

# National Layer-2 Wholesale FWA leveraging VxLAN

ITNOG 10 21/4/2026

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CCIE #39837 - CCSI #34898

# Eupalinos Tunnel

Samos island – Greece



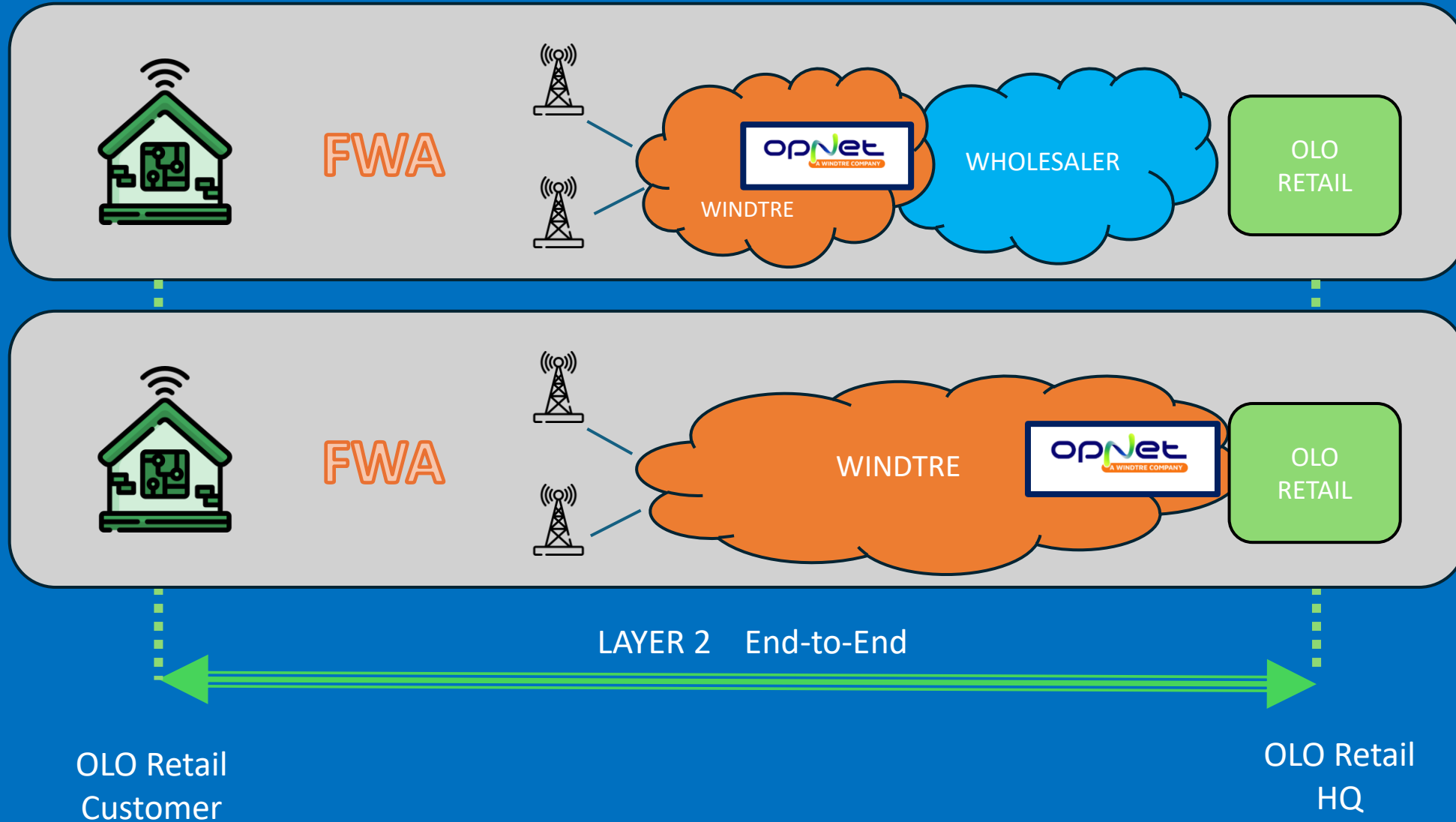
6th c BC

The first engineering work, as a **geometric method**,  
for the construction of a tunnel

It's the **beginning of future** construction techniques

# Goal of the Session

## NEW ARCHITECTURAL DESIGN



# Who I am?

- **CHRISTIAN BIASIBETTI**



IVREA



- Start to work in Telco industry in 1996  
(from interface X.21bis)



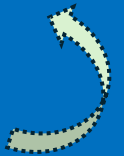
- Domains experienced within the SP:
  - Network Control Center
  - T.A.C. Enterprise / Technical Support
  - Engineering IP
  - Manager Fixed Access
  - Network Architect



- CCSI #34898 Instructor
- CCIE #39837 Routing & Switching  
[CCNA, CCNP, Specialist Enterprise Core/Advanced]



- Road cyclist for about 40 years
- 10.000 km per year by bicycle
- A hundred cycling races
  - Road and Cyclocross (CX)
- Italian CX Master Championships
- World CX Master Championships



# Agenda



Market "OLO Retail" needs Layer 2 ... really sound?



FWA Recap – Layer 3 and Layer 2



Architectural Technical Choice



Challenges faced



Use Case



Conclusion

Market "OLO Retail" needs Layer 2 ... **really sound?**



# Market "OLO Retail" needs Layer 2 ... **really sound?**



## Probably like this:

- **Premium Internet services**
- BNG/BRAS
- VoIP
- **Gaming**
- IPTV
  
- Smart City
- Urban video surveillance
- Cameras in schools, hospitals, and parking lots
- **Limited Traffic Zone (ZTL) gates**
- License plate readers (ANPR - Automatic Number Plate Recognition)
  
- **Industrial IoT**
- Connect factories and warehouses to the data center
- Transport PLCs and L2 industrial protocols
- **Connect robots, systems**
- SCADA systems (Supervisory Control And Data Acquisition)
  
- **Native security**, service segregation
- Each customer/service in a **separate VLAN**

Layer 2 enables the **transparent transport of Ethernet** traffic between End-to-End point

Layer 2 is suitable for those who want to **maintain direct control** over

- ✓ **Routing**
- ✓ **IP management**
- ✓ **Manage services configuration**

... the answer is **YES**



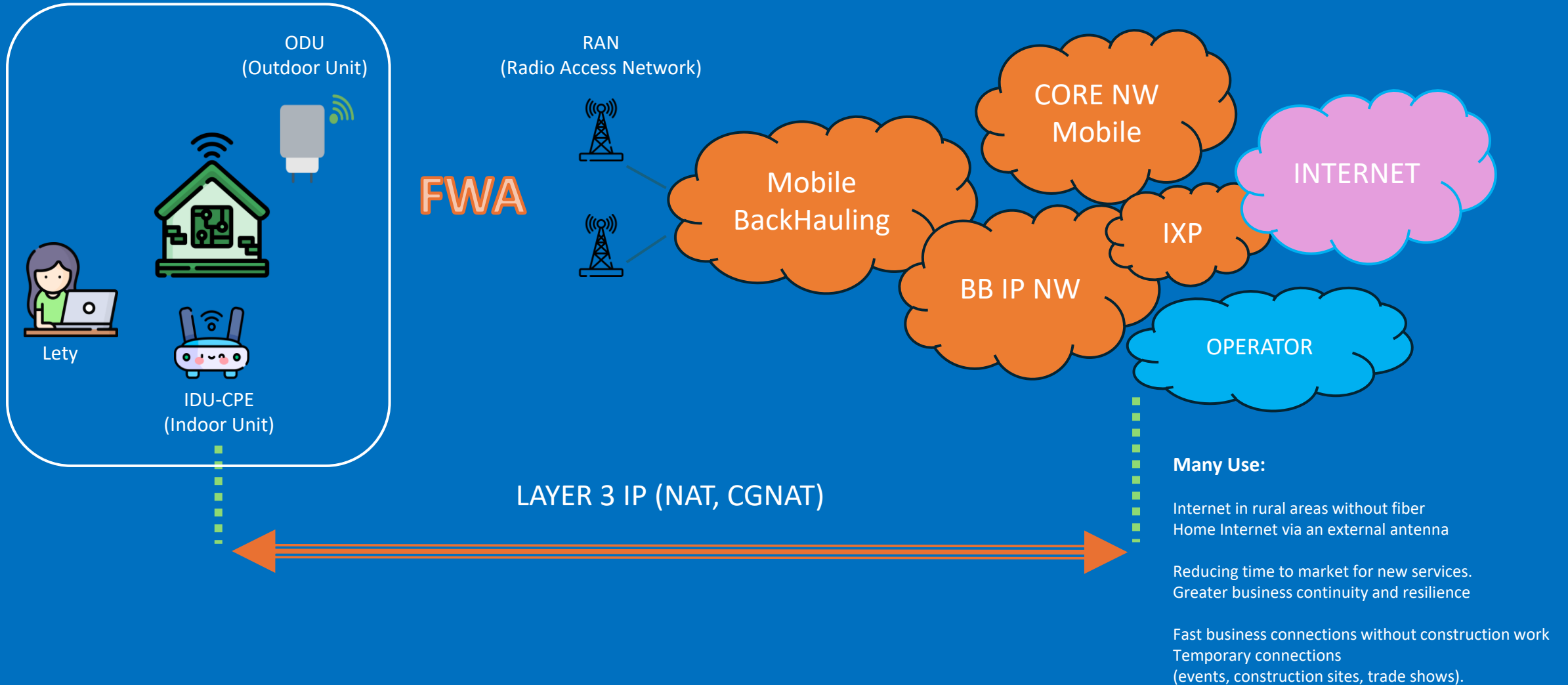
# FWA Recap – Layer 3 and Layer 2



# FWA Recap – Layer 3



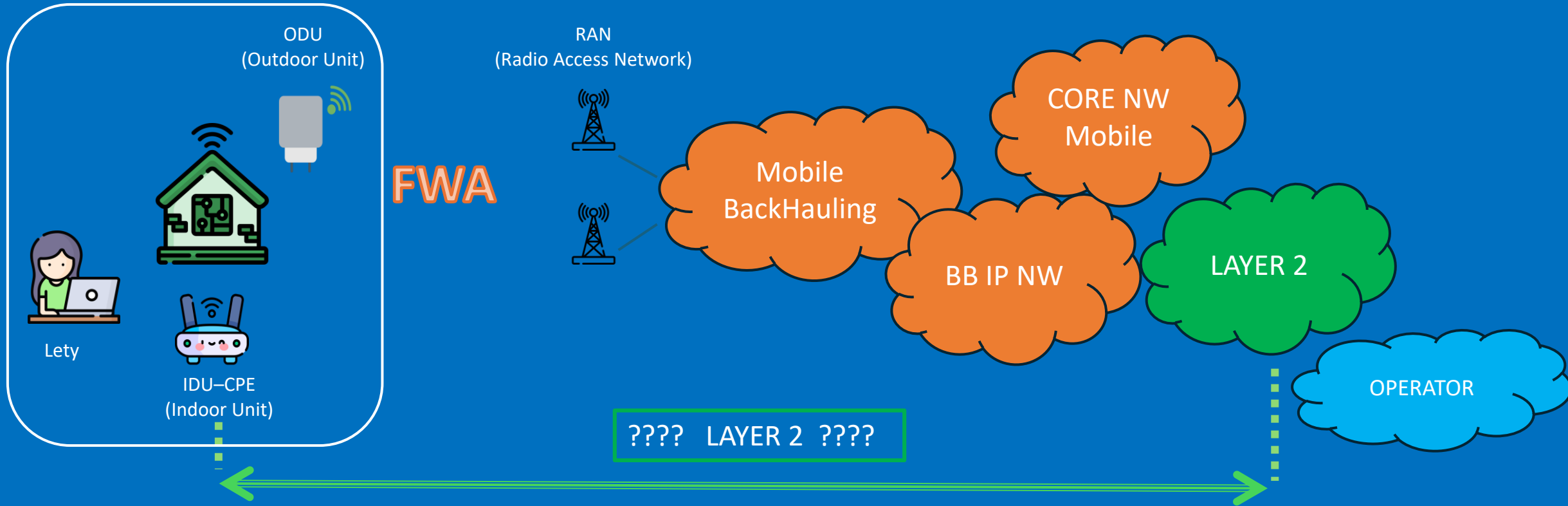
Fixed Wireless Access provide Internet connection using the radio network (4G, 5G ), instead of fiber or copper wire.



# FWA Recap – Layer 2



But what about FWA Layer 2 ?



Why isn't FWA used as a "local loop" **L2 transport**?

We're still talking about VLANs and **Spanning Trees**... even on mobile?

**Why hasn't anyone done it?**

**Few resources** in terms of ASIC CPU/RAM @home

Existing installed base, multi-vendor

**Distinct network** domains

OK, we must STUDY



**OVN**

# Architectural Technical Choice





## OVN: Overlay Virtual Networking

### "LEGACY"

- **L2TPv3** – Layer 2 Tunneling Protocol Version RFC 3931
- **NVGRE** - Network Virtualization using GRE - RFC 7637
- **GENEVE** – Generic Network Virtualization Encapsulation – draft-ietf-nvo3-geneve
- **STT** – Stateless Transport Tunneling (no standard)

### "FUTURE"

- **5G Ethernet PDU Session (3GPP)**  
requires 5GSA  
QoS requires 5G TSN Bridging
- **5G TSN Bridging**  
Ethernet TSN (Time-Sensitive Networking) bridge complex configuration: dedicated TSN-AF, TT, UPF requires very precise sync (non-trivial over radio)

### "CONSOLIDATED"



- **VxLAN – Virtual eXtensible LAN**
  - RFC 7348
  - **MAC-in-UDP** – Well-know port 4789
  - No Spanning-Tree
  - Industry recognized as the "gold standard"
  - 24 bit VNI = over **16 Million VLAN** !!!



- **But VxLAN "means" Data Center !!!**  
*"what do you mean Flash Gordon approaching" (\*)*



(\*) It's only clear to "Generation X" [by Klytus faithful of Ming, Emperor of the Planet Mongo]

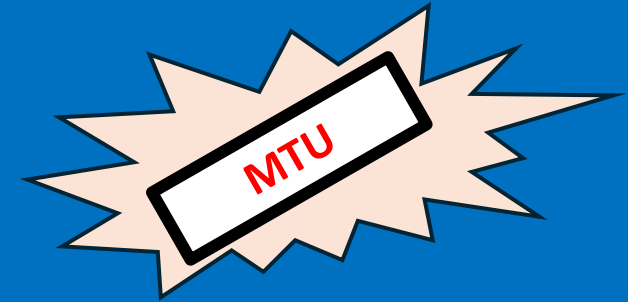
# Architectural Technical Choice



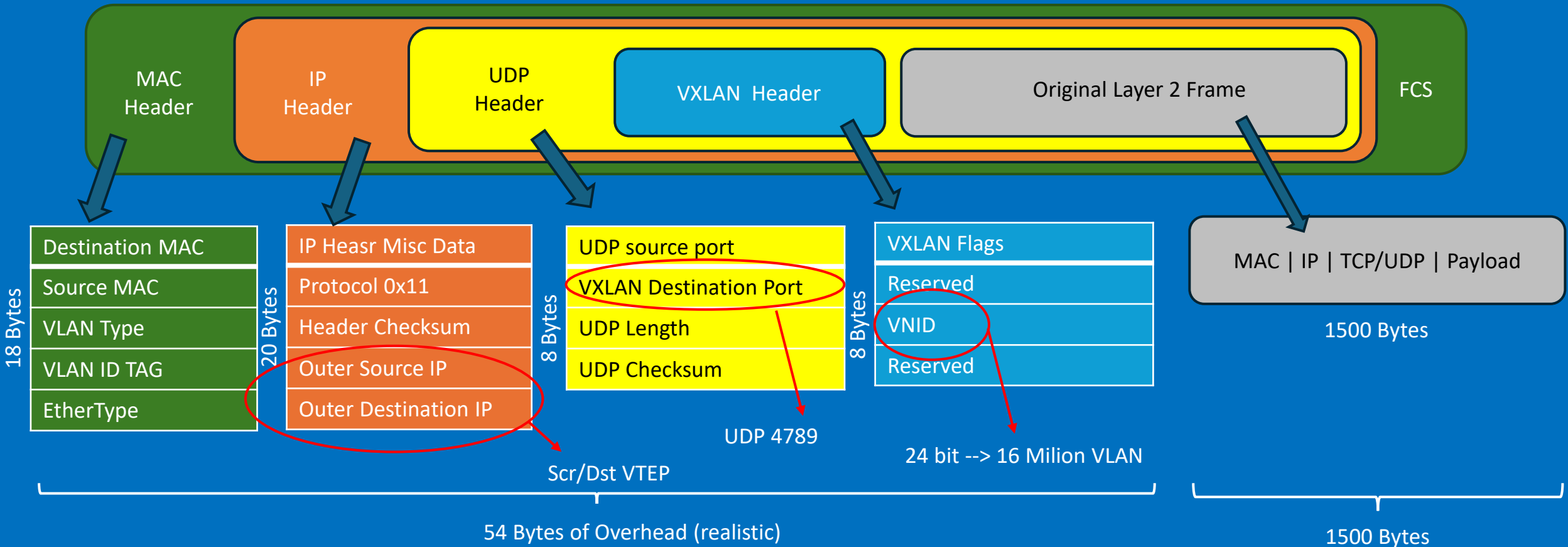
## VxLAN – RFC 7348 (also known as MAC-in-UDP)

**VNI** = VXLAN Network Identifier (24 bit, alias over 16 Milion VLAN)

**VTEP** = VXLAN Tunnel EndPoint



Overlay **Data Plane** VXLAN - Ethernet frame :



# Architectural Technical Choice



## VxLAN – What about Control Plane?

### ➤ BGP EVPN

In this scenario is "too much" !!!

RFC 8365 (VXLAN-EVPN)

AFI 25 / SAFI 70 @home ? No good idea

New infrastructure

High cost

### ➤ Ingress Replication/ Head-end Replication (HER)

Easy configuration

No new infrastructure

Only reachability IP (v4/v6) to remote VTEP

Low Cost



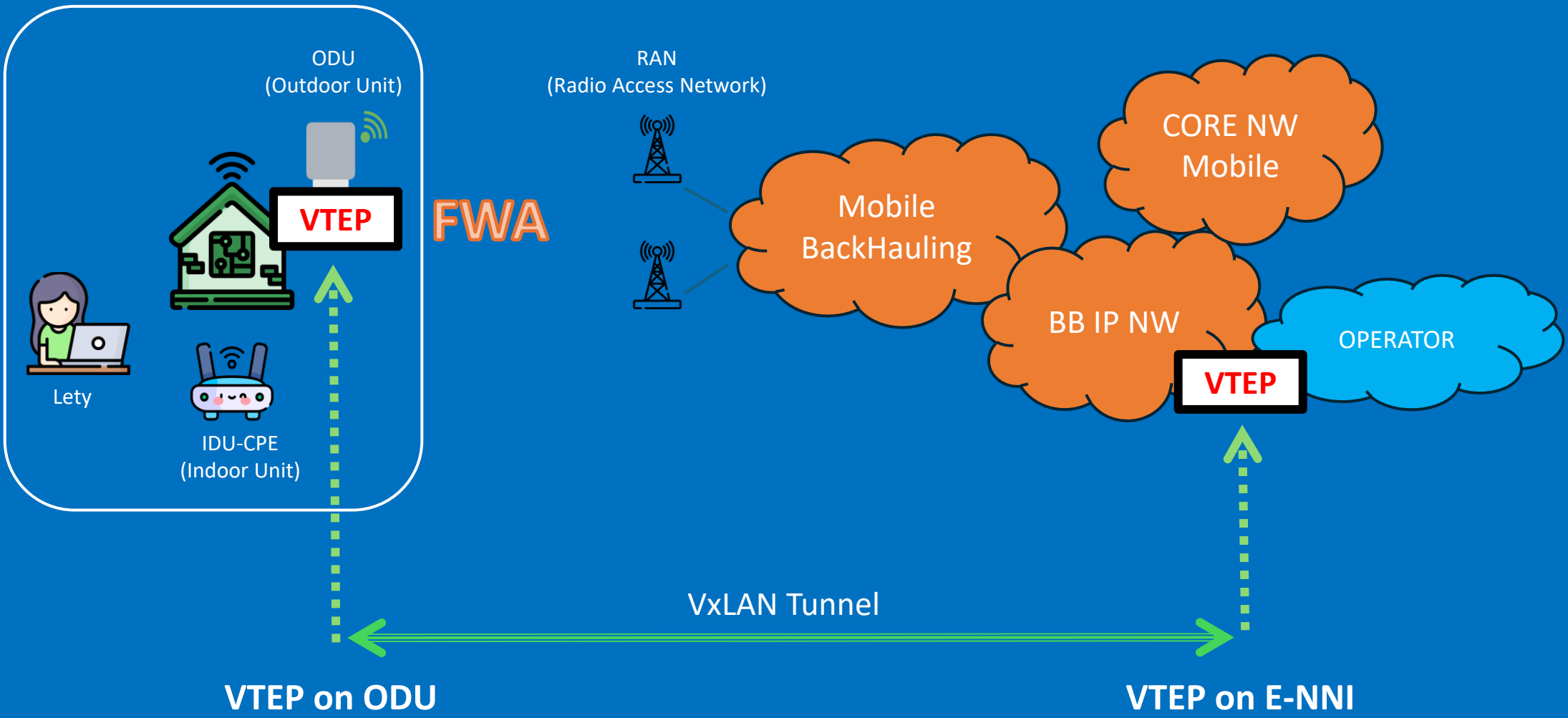
Good, but the question is:

"where do I put the VTEP ? "

# Challenges faced



# Challenges faced: VTEP VXLAN Tunnel End Point place



# Challenges faced: Nobody does it, dubious Vendors

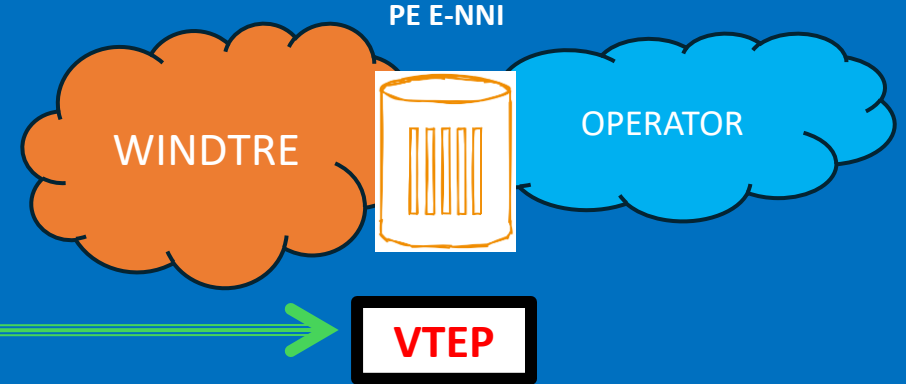


ODU  
(Outdoor Unit)



**VTEP**

VxLAN Tunnel



it's "only" an ODU, not a switch in DC

it's a PE MPLS, not a switch in DC

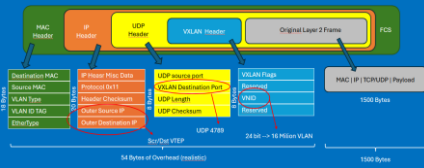
But then:

New Feature VXLAN, QoS  
New Chipset  
New IP management  
New VLAN-TAG  
Easy config

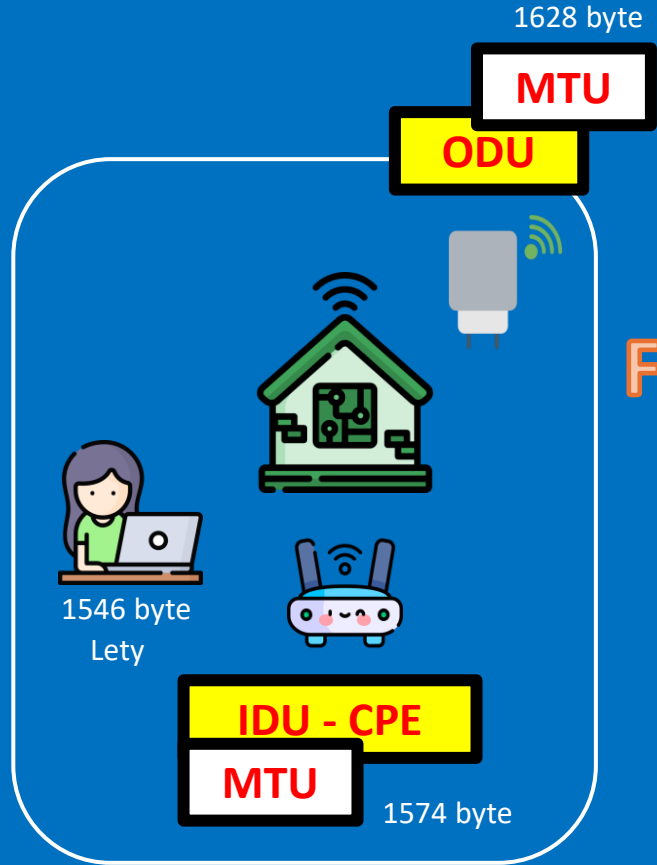
But then:

VTEP single, with multi VRF  
Multi vlan – S/C Vlan  
Manage QoS  
Manage BW  
Manage P-bit

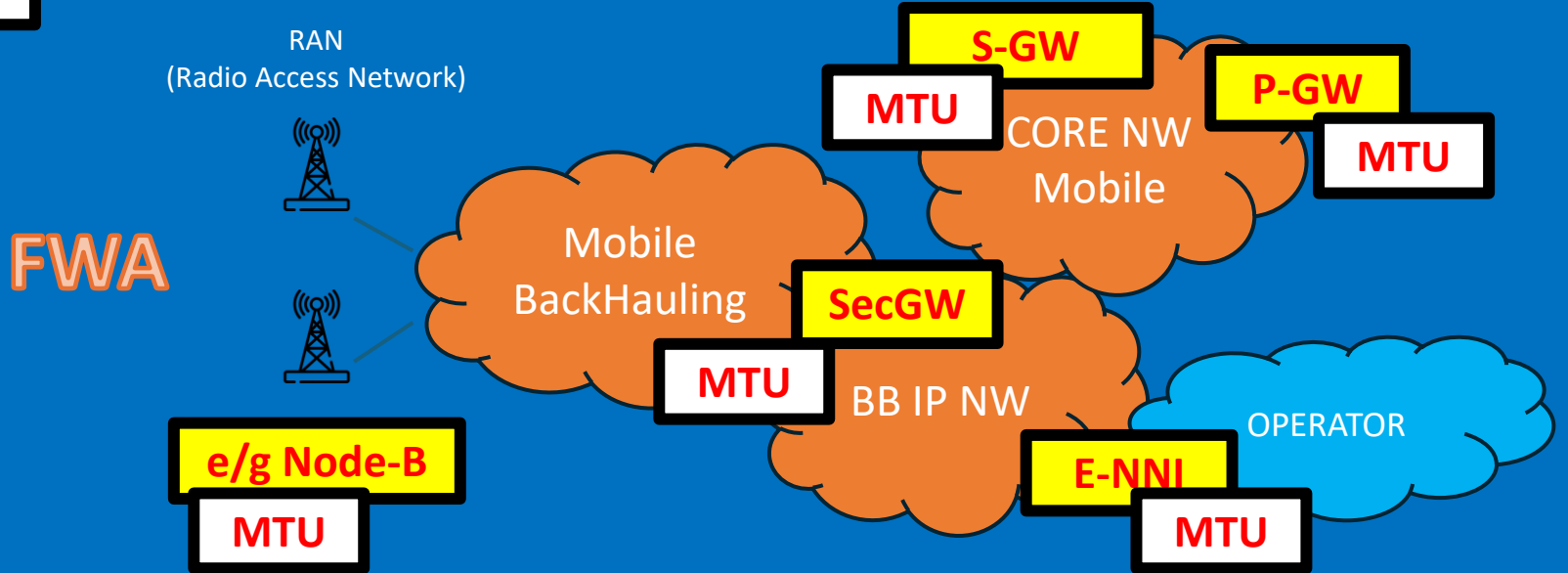
# Challenges faced: MTU



VxLAN 50-54 byte overhead



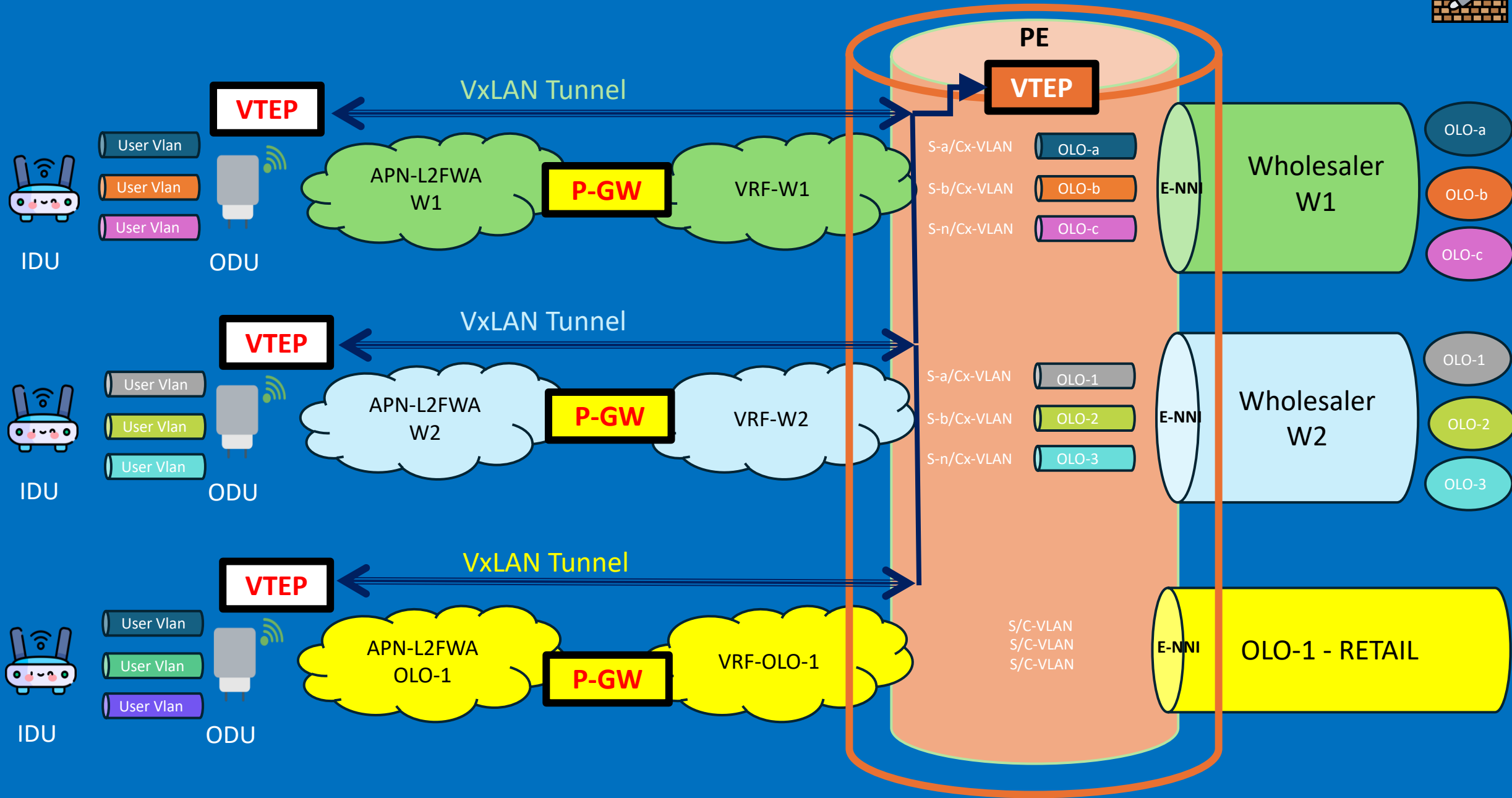
Data Payload 1546 byte  
Don't Fragment



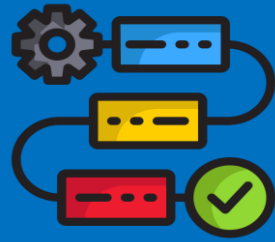
MTU analyzed and optimized End-to-End



# Challenges faced: Multi Wholesaler – Multi OLO Retail

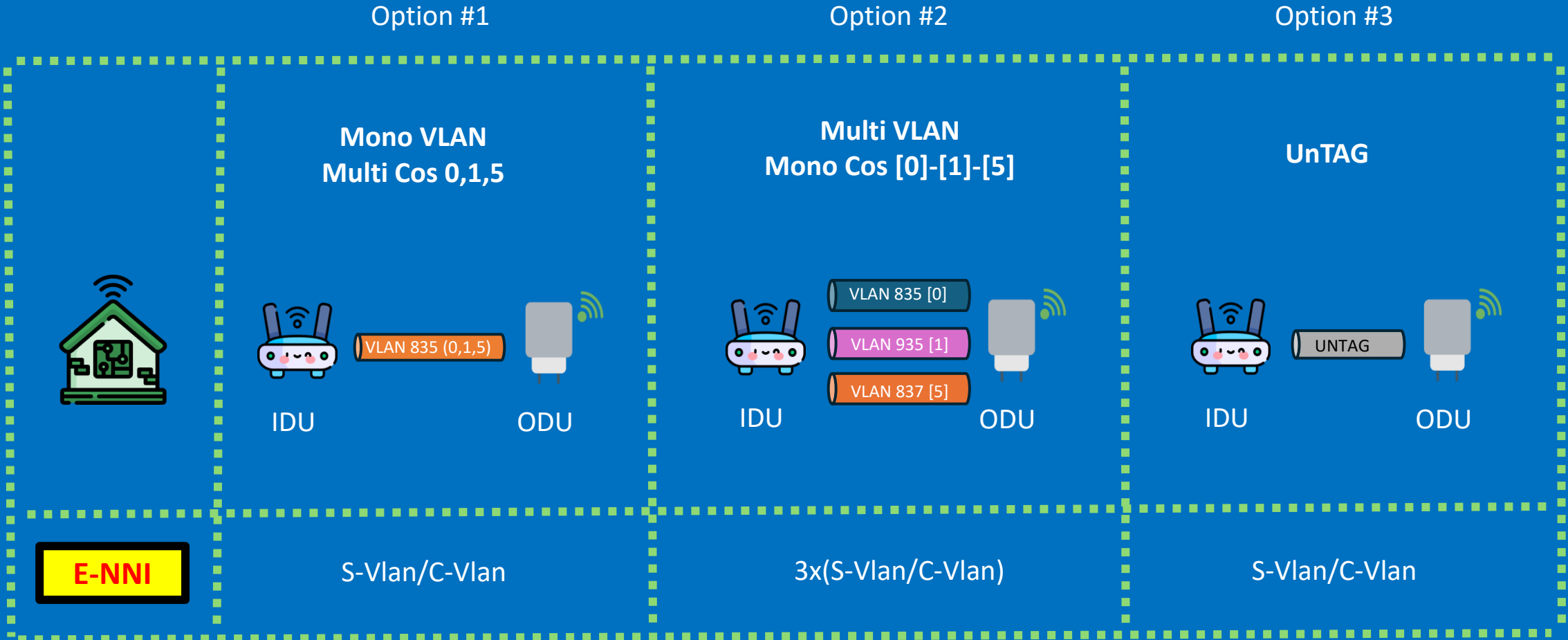


# Use Case





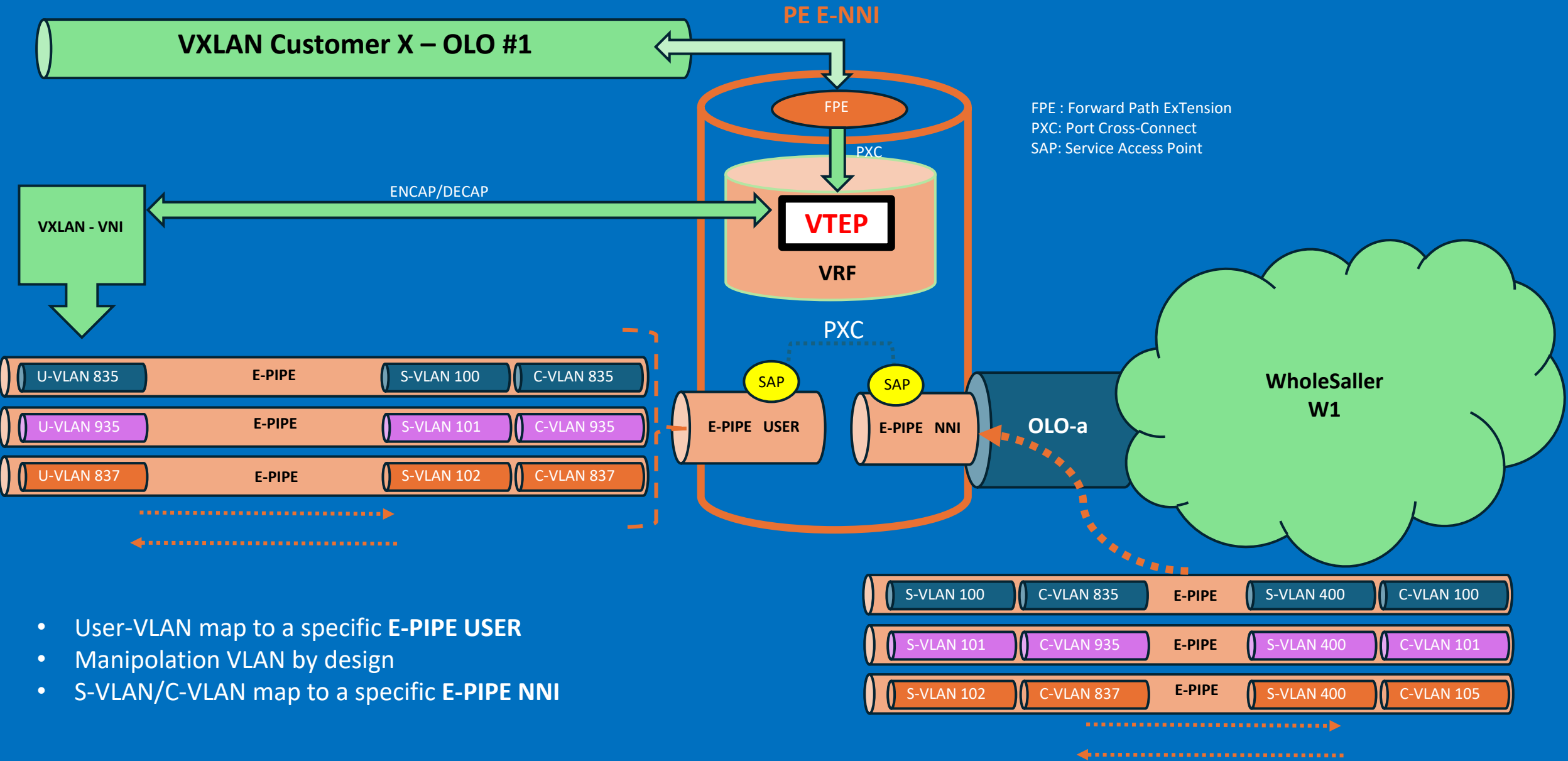
## Delivery Service @home L2FWA based on a predefined portfolio (like fixed access)



Are you thinking about **VLAN MANIPULATION?**

# Use Case

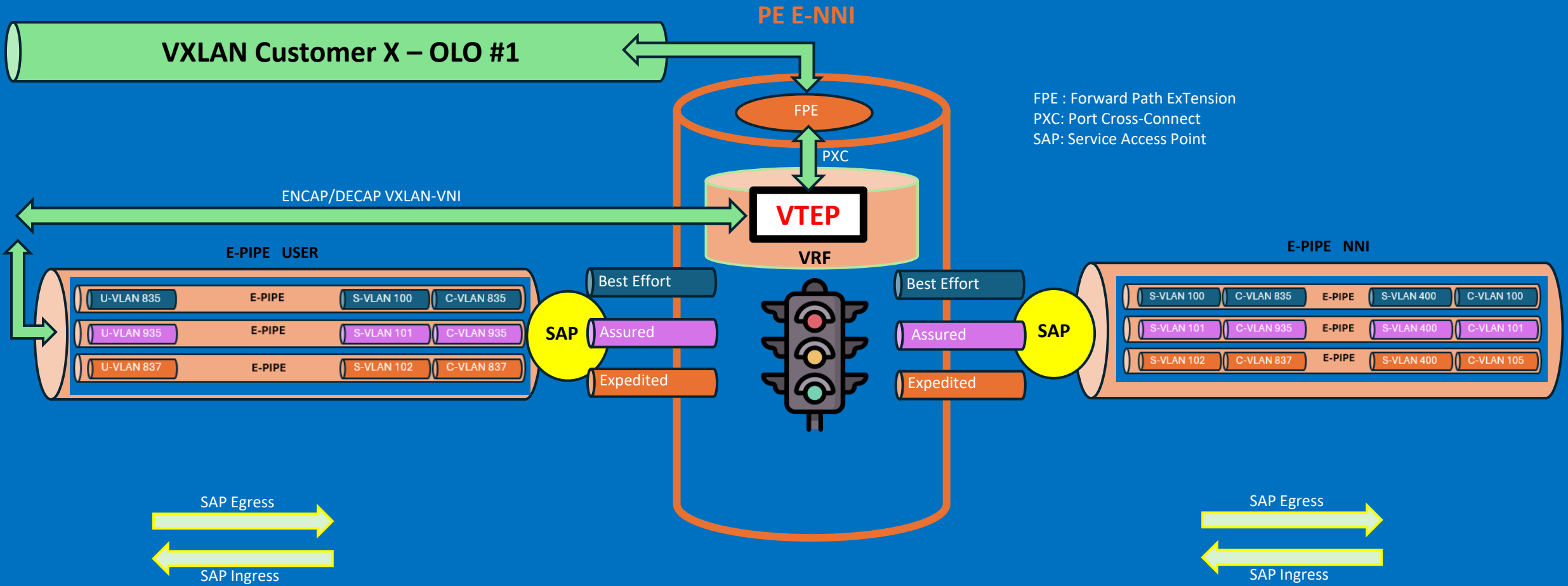
## VLAN Manipulation : Multi VLAN



- User-VLAN map to a specific **E-PIPE USER**
- Manipulation VLAN by design
- S-VLAN/C-VLAN map to a specific **E-PIPE NNI**

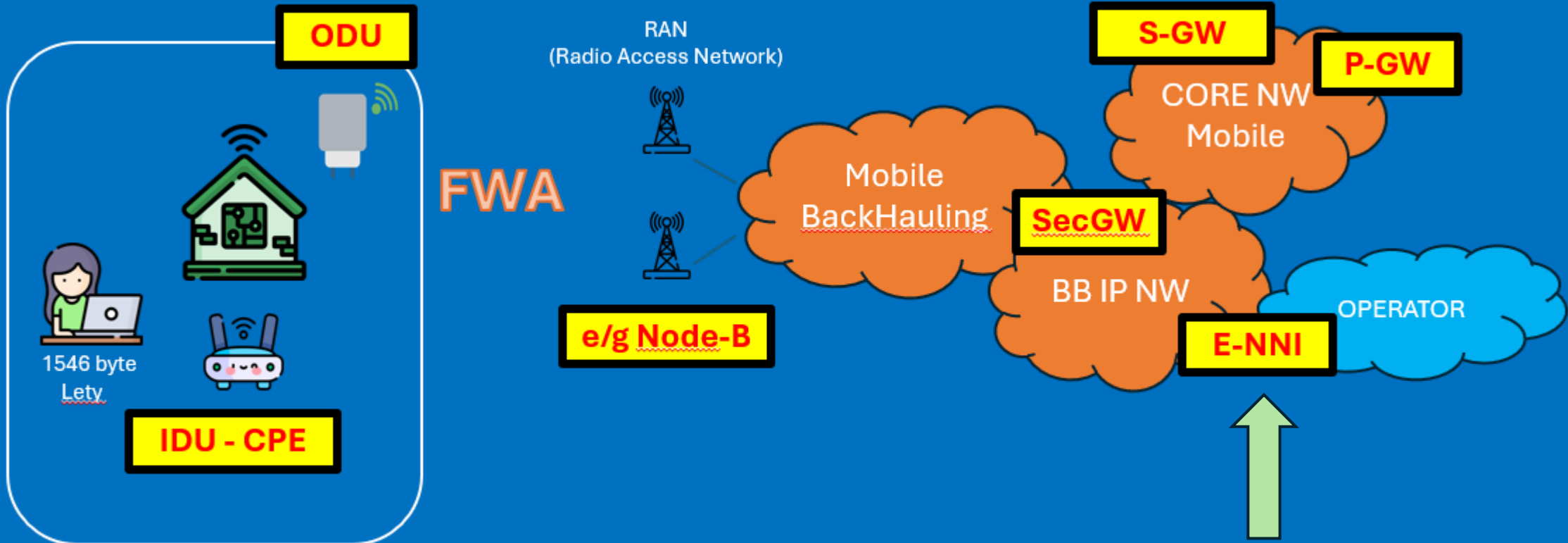
# Use Case

## QoS Manager – Multi VLAN - Mono CoS [0]-[1]-[5]



- Manage & Control P-Bit
- Manage Queues
- Manage PIR/CIR
- Scheduler Policy UP/DOWN traffic

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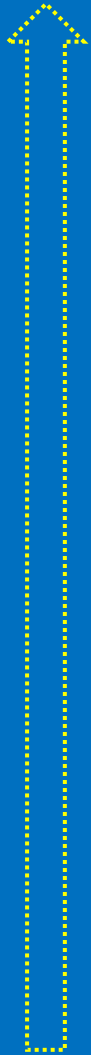


Let's have fun  
with WireShark



# Use Case

Let's see a single: VLAN 835, Cos [1]



READ  
bottom to top

No.	Time	Source	Destination	Protocol	Length	Info
→	36 0.305094	20.24.12.1	20.24.12.2	ICMP	1646	Echo (ping) request id=0x6379
Frame 36: Packet, 1646 bytes on wire (13168 bits); 1646 bytes captured (13168 bits) on interface 0						
Ethernet II, Src: 00:00:00:00:00:01 (00:00:00:00:00:01), Dst: 00:00:00:00:00:02 (00:00:00:00:00:02)						
802.1Q Virtual LAN, PRI: 1, DEI: 0, ID: 1						
Internet Protocol Version 4, Src: 12.4.24.1, Dst: 198.18.3.91						
User Datagram Protocol, Src Port: 39177, Dst Port: 4789						
Virtual eXtensible Local Area Network						
Flags: 0x0800, VXLAN Network ID (VNI)						
Group Policy ID: 0						
VXLAN Network Identifier (VNI): 124						
Reserved: 0						
Ethernet II, Src: 1e:d0:d6:6d:70:33 (1e:d0:d6:6d:70:33), Dst: 1e:d0:d6:6a:de:86 (1e:d0:d6:6a:de:86)						
802.1Q Virtual LAN, PRI: 1, DEI: 0, ID: 835						
001. .... = Priority: Background (1)						
...0 .... = DEI: Ineligible						
... 0011 0100 0011 = ID: 835						
Type: IPv4 (0x0800)						
Internet Protocol Version 4, Src: 20.24.12.1, Dst: 20.24.12.2						
0100 .... = Version: 4						
... 0101 = Header Length: 20 bytes (5)						
Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)						
Total Length: 1574						
Identification: 0x0000 (0)						
010. .... = Flags: 0x2, Don't fragment						
0... .... = Reserved bit: Not set						
.1.. .... = Don't fragment: Set						
..0. .... = More fragments: Not set						
...0 0000 0000 0000 = Fragment Offset: 0						
Time to Live: 30						
Protocol: ICMP (1)						
Header Checksum: 0x16a5 [validation disabled]						
[Header checksum status: Unverified]						
Source Address: 20.24.12.1						
Destination Address: 20.24.12.2						
[Stream index: 5]						
Internet Control Message Protocol						
Type: Echo (ping) request (8)						
Code: 0						
Checksum: 0xf727 [correct]						
[Checksum Status: Good]						
Identifier (BE): 25465 (0x6379)						
Identifier (LE): 31075 (0x7963)						
Sequence Number (BE): 10 (0x000a)						
Sequence Number (LE): 2560 (0x0a00)						
[Response frame: 41]						
Data (1546 bytes)						

- MTU grows
- VTEP Source (ODU), VTEP Destination (E-NNI)
- Well Know UDP port VXLAN (4789)
- VNI used by VTEP (124)
- Priority Cos [1]
- VLAN ID between ODU-IDU (835)
- IP Source/Destination Original Packet (Lety)
- MTU Payload IDU
- Don't Fragment activated
- MTU Payload Original Frame (Lety)

# Use Case Mono VLAN 835 Multi Cos 0,1,5



Applica un filtro di visualizzazione ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
3692	8.822004	50.0.0.2	60.0.0.2	UDP	1554	22960 → 32960 Len=1454

> Frame 3692: Packet, 1554 bytes on wire (12432 bits), 1554 bytes captured (12432 bits)  
> Ethernet II, Src: 00:00:00\_00:00:01 (00:00:00:00:00:01), Dst: 00:00:00\_00:00:02 (00:00:00:00:00:02)  
> 802.1Q Virtual LAN, PRI: 1, DEI: 0, ID: 1  
> Internet Protocol Version 4, Src: 12.4.24.1, Dst: 198.18.3.91  
> User Datagram Protocol, Src Port: 36161, Dst Port: 4789  
> Virtual eXtensible Local Area Network  
> Ethernet II, Src: 1e:d0:d6:6d:70:33 (1e:d0:d6:6d:70:33), Dst: 1e:d0:d6:6a:de:86 (1e:d0:d6:6a:de:86)  
> 802.1Q Virtual LAN, PRI: 0, DEI: 0, ID: 835  
> Internet Protocol Version 4, Src: 50.0.0.2, Dst: 60.0.0.2  
> User Datagram Protocol, Src Port: 22960, Dst Port: 32960  
> Data (1454 bytes)

Applica un filtro di visualizzazione ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
3695	8.827976	50.0.0.4	60.0.0.4	UDP	1554	24331 → 34331 Len=1454

> Frame 3695: Packet, 1554 bytes on wire (12432 bits), 1554 bytes captured (12432 bits)  
> Ethernet II, Src: 00:00:00\_00:00:01 (00:00:00:00:00:01), Dst: 00:00:00\_00:00:02 (00:00:00:00:00:02)  
> 802.1Q Virtual LAN, PRI: 1, DEI: 0, ID: 1  
> Internet Protocol Version 4, Src: 12.4.24.1, Dst: 198.18.3.91  
> User Datagram Protocol, Src Port: 55042, Dst Port: 4789  
> Virtual eXtensible Local Area Network  
> Ethernet II, Src: 1e:d0:d6:6d:70:33 (1e:d0:d6:6d:70:33), Dst: 1e:d0:d6:6a:de:86 (1e:d0:d6:6a:de:86)  
> 802.1Q Virtual LAN, PRI: 5, DEI: 0, ID: 835  
> Internet Protocol Version 4, Src: 50.0.0.4, Dst: 60.0.0.4  
> User Datagram Protocol, Src Port: 24331, Dst Port: 34331  
> Data (1454 bytes)

Applica un filtro di visualizzazione ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
3694	8.827689	50.0.0.3	60.0.0.3	UDP	1554	21541 → 31541 Len=1454

> Frame 3694: Packet, 1554 bytes on wire (12432 bits), 1554 bytes captured (12432 bits)  
> Ethernet II, Src: 00:00:00\_00:00:01 (00:00:00:00:00:01), Dst: 00:00:00\_00:00:02 (00:00:00:00:00:02)  
> 802.1Q Virtual LAN, PRI: 1, DEI: 0, ID: 1  
> Internet Protocol Version 4, Src: 12.4.24.1, Dst: 198.18.3.91  
> User Datagram Protocol, Src Port: 45034, Dst Port: 4789  
> Virtual eXtensible Local Area Network  
> Ethernet II, Src: 1e:d0:d6:6d:70:33 (1e:d0:d6:6d:70:33), Dst: 1e:d0:d6:6a:de:86 (1e:d0:d6:6a:de:86)  
> 802.1Q Virtual LAN, PRI: 1, DEI: 0, ID: 835  
> Internet Protocol Version 4, Src: 50.0.0.3, Dst: 60.0.0.3  
> User Datagram Protocol, Src Port: 21541, Dst Port: 31541  
> Data (1454 bytes)

Single-Mono VLAN (835)

3 different traffic streams

3 different PRIORITY CoS

# Use Case

## Multi VLAN 835,837,935 - different COS [0], [1], [5]



Applica un filtro di visualizzazione ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
75	8.912205	40.0.0.2	20.0.0.2	UDP	1554	20418 → 30418 Len=1454

> Frame 75: Packet, 1554 bytes on wire (12432 bits), 1554 bytes captured (12432 bits)  
> Ethernet II, Src: 00:00:00\_00:00:01 (00:00:00:00:00:01), Dst: 00:00:00\_00:00:02 (00:00:00:00:00:02)  
> 802.1Q Virtual LAN, PRI: 1, DEI: 0, ID: 1  
> Internet Protocol Version 4, Src: 12.4.24.1, Dst: 198.18.3.91  
> User Datagram Protocol, Src Port: 38365, Dst Port: 4789  
> Virtual eXtensible Local Area Network  
> Ethernet II, Src: 1e:d0:d6:6d:70:33 (1e:d0:d6:6d:70:33), Dst: 1e:d0:d6:6a:de:86 (1e:d0:d6:6a:de:86)  
> 802.1Q Virtual LAN, PRI: 0, DEI: 0, ID: 835  
> Internet Protocol Version 4, Src: 40.0.0.2, Dst: 20.0.0.2  
> User Datagram Protocol, Src Port: 20418, Dst Port: 30418  
> Data (1454 bytes)

Applica un filtro di visualizzazione ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
78	8.914113	40.1.0.2	20.1.0.2	UDP	1554	22274 → 32274 Len=1454

> Frame 78: Packet, 1554 bytes on wire (12432 bits), 1554 bytes captured (12432 bits)  
> Ethernet II, Src: 00:00:00\_00:00:01 (00:00:00:00:00:01), Dst: 00:00:00\_00:00:02 (00:00:00:00:00:02)  
> 802.1Q Virtual LAN, PRI: 1, DEI: 0, ID: 1  
> Internet Protocol Version 4, Src: 12.4.24.1, Dst: 198.18.3.91  
> User Datagram Protocol, Src Port: 57205, Dst Port: 4789  
> Virtual eXtensible Local Area Network  
> Ethernet II, Src: 22:d0:d6:6d:70:33 (22:d0:d6:6d:70:33), Dst: 22:d0:d6:6a:de:86 (22:d0:d6:6a:de:86)  
> 802.1Q Virtual LAN, PRI: 1, DEI: 0, ID: 935  
> Internet Protocol Version 4, Src: 40.1.0.2, Dst: 20.1.0.2  
> User Datagram Protocol, Src Port: 22274, Dst Port: 32274  
> Data (1454 bytes)

Applica un filtro di visualizzazione ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
83	8.914166	40.5.0.2	20.5.0.2	UDP	1554	24768 → 34768 Len=1454

> Frame 83: Packet, 1554 bytes on wire (12432 bits), 1554 bytes captured (12432 bits)  
> Ethernet II, Src: 00:00:00\_00:00:01 (00:00:00:00:00:01), Dst: 00:00:00\_00:00:02 (00:00:00:00:00:02)  
> 802.1Q Virtual LAN, PRI: 1, DEI: 0, ID: 1  
> Internet Protocol Version 4, Src: 12.4.24.1, Dst: 198.18.3.91  
> User Datagram Protocol, Src Port: 34604, Dst Port: 4789  
> Virtual eXtensible Local Area Network  
> Ethernet II, Src: 26:d0:d6:6d:70:33 (26:d0:d6:6d:70:33), Dst: 26:d0:d6:6a:de:86 (26:d0:d6:6a:de:86)  
> 802.1Q Virtual LAN, PRI: 5, DEI: 0, ID: 837  
> Internet Protocol Version 4, Src: 40.5.0.2, Dst: 20.5.0.2  
> User Datagram Protocol, Src Port: 24768, Dst Port: 34768  
> Data (1454 bytes)

**MULTI VLAN**  
(835), (837), (935)

**3 different**  
traffic streams

**3 different**  
PRIORITY CoS  
by VLAN

The IPs used are in laboratory settings



## We dit it

We created a **new architectural** solution  
using a robust/proven **VXLAN** protocol  
in a new **FWA (ODU)** context  
opening up multiple stages of implementation and use



Eupalinos Tunnel

# Thank you

to all the people at **WINDTRE** and **OPNET** who believed in this challenge, and dedicated a lot of time to travel together towards the goal



see you at the racetracks

ARCHITECTURE  
IP ENGINEERING  
DEVICE ENGINEERING & TESTING  
RADIO EQUIPMENT DESIGN & TEST  
MOBILE DATA CORE&SIGNALLING ENGINEERING  
TRANSMISSION ENGINEERING  
PROCESS AND PROJECT MANAGEMENT

&  
TECHNOLOGY VENDOR

Special thank to Nicola for the revision

