Practical Network Defense

Master's degree in Cybersecurity 2020-21

IPv6: addressing

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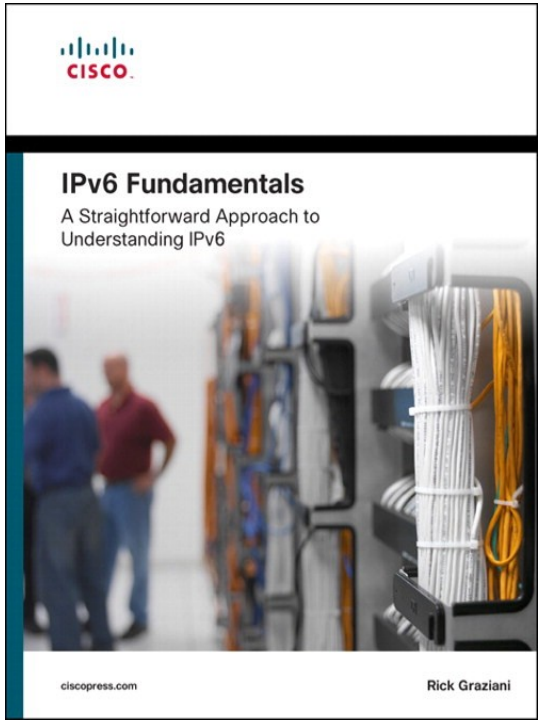
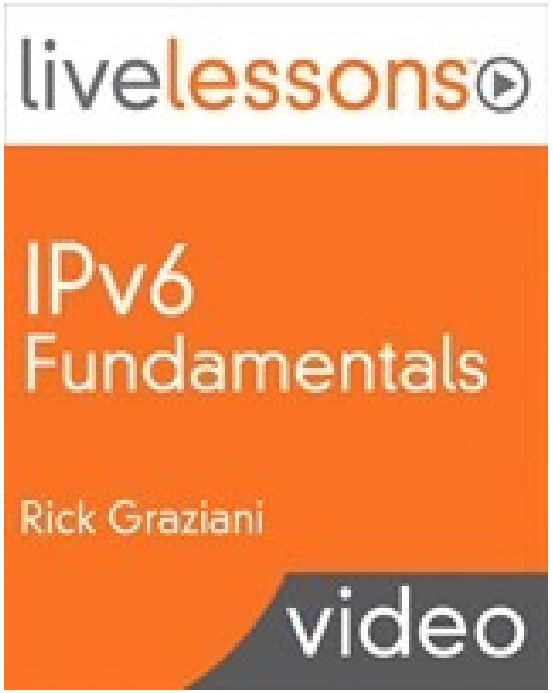
Material taken from Rick Graziani IPv6 courses





IPv6 Fundamentals: A Straightforward Approach to Understanding IPv6

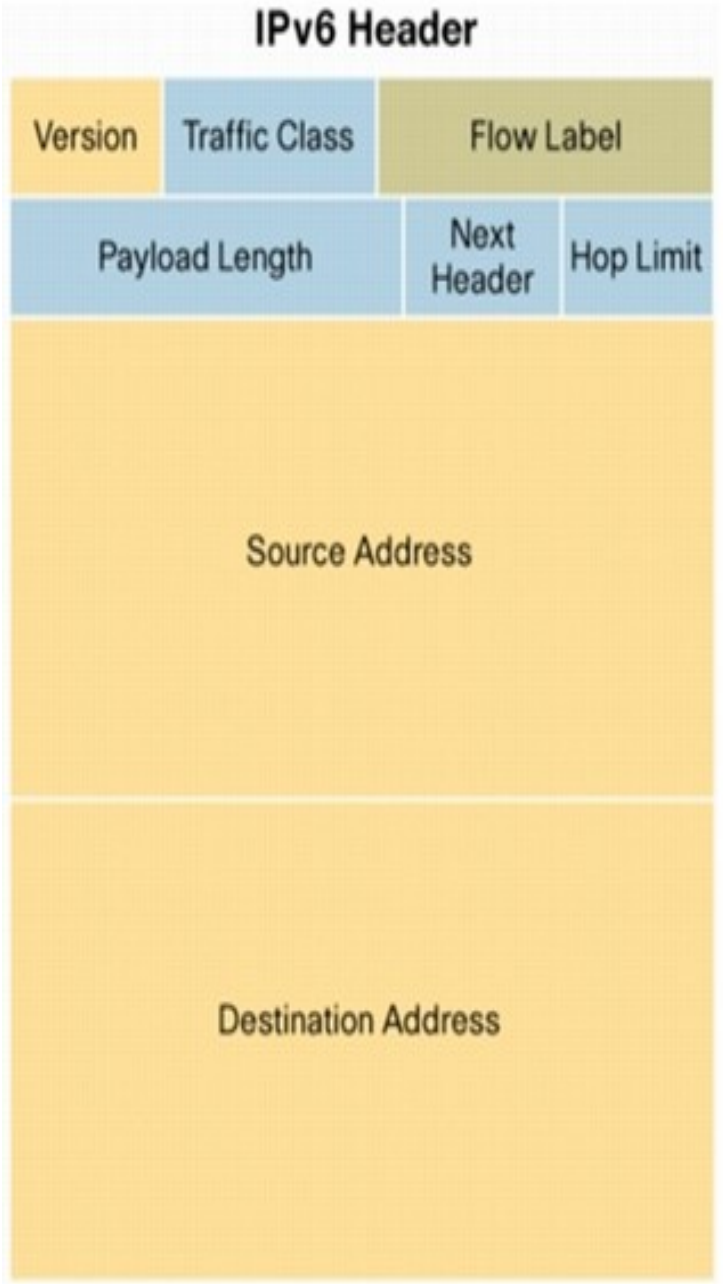
- By Rick Graziani
- ISBN-10: 1-58714-313-5

IPv6 Fundamentals LiveLessons: A Straightforward Approach to Understanding IPv6

- By Rick Graziani
- ISBN-10: 1-58720-457-6

Introducing IPv6

- Not a “new” protocol.
- Developed mid to late 1990s.
- Much learned from IPv4.
- 128-bit address space, written in hexadecimal.
- This gives us 340 undecillion addresses!



128 bits

128 bits

2001:DB8:CAFE:0001::100

340 undecillion
= 340,282,366,920,938,463,463,374,607,431,768,211,456

IPv6

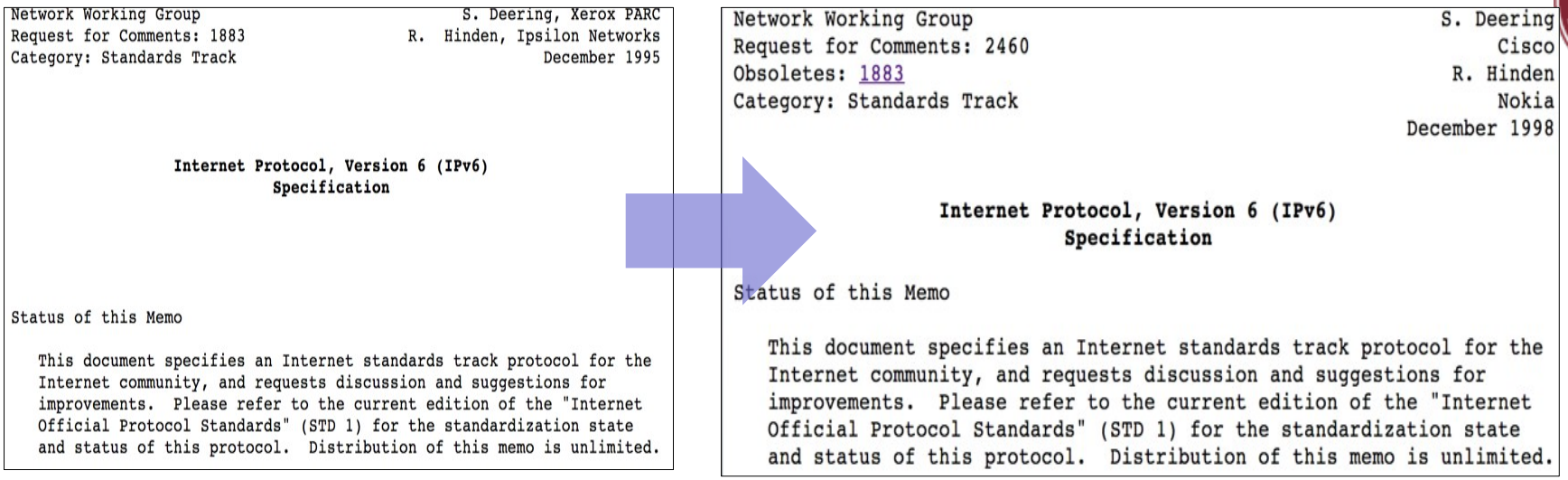
- How many is 340 undecillion?
- 340 undecillion addresses is 10 nonillion addresses per person!
- Internet is a much different place and will continue to evolve:
  - Mobile devices
  - Video on demand
  - Internet of Everything
  - A critical part in how we “live, work, play, and learn”.

10 nonillion
= 10,000,000,000,000,000,000,000,000,000

IPv6

- IPv6 is not just about more addresses:
  - Stateless autoconfiguration
  - End-to-end reachability without private addresses and NAT
  - Better support for mobility
  - Peer-to-peer networking easier to create and maintain, and services such as VoIP and Quality of Service (QoS) become more robust.

IPv6: A Brief History



Network Working Group — S. Deering, Xerox PARC
Request for Comments: 1883 — R. Hinden, Ipsilon Networks
Category: Standards Track — December 1995

Internet Protocol, Version 6 (IPv6) Specification

Status of this Memo

This document specifies an Internet standards track protocol for the Internet community, and requests discussion and suggestions for improvements. Please refer to the current edition of the "Internet Official Protocol Standards" (STD 1) for the standardization state and status of this protocol. Distribution of this memo is unlimited.

Network Working Group — S. Deering
Request for Comments: 2460 — Cisco
Obsoletes: 1883 — R. Hinden
Category: Standards Track — Nokia
December 1998

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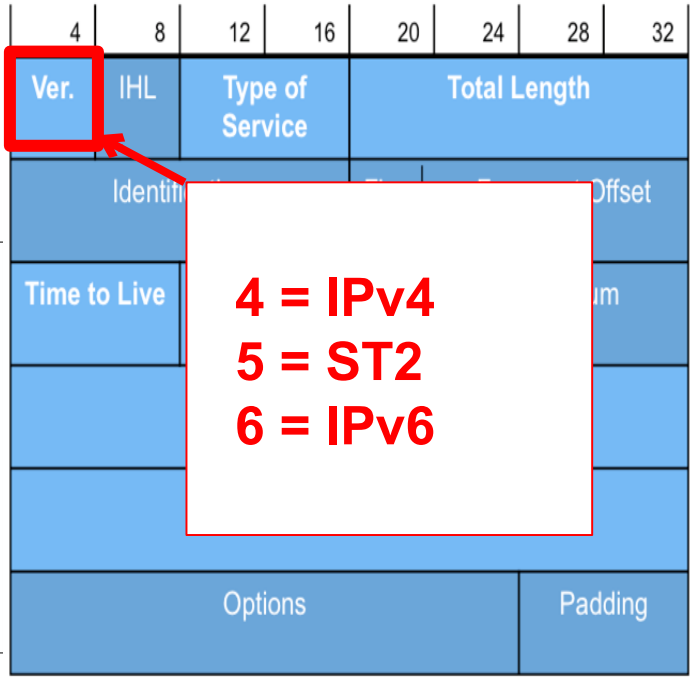
- 1993, IETF announced a call for white papers with RFC 1550 *IP: Next Generation (IPng) White Paper Solicitation*.
- IETF chose Simple Internet Protocol Plus (SIPP) written by Steve Deering, Paul Francis, and Bob Hinden but changed the address size from 64 bits to 128 bits.
- 1995, IETF published RFC 1883 Internet Protocol, Version 6 (IPv6) Specification - later obsoleted by RFC 2460 in 1998.

RFC 1190

What About IPv5?

The ST packet header is not constrained to be compatible with the IP packet header, except for the IP Version Number (the first four bits) that is used to distinguish ST packets (IP Version 5) from IP packets (IP Version 4). The ST packets, or protocol data units (PDUs), can be encapsulated in IP either to provide connectivity (possibly with degraded service) across portions of an internet that do not provide support for ST, or to allow access to services such as security that are not provided directly by ST.



- In the late 1970s, a family of experimental protocols was developed intended to provide quality of service (QoS) for real-time multimedia applications such video and voice.
- Known as Internet Stream Protocol (ST) and later ST2 – (RFC 1190 and RFC 1819).
- Although it was never known as IPv5, when encapsulated in IP, ST uses IP Protocol version 5.

The Need for IPv6

- We are running out of IPv4 address space.
- Monday, January 31, 2011 IANA allocated the last /8 IPv4 address blocks to the RIRs.
- RIR's have very few, if any IPv4 address left.
- Many ISPs are severely limited and some have already run out.

Source: www.potaroo.net/tools/ipv4

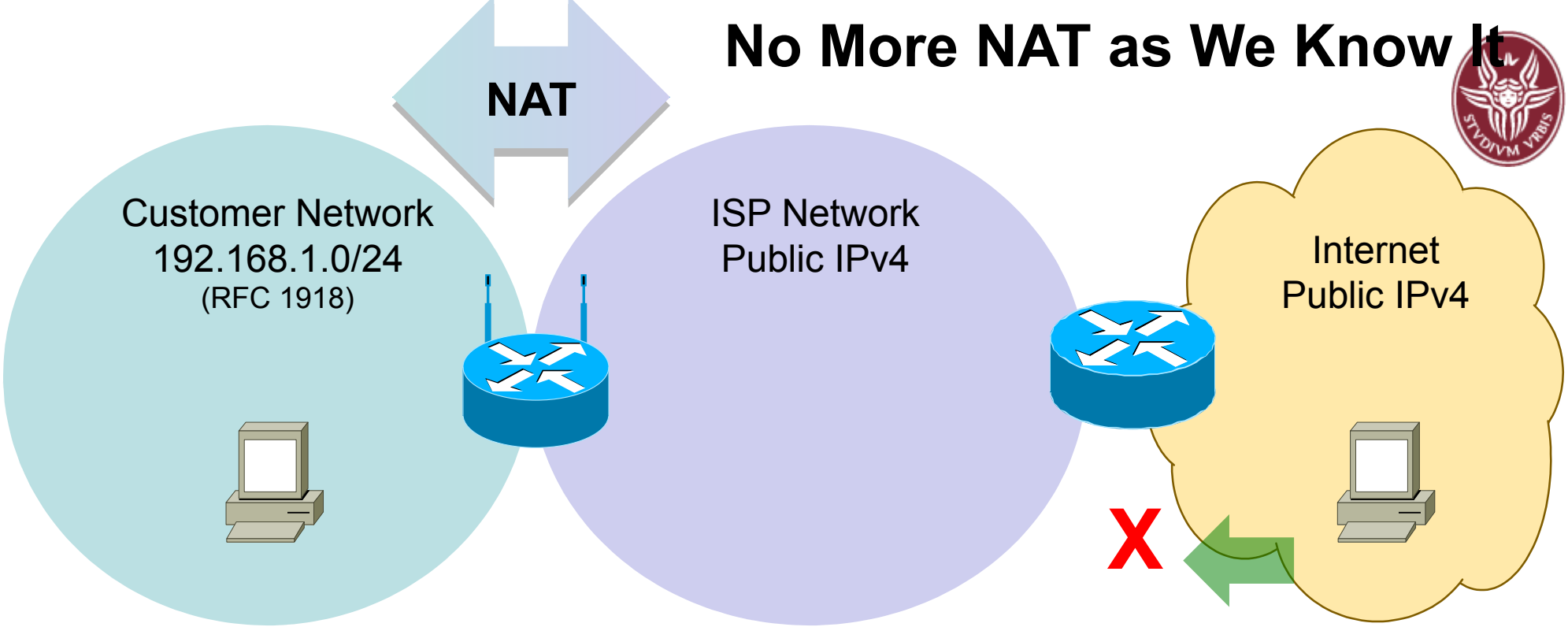
Running Out of IPv4

WORLD INTERNET USAGE AND POPULATION STATISTICS JUNE 30, 2014 - Mid-Year Update						
World Regions	Population (2014 Est.)	Internet Users Dec. 31, 2000	Internet Users Latest Data	Penetration (% Population)	Growth 2000-2014	Users % of Table
Africa	1,125,721,038	4,514,400	297,885,898	26.5 %	6,498.6 %	9.8 %
Asia	3,996,408,007	114,304,000	1,386,188,112	34.7 %	1,112.7 %	45.7 %
Europe	825,824,883	105,096,093	582,441,059	70.5 %	454.2 %	19.2 %
Middle East	231,588,580	3,284,800	111,809,510	48.3 %	3,303.8 %	3.7 %
North America	353,860,227	108,096,800	310,322,257	87.7 %	187.1 %	10.2 %
Latin America / Caribbean	612,279,181	18,068,919	320,312,562	52.3 %	1,672.7 %	10.5 %
Oceania / Australia	36,724,649	7,620,480	26,789,942	72.9 %	251.6 %	0.9 %
WORLD TOTAL	7,182,406,565	360,985,492	3,035,749,340	42.3 %	741.0 %	100.0 %

- The regions with the largest populations have the lowest percentages of people connected to the Internet

Graphic from Internet World Stats, www.internetworldstats.com/stats.htm

No More NAT as We Know It



- NAT has been used to help “hide” customers and works for many client-initiated applications.
- However, NAT also creates some issues, like peer-to-peer networking and accessing our “hidden” systems from other networks.
- Using NAT to “hide” IPv6 networks has been the source of some debate.
- IETF continues to state that NAT is not a security feature.

Benefits of IPv6

The benefits of IPv6 include:

- Larger address space
- Stateless autoconfiguration
- End-to-end reachability without private addresses and NAT
- Better mobility support
- Peer-to-peer networking easier to create and maintain, and services such as VoIP and Quality of Service (QoS) become more robust.
- The “killer application” for the Internet is the Internet itself.

Graphic from IPv6 Forum, www.ipv6ready.org

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Hex and IPv6 Address Representation

The Beauty of Hexadecimal: 4 bits = 1 hex digit

Dec	Hex	Binary 8421	Dec	Hex	Binary 8421
0	0	0000	8	8	1000
1	1	0001	9	9	1001
2	2	0010	10	A	1010
3	3	0011	11	B	1011
4	4	0100	12	C	1100
5	5	0101	13	D	1101
6	6	0110	14	E	1110
7	7	0111	15	F	1111

IPv6 Address Notation

Dec.	Hex.	Binary	Dec.	Hex.	Binary
0	0	0000	8	8	1000
1	1	0001	9	9	1001
2	2	0010	10	A	1010
3	3	0011	11	B	1011
4	4	0100	12	C	1100
5	5	0101	13	D	1101
6	6	0110	14	E	1110
7	7	0111	15	F	1111

2001:0DB8:AAAA:1111:0000:0000:0000:0100

2001 : 0DB8 : AAAA : 1111 : 0000 : 0000 : 0000 : 0100

16 bits 1 | 16 bits 2 | 16 bits 3 | 16 bits 4 | 16 bits 5 | 16 bits 6 | 16 bits 7 | 16 bits 8

IPv6 addresses are 128-bit addresses represented in:

- Hexadecimal: 1 hex digit = 4 bits
- Eight 16-bit segments or “hextets” (not a formal term) between 0000 and FFFF
- Separated by colons
- Reading and subnetting IPv6 is easier than IPv4…. Almost always!

Number of IPv6 Addresses

Number name	Scientific Notation	Number of zeros
1 Thousand	10^{3}	1,000
1 Million	10^{6}	1,000,000
1 Billion	10^{9}	1,000,000,000
1 Trillion	10^{12}	1,000,000,000,000
1 Quadrillion	10^{15}	1,000,000,000,000,000
1 Quintillion	10^{18}	1,000,000,000,000,000,000
1 Sextillion	10^{21}	1,000,000,000,000,000,000,000
1 Septillion	10^{24}	1,000,000,000,000,000,000,000,000
1 Octillion	10^{27}	1,000,000,000,000,000,000,000,000,000
1 Nonillion	10^{30}	1,000,000,000,000,000,000,000,000,000,000
1 Decillion	10^{33}	1,000,000,000,000,000,000,000,000,000,000,000
1 Undecillion	10^{36}	1,000,000,000,000,000,000,000,000,000,000,000,000
340,282,366,920,938,463,463,374,607,431,768,211,456		

IPv4
4.3 billion

IPv4 addresses:
- **4.3 billion**

IPv6 addresses:
- **340 undecillion**

IPv6
340 undecillion

Two Rules for Compressing IPv6 Addresses
Rule 1: Omitting Leading 0s

- Two rules for reducing the size of written IPv6 addresses.
- **First rule:** Leading zeroes in any 16-bit segment do not have to be written.
- ***Only*** leading 0s can be excluded, trailing 0s must be included.

`2001 : 0DB8 : 0001 : 1000 : 0000 : 0000 : 0ef0 : bc00`

`2001 : 0DB8 : 010d : 000a : 00dd : c000 : e000 : 0001`

`2001 : 0DB8 : 0000 : 0000 : 0000 : 0000 : 0000 : 0500`

Two Rules for Compressing IPv6 Addresses
Rule 1: Omitting Leading 0s

- Two rules for reducing the size of written IPv6 addresses.
- **First rule:** Leading zeroes in any 16-bit segment do not have to be written.
- ***Only*** leading 0s can be excluded, trailing 0s must be included.

```
2001 : 0DB8 : 0001 : 1000 : 0000 : 0000 : 0ef0 : bc00
2001 :  DB8 :    1 : 1000 :    0 :    0 :  ef0 : bc00

2001 : 0DB8 : 010d : 000a : 00dd : c000 : e000 : 0001
2001 :  DB8 :  10d :    a :   dd : c000 : e000 :    1

2001 : 0DB8 : 0000 : 0000 : 0000 : 0000 : 0000 : 0500
2001 :  DB8 :    0 :    0 :    0 :    0 :    0 :  500
```

Two Rules for Compressing IPv6 Addresses
Rule 2: Double Colon ::

- The second rule can reduce this address even further:
- **Second rule:** Any single, contiguous string of one or more 16-bit segments consisting of all zeroes can be represented with a double colon (::).

```
2001 : 0DB8 : 1000 : 0000 : 0000 : 0000 : 0000 : 0001
```

Two Rules for Compressing IPv6 Addresses
Rule 2: Double Colon ::

- The second rule can reduce this address even further:
- **Second rule:** Any single, contiguous string of one or more 16-bit segments consisting of all zeroes can be represented with a double colon (::).

Second rule

```
2001 : 0DB8 : 1000 : 0000 : 0000 : 0000 : 0000 : 0001
2001 :  DB8 : 1000 :                      :      1
```

Two Rules for Compressing IPv6 Addresses
Rule 2: Double Colon ::

- The second rule can reduce this address even further:
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First rule

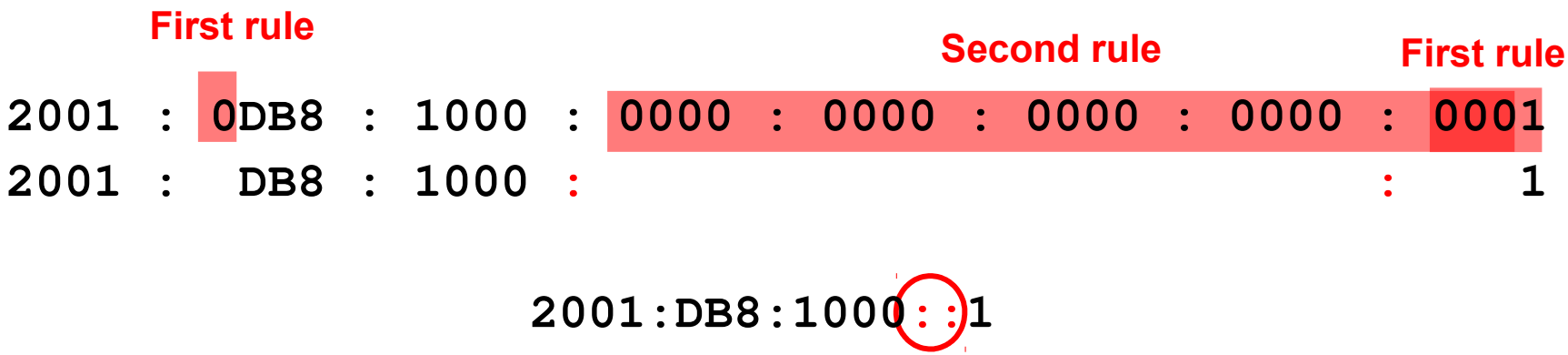
Second rule

First rule

```
2001 : 0DB8 : 1000 : 0000 : 0000 : 0000 : 0000 : 0001
2001 :  DB8 : 1000 :                      :      1
```

Two Rules for Compressing IPv6 Addresses
Rule 2: Double Colon ::

- **Second rule:** Any single, contiguous string of one or more 16-bit segments consisting of all zeroes can be represented with a double colon (::).



If there are multiple possible reductions, RFC 5952 states that **the longest** string of zeroes must be replaced with the :: and if they are equal then only **the first string of 0's** should use the :: representation.

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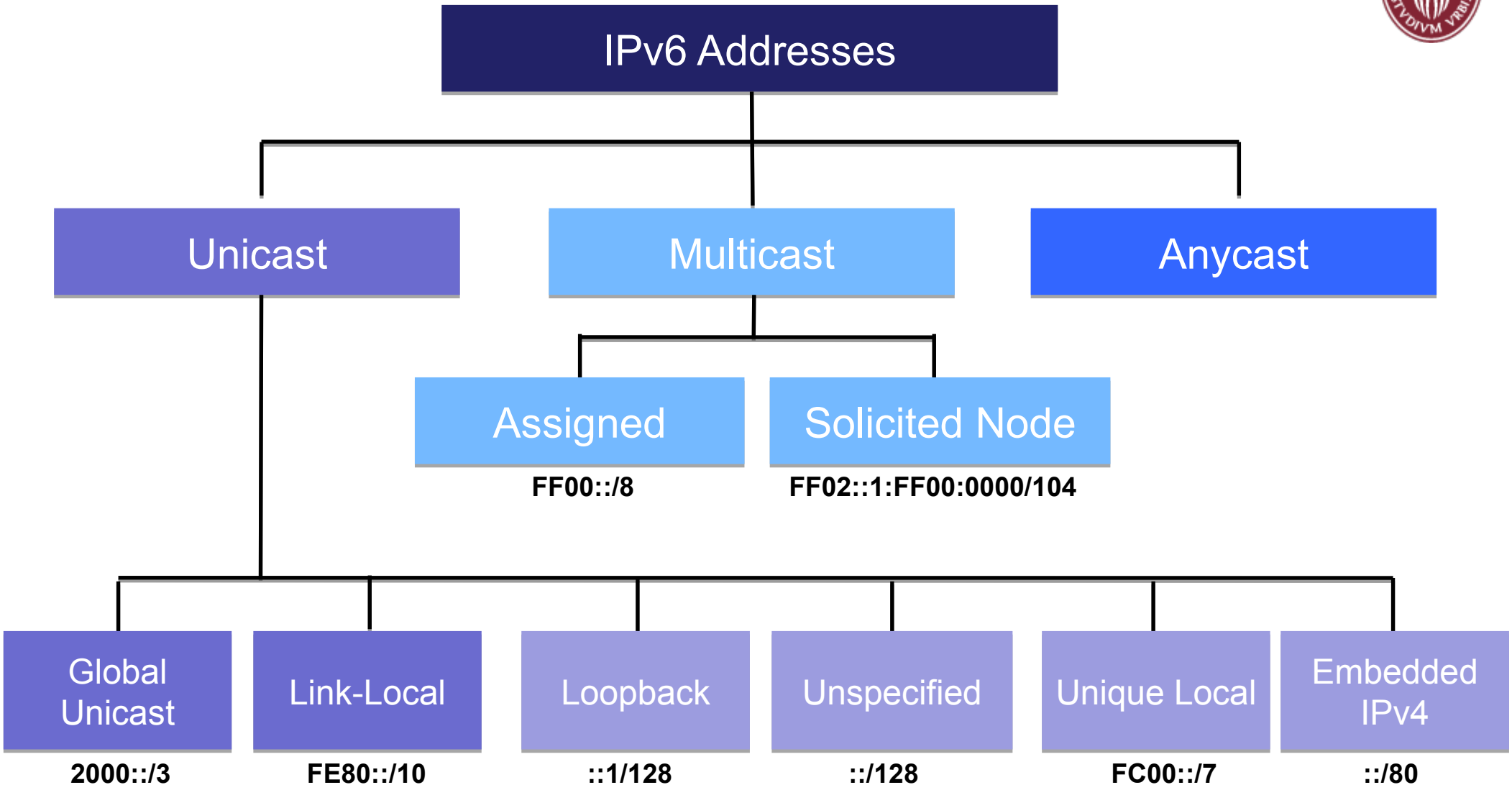
IPv6 Global Unicast Address

The equivalent of public IPv4 address

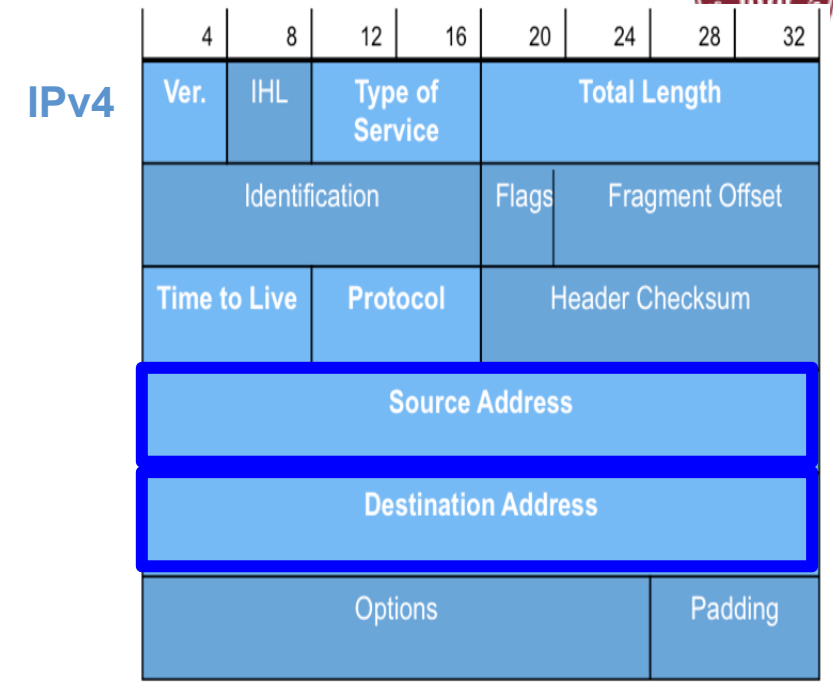
IPv6 Address Types

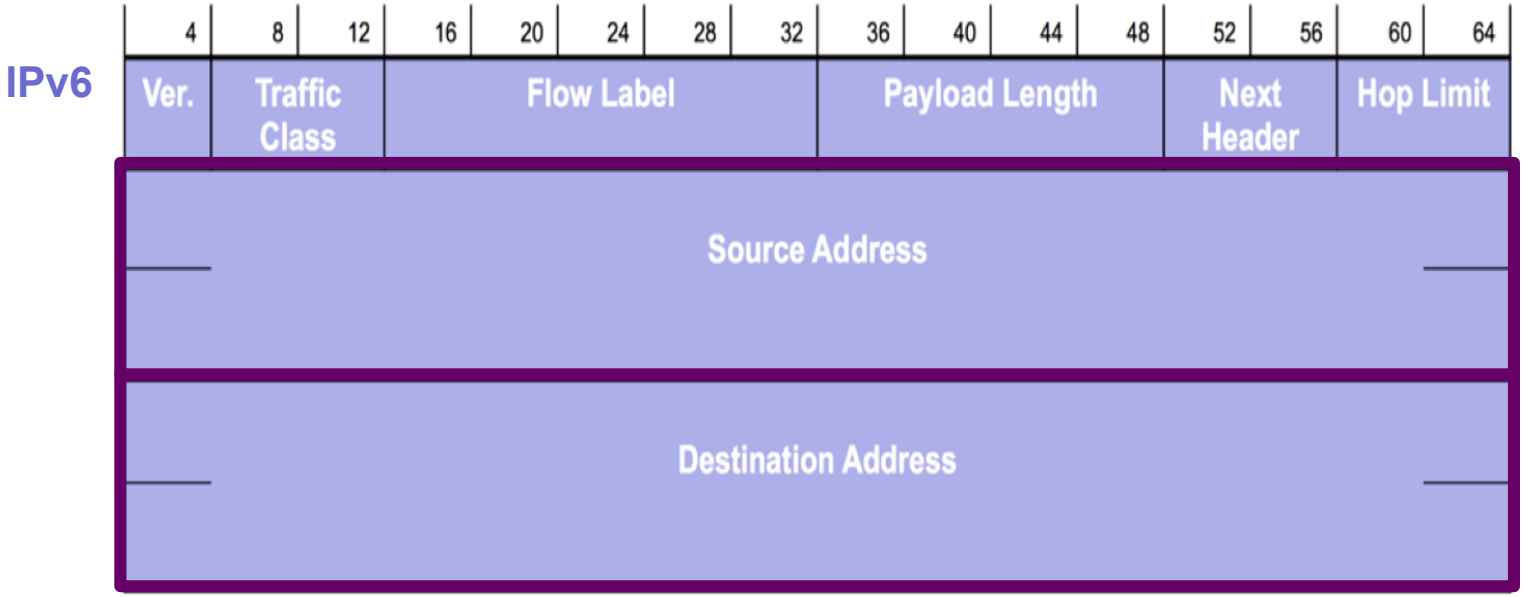


IPv6 does not have a "broadcast" address.

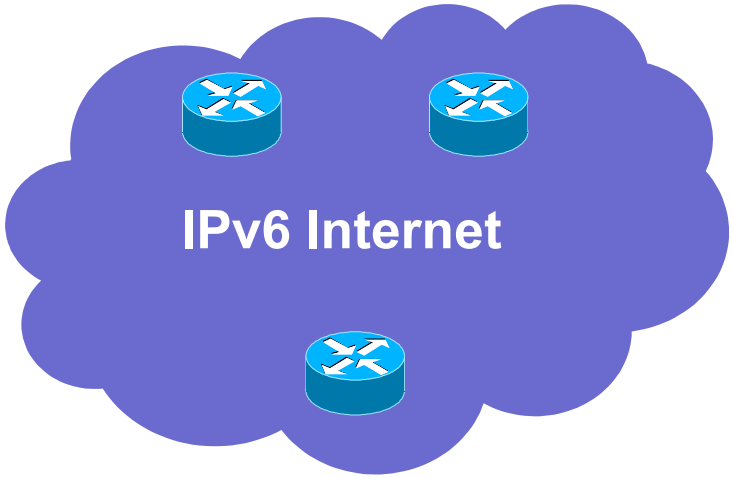
IPv6 Source and Destination Addresses

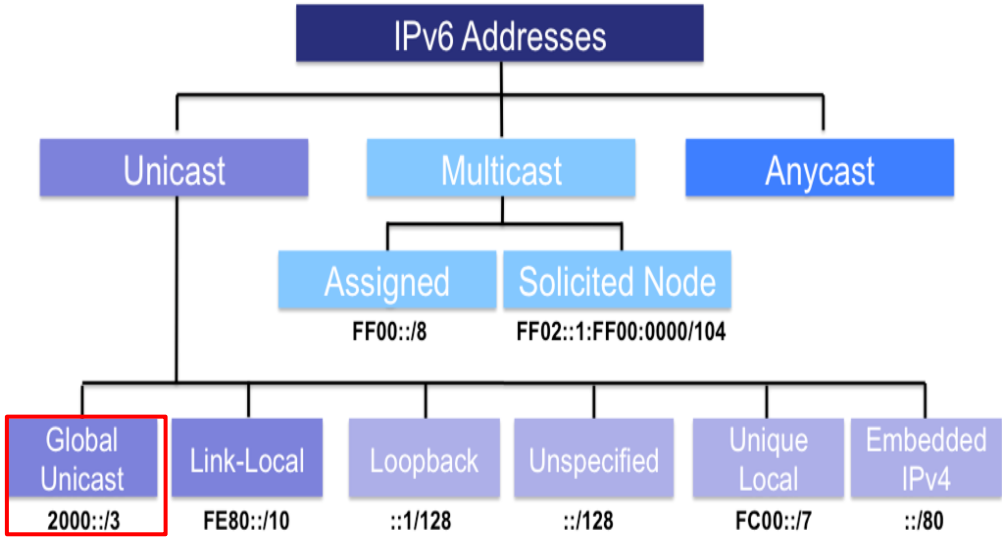
- **IPv6 Source** – Always a unicast (link-local or GUA)
- **IPv6 Destination** – Unicast, multicast, or anycast.





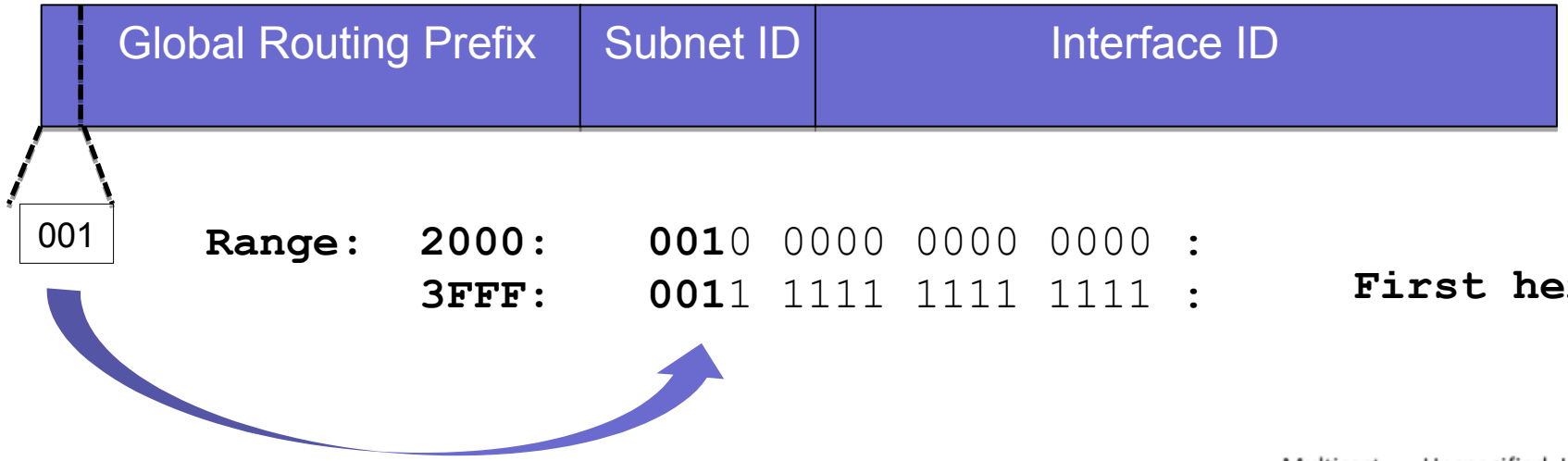
Global Unicast Address



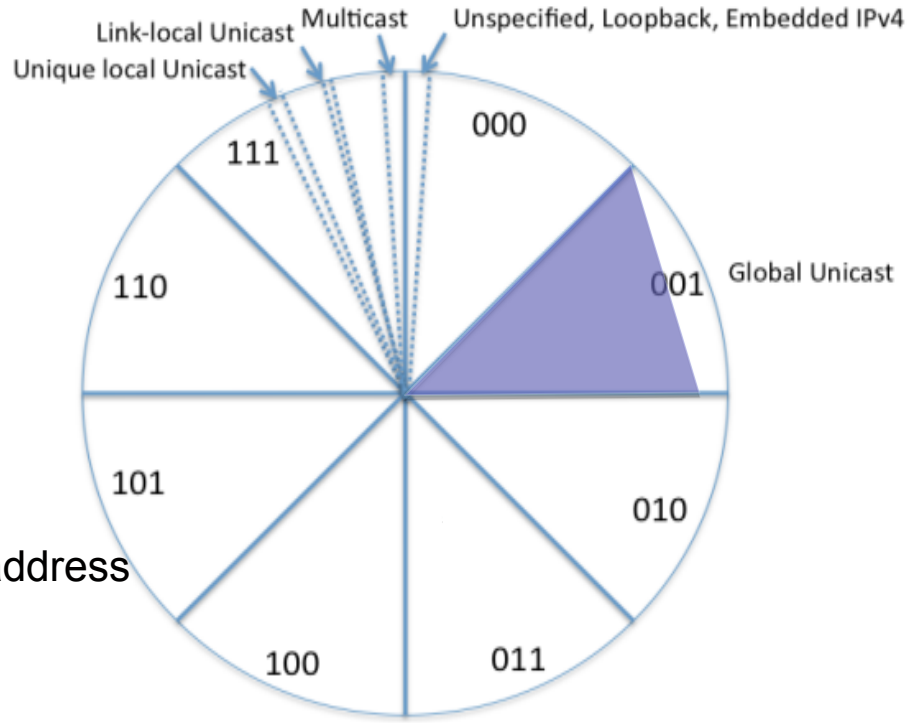


- **Global Unicast Address (GUA)**
  - 2000::/3 (First hextet: 2000::/3 to 3FFF::/3)
  - Globally unique and routable
  - Similar to public IPv4 addresses
  - 2001:DB8::/32 - RFC 2839 and RFC 6890 reserves this range of addresses for documentation
  - These are the addresses we will be referring to the most.

Global Unicast Address Range



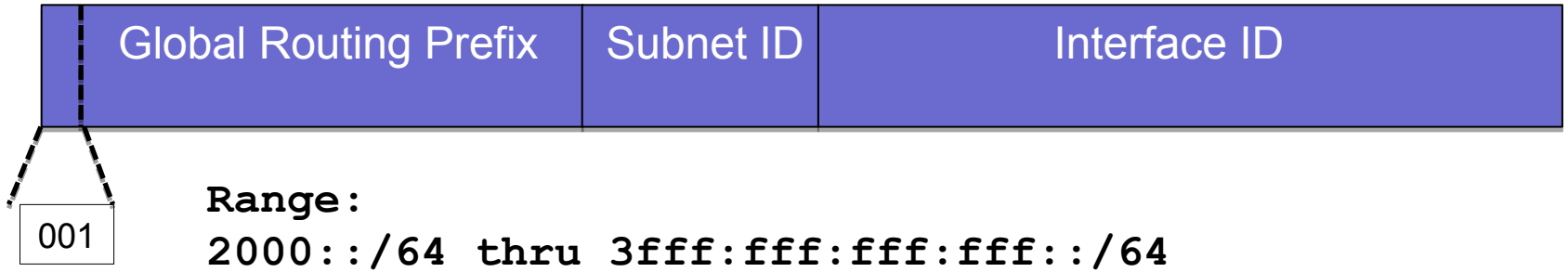
- **Global Unicast Address (GUA)**
  - 2000::/3
  - Range 2000::/64 thru 3fff:ffff:ffff:ffff::/64
  - 1/8th of IPv6 address space



IANA's allocation of IPv6 address space in 1/8th sections

The remaining portion of IPv6 address space are reserved by IETF for future use.

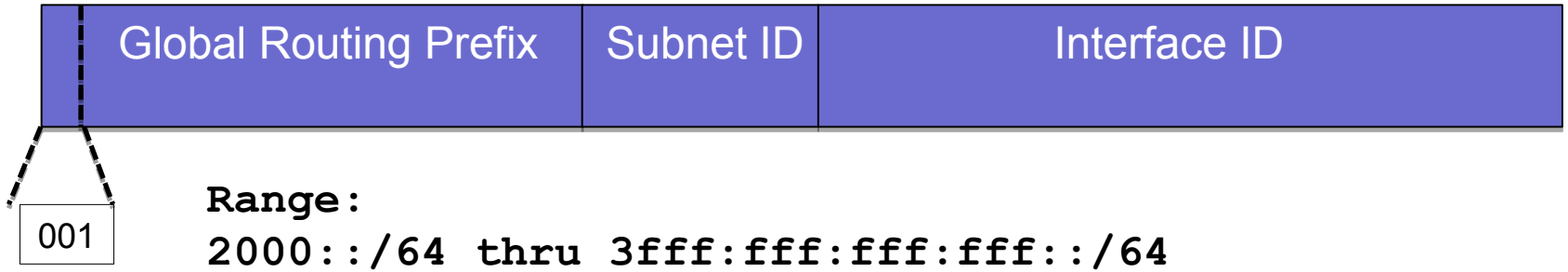
Global Unicast Address Range



Range:
2000::/64 thru 3fff:fff:fff:fff::/64

- Except under very specific circumstances, all end users will have a global unicast address.

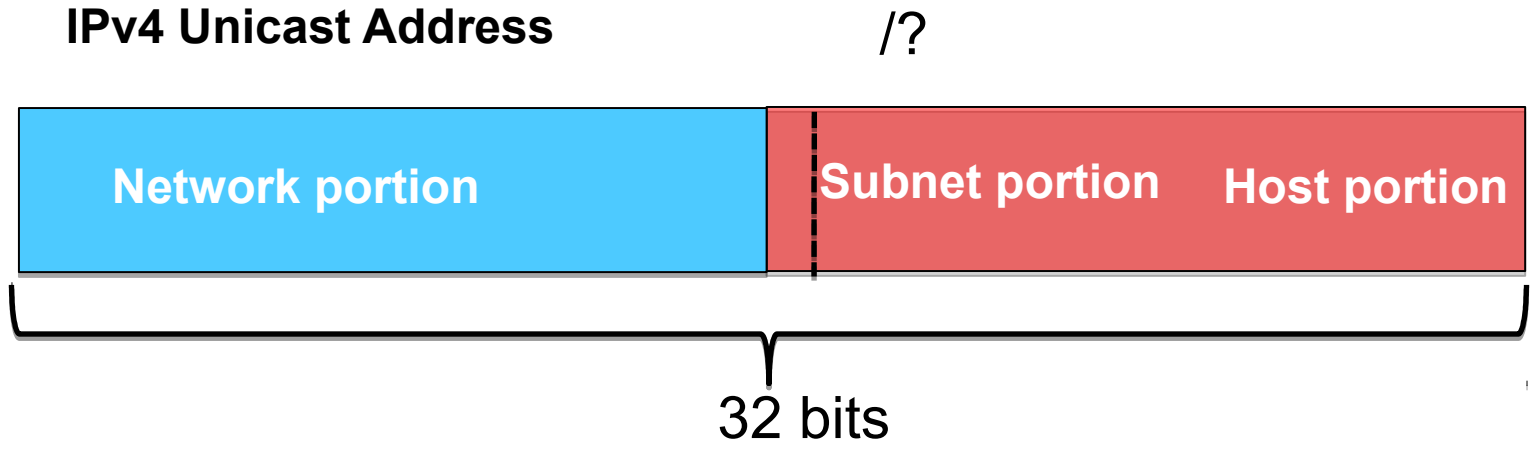
Global Unicast Address Range

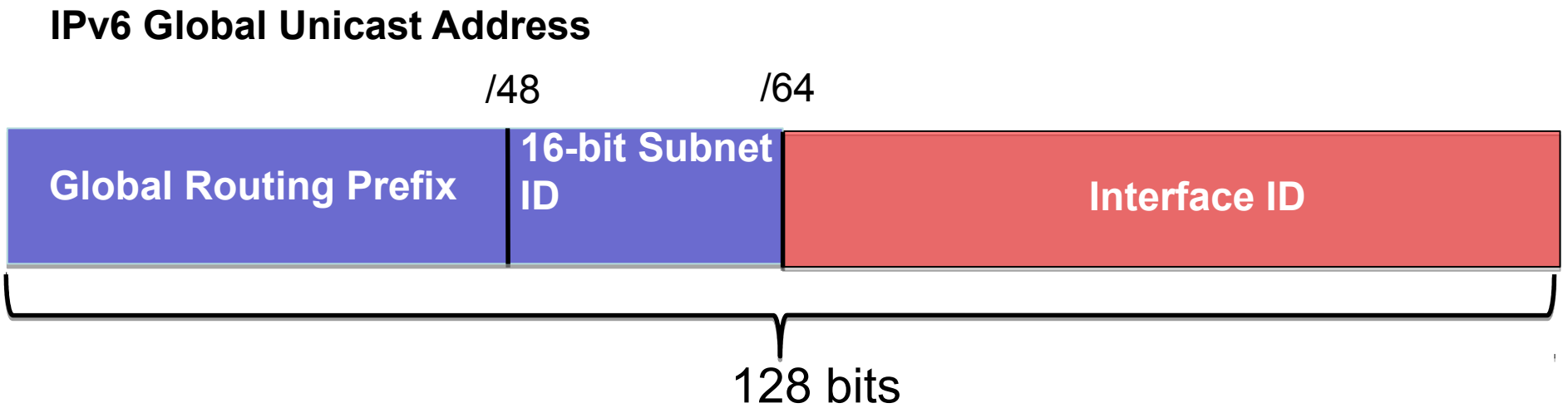



```
Range:
2000::/64 thru 3fff:fff:fff:fff::/64
```

- Except under very specific circumstances, all end users will have a global unicast address.
  - **Note**: A host (an interface) can potentially have multiple IPv6 addresses on the same or different networks.
- Terminology:
  - **Prefix** equivalent to the *network address of an IPv4 address*
  - **Prefix length** equivalent to *subnet mask in IPv4*
  - **Interface ID** equivalent to *host portion of an IPv4 address*

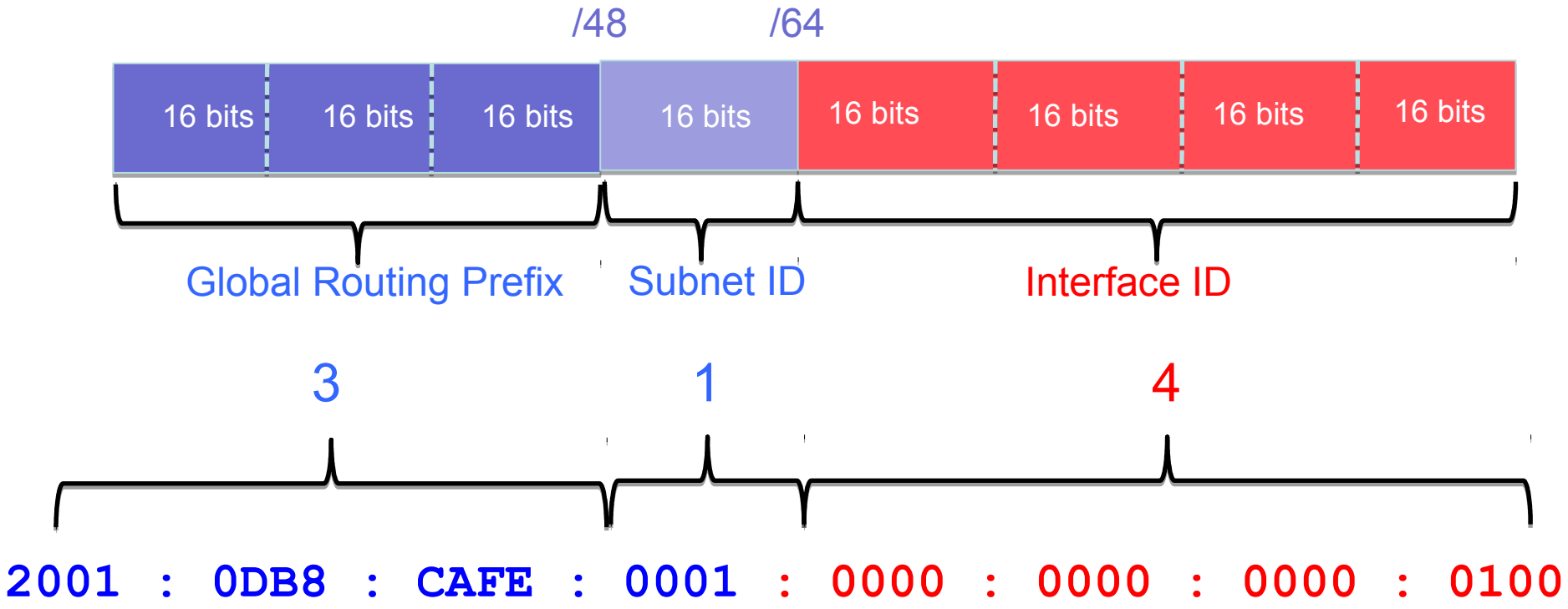
Parts of a Global Unicast Address



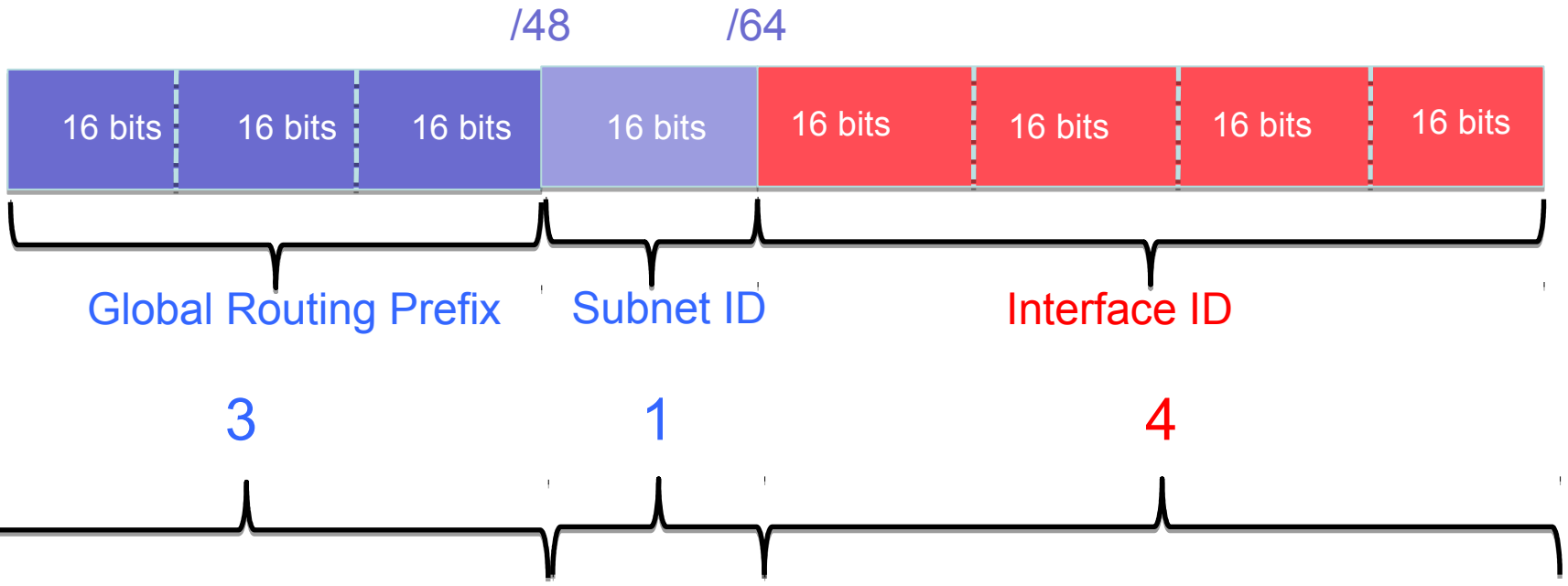


- 64-bit Interface ID = 18 quintillion (18,446,744,073,709,551,616) devices/subnet
- 16-bit Subnet ID (initially recommended) = 65,536 subnets

/64 Global Unicast Address and the 3-1-4 Rule



/64 Global Unicast Address and the 3-1-4 Rule

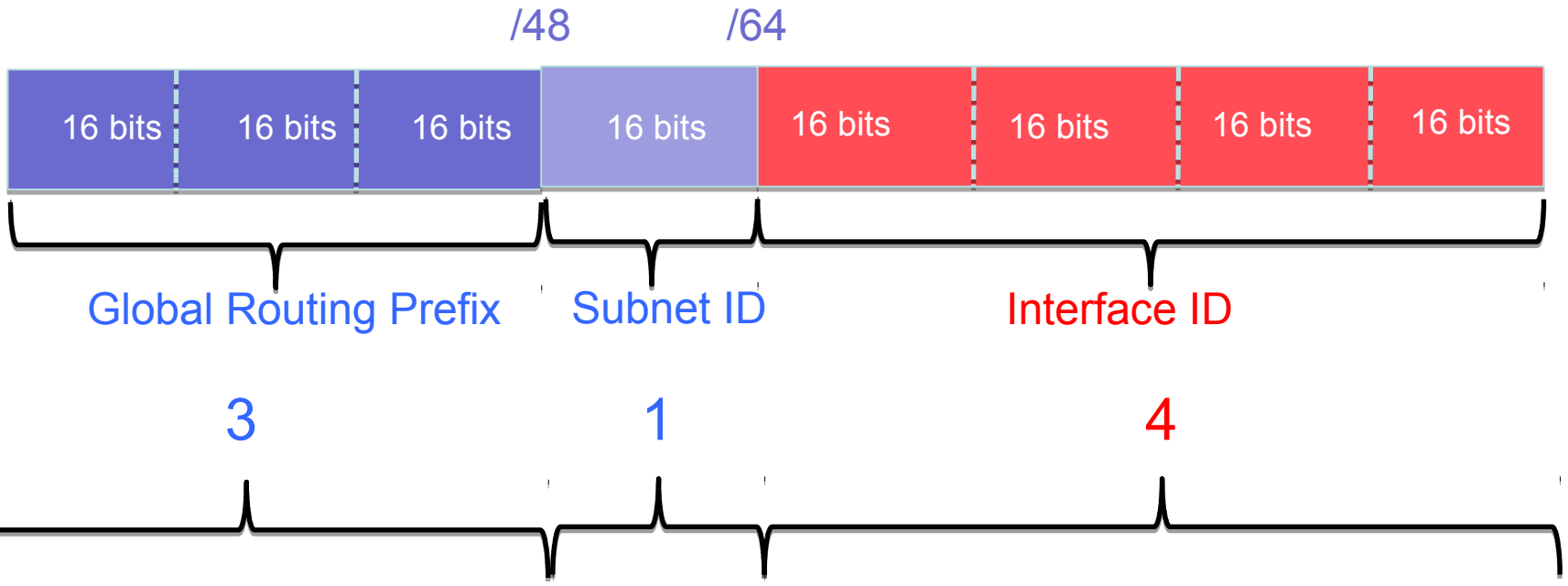


2001 : 0DB8 : CAFE : 0001 : 0000 : 0000 : 0000 : 0100

3 + 1 = 4 (/64) : 4

2001:0DB8:CAFE:0001:0000:0000:0000:0100/64

/64 Global Unicast Address and the 3-1-4 Rule



2001 : 0DB8 : CAFE : 0001 : 0000 : 0000 : 0000 : 0100

3 + 1 = 4 (/64) : 4

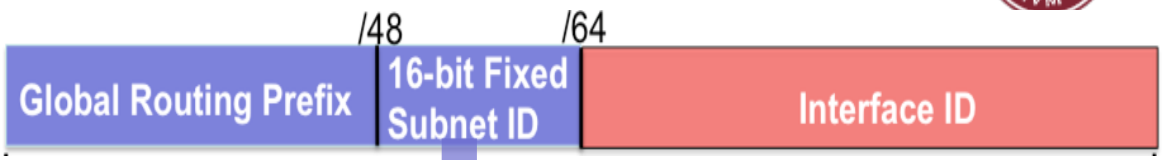
2001:0DB8:CAFE:0001:0000:0000:0000:0100/64

2001:DB8:CAFE:1::100/64

Subnetting IPv6

Can you count in hex?

Just increment by 1 in Hexadecimal



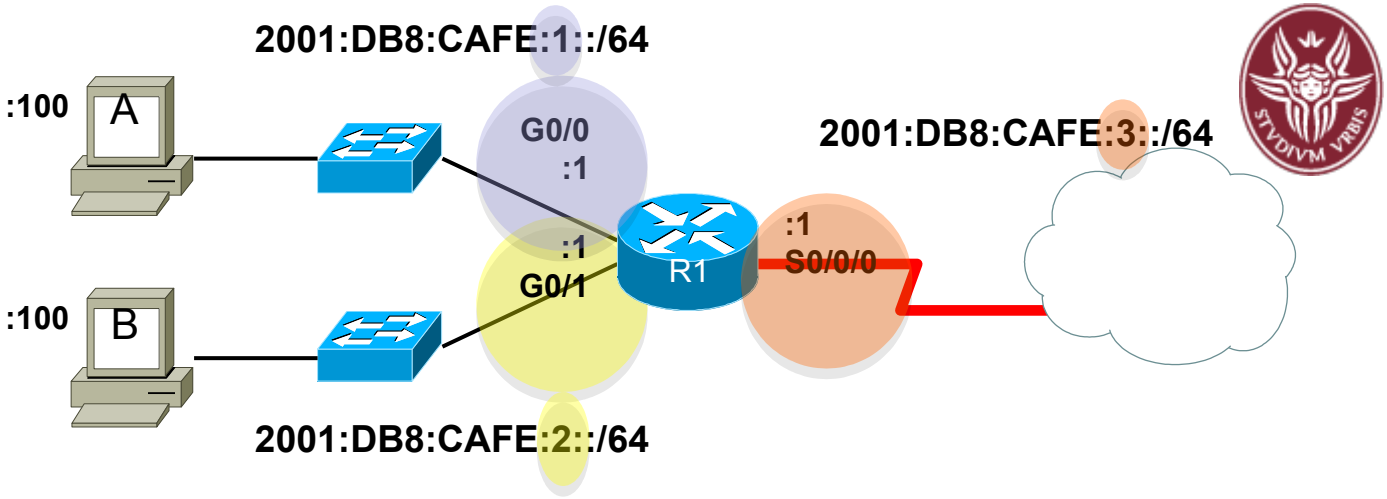

```
2001:0DB8:CAFE:0000::/64
2001:0DB8:CAFE:0001::/64
2001:0DB8:CAFE:0002::/64  ...
2001:0DB8:CAFE:0009::/64
2001:0DB8:CAFE:000A::/64
```

Valid abbreviation is to remove the leading 0s:

```
2001:DB8:CAFE:1::/64
```

3-1-4 Rule

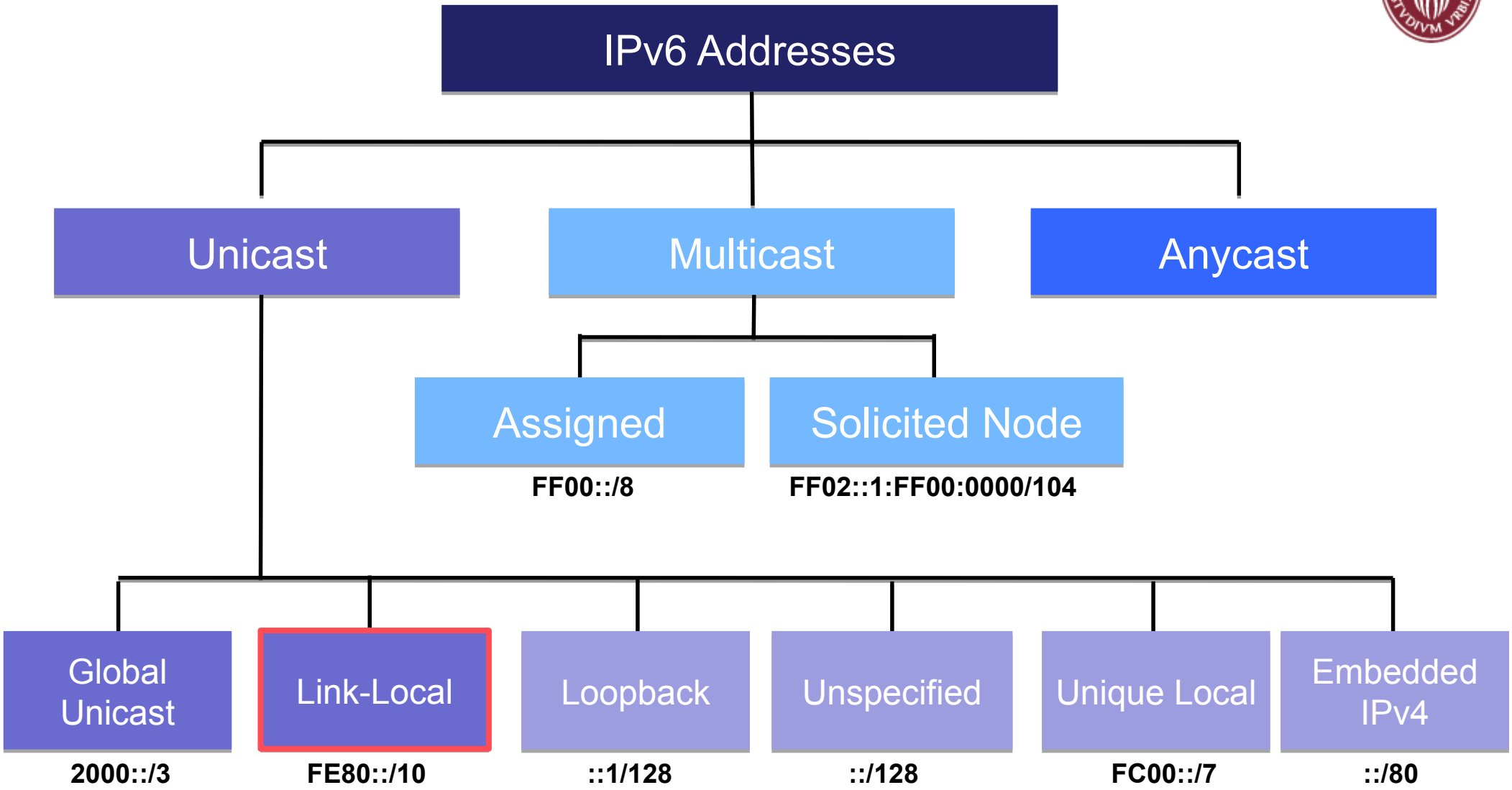
Static GUA Configuration




```
R1(config)#interface gigabitethernet 0/0
R1(config-if)#ipv6 address 2001:db8:cafe:1::1/64
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#interface gigabitethernet 0/1
R1(config-if)#ipv6 address 2001:db8:cafe:2::1/64
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#interface serial 0/0/0
R1(config-if)#ipv6 address 2001:db8:cafe:3::1/64
R1(config-if)#no shutdown
R1(config-if)#exit
```

Link-local Unicast

IPv6 Address Types

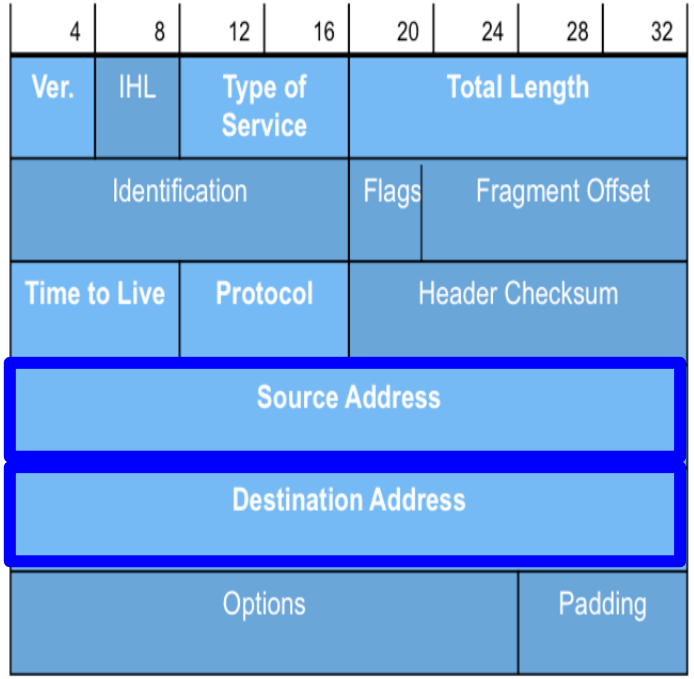


IPv6 does not have a "broadcast" address.

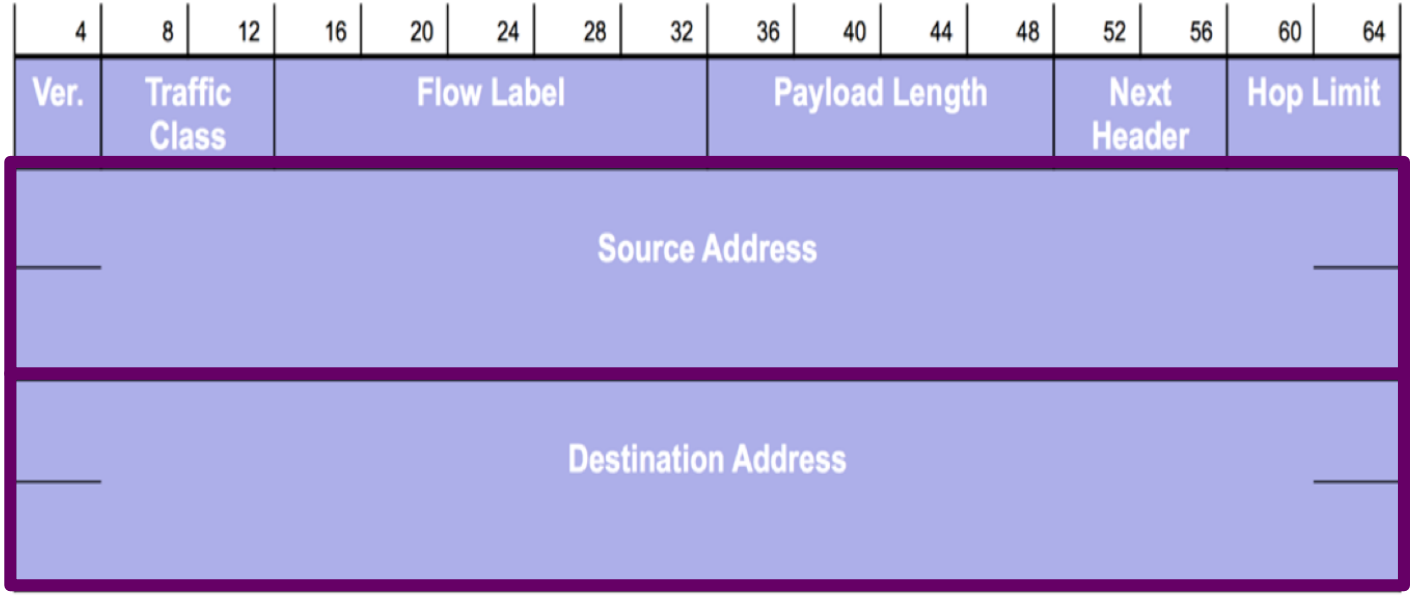
Link-Local Unicast Address

- **IPv6 Source** – Always a unicast
- **IPv6 Destination** – Unicast, multicast, or anycast.
- Unicast, including a ***link-local*** address

IPv4



IPv6



Link-Local Unicast Address

- Used to communicate with other devices on the link.
- Are NOT routable off the link (network).
- ***Only have to be unique on the link.***
- Not included in the IPv6 routing table.
- ***An IPv6 device must have at least a link-local address.***

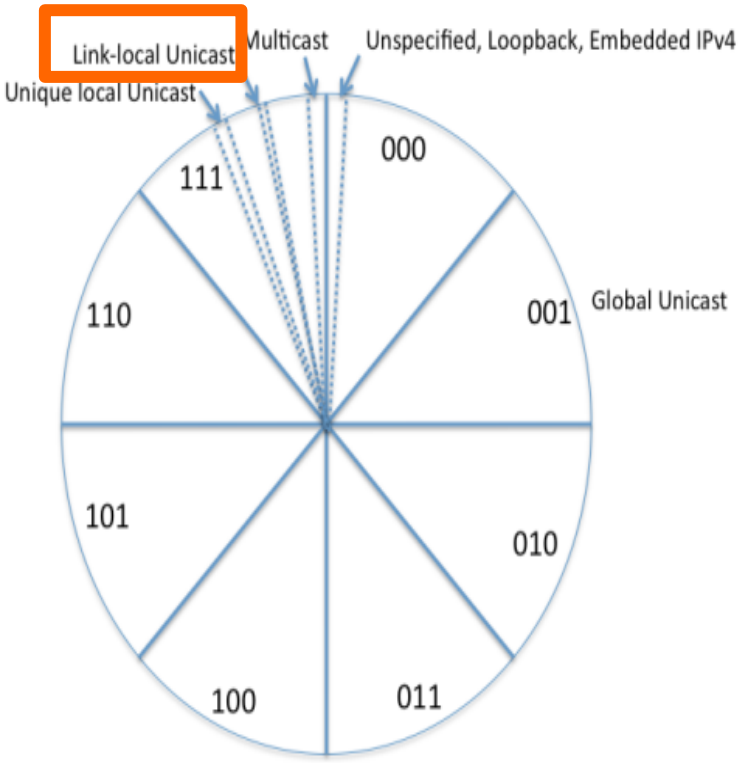
Link-Local Unicast Range

First 10 bits

1111 1110 10xx xxxx	Remaining 54 bits	64-bit Interface ID

Range: **FE80:** **1111 1110 10**00 0000 :
FEBF: **1111 1110 10**11 1111 :

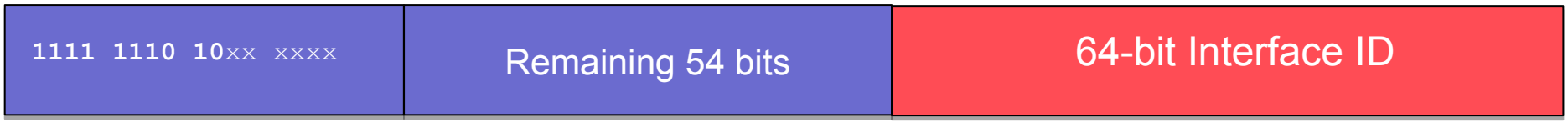
First hextet



The remaining portion of IPv6 address space are reserved by IETF for future use.

- **Link** – Network segment
- Link-local means, local to that link or network.

Link-Local Unicast Address

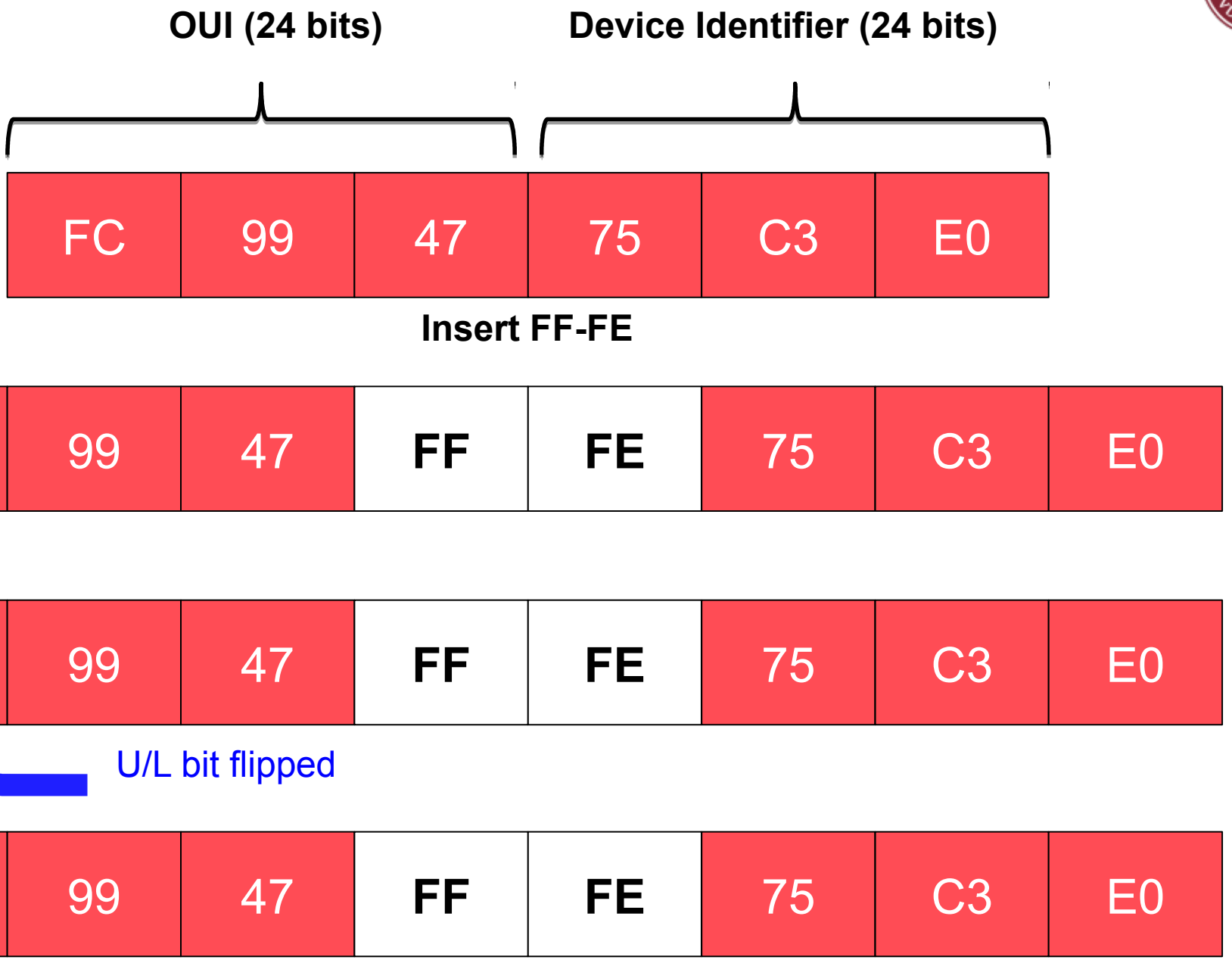


FE80::Interface ID

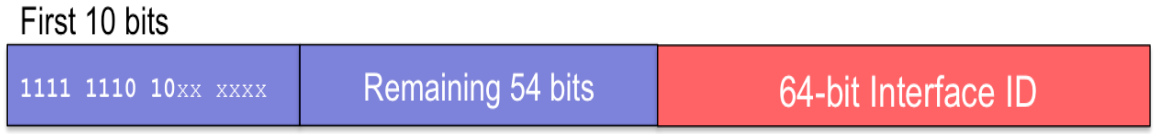
Link-local addresses are created

- **Automatically** :
  - **FE80** (usually) – First 10 bits
  - Interface ID
    - EUI-64 (Cisco routers)
    - Random 64 bits (many host operating systems)
- Static (manual) configuration – Common practice for routers.

Modified EUI-64 Format (Extended Unique Identifier–64)



Verifying the PC's Link-Local Address

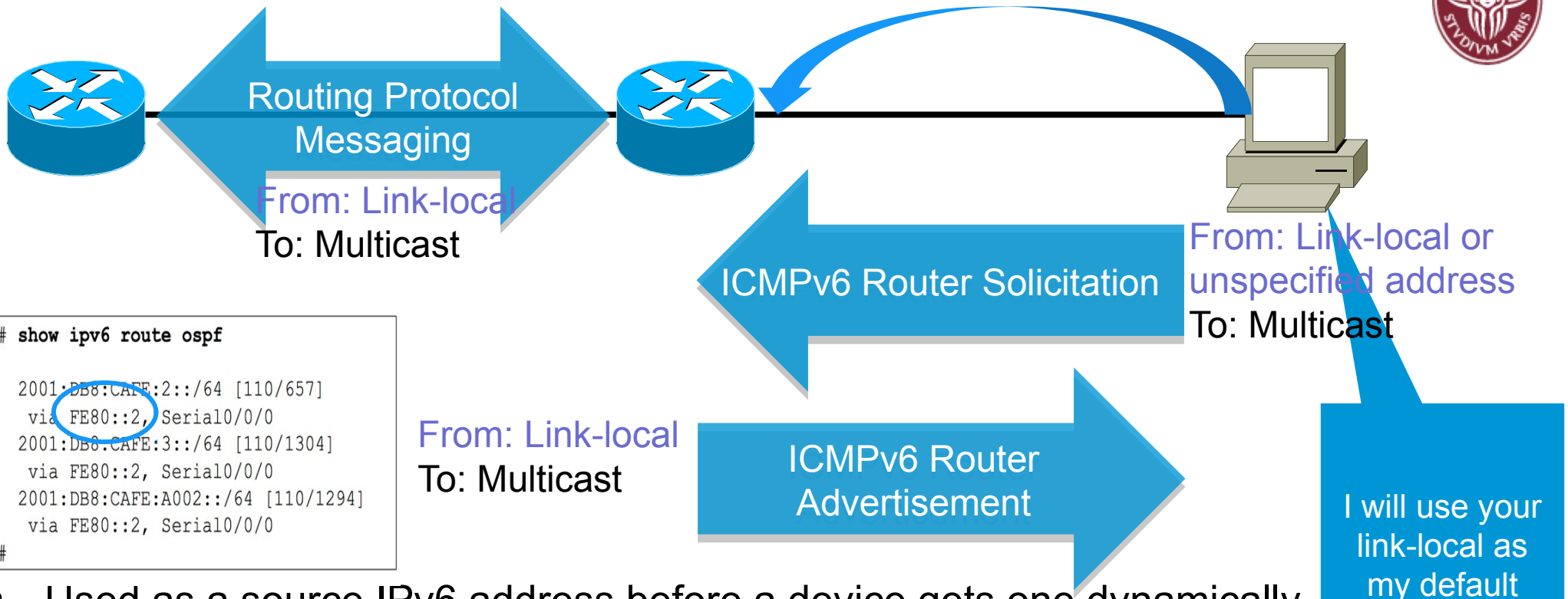


EUI-64 or random 64-bit value

```
PC> ipconfig
Windows IP Configuration
Ethernet adapter Local Area Connection:
   Connection-specific DNS Suffix  :
   Link-local IPv6 Address . . . . : fe80::50a5:8a35:a5bb:66e1
   IPv4 Address. . . . . . . . . . : 192.168.1.101
   Subnet Mask . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . : 192.168.1.1
```

- Many operating systems will use a random 64-bit Interface IDs for GUA and Link-Local IPv6 Addresses.

An Important Role in IPv6




```
R1# show ipv6 route ospf

O   2001:DB8:CAFE:2::/64 [110/657]
     via FE80::2, Serial0/0/0
O   2001:DB8:CAFE:3::/64 [110/1304]
     via FE80::2, Serial0/0/0
O   2001:DB8:CAFE:A002::/64 [110/1294]
     via FE80::2, Serial0/0/0
R1#
```

- Used as a source IPv6 address before a device gets one dynamically (SLAAC and DHCPv6).
  - Router's link-local address is used by devices as the default gateway.
- Routers exchange routing messages.
- Router use the link-local address as the next-hop address in the routing table: via link-local address.

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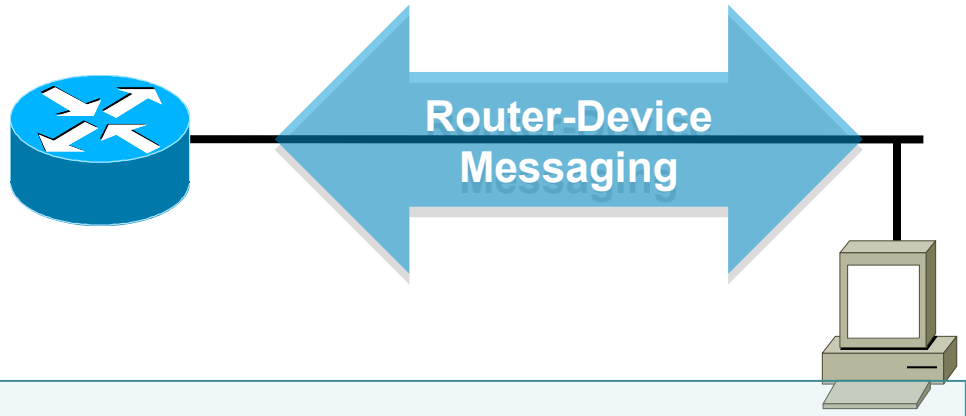
SLAAC
Stateless Address Autoconfiguration

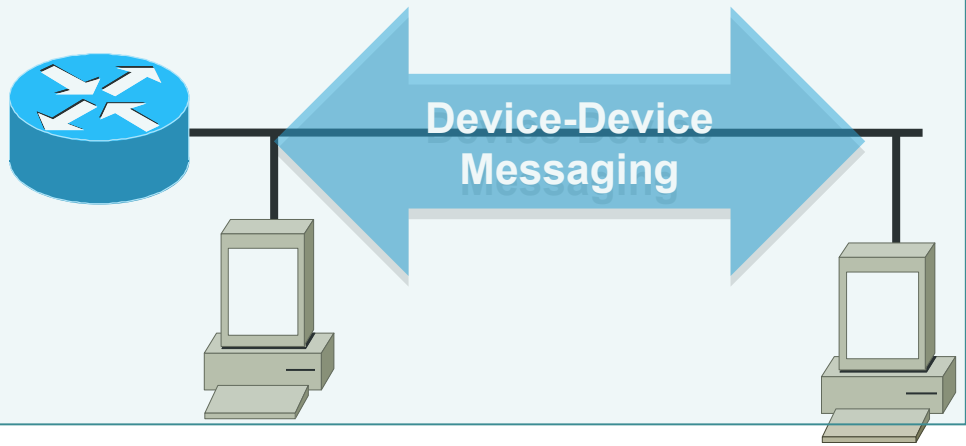
ICMPv6 Neighbor Discover Protocol

ICMPv6 Neighbor Discovery defines 5 different packet types:

- **Router Solicitation Message**
- **Router Advertisement Message**
  Used with dynamic address allocation



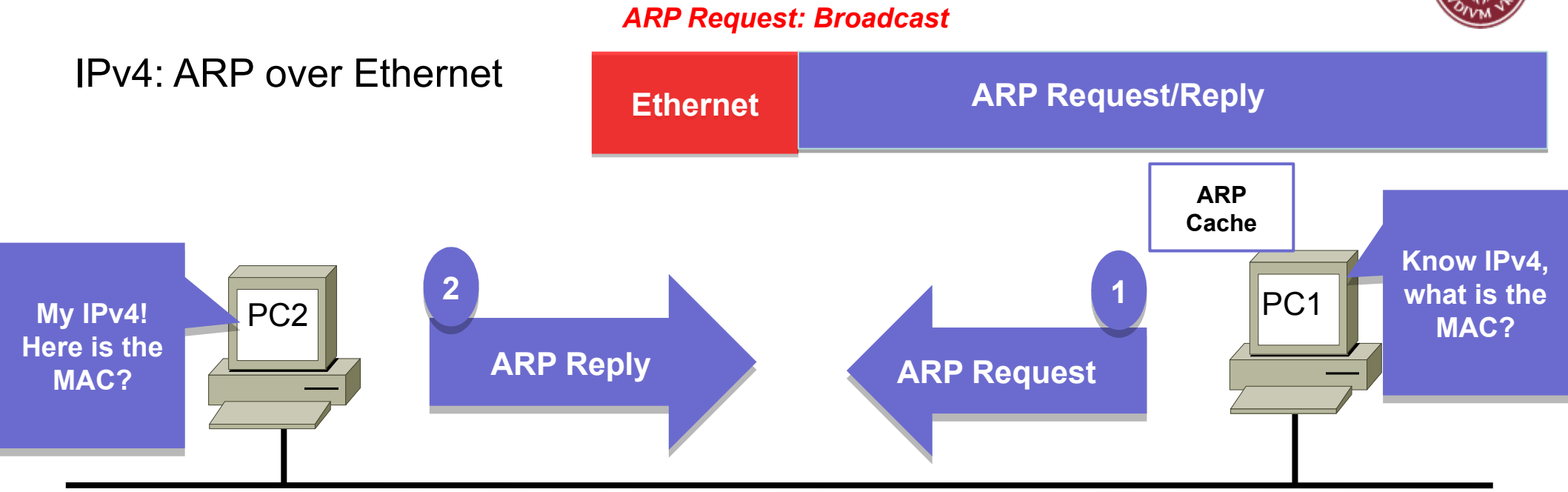
- **Neighbor Solicitation Message**
- **Neighbor Advertisement Message**
  Used with address resolution (IPv4 ARP)



- **Redirect Message**
  Similar to ICMPv4 redirect message
  Router-to-Device messaging

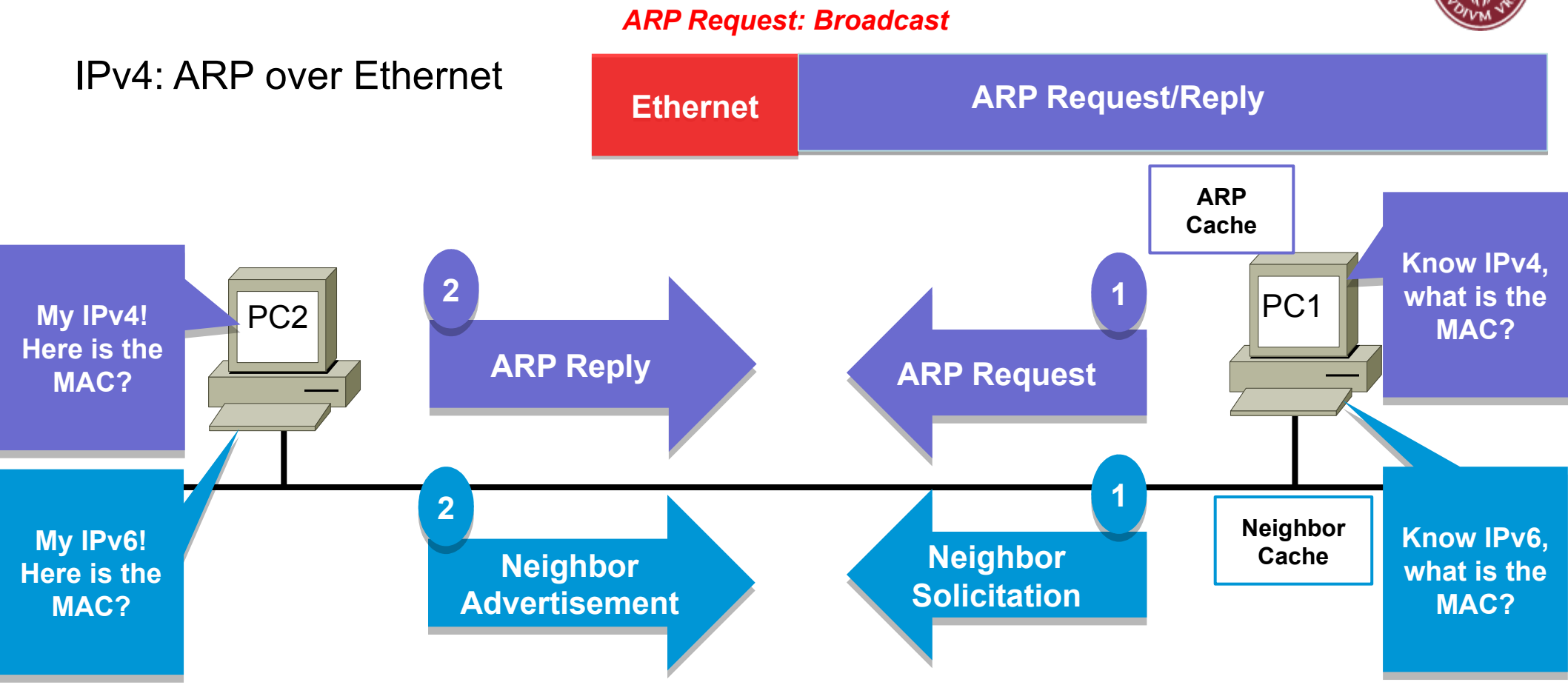
See these processes with:
`R1# debug ipv6 nd`

Address Resolution: IPv4 and IPv6



Address Resolution: IPv4 and IPv6

IPv4: ARP over Ethernet

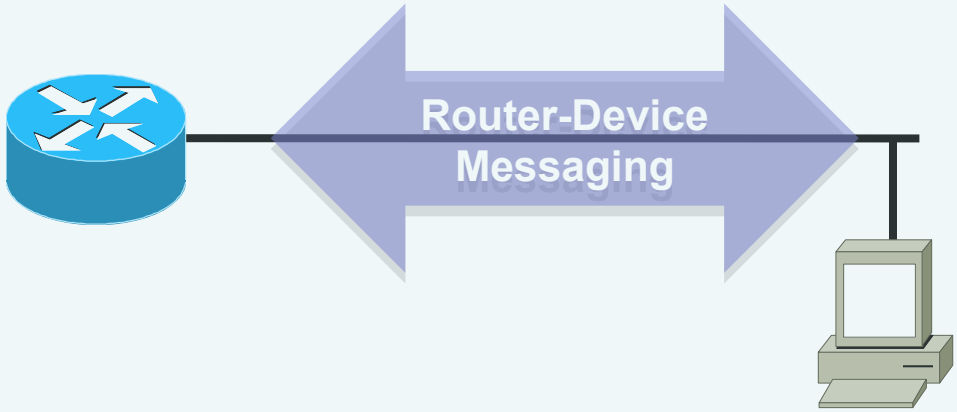


IPv6: ICMPv6 over IPv6 over Ethernet

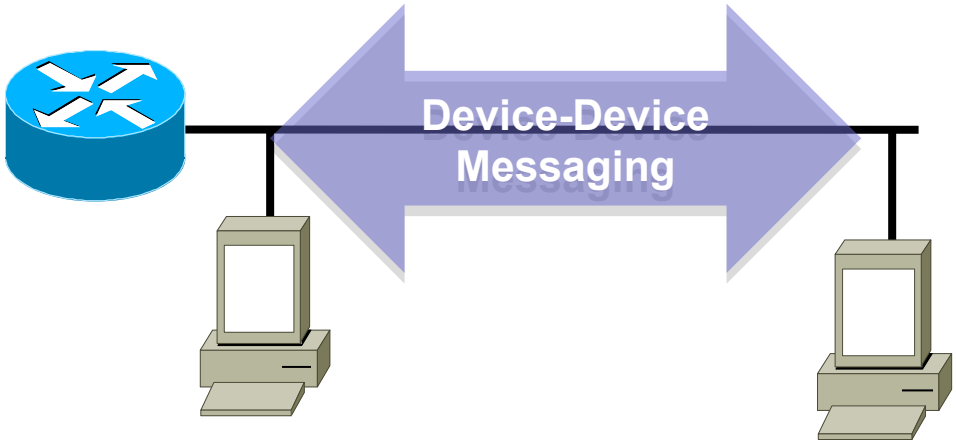
Router Solicitation & Router Advertisement Messages

ICMPv6 Neighbor Discovery defines 5 different packet types:

- **Router Solicitation Message**
- **Router Advertisement Message**
  Used with dynamic address allocation

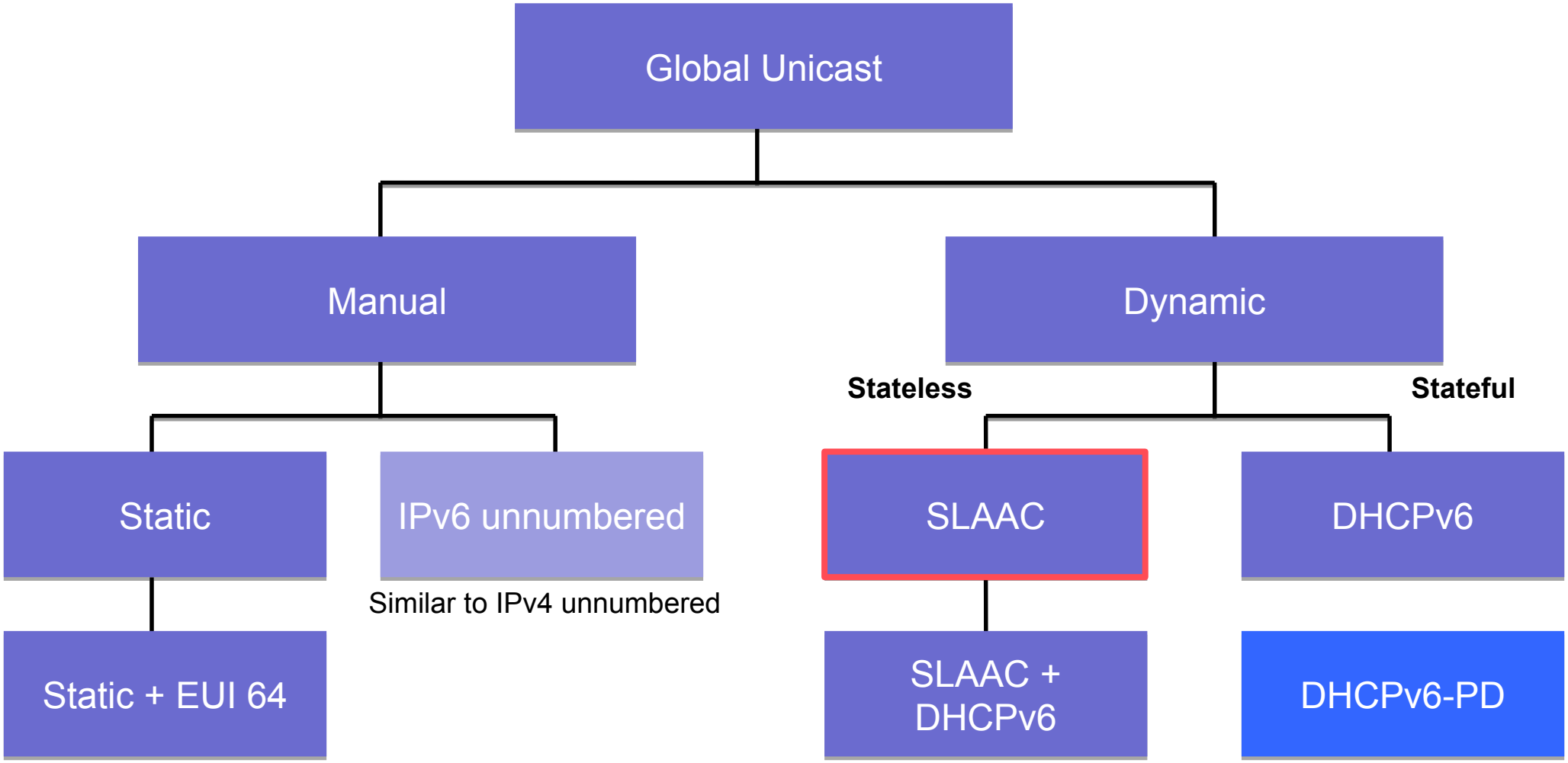


- **Neighbor Solicitation Message**
- **Neighbor Advertisement Message**
  Used with address resolution (IPv4 ARP)

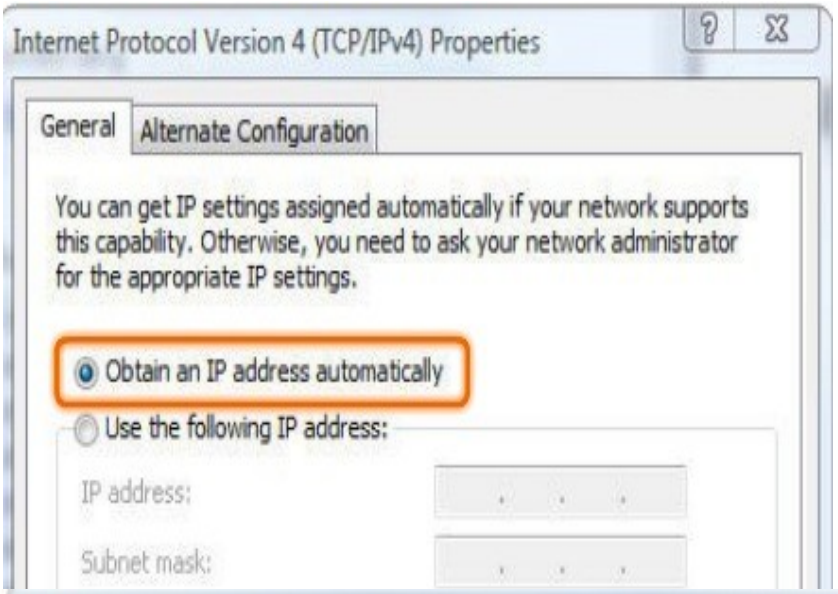


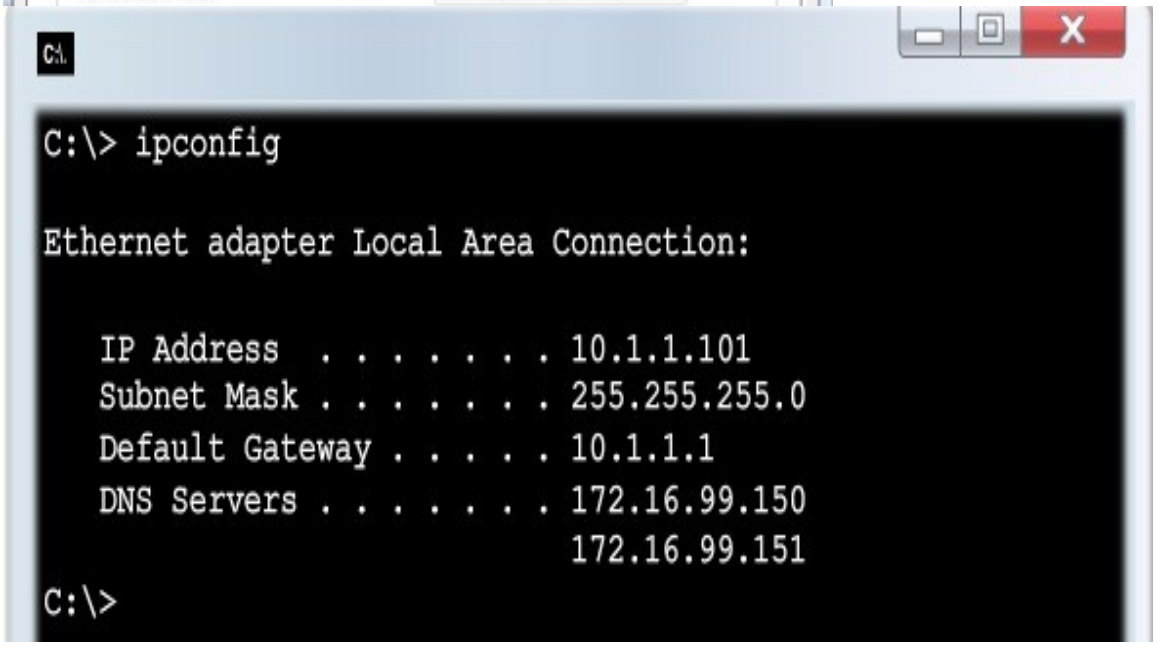
- **Redirect Message**
  Similar to ICMPv4 redirect message
  Router-to-Device messaging

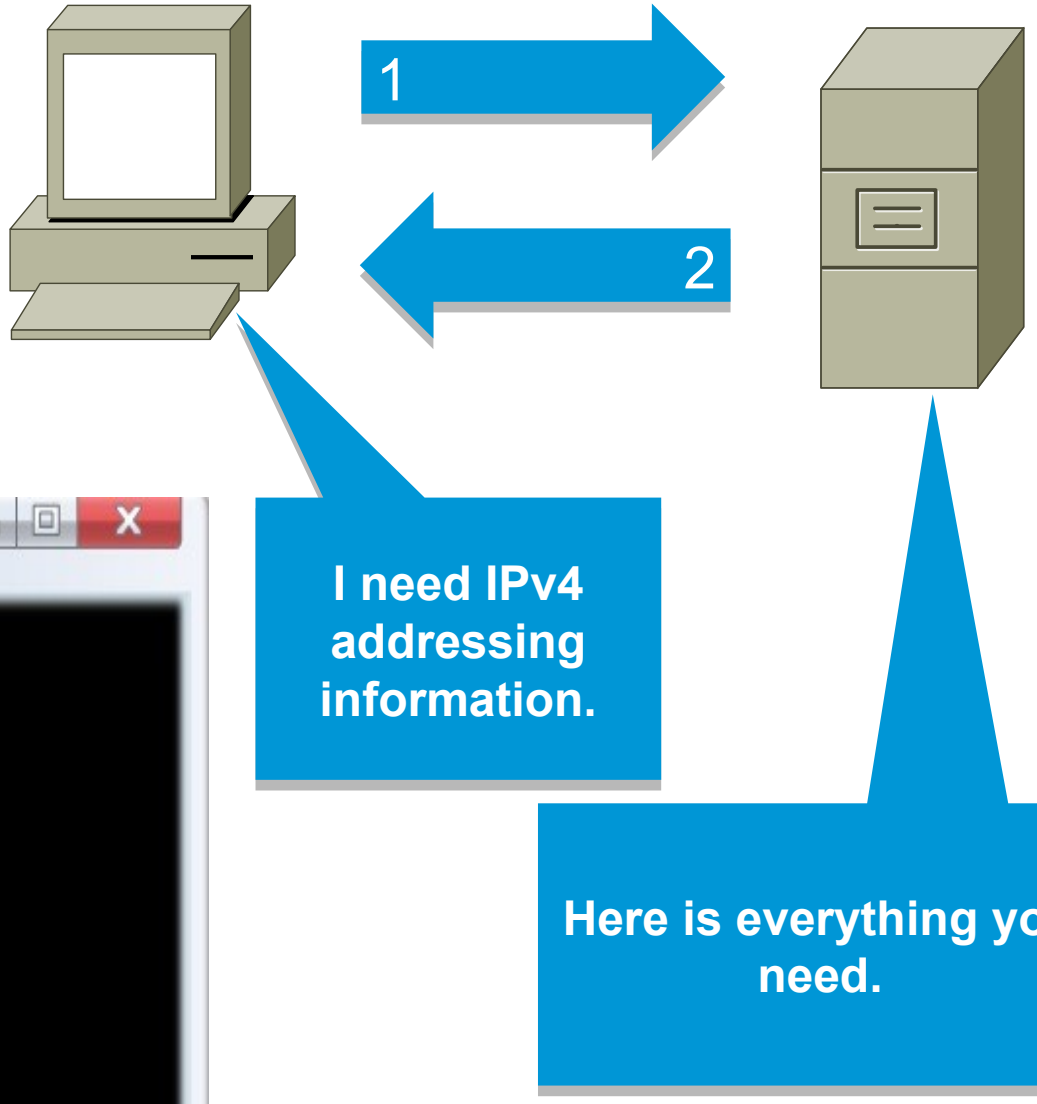
Dynamic IPv6 Address Allocation



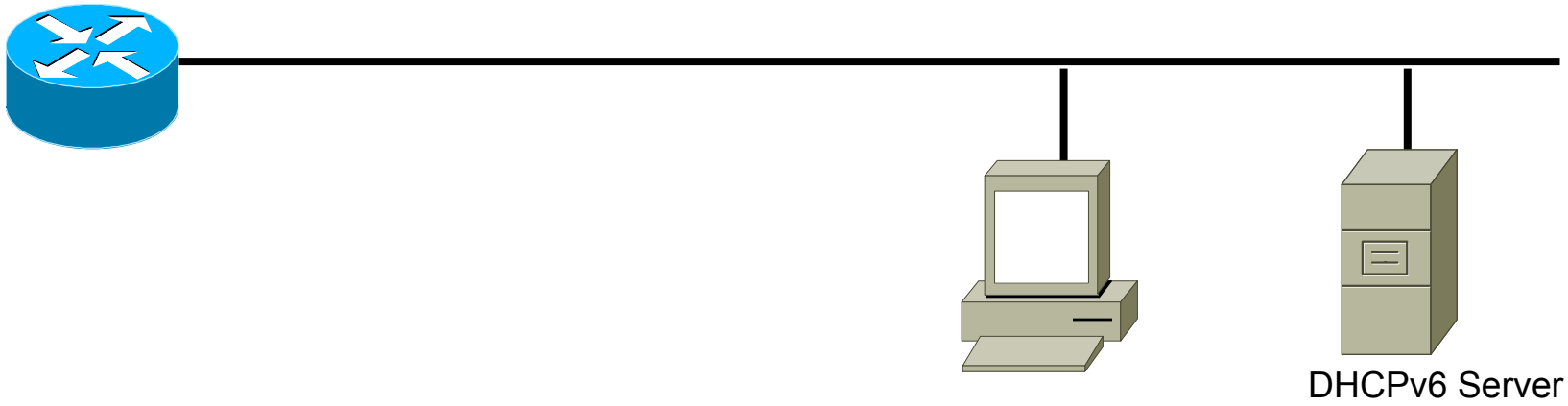
Dynamic Address Allocation in IPv4



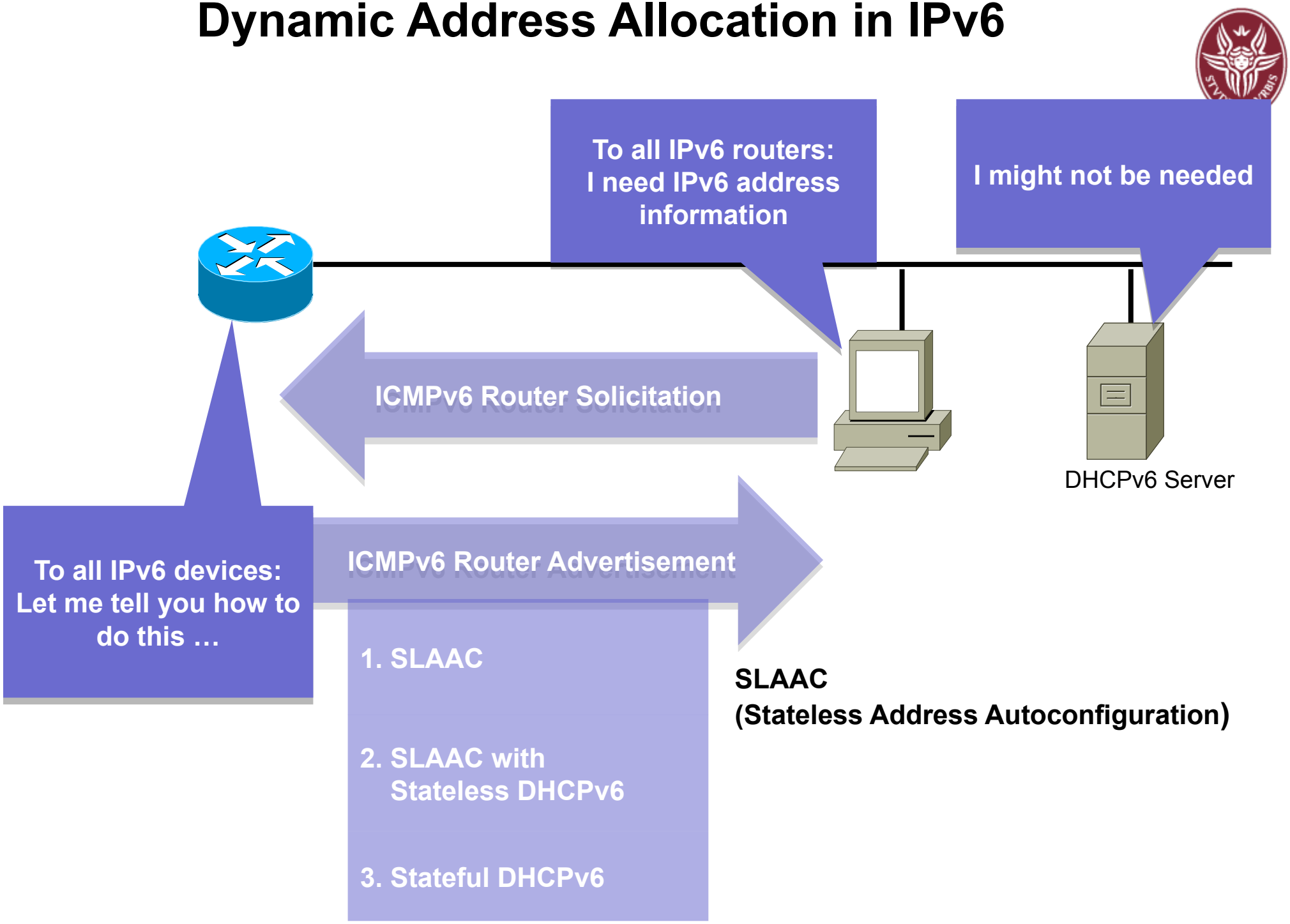




Dynamic Address Allocation in IPv6

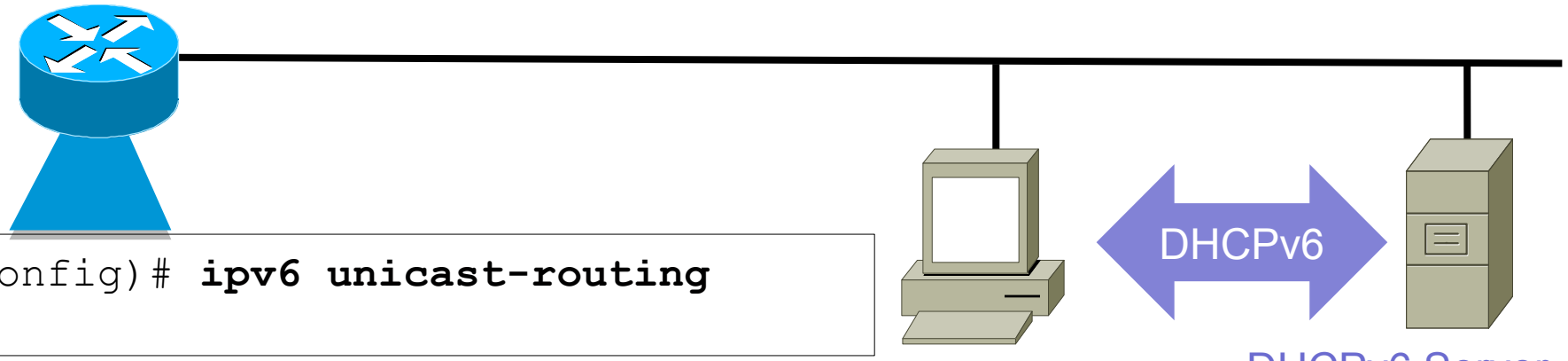


Dynamic Address Allocation in IPv6



SLAAC
(Stateless Address Autoconfiguration)

Router Advertisement: 3 Options




```
Router(config)# ipv6 unicast-routing
```

Option 1: SLAAC – No DHCPv6 (Default on Cisco routers)

"I'm *everything* you need (Prefix, Prefix-length, Default Gateway)"

Option 2: SLAAC + Stateless DHCPv6 for DNS address

"Here is my information but you need to get other information such as DNS addresses from a **DHCPv6 server**." (DNS can be in RA)

Option 3: All addressing except default gateway use DHCPv6

"I can't help you. Ask a **DHCPv6** server for all your information."

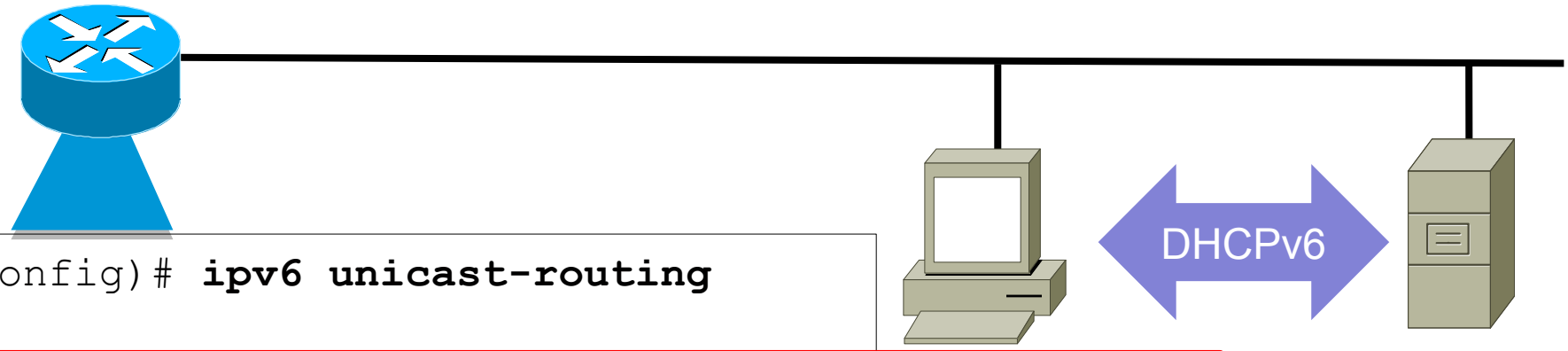
RA

Option 1 and 2: Stateless Address Autoconfiguration

- DHCPv6 Server does not maintain state of addresses

Option 3: Stateful Address Configuration

- Address received from DHCPv6 Server




```
Router(config)# ipv6 unicast-routing
```

Option 1: SLAAC – No DHCPv6 (Default on Cisco routers)

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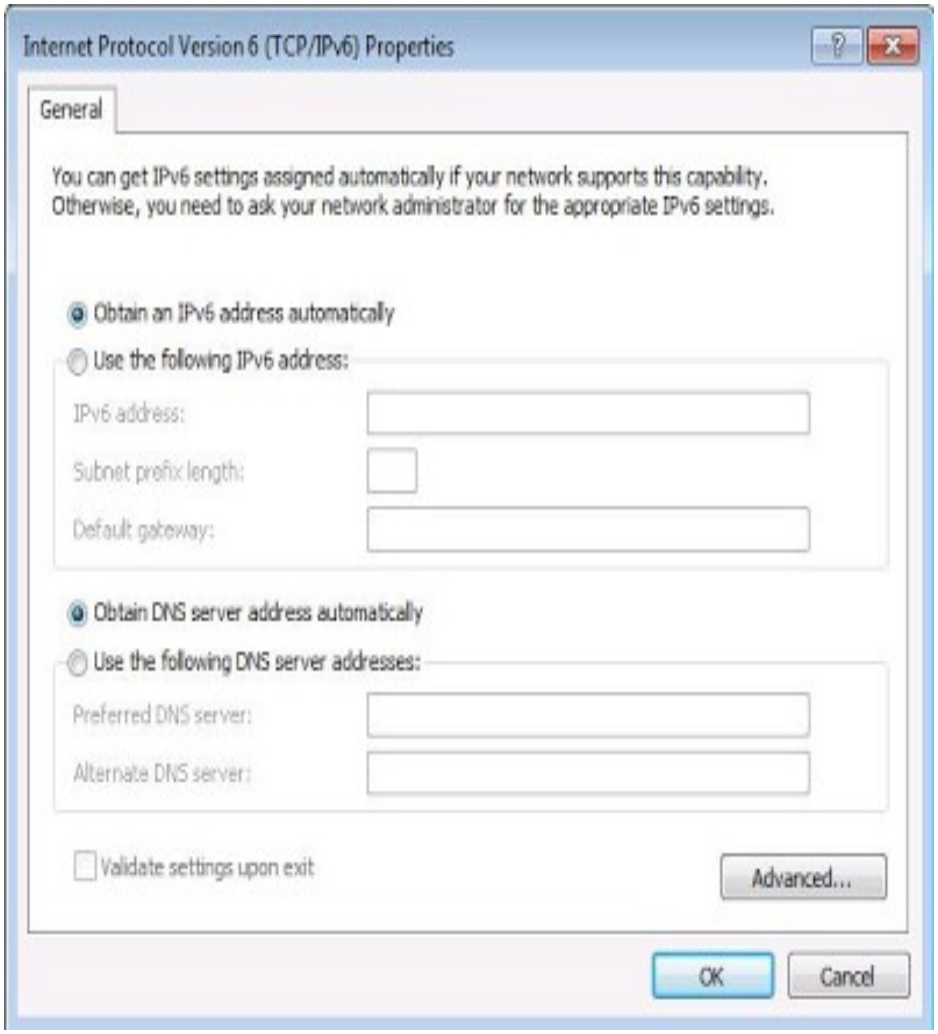
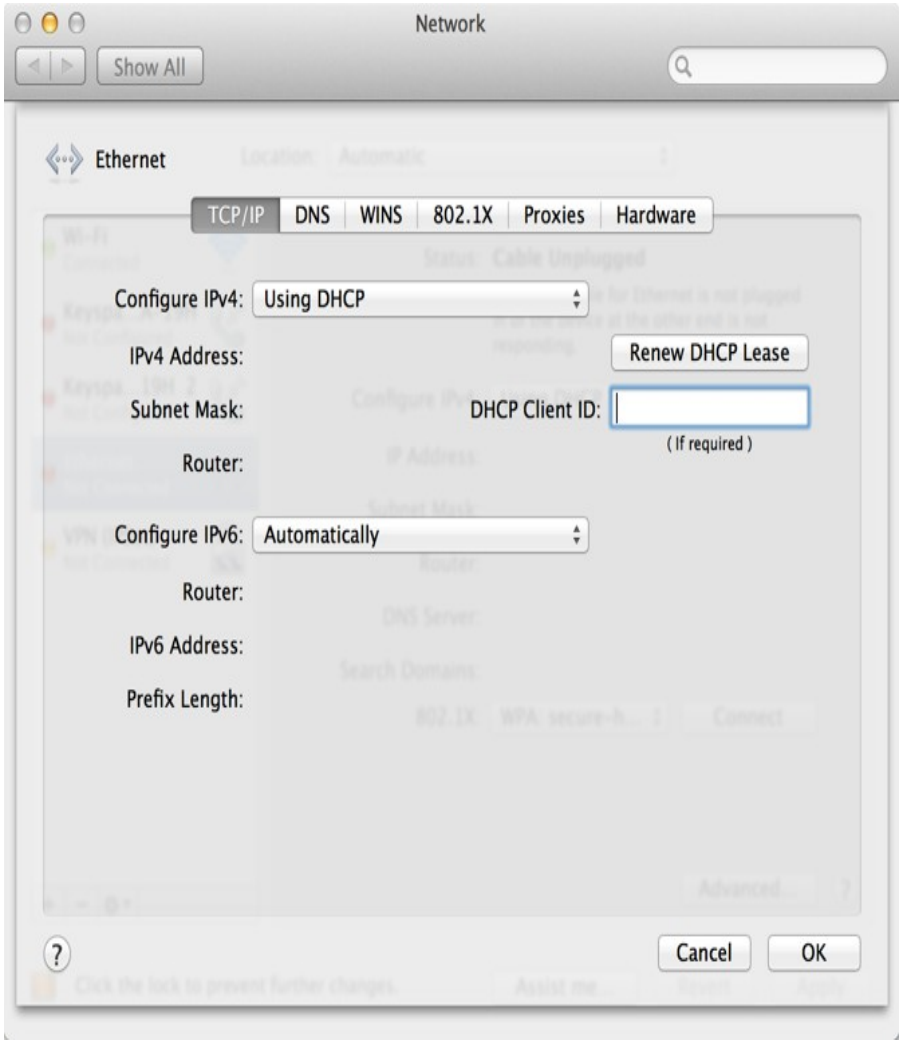
"I can't help you. Ask a **DHCPv6** server for all your information."

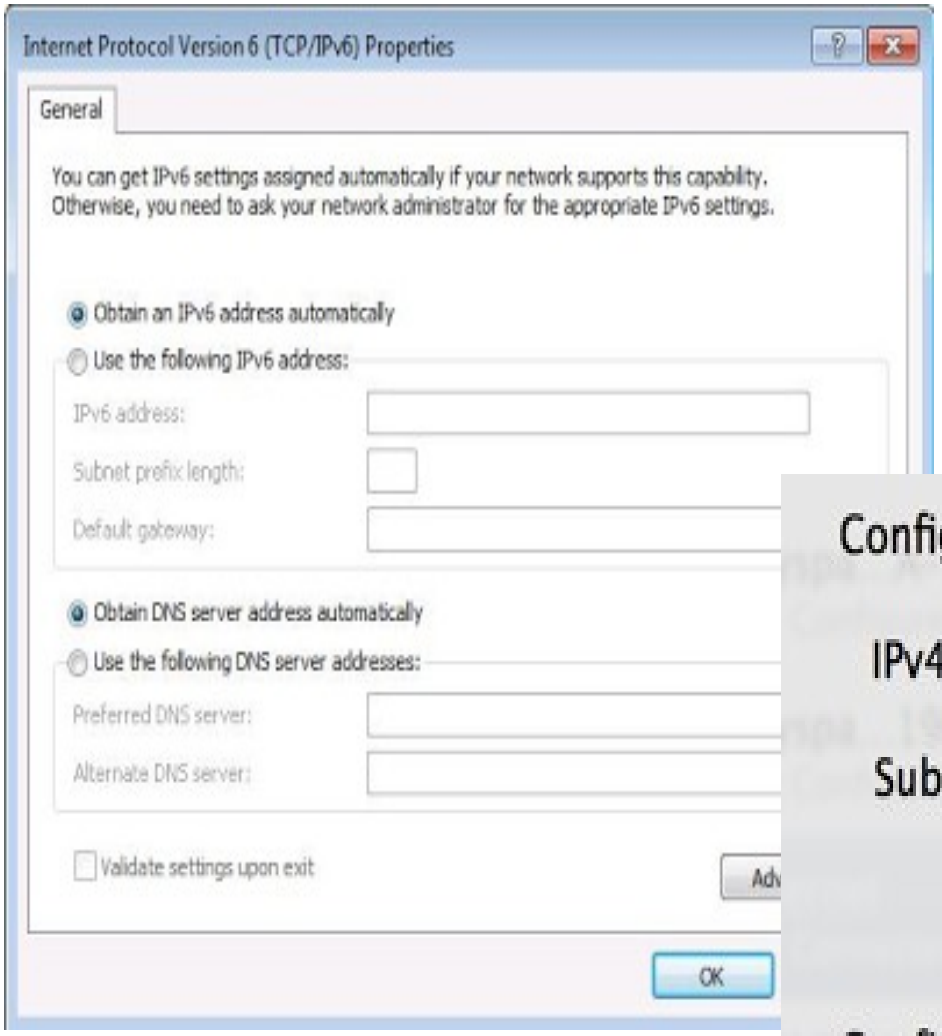
RA

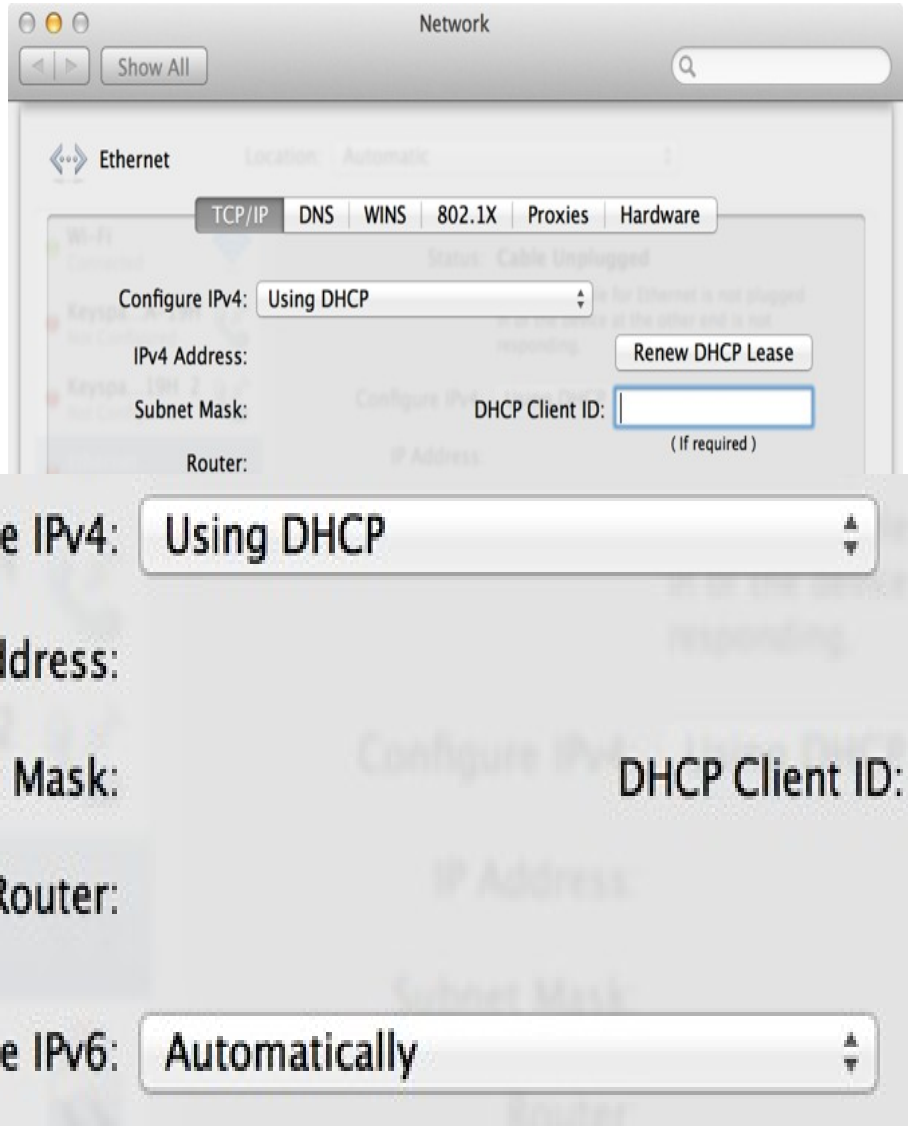
Obtaining an IPv6 Address Automatically





Obtaining an IPv6 Address Automatically

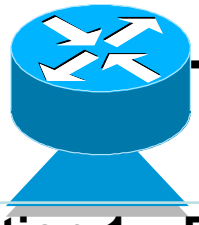




SLAAC: Stateless Address Autoconfiguration

2001:DB8:CAFE:1::/64

MAC: 00-19-D2-8C-E0-4C



1

SLAAC Option 1 – RA Message

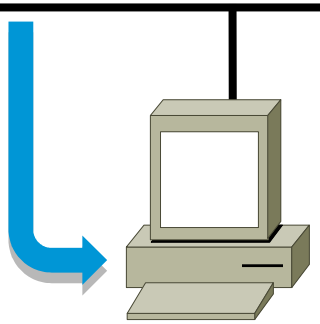
To: **FF02::1** (All-IPv6 devices)

From: **FE80::1** (Link-local address)

Prefix: **2001:DB8:CAFE:1::**

Prefix-length: **/64**

RA



2

Prefix: **2001:DB8:CAFE:1::**

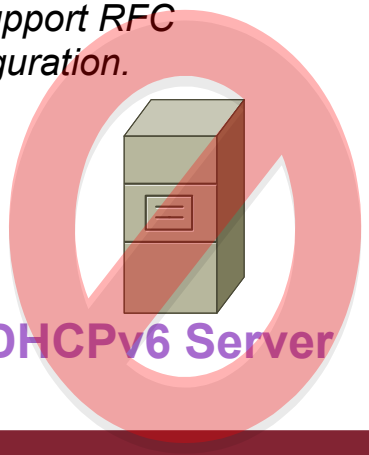
Prefix-length: **/64**

Default Gateway: **FE80::1**

Global Unicast Address:

2001:DB8:CAFE:1: + **Interface ID**

Note: Domain name and DNS server list may be included if router (and end system) support RFC 6106 IPv6 RA Options for DNS Configuration.

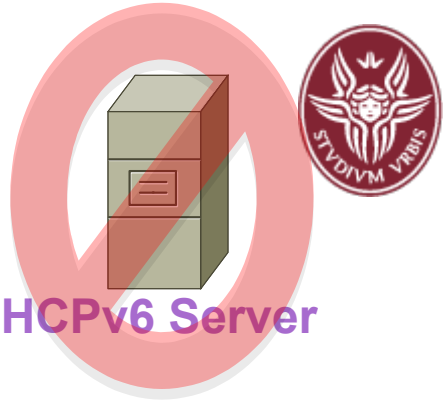


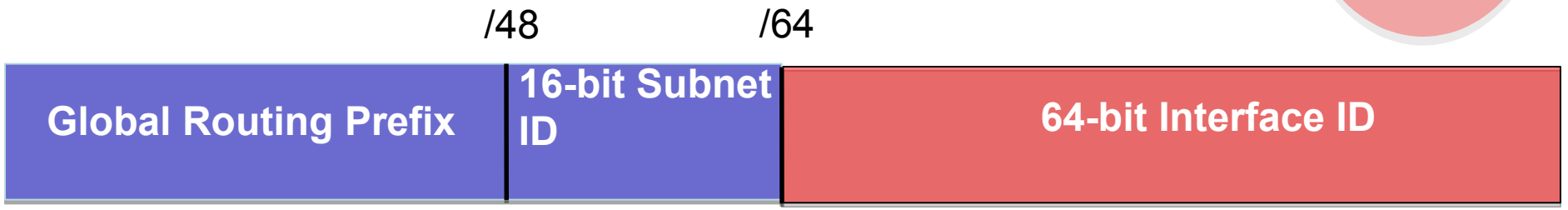
DHCPv6 Server

3

EUI-64 Process or Random 64-bit value

SLAAC: Interface ID





Operating System	EUI-64	Random 64-bit
Windows XP, Server 2003	✔	
Windows Vista and newer		✔
MAC OSX	✔	
Linux		✔

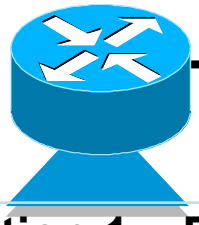
SLAAC

EUI-64 Process

Randomly Generated Number (Privacy Extension)

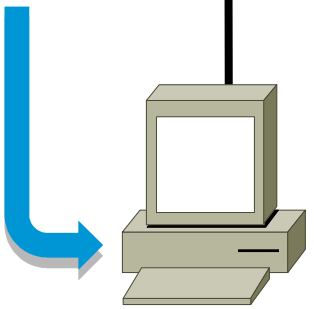
Default OS behavior can be changed.

SLAAC: EUI-64 Option



2001:DB8:CAFE:1::/64

MAC: 00-19-D2-8C-E0-4C



1

SLAAC Option 1 – RA Message

To: **FF02::1** (All-IPv6 devices)

From: **FE80::1** (Link-local address)

Prefix: **2001:DB8:CAFE:1::**

Prefix-length: **/64**

RA

2

Prefix: **2001:DB8:CAFE:1::**

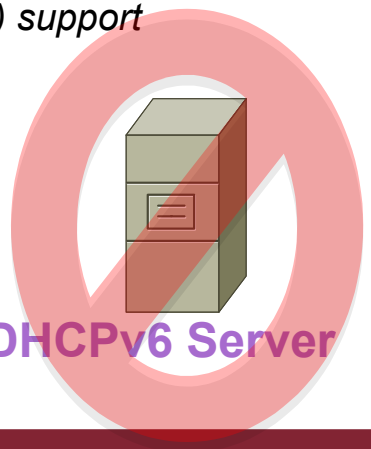
Prefix-length: **/64**

Default Gateway: **FE80::1**

Global Unicast Address:

2001:DB8:CAFE:1: + **Interface ID**

Note: Domain name and DNS server list may be included if router (and end system) support RFC 6106 IPv6 RA Options for DNS Configuration.

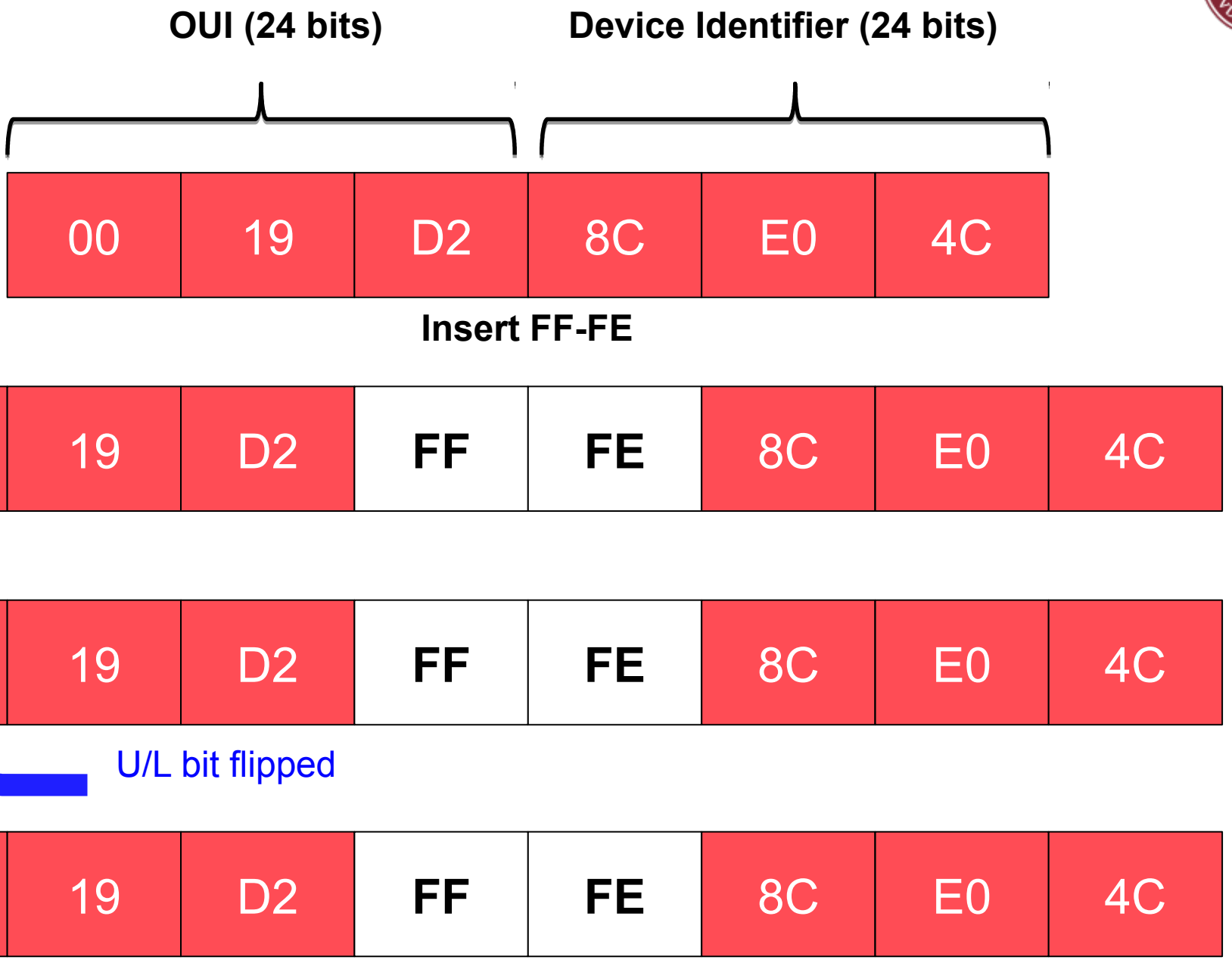


DHCPv6 Server

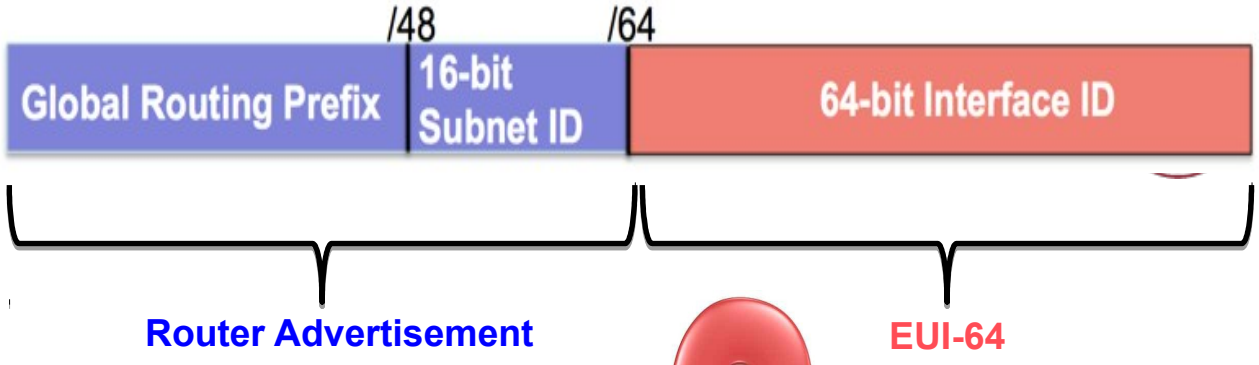
3

E Process or Random 64 bit value

Modified EUI-64 Format (Extended Unique Identifier–64)



Verifying SLAAC on the PC Using EUI-64

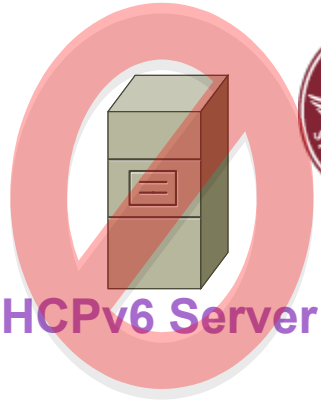



```
PC> ipconfig
Windows IP Configuration
Ethernet adapter Local Area Connection:
   IPv6 Address. . . . . . . . . . : 2001:db8:cafe:1:0219:d2ff:fe8c:e04c
   Link-local IPv6 Address . . . . : fe80::0219:d2ff:fe8c:e04c
   Default Gateway . . . . . . . . : fe80::1
```

A 64-bit Interface ID and the EUI-64 process accommodates:

- The IEEE specification for a 64-bit MAC address
- 64-bit boundary processing

SLAAC: Random 64-bit Interface ID



/48 /64

Global Routing Prefix	16-bit Subnet ID	64-bit Interface ID

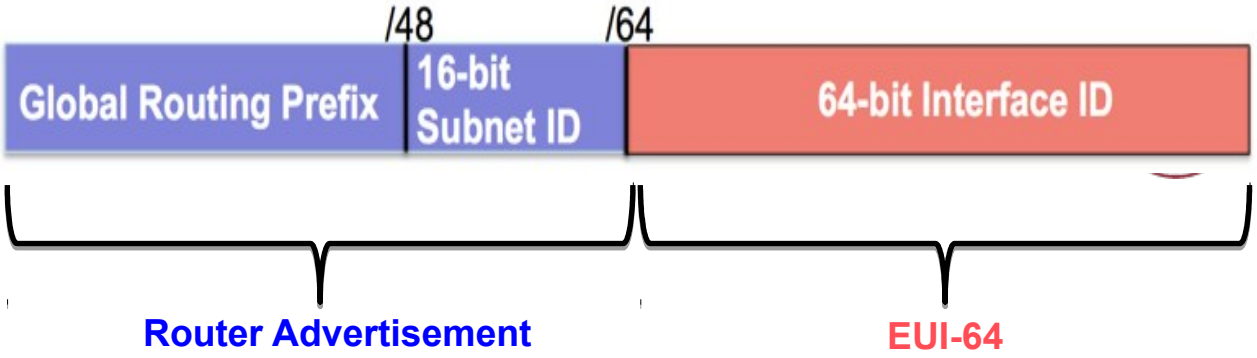
SLAAC

Operating System	EUI-64	Random 64-bit
Windows XP, Server 2003	✔	
Windows Vista and newer		✔
MAC OSX	✔	
Linux		✔

EUI-64 Process

Randomly Generated Number (Privacy Extension)

Verifying SLAAC on the PC Using Privacy Extension

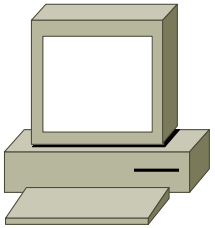



```
PC-Windows7> ipconfig
Windows IP Configuration
Ethernet adapter Local Area Connection:
   IPv6 Address. . . . . . . . . . . : 2001:db8:cafe:1:50a5:8a35:a5bb:66e1
   Link-local IPv6 Address . . . . . : fe80::50a5:8a35:a5bb:66e1
   Default Gateway . . . . . . . . . : fe80::1
```

No FF-FE

Ensuring Unique Unicast Addresses

Global Unicast - `2001:db8:cafe:1:0219:d2ff:fe8c:e04c`
Link-local - `fe80::50a5:8a35:a5bb:66e1`



Neighbor Solicitation

Not received = unique address
Received = duplicate address

Neighbor Advertisement?

- SLAAC is ***stateless***, no entity (DHCPv6 server) maintaining a state address-to-device mappings.
- ***How can we guarantee the address is unique?***
- **Duplicate Address Detection (DAD)**
  - Once required for all unicast addresses (static or dynamic), RFC was updated that DAD is only recommended.
  - /64 Interface IDs!

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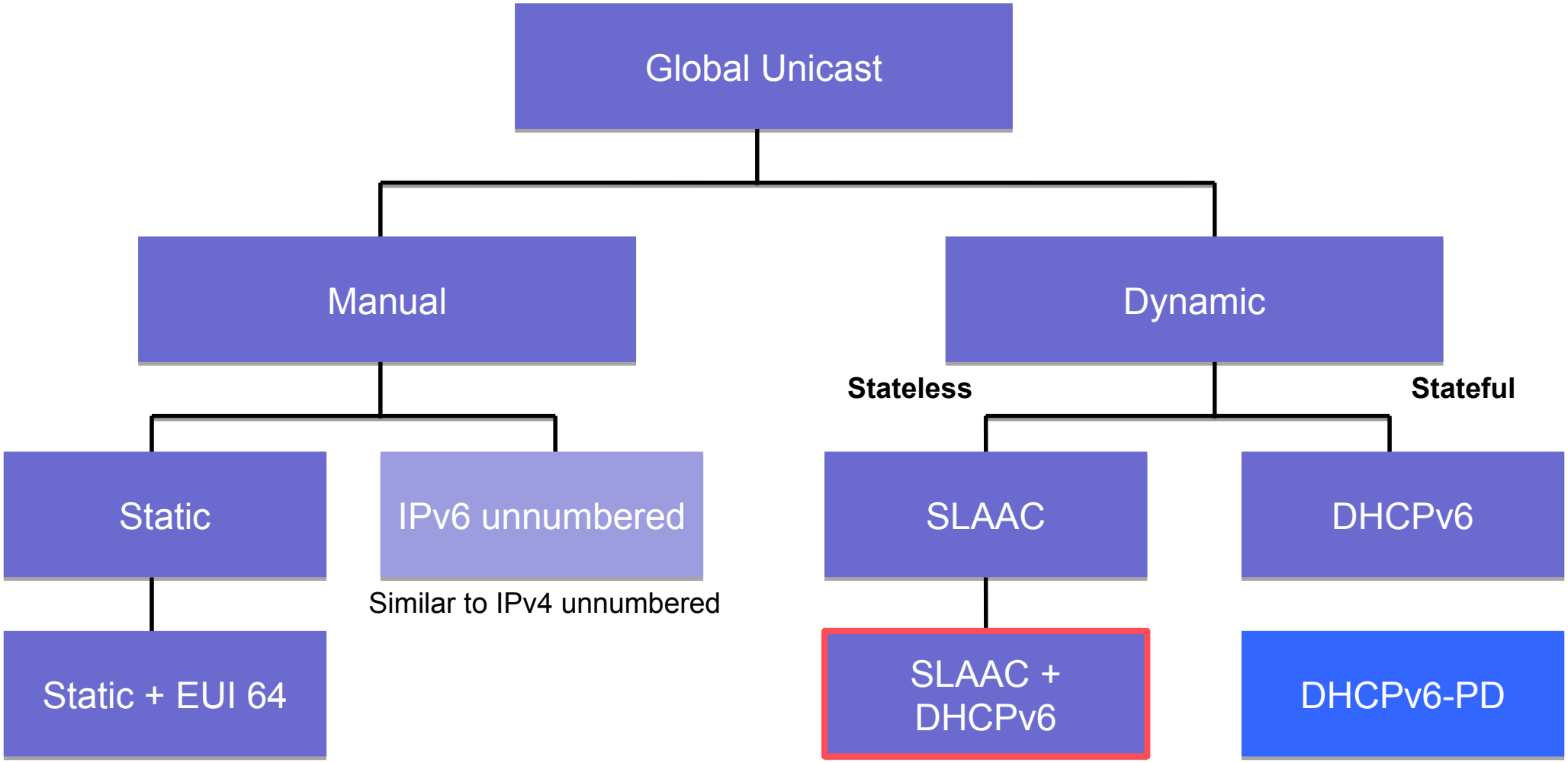
DHCPv6 (Stateless vs Stateful)

DHCPv6


Global Unicast
Manual
Dynamic
Stateless
Stateful
Static
IPv6 unnumbered
SLAAC
DHCPv6
Similar to IPv4 unnumbered
Static + EUI 64
SLAAC + DHCPv6
DHCPv6-PD

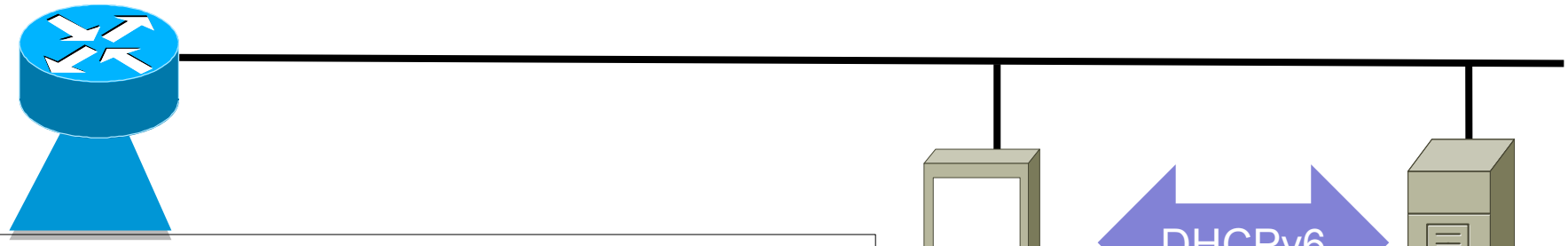
RA Message

Option 1 and 2: Stateless Address Autoconfiguration

- DHCPv6 Server does not maintain state of addresses

Option 3: Stateful Address Configuration

- Address received from DHCPv6 Server



```
Router(config)# ipv6 unicast-routing
```


DHCPv6 Server

Option 1: SLAAC – No DHCPv6 (Default on Cisco routers)

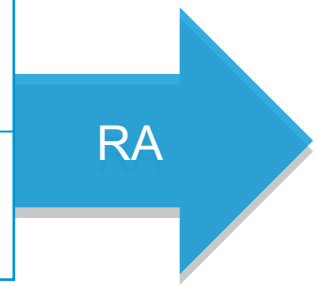
"I'm *everything* you need (Prefix, Prefix-length, Default Gateway)"

Option 2: SLAAC + Stateless DHCPv6 for DNS address

"Here is my information but you need to get other information such as DNS addresses from a **DHCPv6 server**." (DNS can be in RA)

Option 3: All addressing except default gateway use DHCPv6

"I can't help you. Ask a **DHCPv6** server for all your information."



RA Message

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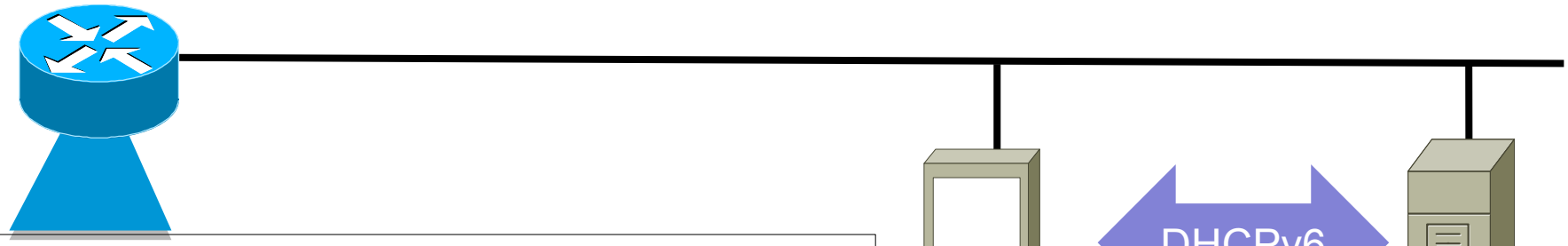

```
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```


DHCPv6 Server

Option 1: SLAAC – No DHCPv6 (Default on Cisco routers)

"I'm *everything* you need (Prefix, Prefix-length, Default Gateway)"

Option 2: SLAAC + Stateless DHCPv6 for DNS address

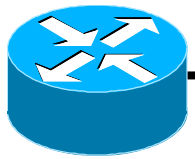
"Here is my information but you need to get other information such as DNS addresses from a **DHCPv6 server**." (DNS can be in RA)

Option 3: All addressing except default gateway use DHCPv6

"I can't help you. Ask a **DHCPv6** server for all your information."

RA

Router as a Stateless DHCPv6 Server

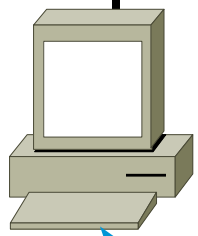


IPv6 Router &
DHCPv6 Server

1 ICMPv6 Router Solicitation

2 ICMPv6 Router Advertisement

- **Option 2: Stateless DHCPv6**
- **O Flag = 1, M Flag = 0**



Note: Domain name and DNS server list may be included if router (and end system) support RFC 6106 IPv6 RA Options for DNS Configuration.

DHCPv6

SOLICIT
To all DHCPv6 Servers
3

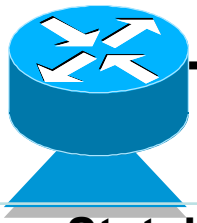
ADVERTISE
Unicast
4

INFORMATION REQUEST
To all DHCPv6 Servers
5

REPLY
Unicast
6

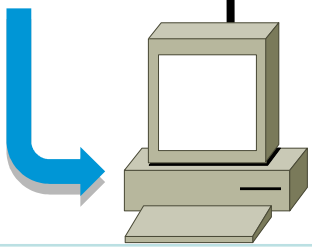
I created my own address (Stateless), and have the default gateway, but I need a DNS address…

SLAAC for Addressing & DNS for Other Information



2001:DB8:CAFE:1::/64

MAC: 00-19-D2-8C-E0-4C



1

RA Message: Stateless DHCPv6

To: **FF02::1** (All-IPv6 devices)

From: **FE80::1** (Link-local address)

Prefix: **2001:DB8:CAFE:1::**

Prefix-length: **/64**

Other Configuration Flag: 1

RA

2

Prefix: **2001:DB8:CAFE:1::**

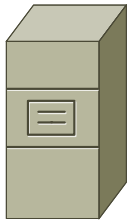
Prefix-length: **/64**

Default Gateway: **FE80::1**

Global Unicast Address:

2001:DB8:CAFE:1: + **Interface ID**

2001:DB8:CAFE:1:6909:cb1c:36a0:a595



Stateless DHCPv6 Server

DHCPv6 For DNS

3

DNS: **2001:DB8:CAFE:1::99**

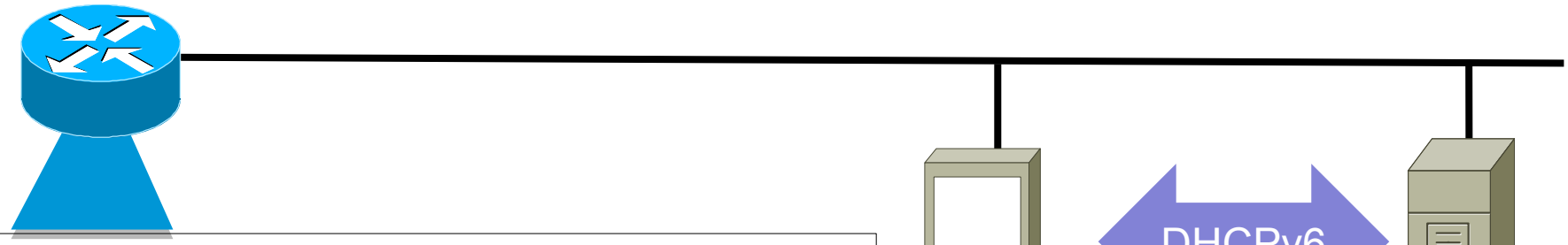
Domain name: **cafe.com**

EUI-64 Process or **Random 64-bit value**

RA Message

Option 1 and 2: Stateless Address Autoconfiguration
- DHCPv6 Server does not maintain state of addresses

Option 3: Stateful Address Configuration
- Address received from DHCPv6 Server




```
Router(config)# ipv6 unicast-routing
```

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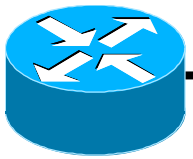
"I can't help you. Ask a DHCPv6 server for all your information."

RA

Router as a Stateful DHCPv6 Server

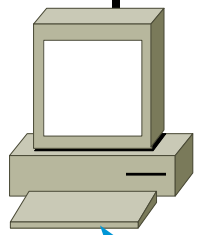


IPv6 Router &
DHCPv6 Server

1 ICMPv6 Router Solicitation

2 ICMPv6 Router Advertisement

- **Option 3: Stateful DHCPv6**
- **O Flag = 0, M Flag = 1**



I'm only using the default gateway address from the RA. I need to contact a stateful DHCPv6 server for all my addressing.

DHCPv6

3 **SOLICIT**
To all DHCPv6 Servers

4 **ADVERTISE**
Unicast

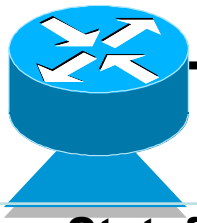
5 **REQUEST**
To all DHCPv6 Servers

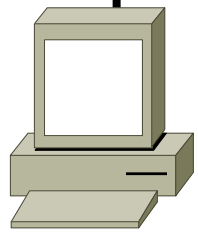
6 **REPLY**
Unicast

Stateful DHCPv6

I need to get all my addressing from DHCPv6, HOWEVER I will use the router as my default gateway.

2001:DB8:CAFE:2::/64





1

RA Message: Stateful DHCPv6

To: **FF02::1** (All-IPv6 devices)

From: **FE80::1** (Link-local address)

Prefix: **2001:DB8:CAFE:2::**

Prefix-length: **/64**

Managed Configuration Flag: 1

RA

2

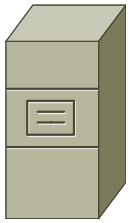
Default Gateway: **FE80::1**

Global Unicast Address: DHCPv6

2001:DB8:CAFE:1:6909:cb1c:36a0:a595

DNS: **2001:DB8:CAFE:1::99**

Domain name: **cafe.com**



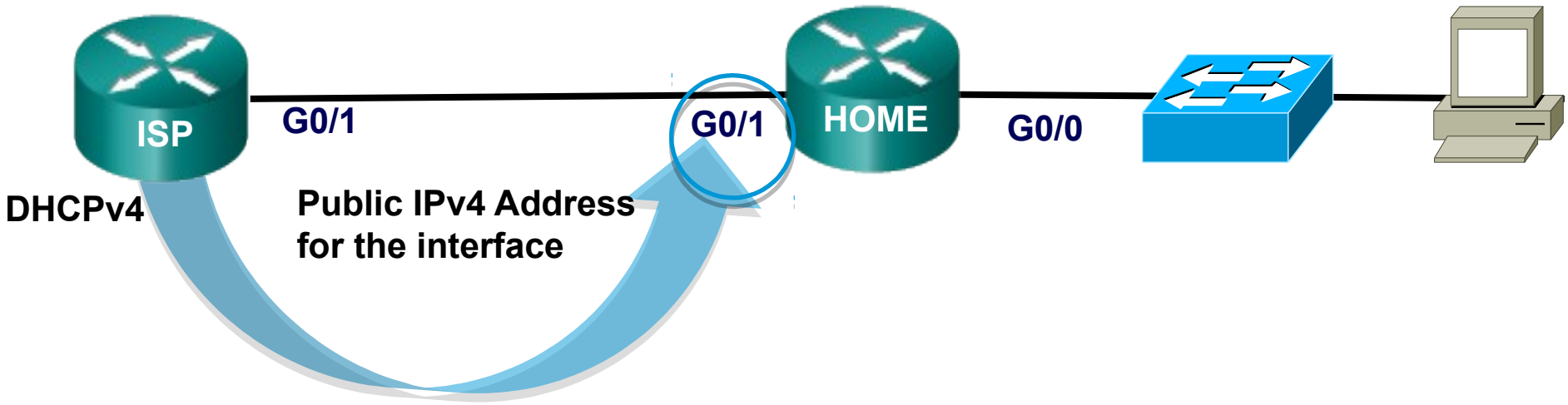
DHCPv6

Stateful DHCPv6 Server

SAPIENZA
UNIVERSITÀ DI ROMA

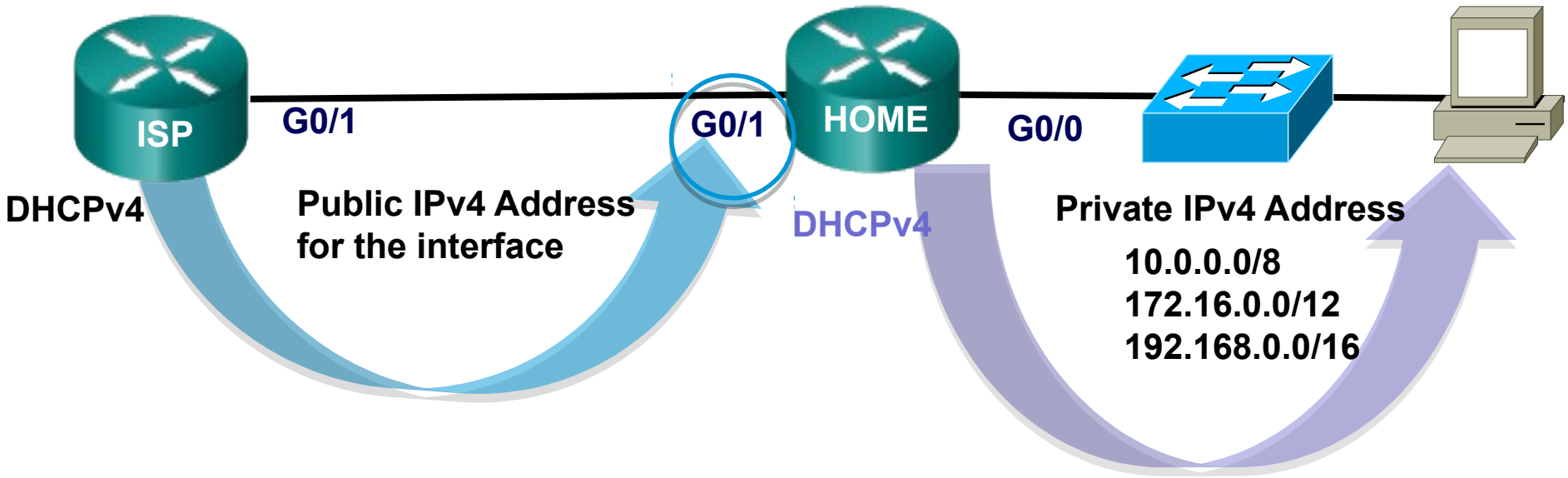
DHCPv6 Prefix Delegation Process

DHCPv4 and Private Addresses for the Home



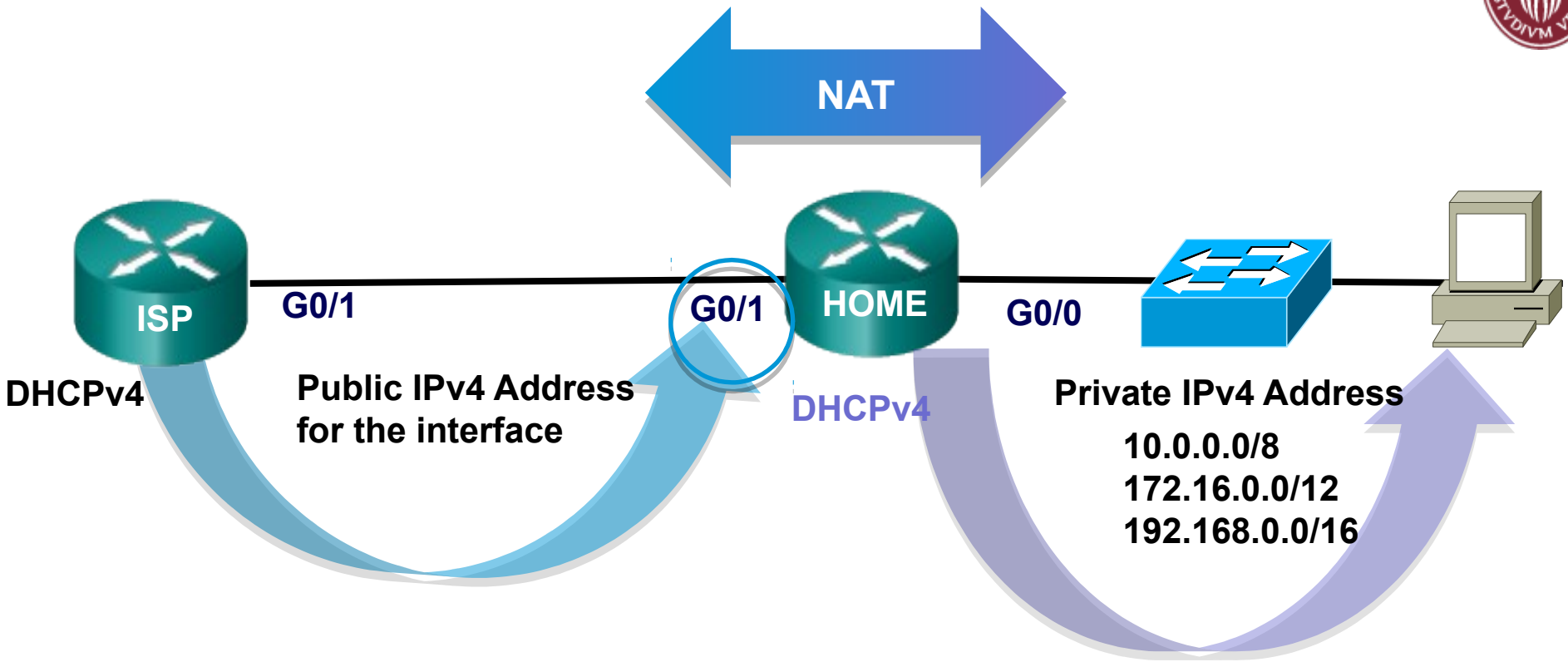
- ISP only has to deliver a public IPv4 address for Home router interface.

DHCPv4 and Private Addresses for the Home



- ISP only has to deliver a public IPv4 address for Home router interface.
- DHCPv4 and RFC 1918 private address space is used for home network.

DHCPv4 and Private Addresses for the Home



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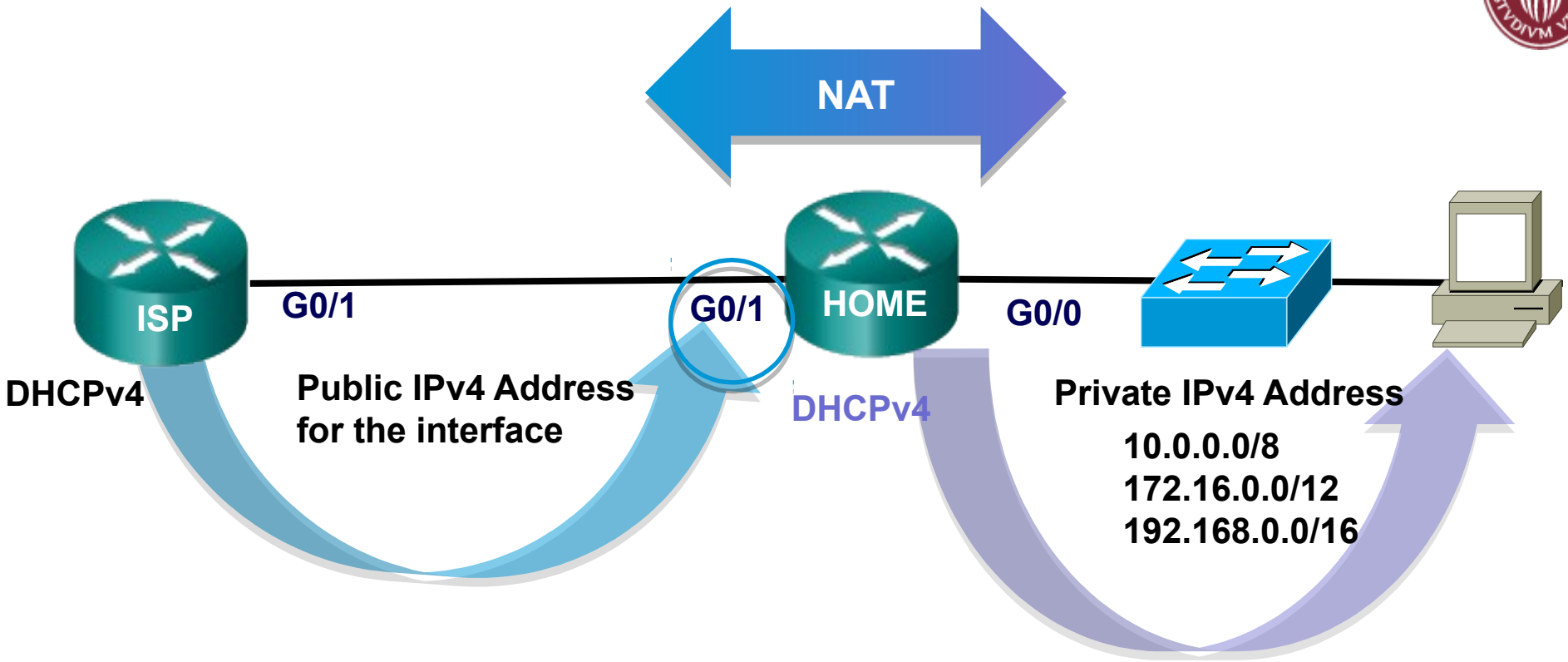
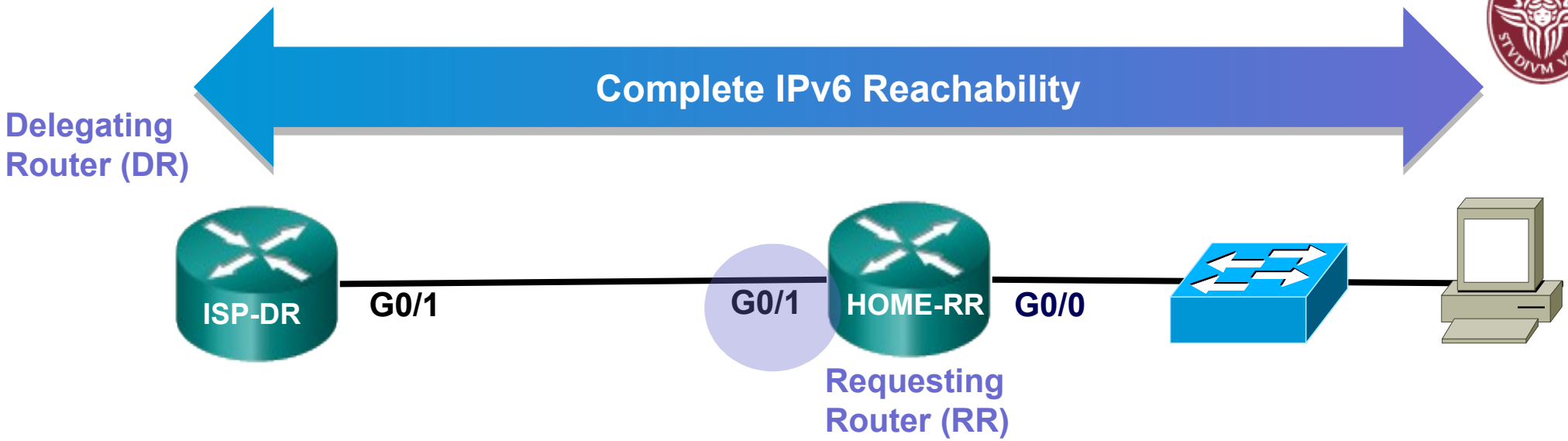
- NAT is used for translation – but has its drawbacks!

DHCPv4 and Private Addresses for the Home



- ISP only has to deliver a public IPv4 address for Home router interface.
- DHCPv4 and RFC 1918 private address space is used for home network.
- NAT is used for translation – but has its drawbacks!
- No NAT between private-public IPv6 (always in debate)

HOME Router's ISP Facing Interface



- First, HOME's ISP facing interface needs an IPv6 address.

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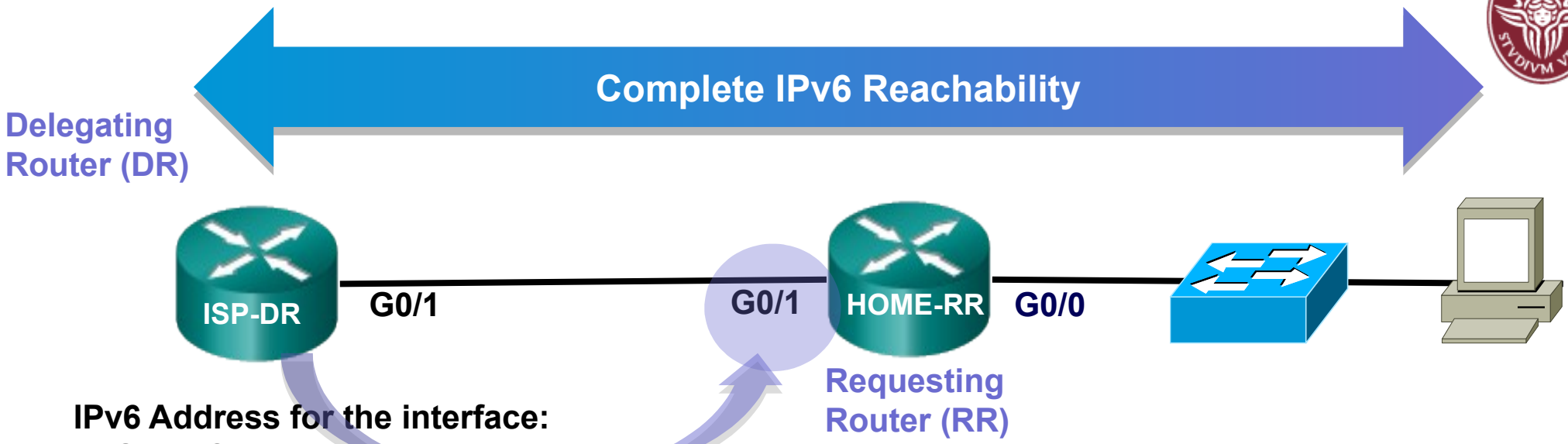

IPv6 Address for the interface:

- **SLAAC**
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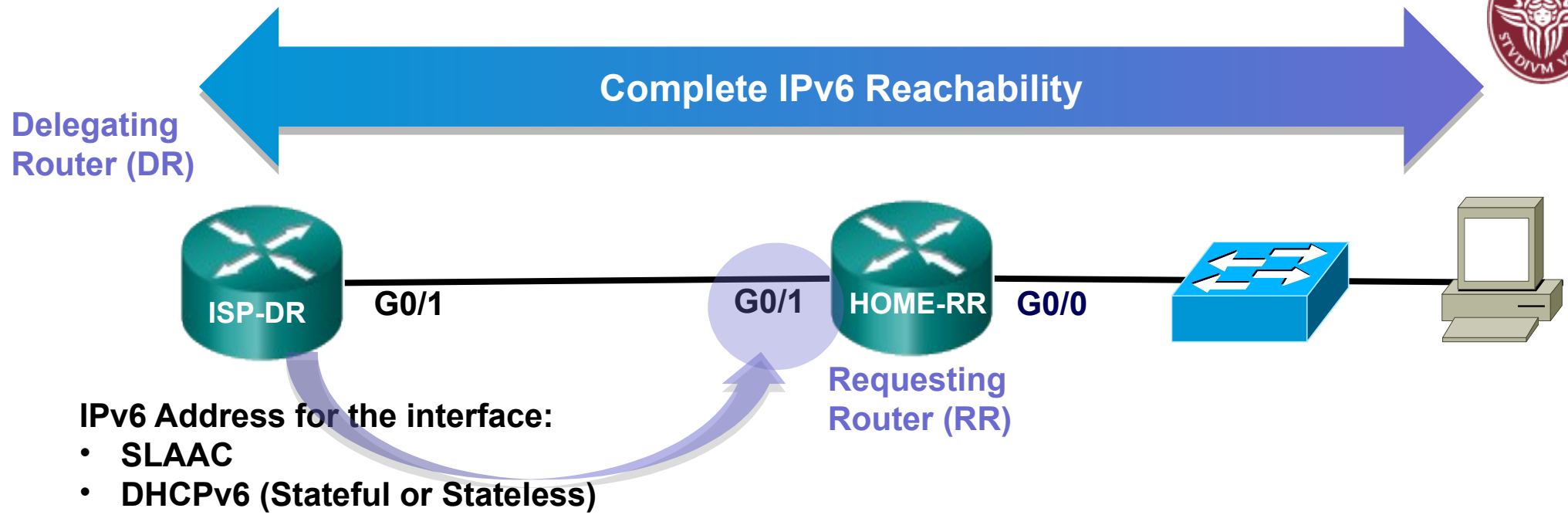

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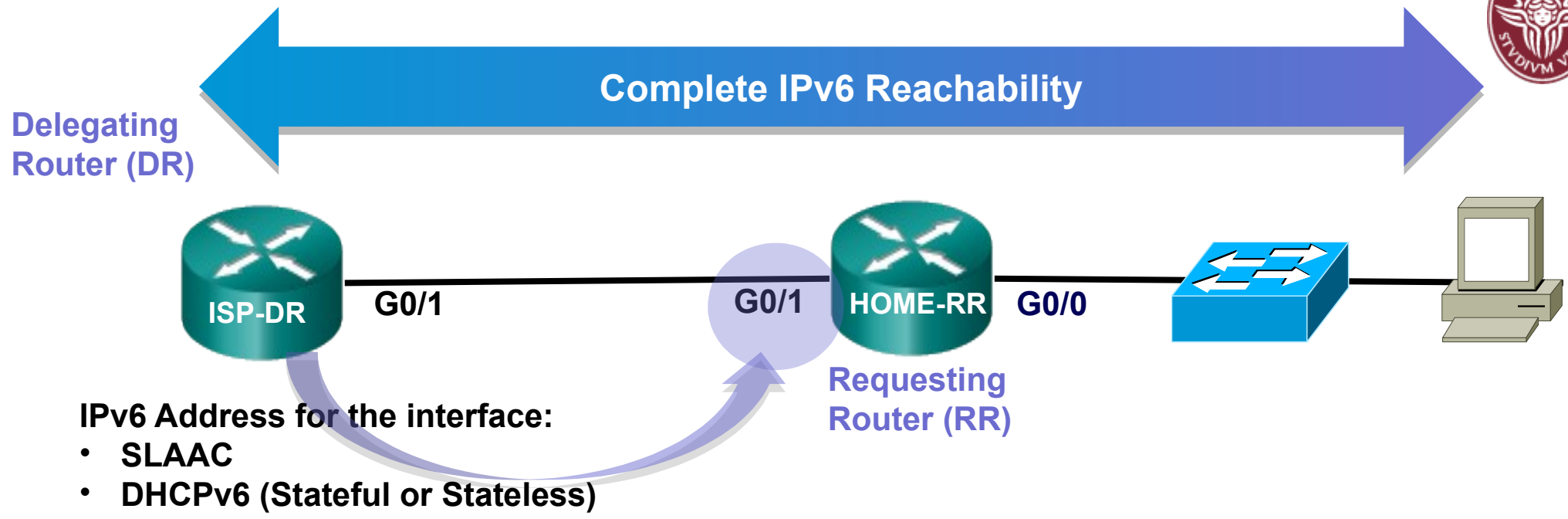

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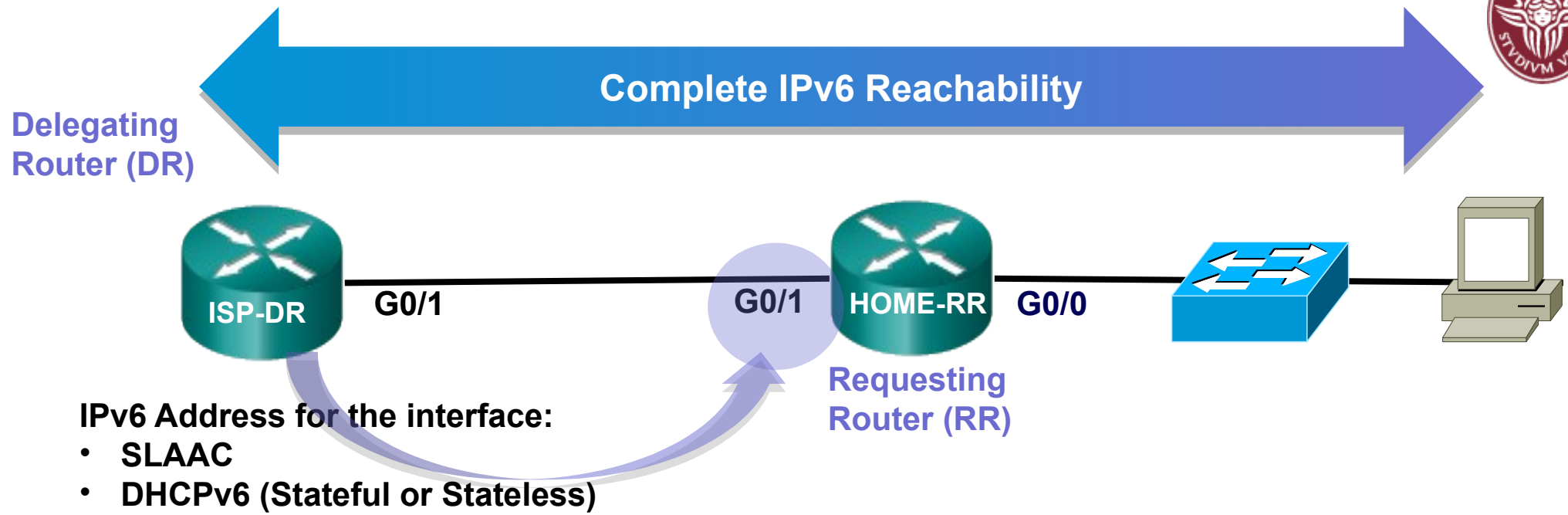

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  - **Stateful DHCPv6** - Like DHCPv4

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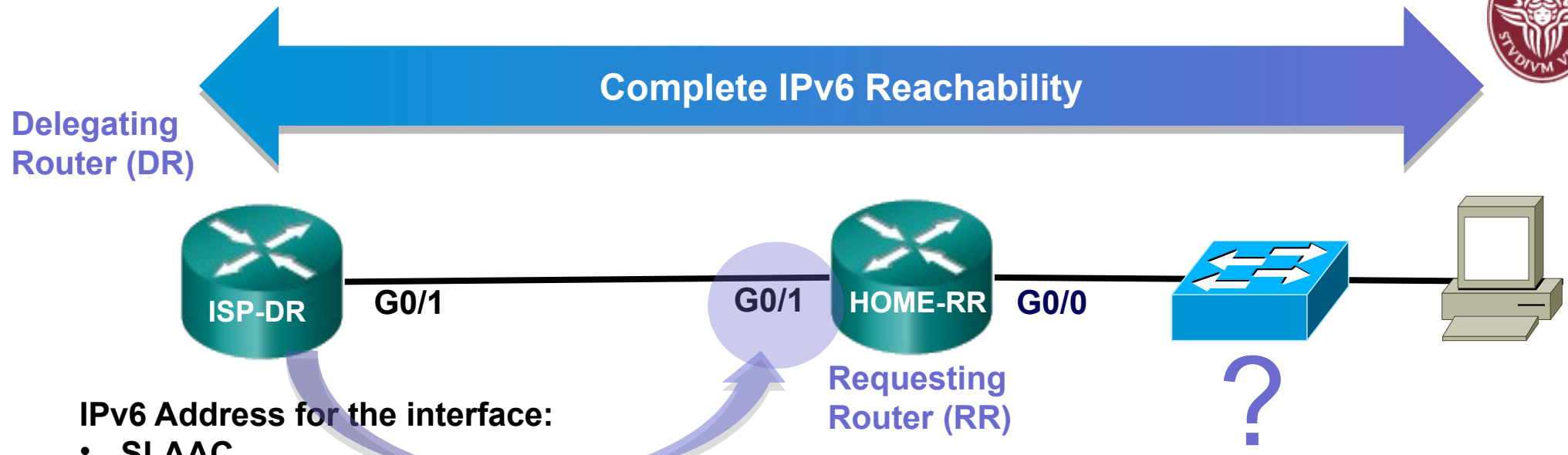

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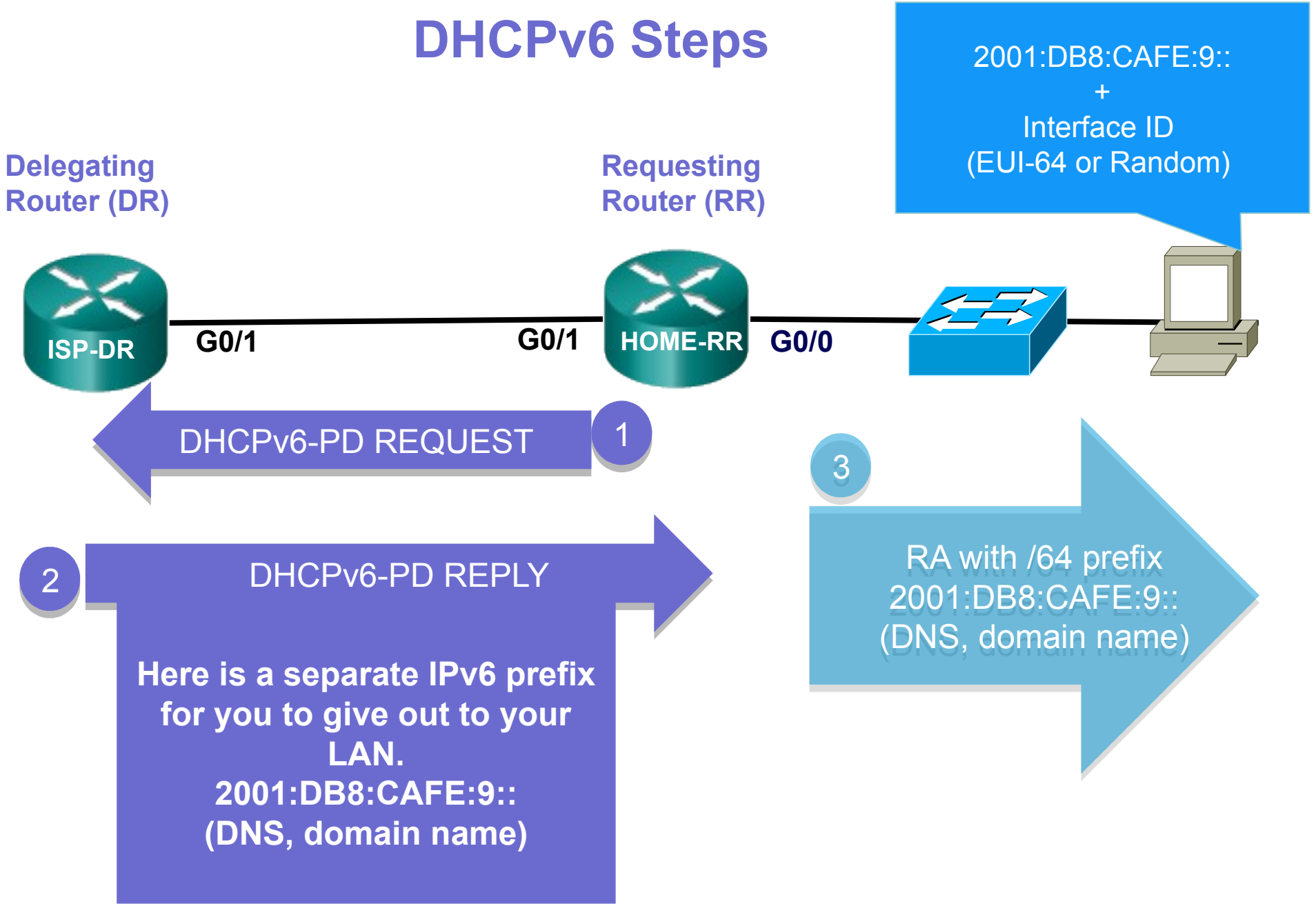
  - **Stateful DHCPv6** - Like DHCPv4
- *What about the address for the HOME LAN?*

DHCPv6 Steps



That's all for today

- **Questions?**
- See you in the lab
- References:
  - http://www.tcpipguide.com/free/t_InternetProtocolVersion6IPv6IPNextGenerationIPng.htm
  - https://www.6diss.org/e-learning/
  - http://www.cabrillo.edu/~rgraziani/ipv6-presentations.html
  - Book chapter 11 (even if quite obsoleted)