

# Radio Communications Systems in rural environments

Inés Belinchón Salas and Manuel Sierra Castañer



PHOTO: Radio communication station on the Rio Napo, Peru. ONGAWA



## CASE STUDIES Radio Communications Systems in rural environments

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# RADIO COMMUNICATIONS SYSTEMS IN RURAL ENVIRONMENTS

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## 1. INTRODUCTION

In this case study the advantages and disadvantages of different designs of radio communication systems for rural applications are discussed, using the example of Acomayo province, Cuzco Region, Peru. First, the context of the area is explained and then, two types of exercises are proposed: a classroom activity and a team homework exercise.

### 1.1. DISCIPLINES COVERED

This project covers subjects based on a basic approach of Radio Communication Systems and Wave Propagation for Electronic or Telecommunication Engineering.

### 1.2. LEARNING OUTCOMES

- The student will know how to design a radio communication system for a rural environment in the context of a developing country.
- The student will be able to design telecommunication services for a rural environment in the context of a developing country.

### 1.3. ACTIVITIES

The first exercise is to be conducted in the classroom by the lecturer, consists of analysing two different radio communication systems. The different ways of designing and building this radio system are explained, depending on the frequency band. In the second exercise, the advantages of the different proposals are analysed to improve the specific solutions proposed. The third activity, addresses questions about the relative level of appropriateness of the radio systems proposed.

The first activity embodies the analysis of the zone in which the case study is based, the education of the inhabitants, the available technologies, the number of hospitals, the health of the families, especially in children and pregnant women, human development and all the aspects that students may consider necessary to determine the context of the area.

In the second activity, students explain the different radio telecommunication systems that can be used in this area, after that, they must select the two best proposals for the case of study, explaining both advantages and disadvantages. The students should be divided into teams of four or five for this exercise.

Finally, in the third activity students select one of the two last proposals and explain why this one is better than the other for this case of study.

## 2. DESCRIPTION OF THE CONTEXT

The context is based on real field experience. The description of the context has two objectives: to give relevant information to understand the later activities and to show a poverty situation from the Human Development perspective. To fulfil the second objective, the description of the poverty situation must be done from the following perspectives (even if they are ultimately not used in the activities):

- Human development
- Rights-based approach
- Gender approach

### 2.1. PERU AT A GLANCE

Peru is the third largest country in Latin America after Brazil and Argentina, with an area of 1,285,216 km<sup>2</sup> (2.5 times the area of Spain). It is the fifth most populous country in Latin America after Brazil, Mexico, Colombia and Argentina, with a population density of 23.7 inhabitants/km<sup>2</sup>, four times lower than Spain. In Peru socially deep inequalities persist. There is a large contrast in Human Development Index (HDI) scores between the capital and the provinces and between urban and rural areas. Although the country has experienced steady economic growth in recent years, there are still major challenges related to social inclusion and gender equality, for example. Many social conflicts, uprisings and protests from people living in the interior of Peru have taken place as a result of a lack of economic investment in this area, despite the economic boom. There are severe limitations on access to good quality basic services such as education, health, water, housing and electricity; as well as poor promotion of economic opportunity and progress for much of the rural population.

Administratively, Peru is divided into 25 regions, 194 provinces and 1624 districts. The elections of regional and local (provincial and district) authorities are held every five years. The complex and rugged geography and the implementation of population concentration policies has created an unequal and asymmetric occupation of the country. This makes it difficult to overcome the various spatial dimensions of development, promote social cohesion and ensure state presence. In addition, an expensive transport and communications infrastructure is required to ensure connectivity.

The country has been experiencing major demographic transition since the mid-1960s. A population explosion has been coupled with increasing migration to the big cities, in particular Lima. It is estimated that the population of Peru in 2014 was 30,814,175 inhabitants, with an annual average growth rate of 1.11%. There is a high concentration of the population in urban areas (73%), especially in Lima, where more than a third of the total population lives. The World Bank report "Peru 2012" stated that 53% of the rural population lives below the national rural poverty line. Peru is characterised by a Human Development Index (HDI) of 0.741 according to 2013 data, which puts it in the group of countries with high HDI, ranking 77 of 185, below Cuba, and above Turkey and Brazil. The Adjusted HDI, which

reflects disparities between the population in income, health and education, is 0.561, 24.3% less than the corresponding HDI.

According to the International Monetary Fund (IMF), in 2013 Peru was considered a middle-income country with a GDP per capita of € 8,132 per inhabitant (compared to € 25,222 per inhabitant in the European Union). Economic reforms during the 1990s were key to an impressive improvement of the Peruvian economy. Important macroeconomic developments and the liberalisation of the telecommunications market favoured private investment. During the nineties, the evolution of investment in utility infrastructure, especially telecommunications and energy, mainly benefited households and businesses in urban areas, neglecting investment in rural infrastructure.

## 2.2. PERU TELECOMMUNICATION SECTOR

Mobile telephony coverage in Peru has had a high annual growth rate, which stood at 82% in 2013, compared with 28.6% in fixed telephony. Comparatively, mobile telephony penetration in Europe was 128% in 2013. Internet access of urban households in Peru was 20% in 2013, compared with just 0.9% of households in rural areas. Across Europe in the same period, 73% of households were connected to the Internet. 36% of urban households in Peru had computer in 2013, compared with 5.8% of households in rural areas of Peru and 77% of households in Europe.

The use of Information and Communication Technology (ICT) services was measured by the Peruvian National Institute for Statistics and Information (INEI) in the census of poverty levels published on 2012, with the results shown in Figure 1.

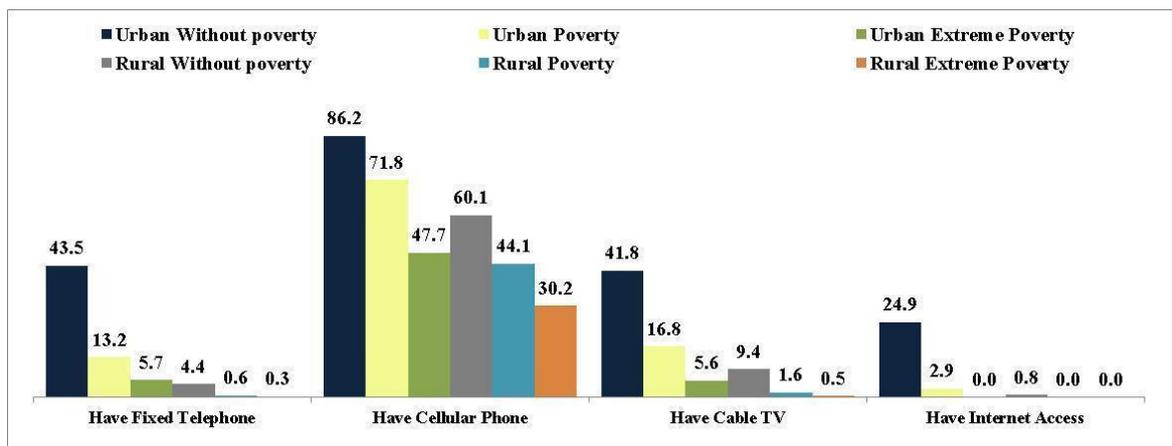


Figure 1: Peruvian households with ICT access by poverty level and area (Source: INEI 2011)

Table 1 summarises the access to telecommunications services in rural and urban areas of Peru. This shows how both poverty and lack of telecommunications services coincide in rural areas.

**Table 1:** *Population living in areas with telecommunications services coverage*

SERVICE	URBAN	RURAL
Fixed telephony	86%	0%
Mobile + Fixed wireless telephony	92%	53%
Fixed broadband access to the Internet (ADSL)	82%	0%
Mobile access to Internet 2.5G (EDGE)	92%	48%
Mobile broadband access to Internet (UMTS)	56%	3%
Cable TV	67%	0%
Satellite TV	100%	100%
Public telephony	94%	56%

### 2.3. GOVERNANCE IN PERU

In Peru, between 2002 and 2009 the government prioritised the improvement of good governance by putting several laws, regulations and national plans into action. These laws, regulations and plans determined and developed the principles of citizen participation, transparency, and accountability of local governments. The state recognised the importance of using ICTs to enhance organisational management and performance. The National Office of Electronic Government and Information Technology (NGOEI) was established, along with several plans for e-government deployment in central and local public administrations. E-government tools were introduced to and incorporated within the priorities of local public entities.

## 2.4. HEALTH

The United Nations (UN) recognises health as one of the key elements of human development, along with education, minimum level of income and the ability to participate in political and social life of the community. The health status of the population is also a factor that affects development. Poor health reduces work capacity and productivity of people and affects the physical development, schooling and learning of children. There is a link between the improvement in nutrition and health with the increase in productivity and school performance. In relative terms, the economic and education advantages that produce an improvement in health generate greater benefits in the poorest population. This is the reason why health was one of the key issues considered in the Millennium Development Goals (MDGs).

According to the World Health Organisation most inequalities in health are due to the conditions in which people are born, live and work, as well as the health system they have access to. That is, access to safe water and adequate sanitation, an adequate supply of safe food, adequate nutrition, adequate housing, healthy working conditions and environment, and adequate social protection. Improving these social determinants of health and reducing inequalities of power, money and resources may help to improve population health.

Often women and men are affected by different social determinants of health, producing gender inequality in access to health. For example, domestic tasks cause women be in contact with contaminated water, fatigue and stress of "double day" of women inside and outside the home, health problems during pregnancy, childbirth and postpartum, etc..

Health is recognised as a Human Right, so governments that have signed international covenants on human rights are obliged to create the conditions that allow all people to live as healthily as possible, including the social determinants of health. The Right to Health is not to be understood as the right to be healthy. Rather, international regulations on the Right to Health require governments to provide access to health care with quality care, non-discrimination and economic conditions that do not prevent access of the poor.

## 2.5 THE WILLAY PROGRAM

The Willay program is implemented in two distinct regions; San Pablo in Cajamarca and Acomayo in Cusco, together having a combined population of 50,000 people. The majority of the population belongs to indigenous communities, whose main economic activity is farming (84% of the active population).

In Acomayo, 46% of the population does not have access to electricity, 23% do not have access to running water, and 62% do not have access to appropriate sanitation. In terms of human development index, Acomayo is ranked ninth out of the thirteen provinces located in the department of Cuzco, with medium-low HDI similar to that of Sudan. Life expectancy is

63 years, 91% of children between 5 and 18 are in school and the illiteracy rate among women is 42%.

Government implementation of national initiatives related to the use of ICT, which are designed based on a developed urban perspective, generated unexpected results in these communities because of the lack of connectivity, capacity for management, and technology at the local level. Since there were neither good connections nor qualified technical staff in rural areas, the rural municipalities opted to establish offices in the respective districts' capitals. These satellite offices added to the municipalities' costs and complicated the human resources management process. There was limited knowledge regarding regulations on adequate use of management tools and deficiencies in using an appropriate language with the population in public entities. Regarding civil society organisations, they had organisational weaknesses; were unaware of their democratic governance rights and experienced limitations in leadership building. Spaces for consensus existed although they were not properly utilised due to a lack of satisfaction on the citizens' side.

The Willay program, meaning "to inform" in Quechua, proposes the use of ICTs in rural areas for democratic governance and citizen participation. The project explores how ICTs could enhance the processes of transparency, citizen participation and the accountability and effectiveness of local governments. This is achieved by building capacities of the stakeholders involved (civil society organisations and public entities like local government, health centres and schools).

In total, 44 local government institutions have been provided with a telecommunication infrastructure shared between them, based on WiFi for Long-Distance (WiLD) technology that offers Internet access and Internet Protocol (IP) telephony. Besides this, it has installed information systems and software, and implemented a system of continuous improvement. Public workers and community leaders have also been trained in participatory budgeting, accountability and transparency of institutions public, citizen surveillance, education management and health management.

### 3. CLASSROOM ACTIVITY

Internet access is low in regions like Acomayo in Peru, so public institutions, hospitals or schools cannot be linked to one another with a connection of high enough quality. The following activity will involve the design of a radio communication system that solves this problem.

The objective of this exercise is the analysis of advantages and disadvantages related to different types of radio communication systems. The student will solve two basic problems: one related to a radio link to connect an isolated area with the network using Wifi-based Long Distance (WiLD) technologies, and the other a satellite link.

1. Analysis of Radio communications systems:

The students should study different alternatives of classical and modern radio communications technologies. Four alternatives have been selected:

- Communication systems by shortwave (HF) among different users through ionospheric propagation.
- Point to point links based in radio communication systems Very High Frequency (VHF)/Ultra High Frequency (UHF).
- Network expansion with WiLD systems (WiFi for long distances).
- Satellite communications between one Earth station and one geostationary satellite.

Explain the advantages and disadvantages of all the different systems listed above based on the listed characteristics:

- Availability and price of the equipment available on the market.
- Operation and maintenance costs.
- Bandwidth.
- System properties.

## 2. Study of the WiLD system:

The second exercise involves a detailed analysis of the WiLD system. In this case, one WiLD system is used to interconnect different stations. In particular, two stations spaced 12km with direct vision have been selected. The first station is a radio relay placed on a hill and has two sectorial antennas pointing to each of the locations, with elevation beamwidth of 10deg and azimuth beamwidth of 90deg. The other is the local station, which has a pencil beam antenna with a gain of 18dBi. In this case we have the following information: central frequency is 5.8GHz, receiver sensitivity -90dBm, connector losses in both antennas 1dB, antenna bandwidth 100MHz.

- a) Draw the schematic radio communication system.
- b) What kind of antennas would you use for the radio system implementation, and what should be their approximate dimensions and electrical properties (beamwidth and gains)?
- c) Use the previous information to calculate the power transmitted.
- d) Estimate the value of signal to noise ratio if the noise factor of the receiver is 3dB, for a bandwidth of 2MHz.
- e) How can the receiver sensitivity and the signal to noise ratio be improved?

## 3. Study of the Satellite link:

In the second case, we are going to analyse the use of the satellite as backhaul for giving connectivity to a rural area. We selected the Hispasat Amazonas satellite, located

approximately 36,000km from the Earth in the area closed to equatorial line. The EIRP (Equivalent Isotropic Radiated Power) from the satellite to the region of Peru is 52dBW. The downlink frequency is 4GHz and the uplink is 6GHz, all the channels have one bandwidth of 8MHz, and the antenna diameter is 1m.

Estimate:

- a) The antenna gain of the Earth station.
- b) The type of antennas that can be used in this satellite communication system for the Earth Station and Satellite.
- c) The downlink signal to noise ratio, if the amplifiers have a noise factor equal to 2dB.
- d) The transmitted power if the Satellite Antenna has a gain of 32dBi at 6GHz. (In transmission (uplink) we can use the same antenna, and we know that the satellite sensitivity is -105dBm)

4. Analyse the applications of both systems for different scenarios.

### 3.1. SOLUTION AND EVALUATION CRITERIA

#### 1. Analysis of radio communications systems:

a) **HF:** The dominant means of long distance communication in this band is sky wave (skip) propagation, in which radio waves directed at an angle into the sky reflect (actually refract) back to Earth from layers of ionised atoms in the ionosphere. By this method HF radio waves can travel beyond the horizon, around the curve of the Earth, and can be received at intercontinental distances (range bigger than VHF waves). The maximum usable frequency regularly drops below 10MHz in darkness during the winter months, while in summer it can easily surpass 30MHz during daylight. The frequency depends on the angle of incidence of the waves; it is lower when the waves are directed straight upwards, and higher with less acute angles. Frequency bands free for use in the 80m band are between 3,500kHz and 3,800kHz, for the 40m band these frequencies are between 7,000 and 7,300kHz. In the 30m band frequencies free to be used are between 10,100 and 10,150kHz. A brief analysis of the aspects under study indicates:

- Availability and prices of the equipment on the market: it is easy to find equipment that functions within the free bands. In fact, they are used by radio amateurs.
- Operation and maintenance costs: there are no operation costs (the bands are free). The maintenance is not complicated and the equipment is robust, but the cost has to be covered by the user.

- Bandwidth: at these frequencies the bandwidth is very small, therefore, this system can be applied mainly to voice, but also to low speed data (e-mail,...) with special modems.
- System properties: due to the sky wave propagation, the users can be located anywhere (vehicles, houses, etc.). However, typical antennas are large.

b) **VHF/UHF**: Is the ITU designation for the range of radio frequency electromagnetic waves from 30MHz to 300MHz for VHF and 300MHz to 3GHz for UHF (the lowest UHF band is used for these purposes). The corresponding wavelengths are one to ten meters. VHF propagation characteristics are ideal for short-distance terrestrial communication, with a range that generally reaches somewhat farther than line-of-sight from the transmitter. Frequency bands free for use in the 6m band are between 50 and 54MHz, in the 2m band frequencies are between 144 and 148MHz. In the metre and fourth band the free frequencies are between 219 and 225MHz, and in the 70 cm band are between 430 and 440MHz.

A brief analysis of the aspects under study indicates:

- Availability and prices of the equipment on the market: it is easy to find equipment that functions within the free bands. In fact, they are also used by radio amateurs. These technologies are used for most walkie-talkies.
- Operation and maintenance costs: there are no operation costs (the bands are free). The maintenance is not complicated and the equipment is robust, but the cost has to be covered by the user.
- Bandwidth: at these frequencies the bandwidth is small, although larger than for HF bands. Therefore, this system can be applied mainly to voice, but also to data (e-mail, low speed internet,...) with special modems.
- System properties: due to the line of sight propagation, the users cannot be located anywhere. Usually, the link is point-to-point between buildings separated up to 30 km. Typical antenna are Yagi-Uda antennas, much smaller and directive than those mentioned in the previous solution (HF).

c) **WiLD**: Long-range Wi-Fi is used for low-cost, unregulated point-to-point computer network connections, as an alternative to other fixed wireless, cellular networks or satellite Internet access. The industrial, scientific and medical (ISM) frequencies for WiLD are 2.4 to 5.8GHz. This standard is an evolution of the classical WiFi standard, with some modifications in the parameters to allow long distance work. WiLD propagation characteristics are ideal for terrestrial communication, with a range generally equivalent to line-of-sight from the transmitter. An analysis of the aspects under study indicates:

- Availability and prices of the equipment on the market: it is easy to find equipment that functions within the free bands, it is the same equipment as used for WiFi but

with special antennas and amplifiers. The antennas used may be grid reflectors or Yagi-Uda antennas and the amplifiers are high powered, within 2.5GHz band.

- Operation and maintenance costs: there are no operation costs (the bands are free). The maintenance is more complicated than the previous possible solutions. The equipment are robust, but the maintenance cost has to be covered by the user.
- Bandwidth: at these frequencies the bandwidth is larger than the previous possible solutions. This system can be applied to data transmission (e-mail, internet, teleservices) and voice communications via Voice over IP (VoIP).
- System properties: due to the line of sight propagation, the users cannot be located anywhere. Usually, the link is point-to-point between buildings separated up to 30km (even up to 100km with very high towers). Typical antennas are Yagi-Uda antennas, which are much smaller and directive than those mentioned in the previous possible solution.

d) **Satellite communication link:** A communication satellite or comsat is an artificial satellite sent to space with a telecommunication purpose. Modern communications satellites use a variety of orbits including geostationary orbits, Molniya orbits, elliptical orbits and low (polar and non-polar) Earth orbits. For fixed (point-to-point) services, communication satellites provide a microwave radio relay technology complementary to cable communication. They are also used for mobile applications, such as communications to ships, vehicles, planes and hand-held terminals, as well as for TV and radio broadcasting. In these cases, where communications take place within an isolated area, Geostationary satellites are often used (although there are some applications with specific low or medium orbit satellites). In the case of the Geostationary satellites, the antenna is fixed, pointing to the satellite. The Earth station can then be connected to a local network, in order to use only one satellite link and reduce the operation cost.

An analysis of the aspects under study indicates:

- Availability and prices of the equipment on the market: it is not difficult to find equipment that function within the free bands, although, usually the satellite provider installs or recommends the equipment to the user.
- Operation and maintenance costs: the operation costs are expensive. The maintenance could be supported by the satellite operator (depending on the agreement). In any case, the equipment is robust enough for the context.
- Bandwidth: at these frequencies the bandwidth is larger than the previous possible solutions. This system can be applied to data transmission (e-mail, internet, teleservices) and voice communications via Voice over IP (VoIP).
- System properties: the antennas are usually parabolic reflectors, and installed on the rooftop of buildings. The communication requires line-of-sight with the satellite.

## 2. WiLD system:

- a) Schematic radio communication system. A possible configuration of the network is the one shown in the figure, which comes from the Enlace Hispano Americano de Salud (EHAS) project ([www.ehas.org](http://www.ehas.org)). In the case of the WiFi network, there are two links, one between a health post and a health centre, and another one between the health centre and the hospital. This can be extended to more complex networks. Also, the last station can give free communications service to users through an omnidirectional antenna.
- b) Different antenna types:
- Vertical linear arrays of dipoles or patches (sectorial antennas). In this case the azimuth beamwidth is bigger than the elevation beamwidth. This is for giving connection to different points.
  - Vertical linear arrays of dipoles for omnidirectional antennas diagram. This is typically used for giving connection to individual users.
  - Grating reflector antennas. This is typically used for point-to-point links.

In all these cases we can calculate the effective area with the expression:  $A_{ef} = \epsilon_A S_A$

In which  $\epsilon_A$  is the aperture efficiency and his value is between 0.5 and 0.8,  $S_A$  is the antenna surface.

The directivity is:  $D = \frac{4\pi}{\lambda^2} A_{ef}$ , with this expression the gain is calculated as  $G = \eta_R D$ , in which  $\eta_R$  is the radiation performance and in most of antennas is setting close to 1. A loss margin of 6dB is included in the link.

c) With Friis expression (in dB):

$$P_R \text{ (dBm)} = P_T \text{ (dBm)} - L_{FE} \text{ (dB)} + G_T \text{ (dBi)} + G_R \text{ (dBi)} - \alpha \text{ (dB)} - L_{\text{margin}} \text{ (dB)}$$

Where LFE are the Free Space Losses,  $L_{FE} = 20 \log(4\pi d/\lambda) = 129.3\text{dB}$  and  $\alpha$  is the antenna connector losses. The receiver gain is:

$$D = \frac{41253}{10 \times 90} = 45.84, \text{ then } G = \eta_{\text{rad}} D \text{ and } G \approx D = 45.84 = 16.6\text{dBi}$$

$$\text{The Friis expression in dB is: } P_R = P_T + G_T + G_R - L_{FE} - \alpha - L_{\text{margin}}$$

$$\text{So } P_T = P_R - G_T - G_R + L_{FE} + 2\text{dB} + 6\text{dB} = 12.7\text{dBm}$$

d) First we must calculate the noise power:

$N_o = K T_e B = -109.2 \text{ dBm}$  Where  $T_e = (f-1)T_o = 290\text{K}$  and  $T_a = 150\text{K}$  is approximately the antenna temperature,  $T = 290 + 150 = 440\text{K}$

$$\text{SNR(dB)} = S_o \text{ (dBm)} - N_o \text{ (dBm)} = -90\text{dBm} + 109.2 = 19.2\text{dB}$$

e) First we must calculate the power of noise:

To improve the sensitivity of the receiver we can increase the gain of the receiver antenna, or to reduce the noise of the receiver. To increase the signal to noise, also we can increase the transmitted power or the gain of the transmitting antenna.

### 3. Satellite system:

- a) The frequency (downlink) is 4 GHz, therefore:  $\lambda=7.5$  cm

The antenna diameter is 1m. If a total efficiency of 0.7 is estimated, the antenna gain is:

$$G_R = \epsilon_A \frac{4\pi}{\lambda^2} S_A = \epsilon_A \frac{4\pi}{\lambda^2} \pi \left(\frac{D}{2}\right)^2 = 1228 \rightarrow 10\log G_R = 30.9\text{dBi}$$

- b) The Earth Station Antennas to be used are Offset Parabolic Reflectors or Cassegrain Reflectors. The Satellite antennas are either Reflectors (Offset Cassegrain) or Antenna Arrays.

- c)  $P_R = P_T + G_T + G_R - L_{fe}$  where PIRE(dBm)= $P_T + G_T=82\text{dBm}$  and

$$L_{fe} = 20\log\left(\frac{4\pi d}{\lambda}\right) = 195.61\text{dB}$$

Then  $P_R = -82.7$  dBm

The noise power is calculated:  $N_o=KT_{\text{tot}}B= -106.4$  dBm

Where  $T_e=(f-1)T_o=169.6\text{K}$  and  $T_a=40\text{K}$  is approximately the antenna temperature,  $T_{\text{tot}}=169.6+40=209.6\text{K}$  and with the signal to noise ratio expression:  $\text{SNR(dB)}=S_o$  (dBm) -  $N_o$  (dBm) =23.7dB. (where  $T_o=290\text{K}$  and  $k=1.38\text{e-}20$  mJ/K)

- d) For the up-link the transmitted antenna is the same, but now the gain has to be recalculated, with  $\lambda=5\text{cm}$ :

$$G_T = \epsilon_A \frac{4\pi}{\lambda^2} S_A = \epsilon_A \frac{4\pi}{\lambda^2} \pi \left(\frac{D}{2}\right)^2 = 2763 \rightarrow 10\log G_T = 34.4\text{dBi}$$

in this case  $L_{FE}=20\log(4\pi d/\lambda) = 199.1\text{dB}$  and the received power is the sensitivity (-105dBm)

Then  $P_T=P_R-G_T-G_R+L_{FE}=27.7\text{dBm}$

Satellite link can be used to connect the network in remote isolated areas. The WiLD system can be used to connect some areas to the network. Both systems could have the same application, and the selection of one or the other should be made on reasons of cost. In any case, both systems can be combined, with an access point (satellite) and a WiLD network to connect some rural areas to that access point.

### **Evaluation criteria**

This exercise is worth 1 point on the class rating; equally divided between the different sections of the exercise, each with a value of 0.25 points.

### **4. HOMEWORK ACTIVITY**

The work will be carried out in groups of three to five students.

This work consists of the design of a radio communication system to cover a certain rural zone of Peru, in order to connect different public institutions, with the possibility of including homes later.

The work has been conducted with consideration of the Acomayo zone, Cusco region, Peru. In this zone mobile phone companies like Claro (narrow band – GSM) can be found.

The technical objective of this activity is to check which communication system is most appropriate for this application.

#### **First section**

Analyse the zone's energy and telecommunication infrastructure, poverty index, Human Development Index, livelihood activities of inhabitants, education index, governability etc.

#### **Second section**

Analyse the advantages and disadvantages of each telecommunication system based on:

1. The use of the telephone network in the zone.
2. The use of the satellite network with VSAT links or similar.
3. The extension of the network with HF telecommunication system.
4. The extension of the network with VHF/UHF telecommunication system.
5. The extension of the network with WiLD system.

Once we have suggested two different proposals for the case study zone and explained their advantages and disadvantages, the coverage areas, type of antennas, emitted power, band of frequencies etc. must be indicated.

#### **Third section**

Choose the best option of the previous two proposed and justify your selection.

Perform a network design from the broadcast point of view.

#### **Comments**

The student must take into account that there are no qualified employees to carry out the equipment maintenance in the rural area under consideration, so NGO's who offer these services will have to be relied on to provide the necessary employees.

#### 4.1. SOLUTION AND EVALUATION CRITERIA

##### **First section:**

There are several different websites to that may provide the information required:

- Website of the Ministry of Employment  
<http://www.mintra.gob.pe>  
[http://www.mintra.gob.pe/archivos/file/estadisticas/peel/estadisticas/Estudio\\_012008\\_%20OSEL\\_CUSCO.pdf](http://www.mintra.gob.pe/archivos/file/estadisticas/peel/estadisticas/Estudio_012008_%20OSEL_CUSCO.pdf)
- Agriculture, public politics and budget smallholder website for Acomayo:  
<http://www.arariwa.org.pe/Peqagriculturaacomayo.pdf>
- Websites of the NGO's in the area, which helps to understand the situation in rural areas of the country.  
<http://www.ongawa.org>  
<http://www.wawared.org>  
<http://www.ehas.org>
- Websites for telephone companies that are in the case study zone.  
<http://www.telefonica.com.pe>  
<http://www.claro.com.pe/wps/portal/pe/sc/personas>
- Website of the Inter-American Development Bank, which provides infrastructure statistics in Latin America.  
<http://www.iadb.org/digilac>
- Orography, for example, Google Maps GIS system.

##### **Second section:**

1. Use of the telephone network in the area:

This indicates that money should be saved up in order to deploy networks and then an amount of money is paid monthly to the telephone company in the zone.

In the case study zone there is Claro, it's low speed (2G). The towns that are serviced by Caro should be listed.

Depending on the provided service, this option may be useful or not (required wideband respect the Claro availability). Basically, Claro offers right now voice and low speed data.

2. Use satellite network through VSAT or an equivalent:

A communications satellite, or comsat, is an artificial satellite sent to space with a telecommunication purpose. Modern communication satellites use a variety of orbits including geostationary orbits, Molniya orbits, elliptical orbits and low (polar and non-polar) Earth orbits. For fixed (point-to-point) services, communications satellites provide a microwave radio relay technology complementary to that provided by communication cables. They are also used for mobile applications such as ships' communications, vehicles, planes and hand-held terminals, as well as TV and radio broadcasting. In this case there should be one station, like the classroom activity. A collective cost management option could be used. This is useful for isolated areas and for high speed data. Also, with the O3B program (Other Three Billion), medium orbit satellite connectivity will be offered to everyone everywhere (<http://www.o3bnetworks.com/>)

3. Network extension through HF system:

The dominant means of long distance communication in this band is sky wave (skip) propagation, in which radio waves directed at an angle into the sky reflects (actually refract) back to the Earth from layers of ionized atoms in the ionosphere. By this method, HF radio waves can travel beyond the horizon, around the curve of the Earth, and can be received across intercontinental distances (range bigger than VHF). The maximum usable frequency regularly drops below 10 MHz in darkness during the winter months, while in summer it can easily surpass 30 MHz during daylight. It depends on the angle of incidence of the waves; it is lowest when the waves are directed straight upwards, and is higher with less acute angles. Frequency bands free to use for the 80m band are between 3,500 kHz and 3,800 kHz. For the 40m band these frequencies are between 7,000 and 7,300 kHz. In 30m band free frequencies are between 10,100 and 10,150 kHz. This kind of network is useful for voice applications and communications in vehicles where line of sight is not required. The main problem is that the frequency has to be adjusted depending on the hour of the day. A connection to the public network could be done with a special modem. Also, very low speed data could be implemented with a modem.

4. Network extension through VHF/UHF system:

The ITU designation is for a range of electromagnetic frequency radio waves from 30 MHz to 300 MHz, with corresponding wavelengths of one to ten metres. VHF propagation characteristics are ideal for short-distance terrestrial communication, with a range that is generally farther than line-of-sight from the transmitter (see formula below). Frequency bands free to use for the 6m band are between 50 and

54MHz. In the 2m band, frequencies that can be freely used are between 144 and 148 MHz. In the metre and fourth band, the free frequencies are between 219 and 225 MHz, and in the 70 cm band they are between 430 and 440MHz. The antennas to be used are Yagi-Uda, and these systems are usually employed to connect one isolated area with the network. Line of sight is required. Voice and medium speed data can be implemented.

5. Network extension through WiLD system:

LONG-range Wi-Fi is used for low-cost, unregulated point-to-point computer network connections, as an alternative to other fixed wireless, cellular networks or satellite Internet access. The ISM frequencies are in the bands 2.4 to 5.8GHz.

The figure below shows the necessary deployment network from a wireless net with WiFi technology, which consists of a backbone and local networks. This is similar to those used in the examples of EHAS (www.ehas.org) or Willay www.ongawa.org/por-paises/peru/) programmes.

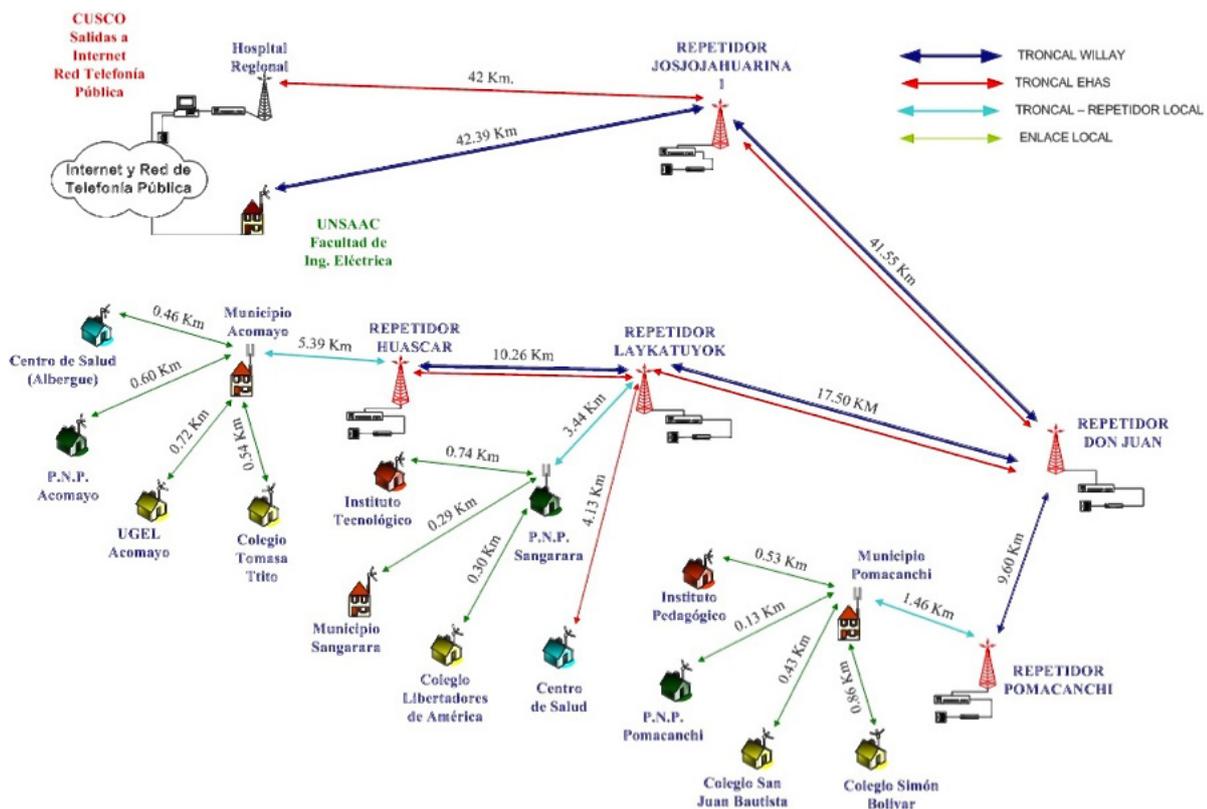


Figure 2: Scheme of the Willay-Cusco network

The advantages and disadvantages of three options taken from the possible solutions presented above (satellite communication, WiLD system and use of an existing GSM network).

### **Geostationary Satellite System:**

#### **Advantages:**

- Flexible (if transparent transponders)
- Easy to install new circuits
- Circuit costs independent from distance
- Broadcast possibilities
- Temporary applications (restoration)
- Niche applications
- Mobile applications (especially "fill-in")
- Terrestrial network "by-pass"
- Provision of service to remote or underdeveloped areas
- User has control over their own network
- 1-for-N multipoint standby possibilities

#### **Disadvantages**

- Large up-front capital costs (space segment and launch)
- Terrestrial breaks even distance expanding (now approx. size of Europe)
- Interference and propagation
- Congestion of frequencies and orbit
- Operation cost

### **WILD System:**

#### **Advantages:**

- Wireless means lower costs for network setup, specifically in large areas of coverage.
- The more nodes you install, the bigger and faster your wireless network becomes.
- They rely on the same WiFi standards (802.11a, b and g) already in place for most wireless networks.
- They are convenient where Ethernet wall connections are lacking, for instance in outdoor concert venues, warehouses or transportation settings.
- They are useful for Non-Line-of-Sight (NLoS) network configurations where wireless signals are intermittently blocked (using relays).
- Mesh networks are "self configuring;" the network automatically incorporates a new node into the existing structure without needing any adjustments by a network administrator.

- Mesh networks are "self healing," since the network automatically finds the fastest and most reliable path to send data, even if nodes are blocked or lose their signal.
- Wireless mesh configurations allow local networks to run faster, because local packets do not have to travel back to a central server.
- Wireless mesh nodes are easy to install and uninstall, making the network extremely adaptable and expandable as more or less coverage is needed.

### **Disadvantages**

The main reason why the use of mesh is not advised is related to the negative sides of mesh: bandwidth consumption and lack of interoperability

### **Existing GSM network:**

#### **Advantages:**

- Using a GSM network means less CAPEX (infrastructure cost), but more OPEX (at least with respect to the WiLD networks).
- The user does not worry about the operation and maintenance.

### **Disadvantages**

The user depends on the availability (coverage) and the quality (wideband) of the network. Nowadays, it is possible to have GSM (2G) in rural areas, but 3G is not possible. However, there are some cellular extension plans, and those ones should be checked.

### **Third section**

A WILD system is chosen so the signal arrives to the repeater station and then goes to the different users. In the first project, these users are public institutions within the zone, which streamlines the procedure and allows for the attainment of a global connection between builds.

A grating reflector antenna with point-to-point vision is used.

For this project the Telefonica wire network that is going to be installed in the next months in all the capital cities of provinces is connected to. If this plan is not possible, the national fibre optic plan could be used, which is a project to be implemented by the Peruvian government.

In the future, the acceptance of the project by habitants in the project zone would be observed and depending on the level of advancement of technologies in the zone the possibility to expand the objectives achieved with the project could be considered.

**Evaluation criteria**

This exercise is worth 3 points; equally divided across the different section of the exercise, each with a value of 1 point.

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