

## **Practical Network Defense**

Master's degree in Cybersecurity 2020-21

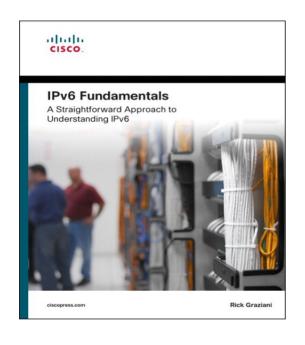
**IPv6: protocol overview** 

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## Material taken from Rick Graziani IPv6 courses







# IPv6 Fundamentals: A Straightforward Approach to Understanding IPv6

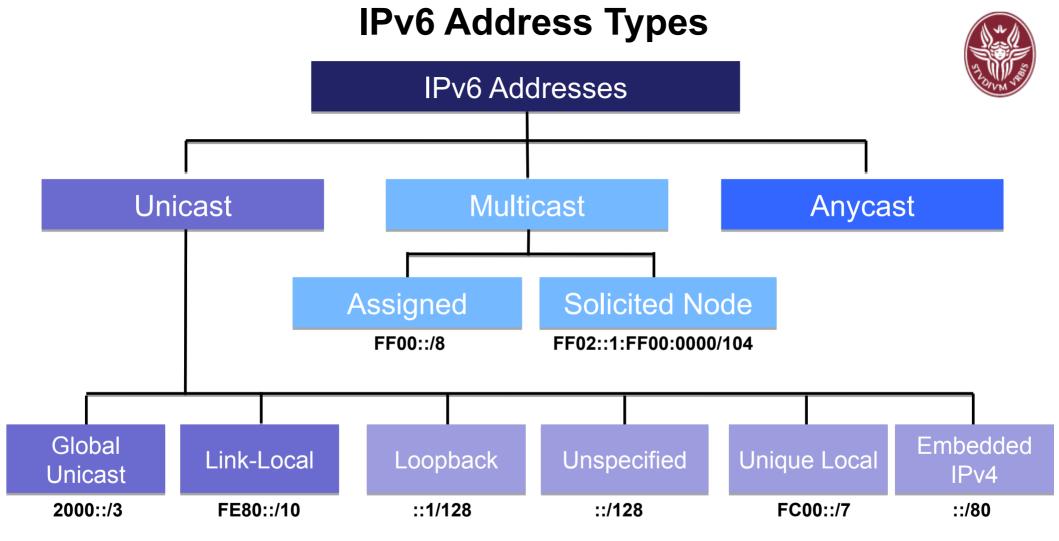
- By Rick Graziani
- ISBN-10: 1-58714-313-5

# IPv6 Fundamentals LiveLessons: A Straightforward Approach to Understanding IPv6

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

# Recap last lectures

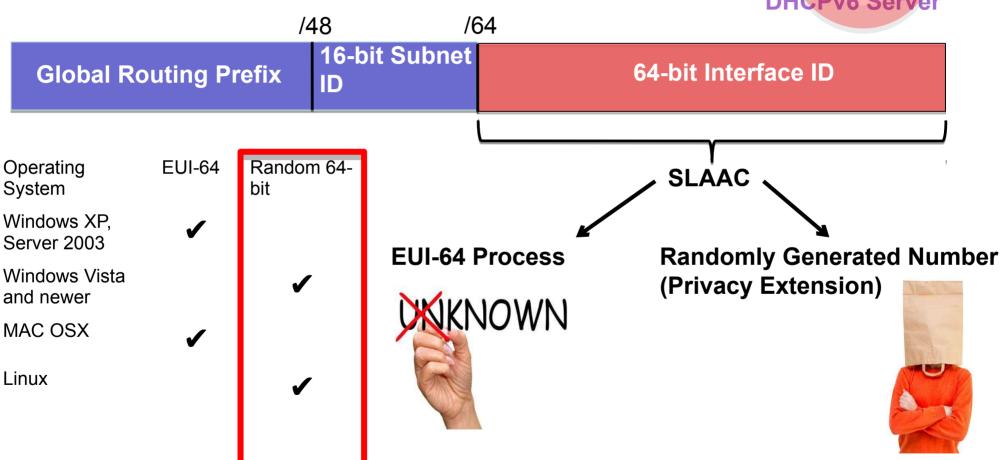
- IPv6 main features
- IPv6 address types
  - Global Unicast Address
  - Local-link unicast Address
- IPv6 dynamic assignment options
  - SLAAC
  - SLAAC+DNS via DHCPv6
  - Stateful DHCPv6
- IPv6 prefix delegation, via DHCPv6-PD



IPv6 does not have a "broadcast" address.

## **SLAAC: Random 64-bit Interface ID**





## **SLAAC: Temporary Addresses**

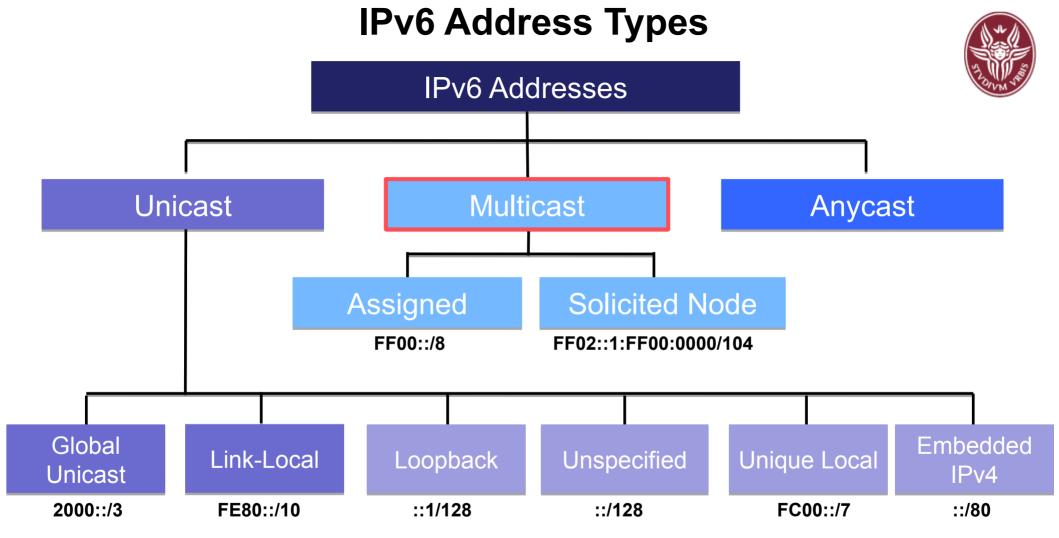
- Idea: provide additional addresses that have relatively short lifetimes and are used as the source address when originating connections
- Same prefix as a public address, randomized value for the Interface ID
- Short lifetime, usually hours or days
- It is common to have multiple temporary addresses to make

sure existing connections can continue while a new temporary address is created for new connections

# LinuxPC# ip -6 addr show dev eth0 2: eth0: <BROADCAST, MULTICAST, UP, LOWER\_UP> mtu 1500 state UNKNOWN qlen1000 inet6 2001:db8:cafe:4:314a:dd3e:762f:e140/64 scope global temporary dynamic valid\_lft 604747sec preferred\_lft 85747sec inet6 2001:db8:cafe:4:250:56ff:feaf:2524/64 scope global dynamic valid\_lft 2591947sec preferred\_lft 604747sec inet6 fe80::250:56ff:feaf:2524/64 scope link valid\_lft forever preferred\_lft forever



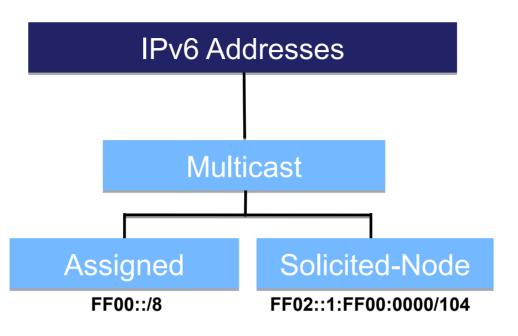
Randomly Generated Number (Privacy Extension)



IPv6 does not have a "broadcast" address.

## **IPv6 Multicast Addresses**

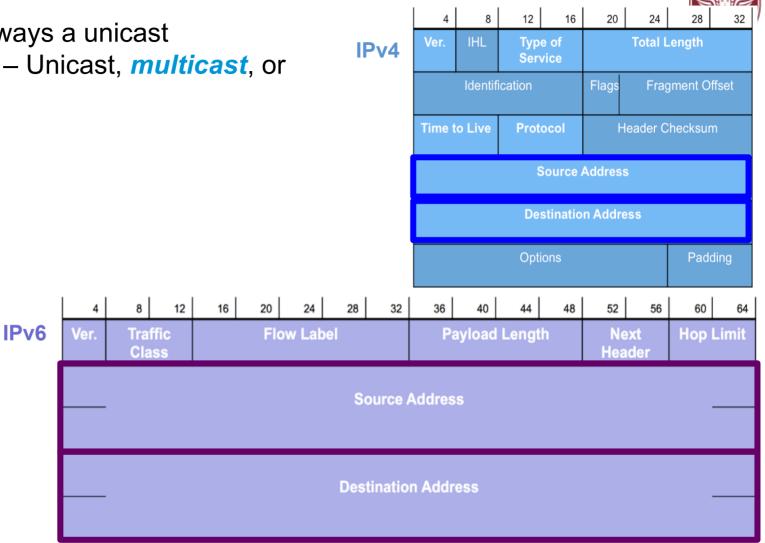




- Used by a device to send a single packet to multiple destinations simultaneously (one-to-many).
- Equivalent to 224.0.0.0/4 in IPv4.
- Two types of multicast addresses:
  - Assigned
  - Solicited-Node

## **IPv6 Multicast Addresses**

- **IPv6 Source** Always a unicast
- IPv6 Destination Unicast, multicast, or anycast.

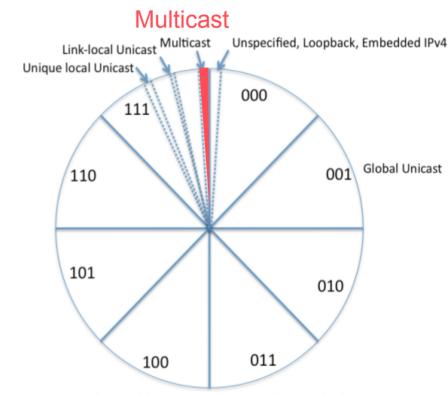


## **Multicast Range**



FF00::/8

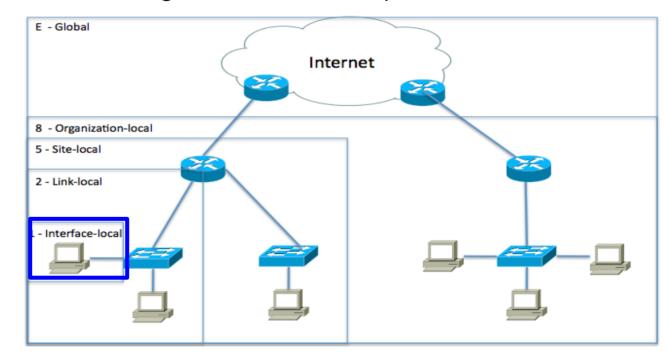
IPv6 multicast addresses have the prefix **FF00::/8** 



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

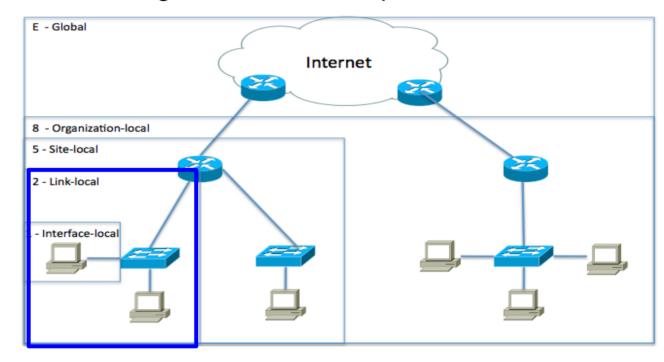


- Scope is a 4-bit field used to define the range of the multicast packet.
- Scope (partial list):
  - 0 Reserved
  - 1 Interface-Local scope



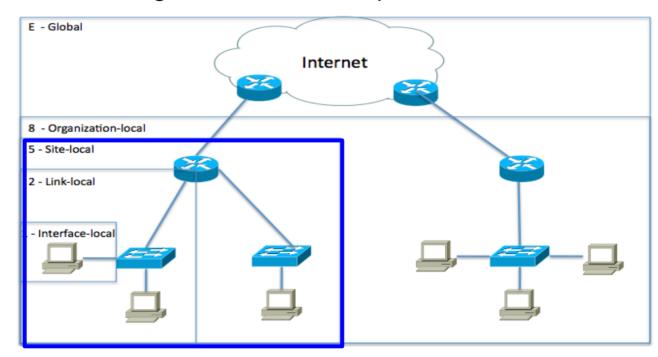


- Scope is a 4-bit field used to define the range of the multicast packet.
- Scope (partial list):
  - 0 Reserved
  - 1 Interface-Local scope
  - 2 Link-Local scope



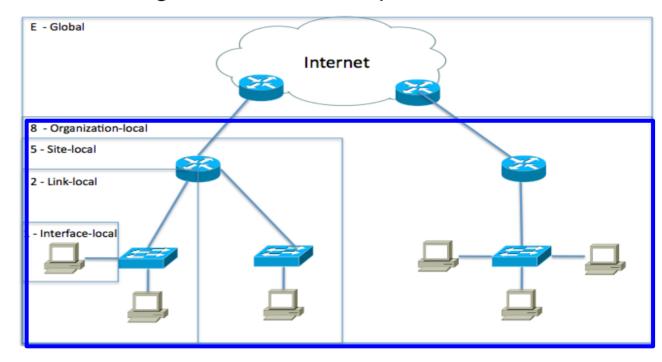


- Scope is a 4-bit field used to define the range of the multicast packet.
- Scope (partial list):
  - 0 Reserved
  - 1 Interface-Local scope
  - 2 Link-Local scope
  - 5 Site-Local scope



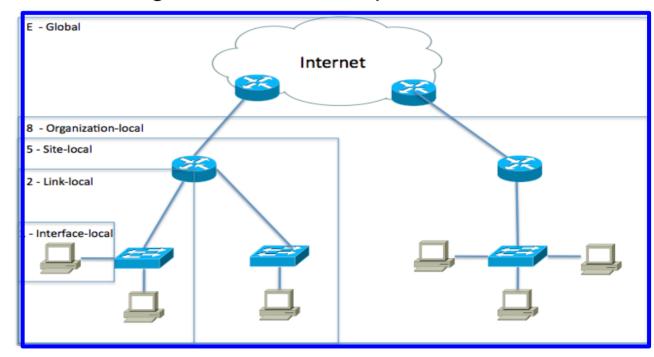


- Scope is a 4-bit field used to define the range of the multicast packet.
- Scope (partial list):
  - 0 Reserved
  - 1 Interface-Local scope
  - 2 Link-Local scope
  - 5 Site-Local scope
  - 8 Organization-Local scope





- Scope is a 4-bit field used to define the range of the multicast packet.
- Scope (partial list):
  - 0 Reserved
  - 1 Interface-Local scope
  - 2 Link-Local scope
  - 5 Site-Local scope
  - 8 Organization-Local scope
  - E Global scope



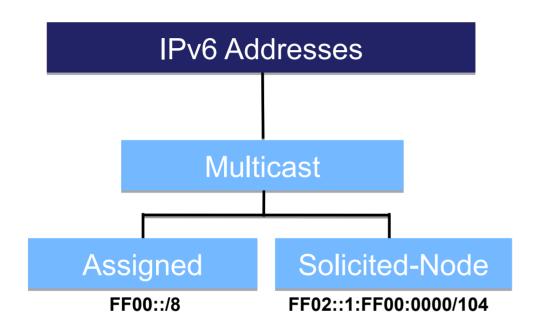
## **IPv6 Multicast Addresses - Flag**



## Flag

- 0 Permanent, well-known multicast address assigned by IANA.
  - Includes both assigned and solicited-node multicast addresses.
- 1 Non-permanently-assigned, "dynamically" assigned multicast address.
  - An example might be FF18::CAFE:1234, used for a multicast application with organizational scope.

## **Assigned IPv6 Multicast Addresses**



## IPv6 Multicast Address Space Registry

Last Updated 2014-08-17 Expert(s) Stig Venaas

IPv6 multicast addresses are defined in "IP Version 6 Addressing Architecture" [RFC4291]. This defines fixed scope and variable scope multicast addresses.

IPv6 multicast addresses are distinguished from unicast addresses by the value of the high-order octet of the addresses: a value of 0xFF (binary 11111111) identifies an address as a multicast address; any other value identifies an address as a unicast address.

The rules for assigning new IPv6 multicast addresses are defined in [RFC33071. IPv6 multicast addresses not listed below are reserved.

#### **Available Formats**



#### Registries included below

- IPv6 Multicast Address Scopes
- Node-Local Scope Multicast Addresse
- Link-Local Scope Multicast Addresse
- Site-Local Scope Multicast Addresses
- Variable Scope Multicast Addresses
- Source-Specific Multicast block

- RFC 2375, IPv6 Multicast Address Assignments, defines the initial assignment of IPv6 multicast addresses that have permanently assigned Global IDs.
- Reference for assigned multicast addresses:
  - (IANA) IPv6 Multicast Address Space Registry http://www.iana.org/assignments/ipv6-multicast-addresses/ipv6-multicastaddresses.xhtml

# Assigned Multicast Addresses with Link-local Scope

Flag = 0, Assigned multicast Scope = 2, Link-local scope



Prefix	Flag	Scope	Predefined Group ID	Compressed Format	Description (IPv6 assumed)
FF	0	2	0:0:0:0:0:0:1	FF02::1	All-devices
FF	0	2	0:0:0:0:0:0:2	FF02::2	All-routers
FF	0	2	0:0:0:0:0:5	FF02::5	OSPF routers
FF	0	2	0:0:0:0:0:6	FF02::6	OSPF DRs
FF	0	2	0:0:0:0:0:0	FF02::9	RIP routers
FF	0	2	0:0:0:0:0:A	FF02::A	EIGRP routers
FF	0	2	0:0:0:0:0:1:2	FF02::1:2	DHCP servers/relay agents

# Assigned Multicast Addresses with Site-local Scop

Flag = 0, Assigned multicast Scope = 5, Site-local scope

8 bits	4 bits	4 bits	112 bits
1111 1111	Flag 0000	Scope	Group ID

Prefix	Flag	Scope	Predefined Group ID	Compressed Format	Description (IPv6 assumed)
FF	0	5	0:0:0:0:0:0:2	FF05::2	All-routers
FF	0	5	0:0:0:0:0:1:3	FF05::1:3	All DHCP servers

- Used to communicate within a "site", possibly routed within the site.
- Must have IPv6 multicast routing enabled:

Router(config) # ipv6 multicast-routing

DHCPv6, relay agents and DHCPv6 multicast addresses are included in Lesson
 8.

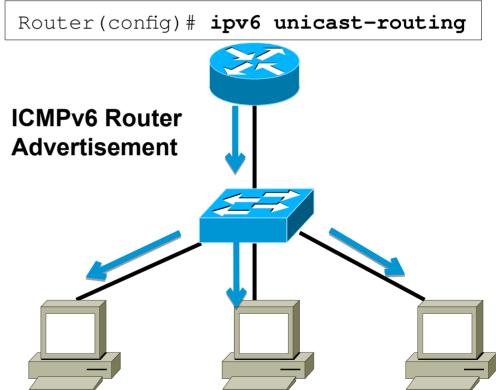
## "All IPv6 Devices" Assigned Multicast Address

## **ICMPv6** Router Advertisement



	FF02::1	FE80::1	Rest of IPv6 Packet		
Destination		Source			
	IPv6 Address	IPv6 Address	Router(config)# ipv		

- FF02::1 All IPv6 Devices
- All IPv6 devices, including the router, belong to this group.
- Every IPv6 device will listen and process packets to this address.
- Isn't this the same as a broadcast?
- No, because it maps to a Layer 2 MAC address which is more efficient... coming soon!



## "All IPv6 Routers" Assigned Multicast Address

### **ICMPv6** Router Solicitation



FF02::2

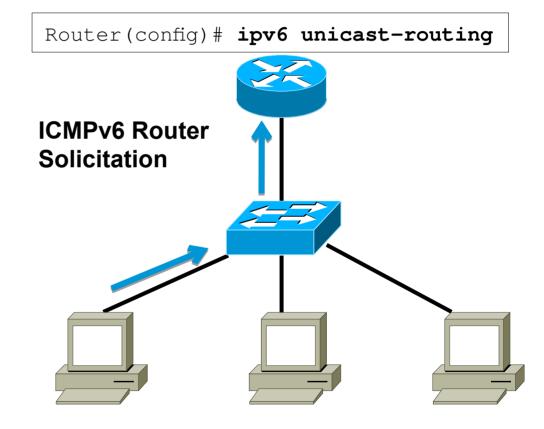
FE80::12:3456: 7890:ABCD

**Rest of IPv6 Packet** 

Destination IPv6 Address

Source IPv6 Address

- FF02::2 All IPv6 Routers
- All IPv6 routers belong to this group. (Process these packets.)
- Used by devices to communicate with an IPv6 Router.





# IPv6 vs. IPv4

## **IPv6** Header

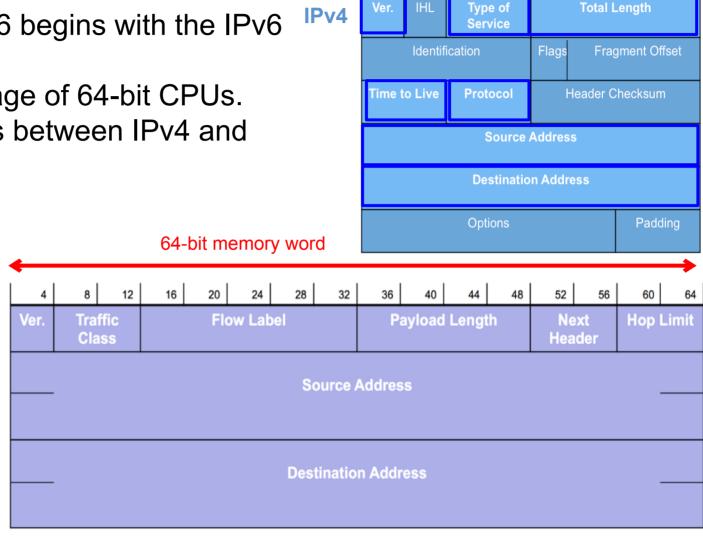
Understanding IPv6 begins with the IPv6 header.

- IPv6 takes advantage of 64-bit CPUs.
- Several differences between IPv4 and IPv6 headers.

Simpler IPv6 header.

IPv<sub>6</sub> Fixed 40 byte IPv6 header.

Lets look at the differences...

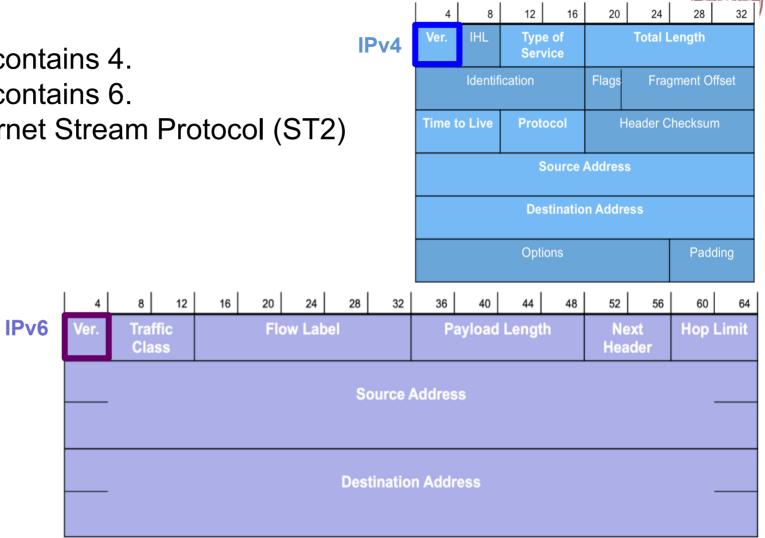


Similar fields

12

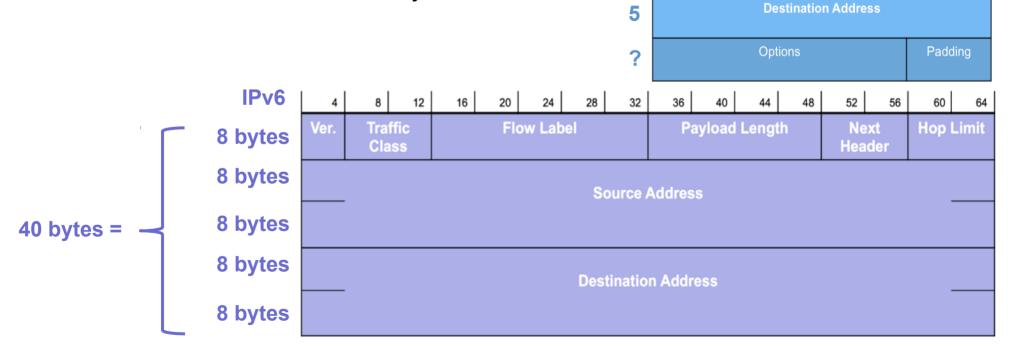
## **IPv6 Version**

- **IPv4 Version** contains 4.
- IPv6 Version contains 6.
- Version 5: Internet Stream Protocol (ST2)



# **IPv4 Internet Header Length**

- IPv4 Internet Header Length (IHL)
  - Length of IPv4 header in 32-bit words including any Options or Padding.
- IPv6
  - IHL for IPv6 is not needed.
  - IPv6 header is fixed at 40 bytes.



IPv4

4

Ver.

Time to Live

20

Flags

Source Address

**Total Length** 

Header Checksum

**Fragment Offset** 

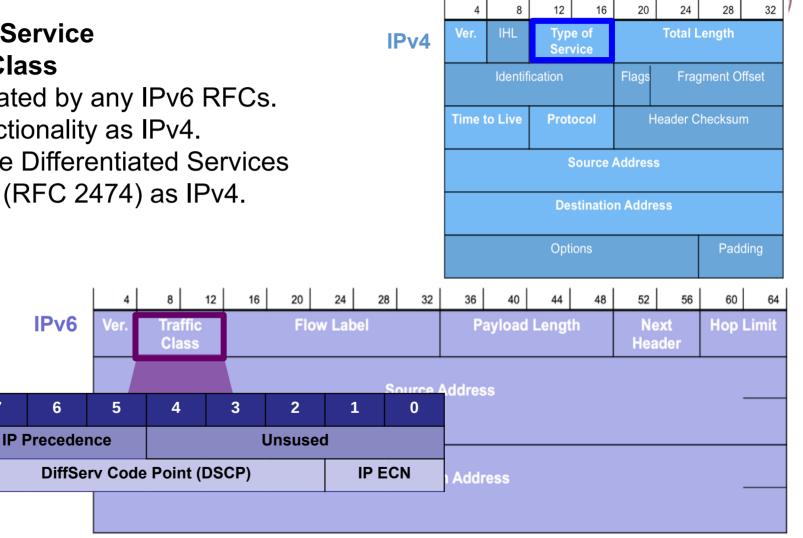
Type of

Service

Protocol

## **IPv6 Traffic Class**

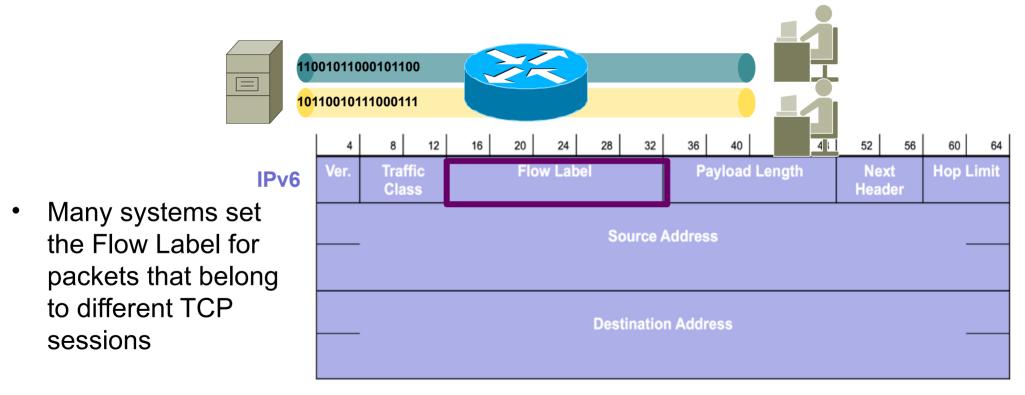
- **IPv4 Type of Service**
- **IPv6 Traffic Class** 
  - Not mandated by any IPv6 RFCs.
  - Same functionality as IPv4.
  - Uses same Differentiated Services technique (RFC 2474) as IPv4.



## **IPv6 Flow Label**



- New field in IPv6 not part of IPv4.
- Flow label is used to identify the packets in a common stream or flow.
- Traffic from source to destination share a common flow label.
- RFC 6437 IPv6 Flow Label Specification

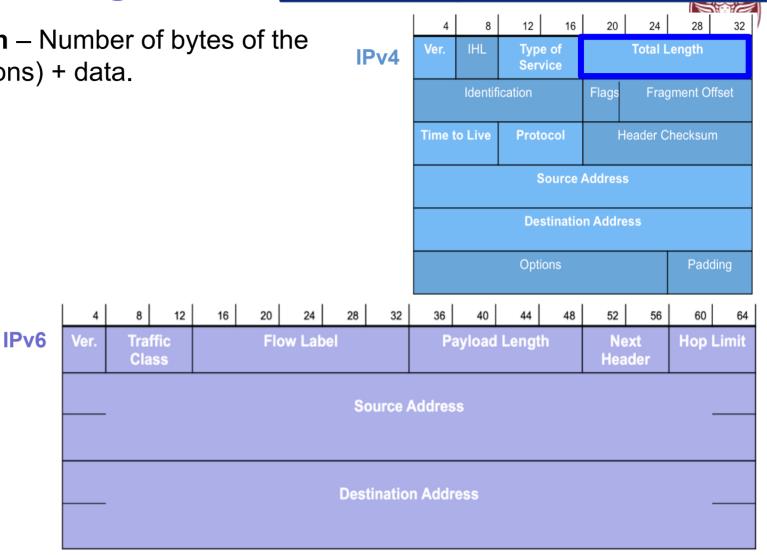


# **IPv6 Payload Length**

**IPv4 Header** 

**Data (Payload)** 

IPv4 Total Length – Number of bytes of the IPv4 header (options) + data.

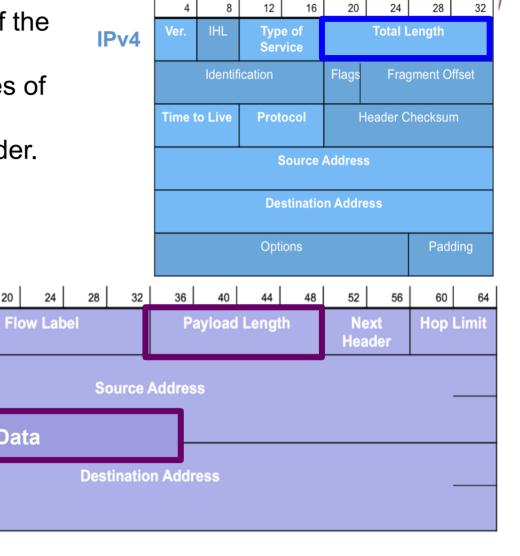


# **IPv6 Payload Length**

**IPv4** Header

**Data (Payload)** 

- **IPv4 Total Length** Number of bytes of the IPv4 header (options) + data.
- IPv6 Payload Length Number of bytes of the payload.
  - Does not include the main IPv6 header.
  - Includes extension headers + data



**IPv6 Header** 

**IPv6 Extension Header (Optional)** 

IPv6

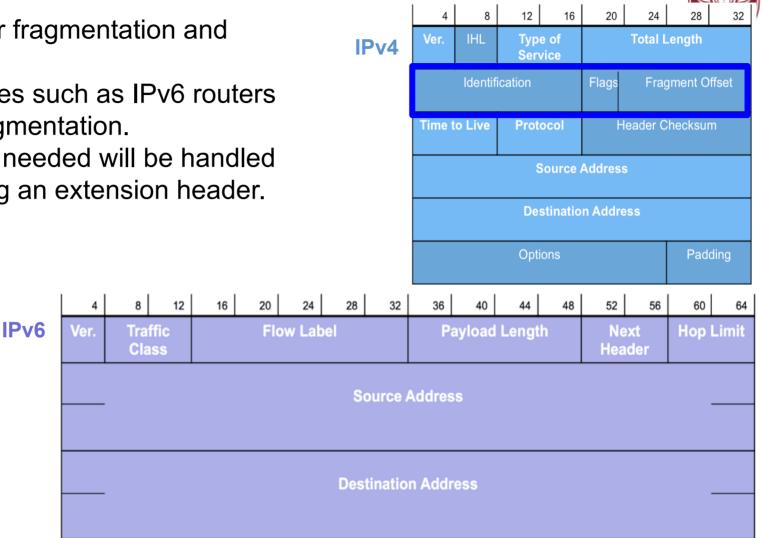
**Payload** 

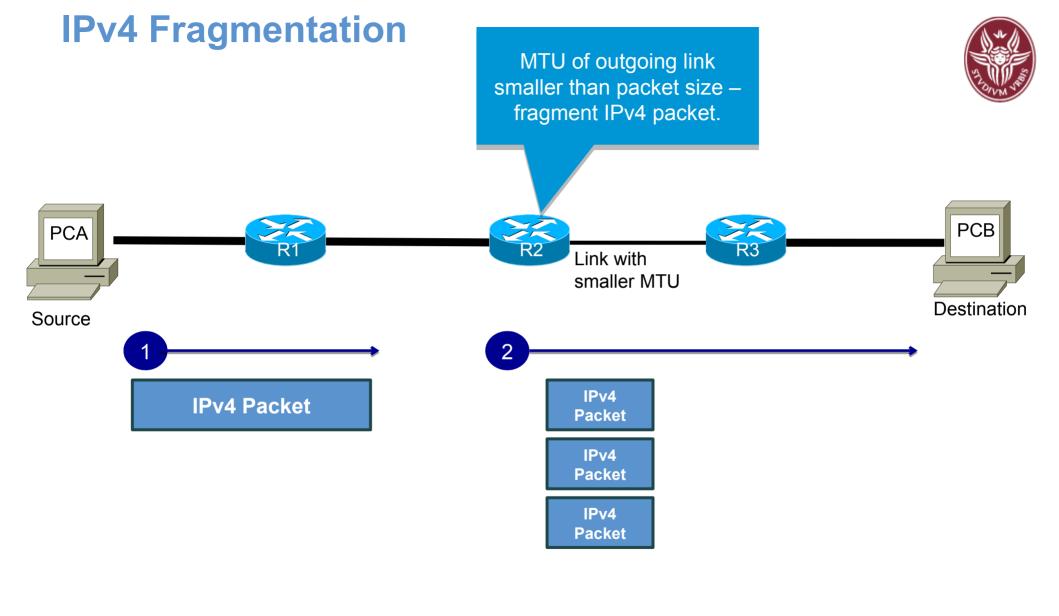
Traffic Class

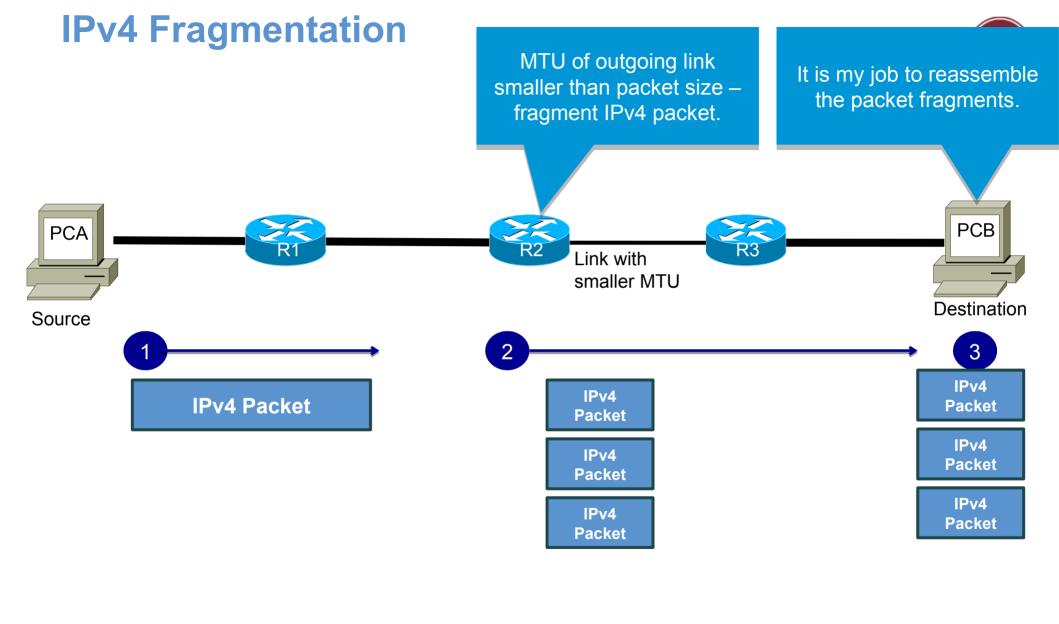
Data

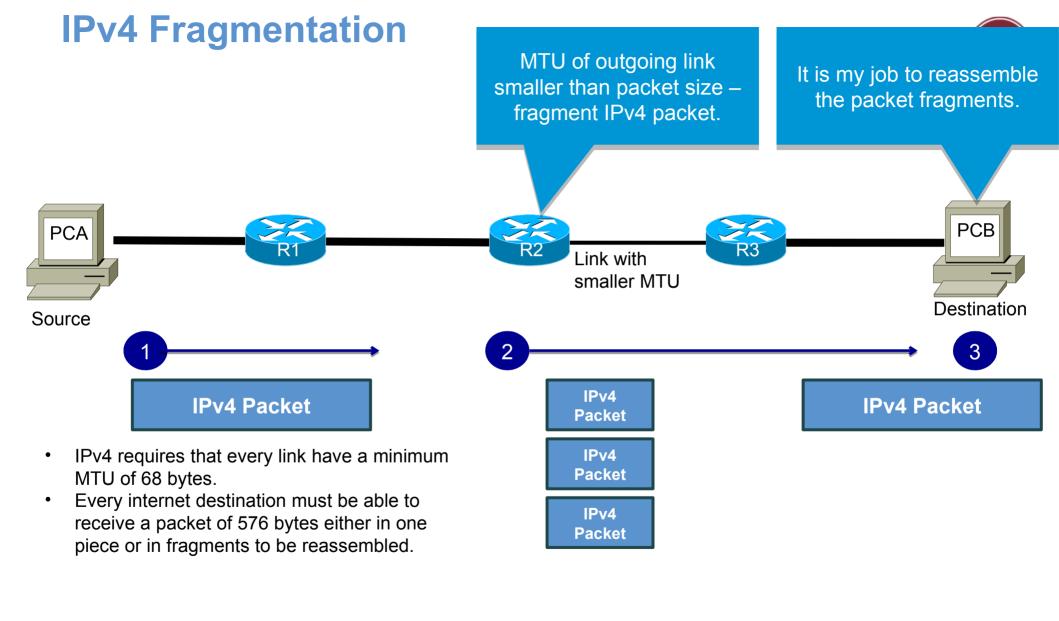
## **IPv4** Fragmentation

- IPv4 fields used for fragmentation and reassembly.
- Intermediate devices such as IPv6 routers do not perform fragmentation.
- Any fragmentation needed will be handled by the source using an extension header.



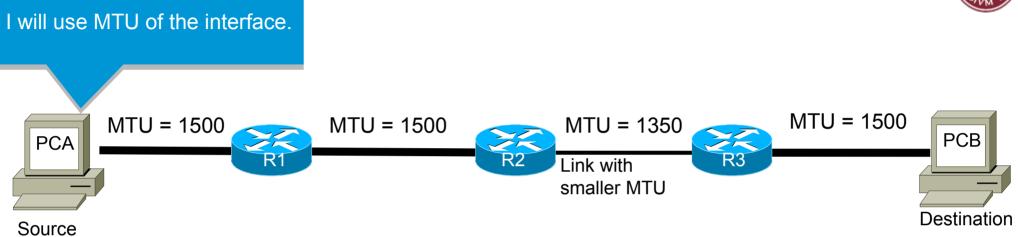


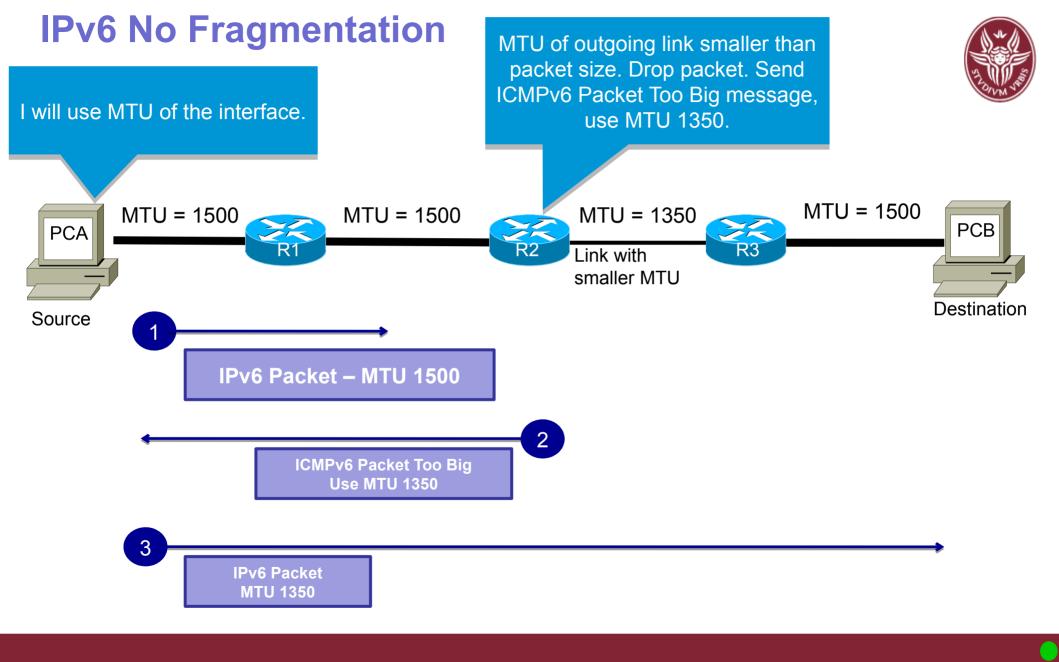


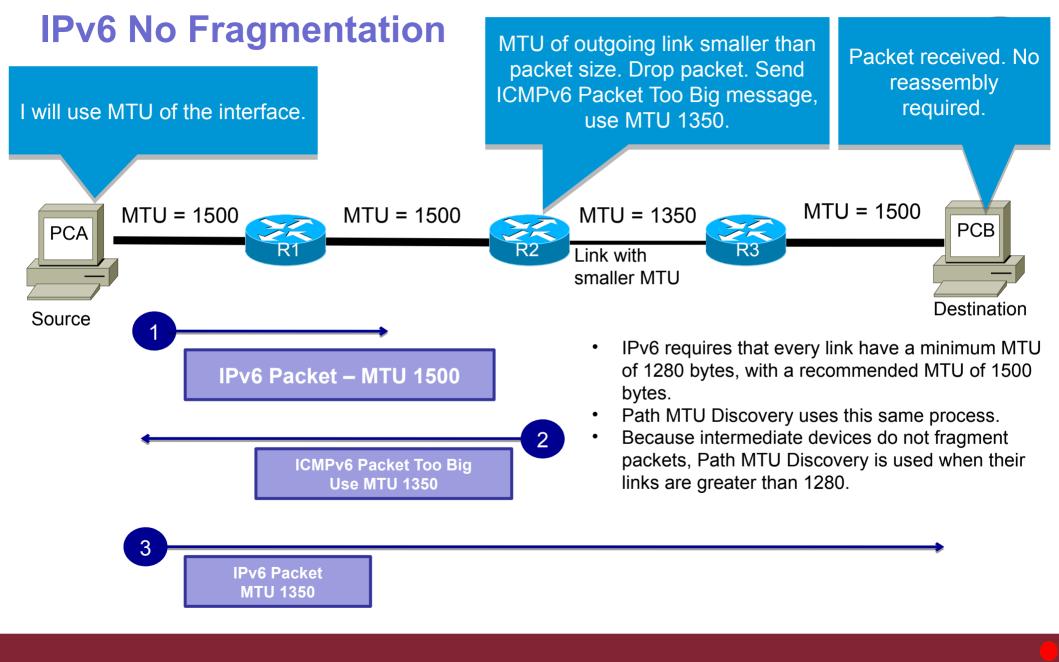


# **IPv6 No Fragmentation**



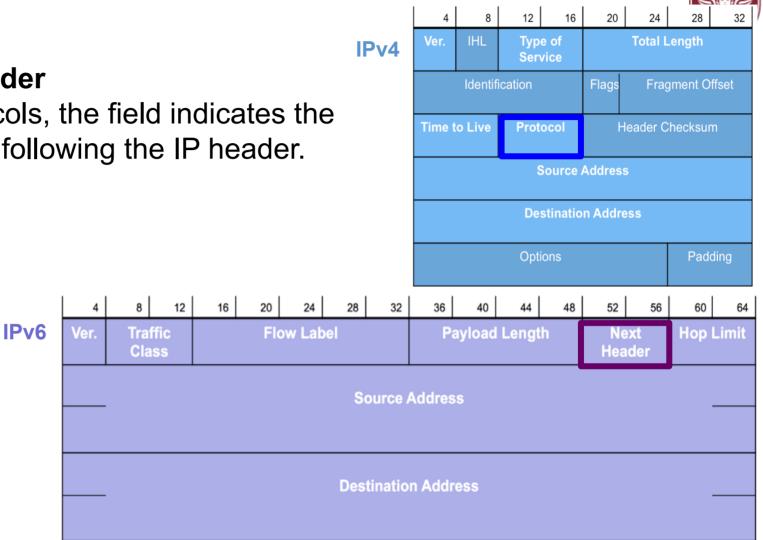






### **IPv6 Next Header**

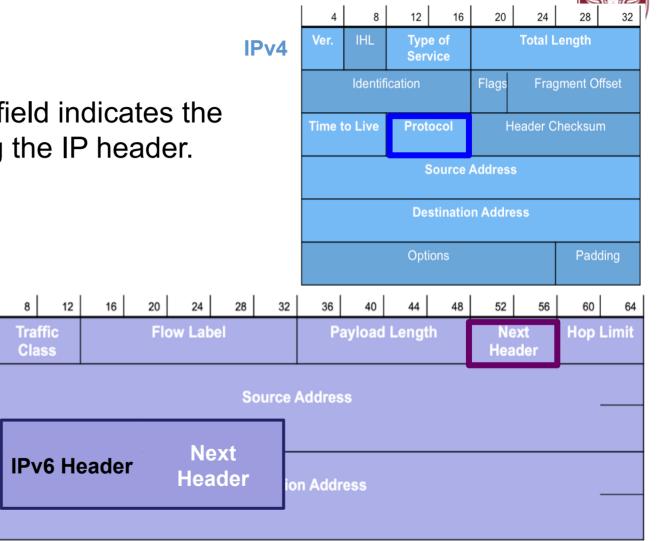
- **IPv4 Protocol**
- **IPv6 Next Header**
- For both protocols, the field indicates the type of header following the IP header.



### **IPv6 Next Header**

- IPv4 Protocol
- IPv6 Next Header
- For both protocols, the field indicates the type of header following the IP header.

IPv6

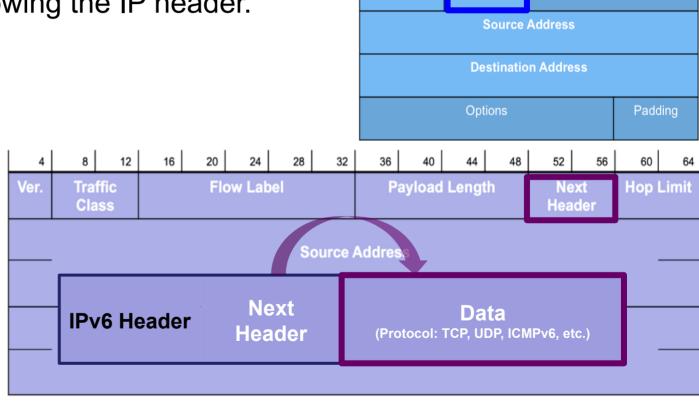


## **IPv6 Next Header**

- IPv4 Protocol
- IPv6 Next Header
- For both protocols, the field indicates the type of header following the IP header.

IPv6

- Common values:
- 6 = TCP
- 17 = UDP
- 58 = ICMPv6
- 88 = EIGRP
- 89 = OSPF



IPv4

12 l

Time to Live

Type of

Service

Protocol

16

20

Flags

**Total Length** 

Header Checksum

**Fragment Offset** 

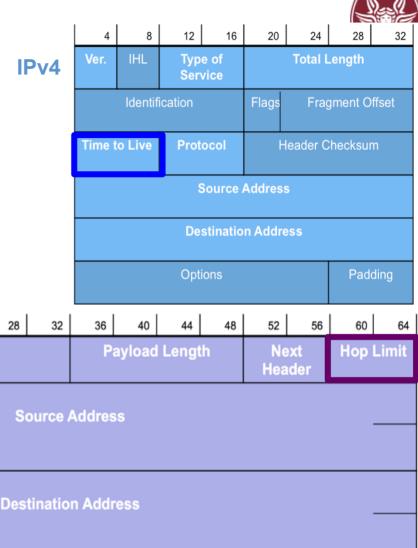
## **IPv6 Hop Limit**

- **IPv4 TTL (Time to Live)**
- **IPv6 Hop Limit**
- Renamed to more accurately reflect process.
- Set by source, every router in path decrements hop limit by 1.

IPv<sub>6</sub>

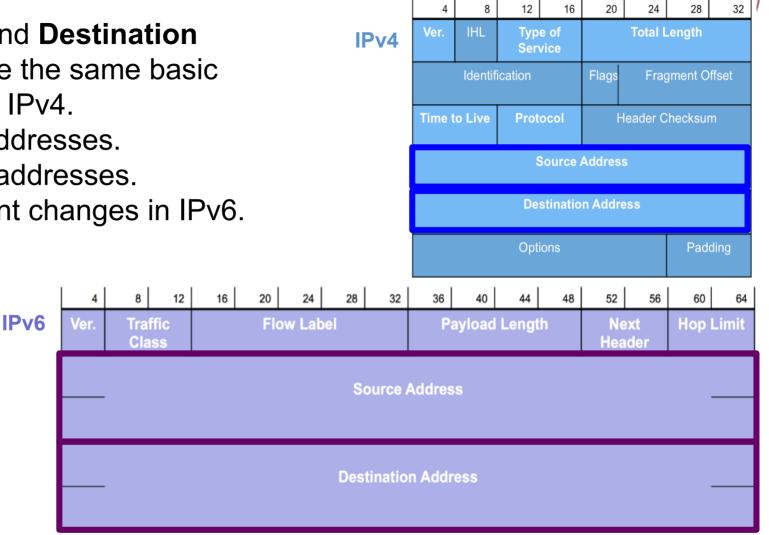
When 0, drop packet.

52 Next **Hop Limit Traffic** Flow Label **Payload Length** Class Header **Source Address Destination Address** 



## **IPv6 Source and Destination Addresses**

- IPv6 Source and Destination addresses have the same basic functionality as IPv4.
- IPv4 32-bit addresses.
- IPv6 128-bit addresses.
- Some significant changes in IPv6.



### **IPv4 Header Checksum**

- IPv4 Header Checksum
- Not used in IPv6.
- Upper-layer protocols generally have a checksum (UDP and TCP).
- So, in IPv4 the UDP checksum is optional.

IPv6

 Because it's not in IPv6, the UDP checksum is now mandatory.

**Destination Address Options** Padding 52 60 **Hop Limit** Traffic Flow Label **Payload Length** Next Class Header **Source Address Destination Address** 

IPv4

Time to Live

12

Type of

Service

Protocol

20

Flags

Source Address

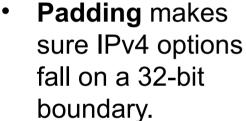
**Total Length** 

Header Checksum

Fragment Offset

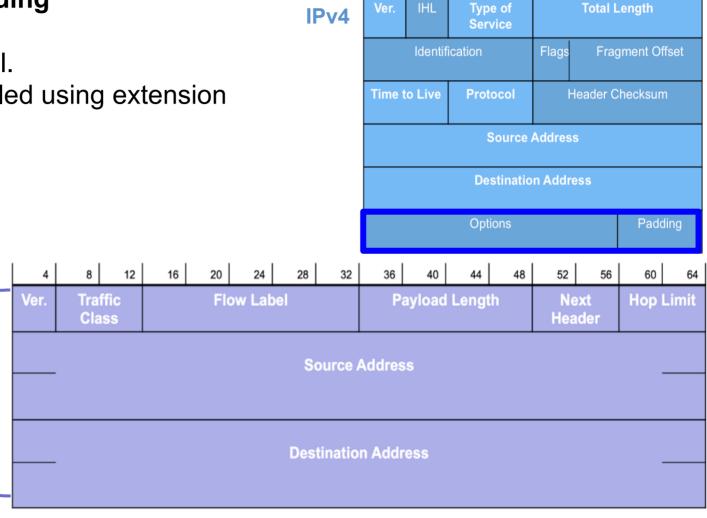
## **IPv4 Options and Padding**

- IPv4 Options and Padding
- Not used in IPv6.
- Variable length, optional.
- IPv4 Options are handled using extension headers in IPv6.



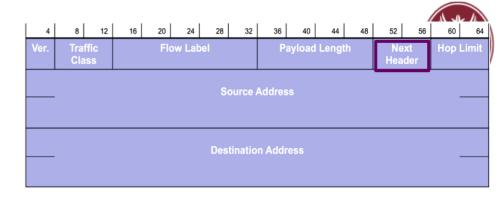
boundary.
 IPv6 header is fixed at 40 bytes.

**40** bytes =



12

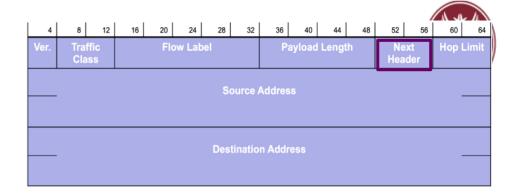
- Next Header identifies:
  - The protocol carried in the data portion of the packet.



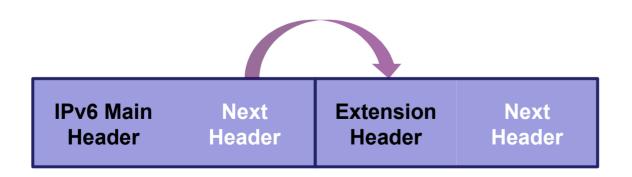
The presence of an extension header.

IPv6 Main Next Header Header

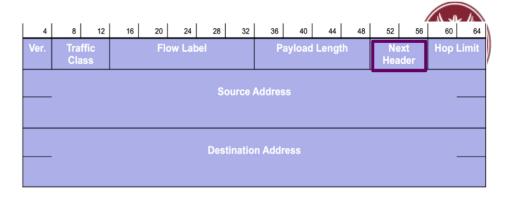
- Next Header identifies:
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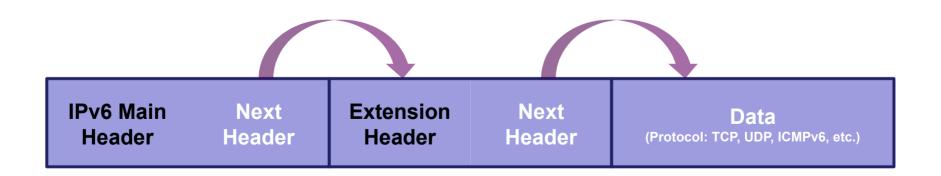
The presence of an extension header.



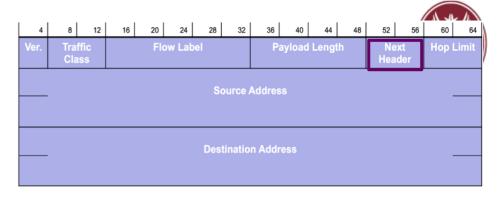
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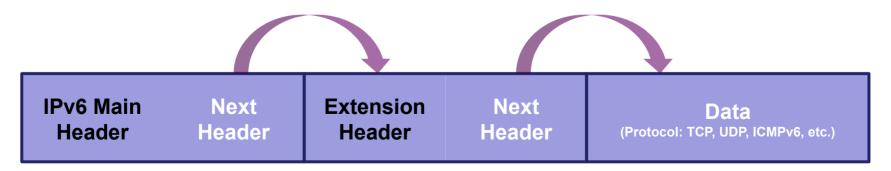
- The presence of an extension header.
- Extension headers are optional and follow the main IPv6 header.
- Provide flexibility and features to the main IPv6 header for future enhancements without having to redesign the entire protocol.



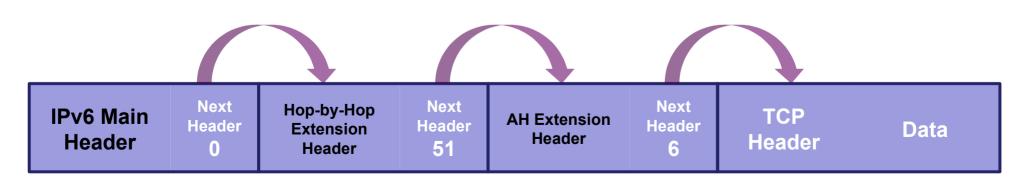
- Next Header identifies:
  - The protocol carried in the data portion of the packet.



- The presence of an extension header.
- Extension headers are optional and follow the main IPv6 header.
- Provide flexibility and features to the main IPv6 header for future enhancements without having to redesign the entire protocol.
- Allows the main IPv6 header to have a fixed size for more efficient processing.

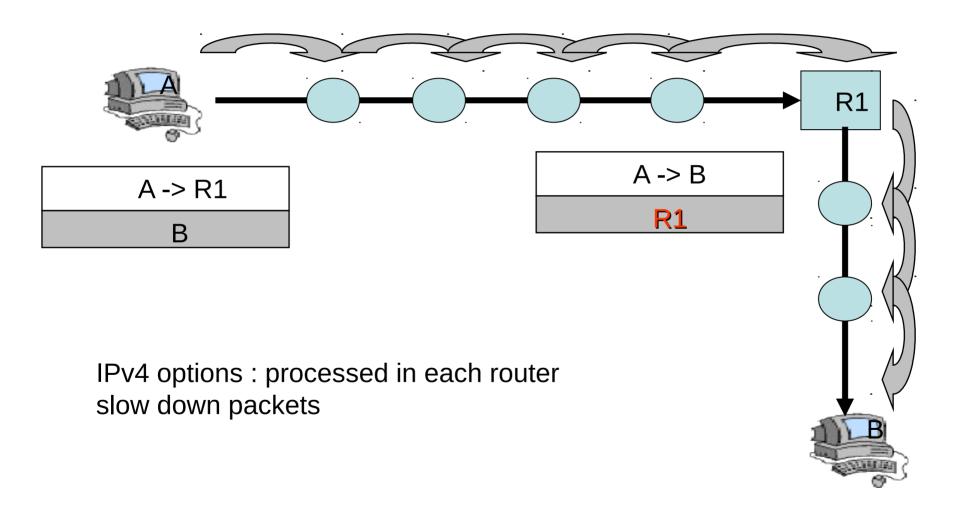


Next Header Value (Decimal)	Extension Header Name	Extension Header Description
0	Hop-by-Hop Options	Used to carry optional information, which must be examined by every router along the path of the packet.
43	Routing	Allows the source of the packet to specify the path to the destination.
44	Fragment	Used to fragment IPv6 packets.
50	Encapsulating Security Payload (ESP)	Used to provide authentication, integrity, and encryption.
51	Authentication Header (AH)	Used to provide authentication and integrity.
60	Destination Options	Used to carry optional information that only needs to be examined by a packet's destination node(s).



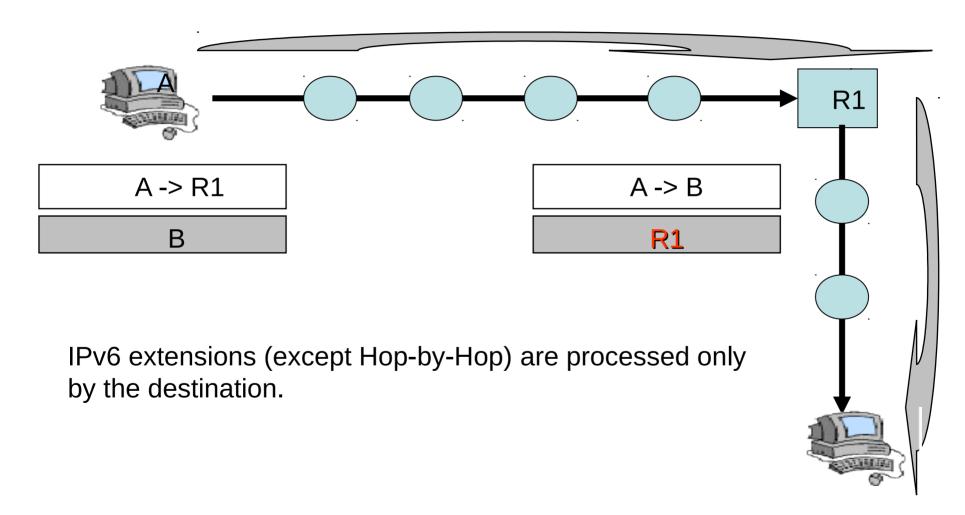
## IPv4 options vs. IPv6 extensions





## IPv4 options vs. IPv6 extensions





# Order is important (RFC 2460)



IPv6	
Hop by hop	Processed by every router
Destination	Processed by routers listed in Routing extension
Routing	List of routers to cross
Fragmentation	Processed by the destination
Authentication	After reassembling the packet
Security	Cipher the content of the remaining information
Destination	Processed <b>only</b> by the destination
Upper Layer	



# That's all for today

- Questions?
- See you on Thursday!!
- 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)