Lecture Notes in Networks and Systems 1040

Marcelo Zambrano Vizuete · Miguel Botto-Tobar · Sonia Casillas · Carina Gonzalez · Carlos Sánchez · Gabriel Gomes · Benjamin Durakovic *Editors*

Innovation and Research – Smart Technologies & Systems

Proceedings of the CI3 2023, Volume 1

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Preface

The 4th edition of the International Research and Innovation Congress – Smart Technologies and Systems, CI3 2023, took place from August 30 to September 1, 2023, at the facilities of the Instituto Tecnológico Universitario Rumiñahui, located in the city of SangolquÍ, Pichincha, Ecuador.

The conference was organized by the Red de Investigación, Innovación y Transferencia de Tecnología RIT2, made up of the most relevant university institutes in Ecuador, among which are ITCA, BOLIVARIANO, ARGOS, VIDA NUEVA, ESPÍRITU SANTO, SUDAMERICANO, ISMAC, SAN ISIDRO, ARTES GRÁFICAS, ORIENTE, HUMANE, SUCRE, CENTRAL TÉCNICO, POLICÍA NACIONAL and RUMIÑAHUI.

Additionally, the event is sponsored by the Secretaría de Educación Superior, Ciencia, Tecnología e Innovación SENESCYT, Labortorio de Comunicación Visual de la Universidad Estatal de Campinas—Brazil, Universidad Ana G. Méndez—Puerto Rico, Centro de Investigaciones Psicopedagógicas y Sociológicas—Cuba, Instituto Superior de Diseño de la Universidad de La Habana—Cuba, GDEON and the Corporación Ecuatoriana para el Desarrollo de la Investigación y la Academia—CEDIA.

The main objective of CI3 2023 is to generate a space for dissemination and collaboration, where academia, industry and government can share their ideas, experiences and results of their projects and research.

"Research as a pillar of higher education and business improvement" is the motto of the Conference and suggests how research, innovation and academia must coincide with the productive sector to leverage social and economic development.

CI3 2023 had 145 papers submitted, of which 52 were accepted for publication and presentation. To guarantee the quality of the publications, the event has a staff of more than 70 experts, from different countries such as Spain, Argentina, Chile, Mexico, Peru, Brazil, Ecuador, among others, who carry out an exhaustive review of each proposal sent.

Likewise, during the event a series of keynote conferences were held, given by both national and international experts, allowing attendees to get in touch with the latest trends and technological advances around the world. Keynote speakers included: Ph.D. Carina González, University of La Laguna, Spain; Ph.D. Gabriel Gómez, State University of Campinas, Brazil; Ph.D. Carlos Sanchez, University of Zaragoza, Spain; Ph.D. Juan Minango, Instituto Tecnológico Superior Rumiñahui; Dr. Iván Cherrez, Universidad Espíritu Santo, Ecuador; and Ph.D. Nela Paustizaca, Escuela Politécnica del Litoral, Ecuador.

The content of this proceeding is related to the following topics:

- Smart Cities
- Innovation and Development
- Applied Technologies
- Economics and Management
- ICT for Educations.

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Contents

CONNECTED Project. Connecting to the Disconnected

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Abstract. The pandemic caused by COVID19 had a disruptive effect throughout the planet, bringing to light the social, economic, and technological gaps that exist in current societies around the world, including such important aspects as connectivity (internet service) and education. Within the educational field, the closure of schools and colleges, as well as the lack of internet service in rural areas, prevented millions of children from continuing with their formal education. The CONNECTED project uses cutting-edge telematics tools and technologies to develop a communications system that allows delivering internet service to rural areas lacking this service; This, in turn, makes it possible for children and young people residing in these areas to continue with their formal education through tele-education processes.

Keywords: Rural Communications · Teleeducation · School Dropout

1 Introduction

During 2020 and part of 2021, COVID19 caused a third of the world's population to be subjected to confinement and strong mobility restrictions [1]. The first case of this virus (SARS-CoV-2.67 - Covid19) was identified in December 2019, in the city of Wuhan, capital of Hubei province, in the People's Republic of China. The World Health Organization (WHO) recognized it as a pandemic on March 11, 2020; By date, more than 118,000 cases had already been reported in 114 countries, and 4,291 people had lost their lives [2]. As of January 16, 2022, more than 350 million confirmed cases of this disease have been reported, with more than 5 million deaths, in more than 250 countries [3].

In addition to the human losses mentioned above, the measures adopted to combat the virus brought with them a drastic reduction in socioeconomic activities such as employment, tourism and education. One of the most important problems has been

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reflected in the education sector: in more than 138 countries, schools and colleges were closed, affecting more than 1.37 billion children and young people who were unable to continue with their basic and secondary academic training [3, 4]. Under these conditions, connectivity and internet service became critical since they made it possible to compensate for the lack of physical contact and distancing using telematic applications and virtuality [5].

In the case of Ecuador, nearly one million children and young people were unable to continue with their formal education due to the difficulties in carrying out effective tele-education processes, mainly due to connectivity problems and the lack of internet service [6, 7]. Approximately, during the 2020–2021 period, more than 150,000 dropouts were registered in the basic and secondary education system of Ecuador [8].

According to figures from the National Institute of Statistics and Censuses (INEC), by April 2021, only 50% of Ecuadorian households, in the urban sector, had internet access and, for the rural sector, the figures worsen, only 40% of households have access to this service. This technological gap has a direct impact on the existing economic and social gaps between the urban and rural sectors [9–11].

To solve the problems, the CONNECTED project is developed, using cutting-edge tools and technologies that make it possible to provide connectivity and internet service to rural areas not covered by conventional providers of this service (dark areas).

It is important to emphasize that the objective of the project has a strictly social nature: to enable children and young people residing in rural areas without internet service to have a formal basic and intermediate level education. This, in turn, enable to improve the quality of life of citizens residing in these areas, reducing the existing socioeconomic gaps between this rural and urban sector.

This document is organized as follows: first, an introduction is made regarding the topics related to the project; second, the methodology used during its development and implementation is described; Third, the tests and results obtained are presented and, finally, fourth, the main conclusions resulting from the project are presented.

2 Methodology

This project is part of applied, qualitative and quantitative research. Applied, since its objective is the practical implementation (prototype) of a technical and technological solution that provides a solution to a real problem. Qualitative, the ultimate goal of the project is to provide connectivity and internet service, yes or no, to rural areas not covered by conventional Internet providers. Quantitative, the quality of Internet service is measured through quantitative variables such as transmission speed and bandwidth.

In general, the methodology used in this project is experimental, that is, after the design and sizing of the solution, the implementation and functionality tests (trial and error) will be carried out. If this is the case, the necessary corrective measures will be made to re-run tests and verify the functionality of the system.

The project is divided into four phases or stages:

1. Literature review and determination of the state of the art. It allowed us to learn about the advances, challenges and current state of the Internet service and tele-education processes in rural areas, as well as the successful models and implementations that

have been developed around this topic. According to this study, the problem was established, determining that in Ecuador, there is a significant lack of this service in rural areas.

2. Design and sizing of the solution. First, the generic architecture of the system was designed, which establishes the requirements, conditions and general structure of the system so that it can provide a solution to the identified problem. Second, the Target Geographic Area that will benefit from the development of this project was determined. Third, the specific architecture was designed taking into consideration the particular characteristics of the geographical area taken as the objective and adapting the generic architecture to these particularities. Finally, the characteristics and quantity of the equipment, devices and electrical and communications elements required for the implementation were determined.
3. Implementation. A prototype of the communications system is implemented in accordance with the area chosen as the objective, the specific architecture and the sizing of the equipment previously carried out.
4. Functionality tests. Since the main objective of the project is to allow the effective execution of tele-education processes within the Target Area, functionality tests were carried out using computer applications such as Microsoft Teams [12] and Zoom [13]. Measurements of bandwidth and data transmission speeds were taken both in the communications backbone and in each of the end users.

2.1 Architecture

The generic architecture of communications system is shown in Fig. 1 and consists of the following elements:

1. Donor, institution that donates a portion of its internet bandwidth for the development of the project.
2. Target Geographic Area, beneficiary area of the project and in which the donated bandwidth will be used.
3. Communications backbone, a set of point-to-point radio links that provides connectivity between the Donor and the Target Geographic Area. It is important to consider that, for licensing reasons, radio links must operate in free bands such as 2.4 GHz or 5 GHz. At these frequencies, the existence of line of sight between the transmitters and receivers of each of them becomes essential. Links deployed for communications backbone can be made up of one or several radio frequency links (hops), everything will depend on the distance between the donor and the Target Geographic Area, as well as the physical obstacles that prevent the line of sight between transmitters and receivers.
4. Base Station, point multipoint telecommunications equipment that allows wireless coverage of the Target Geographic Area. The base station must have connectivity with the last node of the communications backbone installed in the Target Geographic Area.
5. User terminals, telecommunications equipment, installed in the end user locations and that enable communication with the Base Station.
6. Access points, telecommunications equipment that receives the Internet signal from user terminals and distributes it to user locations through an IEEE 802.11 network.

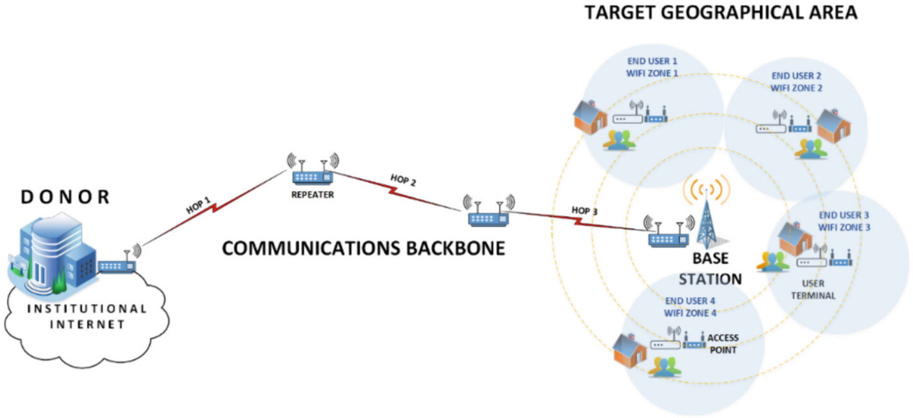


Fig. 1. Generic CONNECTED project architecture.

The San Antonio neighborhood (Ecuador country, Pichincha Province, Rumiñahui canton) was chosen as the Target Geographic Area; a small town located on the slopes of the Pasochoa volcano, at an approximate distance of 15 km from the Rumiñahui Higher Technological Institute (ISTER), which serves as a donor for this project. It was identified that in this area there was a group of approximately 15 people, including children and young people, who had not been able to continue with their formal education during the COVID19 pandemic due to lack of internet service and the impossibility of carrying out teleeducation processes. Figure 2 shows the geographic location of the San Antonio neighborhood and the line of sight study that demonstrates the feasibility of reaching the Target Geographic Area through a single radio link.

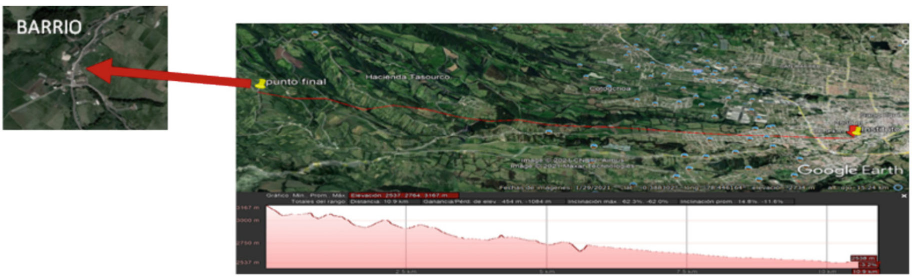


Fig. 2. Line of sight study for the Target Geographic Area: Barrio San Antonio/Pichincha/Rumiñahui.

Once the Target Geographic Area was established, the generic architecture was adapted to the characteristics of that area (geographic, accessibility, electric energy, etc.). Figure 3 shows the specific architecture of the communications system for the San Antonio neighborhood, taking ISTER as a donor, with a bandwidth of 100 Mbps.

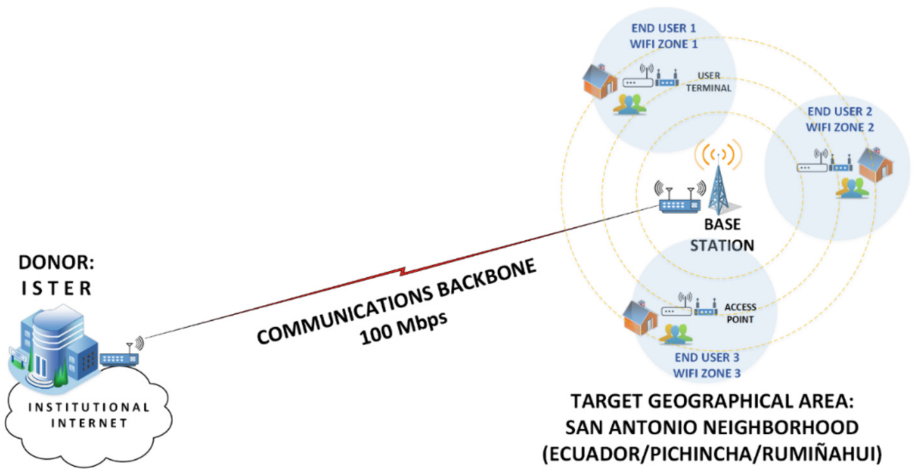


Fig. 3. Specific architecture of the CONNECTED project for the San Antonio neighborhood (Ecuador/Pichincha/Rumiñahui).

2.2 Sizing, Implementation, and Functionality Testing of the System

For the implementation of the system, LigoWave brand equipment [14] was chosen, given its operating frequency characteristics, protection against dust and liquids, traffic management, high tolerance to noise and interference, among others. Although LigoWave equipment can operate under the IEEE 802.11 standard [15, 16], many of the aforementioned features are related to its proprietary layer 2 protocol called Ipoll3 [17, 18].

Ipoll3 makes an improvement to the HCF (Hybrid Coordinate Function) medium access technique, changing the typical control carried out sequentially by the base station, for an intelligent polling carried out individually by each of the access points (APs) subscribed to that station base. Each AP sends a polling frame to the base station and must receive a response before starting to send data. Before polling other APs, the base station must receive data from the AP in question. APs that require less airtime are registered to a low activity or inactivity list, while stations that generate more traffic are registered to an active list. This allows the network to self-regulate so that each wireless link gets the maximum bandwidth with the lowest possible latency.

The equipment used is described in Table 1 below.

Table 1. Equipment used for the implementation of the prototype of the CONNECTED project.

No.	Description	Model	Quantities	Ubication
1	Radio (Antenna included)	LigoPTP 5-23 RapidFire [19]	2	Donor Target Geographical Area
2	Switch layer 2	TPLINK TL-WR840N V2 [20]	1	Donor
3	Base Station (Antenna included)	LigoDLB 5-90n [21]	1	Target Geographical Area
4	User Terminal (Antenna included)	LigoDLB 5-20ac [22]	3	End User site 1 End User site 2 End User site 3
5	Access Point	LigoWave NFT 2ac [23]	3	End User site 1 End User site 2 End User site 3

In addition to the equipment described above, an instance of the LigoWave network management software, called WNMS [24], was implemented. Among the functionalities of this software, can highlight the collection of inventory data, generation of alarms, statistical reports, remote configuration of equipment, among others. In the case of the CONNECTED project, WNMS allowed continuous and real-time monitoring of the radio links and the wireless communications network deployed in the Target Geographic Area.

A prototype of the communications system was implemented, for which ISTER serves as a donor, providing 100 Mbps of its institutional bandwidth for this project. All equipment operates at a frequency of 5 GHz. Figure 4 shows a diagram of the installed equipment.

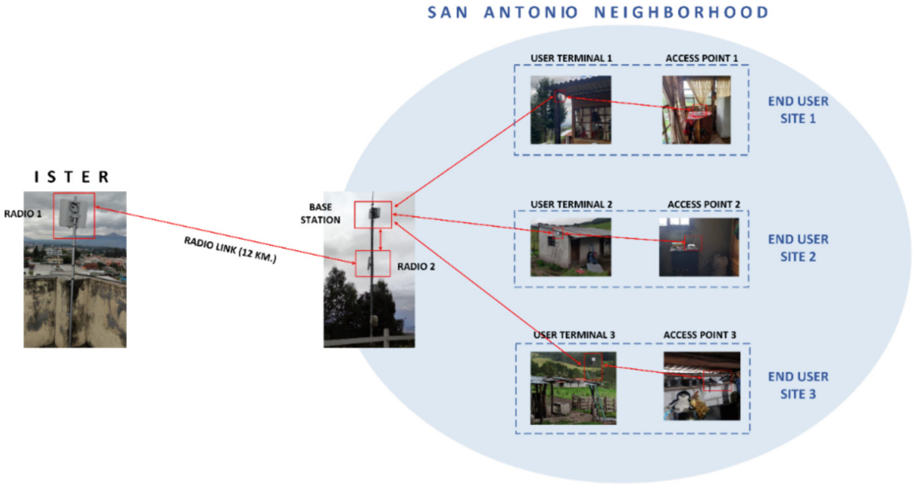


Fig. 4. Prototype of the communications system for the CONNECTED project, San Antonio neighborhood (Ecuador/Pichincha/Rumiñahui).

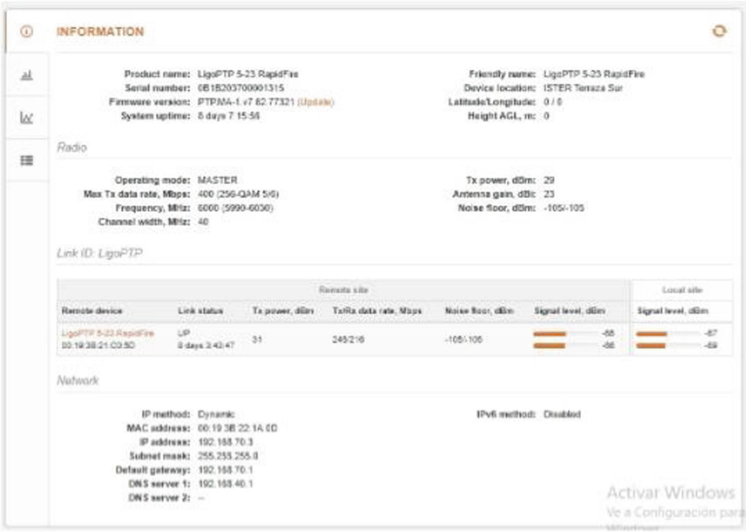
3 Results and Functionality Test

To verify the functionality of the system, multiple audio and video tests were carried out with 9 recurring users, 4 of them used Microsoft Teams and the remaining 5 using ZOOM. 7 of the end users used their smartphone during the tests and 2 used their laptops. The results obtained were satisfactory in 100% of the cases. No packet losses or significant delays were detected during test communications.

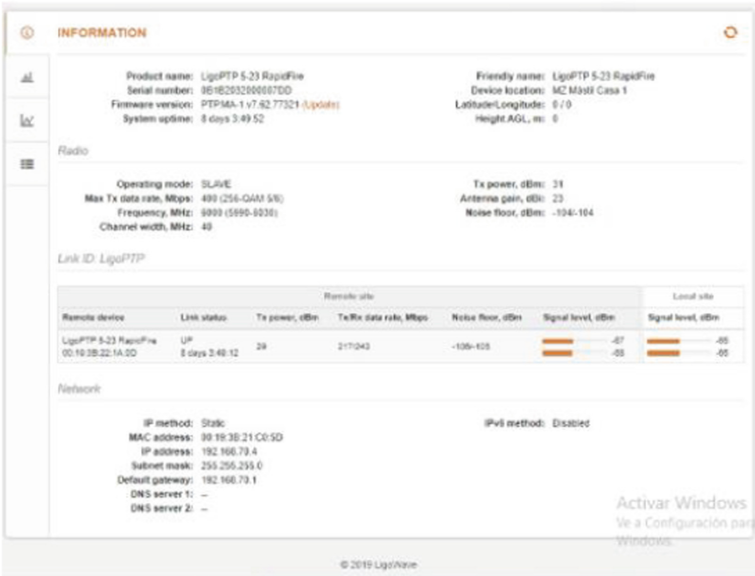
Additionally, 4 transmitters and 4 receivers were chosen at random to carry out text file transfer tests (.docx), each with an approximate size of 10 MB. As in the previous case, the tests were carried out successfully.

Although LigoWave equipment allows it, quality of service (QoS) was not implemented, with the objective of verifying the response of the Ipoll3 protocol to network traffic. It is important to highlight the stability of LigoWave equipment, maintaining minimal variations in transmission speeds and delays in transmissions.

Figure 5 shows the results of the network parameter measurements carried out through the LigoWave WNMS software, both at the donor site and at the Target Geographical Area.

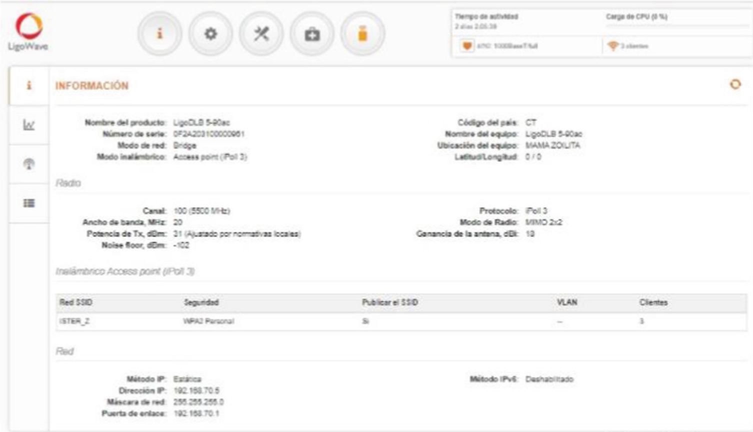


(a)



(b)

Fig. 5. **(a)** Network parameters LigoWave 5-23 RapidFire – ISTER. **(b)** Network parameters LigoWave 5-23 RapidFire – Target Geographical Area. **(c)** Network parameters LigoWave 5-90 Base Station – Target Geographical Area. **(d)** Network parameters LigoWave 5-20ac User Terminal – End User site 3.



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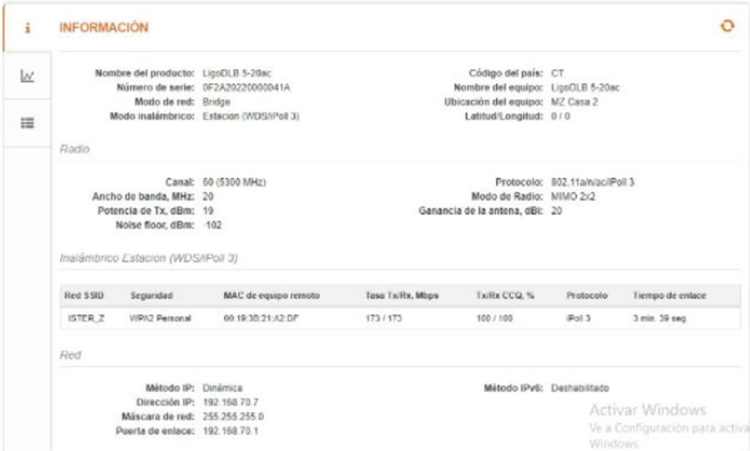

(d)

Fig. 5. (*continued*)

4 Conclusions

The CONNECTED project has a strictly social character, that is, it does not seek economic but social profitability. In the case of this first prototype of the system, the *Instituto Tecnológico Superior Rumiñahui* (ISTER) functions as a donor of the internet service, assigning the project a bandwidth of 100 Mbps. All functionality tests were successful, corroborating the feasibility of the system for the development of Teleeducation effective processes.

It is important to remember that the CONNECTED project is developed jointly by the ISTER and the *Instituto Espíritu Santo* (TES). In addition, it has the support of the *Corporación Ecuatoriana para el Desarrollo de la Investigación y la Academia* (CEDIA).

One of the most difficult activities to accomplish was establishing the location of the radio equipment in the Target Geographic area, since the trees in the area (forested area) are an impediment to reaching the line of sight required between transmitters and receivers to form the link. At first, it was planned to make two jumps to reach the objective point, however, after carrying out the site visit and the field study, it was verified that with the installation of a 6-m-high mast it was possible to reach the line of sight between the radios with a single jump, this, considering that the Ligowave RapidFire equipment has a range of 30 km.

As future work, it is expected to be able to replicate this communications system in other rural locations that have the same problem, considering, if necessary, multiple hops or radio links to reach the Target Geographic Area (this makes it possible to overcome the lack of a line of sight between the donor and the Target Geographic Area). For this, the use of layer 2 switches must be considered in each of the implemented hops, allowing signal regeneration and preventing the bit error rate from increasing. Likewise, it is planned to implement a portable system solution that allows providing communications and/or internet service to areas that have suffered some type of disaster and are cut off.

References

1. Dalponte, B.: COVID-19 y seguridad regional. Macro-seguritización global, adaptaciones locales y dilemas de la cooperación latinoamericana. URVIO. Revista Latinoamericana de Estudios de Seguridad (2021)
2. Maguiña Vargas, C., Gastelo Acosta, R., Tequen Bernilla, A.: El nuevo Coronavirus y la pandemia del Covid-19. Revista Médica Herediana **31**(2), 125–131 (2020)
3. United Nations News Home Page, Más de 156 millones de estudiantes están fuera de la escuela en América Latina debido al coronavirus. https://news.un.org/es/story/2020/03/1471822,2020. Accessed 25 Sept 2023
4. Sanz, I., Sainz, J.: Organización de Estados Iberoamericanos para la Educación, la Ciencia y la Cultura (OEI), Efectos del Coronavirus en la Educación (2020)
5. Bonilla-Guachamin, J.A.: Las dos caras de la educación en el COVID-19. Ciencia América (2020)
6. El Pais. Ecuador: la educación online desde casa es imposible e injusta. Planeta Futuro (2020)
7. El Universo. Un millón de estudiantes sin acceso a educación virtual durante la emergencia sanitaria (2020)
8. Primicias. La pandemia empujó a 150.0000 estudiantes hacia la deserción escolar (2020)
9. Instituto Nacional de Estadísticas y Censos. Indicadores de tecnologías de la información y comunicación. Gobierno en cifras (2021)
10. CEPAL. Pandemia provoca aumento en los niveles de pobreza sin precedentes en las últimas décadas e impacta fuertemente en la desigualdad y el empleo (2021)
11. Reliefweb. El choque COVID-19 en la pobreza, desigualdad y clases sociales en el Ecuador: Una mirada a los hogares con niñas, niños y adolescentes. OCHA Services (2020)
12. Microsoft, Microsoft Teams (2023). https://www.microsoft.com/es/microsoft-teams/group-chat-software. Accessed 16 June 2023
13. Zoom Home Page (2023). https://zoom.us/es. Accessed 16 June 2023
14. LigoWave Home Page. https://www.ligowave.com/es. Accessed 16 June 2023
15. Bellalta, B.: Delay Analysis of IEEE 802.11 be multi-link operation under finite load. IEEE Wireless Commun. Lett. **12**(4), 595–599 (2023)

16. Zubow, A., Memedi, A., Dressler, F.: Towards hybrid electronic-mechanical beamforming for IEEE 802.11 ad. In: 18th Wireless On-Demand Network Systems and Services Conference (WONS). IEEE (2023)
17. LigoWave Ipoll Protocol Home Page. https://www.ligowave.com/wiki/faq/apc-ipoll-protocol/. Accessed 16 June 2023
18. LigoWave, iPoll™- PTMP Protocol, Technical Paper (2016)
19. LigoWave Rapidfire Home Page. https://www.bhphotovideo.com/c/product/1411609-REG/ligowave_ptp_rapidfire_5_23_5ghz_ptp_mimo_700mbps.html?ul=S&gclid=CjwKCAjwyNSoBhA9EiwA5aYlb9w-ytkL6xqdcVAc-TDWSxMw5E3cYO41sD3I_selnEc3_nAyU4mmWxoCX-cQAvD_BwE. Accessed 21 Aug 2023
20. TPlink Wireless Router TL-WR840 Home Page. https://www.tp-link.com/ec/home-networking/wifi-router/tl-wr840n/. Accessed 21 Aug 2023
21. LigoWave LigoDBL-590n Home Page. https://www.ligowave.com/products/ligodlb-5-90n. Accessed 21 June 2023
22. LigoWave LigoDBL-520ac Home Page. https://www.ligowave.com/es/products-2/ligodlb-5-20-ac-3. Accessed 21 June 2023
23. LigoWave NFT-2AC Home Page. https://www.ligowave.com/es/products-2/nft-2ac-3. Accessed 21 June 2023
24. LigoWave Network Monitoring Software Home Page. https://www.ligowave.com/network-monitoring-software. Accessed 21 June 2023