International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (E-ISSN 2250-2459, Scopus Indexed, ISO 9001:2008 Certified Journal, Volume 11, Issue 09, September 2021)
Manuscript Received: 05 August 2021, Received in Revised form: 10 September 2021, Accepted: 18 September 2021 DOI: 10.46338/ijetae0921_07

Design of a Hot Air Balloons for Wireless Internet Transmission in Awajún Communities in Huampami, Amazonas-Perú

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***Abstract*— One of the problems that causes educational inequality is the lack of access to Internet service, this is what happens in the Awajún communities in Huampami Amazonas–Perú, a remote area abandoned by the Peruvian state where Internet access is scarce. According to the province, at the primary level, in Condorcanqui only 5.29% have access to the internet, while at the secondary level 32.43% have access to the Internet service. That is why in this research work, it is proposed to bring the internet service through a point-to-point link using hot air balloons, because this wireless technology has a better performance in terms of service availability, latency, and transmission speed. Finally, through the Radio Mobile software and Google Earth, the simulation of the point-to-point link is carried out where a line of sight is obtained as a result, which indicates that it is feasible to make a radio link, in addition a reception level of - 49.8 dBm and a distance between the two points of 7.79km, it is also determined that the hot air balloon must be at a height of 90 meters for the coverage to be greater.**

***Keywords*— Education; Point to Point Link; Radio Mobile; rural zone; radiolink.**

I. Introduction

Education is one of the main mechanisms that marks, not only the beginning of a prosperous and democratic nation, also the formation of citizens aware of its reality and its uncertainties. In the same way, every individual has the right to educational training without any exclusion, since each one forms an essential piece within our society. However, in Peru there is an educational inequity gap [1] and one of the problems is due to the lack of internet access in many native Peruvian communities that are abandoned by the State.

At the same time, offering a quality education is fundamental, because if the boys and girls attend the schools of the educational system and these services are of low quality, they do not get basic learning, they still do not enjoy the right to education.

School life must unfold in an adequate place of health and hygiene, spacious and well-lit environments suitable for performing artistic, sports and scientific activities, with basic services, with internet Access [2].

According to the results of the III Census of Native Communities 2017, of the 2 thousand 703 communities registered, 57% do not have any communication service, 21.6% have radio and 19.9% have public telephone service. To a lesser extent, native communities have connection to cable or satellite TV (4.9%), radio station (3.6%), internet (2.9%) and cell phone service (0.5%). Likewise, in the Awajún community only 1% of its population has Internet service, so the lack of internet in the community is demonstrated [3].

The Awajún Huampami community, located in the El Cenepa District, Department of Amazonas where education at the primary and secondary level, only 11.1% and 55.4% respectively use information and communication technologies (ICT), while at the national level in the primary and secondary education 38.4% and 71.5% respectively, the access gaps are very wide. According to the province, in primary education the province of Bongará has the highest access (22.7%), whereas in Condorcanqui 5.29% have internet access while at the secondary level the distance is less, the provinces of Chachapoyas, Bongará, Luya have 68%, 67% and 64% respectively, while Condorcanqui has 32.43% it has internet [4].

The main objective of this research work is to implement and simulate a wireless technology for internet transmission using hot air balloons equipped with long-range antennas, thus providing Wi-Fi connectivity in the educational establishments of the community and obtaining a quality education and facilitating the search for digital content.

A hot air balloon is a non-propelled hot air aircraft that uses the principle of Archimedean fluids to fly, understanding air as a fluid. They are made up of a bag that encloses a mass of gas lighter than air and hence they are popularly known as a balloon [8].

Currently, these balloons are being used for different aspects, for example, for video surveillance in rugged territories, in tourism, in transport, to provide internet service in rural areas, even it was used in the military field.

A wireless network is a connection that occurs between two or more computers, where information will be transferred between them without any type of structured cabling. This Wireless technology offers greater signal ranges and mobility in the connection, thus allowing this technology to be known and spread very quickly. It is made up of a base station that fulfills the function of emitting a signal to a transceiver and this allows Wi-Fi connectivity in a certain place.

The following research work is conformed as follows: In section II, the development of the wireless network through the hot air balloon will be presented. In section III, the results are presented through images that we have obtained in the simulations and checking a viable link. In section IV, the discussions of the research work are presented. Finally, in section V, the conclusions and some recommendations of the research work are presented.

II. Literature Review

In [5], different alternatives of internet access in rural educational institutions in Antioquia were investigated, where first the areas where there is a greater number of disconnected rural educational establishments were verified, obtaining as a result the municipality of Sonsón. For this, two possible solutions are proposed using radio links and satellite. To get a good connection and the network works properly, three items must be considered: main access, connection to educational centers and internal network. To connect the rural educational institutions from the main node, it is proposed to install Point-Multi-Point radio links to the educational venues, then it is required (a) Obtain the coordinates in latitude, longitude, and altitude, (b) Calculate the distance between the points, (c) Obtain the altitudinal profile, (d) Apply the Dijsktra algorithm and (e) Calculate the first Fresnel zone. If there is no line of sight or that the Fresnel area is obstructed, the installation of a repeater antenna is considered. It is concluded that the radio link service is cheaper and can also have a better performance in terms of service availability, latency, and transfer speed.

In [6], the implementation of a wireless technology using hot air balloons in disaster areas is proposed. The case study is the town of Cantón Chone in the province of Manabí, which was affected by the electricity and telecommunications facilities by the earthquake in 2016.

The components that will be part of the implementation of the wireless network mounted on a hot air balloon are described. It must be stable enough to lift the equipment. Using the Radio Mobile simulator, the viability of the 5 and 2.4 GHz (Gigahertz) frequency links is studied, which will make it easier for the globe to act as a repeater and thus transmit the internet to mobile devices. It was determined that it will be possible to provide the service to an area of a maximum distance of 500 meters, from the access point to the devices, due to the characteristics of their internal antennas, obtaining 7200 people connected during the day and in case of exceeding this population, it will be necessary to evaluate the number of inhabitants that exist without telecommunication service, in order to average the exact number of balloons that will be launched and supply the majority of those affected. Finally, this project is accepted with 95% of the inhabitants who grant the maximum level of viability of the technological proposal.

In [7], where the demand for internet and telephony has remained low at the rural level despite having increased in urban areas and it is important that all rural towns and communities have access to mass communications. To do this, a mechatronic system is designed in the form of an unmanned aircraft, which will function as a mobile antenna while it flies at a height of 500 meters over the Caserío de Sapchá, in Ancash. The UAV (Unmanned Aerial Vehicle) has the necessary autonomy to be able to operate during the day and in its wings solar panels will be accommodated. It is obtained because of this project that if it is possible for an aircraft to carry wireless communication to rural areas and it will be possible to stay in the air indefinitely if the design parameters are met and consider the change of climate: rain, snow or too much cloudiness. It is concluded that with this design it will be able to provide Internet to the town of Sapchá through a transmission cone of $0.63km^2$ (kilometers squared).

III. Methodology

In this section, the procedures to design a wireless network are developed, first determining the wireless devices that will be used in the base station as in the hot air balloon, also considering the main parameters of a radio link and finally the design of a network of equipment connected to a point-to-point and multipoint tower station. All the steps mentioned can be seen in the following flow chart in Figure 1.

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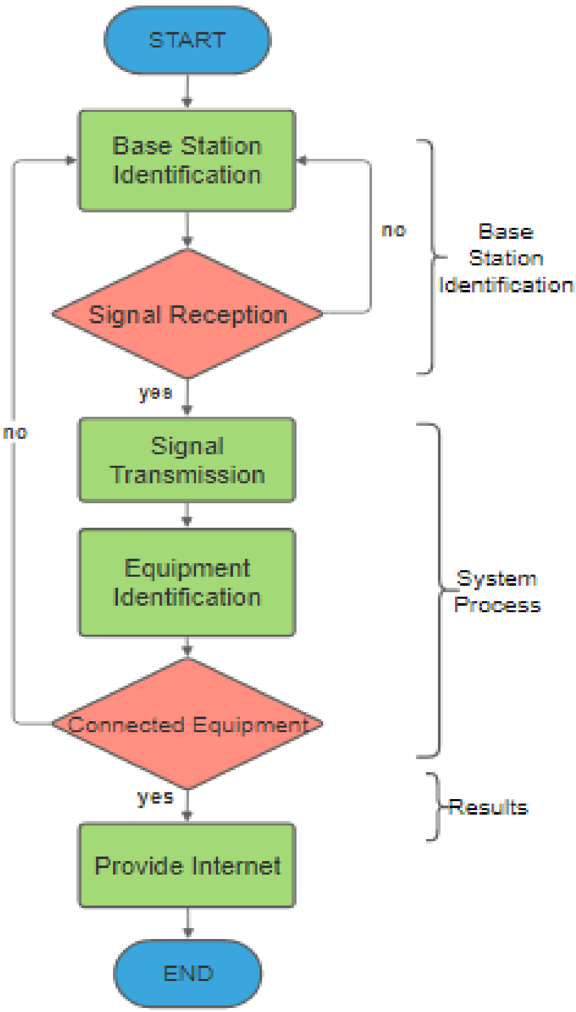

Fig. 1. Diagram of Flow for the Transmission of Internet

A. Base Station Identification

A Base Transceiver Station (BTS) has the function of transmitting and receiving the signals that wants to be send. This data transmission is carried out by electromagnetic waves that propagate in space without any cable in between [9]. The transmitter will insert the information to be transmitted in a support electromagnetic wave called a carrier which will be assigned a frequency value, this process is called modulation. With this, the signal will be able to confront and be more resistant to the effects of the propagation phenomena of the medium.

After the modulated wave is transmitted and travels throughout the atmosphere that separates the transmitting and receiving antennas, the demodulation process will be carried out in which the information of the modulated wave is obtained [10].

The network will be made up of the transmission tower, which will provide internet to the hot air balloon, and this will act as a repeater as can be seen in Figure 2 where the design of the base station to the hot air balloon is carried out.

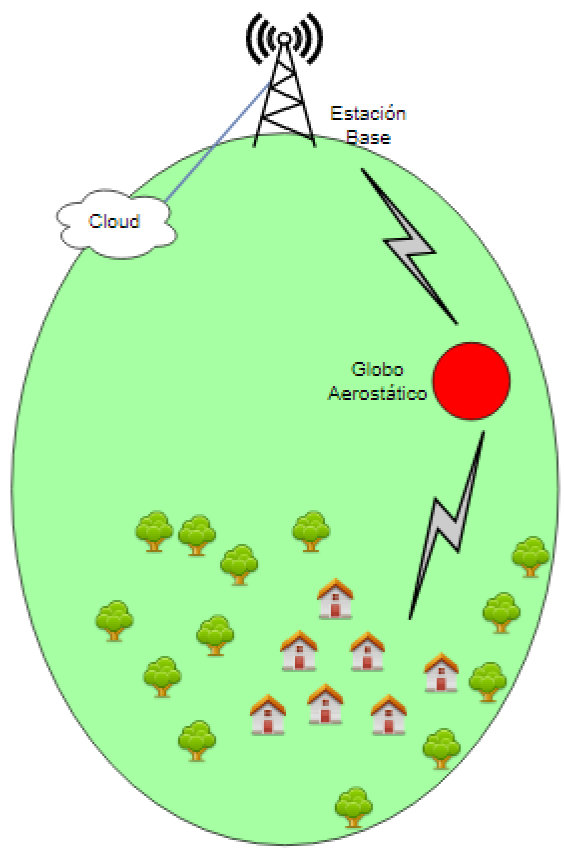

Fig. 2. Wireless Network Design

From the different antenna options that exist in the market and considering that the system to be developed is an external point-to-point radio link and that communication is directional, so it is decided, and it is convenient to use two directional antennas of the same characteristics that will be placed on the Base Transceiver Station (BTS) and on the hot air balloon.

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This will be our first network where two antennas of the RD-5G30 model will be used for the transmitter and receiver, as seen in Figure 3 and whose characteristics are shown in Table I.

Fig. 3. Antenna RD-5G30

Table 1
RD-5G30 Antenna Specifications

Model	RD-5G30
Brand	Ubiquiti Networks
Frequency Range	4.9 – 5.8GHz
Gain	26 - 30 dBi
Polarization	Dual-Linear – 2x2 MiMo
Range (Maximum)	80km

Likewise, we will use a Rocket M5 model radio, a robust device, with high power, MiMo 2x2 radios, TDMA modulation, which will allow it to have a greater range in a point-to-point link [11] and this is connected to a Ubiquiti parabolic antenna. Figure 4 shows the Rocket M5 equipment and its main characteristics in table II.

Fig. 4. Rocket M5

Table 2
Rocket M5 Antenna Specifications

Model	Rocket M5
Brand	Ubiquiti Networks
Frequency Range	4.9 – 5.8GHz
Gain	26 - 30 dBi
Transmit Power	27dBm (500mW)
Rx Sensitivity	-96dBm
Transfer Speed	150Mbps
Polarization	Dual-Linear – 2x2 MiMo
Range (Maximum)	80km

On the other hand, in the Wi-Fi network a sectorial antenna of the AM-2G15-120 model will be used as can be seen in Figure 5 and whose main characteristics are displayed in table III.

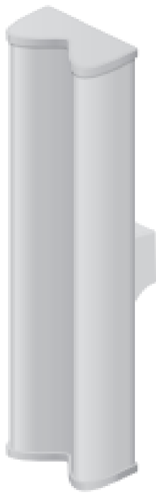

Fig. 5. AM-2G15-120

Table 3
Sector Antenna Characteristics

Model	AirMax AM-2G15-120 2x2 MIMO
Brand	Ubiquiti Networks
Frequency Band	2.4GHz
Gain	15dBi
Transmit Power	25dBm
Velocity	300Mbps

This second network will be made up of three sector antennas where each one only covers a radius of 120°, so it is necessary to use two additional antennas to complete the 360° and thus be able to cover everything around them. These three Access Points (AP) will be connected to the receiving antenna through a splitter as can be seen in Figure 6.

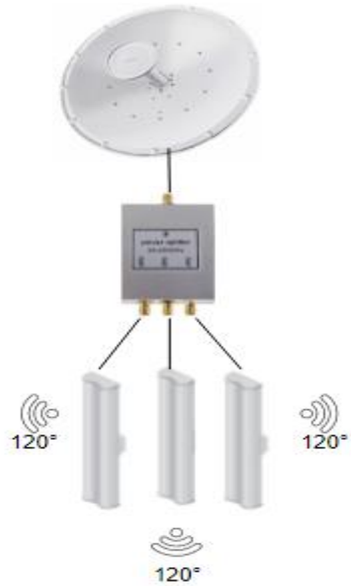

Fig. 6. Wi-Fi Network

Finally, a coaxial cable of the CA-400 LMR-400 model is used as shown in Figure 7, which has an impedance of 50Ω, operates at a frequency of 5GHz and has an attenuation of 32.81 dB per 100 meters [12]. Also, the connectors to be used are of the SMA type since the antennas are from the Ubiquiti brand.

Fig. 7. Coaxial cable and SMA connector

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B. System Process

To plan the design of the radio link system, first the most suitable place is defined, so it is decided to locate the antennas in areas of high relief. Where, the coordinates of the base station and the hot air balloon are displayed in table IV.

Table 4
Coordinates of the Places

Place	Coordinates	
	Latitude	Length
Base Transceiver Station	4°27'26.99"S	78° 9'15.98"O
Hot Air Balloon	4°28'11.13"S	78° 9'22.00"O

These coordinates will be used and entered in the Google Earth tool, which will give satellite views of the points as can be seen in the following Figure 8 to make the radio link in the Huampami community.

Fig. 8. Link Map

In the following Figure 9, it can be seen, in the elevation profile, that the distance that exists in this connection is 7.79 km, where the base station is located on a surface of 256 meters above sea level and the hot air balloon is located on a surface 405 meters above sea level. It can also be seen that in this point-to-point link, the presence of obstacles will obstruct the propagation by line of sight.

Fig. 9. Elevation Profile

To develop the study of the obstacles that can obstruct the radio link, it is carried out through the Fresnel spiral through which the electromagnetic wave travels and it is required that 60% of the first Fresnel Zone is free of obstacles, that is, no obstacle it must affect the first Fresnel Zone [13]. This parameter will depend on the distance of the radio link and the frequency to be used, since at higher frequencies this ellipsoid becomes thinner. To calculate the radius of the first Fresnel Zone, the following equation is used:

$$R_1 = 17.33\sqrt{\frac{d}{4f}} \qquad (1)$$

Where:

- R_1: Radius of the First Fresnel Zone
- d: Link distance
- f: Operating frequency

Replacing the values in equation 1, it is obtained that the radius of the first Fresnel zone is 10.81 meters. Then, so that the system is free of obstructions, the height of the tower is determined, enough to achieve line of sight between the two antennas to have a higher quality of the link, where the base transceiver station tower will measure 29 meters and the hot air balloon at a height of 90 meters so that the Wi-Fi network can cover the entire territory.

To calculate the maximum distance that the radiated signal could reach, through an antenna under ideal conditions, it is calculated with equation 2.

$$A = 3.57\left(\sqrt{Kh_{Tx}} + \sqrt{Kh_{Rx}}\right) \quad (2)$$

Where:

- A: Maximum range or distance
- K: Earth curvature factor (4/3)
- h_{Tx}: Antenna Tx Height in meters
- h_{Rx}: Antenna Rx height in meters

Where replacing the values of the height of the place where the Base Station and the Hot Air Balloon are located (256 m and 405 m respectively) and the height of their towers 29 m and 90 m respectively, the following is obtained:

$$A = 3.57\left(\sqrt{\frac{4}{3}(256+29)} + \sqrt{\frac{4}{3}(405+90)}\right) = 161.30km$$

With this result, it is shown that if communication can be carried out since the distance between the base station and the hot air balloon is approximately 8 km and the distance that the broadcast signal can reach is 161.30 km.

On the other hand, in a radiocommunication system the receiver must receive the signal with an appropriate power level so that it can recover the information, but the wave propagating in the air, spreads over a surface, decreasing its power every time greater than as it separates from the transmitter [14]. This is known as Free Loss Space (FLS) and its equation is as follows:

$$FLS = 92.45 + 20\log(fxd) \quad (3)$$

Where:

f: Frequency in GHz
d: Distance in Km

Replacing in equation 3 where the value of frequency and distance in our research work is 5 GHz and 7.79 km, respectively. The following equation is obtained:

$$FLS = 92.45 + 20\log(5x7.79) = 124.26dB$$

At the same time, we must bear in mind the attenuations that the rains will cause and will depend on the intensity, type, size, frequency, speed, geometry, and deformation of the drops of water when they fall. At higher frequencies, the losses increase and at frequencies lower than 5GHz the losses are negligible.

Based on statistical data, it is possible to obtain the losses that it will cause on the signal. In the absence of information, ITU data and maps can be used to predict rainfall intensity [15]. Rain attenuations are calculated using the following equation:

$$Y_R = KR^{\alpha} \quad (4)$$

Where:

- R: Rain intensity (mm / h)
- k: Regression coefficient
- α: Regression coefficient

As we are going to use a coaxial cable that has a loss of 32.81dB/100m at a frequency of 5GHz and the distance that this cable will cover is approximately 5 meters at each point, we proceed to calculate the losses in the following equation 5:

$$P_c = \frac{32.81}{100} \text{ x } 5 = 1.65dB \quad (5)$$

It is important in a radio link to calculate the power that the receiving antenna will receive. This power can be evaluated through the Friss equation [16] as a function of the gains, powers and main losses of the radio link system:

$$N_{Rx} = P_{Tx} - L_{Tx} + G_{Tx} - y_o + G_{Rx} - L_{Rx} \quad (6)$$

Where:

P_{Tx}: Transmitting antenna power
L_{Tx}: Loss in the riser cables
G_{Tx}: Gain on the transmitting antenna
y_o: Free Loss Space
G_{Rx}: Gain in the receiving antenna
L_{Rx}: Loss in the transmitter drop cables

Replacing with the values specified in the research work, the following is obtained:

$$N_{Rx} = P_{Tx} - L_{Tx} + G_{Tx} - y_o + G_{Rx} - L_{Rx} = -70.23dBm$$

With this data obtained, it helps us to calculate the Margin level of the radiocommunication system, where at least 10dB is needed for a feasible link and in correct operation.

$$LM = N_{Rx} - N_u$$

$$LM = -70.23 - (-96)$$

$$LM = 25dB$$

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Finally, the simulation of the radio link system is carried out. For this, the Radio Mobile software is used to simulate the transmission and reception between the antennas where the parameters of the two networks are first created and configured.

We use Radio Mobile software because it gives us precise data for the calculation of radio links, however, we can find other free software that allows us to calculate radio link systems, for example AirLink and Link Planner.

Subsequently, the technical specifications of the devices in the network systems are added, where the Rocket M5 + RD-5G30 system will be made up of the two antennas that will work with a transmission power of 27dBm located at the base station and the hot air balloon and both participate in the 5GHz link as is seen in Figure 10.

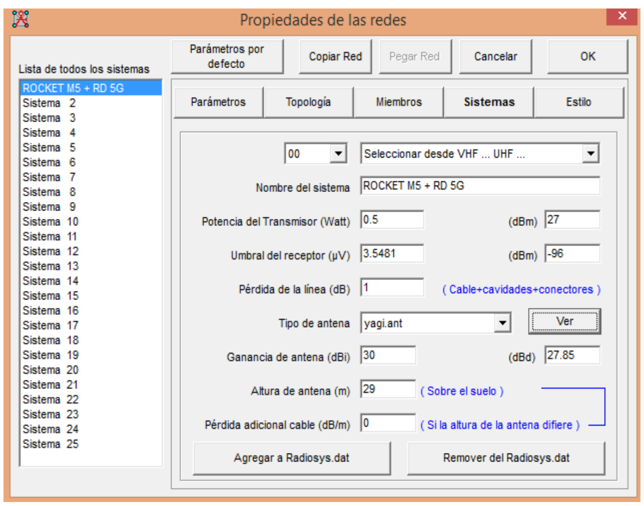

Fig. 10. Transmitter System

The sectoral system will operate at a frequency of 2.4GHz and is made up of the Access Points and members of the Huampami community, for the simulation of the point-to-multipoint link an omnidirectional antenna is used that will work with a transmission power of 25dBm, as can be seen in Figure 11.

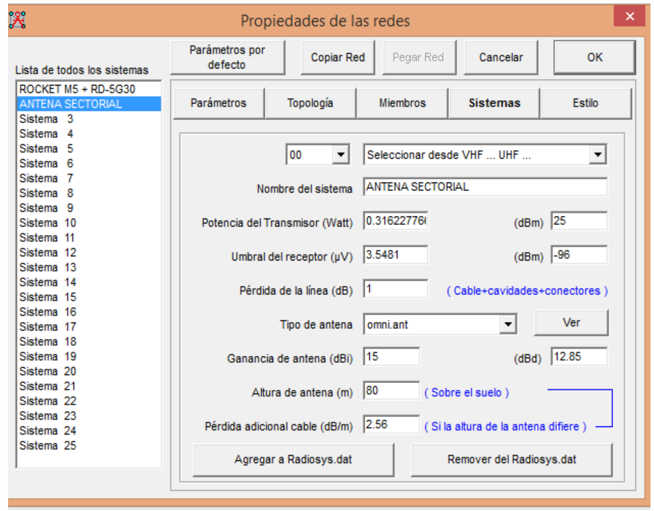

Fig. 11. Sectoral System

In this mobile phone system, the specifications of a cell phone antenna are added and it will be at a height of 2 meters, which is the approximate height that a person and a transmit power of 15 dBm, measures as shown in Figure 12.

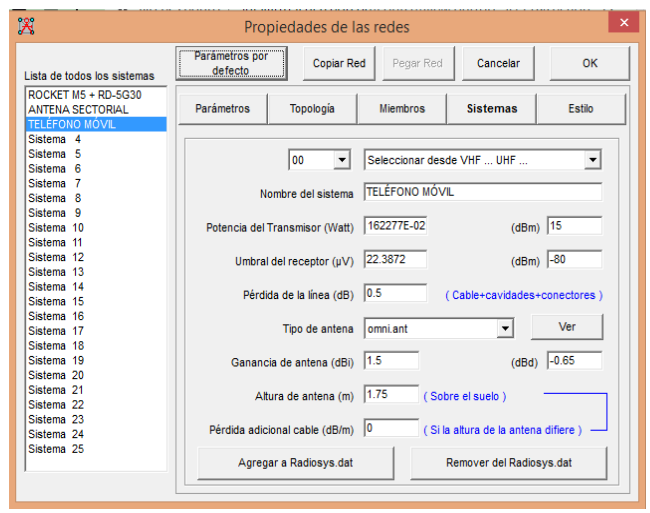

Fig. 12. Mobile Phone sytem

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In case it does not find any equipment, the system will return to the previous step of base station identification and thus try to connect to be able to transmit the Wi-Fi signal.

IV. RESULTS

After configuring and carrying out the simulation between the base station and the hot air balloon, a green line is obtained that indicates the existence of a line of sight between the two antennas and the hot air balloon to the clients as shown in the following Figure 13.

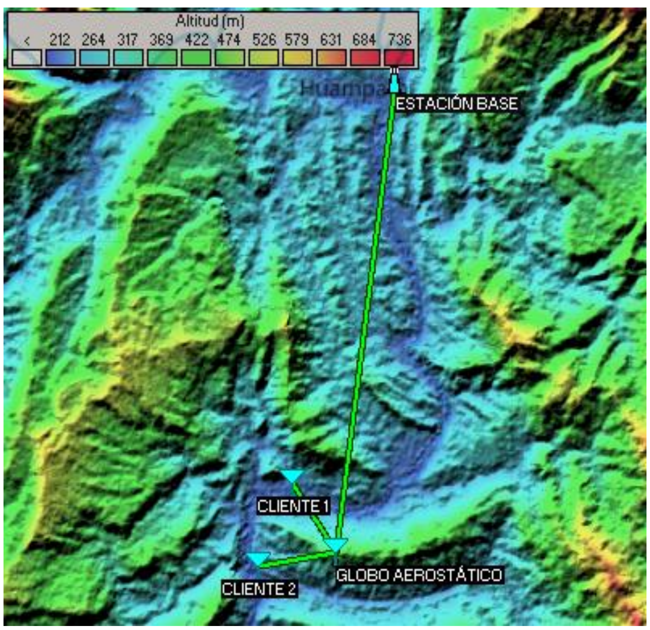

Fig. 13. Point to Point Link

On the way from the base station to the hot air balloon, the Fresnel zone is free of obstacles and therefore the radiocommunication system will not have any problem. In addition, Figure 14 shows a reception level like that obtained from theoretical way.

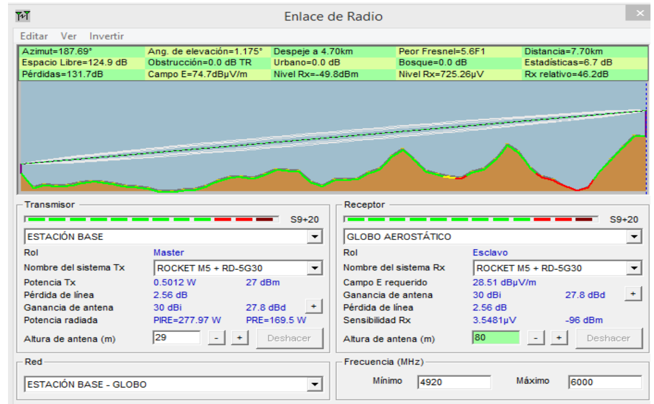

Fig. 14. Radio Link -One

Later, on the path of the hot air balloon and the first customer, a Fresnel zone clear of obstacles is also achieved as shown in Figure 15, knowing that the hot air balloon has an elevation of 90 meters and the customer has a height of 2 meters.

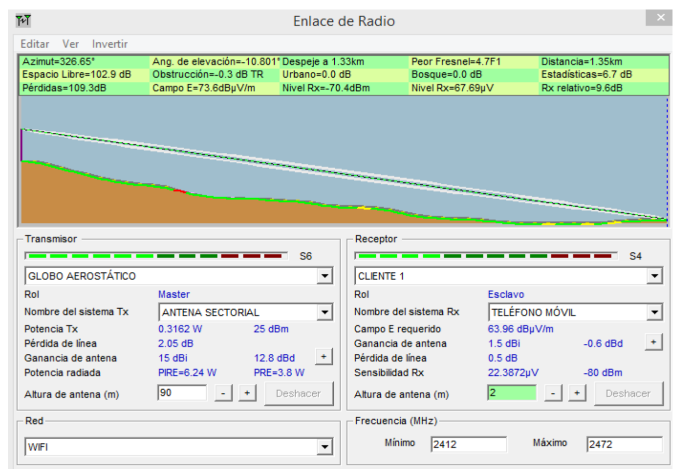

Fig. 15. Radio Link -Two

Likewise, in the path of the hot air balloon with the second client, a correct radio link is achieved since the Fresnel zone is not obstructed as shown in Figure 16.

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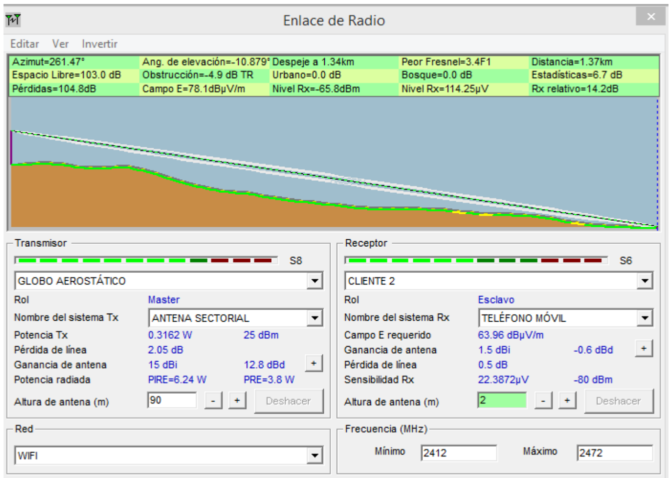

Fig. 16. Radio Link - Three

To determine the coverage that the Access Point will cover over the territory, the file is extracted to the Google Earth software to have a better panorama as shown in Figure where customer 1 is located at a distance of 3.20km from the hot air balloon, a green area that indicates that the signal is very optimal, customer 2 will be at a greater distance of 9km, a yellow area where the signal will gradually deteriorate and client 3 will be at a distance of 7.50km, a red area that indicates that the signal is bad.

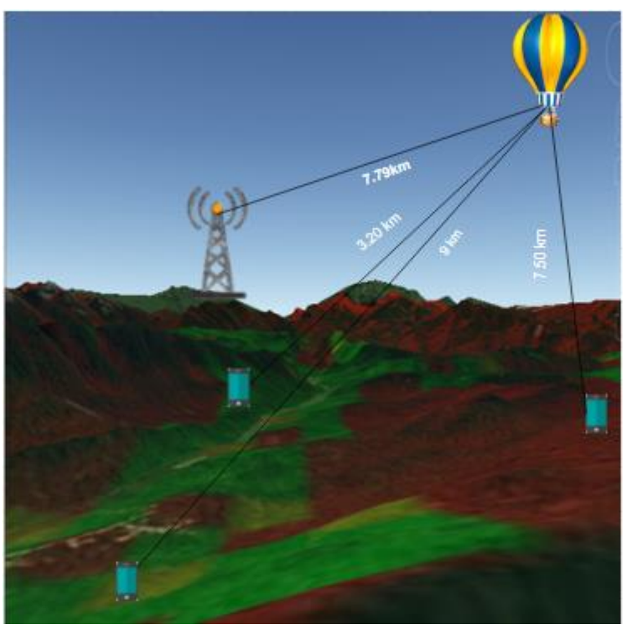

Fig. 17. Radio Coverage

The purpose of the research work is to provide an internet signal in the Awajún communities in Huampami and thus improve the quality of education and reduce the inequality of internet access.

Regarding the geographical position of Peru, the Awajún Huampami community is in a rugged area, which is why it was decided to work with Hot Air Balloons and thus obtain a correct line of sight, raising to a height of 90 meters to cover a larger area. coverage, in case the hot air balloon is raised to a lower height, the obstacle obstructs the point-to-point link, and the signal will not arrive properly.

V. DISCUSSION

I agree with the research work [5] where it is also decided to bring the Internet service to remote areas through radio link systems since it will have better performance and will be cheaper. In addition, it will benefit adolescents to reinforce knowledge with digital content that can be obtained on the Internet.

Comparing with the research work [6] where the hot air balloon is at a height of 50 meters for adequate communication, for this research work an elevation of 90 meters is required for the radiocommunication system to function correctly and the transmission of data covers the entire territory of the Awajún community.

With the research work [7], it can be verified that if the hot air balloon had a height greater than 90 meters, the coverage radius would increase and whose antenna has a transmission power of 25 dBm and a gain of 15 dBi, while in [6] the antenna has a transmitting power of 28 dBm and a gain of 27 dBi.

With this research work, the aim is to bring the internet service to the native Awajún community so that students have a better learning, considering that different software is used to carry out the necessary tests and later carry out the implementation of the system of radiocommunication.

VI. CONCLUSIONS

In this research work, with the values obtained theoretically as in the simulation, it can be concluded that it is possible to carry out the radio link. Likewise, the correct choice of equipment makes connectivity between the base station and the hot air balloon possible.

It is concluded that using wireless technology through hot air balloons reduces the use of cables that are normally used. On the other hand, the lower the sensitivity of the receiving antenna, the better the signal reception.

Finally, in this research work a radio link system is designed to bring connectivity to the Awajún communities in Huampami and reduce the digital gap that exists between rural and urban areas.

In case the obstacle is obstructing 80% of the Fresnel Zone, the signal will not be correct and therefore our radio communication system will not work correctly.

As work in the future, this research work is intended to implement, not only in this community, but also in other rural areas where Internet service and/or radio communication systems are required and where it is feasible to use a Hot Air Balloon with an antenna inserted.

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