introduce technically innovative ICTs that are intended for the development of marginalised rural areas.

Keywords: Innovation, Developmental Information and Communication Technology, Marginalised Rural Areas, ICT4D

INTRODUCTION

The Millennium Development Goals of the United Nations address a series of global social development issues, including halving extreme poverty by 2015 (United Nations MDG, 2008). Since the publication of the millennium goals in 2000, much attention in the field of ICT has been focused on bringing ICT to poverty-stricken areas. Such projects have often not been evaluated scientifically, so there was until recently little evidence of the efficacy of ICT for development (ICT4D) in these environments (Batchelor et al, 2003). However, most evidence supports deployment of ICTs in such areas and by some reports, ICTs can assist with several of the MDGs simultaneously (Harris and Rajora, 2006). Mostly off-the-shelf technologies have been deployed in innovative ways, i.e. technologies which may be innovative in their own right, but whose innovation was not targeted at developmental work in MRAs (visible e.g. in Chand, 2005 & Batchelor, 2003). With the advent of funding by large international development organisations and also private companies, the field of ICT4D has increasingly become an area of technical innovation.

This paper presents an overview of the ICT projects that have been initiated with the explicit aim of deployment in marginalised rural areas (MRA), and where the results of the project are usable by the most disadvantaged members of those communities (this is our definition of ICT4D). By contrast to existing overviews of ICT4D projects, we analyse primarily technical features of the projects. Other overviews, such as Batchelor et al (2003) and the UNICTTF (2003), concern themselves primarily with social effects and do not distinguish between projects which use existing ICTs and those that introduce significant technical innovations.

In the next section, we present background information concerning barriers that face ICT4D projects in MRAs. Taking this information into account is essential for the success of ICT4D projects in deep rural African settings within the next 5 years at least. In the following four sections, we introduce the reader to ICT4D projects that are categorised as follows:

- Complete projects – ready to run.
- Partial projects – projects developing modules.
- Situated projects – projects that cannot easily be reproduced or scaled.
- Events – projects that are limited in time.

In the section following that we present a deeper analysis of the reviewed projects according to several dimensions: 1) access to hardware 2) access to connectivity 3) user enabling measures 4) access to software 5) long-term sustainability. In this section we also make mention of projects that had little technical innovation but applied ICTs in an innovative manner achieving notable results in certain dimensions. These projects demonstrate how ICT4D projects benefit from a multi-disciplinary approach.
The aim of this paper is to make information on ICT4D more accessible to technical audiences in Computer Science and Information Systems departments of universities, as well as software and hardware industry organisations. It is our hope that this will contribute to the degree of innovation in this complex and multi-disciplinary field. This paper has a bias toward African rural conditions, because the author is based in South Africa. However projects from all over the world are presented here.

Barriers to ICT delivery in MRAs

Most of the problems faced by projects attempting to introduce ICTs into MRAs stem from the combination of impoverished low population density spread over vast areas and inept or corrupt governments, that have no interest in delivering services to these areas (Dymond and Oestermann, 2004 & Best and Maclay, 2002). This situation leaves many millions of people without the following services: proper road access, electricity, water and sewerage services, and telephone. However, as pointed out by Best and Maclay (2002), the situation is often perceived as worse than it is.
Primary barriers to ICTs are:

- wired technologies are expensive in such areas, hence the high penetration of mobile communications as opposed to fixed telephone lines (Dymond and Oestermann, 2004), and
- there is no electricity in most such areas, although there are ongoing efforts to provide basic solar power for instance at clinics (see the Solar Electric Light Fund (SELF) or Solar Light for Africa).
- Further the high level of illiteracy means that there is no support or maintenance readily available for ICTs.
- Often harsh environmental conditions, moisture or heat and little secured housing.

All these factors combine to create a particularly difficult environment for ICTs. However, there are projects attempting to deal in innovative ways with each of the problems, as is shown in the following sections.

Complete Projects

This category of projects is ready to be used. Moreover, the projects are not just research projects, but have been designed as products, that one could feasibly use at home or franchise.

One Laptop per Child

The One Laptop per Child (OLPC, 2007) project, also known as the "$100 dollar laptop" project owing to the targeted price of the hardware being produced, is a project initiated by Nicholas Negroponte, being implemented by several large industrial partners and MIT.
Innovative hardware features:

- A very low power consumption owing to the fact that the chips used consume very little power and that motherboard and CPU can be turned off (idle mode) while the screen is displaying a static image or the network is relaying information.
- Small low power high resolution display which also allows viewing outdoors.
- A robust and compact format with some water and dust resistance.
- Broad input voltage allows a variety of power sources to be connected. Included in the hardware is a manual crank which allows charging through work at a planned ratio of 1 to 10 (1 min cranking = 10 min use).

Further features: sound card, camera, microphone, speakers, IEEE 802.11b/g (Wi-Fi, 2008) wireless LAN.
Innovative software features:

- Mesh software allows laptops to self-organize into a LAN. The OLPC-Mesh has not been tested in real-life situations, so robustness of the network has not been shown with typical churn rates - as no typical churn rate data exists. One server per school is meant to provide backhaul connectivity to the Internet.
- Programming environments for children are also provided on the computers. The idea is to allow children to control the virtual environment themselves. These have also not been tested in the field.

All end-user software is meant for children. Software based on OpenOffice (Text and HTML authoring tools), as well as logic games for children are included (Author's experience).

Digital Doorway

The digital doorway is a project of the Meraka institute in South Africa (Meraka, 2007). The project installed several expensive heavy-duty unattended terminals with computing and Internet resources. The first location selected was a rural location. Since then a gradual roll-out is taking place with about 300 nodes, mostly in urban and peri-urban settings, often at training colleges. The terminal has a client-server architecture. Internet access occurs via GPRS. We could not find an analysis of the results obtained at rural installations, although they are reported to still be running after 3 years. Main innovations are multiple-way casing allowing 1 to 4 users simultaneous access to computing resources, very resilient outer shell and a remote camera, which observes activity at the terminal.

BingBee

BingBee is a project of Seven Fountains Digital, a spin-off of Rhodes University in South Africa (Slay et al, 2006). BingBee is essentially a multi-media content delivery system with an innovative input via touch-pad and camera. This system is meant to provide public accessibility in MRAs, by placing expensive hardware in secured buildings like shops, while allowing 24 hour public access through a window. The user can only steal or damage a touch pad, which has no moving parts, is inexpensive and easily replaced. The pad is simply read by a camera (which can be secured along with the other equipment).

Hole-in-the-Wall

The Hole-in-the-Wall project deploys various types of hardware in various Indian settings (Mitra, 2005). It inspired the Digital Doorway project in South Africa. Hardware innovations included reduced power usage, remote monitoring of functions and tamper-proofing. The main innovation lies on the software side. While mostly

existing software was chosen, it was selected and presented in such a way that children were able to navigate and explore the virtual environment by themselves. The project established a strong case for minimally invasive education of basic literacy for young children.

Drishtee

Drishtee Development and Communication Limited is a public for profit company, which is creating a network of Internet kiosks (or telecentres) in India (over 1000 at present) (Drishtee, 2007). The main innovation that Drishtee has introduced to the kiosk concept is a human component, to provide eGovernment services. When a Drishtee user makes an eGovernment request, the requests is sent to the Drishtee office at the nearest government representation, and a Drishtee employee makes the request on behalf of the user. Besides that, Drishtee has a proprietary kiosk setup that requires no installation on behalf of a kiosk owner. The Drishtee model has been shown to be sustainable and works on a tiered franchising principle.

eMexico

eMexico is a cooperation between the Mexican Government and Microsoft to provide eGovernment services to all Mexicans (ICA 2006). The strategy is based on an eGovernment portal, which provides it's citizens electronic services (e.g. in 2006, 100% of corporate tax and 77% of private tax returns were made via Internet) and a plan to build and support 10000 digital community centres for the use of the public by 2006. We do not have any evaluation of the penetration of this programme in MRAs, although it is meant to benefit these as well.

Aleutia

The Aleutia project is an effort to build a hand-held device which focuses on making email functionality freely available in MRAs (Aleutia, 2007). The project is in a conceptual or feasibility phase, so there are no results yet. It combines computing and communication functionality and is extensible to other applications. The device is small and built of very cheap components and is intended to allow affordable pricing – since the product is not yet in production, total costs are as yet unknown. Long range and standardized network connectivity is provided by IEEE 802.11 and radio frequency (900MHz) cards. An innovative Mesh software is intended allow for batch modes of Internet connectivity, which is expected to assist sustainability.

Radio Fala Mulher

Radio Fala Mulher is an innovative project of the Cemina Foundation in Brazil, which uses Internet broadband connections to upload programmes created by women at grass roots level and broadcast them on regular radio stations (Radio Fala Mulher, 2007). The technical innovations consist in the combined usage of mobile radio and mobile Internet to reach and involve rural audiences.

Turn key client – server solutions

Current computers are not used to their capacity when used to run typical office and educational applications. Thin client solutions running from a central server are not innovative, but several companies have created packages which create ready to run telecentres including hardware.

- The **Ndiyo!** project is a client server Internet in a box solution with very sparing electricity requirements and an open source software which controls the system (ndiyo, 2007).

- **Inveneo** is a computer hardware manufacturer based in the U.S.A specialising in thin client-server solutions (Inveneo, 2008).
- The **SolarNetOne** project has created a prototypical complete client-server installation similar to the solutions mentioned above, with the additional feature, that the solution includes its own solar power provision (SolarNetOne, 2008).

Partial Projects

Projects in this category are modules, which need to be used in association with other projects in order to be useful. This category includes web portals and software that is accessible on the web as these projects have not tackled the problem of delivery.

Edubuntu

The Edubuntu Linux project is an Ubuntu Linux distribution with educational software, including drawing programs, math and science programs, diverse educational resources, programming software for children, etc. pre-installed (Edubuntu, 2007). The GUI is also adapted to arouse the interest of children. As an extension of Ubuntu, an open source software project with a considerable community, Edubuntu is a completely free software resource available in many languages, which allows users to update it.

Aryty

Aryty is a web-based microfinance project which allows one to send mobile phone credit to mobile phone subscribers in the Philippines (Aryty, 2007). Credit can be sent via Internet or via SMS. The simplicity of the concept ensures that it works. It is primarily used by persons living in developed nations with relatives in the Philipines (developing nation).

iPath.ch

iPath is a society for the promotion of telemedicine based in Switzerland (iPath, 2007). Their open source software is being run at many global sites around the world including at the Walter Sisulu University in the Eastern Cape, where it is sustainably assisting in improving medical services to MRAs. The software is implemented using PHP and MySQL and is web-based. Doctors are able to upload requests to the system with multimedia content (mainly pictures of the affliction) and to get diagnoses from experts via email.

Situated Projects

Situated projects operate only in a specific area or region. Typically they cannot scale up greatly, multiplying the number of installations, owing to organisational and human resource constraints or because of their research character.

Dwesa/Cwebe

The Dwesa/Cwebe project a joint project of the University of Fort Hare and Rhodes University is an example of an early adopter of VSAT (VSAT, 2008), IEEE 802.16 (WiMAX, 2008) and IEEE 802.11 technologies for rural Internet accessibility (Thinyane et al, 2006). Additionally, an Asterisk server provides VoIP connectivity

between the 5 nodes. The hardware innovations in this project are: It is one of the first to deploy a complete connectivity installation in a marginalized rural community. Further, software applications are being developed to allow research into sustainable community ownership of such infrastructure. The applications should provide important services to inhabitants, mainly eCommerce, eGovernment and communication (VoIP, Internet). An equitable cost sharing software is also being developed. The project has a strong multi-disciplinary approach in that it brings together researchers from computer science, education, linguistics, anthropology and sociology, with the ultimate aim of creating a sustainable and reproducible solution (author's experience).

TIER WiLDNet

The Technology and Infrastructure for Emerging Regions research group at the University of California at Berkeley is investigating several technologies specifically for MRAs. As a research programme there is no emphasis on sustainable roll-out, however technology is validated in the field in Rwanda, Ghana, India, the Philippines, Cambodia and Guinea Bissau. Innovative technologies include long distance point-to-point IEEE 802.11 (Wi-Fi) solutions (WiLDNet), educational software (see below) and speech technology (Plauche et al, 2006). The WiLDNet is based on inexpensive off-the-shelf IEEE 802.11 technology and single-board computers with low power usage. The IEEE 802.11 signal is transmitted over long distances using high-gain directional antennas with line of sight (Patra et al, 2007).

TIER Millee

Millee is a TIER project (see above) which makes English Second Language educational content accessible on Java enabled mobile phones (Kam et al, 2007). The project uses the high penetration of relatively powerful mobile devices even in MRAs, to provide a platform for innovative educational content. The efficacy of this system is being tested in India.

Fantsuam Foundation

The Fantsuam Foundation drives several ICT4D projects for the benefit of marginalised rural communities in Nigeria (Fantsuam, 2007). Besides supporting localization efforts for Nigerian languages, it is also driving projects that will provide connectivity to MRAs.

Events

These are projects whose usefulness has a defined begin and end time (and perhaps periodicity, if repeated), where the duration of the time of usefulness is in the order of hours, days or weeks.

Internet Society South Africa Chapter (ISOC-ZA) Internet Fiesta

The ISOC-ZA Internet Fiesta is a complete mobile computer classroom with a VSAT link and generator, which is able to deliver Internet computing to a 50 workstations at any location which is reachable by road (ISOC-ZA, 2008). The concept is simply to introduce the Internet to persons who have no opportunity to know anything about it in an informal manner.

Analysis

Delivering ICTs

The delivery of ICTs to MRAs can proceed in a number of different ways. Each of the methods must however overcome all the basic barriers to ICT deployment as listed in the second section. We propose that sustainable delivery of ICTs for development in MRAs cannot occur without answering 5 central questions: 1) Is computing hardware accessible to users and is it suited to the conditions (e.g. lack of power)? 2) Is there a sustainable Internet connection? 3) Is there a solution to user-side barriers to accessing the computing infrastructure, e.g. language or literacy problems? 4) Are useful applications run on the infrastructure and can users generate information or are they simply consumers? 5) How has this project solved the problem of sustainability beyond the project life-cycle? In this analysis, we present different ways of answering the questions in the context of the innovations developed by the above mentioned projects.

Access to ICTs

While the main commercial and governmental focus in this field is on telecentre type technology (Batchelor et al, 2003, UNICTTF, 2003 & Dymond and Oestermann, 2004), there are many noteworthy projects that have chosen a different approach. We classify telecentres as a form of ICT that is fixed in location and is available for public use (see Table 1, on p. 6). ICT access via telecentres is of limited use in MRAs, owing to their low population density, The OLPC project is a dramatic departure from this communal form of delivery, and wishes to deliver instead mobile, private computing – one laptop per child. On the other hand, many projects exist to deliver off the shelf, used or donated computers to schools or community centres (DRISA, Fantsuam, Imbewu, Schoolnet, to name just a few). Such ventures deliver public or private computing at a fixed location. We call this private computing, because locals usually feel that the service is not intended for them, even if they are granted access, which is often not the case. Bureaucratic regulations or concern for expensive equipment often make such installations a private good (see Batchelor et al (2003) for general remarks, Chand et al (2005) pp. 18 for an example). To complete the picture, the ISOC Internet Fiesta is a mobile project to bring Internet to the public. This class of ICT project can be likened to the travelling library, which delivers a service at regular intervals. A mode of operation which seems ridiculous from the perspective of broadband connectivity, but a model which might work in MRAs.

Establishing a Connection to End-Users

The cost of Internet access in MRAs is very high, nonetheless Internet access enriches the possibilities that users have in often dramatic ways. Static content on fixed computers can be upgraded to include latest information and news. Online applications allow interactions with persons in other areas and cultures (email, Web 2.0 applications). We have already seen projects that propose a batch mode of interaction with the Internet.

Another innovative approach is that of Mesh networked LAN/WANs. Aleutia, TIER-WiLDNet and OLPC all include innovative Mesh technology to support communication. Several other mesh network protocols, which standardise how nodes can create mesh networks automatically, are now available. Most of them such as Meraki (Li et al, 2007) and BATMAN (Open-Mesh, 2008) were created to link and

share broadband connectivity in urban areas, so they are mentioned for the sake of completeness here. Distributed technologies are used primarily for two purposes:

- To create a local Wide Area Network to promote usage through local interaction and content
- To provide low cost robust wide-range Internet access, in online or offline modes of operation.

(Angelov, 2007) proposes a theoretical peer-to-peer solution, which is cost effectively based on IEEE 802.16 (WiMAX, 2008).

Crossing the Digital Divide

Once ICTs have been delivered to a MRA and a connection to a network been made, existing software already allows users to access the Internet for email, and to participate in Web 2.0 projects or use online resources. However, these applications need to be localized to cater for local most often non-English speaking persons. There are a number of projects working on localizing software e.g. Edubuntu (2007), Fantsuam (2007), Translate.Org (2008) (see also Table 2, p. 6). These mostly use Free Open Source Software (FOSS), as they can be sure that there will be free access to their effort, and it is possible to localize the entire operating system, which is not possible with proprietary operating systems. Further, speech technology can be a method of making online contents accessible even to illiterate persons (Plauche et al, 2006).

Further, we consider that the digital divide has only been successfully bridged, when traffic is flowing in both directions. Two projects that have made a sustainable step in involving the rural populations in information flow and using the Internet to push information are Radio Fala Mulher (2007) and PFNet (Chand et al, 2005). These projects have successfully used the Internet to send articles to newspapers and to broadcast radio programmes.

Web 2.0 applications provide users with strong possibilities of participation in the Internet and successfully crossing the digital divide. A very good example of Web 2.0 technology for MRAs is the Tradenet.biz project, which runs in several African countries and allows users to post their information to the web via mobile phone. (Boadi et al, 2007)

End-User Applications

Table 2. shows the sectors that innovative software applications address in the projects reviewed. These also correspond to the barriers that stand in the way of ICT adoption in MRAs.

Education is the most popular end-user application for which programs are being created. While it does not help to fight illiteracy immediately, it is commonly accepted as a powerful tool for development of marginalised rural communities. In fact, since children are able to learn quicker and have a less constructed view of the world, child education is seen by some social workers as the best way to help rural societies to develop. This statement is borne out by the OLPC and rivalling Intel Classmate PC projects.

eGovernment and eCommerce applications aim to fight poverty and create jobs by new means. In remote areas, which have no prospects of industrial or commercial development, this is an avenue which shows some promise, as shown by e.g. Drishtee (2007).

Telemedicine is also a promising field for innovative applications. Inhabitants of MRAs often have to travel substantial distances to the nearest clinic where nurses stand in for doctors.

Keeping the Connection Up

Sustainability is one of the major barriers faced by ICT projects in marginalised rural communities. Projects that can make a profit and are operated by local inhabitants have the greatest impact on the local community (Keogh and Wood, 2005 & Batchelor et al, 2003). While competition may erode the business in urban areas, they are more likely to survive in MRAs. Table 1. shows that not many complete projects have commercial usage plans.

Sustaining an educational project is another matter altogether. Not only must the infrastructure be maintained (at no small cost), but school leavers have to find a means to support themselves using the skills they have learned. The former is being addressed by software that it robust, self-configuring and self-healing. Besides the OLPC project which does take some self-configuration into account, most other projects are based on operating systems which are not advanced enough in this respect. The latter, is a point for governmental policy and out of the scope of this paper. Nonetheless, if other projects to create jobs are successful, then the possibilities for such skilled persons will be greatly increased.

Introducing ICTs in MRAs also allows virtual assistance to these areas in the form of software updates. Programmers can donate their programming skills for a period of time to diverse projects. Such assistance is common-place among students in the developed world and is even supported by programmes such as the Google Summer of Code (Google, 2007).

Conclusion

Bringing ICTs to an MRA is of necessity a complex project, which can be likened to the construction of a road or providing a water source, under difficult conditions. These are conditions that inspire innovative solutions and that rest on efforts across several disciplines to achieve lasting results.

While this paper has discussed several ICT projects whose core technical innovation addresses developmental issues, there is a much greater number of projects that use off-the-shelf technology. Questions that address the reasons for this disparity have not been investigated. While the economic market conditions that explain the disparity are not very interesting, future work building on this paper will expand the overview so as to be able to answer questions relating to:

- the amount of participation in such ICT projects on the part of developing nations – developing nations as participants and not mere consumers,
- the efficacy of such projects – inclusion of metrics to measure success of an innovation in improving delivery of ICTs to MRAs.

The former question is especially interesting in as far as one might be able to make conclusions about the importance of insider knowledge within the innovation process with regard to complex technical ICT projects.

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Project	Mobile/ Fixed	Public / Private	Power Source	Hardware Innovation	Software Innovation	Human Component [1]	Network Mand-atory	Field Instal-lations	Commercial Deployment	FOSS
OLPC	Mobile	Private	Crank / Grid	++	++	No	No	±1000	Both	Yes
Digital Doorway	Fixed	Public	Grid	++	+	No	No	±300	No	Yes
BingBee	Fixed	Public	Grid	+	+	No	No	1	No	No
Hole-in-the-Wall	Fixed	Public	Grid	++	+	No	No	100+	No	No
Drishtee	Fixed	Public	Grid		+	Yes	Yes	±1000	Yes	No
Ndiyo!	Fixed	Public	Grid	+	+	No	Yes	?	Yes	Yes
Inveneo	Fixed	Public	AC/ DC	+		No	No	75	Yes	Yes
SolarNet One	Fixed	Public	Solar	+		No	No	2	No	Yes
Aleutia	Mobile	Private	AA Batteries	+	++	No	Yes	0	n/a	Yes
eMexico-DCC	Fixed	Public	Grid		+	No	Yes	±1000 0	No	No
ISOC Internet Fiesta	Mobile	Public	Generator	+		No	Yes	1	No	Yes

Key: '+' innovation; '++' innovation in several areas; 'Both' Commercial Sales and Public Funding, commercial deployment is an indicator of sustainability

1. 'Human Component' refers to an integral human component in the services being provided, without which the service cannot function.

TABLE 1: A BRIEF OVERVIEW OF COMPLETE PROJECTS ALONG SEVERAL DIMENSIONS

General Education	School Education	eCommerce/ eGovernment	Telemedicine	Localization	Microfinance
BingBee	Edubuntu	Drishtee	iPath	Edubuntu	Aryty
ISOC Internet Fiesta	Hole-in-the-Wall	Dwesa	TIER-WiLDNet	Fantsuam	
Digital Doorway	TIER Millee	ndiyo!		kilinux	
Radio Fala Mulher	OLPC	eMexico			

TABLE 2: A LISTING OF PROJECTS ACCORDING TO THE END-USER APPLICATIONS SERVED