Communication Access to Small and Remote Communities: The Corral de Lorca Project

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Abstract. Throughout Argentina, like in many developing countries, several rural areas with low population density are present. This distribution becomes an obstacle when seeking solutions to provide broadband services with an efficient internet connection. Alternative solutions are explored which differ from those regularly implemented in developed countries. The solutions examined are related to the use of long range wireless technologies, such as microwaves, 802.11, WiMax, CDMA450 and others with similar features. The reasons behind the implementation of these networks are associated to the speed and lack of difficulty of their set up, as well as the capability to use frequencies without requiring previous authorization. In addition, they avoid reliance on local communication operators. The present work discusses the implementation of 802.11 technology in these areas. Its behavior is analyzed for large coverage areas which differ from the well known solutions employed in large urban settings, where its application for short distances is consistent to its design. In particular, the case of the Corral de Lorca village, in the Argentine province of Mendoza, is presented.

1 Introduction

The Communitarian Private Network (Redes Privadas Comunitarias) Project [1] aims to study, test, and discuss different technologies in order to provide communication links to small and isolated villages with considerable low market value.

In Argentina, there are several small towns where few people live (100 inhabitants or even less in some cases). Commonly, these communities suffer from the lack of a 24 hour power supply service, nor are they covered by the telephone network, and suffer from a lack of communication services such as cell phones or internet. Several of these villages are placed next to former railway tracks, currently out of service. Therefore, it is rather difficult that commercial providers would invest in communication services for these areas. Consequently, alternative approaches need to be considered.

Different Technologies such as PLC, wireless networks, ADSL and so on are taken into account in the Communitarian Private Network Project [1]. In previous CACIC conferences, the authors discussed the PLC technology [2, 3] and 802.11 wireless networks [4] as well. From the cited papers, we conclude that presently PLC it is not a suitable technology for outdoor links. Moreover, as stated in the previous paragraph, electrical lines are not available in many cases. Cost considerations turn unfeasible the use of wired, copper or optical fiber. Thus, wireless networks become a suitable option to provide communication access to small villages in our country.

In this work a feasibility analysis and design of a wireless link to provide communications to the Corral de Lorca village is discussed. In section 2, an overview of this small village is provided. Then, in section 3, the link design is fully discussed to provide a description of Canopy radio equipments [5]; concluding, in section 4, it could become a suitable solution for this particular case.

2 Corral de Lorca Village.

At early stages of the Project, a small town was searched to carry out the field experiments. Due to key facilities provided by both, the City Hall and the local campus of the Technological University Institute (ITU), the Department of General Alvear was chosen. This department is located at the southeast area of the Mendoza Province, as shown in figure 1. The City of General Alvear, the department's capital, is located 350 km from Mendoza City, the capital of the province.

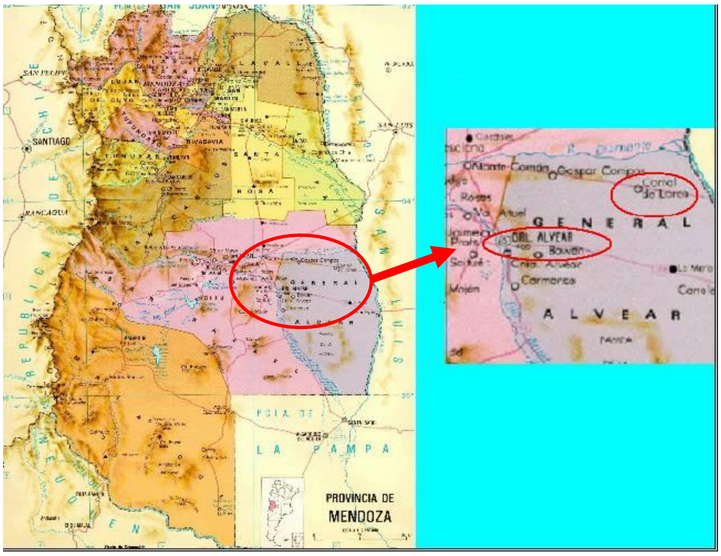

Figure 1: Political map of the Mendoza province. The City of General Alvear and Corral de Lorca village can be observed in the detail.

Corral de Lorca village is located 70 km east of the City of General Alvear in a direct line. A partial dirt road, 80 km long, joins both places. Corral de Lorca is a significantly small community where about 60 inhabitants regularly live.

There is no telephone network available. The power supply service runs 10 hours each day (from 10 am until 20 pm), generated with a diesel engine group. Life in this small community is built around the activities of the school, which runs on a 3 week per month program. In addition to the school, there are a Police Station (only 1 permanent policeman) and a Healthcare Center, in charge of a nurse.

Currently, only two communication services are available: a VHF radio link which connects the Health Center with General Alvear City Hall and a small bandwidth (64 kbps) satellite link servicing the school with the Ministry of Education of the Mendoza Province.

Consequently, few are the means to communicate people with friends or relatives or to access internet for children's education. Analogical cell phone services were temporarily available with a significantly low quality of service. However, the service was discontinued last year.

Undoubtedly, Corral de Lorca is a paradigm of many Argentine small towns, tending to disappear as a result of the disruption of railway services during the 90s. Although it is a difficult technological challenge, life in this community could improve considerably from communication services.

3 Communication Link Design.

After a visit to the field, the existing conditions verified in situ are summarized in Subsection 3.1 Field Characteristics. The link estimation is performed in Subsection 3.2, following this detail of field characteristics.

3.1 Field Characteristics

The geographical coordinates of the City of General Alvear and Corral de Lorca Village were obtained from the Google Earth site [6]. Table 1 details latitude, longitude, and altitude over sea level for both places. The distance between both villages is approximately 70 km.

Deployment of one station at each site is planned. Given the distances involved, a Line of Sight link is not feasible. However, this kind of links is still possible for some frequencies due to refraction of the wave front in the atmosphere.

Alternatively, repeater stations could be installed. However, this choice has several disadvantages: there are neither intermediate villages nor facilities where power supply is available. Consequently, non-supervised stations are required. Solar energy cells, batteries, towers, and other equipment increase the cost of the link. Thus, a direct link is preferred, even with the resultant limitations which arise from a 60 km distance.

Table 1: General Alvear and Corral de Lorca Coordinates

Village	LATITUDE				LONGITUDE				ALTITUDE
	degrees	minutes	seconds		degrees	minutes	seconds		level (m)
General Alvear	34	58	29	S	67	41	08	W	475,50
Corral Lorca	34	41	42	S	67	02	57	W	417,10

In the City of General Alvear, a 20 meter-high tower is installed on the roof of the City Hall building. From this site, the Public Telephone Network is within reach. In Corral de Lorca Village, a 15 meter-high tower is also available.

Under these conditions, the 2.4-2.5 Ghz Band, denoted S-Band, and a 5.725-5.825 Band, denoted as C-Band ISM, are considered suitable candidates for the Project.

3.2 Link Estimations

In order to carry out the link calculation, Radio Mobile Software [7] was used. This software was designed by Roger Coudé and is available on the Internet. It incorporates certain assumptions regarding antenna heights, obstacle attenuation, and atmosphere refraction. They become input data parameters for link estimation.

This tool particularly helps in the implementation of radio communication networks. Before setting a network in the field, it can verify the performance of network radio links. The software evaluates if a radio link is possible between two given sites, and provides the performance of such link, taking into account: i) radio equipment characteristics; ii) radio wave propagation theory (using the US Institute for Telecommunications Science (ITS) propagation prediction model, better known as the Longley-Rice model) [8] [9]

Performance of the radio link is calculated as follows:

Tx (dBm) = 10 $\log_{10}$ (Transmit power in Watts) + 30
L1 (dB) = Transmitter line loss
A1 (dBi) = Transmitter antenna gain relative to an isotropic antenna
P (dB) = Radio propagation loss from the Longley-Rice model (including required fade margin)
A2 (dBi) = Receiver antenna gain relative to an isotropic antenna

L2 (dB) = Receiver line loss
R (dBm) = 20 $\log_{10}$ (Receiver threshold in micro volts) - 107

Performance, shown in dB, is given by the following formula:

$$M\ (dB) = \text{Received signal}\ (dBm) - R\ (dBm)$$

$$M\ (dB) = (Tx - L1 + A1 - P + A2 - L2) - R$$

In order to perform the link estimate, geographical coordinates of both sites are entered and a satellite map of the area is obtained. The map can be enhanced to study land conditions of the working area, obtained from LANDSAT [10]

Once the working area is determined, weather conditions (tropical, desertic, and so on) have to be defined. Later, technical information of the radio equipment such as power, operating frequency, receiver sensitivity, coaxial cable attenuation, type of antenna considered and its gain, and altitude must be entered, among other data.

Figure 2 shows other output data provided by the code; in this case satellite images. The working area can be observed, indicating both stations (General Alvear and Corral de Lorca). On the bottom of the picture, the geographical coordinates are detailed, along with other data.

Figure 2: Satellite Map of the General Alvear and Corral de Lorca area

Initially, an 802.11 radio was considered because it is a well known standard readily accessible in the market. Because of low radio power, the equipment must be installed in the antennas to avoid coaxial cable attenuation. After some estimations, it was discarded because a 100 meter high antenna would be required.

Later, Canopy technology [5] was considered because it has a larger range than the 802.11 equipment. It also works on a free license band, as well as other advantages discussed in section 4.

The frequencies with greater chance to satisfy the required link were analyzed. Frequencies in line with the available equipment were explored, obtaining: 2.4 Ghz or 5.7 Ghz. From these two results, the frequency providing the best signal levels to achieve a 70% in service availability was determined.[1]

The signal in the receiver can be obtained by adding to direct signals others reflected in the atmosphere and the land. The software provides a representation which shows a Fresnel Clearance Zone. Fresnel diagrams obtained are shown for both frequencies studied.

Figure 3 details the Fresnel Diagram for the 2.4 Ghz case. Note that the diagram has the first zone completely obstructed. Then, the signal transmits through the atmosphere reflection component only. Consequently, the quality of the transmitted signal depends completely on atmospheric conditions. While it is not desirable, it can be acceptable in practice because the weather in this area is fairly dry with little rain downfall throughout the year.

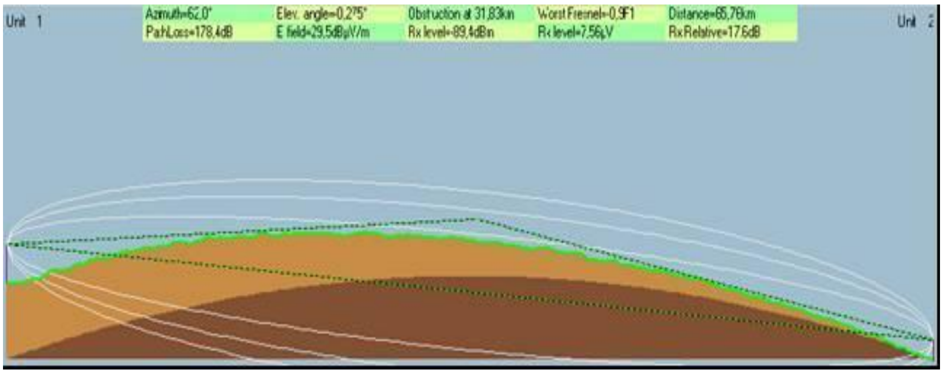

Figure 3: Fresnel Diagram for 2.4 GHz

Figure 4 shows the Fresnel Diagram for the 5.7 Ghz case. No obstructions are present. Thus, from the design study, it follows that it would be advisable to test the 5.7 Ghz frequency as well. From a comparison of both diagrams, it follows that 5.7 Ghz frequency shows a better signal than the 2.4 Ghz case, as has been pointed out. However in practice, it seems simpler to align antennas for the 2.4 Ghz rather than those for the 5.7 Ghz. Therefore, both frequencies are tested in the field.

[1] Operative percentage determined by software.

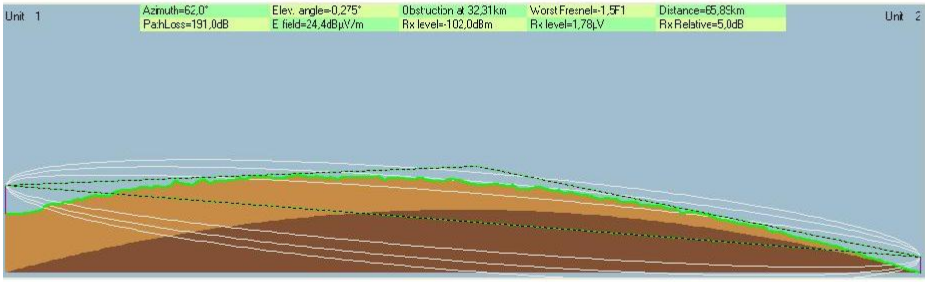

Figure 4: Fresnel Diagram for 5.7 GHz

Other relevant data involves the signal level, obtained from a 360° azimuth sweep, starting from the main antenna with a one degree increase at a time.

Figures 5 and 6 show the signal level values for 2.4 and 5.7 Ghz respectively. Results comprehend a sweep ranging from 40° azimuth to 90°. Note that within such range the link destination limit is included. In addition, graphs indicate in color code the signal levels calculated in the selected area.

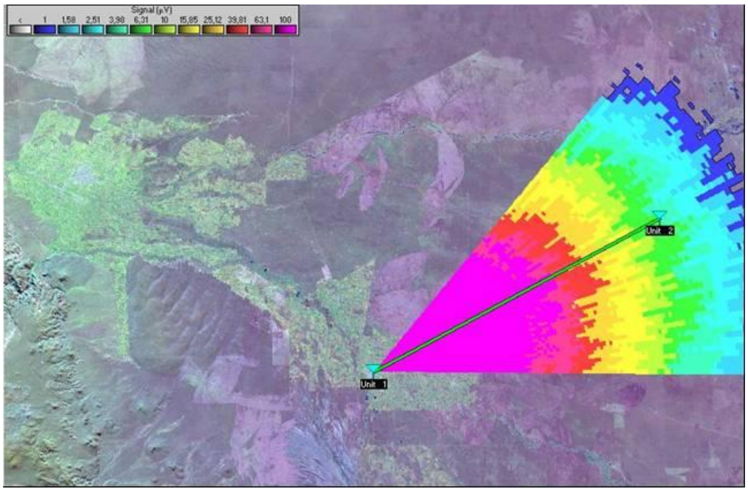

Figure 5: Signal Level Representation for 2.4 Ghz

Although in the case under consideration the link is established in a deserted area, the effects of the presence of trees are studied, not contemplated by the software.

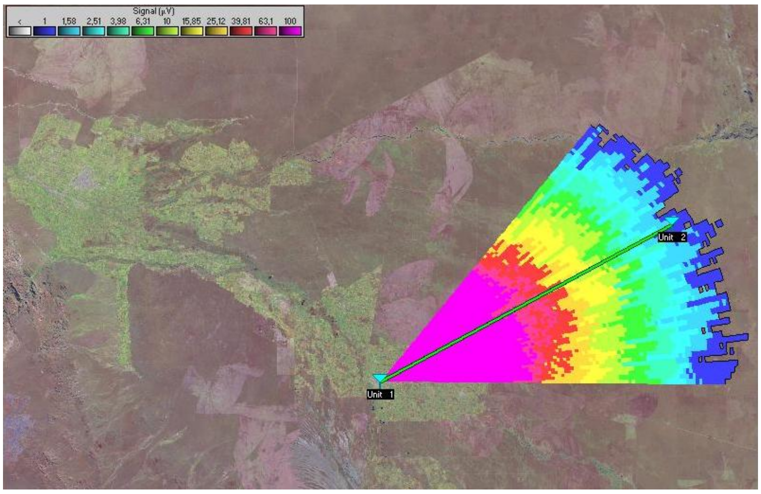

Figure 6: Signal Level Representation for 5.7 GH.

Recommendation ITU-R I.136 [11] establishes that the average attenuation present by the hindrance of woods when an antenna is placed at a 400 meter range is:

$$A = 0{,}2 \text{ x } F^{0{,}3} \text{ x } L^{0{,}6}$$

Where
A = Attenuation due to the close presence of woods
F = Frequency [MHz] (valid up to 10 GHz).
L = Length of the woods [m].

The real attenuation value is a function of parameters such as the vegetation density, leaf humidity, snow accumulation, and others. When trees are close to the antenna, the wave propagates in its interior and suffers attenuation by absorption. On the other hand, if the trees are away from the antenna, they behave as an obstacle of the knife edge type, resulting in diffraction.

4 Concluding remarks.

The design of a wireless link providing communication access to a small and remote community has been discussed. Corral de Lorca and General Alvear cities, in the southeastern area of the Mendoza province, have been presented as well as field conditions.

Different technologies have been studied at the feasibility analysis level: 802.11 and 5.7 Ghz Canopy (rather similar to WiMax). It is important to point out that the distance between the villages under study, 70 km, is fairly greater than the regular distances for 802.11 standards.

In practice, a different behavior of transmitted signals can be expected when compared to regular cases. This assumption arises from the fact that signal is propagated through a rather clean environment, proper of rural areas, instead of the noisy spectra generally found in urban settings.

Radio Mobile Software was used in the estimations. This software is a valuable tool in the design of radio electrical links. It can be freely downloaded from the internet and automatically take into account satellite information for the area under study.

Signal levels and values within the Fresnel Clearance Zone were determined, which suggests the feasibility of using equipment in the frequencies of 2,4 or 5,7 Ghz. In the case of the 2.4 Ghz frequency, the Fresnel Clearance Zone shows that if the first Fresnel finds an obstacle such as trees, the transmitted signal could turn even poorer due to attenuation effects, requiring attention when field tests are carried out.

Note that both technologies are suitable candidates to set up the required link, even with the challenging 70 km distance. From the studies carried out, it follows that the 5.4 Ghz links might have certain advantages in theory.

Experimental tests in the field will follow the present studies. Forthcoming work will report the obtained results. Different parameters like antenna gain and radio potency will be tested in such work.

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