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Thesis

Layer 2 over satellite implementation in iDirect

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Dedication 1

My deepest gratitude goes to God who has provided all that was needed to complete this project

To my dear mother and sister who offered endless support and encouragement through my academic track.

Dedication 2

May the dedication and perseverance showcased in this work serve as a testament to the values instilled in me by my family, as well as a token of my gratitude to each and every one of you.

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Abstract

This thesis examines transmission through one of the best satellite technologies « the VSAT technology » which operates in different frequencies shapes and sizes Normally, the operating frequencies are C-band and Ku-band and work with Star Network (Private Hub), Point-to-Point (Customized Private Hub) capable of supporting a large number of places and Mesh Systems, which are regularly smaller than star systems this type of antenna offers satellite services capable of supporting Internet, LAN, IP Voice, video and data communications; thus, creating powerful public and private networks for reliable communication. Among the best platforms used by VSAT to transmit Data is the iDirectplatform. Among the services (programs) offered by iDirect is the iBuilder program which we use to implement Layer 2 over satellite. A standard iDirect installation is composed by two separate network segments: upstream and tunnel, connected by the upstream router. Two switches are required. The upstream switch is used by all the elements connected to that network segment while the tunnel switch is mainly used for the communication between the Protocol Processor Servers and the Line Cards. The user traffic will appear as clear traffic on the upstream network all the user traffic that needs to be sent towards any particular remote is processed by the Protocol Processor Servers. When configuring a new remote on the network the system will automatically assign one Protocol Processor Server to manage the traffic traveling to that particular remote .When an iDirect network is configured for L2oS, Ethernet frames, rather than IP packets, are transported across the satellite link. Layer 2 connectivity between the hub and remotes is preferred over the Layer 3 IP connections traditionally offered by iDirect. The benefits of using L2oS include: Layer 3 transparency, efficient physical layer and simplified operations.

Key words: VSAT, L2OS configuration, Data transmission, iDirectplatform, Ethernet Frames, iDirectnetwork.

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Acronyms :

ATM: Automated Teller Machine

ATS: Advanced Technology Solutions

BCH: Bose-Chaudhuri-Hocquenghem

bps: Bits per Second.

bs-1: Bits per second

BSS: Broadcasting Satellite Service

C-band: Communications band in the electromagnetic spectrum (around 4 to 8 GHz)

CE: Customer Edge

Comtech: Communications Technology

DAMA: Demand Assigned Multiple Access

DoS: Denial-of-Service

DVB-S: Digital Video Broadcasting by Satellite

EIRP: Effective Isotropic Radiated Power

EVC: Ethernet Virtual Connection

FEC: Forward Error Correction

FSS: Fixed Satellite Service

G/T: Gain-to-Noise Temperature ratio

GQoS: Group Quality of Service

HLC : Hub Line Card

iDirect: Integrated Direct

IP: Internet Protocol

ITU: International Telecommunication Union

Ka-band: Communications band in the electromagnetic spectrum (around 26.5 to 40 GHz)

Ku-band: Communications band in the electromagnetic spectrum (around 12 to 18 GHz)

L2oS: Layer 2 over Satellite

LAN: Local Area Network

Layer 2: Second Layer of the OSI Model

Layer 3: Third Layer of the OSI Model

LDPC: Low-Density Parity Coding

LNB: Low-Noise Block downconverter

MAC: Media Access Control

MODCOD: Combination of Modulation Types and Error Coding schemes supported by the DVB-S2 standard.

Newtec: New Technology

NMS: Network Management System

NTSC: National Television System Committee

OPT: Option File

PAL: Phase Alternating Line

PAMA: Pre Assigned Multiple Access

PC: Personal Computer

PE: Provider Edge

POS: Point-of-Sale

PP: Packet Processor

PSK: Phase Shift Keying

RJ-45: Registered Jack 45 (a connector commonly used for Ethernet connections)

RS-232: Recommended Standard 232

RS-422: Recommended Standard 422

RTT: Round-Trip Time

SAT: Satellite

SCPC: Single Channel Per Carrier

SDT: Satellite Data Terminal

SECAM: Séquentiel couleur à mémoire (Sequential Color with Memory)

SVN: Satellite Virtual Network

TDMA: Time Division Multiple Access

TV: Television

V35: V.35 (a serial interface standard)

VLAN: Virtual Local Area Network

VLAN: Virtual Local Area Network

VPLS: Virtual Private LAN Service

VPWS: Virtual Private Wire Service

VPWSEPC: Virtual Private Wire Service-Evolved Packet Core

VSAT: Very Small Aperture Terminal

X21: X.21 (a serial interface standard)

X-band: Communications band in the electromagnetic spectrum (around 8 to 12 GHz)

General Introduction

Since the ancient times, man has constantly tried to make improvements in our daily lives in different areas, in order to make life easier. These areas include telecommunications - transmission or reception of signals, data, sounds, images, videos and any other information by wire, optical or other electromagnetic system- whose current development sees the introduction of new information transfer techniques such as satellite[1]. Currently, satellite communications are one of the most important foundations of our telecommunications systems. Their uses have become more frequent in everyday life and offer as services: teaching, live chat, link regions (in the event of natural disasters or wars).[2]

Very Small Aperture Terminal technology is considered one of the most advanced satellite technologies available. It encompasses a variety of frequencies, shapes, and sizes, catering to different communication needs. [3]Typically, VSAT systems operate in the C-band and Ku-band frequencies, utilizing various network configurations such as Star Network (Private Hub), Point-to-Point (Customized Private Hub), and Mesh Systems[3]. These configurations enable the technology to accommodate a wide range of locations, with Mesh Systems being particularly suitable for smaller networks comprising around 5 to 30 sites.[3]

The versatility of VSAT technology extends to its ability to support diverse communication services. With this type of antenna, satellite services can facilitate Internet access, LAN connectivity, IP Voice, as well as video and data communications. [3]This comprehensive support allows for the creation of robust public and private networks,ensuring reliable and efficient communication channels. [3]

VSATs use different platforms to transmit and receive data via satellites, egiDirect, Newtec, Comtech, Datum.***4 With a culture of innovation and a long history of pushing technology boundaries iDirect represents one of the best platform choices.[4]

The implementation of Layer 2 over Satellite (L2oS) in iDirect provides service providers with a valuable choice for operating their networks. It offers an efficient Layer 2 bridging mode as an alternative to the conventional Layer 3 routing architecture. This end-of-study work entitled “Layer 2 over Satellite implementation in iDirect” is presented under the following 3 chapters:

Chapter 1: " VSAT technology" in which we presented general concepts on the VSAT network, its architecture and design, the applications and the services offered by this technology.

Chapter 2: "The implementation of L2os in the iDirectplatform " in which we presented the iDirect architecture , the definition of L2oS , its reference model and configuration also the benefits obtained through using L2oS

Chapter 3: "Practical case" In this chapter, we will simulate a practical case of configuring L2oS using the iDirect platform.

Chapter 1: VSAT Technology

1 Introduction to VSAT technology:

Originally, VSAT stood for Very Small Aperture Terminal, and it was initially introduced as a trademark by Telecom General in the 1980s within the small earth station market in the USA. Over time, it has become a widely used generic term, likely due to the appealing association of its first letter "V," evoking a sense of victory, and "SAT," which unmistakably relates to satellite communications. The purpose of this chapter is to examine the configuration, applications, and design of VSAT networks.

2 VSAT definition :

A VSAT, also known as an earth station, serves as a device for receiving satellite transmissions. The term "very small" in the VSAT acronym pertains to the size of the dish antenna, typically ranging from 3 to 6 feet in diameter. This antenna is typically mounted on a roof, wall, or placed on the ground. Together with the attached low-noise blocker (LNB) that receives satellite signals and the transmitter responsible for signal transmission, the outdoor unit forms a vital component of the VSAT earth station.

The indoor unit comprises the second component of the VSAT earth station. It takes the form of a compact desktop box or PC housing receiver and transmitter boards, as well as an interface to establish communication with existing in-house equipment such as LANs, servers, PCs, and TVs. To establish connectivity, the indoor unit is linked to the outdoor unit via a pair of cables. [5]

3 VSAT architecture and design:

The VSAT network can be configured in two possible topologies, starry and meshed. Star topology enables point-to-point connectivity multipoint whose communications pass through the Hub where they are controlled.

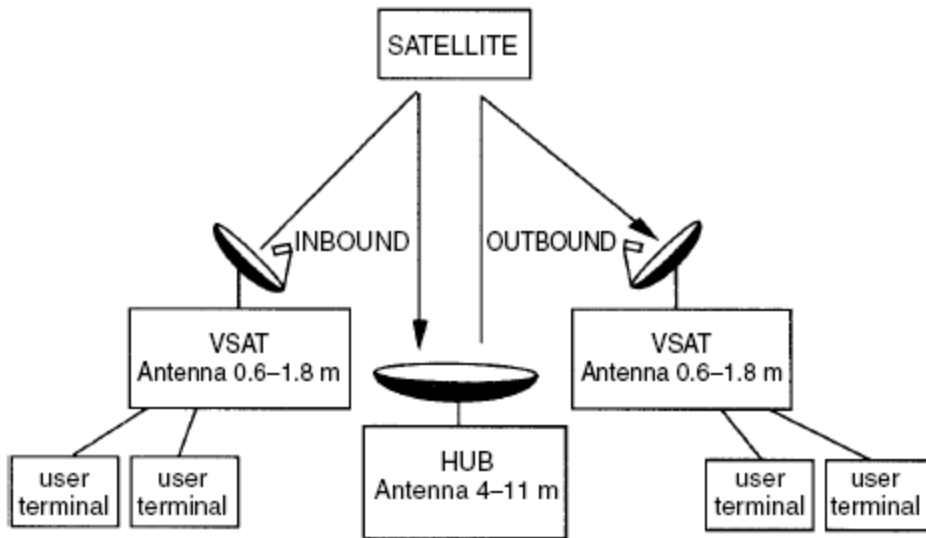


Figure 1 :Star Topology

For the mesh network, permanent or temporary point-to-point connectivity exists between each pair of VSAT passing through the satellite. The choice of the appropriate architecture depends on three factors :

- the structure of information flow within the network;
- the requested link quality and capacity.
- the transmission delay.

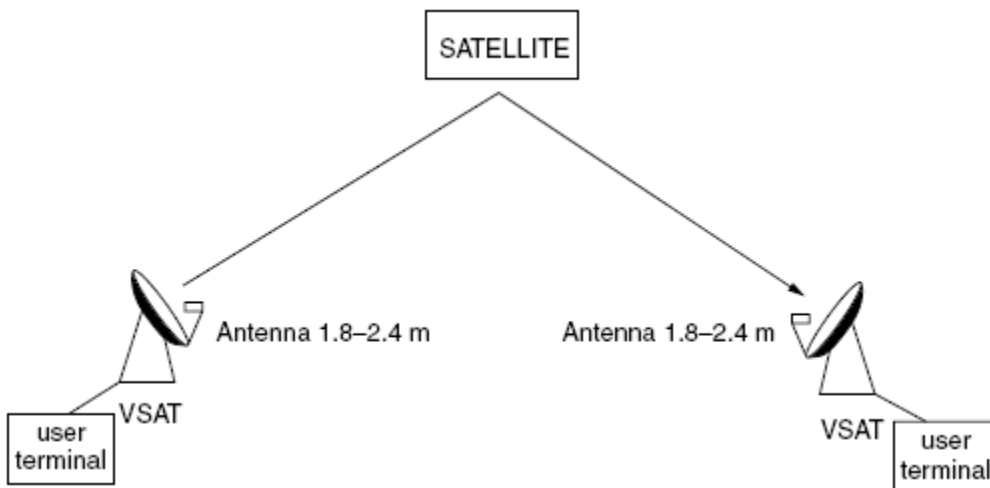


Figure 2: Mesh Topology

3.1 Structure of information flow :

Each type of application supported by VSAT networks requires an optimal network configuration:

3.1.1 Broadcasting:

In a scenario where a central site distributes information to multiple remote sites without any backflow of information, a cost-effective approach is to employ a star-shaped one-way network to support the service.

3.1.2 Corporate network:

In many cases, companies adopt a centralized structure where administration and management activities are concentrated at a central site, while manufacturing or sales operations are dispersed across various locations. Effective decision-making requires gathering information from remote sites to the central site, while distributing relevant information such as task sharing details from the central site to the remote ones. To support this information flow, a star-shaped one-way VSAT network can be utilized for partial functions like information distribution. Alternatively, a two-way star-shaped VSAT network can be employed to fully support the flow of information between the central and remote sites.

3.1.3 Interactivity between distribution sites:

Companies or organizations with a decentralized structure often consist of multiple sites that interact with each other. In such cases, a meshed VSAT network with direct single hop connections between VSATs becomes the preferred choice. Alternatively, a two-way star-shaped network with double hop connections from VSAT to VSAT via the hub can also be considered as an option.

The table below illustrates suitable VSAT network configurations for specific applications.

Application	Network configuration		
	Star shaped		Meshed two-way
	One way	twoway	

Broadcasting	X		
Corporate network (hub at companyhead headquarters, VSATs at branches)	X	X	
Corporate network (distrubuted sites)		X (Double hop)	X (Single hop)

Table 1: VSAT network configuration appropriate to a specific application

3.1.4 Quality and capacity of the link

The considered link in this context refers to the connection between the transmitting station and the receiving station, which can consist of multiple parts. For example, a single hop link consists of an uplink and a downlink, while a double hop link comprises two single hop links, one inbound and one outbound. When assessing link quality, it is important to consider the quality of both the modulated carrier at the receiver input and the baseband signals delivered to the user terminal after carrier demodulation. The receiver input represents the complete radio frequency link from the transmitting station to the receiving station, including the uplink and downlink components. The interface between the earth station and the user terminal represents the baseband link connecting the device generating bits (message source) to the device receiving those bits (message sink).

3.1.5 Transmission delay:

In a meshed network with a single hop link from VSAT to VSAT, the propagation delay typically amounts to approximately 0.25 seconds. However, when utilizing a double hop link from VSAT to VSAT via the hub, the propagation delay doubles, resulting in approximately 0.5 seconds. While the double hop configuration may present challenges for voice communications, it is less problematic for video or data transmission. Table 2-3 provides a summary of the aforementioned discussion. Based on the EIRP and G/T values for a VSAT, network designers can make decisions

regarding trade-offs between a larger delay and higher capacity or a smaller delay and lower capacity by implementing either a star-shaped or meshed network configuration [6].

The table below shows the characteristics of configurations in the star and mesh network:

	<u>Network configuration</u>	
	Star-shaped (double hop)	Meshed (single hop)
Capacity (given VSAT EIRP and G/T)	Large	Small
Delay (from VSAT to VSAT)	0.5s	0.25 s

Table 2 :characteristics of star and mesh network configurations

4 The components of Vsat network

A VSAT network comprises three primary components: a central hub, also known as a master earth station, the satellite infrastructure, and an extensive number of VSAT earth stations scattered across multiple locations throughout the country [5].

5 VSAT Network Configurations :

As shown in (Figure 3), VSATs are interconnected through radio frequency (RF) links using a satellite. This involves an uplink from the station to the satellite and a downlink from the satellite to the station. The complete link between stations, referred to as a "hop," consists of both the uplink and the downlink. A radio frequency link functions by transmitting modulated carriers that carry information. In the case of VSAT networks, geostationary satellites (as shown in Figure 4) are commonly employed. These satellites orbit the Earth's equatorial plane at an altitude of approximately 35,786 km, ensuring they remain stationary relative to the Earth's surface.

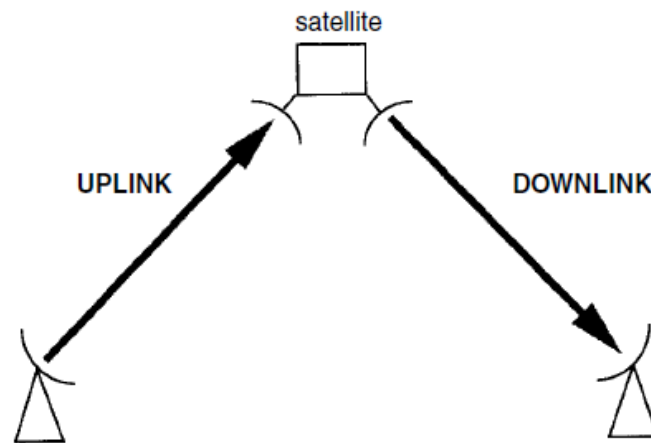


Figure 3 :definition of uplink and downlink

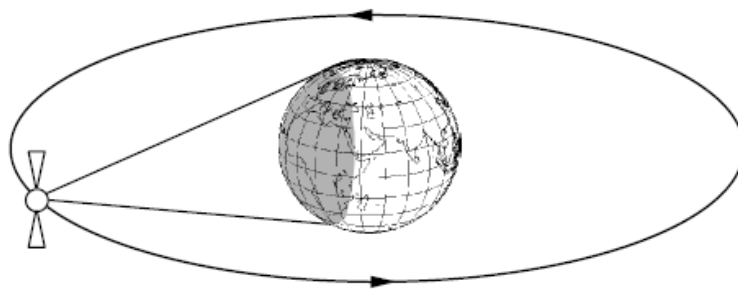


Figure 4 : Stationary satellite

6 VSAT transmission technologies:

The customer's requirements determine whether they need to transmit a specific type of signal or a combination of different signals. Data and voice signals are typically transmitted in a digital format, while video signals can be either analog or digital. In the case of digital video, bandwidth-efficient compression techniques can be applied to optimize transmission.

6.1 – Data communication:

VSATs have emerged primarily to meet the demand for data transmission. Standard VSAT products are designed to offer reliable data transmission capabilities. The user rates provided by these systems typically range from 50 bits per second (bps) to 64 kilobits per second (kbps), with interface ports such as RS-232 for lower bit rates below 20 kbps, and RS-422, V35, and X21 for higher bit rates. Additionally, a local area network (LAN) interface is commonly included, often utilizing an RJ-45 connector. Appendix 3 provides further information on the functionalities of

these ports. Data distribution can be combined with video transmission, utilizing standards like DVB-S for efficient implementation

6.2 Communication of voice:

Voice communications are specifically relevant in two-way networks. They can be conducted at lower rates using voice encoding techniques, such as vocoders. Typical information rates in such cases range from 4.8 kbps to 9.6 kbps. Alternatively, voice communications can be combined with data communications, allowing for the multiplexing of up to 4 voice channels with data or facsimile channels on a single 64 kbps channel. However, it's important to note that voice communications on VSAT networks may experience certain delays. These include the delay associated with vocoder processing (approximately 50 milliseconds) and the propagation delay on satellite links (around 500 milliseconds for a double hop). Consequently, users may opt to connect to terrestrial networks, which offer lower latency. Voice communications can serve as a niche market for VSATs, providing services to locations without access to landlines or for transportable terminal applications.

6.3 Communications of video:

Video communications over VSAT can be implemented using different techniques on the outbound and inbound links:

Outbound link (from hub to VSAT):

Video communications on the outbound link utilize standard TV formats such as NTSC, PAL, or SECAM, combined with FM modulation. Alternatively, the Digital Video Broadcasting by Satellite (DVB-S) standard can be employed, often in conjunction with data distribution.

Inbound link:

Due to the restricted power of the VSAT on the uplink, video transmission is feasible at a lower rate. This may involve slow-motion image transmission using video coding and compression techniques.

Overall, VSAT transmission technologies provide a flexible solution for transmitting data, voice, and video signals, catering to the specific requirements of the customer.

7 Frequency bands :

VSAT networks are supposed to operate within the so-called 'fixed satellite service' (FSS) defined within the International Telecommunication Union (ITU). The only exception is when data is broadcasting association with broadcasting of television or audio programs, within the so-called 'broadcasting satellite service' (BSS). The FSS covers all satellite communications between stations located while operating at given 'specified fixed points' of the earth. Transportable stations belong to this category, and hence the so called 'fly-away' stations should use the same frequency bands as fixed VSATs. The most commonly used bands for commercial applications are those allocated to the FSS at C-band and Ku-band. X-band is used by military systems. Few VSAT networks at Ka-band are commercial, most are experimental.

The choice of frequency band for a VSAT network operation primarily relies on the presence of satellites that cover the intended region where the network will be deployed. Additionally, consideration should be given to the potential issue of interference. Interference refers to the undesired signals that enter the receiving equipment alongside the desired signals. These unwanted signals disrupt the demodulator's performance by introducing noise, which adds to the inherent thermal noise. Interference poses a challenge for VSATs due to the relatively small size of their antennas, resulting in a radiation pattern with a wide beamwidth.

For high frequencies (Ka and Ku band), interference is not increased problems, but we should not draw hasty conclusions about the disadvantage of low frequencies. In fact, interference is minimized by using high gain antennas. At this point, as the C band is a low frequency range compared with the Ka and Ku band, and seen its sharing by several services, it is more prone to interference than the Ka and Ku bands. Two other factors intervene when choosing between the C and Ku bands, the attenuation due to rain generally, stronger at the Ku band than at the C band and the cost of equipment which is less expensive in the case of the C band.

8 Hub options:

8.1 Dedicated large hub:

A dedicated large hub, equipped with an antenna typically ranging from 8 to 10 meters in size, serves as the backbone of a fully integrated network, capable of accommodating thousands of connected VSATs. This hub can be strategically positioned at the central site of the customer's

organization, directly linked to the host computer, providing complete network control. However, it's important to note that a dedicated hub is a more costly option and is justifiable only when the expenses can be spread across a significant number of VSATs within the network.

8.2 Shared hub:

Shared hubs offer the possibility for multiple independent networks to utilize a single hub. In this scenario, hub services are leased to VSAT network operators, allowing them to minimize their capital investment. This makes shared hubs particularly advantageous for the initial deployment of smaller VSAT networks with fewer than 50 VSATs. However, it's important to acknowledge that sharing a hub comes with certain drawbacks.

Need for hub-to-host connection:

In most cases, a shared hub facility is not located in close proximity to the customer's host computer. As a result, a backhaul circuit is required to establish a connection between the hub and the host. This circuit can be either a leased line or a connection provided by a terrestrial switched telephone network, which incurs additional costs for operating the VSAT network. Additionally, operational experience has revealed that the backhaul circuit is often the weakest link in the network, posing an increased risk of failure. To address this potential issue, employing route diversity could be a viable solution, such as utilizing a microwave or satellite link as a backup for this interconnection.

Possible limitation in future expansion:

Network operators utilizing a shared hub may encounter unforeseen capacity limitations, as the available capacity can be leased without prior notice to other operators sharing the hub. To mitigate this potential issue, it is advisable for network operators to request contractual guarantees regarding capacity allocation and availability..

8.3 Mini-hub:

The mini-hub is a compact hub, featuring a smaller antenna size ranging from 2 to 5 meters. It offers a cost-effective solution compared to other types of hubs. The mini-hub combines the benefits of a dedicated hub with a more affordable price point. Typically, a mini-hub has the capacity to support around 300 to 400 remote VSATs.

9 Modulation and coding techniques :

MODCOD stands for Modulation and Coding, which represents the combinations of Modulation Types and Error Coding schemes available within the DVB-S2 standard. The MODCOD value determines the efficiency and capacity of the transmission. A higher MODCOD indicates a higher number of bits that can be transmitted per symbol or per second per Hz (bits per symbol or bps/Hz), resulting in increased data throughput and improved spectral efficiency.

9.1 Modulation :

Modulation is a fundamental technique used in transmitting data, where the baseband information is imposed on a carrier signal. Various modulation techniques have been developed over time, and one of the basic methods used in digital data transmission is Phase Shift Keying (PSK). PSK gets its name from the fact that digital data is represented by the phase relationship of the RF carrier signal. In this technique, the data is encoded as 0s and 1s.

9.2 Coding :

Coding refers to the error-correction coding schemes available. Low-Density Parity Coding (LDPC) and Bose-Chaudhuri-Hocquenghem (BCH) codes are used in DVB-S2.

9.3 Forward error correction :

Forward Error Correction (FEC) is a technique in which additional coding bits are inserted into the original data stream. These extra bits are designed to detect and correct errors that may occur during transmission, ensuring better bit error rates and a lower carrier-to-noise ratio at the receiving end. FEC employs various coding techniques.

In these coding schemes, the numerator represents the number of actual information bits, while the denominator represents the total number of bits including both information and coding bits.

10 Accesstechniques :

VSATs use SCPC (Single Channel Per Carrier) as an access method for communication. SCPC assigns dedicated channels to each VSAT, which can be operated through PAMA or DAMA. PAMA involves pre-assigning channels, while DAMA assigns channels dynamically based on demand. These methods ensure efficient and reliable communication within the VSAT network.

TDM/TDMA:In a TDMA network, remote VSATs communicate with a central hub station using Time Division Multiple Access (TDMA) modes. The network operates in a Star topology, with the hub re-transmitting the signal to the destination VSATs using TDM technology. The TDMA access mechanism uses Slotted Aloha, where remote VSATs contend for time divisional slots to transmit their packets to the hub. The Return Link channels, used by the remotes to communicate with the hub, operate at a maximum of 128 Kbps. The hub communicates with the destination remotes using TDM technology through the Outbound or Outlink channel, which operates at 256 Kbps.

TDMA PAMA:TDMA PAMA (Pre Assigned Multiple Access) is an access scheme in which two VSATs are allocated a dedicated bandwidth for exclusive communication. This assigned bandwidth remains available to the VSATs permanently. The link can be either symmetric or asymmetric, depending on the bandwidth allocation for upstream and downstream communication.

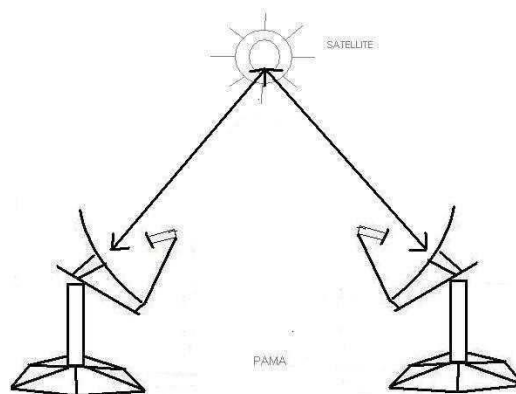


Figure 5 : Point to Point connectivity, Leased Line in the sky

PAMA is a reliable and cost-effective solution for connecting high data traffic sites within an organization, offering an alternative to leased lines for mission-critical applications.

DAMA: (Demand Assigned Multiple Access) is a communication scheme similar to a telephone connection. In DAMA, when there is a need to communicate with someone, a connection is established by requesting access through the HUB, which functions as a telephone exchange. This enables point-to-point voice, fax, and data communication between remote sites. DAMA offers a cost-effective and reliable solution for businesses with high internal communication needs, as well as for organizations operating in remote areas seeking to establish a dependable network.

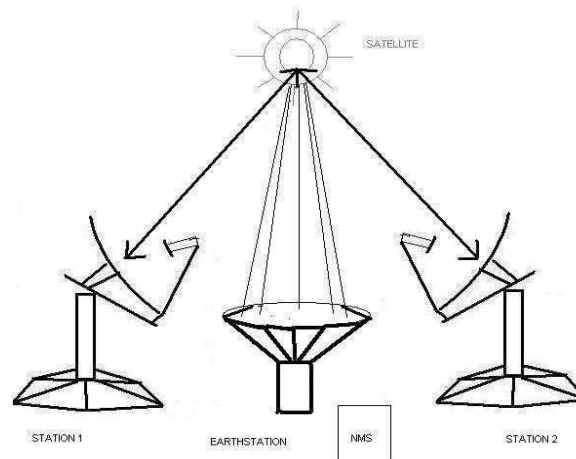


Figure 6 : Typical DAMA / PAMA Network

11 VSAT network management

11.1 Network planning:

VSAT networks are used to provide high-speed and reliable communication services to remote locations where terrestrial infrastructure is not available or feasible [7]. VSAT network planning involves the design and implementation of satellite communication systems, including the selection of satellite platforms, ground equipment, and network architecture [8]. The planning process typically involves assessing the communication needs of the target location, evaluating the available satellite technology options, and designing a customized solution that meets the specific requirements of the location. The planning process should also take into consideration the cost-effectiveness of the solution, as well as the reliability and availability of the satellite technology. A well-designed VSAT network can provide reliable connectivity for a wide range of applications, including voice, data, and video services.[7] [8].

11.2 Installation:

VSAT installation involves the setup of a satellite communication system, which enables high-speed and reliable connectivity to remote locations. The installation process typically involves site survey, antenna installation, and alignment [7], followed by the installation of the indoor equipment, including the modem and the router. The site survey is an important aspect of the installation process as it helps in identifying the most suitable location for the antenna and ensuring that the site has a clear line-of-sight to the satellite. Antenna installation and alignment are critical steps that require specialized skills and equipment to ensure that the antenna is pointed accurately at

the satellite. Once the antenna is installed and aligned, the indoor equipment can be installed and configured, which includes the modem and the router. The installation process should also include testing and verification of the system to ensure that it is operating correctly [8].

12 VSAT security :

12.1 Security measures to protect VSAT networks:

VSAT network security refers to the measures and protocols put in place to protect the communication system against unauthorized access, data breaches, and other security threats [9][10]. VSAT networks are vulnerable to security threats such as eavesdropping, data interception, and denial-of-service (DoS) attacks, which can compromise the confidentiality, integrity, and availability of the communication system. To ensure the security of VSAT networks, various security mechanisms can be implemented, including encryption of data in transit, firewall protection, intrusion detection and prevention systems, and secure authentication protocols. It is also important to regularly update software and firmware to patch vulnerabilities and implement security best practices, including access control and password management. Regular security audits and vulnerability assessments can help identify potential weaknesses and vulnerabilities in the system, enabling prompt remediation before a security breach occurs. Overall, implementing robust security measures is essential to protect VSAT networks and ensure the confidentiality, integrity, and availability of communication services.

13 Services offered by VSAT:

VSAT (Very Small Aperture Terminal) networks provide a wide range of communication services to businesses, governments, and individuals in remote or underserved locations[7][8]. These services include voice, data, video, and multimedia applications, such as:

Internet Access: VSAT networks can provide high-speed internet access to remote locations where traditional terrestrial infrastructure is not available.

Voice and Video Conferencing: VSAT networks can support high-quality voice and video conferencing services, enabling remote teams to collaborate effectively.

Point-of-Sale (POS) and ATM Services: VSAT networks can support secure and reliable POS and ATM transactions in remote or underserved areas.

Distance Learning and Telemedicine: VSAT networks can enable distance learning and telemedicine applications, enabling access to education and healthcare services in remote locations.

Disaster Recovery and Emergency Communications: VSAT networks can provide reliable communication services in emergency situations, enabling first responders and relief workers to coordinate their efforts effectively.

Oil and Gas Exploration: VSAT networks can support communication services for oil and gas exploration companies operating in remote or offshore locations.

Conclusion :

VSAT technology is a versatile and reliable communication solution that utilizes satellite systems to provide connectivity in remote and underserved areas. With its global coverage, high-speed capabilities, scalability, and cost-effectiveness, VSAT technology enables businesses, governments, and individuals to access essential services and bridge the digital divide. Whether it's for telecommunication, broadband internet access, enterprise networking, or disaster recovery, VSAT technology plays a crucial role in connecting the world and empowering communities.

Chapter 2 :Layer 2 over satellite implementation in iDirect

1 Introduction:

VSATs use different platforms to transmit and receive data via satellites, such as iDirect, Newtec, Comtech, Datum. Among these, iDirect stands out by offering a range of solutions for VSAT connections, including high connectivity and improved quality of service^[7]. In many VSAT applications, the preference leans towards Layer 2 connectivity between the hub and remote sites, as opposed to the Layer 3 IP connections traditionally provided by iDirect. This preference arises from the advantages of utilizing Layer 2 over Satellite (L2oS). The primary objective of this chapter is to present the iDirect system comprehensively and to provide an in-depth understanding of L2oS, its architectural components, and the key considerations involved in its implementation. By exploring the benefits of Layer 2 over satellite, this technology enhances communication capabilities in various applications.

2 iDirect platform :

The iDirect platform provides modem solutions that deliver reliable connectivity in any location and at any time. It is designed to meet diverse networking needs, whether it's for bandwidth requirements, satellite frequency, network topology, or specific applications. The platform incorporates innovative technology and solutions to ensure the highest quality of connectivity for various networking requirements.[10]

3 iDirect architecture :

Typical hub configuration

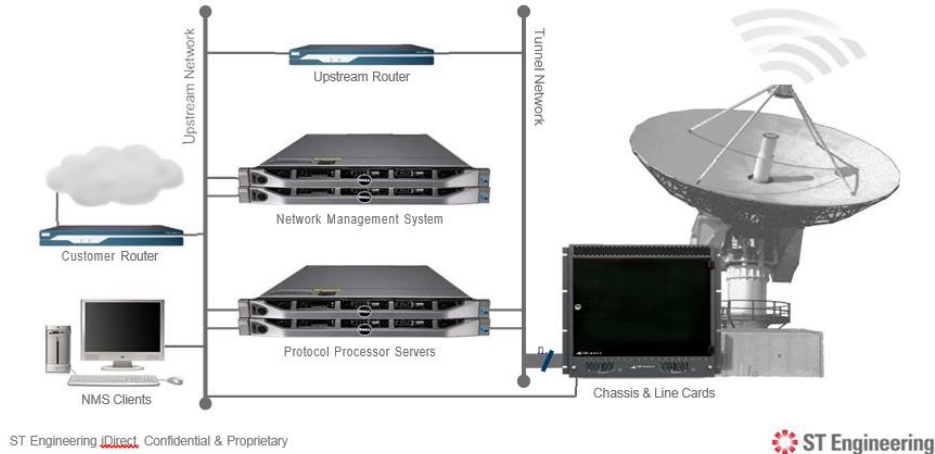


Figure 7: HUB configuration in iDirect

A standard iDirect installation is composed by two separate network segments: upstream and tunnel, connected by the upstream router. Two switches are required. The upstream switch is used by all the elements connected to that network segment (NMS Servers, Local NMS Clients, Protocol Processor Servers, EDAS/MIDAS Chassis Card, Customer Routers, etc.) while the tunnel switch is mainly used for the communication between the Protocol Processor Servers and the Line Cards. The user traffic will appear as clear traffic on the upstream network, while it will appear as UDP tunneled traffic on the tunnel network, hence the name of that network segment.

All the user traffic that needs to be sent towards any particular remote is processed by the Protocol Processor Servers. When configuring a new remote on the network the system will automatically assign one Protocol Processor Server to manage the traffic traveling to that particular remote. This assignment is done automatically by the NMS Server each time a remote is created and won't be changed unless a Protocol Processor Server Rebalance event is triggered. This can happen automatically if any Protocol Processor Server fails, as part of the PP Failover Mechanism, or be manually triggered by logging in on the Protocol Processor Controller.[12]

3.1 The NMS server (Network Management System):

The NMS is the brain of the iDirect configuration, it is a mini computer or a workstation, equipped with software and display tools, physically it is the same as the Protocol Processor except that there is the iDirectNMS software installed. This server is connected to both the switch tunnel and the upstream switch.

3.2 The server protocol processor (PP):

It is the heart of the HUB, it is responsible for processing information in the iDirect network. This server is connected to both the tunnel switch and the upstream switch.

3.3 The tunnel switch:

Used as a tunnel for routing packets between HLC and PP.

3.4 The upstream switch:

Responsible for delivering IP packets after they are decapsulated by the protocol processor.[12]

4 Layer 2 over Satellite:

Layer 2 over Satellite enables the satellite link to emulate an Ethernet connection. When an iDirect network is configured for L2oS, Ethernet frames, rather than IP packets, are transported across the satellite link. In terms of data networking, this is “moving down the stack” from the traditional iDirect model of IP network layer connectivity over the satellite (OSI Layer 3) to Ethernet link layer connectivity (OSI Layer 2).

This section provides a description of the L2oS feature as implemented in iDirect.

4.1 L2oS Reference Model:

The L2oS Reference Model defines a conceptual framework that outlines the key components and interactions involved in the implementation of Layer 2 over satellite (L2oS) technology

L2oS reference model is composed of: CustomerEdge, Provider edge, Attachments circuit and an Ethernet virtual connection as shown in the following figure:

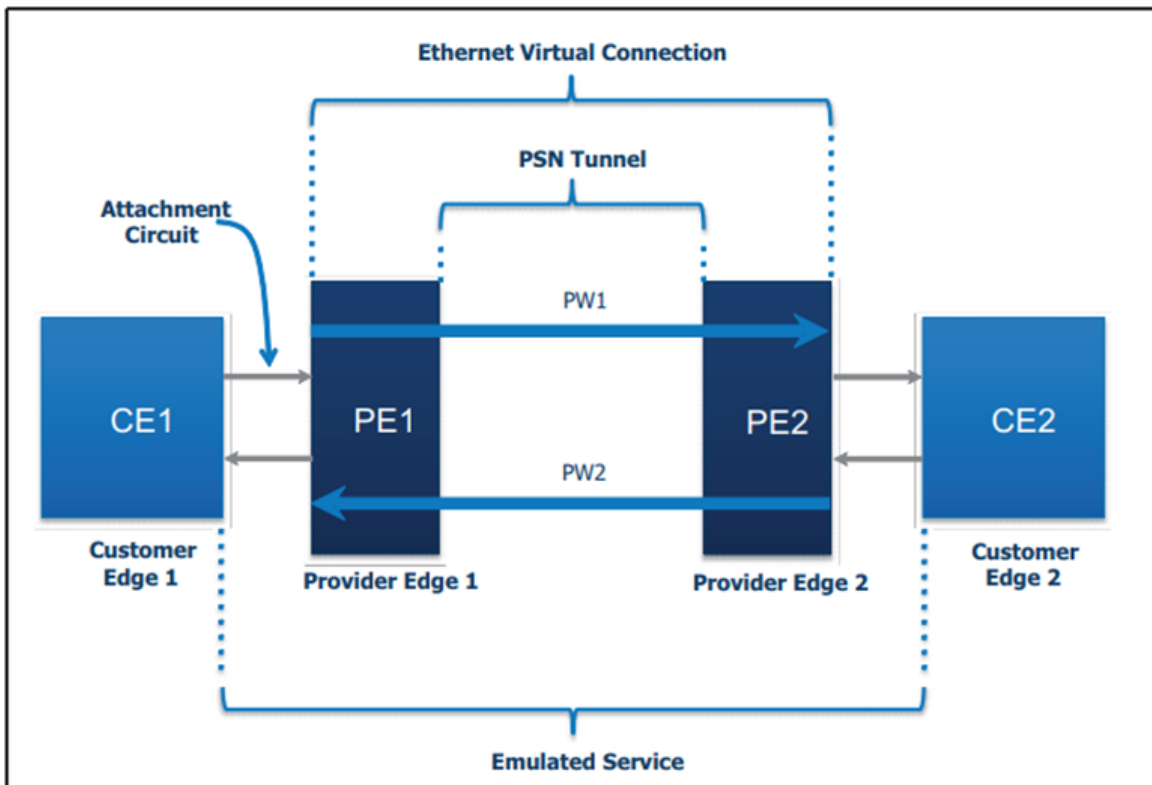


Figure 8:L2oS reference model

- **Customer Edge (CE):**A Customer Edge is a device such as a switch or router that provides an entry point into the customer network. In the case of the iDirect L2oS feature, a CE is directly connected to iDirect hub equipment or an iDirect remote modem.
- **Provider Edge (PE):**A Provider Edge is a device such as a switch or router that provides an entry point into the provider network. In the case of the iDirect L2oS feature, a PE is iDirect hub equipment or an iDirect remote modem.
- **Attachment Circuit:**An Attachment Circuit is a connection between CE and PE devices. In the case of the iDirect L2oS feature, an Attachment Circuit is an Ethernet connection between a CE and iDirect hub equipment or between a CE and an iDirect remote modem.
- **Ethernet Virtual Connection (EVC):**An Ethernet Virtual Connection is a logical connection between two PEs. In an iDirect satellite network, one end of the EVC is always the hub; the other end of the EVC is always one or more remote modems.[11]

4.2 L2os reference model application to iDirect:

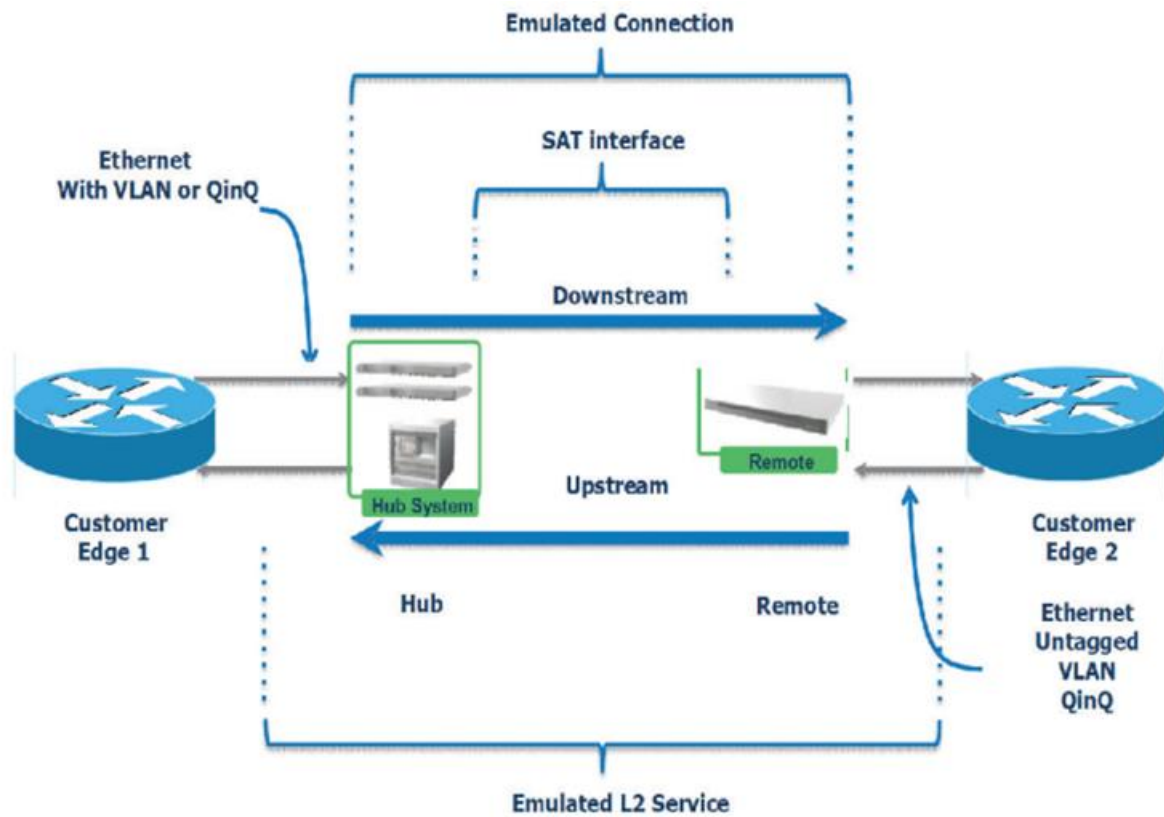


Figure 9:L2os reference model applied to iDirect

Traffic on an L2oS connection may be segregated into Satellite Virtual Networks (SVNs) by the use of VLAN Service Delimiting Tags (SDTs) in the Ethernet frames.

5 Satellite Virtual Network and Service Delimiting Tags:

An L2oS satellite network is partitioned into one or more Satellite Virtual Networks (SVNs). SVNs provide segregation of Layer 2 traffic into streams that behave as if user data is being transmitted over separate networks. Each remote in the satellite network belongs to one or more SVNs.

Service Delimiting Tags (SDTs) associate Ethernet frames with specific SVNs. The iDirect system supports two types of SDT:

- IEEE 802.1q VLAN tags
- IEEE 802.1ad QinQ tags

VLAN tags allow the Layer 2 emulation to provide traditional VLAN VPN functionality. When VLAN tags are used, only the outermost tag of an Ethernet frame determines the SVN to

which the frame belongs. The SVN number is the VLAN ID of the first VLAN tag (Figure 10) in the frame. Any additional inner VLAN tags are passed through transparently. [11]

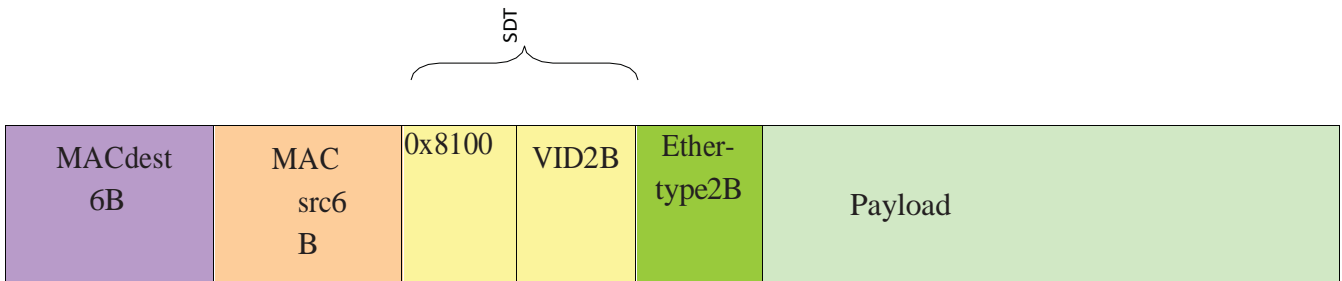


Figure 10 : SDT VLAN Mode

SDTs are always used on the hub side. It is the responsibility of the Gateway CE to add the appropriate SDT for downstream traffic; it is the responsibility of the iDirect hub to add the appropriate SDT for upstream traffic. The hub SDT Mode is a global setting for either VLAN. The hub and its associated gateway CE should be configured in the same mode.

SDTs are optional on the remote side. When used, it is the responsibility of the CE attached to the remote modem to add the appropriate SDT for upstream traffic; it is the responsibility of the remote to add the appropriate SDT for downstream traffic.

SDTs can be omitted on the remote side by configuring a remote LAN port as an Access Port and associating the port with a single SVN. All Ethernet frames received on the port are transmitted on the configured SVN.

6 L2oS ServiceModes:

- Virtual Private LAN Service (VPLS)
- Virtual Private Wire Service (VPWS)
- Virtual Private Wire Service-Evolved Packet Core (VPWSEPC)

In our project we use VPLS only

6.1 Virtual Private LAN Service

When using Virtual Private LAN Service (VPLS), all Customer Edge (CE) devices have Layer 2 visibility to all other CE devices within a VLAN, as though they were all on a single LAN segment. A VPLS can contain a single VLAN or multiple VLANs.

Chapter 2 :Layer 2 over satellite implementation in iDirect

VPLS is required for remotes to communicate with each other directly, rather than through a router. In VPLS mode, the hub replicates upstream data to the downstream as required for remote-to-remote traffic. This replication process is referred to as "hairpinning." For example, VPLS is appropriate if all Layer 3 devices at all remotes are in the same IP subnet.

On a traditional LAN segment, each device receives all Ethernet frames transmitted by all other devices. A VPLS emulated LAN in an iDirect satellite network behaves differently:

- To conserve satellite bandwidth, Ethernet frames received by the hub on the upstream are replicated on the downstream only if necessary.
- To improve performance, a downstream unicast frame is directed only to the remote that requires it whenever possible. This is done based on MAC address learning.[11]

7 Layer 2/3 Hybrid Mode:

iDirect introduces the Layer 2/Layer 3 Hybrid Mode feature to allow both Layer 2 and Layer 3 traffic to traverse a single VSAT network at the same time, sharing the same NMS, PP stack, line cards, and satellite bandwidth. In addition, iQ Series can simultaneously carry Layer 2 and Layer 3 traffic, enabling unprecedented level of flexibility.

When transported in the same network, Layer 2 and Layer 3 traffic is separated by an individual Satellite Virtual Networks (SVN). In other words, SVNs will be marked as either Layer 2 or Layer 3 during network configuration.[11]

The most common use cases for this feature include:

- Introducing Layer 2 in Existing Layer 3 Network—In this use case, for a network operator currently running a Layer 3 iDirect network, a new Layer 2 connection to new sites can be introduced, leveraging its protocol transparency and other benefits, without having to set up a brand new network.
- Running Persistent Multicast along with Layer 2 — In this use case, a network operator can take advantage of Layer 2 network architecture while providing multicast service such as video distribution using the tried-and-tested persistent multicast feature in Layer 3.[11]

8 MAC address learning :

When the hub receives a unicast Ethernet frame from the Gateway CE, it forwards the frame over-the-air only when the frame is addressed to a known MAC address on a known SVN. To accomplish this, the hub learns, stores, and dynamically updates the MAC addresses of all remote devices on all SVNs. The hub uses this information to determine the SVN and destination remote for Ethernet frames that are sent over the air, and to filter out unwanted frames.

In addition, the remote must learn the MAC addresses of the devices on the local LAN. This allows the remote to filter out local LAN traffic when determining which frames to send over- the-air and to avoid endless traffic loops.

The learned MAC addresses on both, the hub and the remotes, will expire if the remote devices with the MAC addresses have not transmitted for a specific duration. This duration is called MAC Aging Timeout. This duration is default at 6 hours for the hub, and 5 minutes for the remote. The default value for the hub is chosen based on the default ARP cache timeout of 4 hours for Cisco routers.[11]

8.1 MAC addresses scalability:

The number of MAC addresses an iQ series remote can learn is 140 although the MAC address learning has been tested to 250 for these remotes. The over-the-air message from the remote to the protocol processor limits the number of MAC addresses a remote can update a protocol processor to only 140, hence the official limit.

At the hub side, one SVN can support up to 50,000 MAC addresses, and the limit at the iDirect network level is 100,000.

9 Forwarding rules :

This section contains the rules for forwarding Ethernet frames received by the iDirect hub equipment and remote modems

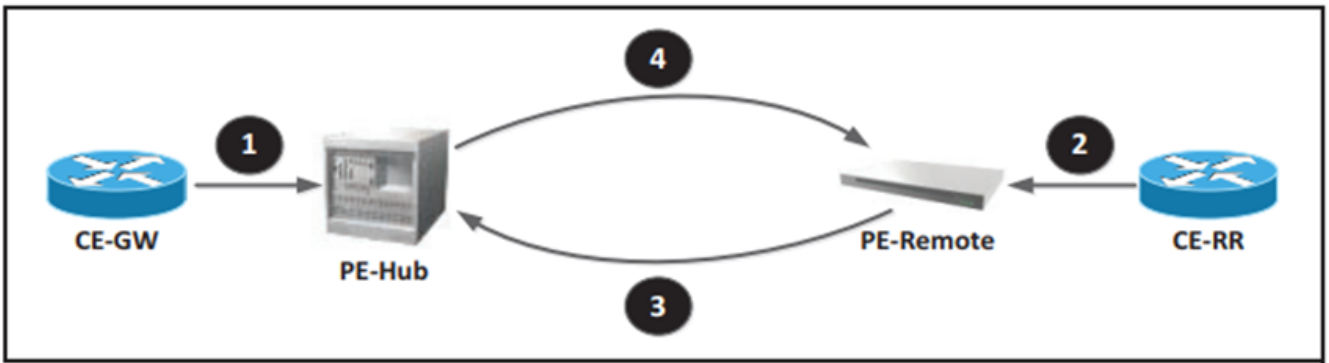


Figure 11: L2oS Forwarding Rules

-When Ethernet frames are received by the hub from the Gateway CE:

- The hub discards frames that do not map to any known SVN.
- The hub sends over-the-air all unicast frames that map to a known SVN and destination MAC address.
- The hub broadcasts over-the-air all multicast and broadcast frames that map to a known SVN.

-When Ethernet frames are received by the remote from the Remote CE:

- The remote discards all frames with a local destination MAC Address.
- If configured as an Access Port:
- The remote sends all frames over-the-air on the configured SVN.

If the remote is configured for VLAN tagging (trunk) :

- The remote sends over-the-air all frames that map to a configured SVN.

-When Ethernet frames are received over-the-air by the hub from a remote:

The service mode of the SVN is VPLS:

- If a frame is a unicast frame:
- If a frame maps to a known remote MAC Address in the SVN, the hub resends the frame over-the-air to the destination remote.
- If a frame is addressed to an unknown MAC address, the hub directs the frame to the local LAN.

Chapter 2 :Layer 2 over satellite implementation in iDirect

- If a frame is a multicast or broadcast frame:
 - The hub directs the frame to the local LAN.
 - The hub retransmits the frame over-the-air to all remotes in the SVN.
- When Ethernet frames are received over-the-air by a remote from the hub:
- The remote discards all frames that do not match any configured SVN.
 - The remote discards all frames with a local source MAC Address.
 - The remote forwards all remaining frames to the local LAN.

10 L2oS configuration:

This section discusses the L2oS parameters that can be configured in iBuilder which is a program that enables rapid configuration of any size network. Whether you need to configure or modify individual remotes, groups of remotes, or the entire network, you can do it from one central location, fast.

10.1 Layer 2/Layer 3 hybrid mode configuration:

Each individual networks and remotes can carry both Layer 2 and Layer 3 traffic simultaneously. SVNs are configured as either Layer 2 or Layer 3. Network traffic coming into the Protocol Processor (PP) or remote are identified as either Layer 2 or Layer 3 traffic using the Service Delimiting Tag (SDT). Layer 2 traffic is matched to pre-configured SVNs based on their tags and transmitted as traffic on Layer 2 SVNs (L2-SVN) and Layer 3 traffic is matched to pre-configured SVNs and will be transmitted as a Layer 3 SVN (L3-SVN).

The SDT of the links connecting to the PP can be either 802.1Q VLAN or 802.1ad Q-in-Q trunks and the SDT of links connecting to the remote can only be in 802.1Q VLAN mode when carrying both Layer 2 and Layer 3 traffic. When the hub side SDT is 802.1ad Q-in-Q, the outer (SP) tag of all Layer 3 traffic must match the Reserved Outer Tag pre-configured in the NMS.

11 Layer 2 categorizes:

Layer 2 categorizes include:

Source MAC: The Source MAC address of the Ethernet frame

Destination MAC: The Destination MAC address of the Ethernet frame

SVN ID: The SVN ID of the Ethernet frame

SVN PCP: The PCP (Priority Code Point) field of the SDT

Ethernet Type: The first Ether type in the Ethernet frame after the STD

Effective Ethernet Type: The inner most Ether type in the Ethernet frame. This is applicable if there are multiple Ether types after the STD.

VLAN PCP: The PCP field of the VLAN tag after the SDT headers are removed.[11]

12 L2oS benefits:

In many VSAT applications, Layer 2 connectivity between the hub and remotes is preferred over the Layer 3 IP connections traditionally offered by iDirect. The benefits of using L2oS include:

- **Layer 3 Transparency:** Because an iDirect L2oS VSAT network behaves as a switched Ethernet network, the satellite network is invisible to higher-layer protocols. Therefore, any Layer 3 protocol, such as IPv6, OSPF, and BGP, is transported transparently across the satellite network
- **Simplified Operation:** In a traditional iDirect Layer 3 network, services such as Virtual Private Networks typically require allocation and configuration of a large number of IP addresses on the iDirect protocol processor and remote satellite routers. With Layer 3 transparency, this IP address allocation is no longer required. The only VLAN IP addresses required on an L2oS network are for the default VLAN used for iDirect network management.
- **Efficient Physical Layer:** As in traditional iDirect IP networks, L2oS networks carry traffic over iDirect's highly-optimized DVB-S2 outbound and TDMA inbound carriers. All the advantages of features such as DVB-S2 ACM and TDMA 2D 16-State coding are preserved when using L2oS.
- **Group QoS Support:** L2oS supports all of the Group QoS features that exist for iDirect IP networks. In addition, for L2oS networks, Layer 2 classifiers, such as source and destination MAC address, have been added to the Service Level and Filter Rules in iBuilder. IPV6 source and destination IP address classifiers have also been added.[11]

Conclusion:

iDirect is one of the best platforms for different businesses and industries.

L2oS reference model implementation in iDirect presents various important benefits such as Layer 3 Transparency and Efficient physical layer .

Chapter3 : Practical case of l2os implementation

1. Introduction:

In this chapter, we will discuss the configuration of a practical L2oS link using the iDirect platform. Firstly, we will introduce the software utilized for this purpose. Subsequently, we will present a step-by-step guide to the configuration process, accompanied by relevant screenshots to enhance understanding.

2. Network architecture:

To set up the L2oS link using the iDirect platform, we will begin by creating a network architecture comprising two remote sites, both located at ATS Lakhdoria. This network configuration will allow seamless communication between the two remote sites.

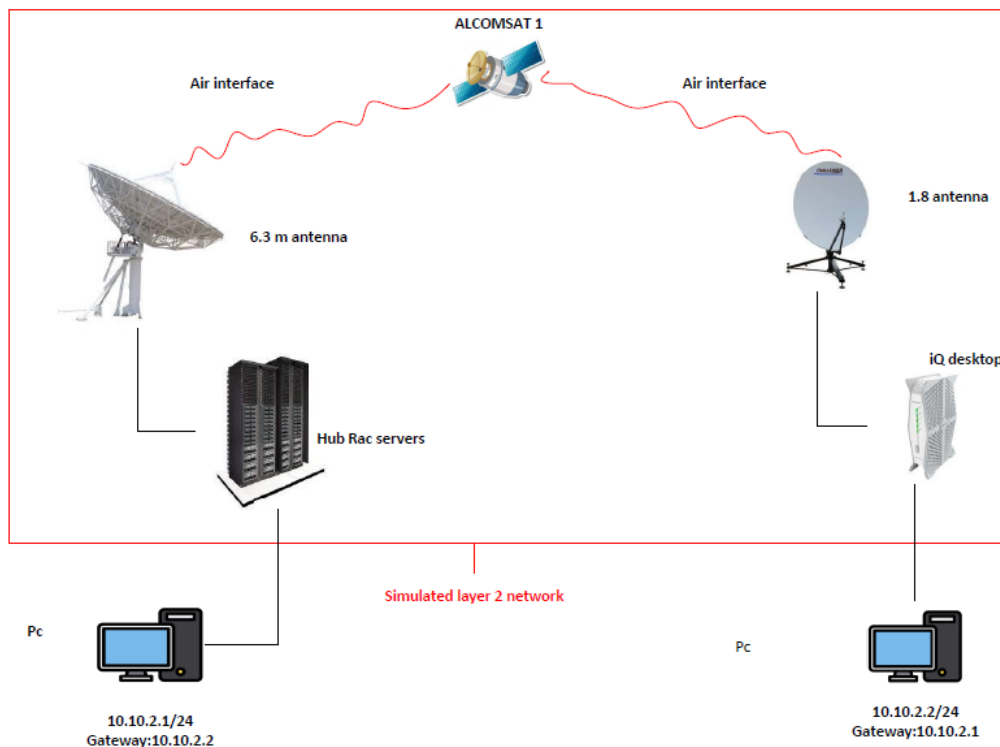


Figure 12: network architecture implemented

Here are the detailed steps to create this network architecture

Chaptre3 : Practical case of l2os implementation

Step 1: Determine the network requirements before proceeding with the configuration, it is essential to gather the necessary information about the network requirements. This includes the IP addressing scheme, subnet masks, gateway addresses, and any other relevant details specific to the network setup at ATS Lakhdaria.

Step 2: Connect the remote sites physically then ensuring that the network cables are properly connected to the respective computers. After that verify the network connectivity by checking the link on the network interfaces.

Step 3: Assign unique IP addresses to each computer at the remote sites and make sure that the IP addresses are within the same subnet range to facilitate communication between the two sites.

Step4 : Verify the connectivity between the two computers. Use the iDirect platform's built-in network testing tools or command-line utilities (such as ping) to ensure that the remote sites can communicate with each other successfully.

3. Software used in L2oS configuration:

When configuring a L2oS connection, several software components are typically involved in the process. These software tools play essential roles in setting up and managing the L2oS link. The following are some of the key software components used in L2oS configuration:

3.1 iBuilder:

Allows quick and intuitive configuration of any iDirect VSAT network. It allows to easily add components to your network, change your current configuration. iBuilder Server Review provides automated software and update management for your remote satellite routers. The iBuilder Group QoS (GQoS) user interface offers network operators a high degree of flexibility in remote locations with different levels of services to suit their networking needs.[9]



Figure 13 : iBuilder icon

4. L2oS Configuration:

This section discusses the L2oS parameters which are configured in iBuilder

4.1 Configuration steps:

4.1.1 L2oS Hub Parameters:

- Access to NMS server to configurate the new modem with layer 2
- Go into Protocol Processor and enabling L2oS

The L2oS field on the Protocol Processor Information tab is:

- L2oS Enabled (Disabled by default): When selected, only Layer 2 or Layer 2/Layer 3 hybrid networks can be configured under this Protocol Processor.

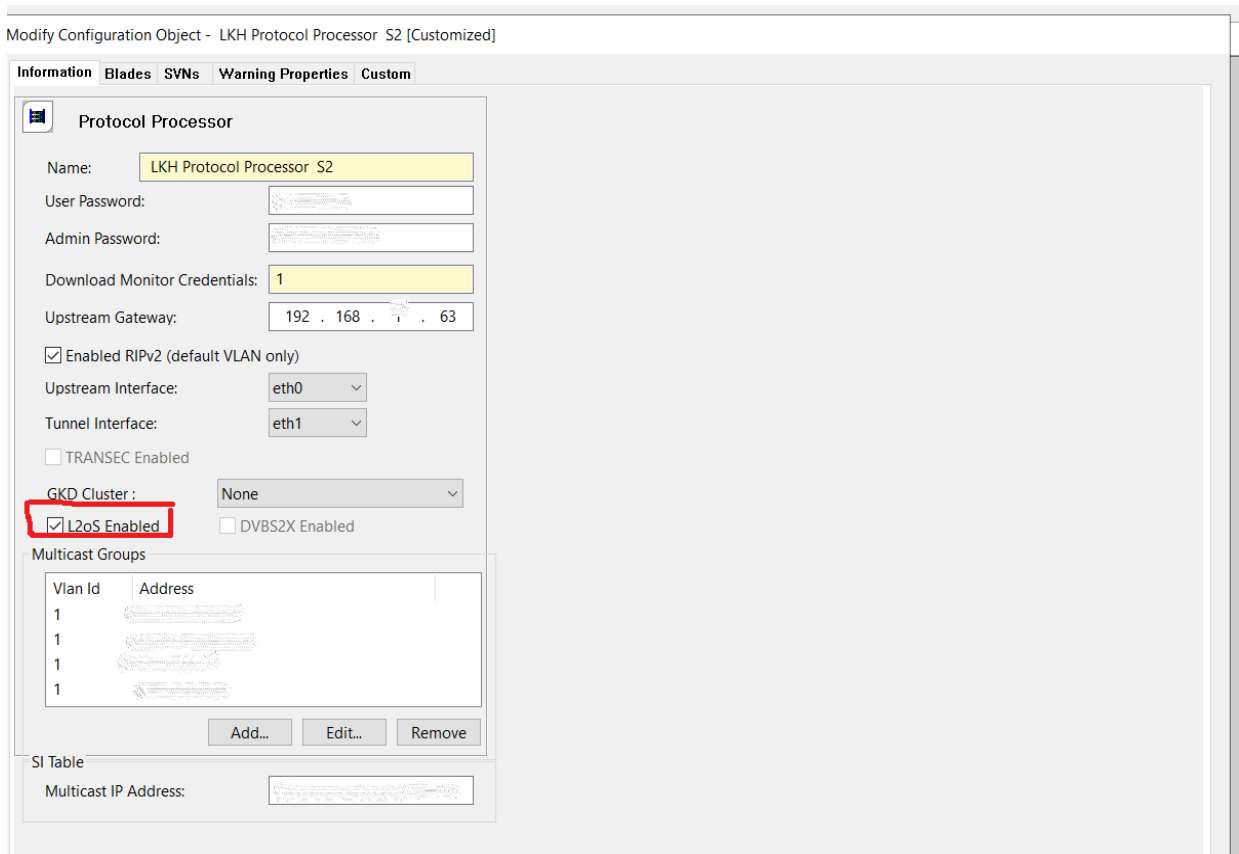


Figure 14 :enabling l2os

Chaptre3 : Practical case of l2os implementation

The remaining L2oS parameters for the hub are configured in iBuilder on the SVN's tab of the Protocol Processor, The SVN's tab is displayed only if L2oS is enabled on the Protocol Processor Information tab.

4.1.2 iBuilderconfiguration:

Creating SVN 1103 needed for our test named (Master_test):

The SDT parameters determine if VLAN tagging is used on the hub connection to the CE. The SDT parameters are:

- Mode: VLAN (default)
- Ethertype 1: Defaults: 0x8100

The L2SW Default parameters determine the default L2oS service mode. This service mode is used for any SVN that does not have an optional override defined. The L2SW Default parameters are:

- Mode: Selections are VPLS (default),

The SVN section of the remote L2oS tab defines the set of SVN's over which Layer 2 traffic flows over-the-air to and from this remote. The selection of SVN's is limited to the Layer 2 SVN's already configured on the PP. The remote only accepts downstream traffic received on matching SVN IDs. If Mode is VLAN , the tag or tags for Ethernet frames received on the local LAN must match a configured SVN Id for the frame to be transmitted on the upstream carrier. When a Local ID is configured for an SVN, the tag on the local LAN side is modified to this ID. Only the ingress Ethernet frames matching the Local ID, not the SVN ID, are to be transmitted on the upstream carrier.

The following fields are used to configure each SVN in the network:

- SVN Id: The identifier of the Satellite Virtual Network. When SDT Mode is set to VLAN, this is the VLAN ID.
- Name: A name for the SVN.
- Type: Layer 2 or Layer 3 which delineates the layer 2 SVN's from Layer 3 SVN's.

Chaptre3 : Practical case of l2os implementation

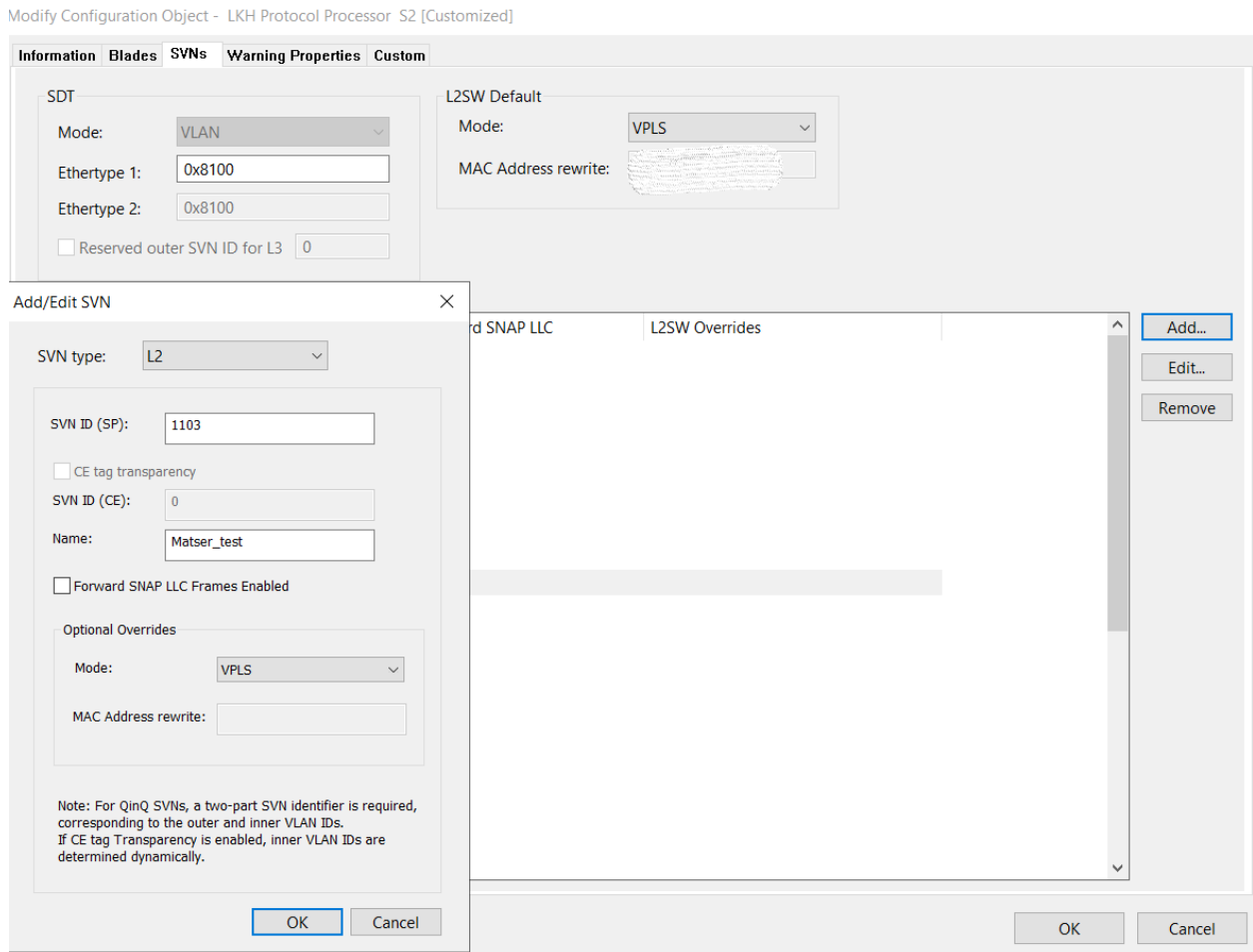


Figure 15: creating SVN

Creating a new modem

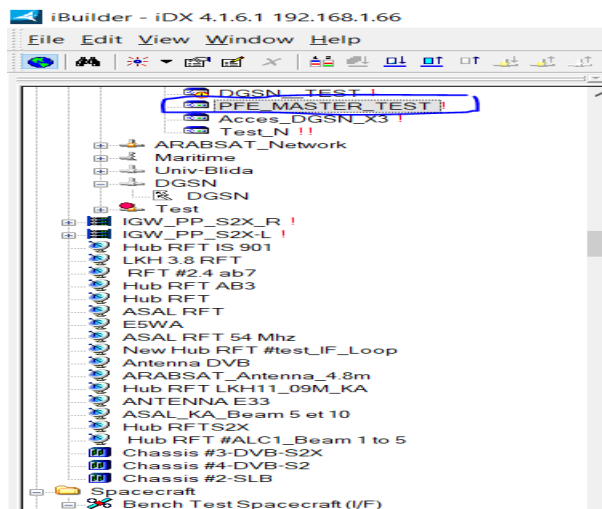


Figure 16 : creating a modem

4.1.3 Information tab:

- In general information we put the name, type and serial number of the modem.

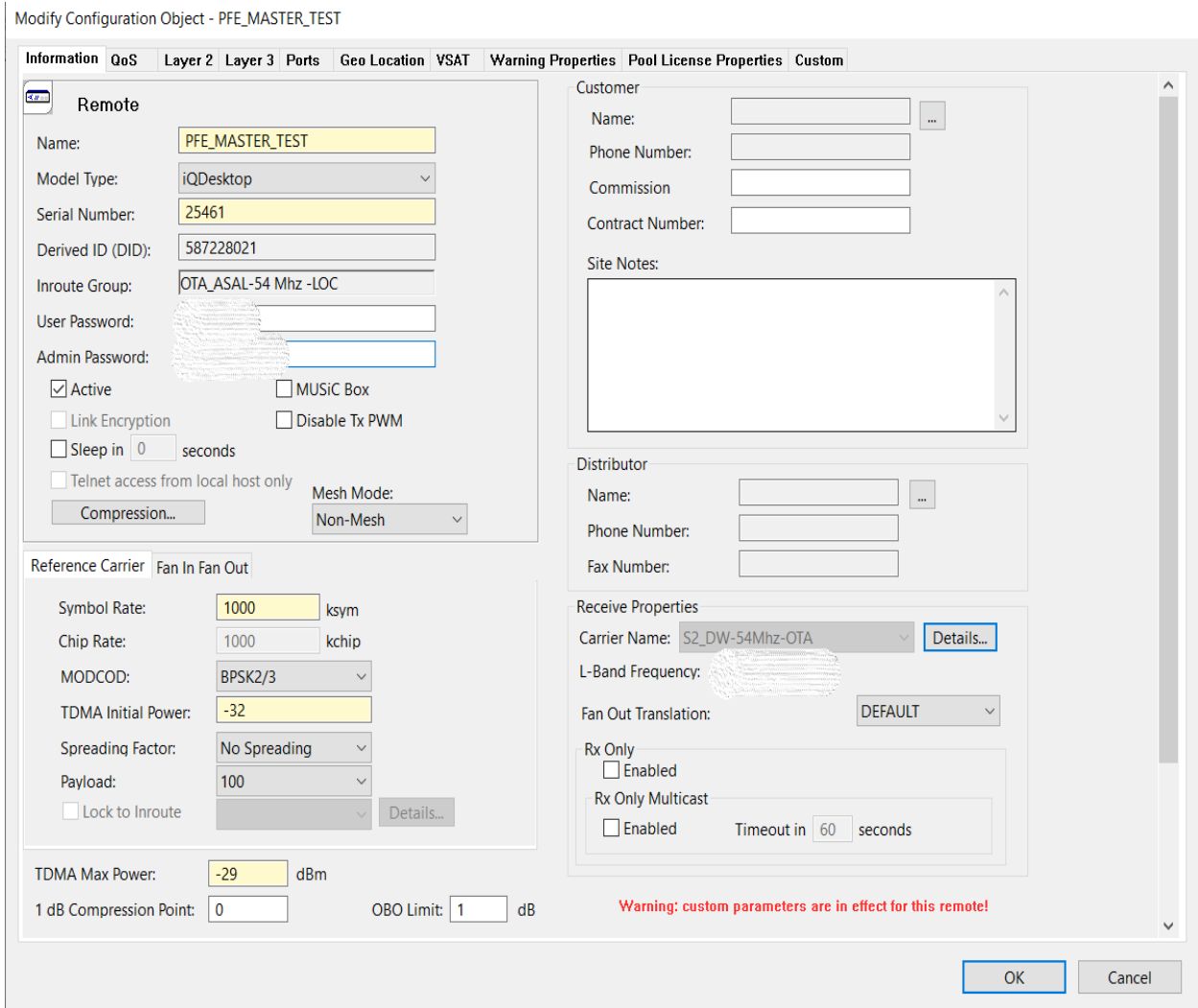


Figure 17: information tab

Layer 2 configuring :

We choose the SVN 1103 (Master_test)

Chaptre3 : Practical case of l2os implementation

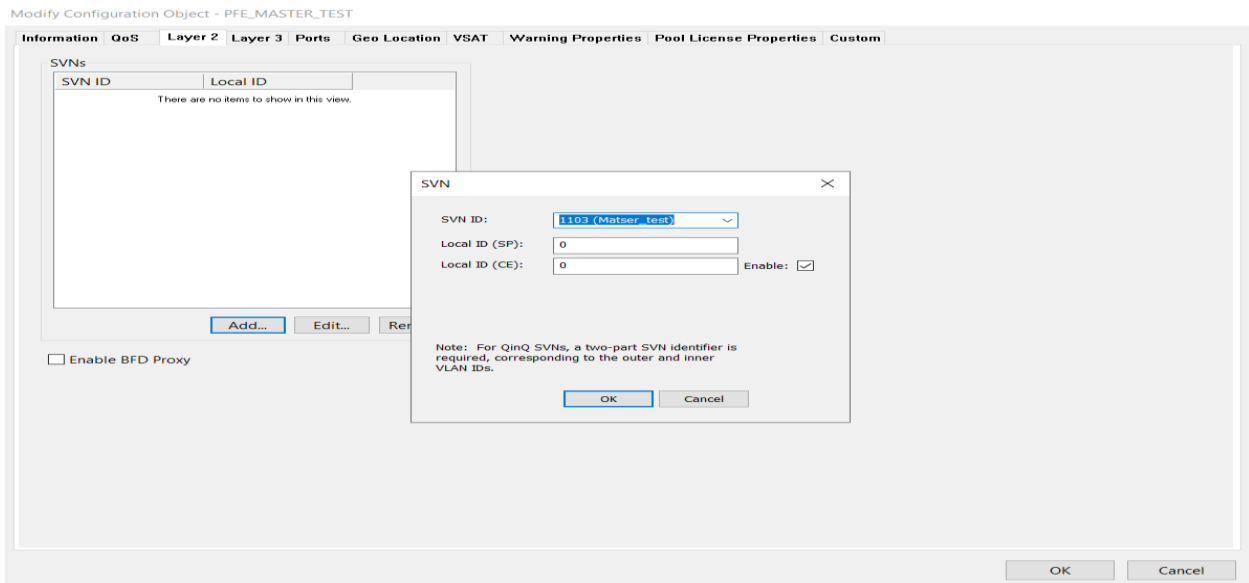


Figure 18: layer 2 configuration

L3 Configuring :

Used for accessing the modem locally and remotely.

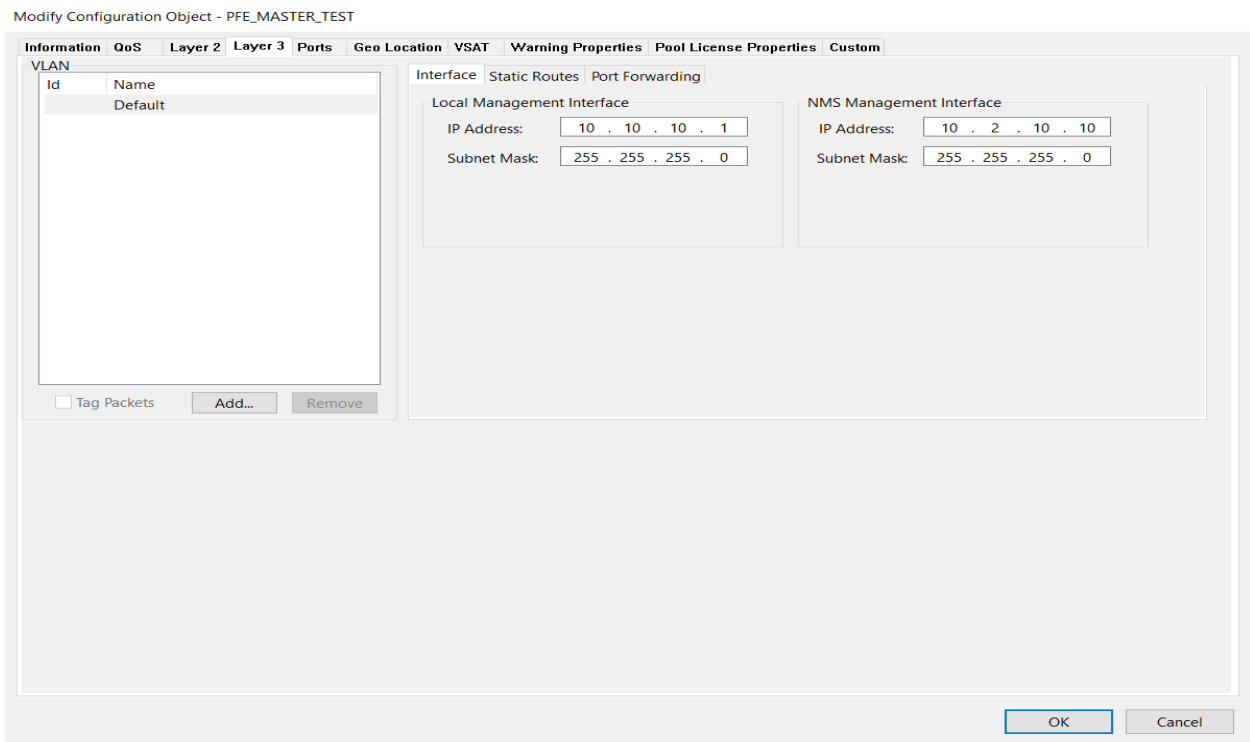


Figure 19 : layer 3 configuration

Ports configuration :

An iQ Desktop modem contains 2 ports :

Chaptre3 : Practical case of l2os implementation

Port 1: configured for l2os

Port 2: configured for local access

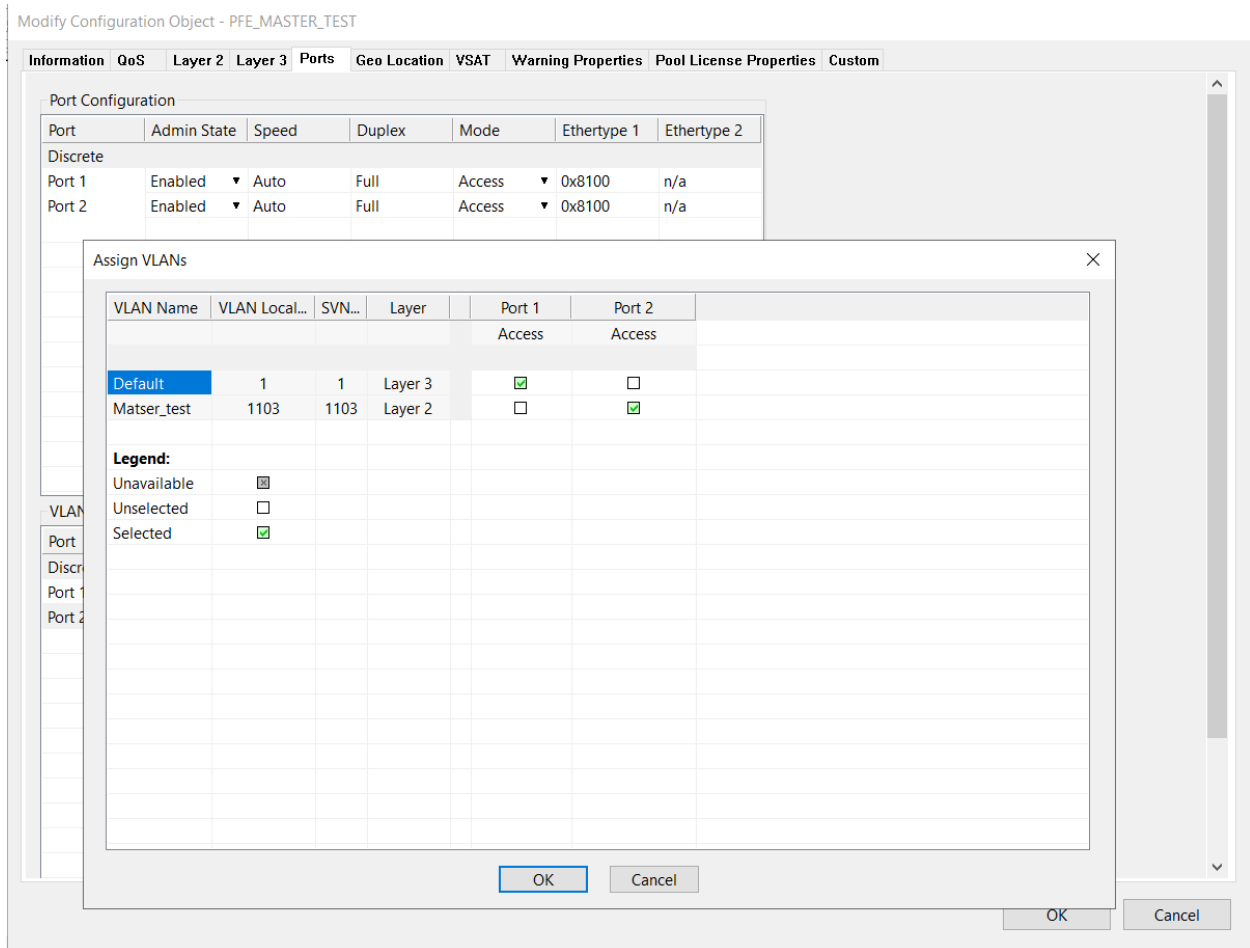


Figure 20: ports configuration

GPS coordinate configuration:

[GPS of Lakhdaria where we placed the two antennas]

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Modify Configuration Object - PFE_MASTER_TEST

Information QoS Layer 2 Layer 3 Ports Geo Location VSAT Warning Properties Pool License Properties Custom

Stationary:

Latitude: North 36.562468 decimal degrees
36 degrees 33 minutes 44.892 seconds

Longitude: East 3.60194 decimal degrees
3 degrees 36 minutes 6.984 seconds

Mobile:

GPS input

Manual Baud Rate: 4800
 Antenna Data: 8
 Serial or NMEA Parity: None
Device: ttyS0 Stop Bit: 1
Sample (sec): 120

Handshake Signalling
 Mobile Security

Minimum Look Angle

Inherit from satellite
 Override: 0 degrees

Maximum Skew

Inherit from satellite
 Override: 90 degrees

Skew Margin

Inherit from satellite
 Override: 90 degrees

COTM

Type: Maritime
(range from 0 to 30 mph)

OK Cancel

Figure 21: GPS configuration

4.2 Generating OPT file from NMS

OPT: An option file is a configuration file used by various software applications to store settings or options. These files typically contain parameters and settings that configure how a program behaves. It is the configuration file used by the remote modem to access or acquire the network.

Generating an OPT file from an NMS empowers users to customize and optimize the NMS software, enabling precise control over network management operations. It enhances efficiency, consistency, and the ability to adapt to changing network requirements, ultimately improving the overall effectiveness of network management processes.[2]

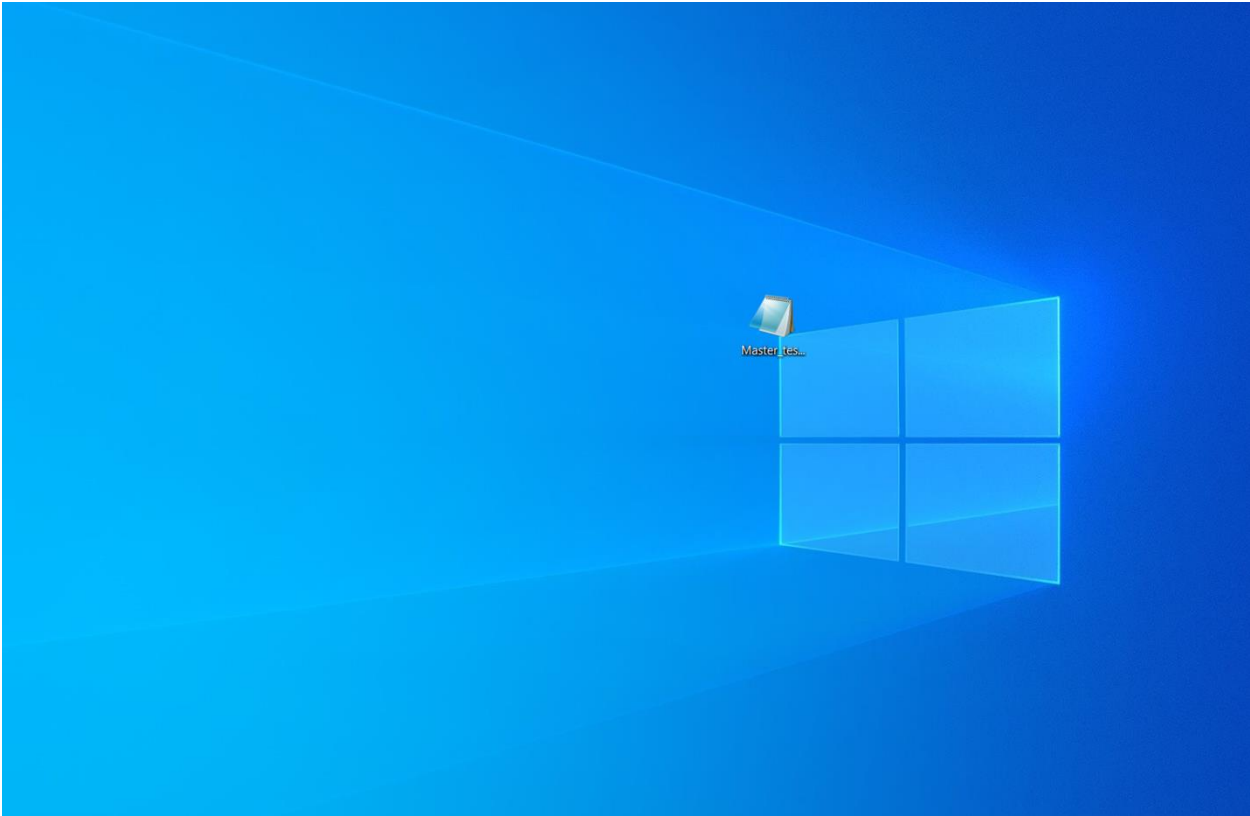


Figure 22: opt file

OPT injection:

The injection of an OPT file into a modem typically involves the following steps:

- Obtain the desired OPT file: You need to acquire the OPT file that contains the specific configuration options or updates you want to apply to the modem. This file may be provided by the manufacturer, service provider, or network administrator.
- Access the modem's administration interface: Connect to the modem's administration interface through a web browser or a dedicated software application. Typically, you need to enter the modem's IP address or a specific URL provided by the manufacturer.

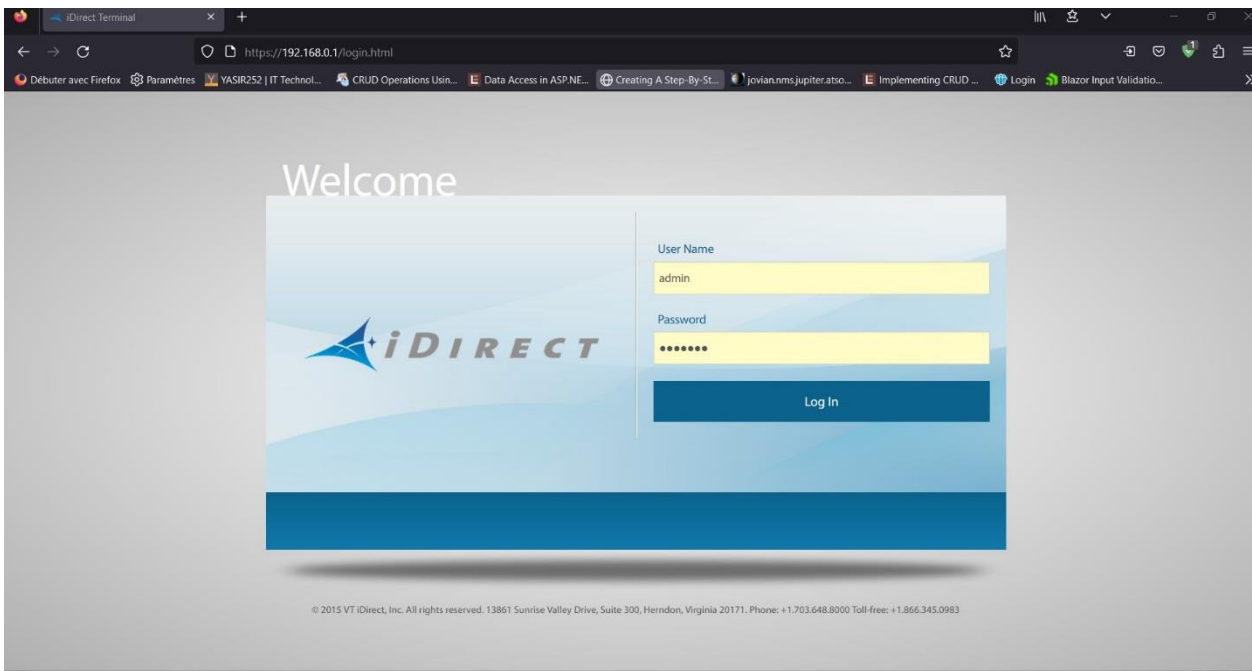


Figure 23: idirect account interface

- Authenticate and navigate to the configuration settings: Log in to the modem's administration interface using the appropriate credentials. Once logged in, locate the section or menu that allows you to upload or inject the OPT file. This section may be labeled as "Configuration," "Settings," or "Firmware Update."
- Upload the OPT file: Follow the instructions provided in the administration interface to upload or inject the OPT file. This usually involves selecting the file from your local storage and initiating the upload process. Depending on the modem model, you may need to confirm the upload or specify additional settings.
- Apply the changes: After the OPT file is successfully uploaded, the modem will apply the new configuration settings or updates contained in the file. This process may take a few moments, during which the modem may restart or undergo a firmware upgrade.
- Verify the changes: Once the injection process is complete, you can verify the applied changes by navigating through the modem's administration interface. Check the relevant settings or features to ensure that they reflect the modifications specified in the OPT file.

Chaptre3 : Practical case of L2oS implementation

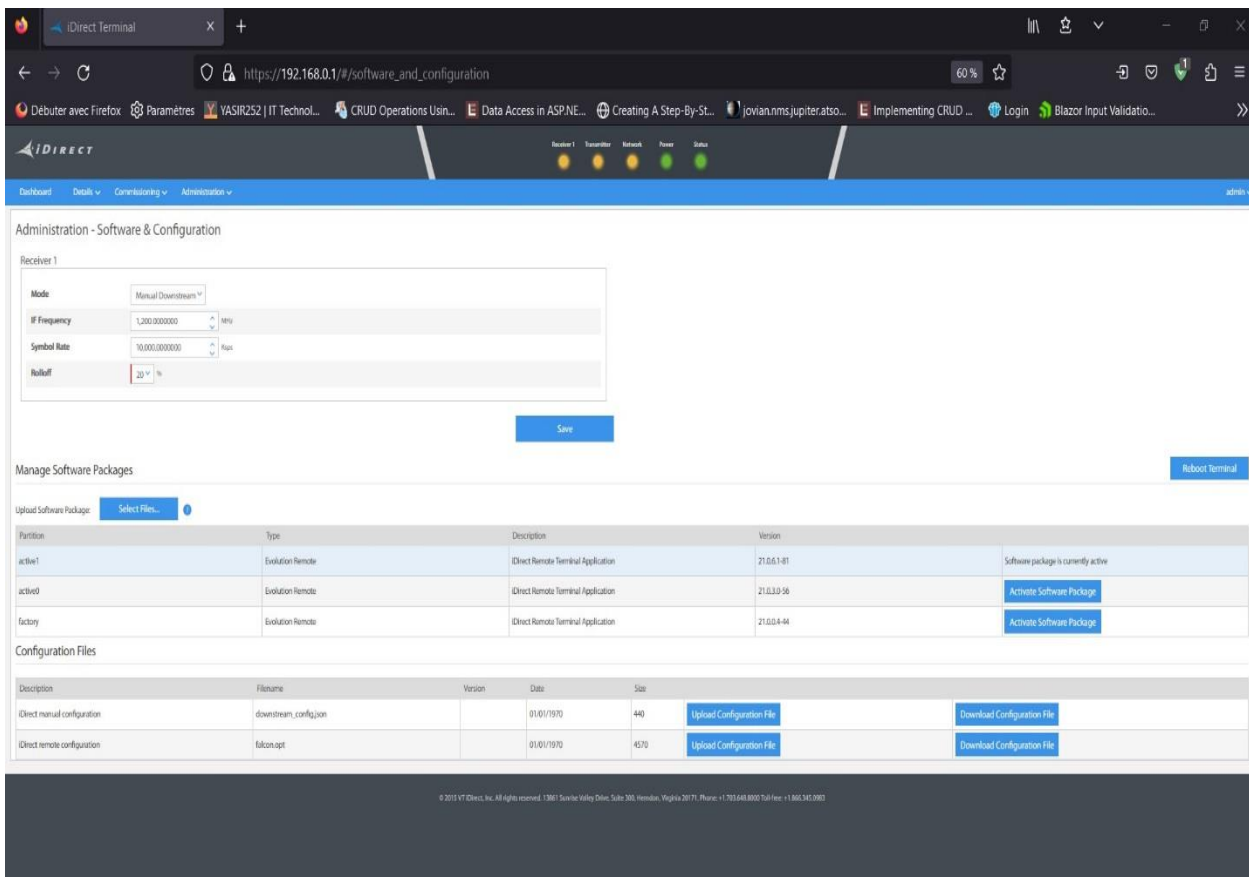


Figure 24: injecting opt file

5. Traffic in L2oS:

In Layer 2 over Satellite, traffic refers to the data packets or information being transmitted over the satellite link. This can include Ethernet frames or other Layer 2 protocol-specific data that is sent between network devices connected via the satellite link. [14]

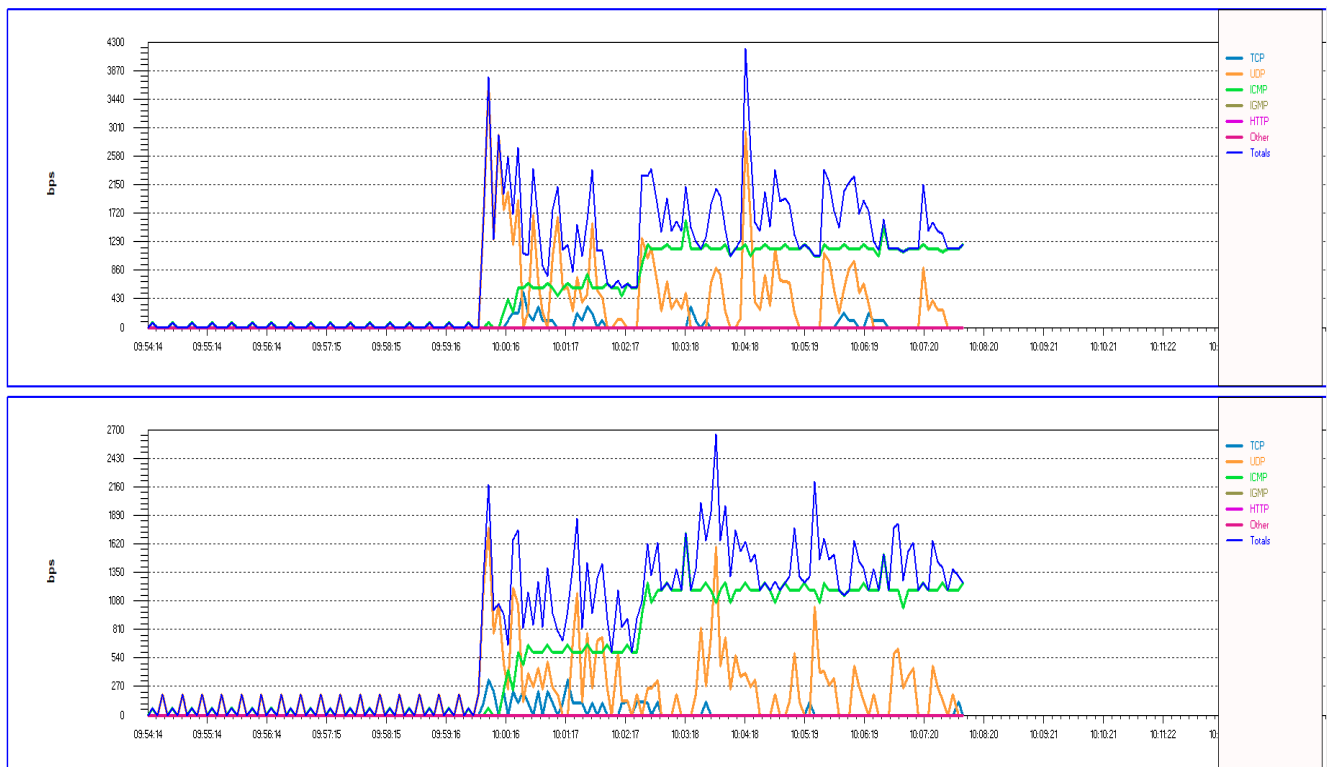


Figure 25: IP traffic in l2os

6. Latency in L2oS:

Latency in Layer 2 over Satellite refers to the time delay experienced by data packets as they travel between network devices over the satellite link. Satellite communication introduces higher latency compared to terrestrial networks due to the long distance the signals need to travel. Factors such as the satellite's orbit, signal propagation delay, and processing time at the satellite and ground stations contribute to latency.[15][16][17]

6.1 Calculating latency

Latency can be calculated by measuring the time it takes for a packet of data to travel from the source to the destination and back again. Here's a general method for calculating latency:

Choose a tool or method: Determine the approach you will use to measure latency. You can use specialized network monitoring tools, command-line utilities like ping, or application-specific tools designed for latency measurement. In our case, we use ping [16].

Select the source and destination: Identify the source and destination devices or network endpoints between which you want to measure latency. This could be between two computers, network devices, or specific IP addresses [16].

Chaptre3 : Practical case of I2os implementation

Start the measurement: Initiate the latency measurement tool or command. This will send a packet of data from the source to the destination.

Measure round-trip time: The measurement tool will record the time it takes for the packet to reach the destination and return back to the source. This is known as the round-trip time (RTT). Approximately 500 ms [16].

Calculate latency: Divide the round-trip time (RTT) by 2 to obtain the one-way latency. Since RTT accounts for both the time taken for the packet to travel to the destination and the return journey, halving it provides an estimate of the one-way latency. [16]

```
C:\Users\oualid>ping 10.10.2.1 -t
Pinging 10.10.2.1 with 32 bytes of data:
Reply from 10.10.2.1: bytes=32 time=565ms TTL=128
Reply from 10.10.2.1: bytes=32 time=576ms TTL=128
Reply from 10.10.2.1: bytes=32 time=563ms TTL=128
Reply from 10.10.2.1: bytes=32 time=558ms TTL=128
Reply from 10.10.2.1: bytes=32 time=610ms TTL=128
Reply from 10.10.2.1: bytes=32 time=583ms TTL=128
Reply from 10.10.2.1: bytes=32 time=581ms TTL=128
Reply from 10.10.2.1: bytes=32 time=572ms TTL=128
Reply from 10.10.2.1: bytes=32 time=565ms TTL=128
Reply from 10.10.2.1: bytes=32 time=592ms TTL=128
Reply from 10.10.2.1: bytes=32 time=550ms TTL=128
Reply from 10.10.2.1: bytes=32 time=583ms TTL=128
Reply from 10.10.2.1: bytes=32 time=576ms TTL=128
Reply from 10.10.2.1: bytes=32 time=638ms TTL=128
Reply from 10.10.2.1: bytes=32 time=547ms TTL=128
Reply from 10.10.2.1: bytes=32 time=571ms TTL=128
Reply from 10.10.2.1: bytes=32 time=575ms TTL=128
Reply from 10.10.2.1: bytes=32 time=570ms TTL=128
Reply from 10.10.2.1: bytes=32 time=552ms TTL=128
Reply from 10.10.2.1: bytes=32 time=565ms TTL=128
Reply from 10.10.2.1: bytes=32 time=562ms TTL=128
Reply from 10.10.2.1: bytes=32 time=670ms TTL=128
Reply from 10.10.2.1: bytes=32 time=659ms TTL=128
Reply from 10.10.2.1: bytes=32 time=566ms TTL=128
Reply from 10.10.2.1: bytes=32 time=560ms TTL=128
Reply from 10.10.2.1: bytes=32 time=552ms TTL=128
Reply from 10.10.2.1: bytes=32 time=551ms TTL=128
Reply from 10.10.2.1: bytes=32 time=579ms TTL=128
Reply from 10.10.2.1: bytes=32 time=594ms TTL=128
Reply from 10.10.2.1: bytes=32 time=573ms TTL=128
Reply from 10.10.2.1: bytes=32 time=567ms TTL=128
Reply from 10.10.2.1: bytes=32 time=569ms TTL=128
Reply from 10.10.2.1: bytes=32 time=562ms TTL=128
Reply from 10.10.2.1: bytes=32 time=557ms TTL=128
Reply from 10.10.2.1: bytes=32 time=581ms TTL=128
Reply from 10.10.2.1: bytes=32 time=575ms TTL=128
Reply from 10.10.2.1: bytes=32 time=545ms TTL=128
Reply from 10.10.2.1: bytes=32 time=574ms TTL=128
Reply from 10.10.2.1: bytes=32 time=550ms TTL=128
Reply from 10.10.2.1: bytes=32 time=603ms TTL=128
Reply from 10.10.2.1: bytes=32 time=559ms TTL=128
Reply from 10.10.2.1: bytes=32 time=575ms TTL=128
Reply from 10.10.2.1: bytes=32 time=568ms TTL=128
Reply from 10.10.2.1: bytes=32 time=583ms TTL=128
Reply from 10.10.2.1: bytes=32 time=577ms TTL=128
```

Figure 26 : ping table

7. Throughput in L2OS :

Throughput in Layer 2 over Satellite represents the rate at which data can be transmitted over the satellite link. It indicates the capacity of the link to handle data transfer and is typically measured in bits per second (bps). Throughput in satellite communication can be affected by factors such as bandwidth limitations, link quality, modulation schemes used, and interference.[15]

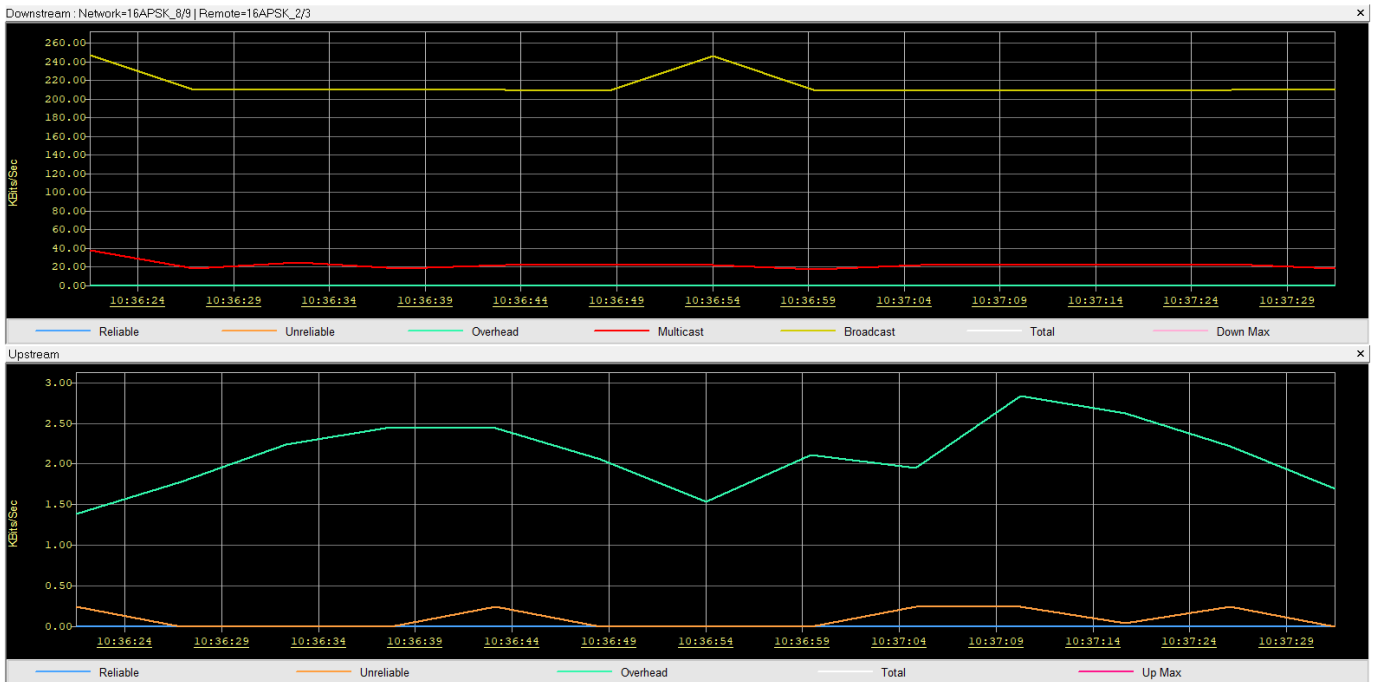


Figure 27: satellite traffic

8. Latency comparing between layer 2 and layer 3

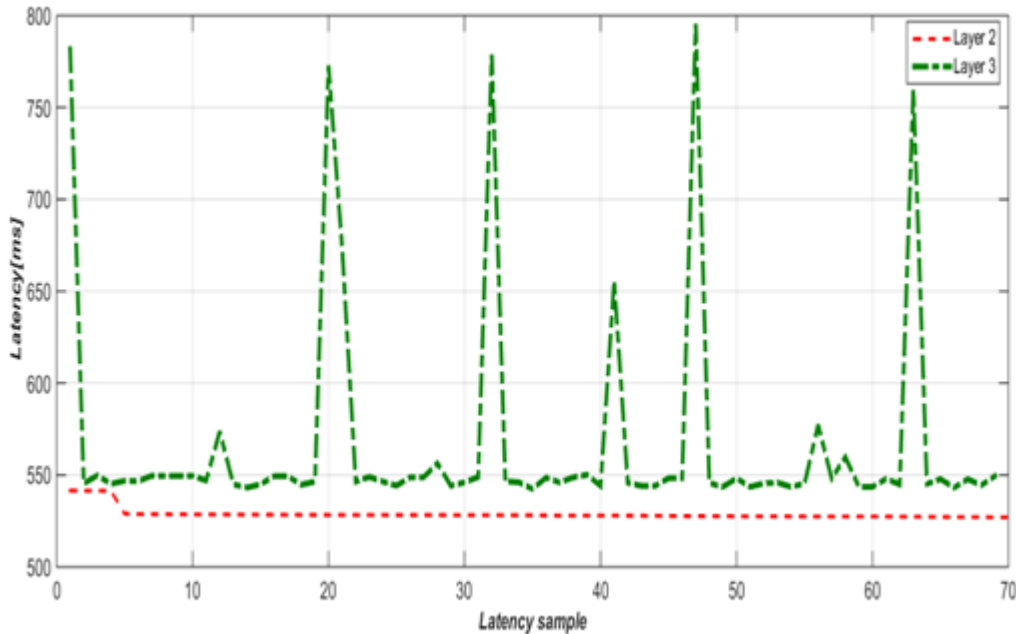


Figure 28 : latency comparing between layer 2 and layer 3

Figure 28 shows latency comparing between layer 2 and layer 3. Layer 2 networks tend to offer lower latency due to their local nature and direct MAC-based switching. Layer 3 networks, while introducing additional latency due to routing and IP processing, provide the necessary functionality for connecting disparate networks and enabling communication on a global scale. The choice between Layer 2 and Layer 3 depends on the specific requirements and priorities of the application or network deployment.

Conclusion :

In this chapter, we have provided an overview of the work environment and software required for the setup and implementation of the L2oS link. We discussed the selected software tools to ensure a successful L2oS configuration. Subsequently, we delved into the details of the L2oS configuration process. We explored the steps involved in setting up the L2oS link using the iBuilder platform, including the network architecture, software components, and necessary configurations. The configuration process was presented through detailed explanations and, where applicable, accompanied by screenshots to enhance clarity.

General conclusion

Throughout this project, we have explored the implementation of Layer 2 over Satellite (L2oS) using the iDirect platform. The project was divided into three chapters, each focusing on different aspects of the implementation process.

Chapter 1: In this chapter, we provided a comprehensive overview of VSAT technology. We discussed the fundamental concepts, components, and architecture of VSAT systems. Understanding VSAT technology was essential as it forms the foundation for implementing L2oS over satellite.

In **Chapter 2**, we delved into the implementation of Layer 2 over Satellite using the iDirect platform. We presented the software and tools necessary for configuring and managing the L2oS link. We highlighted the importance of proper configuration and network planning to ensure optimal performance.

In the **final chapter**, we presented a practical case study of L2oS implementation. We focused on a specific scenario involving two remote sites at ATS Lakhdaria. We discussed the network architecture, IP addressing, configuration steps, and tested the functionality of our implementation.

This project has provided us with a deep understanding of L2oS implementation over satellite using the iDirect platform. We have explored the underlying technology, gained insights into the configuration process, and witnessed the practical application of L2oS in a specific case study. Implementing L2oS offers numerous benefits, including enhanced connectivity, improved network performance, and seamless communication between remote sites.

While this project marks the completion of our exploration of L2oS implementation, it is crucial to acknowledge that satellite communication technology is continually evolving. Ongoing monitoring, maintenance, and regular updates will be necessary to adapt to emerging technologies, optimize network performance, and address any evolving requirements or challenges.

This work which was proposed to us at the ATS Lakhdaria allowed us to improve our knowledge in the field of telecommunications and computing in general and to acquire practical notions in the field of transmissions. During the internship, we were able to enrich our knowledge

of the VSAT network its components and configuration .we have also been introduced to the use of the iDirect platform.

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Resumé

Cette thèse examine la transmission à travers l'une des meilleures technologies satellitaires «la technologie vsat» qui fonctionne dans différentes formes et tailles de fréquences. Normalement, les fréquences de fonctionnement sont en bande C et en bande Ku et fonctionnent avec la topologie étoile (hub privé), Point-a-Point (Hub privé personnalisé) capable de supporter un grand nombre de lieux et les systèmes de la topologie maillée, régulièrement plus petits que les systèmes de la topologie étoile ce type d'antenne offre des services satellitaires capables de supporter les communications Internet, LAN, Voix IP, vidéo et data ; créant ainsi de puissants réseaux publics et privés pour une communication fiable. Parmi les meilleures plates-formes utilisées par Vsat pour transmettre des données on a la plate-forme iDirect. Parmi les services (programmes) offerts par iDirect est le programme iBuilder que nous utilisons pour mettre en œuvre la couche 2 sur satellite. Une installation iDirect standard est composée de deux segments de réseau distincts : upstream et en tunnel, connectés par le routeur upstream. Deux interrupteurs sont nécessaires. Le commutateur en upstream est utilisé par tous les éléments connectés à ce segment de réseau tandis que le commutateur de tunnel est principalement utilisé pour la communication entre les serveurs de processeur de protocole et les cartes de ligne. Le trafic utilisateur apparaîtra comme un trafic clair sur le réseau en upstream. Tout le trafic utilisateur qui doit être envoyé vers une remote particulière est traité par les serveurs de processeur de protocole. Lors de la configuration d'une nouvelle remote sur le réseau, le système attribue automatiquement un serveur de processeur de protocole pour gérer le trafic acheminé vers cette 'remote' particulière. Lorsqu'un réseau iDirect est configuré pour L2oS, les trames Ethernet, plutôt que les paquets IP, sont transportées via la liaison satellite. La connectivité de la couche 2 entre le hub et remote est préférée aux connexions IP de la couche 3 traditionnellement proposées par iDirect. Les avantages de l'utilisation de L2oS incluent : la transparence de la couche 3, une couche physique efficace et des opérations simplifiées.

Mots clés : VSAT, configuration L2OS, transmission de données, plate-forme iDirect, trames Ethernet, réseau iDirect.

ملخص

تبحث هذه الرسالة في الإرسال من خلال واحدة من أفضل تقنيات الأقمار الصناعية «تقنية vsat» التي تعمل بأشكال وأحجام تردد مختلفة ، وعادة ما تكون ترددات التشغيل هي C-band و Ku-band وتعمل مع الأنظمة النجمية (Private Hub) ، نقطة-إلى-نقطة (محور خاص مخصص) قادرة على دعم عدد كبير من الأماكن وأنظمة الشبكات ، والتي تكون أصغر من الأنظمة النجمية بانتظام ، يوفر هذا النوع من الهوائي خدمات الأقمار الصناعية القادرة على دعم الإنترنت ، وشبكة المنطقة المحلية ، والصوت عبر بروتوكول الإنترنت ، والفيديو واتصالات البيانات ؛ وبالتالي ، إنشاء شبكات قوية عامة وخاصة للاتصالات الموثوقة. من بين أفضل المنصات التي تستخدمها Vsat لنقل البيانات. iDirect من بين الخدمات (البرامج) التي تقدمها iDirect برنامج iBuilder الذي نستخدمه لتنفيذ الطبقة الثانية عبر القمر الصناعي. يتكون تثبيت iDirect القياسي من جزأين منفصلين للشبكة: المنبع والنفق ، متصلان بواسطة جهاز التوجيه الرئيسي. مطلوب مبدلين . يتم استخدام المحول الرئيسي بواسطة جميع العناصر المتصلة بجزء الشبكة هذا بينما يستخدم محول النفق بشكل أساسي للاتصال بين خوادم معالج البروتوكول وبطاقات الخط. ستظهر حركة معلومات المستخدم كحركة واضحة على شبكة المنبع تتم معالجة جميع حركة معلومات المستخدم التي يجب إرسالها إلى أي جهاز بعيد بواسطة خوادم معالج البروتوكول. عند تكوين جهاز تحكم عن بعد جديد على الشبكة ، سيقوم النظام تلقائيًا بتعيين خادم معالج بروتوكول واحد لإدارة حركة المعلومات التي تنتقل إلى ذلك remote عندما يتم تكوين شبكة iDirect-L2oS ، يتم إرسال إطارات Ethernet ، بدلاً من حزم IP ، عبر ربط القمر الصناعي. يُفضل اتصال الطبقة الثانية بين لوحة الوصل وأجهزة التحكم عن بُعد على اتصالات IP من الطبقة الثالثة التي تقدمها iDirect تقليديًا. تشمل مزايا استخدام L2oS ما يلي: شفافية الطبقة الثالثة ، والطبقة المادية الفعالة ، والعمليات المبسطة.

iDirect ، شبكة Ethernet ، إطارات iDirect ، نقل البيانات ، منصة L2OS ، تكوين VSAT :الكلمات الرئيسية