ISBN: 978-628-95207-8-1. ISSN: 2414-6390. Digital Object Identifier: 10.18687/LACCEI2024.1.1.802

# Development and implementation of an itinerant satellite Internet access station for the Inca Trail in Cusco-Machu Picchu – Perú

Pastor David Chavez Muñoz[1] , Darwin Auccapuri Quispetupa [2] , Juan Paco Fernandez [3], Yuri Ronald Pacheco Jurado[4] , and Jordy Alania Guadalupe [5]

[1,2,3,4,5] Pontificia Universidad Catolica del Perú, Perú, dchavez@pucp.edu.pe, dauccapuri@pucp.edu.pe, jpaco@pucp.edu.pe, psptel@pucp.edu.pe, a20111019@pucp.pe

***Abstract*– This paper presents the design and implementation of a portable satellite station (Ku band) for itinerant multimodal Internet access, to be used on the Inca Trail route to the citadel of Machu Picchu – Cusco – Perú. A restrictive and challenging set of requirements had to be meet or exceeded such as low energy consumption, portability, and ease of deployment, all of them achieved via a field-tested prototype based on a simple but innovative approach.***

***Keywords-- tourism, satellite, Ku-band, Inca-trail, itinerant-wireless-communication.***

## I. Introduction

The Inca Trail is one of the established routes to reach the citadel of Machu Picchu. It is part of the so-called *Qhapaq Ñan* (Inca Road system) [1], which, since being declared a World Heritage site, has restrictions about infrastructure deployment. This route has an approximate length of 40 km, and in more than 90% of its course, there is no access to telecommunications services or electric energy supply of any kind being this a rural, isolated, and technology-deprived scenario, very common in rural Latin America. This situation makes it difficult for visitors (mostly international or national tourists) to access valuable information about the route and to carry out other relevant activities, such as communicating with their families or accessing social networks. On the other hand, tourism companies responsible for providing services to visitors cannot report and receive valuable information related to administrative management, control, and supervision of the service through their guide staff. Fig. 1 summarizes the specific characteristics regarding the deficit in access to telecommunications, energy, and transportation services. To address this engineering challenge, a portable station has been developed to provide itinerant Internet access.

Based on the identified challenge, a work - hypothesis has been formulated: the implementation of a connectivity system, initially using satellite technology due to the unique conditions of the Inca Trail route, as well as its historical significance, and due to its portability, would enable internet access at rest stops and facilitate the administrative management of the company.

**Digital Object Identifier:** (only for full papers, inserted by LACCEI).
**ISSN, ISBN:** (to be inserted by LACCEI).
**DO NOT REMOVE**

This benefit would constitute a significant competitive advantage and add value to the business model established by the company utilizing this solution.

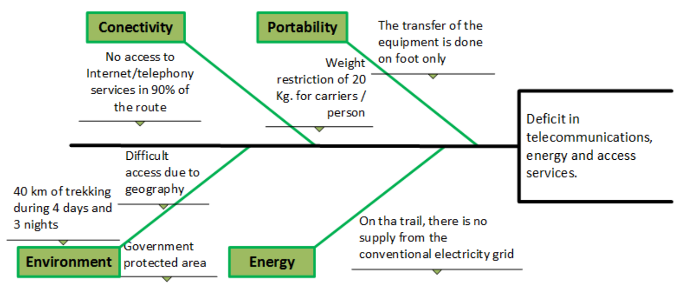


Fig. 1: Root-Cause analysis for the Inca Trail challenge, in terms of characterization for connectivity and access to energy and transportation

Based on the information provided above, the following objective was established: to implement a connectivity solution by means of a portable satellite station. This solution should enable the management of wireless internet access for visitors and guide staff (WLAN) and must come with a corresponding power support. Additionally, it should have a system that allows it to be positioned in rugged environments quickly and easily, with minimum usage of tools and appliances.

On the other hand, considering that the journey along the Inca Trail towards the citadel of Machu Picchu takes four days and three nights on foot, there are established places where visitors can rest, eat, and spend the night by setting up temporary camps as can be seen in Fig. 2.
The use of the portable connectivity solution will be enabled in these rest areas.

## II. METHODOLOGY

The following are the techniques and methods used to design and implement the prototype of the portable satellite internet access station:

a) Evaluation of the Inca Trail Route Scenario and its restrictions: topography, climate, flora, and fauna, among other aspects, must be considered. With its challenging 40 km extension, this route requires careful logistics for the transport of inputs. The porters, the real heroes of this footpath, face stringent weight restrictions according to Law 31614 [7]. Men can carry up to 20 kg, while women are limited to 15 kg. This compliance is monitored on the route. Therefore, it is important to consider the indicated restrictions in order to select the equipment and material associated with the overall solution. Exceeding the volume (due to narrow tunnels on the route) in addition to the weight, can make it difficult to move on the route, so it is essential to find a balance between efficiency, sustainability and compliance with the restrictions imposed by the environment and the authorities.

b) Technological assessment for internet service access and power system: the availability of technology for internet service access and the necessary resources for implementation should be evaluated. Additionally, options for power supply in the area must be considered.
c) Evaluation and development of mechanical support and housing: assess the users' needs, terrain, and weather conditions to develop suitable support structures. Also, considering options for housing the equipment to be transported and used in the area.

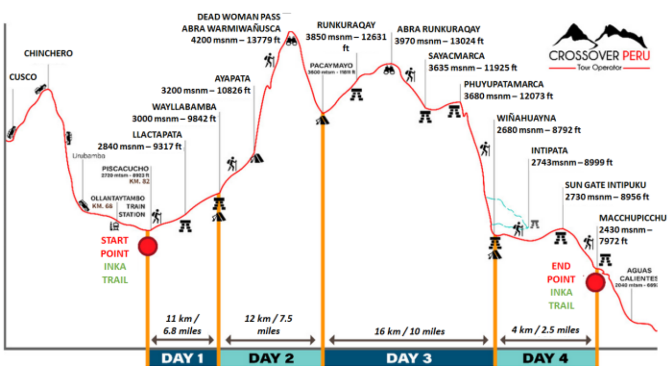

Fig. 2: Inca Trail route plan

d) Integration and laboratory testing: conduct tests with the different components of the system to ensure their proper functioning.
e) Deployment and field testing: perform tests under realistic conditions to ensure the system's proper operation. Also, consider deployment options available in the area.

## III. IMPLEMENTATION PROCESS

To achieve the established objective, from a technical standpoint, the solution has been organized into four main components or subsystems:

### *A. Satellite Connectivity Subsystem*

Para la selección de la conectividad satelital, se espera garantizar al menos una velocidad de conexión mayor a 500 Kbps y con acceso a datos de forma ilimitada, debido a que se espera el uso por hasta 16 usuarios, para ello se exploraron diversos fabricantes disponibles en el país, debido a su cobertura, portabilidad y presencia en el país, considerándose los siguientes:

a) Iridium GO [8][9], has international coverage, provides satellite connection speeds of up to 2.5 Kbps, and can provide access point via Wifi up to 30 m, allowing the connection of up to 5 users.
b) Cobham Explorer 710 BGAN Satellite Terminal [10], Proporciona velocidades de streaming de más de 600 Kbps out of the box, 3,5 Kg, 4h upload @ 128 kbps o 1h45 Streaming @ HDR.
c) HUGHES NET PERU [11], has an Internet access solution with speeds higher than 500 Kbps, which is achieved with fixed or static stations, which also require 1.2m antennas, and structures for their installation and fastening, which adding the weight can exceed 70 Kg (considering also a photovoltaic power supply with batteries), and access plans are limited in terms of data and use.

After extensive exploration, none of the three solutions were suitable for our needs. This was mainly due to the speed of Internet access, mobility and the lack of unlimited data plans. Since we are working on a route with little connectivity to other telecommunications services, our priority is to ensure connectivity at all times. We opted for a conventional solution, which will require specific adjustments according to the particular conditions of the Project, in addition to guaranteeing a certain robustness against the particular weather conditions of the site.

Therefore, an evaluation of the use of Ka and Ku frequency bands was conducted to determine which one performs better, considering specific characteristics of the project's intervention zone, such as weather conditions, the availability of transportable technology, attenuation and losses, and data packet transmission availability. Table 1 summarizes the specific characteristics of this satellite technology, as well as its availability in the Peruvian territory. Additionally, it should be noted that the assessment of options offered by satellite connectivity service providers in Peru was carried out in the year 2022.

Therefore, according to the evaluation, the Ku band is the one that meets the requirements for the project:

- This implies that the satellite station will be able to operate at the various points chosen along the Inca Trail route.
- Attenuation: The losses generated in satellite wireless communication due to weather conditions are considerable when there is presence of rain, cloudiness, and others. This is reflected with attenuation ranges quantified in other satellite stations according to the study

of [2]. Where the Ku band, operating at a lower frequency, is less attenuated than the Ka band.

- Package availability: According to inquiries from some providers such as Hughes net and ANDESAT, the second company is the one that provides service with unlimited packages.
- Although Ku-band access costs are expensive, they still allow to manage costs with respect to the business model in place, as well as guaranteeing speeds higher than 1 Mbps.

TABLE 1
CHARACTERISTICS AND COMPARISON OF KU-BAND AND KA-BAND SATELLITE SOLUTIONS.

| Characteristics | Ka Band | Ku Band |
|---|---|---|
| **Spectra** | 20/30 GHZ | 12/14 GHZ |
| **Weather conditions on the Inca Trail.** | In Cusco, Machu Picchu and the Inca Trail there are two distinct seasons: the dry season (April to October) and the rainy season (November to March). The rainiest months are January, February and March. | |
| **Availability of technology that enables transportation.** | No | Available |
| **Referential attenuation:** | 0,7 y 1,1, dB [2] | 0,11 dB a 0,18 dB [2] |
| **Availability of Data Package** | Limited Plans Company Ref. Hughes Net. | Unlimited Plans Company Andesat |
| **Price per Mbps** | Accessible | Expensive |
| **Access Speed** | higher than 1 Mbps | higher than 1 Mbps |

According to the premise, the selected satellite equipment must operate in Ku band, which will be composed by: satellite dish, satellite modem and connection accessories. Table 2 shows the components and characteristics of this satellite kit.

TABLE 2
CHARACTERISTICS OF SATELLITE KIT.

| Equipment | Description |
|---|---|
| VSAT satellite kit<br>Ku band | 1 Modem iDirect iQ:<br>• DVB-S2X (up to 100 Msps) outbound<br>• MODCODs up to 256APSK<br>• Adaptive TDMA return channel<br>• Dual GigE ports:1 for user traffic and 1 for mgmt. traffic<br>• 10 and 50MHz reference for BUC compatibility<br>• Modulation: QPSK, 8PSK, 16APSK, 32APSK, 64APSK, 128APSK, 256APSK<br>• Protocols Supported: TCP, UDP, ICMP, DHCP, NAT/PAT, DNS, ROHCv2, RIPv2, IGMPv2, IGMPv3, ICMP, IPv4 (IPv6 over L2oS), L3<br>1 BUC (Block Upconverter, 3W)<br>1 LNB (Low Noise Block) |
| | Input voltage between 100-240 V AC at 50-60Hz. Operating humidity is between 10-90% (non-condensing) and the operating temperature covers the range between 0° to 40°C (32° to 104°F) or between 0° to 35°C (32° to 95°F) at 10,000 ft. |
| Dish antenna | 1.2 meters fiberglass antenna in Ku band |

For the selection of this Ku band equipment, the following characteristics were considered:

- Less volume and weight: due to weight restrictions. The porters are support personnel on the road, who transport the materials, and the maximum weight is approximately 20 kg per person.
- Unlimited internet access: due to the concurrency of internet access by the staff of guides and users, it is required that the data plan be unlimited and unrestricted.
- Allow mobility: satellite technology must allow providing connectivity service using the same satellite station in different locations. This implies that the equipment must be able to provide satellite pointing and self-manage its own power supply.

In addition, there is a restriction due to volume issues, originated by the satellite dish, which has a diameter of 1.2 m, whose size represents a difficulty for transportation on the Inca Trail route. This is why its sectioning is proposed to transform the antenna into one like the fly away type, but at a lower cost as can be seen in Fig. 3.

Fig. 3: Satellite dish segmentation

To facilitate the transport of the satellite dish, a high-pressure water jet cutting process was used. This cutting method is fast and produces less deformation in the material, which ensures that the geometry of the dish is not altered and that the electromagnetic waves are adequately concentrated towards the LNB. In this way, the volume of the satellite dish is reduced, and transportation is facilitated without compromising performance. Fig. 4 shows the ideal positioning of the satellite dish as well as the sectioned components.

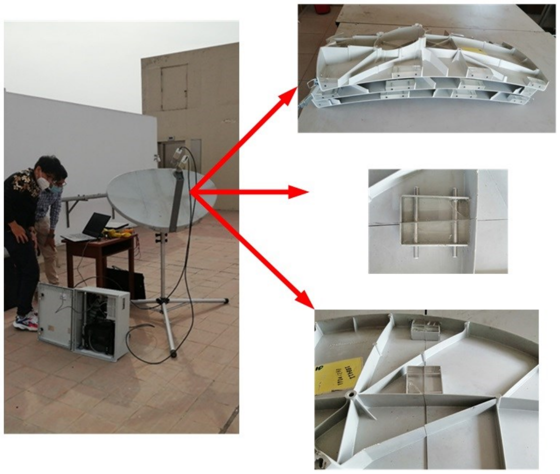

Fig. 4: Satellite dish segmentation test.

### B. *WLAN Subsystem*

For this subsystem, WiFi technology was evaluated, which is considered the most appropriate technology for the project scenario, considering its low power consumption, in addition to supporting a maximum of 16 users. The WiFi network access policies were determined for both guide staff and passengers. For this purpose, Mikrotik Groove52A model Wi-Fi equipment was tested, which operates in the 2.4GHz frequency and has been integrated with the satellite modem. This model has been tested in other scenarios, with low power consumption (6W) and features such an omnidirectional antenna to ensure coverage of at least 10 to 20 m around. Fig. 5 shows the type of connection.

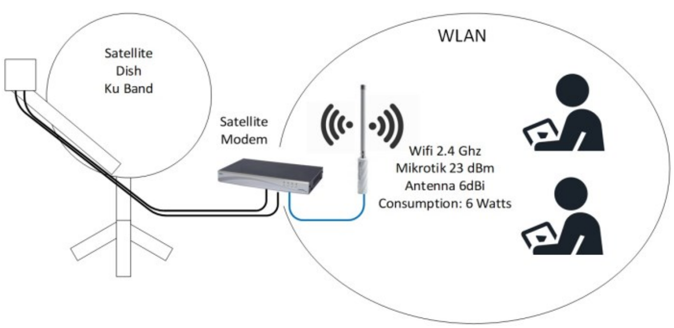


Fig. 5: Wireless LAN subsystem – connections

For equipment selection of the following criteria were considered: power consumption in W, operating frequency, external antenna, IP protection for outdoor use and operating temperature.

According to Table 3, the equipment selected is the Groove52 model, since it offers a higher operating temperature range. This is important since the equipment will operate in climatic conditions such as the Amazon Basin rain forest or Andean valley with high temperatures, a peculiar characteristic of the Inca Trail route. In addition, the equipment is designed to operate outdoors. While the other equipment, although they have lower energy consumption and allow outdoor operation, they have a limited range of operation at high temperatures.

TABLE 3
COMPARISON OF WIRELESS EQUIPMENT FOR THE ACCESS NETWORK.

| Features | Groove 52 Mikrotik | DAP-1665 | TL-WA901ND |
|---|---|---|---|
| **Operating frequency** | 2.4 GHz | 2.4 GHz | 2.4 GHz |
| **External antenna** | yes | yes | yes |
| **Consumption** | 6 W | 5.18 W | 5.8 W |
| **External use** | Yes | No | No |
| **Operating Temperature** | -30°C to +70°C | 0 to 40 °C | 0°C-40°C |

### C. *Energy supply subsystem.*

Since the intervention area is a nature reserve (no emission of polluting gases, no modification of the environment, etc.), the only option for power supply was a photovoltaic system. To design this solution, the energy consumption of the satellite station and the other components was evaluated. This analysis made it possible to calculate the capacity required for the battery and the solar panel. Another parameter considered was the total weight of the photovoltaic system, as it was essential to ensure its portability (low weight and ease of deployment). The following activities were carried out for the design of the energy system:

- Estimation of the expected solar radiation availability based on the historical record for the Inca Trail area.
- Estimation of the energy consumption of the satellite system according to the usage regime defined by the company.
- Calculation of the capacity of the battery bank and solar panels needed to cover the demand.

#### i. *Estimation of solar radiation availability*

To estimate the availability of solar radiation on the Inca Trail, two sources of information were compared: the information on daily incident solar energy contained in the Solar Energy Atlas of Peru for the Cusco Region prepared by SENAMHI (period 1975 - 1990) and the historical information corresponding to the period between January 1, 1984 and December 31, 2021 according to NASA records.

According to the SENAMHI Solar Energy Map (see Fig. 6), the worst case of radiation occurs yearly in the month of August, and, for the Inca Trail area, it circles around a value of 4.6 kW-h/$m^2$/day.

On the other hand, to obtain the historical information in the NASA tool, geographic coordinates corresponding to the central area of the Inca Trail were used, considering that the differences in values with readings from other points along this route are minimal.

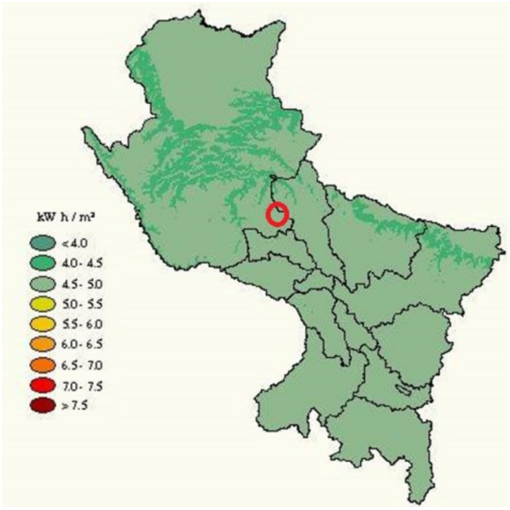


Fig. 6: Solar Radiation in Cusco - SENAMHI, August, yearly most unfavorable month in records.

A first statistical analysis was performed on this information, which is shown in Fig. 7. Then, having identified the maximum and minimum values, an estimation of the worst case of radiation was made based on the statistical distribution of the data.

As can be seen, only 10% of values are below 4 kW-h/m$^2$/day, this value being a first approximation to define the worst case. Based on this first approximation, the segment between 4 and 5 kW-h/m$^2$/day was analysed considering only all the months of August (38 years, 1178 records).

| Clase | Frecuencia | % acumulado |
|---|---|---|
| 0 | 0 | 0.00% |
| 1 | 1 | 0.01% |
| 2 | 19 | 0.14% |
| 3 | 198 | 1.57% |
| 4 | 1168 | 9.99% |
| 5 | 3557 | 35.61% |
| 6 | 5272 | 73.60% |
| 7 | 2828 | 93.97% |
| 8 | 715 | 99.12% |
| 9 | 118 | 99.97% |
| 10 | 4 | 100.00% |
| y mayor... | 0 | 100.00% |

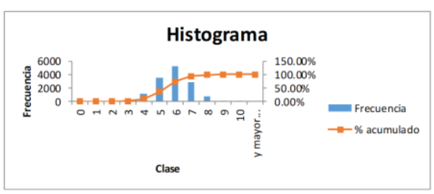


Fig. 7: Distribution of occurrence of solar irradiance readings.

According to the information provided by NASA, solar irradiance on the Inca Trail has been greater than or equal to 4.6 kW-h/m$^2$/day on at least 80% of the total days during the months of August (see Table 3). With this result, it is considered sufficient, as a worst case, to assume the value obtained from the SENAMHI map (4.6 kW-h/m$^2$/day).

TABLE 3
SOLAR IRRADIATION ON THE INCA TRAIL (MONTH OF AUGUST).

| Range | Quantity. | Percentage |
|---|---|---|
| less than 4 | 119 | 10.11% |
| less than 4.6 | 229 | 19.46% |
| less than 5 | 342 | 29.06% |

*ii. Energy demand estimation*

Having determined the minimum expected irradiation for the Inca Trail, the energy demand for the portable satellite system was calculated according to the usage regime proposed by the company. The number of hours of use of the satellite system is shown for each day during the trip (see Table 4). It should be noted that the system is used only when the camp is deployed in selected locations on the Inca Trail.

TABLE 4
DAILY RATE OF USE

| Summary per day | Day 1 | Day 2 | Day 3 | Day 4 | Average |
|---|---|---|---|---|---|
| Charging hours | 5.5 h | 4.5 h | 5.5 h | Not in use | 5.17 h |
| Hours of use during the day | 2 h | 3.5 h | 4.5 h | Not in use | 3.33 h |
| Hours of use at night | 1.5 h | 1 h | 2.5 h | Not in use | 1.67 h |
| | Start of tour | | | Arrival at Machupicchu | |

*iii. Calculation of the photovoltaic system capacity*

To determine the characteristics of each component it was necessary to perform the corresponding calculation for each site. They are calculated according to the criterium suggested by Araujo et al. [3], where the capacity of the batteries in AH and the capacity in Wp of the solar panels are calculated. In addition to the estimated autonomy for each site, which varies depending on the amount of equipment and about what is established by the daily consumption regime, which is shown in Table 5.

TABLE 5
HOURS OF OPERATION PER DAY

| LOAD | Consumption (W) | Qty. | Hours (aprox.) |
|---|---|---|---|
| Satellite Modem | 42 | 1 | 5 |
| Access point - Mikrotik Groove | 10 | 1 | 5 |
| Solar charging and inverter equipment (self-consumption) | 6 | 1 | 5 |

As a result, a 120 Wp panel and a 50 Ah battery are needed to cover the daily energy requirements of the portable satellite system during the Inca Trail. Additionally, two battery models were evaluated (see Table 6), choosing the smart battery due to its lower weight and additional features.

TABLE 1
BATTERIES EVALUATED

| Type of battery | Weight | Size | Brand |
|---|---|---|---|
| Pb Gel 55Ah, AGM | 15.5 kg | 22.9X13.8X21.6 mm | RITAR [4] |
| LFP (LiFePo4) 50 Ah 12 VDC | 6.75 kg | 195.6x163.8x171.5 mm | SMART BATTERY [5] |

### *D. Mechanical support and portability*

The development and manufacture of the mechanical support was based on the needs formulated by the user: positioning in rough terrain, positioning for satellite alignment manually and no tools required for the assembly.

Based on the requirements, a tripod has been built and modified, which allows to be assembled in a simple way, in addition to a positioning system for rough floors and to have a guaranteed horizontal level for the satellite dish, as well as for its adequate transportation.

The process is shown in Fig.8. For the manufacture of a tripod of such characteristics market-available building materials were used such as tubes, plates, aluminium angles and rivets, bolts, nuts, and epoxy resin (in liquid form).

In turn, for the canister, an important part of the positioning system for the satellite station, an adaptation was performed according to the requirement that everything be manual and not require the use of any tools, in addition to lightening the weight of the canister that comes from the factory. Fig. 9 shows the comparison and the installation mode.

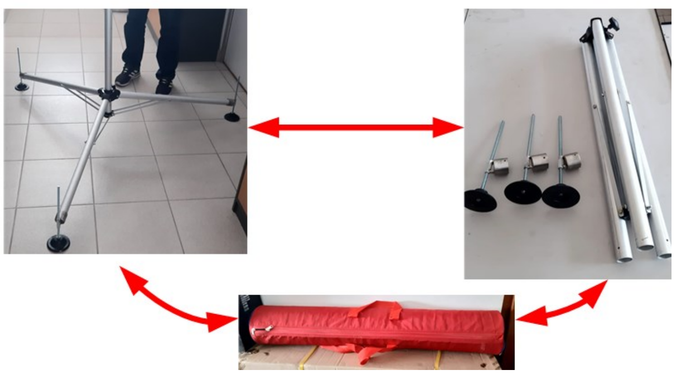

Fig. 1: Mechanical tripod support

Finally, for the housing of the equipment, it was necessary to use an IP65 enclosure, suitable enough for outdoor use. This is shown together with the integration of the entire portable satellite system in Fig. 10.

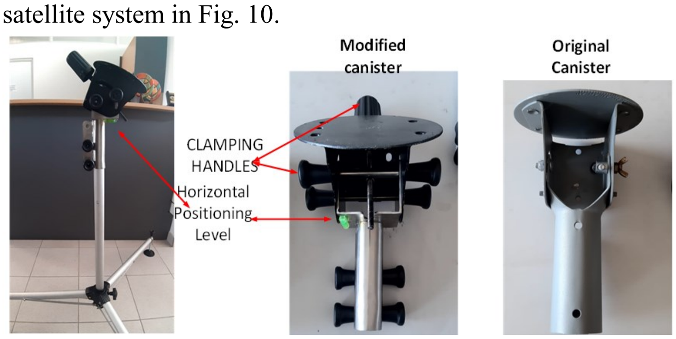


Fig. 9: Modification of canister - satellite station.

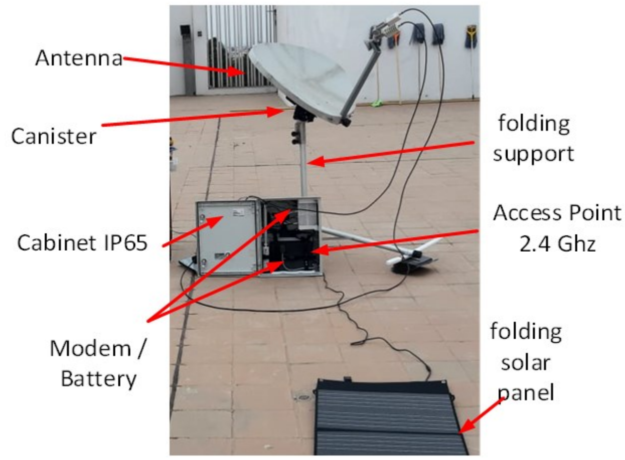


Fig. 2: Integration of support and equipment.

## IV. TESTS AND RESULTS

For the validation of the prototype operation a set of tests were designed and carried out with the following objectives:

- Verification of the performance offered by the satellite service contracted to ANDESAT and the impact of the parabolic reflector sectioning (dish antenna).
- Performance testing of the wireless equipment (WiFi network).
- Evaluation of the performance of the power supply system (autonomy time, charging and discharging).
- Validation of the functionality of the VSAT mechanical alignment and support system, which was modified to avoid the use of tools and reduce installation time.

### *i. Satellite link performance:*

The tests were performed at the PUCP campus. With geo referential location at 12.04.23 S 77.04.58 W, azimuth of 51° and elevation of 68.33°, antenna gain: 37.8 dBi RX / 39.3 dBi TX (+-2dBi), FEC: DVB-S2 16APSK 5/6 64800 and coding efficiency: 56%.

The Speedtest.com tool was used, running in a device connected as the only client to the LAN network. Obtaining the speed of 0.37/0.8 Mbps considering a 2Mbps/1Mbps plan at 40% capacity. See Fig. 11.


Fig. 3: Satellite link capacity measurement results

On the other hand, considering that the solution for the portable system implied that the reflector be sectioned into three pieces, the reception level of the station was measured using both an un-sectioned reflector and the one that had already been sectioned.

While the values vary for each measurement, the SNR value for the second case was lower but quite close (difference of less than 0.2 dB) to the value measured using the unmodified reflector (values around 13.6 dB with good alignment).

Wireless network (WiFi) range: The tests were performed in open space and with the VSAT system in operation. The test range was between 1 and 20 meters from the system to the terminal device for tests, with measurements at every 1 meter. The limitation of the distance is because the campsites have in some cases a reduced camping space of 15m across.

For this purpose, 2 measurements were performed, which are shown in Fig. 12. The signal level in no case was less than -67 dBm for a range equal to or less than 15m. These levels are considered within the "Good" classification defined by the application.

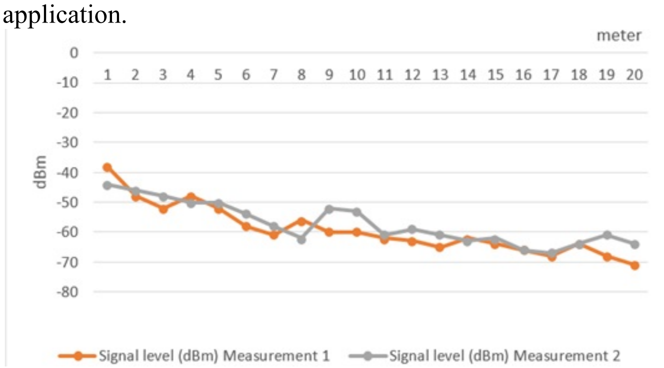


Fig. 12: WiFi - Signal level vs. distance.

*ii. Evaluation of the energy supply system:*

For the evaluation of the photovoltaic power supply system, two possible scenarios or configuration alternatives were defined:

- A kit that integrates the three necessary equipment in a PV system (battery, controller, and inverter) was used.
- The second scenario consisted of using the battery, controller, and inverter as separate elements.

For the first test, an AllPowers integrated power supply, model AP-SS-007, was used, which provides 606Wh, which is close to the 600Wh that a 12 VDC/50Ah battery would generate independently. Being an equipment with similar capacity. And as a result of the consumption, without the use of solar panel, having all the equipment of the satellite station, a verification of the capacity of this equipment was made, which during an operation of more than 5 hours the capacity of the integrated power supply was still maintained at 70% of its capacity (see fig.13), which means that we could exceed 10 hours considering about 10 hours of operation. This exceeds the requirements of the entity for use on the Inca Trail.

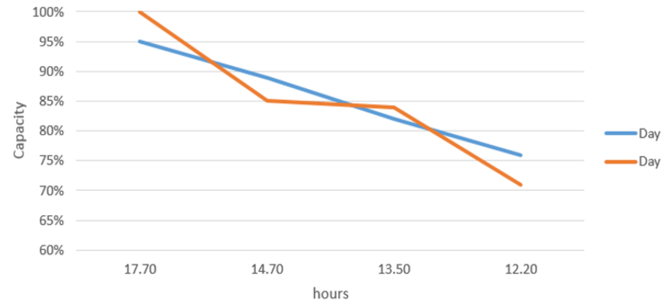


Fig. 13: AllPower Power Supply capability during operation, without solar panel.

For the second test scenario, an ExperTPower battery, model LiFePO4, a Victron Energy voltage inverter, model Phoenix12, a DOKIO 12/24V solar controller and a DOKIO solar panel, model FFSP-220M, were used. Table 7 shows the readings for the system in operation.

Taking as evaluation criteria the performance, ease of installation and total weight, the system with integrated power supply was the final choice. After that, the performance of the portable system was evaluated, considering the incorporation of a solar panel, in this case a 120 W ECO-WORTHY panel, model 12V Foldable Solar Panel Suitcase.

TABLE 7
MEASUREMENTS, CONSUMPTION SEPARATE SYSTEM.

| Test | Hour | Battery | | In Inverter | | Out Inverter | |
|---|---|---|---|---|---|---|---|
| | | Voltage (DC) | Current (DC) | Voltage (DC) | Current (DC) | Voltage (AC) | Current (AC) |
| Test1 | 13.16 | 13.58 v | 3.9 A | 13.69 V | 2.75 A | 227 V | 0.146 A |
| Test2 | 13.46 | 13.54 v | 3.49 A | 13.62 V | 2.72 A | 227 V | 0.145 A |

The scenarios considered where “cloudy sky” and “sunny sky”, obtaining that in sunny sky conditions, the approximate exposure of one hour could yield an increase of 8% more operating capacity for the integrated power source which is about 60 minutes of increase in operation time. In cloudy sky conditions, only an increase of about 20 minutes of operation time is expected (see Table 8).

TABLE 8
FUNCTIONAL TEST INCORPORATING SOLAR PANEL.

| Weather | Usable capacity of the portable power supply (all power) | | | | Test Time (minutes) |
|---|---|---|---|---|---|
| | Start | End | Increase of capacity (%) | Increase of capacity (minutes) | |
| Sunny | 37% | 41% | 4% | - | 30 |
| | 42% | 50% | 8% | 65 | 60 |
| Cloudy | 50% | 53% | 3% | 20 | 60 |
| | 53% | 54% | 1% | 21 | 60 |


Fig. 4: Portable satellite station testing at 4 campsites along the Inca Trail Route.

In summary, the result was a fully functional prototype that meets the requirements of the activity for which it was designed and incorporates innovative aspects that provide a competitive advantage over equivalent products on the market.

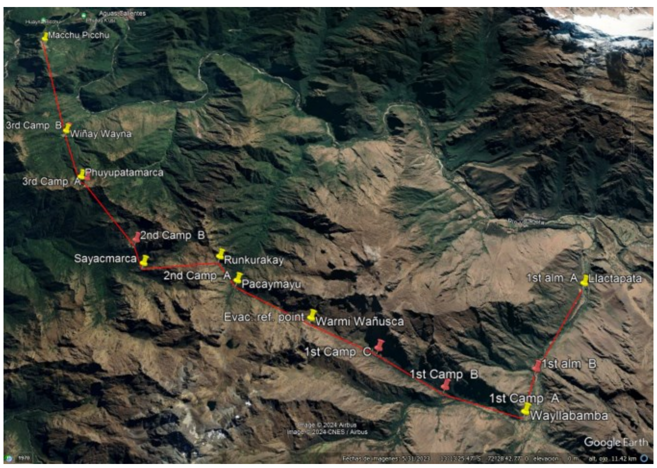


Fig. 5: Inca Trail Route. It starts at the 82nd km of the railroad to Macchu Picchu.

## V. CONCLUSIONS AND FUTURE WORK

- A portable solution was designed and validated able to provide connectivity (Internet access) on the Inca Trail route with independent power supply (photovoltaic system).
- Considering that the assembly and operation of the station requires an average of 16 minutes, its use is considered viable from the functional point of view.
- The adaptation of the tripod and the satellite dish to be set up without requiring any tools has proven to be an important factor that facilitates deployment and makes it accessible to people with basic knowledge of the system.
- Despite the above, it is considered necessary for the personnel in charge of the operation to have basic knowledge of electricity and networks.
- By extension, this solution can be applicable to various rural environments in third world countries that do not have access to telecommunication services and power supply. This portable station could even be used in nature reserves and protected areas such as the Inca Trail.
- Considering that this solution was chosen as a finalist in the national inventors contest 2022 [6] and that a patent application for a utility model is being processed at INDECOPI, there will be a continuation of the optimization incorporating improvements in the power system and testing with an Internet access service based on low earth orbit (LEO) satellites. In relation to the patent application, it is considered that the publication of this article would not affect this process since the application was filed at the beginning of the year 2023.

## ACKNOWLEDGMENT

The research resulting in the present paper has been sponsored by the Rural Telecommunications Research Group (GTR PUCP) from the Department of Engineering at PUCP , CROSSOVER PERU SAC Company, and ProInnovate.

## REFERENCES

[1] UNESCO, "Qhapaq Ñan - Sistema vial andino" 2014. [Online]. Available: https://whc.unesco.org/es/list/1459. [Accessed 01 09 2023].

[2] T. Omotosho, "Atmospheric Gas Impact on Fixed Satellite Communication Link," Proceeding of the 2011 IEEE International Conference on Space Science and Communication (IconSpace), p. 1, 2011.

[3] G. C. L. C. D. C. C. C. J. R. Araujo, "Redes inalámbricas para zonas rurales (2da edición).," 2011. [Online]. Available: http://gtr.telecom.pucp.edu.pe/download/publicaciones/Libro%20RIpZR%. [Accessed 01 09 2023].

[4] ES, "RITAR RA12-55," 2023. [Online]. Available: https://nes.com.pe/wp-content/uploads/2022/10/RA12-55.pdf?v=3827b7f36786. [Accessed 01 09 2023].

[5] E. SOLAR, "12V 50AH Lithium ion Battery," 2023. [Online]. Available: https://www.enfsolar.com/pv/storage-system-datasheet/1102?gclid=Cj0KCQjw9MCnBhCYARIsAB1WQVVbTgWpyLoWOkajFMg-ySrnR10w8xDuonXLH-7zsgfesO6vlEMXKQwaAv5wEALw_wcB. [Accessed 01 09 2023].

[6] INDECOPI, "FINALISTAS DEL CONCURSO NACIONAL DE INVENCIONES 2022," [Online]. Available: https://www.indecopi.gob.pe/documents/2487468/3447881/FINALISTAS+CNI+2022.pdf. [Accessed 01 09 2023].

[7] Nueva Ley del trabajador Porteador, LEY nº 31614, Congreso de la República del Perú.2022. [Online]. Available: https://busquedas.elperuano.pe/dispositivo/NL/2124493-4. [Accessed 05 05 2024].

[8] IRIDIUM GO !,Iridium Communications, [Online]. Available: https://www.iridium.com/products/iridium-go/

[9] Teléfono satellite IRIDIUM GO, VERASAT, Satelite Communications [Online]. Available: https://www.verasatglobal.com/producto/telefonos-via-satelite/iridium-go/

[10] Cobham Explorer 710 BGAN Satellite Terminal [Online]. Available: https://www.bluesat.com/cobham-explorer-710-bgan-terminal.html

[11] Planes de Conexión, HUGHES NET PERU, [Online]. Available: https://www.hughesnet.com.pe/buscar-planes