

# Mikrotik complete solution for ISP

Flávio Gomes Figueira Camacho



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Mikrotik User Meeting in EU  
Vienna, March 07 - 08, 2019

# Introduction



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# Summary of the Presentation

- Vipnet is a telecommunications operator in Brazil that uses only Mikrotik.
- I will introduce and show how we implemented:
  - Border, Backbone, Access and CPE with Mikrotik
  - IPv4, IPv6 allocation and CGNAT
  - QoS Rules and Firewall
- The presentation is a tutorial on how Vipnet implement a complete and extremely functional solution with Mikrotik.



# Flávio Gomes Figueira Camacho

- Enginner with master's degree in telecommunications engineering
- Presentations:
  - - MUM 2009BR, MUM 2010BR, MUM 2011BR, MUM 2012BR, MUM 2013BR, MUM 2014BR, MUM 2015BR, MUM 2016BR, MUM 2017BR, MUM 2018UK.
- Certifications: MTCNA, MTCRE, MTCWE, MTCINE, MTCTCE, MTCIPv6 and MTCUME
- Oficial Trainer Mikrotik.



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# Mikrotik Technologies



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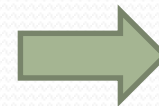
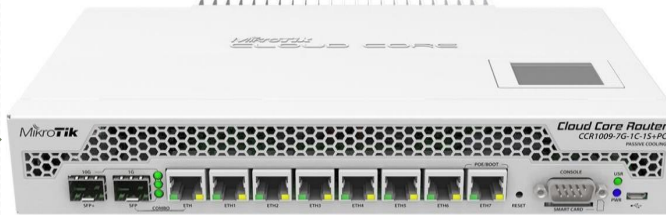
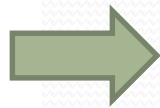
# Introduction

- Importance of Mikrotik for an internet provider
  - User Authentication
  - Bandwidth control over these users
  - Network Routing (OSPF and BGP)
  - Customer management
  - Service quality
  - Monitoring
  - Backbone - Access Network - Distribution Network



# Introduction

# MikroTik



Customers



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# Introduction

- When you receive a link you need a tool to share this link and configure.
  - BGP and Routing - Mikrotik
- Implement security against external attacks from hackers and from customers themselves.
  - Firewall – Mikrotik
- Authenticate users and block defaulters.
  - PPPoE, Hotspot... - Mikrotik





# Introduction

- Control the band and plans of each.
  - Queues - Mikrotik
- Server for centralized authentication.
  - Radius – Mikrotik (UserManager)
- Internal network routing.
  - OSPF – Mikrotik
- Control of quality of service.
  - QoS – Mikrotik



# Introduction

- Monitoring Devices.
  - Manager – Mikrotik (The Dude)
- Network Interfaces.
  - Fiber, Ethernet, Wireless – Mikrotik
- Build a network to take the internet to customers.
  - Radios, antennas, fiber converters, switches – Mikrotik



# Introduction

- Mikrotik has it all on a unique and extremely versatile platform. Nothing from multiple vendors with different solutions that are difficult to manage and integrate.



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# Vipnet Network Design



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# Vipnet Network

<b>Network Levels</b>	<b>Function</b>	<b>Equipment</b>
Border	BGP / Nat / Log / Firewall / QoS / Queues	CCR Router and Servers
Backbone	Routing / QoS	PtP - Fiber / Radios
Access	PPPoE Server / Firewall / QoS / Queues	FTTH / RouterBoard / AP
CPE MK	PPPoE Client / WiFi / DHCP / Slaac ...	hAP light, SXT ...

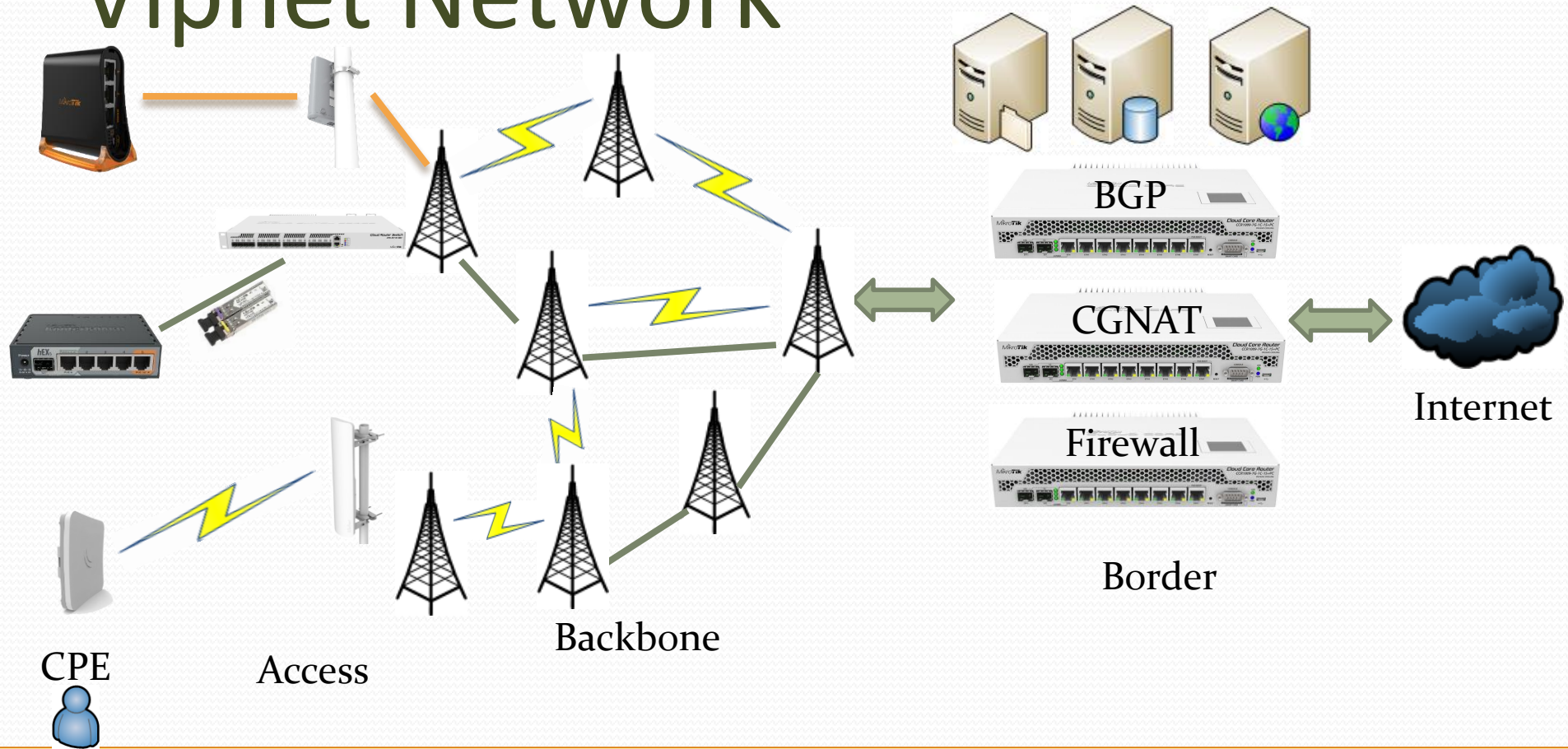


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# Vipnet Network



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# Vipnet 2017

	2009	2012	2017
Active Network Devices	34	194	1198
POP - Point of Presence	10	26	118
Cities	2	8	17



How to deploy high availability networks and resistant to failure with Mikotik - OSPF / BGP / VPLS / ECMP / MPLS

Flávio G.F. Camacho - Case of Vipnettelecom

Mikrotik User Meeting in UK  
Birmingham October 08, 2018



# Vipnet Network Border

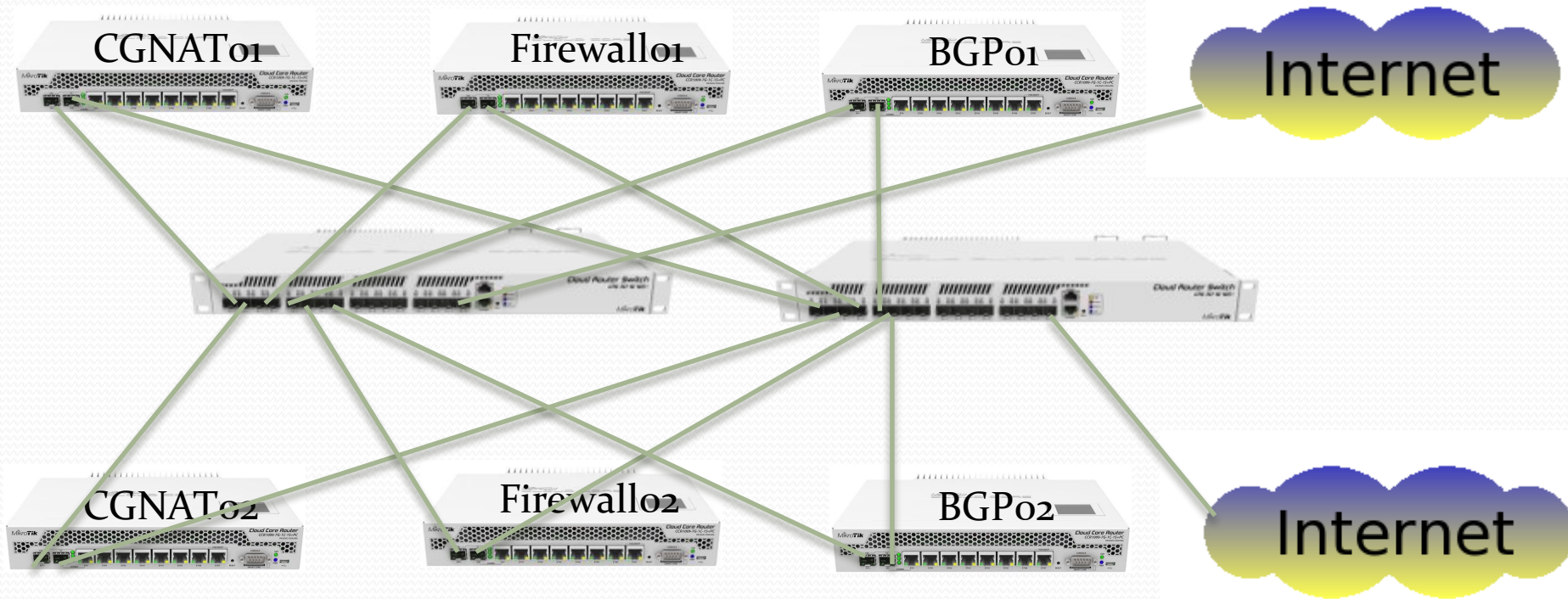


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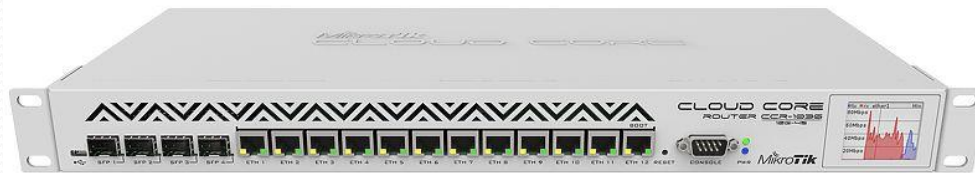
# Border



Distribute services between different equipment  
Redundancy of services and equipment

# Border – BGP / Firewall / CGNAT

- CCR1036-12G-4S-EM



- CCR1036-8G-2S + EM



# Switch

- CRS317-1G-16S + RM
  - 1 Gigabit port switch with 16 SFP+
- CRS326-24G-2S+RM
  - 24 Gigabit port switch with 2 SFP+



# Vipnet Network Backbone



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# Backbone Radio

- Radio Backbone
  - Good transport capacity
  - Very accessible prices
  - OSPF Routing
  - Quick to install
  - Reaches great distances



# Backbone Radio – Antennas

- 30dBi
- Sleeve30



# Backbone Radio - PtP – NetMetal

- NetMetal 5SHP - 866Mbps
- NetMetal Trible - 1.3Gbps





# Specifications and results

## Frequency

5 GHz

Desired data rate: 975 Mbps



## Tx device



## Rx device



NetMetal 5SHP

NetMetal 5SHP

## Tx Gain (dBi)

30

## Rx Gain (dBi)

30

## RX Sensitivity (dBm)

-77

## RX Sensitivity (dBm)

-77

## Output Power (dBm)

29

## Output Power (dBm)

29

## Point A, Point B

Distance: 75.0 Km (46.58 miles)

Free Space Path Loss: 144.639 dB

Theoretical signal level at TX: -59

Theoretical signal level at RX: -59

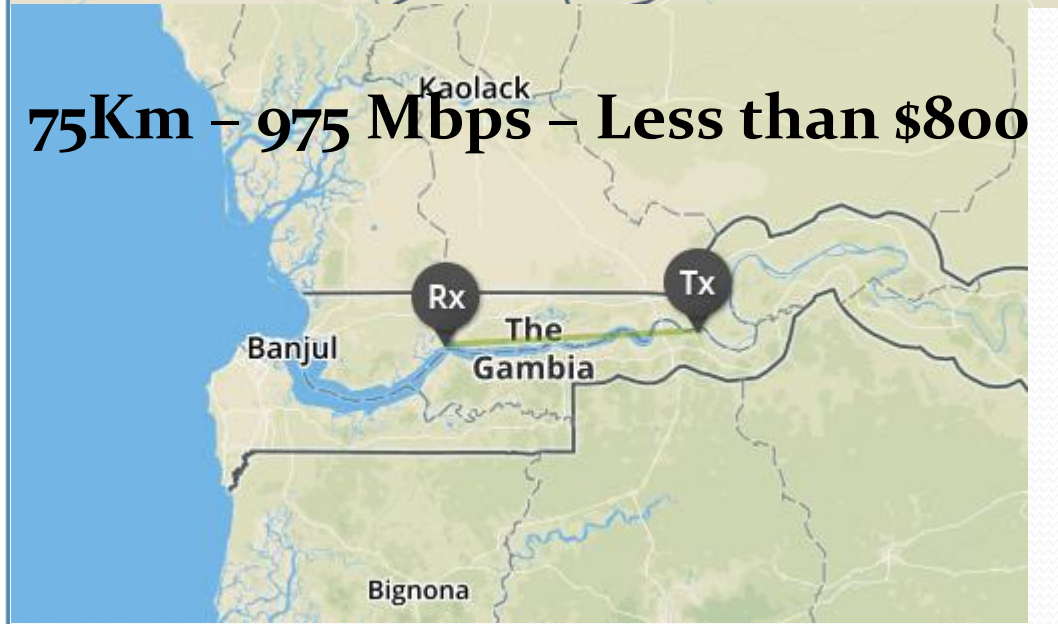
Link status: **Reliable**

Size of 1st Fresnel Zone: 7 meters

60% of 1st Fresnel Zone: 4.2 meters



75Km - 975 Mbps - Less than \$800



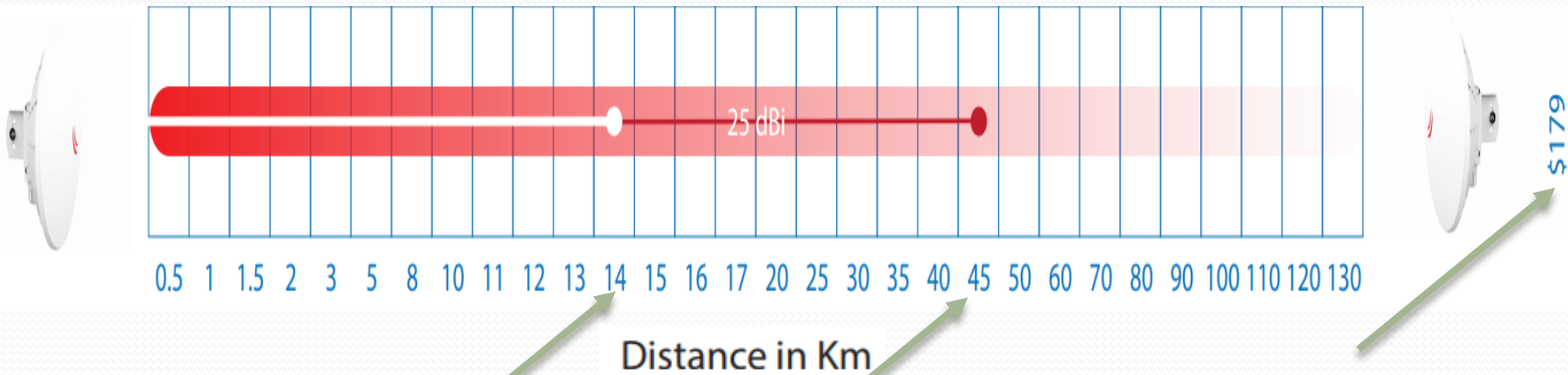
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# PtP - Dynadish 25dBi 6GHz

Dynadish



○ Distance at max supported 802.11ac data rate (eg. 866Mbit)

● Distance at max supported 802.11n data rate (eg. 300Mbit)

Max range at -70 signal



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# BackBone Wireless

- Wireless Wire Dish - \$ 298,00
- 60GHz – 2Gbps – 1500m

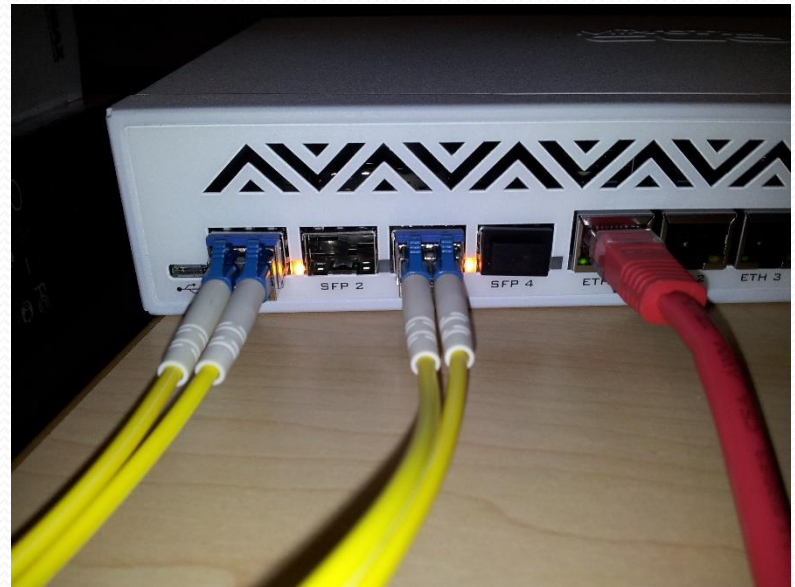


# Backbone Fiber

- Fiber is the future has no escape
  - No interference
  - High transport capacity

But:

- High cost of deployment
- High maintenance cost



# Backbone - Fiber

- S-4554LC8oD
  - Pair of SFP 1.25-G module for 80km links with Single LC-connectors



# Backbone - Fiber

- S+2332LC10D
  - Pair of SFP+ (10Gbit) modules, 10km, for single optical cable



# Backbone – Fiber Switch

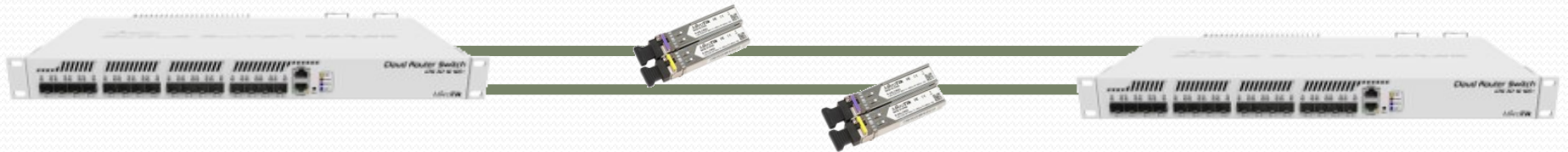
- CRS317-1G-16S + RM
  - 1 Gigabit port switch with 16 SFP+
- CRS326-24G-2S+RM
  - 24 Gigabit port switch with 2 SFP+



# Backbone – Fiber



**80 Km - 1.25Gbps**



**80 Km - 2,5Gbps**

**Cable 24F = 30Gbps**



**10 Km - 10Gbps**



# Vipnet Network Access



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# Vipnet Network Access

- Scenario 1 - Residential Wireless
- Scenario 2 - Residential Ethernet
- Scenario 3 - Residential Fiber
- Scenario 4 - Corporate Fiber
- Scenario 5 - Corporate Radio

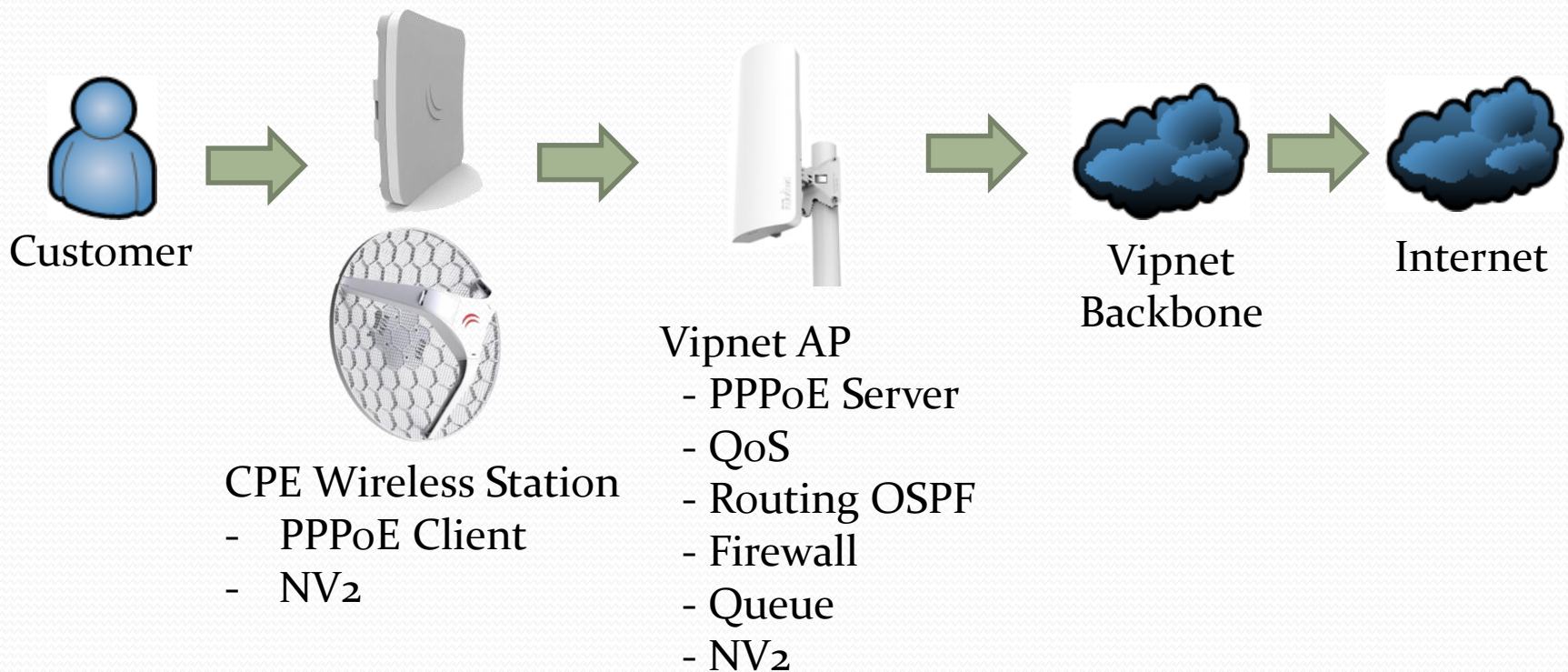


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# Scenario 1 - Residential Wireless



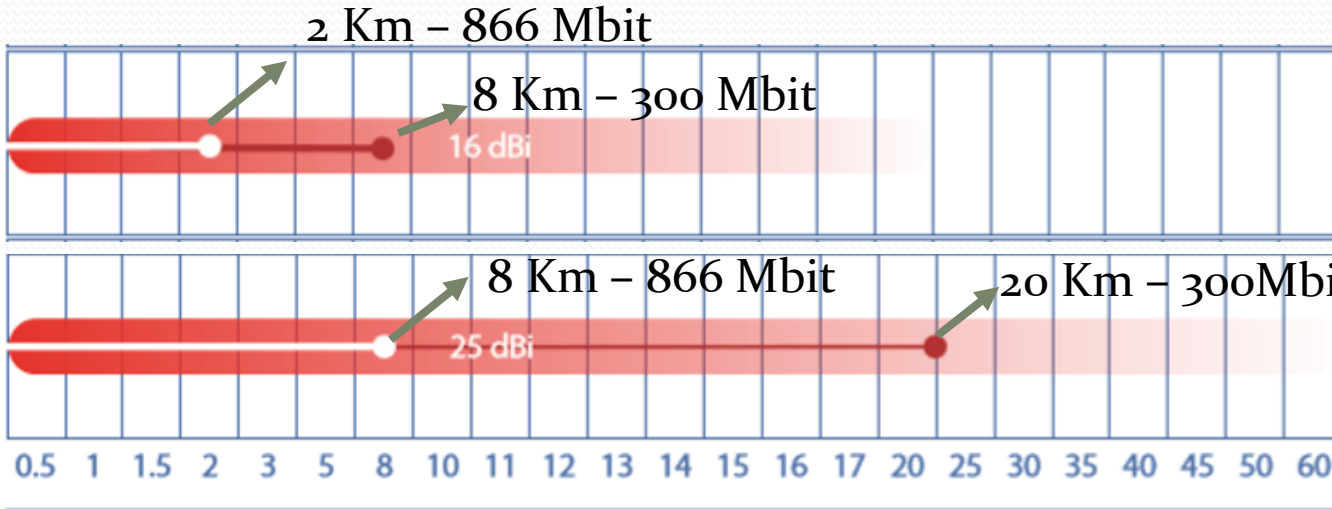
# AP 802.11ac 120°

- 15dBi – 31dBm
- 19dBi – 31dBm



# PmP

SXT 5 ac  
\$109



Dynadish  
\$179



Distance in Km

○ Distance at max supported 802.11ac data rate (eg. 866Mbit)

● Distance at max supported 802.11n data rate (eg. 300Mbit)

■ Max range at -70 signal

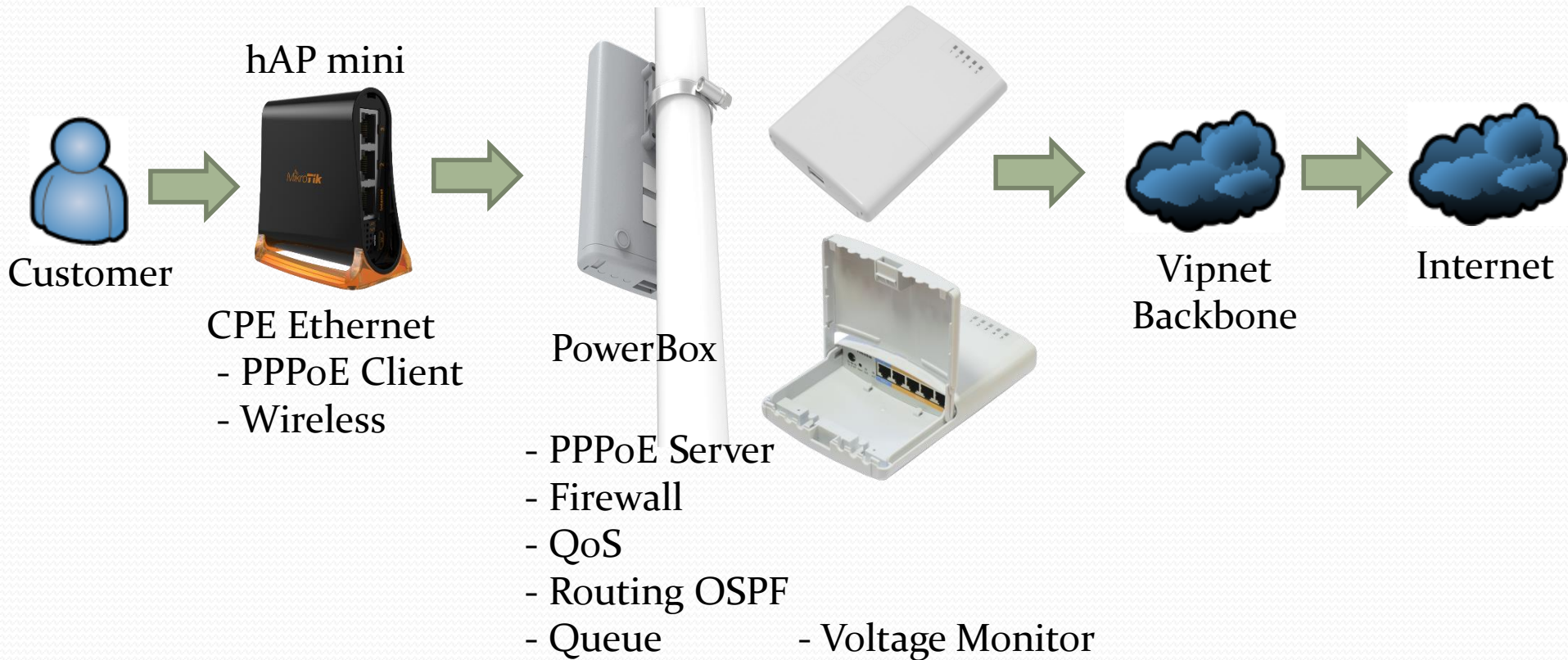


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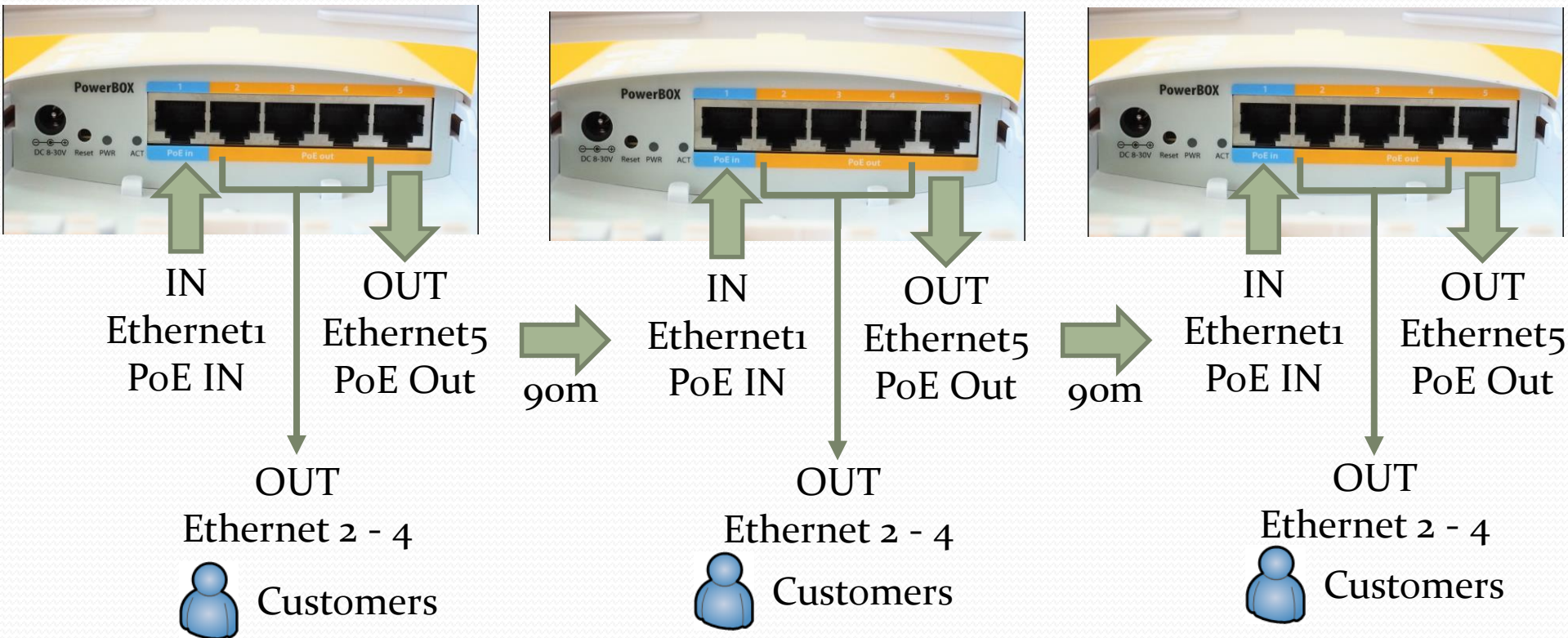
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# Scenario 2 - Residential Ethernet



# Scenario 2 - Residential Ethernet

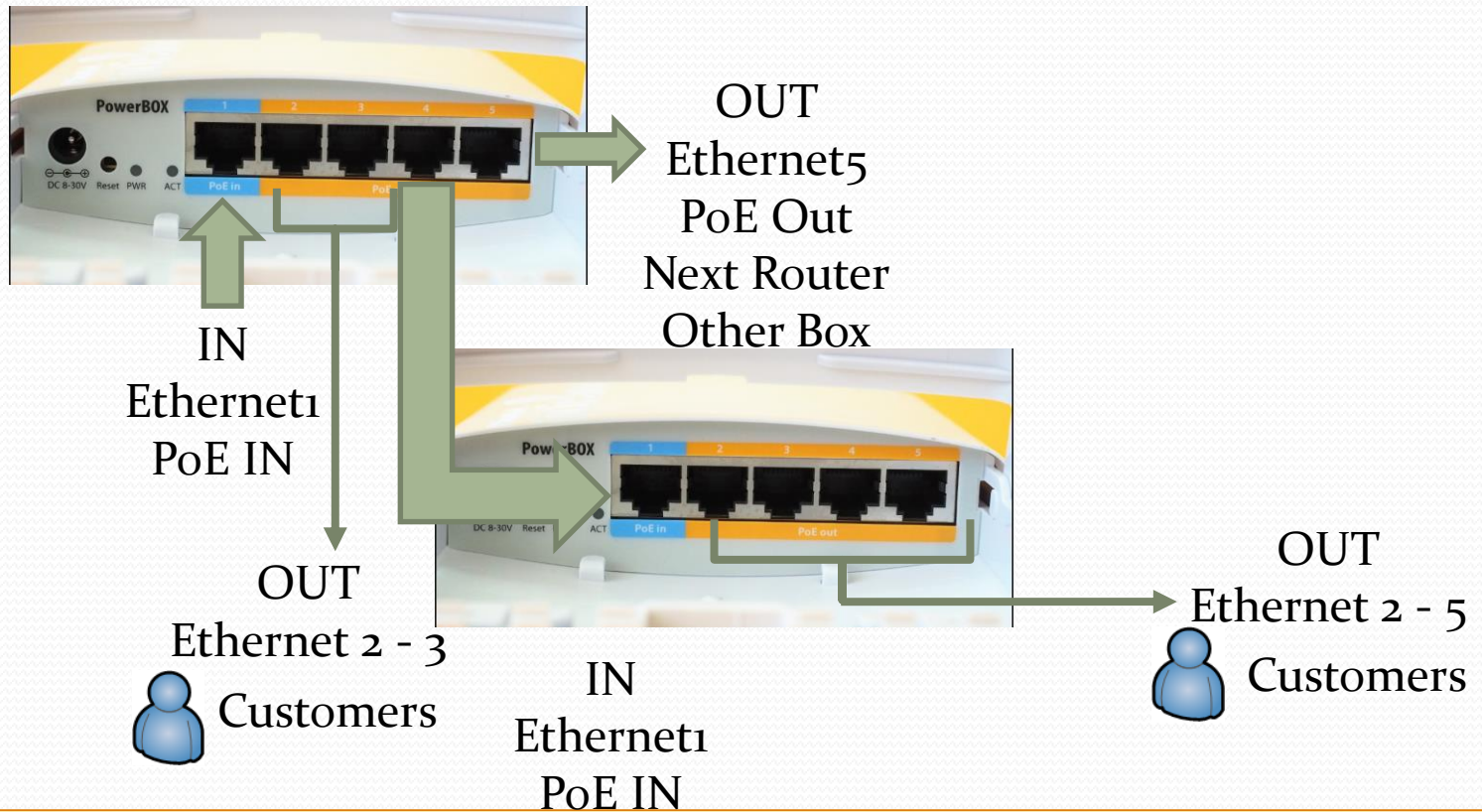


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# Scenario 2 - Residential Ethernet

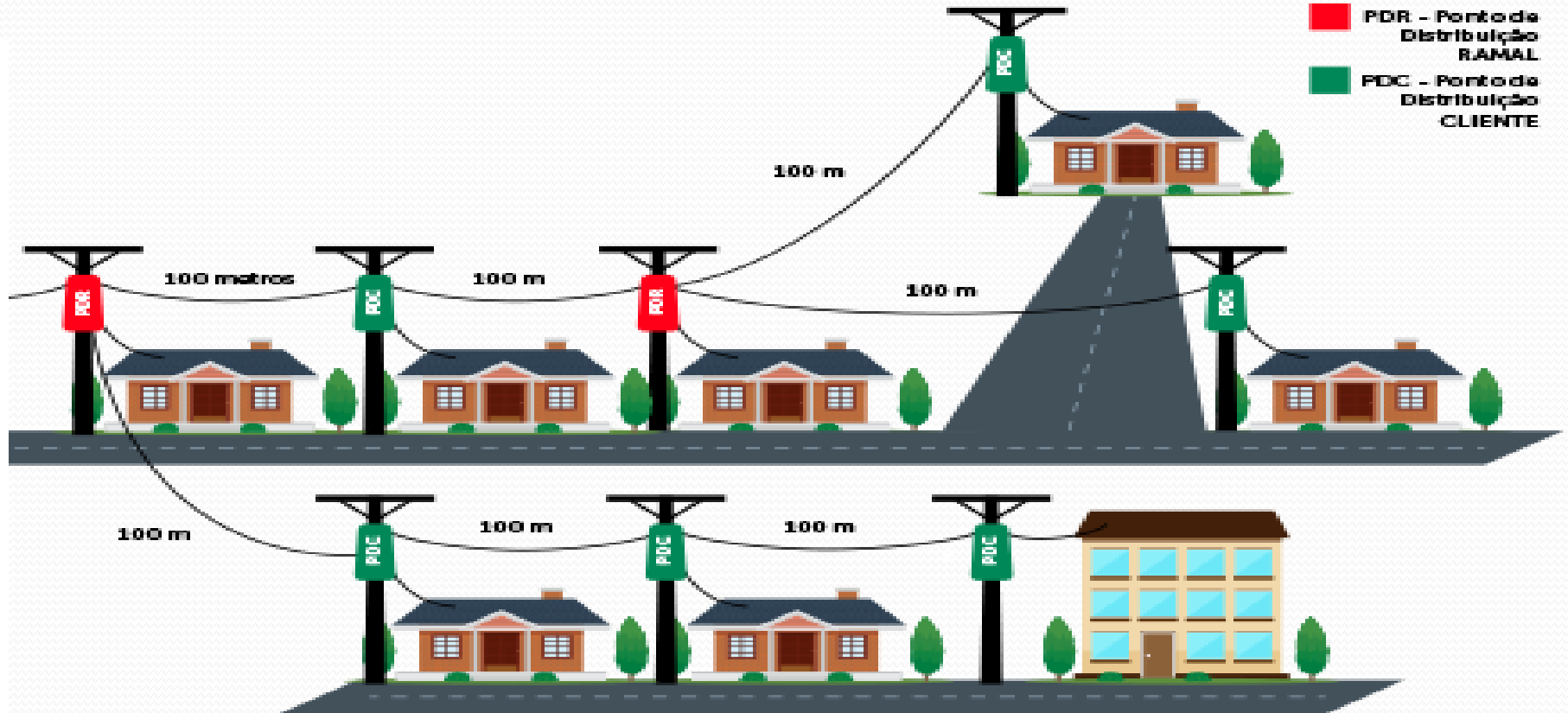




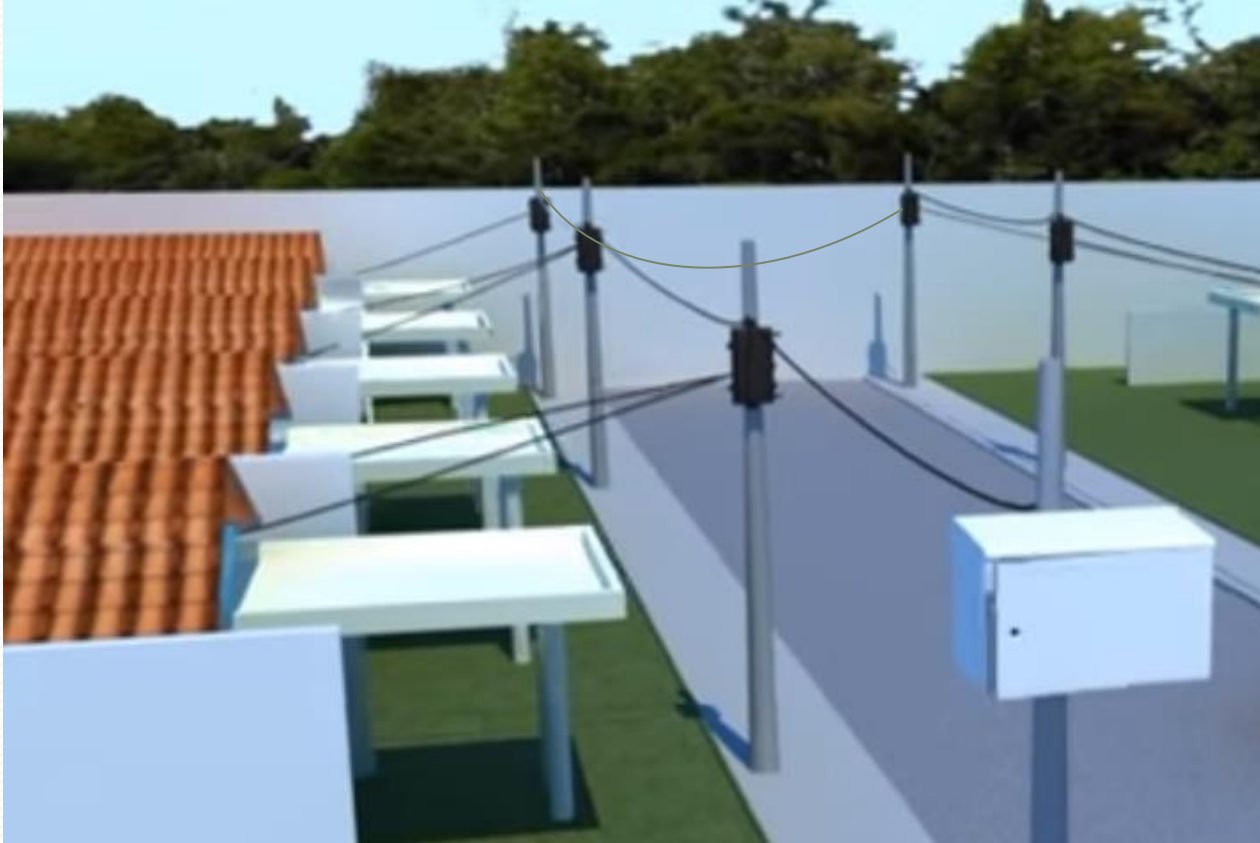
# Scenario 2 - Residential Ethernet



# Scenario 2 - Residential Ethernet



# Scenario 2 - Residential Ethernet



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# Scenario 3 - Residential Fiber



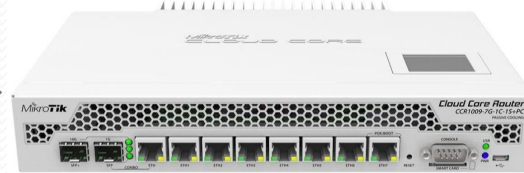
Customer



CPE SFP ONU  
- PPPoE Client



OLT



- PPPoE Server
- Firewall
- QoS
- Routing OSPF
- Queue



Vipnet  
Backbone



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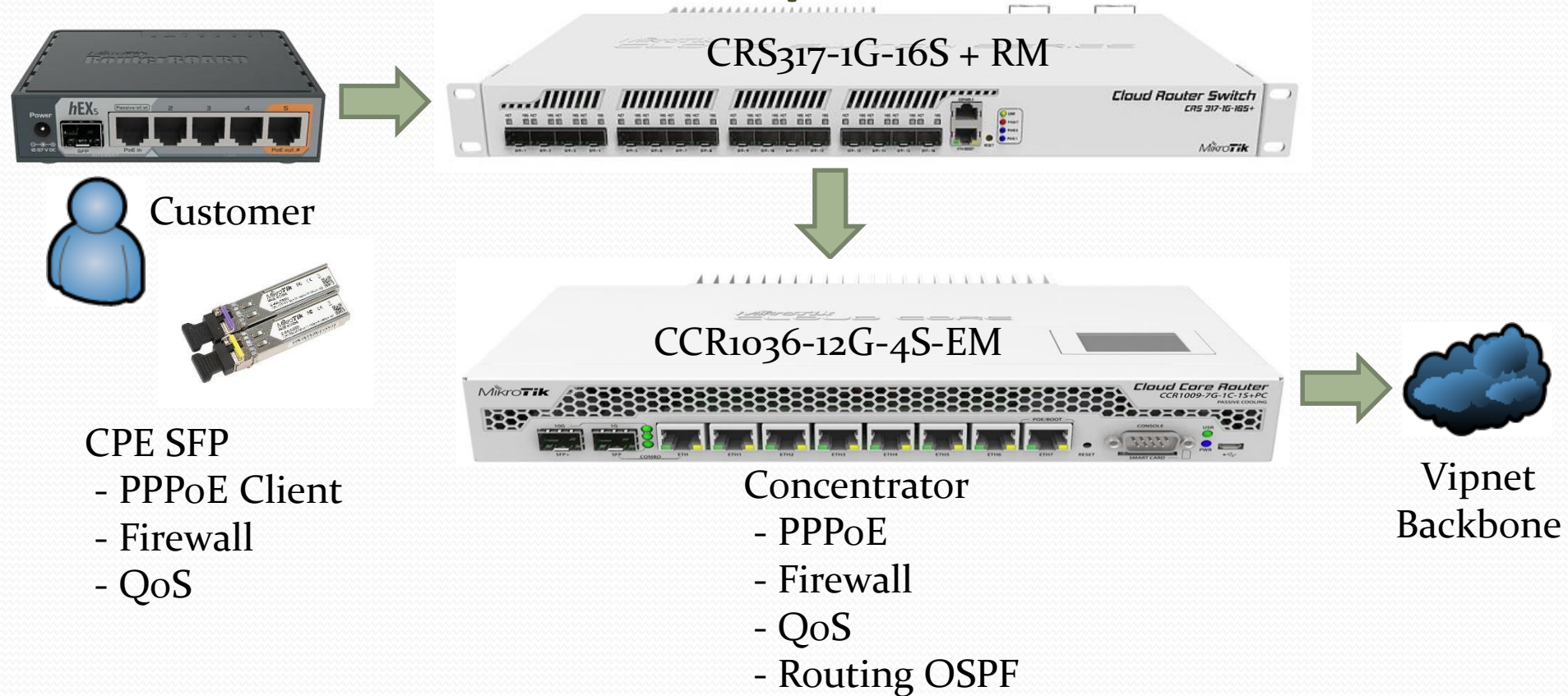
# Scenario 3 - Residential Fiber



IN  
Network  
Fiber

More Clients with only one fiber and SFP.

# Scenario 4 - Corporate Fiber

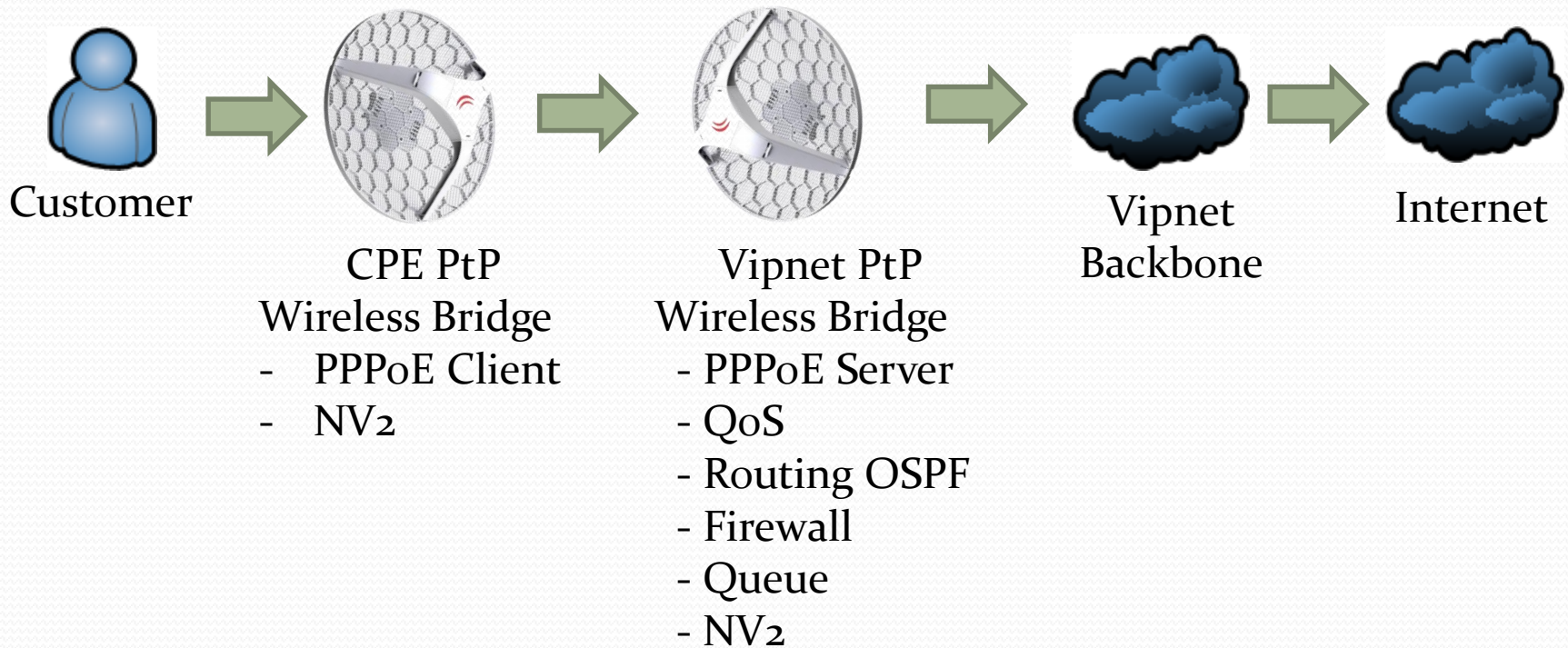


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# Scenario 5 - Corporate Radio



# Distribution of IPs



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# Distribution of IPs

- RFC 6598 100.64.0.0/10
  - 100.64.0.0/11 customers (100.64.0.0-100.95.255.255)
  - Each concentrator receives a / 19 that holds 1024 clients, and can be summarized by OSPF.
  - Ex.
    - Concentrator 1 100.64.0.0/19 IP 100.64.0.0 – 100.64.15.64
    - Concentrator 2 100.64.16.0/19 IP 100.64.16.0 – 100.64.31.64
  - 100.127.0.0/16 for addressing the internal routers of the network.



# Distribution of IPs

- Each public IP has 1000 ports associated with the IP of the clients, this association is fixed, so it is easy through the logs to locate the client.
  - Ex. 192.0.2.1 ports 1101-2100 – 100.64.0.1
  - Ex. 192.0.2.1 ports 2101-3100 - 100.64.0.2
  - Ex. 192.0.2.1 ports 3101-4100 - 100.64.0.3
  - ...
  - Ex. 192.0.2.1 ports 63101-64100 - 100.64.0.63
  - Ex. 192.0.2.1 ports 64101-65100 - 100.64.0.64

# Distribution of IPs

- IPv4
  - 100.64.0.1
  - 100.64.0.2
  - 100.64.0.3
  - ...
  - 100.64.0.63
  - 100.64.0.64

# Distribution of IPs

- Currently recommended allocation size (RFC6177):
  - /56 for residential customers
  - /48 for business customers



# Distribution of IPs

IPv4

100.XX.YY.ZZ

ZZ = 1-64 - 64 possibilities

Each /24 they fit 64 customers

YY = 0-99 - 100 possibilities

With 100 /24 = 6.400 customers

XX = 64-95 - 31 possibilities

Each 31 /24 they fit = 198.400 customers



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# Distribution of IPs

IPv4	IPv6
100.XX.YY.ZZ	2001:db8:XXYY:ZZ::/56
Ex:	
100.64.0.1	<b>2001:db8:6400:01::/56</b>
100.76.53.63	<b>2001:db8:7653:63::/56</b>
100.95.99.64	<b>2001:db8:9599:64::/56</b>



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# CPE - Customer Premises Equipment



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# CPE - Customer Premises Equipment

- The importance of a Mikrotik client CPE on each client.
  - Customer management
  - Client isolation from the rest of the network
  - Implementing bandwidth and firewall controls directly in the client's home
  - Offer a wireless service to add value
  - Mark client packages to implement QoS
  - Very low cost
  - Provide graphics services for usage monitoring.



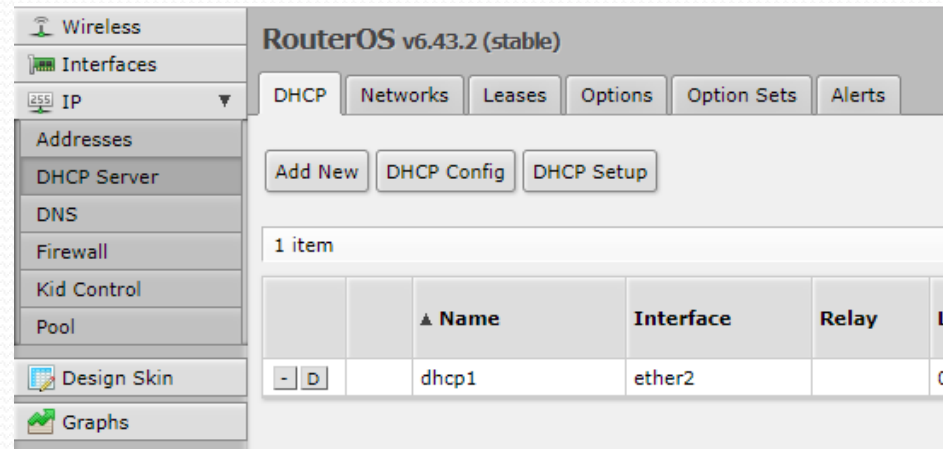


# CPE - Customer Premises Equipment

- Each residential client has a CPE hAP light where the client has access to a web password with unique function rename the AP and the password of the same.
- This CPE connects in the access network where there is a PPPoE server and no IP configured in the interface.
- The CPE has a DHCP server enabled to facilitate the client's browsing.

# CPE Customer

- Provides DHCP.
- Implements firewall.
- Provides Wifi
  - There is a page where the client can configure the wi-fi password and the network name, besides being able to modify the IP of the internal network, and to see the graphics, besides redirection of doors.
- Bridge between Wi-Fi and network ports.
- It has a PPPoE dialer.
- Implements SLAAC.



# CPE Customer

- DHCP
  - IP with port 80 reserved 192.168.88.80
  - IP with port 22 reserved 192.168.88.22
  - IP with port 443 reserved 192.168.88.43
  - IP with port 53 reserved 192.168.88.53
  - IP with port 110 reserved 192.168.88.110
  - IP with port XX reserved 192.168.88.XX
  - Pool available by DHCP 192.168.88.200-253
  - Gateway 192.168.88.254



# CPE – Home Ethernet

- hAP mini \$19,95
- hAP Lite TC \$21,95



# CPE - SFP

- hEX S
- RB260 GS



# CPE - Wireless

- 16dBi -- <8Km
- SXTsq - SXTsq 5 ac
  
- 24,5dBi
- LHG5 - LHG 5 ac
  
- 27 dBi -- 25Km
- LHG XL HP5 - LHG XL 5 ac



# ONU - FTTx

- Mikrotik S-GPON



# CGNAT



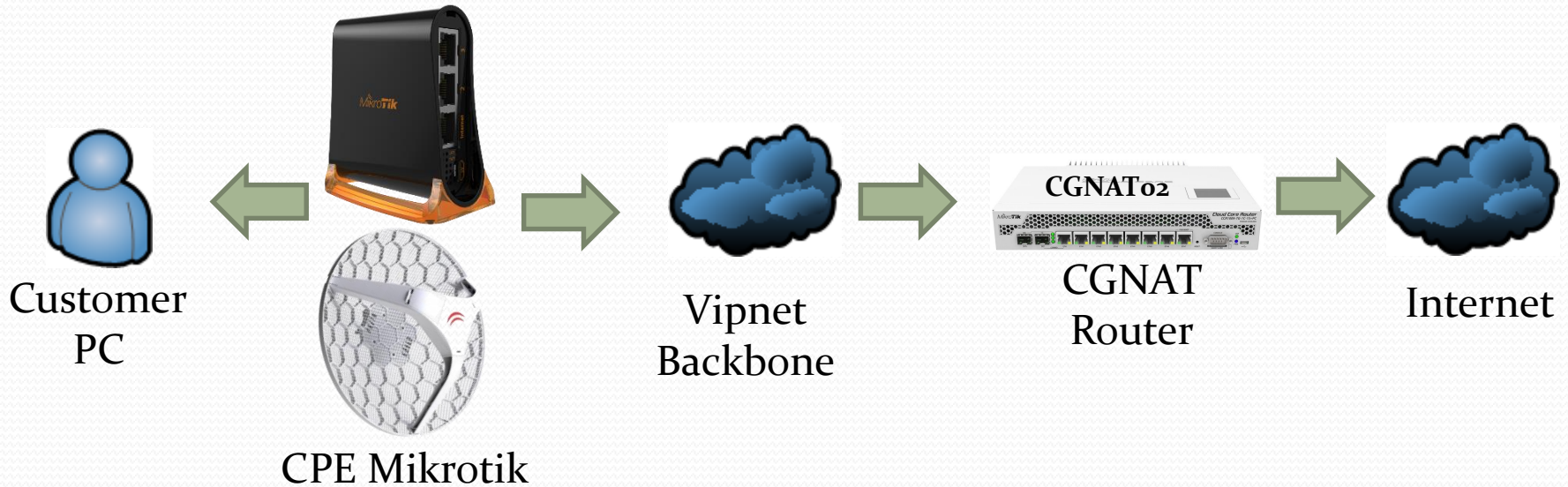
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# CGNat - Three different IPv4 address spaces are involved.



192.168.88.0/24  
Privided Network  
RFC1918

10.64.0.0/10  
Carrier Network  
RFC6598

192.0.2.0/24  
Public  
Network

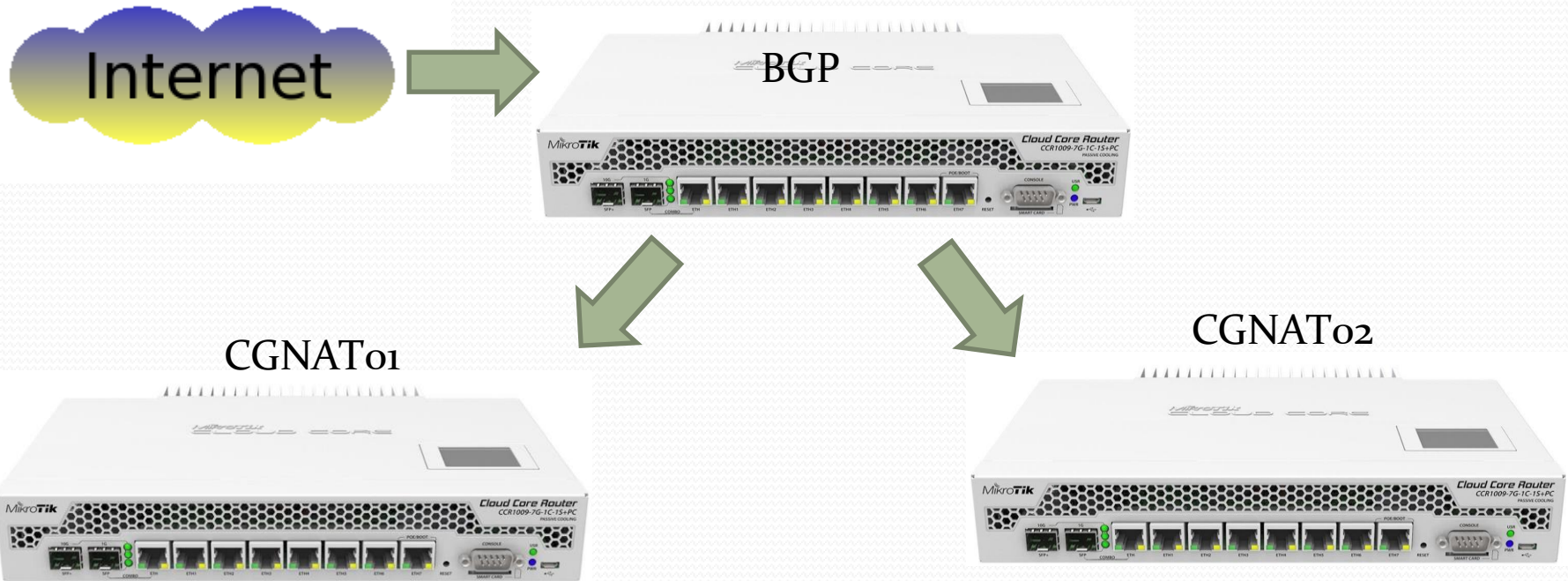


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# CGNAT - Backbone



192.0.2.0/26 > 100.64.0.0/18

192.0.2.128/25 > 100.64.64.0/18

Each CGNAT do Nat for 4096 customers



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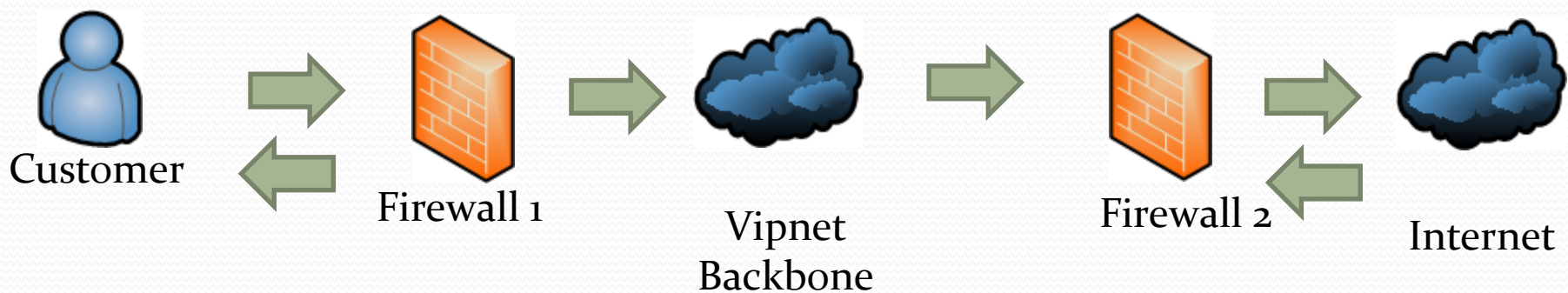
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# Firewall





# Firewalls Vipnet





# Firewall 1



- Control de traffic from the customers to the network.
- Implemented in AP or First Router.



# Firewall 2



- Control de trafic from the internet.
- Implemented in CCR





# Firewalls Vipnet – Anti-spoof

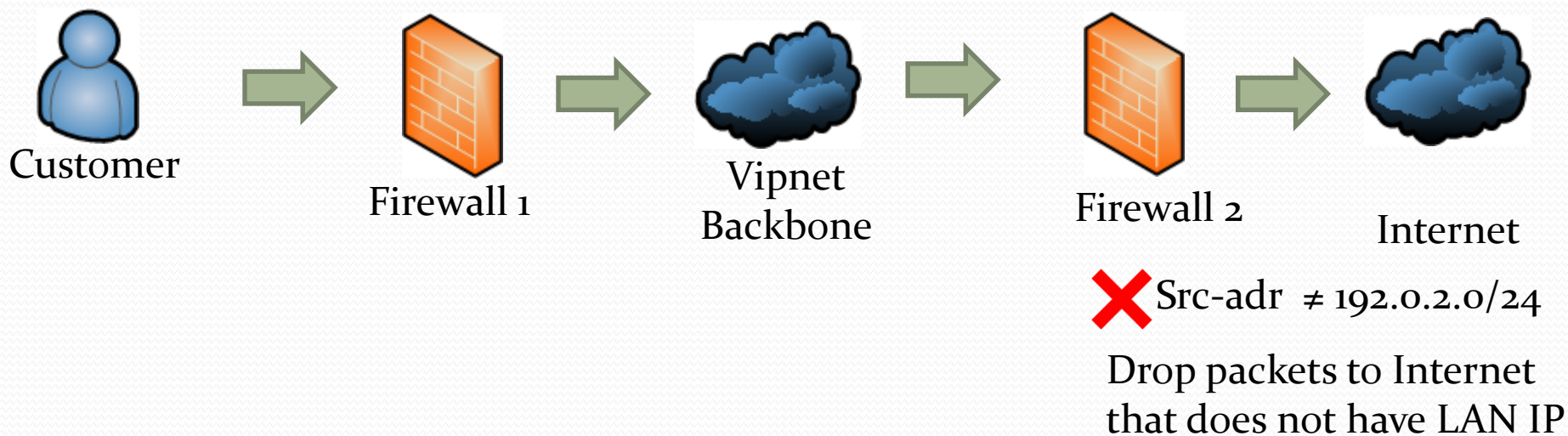


**✗** Src-adr  $\neq$  192.0.2.0/24

Drop packets from LAN that does not have LAN IP.  
192.0.2.0/24 is local network used subnet



# Firewalls Vipnet – Anti-spoof







# Firewall – Bogons

<b>0.0.0.0/8</b>	<b>192.0.0.0/24</b>
<b>172.16.0.0/12</b>	<b>192.0.2.0/24</b>
<b>192.168.0.0/16</b>	<b>198.51.100.0/24</b>
<b>10.0.0.0/8</b>	<b>203.0.113.0/24</b>
<b>169.254.0.0/16</b>	<b>100.64.0.0/10</b>
<b>127.0.0.0/8</b>	<b>240.0.0.0/4</b>
<b>224.0.0.0/4</b>	<b>192.88.99.0/24</b>
<b>198.18.0.0/15</b>	

- RFC 1918, 3069, 5735, 6598 adn 6890



# Firewalls Vipnet – Drop Bogon



**×** Src-adr = Bogon

Drop packets from Internet  
that does not have valid IP



# Firewalls Vipnet – Drop Bogon



**✗** Dst-adr = Bogon

Drop packets to Internet  
that does not have valid IP

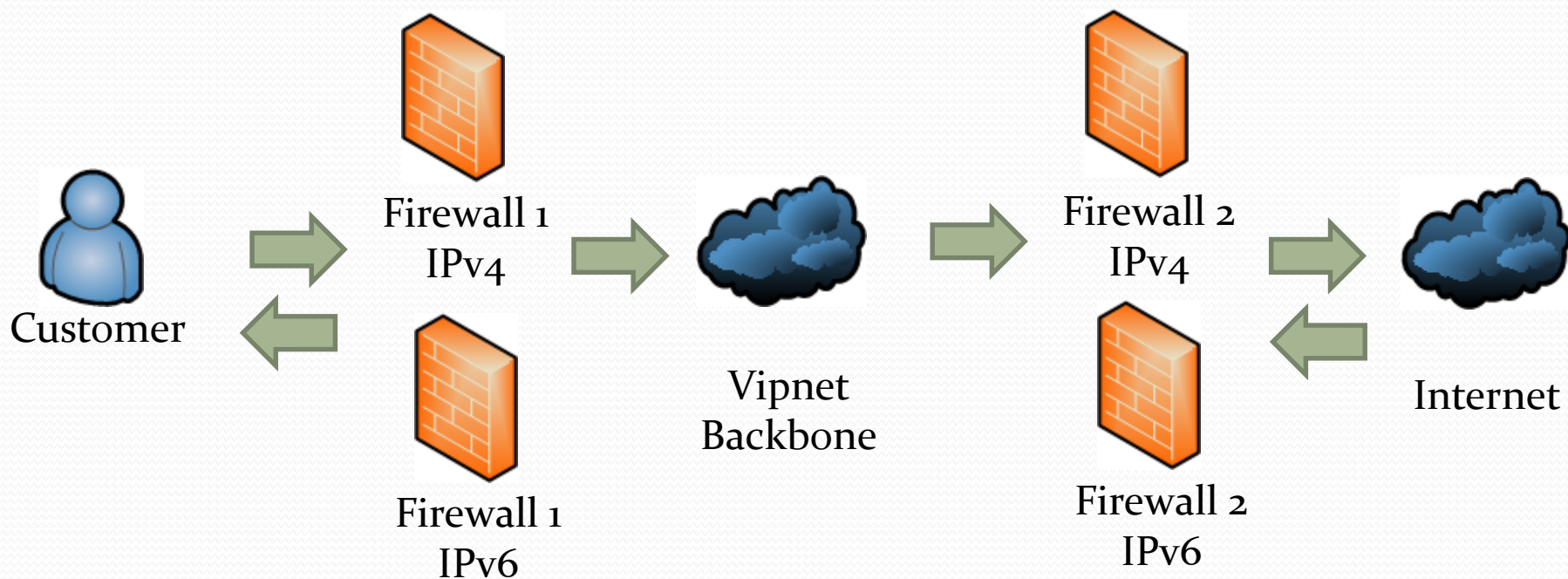


# Firewall – Input

- Create address-list for IP addresses, that are allowed to access your router;
  - ✓ • IPs from routers for OSPF work
  - ✓ • IPs of management.
- Drop everything else and log



# Firewalls Vipnet



# QoS



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# QoS - Vipnet

- We have five different classes of service:
  - **Monitoring:** At this class we have the network of monitoring and the routers. Bigger priority
  - **VoIP:** At this class we have the VoIP servers.
  - **VIP:** At this class we have the clients with full guarantee of band and the more important.
  - **Business:** Companies with more guaranteed band.
  - **Residential:** Residential customers with low ticket. Smaller Priority

# QoS - Vipnet

2 3 5 6 7

Class	Max-Limit	Limit-at	Priority	Packet Mark (TOS)
Monitoring	Small	= Max-Limit	2	2
VoIP	Medium	= Max-Limit	3	3
VIP	Variable	= 100% Max-Limit	5	5
Business	Variable	= 50% Max-Limit	6	6
Residential	Variable	= 25% Max-Limit	7	7



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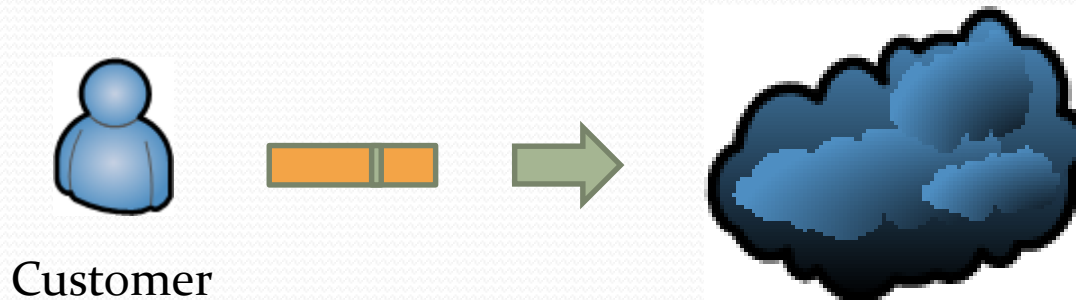
# QoS – Type of Service

- What is Type of Service?

0	4	8	16	19	31
Version	IHL	Type of Service	Total Length		
Identification			Flags	Fragment Offset	
Time To Live		Protocol	Header Checksum		
Source IP Address					
Destination IP Address					
Options				Padding	

# QoS – Type of Service

- Why we use is Type of Service?

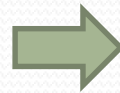


# QoS – VoIP internal

- IP based marking for VoIP Server



VoIP Server



Src-address = VoIP Server



Dst-address = VoIP Server



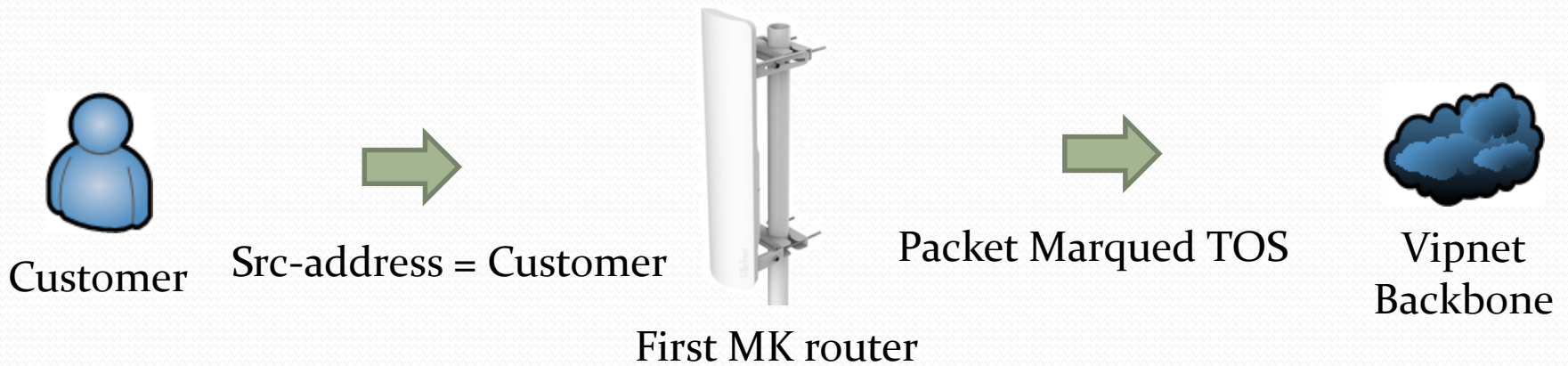
Customer

QoS

QUALITY OF SERVICE

# QoS – Customer > Internet

- Paquet Mark with TOS



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QoS

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# QoS – Internet > Customer

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# QoS

## QUALITY OF SERVICE

# QoS - Use of Address Lists

The screenshot shows the Mikrotik WinBox Firewall configuration window, specifically the 'Address Lists' tab. The window title is 'Firewall'. Below the title bar are tabs for 'Filter Rules', 'NAT', 'Mangle', 'Raw', 'Service Ports', 'Connections', 'Address Lists', and 'Layer7 Protocols'. A toolbar contains icons for adding, deleting, and filtering. A search box labeled 'Find' has 'all' entered. Below the toolbar is a table with the following data:

Name	Address	Timeout	Creation Time
TOS2	201.70.111.0/24		Jan/10/2017 11:29:03
TOS3	189.21.0.0/29		Jan/10/2017 11:29:38
TOS5	10.64.0.2		Jan/10/2017 11:30:22
TOS5	10.64.0.6		Jan/10/2017 11:30:33
TOS5	10.64.0.7		Jan/10/2017 11:33:23

To the right of the table is a dropdown menu with a search icon, showing a list of address lists: TOS2, TOS3, TOS5, TOS6, TOS7, and 'all' (highlighted).

- PPP Profile
  - Address List

The screenshot shows the Mikrotik WinBox PPP Profile configuration window, titled 'PPP Profile <VIP>'. The 'General' tab is selected. The 'Name' field contains 'VIP'. The 'Address List' dropdown menu is set to 'TOS5'. There are 'OK' and 'Cancel' buttons on the right side of the window.

# QoS

## QUALITY OF SERVICE

# QoS – VoIP Server

Firewall								
Filter Rules		NAT	Mangle	Raw	Service Ports	Connections	Address Lists	Layer7 Protocols
#	Action	Chain	Src. Address	Dst. Address	New DSCP (TOS)			
::: Mark connection VoIP Server								
0	mark connection	prerouting	192.0.2.1					
::: Mark connection VoIP Server								
1	mark connection	prerouting		192.0.2.1				
::: Mark packets VoIP Server								
2	mark packet	prerouting						
::: Change TOS packets VoIP Server								
3	change DSCP (TOS)	prerouting			3			



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## QoS – VoIP Server

Mangle Rule <192.0.2.1>

General Advanced Extra Action Statistics

Chain: prerouting

Src. Address:  192.0.2.1

Dst. Address:

OK Cancel Apply Disable

Mangle Rule <192.0.2.1>

General Advanced Extra Action Statistics

Chain: prerouting

Src. Address:

Dst. Address:  192.0.2.1

OK Cancel Apply Disable

Mangle Rule <192.0.2.1>

General Advanced Extra Action Statistics

Action: mark connection

Log

Log Prefix:

New Connection Mark: VoIP\_con

Passthrough

OK Cancel Apply Disable Comment Copy

Mangle Rule <192.0.2.1>

General Advanced Extra Action Statistics

Action: mark connection

Log

Log Prefix:

New Connection Mark: VoIP\_con

Passthrough

OK Cancel Apply Disable Comment Copy



# QoS – VoIP Server

**QoS**  
QUALITY OF SERVICE

Mangle Rule <>

General | Advanced | Extra | Action | Statistics

Chain: prerouting

Src. Address:

Dst. Address:

Packet Mark:

Connection Mark:  VoIP\_con

OK

Cancel

Apply

Mangle Rule <>

General | Advanced | Extra | Action | Statistics

Chain: prerouting

Src. Address:

Dst. Address:

Packet Mark:  VoIP\_pack

OK

Cancel

Apply

Disable

Mangle Rule <>

General | Advanced | Extra | Action | Statistics

Action: mark packet

Log

Log Prefix:

New Packet Mark: VoIP\_pack

Passthrough

OK

Cancel

Apply

Disable

Comment

Copy

Remove

Mangle Rule <>

General | Advanced | Extra | Action | Statistics

Action: change DSCP (TOS)

Log

Log Prefix:

New DSCP (TOS): 3

Passthrough

OK

Cancel

Apply

Disable

Comment

Copy

Remove



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# QoS – Pack Clients Access

**QoS**  
QUALITY OF SERVICE

Firewall

Filter Rules NAT Mangle Raw Service Ports Connections Address Lists Layer7 Protocols

+ - ✓ ✗ [icon] [icon] 00 Reset Counters 00 Reset All Counters

#	Action	Chain	Src. Address	Dst. Address	New DSCP (TOS)
::: Mark Connection VIP					
0	mark connection	prerouting			
::: Mark VIP_con					
1	mark connection	prerouting			
::: Mark VIP pack					
2	mark packet	prerouting			
::: Change TOS VIP					
3	change DSCP (TOS)	prerouting			5

# QoS

## QUALITY OF SERVICE

# QoS – Pack Clients Access

Mangle Rule <>

General Advanced Extra Action Statistics

Chain: prerouting

Src. Address:

OK Cancel Apply

Mangle Rule <>

General Advanced Extra Action Statistics

Chain: prerouting

Src. Address:

OK Cancel Apply

Mangle Rule <>

General Advanced Extra Action Statistics

Src. Address List: TOS5

Dst. Address List:

OK Cancel Apply

Mangle Rule <>

General Advanced Extra Action Statistics

Src. Address List:

Dst. Address List: TOS5

OK Cancel Apply

Mangle Rule <>

General Advanced Extra Action Statistics

Action: mark connection

Log

Log Prefix:

New Connection Mark: VIP\_con

Passthrough

OK Cancel Apply Disable Comment Copy

Mangle Rule <>

General Advanced Extra Action Statistics

Action: mark connection

Log

Log Prefix:

New Connection Mark: VIP\_con

Passthrough

OK Cancel Apply Disable Comment Copy



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# QoS – Pack Clients Access

**QoS**  
QUALITY OF SERVICE

Mangle Rule <>

General | Advanced | Extra | Action | Statistics

Chain: prerouting

Src. Address:

OK

Cancel

Apply

Mangle Rule <>

General | Advanced | Extra | Action | Statistics

Chain: prerouting

Src. Address:

OK

Cancel

Apply

Connection Mark:  VIP\_con

Packet Mark:  VIP\_pack

Mangle Rule <>

General | Advanced | Extra | Action | Statistics

Action: mark packet

Log

Log Prefix:

New Packet Mark: VIP\_pack

Passthrough

OK

Cancel

Apply

Disable

Comment

Copy

Remove

Mangle Rule <>

General | Advanced | Extra | Action | Statistics

Action: change DSCP (TOS)

Log

Log Prefix:

New DSCP (TOS): 5

Passthrough

OK

Cancel

Apply

Disable

Comment

Copy

# QoS – Routers

**QoS**  
QUALITY OF SERVICE

The screenshot displays the Mikrotik WinBox Firewall configuration interface. The main window shows a table of firewall rules with the following data:

#	Action	Chain	Src. Address	Dst. Address	DSCP (TOS)	Ne
0	mark packet	prerouting			5	

Three 'Mangle Rule' dialog boxes are overlaid on the right side of the screen, showing the configuration for the rule:

- Mangle Rule 1:** Chain: prerouting
- Mangle Rule 2:** DSCP (TOS): 5
- Mangle Rule 3:** Action: mark packet, Log: , Log Prefix: [empty], New Packet Mark: VIP\_pack, Passthrough:



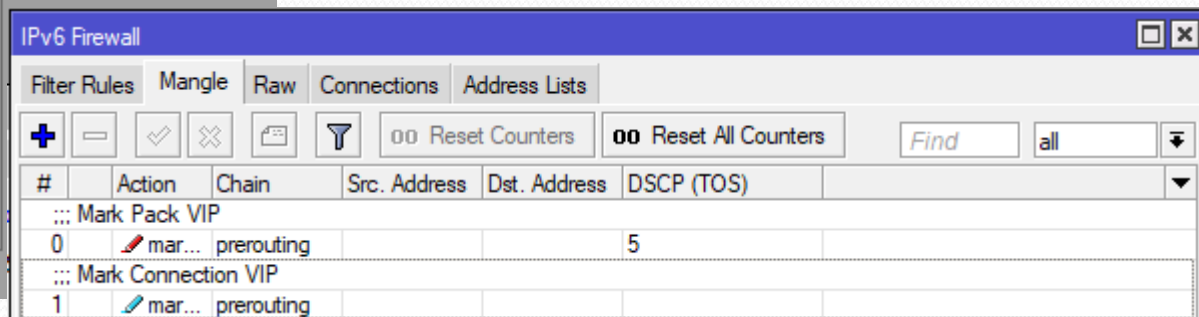
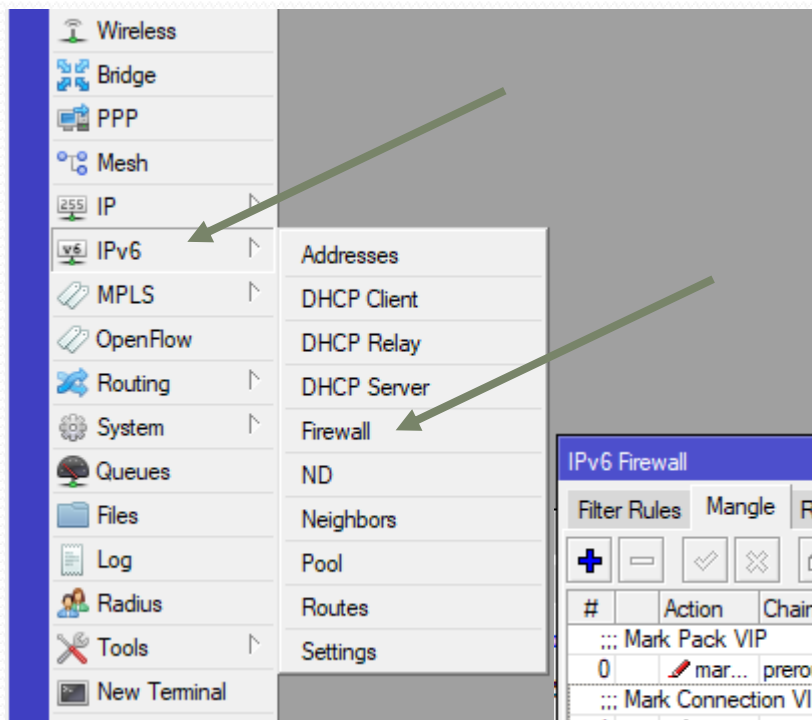
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# QoS – IPv6

**QoS**  
QUALITY OF SERVICE



# Conclusion

The Vipnet Company started operating in 2004, in 2007 we started using Mikrotik, in 2017 we had 14,000 customers using only Mikrotik radios and routers.

We are a success story and Mikrotik is part of that.



# Thank you!

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