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Case Studies

No matter how much planning goes into building a link or node location, you will inevitably have to jump in and actually install something. This is the moment of truth that demonstrates just how accurate your estimates and predictions prove to be.

It is a rare day when everything goes precisely as planned. Even after you install your 1st, 10th, or 100th node, you will still find that things do not always work out as you might have intended. This chapter describes some of our more memorable network projects. Whether you are about to embark on your first wireless project or you are an old hand at this, it is reassuring to remember that there is always more to learn.

General advice

The economies of developing countries are very different from the developed world, and thus a process or solution designed for a more developed country may not be suitable in West Africa, or Southern Asia. Specifically, the cost of locally produced materials and the cost of labour will be negligible, whereas imported goods can be much more expensive when compared to its cost in the developed world. For example, one can manufacture and install a tower for a tenth of the cost of a tower in the United States, but the price of an antenna might be double. Solutions that capitalize on local competitive advantages, namely cheap labour and locally found materials, will be the easiest to replicate.

Finding the right equipment is one of the most difficult tasks in developing markets. Because transportation, communication and economic systems are not developed, the right materials or equipment can be difficult and often impossible to find. A fuse, for example, is difficult to find, thus finding wire that has a burn-up at a certain amperage and can substitute is a great advantage.

Finding local substitutes for materials also encourages local entrepreneurship, ownership, and can save money.

Equipment enclosures

Cheap plastics are everywhere in the developing world, but they are made of poor materials and are thin, thus mostly unsuitable for enclosing equipment. PVC tubing is far more resilient and is made to be waterproof. In West Africa, the most common PVC is found in plumbing, sized from 90mm to 220mm. Access points such as the Routerboard 500 and 200 can fit into such tubing, and with end-caps that are torched-on, they can make very robust waterproof enclosures. They also have the added benefit of being aerodynamic and uninteresting to passers-by. The resulting space left around the equipment assures adequate air circulation. Also, it is often best to leave an exhaust hole at the bottom of the PVC enclosure. The author did find that leaving open holes can become a problem. In one instance ants decided to nest 25 meters above ground inside the PVC holding the access point. Using a wire mesh cover made from locally available screen material is advised to secure the exhaust hole from infestations.

Antenna masts

Recovering used materials has become an important industry for the poorest countries. From old cars to televisions, any material that has value will be stripped, sold, or re-used. For example, you will see vehicles torn apart piece by piece and day by day. The resulting metal is sorted and then tossed into a truck to be sold. Local metal workers will already be familiar with how to make television masts from scrap metal. A few quick adaptations and these same masts can be re-purposed for wireless networks.

The typical mast is the 5 meter pole, comprised of a single 30mm diameter pipe which is then planted into cement. It's best to construct the mast in two parts, with a removable mast that fits into a base which is slightly larger in diameter. Alternately, the mast may be made with arms that can be securely cemented into a wall. This project is easy, but requires the use of a ladder to complete and therefore some caution is suggested.

This type of mast can be augmented by several meters with the use of guy lines. To sturdy the pole, plant three lines 120 degrees apart, at a decline of at least 33 degrees from the tip of the tower.

Above all: involve the local community

Community involvement is imperative in assuring the success and sustainability of a project. Involving the community in a project can be the greatest challenge, but if the community is not involved the technology will not serve their needs, nor will it be accepted. Moreover, a community might be afraid and could subvert an initiative. Regardless of the complexity of the undertaking, a successful project needs support and buy-in from those it will serve.

An effective strategy in gaining support is to find a respected champion whose motives are palatable. Find the person, or persons whom are most likely to be interested in the project. Often, you will need to involve such champions as advisors, or as members of a steering committee. These people will already have the trust of the community, will know who to approach, and can speak the language of the community. Take your time and be selective in finding the right people for your project. No other decision will affect your project more than having effective, trusted local people on your team.

In addition, take note of key players in an institution, or community. Identify those people whom are likely to be opponents and proponents of your project. As early as possible, attempt to earn the support of the potential proponents and to diffuse the opponents. This is a difficult task and one that requires intimate knowledge of the institution or community. If the project does not have a local ally, the project must take time to acquire this knowledge and trust from the community.

Be careful in choosing your allies. A "town-hall" meeting is often useful to see local politics, alliances, and feuds in play. Thereafter, it is easier to decide on whom to ally, champion and whom to diffuse. Try to not build unwarranted enthusiasm. It is important to be honest, frank, and not to make promises that you cannot keep.

In largely illiterate communities, focus on digital to analog services such as Internet for radio stations, printing on-line articles and photos, and other non-textual applications. Do not try to introduce a technology to a community without understanding which applications will truly will serve the community. Often the community will have little idea how new technologies will help their problems. Simply providing new features is useless without an understanding of how the community will benefit.

When gathering information, verify the facts that you are given. If you want to know the financial status of a company/organization, ask to see an electricity bill, or phone bill. Have they been paying their bills? At times, potential beneficiaries will compromise their own values in hopes of winning funds or equipment. Most often, local partners who trust you will be very frank, honest, and helpful.

Another common pitfall is what I call "divorced parents" syndrome, where NGOs, donors, and partners are not told of each others involvement with the beneficiary. Savvy beneficiaries can earn handsome rewards by letting NGOs and donors lavish them with equipment, training and funds. It is important to know which other organizations are involved so you can understand how their activities might impact your own. For example, I once designed a project for a rural school in Mali. My team installed an open source system with used computers and spent several days training people how to use it. The project was deemed a success, but shortly after the installation, another donor arrived with brand-new Pentium 4 computers running Windows XP. The students quickly abandoned the older computers and lined-up to use the new computers. It would have been better to negotiate with the school in advance, to know their commitment to the project. If they had been frank, the computers that are now sitting unused could have been deployed to another school where they would be used.

In many rural communities in under-developed economies, law and policies are weak, and contracts can be effectively meaningless. Often, other assurances must be found. This is where pre-paid services are ideal, as they do not require a legal contract. Commitment is assured by the investment of funds before service is given.

Buy-in also requires that those involved invest in the project themselves. A project should ask for reciprocal involvement from the community.

Above all, the "no-go" option should always be evaluated. If a local ally and community buy-in cannot be had, the project should consider choosing a different community or beneficiary. There must be a negotiation; equipment, money, and training cannot be gifts. The community must be involved and they too must contribute.

—Ian Howard

Case study: Crossing the divide with a simple bridge in Timbuktu

Networks ultimately connect people together, and therefore always involve a political component. The cost of Internet in less developed economies is high and the ability to pay is low, which adds to the political challenges. Attempting to superimpose a network where human networks are not fully functioning is nearly impossible in the long term. Trying to do so can leave a project on unstable social ground, threatening its existence. This is where the low cost and mobility of a wireless network can be advantageous.

The author's team was asked by funders to determine how to connect a rural radio station with a very small (2 computer) telecentre to the Internet in Timbuktu, the desert capital of Mali. Timbuktu is widely known as an outpost in the most remote area of the world. At this site, the team decided to implement a model which has been called the ***parasitic wireless model***. This model takes a wireless “feed” that is spliced from an existing network, and extends that network to a client site using a simple bridged network. This model was chosen because it requires no significant investment by the supporting organization. While it added a source of revenue for the telecentre, it did not add a significant operational cost. This solution meant that the client site could get cheap Internet, albeit not as fast or as reliable as a dedicated solution. Because of opposed usage patterns between an office and a telecentre there was no perceptible slowing of the network for either party. Though in an ideal situation it would be best to encourage more development of the small telecentre into an ISP, neither the telecentre nor the market were deemed ready. As is often the case, there were serious concerns about whether this telecentre could become self-sustaining once its funders departed. Thus, this solution minimized the initial investment while achieving two goals: first, it extended the Internet to the target beneficiary, a radio station, at an affordable cost. Second, it added a small additional revenue source for the telecentre while not increasing its operational costs, or adding complexity to the system.

The people

Timbuktu is remote, though having a world renowned name. Being a symbol of remoteness, many projects have wanted to “stake a flag” in the sands of this desert city. Thus, there are a number of information and communications technologies (ICT) activities in the area. At last count there were 8 satellite connections into Timbuktu, most of which service special interests except for the two carriers, SOTELMA and Ikatel. They currently use VSAT to link their telephone networks to the rest of the country. This telecentre used an X.25 connection to one of these telcos, which then relayed the connection back to Bamako. Relative to other remote cities in the country, Timbuktu has a fair number of trained IT staff, three existing telecentres, plus the newly installed telecentre at the radio station. The city is to some degree over saturated with Internet, precluding any private, commercial interests from being sustainable.

Design Choices

In this installation the client site is only 1 km away directly by line of sight. Two modified Linksys access points, flashed with OpenWRT and set to bridge mode, were installed. One was installed on the wall of the telecentre, and the other was installed 5 meters up the radio station's mast. The only configuration parameters required on both devices were the ssid and the channel. Simple 14 dBi panel antennas (from *http://hyperlinktech.com/*) were used. At the Internet side, the access point and antenna were fastened using cement plugs and screws onto the side of the building, facing the client site. At the client site, an existing antenna mast was used. The access point and antenna were mounted using pipe rings.

To disconnect the client, the telecentre simply unplugs the bridge on their side. An additional site will eventually be installed, and it too will have its own bridge at the telecentre so that staff can physically disconnect the client if they have not paid. Though crude, this solution is effective and reduces risk that the staff would make a mistake while making changes to the configuration of the system. Having a bridge dedicated to one connection also simplified installation at the central site. as the installation team was able to choose the best spot for connecting the client sites. Though it is not optimal to bridge a network (rather than route network traffic), when technology knowledge is low and one wants to install a very simple system this can be a reasonable solution for small networks. The bridge makes systems installed at the remote site (the radio station) appear as though they are simply connected to the local network.

Financial model

The financial model here is simple. The telecentre charges a monthly fee, about $30 per connected computer to the radio station. This was many times cheaper than the alternative. The telecentre is located in the court of the Mayor's office, so the principle client of the telecentre is the Mayor’s staff. This was important because the radio station did not want to compete for clientele with the telecentre and the radio station's systems were primarily intended for the radio station staff. This quick bridge reduced costs, meaning that this selective client base could support the cost of the Internet without competing with the telecentre, its supplier. The telecentre also has the ability to easily disconnect the radio station should they not pay. This model also allowed sharing of network resources. For example, the radio station has a new laser printer, while the telecentre has a colour printer. Because the client systems are on the same network, clients can print at either site.

Training

To support this network, very little training was required. The telecentre staff were shown how to install the equipment and basic trouble shooting, such as rebooting (power cycling) the access points, and how to replace the unit should one fail. This allows the author's team to simply ship a replacement and avoid the two day trek to Timbuktu.

Summary

The installation was considered an interim measure. It was meant to serve as a stop-gap measure while moving forward with a more complete solution. While it can be considered a success, it has not yet led to building more physical infrastructure. It has brought ICTs closer to a radio solution, and re-enforced local client/supplier relationships.

As it stands, Internet access is still an expensive undertaking in Timbuktu. Local politics and competing subsidized initiatives are underway, but this simple solution has proven to be an ideal use case. It took the team several months of analysis and critical thought to arrive here, but it seems the simplest solution provided the most benefit.

—Ian Howard

Case study: Finding solid ground in Gao

One day's drive east from Timbuktu, in Eastern Mali, is Gao. This rural city, which seems more more like a big village, sits up the the river Niger just before it dips South crossing into Niger and onto Nigeria. The city slopes into the river gently, and has few buildings taller than two stories. In 2004, a telecentre was installed in Gao. The project's goal was to provide information to the community in the hope that a better informed community would yield a healthier and more educated citizenry.

The centre provides information via CD-ROMs, films and radio, but the cornucopic source of information for the centre is the Internet. It is a standard telecentre, with 8 computers, an all-in-one printer, scanner, fax, a telephone and a digital camera. A small two room building was built to house the telecentre. It is located a bit outside of downtown, which is not an ideal location for attracting customers, but the site was chosen because of its sympathetic host. The site received funding for all construction needed, and equipment and initial training was supplied as well. The telecentre was expected to be self-sustaining after one year.

Several months after its opening, the telecentre was attracting few customers. It used a modem to dial-up to connect to an Internet provider in the capital. This connection was too slow and unreliable, and so the funder sponsored the installation of a VSAT system. There are a number of VSAT systems now available to the region; most of these services have just recently become available. Previously only C-band (which cover a larger area than Ku-band) systems were available. Recently, fiber has been laid in almost every subway tunnel and canal throughout Europe, and thus it has supplanted the more expensive satellite services. As a result, providers are now redirecting their VSAT systems to new markets, including middle and Western Africa, and South Asia. This has led to a number of projects which use satellite systems for an Internet connection.

After the VSAT was installed, the connection provided 128 Kbps down and 64 Kbps up, and cost about $400 per month. The site was having trouble earning enough revenue to pay for this high monthly cost, so the telecentre asked for help. A private contractor was hired, who had been trained by the author to install a wireless system. This system would split the connection between three clients: a second beneficiary, a radio station, and the telecentre, each paying $140. This collectively covered the costs of the VSAT, and the extra revenue from the telecentre and the radio station would cover support and administration of the system.

The people

Though capable and willing, the author's team did not do the actual installation. Instead, we encouraged the telecentre to hire the local contractor to do it. We were able to reassure the client by agreeing to train and support the contractor in the fulfillment of this installation. The premise of this decision was to discourage a reliance on a short-term NGO, and rather to build trust and relationships between domestic service providers and their clients. This design proved to be fruitful. This approach took much more time from the author's team, perhaps twice as much, but this investment has already begun to pay-off. Networks are still being installed and the author and his team are now home in Europe and North America.

Design choices

Initially, it was conceived that a backbone connection would be made to the radio station, which already had a 25 meter tower. That tower would be used to relay to the other clients, avoiding the need to install towers at the client sites, as this tower was well above any obstacles in the city. To do this, three approaches were discussed: installing an access point in repeater mode, using the WDS protocol, or using a mesh routing protocol. A repeater was not desirable as it would introduce latency (due to the one-armed repeater problem) to an already slow connection. VSAT connections need to send packets up to the satellite and back down, often introducing up to 3000 ms in delay for a round trip. To avoid this problem, it was decided to use one radio to connect to clients, and a second radio for to the dedicated backbone connection. For simplicity it was decided to make that link a simple bridge, so that the access point at the radio station would appear to be on the same physical LAN as the telecentre.

In testing this approach functioned, though in the real world, its performance was dismal. After many different changes, including replacing the access points, the technician decided that there must be a software or hardware bug affecting this design. The installer then decided to place the access point at the telecentre directly using a small 3 meter mast, and to not use a relay site at the radio station. The client sites also required small masts in this design. All sites were able to connect, though the connections were at times too feeble, and introduced massive packet loss.

Later, during the dust season, these connections became more erratic and even less stable. The client sites were 2 to 5 km away, using 802.11b. The team theorized that the towers on either side were too short, cutting off too much of the Fresnel zone. After discussing many theories, the team also realized the problem with the performance at the radio station: the radio frequency 90.0 MHz was about the same as the frequency of the high-speed (100BT) Ethernet connection. While transmitting, the FM signal (at 500 watts) was completely consuming the signal on the Ethernet cable. Thus, shielded cable would be required, or the frequency of the Ethernet link would need to be changed. The masts were then raised, and at the radio station the speed of the Ethernet was changed to 10 Mbps. This changed the frequency on the wire to 20 MHz, and so avoided interference from the FM transmission. These changes resolved both problems, increasing the strength and reliability of the network. The advantage of using mesh or WDS here would be that client sites could connect to either access point, either directly to the telecentre to the radio station. Eventually, removing the reliance on the radio station as a repeater likely made the installation more stable in the longer-term.

Financial model

The satellite system used at this site cost approximately $400 per month. For many IT for Development projects this expensive monthly cost is difficult to manage. Typically these projects can purchase equipment and pay for the establishment of a wireless network, but most are not able to pay for the cost of the network after a short period of time (including the recurring Internet costs and operational costs). It is necessary to find a model where the monthly costs for a network can be met by those who use. For most community telecenters or radio stations, this is simply too expensive. Often, the only feasible plan is to share the costs with other users. To make the Internet more affordable, this site used wireless to share the Internet to the community, allowing a greater number of organizations to access the Internet while reducing the cost per client.

Typically in Mali, a rural community has only a few organizations or companies that could afford an Internet connection. Where there are few clients, and the Internet connection cost is high, the model developed by his team included ***anchor clients***: clients whom are solid and are low-risk. For this region, foreign NGOs (Non Governmental Organizations), the United Nations Agencies and large commercial enterprises are among the very few whom qualify.

Among the clients selected for this project were three anchor clients, who collectively paid the entire monthly cost of the satellite connection. A second beneficiary, a community radio station, was also connected. Any revenue earned from the beneficiaries contributed to a windfall, or deposit for future costs, but was not counted upon due to the small margins that both of these community services operated on. Those clients could be disconnected and could resume their service once they can afford it again.

Training needed: who, what, for how long

The contractor taught the telecentre technician the basics of supporting the network, which was fairly rudimentary. Any non-routine work, such as adding a new client, was contracted out. Therefore it was not imperative to teach the telecentre staff how to support the system in its entirety.

Lessons learned

By sharing the connection, the telecentre is now self-sustaining, and in addition, three other sites have Internet access. Though it takes more time and perhaps more money, it is valuable to find the right local talent and to encourage them to build relationships with clients. A local implementor will be able to provide the follow-up support needed to maintain and expand a network. This activity is building local expertise, and demand, which will allow subsequent ICT projects to build on this base.

—Ian Howard

Case Study: Spectropolis, New York

In September 2003 and October 2004, NYCwireless produced Spectropolis. This event celebrated the availability of open wireless (Wi-Fi) networks in Lower Manhattan and explored their implications for art, community, and shared space. Spectropolis is the world's first wireless arts festival, and was envisioned as a way to bring the techno-centric nature of Wi-Fi into a more accessible form. The idea was to create a way for average residents and visitors to New York to "see" and "feel" the wireless signals that permeate the city (especially the free Wi-Fi that NYCwireless provides in many city parks) that are otherwise invisible.

The idea for Spectropolis came from a series of discussions in the winter of 2003 between Dana Spiegel, then a member-at-large for NYCwireless, and Brooke Singer, an independent New Media artist and associate professor at SUNY Purchase.

Spectropolis took place at City Hall Park, a well-known free wireless hotspot in New York City, New York. The festival featured works of art from 12 international artists. Each art piece integrated and made use of one or more forms of wireless technology, including Wi-Fi, Bluetooth, Radio, GPS, and others. Each piece was intended to explore how wireless technologies affect our everyday urban experiences. The pieces were exhibited outdoors in the park for three days, and the artists were out exhibiting artwork and explaining their work to park visitors.

In addition to the works of art, Spectropolis offered five workshops and three panel discussions. The workshops offered an up-close look at wireless communication technologies and an opportunity for hands-on play and participation. The workshops aimed to educate both the technical and non-technical public and demystify a range of technologies through engaging presentations.

The panels explored the larger scale implications of wireless technologies for society, public policy, activism, and art. Each panel focussed on a particular area of influence for wireless technology, with commentary by a number of recognized leaders.

An outdoor park/public space was chosen for the event primarily because this location provided a way to both attract a large number of attendees as well as situate the event in a space that many people pass through both during the workday and on the weekend. One of the goals of the event was to reach out to local residents and people who wouldn't otherwise attend a technology-centric event. During the time that Spectropolis was in City Hall Park, thousands of people came through the park each day, and many stopped to look at one or more artworks.

From a visibility point of view, holding Spectropolis in an outdoor public space was important, and the foot traffic around the area definitely resulted in attracting a number of people into the park who would otherwise not have come to the event. In addition, New York City has a long history of outdoor public art, however this art is almost entirely sculptural in form, and meant to participate in the landscape but not really be interactive. Bringing highly interactive new media art from a museum or gallery into an outdoor public space created discordance with people's expectations.

Why Spectropolis is important

Spectropolis is an attempt to give wireless technology and Wi-Fi in particular a life beyond email and websurfing. The interactive works of art showcased at Spectropolis are engaging beyond the “work-use” that is associated with Wi-Fi by the general public. By introducing wireless technologies via “play” and “exploration”, Spectropolis removes much of the fear that people have about new technologies, and enables people to consider the larger implications of wireless technologies and their lives without getting caught up in the “how” of the technology itself.

Spectropolis is a unique event because it focuses on the social impact of wireless technologies, as opposed to the technologies themselves. The vast majority of people are either scared by raw technology (this is common in adults more than children) or are merely disinterested. While Wi-Fi and cellular technologies have made significant inroads into general society, they have done so by riding on the coat-tails of two well established social activities: talking on the phone and accessing the Internet (email, web, IM, etc.)

In addition, Spectropolis puts a face on the ethereal nature of wireless signals. That Wi-Fi is available in a park may be indicated by signs and stickers on windows, but creating a tangible artifact in the form of works of art drives this concept home in the same way that benches, trees, and grass showcase the public amenities that a park provides. Wi-Fi in public spaces isn't a gated community, but rather a public resource that can be shared and appreciated by all just like the shade of a large tree.

Participating organizations

NYCwireless, through Dana Spiegel, took on the role of producing Spectropolis. NYCwireless is a non-profit organization that advocates and enables the growth of free, public wireless Internet access in New York City and surrounding areas. NYCwireless, founded in 2001, is an all-volunteer organization with seven board members, five special interest working groups and approximately sixty active members.

NYCwireless partnered with other local organizations and prominent individuals from the New York Arts community who volunteered their time to help curate and produce the event. Spectropolis was sponsored by the Alliance for Downtown New York (DTA), a Business Improvement District (BID) company. The DTA also sponsors a number of free, public, wireless hotspots in downtown New York, including the hotspot at City Hall Park, where Spectropolis was held. The Lower Manhattan Cultural Council (LMCC), an arts funding and promotion organization, sponsored the curation of Spectropolis. LMCC hosted a number of meetings and oversaw the process of inviting and evaluating artists and their works in preparation of the event. In addition, a number of individuals contributed a significant amount of time to Spectropolis: Wayne Ashley (Curator, LMCC), Yury Gitman (Curator), Jordan Silbert (Producer), and Jordan Schuster (Producer)

Community Reception

The local community received Spectropolis quite well. The primary groups of people who attended the event were: wireless researchers, wireless proponents, artists, and the general public.

Leading up to the event, we reached out to the local artist and local university communities to generate interest. We received a large number of email inquiries from people both locally and around the continent (primarily US and

Canada) about attending the event. Some wireless enthusiasts even traveled from Europe in order to attend. The local university community was particularly interested, with students from NYU, SUNY, New School, Parsons, and other nearby schools attending. During the event we even had a few people bring their own projects to the park and set them up.

We also sent out a press release to local media outlets and websites to inform the general NYC community about the event. While we weren't contacted prior to the event by anyone from the general public, there were some people from this group who signed up for our workshops and our panels who had not ever handled wireless equipment. Primarily, local residents and visitors just showed up to the event to experience the artwork. We had thousands of people each day come through the park and experience at least a few of the works.

In addition to the art, we had a number of people ask questions about wireless technology in general, and public Wi-Fi in specific. Many of these people were directed to the NYCwireless information booth that was set up in the middle of the park. A number did speak directly to the artists (we had expected this, and this was one of the reasons why we wanted artists to show their own work) about the works they created, and ask about how they worked and why the artist created the work.

For a number of attendees, Spectropolis was the first time they experienced Wi-Fi as something more than just an Internet technology. Many were surprised that wireless technologies could be more than just a cell phone call or a web page in a cafe, and they were pleased to get a better grasp on the alternative uses for Wi-Fi that the art works explored. In some instances, the relationship between wireless signals and the works of art were hidden and obscure--such as Akitsugu Maebayashi's Sonic Interface. In other works, like Upper Air by the DSP Music Syndicate, the art was designed to support the existence of the wireless technology, and the piece explored the the technology's relationship to both the viewer and the art.

Some pieces, such as Jabberwocky by Eric John Paulos and Elizabeth Goodman, made use of the technology to explore social relationships in urban environments. These works were important and meaningful because they related wireless technology to something that is clearly a human experience, such as seeing familiar strangers in a crowd. In Jabberwocky in particular, the viewer is forced to see also the limits of the wireless technology, and make use of human abilities to fill in the gaps.

GPS drawings, a workshop held by Jeremy Wood, extended the notion of humans + technology equaling something greater than the sum of its parts. Wood actually led groups of people around parts of downtown New York City to create large scale drawings out of their movements. This artwork personalized the experience of wireless technologies more than any other project.

All of the projects forced people to re-evaluate their relationships with their technologies. More than just seeing public spectrum and wireless networks in a new light, Spectropolis caused people to think about how these technologies enrich and permeate their lives. In speaking with artists after the event, all of them were surprised by how engaged people were. People who interacted with the artworks had a better understanding of the otherwise ephemeral nature of wireless signals. For visitors to the event, Spectropolis made abstract concepts of spectrum and public wireless much more concrete, and gave them a way to understand these concepts in a way that merely using a cell phone or Wi-Fi laptop could not, and in this way, Spectropolis was a complete success.

Projects

Spectropolis featured the following projects and artists:

- **WiFi Ephemera Cache** by Julian Bleecker,
- **UMBRELLA.net** by Jonah Brucker-Cohen and Katherine Moriwaki
- **Microrardio Sound Walk** by free103point9 Transmission Artists
- **Urballoon** by Carlos J. Gomez de Llarena
- **Bikes Against Bush** by Joshua Kinberg
- **InterUrban** by Jeff Knowlton and Naomi Spellman
- **Hotspot Bloom** by Karen Lee
- **Sonic Interface** by Akitsugu Maebayashi
- **Jabberwocky** by Eric John Paulos and Elizabeth Goodman
- **Upper Air** by The DSP Music Syndicate
- **Twenty-Four Dollar Island** by Trebor Scholz
- **Text Messaging Service** and **Following 'The Man of the Crowd'** by Dodgeball + Glowlab

Planning

The planning for Spectropolis began about one year prior to the event. At the outset, representatives from NYCwireless, LMCC, and DTA, as well as the producers and curators, met on a monthly basis to establish the plan and execute the event. The cost of producing Spectropolis was about $11,000 USD.

More information can be found on the Spectropolis 2004 website at *http://www.spectropolis.info/* and at my Wireless Community blog at *http://www.wirelesscommunity.info/spectropolis.*

—Dana Spiegel

Case study: The quest for affordable Internet in rural Mali

For several years the international development community has promoted the idea of closing the digital divide. This invisible chasm that has formed separating access to the wealth of information and communications technologies (ICT) between the developed and the developing world. Access to information and communications tools has been shown to have a dramatic impact on quality of life. For many donors fatigued by decades of supporting traditional development activities, the installation of a telecentre in the developing world seems like a realizable and worthwhile effort. Because the infrastructure does not exist, this is much more expensive and difficult to do in the developing world than it is in the West. Moreover, few models have been shown to sustain these activities. To help mitigate some of the cost of bringing the Internet to rural areas of the developed world, the author's team has promoted the use of wireless systems to share the cost of an Internet connection. In November of 2004, an affiliated project asked the author's team to pilot such a wireless system at a recently installed telecentre in rural Mali, 8 hours South-West by four-by-four from Bamako, the capital.

This rural city, located on the margin of a man-made reservoir, holds water for the Manitali dam that powers a third of the country. This location is fortunate as hydroelectric power is much more stable and available than diesel generated power. While diesel generated power is far less stable, some rural communities are lucky to have any electricity at all.

The city is also endowed to be in one of the most fertile regions of the country, in its cotton belt, Mali's main cash crop. It was believed that this site would be the least difficult of the rural areas in Mali to make a self-sustaining telecentre. Like many experiments, this pilot was fraught with challenges.

Technologically it was a simple task. In 24 hours the team installed an 802.11b wireless network that shares the telecenter's VSAT Internet connection with 5 other local services: the Mayor, the Governor, the health service, the district's Mayor's council (CC) and the community advisory service (CCC).

These clients had been selected during a reconnaissance two months prior. During that visit the team had interviewed potential clients and determined which clients could be connected without complicated or expensive installations. The telecentre itself is housed at the community radio station. Radio stations tend to be great sites to host wireless networks in rural Mali as they are often well placed, have electricity, security and people who understand at least the basics of radio transmissions. They are also natural hubs for a village. Providing Internet to a radio station provides better information to its listeners. And for a culture which is principally oral, radio happens to be the most effect means to provide information.

From the list of clients above, you will note that the clients were all government or para-governmental. This proved to be a difficult mix, as there is considerable animosity and resentment between the various levels of government, and there were continuing disputes regarding taxes and other fiscal matters. Fortunately the director of the radio station, the network's champion, was very dynamic and was able to wade through most of these politics, though not all.

Design choices

The technical team determined that the access point would be installed at 20 meters up the radio station tower, just below the FM radio dipoles, and not so high as to interfere with coverage to client sites below in the bowl-like depression where most were found. The team then focused on how to connect each client site to this site. An 8 dBi omni (from Hyperlinktech, *http://hyperlinktech.com/*) would suffice, providing coverage to all client sites. The 8 dBi antenna that was chosen has a 15 degree down-tilt, assuring that the two clients less than a kilometer away could still receive a strong signal. Some antennae have very narrow beam width and thus "overshoot" sites that are close. Panel antennae were considered, though at least two would be required and either a second radio or a channel splitter. It was deemed unnecessary for this installation. The following calculation shows how to calculate the angle between the client site's antenna and the base station's antenna, using standard trigonometry.

```
tan(x) = difference in elevation
       + height of base station antenna
       - height of CPE antenna
       / distance between the sites

    tan(x) = 5m + 20m - 3m / 400m
         x = tan-1 (22m / 400m)
         x =~ 3 degrees
```

In addition to the equipment in the telecentre (4 computers, a laser printer, 16 port switch), the radio station itself has one Linux workstation installed by the author's project for audio editing. A small switch was installed in the radio station, an Ethernet cable was run through plastic tubing buried at 5 cm across to the telecentre, across the yard.

From the main switch, two cables run up to a Mikrotik RB220, access point. The RB220 has two Ethernet ports, one that connects to the VSAT through a cross-over cable, and the second that connects to the radio station's central switch. The RB 220 is housed in a D-I-Y PVC enclosure and an 8 dBi omni (Hyperlink Technologies) is mounted directly to the top of the PVC cap.

The RB220, runs a derivative of Linux, Mikrotik version 2.8.27. It controls the network and provides DHCP, firewall, DNS-caching and routes traffic to the VSAT, using NAT. The Mikrotik comes with a powerful command line and a relatively friendly and comprehensive graphical interface. It is a small x86 based computer, that is designed for use as an access point or embedded computer. These access points are POE capable, have two Ethernet ports, a mini-pci port, two PCMCIA slots, a CF reader (which is used for its NVRAM), are temperature tolerant and support a variety of x86 operating systems. Despite that the Mikrotik software requires licensing, there was already a substantial install base in Mali and the system has a powerful and friendly graphical interface that was superior to other products. Due to the above factors the team agreed to use these systems, including the Mikrotik software to control these networks. The total cost of the RB220, with License Level 5, Altheros mini-pci a/b/g and POE was $461. You can find these parts at Mikrotik online at *http://www.mikrotik.com/routers.php#linx1part0.*

The network was designed to accommodate expansion by segregating the various sub-networks of each client; 24 bit private subnets were alloted. The AP has a virtual interface on each subnet and does all routing between, also allowing fire-walling at the IP layer. Note: this does not provide a firewall at the network layer, thus, using a network sniffer like tcpdump one can see all traffic on the wireless link.

To limit access to subscribers, the network uses MAC level access control. There was little perceived security risk to the network. For this first phase, a more thorough security system was left to be implemented in the future,, when time could be found to find an easier interface for controlling access. Users were encouraged to use secure protocols, such as https, pops, imaps etc.

The affiliate project had installed a C-band VSAT (DVB-S) system. These satellite systems are normally very reliable and are often used by ISPs. It is a large unit, in this case the dish was 2.2 meters in diameter and expensive, costing approximately $12,000 including installation. It is also expensive to operate. A 128 kbps down and 64 kbps up Internet connection costs approximately $700 per month. This system has several advantages compared to a Ku system though, including: greater resilience to bad weather, lower contention rates (number of competing users on the same service) and it is more efficient at transferring data.

The installation of this VSAT was not ideal. Since the system ran Windows, users were able to quickly change a few settings, including adding a password to the default account. The system had no UPS or battery back up, so once a power outage occurred the system would reboot and sit waiting for a password, which had since been forgotten. To make this situation worse, because the VSAT software was not configured as an automatic background service it did not automatically launch and establish the link. Though the C-band systems are typically reliable, this installation caused needless outages which could have been resolved with the use of a UPS, proper configuration of the VSAT software as a service, and by limiting physical access to the modem. Like all owners of new equipment, the radio station wanted to display it, hence it was not hidden from view. Preferably a space with glass doors would have kept the unit secure while keeping it visible.

The wireless system was fairly simple. All of the client sites selected were within 2 km of the radio station. Each site had a part of the building that could physically see the radio station. At the client site, the team chose to use commercial, client grade CPEs: Based on price, the Powernoc 802.11b CPE bridge, small SuperPass 7 dBi patch antennas and home-made Power Over Ethernet (POE) adaptors. To facilitate installation, the CPE and the patch antenna were mounted on a small piece of wood that could be installed on the outside wall of the building facing the radio station.

In some cases the piece of wood was an angled block to optimize the position of the antenna. Inside, a POE made from a repurposed television signal amplifier (12V) was used to power the units. At the client sites there were not local networks, so the team also had to install cable and hubs to provide Internet for each computer. In some cases it was necessary to install Ethernet adapters and their drivers (this was not determined during the assessment). It was decided that because the client's networks were simple, that it would be easiest to bridge their networks. Should it be required, the IP architecture could allow future partitioning and the CPE equipment supported STA mode. We used a PowerNOC CPE bridge that cost $249 (available at *http://powernoc.us/outdoor_bridge.html*).

Local staff were involved during the installation of the wireless network. They learned everything from wiring to antenna placement. An intensive training program followed the installation. It lasted several weeks, and was meant to teach the staff the day to day tasks, as well as basic network troubleshooting.

A young university graduate who had returned to the community was chosen to support the system, except for the cable installation, which the radio station technician quickly learned. Wiring Ethernet networks is very similar to coaxial cable repairs and installations which the radio technician already performed regularly. The young graduate also required little training. The team spent most of its time helping him learn how to support the basics of the system and the telecentre. Soon after the telecentre opened, students were lined up for the computer training, which offered 20 hours of training and Internet use per month for only $40, a bargain compared to the $2 an hour for Internet access. Providing this training was a significant revenue and was a task that the young computer savvy graduate was well suited for.

Unfortunately, and somewhat unsurprisingly, the young graduate left for the capital, Bamako, after receiving an offer for a government job. This left the telecentre effectively marooned. Their most technically savvy member, and the only one who was trained in how to support the system, had left. Most of the knowledge needed to operate the telecentre and network left with him. After much deliberation, the team determined that it was best not to train another tech savvy youth, but rather to focus on the permanent local staff, despite their limited technical experience. This took much more time. Our trainers have had to return for a total of 150 hours of training. Several people were taught each function, and the telecentre support tasks were divided among the staff.

Training did not stop there. Once the community services were connected, they too needed access. It seemed that although they were participating, the principals, including the mayor, were not using the systems themselves. The team realized the importance of assuring that the decision makers used the system, and provided training for them and their staff. This did remove some of the mystique of the network and got the city's decision makers involved.

Following training, the program monitored the site and began to provide input, evaluating ways that this model could be improved. Lessons learned here were applied to other sites.

Financial Model

The community telecentre was already established as a non-profit, and was mandated to be self-sustaining through the sale of its services. The wireless system was included as a supplementary source of revenue because early financial projections for the telecentre indicated that they would fall short of paying for the VSAT connection.

Based on the survey, and in consultation with the radio station whom manages the telecentre, several clients were selected. The radio station negotiated contracts with some support from its funding partner. For this first phase, clients were selected based on ease of installation and expressed ability to pay. Clients were asked to pay a subscription fee, as described later.

Deciding how much to charge was a major activity which required consultation and expertise that the community did not have in financial projections. The equipment was paid for by the grant, to help offset the costs to the community, but clients were still required to pay a subscription fee, which served to assure their commitment. This was equivalent to one month of the service fee.

To determine the monthly cost for an equal slice of bandwidth we started with the following formula:

```
VSAT + salaries + expenses (electricity, supplies) =
telecentre revenue + wireless client revenue
```

We had estimated that the telecentre should earn about $200 to $300 per month in revenue. Total expenses were estimated to be $1050 per month, and were broken down as: $700 for the VSAT, $100 for salaries, $150 for electricity, and about $100 for supplies. About $750 in revenue from the wireless clients was required to balance this equation. This amounted to roughly $150 from each client. This was just tolerable by the clients, and looked feasible, but required fair weather, and had no room for complications.

Because this was becoming complicated, we brought in business geeks, who modified the formula as such:

```
Monthly expenses + amortization + safety funds = total
revenue
```

The business experts were quick to point out the need of amortization of the equipment, or one could say "re-investment funds" as well as safety funds, to assure that the network can continue if a client defaults, or if some equipment breaks. This added about $150 per month for amortization (equipment valued at about $3,000, amortized over 24 months) and the value of one client for default payments, at $100. Add another 10% to account for currency devaluation ($80), and that equals an expense of $1380 per month. In trying to implement this model, it was finally determined that amortization is a concept that was too difficult to convey to the community, and that they would not consider that clients might default on payment. Thus, both formulae were used, the first by the telecentre and the second for our internal analysis.

As was soon discovered, regular payments are not part of the culture in rural Mali. In an agrarian society everything is seasonal, and so too is income. This means that the community's income fluctuates wildly. Moreover, as many public institutions were involved, they had long budget cycles with little flexibility. Although they theoretically had the budget to pay for their service, it would take many months for the payments to be made. Other fiscal complications arose as well. For example, the mayor signed on and used the back-taxes owed by the radio to pay for its subscription. This of course did not contribute to cash flow. Unfortunately, the VSAT providers have little flexibility or patience, as they have limited bandwidth and only have room for those that can pay.

Cash flow management became a primary concern. First, the revenue foreseen in financial projections showed that even with an optimistic outlook, they would not only have trouble earning enough revenue on time to pay the fee, but getting the money to the Bamako-based bank also presented a problem. Roads near the village can be dangerous, due to the number of smugglers from Guinea and wayward rebels from the Ivory Coast. As projected, the telecentre was not able to pay for its service and its service was suspended, thereby suspending payment from their clients as well.

Before the project was able to find solutions to these problems, the cost of the VSAT already began to dig the telecentre into debt. After several months, due to technical problems, as well as concerns raised in this analysis, the large C-band VSAT was replaced with a cheaper Ku band system. Although cheaper, it still sufficed for the size of the network. This system was only $450, which by ignoring amortization and safety margins is affordable by the network. Unfortunately, due to default payments, the network was not able to pay for the VSAT connection after the initial subsidized period.

Conclusions

Building a wireless network is relatively easy, but making it work is much more of a business problem than a technical problem. A payment model that considers re-investment and risk is a necessity, or eventually the network will fail. In this case, the payment model was not appropriate as it did not conform to fiscal cycles of the clients, nor did it conform to social expectations. A proper risk analysis would have concluded that a $700 (or even a $450) monthly payment left too narrow a margin between revenue and expenses to compensate for fiscal shortcomings. High demand and education needs limited the expansion of the network.

Following training the network operated for 8 months without significant technical problems. Then, a major power surge caused by a lightning strike destroyed much of the equipment at the station, including the access point and VSAT. As a result, the telecentre was still off-line at the time that this book was written. By that time this formula was finally deemed an unsuitable solution.

—Ian Howard

Case study: Commercial deployments in East Africa

Describing commercial wireless deployments in Tanzania and Kenya, this chapter highlights technical solutions providing solid, 99.5% availability Internet and data connectivity in developing countries. In contrast to projects devoted to ubiquitous access, we focused on delivering services to organizations, typically those with critical international communications needs. I will describe two radically different commercial approaches to wireless data connectivity, summarizing key lessons learned over ten years in East Africa.

Tanzania

In 1995, with Bill Sangiwa, I founded CyberTwiga, one of the first ISPs in Africa. Commercial services, limited to dialup email traffic carried over a 9.6 kbps SITA link (costing over $4000/month!), began in mid-1996. Frustrated by erratic PSTN services, and buoyed by a successful deployment of a 3-node point-multipoint (PMP) network for the Tanzania Harbours authority, we negotiated with a local cellular company to place a PMP base station on their central mast. Connecting a handful of corporations to this WiLan proprietary 2.4 GHz system in late 1998, we validated the market and our technical capacity to provide wireless services.

As competitors haphazardly deployed 2.4 GHz networks, two facts emerged: a healthy market for wireless services existed, but a rising RF noise floor in 2.4 GHz would diminish network quality. Our merger with the cellular carrier, in mid-2000, included plans for a nationwide wireless network built on the existing cellular infrastructure (towers and transmission links) and proprietary RF spectrum allocations.

Infrastructure was in place (cellular towers, transmission links, etc.) so wireless data network design and deployment were straightforward. Dar es Salaam is very flat, and because the cellular partner operated an analog network, towers were very tall. A sister company in the UK, Tele2, had commenced operations with Breezecom (now Alvarion) equipment in 3.8/3.9 GHz, so we followed their lead.

By late 2000, we had established coverage in several cities, using fractional E1 transmission circuits for backhaul. In most cases the small size of the cities connected justified the use of a single omnidirectional PMP base station; only in the commercial capital, Dar es Salaam, were 3-sector base stations installed. Bandwidth limits were configured directly on the customer radio; clients were normally issued a single public IP address. Leaf routers at each base station sent traffic to static IP addresses at client locations, and prevented broadcast traffic from suffocating the network. Market pressures kept prices down to about $100/month for 64 kbps, but at that time (mid/late 2000) ISPs could operate with impressive, very profitable, contention ratios. Hungry applications such as peer-peer file sharing, voice, and ERPs simply did not exist in East Africa. With grossly high PSTN international charges, organizations rapidly shifted from fax to email traffic, even though their wireless equipment purchase costs ranged from $2000-3000.

Technical capabilities were developed in-house, requiring staff training overseas in subjects such as SNMP and UNIX. Beyond enhancing the company skills set, these training opportunities generated staff loyalty. We had to compete in a very limited IT labor market with international gold mining companies, the UN, and other international agencies.

To insure quality at customer sites, a top local radio and telecoms contractor executed installations, tightly tracking progress with job cards. High temperatures, harsh equatorial sunlight, drenching rain, and lightning were among the environmental insults tossed at outside plant components; RF cabling integrity was vital.

Customers often lacked competent IT staff, burdening our employees with the task of configuring many species of network hardware and topology.

Infrastructure and regulatory obstacles often impeded operations. The cellular company tightly controlled towers, so that if there was a technical issue at a base station hours or days could pass before we gained access. Despite backup generators and UPS systems at every site, electrical power was always problematic. For the cellular company, electrical mains supplies at base stations were less critical. Cellular subscribers simply associated with a different base station; our fixed wireless data subscribers went offline.

On the regulatory side, a major disruption occurred when the telecoms authority decided that our operation was responsible for disrupting C-band satellite operations for the entire country and ordered us to shut down our network.

Despite hard data demonstrating that we were not at fault, the regulator conducted a highly publicized seizure of our equipment. Of course the interference persisted, and later was determined to emanate from a Russian radar ship, involved in tracking space activities. We quietly negotiated with the regulator, and ultimately were rewarded with 2 x 42 MHz of proprietary spectrum in the 3.4/3.5 GHz bands. Customers were switched over to dialup in the month or so it took to reconfigure base stations and install new CPE.

Ultimately the network grew to about 100 nodes providing good, although not great, connectivity to 7 cities over 3000+km of transmission links. Only the merger with the cellular operator made this network feasible—the scale of the Internet/data business alone would not have justified building a data network of these dimensions and making the investments needed for proprietary frequencies. Unfortunately, the cellular operator took the decision to close the Internet business in mid-2002.

Nairobi

In early 2003 I was approached by a Kenyan company, AccessKenya, with strong UK business and technical backup to design and deploy a wireless network in Nairobi and environs. Benefiting from superb networking and business professionals, improved wireless hardware, progress in internetworking, and bigger market we designed a high availability network in line with regulatory constraints.

Two regulatory factors drove our network design. At the time in Kenya, Internet services were licensed separately from public data network operators, and a single company could not hold both licenses. Carrying traffic of multiple, competing ISPs or corporate users, the network had to operate with total neutrality. Also, "proprietary" frequencies, namely 3.4/3.5 GHz, were not exclusively licensed to a single provider, and we were concerned about interference and the technical ability/political will of the regulator to enforce. Also, spectrum in 3.4/3.5 GHz was expensive, costing about USD1000 per MHz per year per base station. Restated, a base station using 2 x 12 MHz attracted license fees of over $10,000 year. Since Nairobi is a hilly place with lots of tall trees and valleys, wireless broadband networks demanded many base stations. The licensing overheads simply were not sensible. In contrast, 5.7/5.8 GHz frequencies were subject only to an annual fee, about USD 120, per deployed radio.

To meet the first regulatory requirement we chose to provide services using point-point VPN tunnels, not via a network of static IP routes. An ISP would deliver a public IP address to our network at their NOC. Our network conducted a public-private IP conversion, and traffic transited our network in private IP space. At the customer site, a private-public IP conversion delivered the globally routable address (or range) to the customer network.

Security and encryption added to network neutrality, and flexibility, as unique sales properties of our network. Bandwidth was limited at the VPN tunnel level. Based on the operating experience of our sister UK company, VirtualIT, we selected Netscreen (now subsumed under Juniper Networks) as the vendor for VPN firewall routers.

Our criteria for wireless broadband equipment eliminated big pipes and feature-rich, high performance gear. Form factor, reliability, and ease of installation and management were more important than throughput. All international Internet connections to Kenya in 2003, and at this writing, are carried by satellite. With costs 100X greater than global fiber, satellite connectivity put a financial ceiling on the amount of bandwidth purchased by end-users. We judged that the bulk of our user population required capacity on the order of 128 to 256 kbps. We selected Motorola's recently introduced Canopy platform in line with our business and network model.

Broadband Access, Ltd., went live in July 2003, launching the "Blue" network. We started small, with a single base station. We wanted demand to drive our network expansion, rather than relying on a strategy of building big pipes and hoping we could fill them.

Canopy, and third-party enhancements such as omnidirectional base stations, permitted us to grow our network as traffic grew, softening initial capital expenditures. We knew the tradeoff was that as the network expanded, we would have to sectorize traffic and realign client radios. The gentle learning curve of a small network paid big dividends later. Technical staff became comfortable with customer support issues in a simple network environment, rather than have to deal with them on top of a complex RF and logical framework. Technical staff attended two-day Motorola training sessions.

A typical PMP design, with base stations linked to a central facility via a Canopy high-speed microwave backbone, the network was deployed on building rooftops, not antenna towers. All leases stipulated 24x7 access for staff, mains power and, critically, protected the exclusivity of our radio frequencies. We did not want to restrict landlords from offering roof space to competitors, rather to simply guarantee that our own services would not be interrupted.

Rooftop deployments provided many advantages. Unlimited physical access, unconstrained by night or rain, helped meet the goal of 99.5% network availability. Big buildings also housed many big clients, and it was possible to connect them directly into our core microwave network. Rooftop sites did have the downside of more human traffic—workers maintaining equipment (a/c) or patching leaks would occasionally damage cabling. As a result all base stations were set up with two sets of cabling for all network elements, a primary and a spare.

Site surveys confirmed radio path availability and client requirements. Survey staff logged GPS positions for each client, and carried a laser range-finder to determine height of obstacles. Following receipt of payment for hardware, contractors under the supervision of a technical staffer performed installations. Canopy has the advantage that the CPE and base station elements are light, so that most installations do not need extensive civil works or guying. Cabling Canopy units was also simple, with outdoor UTP connecting radios directly to customer networks. Proper planning enabled completion of many installations in less than an hour, and contractor crews did not need any advanced training or tools.

As we compiled hundreds of customer GPS positions we began to work closely with a local survey company to overlay these sites on topographical maps. These became a key planning tool for base station placement.

Note that the point-point VPN tunnel architecture, with its separate physical and logical layers, required clients to purchase both wireless broadband and VPN hardware. In order to tightly control quality, we categorically refused to permit clients to supply their own hardware—they had to buy from us in order to have service and hardware guarantees. Every client had the same hardware package. Typical installations cost on the order of USD 2500, but that compares to the $500-600 monthly charges for 64 to 128 kbps of bandwidth. A benefit of the VPN tunnel approach was that we could prevent a client's traffic from passing over the logical network (i.e. if their network was hit by a worm or if they didn't pay a bill) while the radio layer remained intact and manageable.

As it grew from one base station to ten, and service was expanded to Mombasa, the network RF design evolved and wherever possible network elements (routers) were configured with fallover or hot swap redundancy. Major investments in inverters and dual conversion UPS equipment at each base station were required to keep the network stable in the face of an erratic power grid. After a number of customer issues (dropped VPN connections) were ascribed to power blackouts, we simply included a small UPS as part of the equipment package.

Adding a portable spectrum analyzer to our initial capital investment was costly, but hugely justified as we operated the network. Tracing rogue operators, confirming the operating characteristics of equipment, and verifying RF coverage enhanced our performance.

Fanatical attention to monitoring permitted us to uptweak network performance, and gather valuable historical data. Graphed via MRTG or Cacti (as described in chapter six), parameters such as jitter, RSSI, and traffic warned of rogue operators, potential deterioration of cable/connectors, and presence of worms in client networks. It was not uncommon for clients to claim that service to their site had been interrupted for hours/days and demand a credit. Historical monitoring verified or invalidated these claims.

The Blue network combined a number of lessons from Tanzania with improved RF and networking technologies.

Lessons learned

For the next few years satellite circuits will provide all international Internet connectivity in East Africa. Several groups have floated proposals for submarine fiber connectivity, which will energize telecommunications when it happens. Compared to regions with fiber connectivity, bandwidth costs in East Africa will remain very high.

Wireless broadband networks for delivery of Internet services therefore do not need to focus on throughput. Instead, emphasis should be placed on reliability, redundancy, and flexibility.

Reliability for our wireless networks was our key selling point. On the network side this translated into sizable investments in infrastructure substitution, such as backup power, and attention to details such as crimping and cabling. The most ordinary reasons for a single customer to lose connectivity were cabling or crimping issues. Radio failures were essentially unheard of. A key competitive advantage of our customer installation process is that we pushed contractors to adhere to tight specifications. It was common for well-managed customer sites to remain connected for hundreds of days with zero unscheduled downtime. We controlled as much of our infrastructure as possible (i.e building rooftops).

As attractive as potential alliances with cellular providers seem, in our experience they raise more problems than they solve. In East Africa, Internet businesses generate a fraction of the revenue of mobile telephony, and so are marginal to the cellular companies. Trying to run a network on top of infrastructure that doesn't belong to you and is, from the point of view of the cellular provider, a goodwill gesture, will make it impossible to meet service commitments.

Implementing fully redundant networks, with fail-over or hotswap capability is an expensive proposition in Africa. Nonetheless the core routers and VPN hardware at our central point of presence were fully redundant, configured for seamless fail-over, and routinely tested. For base stations we took the decision not to install dual routers, but kept spare routers in stock. We judged that the 2-3 hours of downtime in the worst case (failure at 1AM Sunday morning in the rain) would be acceptable to clients. Similarly weekend staff members had access to an emergency cupboard containing spare customer premises equipment, such as radios and power supplies.

Flexibility was engineered into both the logical and RF designs of the network. The point-to-point VPN tunnel architecture rolled out in Nairobi was extraordinarily flexible in service of client or network needs. Client connections could be set to burst during off-peak hours to enable offsite backup, as a single example. We could also sell multiple links to separate destinations, increasing the return on our network investments while opening up new services (such remote monitoring of CCTV cameras) to clients.

On the RF side we had enough spectrum to plan for expansion, as well as cook up an alternative radio network design in case of interference. With the growing number of base stations, probably 80% of our customer sites had two possible base station radios in sight so that if a base station were destroyed we could restore service rapidly.

Separating the logical and RF layers of the Blue network introduced an additional level of complexity and cost. Consider the long-term reality that radio technologies will advance more rapidly than internetworking techniques. Separating the networks, in theory, gives us the flexibility to replace the existing RF network without upsetting the logical network. Or we may install a different radio network in line with evolving technologies (Wimax) or client needs, while maintaining the logical network.

Finally, one must surrender to the obvious point that the exquisite networks we deployed would be utterly useless without unrelenting commitment to customer service. That is, after all, what we got paid for.

More information

- Broadband Access, Ltd. *http://www.blue.co.ke/*
- AccessKenya, Ltd. *http://www.accesskenya.com/*
- VirtualIT *http://www.virtualit.biz/*

—Adam Messer, Ph.D.