# Bridging Communications Across the Digital Divide *

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**Abstract**

Connecting people across the Digital Divide is as much a social effort as a technological one. We are developing a community-centered approach to learn how interaction techniques can compensate for poor communication across the Digital Divide.
We have incorporated the lessons learnt regarding Social Intelligence Design in an (abstract) device called the SoftBridge. The device allows information to flow from endpoints through adapters (getting converted if necessary), and out to destination endpoints.
Field trials are underway with two communities in South Africa, disadvantaged deaf users and an isolated rural community. First lessons learned show that we have to design user interfaces that allow users to understand and cope with delay (latency) as a necessary consequence of our approach.

**Keywords:** Community-centered, Digital Divide, Information Society, Multi-Modal, User Interface, User-Centered Design.

## 1 Information Society and the Digital Divide

One might characterize a developing country as one where there is a great need for better access to resources. Some of these resources are necessarily limited and their distribution is the outcome of a zero-sum game; other resources, and *knowledge* is amongst them, can potentially be distributed to the *have-nots* without taking away from the *haves*. This is a partial answer to the "bread" *versus* "broadband" conundrum.

One of the prime applications of Information Technology (IT) in a developing country is to extend the distribution of scarce knowledge resources. We employ the concept of an *Information Society* to mean the desired outcome of the information revolution sparked by information and communications technology. This technological revolution has universal impact because Information Technology is a Universal Enabling Technology: it acts as an enabler in all aspects of our lives.

The definition of the Information Society makes it clear that Information Technology development depends on the formulation of clear goals for society. Technology cannot be appropriately applied when what is appropriate is not known. But, whatever the societal goals that are defined, we can assume that IT can provide a cost effective way of reaching *some* of those goals. There are major disparities in the penetration of the Information Society in the developing world. The term *Digital Divide* is to be seen in this light.

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"Digital Divide" is the growing gap that exists between those who have access to the Information Society those who are deprived of such access due to cultural bias in the applications and contents, gaps in their education (for example, illiteracy), personal handicap, poor digital infrastructure, or lack of appropriate computer equipment.

The South African Digital Divide grows out of a particular history which is one of great prior division and historical backlogs for large parts of the people: the particular South African version of colonial history. The digital divide is also related to global economic circumstances in which all developing countries find themselves. So it is that we can identify at least two aspects of a Digital Divide:

A. THE GLOBAL DIGITAL DIVIDE
This is the global disparity between those countries at the forefront of the Information Economy and those developing countries who are striving to enter that system.

B. THE LOCAL DIGITAL DIVIDE
This refers to the disparities between the various people in a particular country. Clearly it is much more than simply a digital equipment divide.

## 1.1 BRIDGING THE DIVIDE

Bridging the Digital Divide is the effort to provide increased access to information and communication to those who have little or none at all. "Communication bridges" involve social dynamics as well as the technological tools that support social interaction. Our community-centered approach has produced innovative systems that provide completely new solutions to the issues that arise in building communication bridges. We support our user communities with new communication systems that are adapted to their requirements.

This must be understood quite literally. We build new computer based artefacts that act as automatic communication bridges between various groups. The basic building block is called a SoftBridge [Lewis et al. (2002, 2003)]. One application is to bridge communications between disadvantaged deaf users by translating from text to speech and back again, Tucker et al. (2003). Another is to provide access to professional medical information for nurses in remote rural clinics, in the face of frequent power and other infrastructure outages, Chetty et al. (2003).

We are developing a methodology to support this design process as well. We have found that sophisticated bridging systems impose delays upon the communication process. Additionally, the unreliable nature of the infrastructure also can result in extended breaks in communication. Thus, compensating for delay is of major importance in building automatic communication bridges over the Digital Divide.

Allowing communications between different groups across the various digital divides requires a number of innovations. The issues we intend addressing are:

1. Changes in the way we design IT based applications and contents,
2. Putting the notion of bridging and translation central to our software systems and building that intelligence into the system, and
3. Altering IT related policy that impedes social development.

We shall consider these in the following sections. In Section 2 we discuss a methodology for designing appropriate IT solutions, then, in Section 3 we present our abstraction that incorporates the Social Intelligence, namely the SoftBridge. In Section 4 we discuss the very first results from deploying our systems in two disadvantaged communities, one urban and the other rural. We emphasize the need to act on a political level as well in Section 5 and finally we provide a short Conclusion.

# 2 IT APPLICATION AND CONTENTS DESIGN METHODOLOGY

We believe a user-centered approach is most appropriate to address the design of our systems. We have considered a number of approaches, using various ideas from *Critical Action Research*[Lewin (1948),Stringer

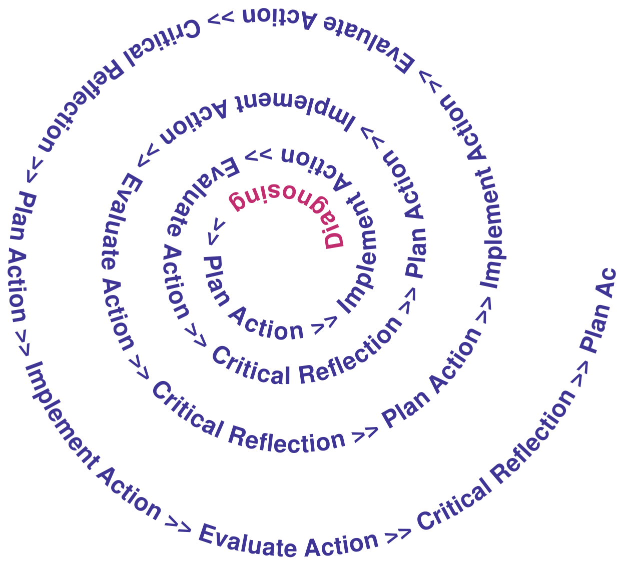


Figure 1: The Cycles of Action Research as a spiral to indicate progress in meeting user needs.

(1997),Carr and Kemmis (1991)] design and cyclical software development process based on participatory design and prototype evaluation. Our method retains the cycles of Critical Action Research of diagnosing, planning, implementing the plan, observing results and reflecting on the results. Evaluations of each acting stage form the basis for correctly planning the next step in the process. Each evaluation may lead to modifications in the ultimate goal (see Figure 1).

Critical Action Research has a strong emphasis on the empowerment of groups. It involves facilitating a change in a community through facilitating action. This is done in collaboration with the community members. The flaw in this from our point of view, in terms of design, is that it assumes at least a degree of sophistication of the user community in relation to technological possibilities and an ability of software designers to bridge large cultural and linguistic gaps. This may not be possible.

The cultural gaps can be enormous. The technological requirements exist within a complex web of other needs, relationships and societal obligations. Misinterpretation (on both sides) and unexpected needs are common. It is difficult for IT practitioners to appreciate, for example, how an IT empowerment exercise may threaten power relations in such communities with dangerous consequences for several participants. For many reasons therefore, end-user participation in the process can be problematic. Dray and Siegel (2003) have found a similar need for a wide, and culturally sensitive, view on the software process.

Our approach is therefore to extend the team with advisers and consultants that are drawn in in various stages of the design and development process. We have used the services of non-governmental organizations (NGOs), other researchers already involved with a particular community, and professionals serving the community in other capacities (e.g., doctors). In the initial stages these people form our "human access points" into the community. Rather than focus on empowering the particular individuals who will be the users of the system, we engage a wider community. We must always be aware of social subtleties. We call this a community-centered approach.

Nishida (2002) has referred to the two aspects of Social Intelligence as firstly the "conventional" one of an individual's capacity to act wisely in accordance with social rules and, secondly, the ability of a system to manage complexity of interaction. We believe this corresponds in our case to the abilities of the designers to discover and operate within the rules of the community (our community-centered method) and secondly to design a system to deal with some of the complexity (our SoftBridge abstraction).

The drawback in terms of experimental results is that such large team design and iterative development processes do not lend themselves to easy documentation of final results. There is no defined group of users that can serve as experimental subjects — we are all co-designers. Therefore we can only strive to combine largely qualitative work with some quantitative empirical results where ever possible.

A measurement system operates alongside the technology development cycle. Starting with an initial baseline, participants are surveyed to determine how they tolerate problems with their communication systems. Further measurements are made as subsequent software modifications are introduced in the field. The software is also instrumented to record actual activity metrics, such as latency. These metrics are correlated with participants subjective experiences to give a quantitative measure of how well the interaction mechanisms compensate for problems with the bridge. This corresponds to Fujihara (2001) on control conditions: that is using the system with and without the proposed enhancements as a means of measuring effectiveness within a spiral of developments.

## 3 Automatic Communication Bridges

Our underlying systems level abstraction is that of a generalization of the notion of Quality of Service in networked communication. We call this "Quality of Communication". It refers to the ability of a system to support communication by bridging between different user abilities, sensory and media modalities, infrastructure capabilities and terminal equipment facilities.

In terms of "Social Intelligence" it reflects both the aspect of the social intelligence of users to conduct meaningful exchanges *in spite* of the limitations of technologies ("where there is a will there is a way") and also the aspect of social intelligence of the system where it adapts automatically to the user and system capabilities and bridges between different communication paths (text for deaf users to speech for hearing users, Tucker (2003)).

The bridging is implemented by the *SoftBridge* (see below in Section 3.1 for more details). SoftBridge exists both as an actual implemented Computer Artefact as well as an abstraction for all those intelligent operation that cannot be realized with current technology.

As an actual implemented system [Lewis et al. (2002, 2003)] it can tackle certain bridging operations. It can translate between the format used by the basic South African text-phone for deaf users (Teldem) and Internet based chat. It can break out to the public phone system and it can translate text to speech with a North American accent and has limited success in translating North American accented spoken English into text. There are currently efforts (by other groups) to tackle the eleven official languages of South Africa, including the local South African ("Sef Efriken") version of English. In the meantime the SoftBridge as an abstraction exists and is simulated in practice by a human who acts as the speech to text translator.

What has become clear is that whatever the SoftBridge is, the users will almost certainly always have to deal with *delay*. The processing inherent in the SoftBridge imposes delay. Delay in delivering messages also arises due to poor infrastructure in rural areas. Extended power outages are common place in rural areas. Phone lines can often be down as well (copper wire is stolen). A useful system must be able to switch seamlessly between synchronous and asynchronous modes of communication.

Our first result, namely the necessity of delay, may seem mundane, but it has far reaching implications. Dealing with delay or latency in a Socially Intelligent fashion is therefore a prime problem and a focus of some of our current user based research. The user must retain an appropriate sense of *co-presence* [Zhao (2003)] of the other person that is being communicated with. If the link is down but the person can still be contacted, albeit with delay, that sense of another being there must remain. Alternatively, even if the link is up but the other person has left, that fact has to be communicated.

We are concentrating on adapting communication content and its interfaces to user capabilities. By capabilities, we do not only refer to computer hardware and software, but also the capabilities of the user.

This adaptation process is performed by a system we have called a SoftBridge. It is an embodiment of Social Intelligence Design: both as an abstraction and as a concrete embodiment. The SoftBridge relies on the abstraction of communications mechanisms such as text, voice, video and VR.

A SoftBridge enables us to design and, where practical, build applications that bridge vastly different access equipment (telephones, cellphones, handheld Mobile IP devices, laptops, personal computers, HMDs) to communicate seamlessly using various communications media (text, voice, video, VR) without regard to underlying mechanics of the process.

It also adapts to the user. For instance, if a user is blind, then the system would only deliver audio, or translate text into speech. And if they were deaf, speech would be converted into text. As another example,

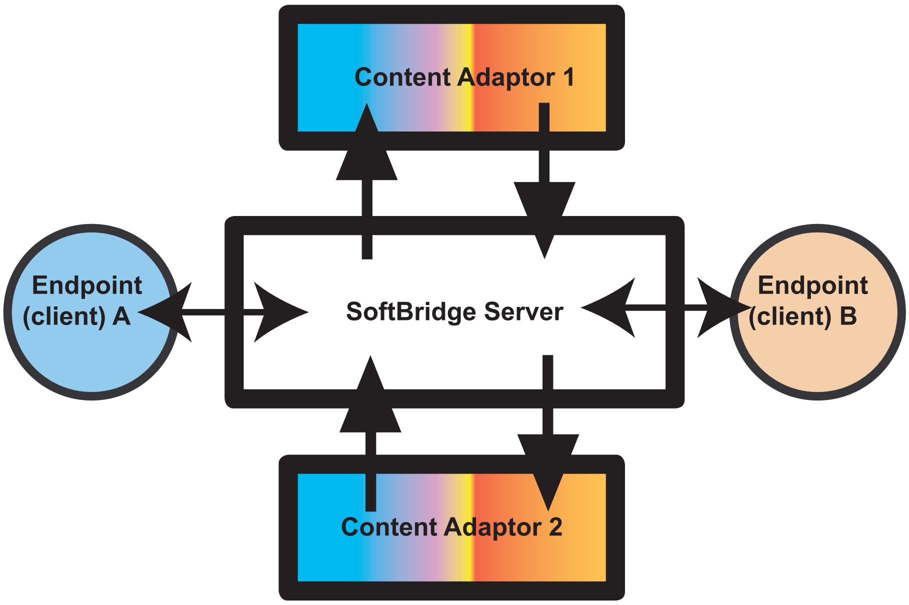


Figure 2: The Data Flow Architecture of the SoftBridge. The diagram shows how the server calls adaptation services to bridge between different endpoint needs.

we can extract human communication from an information and graphics-rich CVE and bridge it to a low end user. Consider a text chat tool inside an immersive Virtual Reality CVE with an IP bridge to a text chat tool running in a web browser. The content (text) and endpoint (HMD and CRT) abilities remain, but the interfaces are bridged. User preferences and profiles can also be taken into account. For instance, if the sender is male, he may prefer that messages from him are read out in a male voice.

## 3.1 SoftBridge

The architecture is based on the "Data Flow" model of computation (see Figure 2), and consists of the following components:

1. Endpoints.

   Endpoints are the locations where humans interact with the system, and typically consist of devices such as personal computers, cell phones, telephones and wireless handhelds.

2. Content Adapters

   Adapters convert information from a form produced by one endpoint into a form consumable by another endpoint. For instance, if endpoint A produces speech, and endpoint B consumes text, adapter AB will convert speech to text.

3. Control/Location/Billing

   The control function deals with the allocation of adapters and the synchronization of components. It also coordinates the dynamic relocation of adapters as network conditions change. The network conditions are discovered by using Quality of Service (QoS) parameters such as jitter, latency and packet loss. Endpoints register themselves with the Control component when they connect to the system. This allows the Control component to keep track of all currently connected endpoints and simplifies billing.

### 3.2 An Example Scenario: Bridging Deaf and Hearing

> Andile calls Noxolo with his mobile. She is deaf, so her handheld vibrates to announce the incoming call. Andile's speech is converted to text and relayed to her. She responds in writing that is converted to speech, imitating her voice. The specialized semi-synchronous conversation interface enables them to feel connected despite the delay.

This example illustrates the action of the SoftBridge in translating between the requirements of the two users. Such requirements arise from the combination of personal requirements, the system capabilities at the two ends of the link and the quality of the infrastructure between them. As explained above the SoftBridge will act to link the two users automatically according to these conditions.

A further design issue requiring Social Intelligence is dealing with the inevitable latency issues. There are many possible sources for delay other than transmission latency. For example, the communication could involve bridging from one modality of communication to another, or the communication channel can be inherently unstable.

The user interface can help in dealing with these situations. When a user believes that lack of response means a broken communication link, s/he often gives up. An interface that indicates that a response is on its way could save the situation and encourage a bit of patience. The interface has the potential to provide a social link between the parties even when communication is not being explicitly exchanged. Social software features would address presence, awareness of the other's activities, and persistence of communication threads. These features encourage social connectivity over poor delay situations.

## 4 Current Status

Field trials are underway with two communities in South Africa.

The Bastion Centre for the Deaf serves a "disadvantaged" community in Cape Town that is marginalized from mainstream communications due to both poverty and hearing disorders. Voice/text relay enables a deaf person to use a "text telephone" to communicate with someone on a normal telephone via an operator with both devices. Because this service is not available in South Africa, we have built an automated voice/text relay system based on web services. Automated Speech Recognition (ASR) weakens the communication bridges by increasing real-time delay via processing overhead. As noted before, ASR also performs poorly with South African accented English. Preliminary trials have influenced back-end development, Lewis et al. (2003) as well as interfaces targeted for both deaf and hearing users, Tucker et al. (2003).

The second community is located in a remote rural region. Tsilitwa (Eastern Cape, South Africa) has a clinic without a doctor that serves roughly 10,000 people. The Centre for Scientific and Industrial Research (CSIR) has installed a wireless Ethernet network with basic voice and video over IP to allow clinic nurses to communicate with a doctor in a neighboring village. However, the system is rarely used due to frequent power outages. Visits to Tsilitwa, workshops with the CSIR and frequent communication with a local NGO called bridges.org, together have yielded software requirements for a multi-modal store-and-forward system to overcome the power problems. A prototype is now ready for extended testing, Chetty et al. (2003).

### 4.1 Initial Results from the Deaf-Hearing Bridging Project

As noted before our testing proceeds in cycles. The first cycle of testing of the Deaf telephony project involved a single Deaf user (DU). We conducted three tests varying the input/output modalities of the hearing user (HU). The DU had a standard text in/text out Instant Messaging client. The HU client used the following specific modality combinations: Text and Text-to-Speech (TTS) in/Text out, TTS in/Text out and TTS in/Text and Automatic Speech Recognition (ASR) out. The SoftBridge logged the conversations for subsequent analysis.

The trial showed a largely successful conversation. Success factors included a) a text and computer literate DU who is familiar with research practice, b) using the system to explain the research as we conducted it and c) that the multi-modal bridging capabilities overcame the expected shortcomings of TTS and especially ASR.

It showed:

1. Deaf users use a different grammar (related to South African Sign Language, SASL) and this cannot be automatically corrected for hearing users. This point was emphasized by the deaf user. Thus hearing users have to deal with the poor language skills of deaf users.

2. ASR (Automatic Speech Recognition) is inadequate to the task of recognizing South African English and other South African Official Languages. There are projects elsewhere to address this and in the meantime we will have to mimic ASR by employing a person to provide the service.

3. Presence indicators are needed to show continuation of the conversation when there is no visible activity due to delays.

### 4.2 Some Preliminary Results from the Rural Tele-Health Project

The Tele-Health software has recently been deployed. This occurred on our third visit to the target community, the first being an orientation visit and the second the presentation of a paper prototype.

In introducing the software we have been struck by the complicated community interactions that determine whether a IT solution will be accepted. For example, the existing power-relations may prevent solutions that help the poorest people in the village.

The essential idea is to allow nurses in outlying villages to communicate with the one or two doctors at the local town hospital. A video conference link is problematic because frequent power failures render it useless for lengthy periods. Due to the shortage of staff at the hospital, tele-medicine is an additional workload for the doctor who is solely responsible for the entire hospital. It is therefore difficult to schedule times when a synchronous tele-medicine consultation can occur.

We decided that combining a store and forward approach with VoIP would resolve the communication problems. Store and forward was explained to participants in terms of voicemail on cellular telephones and everyone was familiar with these. A store and forward approach allows patient data to be captured at any time and then sent to the recipient site when a network connection becomes available. We decided to introduce laptops since they offer several hours of battery life. This means that data can be captured even during a power failure for as long as the battery lasts.

The software was required to support synchronous voice calls and asynchronous sending of messages between the clinic and the hospital. These messages were to contain text indicating the patients illness and medical history, digital pictures of the patient or particular problem area and voice recordings.

We have now installed the software (see Figure 3) on the new laptops at the hospital and the clinic and connected these to the Wi-Fi network. The initial feedback received from interviews with the doctor and nurses in the area was positive. The doctor felt that our system would allow him to process and reply to messages in his own time without being constantly interrupted during tele-medicine consultations by emergency calls. The nurse at the clinic felt that the system would increase the processing of patients and felt that the digital images and text would help the doctor accurately diagnose problems with a patient.

## 5 Influencing IT Policy

Social Intelligence with respect to IT is not just a matter for the target communities. As our NGO partners have long known, work on the ground has to be accompanied with work in the upper reaches of government. The Governments of Developing Countries also have to be advised and educated about the implications and potential of IT.

It is necessary therefore to include the influencing of IT policy as one of the essential outcomes of IT research for Development. It is another aspect of a Critical research approach.

In South Africa, for example, the use of Voice over IP is subject to many restrictions. According to SA Telecommunications legislation, VoIP may only be provided by Telkom (the current telecommunications monopoly holder), the long-awaited Second National Operator (SNO) and the Under-Serviced Area Licensees (USALs) [SA Government (1996, 2001)]. USALs are being granted to one Small, Medium and Micro Enterprise (SMME) per geographic area where the less than five percent of the population have access to telecommunications services or facilities. A USAL enables an SMME to provide telecommunications services and use VoIP. In practice this is not effective.

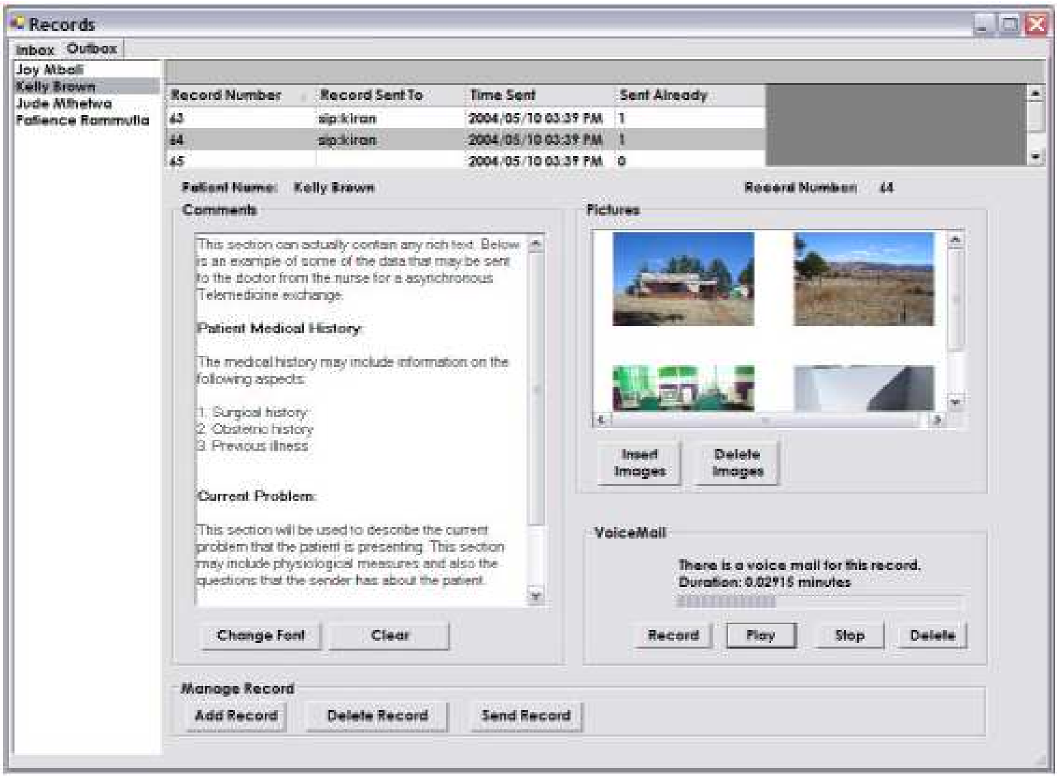


Figure 3: Telehealth Project. This screenshot shows the records dialogue where records are displayed per patient in an Inbox and an Outbox. This screenshot shows a dummy record to illustrate that a record can contain text, images and voicemail. Images may also be viewed in a separate image viewer which allows enlargement.

The high cost of network communication and the lack of affordable bandwidth was the most frequently cited constraint on the realization of an Information Society in South Africa. It is setting back education and research. While there have been some very innovative approaches to the problem[1] these cannot be a substitute for changing the policy environment in which we operate.

It is important there fore to generate research results that politicians will understand; and mostly this means ones that will translate into votes. Highly visible applications and good ones that generate good publicity are thus required.

## 6 Conclusion

We have shown how "Social Intelligence Design" can be applied in a developing country. The aspects of Social Intelligence influence the systems, the users and the researchers. It is especially the IT professionals who have to move from a Software Development Lifecycle based view of systems development, to seeing both the microcosm in which their users operate: the community, and the macrocosm in which everyone exists: the laws of the society.

The implications for IT Artefact development is that one has to develop a methodology that can operate in a very sensitive manner within the culture of the users (our community-centered method) and help those users to deal automatically with the complexities of communicating knowledge (abstracted as the

[1]Wizzy: The firm Wizzy (www.wizzy.org.za) has found a unique high bandwidth solution to providing Internet access to deprived schools in townships and rural areas. Transporting the data by road on a high capacity disk! It is a sorry reflection on the skewed cost of bandwidth that one has to resort to such solutions. Wizzy has several other excellent ideas to ensure ease of operation and security and it is able to provide a high-quality solution. By the way, notice the role that latency plays in this solution!

SoftBridge). These are both aspects of Social Intelligence Design.

In the work we have done so far we have shown that, beyond this, when building a device such as the SoftBridge, that dealing with delay is an essential feature. We have argued that this has major implications for user interface design.

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