Wireless Mesh Networking: Low Cost Internet Connectivity. A Test bed for Its Possible Implementation and Community Actions in a Barrio "carenciado", Argentina.

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ABSTRACT
A very poor neighborhood in Argentina that has many features of lower middle class is called "barrio carenciado". Many heads of the families are unemployed and although children have access to schools it is common that they do not finish their basic instruction. In many cases NGOs play a fundamental role in changing this reality. In this presentation we detail the implementation of a test bed where 14 families and a school are provided with computers, Internet access and are educated out of digital illiteracy. Connectivity is provided by Wireless Mesh Networking (WMN). The research project, is being carried out by a group of researchers from the Universidad de La Plata with different backgrounds in collaboration with the NGO Barrios del Plata (a chapter of Muhammad Yunus´s Grameen Bank). The study monitors the changes in families' life (in particularly children education and parents opportunities related to obtaining work). The deployment of WMN in a such a broad area, aims to define the possible lowest cost implementation, and conforms an important part of the research activities. The project was financed through an award given in a public competition by Microsoft research.

Categories and Subject Descriptors
J.4 [**SOCIAL AND BEHAVIORAL SCIENCES**]: Economics, Sociology.

General Terms
Economics, Security, Human Factors.

Keywords
ICT for development, Digital Inclusion, Wireless Mesh Networking.

1. INTRODUCTION
If true what Thomas Friedman states in his best seller "The World is Flat"[1], then underdeveloped countries have a great opportunity [2],. Meaning, an opportunity for the promotion of new businesses and changes in areas such as education, R&D, health and many others.

The facts that Friedman stated made the world to become flat go from Ethernet's invention, the Personal Computer, Internet, the dot com bubble (that filled the earth with optical fiber), Netscape, XML, SOAP (which gives the possibility of connecting very varied applications), free access to information (search engines such as Google, Yahoo and MSN) to the most recent advances such as mobiles, wireless, virtualization and quadruple-play. All these factors, happening in conjunction with some very particular political events.

In resume, a more planar world has been generated, where information is a click away. Some countries are better prepared than others after the technological changes of the last years. And it's these countries that can obtain innumerable benefits from the use of ICTs. They have acquired the necessary physical infrastructure (as optical fiber) and possess the human capital required to operate the associated systems. Its use, cannot bring any other consequence than economical growth and improved standards of living.

When PCs still did not interconnect, the challenge to break the "digital divide" was enormous for underdeveloped economies. The panorama was dull since those societies with access to computers and the applications running on top of them would become more and more apart from those that needed first to come out of digital illiteracy to just then start benefiting from the so called "Information Society".

"Those rich in information would become richer and those in need would be still poorer".

With this phrase, Nicholas Negroponte expressed in his article "One-Room Rural Schools" which appeared in Wired Magazine (of which he was founder), in September 1998, his concern for the increasing separation of those with access to computers and those who didn't.

But access to internet and the many ingredients that made the earth flat modified this situation, transforming a problem into a challenge. The same tools of IT and advances in telecommunication (today nearly convergent) gave the tools to solve the problem.

There is no doubt that the opportunity is there, the important issue is to know how to take advantage of it. Some countries like India are already immersed in big changes. In Africa the problem is still more complex since huge investments in physical infrastructure are needed. Many Latin-American countries that have the necessary physical infrastructure are still "deciding" what to do.

But, the fact that the earth is flat, the free access to libraries and their content offered by Internet, thousands of developers willing to help in open-source projects, the multiplicative effects for education and many other areas makes it possible to perform a radical change in poor countries. Simple: start tackling problems.

From our perspective two of the most urgent and key actions are: Internet connectivity and teacher's digital literacy.

2. ICT4D-AR, UNLP

ICT4D-AR (known as ICT4DAR) is a project that gathers researchers from different backgrounds, mostly from the Universidad Nacional de La Plata and that belong to the most prestigious research institutions in Argentina: CONICET and CIC. Its main objective is to investigate the design and implementation of new technologies that favor underdeveloped regions.

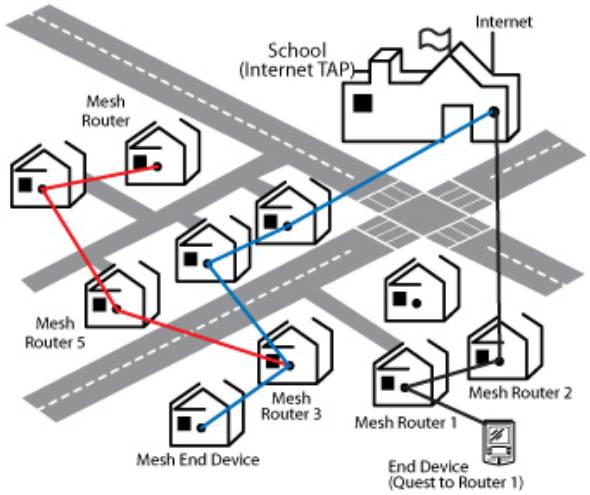

Figure 1. Diagram of "barrio carenciado" and Mesh nodes

The purpose of ICT4DAR is to focus on the challenges posed by the ICT revolution to those that live in countries where great parts of their population are below the poverty line. The great majority of this type of projects use technologies developed in countries with intellectual, economical and educational wealth. The sheer implementation of many of them simply fails since no questioning is made on costs, feasibility of implementation, energy problems or the need to orchestrate the appropriate educational support and study these technologies within the local eco-systems. What's the value of giving away laptops to primary school children if their teachers never used a word processor nor sent an e-mail?

ICT4DAR tackles problems related to hardware, software, connectivity and its influence in education and work opportunities. The project, finally, pretends to give a diagnosis, promote the proper technologies that eventually might be adopted by governments and corporations.

Today ICT4DAR is focused on two projects: wireless connectivity using WMN and innovative methodologies for ICT training of primary school teachers.

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The project's participants come from different backgrounds and include technologists, scientists from the hard sciences, engineering and social areas. One of the pre requisites of any new project is that it should be carried out in real environments (pilot tests, test-beds). This is vital, since it provides the answer to its feasibility and gives a diagnosis for scalability.

3. PROJECT WIRELESS MESH NETWORKING

In 2004 Tom Krag and Sebastian Buettrich [3] proposed, during the Emerging Technology Conference organized by Tim O´Reilly that took place in San Diego, CA., how WMN could become an important technology for the promotion of wireless and internet access in underdeveloped regions. They addressed the question of how one could give access to internet and connectivity to those places not included in the commercial plans of telecom companies or if the connectivity was there, how it could be provided at a low cost.

One of their main arguments in their analysis was the need to have a decentralized connectivity infrastructure. In this manner one avoided a single point of failure. Another, that the technology would be sufficiently simple and low cost so that it could be maintained and expanded by local participants with very little technological experience.

It basically proposed the use of low cost hardware, home constructed antennas and ubiquitous technologies simple to implement.

Wi-fi (802.11b/g) prompted as a candidate technology and connectivity in mesh architecture a promising ingredient.

In the last years the group of Dr. Victor Bahl, from Microsoft Research implemented mesh technology as part of Windows XP [4].

Krag´s and Buettrich´s proposal made us interested in the idea. In 2006 the project won a RFP made by Microsoft Research for the implantation of the test bed described in this paper using the technologies developed by Dr. Bahl´s group.

Definition of Mesh Networking

"A mesh network is a network that employs one of two connection arrangements, full mesh topology or partial mesh topology. In the full mesh topology, each node is connected directly to each of the others. In the partial mesh topology, nodes are connected to only some, not all, of the other nodes" [3].

When we speak of mesh networking, we understand a network that has connections many to many and capable of dynamically updating an optimizing these connections.

The nodes can be mobile or not. In our case they are not mobile since their position as a function of time does not change. Figure 1 shows a diagram of a possible mesh implementation. The biggest challenge for any mesh configuration is the administration of the complex information from the routing tables since they must include external networks and the internet gateways.

Mesh network technologies have matured and have found a place together to other possible wireless technologies. Some of the outstanding issues, adapted to our scenario, as pointed by Krag and Buettrich [3], are:

Price: 802.11 radios have become relatively inexpensive, although they are still among the most expensive elements of such a network. It's the fact that each mesh node runs both as a client and as a repeater, which permits saving on the number of radios needed and thus the total cost.

Ease and simplicity: In our case each node is a PC running Windows XP with wireless mesh software and uses standard wireless protocols such as 802.11b/g and the setup is extremely simple.

Organization and business models: The decentralized nature of mesh networks.

Network robustness: Mesh topology and ad-hoc routing should provide more stability in the face of changing conditions or failure at single nodes.

Today a mesh infrastructure can be built with hardware from CISCO or Motorola but they are very expensive. The challenge is a low cost implementation.

4. PROJECT ESCUELA # 502: ICT TRAINING FOR TEACHERS.

"Laboratory for the use of innovative methodologies in ICT training of primary school teachers:"

The laboratory has been implemented in the Escuela Especial #502 (see Figure 2) (Villa Elvira. La Plata) of the Provincia de Buenos Aires for children with learning disabilities. Its formal inauguration will be November 2007 although already many actions have been made as pilot tests using a reduced infrastructure.

Figure 2. Front image of Escuela #502.

Within the project researchers and university professors from the Universidad Nacional de La Plata, CONICET and CIC will be in charge for the training of primary school teachers.

It is planned that the theoretical propositions made for obtaining a Masters Degree in Tecnologias Educativas can use the laboratory as a test bed. As an example we mention the pilot work that has been carried out with professors from the Facultad de Bellas artes from the UNLP.

The teachers find an environment of great academic level for their training immersed in original and creative projects. The laboratory should also become a resource for the benefit of the education of the children (with learning disabilities) at the school.

First, the training will involve those that teach in the school and will continue expanding to teachers from other establishments. Several teachers have already been detected with great interest in the project and will be trained so as to be involved in future cycles. Part of the projects objective is this multiplicative factor.

The richness of the proposal resides in its link to the University of La Plata. Researchers and professors will utilize the Laboratory as a test bed for new pedagogical experiences

The coordination is made by the Instituto de Investigación en Informática (LIDI), Facultad de Informática, UNLP together with the Cátedra de Postgrado de la UNLP one Tecnologías educativas.

http://www.info.unlp.edu.ar/externas/postgrado/

5. BARRIO CARENCIADO, NGO "BARRIOS DEL PLATA" AND TEST BED

The test bed links 15 homes (with children in primary school age and unemployed parents) and has its gateway to the Internet in a local community meeting place ("El Obrador, Figure 3). One of the selected nodes is the primary "Special School #502" for children with learning disabilities. Each of the families uses Internet for different purposes but, the study concentrates on educational issues of primary school children and providing possible means for reverting the parent's situation of unemployment.

The idea of Grameen Bank started by Muhammad Yunus, has helped improve millions of peoples life worldwide. In Argentina Grameen Bank exists since 1999 as "Aldeas Argentinas". Our project rests on the NGO as the way for selecting the families that have received the computers, give them support in education and guiding the participants as a community. "El Obrador", normally the meeting place of the ONG, has practically been converted in a training center. For the past months the families have been receiving courses and several very interesting experiences and positive returns are already emerging. Although the project services the antennas and connectivity, the community realized the importance of computer maintenance and repair. For this purpose a course on "reparador the PC" was implemented. As the word spread in the neighborhood, several attendees outside the group of families in the project were admitted. Many ideas for new actions are daily proposed. The use of the network on health prevention is today in high priority.

6. WMN: REALITY VERSUS LABORATORY

In 2004 in the Freifunk Summer Convention in Berlin, Krag and Buettrich [1], demonstrated de feasibility of a mesh network using a few laptops connected using the protocol Mobile Mesh on top of the GNU/Linux kernel 2.2 in the streets of Berlin surrounding a park.

Could it be possible to implement this at a very low cost in a real environment and not as an experimental laboratory? This was basically the question that made us implement the project.

Our 15 nodes were distributed as shown in Figure 4. Two groups of 5-6 nodes and 4 nodes at the border.

In parallel to the study of connectivity each family assisted to training in basic informatics tools (Word, Excel, PowerPoint). All the training was done in the node called “El Obrador” that also served as the gateway for Internet using an ADSL connection of 512Kbps.

Figure 3. El Obrador

Two advanced engineering students from the Facultad de Telecommunications of the UNLP made the appropriate deployment. They had special contracts through university fellowships, a legal figure called “pasantes”. They were in charge of deployment and monitoring of the network.

Each node consists of a PC running windows XP, a wireless network card 802.11g and an external antenna 5m high placed on the roofs of the precarious housing of each family.

In the implementation we make use of the “Mesh Networking Academic Resource Toolkit 2005” offered by Microsoft Research. The protocol used is called Link Quality Source Routing (LQSR) based on Dynamic Source Routing. The MCL (Mesh Connectivity Layer) driver was installed in each wireless card.

Linksys WMP54G cards were used on each node, connected to an 8Bdi antenna. A coaxial RG8 cable of little loss was used for connecting the antenna and the PC. The antenna was held together with the TV antenna of each home.

Although not optimal due to losses in the cable, this solution was decided due to cost. Use of a bi-directional amplifier or LNA would increase total cost.

It is always in the spirit of the implementation a search for lowest cost implementation. Although commercial antennas were used, the final aim is to replace them by home made ones.

The Escuela#502 was included as one of the nodes.

Implementation #1: The first implementation was a full mesh topology where all the nodes participated meshing and a single gateway was located at the node called “El Obrador”.

Omini directional antennas of 8Dbi were installed at a cost of U$50 each.

Connectivity was achieved between all 16 nodes but several factors attempted against the stability of the network.

The Mesh protocol was installed in “zero configuration” . This brought many problems. If a node needed to be reset, it would modify some parameters and technical personal needed to be called to reconfigure.

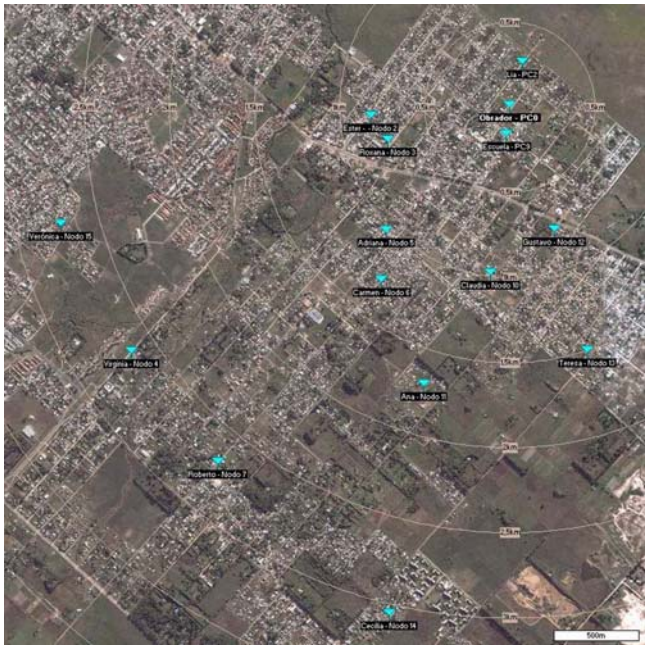

Figure 4. Map of Villa Elvira and nodes.

Given the small number of nodes, the disappearance of one of them would leave several others without connectivity.

Zero configuration was finally eliminated in the installation scripts. This made that many of the problems described when resetting disappear.

Implementation #2: As a possible solution to the instability observed in implementation #1 the antennas of some nodes were changed for directional ones of 24 dBi.

This hybrid model then had mesh in the two more dense areas and the rest in infrastructure mode.

Implementation #3: Due to the many inconveniences that we were still facing a new strategy was planned: 3 gateways were contracted (ADSL 512Kbps) and located centered within the more dense groups of nodes. This work is still under deployment.

7. RESULTS AND CONCLUSIONS

The project is carried out by a multidisciplinary research group from the Universidad Nacional de La Plata in conjunction with the NGO Barrios del Plata.

It is now in its tenth month and already several conclusions can be obtained:

- The implementation of the wireless mesh was far more complicated than originally assumed. Laboratory test beds are described in the literature but many complications as antennas, selection of wireless NICs, and other details make the deployment far more difficult. This part of the project became more complex than what was originally planned.
- Dealing with the paperwork due to regulations from CNC (Comision Nacional de Comunicaciones) for sharing an Internet connection through a broad area was also a hurdle that took energy and was not originally contemplated as to be so complicated.
- The main conclusion after these months of experience is the importance of having an NGO involved. They have been many years in the neighborhood, know the families and are there for the daily issues. A Test bed deployment with out such a support would surely end in failure.
- One family that received a computer with access to Internet was selected independently from the NGO. The idea was to monitor changes in their life as compared to the rest. They, of course were free to pursue actions with out constrains. Interestingly, the mother of the family found a small mosaic factory that offered her part-time work using her computer in processing daily excel editing. Since she was totally digital illiterate she approached the NGO and finally had instruction in “El Obrador”.
- The “Special School #502” was originally incorporated as a node that provided Internet to the establishment. A few months later, a teaching/research laboratory was planned. Some pilot educational projects were carried out.. At present a complete learning laboratory has been implemented.
- Four families have established a small enterprise using the computer and internet.

8. ACKNOWLEDGMENTS

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