BoulSat Project: Low-Cost Wireless Metropolitan Network Implementation in Burkina Faso

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Abstract. The BoulSat Project involves the realization of a bidirectional VSAT (satellite connection system) and the study of "poor" a Wireless Metropolitan Area Network (WMAN) to extend the Internet connectivity to the public institutions in the town area. Low-cost or waste materials have been used to build components where possible, thus to make possible for the local technicians with no specific and theoretical skills to build their network components by hand. This pilot scheme has been applied in Boulsa, in the Sahel region at the north of Burkina Faso. Besides the Boulsa case study, the whole work analyses a typical situation, due to the wide range of problems which have been handled, of remote communities in the South of the World. The aim is to characterize a standard of intervention, suitable for Developing Countries, to set up low-cost wireless telecommunication infrastructures.

Keywords: poor-wlan, digital divide, telecommunications infrastructures, wireless networks, wi-fi/hyperlan, technology transfer.

1 Introduction

According to the UN reports[1], Burkina Faso (ex Alto Volta, a former French colony) is one of the poorest countries in the world. Boulsa is the main city of the Namentenga province, situated in the north-east region at about 190 km from the capital city Ouagadougou. According to the local statistics, the Namentenga is the poorest district among the country, counting more than 300'000 inhabitants. The Nasongdo[2] Association has been one of the Project main partners. Born in Boulsa in the sixties it is now a recognized NGO with more than a thousand associates organized in 50 more groups, engaged in a plethora of

[1] For more informations refer to: World Health Organization WHOSIS, UNICEF, World Development Indicators database (World Bank sources of data).
[2] *Help ourself* in the local Moore language.

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different development activities in various fields: alphabetization, water access, agriculture, basic professional courses and digital divide among the others.

The BoulSat Project[2] was originated from a request conveyed by Centro Sviluppo Umano ONLUS [3], an Italian no-profit association which has been active in the Namentenga district since 1999. The first contact between ISF/EWB Italian network[1] and Nasongdo was so established in 2005.

1.1 Need of Telecommunications in the Context Scenario

The first question coming to mind could be: is there a real need of an Internet connection in such context? The answer may seem trivial, but it is not. At least, not always. Presently, we deem none has valid and absolute answer to the question: access to information and communication is intended as a necessary condition to reach medium and/or long term development goals, but indeed it is not sufficient. Lots of other pre-conditions are necessary, thus we deem each case has to be really well evaluated in its particularity.

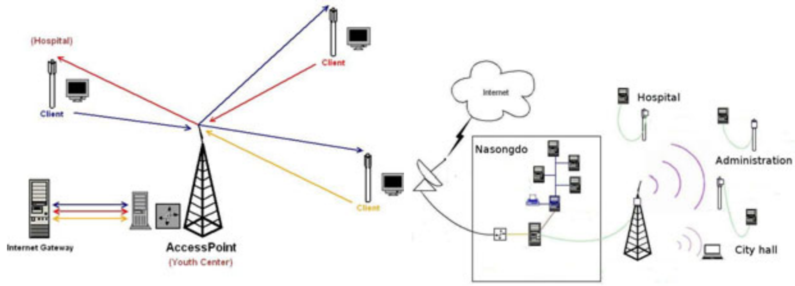
As of august 2005, the main city of Boulsa was provided with decent electrical energy, mobile phone coverage was work-in-progress and landlines were slightly stable just for voice calls. In fact the ONATEL[3] central telephone exchange is not actually connected to the national telecommunication network neither via a fibre optic nor with the old copper twisted pair cable. Instead there is an old and overloaded medium frequency radio bridge with the capital city. Neither wired nor wireless improvement were/are planned on the infrastructure, and the telephone exchange is full, making really difficult to have a new line activated. The existing ones are suffering due to the unreliability of the radio connection between the telephone exchange and the rest of the national network, so Internet access was only possible via slow PSTN (analog) modems connected to the telephone line (if any), prone to signal degradation and to very frequent call droppings, especially in the rainy season.

2 Materials and Methods

In this scenario, the aim of the BoulSat project was to bring the Internet connection to Nasongdo offices and laboratories and to share it to the hospital, the Health Administration, the Town Hall. The technical subjects of study were two different and well identified problems. To guarantee the access to a wide Internet band, and to design a distribution network to cover the town area with Internet services.

Instead to implement a standard wireless network with common commercial components, ISF worked on an easy replicable and very low cost solution using the materials available on-site[4]. We used recycled metal cans to develop and to optimize a home made sector antenna (Cantenna); dismantled water pipes were adopted to design and realize the antenna masts up to a height of

[3] Office Nationale de TELecomunication, the Burkinabè local telco (telecommunication company).



(a) (b)

Fig. 1. (a)A point-to-multipoint star topology to realize the distribution WMAN network; all the data-traffic pass through the central node which is located close to the satellite gateway; (b) The definitive network: WMAN and WLAN realize the metropolitan distribution network until the final wireless or wired user.

20 meters; self assembled low power, multi-standard transmitters complete the wireless infrastructure. For these reasons we defined our wireless network as *poor*.

The current configuration of the whole communication system is showed in figures 1(a) and 1(b). The satellite system is placed at the Nasongdo premises and it allows the local NGO offices and the computer laboratory to access the Internet. Then, by means of the point-to-multipoint WAN the three main nodes are linked: the Town Hall, the Hospital, and the Health Administration. An indoor/outdoor hotspot area in two of the connected nodes gives Internet and Intranet wireless access to local users without the need of a cabled network.

2.1 The Poor WLAN

As stated above, the distribution network must be very low cost, scalable, locally repeatable and easy to manage. The *Poor WLAN* (this name refers to the whole wireless network designed by the ISF team, WLAN and WMAN) is a proper solution to fulfil these requirements. Renouncing to the latest technologies for more stable and solid ones, by using open hardware/software and self-made components, the *Poor WLAN* allows to achieve the desired performances with rock-solid and very low-cost systems and offers a solution which is easy to manage and sustain for the local community.

The Poor WLAN solution consist of the following components:

1. self assembled wireless transmitters;
2. home-made sector antennas (Cantenna);
3. water-pipe antenna masts.

Each of this peculiarities is illustrated in detail it this paper.

2.2 The Wireless Transmitters

The so called transmitters represent the radio, routing and processing units of the wireless network. They have been implemented mounting proper wireless cards (mini-PCI devices) on rock-solid SBCs (single-board computers) which are highly integrated, fan-less and low power devices designed to run in harsh environments. A single board can supply one or more wireless cards realizing, on a single hardware, more transmitters working at different radio standards. The hardware is compliant with both open source and proprietary specific operating systems. The typical transmitter has small size (150 x 200 x 55 mm), low weight (less than 1 kg) and low power consumption (less than 23 W); it can be easily set up in different hostile environments and supplied by a small renewable energy system. The reliability is guaranteed by the few number of fan-less components (a single board computer and a radio card) closed in a proper outdoor-case shielded from any possible interference. In a typical set-up the transmitter is fixed on the mast near the antenna so to reduce the coaxial cable attenuation.

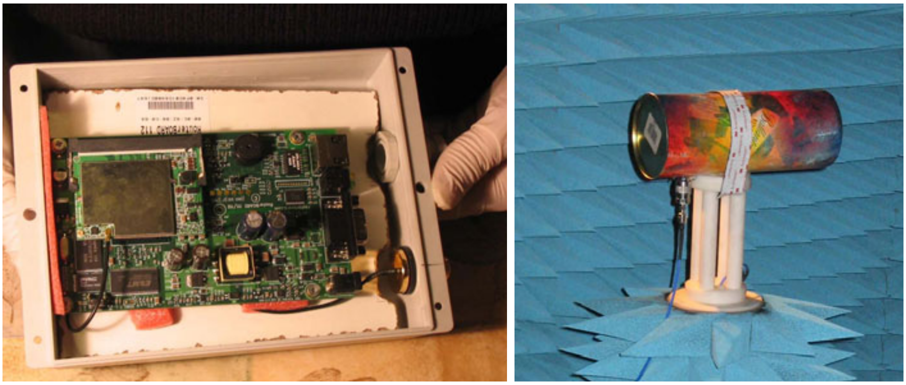
The power supply system can be positioned in a more convenient and safe location, typically inside the building at the base of the mast; the transmitter can be supplied with Power over Ethernet (PoE) technology. A final unit placed into a proper waterproof case and ready to be connected to one or more antennas, is shown in Fig. 2(a).

2.3 Home-Made Cantenna

One of the most innovative solution adopted by the Poor WLAN is the use of hand-made sector antenna. In our case study, but in many cases as well, the wireless distribution network includes cellular coverage over local areas (WLAN) and short/medium range point-to point or point-to-multipoint links between strategic locations (WMAN). A sector antenna is a compromise which fits very well in small scale distribution network, as for the town area of Boulsa, and can be used as the standard antenna.

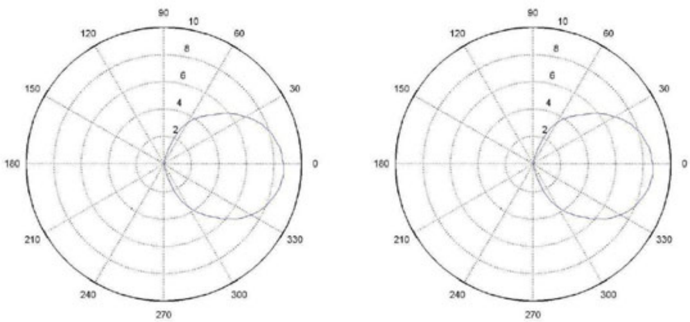
The ISF team have worked to improve and standardize the known concept of Cantenna: an aperture antenna hand made by adapting a commercial metal can to a wave-guide. Two standard cans (Ballantines and Seed-Oil) have been chosen for their universal availability all over the world. The main goal has been to improve antenna gain and efficiency of radiation in a standard very low cost realization for Wi-Fi applications (within 2.4 GHz ISM frequency band) which can be easily reproduced everywhere and by everyone with a cost of about 2 Euro.

The final result is a sector antenna with an high efficiency of radiation, a gain of about 8 dBi and an Half Power Beam Width (HPBW) of about 60 degrees in both vertical and horizontal plane. Table 1 shows the measured matching performances of both Cantennas (Ballantines and Seed-Oil). The return loss values have been measured with a spectrum analyser within the Wi-Fi frequency band. The Voltage Standing Wave Ratio (VSWR) values have been calculated analytically, as it is shown in tables 1 and 2. The handmade Cantennas have an optimum efficiency of radiation which, for the Ballantines Can, is better than



(a) (b)

Fig. 2. (a) A self-assembled Hiperlan/Wi-Fi transmitter for local or metropolitan distribution networks. This prototype is implemented with a Mikrotik RouterBoard with a multi-standard wireless card on-board; (b) The Ballantine Cantenna measured in the anechoic chamber of the Politecnico of Torino.



(a) (b)

Fig. 3. Measured gain in dB on (a) the vertical plane (E-plane) and (b) on the horizontal plane (H-plane)

99% at the centre frequency. In that condition more than 99% of the transmitted power from the wireless card is irradiated, almost without reflection back to the transmitter. This means high quality transmissions and low risk to damage the transmitter because of reflected power.

The best prototype, the Ballantines Cantenna, has been measured in the anechoic chamber of the Politecnico of Torino (Fig. 2(b)). Table 3 summarizes the relevant results which show the typical performance of a sector antenna. The measured gain pattern of both vertical and horizontal plane are illustrated respectively by figures 3(a) and 3(b).

Table 1. Measured Return Loss and calculated VSWR within the Wi-Fi frequency band for both prototypes of Cantenna

	@***2.41GHz***	@***2.44GHz***	@***2.48GHz***
(Ballantines Can)			
Return Loss	-22 dB	-43 dB	-22 dB
VSWR	1.17	1.02	1.17
(Seed-oil Can)			
Return Loss	-15 dB	-15 dB	-13 dB
VSWR	1.43	1.38	1.58

Table 2. Efficiency of radiation corresponding to different VSWR values; the percentage is relation to the transmitted power

VSWR	***Efficiency of radiation***
1.6	94.7%
1.4	97.2%
1.3	98.3%
1.2	99.2%

Table 3. Measured gain and Half Power Beam Width (HPBW) at the central frequency of the WiFi band; these values are relative of the Ballantines Cantennas

Ballantines Cantenna	***Gain***	***HPBW***
E-Plane	8.2 dB	68 degrees
H-Plane	8.7 dB	56 degrees

2.4 Low-Cost Antenna Mast

A demanding job has been to design and realize, together with the partner Nasongdo, simple and low-cost antenna masts in a brief time and with locally available materials. The required height was about 20 metres. A professional telecommunication mast of this size (a self supported or a monopole tower) was completely out of budget and also its shipment and assemblage would have required ulterior time and costs. The definitive idea was to assemble a very simple structure realized by properly welding together water pipes of six meters each, with steel connecting rods to guarantee the mast stability. This solution has the characteristic to be exclusively feasible with local materials, by the local community and consequently is very low-cost. Anyway there are also heavy drawbacks: this tower is not a modular structure and then it has to be raised up in one step; the construction material is not suitable for this purpose, it is heavy and this leads the mast to easily bend. The mast design does not provide any

(a) (b)

Fig. 4. (a) The cantenna with a PVC radome ready to be installed; all the material is low-cost, recycled and locally available; (b) The set up of an antenna mast made by water pipes (third expedition, Jan. 2007)

possibilities to set a grounding solution. Moreover this structure is not climbable and therefore all the wireless network equipment have to be fixed when the mast is down. The mast rising is a difficult and delicate phase; the risk of failure is not negligible. The mast dismounting for any maintenances is allowed only in emergency, i.e. when the system does not work at all. In Boulsa there was not any crane or other mechanical facility to rise up the mast, thus this operation has to be completely carried out by hand. At least thirty people were necessary for rising a mast (Fig. 4(b)).

According to the aforementioned drawbacks, a planned step in the system follow-up will be to substitute the pipe masts with appropriate antenna masts made by reticular modules allowing a relative easiness of the transmitter maintenance without loosing the robust concept of using locally available structural components.

2.5 Network Implementation

The first operating phase started in August 2006 when ISF implemented the VSAT system.

The second phase of the project consisted of the installation of the wireless infrastructure (Fig. 4(a)). This phase has been divided in some intermediate steps. First, ISF performed a technical site survey (August 2006) to know in detail the orographic and morphological characteristics of the area and to understand indications and expectations of the local community. Then, the entire technical solution was developed and tested in Italy by means of some trials and experimental wireless links. In January 2007 a second operating phase began. The main difficulties implementing the Poor WLAN concerned the set up and the management of the antenna masts, but after three weeks of work with local technicians all the nodes were connected with good performance: at least 5 Mbps of data-traffic over each wireless link. One year later the fourth expedition has been in charge of the monitoring of the system and further formation of the local technicians.

3 Results, Discussion and Future Developments

After two years from the first installation, the system is still running and usable. The satellite connection located at Nasongdo is working and the three node linked through the Poor WLAN are running. During this period some maintenance operations has been performed as periodic new pointing of the satellite antenna and the replacement of some electronic components which were damaged. On the whole the materials and the structures we used resisted to rains, wind and dust. However, the most important result we got is the involvement of the local community in using the new technology and the awareness they developed about it. For example, the employees of the health administration use the Internet connection to find up-to-date sanitary informations and communicate via e-mail. In general, the community exploits the new technology for communications (mail and VoIP), for education (computer science courses) and to support their work finding informations. This is important because the target of the project in the long term is to aid the development of the entire community.

Future developments concern the implementation of point-to-point wireless links over huge distances (more than 100 km). This is a key point of the whole project as this step would allow to transfer a wide band connection, for example a DSL, from a source location (for example the city of Koupela, about a hundred km in the south) to the remote area of Namentenga bypassing the VSAT links. For such cases we sized a photovoltaic system to be completely autonomous and relatively easy to build, transport and install, as described in [5]. This full wireless solution, independent from any satellite link, introduce relevant benefits if compared to the actual solution: wider bandwidth, much lower round trip times (which means possibility of efficient real-time services), higher reliability and scalability, full control and management of the whole telecommunication infrastructure, important economical save especially over long-term periods.

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