CMP3214
Computer
Communication Networks

Lecture 6

Internet Protocol – Next Generation

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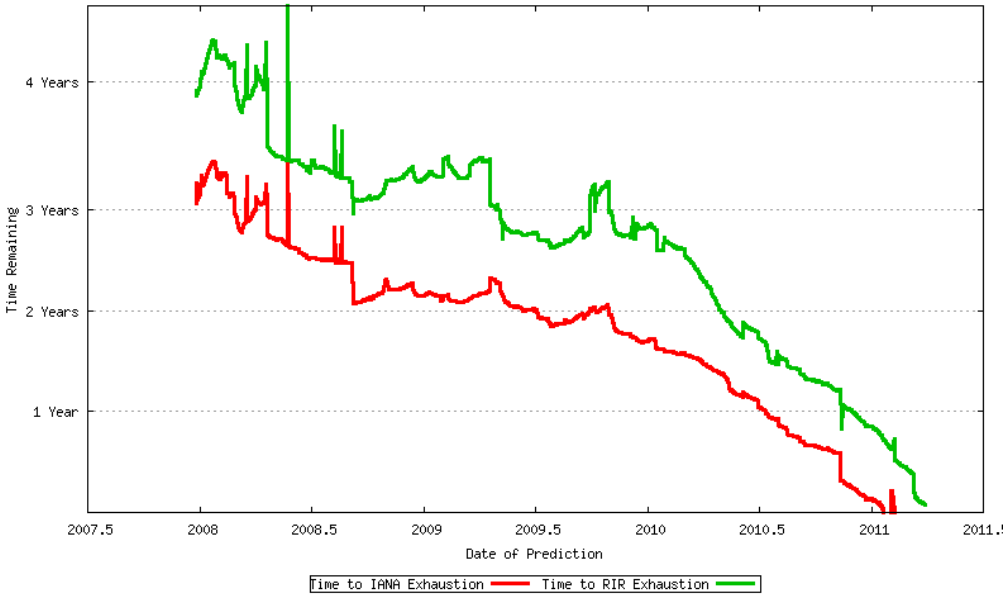
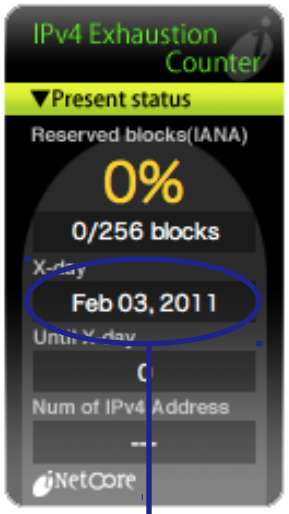
2 Billion users on the Internet

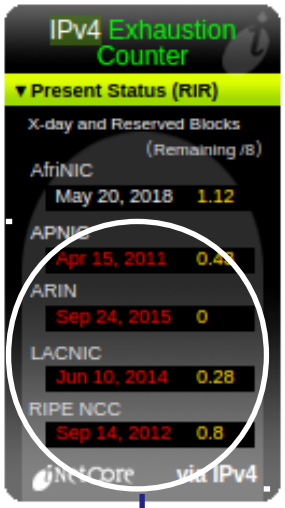
IPv4 is has now exhausted



IANA



RIRs



- IANA have no IP addresses
- RIRs are have also run out
- AFRINIC actually ran out on 3 April 2017 !!
- Black market €12/IP and NAT { Bad idea }

Where does she get her IP address ?

Solution ?

IPv4 extension

- RFC 3022 - Traditional IP Network Address Translator
- 2001

Replace IPv4

- Forklift upgrade ??

Solution ?

IPv4 extension

- ~~RFC 3022 - Traditional IP Network Address Translator~~
- 2001  2011

Replace IPv4 with IPv6

- 128 bit addressing – 3.4×10^{38}
  - IPv4 – 4.3×10^{9}
  - 7.9×10^{28} more addresses
- "**Dual Stack**" for compatibility with IPv4
- Similar routing concepts to IPv4

Why IPv6 ? – Much larger address space

- IPv4 address exhaustion
  - 12 addresses per person in USA
  - 14 people per address outside USA
  - 0.62 addresses per person on the planet.
- IPv6
  - 4.9×10^{28} address per person on the planet.
  - Greater than 1500 addresses per m2 of the planet.
  - Routing table growth and manageability.
  - Current addressing and routing are complicated.
  - Some routes can not be summarised effectively in IPv4.
  - NATs are disadvantageous for the Internet.

Why IPv6 ?

- Multicast
  - Multicast is part of the base protocol suite in IPv6. In IPv4 it is optional.
- Jumbograms
  - Packets payloads greater than 64 KB.
- Faster routing.
- Network Layer Security
  - IPSec.
- Mobility.

IPv6 Security

- Security features are standardised and mandated, i.e. all implementation must offer them.
- Extension of RFC-2401 Security Architecture for the Internet Protocol (IPSec)
  - Authentication and Encryption.
- Invisible to applications as it operates within the IP layer.
- It protects all upper layer protocols.
- It protects both end-to-end and router-to-router communication (secure gateway).

Mobile IPv6

- IPv6 was designed to support mobility.
- Mobility is not an add-on feature
  - IPv6 Neighbour Discovery (ND) and Address Auto-configuration allow hosts to operate in any locations without any special support.
- It is more scalable and the performance is better because less traffic passes through the home link and less redirection and less rerouting.
- No single point of failure.

Address Format

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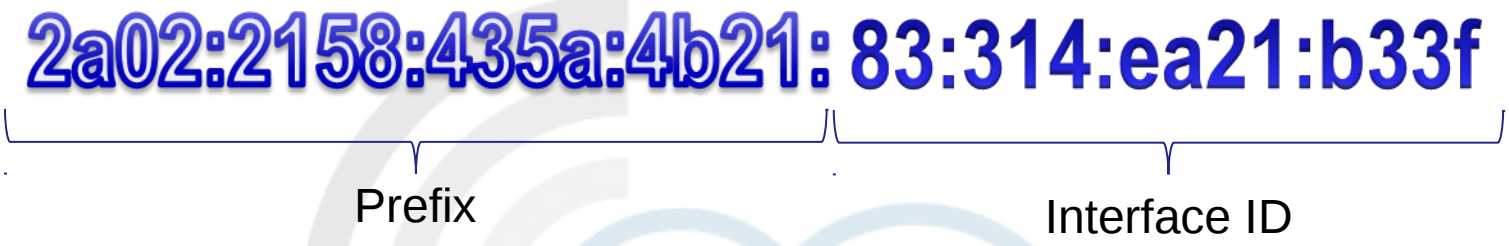
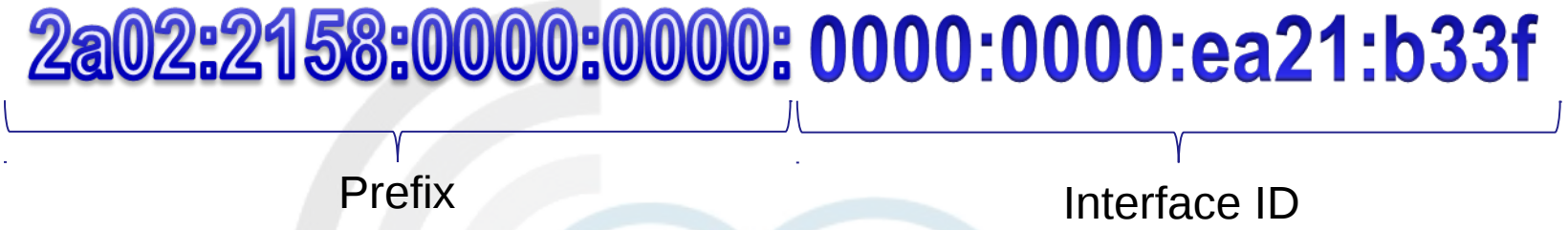
IPv6 Addressing model



- Separation of “who u are” from “where u are connected to”
  - Prefix: depends on the routing topology.
  - Interface ID: identifies a node (EUI-64 MAC Address).
- New Anycast addresses:
  - Unicast: from one host to another.
  - Multicast: from one to all belonging to a group.
  - Anycast: from one to the nearest belonging to a group.
- IPv4 Broadcast concept disappears
  - Replaced by All hosts multicast.

128 bits
↓
32 nibbles
↓
8 x 4 nibble groups

IPv6 Address model

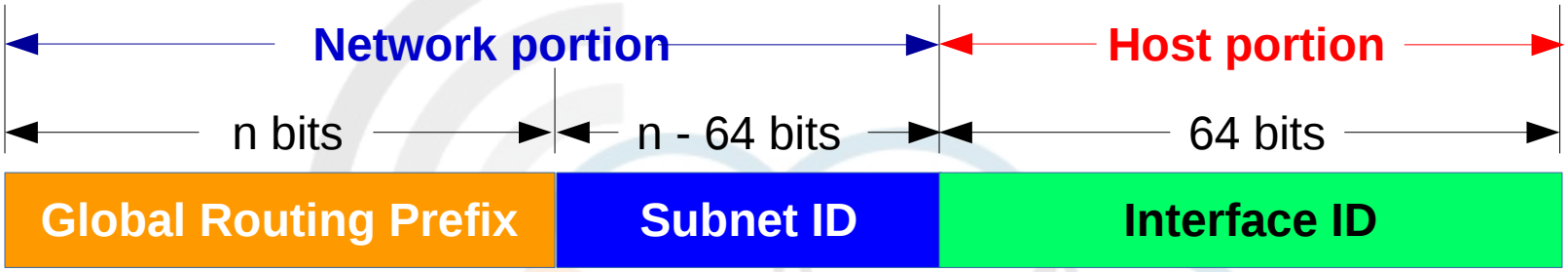


- **The Zero Compression rule**
  - Leading zeros in a group can be omitted.
- **The Zero Compression rule**
  - Contiguous groups of ‘0‘ can be replaced with ‘::’ as long as there is only one double colon used in an address.

2a02:2158:0:0:0:0:ea21:b33f
2a02:2158:0::0:ea21:b33f
2a02:2158::ea21:b33f

Note: Having more than one double-colon abbreviation in an address is invalid.

IPv6 Network Notation



2a02:2158:435a:330::9bc2:45/64

Special IPv6 addresses

- Unspecified address

::

- Default route address

0:0:0:0:0:0:0:0 → ::0

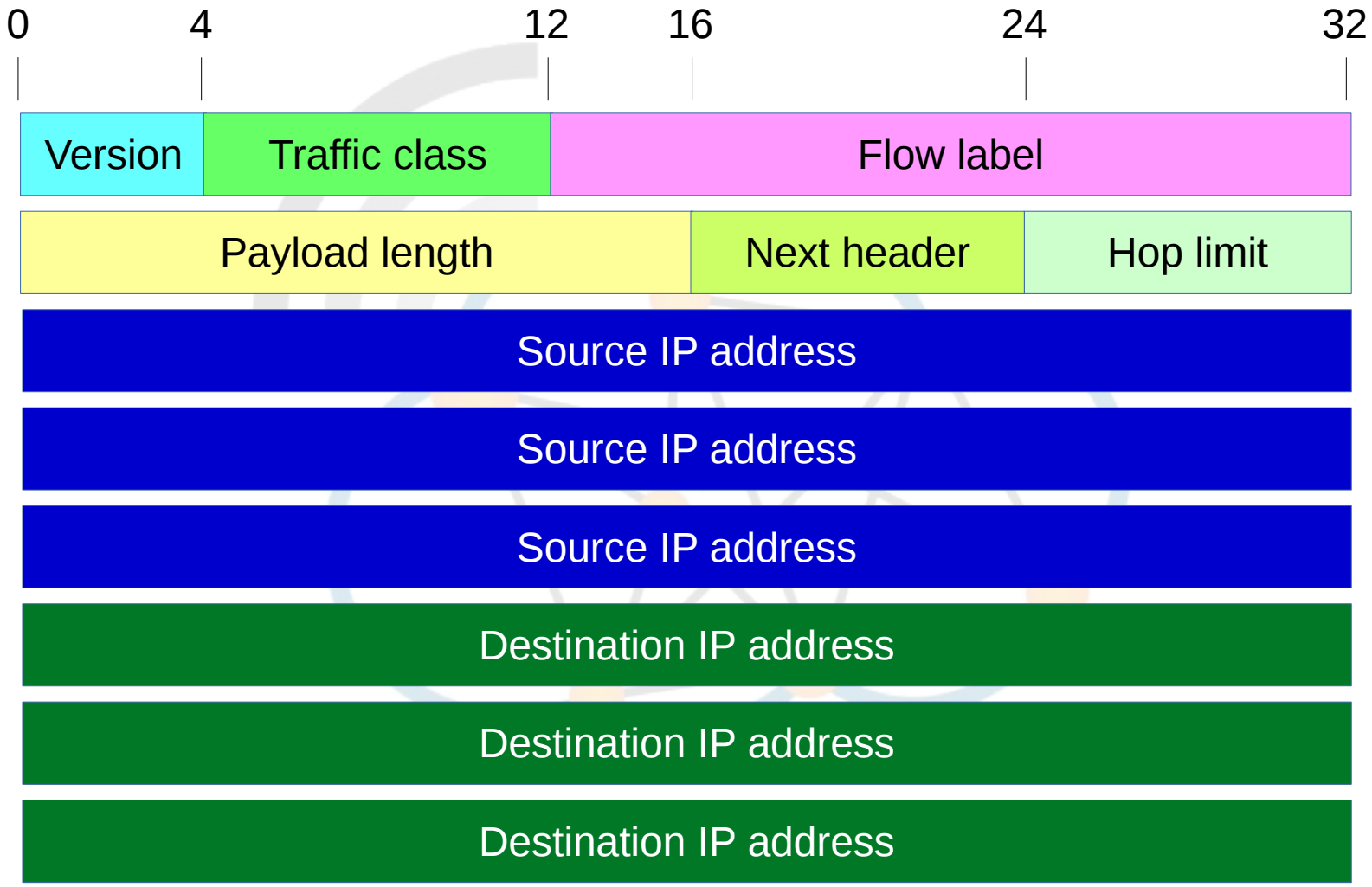
- Loopback

0:0:0:0:0:0:0:1 → ::1

- Link-local IPv6 Address (LLA)

fe80::9088:3062:ea21:b33f

IPv6 packet architecture



IPv4 Vs IPv6 Fields

Ver	Traffic Class	Flow Label	
Payload Length		Next Header	Hop Limit
Source IP Address			
Destination IP Address			

IPv6

Ver	Hlength	TOS	Datagram Length	
Datagram ID			Flags	Flag Offset
TTL	Protocol		Checksum	
Source IP Address				
Destination IP Address				
IP Options				

IPv4

“IPv6 Packet

Ethernet II, Src: 00:16:17:ba:0e:74, Dst: 00:12:3f:dc:ab:47
Destination: 00:12:3f:dc:ab:47
Source: 00:16:17:ba:0e:74
Type: **IPv6** (0x86dd)
Internet Protocol Version 6
0110 .... = **Version: 6**
.... 0000 0000 .... = Traffic class: 0x00000000
.... 0000 0000 0000 0000 0000 = Flowlabel: 0x00000000
Payload length: 40
Next header: **ICMPv6** (0x3a)
Hop limit: 128
Source: 2001::ffff:10
Destination: 2001::ffff:20
Internet Control Message Protocol v6
Type: 128 (Echo request)
Code: 0
Checksum: 0x94bb [correct]
ID: 0x0001
Sequence: 0x000b
Data (32 bytes)

“Similar and Evolving” fields

Ver	Traffic Class	Flow Label	
Payload Length		Next Header	Hop Limit
Source IP Address			
Destination IP Address			

IPv6

Ver	Hlength	TOS	Datagram Length	
Datagram ID			Flags	Flag Offset
TTL	Protocol	Checksum		
Source IP Address				
Destination IP Address				
IP Options				

IPv4

“Removed” fields

Ver	Traffic Class	Flow Label	
Payload Length		Next Header	Hop Limit
Source IP Address			
Destination IP Address			

IPv6

Ver	Hlength	TOS	Datagram Length
Datagram ID		Flags	Flag Offset
TTL	Protocol	Checksum	
Source IP Address			
Destination IP Address			
IP Options			

IPv4

Extensions & Options

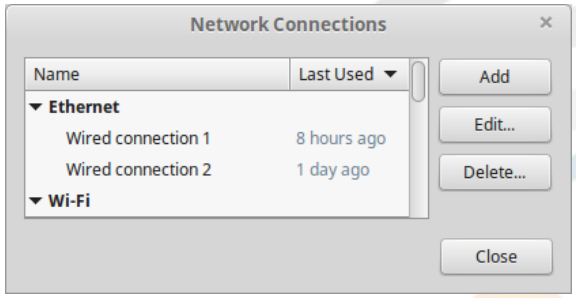
- Options
  - IPv4 – At end of IP Header.
  - IPv6 – Extensions Headers.
- Extension Headers
  - Only processed as necessary
    - i.e. Only routers process “Hop by Hop options header”.
  - Easier to define new extensions and options.

Extension Headers

- Hop by Hop options header.
- Destination options header.
- Routing header.
- Fragment header.
- Authentication header (AH).
- Encapsulation security payload (ESP) header.

Configuring IPv6 Address on UNIX/Linux

- Use the nm-connection-editor




```
Debian # ping6 2001::ffff:10
PING 2001::ffff:10(2001::ffff:10) 56 data bytes
64 bytes from 2001::ffff:10: icmp_seq=1 ttl=128 time=1.44 ms
64 bytes from 2001::ffff:10: icmp_seq=2 ttl=128 time=0.458 ms
64 bytes from 2001::ffff:10: icmp_seq=3 ttl=128 time=0.477 ms
64 bytes from 2001::ffff:10: icmp_seq=4 ttl=128 time=0.456 ms
64 bytes from 2001::ffff:10: icmp_seq=5 ttl=128 time=0.463 ms

--- 2001::ffff:10 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 3998ms
rtt min/avg/max/mdev = 0.456/0.660/1.446/0.393 ms
```

- Use the command shell

```
# ip -6 addr add 2001::ffff:0020/112 dev eth0
# ip -6 route add ::/0 via 2001::ffff:0001
```

review

```
# ip -6 addr show dev eth0
# ip -6 route show
```

Configuring IPv6 Address on UNIX/Linux

- GNU/Linux persistent change edit

`/etc/network/interfaces`

```
# vi /etc/network/interfaces
  iface eth0 inet6 static
    address 2001::ffff:0020
    netmask 112
    gateway 2001::ffff:0001
  ~
  :wq!

# ip link set dev eth0 down
# ip link set dev eth0 up
```

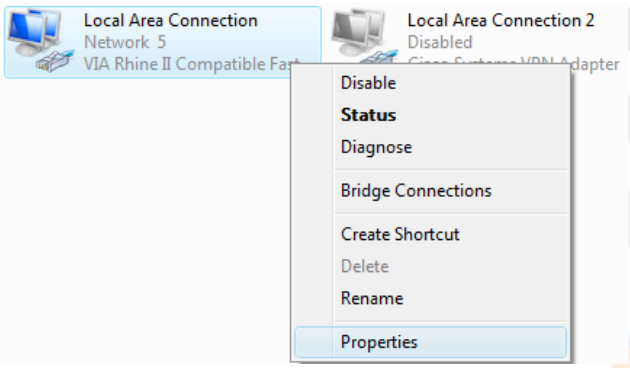
Configuring IPv6 Address on UNIX/Linux

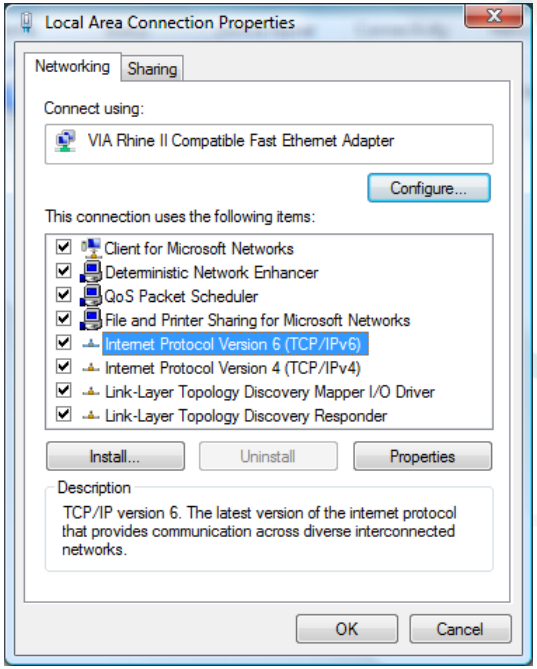
- Add the following line to the `/etc/resolv.conf` file.

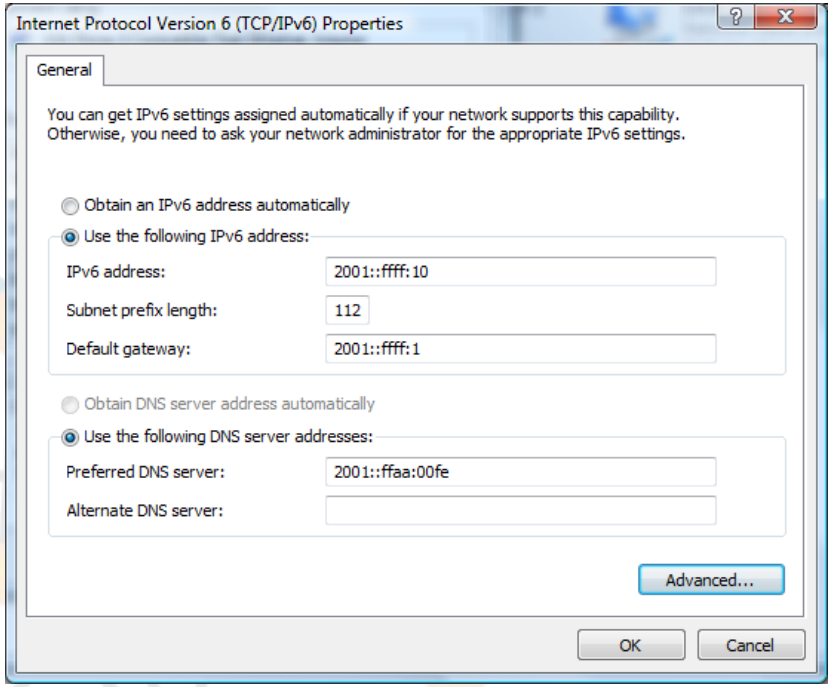
```
# vi /etc/resolv.conf
  nameserver 2001::ffaa:00fe
  ~
  ~
  :wq!
```

Configuring IPv6 Address on Windows

Start → Settings → Network Connections







C:\> **ping 2001::ffff:20**

Pinging 2001::ffff:20 from 2001::ffff:10 with 32 bytes of data:

Reply from 2001::ffff:20: time<1ms
Reply from 2001::ffff:20: time<1ms
Reply from 2001::ffff:20: time<1ms
Reply from 2001::ffff:20: time<1ms

Ping statistics for 2001::ffff:20:
Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
Minimum = 0ms, Maximum = 0ms, Average = 0ms

Prefix Terminology

- Prefix Terms

Prefix Term	Assigned by	Example prefix
Registry Prefix	Assigned to regional registry	2a02::/12
ISP Prefix	Assigned to ISP	2a02:2158::/32
Site Prefix	Assigned to Large Company	2a02:2158:1111/48
Site Prefix	Assigned to Smaller Company	2a02:2158:1111:100::/56
Subnet Prefix	Internal subnet within company	2a02:2158:1111:110::/64
A host address	IT Department in a company	2a02:2158:1111:110::10/128

- IPv6 Relative Network Sizes

/128	1 IPv6 address	A network interface
/64	1 IPv6 subnet	18,446,744,073,709,551,616 IPv6 addresses
/56	256 LAN segments	Popular prefix size for smaller subscriber site
/48	65,536 LAN segments	Popular prefix size for larger subscriber site
/32	65,536 /48 subscriber sites	Minimum IPv6 allocation
/24	16,777,216 subscriber sites	256 times larger than the minimum IPv6 allocation

Link Local Addresss (LLA)

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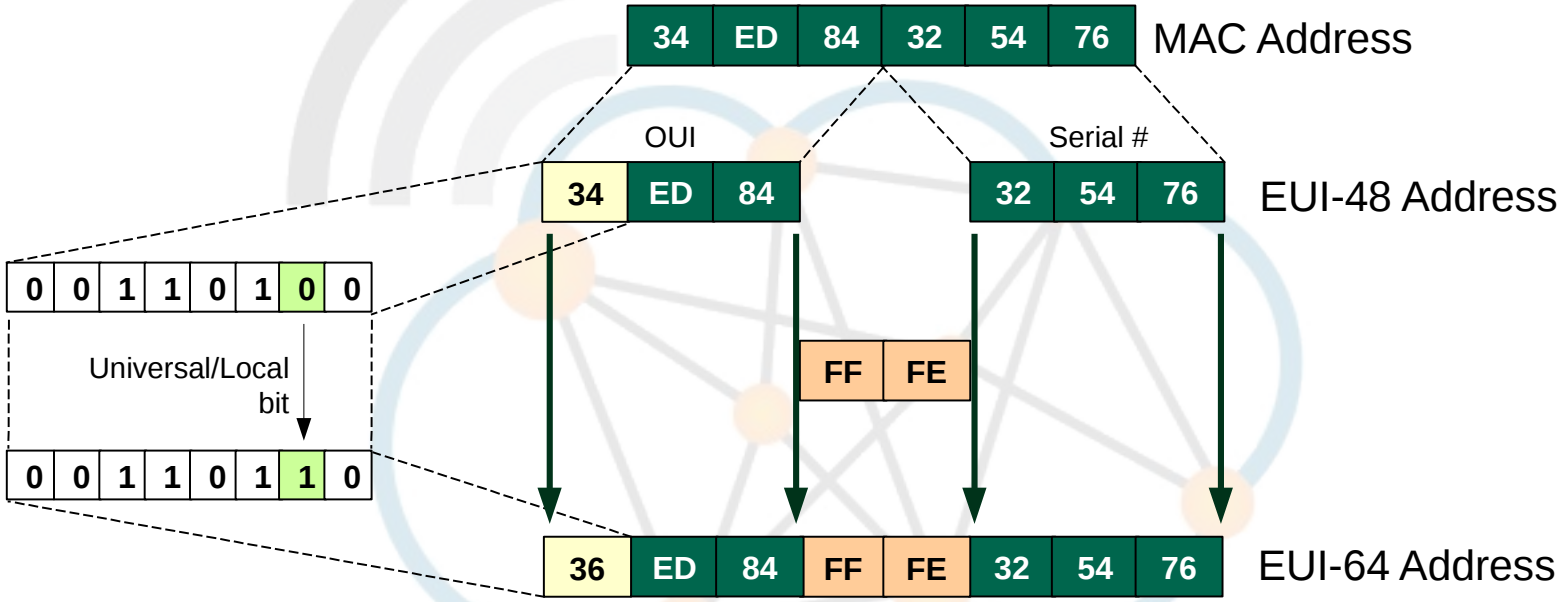
EUI-48 MAC to EUI-64 to LLA

- EUI-48 : 34ed:8432:5476



- EUI-64 : 36ed:84ff:fe32:5476
- IPv6 Host ID : ff80::36ed:84ff:fe32:5476

Multicast

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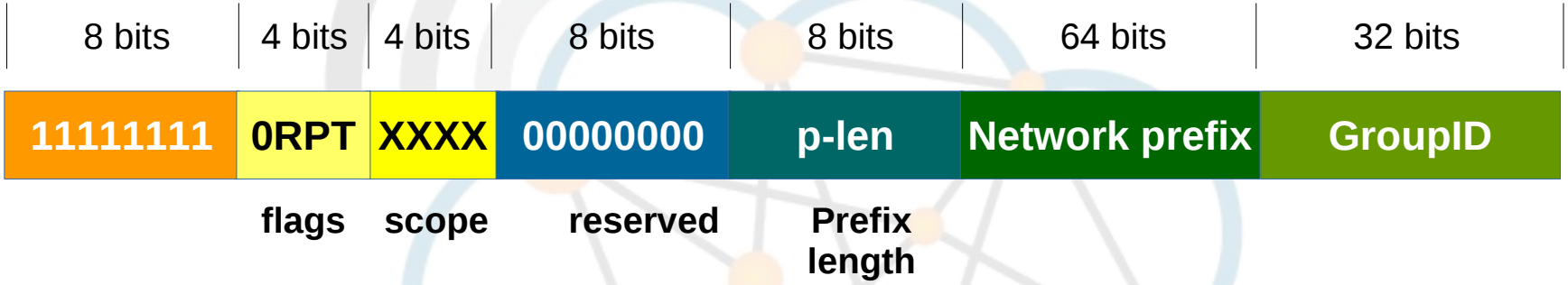
Multicast address



IPv6 Addressing model

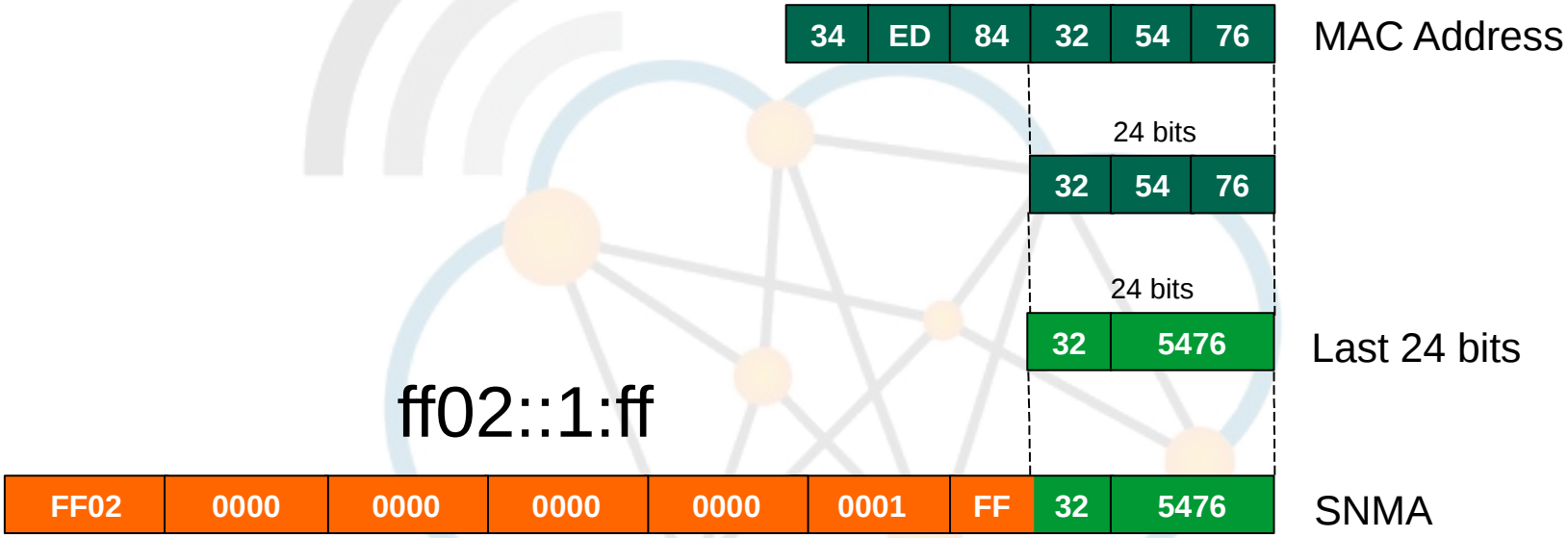
- Multicast **ff0X::/8**

	Multicast Scope
0x1	Interface local
0x2	Link local
0x4	Admin local
0x5	Site local
0x8	Organisation local
0xE	Global
0x0	Reserved
0xF	Reserved

- i.e. **ff02::1**
  - All nodes on the local link.

Solicited-Node Multicast Address (SNMA)

- EUI-48 : 34ed:8432:5476



- EUI-48 : 34ed:8432:5476
- SNMA : ff02::1::ff32:5476

IPv6 Assigned Prefixes

- Address Type indicated by Format Prefix (FP).

Type	Format Prefix (FP)	Fraction	Prefix
Loopback			::1/128
IPX	0000 101	1/128	0400::/7
GUA	001	1/8	2000::/3
LLA	1111 1110 10	1/1024	fe80::/10
Local unicast	1111 110	1/128	fc00::/7
Multicast	1111 1111	1/256	ff00::/8
Pre-defined Multicast	1111 1111 0000 0001	1/4096	ff01::/12
IPv4		$1/5.90e^{20}$	::ffff:0:0/96
6to4 Translation	0000 0000 0110 0100 1111 1111 1001 1011	$1/5.90e^{20}$	64:ff9b::/96

- Anycast addresses allocated from unicast prefixes.
  - Assigning a unicast address to more than one interface turns a unicast address into an anycast address.
- Approx 1/8 of the available addressing space has been allocated.

Applications

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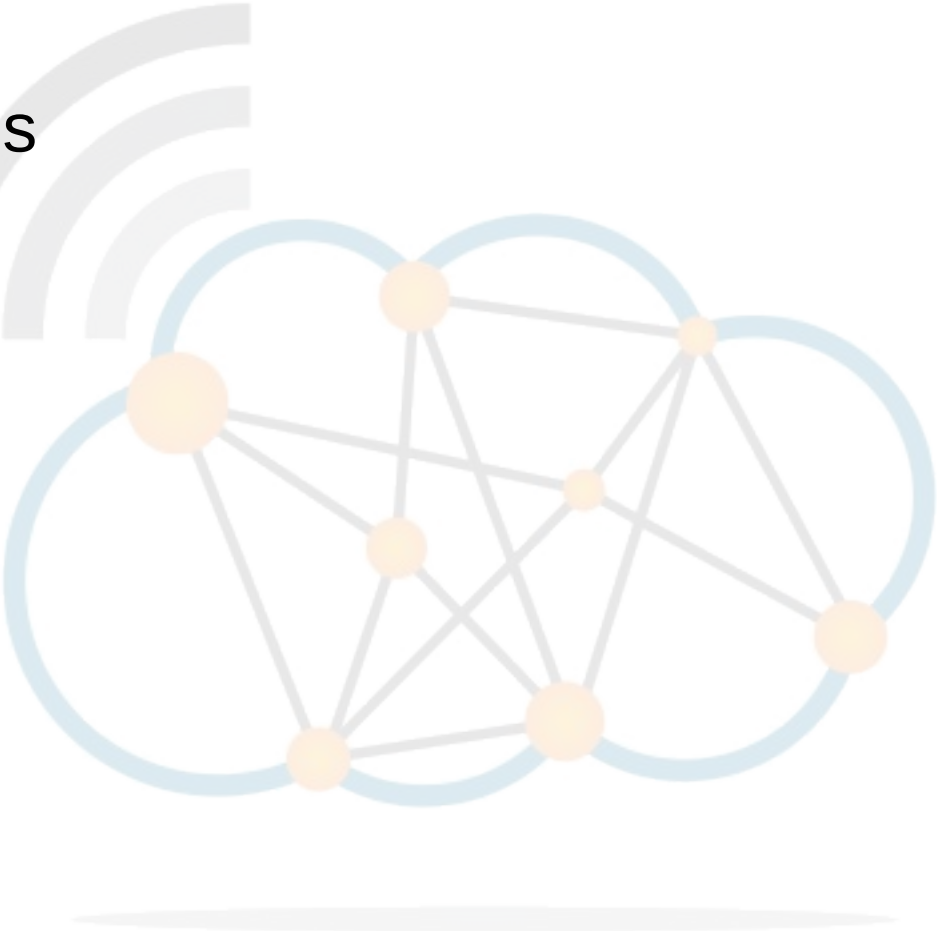
IPv6 EGP Routing Protocols

- DHCPv6
  - Stateless
  - Stateful
- DNSv6
- ICMPv6



Stateless Autoconfiguration (SLAAC) Neighbour Discovery (ND)

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IPv6 Neighbour Discovery

- Stateless auto-configuration (SLAAC)
  - Creation of Global Unique Address (GUA).
  - Based in ICMPv6.
  - Creation of Link-local Address (LLA)
    - Assumes that each interface can provide a unique identifier.
    - With duplicate address detection.
  - Security to disable hackers plug & play.
- Stateful auto-configuration
  - Use of Stateful DHCPv6.

IPv6 SLAAC process

- Host creates a Solicited-Node Multicast Address (SNMA)
- Host registers a Multicast Listener Report for SNMA to join group
  - from (::) to ff02::16 Multicast Listener Discovery (MLD)
- Host creates a LLA
    - Sends Neighbour Solicitation (NS) (135) from (::) to SNMA with LLA target
    - If Neighbour Advertisement (NA) (136) received auto-configuration stops.
- Host registers a Multicast Listener Report for SNMA address to join group
  - from LLA to ff02::16 MLD
- Host sends Router Solicitation (133) to ff02::2 ‘All routers’ from LLA
- Router sends Router Advertisement (134) to ff02::1 ‘All nodes’ from its LLA with prefix
- Host creates GUA from prefix and MAC
  - Sends NS (135) from (::) to SNMA with GUA target
  - If NA (136) received auto-configuration stops.
- Finish SLAAC.

MLD to join multicast group

Solicited-Node multicast Address (SNMA)

00:00:00:aa:00:02 – EUI-48

↓

ff02::1:ffaa:2

Link-local address

00:00:00:aa:00:02 – EUI-48

↓

02:00:00:ff:fe:aa:00:02 – EUI-64

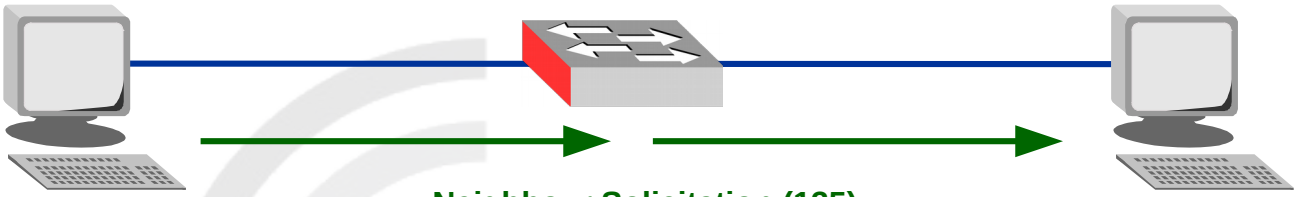
↓

fe80::200:ff:feaa:2

Multicast Listener Report

Ethernet II, Dst: **33:33:**ff:aa:00:02, Src: 00:00:00:aa:00:02; Type: IPv6 (0x86dd)
Internet Protocol Version 6, Src: **::**, Dst: **ff02::16**
Payload length: 36
Next header: **IPv6 Hop-by-Hop Option (0)**
Hop limit: 255
Hop-by-Hop Options
Next Header: **ICMPv6 (58)**
Internet Control Message Protocol v6
Type: **Multicast Listener Report Message v2 (143)**
Multicast Address Record Changed to exclude: **fe80::200:ff:feaa:2**

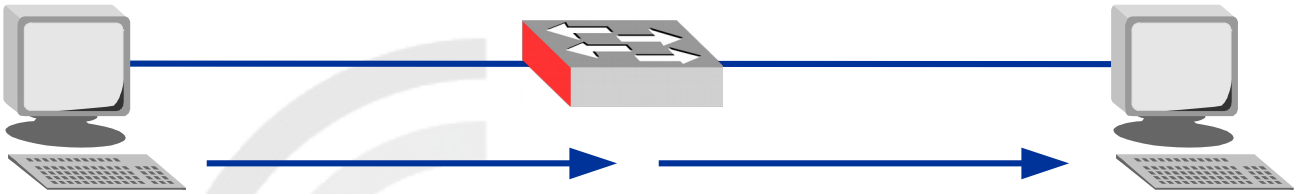
Neighbour Solicitation (135)




```
Ethernet II, Dst: 33:33:ff:aa:00:02, Src: 00:00:00:aa:00:02; Type: IPv6 (0x86dd)
Internet Protocol Version 6, Src: ::, Dst: ff02::1:ffaa:2
    Payload length: 24
    Next header: ICMPv6 (58)
    Hop limit: 255
Internet Control Message Protocol v6
    Type: Neighbor Solicitation (135)
    Target Address: fe80::200:ff:feaa:2
```

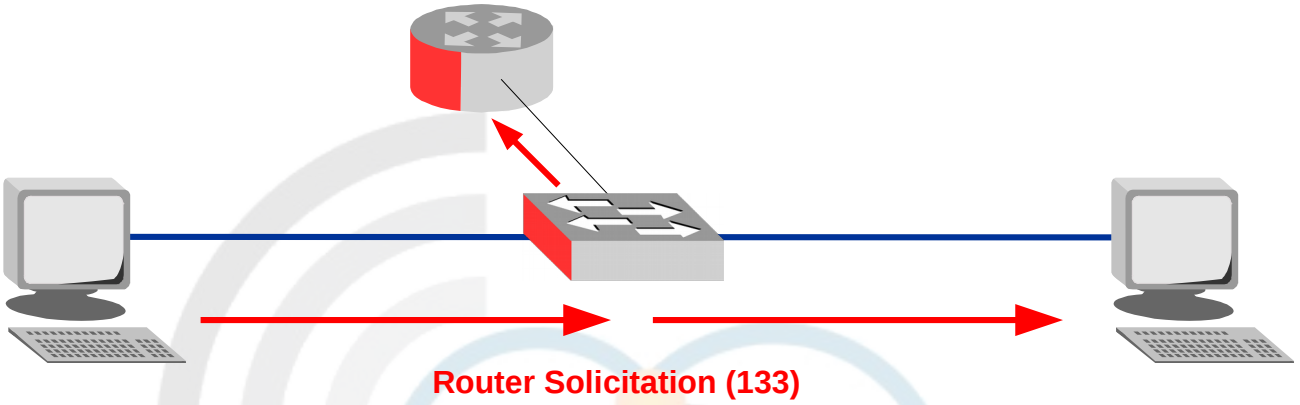
- No Neighbour Advertisement (136) is received
- No duplicate for LLA detected

MLD to join multicast group



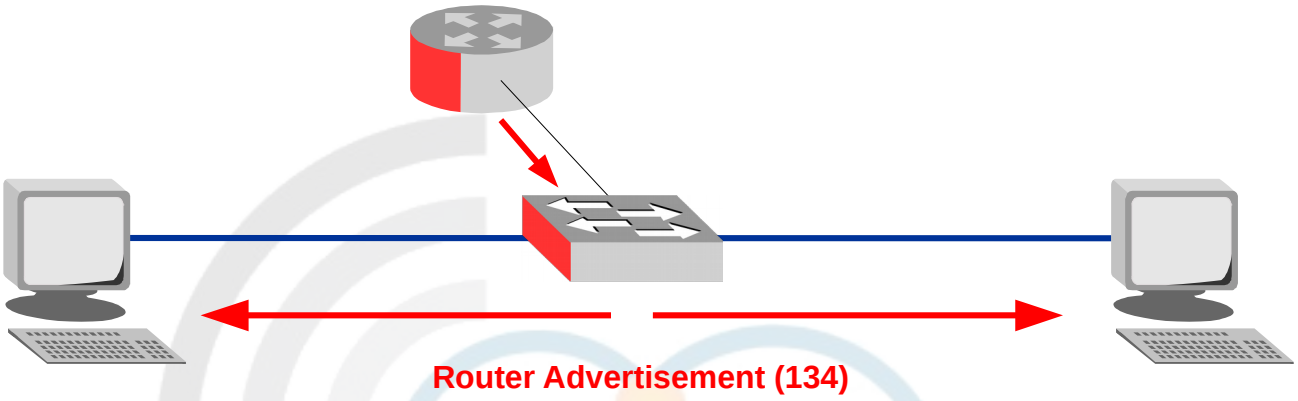
Ethernet II, Dst: 33:33:00:00:00:16, Src: 00:00:00:aa:00:02; Type: IPv6 (0x86dd)
Internet Protocol Version 6, Src: fe80::200:ff:feaa:2, Dst: ff02::16
    Payload length: 36
    Next header: IPv6 Hop-by-Hop Option (0)
    Hop limit: 255
    Hop-by-Hop Options
        Next Header: ICMPv6 (58)
Internet Control Message Protocol v6
    Type: Multicast Listener Report Message v2 (143)
    Multicast Address Record Changed to exclude: ff02::1:ffaa:2

Router Solicitation (135)



Ethernet II, Dst: **33:33**:00:00:00:02, Src: 00:00:00:aa:00:02;
Type: IPv6 (0x86dd)
Internet Protocol Version 6, Src: **fe80::200:ff:feaa:2**, Dst: **ff02:2**
    Payload length: 16
    Next header: **ICMPv6 (58)**
    Hop limit: 255
Internet Control Message Protocol v6
    Type: **Router Solicitation (133)**
    Link-layer address: **00:00:00:aa:00:02**

Router Advertisement (134)




```
Ethernet II, Dst: 33:33:00:00:00:01, Src: 00:00:00:aa:00:03; Type: IPv6 (0x86dd)
Internet Protocol Version 6, Src: fe80::200:ff:feaa:3, Dst: ff02:1
    Payload length: 16
    Next header: ICMPv6 (58)
    Hop limit: 255
Internet Control Message Protocol v6
    Type: Router Advertisement (134)
    Flags: 0xc0          .1.. .... = Other configuration: Set
    ICMPv6 Option, Prefix information
        Prefix Length: 64
        Flag: 0xc0       1... .... = On-link flag(L): Set
                         .1.. .... = Autonomous address-configuration flag(A): Set
        Valid Lifetime: 86400, Preferred Lifetime: 86400
        Prefix: 2001:a::
    ICMPv6 Option
        Link-layer address: 00:00:00:aa:00:03
```

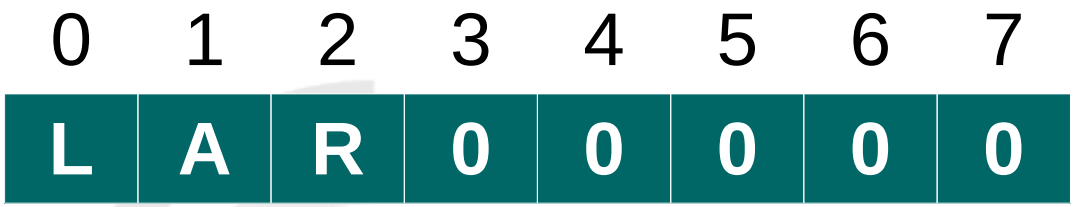
RA Flags

- **M - Managed Address Configuration Flag**
- **O - Other Configuration Flag**
- H - Mobile IPv6 Home Agent Flag
- Prf - Router Selection Preferences
- P - Neighbour Discovery Proxy Flag
- R – Reserved

ICMPv6 Option (Prefix information)
Type: Prefix information (3)
Length: 32
Prefix length: **64**
Flags: **0xc0**
0... .... = IP Address not DHCPv6
.1.. .... = Other config on DHCPv6
..0. .... = Not router address
...0 .... = Not site prefix
Valid lifetime: **86400**
Preferred lifetime: **86400**
Prefix: **2001:a::**

- If the M flag is set to 0 & the O flag is set to 1, use DHCPv6 to obtain additional configuration parameters.

RA Flags – Additional Prefix flags



ICMPv6 Option (Prefix information : 2001:a::/64)
- Type: Prefix information (3)
- Length: 4 (32 bytes)
- Prefix Length: **64**
- Flag: **0xc0**
  - **1... .... = On-link flag(L): Set**
  - **.1.. .... = Autonomous address-configuration flag(A): Set**
  - ..0. .... = Router address flag(R): Not set
  - ...0 0000 = Reserved: 0
- Valid Lifetime: 86400
- Preferred Lifetime: 86400
- Reserved
- Prefix: **2001:a::**

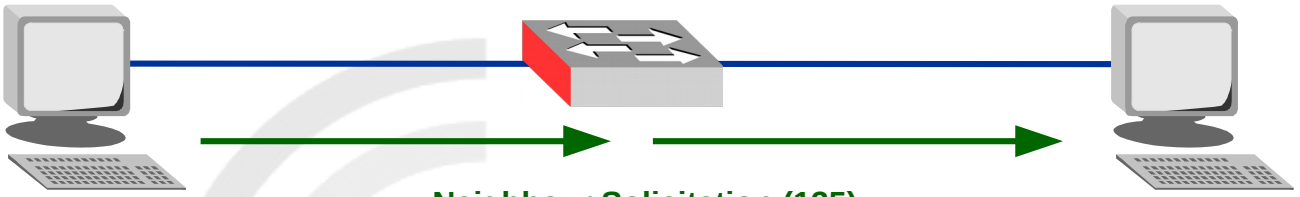
- **L Flag -** indicates whether or not the option even applies to stateless autoconfiguration.
- **A Flag -** indicate a prefix identifying a range of addresses that should be considered on-link.

RA Flags – influence on auto-configuration

M	A	Resulting non-Link Local addresses on client
0	**0**	No addresses will be auto-configured
0	**1**	Address generated from prefix in RAs
1	**1**	Address generated from prefix) in RAs Full address from DHCP server
1	**0**	Full address(es) from DHCP server

- **Note**
  - The hosts must be set to obtain IP address ‘automatically’
  - All hosts always generate and use a Link Local address.

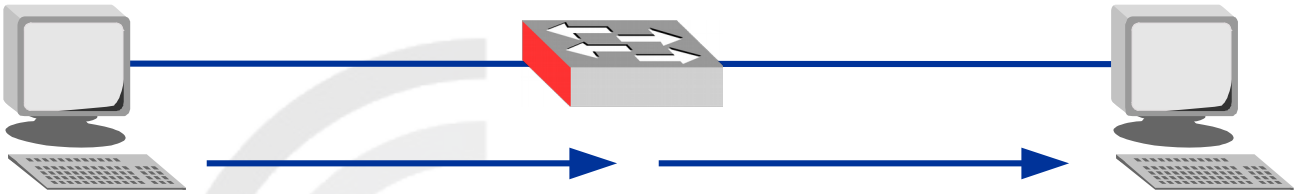
Neighbour Solicitation (135)




```
Ethernet II, Dst: 33:33:ff:aa:00:02, Src: 00:00:00:aa:00:02; Type: IPv6 (0x86dd)
Internet Protocol Version 6, Src: ::, Dst: ff02::1:ffaa:2
    Payload length: 24
    Next header: ICMPv6 (58)
    Hop limit: 255
Internet Control Message Protocol v6
    Type: Neighbor Solicitation (135)
    Target Address: 2001:a::200:ff:feaa:2
```

- No Neighbour Advertisement (136) is received
- No duplicate for GUA detected

MLD to join multicast group



Ethernet II, Dst: 33:33:00:00:00:16, Src: 00:00:00:aa:00:02; Type: IPv6 (0x86dd)
Internet Protocol Version 6, Src: fe80::200:ff:feaa:2, Dst: ff02::16
    Payload length: 36
    Next header: IPv6 Hop-by-Hop Option (0)
    Hop limit: 255
    Hop-by-Hop Options
        Next Header: ICMPv6 (58)
Internet Control Message Protocol v6
    Type: Multicast Listener Report Message v2 (143)
    Multicast Address Record Changed to exclude: ff02::1:ffaa:2

DNS via Stateless DHCPv6 in SLAAC

- Stateless DHCPv6 is an extension of SLAAC to pass information like the DNS Servers and the domain name for the network to hosts.
- Because IPv6 has SLAAC the DHCPv6 server can remain stateless as it does not need to record leases as it would for IPv4.

IPv6 Stateful Autoconfiguration

- Stateful autoconfiguration requires access to a network DHCPv6 server to provide the addressing much like for IPv4.
- Address assignment is centrally managed and clients must obtain configuration information not available through protocols such as address autoconfiguration and neighbour discovery.

Address Resolution and Redirection

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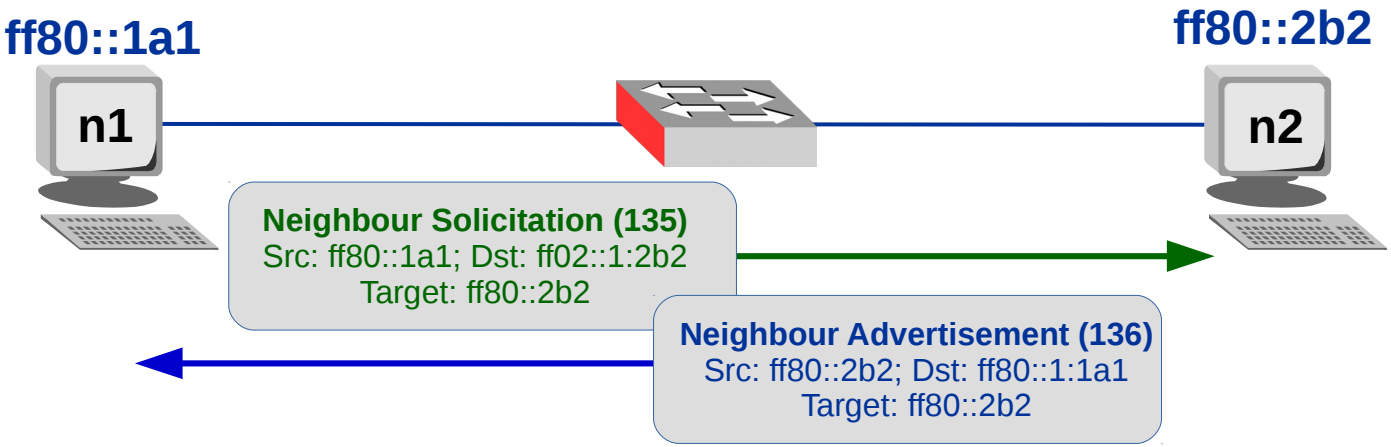
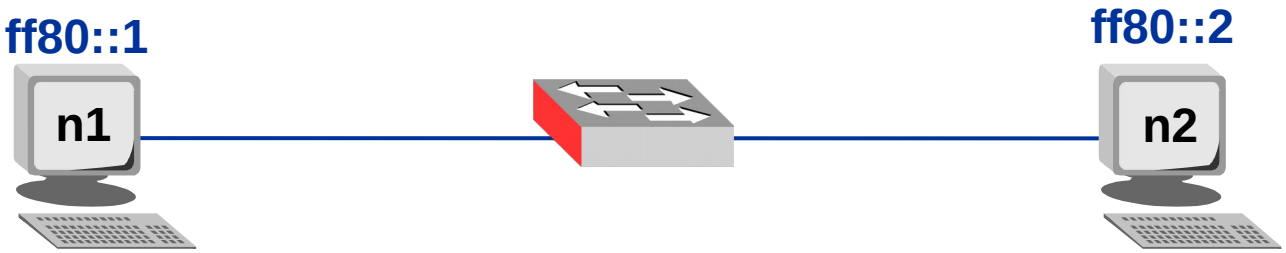
Address Resolution

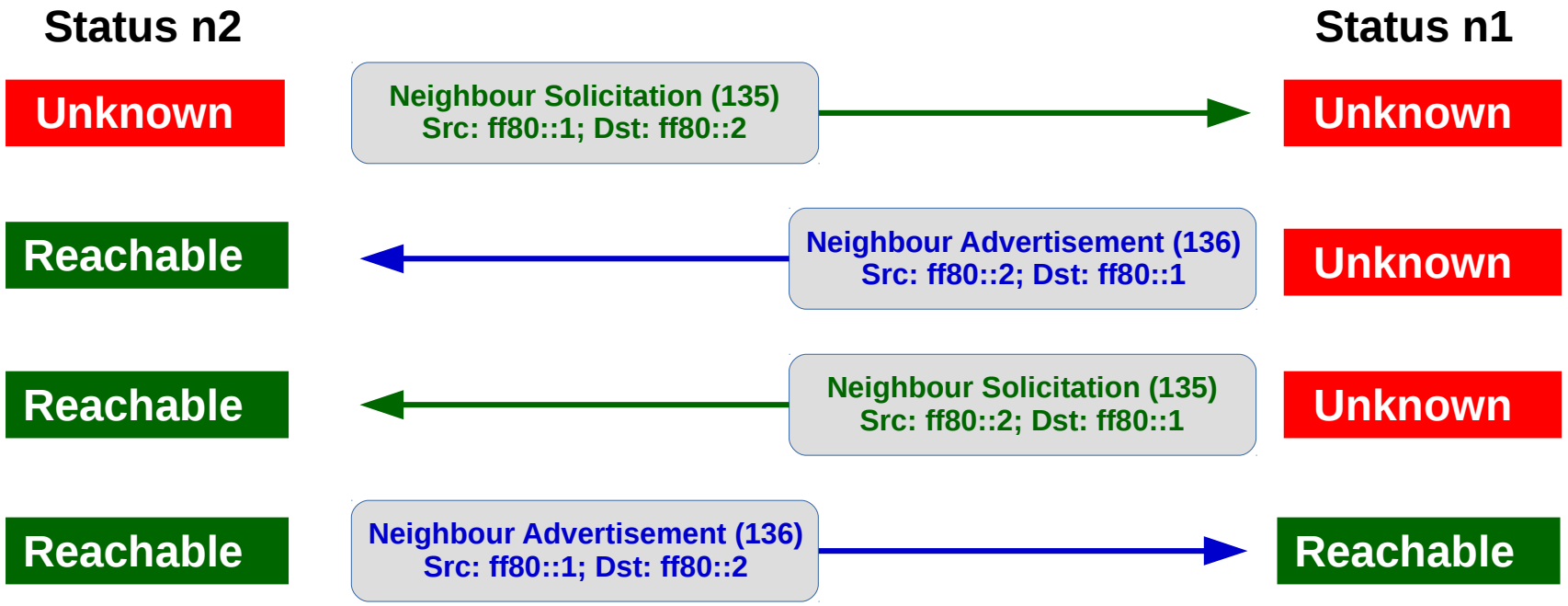


- Host sends a NS (135) message.
- Host retains packets for the requested host in a queue.
- Host received NA (136) from distant host.
- NA (136) is added to the Neighbour cache.

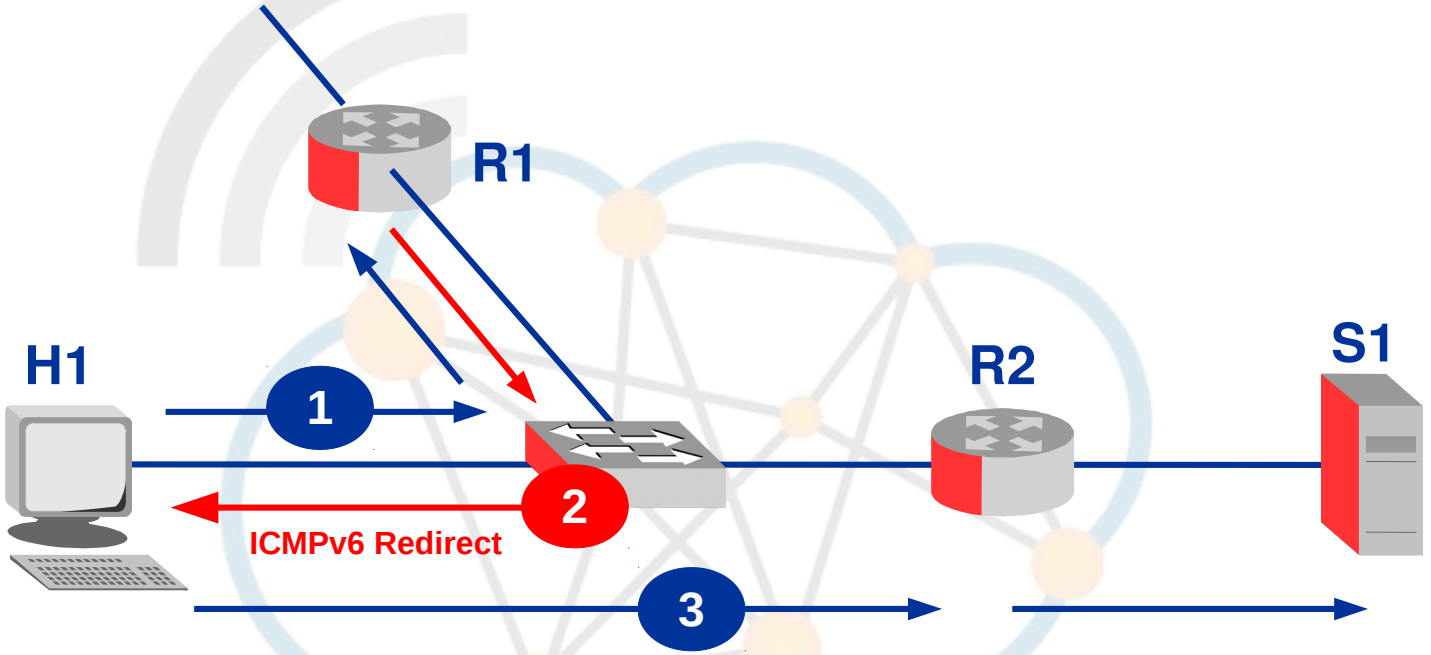
Neighbour Unreachability Detection (NUD)

- Solicit a NA using a unicast probe (NS)





ICMPv6 Redirect



Best practice

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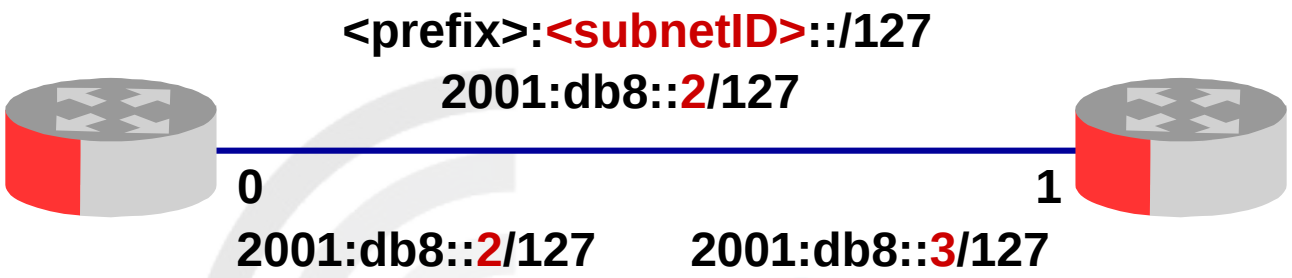
Configuration best practice

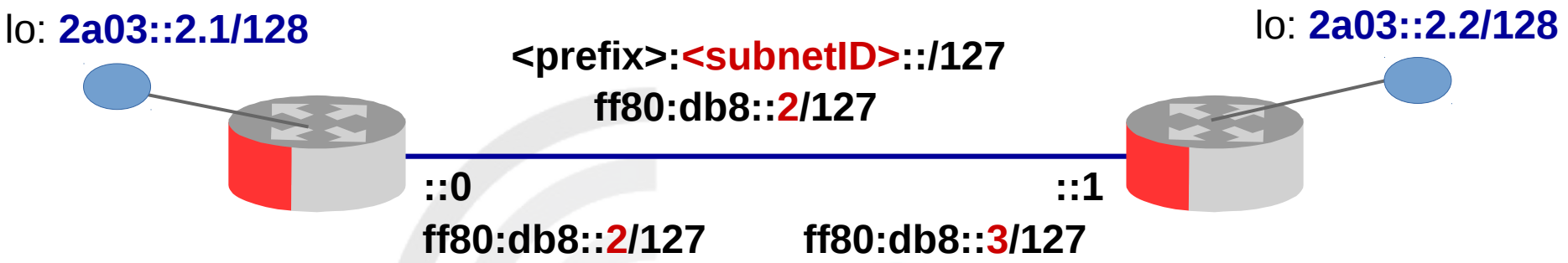
- Don’t fit your network into RIR minimums
  - (/32, /36 & /48)
- Typical prefix lengths
  - Multi-host LAN subnets: /64
  - Inter-router links: /127
  - Loopback addresses: /128
- Plan a hierarchical scheme to optimise for aggregation
- Ensure all prefixes fall on nibble (4 bit) boundaries

Configuration best practice - Inter-router links



- Improves security by eliminating
  - Forwarding loops (ping pong) on some p2p links
  - Neighbour Exhaustion Attacks
- Addresses with the following 64 bits must NOT be used:
  - 0000:0000:0000:0000
  - ffff:ffff:ffff:ff7f ➠ 0000:0000:0000:ffff

Configuration best practice - Inter-router links



- Improves security by eliminating
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- Addresses with the following 64 bits must NOT be used:
  - 0000:0000:0000:0000
  - ffff:ffff:ffff:ff7f ➠ 0000:0000:0000:ffff

IP Address planning

- How many addresses to request from the RIR needs to plan their address space.
- ISP
  - 10 regions
  - 50 Points of Presence (POP)
  - 3,500 clients/POP.

- Calculate the number of bits in the mask for each tier in multiples of 4 (i.e. nibbles).
  - Take the value that gives a result higher that the requirement.
- A similar process is carried out for each item as outlined below.
  - Assuming each client is assigned a /48 the mask
    - POPs can be determined by subtracting 12 from 48 giving a /36
    - Subtract 8 from 36 to give a /28 for Regions
    - Subtract 4 from 28 gives a /24 for the ISP.
  - Therefore in this example the IPS requires a /24 from the RIR.

Item	#	Bits (multiple of 4)	Possible #	Mask
ISP	1	1	2	/24
Regions	10	4	16	/28
POPs	50	8	256	/36
Clients	3,500	12	4,096	***/48***
		24		

Routing

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IPv6 IGP Routing Protocols

- RIPng (RFC 2080)
  - Distance vector algorithm like the IPv4 version.
  - Implementations: GateD, MRTd, Kame, route6d, Zebra, Cisco, Juniper, MikroTik.
- OSPFv3 (RFC 2740)
  - Link State algorithm like the IPv4 version.
  - Recommended IGP of IETF.
  - Changes from OSPFv2
    - Security removed (it uses IPv6's security).
    - Format of addresses for IPv6.
  - Implementations: GateD, MRTd, Kame, route6d, Zebra, Ericsson-Telebit, IBM, Cisco, Juniper, MikroTik.

IPv6 EGP Routing Protocols

- BGP4+ (RFC 2545 and RFC 2858)
  - Inter domain routing protocol.
  - Used between ISPs and carriers.
  - RFC 2858 defines BGP4 extensions (IPX, IPv6 etc).
  - RFC 2545 defines how to use IPv6 extensions (Scopes, next hop etc).
  - Used in 6BONE.
  - Implementations: GateD, MTRd, Kame, BGPd, Zebra, Cisco, Juniper, MikroTik.

Transition mechanisms

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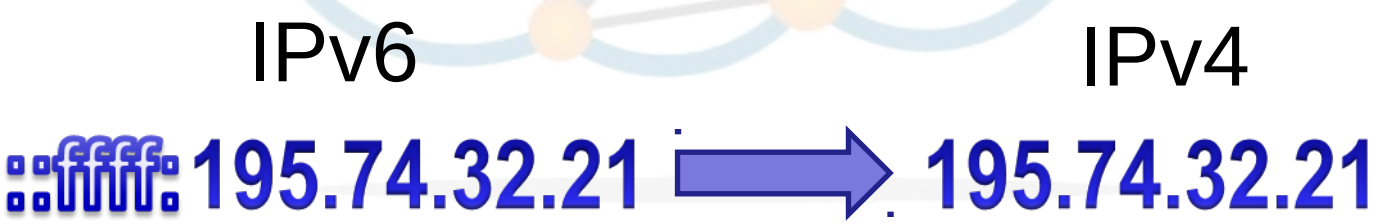
IPv6 transition mechanisms

- RFC 4213 Dual stack
  - Currently most common implementation.
  - Hosts have IPv4 and IPv6 IP Address.
  - OS has hybrid sockets designed to accept both IPv4 and IPv6 packets.
  - When used in IPv4 communications, hybrid stacks use an IPv6 API and represent IPv4 addresses in a special address format, the IPv4-mapped IPv6 address.



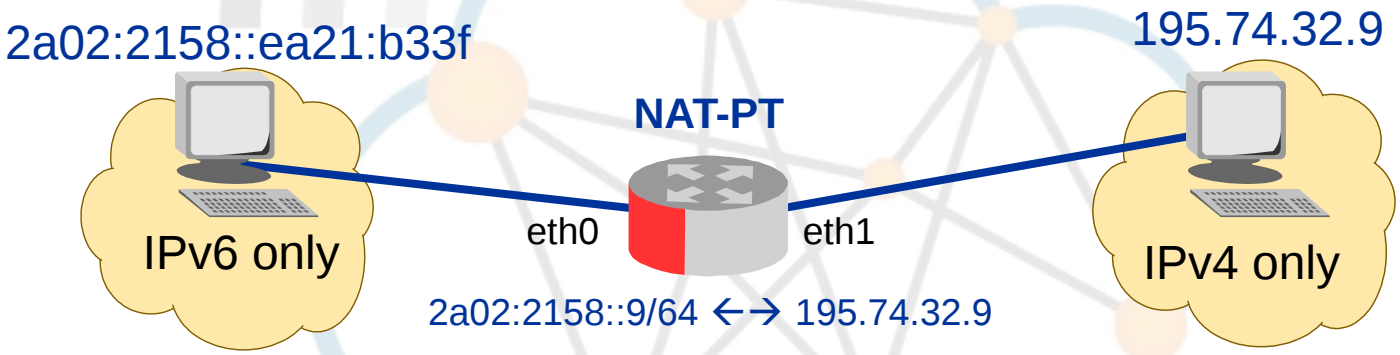
IPv6 transition mechanisms

- IPv4 compatible address prefix ::ffff:0:0/96 or ::ffff:0:a.b.c.d

- RFC 2765 - Stateless IP/ICMP Translation (SIIT)
  - SIIT translates between the packet header formats in IPv6 and IPv4.
  - SIIT can be used to allow IPv6 hosts, that are not Dual Stack, to communicate with IPv4-only hosts.

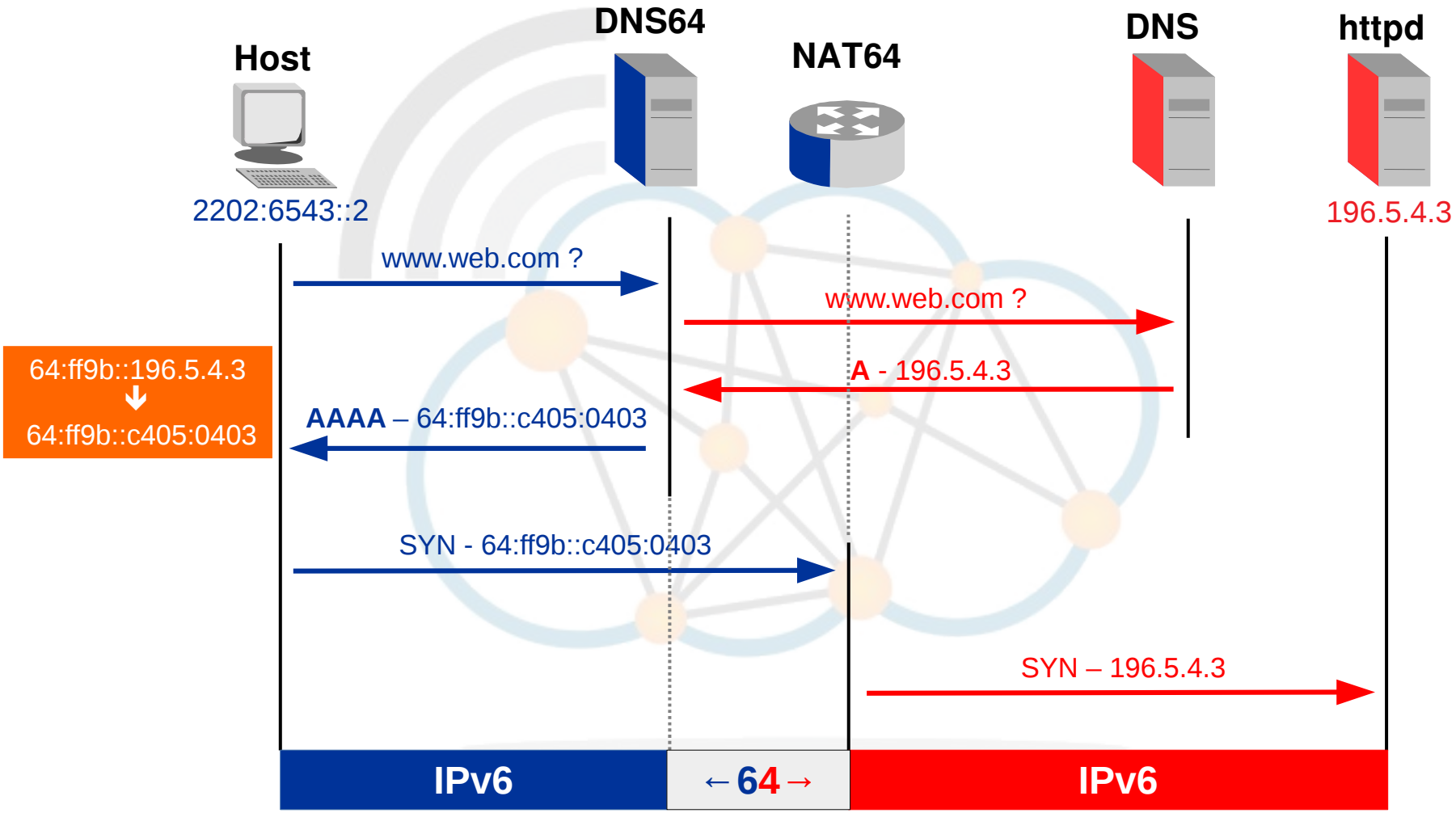
IPv6 transition mechanisms

- Network Address Translation/Protocol Translation (NAT-PT)
  - Protocol translator between IPv6 and IPv4.



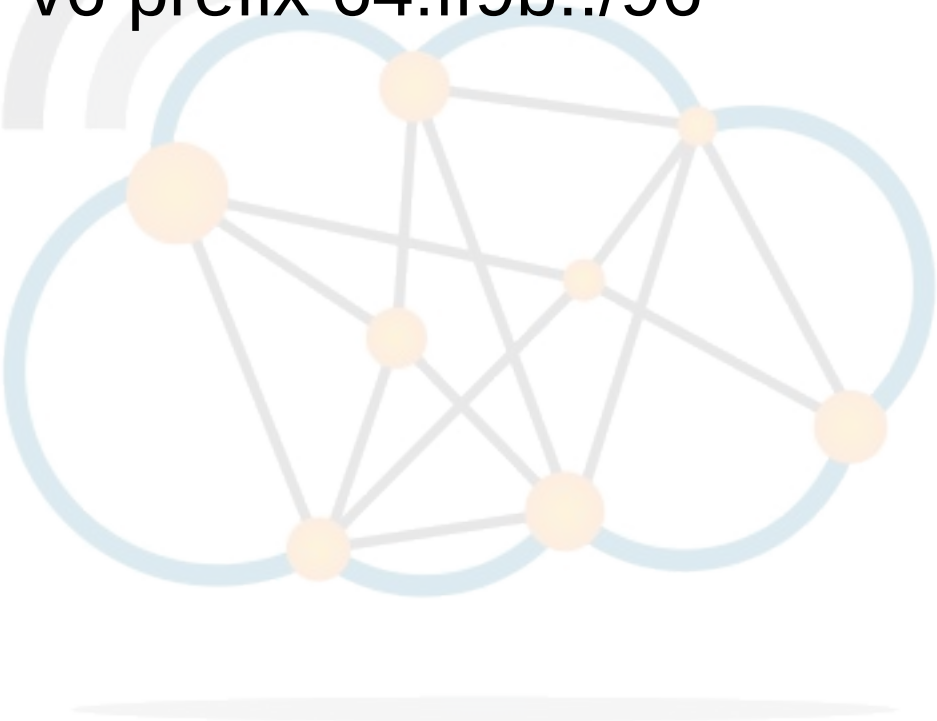

```
NAT-PT Router(config)# interface ethernet 1/0
NAT-PT Router(config-if)# ipv6 address 2a02:2158::9/64
NAT-PT Router(config-if)# ipv6 nat
NAT-PT Router(config-if)# exit
NAT-PT Router(config)# interface ethernet 1/1
NAT-PT Router(config-if)# ip address 195.74.32.9 255.255.255.0
NAT-PT Router(config-if)# ipv6 nat
```

NAT64 / DNS64


Host
DNS64
NAT64
DNS
httpd
2202:6543::2
196.5.4.3
www.web.com ?
www.web.com ?
A - 196.5.4.3
64:ff9b::196.5.4.3
64:ff9b::c405:0403
AAAA – 64:ff9b::c405:0403
SYN - 64:ff9b::c405:0403
SYN – 196.5.4.3
IPv6
←64→
IPv6

NAT64 / DNS64

- NAT64 enables v6 only host to communicate with v4 only servers
- Uses the IPv6 prefix 64:ff9b::/96



IPIPv6
IPv6 tunnelling over IPv4

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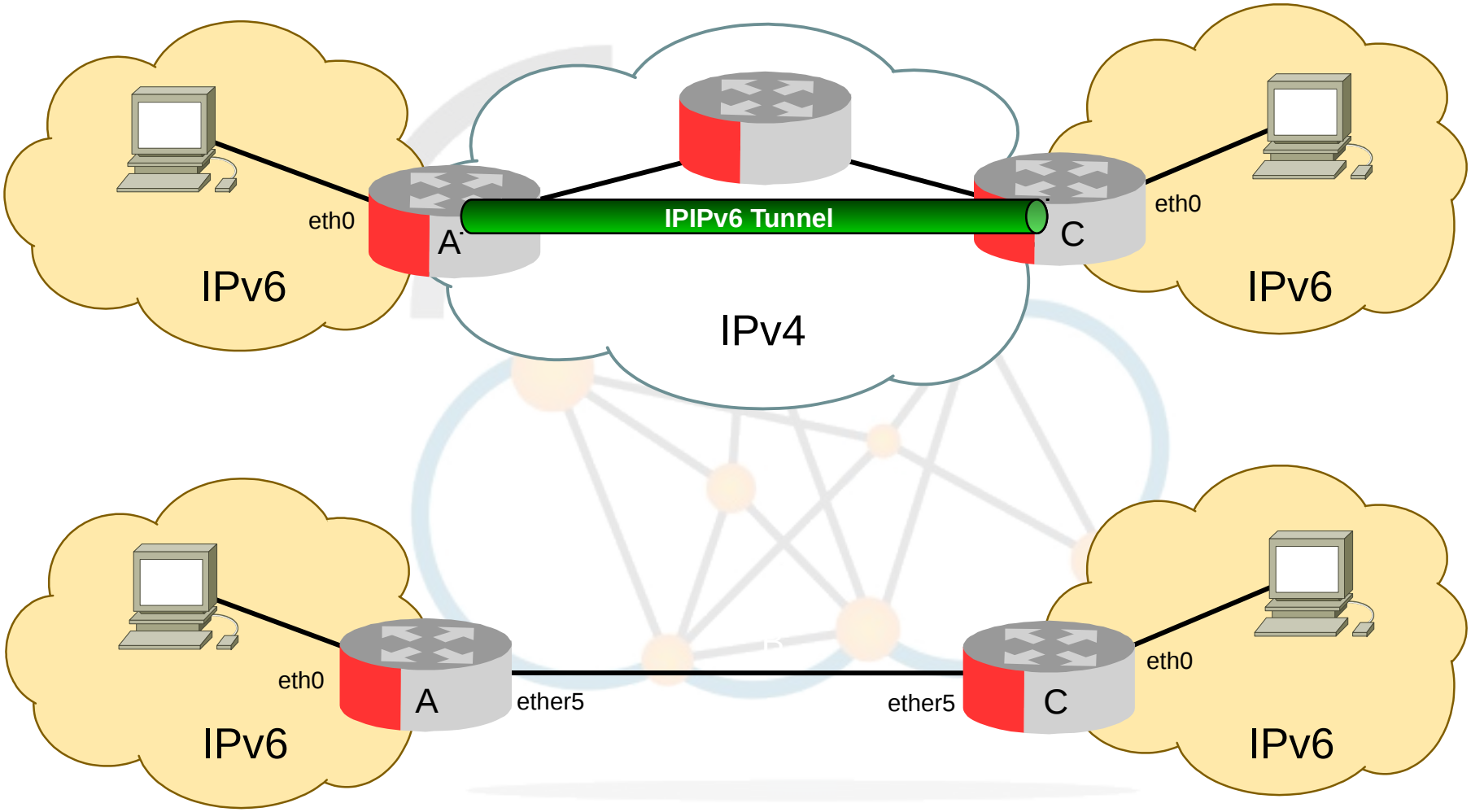
IPv6 tunnelling mechanisms

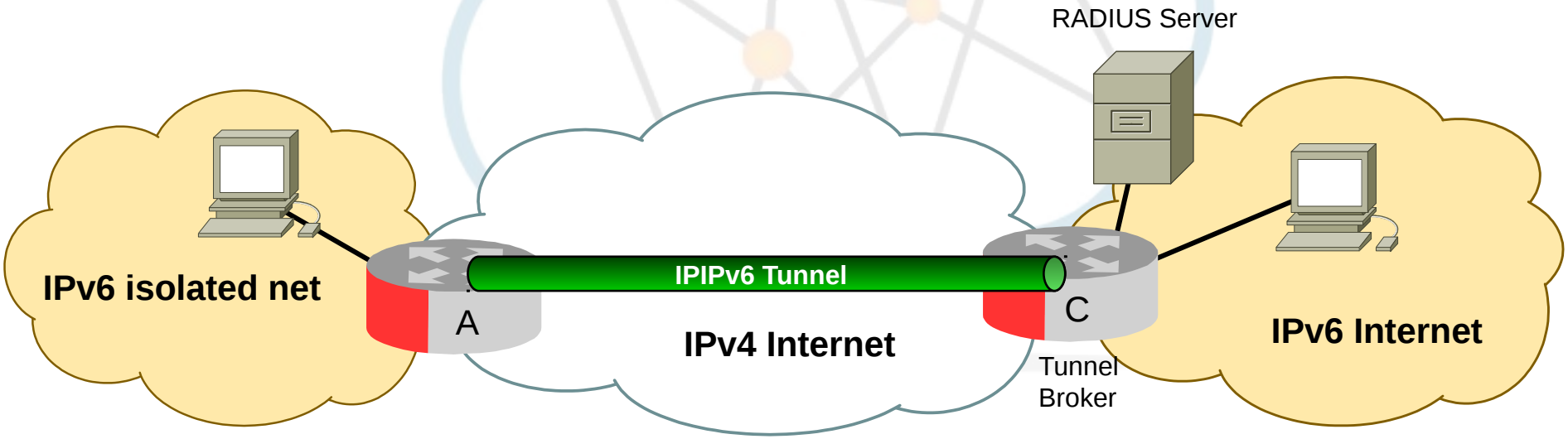
- Manual tunnelling
- Automatic 6to4 tunnelling
  - Allows isolated IPv6 sites to easily connect together without having to wait for IPv4 ISPs to deliver native IPv6 services.
  - This is very well suited for extranet and virtual private networks.
    - RFC 3056 Connection of IPv6 Domains via IPv4 Clouds (protocol 41 encapsulation)
    - RFC 4380/5991 Teredo: Tunnelling IPv6 over UDP through NATs.
    - RFC 4214 Intra-Site Automatic Tunnel Addressing Protocol (ISATAP).

Overlay Tunnels for IPv6



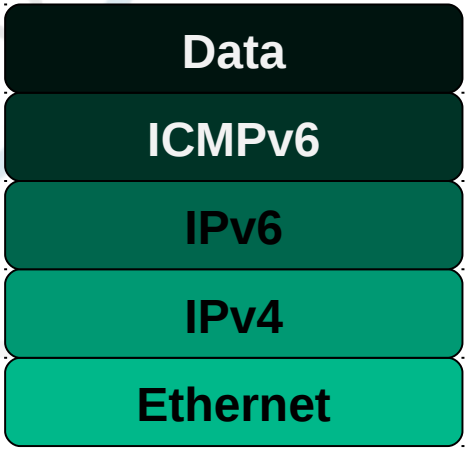
IPv6 tunnelling mechanisms

- RFC 3053 Tunnel Broker (TB)
  - Allows isolated users/routers to connect to the IPv6 network via a TB.
    - The router or host establishes an IPv6 encapsulation over IPv4 to the TB.
    - The TB authenticates the connection using RADIUS.
    - The router or host is assigned an IPv6 address and can now route IPv6.



IPIPv6 – IPv6 traffic over IPv4

```
Frame: 138 bytes on wire (1104 bits),
Ethernet II, Src:  00:0c:42:5e:9e:ff, Dst: 00:0c:42:b4:46:ee
Internet Protocol Version 4, Src: 200.200.200.11, Dst: 200.200.200.12
    Version: 4
    Header length: 20 bytes
    Differentiated Services Field: 0x00 (DSCP 0x00: Default; ECN: 0x00: Not-ECT (Not ECN-Capable Transport))
    Total Length: 124
    Identification: 0x0000 (0)
    Flags: 0x02 (Don't Fragment)
    Fragment offset: 0
    Time to live: 64
    Protocol: IPv6 (41)
    Header checksum: 0x18b0 [correct]
    Source: 200.200.200.11
    Destination: 200.200.200.12
Internet Protocol Version 6, Src: 2002:aaaa:1:0:212:3fff:fedc:ab47, Dst: 2002:aaaa:2:0:224:1dff:fe11:30d7
    0110 .... = Version: 6
    .... 0000 0000 .... .... .... .... .... = Traffic class: 0x00000000
    .... .... .... 0000 0000 0000 0000 0000 = Flowlabel: 0x00000000
    Payload length: 64
    Next header: ICMPv6 (0x3a)
    Hop limit: 254
    Source: 2002:aaaa:1:0:212:3fff:fedc:ab47
    [Source 6to4 Gateway IPv4: 170.170.0.1]
    [Source 6to4 SLA ID: 0]
    [Source SA MAC: Dell_dc:ab:47]
    Destination: 2002:aaaa:2:0:224:1dff:fe11:30d7
    [Destination 6to4 Gateway IPv4: 170.170.0.2]
    [Destination 6to4 SLA ID: 0]
    [Destination SA MAC: Giga-Byt_11:30:d7]
Internet Control Message Protocol v6
```



Thank You

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