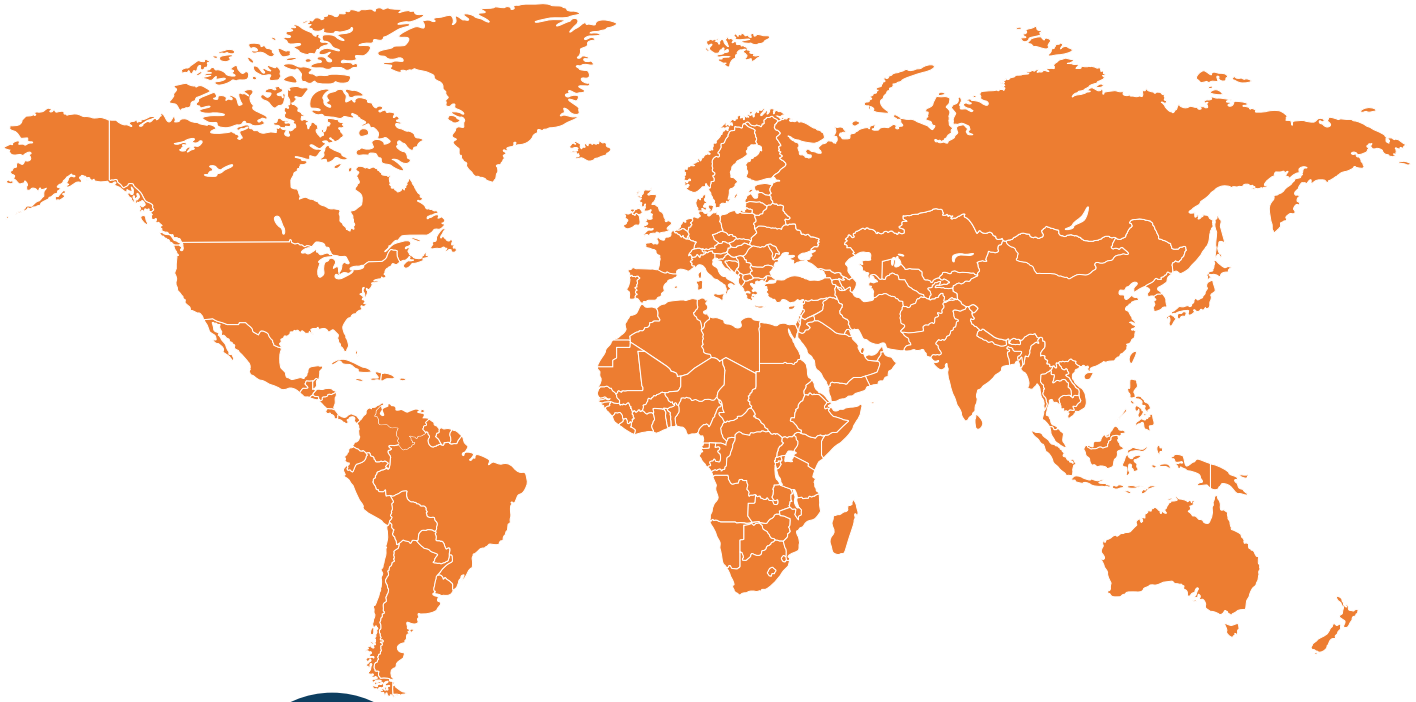

2001:db8:c01d:c01a::/64
IP
Deploying IPv6 for WISPs & FISPs
Design, Implementation & System Integration

IP Architechs the story

IP ArchiTechs is a global network engineering and design firm that covers a wide spectrum of environments. Our expertise spans service providers, datacenters, and enterprises.



GLOBAL

Offices in the US, Europe and South America

6

100+ Active Projects

1000s of clients across 6 continents

IPA | Who we are?

- Network engineering resources covering 20+ time zones around the world, providing services in 6 languages.
- building, growing, upgrading networks at various stages of their growth cycle. From start up WISP, to Fortune 50 global enterprise…and everything in between.
- Routing/Switching protocol experts
- Experience in service provider, data center, and enterprise – we understand the nuances of each space and their own operational and functional needs.
- We are **not** a VAR – We only sell our time, not hardware. We work towards what is right for your business, not hardware/margin incentives. Sometimes Juniper is the right choice, sometimes it is MikroTik, we align on the right design for your use case.
- Experience with over 30 major hardware routing/switch vendors and platforms.
- We're geeks and nerds. We like to get stuff done, not build PowerPoint presentations (as you'll find out soon enough)

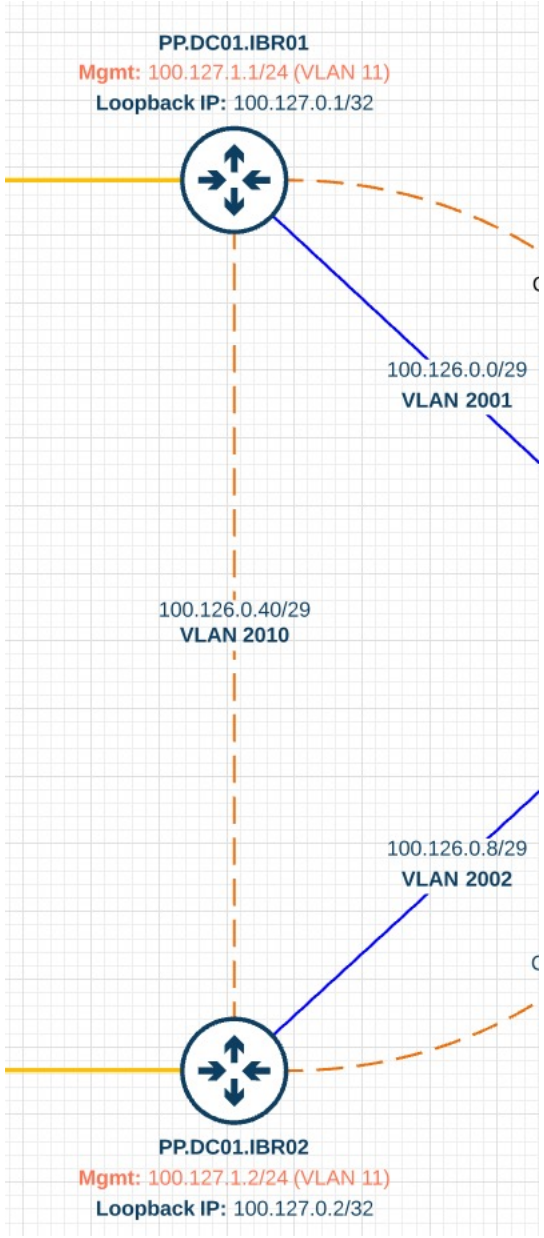
IPA | What we do?

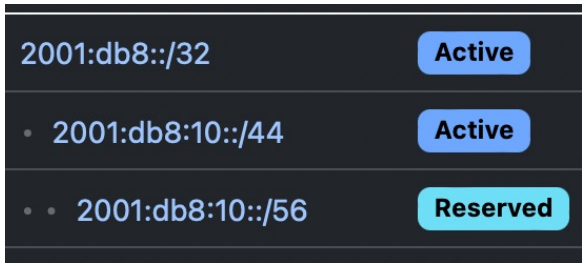
Here are some typical engagement contexts our clients come to us with.

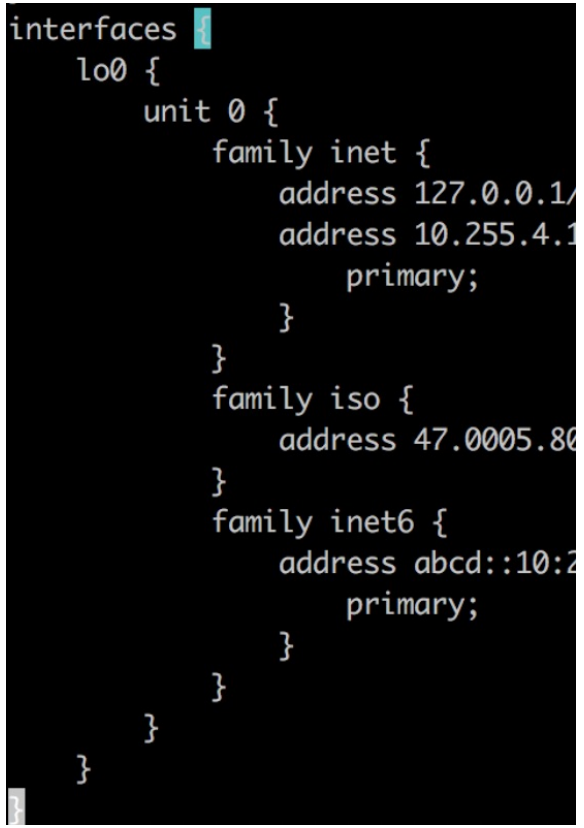
- Network Discovery/Audit – Consultative review of observations and findings
- Strategy consultation on network growth cycles. (Bridged -> Routed -> Basic Dynamic Routing -> and beyond)
- Systems/Software Integration and Automation
- Network migration planning, simulation, execution. We can take the driver seat and get things done that you otherwise don't have time for.
- Break/Fix Troubleshooting and Incident Response

We'll work with you to identify the best path forward, considering business goals. We can help strategize, plan, configure, and implement.

The operational tempo of our team has us uniquely trained to plan and lead executions of network migrations at any size.







IPv6 – What is it and how does it help?

01 **IPv6 basics – addressing, subnetting, types**

02 **IPv6 design and deployment**

03 **IPv6 subscriber provisioning considerations (with example)**


2001:db8:c01d:c01a::/64
IP
S1 |IPv6 Basics
Getting IPv6 into your network

Section 1 | IPv6 basics – addressing, subnetting, types

01

- Introduction to IPv6 – history/background
- Why is it important?
- Protocol Overview
- Differences between IPv6 and IPv4
- How do I get IPv6? (PA, RIR)

S1.1 | Introduction to IPv6

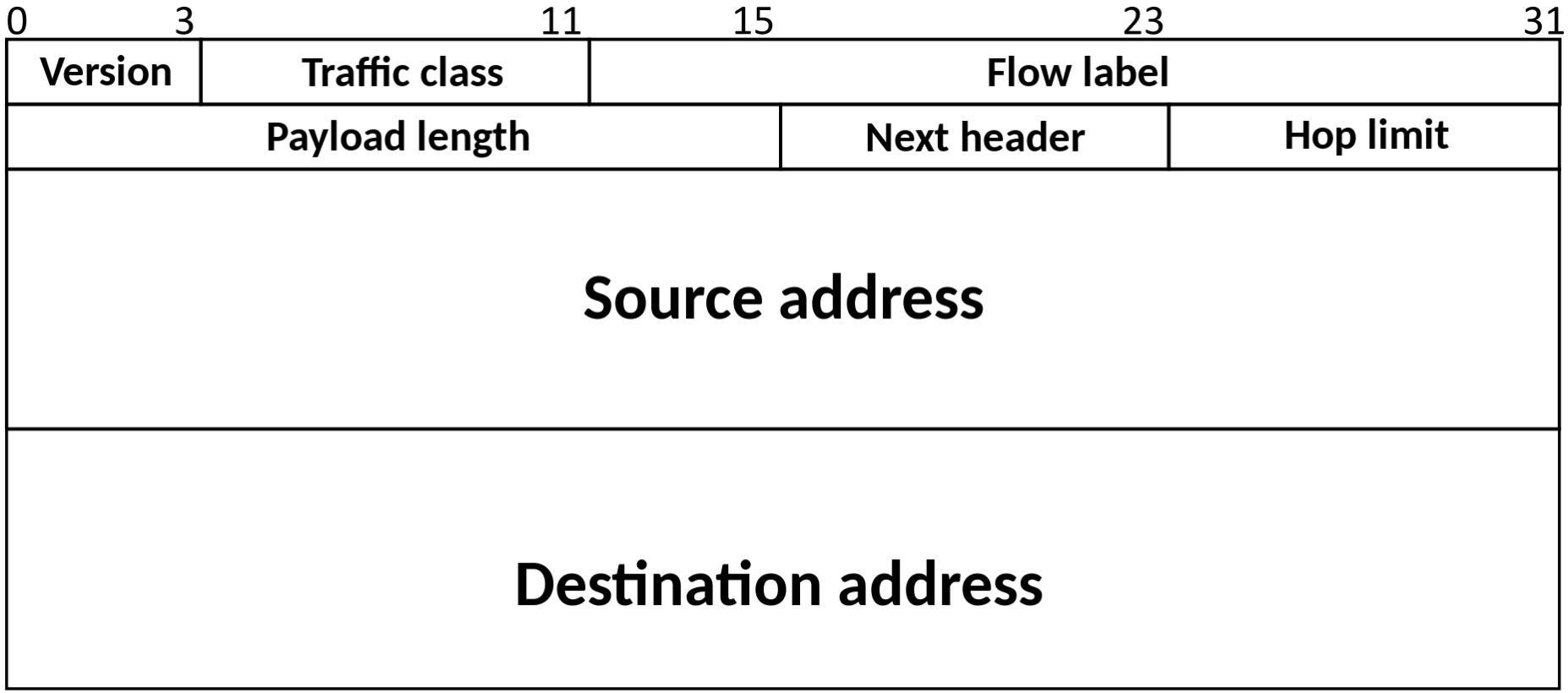
IPv6 **RFC 2460**

- **Began IETF discussions in 1994* and first published in 1998 under RFC 2460**
- **Why was it needed?**
  - IPv4 was first deployed in 1983 on ARPANET. The IETF realized in the mid 1990s that a successor to IPv4 was needed to deal with the scale of the Internet.
- **Why has it taken so long to adopt IPv6?**
  - The use of NAT and slower than predicted enterprise/DC/ISP adoption has extended the life of IPv4 far beyond the timelines originally anticipated
  - Hexadecimal addressing is perceived to be harder for humans to work with – DNS and automation are needed.

S1.2 | Why is IPv6 important?

- **Better user experience**
  - Less state without NAT points
  - End to end addressing Is better for realtime traffic like voice and video
  - Plenty of native IPv6 content in 2022 (Netflix, YouTube, Facebook, etc)
  - Publicly routable addressing for all subscribers will lower operational cost and improve user experience by limiting the need for port forwarding or other NAT workarounds
  - Streamlined header – more compressible for RF networks when using radios that dedup and compress headers
- **Is it "Faster?"**
  - Apple delivered performance data in 2020 showing 30% improvement on apps with IPv6
- **IPv4 *really* is running out and the IPv6 Internet, while not finished, is ready**
  - IPv4 has become harder and more expensive to obtain and sometimes IPv4 space is being taken away by ISPs if they feel it's not being used.

S1.3 | Protocol overview



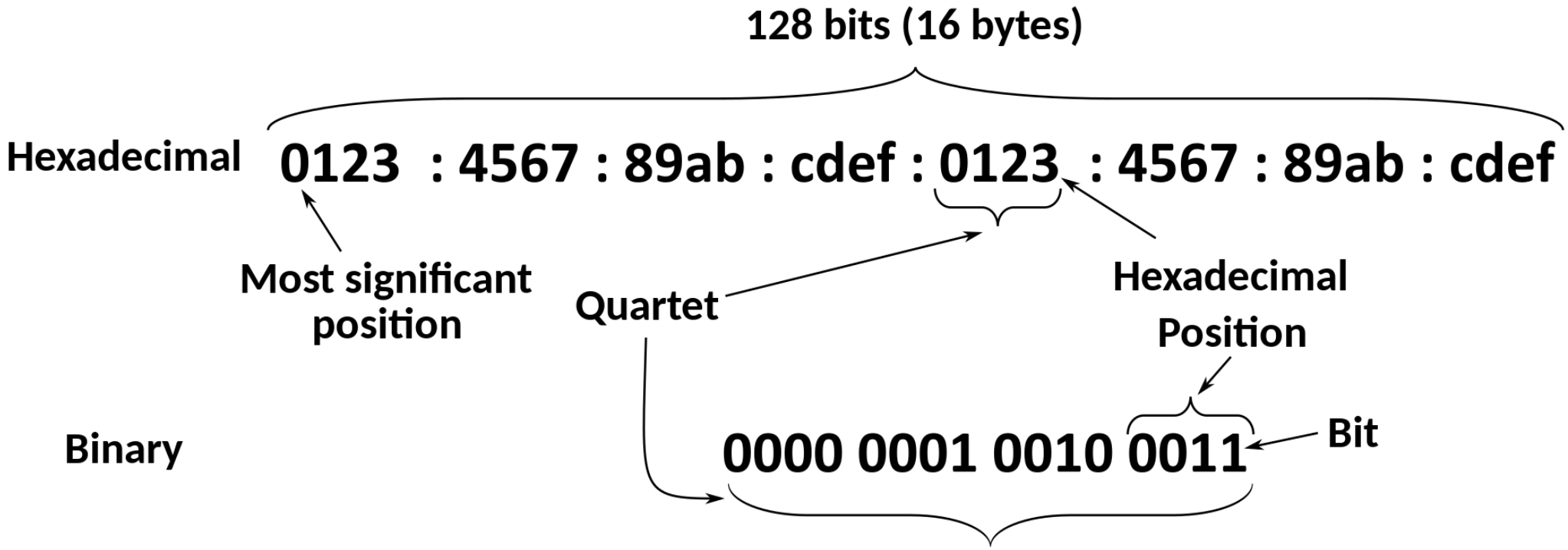
IPv6 header format (source: Wikipedia)

S1.3 | Protocol overview


```
[zuul@ccr2116-01.test.lab.ipa.net] > ipv6/address/print where address="2001:db8:4545:3:200:f8ff:fe21:67cf/64"
Flags: I, D - DYNAMIC; G, L - LINK-LOCAL
Columns: ADDRESS, INTERFACE, ADVERTISE
#    ADDRESS                                INTERFACE  ADVERTISE
4 IG 2001:db8:4545:3:200:f8ff:fe21:67cf/64  lo0        yes
```

IPv6 prefix example (source: ARIN)

S1.3 | Protocol overview



IPv6 addressing format (source: Wikipedia)

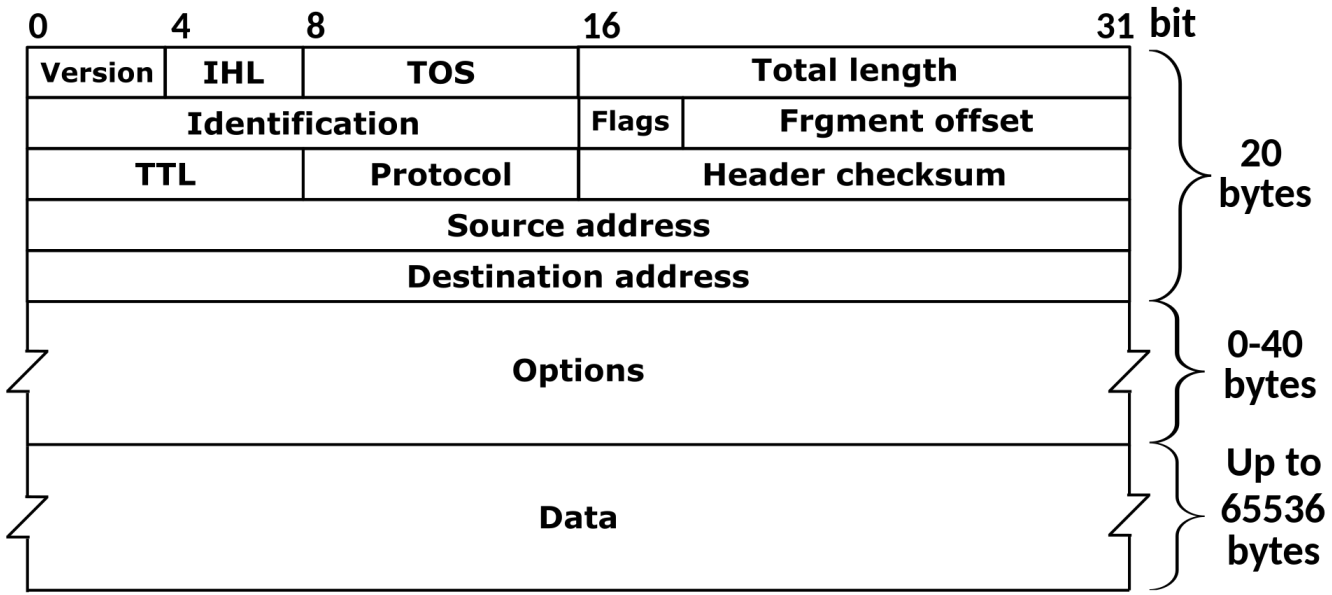
S1.3 | Protocol Overview

Type	Range
Link local	fe80::/10
Global unicast	2000::/3
Multicast	ff00::/8
Unique local	fc00::/7

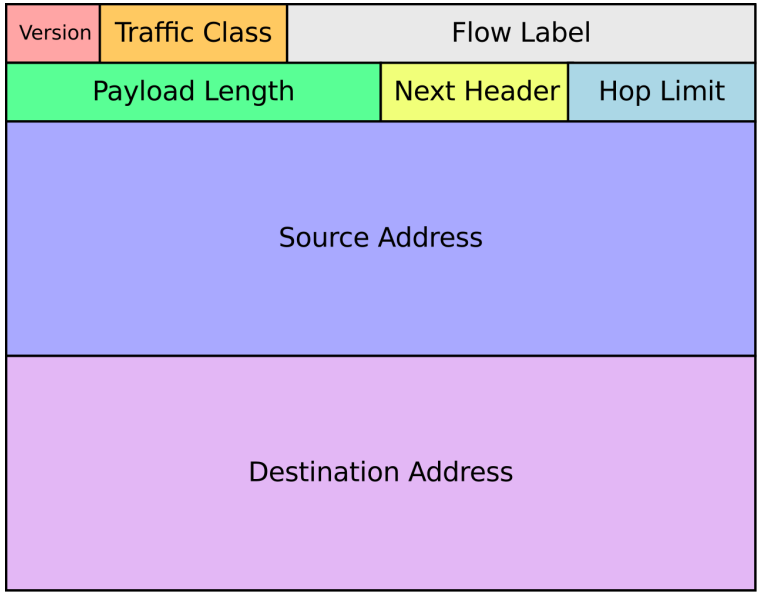
IPv6 address types (source: MikroTik)

S1.4 | IPv4 and IPv6 comparison

IPv4 header (source: Wikipedia)



IPv6 header (source: Wikipedia)



S1.4 | IPv4 and IPv6 comparison

- **ARP is replaced by ICMPv6**
  - Broadcast is replaced by multicast
  - ICMPv6 becomes required for proper operation (do not block)
  - Neighbor Discovery allows hosts and routers
  - Router Advertisements communicate information within a LAN segment
- **No Fragmentation**
  - PMTUD and MTU become even more important
  - Min MTU of 1280 (can’t use Path MTU)
  - Ideal MTU 1500 (less on some RF networks like LTE/CBRS)
  - Routers cannot fragment – only the source node can

S1.4 | IPv4 and IPv6 comparison

Foundational differences in operation

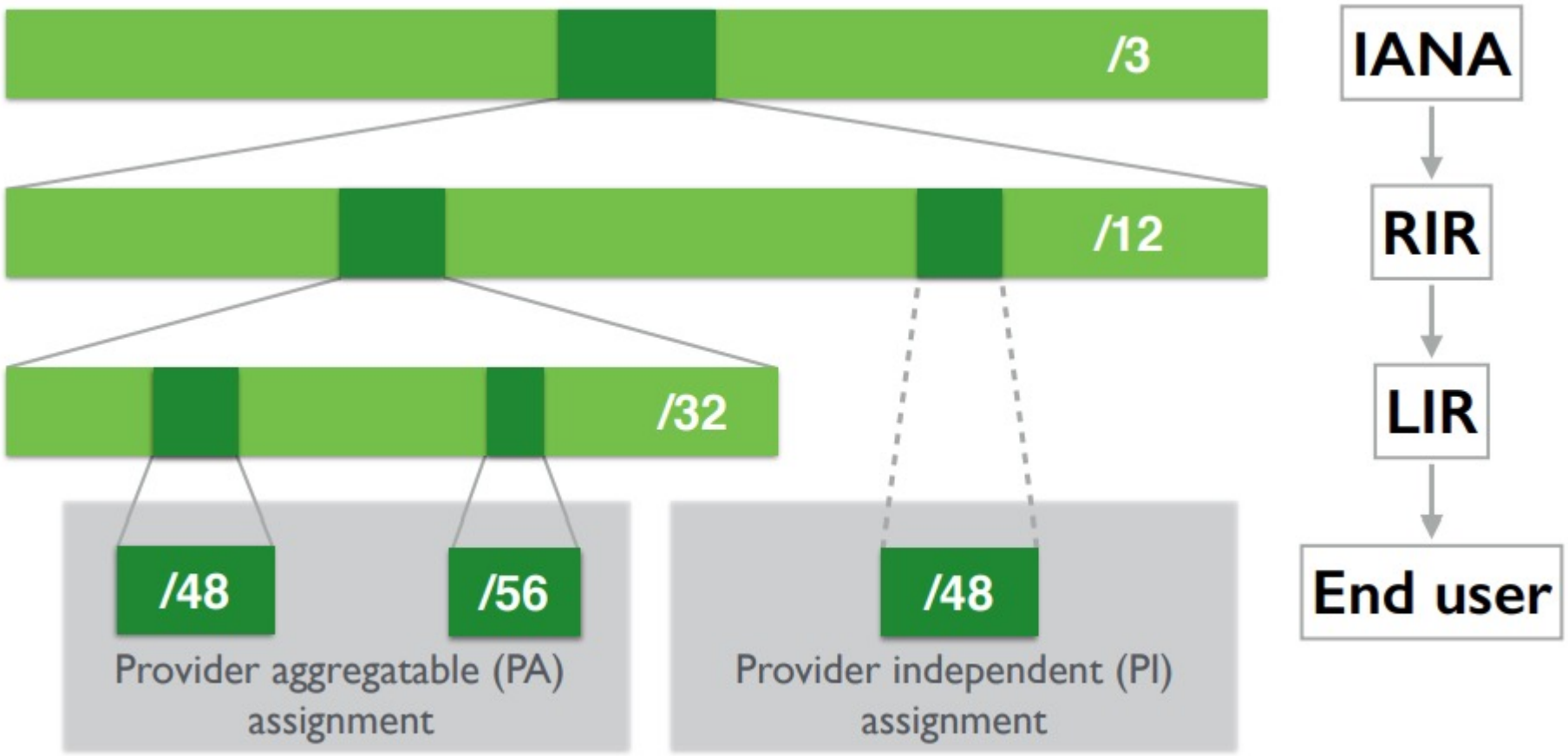
- **Link Local**
  - Fe80::/10 (169.254.x.x in IPv4)
  - Used for routing adjacencies (GUA is helpful for traceroutes)
  - Used for next hops
- **Multiple Addresses per Interface**
  - Possible and *normal* to have multiple addresses per interface

S1.4 | IPv4 and IPv6 comparison

Foundational differences in operation

- **Handing out addresses (IPv4)**
  - Static
  - DHCPv4 (hands out addresses)
  - PPPoE
- **Handing out addresses and prefixes (IPv6)**
  - Static
  - DHCPv6-PD (hands out prefixes)
  - SLAAC
  - PPPoE (uses DHCPv6-PD)

S1.5 | How do I get IPv6?



IPv6 allocation (source: RIPE)

S1.5 | How do I get IPv6?

Home > IP Addresses & ASNs > Get Started > IPv6 Information > Your First IPv6 Request

[Your First IPv6 Request - American Registry for Internet Numbers (arin.net)]

Your First IPv6 Request

Are you ready to deploy IPv6, but you're not sure where to begin? Whether you are an end user or an Internet Service Provider (ISP), ARIN can help you determine how much IPv6 address space is appropriate for your organization and tell you how to request space.

IPv6 Information

Your First IPv6 Request

The History of IPv6 @ ARIN

Related

IPv6 Information

IPv6 Case Studies

Registration Services Help Desk
7:00 AM to 7:00 PM ET
Phone: +1.703.227.0660
Fax: +1.703.997.8844

Tips for Calling the Help Desk

S2 | Design & Deployment

Getting IPv6 into your network

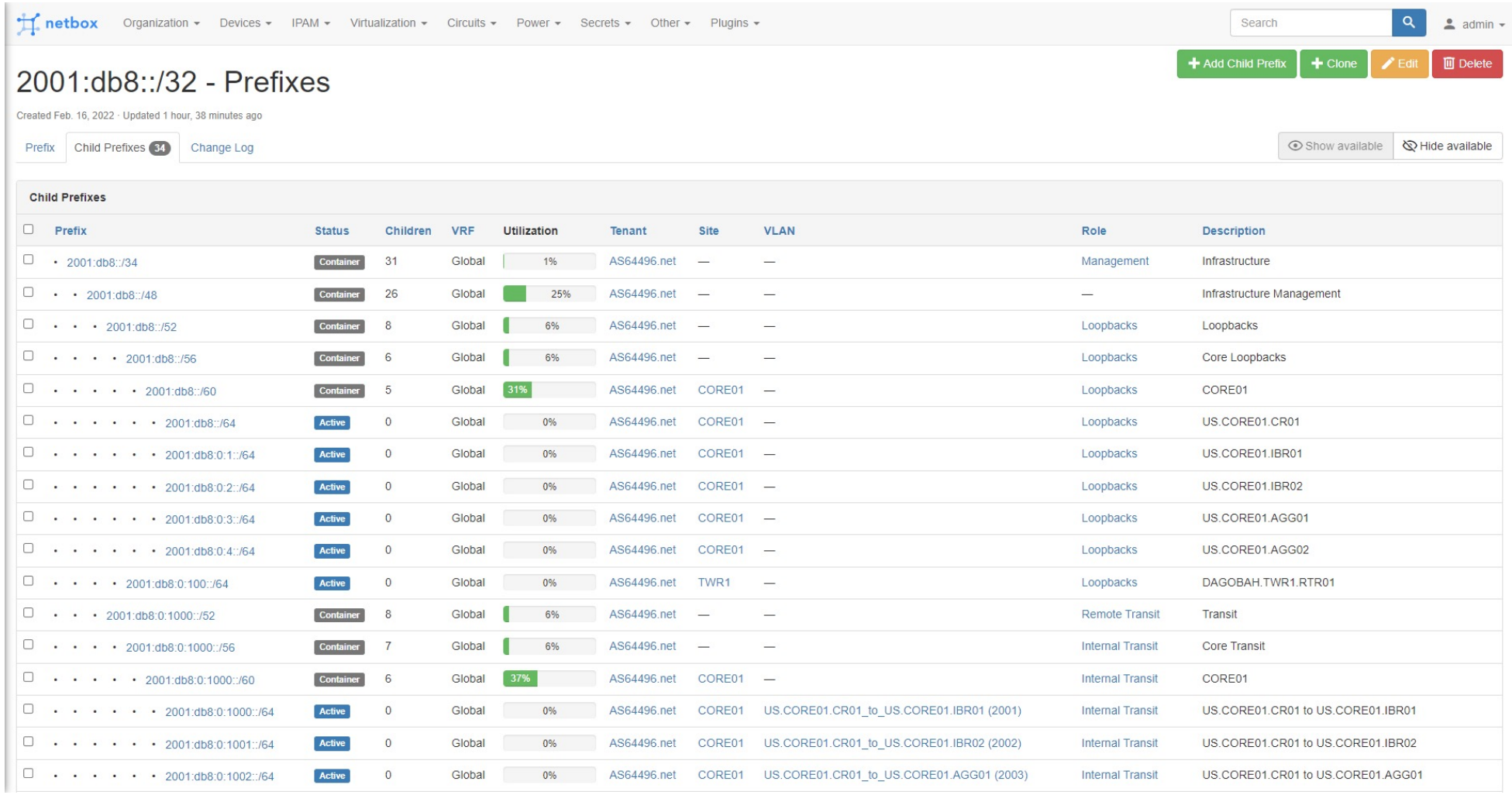
Section 2 | IPv6 Design and Deployment

02

- How do I break up the address space?
- Where do I start?
- Dual Stack design
- Single Stack

S2.1 | How do I break up the address space?

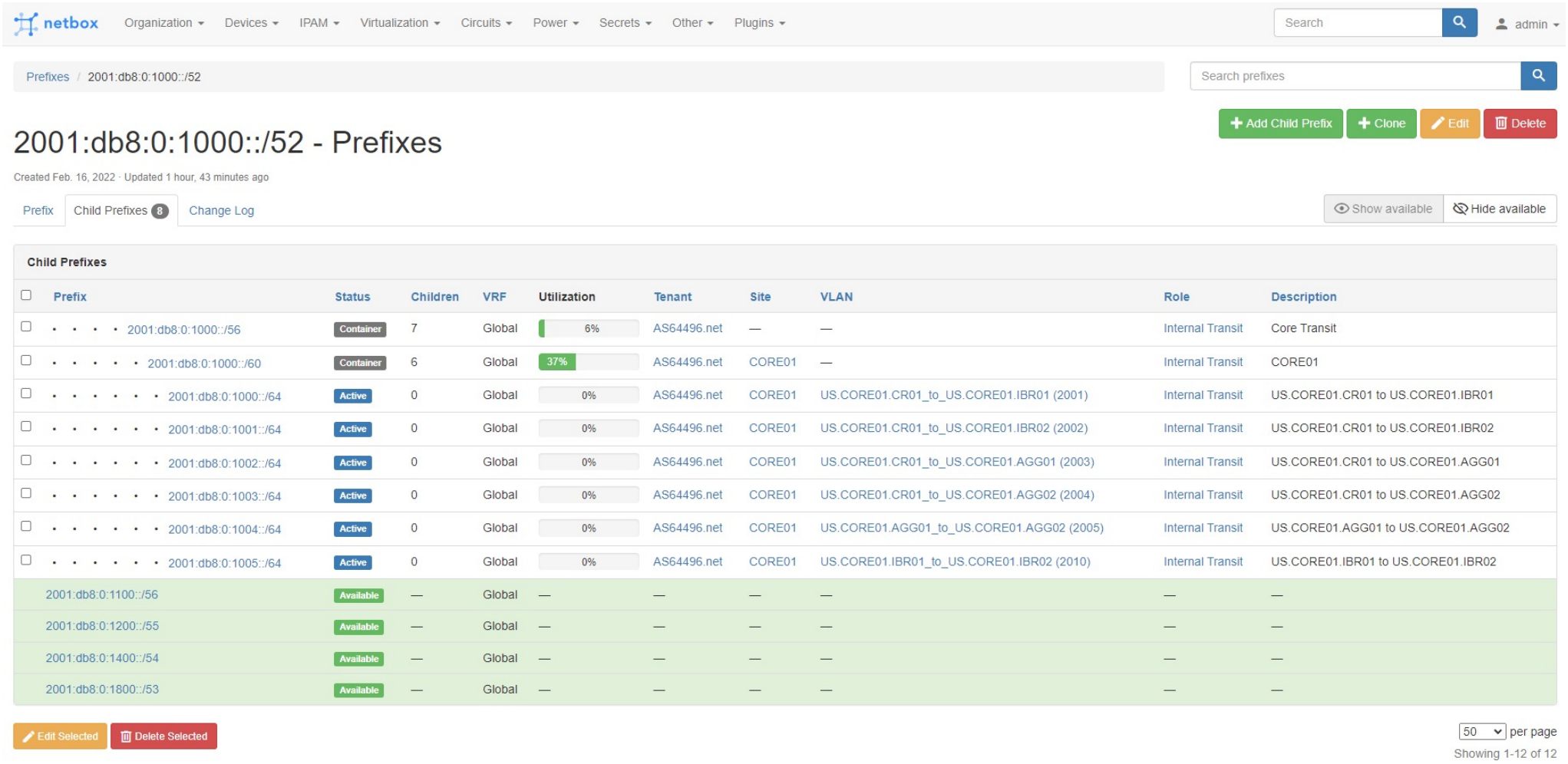
Getting IPv6 into your network



Prefix	Status	Children	VRF	Utilization	Tenant	Site	VLAN	Role	Description
2001:db8::/34	Container	31	Global	1%	AS64496.net	—	—	Management	Infrastructure
2001:db8::/48	Container	26	Global	25%	AS64496.net	—	—	—	Infrastructure Management
2001:db8::/52	Container	8	Global	6%	AS64496.net	—	—	Loopbacks	Loopbacks
2001:db8::/56	Container	6	Global	6%	AS64496.net	—	—	Loopbacks	Core Loopbacks
2001:db8::/60	Container	5	Global	31%	AS64496.net	CORE01	—	Loopbacks	CORE01
2001:db8::/64	Active	0	Global	0%	AS64496.net	CORE01	—	Loopbacks	US.CORE01.CR01
2001:db8:0:1::/64	Active	0	Global	0%	AS64496.net	CORE01	—	Loopbacks	US.CORE01.IBR01
2001:db8:0:2::/64	Active	0	Global	0%	AS64496.net	CORE01	—	Loopbacks	US.CORE01.IBR02
2001:db8:0:3::/64	Active	0	Global	0%	AS64496.net	CORE01	—	Loopbacks	US.CORE01.AGG01
2001:db8:0:4::/64	Active	0	Global	0%	AS64496.net	CORE01	—	Loopbacks	US.CORE01.AGG02
2001:db8:0:100::/64	Active	0	Global	0%	AS64496.net	TWR1	—	Loopbacks	DAGOBAH.TWR1.RTR01
2001:db8:0:1000::/52	Container	8	Global	6%	AS64496.net	—	—	Remote Transit	Transit
2001:db8:0:1000::/56	Container	7	Global	6%	AS64496.net	—	—	Internal Transit	Core Transit
2001:db8:0:1000::/60	Container	6	Global	37%	AS64496.net	CORE01	—	Internal Transit	CORE01
2001:db8:0:1000::/64	Active	0	Global	0%	AS64496.net	CORE01	US.CORE01.CR01_to_US.CORE01.IBR01 (2001)	Internal Transit	US.CORE01.CR01 to US.CORE01.IBR01
2001:db8:0:1001::/64	Active	0	Global	0%	AS64496.net	CORE01	US.CORE01.CR01_to_US.CORE01.IBR02 (2002)	Internal Transit	US.CORE01.CR01 to US.CORE01.IBR02
2001:db8:0:1002::/64	Active	0	Global	0%	AS64496.net	CORE01	US.CORE01.CR01_to_US.CORE01.AGG01 (2003)	Internal Transit	US.CORE01.CR01 to US.CORE01.AGG01

S2.1 | How do I break up the address space?

Getting IPv6 into your network



S2.1 | How do I break up the address space?

Getting IPv6 into your network

Max Length

Prefixes

Prefix	Status	Children	VRF	Utilization	Tenant	Site	VLAN	Role	Description
100.80.0.0/21	Active	1	Global	0%	AS64496.net	TWR1	—	Customer Internal	TWR1 Customer Subnets
100.80.0.0/24	Active	0	Global	0%	AS64496.net	TWR1	CUST DATAPLANE (1101)	Customer Internal	TWR1 Customer Dataplane 1
100.112.8.0/22	Active	2	Global	0%	AS64496.net	TWR1	—	Management	TWR1 Management
100.112.8.0/24	Active	0	Global	0%	AS64496.net	TWR1	MGMT (11)	Management	TWR1 MGMT
100.112.10.0/23	Active	0	Global	0%	AS64496.net	TWR1	CPE MGMT (101)	Customer	TWR1 CPE MGMT
2001:db8:0:100::/64	Active	0	Global	0%	AS64496.net	TWR1	—	Loopbacks	DAGOBAH.TWR1.RTR01
2001:db8:0:3000::/60	Active	2	Global	0%	AS64496.net	TWR1	—	—	TWR1
2001:db8:0:3000::/64	Active	0	Global	0%	AS64496.net	TWR1	MGMT (11)	—	TWR1 MGMT
2001:db8:0:3001::/64	Active	0	Global	0%	AS64496.net	TWR1	CPE MGMT (101)	Customer	TWR1 CPE MGMT
2001:db8:8000::/40	Active	0	Global	0%	AS64496.net	TWR1	CUST DATAPLANE (1101)	—	TWR1 CUST DATAPLANE 1
2001:db8:8100::/40	Active	0	Global	0%	AS64496.net	TWR1	CUST DATAPLANE (1101)	—	TWR1 CUST DATAPLANE 2
2001:db8:8200::/40	Active	0	Global	0%	AS64496.net	TWR1	PUBLIC CUST DATAPLANE (1202)	—	TWR1 CUST DATAPLANE 3

Secure the control plane first!

```
/ipv6 firewall filter
add action=accept chain=input comment="defconf: accept ICMPv6 after RAW" protocol=icmpv6
add action=accept chain=input comment="defconf: accept established,related,untracked" connection-state=established,related,untracked
add action=accept chain=input comment="defconf: accept UDP traceroute" port=33434-33534 protocol=udp
add action=accept chain=input comment="defconf: accept DHCPv6-Client prefix delegation." dst-port=546 protocol=udp src-address=fe80::/16
add action=accept chain=input comment="defconf: accept IKE" dst-port=500,4500 protocol=udp
add action=accept chain=input comment="defconf: accept IPSec AH" protocol=ipsec-ah
add action=accept chain=input comment="defconf: accept IPSec ESP" protocol=ipsec-esp
add action=drop chain=input comment="defconf: drop all not coming from LAN" in-interface-list=!LAN
```

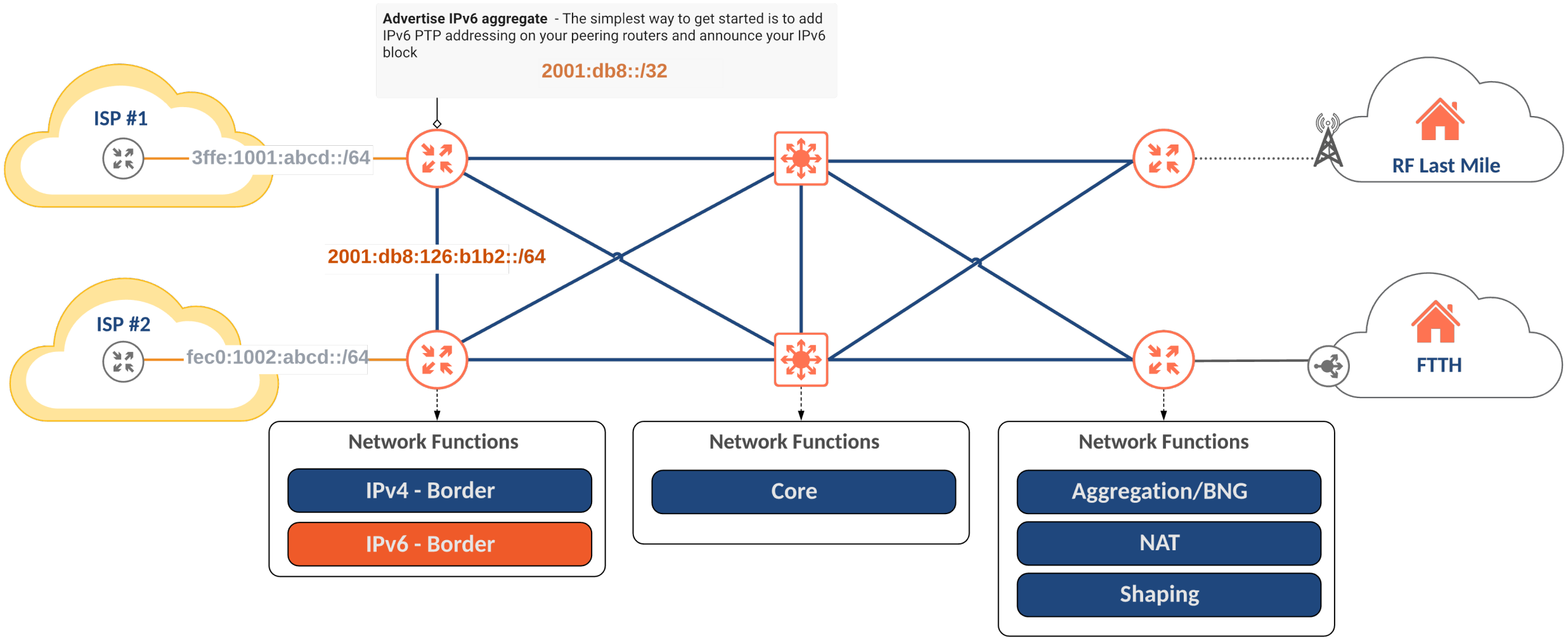
Add protocols you use – BGP, OSPF, LDP etc

(example only – edit before using this in your network)

Building Your First Firewall - RouterOS - MikroTik Documentation

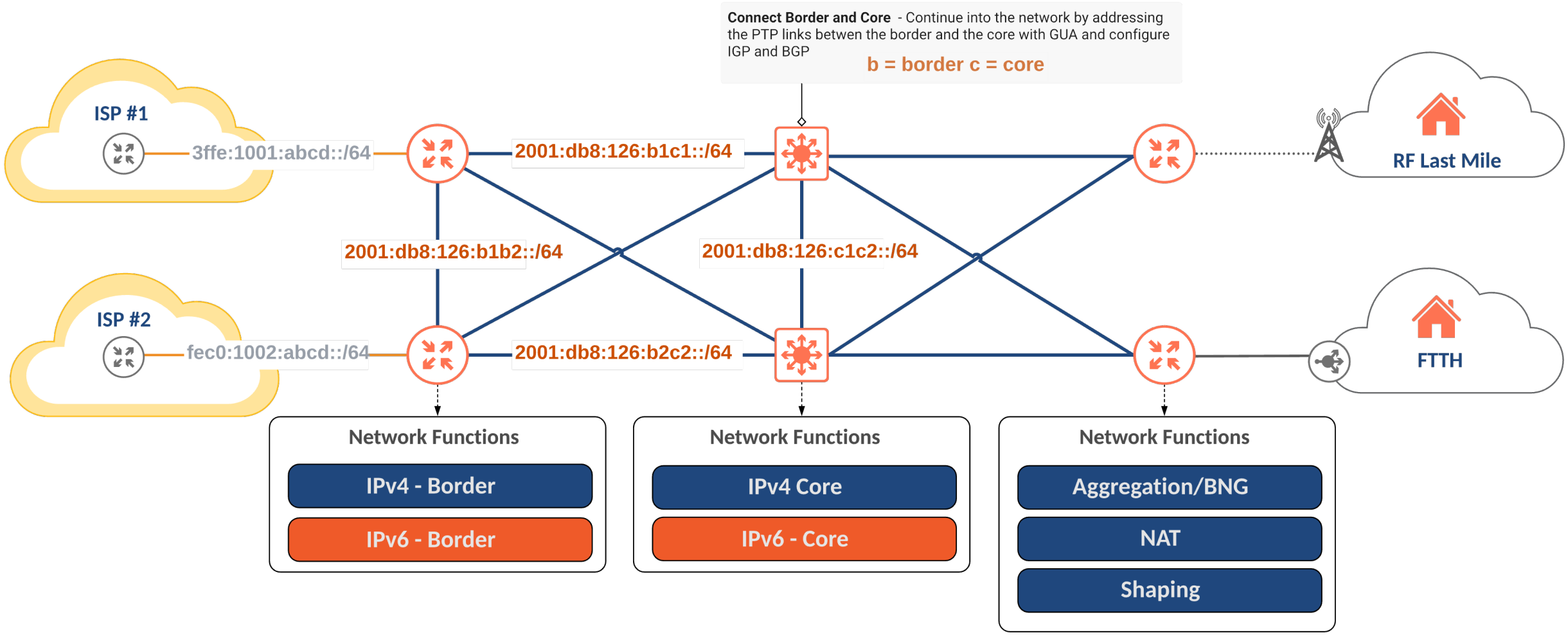
S2.2 | Where do I start?

Getting IPv6 into your network



S2.2 | Where do I start?

Getting IPv6 into your network

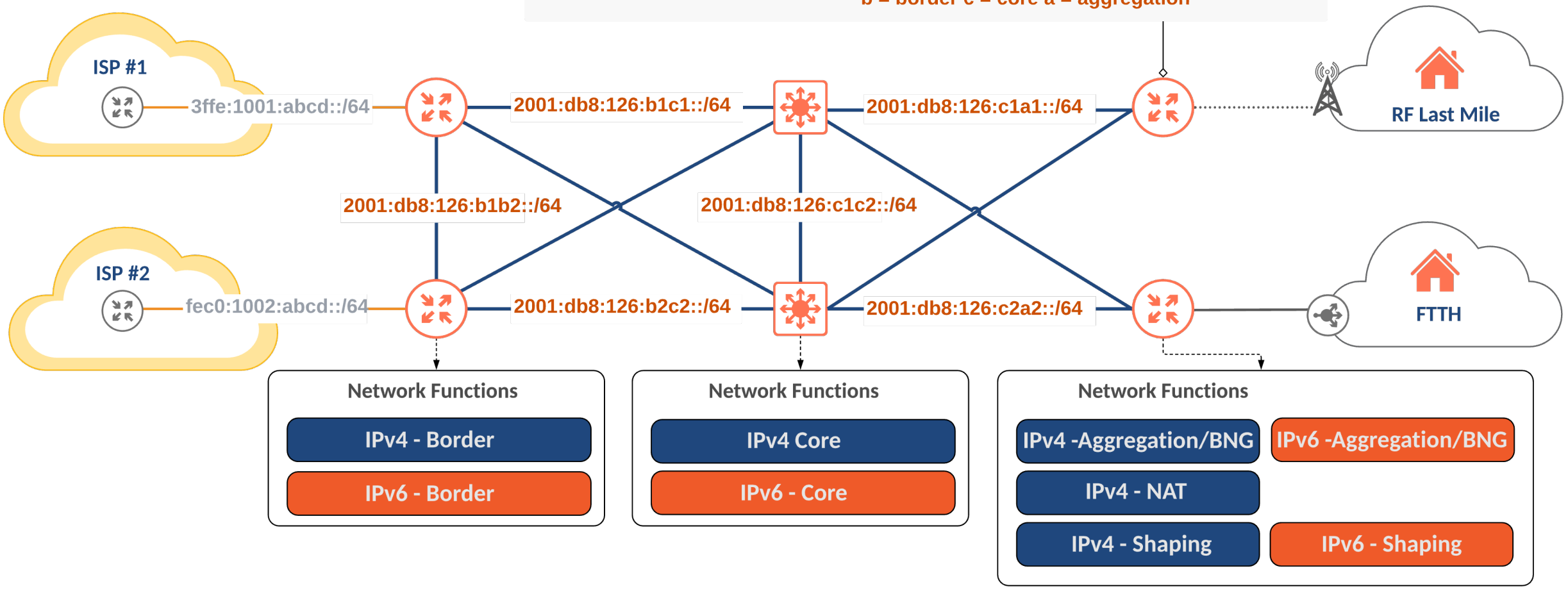


S2.2 | Where do I start?

Getting IPv6 into your network

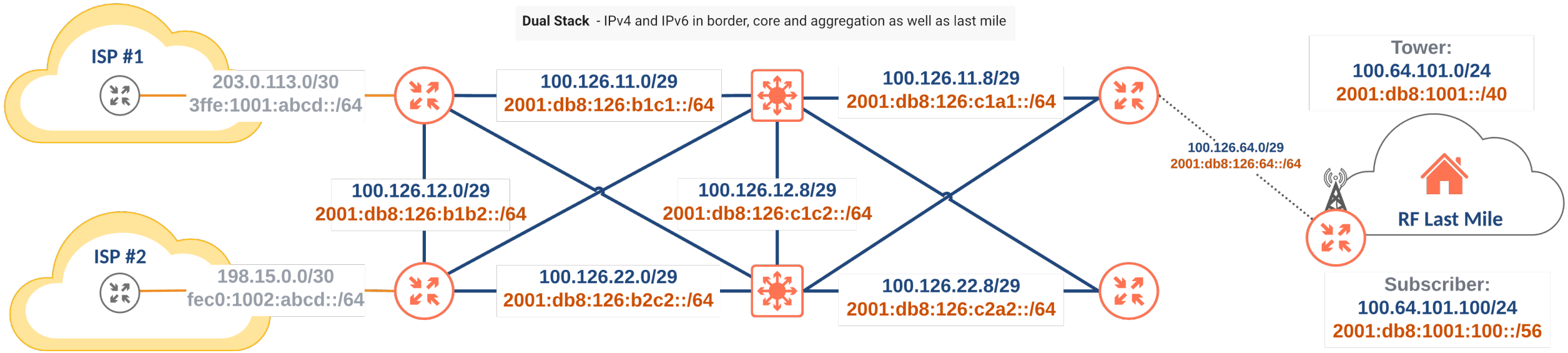
Connect Core and Aggregation - Now that IPv6 routing protocols are connecting the border and core, things get a little easier to connect core and aggregation.

b = border c = core a = aggregation



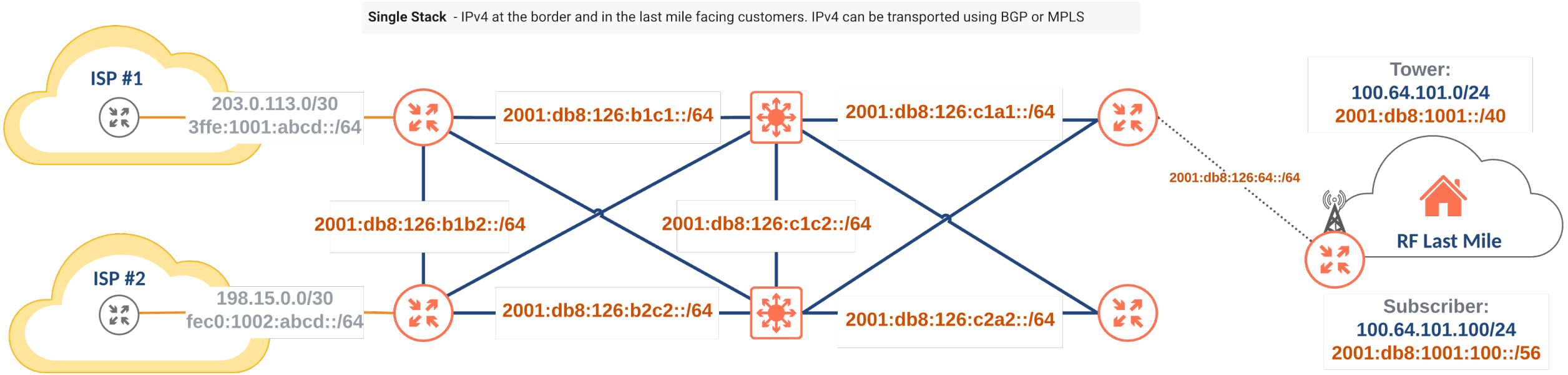
S2.3 | Dual Stack

Getting IPv6 into your network



S2.4 | Single Stack

Getting IPv6 into your network



2001:db8:c01d:c01a::/64

S3 | Systems & Operations

Getting IPv6 into your network

Section 3 | IPv6 Systems and Operations

03

- Embrace v6 In Applications
- Subscriber Provisioning Challenges
- Subscriber Provisioning Solutions
- Powercode Middleware Proof Of Concept

S3.1 | Embrace v6 In Applications

- IPv6 Native Mindset When Deploying Applications
- Monitoring Servers
- Web Servers
- Email Servers
- DNS Servers
  - Start creating AAAA records!

Most widely used applications run on de facto standard tools that have supported IPv6 for years.

Often, just a simple config change is needed to have IPv6 support!

```
####################################
# local-address IP addresses to li
#
local-address=0.0.0.0

####################################
```

```
####################################
# local-address IP addresses to li
#
local-address=0.0.0.0,::0

####################################
```

S3.2 | Subscriber Provisioning Challenges

Provisioning Goals

- IP Assignments To Subscriber
  (172.16.20.103 is definitively John Smith)
- Provision and Enforce Speed Packages
  (John Smith Subscribes To 10M/10M, Apply On 172.16.20.103)
  - *Auto Provision ISP Controlled CPE*
  - *Apply Queuing/Shaping Against IP At Routed Point*
  - *Apply Queuing/Shaping On SubInterface*
  - *Apply Queuing/Shaping At Core/Edge*
- Bandwidth Usage Tracking
- Handle Lifecycle Events
  - *Subscriber Billing Is Delinquent*
  - *Subscriber Changes Router*

S3.2 | Subscriber Provisioning Challenges

Provisioning Goals

- IP Assignments To Subscriber
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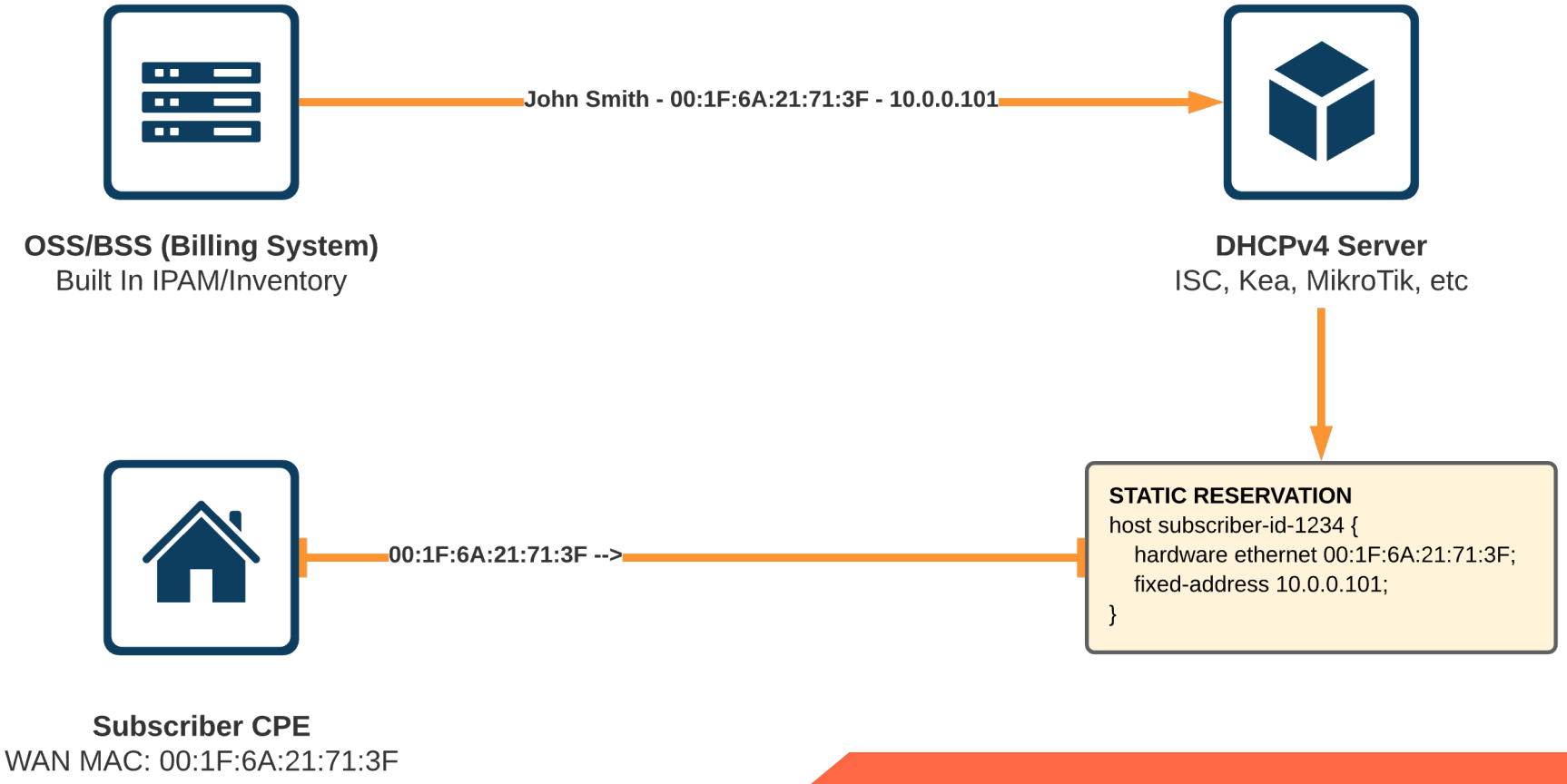
  - *Subscriber Changes Router*

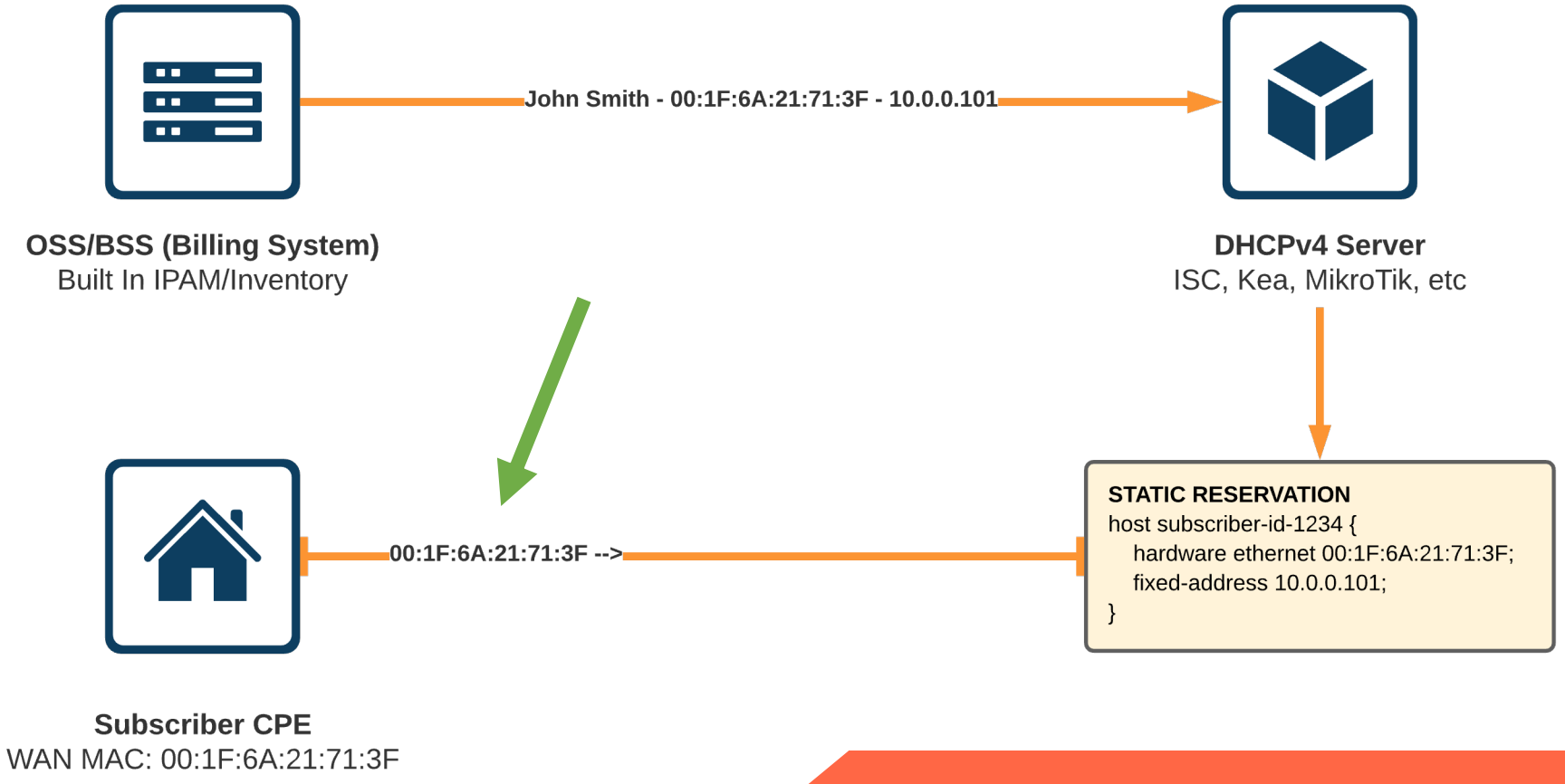
S3.2 | Subscriber Provisioning Challenges

Current Example IPv4 Assignment Method



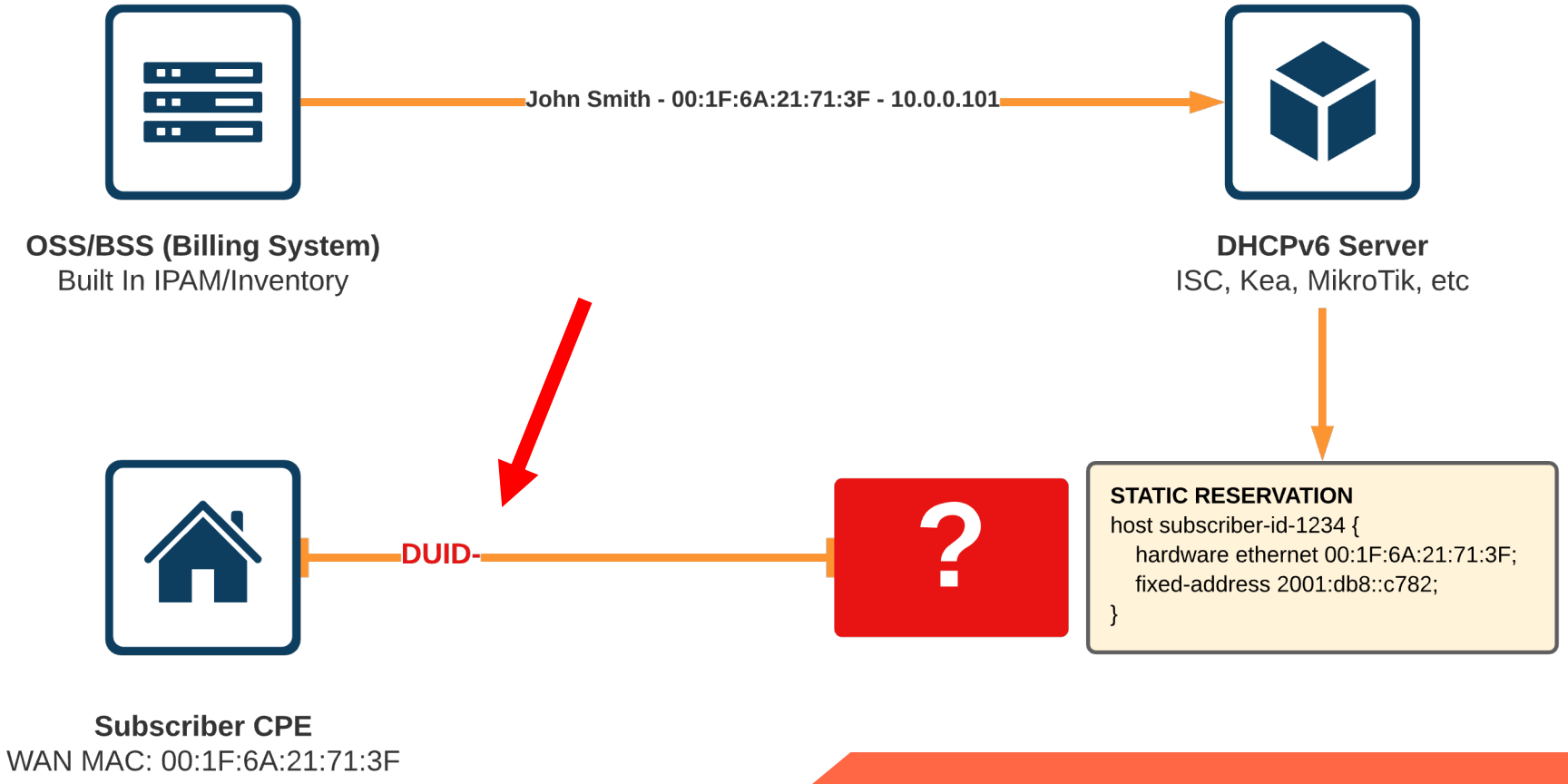
S3.2 | Subscriber Provisioning Challenges

Current Example IPv4 Assignment Method



S3.2 | Subscriber Provisioning Challenges

Where IPv6 Breaks Down



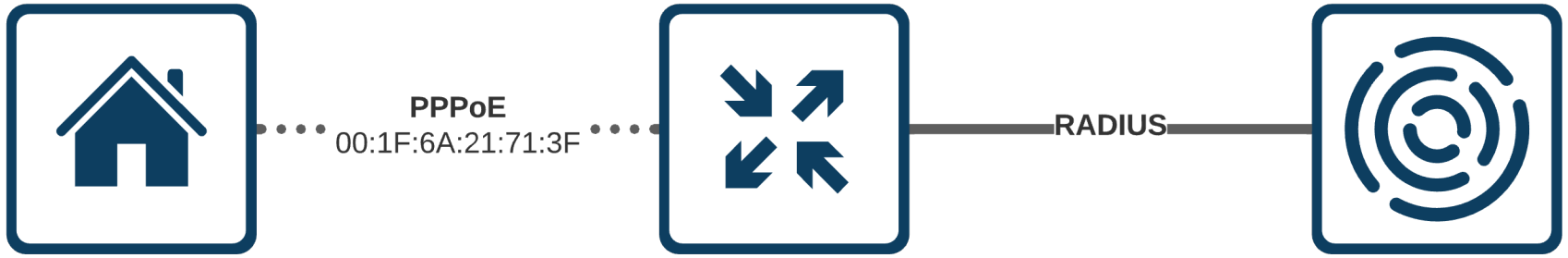
S3.2 | Subscriber Provisioning Challenges

IPv6 Presents Challenges In Identification

- SLAAC gives no reliable insight into assignments.
- Vendor disparity in DUID generation, multiple RFCs/methods
  - Link-layer address plus time (DUID-LLT)
  - Vendor-assigned unique ID based on enterprise number (DUID-EN)
  - Link-layer address (DUID-LL)
  - UUID-based DUID (DUID-UUID)
  - RFC 6939 (adoption?)
- RFC 4472 - Operational Considerations and Issues with IPv6 DNS
  - Granted, some items have been addressed with later RFCs.

S3.2 | Subscriber Provisioning Challenges

PPPoE with RADIUS is not an ideal solution. **Look in chat for PPPoE Pros/Cons Debate**



Subscriber CPE
WAN MAC: 00:1F:6A:21:71:3F

Site Router

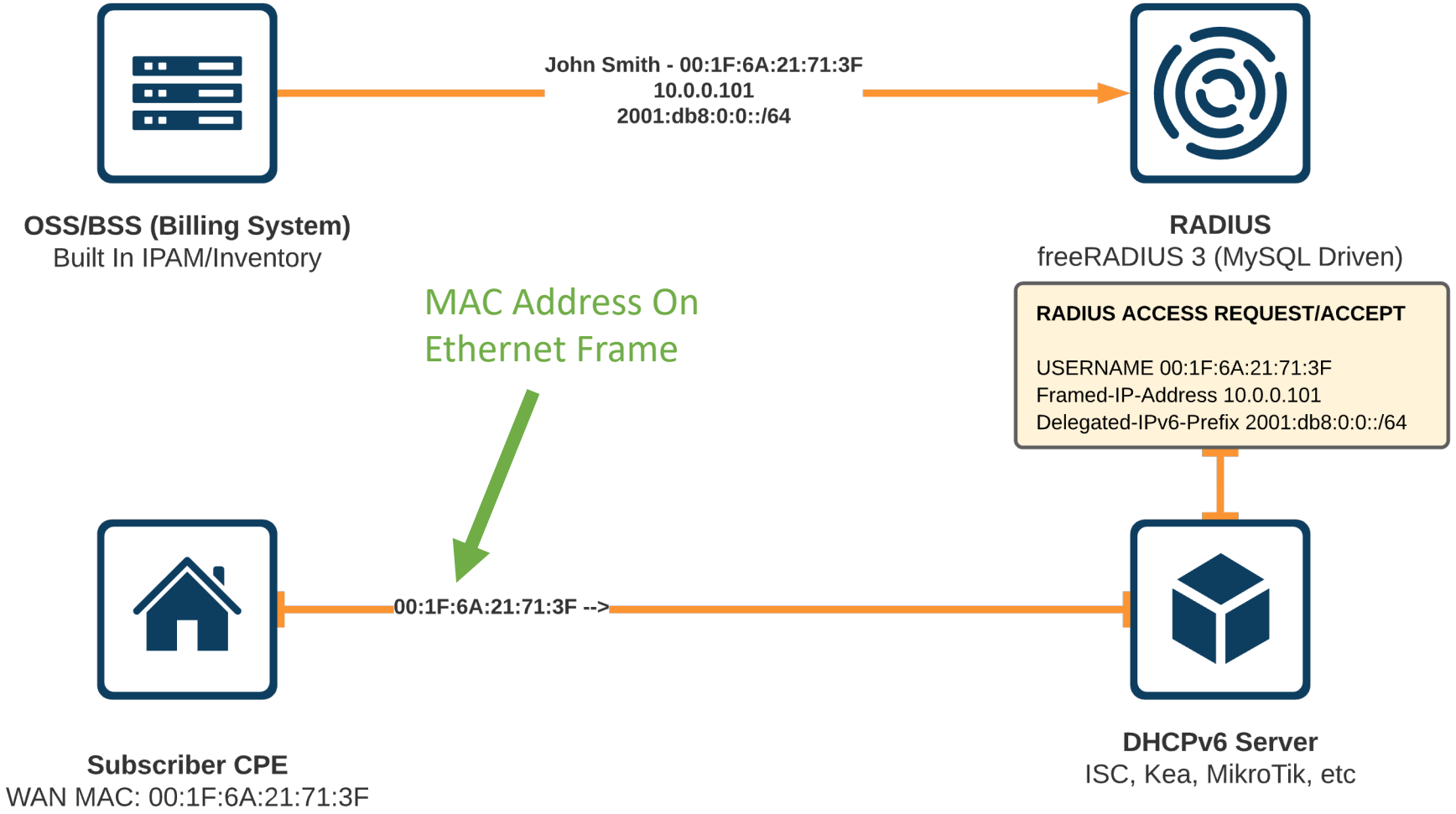
freeRADIUS 3

RADIUS ACCESS REQUEST/ACCEPT

USERNAME 00:1F:6A:21:71:3F
Framed-IP-Address 10.0.0.101
Delegated-IPv6-Prefix 2001:db8:0:0::/64;

S3.3 | Subscriber Provisioning Solutions

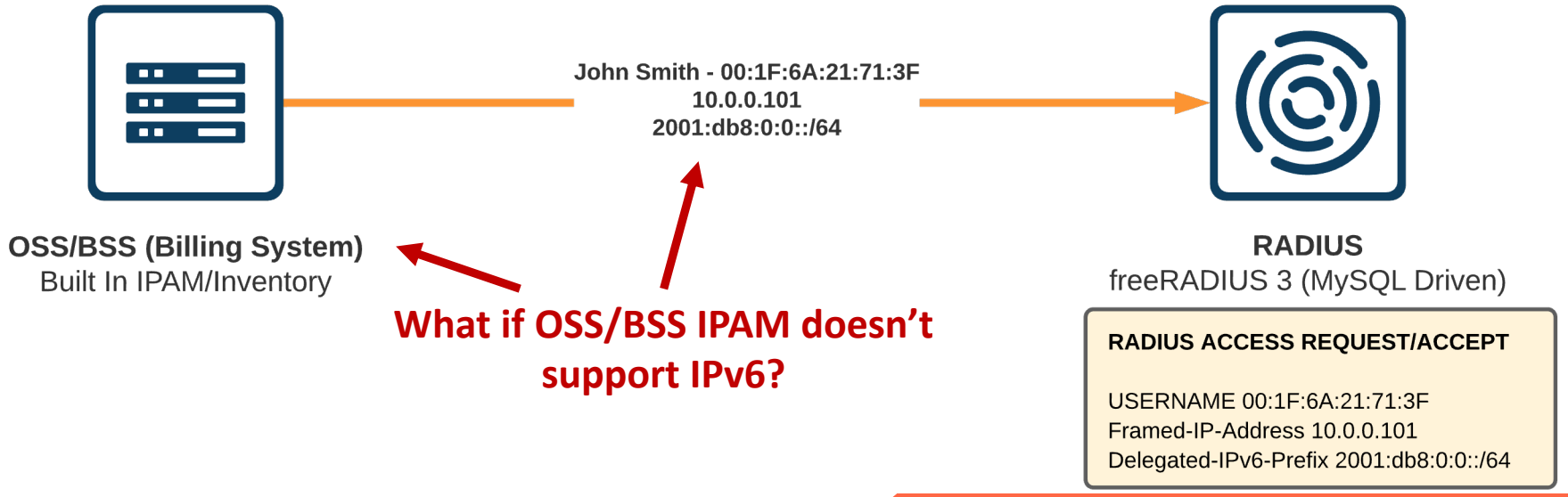
DHCPv6 With RADIUS



S3.3 | Subscriber Provisioning Solutions

RADIUS Is Always The Answer…but don't worry – it's still "DHCP"!

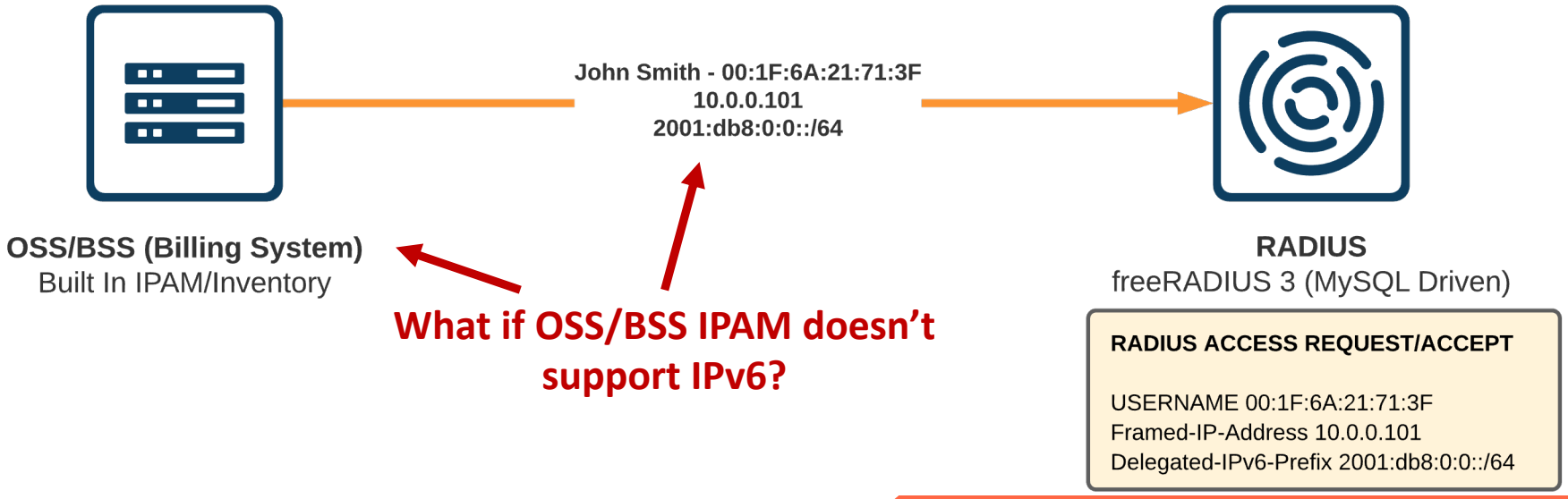
- **Deterministic Provisioning Of IPv6**
- Breaks you free of native, vendor driven integrations with your OSS/BSS system.
- Via Attributes can support signaling plan speed provisioning, VLAN assignments, service classification, and more thro



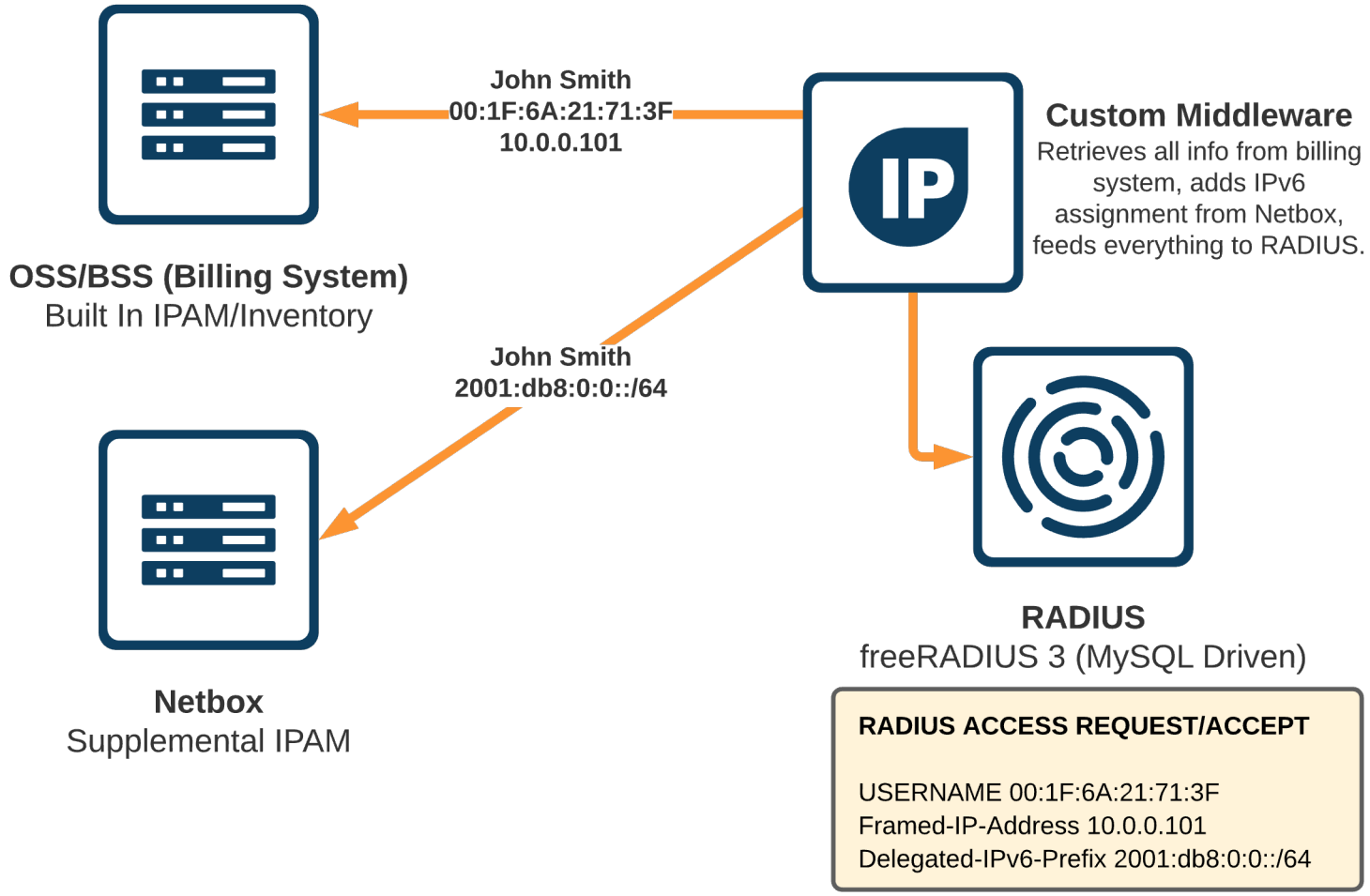
S3.3 | Subscriber Provisioning Solutions

Netbox To The Rescue!

- Some custom development for middleware.
- Easy supplement of IPv6 determination, record keeping, IPAM to existing OSS/BSS IPv4 implementation.



S3.3 | Subscriber Provisioning Solutions



S3.4 | Powercode Middleware Proof of Concept

Powercode Example – Proof Of Concept

1. Create Tower Prefix In Netbox (/44 as example)
    1. ‘Role’ Set To ‘Subscriber Prefix”
2. Map Powercode IPv4 Range to Netbox IPv6 Prefix

…that’s it! All existing workflow can remain the same, with automated, IPv6 generation and assignment happening in background through custom middleware and Netbox.

When a customer equipment is added in Powercode to a IPv4 range that has a Netbox IPv6 prefix, middleware will ask Netbox to reserve the next available /56 (or /64) and record relevant identifying data.

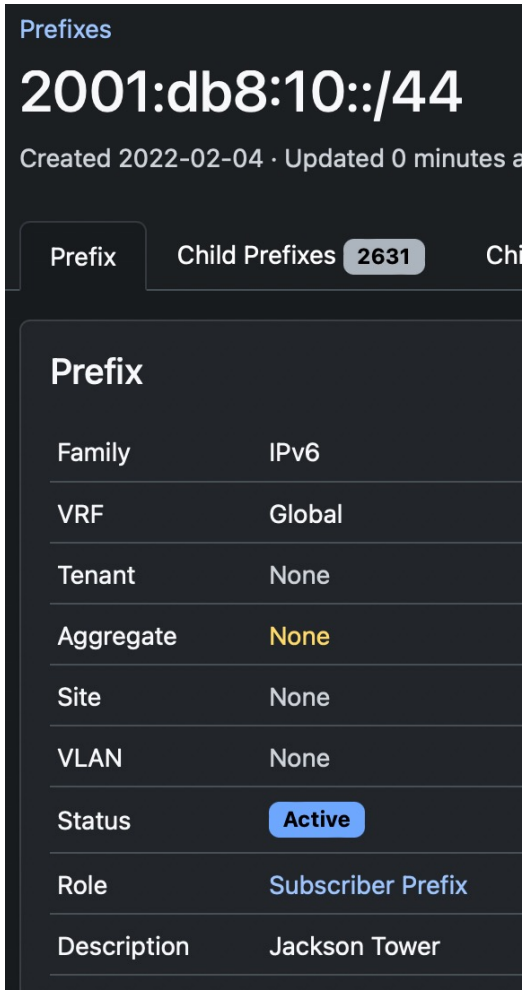
S3.4 | Powercode Middleware Proof of Concept

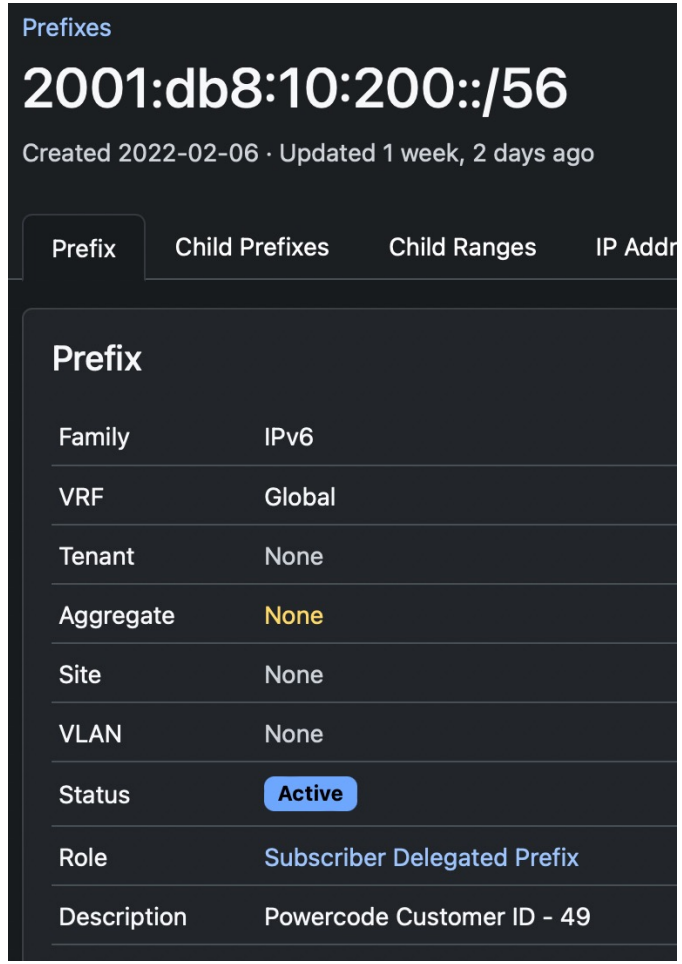
IP ArchiTechs BNG Helper Dashboard Address Ranges Sajan Parikh

Address Ranges

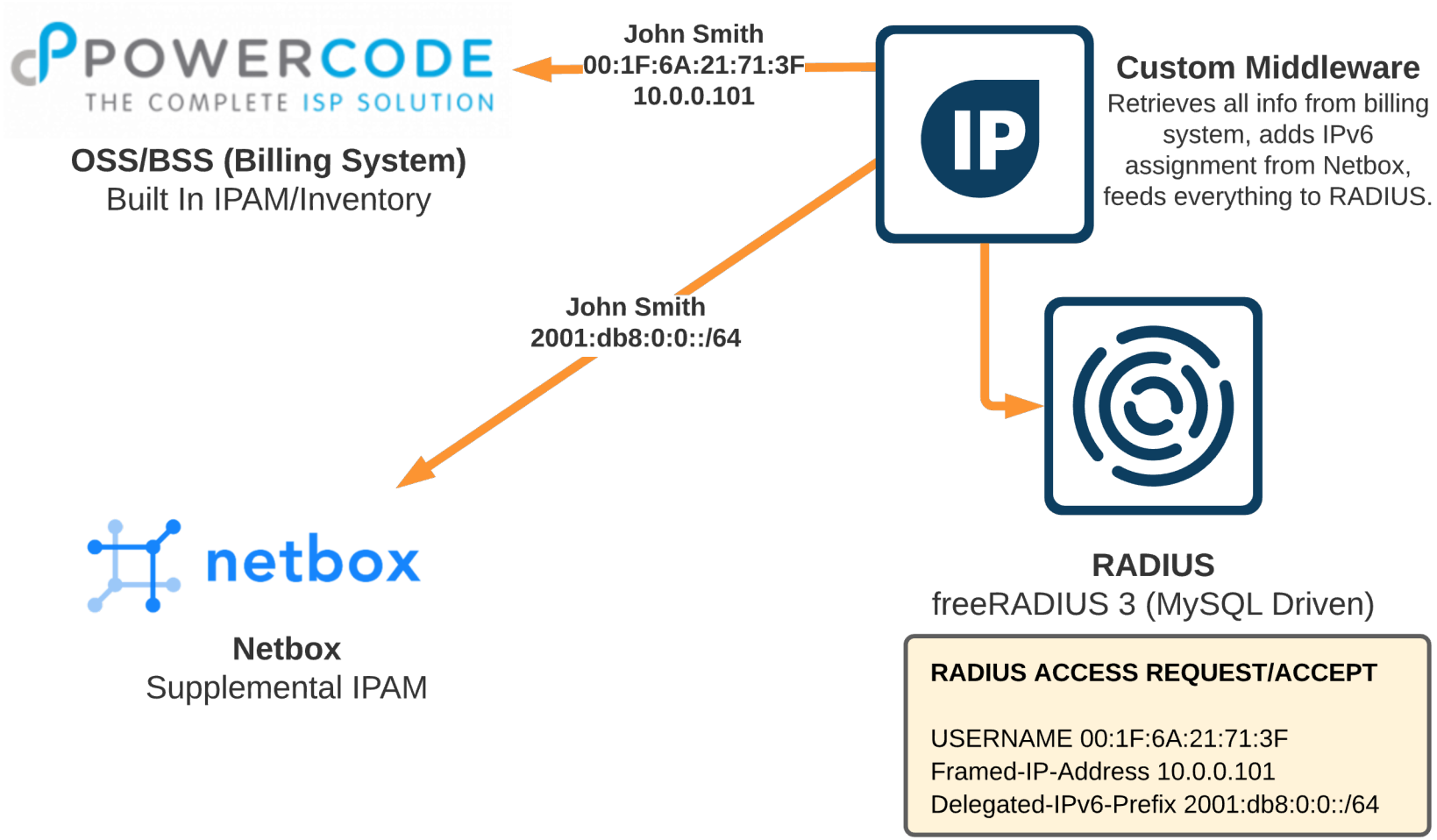
Address Range ID	Address Range Name	Address Range Subnet	Netbox IPv6 Prefix Name	Netbox IPv6 Subnet	Actions
10034	Jackson Customer DHCP Public	1.1.1.0/24	Jackson Tower	2001:db8:10::/44	Edit Mapping
10034	Jackson Customer DHCP 1	172.16.18.0/24	Jackson Tower	2001:db8:10::/44	Edit Mapping
10043	Jackson SM Management	10.16.18.0/24	NO MAPPING		Edit Mapping

S3.4 | Powercode Middleware Proof of Concept





S3.4 | Powercode Middleware Proof of Concept



S3.3 | Subscriber Provisioning Solutions

BNG DHCPv6 With RADIUS

netElastic systems

casa systems

NOKIA

JUNIPER NETWORKS

MikroTik

OSS/BSS (Billing System)
Built In IPAM/Inventory

John Smith - 00:1F:6A:21:71:3F
10.0.0.101
2001:db8:0:0::/64

RADIUS
freeRADIUS 3 (MySQL Driven)

RADIUS ACCESS REQUEST/ACCEPT

USERNAME 00:1F:6A:21:71:3F
Framed-IP-Address 10.0.0.101
Delegated-IPv6-Prefix 2001:db8:0:0::/64

Can use any DHCP(v6)/RADIUS based solution available. Without native integration from billing vendor.

00:1F:6A:21:71:3F -->

Subscriber CPE
WAN MAC: 00:1F:6A:21:71:3F

DHCPv6 Server
ISC, Kea, MikroTik, etc

Thank you!

Thank you for joining us today! IPv6 is a large topic with plenty of nuances, if you'd like to brainstorm with us your deployment, network architecture, or software ecosystem, do not hesitate to contact us using the information below.

We are a full-service networking firm that can help identify areas of improvement, design network architecture, as well as plan and execute your migration windows.

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