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Design and initial implementation of telehealth and rural telemedicine services for deployment in Rio Santiago Network, Condorcanqui - Amazonas, Peru

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***Abstract*– The isolation barriers of the multiple communities settled in the Amazon rain forest region greatly affect the living conditions of its population. For the case reported in this paper, is around 9500 inhabitants in the five intervention localities of the Santiago River basin. The Santiago River Health Network operates one health center staffed with one physician, while the remaining four health posts are managed by health technicians with basic medical training (health Technicians have a minimum of 3 years of studies in health technical schools). The applied research work reported here aims to strengthen diagnostic and treatment capacities for public maternal and child health care in the Santiago River Basin of the Peruvian Amazon at a time of great vulnerability for Primary Health Care due to the SARS-CoV2 virus and COVID19 pandemic. It relies on rural telemedicine applications to bring health services where they do not reach or reach precariously and contribute to the population's access to quality health services. In this context, the initiative puts Information and Communication Technologies (ICT) at the service of health so that rural health technicians can make better decisions with remote support from specialists who advise them, provide safer and higher quality care to the population, especially women and their children, and so that the later can decide on their own health with more informed decision-making. Consequently, the focus was on a single result: the design of a Telemedicine System oriented towards the promotion, prevention, and care of maternal and child health for its future implementation.**

***Keywords*—rural telemedicine, rural quality health systems, empowerment of technical health staff.**

I. INTRODUCTION

Localities in rural areas of Peru, especially those located in the Amazon region, present various difficulties such as a deficit in access to basic health services and education, in addition to not having infrastructure that allows them to have access to drinking water, electricity, and telecommunications services of quality. Another critical point regarding health is the lack of transportation infrastructure, which makes it difficult to access most of the health posts, infirmaries, or medical centers. And in most cases the means of transportation are long-distance only (encompassing tens to hundreds of kilometers per trip).

This situation yields direct consequences for the population, such as the low level of human development, the difficulty of having health personnel willing to work in these areas, the cost of transportation, the scarcity of internet access and, a very important factor, the insufficiency of health infrastructures [1] as well as the insufficiency of human personnel with resolution capacities for cases that require specialties that are not covered in these isolated areas. The causes of maternal and infant deaths in developing Amazon rural areas are mostly preventable, provided that access to health care services with qualified and well-equipped personnel is facilitated.

Consideration should be given to the connectivity they should have for the development of technology in terms of communication systems for education, health, work, etc. It has been determined that, since 2017, in average, 96% of the population of the Amazon do not have internet access. Which is the case for 96.3% of the population of the province of Condorcanqui, and for 99.93% of the district of Rio Santiago [2]. Based on this, the general objective of this initiative was to design a protocol system for telehealth care and rural telemedicine within the Rio Santiago network for the deployment of rural telemedicine services, focused on guaranteeing access to maternal and child health services for vulnerable groups in the region.

The specific objectives consisted of the design and initial installation in 6 locations: Santa María de Nieva, Pagkintsa, Belén, Guayabal, Yutupis and Galilea. The first two localities belonged to the Santa María de Nieva Micro-Network and the last four belonged to the Galilea Micro-Network.(see Fig. 1).

Fig. 1. Location of target health facilities within the Rio Santiago network.

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Each of these communities has the Santa María de Nieva Hospital as a second level referral center within the Condorcanqui Health Network, in the province of Condorcanqui, along the course of the Santiago River. Another important fact is the population, which reaches 9580 inhabitants. Total population reaches 9580 inhabitants [3].

The set of telemedicine services consisted of telemonitoring, tele-guidance, tele-consultation and tele-diagnostic support through teledermatology and tele-echography. The implementation of these services is aimed at reducing maternal and infant mortality in the aforementioned communities and improving the diagnostic capabilities of health professionals.

This also has an impact on the population's perception of the health facilities, since patients' confidence is also increased by knowing that they can count on medical support in case of need. Telemedicine brings benefits to rural areas, such as timely, specialized and quality care at a distance, thus reducing the cost of mobilizing patients from their home towns to more specialized health centers.

This is why this type of telemedicine, as opposed to highly complex telemedicine, is classified as rural telemedicine. There are four important ser- vices offered in telemedicine: teleinterconsultation, teleconsultation, telemonitoring and teleorientation, in addition to two services that support the remote diagnostic: tele-ecography for prenatal controls and tele-dermatology for skin infections [4].

1) Teleinterconsultation: Remote consultation through the use of ICTs and carried out by a technician or health professional to another health professional regarding the care of a patient within the framework of competencies, for the purposes of prevention, promotion, diagnosis, treatment, recovery, rehabilitation and palliative care as appropriate.[11]

2) Telemonitoring: Remote monitoring and/or follow-up of the patient or user, in the IPRESS where clinical information is transmitted and managed. [11]

3) Teleorientation: Set of actions developed by a health professional using ICT. The objective is to provide the patient and/or health user with advice and counseling for the purpose of health promotion and disease prevention, recovery or rehabilitation. [11]

4) Tele-diagnostic support services:

a) Tele-echography: Remote ultrasound is a mod- ern telemedicine method recently tested in Peru. Diagnostic imaging by ultrasound helps to detect problems in pregnancy and other areas such as the abdomen and kidneys. This method was chosen to address especially in obstetric problems frequent in the target areas.

b) Tele-dermatology: this system allows specialized interpretation of the images by digitizing and transferring the data without the need to transfer the patient to the referral center. Tele- dermatology is required in these areas of the Amazon because dermatological infections are very common and are more harmful to children and newborns.

Innovative healthcare involves providing essential equipment and expertise to conduct definitive risk detection tests in regions lacking adequate funds and resources. Telecommunication networks play a vital role by connecting experts located many kilometers away. The reported initiative is demonstrated by the initial field implementation of the services along with future execution in the development of the design and acceptance by the community, the health facilities involved and the health personnel.

II. TECHNICAL CRITERIA AND METHODS

A. Design Criteria

For the analysis of the network architecture and the design of the telehealth system, only the six localities belonging to the project from Nieva to Galilea are considered (see Fig. 1), places where the telehealth network plan and telemedicine services will be implemented. Within this stage, the following should be considered:

- Deploy or extend connectivity all 5 health facilities in addition to the Hospital (Nieva).

- To guarantee connectivity, a technical evaluation is necessary in the cabinet for the future implementation of the transport network and telecommunications access.

This entails a consideration of the ground, the infrastructure of towers, the type of radio and antenna to be installed, frequency of operation, electrical protection and the energy system that will guarantee the continuous operation of the entire network.

- Likewise, it is necessary to establish agreements with the native communities of the areas, such as those belonging to Awajun and Awampis native nations, from whom strategic support is expected to strengthen the sustainability of the project.

- For the procurement of medical devices, the technology and capacity of each health facilities must be known in advance. In this specific case, each heath post was assigned a network data quota (data plan) and computers and portable devices for the use of telemedicine services.

- The consumption in Mbps must be anticipated for each type of telemedicine service to be implemented and determine, if required, unidirectional or bidirectional data traffic, in addition to considering cases of concurrency in use by more than one location at a given time.

Previous to the deployment of telehealth services such as remote training for health personnel, the existing staff for each health post should be mapped and identified. The difference in the number of health personnel and specialties per different locations should be considered in order to establish the correct flow of health care. For this reason, the number of personnel and the type of health facility in each community were analyzed, as shown in TABLE 1

B. System Structure Design

The design of the system structure, the protocol of care services and the management model for the use of services will be based mainly on the provisions of the Framework Law on Telehealth in Peru. The assurance of the management and introduction of ICT in health services at the national level, together with the "Dirección de Telemedicina" of the Peruvian Ministry of Health, allow this system to be formulated and innovated within the telehealth network of Condorcanqui, Amazonas [5].

TABLE I.
CATEGORY AND HEALTH PERSONNEL IN THE TARGET LOCALITIES

	Category	Health Facilities	N° Personnel
Health Posts	I − 1	Pagkinsta	13 health p.
	I − 1	Belén	4 health p.
	I − 1	Guayabal	3 health p.
	I − 1	Yutupis	17 health p.
Health Centres	I − 3	Red de Salud Condorcanqui	33 health p.
	I − 3	Puerto Galilea	14 health p.
	II − 1	Hospital Santa Maria Nieva	111 health p.

For the design of the telecommunications network, the complicated geography of the Santiago River basin, whose only transportation access is by river from the town of Nieva onwards, has been considered. For this reason, the telecommunications network has been divided in two parts: a backbone network and an access network, where the different client stations are interconnected in each locality.

A typical client station (see Fig. 2 and Fig. 3) is composed of equipment that enables wireless connection to the communication towers using the 5GHz band, and has equipment that provides wireless internet locally using the 2.4GHz band, in addition to a wired internet point of access, which will allow the user to connect in a specific place or in a place where local coverage is guaranteed. Likewise, to strengthen local communication between health sector institutions, there is an IP telephony system. And for power supply purposes, all stations obtain energy through solar panels and batteries, since in most locations a regular electrical utility is non-existent.

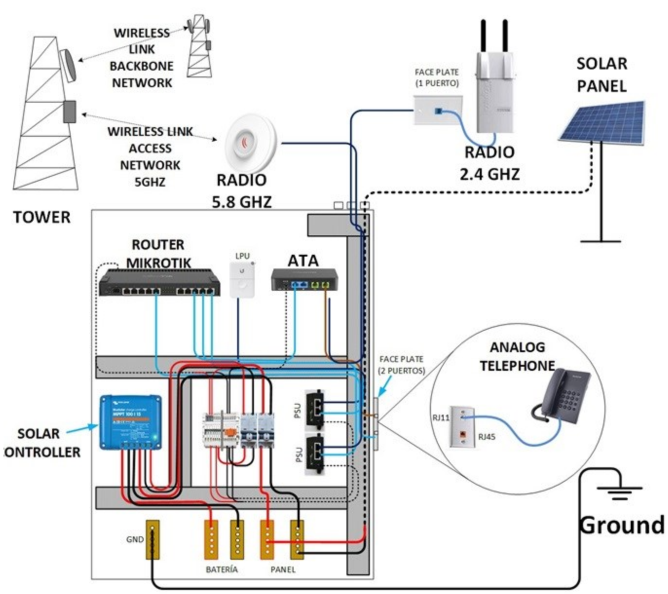

Fig. 2. Client Station system architecture

Therefore, each standard health post would have at least one laptop, VoIP telephony and internet connection for telehealth and telemedicine services, as well as a photovoltaic power supply and a power protection system. Suggested equipment to be installed are:

1) Mikrotik DISC Lite5 Radio 5.8 (to be used for interconnection with the tower and backbone).
2) Mikrotik BaseBox 2 Radio 2.4 (to provide local wireless connectivity)
3) ATA Gateway Grandstream HT812 and Analog telephone (for IP telephony)
4) Mikrotik RB2011iGS+RM (Router)

Finally, the EHAS Foundation proposed the Antari videoconferencing telemedicine platform of the Spanish technology company GMV. The Antari server, to be used as a healthcare platform, would be located in Nieva and would allow communication between networks, especially for telemedicine services via teleconferencing, so that each location would have a defined IP address within a corresponding pool of addresses.

III. TELEMEDICINE SERVICES DESIGN

The organizational scheme of the health network, together with the standard protocols for medical care in telemedicine, the Peruvian legal and regulatory basis, and finally the design criteria together with the protocol for compliance with network requirements, make it possible to describe the process of care and execution of procedures for medical activities in telemedicine in a sequential manner. This process comprises the actions executed by health professionals through the use of ICTs with the objective of providing counseling and advice to the user for the purpose of health promotion, prevention, recovery or rehabilitation of the medical situation [6].

Within this process, the protocol of care in the four areas for rural telemedicine are: teleinterconsultation, telemonitoring, teleorientation and telediagnostic support. Within the process of the last item, a different and more detailed flow is developed by specialization in two teleassistance processes: teledermatology and teleecography. For the first three telemedicine processes, the process flow of each activity in the framework of rural telehealth care is established.

A. Attention in rural telemonitoring

The telemonitoring care protocol will follow the same procedure as tele-consultation. The objective is to provide remote health care to users who require follow-up, control and monitoring of prevalent diseases in the rural area of Condorcanqui.

Fig. 3. Client station cabinets completed in initial phase (Hospital and Health network of Condorcanqui): a) Telephone for VoIP communication installed. b) Internal wiring for battery power consumption, connection to Access Point, ATA and batteries.

The scope of the rural telemonitoring service ranges from the reception of patients, together with their respective location, who require follow-up and the updating of data in the system, within the health care localities of Condorcanqui and Nieva. Figure 4 shows the system flow proposed for this service.

B. Attention in rural teleinterconsultation

For the protocol we define the input of the objective in the process, and the output will be the result of the process if it meets the defined objective. Within this we also detail the equipment/input along with the health personnel required. The objective is to provide the correct clinical advice and guidance in the treatment and care of the patient to the medical professional corresponding to the determined health facility.

As a scope, the care in rural teleinterconsultation begins with the request by the teleconsultant, processed, received and registered by the teleconsulted professional. All sup- ported through ICTs, ending with the reception of the user's consultation information and the printing of the final docu- ments generated for the file; within the health care localities of Condorcanqui and Nieva. Figure 5 shows the system flow proposed for this service.

C. Attention in rural teleorientation

In the same way as the other services provided, rural teleorientation services follow the same protocol. The objective is to provide counseling and advisory services in different specialties such as health care and promotion, risk and disease prevention and recovery or rehabilitation through ICTs in order to meet the demand for health guidance, reduce costs and differentiation in care within what can be covered in the planned health facilities in Condorcanqui and Nieva.

The general scope of rural tele-guidance care ranges from the users' request for tele-guidance to the registration of diagnosis and recommendations in the "Teleatiendo" web page of MINSA (Peruvian Ministry of Health), within the health care localities in Condorcanqui and Nieva. Figure 6 shows the system flow proposed for this service.

D. Rural Tele-diagnostic Support Services: Tele- dermatology

Teledermatology, as a remote dermatology practice, con- sists of care using ICTs to exchange medical information regarding skin conditions and diseases at a distance using audiovisual and data communication, including interaction between local medical staff and dermatological physicians who can define the diagnosis [7].

The diagnosis depends largely on the quality of the images sent. The correct diagnosis requires an overview about the distribution-location of the lesions on the skin, so the image capture and sending procedure must be adequate. Among the considerations for the project, there is a Manual for the Capture of Dermatological Images, which will be included in the telemedicine process of tele-diagnosis support.

E. Rural Tele-diagnostic Support Services: Tele-echography

Tele-echography has been tested in rural areas of countries on the African continent, where the process included the training of health personnel as operators for the acquisition of the images, so that the ultrasound is given in any remote context [8].

The functionality of tele-ultrasound in these cases consists of the health personnel acquiring the images with a portable ultrasound system. Then, these images are sent compressed and encrypted to the cloud where the specialist physician can generate the diagnosis.

For the particular case, the use of the Philips Lumify Ultrasound System will be employed, which offers mobile app-based ultrasound and provides an intuitive interface that aids in decision making and promotes confidence in treatment [9]. The technologies required for tele-ultrasound are an ultrasound scanner, an image acquisition system, and a diagnostic system. These features will help in the process with gestational checks, which are part of the most frequent clinical procedures with patients in the areas where the project is established.

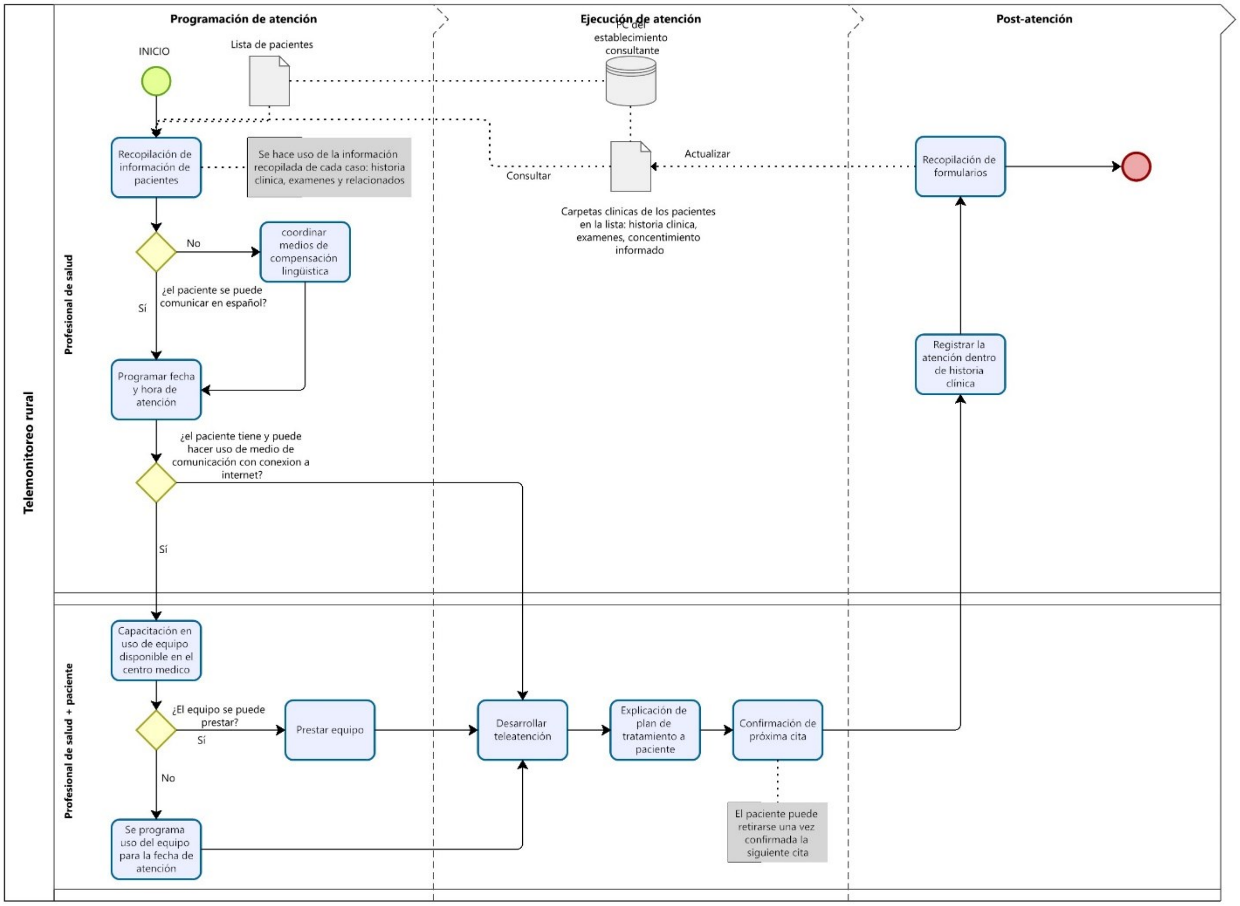

Fig. 4. Flow of attention in rural Telemonitoring service

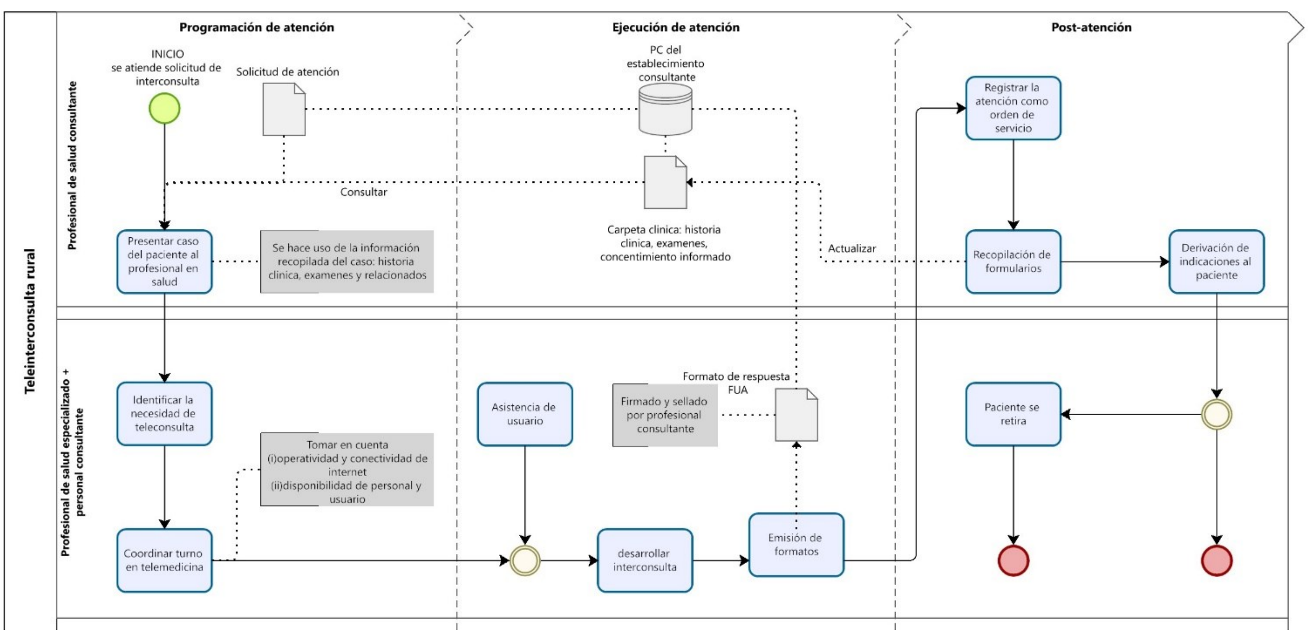

Fig. 5. Flow of attention in rural teleinterconsultation service

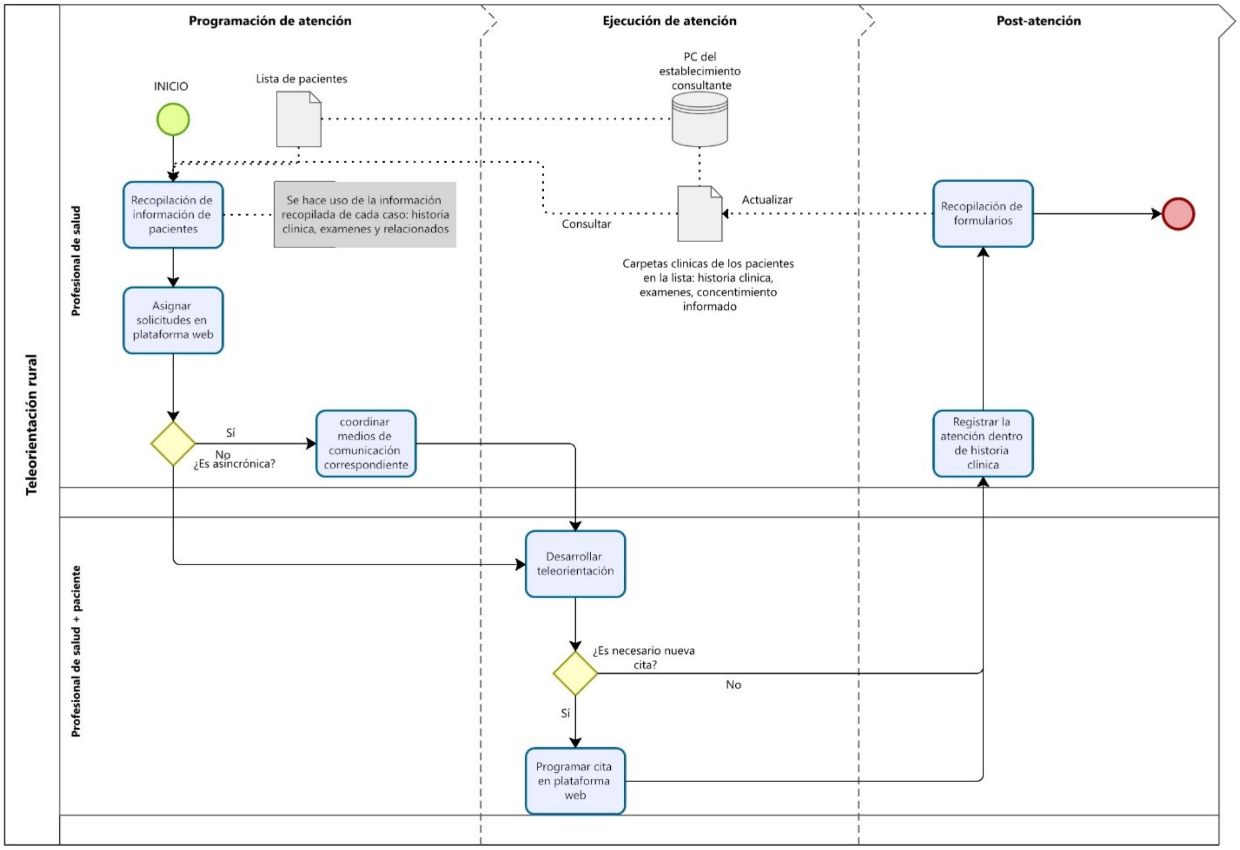

Fig. 6. Flow of attention in rural teleorientation service.

IV. RESULTS

In the initial phase of our fieldwork, we achieved significant milestones. We successfully established a robust network connection involving four stations in Nieva's primary locality. Notably, this included the Hospital of Nieva (HISMN) and two key entities within the Condorcanqui Health Network. To gauge the network's effectiveness, we conducted PING tests, revealing a low latency of 2 to 9ms and no packet loss. These results are well within the accept- able range, as indicated by prior research[10]. More complex telemedicine processes typically tolerate latencies up to 200 or 250ms, making our achievement noteworthy. During our extensive engagements with the micro-network, we achieved significant progress, particularly at HISMN Hospital. The hospital's director, along with the medical, nursing, and technical teams, wholeheartedly endorsed our telemedicine plan. This endorsement was formalized through a signed acceptance agreement, marking a monumental milestone.

This unanimous approval not only signifies a crucial step forward but also heralds a transformative era for healthcare in the region. The signed agreement not only validates our proposed telemedicine plan but also lays the foundation for a promising future of improved healthcare services throughout the region. Furthermore, the successful PING tests in both the Condorcanqui Health Center and HISMN Hospital mark the initiation of our telehealth initiative.

These accomplishments serve as foundational steps, paving the way for the broader implementation of telehealth services across the remaining communities in the Santiago River basin.

These developments not only affirm the viability of our rural telecommunications plan but also underline the promising future of telehealth and telemedicine services in the region.

V. DISCUSSIONS AND CONCLUSION

This work, together with the general proposal of the connectivity project, represents a significant challenge in the field of digital transformation and the development of Information and Communication Technologies (ICT) in rural areas of Peru, while contributing to improve the health of those who need it most today.

This approach and the solutions developed provide remote support to staff working in rural public institutions, giving them access to online content and tools related to their field, which in turn improves the quality of public services offered and transforms the perspective of health care in rural areas of Peru.

Both the field work and the development of the overall project have faced several complications and delays, challenges from external factors, such as the environmental conditions of the area, natural factors and incidences, as well as the collaboration and participation of local communities, infrastructure and location problems.

This has led to the conclusion that this type of initiative and related work requires the ability to face and solve problems, mostly of an engineering nature (but not limited to), in order to achieve success.

The key to innovation in health lies in the provision of equipment and human skills to perform fundamental tests for the detection of risks in places with few resources. In this case, telemedicine and telemedicine diagnostic support services were implemented, especially focused on maternal and neonatal health care.

With an effective connection between clients and servers, and the approval of the HISMN as a micro-network to advance this plan, it is concluded that the project initially proposed and the progress made by the authors have been satisfactorily completed.

As a future commitment, a further evaluation of the performance of telemedicine services implemented in health facilities will be carried out. This evaluation will address several aspects, including the performance of the telecommunications networks (both in transport and access) and the perception of users regarding the use of these networks and the services available. It is relevant to note that the current research was developed in an initial stage of the implementation of the telemedicine network, prioritizing the validation of the protocol proposal for its application in the interaction zone by Condorcanqui, located in a rural area of Peru. This proposal was locally approved by the Health Entity of the Rio Santiago basin, in addition to achieving acceptable values in terms of latency of the telecommunications network in one of the important locations of the project in general, which establishes an important metric to be replicated in the other stations.

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