Design of the wireless network to provide access to the Internet using IEEE 802.11ac technology in the lake basin of san pablo for the company NETSERVICE

Edgar A. Maya, Edy J. Antamba

***Summary*-The present project consists of the design of the wireless network to provide access to the Internet using the IEEE 802.11ac standard in the San Pablo Lake basin for the company NETSERVICE, which will allow access to the internet in the area, for the purpose To contribute to reduce the digital divide, thereby improving the quality of life both work and personal in aspects of information and communication technologies (TIC).**

***Keywords* —IEEE 802.11ac, WLAN, TIC, RADIO MOBILE, GOOGLE EARTH.**

I. INTRODUCCTION

The demand for internet service and the development of telecommunications in recent years. They have been based on wired communication networks (coaxial cable, xDSL, fiber optics) that reach the user to access the internet has a very high cost in the installation. In addition it is difficult to install this technology rural areas.

With the aforementioned, they gave way to the development of the wireless standards IEEE 802.11 (better known as WiFi), this is an alternative to the conventional means with which the services were accessed. With the incursion of this way of transmitting the information and the improvement in the telecommunication service, they try to satisfy the users' needs in the most remote rural areas.

urrently the technology that is booming in wireless networks is the IEEE 802.11n standard, with its maximum speeds of 100Mbps, which has enabled the development and transfer of information from wireless devices in minutes. But this is still not enough for the user. [1]

The 802.11ac standard, also known as "Gigabit Wi-Fi," is an evolutionary step of the 802.11n standard, as this standard relies substantially on the development of the 802.11n standard. The 802.11ac standard will be offered in two waves.

Wave 1. Covers devices that can reach speeds of up to 1.3 Gbps using wider linked channels, increasing modulation and up to three spatial streams.

Wave 2. It includes devices with speeds of up to 3.4 Gbps with the introduction of wide channel joining, up to 8 spatial streams and multi-user multi-input and multi-output (MU-MIMO) technology will be possible

E.A. Maya, Universidad Técnica del Norte, Ibarra, Ecuador, eamaya@utn.edu.ec
E.J. Antamba, Universidad Técnica del Norte, Ibarra, Ecuador, ejantambay@utn.edu.ec

II. IEEE 802.11AC STANDARD

With the passing of days, both at home and in businesses, they need applications with greater bandwidth, such as video conferencing, streaming movies with greater definition full HD. These applications with 802.11n will be a solution for some users, but as it increases considerably in the use of these applications decreases the available bandwidth for each one of them.

For this reason the IEEE has launched the fifth generation of the standard for Wi-Fi networks (802.11ac), which will allow to mitigate these situations or inconveniences presented to the user

A. Factors contributing to the progress of the 802.11ac standard802.11ac

- More users. The Wi-Fi connection has been quite successful and the volume of traffic has grown with the passing of days which has displaced the Ethernet connections in the access to the corporate network, so that there are more Wi-Fi users creating traffic .
- More devices per user. Now users tend to carry at least two devices, a mobile phone and a laptop, and in many cases also a Tablet. This implies that a dense population of devices is created that want to access the wireless network, which would generate more traffic and forces the company to design new Wi-Fi networks.Aplicaciones.
- Applications. Users are running applications at the same time using a large bandwidth, such as synchronization services such as Google Drive, video in high definition, video conferencing, social networking applications among others. [2]

In contrast to 802.11n, new important features were developed to improve the efficiency of the 802.11ac standard and can be mentioned in the following table 1.

Table 1. *Difference between 802.11n and 802.11ac*

PHY / feature	802.11n	Onda-1 802.11ac	Onda-2 802.11ac
Channel Width	20, 40 MHz	20, 40 MHz	20, 40, 80, 160MHz
Spatial Streams (SS)	1, 2, 3	2, 3	2, 3, 4
QAM Modulation	64 QAM	256 QAM	256 QAM
MIMO type	SU-MIMO	SU-MIMO	MU-MIMO
MCS	MCS from 0	MCS from 0	MCS from 0 to

Compatibility	to 23 for SS 1, 2, 3	to 9 for SS 1, 2, 3	9 for SS 1, 2, 3, 4
Maximum data rate	450 Mbps	1.3 Gbps	3.467 Gbps
Radio Variations	2x2:2, 3x3:2, 3x3:3	2x2:2, 3x3:3	4x4:4*

B. *Key Features of the IEEE 802.11ac Standard*

- **CHANNELS WIDE**. Devices in the 802.11n standard can support 20 MHz or 40 MHz channels. In contrast, 802.11ac Wave-1 devices support 20-, 40-, and 80-MHz channels, meanwhile Wave-2 devices support 20, 40, 80 and 160 MHz.
- **TRANSMISSION BY USING THE 256QAM MODULATION.** Modulation is the means by which data is encoded in carrier waves. 802.11n works on 64 QAM modulation, while 802.11ac introduced 256 QAM. 256 QAM is a more complex modulation that supports data bits, which it is possible to send eight bits per period of symbols. This allows higher data speeds to be achieved.
- **BEAMFORMING.** 802.11ac adapts beamforming technology to reduce interference and improve the characteristics of the Wi-Fi signal, allowing the transmission of data to specific addresses, instead of radiating data in all directions, that is, data can be sent directly to specific devices , As if it were a laser that can focus its strength, so you can go further.
- **MULTIMEDIA MIMO (MU-MIMO**). Multi-user MIMO allows an AP to send frames to multiple users at the same time on the same frequency. It can be said that it can act like an Ethernet switch instead of a hub, assisting more users, this makes it possible to optimize the wireless bandwidth.

C. ***Physical Layer***

The physical layer of the 802.11ac standard defines radio wave modulation and signaling characteristics for data transmission.

D. *Frame structure of the PHY layer*

To design the frame of the PHY layer were based on the characteristics of new standard to be met and the compatibility of the physical layer of previous standards, whether the frame is very similar to the standard 802.11n. As an 802.11ac device when transmitting, the 802.11a and 802.11n devices must be able to know the length of the frame not to transmit in that same time interval.
In Figure 1, the frame format of the VHT physical layer of 802.11ac is shown that is similar to the format of the 802.11n frame and begins with the same fields as 802.11a. The difference is that it includes a header to allow multiuser MIMO, so it must be able to include the number of spatial sequences and allow multiple receivers to receive the frames.

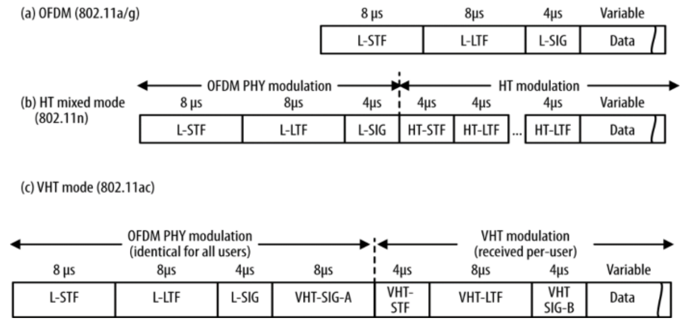

Fig 1. VHT Physical Layer Frame Format

E. *SUBCAPA MAC*

Most of the 802.11ac MAC sublayer is inherited from the main fields and enhancements introduced in 802.11n. The work of the 802.11ac MAC sublayer consists of adding new features of the physical layer. Maintaining the frame structure used in previous standards.

Figure 2 shows the format of the MAC sublayer

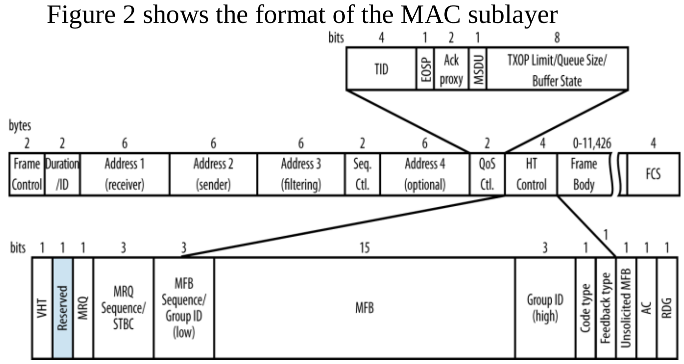

Fig 2. MAC 802.11ac MAC subframe frame format

III. STUDY OF THE DEMOGRAPHIC SITUATION AND NETWORK DESIGN REQUIREMENTS

Netservice is a telecommunications and internet company that provides goods and services, with the aim of providing better internet services through wireless systems, structured cabling, web design, etc. In the northern part of Ecuador.

Netservice seeks to satisfy the needs of its clients, offering cutting-edge technology and excellence in customer service, working with business qualities of high human and professional content such as assertiveness and proactivity to anticipate and anticipate the demands of the current market. [3]

A. *Otavalo Parish Entering The Project.*

Figure 3 shows the parishes of the canton Otavalo that enter the project. San Pablo, Gonzales Suarez, San Rafael, Eugenio Espejo and El Jordán-Otavalo.

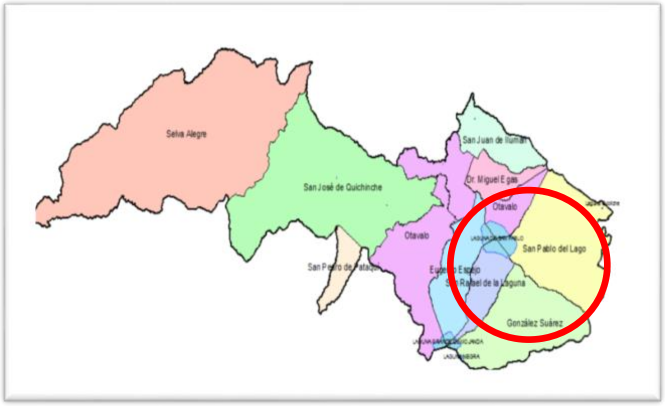

Fig 3. Parishes of the canton Otavalo entering the project.

Population of the parishes of the canton otavalo, According to the last census of population 2010, the inhabitants in the urban area amount to 37.58% and in the rural area it is 62.48%. It is observed that the rural population occupies the greater part of the territory, reason why in the following table 8 it is described the number of inhabitants of the canton Otavalo by parish and sex.

Table 2. Total population and projection of parishes to intervene in the project

	POBLACIÓN			
PARISHES	**Men**	**Women**	**Total**	**Projection 2017**
Eugenio Espejo	3499	3858	7357	8416
Gonzáles Suárez	2753	2877	5630	6440
San Rafael	2561	2860	5421	6201
San Pablo	4701	5200	9901	11326
Otavalo-Compañía-Camuendo	1121	1223	2344	2681
Total	**14635**	**16018**	**30653**	**35064**

B. TECHNICAL SPECIFICATIONS FOR THE DESIGN OF THE NETWORK.

The project consists of interconnecting, through radio link repeaters at strategic points of the area to intervene.

The location of the transmission nodes is of vital importance which will allow me to link two points correctly, so some aspects must be taken.

- The link between two points must have a direct line of sight, without obstacles for the proper propagation of radio waves.
- It is important to consider a suitable height that allows direct transmission visibility. This can be for both point-to-point links and for omnidirectional transmission to users.
- The terrain profile and height calculation must be considered in order to correctly position the node.
- Consider different factors that may degrade the signal such as noise.

C. SELECTION OF NODE LOCATIONS

Two locations were selected and the appropriate design point checked, the above aspects and other factors taken into account.

1. Node 1.

I chose this location because it is easy to mount the structure on a concrete slab and in addition to the availability of electrical power for the equipment, reducing the cost of time to assemble the structure and economic cost. As shown in fig 4 of the Belavista node.

Fig 4. Location of Bellavista Node

2. Node 2

This location was considered because it has a direct line of sight throughout the network node. As shown in Figure 5 for the San Rafael node.

Fig 5. Location of Nodo San Rafael

3. Node 3

This location was considered because it is possible to mount the structure on a concrete slab and in addition to the availability of electric power for the equipment, reducing the cost of investment and is shown in fig 6.

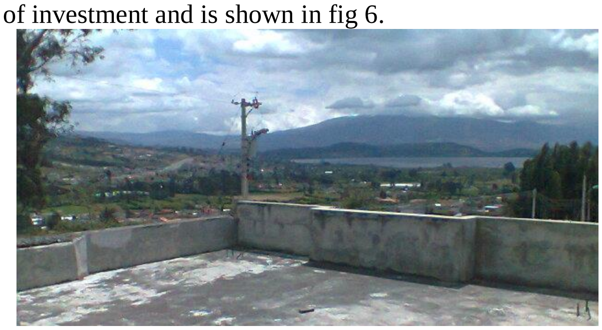

Fig 6. . Location of Nodo Gonzales Suarez

D. Sizing the network

Table 3 shows the geographical coordinates of the repeaters in length, latitude and height of the same.

Table 3. Geographic coordinates of the Nodes

Points	Latitude(N)	Length(O)	Height (m.s.n.m)
Node Cerro Cotacachi	0°19'48.84"	78°20'19.29"	3974
Node Bellavista	0°12'40.14"	78°12'30.95"	2703
Node San Rafael	0°11'24.59"	78°13'33.17"	2757
Node Gonzales Suarez	0°10'44.63"	78°12'3.29"	2721

The design of the network is divided into three subnetworks as mentioned below.

- Backbone network: interconnects with the repeater located in the parish of San Pablo de Lago-Comunidad Araque- Bellavista neighborhood and the San Rafael node located in the parish of San Rafael. A point-to-point connection between the Cotacachi repeater using IEEE 802.11ac technology and operating in the 5 GHz band will be established.
- Secondary backbone: interconnection between secondary repeaters or nodes located in strategic zones in the area of the Lake San Pablo-Otavalo basin.
- Access network: In the secondary repeaters will be installed sector antennas that will allow the signal to radiate throughout the area.

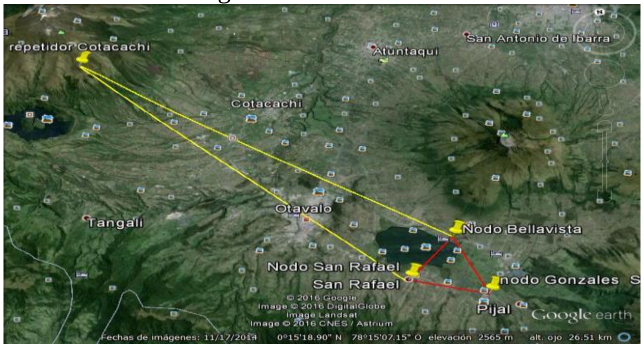

Fig 7. Interconnection of the primary backbone network

E. Sizing of the bandwidth

It is essential to plan the network and analyze the type of traffic that the network will support, it will depend exclusively on the bandwidth required. The type of traffic that the network must support is the following:

- Email.
- Web applications.
- Real-time video and audio
- Voice over IP
- Social networks

The different applications of internet will require different bandwidth, in the following table 4 will describe some applications that will require a bandwidth for its functionality. [4]

Table 4. Bandwidth Requirements

Application	Bandwidth requirements per user (Kbps)
Email	100(kbps)
Web Browsing	100(kbps)
Real-time video	200(kbps)
Real-time audio	160(kbps)
Social Networking	100(kbps)
Total Bandwidth	**660(Kbps)**

Considering a sharing of 8: 1 that the company makes to provide the internet service therefore the 6 Mbps will be shared by the 8 users so if at the same time the eight users are browsing it will divide the bandwidth, 6Mbps / 8 = 750 Kbps for each user, satisfying the need of the user, however, if only one user is connected the entire bandwidth will be available.

Now to calculate the total bandwidth for the 153 users a bandwidth of 120 Mbps is required to be transmitted by the network, to cover the demand, with a percentage growth of 25.3% per year according to the ministry of telecommunications. Therefore it is necessary to select the equipment that transported a bandwidth of 120 Mbps and a demand for the four years requires a bandwidth of 360 Mbps. Therefore it is necessary equipment and technology that can transmit this bandwidth by network..

F. Network architecture

The communication architecture of a network specifies the functionality of the system and its network components, ie only describes the elements of the system and their arrangement thereof, the network architecture of the project is shown in Figure 8.

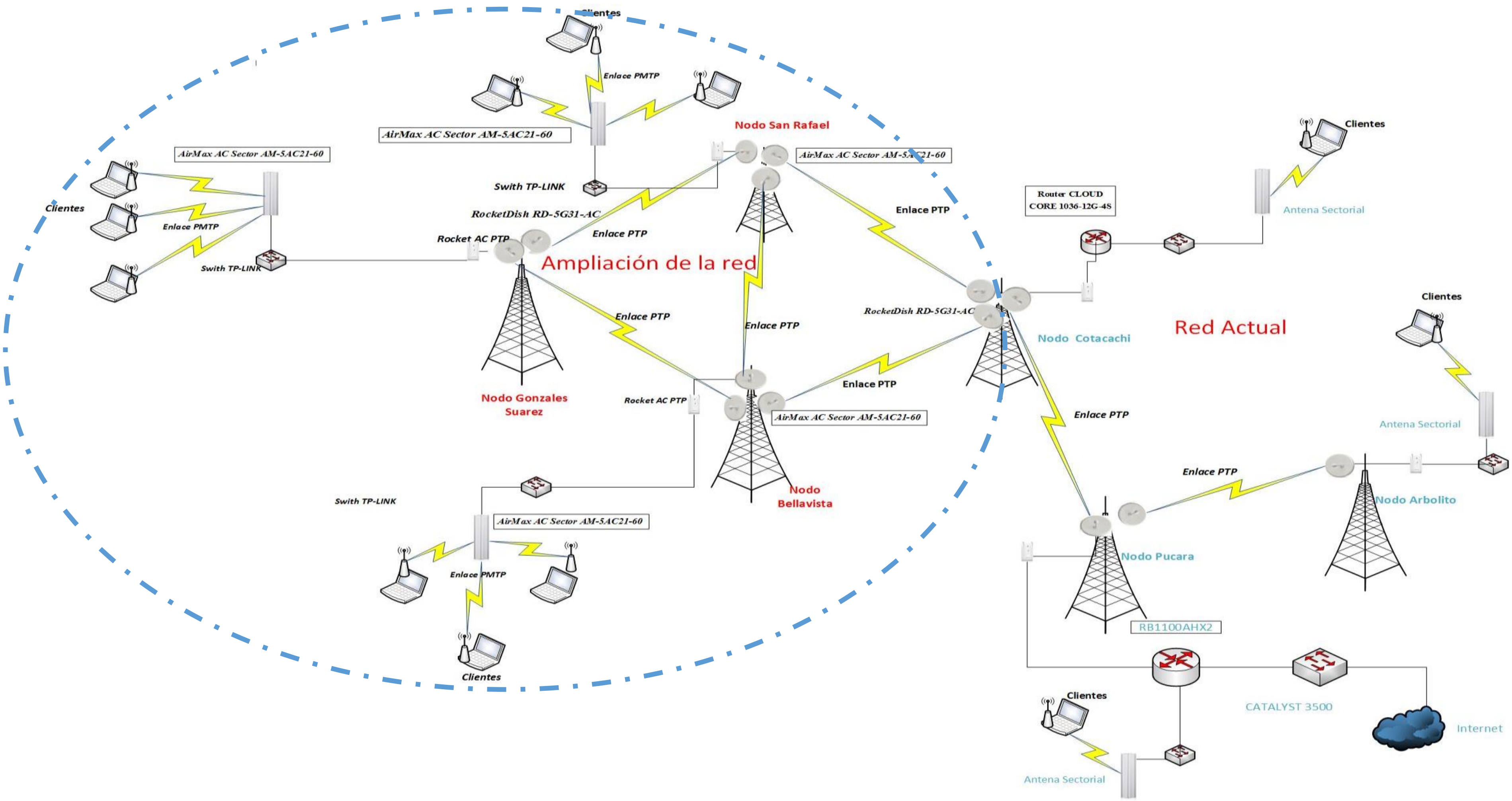

Fig 8. San Pablo Lake Basin Network Architecture

IV. DESIGN OF THE NETWORK

A. Structure of the network

New nodes will be located to cover the proposed area, using a structure as shown in fig 9.

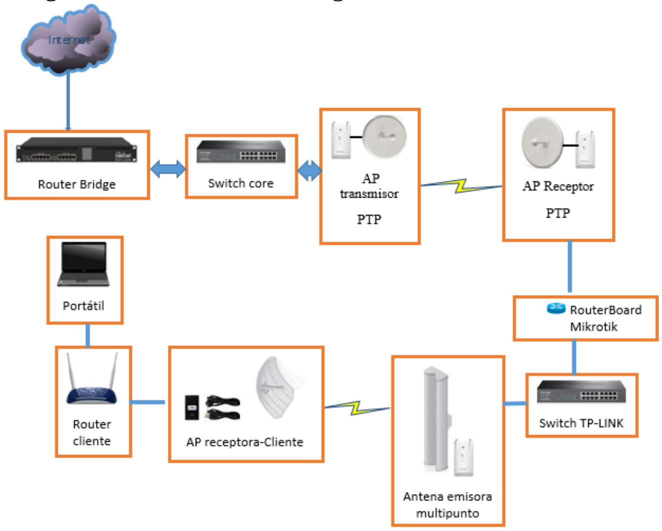

Fig 9. General structure of the network

B. Network hierarchization

Specific that define their function within the general network. This will help me design the network to optimize and select the features of both suitable network hardware and software. The hierarchical model applies to the design of the LAN and WAN. [5]

The overall hierarchical LAN network design includes the following three layers:

- Access layer: Provides network access for workgroups and users. In other words, it allows the connection between the final devices (pc, laptor, printers, samrtphones) providing the connection through switch, router, Access point.
- Layer Layout - Provides policy-based connectivity and controls the flow of access layer information.
- Core Layer - Provides rapid transportation between on-campus distribution switches. In other words, it is the high-speed backbone that a router will provide the internet access and join the different sections of the network into a single network.

The hierarchical network is shown in Fig 10.

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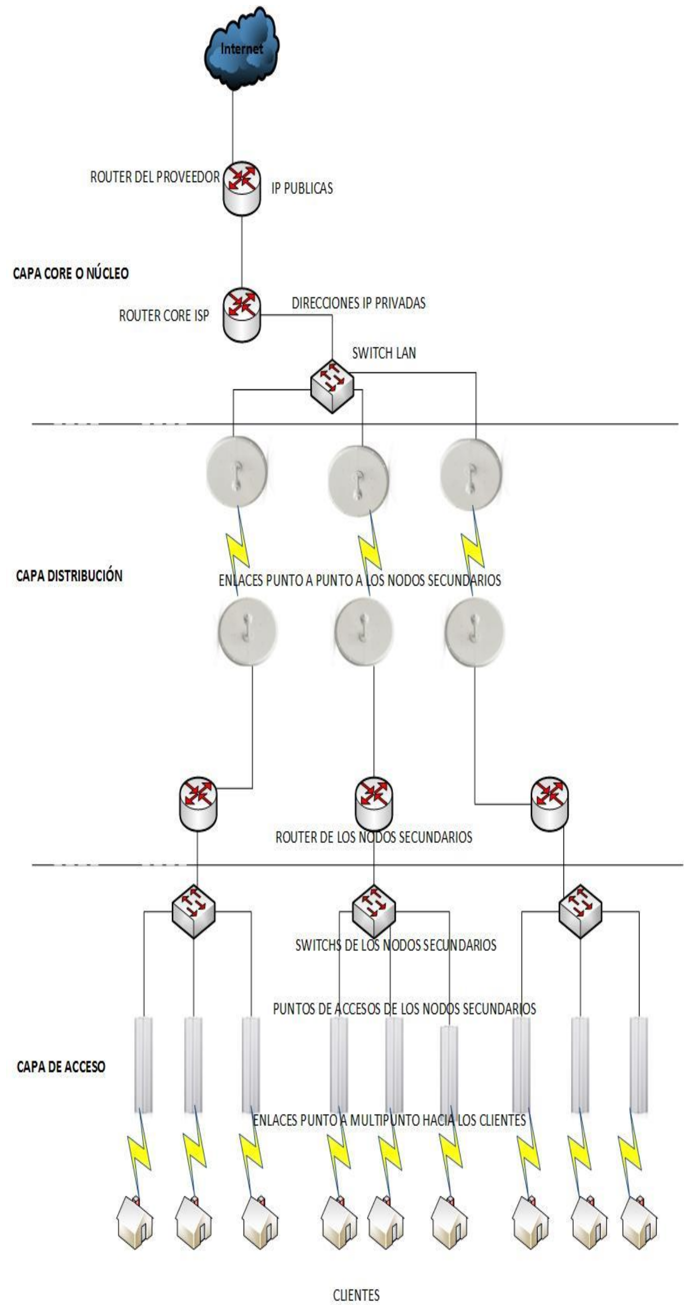

Fig 10. Hierarchical network of the project

C. Link Calculations

To calculate it is necessary to know the characteristics of the technology to be used. To calculate the capacity of a link, it is necessary to understand the speed of a wireless device that refers to the rate at which the radios exchange symbols in baud, not the usable flow rate that can be exploited. Throughput is also known as channel capacity, or simply bandwidth.

D. Calculation of the budget of the link

he process for determining whether a link is feasible is called link budget calculation or power balance and can be done manually or using specialized tools. Before using a simulation tool, you will perform the calculations manually with the features of the new IEEE 802.11ac standard

A basic wireless communication system is shown in Fig 11.

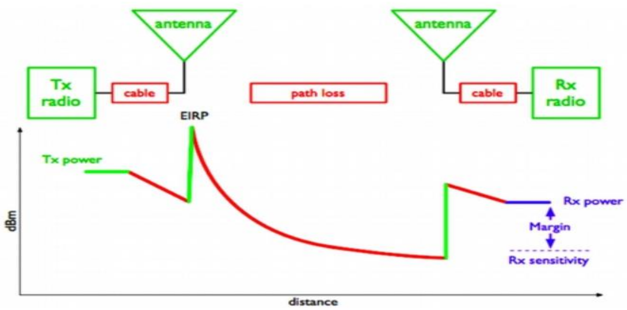

Fig 11. Basic Wireless Communication System

E. Link cerro Cotacahi-Bellavista

Calculation of the distance zero Cotacachi-Bellavista
Figure 12 shows the structure and distance of the link

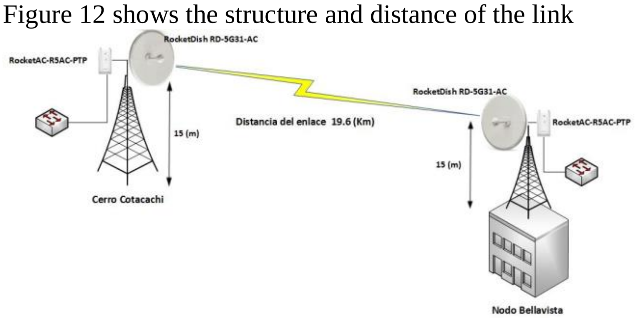

Fig 12. Link cerro Cotacachi-Bellavista

d=r* arcos [sen (lat1)*sen (lat2) + cos (lat1) * cos (lat2)*cos (lon2 - lon1)] (1)

d=111.19*Arcos[(sen(0.33023)*sen(0.21115)+cos(0.33023)*cos(0.21115)*cos(-78.20859+78.33869)]

d=19.61(Km)

Lost in free space
Lost in free space for two links can be calculated using the equation described below.

FSL (dB)=32.44+20logf (Mhz)+20logd (km) (2)

Where:
L = lost in free space
F = frequency in Mhz
D = the distance in kmD=14.57 (km)
F=5800 (Mhz)

FSL (dB)=32.44+20log (5800(Mhz))+20log (19.65 (km))
FSL (dB)=32.44+20*3.7634+20*1.293
FSL (dB)=32.44+75.268+25.86
FSL (dB)=133.575(dB)

Total link budget

Table 5. Calculation of the budget of the Cotacachi-Bellavista link

Data	Elements	Values
	Transmitter output power	+23 dBm
	TX antenna gain	+31dBi
Distance: 19.65(Km) Frecuency: 5,8 GHz	Cables and connectors TX	-3 dB
	Gain of antenna RX	+31 dBi
	Cables and connectors RX	-3 dB
	Total Gain=	79 dB
	Losses in free space (FSL)	-133.57dB
	Minimum signal level Received in Rx (RSL) = Total gain-FSL	-54.57dBm
	Receiver Sensitivity	-69 dBm
	Total (Margin) = Expected signal level RX - (- Receiver Sensitivity)	+14.43dB

F. Simulation of the Coracachi-Bellavista network

Table 6 shows the configuration parameters in the Radio Mobile Simulator.

Table 6. Configuration parameters of the Cotacachi-Bellavista Node simulationCotacachi-Bellavista

Node Cotacachi		**Node Bellavista**	
Characteristic	Specification	**Characteristic**	Specification
Latitude	0°19'48.84"N	**Latitude**	0°12'40.14"N
Length	78°20'19.29"O	**Length**	78°12'30.95"
Elevation	3974 m	**Elevation**	2703 m
Tower height	18m	**Tower height**	15 m
RADIO SYSTEMS			
type of Antenna	RocketDish RD-5G31-AC	**type of Antenna**	RocketDish RD-5G31-AC
Tx Antenna Gain	31 dBi	**Tx Antenna Gain**	31 dBi
Type of Radio	RocketAC - R5AC-PTP	**Type of Radio**	RocketAC - R5AC-PTP
Tx power (dBm)	23 dBm	**Tx power (dBm)**	23 dBm
Reception sensitivity Rx (dBm)	-69 dBm	**Reception sensitivity Rx (dBm)**	-69 dBm
Frecuency (GHz)	(5100-5800) GHz	**Frecuency (GHz)**	(5100-5800) GHz

Figure 13 shows the parameters of the link between the nodes of Cerro Cotacachi-Bellavista, the transmitting station is Cerro Cotacachi and the receiver is the node Bellavista.

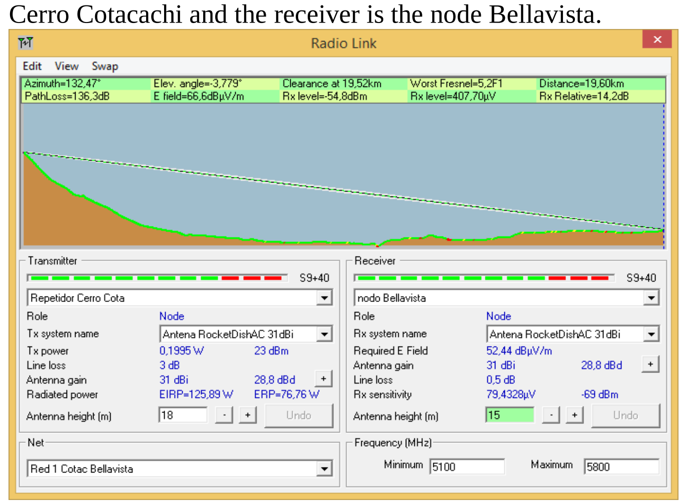

Fig 13. Profile of the link between Cerro Cotacachi-Bellavista

Table 7 shows the results obtained from mathematically calculated data and in the Radio Mobile software, there is a margin of error due to the fact that the software determines additional losses due to multiple trajectories and obstacles, besides that there is no type in the simulator RocketDish antenna RD-5G31-AC, so you should choose a similar antenna in propagation of the radiation lobe that is the Corner Antenna, because of these factors is the variation of the results.

Table 7. Comparación datos calculados y simulados de los radioenlaces

Link	**Characteristics**	**Calculated Data**	**Simulated Data**
Cotacachi-Bellavista	Lost in free space	133,57(dB)	136,3(dB)
	Minimum signal level received in Rx	-54,57 (dBm)	-54,8(dBm)
	Rx power range	14,43 (dB)	14,2(dB)
Cotacachi-San Rafael	Lost in free space	133.69(dB	139.0(dB)
	Minimum signal level received in Rx	-54.69 (dBm)	-55.0(dBm)
	Rx power range	14.30(dB)	14.0(dB)
Bellavista-San Rafael	Lost in free space	116.8(dB)	119.2(dB)
	Minimum signal level received in Rx	-37.87(dBm)	-35.2(dBm
	Rx power range	31.12(dB)	33.8(dB)
San Rafael-Gonzales Suarez	Lost in free space	117.03(dB)	122.8(dB)
	Minimum signal level received in Rx	-38.03(dBm)	-38.8(dBm)
	Rx power range	30,9(dB)	30.2(dB)
Bellavista-Gonzales Suarez	Lost in free space	118.97(dB)	125.0(dB)
	Minimum signal level received in Rx	-39.97(dBm)	-41.0(dBm)
	Rx power range	29(dB)	28.0(dB)

G. *UPS Power Calculation*

It can be defined to a UPS (Interruptible Power System), is a device in charge of supplying power in the event of an interruption of the same, integrates special circuitry that allows to feed a set of internal rechargeable batteries, its function is to improve the power supply to Equipment for a period of time automatically.

Table 8 describes the calculation for determining the power of a UPS.

Table 8. UPS Power Calculation

Equipment	**N° de Equipment**	**Volts(V)**	**Amperes(A)**	**VA(Volt*Amperes)**
RocketAC R5AC-PTP	3	24	0.5	36(VA)
RocketAC R5AC-PTMP	3	24	0.5	36(VA)
Router Core CCR1036-12G-4S	1	110	0.54	60(VA)
Switch TL-SG1016DE	1	100-240	2.5	270(VA)
Subtotal				402(VA)
Growth factor (25% of subtotal)				103(VA)
VA required				502(VA
Total Capacity				1KVA

H. *Legal framework*

New organic telecommunications law

The Constitution of the Republic of Ecuador in its article 408, determines that the radioelectric spectrum is a natural resource inalienable property, imprescriptible and non-releasable state. Therefore, in article 16, it enshrines the right of all individuals individually or collectively to access under equal conditions to the use of radio spectrum frequencies for the management of stations in free bands for the operation of wireless networks. [6]

For the provision of telecommunications services in article 15 of the LOT, for the private initiative, qualifying titles are granted for the provision of public telecommunications services and for the use of the radioelectric spectrum associated with such provision, in the following cases:

1. When necessary and appropriate to satisfy the public, collective or general interest;
2. When the service demand can not be covered by public or mixed companies in which the State has a majority shareholding;
3. When the State does not have the technical or economic capacity;
4. When telecommunications services are being provided under competition by public and private telecommunications companies;
5. Where necessary to promote competition in a particular market; Y,
6. To guarantee the right of users to have public telecommunications services of the highest quality at fair prices and tariffs.

General requirements for the expansion of a network

Arcotel forms for enabling permission. [7]

- RC-1B Form for legal information (digital modulation systems BA)
- ST-2A form for technical information.
- RC-2A form for information on the infrastructure of the radiocommunication systems
- RC-3A form for antenna information
- RC-4A form for equipment information
- RC-9A form for digital broadband modulation systems (point-to-point links)
- Form SAI-T-ATH-01 (Form for detailed technical description of the proposed service and coverage)
- Form SAI-T-ATH-02 (Form for description of physical nodes and equipment and systems)
- Form SAI-T-ATH-*06 (Form for Description of Other Annexes*)

I. *Project Reference Budget*

Table 9 shows the initial investment for the start up of the project.

Table 9. Total investment budget of the nodes

Total budget of the nodes	
Total direct costs	$ 480,00
Total indirect costs	$ 440,00
Total indirect costs	$ 9156,00

Total Network Devices costs	$ 13605,52
Total operating radio-links	$ 653,59
Installation budget	$ 574,00
Maintenance and administration budget	$ 1180,47
Total budget of the network	**$ 26089,58**

V. Conclusions

The design of the network was used the new standard IEEE 802.11ac operates in the 5GHz free band which is less congestion with respect to the 2.4 GHz band, reason why it is less prone to interference, contributing with advantages referring to the Previous standards by increasing transmission speed by 33%, making the network robust and scalable.

Access to the internet in a rural area will help to reduce the digital divide by allowing citizens access to employment and personal development opportunities, which in turn will allow them to be included in the field of information technologies (ICTs). Policies such as the National Plan for digital isolation and the Plan of Good Living promoted by the national government.

The project will provide wireless internet access in the San Pablo Lake basin at an affordable price for subscribers who require the service. So in the survey made 79% if you are willing to hire the service.

The location of three points to cover the San Pablo Lake basin was established so that customers can access the internet access, establishing radio links with equipment that supports the IEEE 802.11ac standard, these points were considered according to the line of sight Between the points.

With the analysis made for the sizing of the bandwidth of the different applications, it was possible to establish how much traffic crosses the network to satisfy the demand of 153 clients will be of 120 Mbps.

Radio links were made using the Radio Mobile and Google Earth simulation software of the 5 links established in the network topology, so once the radio links were made, one of the important parameters is the level of the signal in the receiver, the Which fulfill the 5 links in acceptable range.

The initial investment will be $ 26089.58 dollars for the start-up of the project, There are 153 potential customers according to the survey made take 25% growth of the internet in rural areas according to the Ministry of Telecommunications and Information Society, Therefore, 153 gives us 38 clients who started contracting the service in the first month. Thus, at the beginning of the first year, it will have a Net Present Value (NPV) of - $ 4128.17 dollars, so that in the second year the investment will be recovered with a value of $ 6824.90 net profit. Because the execution of the project is viable.

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Edgar A. Maya O. He was born in Ibarra province of Imbabura on April 22, 1980. Computer Systems Engineer, Technical University of North Ibarra-Ecuador in 2006. He is currently teaching the Engineering Career in Electronics and Communication Networks at the North Technical University. He obtained his master's degree in Communication Networks at the Pontifical Catholic University of Ecuador, Quito-Ecuador

Edy J. Antamba Y He was born in Otavalo-Ecuador on January 20, 1985. His primary studies were at the "Andrés Bello" school, his secondary studies at "San Pablo" school and he is currently a graduate of the Engineering in Electronics and Communication Networks of the North Technical University.