Wireless network design through Wi-Fi Long Distance Technology for educational institutions within de Andes area of the Cotacachi sector.

Ing. Irving M. Reascos, Sofía E. Rosero.

***Abstract*—this study contains a brief description of the most important aspects required for the setting up of a Communications Network that benefits schools within the Andean Cotacachi sector through the implementation of low-cost technology and high quality WILD or Wi-Fi long distance service.**

This type of design confirms the initial requirements to develop this project, it promotes maximum capacity required by the network and by hardware technical specifications, and it establishes architecture and topology that wireless networks require in addition to providing feasibility study coverage of the preliminary topology written links.

***Indexed Terms*— WILD, IEEE, MINTEL, WLAN**

I. INTRODUCTION

THE parishes that shape the Andean sector of Cotacachi are Imantag, San Francisco, El Sagragrio and Quiroga according to the Ministry of Education during the academic year 2012-2013 has the most students holding 40 educational institutions where 9082 students attend being taught by 482 teachers.

At the Cotacachi sector, average internet access is 3,98% which tell us that there is a lack of internet service and data transfer turning into a very limited and inexistence service to low income schools in the rural areas. [1]

For this reason the Gobierno Autonomo Descentralizado Municipal Santa Ana de Cotacachi, complying with the municipal ordinance and development in the area of infrastructure and transportation system, energy and telecommunications aims to start this connectivity project over the development of a network that includes long range wireless technology and implement it to rural remote areas. Such technology refers to voice and data wireless transmission based on the 802.11 protocol.

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I.M. Reascos, Teaching at the Universidad Técnica del Norte, at the Carrera de Ingeniería en Sistemas, Av. 17 de Julio "El Olivo" neighborhood, Ibarra-Ecuador (e-mail: ireascos@gmail.com).

S.R. Arévalo, egresada de la Carrera de Ingeniería en Electrónica y Redes de Comunicación (e-mail: sera_939@hotmail.com).

II. BASIC CONCEPTS

A. *IEEE 802.11*

Standard IEEE 802.11 is known as the father of all standards WLAN. It refers to a protocol family which is a wireless standard that defines connectivity for fixed stations, portable and mobiles within local and metropolitan areas. LAN wireless technologies offer connectivity within buildings, campuses and extensive areas. The 802.1 norm has evolved for the past decade, producing several devise specific norms such as 802.11, 802.11b, 80211a, 802.11g, 802.11n and 802.11ac among others. Standard 802.11 is originally called Standard IEEE for MAC and PHY specifications from WLAN. [2]

Characteristics:

- Operation in free frequency bands, not licensed
- It establishes access to CSMA/CA media
- Multiplexing: OFDM – DSSS – MIMO
- Broad band transmission speed, quantity flow MIMO and compatibility depend on the standard IEEE 802.11 version (see Table 1)

Table 1: Standard 802.11 versions comparison

Version	Frequency (GHz)	Rate (Mbps)	Bandwidth (MHz)	MIMO stream	Compatibility
Original	2.4 GHz	2 Mbps	20 MHz	1	NO
802.11a	5 GHz	54 Mbps	20 MHz	1	NO
802.11b	2.4 GHz	11 Mbps	20 MHz	1	SI (g)
802.11g	2.4 GHz	54 Mbps	20 MHz	1	SI (b)
802.11n	2.4 GHz o 5 GHz	600 Mbps	40 MHz	4	SI (a, b ,g)
802.11ac	5 GHz	1.3 Gbps	160 MHz	8	SI (a, n)

Architecture

Some protocols like the Ethernet and Wi-Fi have a similar structure to its 802 standard and in 802.11 the physical layer and the data link layer corresponds to the reference model OSI with some variations. The data link layer is divided into 2 sub-layers: logical control link and medium access control.

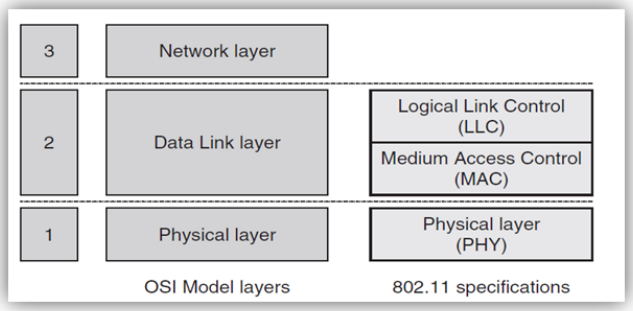


Figure 1: 802.11 Logical Architecture corresponding to OSI model
Source: Rackley S. (2011). *Wireless Networking Technology From Principles to Successful Implementation.* Great Britain: Elsevier.

Physical Layer

The physical layer is the IEEE 802.11 standard and it specifies wireless signaling techniques used to transmit and receive information through radio-electric waves, besides to providing service to the MAC IEEE sub-layer 802.11.

There are tree functionality levels:

- Frames transmission to the non-guided means using different modulation types
- Sending data to the data link layer over the transmission channel, if during this period a signal in the frequency band is transmitted
- Frames interexchange with the link layer

Link Data Layer

This layer is divided into two sublayers that are defined as:

- Media access control (MAC)
- Logical link control (LLC)

The LLC sublayer is normal for all 802.X standards. It supplies a common front end unique among superior layers and the MAC sublayer. The combination of the LLC 802.2 standard together with the access control protocol to MAC media is defined as the equivalent to the model OSI data link layer.

Media Access Control sublayer (MAC)

MAC is a sublayer responsible for addressing mechanisms which control media access management that make possible nodules communication with the network.

This layer provides the following main functions:

- Data delivery among stations.- This process includes media access, data frames interexchange, errors retrieval, fragmentation and encryption.
- Connectivity. - Before a 802.11 station is capable of sending and receive data, it must connect to the network. This process includes network scanning, authentication and association to the network.
- Synchronization.- due to the wireless media is shares with 802.11 stations and must comply with strict synchronism norms.
- Defining an access method to CSMA/CA media is a contention multiple access protocol which allows several stations transmission media sharing, avoiding the most collisions.

B. WIFI LONG DISTANCE

WIL Wi-Fi based Long Distance, given term by TIER Technology and Infrastructure for Emerging Regions, a University of California Berkeley investigative group. It refers to the set of solutions for voice and data transmission based on the 802.11 protocol, whose most notable virtue is to reach long distance connections (between 50 and 100 km) much longer distances originally designed for protocol 802.11. [3]

Standard 802.11 Modifications

Because Wi-Fi technology had been designed to local area networks, there is a great deal of difficulty when applied to long distance services, thus techniques that allow their uses in long range are analyzed.

Long Distance Physical Layer

By establishing a long distance connection the most important point is making sure that the wireless signal is strong enough to support communication. Computation of specifications connection must be denominated. The connections viability depend on the transmission's ratio and antennas gain, in addition to cables losses, connectors and losses throughout wireless access routes.
A wireless connection using Wi-Fi technology can reach most range by reaching and specific parameters balance:

- Maximum potency and allowed transmission gain
- Propagation losses
- Reception sensibility
- Minimum acceptable signal-noise relation

MAC Long distance layer

Range extending techniques as being presented for Wi-Fi Technology physical layers work in point-to-point connections and comprise dozens of kilometers offering good wireless signal.
Being that MAC layer 802.11 was designed to work in short distances when constant timing intervals are made during the transmission process, multiple access protocol CSMA/CA depends on the containment listening means. Such process results inappropriate over long distance, since long waiting periods are generated between stations transmissions, so limiting principles that impose long distance to benefit MAC 802.11 layer are defined:

- Frames Delivery confirmation.- over the use of ACK timeout or the time that the transmitting station awaits the ACK arrival. This is called package sending confirmation.
- Time intervals.- they indicate channel's transmission state (available/busy), Slot Time or Inter Frame.

- NAV.- is the transmission estimate length of time that a predetermined station takes to set free a transmission and sending of a channel from another station. This method does not take into account propagation time therefore failing by distance.

Considering these limitations, connections balance may work in low-capacity, but they would depend on the kind of equipment used and on the standard version. With the first 802.11 versions, systems problems were more prominent in distances from 6 to 20 kms.

Adapting parameters: ACK Time out, CTST Time out and Slot Time to the MAC 802.11 sublayer in certain systems based on Atheros Semiconductors sets of circuits, connections performance is practically error free.

Antennas utilized in Long Distance

Antennas are physical devices fundamental to wireless devices since they act as a front-end to the sending or reception of electromagnetic waves launched through radio electric spaces.

Types of antennas

When a signal is fed in an antenna, it will send radiation distributed in space in a predetermined way. A radiation pattern is a relative distribution of radiated potency into space.

According to the signal coverage, they are classified in three types:

- Omnidirectional
- Directional or bidirectional
- Sectorial

Calculation of the link budget

For each connection or link, an estimate of the expected level and the fade margin must be made. It consists of creating a potency balance. The following equation shows the basic elements that must be considered when calculating of the link budget:

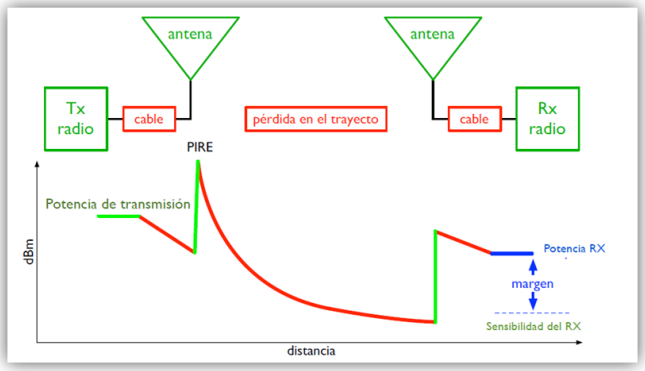


Figure 5: Influencing factors of the link budget
Source: WNDW. (2013). Redes Inalámbricas en los Países en Desarrollo (4 ed.). Copenhagen: WNDW.

$$PRx_{dBm} = PTx_{dBm} - LTx_{dB} + GTx_{dBi} - FSL_{dB} + GRx_{dBi} - LRx_{dB}$$

Equation 1: Calculation powers balance link

Where:

PTx_{dBm} Transmitter power
LTx_{dB} Cable and power transmitter losses
LRx_{dB} Cable and receptor transmitter losses
GTx_{dBi} Antenna gain transmission
GRx_{dBi} Antenna gain reception
FSL_{dB} Free space losses
PRx_{dBm} Receiver power

Fade Margin

Defining fade margin is the most important step in designing radio links. If the margin is low, the connection will be unstable. When there is a secure fade margin, where the receptor acquired potency (PRx) must be higher than the Receptor's Sensibility (SRx). This value must be higher or equal to 10 dB. Reception power margin is provided by the following formula:

$$M_{dB} = PRx_{dBm} - SRx_{dBm}$$

Equation 2: Calculation fade margin

Where:

PRxdBm Receiver power
SRxdBm Receptor sensibility

III. LEGAL AND REGULATORY ASPECTS ANALYSIS

The Constitution recognizes the Government as a proprietor and administrator of the radio electric spectrum, for such the Government assigns entities as competencies to regulate this spectrum as shown in the following is an organizational chart:

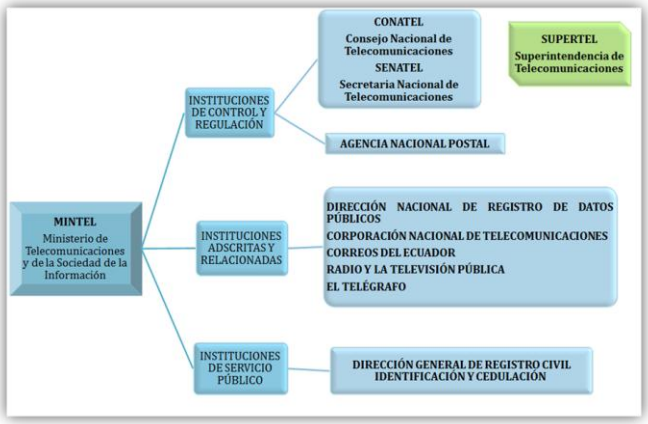


Figure 6: Telecommunications Regulatory Entities in Ecuador
Source: http://repositorio.espe.edu.ec/bitstream/21000/211/1/T-ESPE-027397.pdf.

A. *Norms for the Implementation of Digital Broad Band Modulation Systems Operation*

According to the regulatory framework governing telecommunications in Ecuador, this legislation is contemplated in order to provide broad band wireless access services.

SENATEL is in charge of issuing Digital Modulation Registry Systems Certificates. Such certifications include the registered system's description after complying with the following requirements:

Approval: All hardware that uses broad band digital modulation must be approved by the Superintendencia de Telecommunicaciones.

Frequency Bands: Operating in frequency bands registered in the attribution box of frequency bands. Radio communication operation systems will be approved as long as they utilize digital modulation techniques in broad band with the following frequency bands:

Table 1: Frequency bands allowed to SMDBA

BAND (MHz)	ASSIGNATION
902 – 928	ICM
2400 - 2483.5	ICM
5150 – 5250	INI
5250 – 5350	INI
5470 – 5725	INI
5725 – 5850	ICM, INI

INI and ICM Bands are defined for the development of the National Information Infrastructure and the Scientific and Medical Industrial Applications

Systems Configuration: Systems operation with Broad Band Digital Modulation techniques will be approved on the following configurations:

- Point – Point Systems
- Multipoint—Point Systems
- Mobile Systems

Transmitter Maximum Peak Power: according to Operation Frequency: Maximum power allowed according to the technical norm for the operation in several frequency bands and in different types of systems configuration.

Table 2: Transmitter Maximum Peak Power with respect to Operation Frequency

Systems Configuration	Operation Frequency Band (MHz)	Transmitter Maximum Peak Power (mW)
Point – Point Multipoint—Point Mobile	902 - 928 250	250
Point – Point Multipoint—Point Mobile	2400-2483.5	1000
Point – Point Multipoint—Point Mobile	5150-5250	50
Point – Point Multipoint—Point Mobile	5250 - 5350	250
Point – Point Multipoint—Point Mobile	5470 - 5725	250
Point – Point Multipoint—Point Mobile	5725 - 5850	1000

Necessary forms to broad band digital modulation systems

As follows:

- Legal information form (broad band digital modulation systems) RC—1B
- Radio communications system infrastructure information form RC—2A
- Antennas information form RC—3A
- Hardware information form RC—4A
- Broad band digital modulation systems form (point—point system) RC—9A
- Broad band digital modulation systems form (multipoint system) RC—9B
- Radio communications System scheme Form RC—14A. [4]

IV. Design

When designing a network is essential to have good knowledge of geo referenced coordinate points, information regarding infrastructure and who the beneficiaries will be as well as functions features like the main distance towards trunk nodule and service availability. Topology is the best guide to follow according to system's needs.

A. Involved network points

Interconnectivity and internet access project for the educational institutions is born of an initiative of the Municipio de Santa Ana de Cotacachi with the objective of providing internet services to schools within that sector.
Places which the proposed internet project:

- Municipalidad de Santa Ana de Cotacachi
- Selected nodes for the Transport or Trunk Network
- Imantag Parish Educational institutions
- Quiroga Parish Educational institutions
- Main urban-rural Cotacachi Parish Educational institutions

B. Cotacachi Municipality Data Processing Center

Figure 7: Cotacachi Municipality Location

Data Processing Management point located at Gonzalez Suarez and Garcia Moreno Streets in the Cotacachi's Municipality Building is where the trunk network is interconnected and users' network internet broad band service is supplied by an authorized internet provider. This place is also a key point where servers as firewall proxy and optional servers as web server, email video surveillance (video streaming) and voice over IP are managed.

C. Main Trunk Link

Wireless Trunk Network is composed of two main parts at the Cotacachi Municipality which functions as Data Processing

Center. Transport nodes located during the Andes area are responsible for network access coverage.
The points that take part in the main trunk network are described as follows:

- Trunk node located at the Yanahurco Cerro or Loma Negra
- Trunk node located at the Cotacachi Municipality
- Trunk node located at the Marcelino Alzamora school

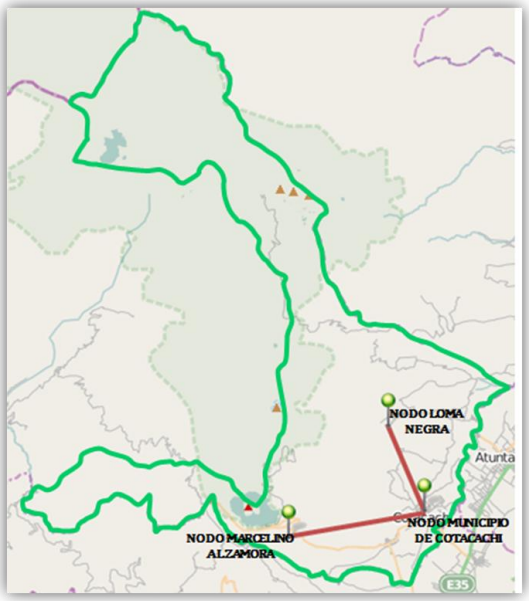


Figure 8: Geographical location of Trunk Connection of all selected nodes

D. Institutions that get benefited

Entities that will be benefited by this project are those public institutions of the Andean urban area that at present do not count with internet service and are part of the Fondo de Desarrollo de Telecomunicaciones. Thirty four educational institutions will have internet services.

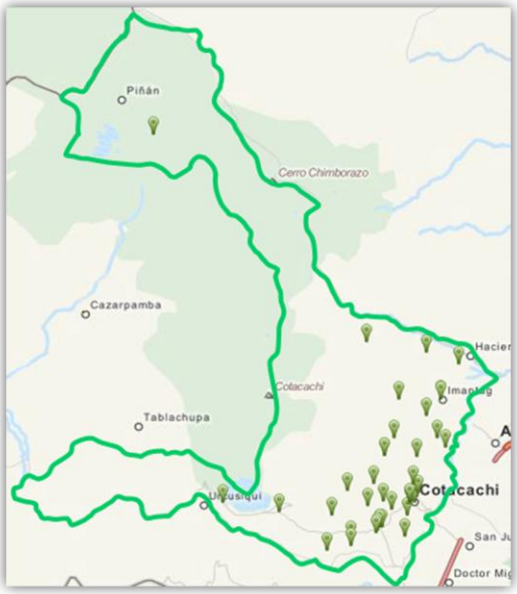


Figure 9: Geographical location of institutions of the Andean urban area.

E. Infrastructure Information and Beneficiaries

The following table contains infrastructure information as number of computers available in each school, number of students and teachers that will be benefited at each parish that is part of the Cotacachi sector.

Table 3: Beneficiaries per school

Establecimientos De La Parroquia De Inmantag	Num Alumnos	Num Profesores	Total Pcs
Marco Herrera Escalante	50	4	7
Red Educativa Imantag	704	31	29
Provincia De El Oro	111	10	9
Monseñor Bernardino Echeverría	45	3	6
Cecib Alejo Saes	16	1	6
Luis Alberto Moreno	94	6	8
Hernando De Magallanes	166	13	11
Abelardo Moran Muñoz	63	3	7
Dr. Ignacio Salazar	32	2	5
Establecimientos De La Parroquia De Quiroga	**Num Alumnos**	**Num Profesores**	**Total Pcs**
Andrés Avelino De La Torre	332	22	15
Segundo Luis Moreno	92	4	9
Eloy Proaño	418	21	20
Leticia Proaño Reyes	235	13	14
28 De Junio	130	6	9
Virgilio Torres Valencia	28	2	7
Cuicocha	10	1	6
Marcelino Alzamora Y Peñaherrera	97	7	6
Luis Plutarco Cevallos	384	21	18
Establecimientos De La Parroquia De Cotacachi	**Num Alumnos**	**Num Profesores**	**Total Pcs**
Marco Tulio Hidrobo	42	3	5
Juan Francisco Cevallos	201	10	5
San Jacinto	287	13	13
Jorge Gómez Andrade	47	4	7
Martin Alonso González Lalanne	26	4	6
Piava San Pedro O Luis Felipe Borja	15	1	6
Trajano Naranjo	25	1	6
Nazacota Puento	131	9	5
Rcecib Cotacachi José Domingo Albuja	60	5	8
Pichincha	107	9	10
Enrique Vacas Galindo	32	3	5
Miguel De Cervantes	52	7	8
José Vasconcelos	85	5	9
Luis Ulpiano De La Torre	1252	79	13
6 De Julio	629	24	32
Modesto Aurelio Peñaherrera	505	21	26
Hortensia Yépez Tobar	67	3	7
Manuela Cañizares	512	20	22
SUMA TOTAL	**7082**	**391**	**385**

The type of hardware used to design a network must be approved by the Proyecto de Interconectividad Cantonal para servicios Municipales y acceso a Internet en Unidades Educativas y Entidades Estatales del cantón Cotacachi en la Provincia de Imbabura. Such project demands that each school has a minimum of five computers given by the Municipality to complement the current hardware. Moreover TIC indicators issued by the Ministerio de Education specifies that at least one computer must exist for every 20 registered students. The preceding table shows the total number of computers once the network is inter-connected.

Calculation system

In order to obtain the maximum capacity required, there must be an average of 256 Kbps broad band per each fixed computer due to the fact that computer's use is for education purposes thus main services include web surfing, email and educational files downloads.
To size a wireless network and calculate wireless interconnection points, a maximum transfer of 128 Kbps per wireless access is required. However for the transferring of total speed, a sum of speed consumption per each device is required in the following way:

Table 4: Demand transfer rate

Description	Upstream	Downstream
385 PC = Internet	256 Kbps x 385 =98560 Kbps	256 Kbps x 385 =98560 Kbps
855 Accesos Inalámbricos	128 Kbps x 855 =109440 Kbps	128 Kbps x 855 =109440 Kbps
TOTAL	208000 Kbps	208000 Kbps

Optimum use of the network continuously and simultaneously brings up a total theoretical load of 208 Mbps. Providing that fixed and wireless network users access the internet in the afternoon and do educational consulting, smaller scale applications involve the use of broad band controlled consumption utilizing as a result less resources which keep a 0,2 simultaneity factor, in other words 20% of total users will access internet services simultaneously around rural environments. This factor is determined over the following calculation:

$$C\ salida = Carga\ Total\ x\ Factor\ de\ simultaneidad$$
$$C\ salida = 208\ Mbps\ x\ 20\,\% = 41600\ Kbps$$

Equation 3: Guaranteed maximum start capacity calculated for the network

It guarantees 42 Mbps channel capacity through link sharing 1:1 for internet startup. The network requires this capacity for optimum band operation.

F. Technical Project Description

Wireless Network Architecture

Generally, it consists of two significant sections, backhaul (transport network) and access network.

Under this type of architecture, the project consists of the interconnection through access network located at the Imantag parish, Quiroga, San Francisco and el Sagrario in the Cotacachi sector.

Starting from the Cotacachi Municipality where the Data Processing Center (CPD) is located, servers for network and access management link to the Transport Network or Trunk between rep points located at the Cerro Yanahurco or Loma Negra in the Marcelino Alzamora School and Peñaherrera which are strategic points to launch wireless coverage as shown in figure 10.

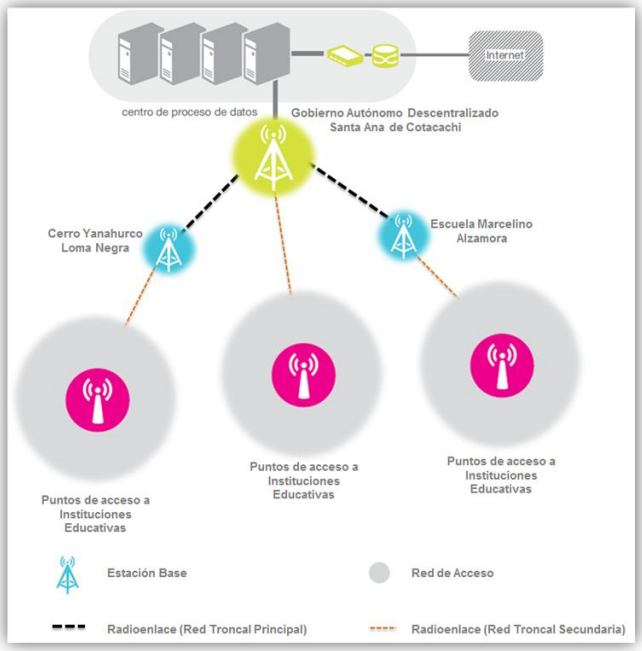


Figure 10: Geographical location of the total benefited institutions in the Andean area

Geographical location of the total benefited institutions in the Andean area

Considering as a reference basic architecture, wireless operating mode is based on the cell formation criteria over several emission points. These have the tendency to form point to multipoint network topology used in the final access point interconnection, while the backhaul trunk links maintain point to point topology.

Selected wild technology features

WILD or Wi-Fi is a Metropolitan Area Network used in long distances under the 802.11 standard.

Standard 802.11n-2009: is the same version as Standard 802.11 created specifically to widen network range in the metropolitan area and it has the following features:
Frequency bands: 5,8 are used and offer a less congested spectrum and better immunity before unknown sources interference.

Band width: Channels band width for this version is 40 MHz which provides twice as much capacity compared to older versions increasing baud.

Data Transfer Rate or Thoughput: This standard allows transfer rates of 300 or 600 Mbps theoretically that guarantee network feasible apps transmission such as voice, data and video.

Flows: Applying the use of multiple antennas with the MIMO system in the same channel and frequency takes advantage of multiple paths spread to improve transmission speed so that faulty bits rate decreases.

Technical Hardware Requirements

Technical hardware data analysis, antennas and radio frequency signals for each link is essential for radio electrical planning.
In order to work with hardware based on WILD technology, a predetermined setting consisting of the following parts must be done:

- *Long Distance Wireless Router*

A router that allows wireless network interconnection has the features of a regular computer, to include a RAM memory card, microprocessors and interface ports in addition to incorporating a long range operating system for configuration links.

Primary and secondary Backhaul network routers

RB433AH Mikrotik Router Board widely used device for high performance backhaul.

Client Access Router

RB411 Mikrotik Router Board widely used device for access networks

- *Wireless Network Cards*

The PCI R52HN mini interface allows the running of the technical specifications 802.11a/b/g/n standard that adjusts to design requirements.

- *Antennas*

Depending on installation requirements from point-to-point links to point to multipoint links:

Backhaul wireless link directive antennas

Antenna Ubiquiti Airmax DISH generally utilized for backhaul links in point-to-point systems. Such antennas are parabolic reflectors ranging from 30 dBi to 5GHz.

Distribution link sectorial antennas

Generally used from point-to-multipoint distribution connections in sector based stations, this antenna covers areas from 90 –120 . Ubiquiti Sector 5GHz AirMAX antennas also cover from 90 –120 .

Backhaul and client stations directive antennas

Generally used for point-to-point and point-to-multipoint systems, antennas Lanbowan grill type ANT4958D28PG-DP 5GHz 28 dBi.

- *Pigtails*

Pigtails are coaxial cables appropriate for wireless connection devices (mini-pci and access point) and wireless cards.
In order to choose the most suitable pigtail for a network design, the most common connecting devices for wireless cards type mini-PCI, UFL and MMCX should be considered, on the other hand, connectors used toward the antenna types RPSMA, N or SMA should be used. The shorter the better so that attenuation is avoided.

Radio electric Planning

Once the intermediate supporting points have been decided upon a radio electrical beam clearance theoretical study pertaining to the topographical terrain's profile must be done through an adequate software processing and a simulation tool defined as Radio Mobile which is free distribution software used for radio links calculations thus geographical terrain profiles will provide the expected results.´

- *Location Coverage research from Backhaul wireless links to access networks*

Signal levels must be considered as wireless networks provide and meet proposed technical solutions requirements for specified coverages.
Calculation of coverage from repetition central stations is based on Radio Mobile cartographic maps, showing power signal levels received by the clients in connection with the following color scale where -67 dBm is considered an optimum signal level represented by white colors while -107 dBm being the lowest /worst level represented by blue colors:

Figure18: dBm Power Reception Color Scale chart

The following figures show coverage area from each repetition point toward all educational institutions

Figure 19: Coverage area of the 120^{o} sector antenna and directive antenna Node Loma Negra; Radio Mobile software simulation.

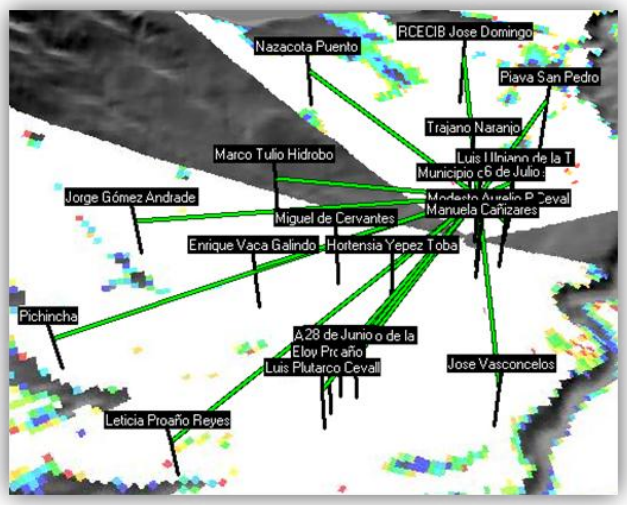


Figure 20: Coverage área of the 120^{o} and 180^{o} sector antenna Node Municipio Cotacachi; Radio Mobile software simulation..

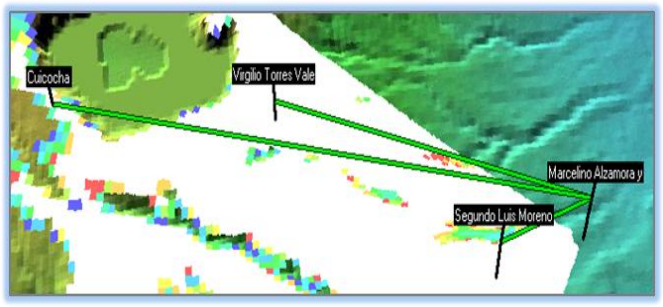


Figure 21: Coverage area of the 90^{o} sector antenna Node Marcelino alzamora; Radio Mobile software simulation.

The following figure shows Client Access and Distribution Network detailed topology once an optimum coverage is reached.

Topology

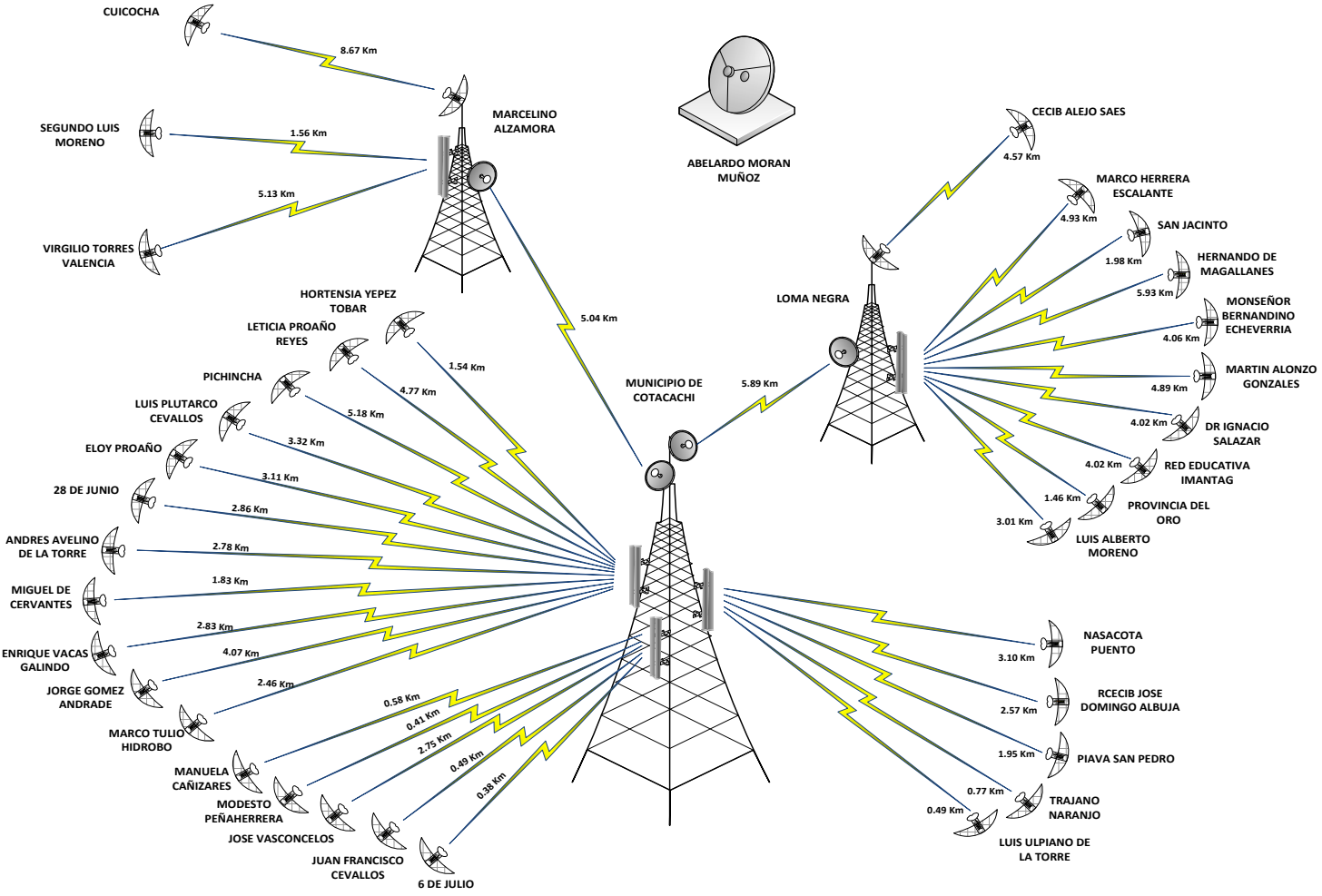


Figure 22: Client Access and Distribution Network

Radiolinks Simulation

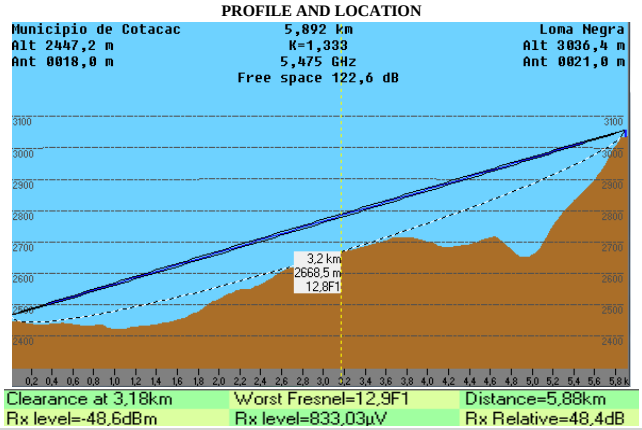
To determine feasibility in a link, a Radio Mobile simulation tools is used which shows topographic profiles allowing the study of: line of view, obstruction degree having a 60% profile (from the first Fersnel zone), signal reception level with regards to the receptor sensibility margin (>-97dBm), minimum recommended antenna's height, link length and minimum technical hardware features.

- *Cálculo del Enlace Municipio de Cotacachi- Loma Negra*

As link parameters are determined, such as operational frequency (5475 MHz), height, antenna gain for each location, transmission and reception power (25 dBm) and reception sensibility (-97 dBm) simulation results in Radio Mobile software show a visual clean line between the Loma Negra station and the Municipio de Cotacachi, separated by a distance of 5.89 kms, having a 12.9 clearance. It also shows that the first Fresnel zone is higher than the established limit of 0.6 FI or 60% requirement.

Losses of free space that the link shows have a value of 122.6 dB and are calculated by signal distance and frequency the link operates. The received signal level is -48.6 dBm this value being higher to the minimum level of signal reception -97 dBm. Additionally a higher than 10 dB or more precise 48.4 dB fading margin value is obtained,

According to analysis results obtained at Loma Negra-Municipio de Cotacachi, this study is viable.



MUNICIPIO DE COTACACHI		**LOMA NEGRA**	
Latitud: 00°18'3.05'' N		Latitud: 00°21''1.33'' N	
Longitud: 78°15'59.5'' W		Longitud: 78°17'7.64'' W	
Elevación: 2447.2 m		Elevación: 3036.4 m	
Altura de la Antena: 18 m		Altura de la Antena: 21 m	
SISTEMA DE RADIO			
Tipo de radio: Mikrotik RB433AH		Tipo de radio: Mikrotik RB433AH	
Potencia Tx(dBm): 25 dBm		Potencia Tx(dBm): 25 dBm	
Tipo de Antena: Directiva RD-5G-30		Tipo de Antena: Directiva RD-5G-30	
Ganancia de antena Tx (dBi): 30 dBi		Ganancia de antena Tx (dBi): 30 dBi	
Entradas MIMO: 2x2		Entradas MIMO: 2x2	
Perdidas en el cable (dB): 0.5dB		Perdidas en el cable (dB): 0.5dB	
Sensibilidad de Rx (dBm): -97dBm		Sensibilidad de Rx (dBm): -97dBm	
RENDIMIENTO			
Distancia (km)	5.89 Km	**Frecuencia (GHz)**	5.475 GHz
Perdidas en el espacio libre (dB)			122.6 dB
1ª zona de fresnel (F1)			12.9 F1
PIRE (dBm)			54.5 dBm
Nivel de señal recibido (dBm)			-48,6 dBm
Margen de Desvanecimiento (dB)			48.4 dB

Logical Addressing

This project considers 35 clients to provide internet service, an assigned subnetwork by the DTI from the Cotacachi Municipality 192.168.10.0/24.

A subnetwork must be added for hardware administration according to the following chart:

Data:

- Addressing Protocol: IPv4
- Private subnetwork assigned by the Cotacachi Municipality:192.16.0.0 starts with subnetwork 192.168.10.0
- C Class: 255.255.255.0
- Logical Addressing type: Addressing without VLSM due to each subnetwork's expansion.

Table 5: Assigned subnetwork and number of hosts required by this project

#	Network	Host Number	Subnetwork
1	Administración	49	192.168.10.0/24
2	Marco Herrera Escalante	7	192.168.11.0/24
3	Red Educativa Imantag	29	192.168.12.0/24
4	Provincia De El Oro	9	192.168.13.0/24
5	Monseñor Bernardino Echeverría	6	192.168.14.0/24
6	Cecib Alejo Saes	6	192.168.15.0/24
7	Luis Alberto Moreno	8	192.168.16.0/24
8	Hernando De Magallanes	11	192.168.17.0/24
9	Dr. Ignacio Salazar	5	192.168.18.0/24
10	Andrés Avelino De La Torre	15	192.168.19.0/24
11	Segundo Luis Moreno	9	192.168.20.0/24
12	Eloy Proaño	20	192.168.21.0/24
13	Leticia Proaño Reyes	14	192.168.22.0/24
14	28 De Junio	9	192.168.23.0/24
15	Virgilio Torres Valencia	7	192.168.24.0/24
16	Cuicocha	6	192.168.25.0/24
17	Marcelino Alzamora Y Peñaherrera	6	192.168.26.0/24
18	Luis Plutarco Cevallos	18	192.168.27.0/24
19	Marco Tulio Hidrobo	5	192.168.28.0/24
20	Juan Francisco Cevallos	5	192.168.29.0/24
21	San Jacinto	13	192.168.30.0/24
22	Jorge Gómez Andrade	7	192.168.31.0/24
23	Martin Alonso González Lalanne	6	192.168.32.0/24
24	Piava San Pedro O Luis Felipe Borja	6	192.168.33.0/24
25	Trajano Naranjo	6	192.168.34.0/24
26	Nazacota Puento	5	192.168.35.0/24
27	Rcecib Cotacachi José Domingo Albuja	8	192.168.36.0/24
28	Pichincha	10	192.168.37.0/24
29	Enrique Vacas Galindo	5	192.168.38.0/24
30	Miguel De Cervantes	8	192.168.39.0/24
31	José Vasconcelos	9	192.168.40.0/24
32	Luis Ulpiano De La Torre	13	192.168.41.0/24
33	6 De Julio	32	192.168.42.0/24
34	Modesto Aurelio Peñaherrera	26	192.168.43.0/24
35	Hortensia Yépez Tobar	7	192.168.44.0/24
36	Manuela Cañizares	22	192.168.45.0/24

Access Control Policies

Nowadays, educational organizations use information technology for their day-to-day operations. However, in order to use network infrastructure adequately by the users, it is necessary to comply with certain web page access control policies to create awareness among all members of such

entities regarding data internet content's importance and sensibility.

WEB filter policy

Internet service is designed toward the academic sector so not suitable content should be filtered for both students and society.

For the application of this policy, it is important to identify content to be blocked according to the following table:

Table 61: Proxy Server Access Content Rules

CATEGORY	ACCION	DESCRIPTION
Pornografía y Lenguaje obsceno	Denegar	No apropiado
Crueldad y violencia	Denegar	No apropiado
Entretenimiento y Juego online	Denegar	No apropiado
Actividad ilegal	Denegar	No apropiado
Drogas y armas	Denegar	No apropiado
Publicidad en línea.	Denegar	No apropiado
Cualquier contenido	Permitir	Apropiado

To make these rules effective, the permissive policies model must be applied, which will allow all content to be seen except operations imposed by the web proxy's server services.

Architecture

In order to implement this type of security, the device must work between internal network (LAN) and internet service. According to the following figure all internet requests are analyzed and filtered.

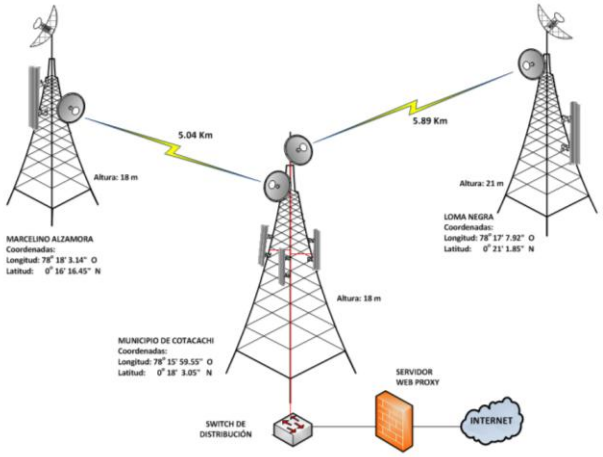


Figure 231: Proxy Server Architecture

Proxy's Server main functions for best performance

1. Device providing web filtering must have its repositories predefined and constantly updated on line.

   Examples:
   - https://www.stopbadware.org/
   - http://www.sophos.com/
   - http://dansguardian.org/

2. It must contain tools that allow generate black and white lists with a URL to personalize filtering.
3. It must filter web sites that work with HTTP as well as HTTPS protocols
4. It must allow cache memory management for server maintenance and trouble shooting
5. It must work with transparent proxy function to avoid configuration in each of the users IP addressing

V. COST BENEFIT

The budget is presented based on the proposed final design thus investment and operation approximate costs for the next five years will provide the essential elements to sustain this operation through expected benefits.

Project total cost

It is the sum of infrastructure, telecommunication, energy and protection costs, as well as information systems hardware costs.

Table 72: Contemplated total project cost:

COST	TOTAL COST
Costo de Infraestructura	14109.40 USD
Costo de Telecomunicaciones	31211.04 USD
Costos de Energía y Protección Eléctrica	17829.28 USD
Costos del Sistema Informático	117600.00 USD
Costos de Operación	232814.40 USD
Costos varios no contemplados	3000.00 USD
TOTAL	**416645.12 USD**

Total budget proposal: $416,645.12 USD **(FOUR HUNDRED AND SISTEEN THOUSAND SIX HUNDRED AND FOURTY FIVE DOLLARS AND TWELVE CENTS)**

Implementation benefit analysis

The proposal for this wireless network represents for the Cotacachi Sector many overall improvements by guaranteeing universal access to Information and Communication Technologies (TIC) as well as to satisfy services that will help economic, social and cultural, development to the community.

Among those who get direct benefits are a total of 9082 students and 482 teachers. Indirect beneficiaries of the services that this project may conceive are approximately 18970 dwellers of the Andean area of the Cotacachi sector.

Allowing users dispose of flexibility within the coverage ratio pre-established by the design, broad band internet service connectivity, not suitable web page filtering and maintaining multiple applications and functionalities represent internet access for general collectivity.

There is a need to achieve gradual technological alphabetization especially in the areas' rural sectors by using internet services as a complementing tool to modernize learning methodologies integrating Information and Communication Technologies.

Obtaining socioeconomic development and progress by creating training centers and TIC's use will allow an increase in productive capacity in the general population.
Improving Public management and bringing people together over proper administrative, informative procedures and online consultations.

CONCLUSIONS

- During the academic period 2012-2013 the Cotacachi Sector has 40 educational institutions, three of which are private and the millennium educational facility that counts with its own internet connection. The rest of schools are public.
- The study of WILD Wi-Fi technology is based on 802.11 protocols and it is a set of solutions for voice and data transmission which reaches distances between 50-100 kms with the use of ISM and UNII non licensed bands. It also utilizes certain techniques over the physical layer and on the data base link layer to establish a specific balance in some parameters that define long distance connections.
- The Ecuadorian Government and the development of activities within the telecommunications sector are ruled by Organisms responsible of the control, supervision and regulations compliance regarding the deployment of wireless networks aside from the Broad Band Digital Modulation Norm that mainly define allowed power transmission, antenna gain and band frequency parameters in addition to the required forms for the implementation of the broad band modulation systems project.
- In the present design, three repetition points located at the Municipio de Cotacachi, Loma Negra and the Marcelino Alzamora School distribute maximum capacity of 42 Mbps (broad band estimate of the study) to 34 educational institutions. Hardware that comply with the project's technical requirements was Mikrotik RB433 used in based stations and RB411 for client stations, each one with a R52Hn ratio that works with the 802.11n standard.
- To verify road connection the results obtained by each topographical software simulation profile and by the compliance of specific requirements such as sight lines when obtaining 60% ratio clearance on the first Fersnel zone having a higher or equal value of 0.6 F1. The received signal level showed higher results to the maximum signal reception which is (-97 dBm), fading margin value is higher than 10 dB, minimum recommended for hardware location and technical specification.
- For the wireless network cost benefit analysis, investment and operations costs were estimated during a period of five years.
- Justification of the investment of this project is relatively low compared to the benefits that represent the actual project for 9082 students and 482 teachers. Indirect beneficiaries of such services are approximately 18970 area dwellers in the Andean area of the Cotacachi Sector.

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REFERENCIAS

[1] GAD Cotacachi. (Marzo de 2011). *Plan de Desarrollo Cantonal y Ordenamiento Territorial del Cantón Cotacachi (PDOT).* Cotacachi.
[2] Cisco System, I. (2006). *Fundamentos de redes inalambricas.* Madrid.: Pearson Educacion.
[3] Rendón, Á., Ludeña, P., & Martínez, A. (2011). *Tecnologías de la Información y las Comunicaciones para zonas rurales Aplicación a la atención de salud en países en Desarrollo* (1 ed.). Madrid: CYTED.
[4] WNDW. (2013). *Redes Inalámbricas en los Países en Desarrollo* (4 ed.). Copenhagen: WNDW. Obtenido de http://wndw.net/pdf/wndw3-es/wndw3-es-ebook.pdf
[5] Consejo Nacional de Telecomunicaciones. (2014). *CONATEL*. Obtenido de http://www.regulaciontelecomunicaciones.gob.ec/conatel/
[6] Departamento de Tecnologías Informáticas GAD Cotacachi. (2013). *Proyecto de Interconectividad Cantonal para Servicios Municipales y Acceso a Internet en Unidades Educativas y Entidades Estatales del Cantón Cotacachi en la Provincia de Imbabura.* Cotacachi: GAD Santa Ana de Cotacachi.
[7] Mikrotik. (Junio de 2014). *RouterBOARD 433AH*. Obtenido de http://routerboard.com/RB433AH
[8] Mikrotik. (Junio de 2014). *RouterBOARD R52Hn*. Obtenido de http://routerboard.com/R52Hn
[9] Mikrotik. (Junio de 2014). *RouterBOARD411*. Obtenido de http://routerboard.com/RB411
[10] Mini Service Online. (Enero de 2010). *Pigtails*. Obtenido de http://www.miniserviceonline.com/productos/Cables.htm#
[11] Ubiquiti Networks. (Junio de 2014). *Antenas Sectoriales AirMAX* . Obtenido de http://dl.ubnt.com/datasheets/airmaxsector/airMAX_Sector_Antennas_DS.pdf
[12] Ubiquiti Networks. (Junio de 2014). *Rocket Dish*. Obtenido de http://dl.ubnt.com/datasheets/rocketdish/rd_ds_web.pdf
[13] Lanbowan. (Junio de 2014). *Lanbowan Antena*. Obtenido de http://www.lanbowan.com/ANT4958D28PG-DP.htm
[14] Luis Camacho, R. Q. (2009). *WiFi Based Long Distance.* GTR-PUCP.

Sofía E. Rosero A.

Born in Ibarra, Ecuador, on March 31st 1989. She studied in "La Inmaculada Concepción"High School. In 2006 she obtained the Bachelor of Mathematical Physics. Currently, she studies of the School of Engineering in Electronics and Communication Networks at the Universidad Técnica del Norte, Ibarra-Ecuador