

# MPLS for ISPs – PPPoE over VPLS

MPLS, VPLS, PPPoE

# Presenter information

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Network design  
Security, wireless  
Servers  
Virtualization

MikroTik Certified Trainer

Atris, Slovakia

Established 1991

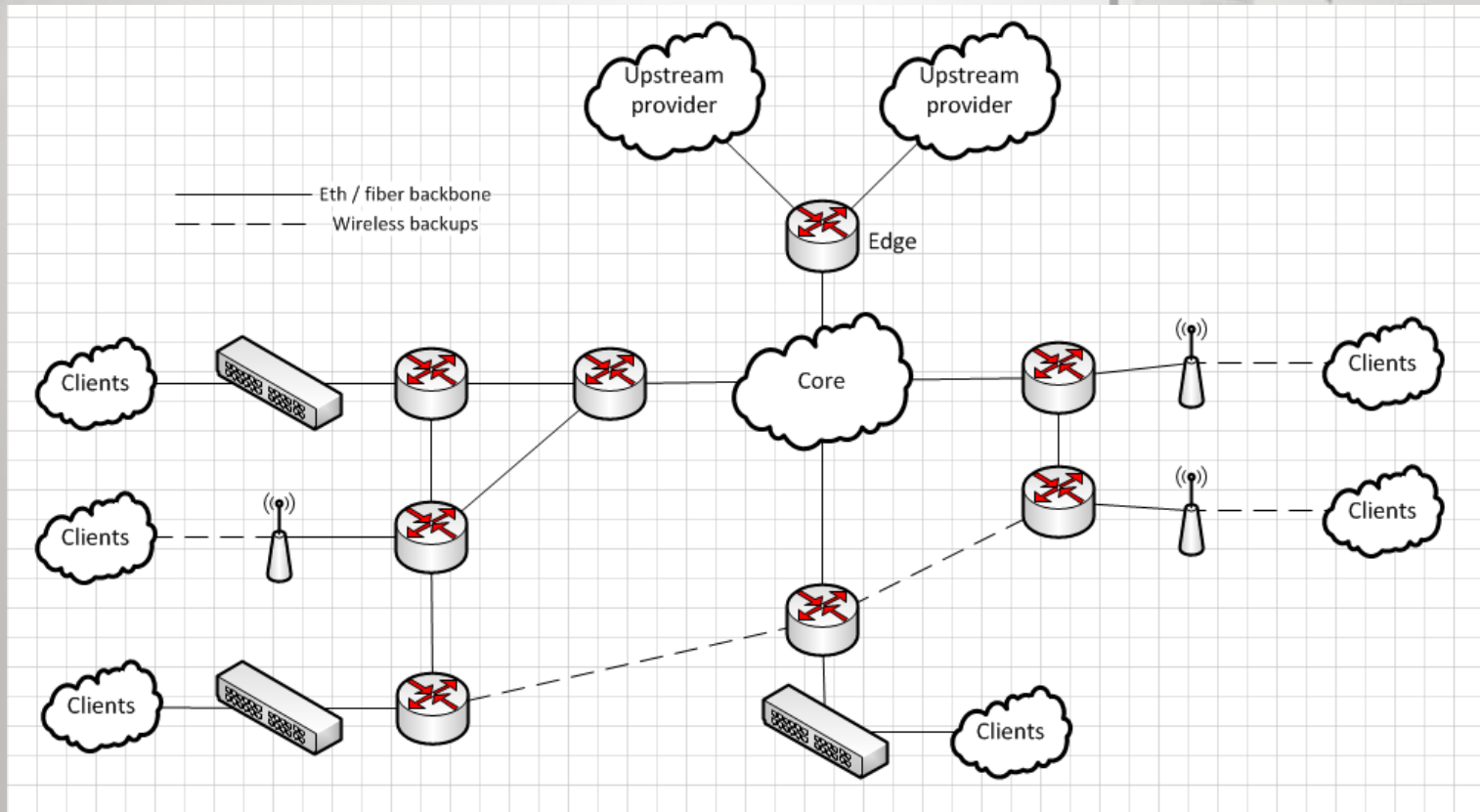


Complete IT solutions  
Networking, servers  
Virtualization  
IP security systems

# Agenda:

- PPPoE basics and advantages
- MPLS and VPLS
- MTU and MTU calculations
- MPLS PHP and ICMP in MPLS
- Configuring everything
- Tips, tricks, problems

# Example provider network



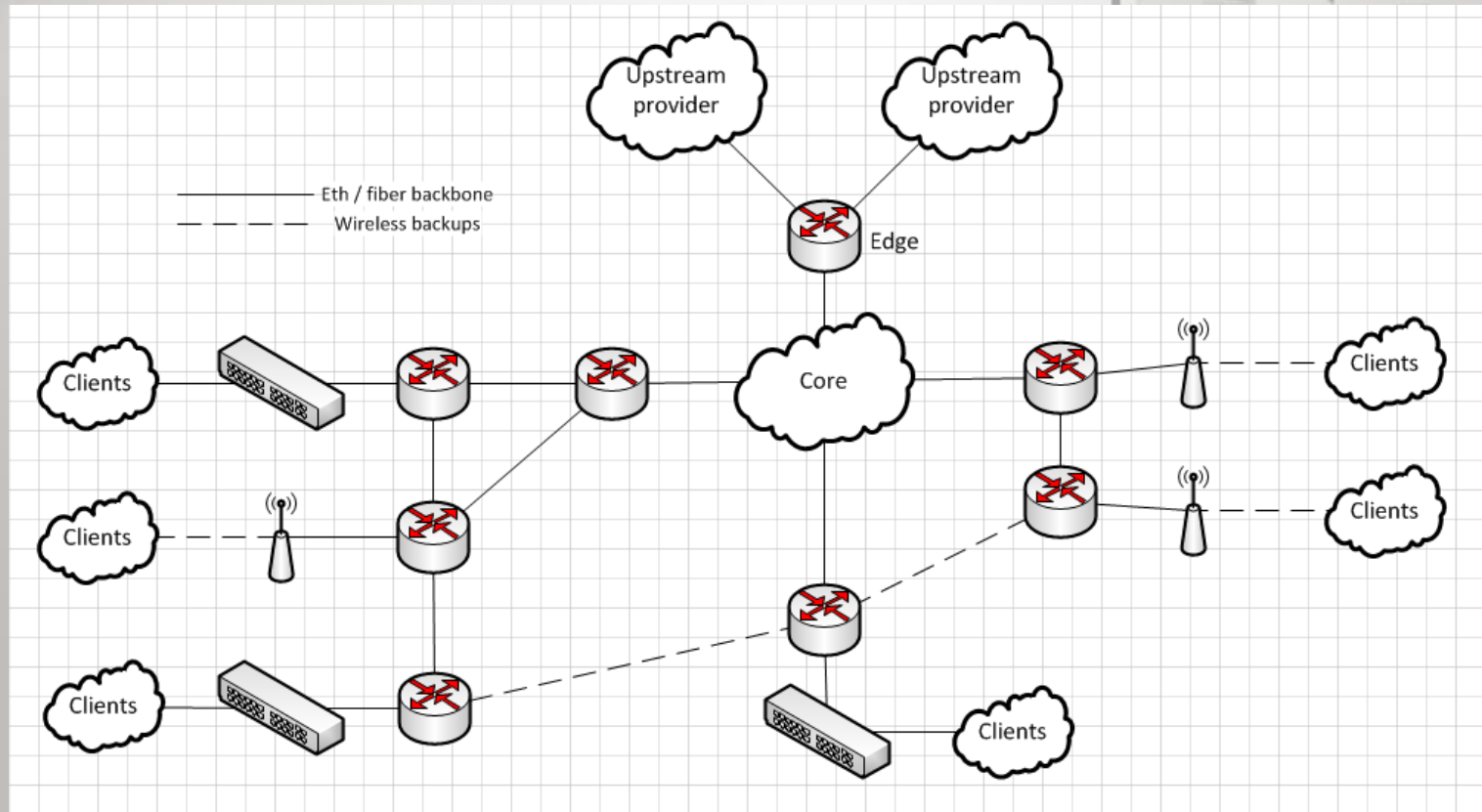
# A few assumptions:

- The network is fully routed.
- OSPF is deployed and properly configured.
- Router IDs and loopbacks properly implemented.
- PPPoE is an acceptable delivery method.
- All devices support MPLS and jumbo frames.

# Goals:

- Public IP assignment without the need to stretch subnets around the network.
- Conserve public IP space with use of /32s.
- Single point for authentication and accounting.
- Secure and minimize L2 segments.
- New products for customers – L2 and L3 VPNs.

# Example provider network

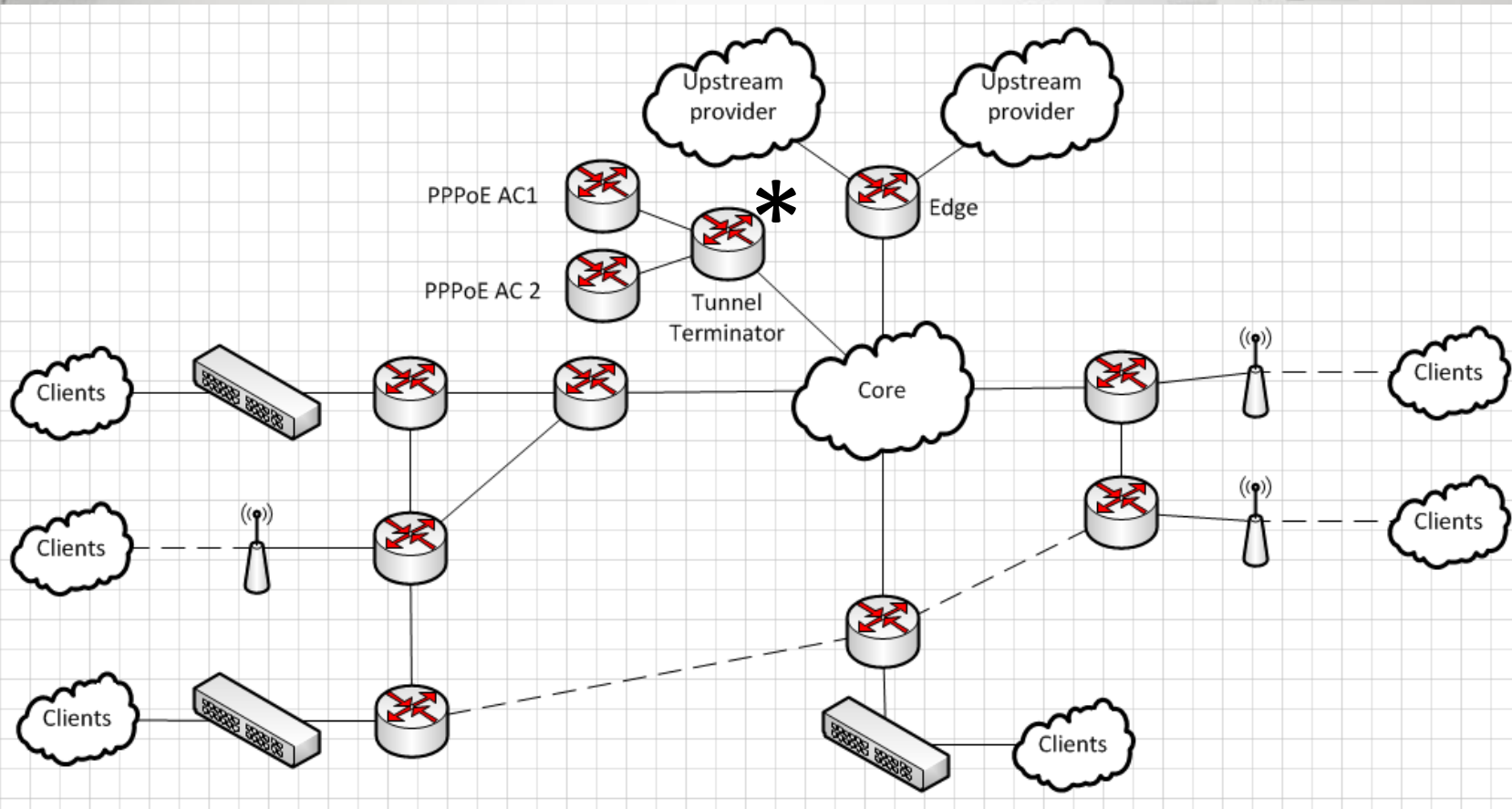


# PPPoE Point-to-Point Protocol over Ethernet

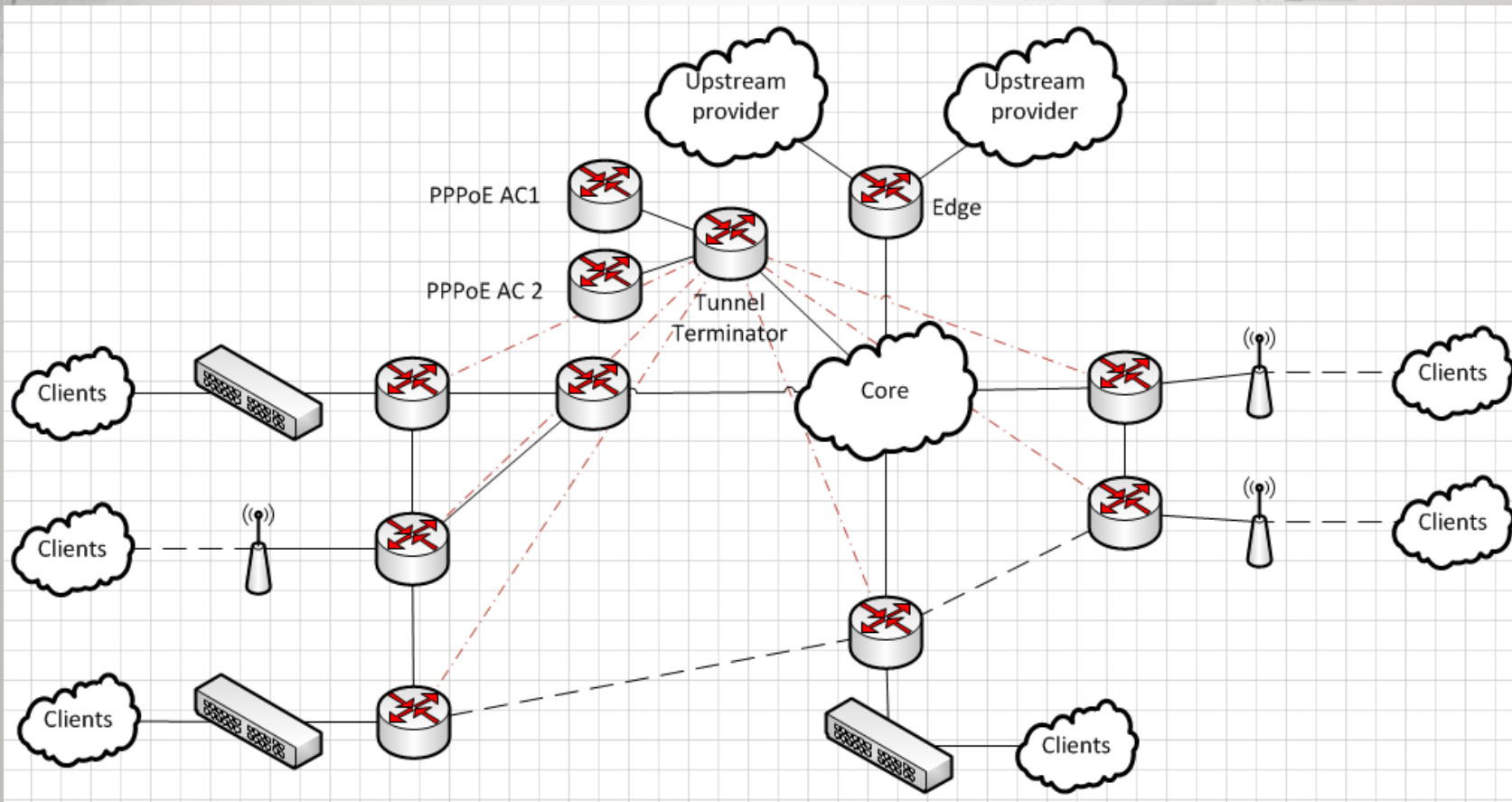
- PPPoE builds a point-to-point tunnel between 2 network devices.
- Direct L2 communication between the AC and the client needed to work.
- Since the tunnel is PtP, each client can (should) be its own L2 segment.
- Username/password authentication – Radius.



# Accomplishing the goals



# Accomplishing the goals



# Stretching L2 over L3

- EoIP could be a solution for tunneling L2 over L3.
- EoIP disadvantages:
  - Fragmentation of L2 frames over multiple L3 packets
  - Performance issues
- VPLS advantages:
  - No fragmentation.
  - 60% more performance than EoIP.

	64 byte pps	512 byte pps
EoIP	190 000	183 900
VPLS	332 500	301 000

# VPLS Virtual Private LAN Service

- VPLS is a method of creating transparent L2 tunnels based on MPLS signaling.
- A VPLS tunnel is presented as a separate interface to the router (same as EoIP)
- VPLS tunnel adds one VPLS tag to the MPLS frame.

# MPLS Multi-Protocol Label Switching

- In a MPLS network, each data frame is assigned a label.
- Packet-forwarding (switching) decisions are made solely on the contents of this label – no need to examine the packet itself.
- Speed benefit, since no IP routing table lookup is performed.

# MPLS and label switching

- MPLS is considered a L2.5 protocol – it falls between L2 and L3.
- MPLS tags – tags are added between L2 and L3 headers
- A VPLS tag is one of multiple possible MPLS tag types

eth header	MPLS tag	VPLS tag	IP header	data
14 byte	4byte	4byte	20 byte	1480 byte

# MTU Maximum Transmission Unit

- Defines the maximum byte-size of a frame that the device can handle.
- Frames larger than maximum allowed MTU are silently discarded.
- No ICMP or any other kind of error are produced, the frame is dropped without notice.

# MTU Maximum Transmit Unit

- A normal frame for a switch/router

L2 MTU - 1514				
L3 MTU - 1500				
inter-packet delay	eth header	IP header	data	FCS
20byte	14 byte	20 byte	1480 byte	4byte

- MPLS frame inside a vlan

L2 MTU - 1526							
L3 MTU - 1500							
inter-packet delay	eth header	vlan	MPLS	MPLS	IP header	data	FCS
20byte	14 byte	4byte	4byte	4byte	20 byte	1480 byte	4byte

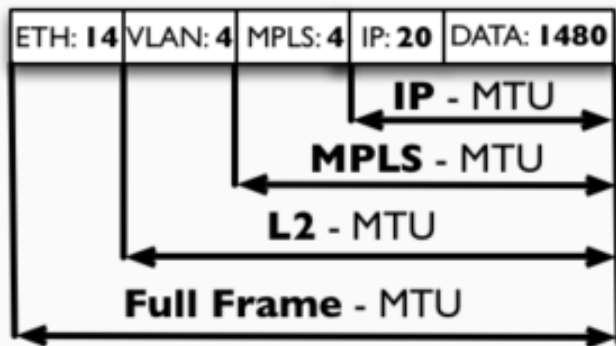


# MTU on switches/routers

- Cheap/unmanaged switches usually only support L2MTU of 1514.
- On many switches you have to turn on “Jumbo Frames” to enable support for MTU over 1514
- Make sure your L2 infrastructure wont drop your MPLS frames, this is the biggest and most common problem with integrating MPLS.

# Update for MikroTik

## MTU on RouterOS



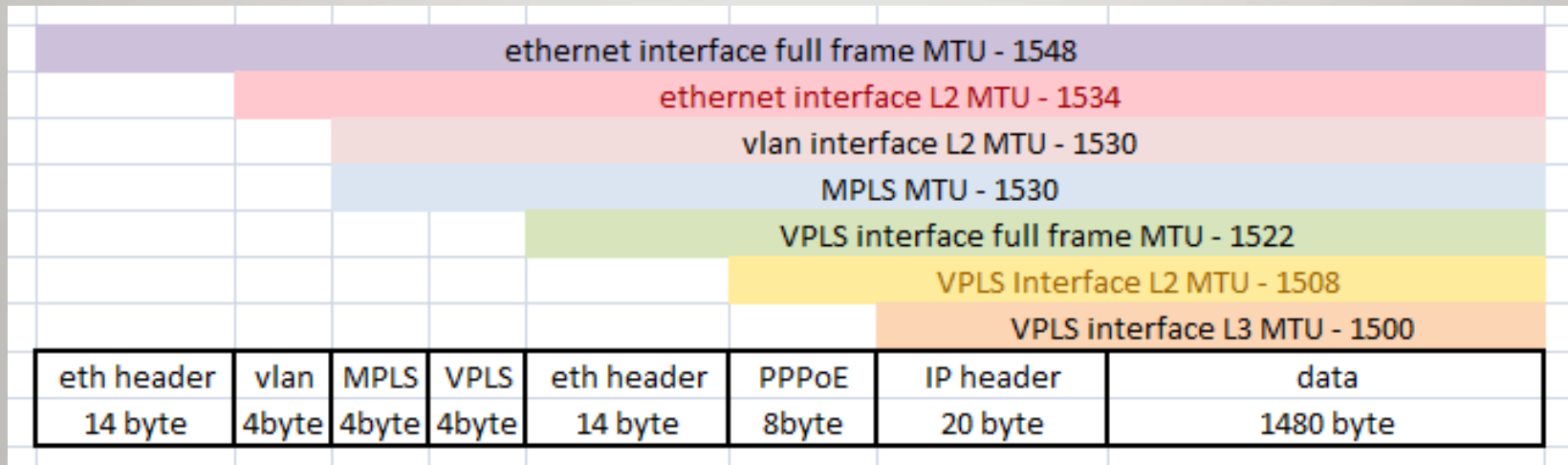
Mikrotik RouterOS recognizes several types of MTU:

- ▶ IP/Layer-3/L3 MTU
- ▶ MPLS/Layer-2.5/L2.5 MTU
- ▶ MAC/Layer-2/L2 MTU
- ▶ Full frame MTU

Check how your switch vendor defines L2MTU to avoid confusion and problems.

# PPPoE over VPLS frames

- Our goal is to implement PPPoE over VPLS.
- We want full 1500 L3 MTU for our clients.



# PPPoE over VPLS frames 2

Wireshark frame example.

# MPLS basics

- Router:
  - Assigns a separate label to each prefix in the routing table
  - Tells its peers about its label bindings
- MPLS Cloud:
  - Each router in the MPLS Cloud assigns its own label to every prefix in the routers routing table
  - Every MPLS router tells its peers about its label bindings
  - This way, all peers know about each others label bindings

# MPLS tables:

MPLS

LDP Interface LDP Neighbor Accept Filter Advertise Filter Forwarding Table MPLS Interface Local Bindings Remote Bindings

	Dst. Address	Label	Advertised Path	Peers
DAG	0.0.0.0/0	impl-null	empty	10.0.0.3:0, 10.0.0.6:0, 10.0.1.2:0, 10.0.0.101:0, 10.0.0.5:0, 10.0.0.100:0, 10.0.2.1:0, 10.0.0.4:0
DAG	10.0.0.1	49	empty	10.0.0.3:0, 10.0.0.6:0, 10.0.1.2:0, 10.0.0.101:0, 10.0.0.5:0, 10.0.0.100:0, 10.0.2.1:0, 10.0.0.4:0
DAEL	10.0.0.2	impl-null	empty	10.0.0.3:0, 10.0.0.6:0, 10.0.1.2:0, 10.0.0.101:0, 10.0.0.5:0, 10.0.0.100:0, 10.0.2.1:0, 10.0.0.4:0
DAG	10.0.0.3	46	empty	10.0.0.3:0, 10.0.0.6:0, 10.0.1.2:0, 10.0.0.101:0, 10.0.0.5:0, 10.0.0.100:0, 10.0.2.1:0, 10.0.0.4:0
DAG	10.0.0.4	245	empty	10.0.0.3:0, 10.0.0.6:0, 10.0.1.2:0, 10.0.0.101:0, 10.0.0.5:0, 10.0.0.100:0, 10.0.2.1:0, 10.0.0.4:0
DAG	10.0.0.5	139	empty	10.0.0.3:0, 10.0.0.6:0, 10.0.1.2:0, 10.0.0.101:0, 10.0.0.5:0, 10.0.0.100:0, 10.0.2.1:0, 10.0.0.4:0
DAG	10.0.0.6	45	empty	10.0.0.3:0, 10.0.0.6:0, 10.0.1.2:0, 10.0.0.101:0, 10.0.0.5:0, 10.0.0.100:0, 10.0.2.1:0, 10.0.0.4:0
DAG	10.0.0.7	222	empty	10.0.0.3:0, 10.0.0.6:0, 10.0.1.2:0, 10.0.0.101:0, 10.0.0.5:0, 10.0.0.100:0, 10.0.2.1:0, 10.0.0.4:0
DAG	10.0.0.100	173	empty	10.0.0.3:0, 10.0.0.6:0, 10.0.1.2:0, 10.0.0.101:0, 10.0.0.5:0, 10.0.0.100:0, 10.0.2.1:0, 10.0.0.4:0

MPLS

LDP Interface LDP Neighbor Accept Filter Advertise Filter Forwarding Table MPLS Interface Local Bindings Remote Bindings

	Dst. Address	Label	NextHop	Peer	Path
D	0.0.0.0/0	impl-null	0.0.0.0	10.0.0.3:0	empty
D	0.0.0.0/0	impl-null	0.0.0.0	10.0.0.4:0	empty
D	0.0.0.0/0	impl-null	0.0.0.0	10.0.0.5:0	empty
D	0.0.0.0/0	impl-null	0.0.0.0	10.0.0.6:0	empty
D	0.0.0.0/0	impl-null	0.0.0.0	10.0.0.100:0	empty
D	0.0.0.0/0	impl-null	0.0.0.0	10.0.0.101:0	empty
DA	0.0.0.0/0	impl-null	10.1.0.1	10.0.1.2:0	empty
D	0.0.0.0/0	impl-null	0.0.0.0	10.0.2.1:0	empty
D	10.0.0.1	24	0.0.0.0	10.0.0.3:0	empty
D	10.0.0.1	47	0.0.0.0	10.0.0.4:0	empty
D	10.0.0.1	39	0.0.0.0	10.0.0.5:0	empty

# After creating the MPLS forwarding table:

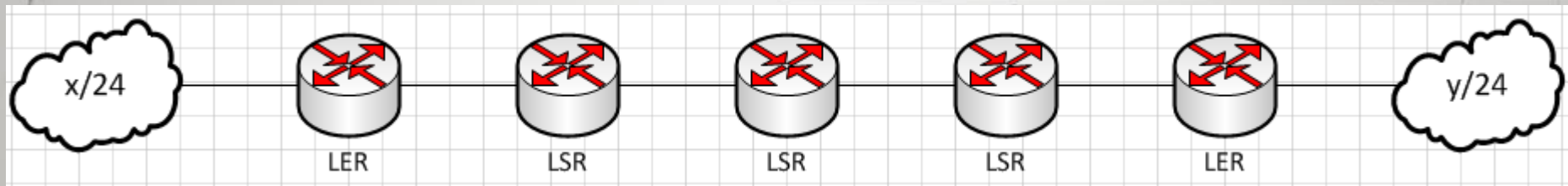
MPLS							
LDP Interface	LDP Neighbor	Accept Filter	Advertise Filter	Forwarding Table	MPLS Interface	Local Bindings	Remote Bindings
Y							
In Label	Out Labels	Interface	Nexthop	Destination	Bytes	Packets	
expl-null						0	0
49		eth1-Backbone	10.1.0.1	10.0.0.1	0	0	
46		eth1-Backbone	10.1.0.3	10.0.0.3	0	0	
245		eth1-Backbone	10.1.0.4	10.0.0.4	0	0	
139		eth1-Backbone	10.1.0.5	10.0.0.5	0	0	
45		eth1-Backbone	10.1.0.6	10.0.0.6	0	0	
222		eth1-Backbone	10.1.0.7	10.0.0.7	0	0	
173		eth1-Backbone	10.1.0.100	10.0.0.100	0	0	
58		eth1-Backbone	10.1.0.101	10.0.0.101	0	0	
55	185	eth1-Backbone	10.1.0.1	10.0.1.1	0	0	
38		eth1-Backbone	10.1.0.1	10.0.1.2	0	0	
221		eth1-Backbone	10.1.0.7	10.0.2.1	0	0	
220	20	eth1-Backbone	10.1.0.7	10.0.2.2	0	0	
219	25	eth1-Backbone	10.1.0.7	10.0.2.3	0	0	
218	23	eth1-Backbone	10.1.0.7	10.0.2.4	0	0	
217	19	eth1-Backbone	10.1.0.7	10.0.2.5	0	0	

# LDP Label distribution protocol

- LDP allows the routers to learn the label bindings of their peers.
- LDP runs over IP protocol, UDP and TCP 646



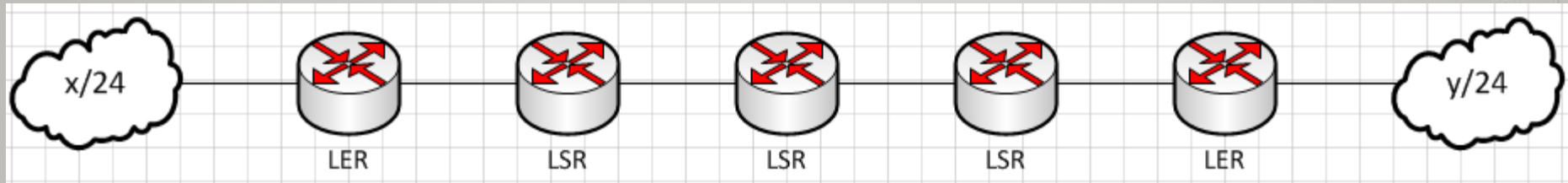
# Router roles in MPLS



- LER – Label Edge Router
- LSR – Label Switch router
  - A single router can be a LER and LSR at the same time

# Actions performed on a MPLS frame

- Push – add a label
- Pop – remove a label
- Swap – change the label



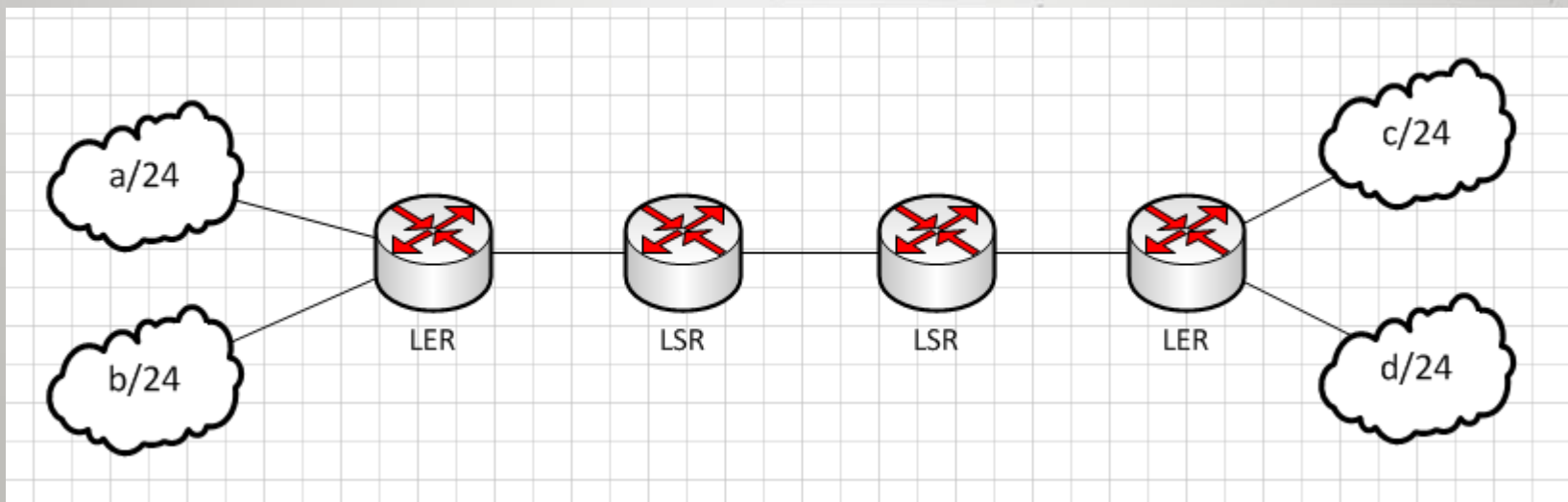
# MPLS forwarding table:

MPLS							
LDP Interface	LDP Neighbor	Accept Filter	Advertise Filter	Forwarding Table	MPLS Interface	Local Bindings	Remote Bindings
Y							
In Label	Out Labels	Interface	Nexthop	Destination	Bytes	Packets	
expl-null					0	0	
49		eth1-Backbone	10.1.0.1	10.0.0.1	0	0	
46		eth1-Backbone	10.1.0.3	10.0.0.3	0	0	
245		eth1-Backbone	10.1.0.4	10.0.0.4	0	0	
139		eth1-Backbone	10.1.0.5	10.0.0.5	0	0	
45		eth1-Backbone	10.1.0.6	10.0.0.6	0	0	
222		eth1-Backbone	10.1.0.7	10.0.0.7	0	0	
173		eth1-Backbone	10.1.0.100	10.0.0.100	0	0	
58		eth1-Backbone	10.1.0.101	10.0.0.101	0	0	
55	185	eth1-Backbone	10.1.0.1	10.0.1.1	0	0	
38		eth1-Backbone	10.1.0.1	10.0.1.2	0	0	
221		eth1-Backbone	10.1.0.7	10.0.2.1	0	0	
220	20	eth1-Backbone	10.1.0.7	10.0.2.2	0	0	
219	25	eth1-Backbone	10.1.0.7	10.0.2.3	0	0	
218	23	eth1-Backbone	10.1.0.7	10.0.2.4	0	0	
217	19	eth1-Backbone	10.1.0.7	10.0.2.5	0	0	

# PHP

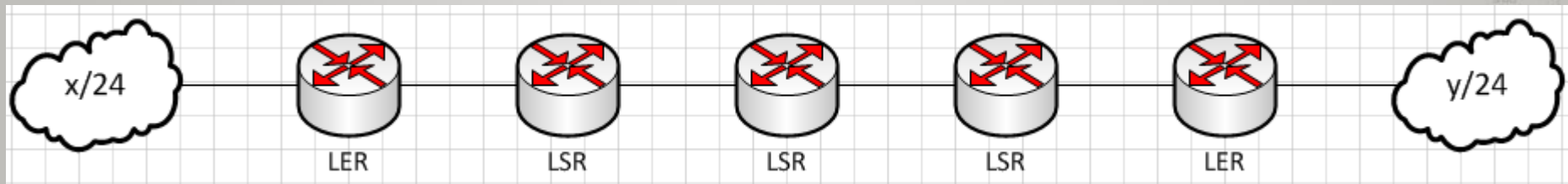
- MPLS PHP
  - Penultimate hop popping
- PHP is implemented for performance reasons.
  - Without PHP, the LER would have to do 2 lookups (MPLS label forwarding table and IP routing table)

# MPLS PHP



# Complications - ICMP

- In a MPLS network, ICMP error packets are forwarded all the way to the original destination, not to the packets source (the source of the packet that caused the ICMP error)



# MPLS ICMP Explained

- This behavior is implemented because an MPLS switch doesn't have to be a router.
- It might not have a route to the source of the packet that caused the ICMP error. (L3 VPNs)
- The MPLS switch might not even support the IP protocol, or ICMP.

# Implications

- In MPLS networks, when using trace-routes, remember the ICMP behavior.
- As long as there is a break on the MPLS path, the packet will not make it past the 1<sup>st</sup> hop, but that doesn't mean that the 2<sup>nd</sup> hop is dead.



# Implications 2

- Ping times will not be reported correctly.
- Because of the MPLS ICMP behavior, the only ping you will see for all hops is the full round-trip.

IP: 10.3.4.2

Sample Set Time: 19. 9. 2013 15:35:48 - 19. 9. 2013 15:52:45

201-500 ms

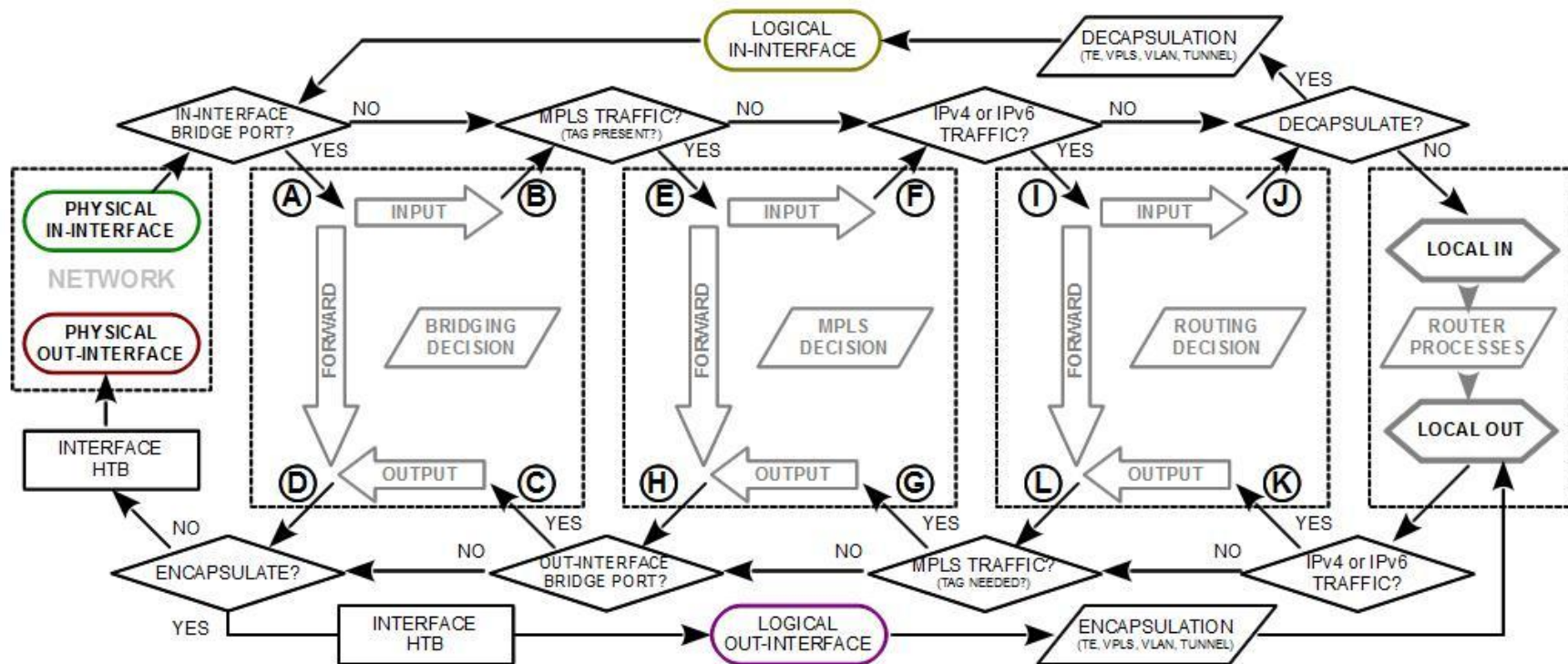
501 ms and up

Hop	PL%	IP	DNSName	Avg	Cur	Graph
1		10.3.1.1	router.atris.local	0	0	
2		10.1.0.7	router.atris.wlan1.local	13	15	
3		10.1.2.2	b1.router.rd1.wlan1.local	13	21	
4		10.1.2.10	b2.router.rd2.wlan1.local	13	11	
5		10.1.2.18	b3.router.home.wlan1.local	13	24	
6		10.3.4.2		13	19	
<b>Round Trip:</b>				<b>13</b>	<b>19</b>	

# MPLS packet behavior:

- MPLS switched traffic:
  - Doesn't pass through firewall
  - Doesn't pass through NAT
  - Doesn't pass through mangle
  - Doesn't pass through QoS
  - Etc.
- On the LERs the traffic **will** pass the routing engine!

# MikroTik RouterOS Packet Flow Diagram for version 6.x



# How do I MPLS?

```
/mpls interface
```

```
set [ find default=yes ] mpls-mtu=1550
```

```
/mpls ldp
```

```
set enabled=yes lsr-id=RouterID transport-address=RouterID
```

```
/mpls ldp interface
```

```
add interface="ether1.vlan1000 - backbone.local"
```

- Remember that the RouterID from OSPF should be an actual IP on a loopback interface and be reachable.

# Adding VPLS – TT

```
/interface vpls
```

```
add advertised-l2mtu=1508 name="ether1.vlan1000.vpls1" remote-peer=10.0.2.2 vpls-id=1:0
```

```
add advertised-l2mtu=1508 name=" ether1.vlan1000.vpls2" remote-peer=10.0.2.5 vpls-id=1:0
```

```
/interface bridge
```

```
add l2mtu=1508 name="br2 - PPPoE AC"
```

```
/interface bridge port
```

```
add bridge="br2 - PPPoE AC" horizon=1 interface="ether1.vlan4000 - customers.local"
```

```
add bridge="br2 - PPPoE AC" horizon=1 interface="ether1.vlan1000.vpls1"
```

```
add bridge="br2 - PPPoE AC" horizon=1 interface="ether1.vlan1000.vpls2"
```

# Securing L2 - bridges

- On RouterOS the bridge split horizon will allow us to secure the L2 segment.
- Only ports with different horizon value can communicate with each other.

# Adding VPLS – Wireless AP

```
/mpls interface
set [ find default=yes ] mpls-mtu=1550
/mpls ldp
set enabled=yes lsr-id=RouterID transport-address=RouterID
/mpls ldp interface
add interface="eth1 - c1.wlan1.local"

/interface vpls
add advertised-l2mtu=1508 name="eth1.vpls1 - pppoe.ac.backbone.local"
remote-peer=10.0.0.100 vpls-id=1:0
```

# PPPoE AC Config

```
/ppp profile
```

```
add name="PPPoE" change-tcp-mss=no local-address=10.4.255.255 remote-address=PPPoE-pool
```

```
/ppp aaa
```

```
set use-radius=yes
```

```
/radius
```

```
add address=10.2.128.9 secret=password service=ppp
```

```
/interface pppoe-server server
```

```
add default-profile="PPPoE" disabled=no interface=ether1 max-mru=1500  
max-mtu=1500
```



# Securing L2 – customers

- PPPoE, being a PtP tunnel, only requires L2 connectivity between the endpoints.
- For security reasons its desired to block direct L2 communication, so your customers are protected.
- For wireless links, simply uncheck default-forward.
- For wired clients, enable port isolation on the switch.

# Securing L2 - customers

Security > Port Isolate Group Save | Help | Logout

swch-rack

- Wizard
- Stack
- Summary
- Device
- Network
- Authentication
- Security

**Port Isolate Group**

Authorized IP

QoS

Summary **Port Setup**

Config type:  Isolated port  Uplink port

Select port(s)

1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	HP V1910-48G Sw...			
2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	49	50	51	52

▼ Aggregation ports

BAGG1	BAGG2	BAGG3	BAGG4	BAGG5	BAGG6
Select All Select None					

Isolated port Uplink port

GE1/0/9-GE1/0/48

Apply

<http://10.2.128.22/wcn/frame/tree?uid=8A7B5CC9437B2A0D63E292BA4372040> © 2013 Hewlett-Packard Development Company, L.P.

DFS Mode: none

Proprietary Extensions: post-2.9.25

Bridge Mode: disabled

Default AP Tx Rate: bps

Default Client Tx Rate: bps

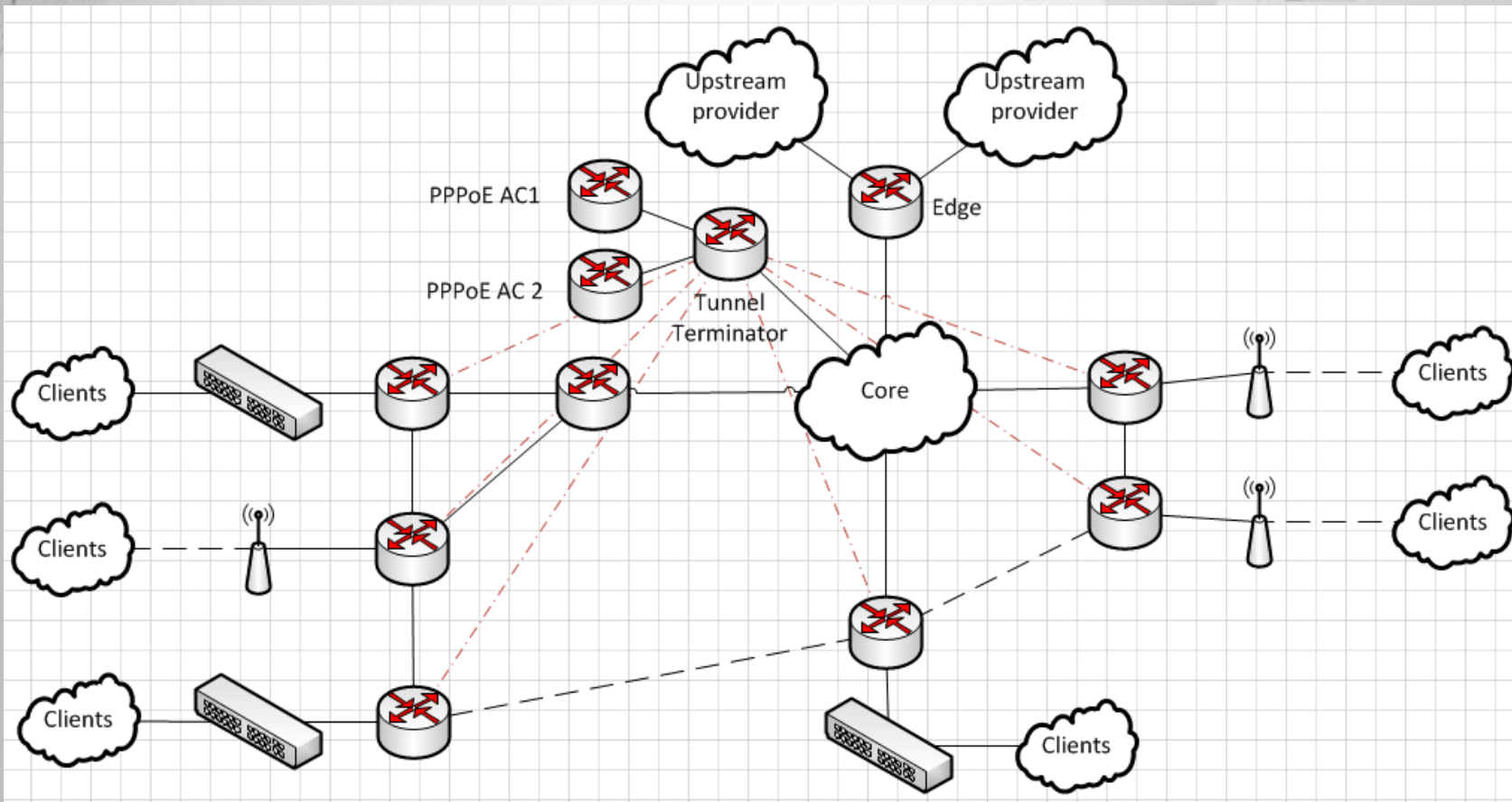
Default Authenticate

Default Forward

Multicast Helper: default

enabled running slave running ap

# Accomplishing the goals



## Tip: L2 VPNs

- You can offer a service for your customers, of transparent L2 VPNs just by building a VPLS tunnel, and bridging it to them.
- New service for your customers, without implementing anything. (you already have VPLS because of PPPoE)

# Tips

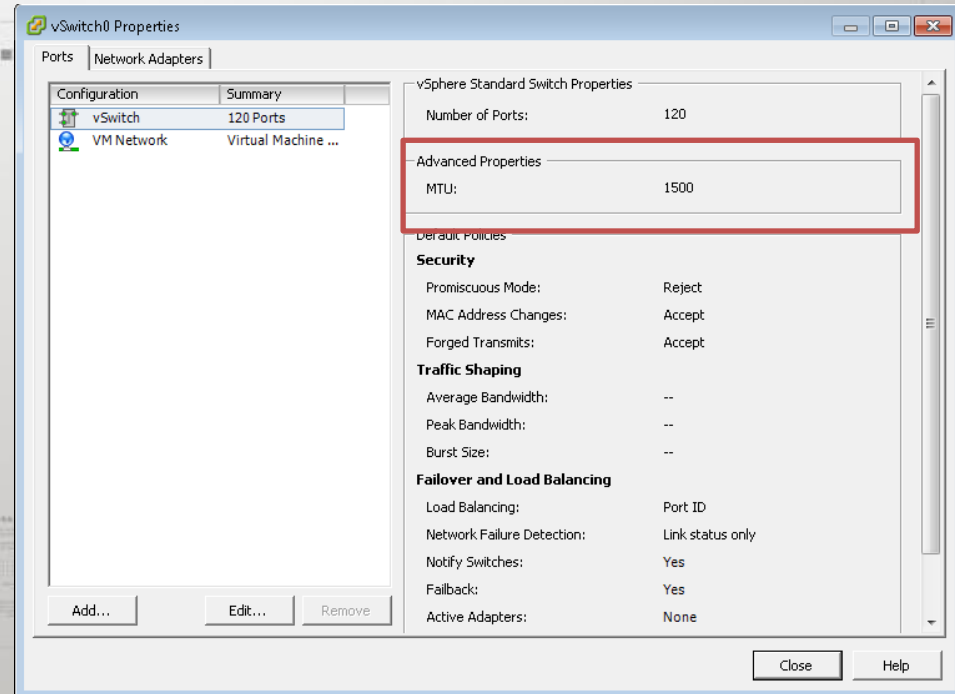
- If something is not working, and you are sure your config is good, its probably MTU.
- Look for unmanaged switches across the MPLS path. Make sure jumbo is supported on all equipment in the MPLS path.

# Watch out for cheap NICs

- Some NICs will not report their Max L2MTU to RouterOS.
- In this case, since RouterOS doesn't know the NICs Max L2MTU, it ignores any frames that are >1500 (even if NIC actually supports jumbo).
- Only a problem on x86 or if ROS is a VM.

# ESXi Tips

- If you are virtualizing, don't forget to check MTU everywhere.
- Example: e1000 NIC in ESXi doesn't support MTU >1500, even if the vSwitch does.
- Use e1000e (edit .vmx manually if needed)



# MPLS binding issue

- RouterOS creates a label binding for all prefixes in the routing table, even if the next hop is not MPLS enabled.
- Watch out for this on LERs, and create manual expl-null bindings as needed.
- Note: there is a bug in <6.3, where you cant create more than one expl-null binding.



# MTU issues on ROS

- Even on RouterOS, there are MTU issues.
- Currently, a bonding interface does NOT report Max L2MTU.
- You can not use MTU >1500 if you use bonding. (no MPLS)
- Bug is reported, hopefully will be fixed. (2 months in waiting)

# Issues: L3 VPNs

- L3 VPNs on v6.x are broken.
  - BGP routes not properly withdrawn
  - Redistribution inside VRF doesn't work
  - Route leaking not working, etc.
- Use v5 if you need L3 VPNs (test test test)
- Currently L3 VPNs are not possible on CCR.
- Mikrotik support says these problems are not a priority, probably because of major changes needed to the routing engine to fix them. Lets hope for v7.

# Problem with PPPoE

- One problem this delivery mechanism (PPPoE over VPLS) has is IPTV.
- Implementing IPTV with multicast requires a routed network, but you are providing PtP tunnels for each customer (therefore, multicast will not save bandwidth)
- Consider deploying multicast beside PPPoE, for example, in a separate VLAN.

# Overall state of MPLS

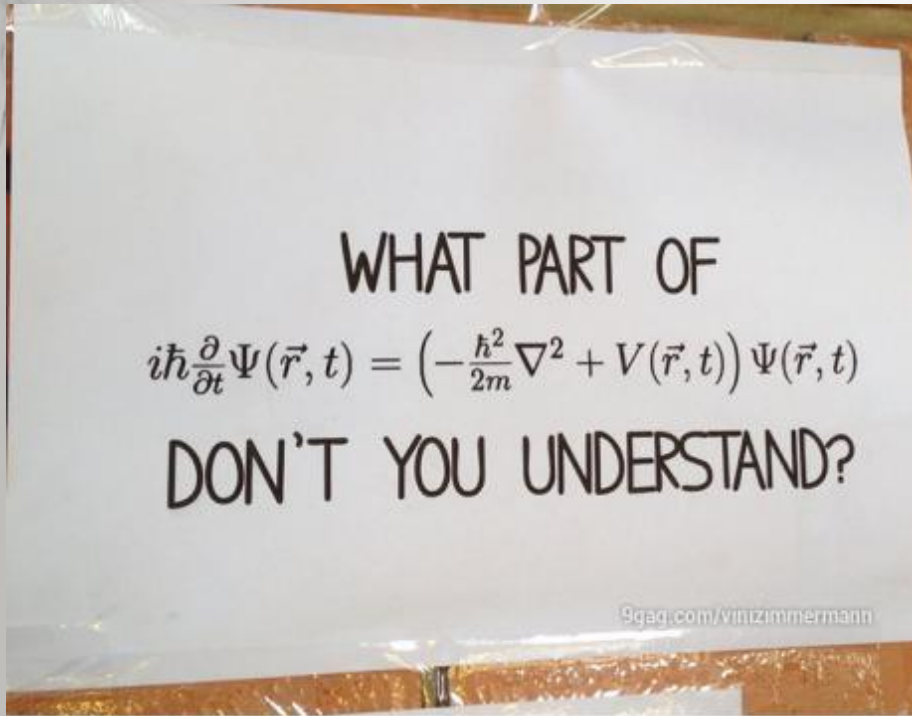
- Overall, MPLS on Mikrotik is functional, and deployable in production (minus L3 VPNs)
- As long as you are aware of how MPLS works (ICMP) it's a great tool in Mikrotiks toolkit.

# Final notes:

- This presentation is by no means a complete ready-to-implement solution.
- MPLS and its deployment require topology and network considerations and planning.

# More material:

- If you liked this presentation look at Tiktube.com:
- US12:
  - Bandwidth-based load-balancing without MPLS TE
- EU13:
  - Building a scalable IPsec infrastructure with MikroTik



If you have any questions, please ask now, or find me after the presentation.



Thanks for listening

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