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

Case study: Dharamsala Community Wireless Mesh Network

The Dharamsala Wireless-Mesh Community Network came to life in February 2005, following the deregulation of WiFi for outdoor use in India. By the end of February 2005, the mesh had already connected 8 campuses.

Extensive testing during February of 2005 showed that the hard mountainous terrain is most suitable for mesh networking, as conventional point-to-multipoint networks, cannot overcome the line-of-sight limitations presented by the mountains. mesh topology also offered much larger area coverage, while the “self healing” nature of mesh routing, proved to be essential in places where electricity supply is very erratic at best.

The mesh backbone includes over 30 nodes, all sharing a single radio channel. Broadband Internet services are provided to all mesh members. The total upstream Internet bandwidth available is 6 Mbps. There are over 2,000 computers connected to the mesh, The broadband internet connection is putting the mesh under great load. At present, the system seems to handle the load without any increase in latency or packet-loss. It is clear that scalability will become an issue if we continue to use a single radio channel. To solve this problem, new mesh routers with multiple radio channel support are being developed and tested in Dharamsala, with an emphasis on products that meet our technical requirements and our economically viable. The initial results are very promising.

The mesh network is based on recurring deployments of a hardware device, which is designed and built locally – known as the ***Himalayan-Mesh-Router*** (*http://drupal.airjaldi.com/node/9*). The same mesh-routers are installed at every location, with only different antennas, depending on the geographical locations and needs. We use a wide range of antennas, from 8 - 11 dBi omnidirectional, to 12 - 24 dBi directional antennas and occasionally some high-gain (and cost) sector antennas.

The mesh is primarily used for:

- Internet access
- File-sharing applications
- Off-site backups
- Playback of high quality video from remote archives.

A central VoIP, software-based PBX is installed (Asterisk) and it provides advanced telephony services to members. The Asterisk PBX is also interfacing the PSTN telephone network. However, due to legal issues it is presently used only for incoming calls into the mesh. Subscribers use a large variety of software-phones, as well as numerous ATAs (Analog Telephone Adaptors) and full-featured IP phones.

Figure 11.5: Dharamsala installer working on a tower

The encrypted mesh back-bone does not allow access to roaming mobile devices (notebooks and PDAs), so we have placed multiple 802.11b access-points at many of the same locations where mesh-routers are installed. The mesh provides the backbone infrastructure while these APs provide access to mobile roaming devices, where needed.

Access to the mesh back-bone is only possible by mesh-routers. Simple wireless clients lack the intelligence needed to “speak” the mesh routing protocols and strict access policies. The mesh channel is therefore encrypted (WPA), and also “hidden” to prevent mobile devices from finding it or attempting to access it. Allowing access to the mesh only by mesh-routers allows for strict access control policies and limitations to be enforced at the CPE (Client Premises Equipment) which is a crucial element needed to achieve end-to-end security, traffic-shaping, and quality-of-service.

Power consumption of the mesh-Router is less than 4 Watts. This makes them ideal for using with solar panels. Many of the Dharamsala Mesh routers are powered solely by small solar panels. The use of solar power in combination with small antennas and low power routers is ideally suitable for disaster areas, as it very likely to survive when all other communication infrastructure is damaged.

--AirJaldi, http://airjaldi.com/

Case study: Networking Mérida State

The city of Mérida lies at the foot of the highest mountain in Venezuela, on a plateau at about 1600 m. It is the capital of the state of Mérida, and home to a two- centuries-old university, with some 35,000 students. The University of Los Andes (ULA) deployed the first academic computer network in 1989 which, despite economic limitations, has grown to encompass 26 km of fiber optic cable over which both a TDM and an ATM (asynchronous transfer mode) network are overlaid. In 2006, over the same fiber optic cable, a 50 km Gigabit Ethernet network has been deployed.

Figure 11.6: Mérida is one of the three mountainous states of Venezuela, where the Andes reach 5000 m.

Nevertheless, many places in the city and the surrounding villages are out of reach of the fiber optic ring. The university operates a communication server with telephone lines to provide remote access to its network, but local calls are charged by the minute and many villages lack phone lines altogether.

For these reasons, efforts to develop wireless access to the university's network, called RedULA, were undertaken from the very beginning. The first attempts took advantage of the existing packet network operated by radio amateurs. As early as 1987, amateurs had a gateway with an ***HF*** (***High Frequency***) station working at 300 bps for contacts overseas, as well as several ***VHF*** (***Very High Frequency***) stations linked at 1200 bps that crisscrossed the country.

While the rugged mountains of the region are a big obstacle for laying cables and building roads, they can be helpful in deploying a radio network. This task is aided by the existence of a cable car system, reputedly the highest in the world, which links the city to a 4765 m peak.

Figure 11.7: On its way to the peak, the cable car passes by an intermediate station called La Aguada, which is 3450 m high and has an astounding view of the city of Mérida and other villages at distances up to 50 km.

Packet radio

Local amateurs operate a packet radio network. Initially it worked at 1200 bps, using VHF amateur FM voice radios connected to a personal computer by means of a ***terminal node controller*** (***TNC***). The TNC is the interface between the analog radio and the digital signals handled by the PC.

The TNC keys the Push To Talk circuits in the radio to change from transmit to receive, performs modulation/demodulation and the assembly/disassembly of packets using a variation of the X.25 protocol known as ***AX.25***. Gateways between VHF and HF radios were built by attaching two modems to the same TNC and computer. Typically, a gateway would connect the local VHF packet network to stations overseas by means of HF stations that could span thousands of kilometers, albeit at a speed of only 300 bps. A national packet radio network was also built, which relayed on ***digipeaters*** (digital repeaters, essentially a TNC connected to two radios with antennas pointing in different directions), to extend the network from Mérida to Caracas by means of just two such repeater stations. The digipeaters operated at 1200 bps and allowed for the sharing of programs and some text files among amateurs.

Phil Karn, a radio amateur with a strong background in computer networks, wrote the KA9Q program that implements TCP/IP over AX.25. Using this program, named after the call sign of its developer, amateurs all over the world were soon able to connect to the Internet using different kinds of radios. KA9Q keeps the functions of the TNC to a bare minimum, harnessing the power of the attached PC for most processing functions. This approach allows for much greater flexibility and easy upgrades. In Mérida, we were soon able to upgrade our network to 9600 bps by use of more advanced modems, and several radio amateurs were now able to access the Internet through the RedULA wired network. The limit on the radio bandwidth available on the VHF band puts a cap on the highest attainable speed. To increase that speed, one must move to higher frequency carriers.

Amateurs are allowed to use 100 kHz wide channels using ***UHF*** (***Ultra-High Frequency***) signals. Digital radios coupled with 19.2 kbps modems doubled the transmission bandwidth. A project was developed using this technology to link the House of Science in the city of El Vigia, to Mérida and the Internet. UHF antennas were built at LabCom, the communications laboratory of ULA.

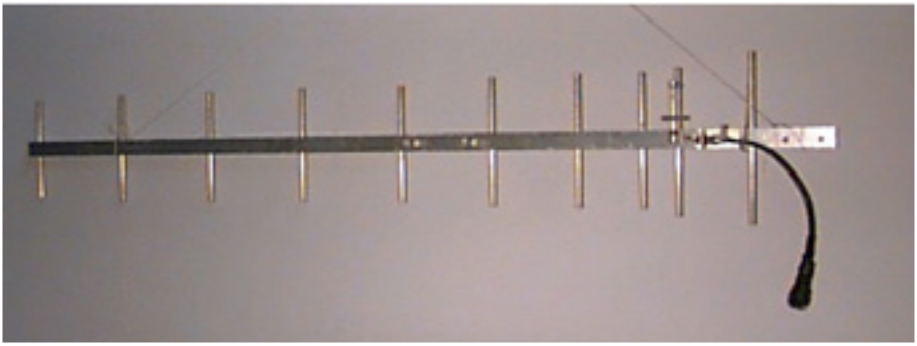

Figure 11.8: A UHF antenna for packet radio developed at ULA, LabCom.

Although El Vigia is only 100 km from Mérida by road, the mountainous terrain called for the use of two repeaters. One is located at La Aguada, at 3600 m altitude, and the other at Tusta, at 2000 m. The project was financed by FUNDACITE MERIDA, a government institution that promotes science and technology in the state. FUNDACITE also operates a pool of 56 kbps telephone modems to provide Internet access for institutions and individuals. The need for two repeater stations underscores the limitations imposed by using higher frequency carriers, which require line of sight to establish a reliable transmission. In the much lower VHF band, signals are easily reflected and can reach beyond hills.

Sometimes it is possible to reflect signals using a ***passive repeater,*** which is made by connecting two directional antennas back to back with a coaxial cable, without any radio. This scheme was tested to connect my residence to LabCom. The distance is only 11 km, but there is a hill in between that blocks radio signals. A connection was made by using a passive repeater to reflect off La Aguada, with the two antennas of the repeater pointing 40 degrees apart. While this was very exciting and certainly much cheaper than access through the telephone modems, a faster medium would obviously be needed for a wireless backbone to connect remote villages.

We therefore explored the use of 56 kbps modems developed by Dale Heatherington. These modems are housed in a PI2 card built by Ottawa amateurs, and connected directly to a PC using Linux as the network operating system. While this system functions very well, the emergence of the World Wide Web with its plethora of images and other bandwidth-hogging files made it clear that if we were to satisfy the needs of schools and hospitals we had to deploy a higher bandwidth solution, at least on the backbone. This meant the use of even higher carrier frequencies in the microwave range, which entailed high costs.

Fortunately, an alternative technology widely used in military applications was becoming available for civilian uses at affordable prices. Called ***spread spectrum***, it first found a use in civilian applications as a short-reach wireless local area network, but soon proved to be very useful in places where the electromagnetic spectrum is not overcrowded, allowing the bridging of distances of several kilometers.

Spread spectrum

Spread spectrum uses low power signals with its spectrum expanded on purpose to span all the allocated bandwidth, while at the same time allowing a number of users to share the medium by using different codes for each subscriber.

There are two ways to accomplish this: ***Direct Sequence Spread Spectrum*** (***DSSS***) and ***Frequency Hopping Spread Spectrum*** (***FHSS***).

- In DSSS the information to be transmitted is digitally multiplied by a higher frequency sequence, thereby augmenting the transmission bandwidth. Although this might seem to be a waste of bandwidth, the recovery system is so efficient that it can decode very weak signals, allowing for the simultaneous use of the same spectrum by several stations.

- In FHSS, the transmitter is constantly changing its carrier frequency inside the allotted bandwidth according to a specified code. The receiver must know this code in order to track the carrier frequency.

Both techniques exchange transmission power for bandwidth, allowing many stations to share a certain portion of the spectrum. During the First Latin American Networking School (EsLaRed '92), held in Mérida in 1992, we were able to demonstrate this technique. We established some trial networks making use of external antennas built at the LabCom, allowing transmission at several kilometers. In 1993, the Venezuelan Ministry of Telecommunications opened up four bands for use with DSSS:

- 400 - 512 MHz
- 806 - 960 MHz
- 2.4 - 2.4835 GHz
- 5.725 - 5.850 GHz

In any of the above bands, maximum transmitter power was restricted to 1 Watt and the maximum antenna gain to 6 dBi, for a total EIRP (effective isotropic radiated power) of 36 dBm. This ruling paved the way for the deployment of a DSSS network with a nominal bandwidth of 2 Mbps in the 900 MHz band. This technology satisfied the needs caused by the surge in World Wide Web activity.

The network started at LabCom, where the connection to RedULA was available. LabCom housed an inhouse-built Yagi antenna pointed towards a corner reflector at Aguada. This provided a 90 degree beamwidth, illuminating most of the city of Mérida. Several subscriber sites, all sharing the nominal 2 Mbps bandwidth, were soon exchanging files, including images and video clips. Some subscriber sites that required longer cables between the antenna and the spread spectrum radio were accommodated by the use of bidirectional amplifiers.

These encouraging results were reported to a group set up at the International Centre for Theoretical Physics (ICTP) in Trieste, Italy, in 1995. This group was aimed at providing connectivity between the Computer Center, Physical Sciences Building, and the Technology Building at the University of Ile-Ife in Nigeria. Later that year, the network was set up by ICTP staff with funding from the United Nations University and has been running satisfactorily ever since, proving to be a much more cost-effective solution than the fiber optic network originally planned would have been.

Back in Mérida, as the number of sites increased, the observed throughput per user declined. We started looking at the 2.4 GHz band to provide additional capacity. This band can carry three simultaneously independent 2 Mbps streams, but the effective range is lower than what can be achieved in the 900 MHz band. We were very busy planning the extension of the backbone using

2.4 GHz when we found out about a start-up company that was offering a new solution that promised longer distances, dramatically higher throughput, and the possibility of frequency reuse with narrowband microwaves.

Broadband delivery system

After visiting the Nashua, New Hampshire, facilities of Spike Technologies, we were convinced that their proprietary antenna and radio system was the best solution for the requirements of our state network, for the following reasons:

Their broadband delivery system employs a special sectored antenna (**Figure 11.9**), with 20 dBi gain on each of up to 22 independent sectors. Each sector transmits and receives on independent channels at 10 Mbps full duplex, for an aggregate throughput of 440 Mbps. Frequency reuse on interleaved sectors makes for a spectrally efficient system.

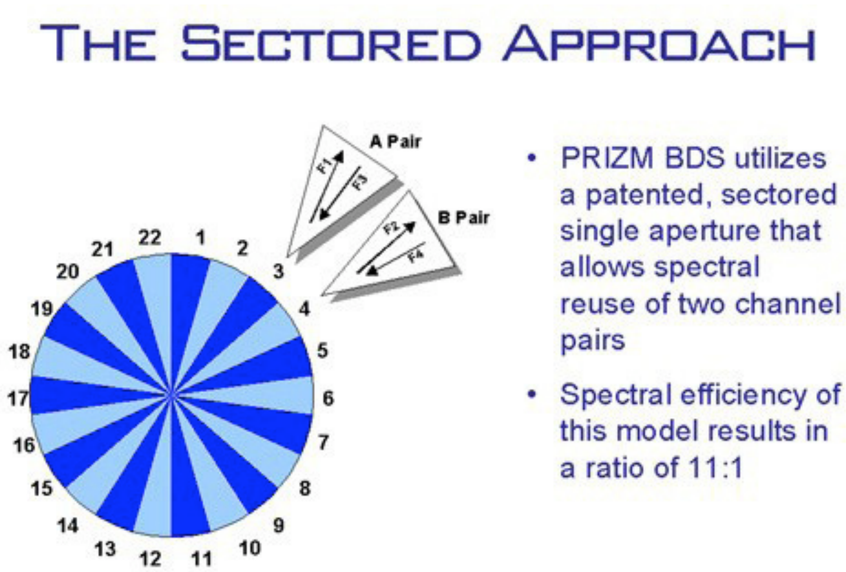

Figure 11.9: Spike Technologies' full duplex, high density sectoral system.

The narrowband digital radios can operate anywhere from 1 to 10 GHz, with a coverage of up to 50 km. The radios work with a variety of cable TV modems, delivering a standard 10Base-T LAN connection to the subscriber. At the base station, the sectors are interconnected with a high-speed switch that has a very small latency (see **Figure 11.10**), allowing applications such as streaming video at up to 30 frames per second. Each sector acts as an independent Ethernet LAN.

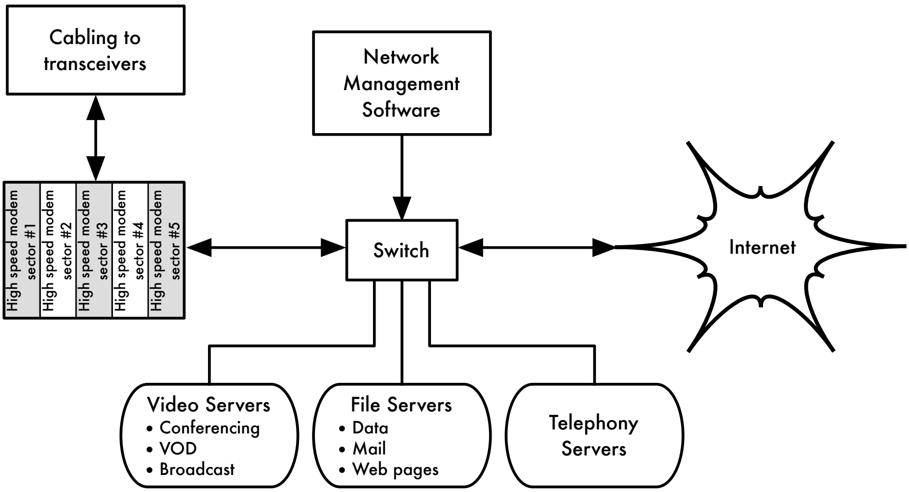

Figure 11.10: Spike Technologies' system interconnections.

At the subscriber site, a similar radio and modem provide a 10BaseT connection to the local Ethernet.

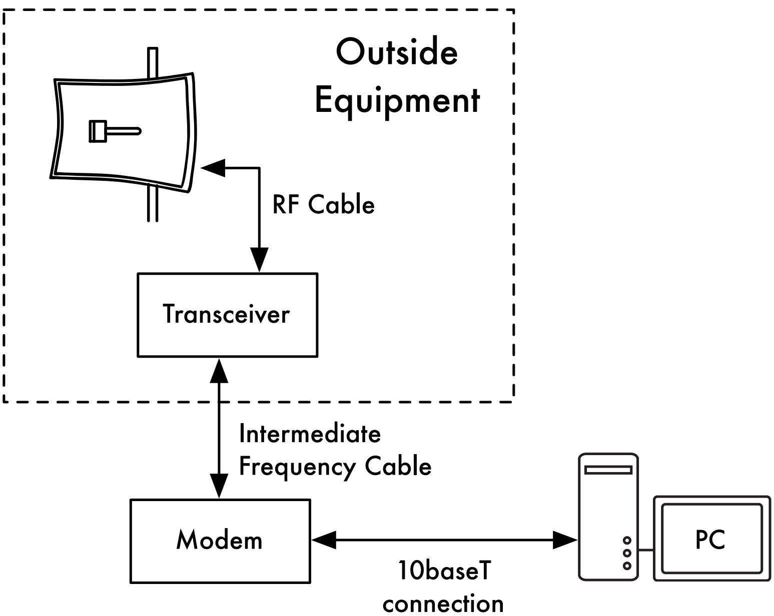

Figure 11.11: The subscriber end of the link.

With funding from Fundacite, a trial system was soon installed in Mérida, with the base station located just above the cable car station of La Aguada at an altitude of 3600 m.

Figure 11.12: Installation above Mérida at La Aguada, at 3600 meters.

Initially only 5 sectors were installed, with a beamwidth of 16 degrees each. The first subscriber site was at Fundacite´s premises, where a satellite system provides Internet access. Sector two served the Governor's Palace. Sector three served FUNDEM, a relief organization of the local government. Sector four served a penitentiary near the town of Lagunillas, about 35 km from Mérida. The fifth sector transmitted to a mountaintop repeater close to the village of La Trampa, 40 km from La Aguada. From La Trampa, another 41 km link extended the network to the House of Science in the town of Tovar.

On January 31, 1998, a videoconference between the penitentiary and the Justice Palace in Mérida proved that, aside from Internet access, the system could also support streaming video. In this case it was used for the arraignment of prisoners, thus avoiding the inconveniences and risks of their transportation.

The success of the trial prompted the state government to allocate the funding for a complete system to give high-speed Internet access to the state health system, educational system, libraries, community centers, and several governmental agencies. In January 1999 we had 3 hospitals, 6 educational institutions, 4 research institutions, 2 newspapers, 1 TV station, 1 public library, and 20 social and governmental institutions sharing information and accessing the Internet. Plans call for 400 sites to be connected within this year at full duplex 10 Mbps speed, and funding has already been allocated for this purpose.

Figure 11.13 shows a map of the state of Mérida. The dark lines show the initial backbone, while the light lines show the extension.

Figure 11.13: The Mérida State network

Among the many activities supported by the network, it is worthwhile to mention the following:

- **Educational**: Schools have found an endless supply of material of the highest quality for pupils and teachers, especially in the areas of geography, languages, and sciences, and as a tool to communicate with other groups that share common interests. Libraries have rooms with computers accessible to the general public with full Internet capabilities. Newspaper and TV stations have an amazing source of information to make available to their audience.

- **Health**: The university hospital has a direct link to the intensive care unit, where a staff of specialist physicians is always on duty. These doctors are available to be queried by their colleagues in remote villages to discuss specific cases. A group of researchers at the university is developing several telemedicine applications based on the network.

- **Research**: The astronomic observatory of Llano del Hato, located on a mountain at 3600 m and 8 degrees off the equator will soon be linked, allowing astronomers from all over the world access to the images collected there. Field researchers in many villages will enjoy Internet access.
- **Government**: Most government agencies are already connected and starting to put information online for the citizens. We expect this to have a profound impact on the relationship of citizens with the government. Relief agencies and law enforcement agencies make heavy use of the network.
- **Entertainment and Productivity**: For people living outside the city, the opportunities offered by the Net have a significant impact on the quality of their lives. We hope that this will help to reverse the trend of migrating out of the countryside, alleviating the overcrowding of the urban areas. Farmers have access to information about the commanding prices of their crops and supplies, as well as improved agricultural practices.

SUPERCOMM '98, held in Atlanta in June, cited the Mérida broadband delivery network as winner of the SUPERQuest award in category 8-Remote Access as the best in that particular field of nominees.

Training

Since our earliest efforts to establish a computer network, we realized that training was of paramount importance for the people involved in the network construction, management, and maintenance. Given our very limited budget, we decided that we had to pool our resources with those of other people who also required training. In 1990 the ICTP organized the First International School on computer network analysis and management, which was attended by Professor Jose Silva and Professor Luis Nunez from our university. Upon returning to Mérida, they proposed that we should somehow emulate this activity in our university. To this end, taking advantage of my sabbatical, I spent three months at Bellcore in Morristown, New Jersey, and three more months at the ICTP helping in the preparation of the Second Networking School in 1992, where I was joined by my colleague Professor Edmundo Vitale. I spent the rest of my sabbatical at SURANET in College Park, Maryland, under the guidance of Dr. Glenn Ricart, who introduced me to Dr. Saul Hahn of the Organization of American States, who offered financial support for a training activity in Latin America. These experiences allowed us to launch the First Latin American Networking School (EsLaRed'92) in Mérida, attended by 45 participants from 8 countries in the region, with instructors from Europe, the United States, and Latin America. This hands-on training lasted three weeks, and wireless technologies were emphasized.

EsLaRed'95 gathered again in Mérida with 110 participants and 20 instructors. EsLaRed'97 had 120 participants, and it was endorsed by the Internet Society, which also sponsored a Spanish and Portuguese first Networking

Workshop for Latin America and the Caribbean, held in Rio de Janeiro in 1998 with EsLaRed responsible for the training content. Now ten years later, EsLaRed continues to expand its training efforts throughout South America.

Concluding remarks

The Internet has an even more profound impact in developing countries than elsewhere, owing to the high cost of international phone calls, faxes, magazines, and books. This is obviously exacerbated by the lower average income of people. Some dwellers in remote villages that do not have telephones are experiencing a transition from the 19th to the 21st century thanks to wireless networking. It is hoped that this will contribute to the improvement of lifestyles in the fields of health, education, entertainment, and productivity, as well as create a more equitable relationship between citizens and government.

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- Escuela Latinoamericana de Redes, *http://www.eslared.org.ve/*

--Ermanno Pietrosemoli

Case study: Chilesincables.org

Recent wireless data transmission technologies allow the creation of high speed, geographically separated networks at a relatively low cost. If these networks are built around the idea of removing restrictions to data access, we call them ***free networks.*** Such networks can bring great benefits to every user, independent of the their political, economic, or social conditions. This kind of network is a direct response to the often restrictive commercial model ruling over much of our modern western society.

In order for free networks to flourish, wireless technologies must be adapted and put to the best possible use. This is carried out by groups of hackers who do the research, investigation, development and implementation of projects, as well as permit free access to the knowledge gained.

Chilesincables.org endeavors to promote and organize wireless free networks in Chile in a professional way. We do this by providing education about the related legal and technical aspects of wireless networking; encouraging the adaptation of new technologies through adequate research; and stimulating the adaptation of these technologies to meet the specific needs of Chilean communities and society.

Description of technology

We employ a variety of wireless technologies, including IEEE 802.11a/b/g. We are also investigating recent innovations in the field, such as WiMAX. In most cases, the equipment has been modified in order to be accept external locally built antennas which meet local telecommunications regulations.

Even though a majority of wireless hardware available on the market will suit our goals, we encourage utilization and exploration of a few vendors that allow for better control and adaptation to our needs (without necessarily increasing the prices). These include Wi-Fi cards with chipsets offered by Atheros, Prism, Orinoco, and Ralink, as well as some models of access points manufactured by Linksys, Netgear, and Motorola. The hacker community has developed firmware that provides new functionality on this equipment.

For the network backbone itself, we employ Open Source operating systems, including GNU/Linux, FreeBSD, OpenBSD, and Minix. This fits our needs in the areas of routing as well as implementation of services such as proxies, web and FTP servers, etc. In addition, they share our project's philosophy of being free technology with open source code.

Uses and applications

The networks implemented so far allow the following tasks:

- Transfer of data via FTP or web servers
- VoIP services
- Audio and video streaming
- Instant messaging
- Exploration and implementation of new services such as LDAP, name resolution, new security methods, etc.
- Services provided by the clients. The users are free to use the net's infrastructure in order to create their own services.

Administration and maintenance

The operational unit of the network is the ***node***. Each node allows clients to associate to the network and obtain basic network services. In addition, each node must be associated to at least another node, by convention. This allows the network to grow and to make more services available to every client.

A node is maintained by an administrator who is a member of the community committed to the following tasks:

- Maintenance of an adequate uptime (over 90%).
- Providing basic services (typically web access).
- Keeping the clients updated about the node's services (for example, how to get access to the network). This is generally provided by a captive portal.

The general administration of the network (specifically, tasks related to deployment of new nodes, selection of sites, network's topology, etc.) is carried out by the board of the community, or by technicians trained for this purpose.

Chilesincables.org is currently in the process of acquiring legal organization status, a step that will allow the regulation of its internal administrative procedures and the formalization of the community in our society.

Training and capacity building

Chilesincables.org considers training of its members and clients to be of vital importance for the following reasons:

- The radio spectrum must be kept as clear as possible in order to guarantee adequate quality of wireless connections. Therefore, training in radio communications techniques is essential.
- The employment of materials and methods approved by the current regulations is a requirement for the normal development of the activities.
- In order to comply with Internet standards, all of our network administrators are trained in TCP/IP networking.
- To ensure continuity in network operations, knowledge of networking technology must be transferred to the users.

To support these principles, Chilesincables.org undertakes the following activities:

- **Antenna Workshop.** Attendees are trained in the construction of antennas, and introduced to basic concepts of radio communication.
- **Operating Systems Workshop.** Training on the implementation of routers and other devices based on GNU/Linux or other software such as m0n0wall or pfsense. Basic networking concepts are also taught.
- **Promotion and Advertising.** Events for different communities that pursue our same goals are promoted. These include college workshops, lectures, free software gatherings, etc.
- **Updating of Materials.** Chilesincables.org maintains a number of free-access documents and materials made available to people interested in a specific activity.

The pictures on the following pages present a brief account of the activities in our community.

Figure 11.14: Omnidirectional slotted antenna workshop. In this session, attendants learned about building antennas and related theory.

Figure 11.15: One of our staff members lecturing on the implementation of a m0nowall-based router in the administration of a node.

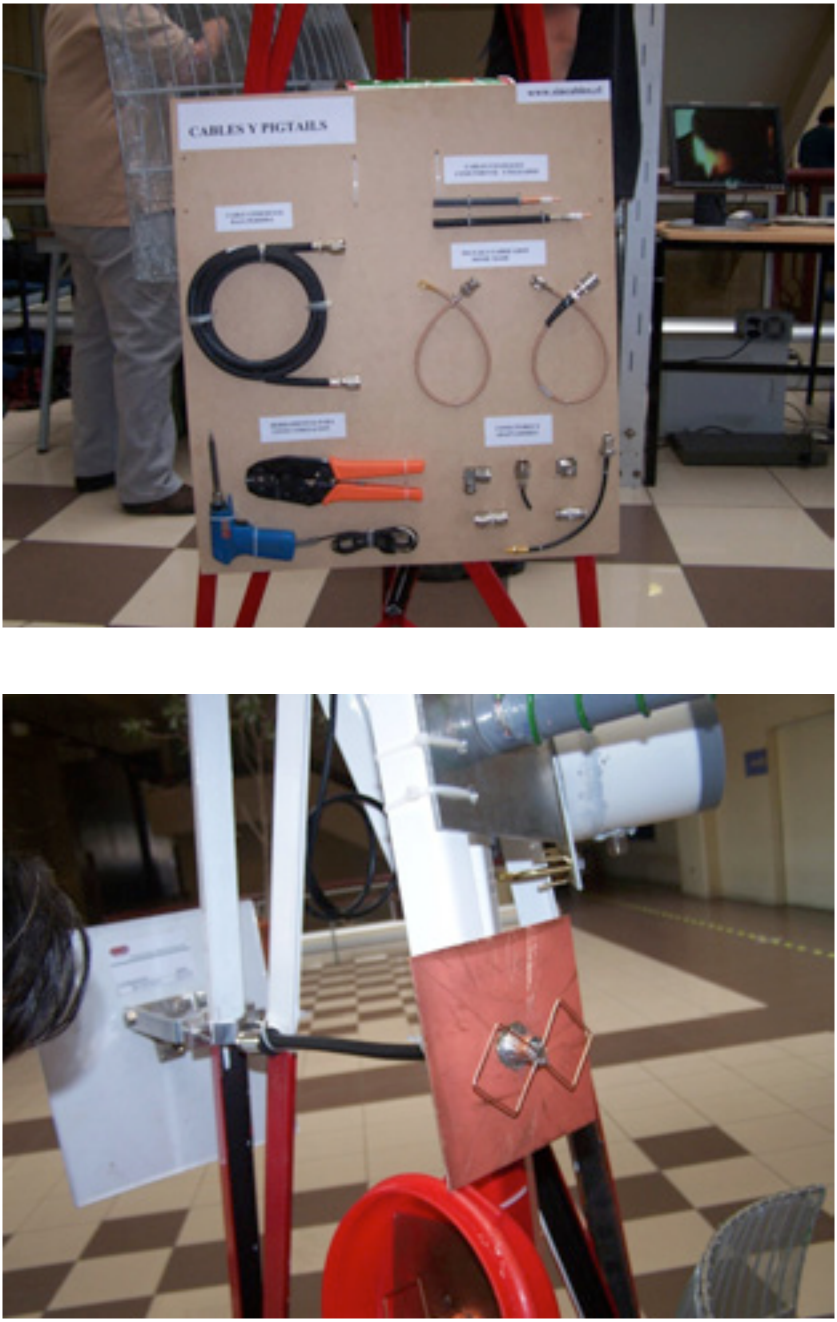

Figure 11.16: Detail of mini tower with samples of antennas, cables and pigtails.

Figure 11.17: Wireless station and parabolic antenna used for the transmission of Santiago-2006 FLISOL via streaming video.

Figure 11.18: Location of the other end of the link.