CMSC417

Computer Networks

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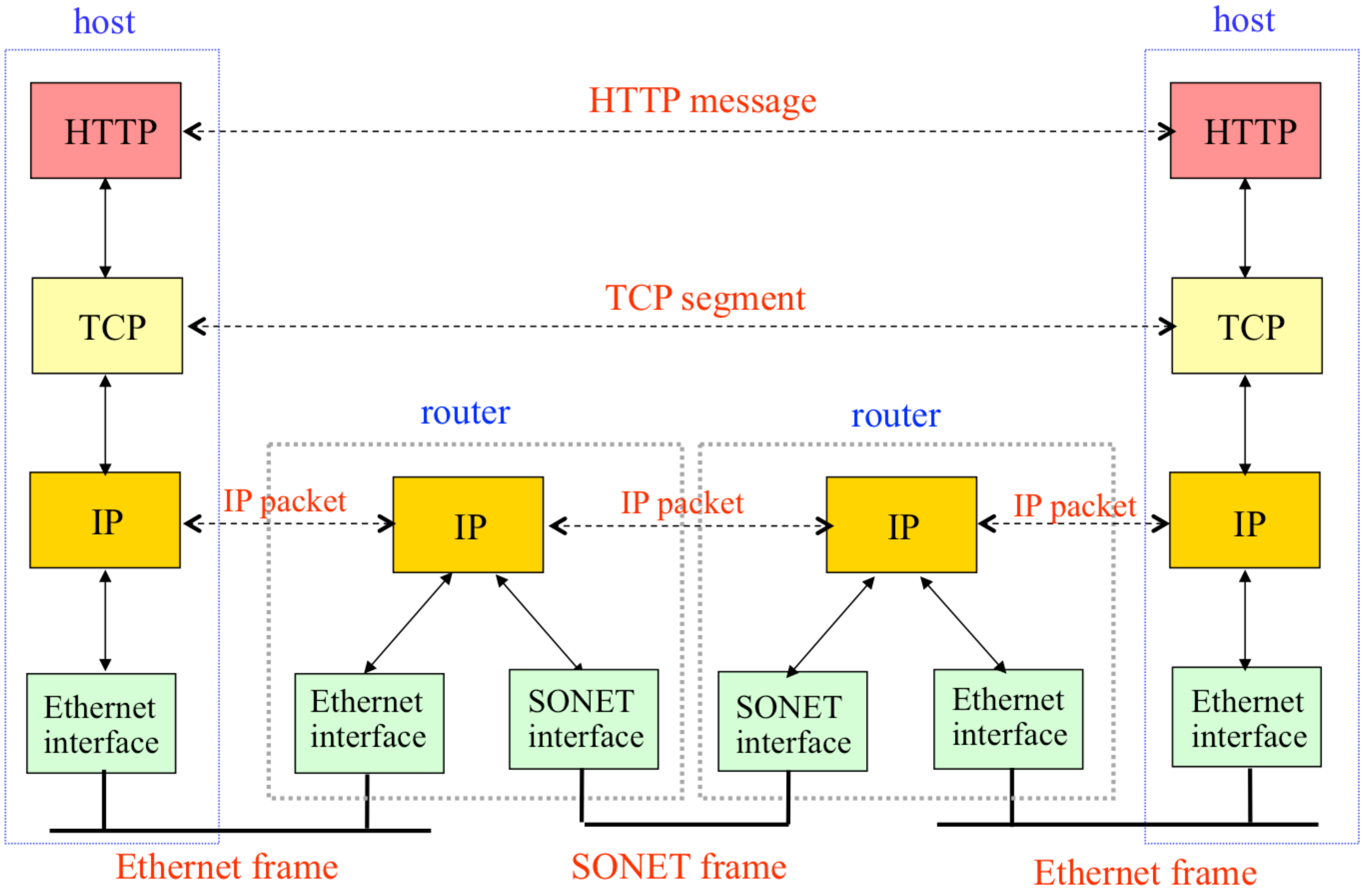
October 4, 2018

Message, Segment, Packet, and Frame



Internet Control Protocols (1)

IP works with the help of several control protocols:

- ICMP is a companion to IP that returns error info
  - Required, and used in many ways, e.g., for traceroute
- ARP finds Ethernet address of a local IP address
  - Glue that is needed to send any IP packets
  - Host queries an address and the owner replies
- DHCP assigns a local IP address to a host
  - Gets host started by automatically configuring it
  - Host sends request to server, which grants a lease

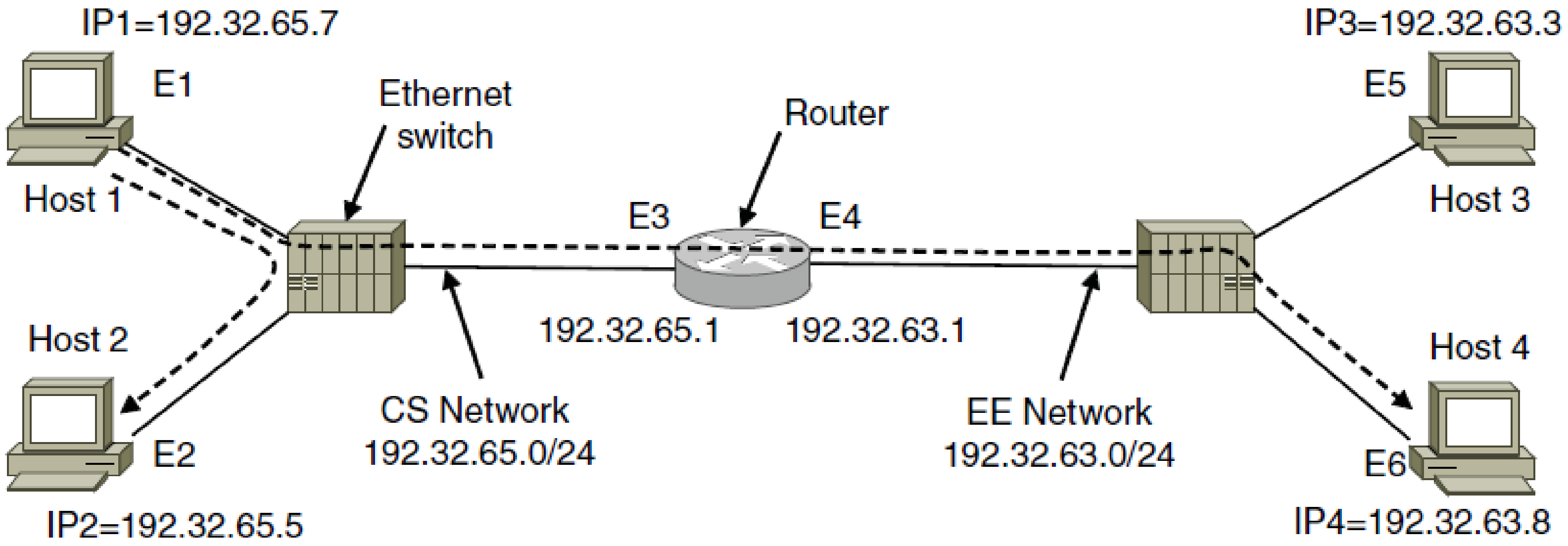
Internet Control Protocols (2)

Main ICMP (Internet Control Message Protocol) types:

Message type	Description
Destination unreachable	Packet could not be delivered
Time exceeded	Time to live field hit 0
Parameter problem	Invalid header field
Source quench	Choke packet
Redirect	Teach a router about geography
Echo and Echo reply	Check if a machine is alive
Timestamp request/reply	Same as Echo, but with timestamp
Router advertisement/solicitation	Find a nearby router

Internet Control Protocols (3)

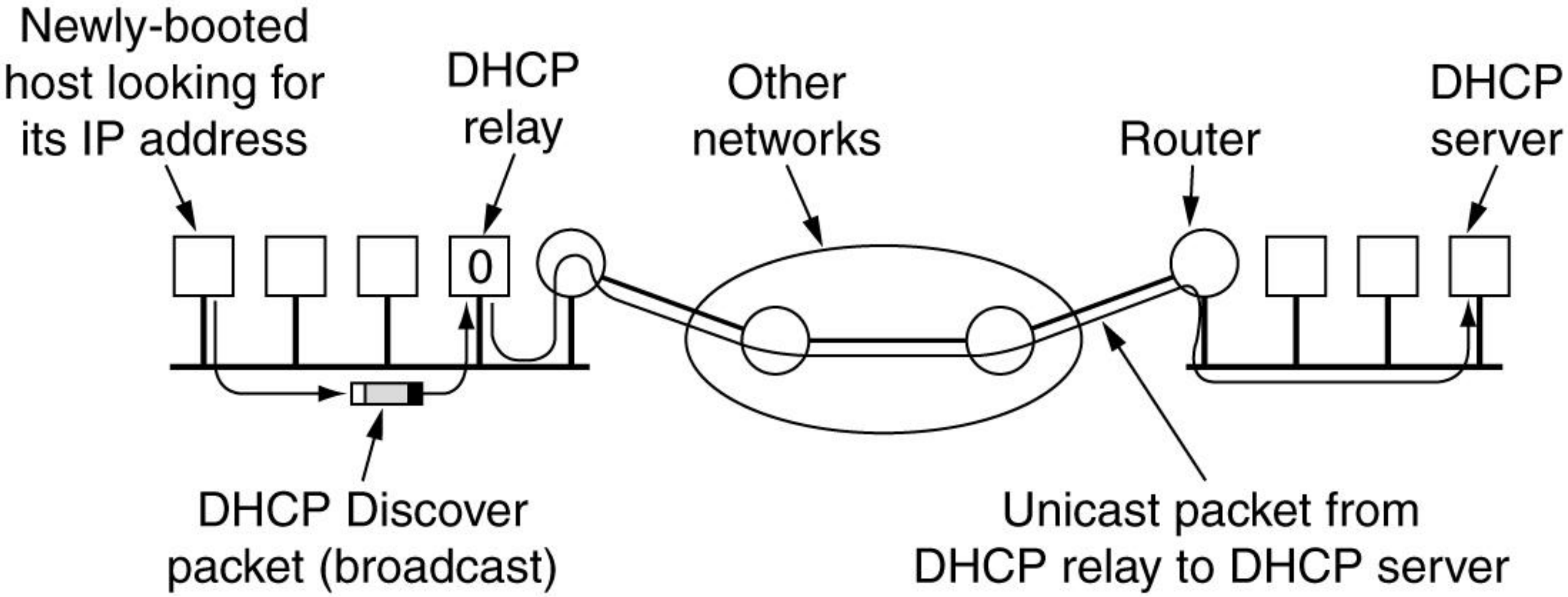
- ARP (Address Resolution Protocol) lets nodes find target Ethernet addresses [pink] from their IP addresses



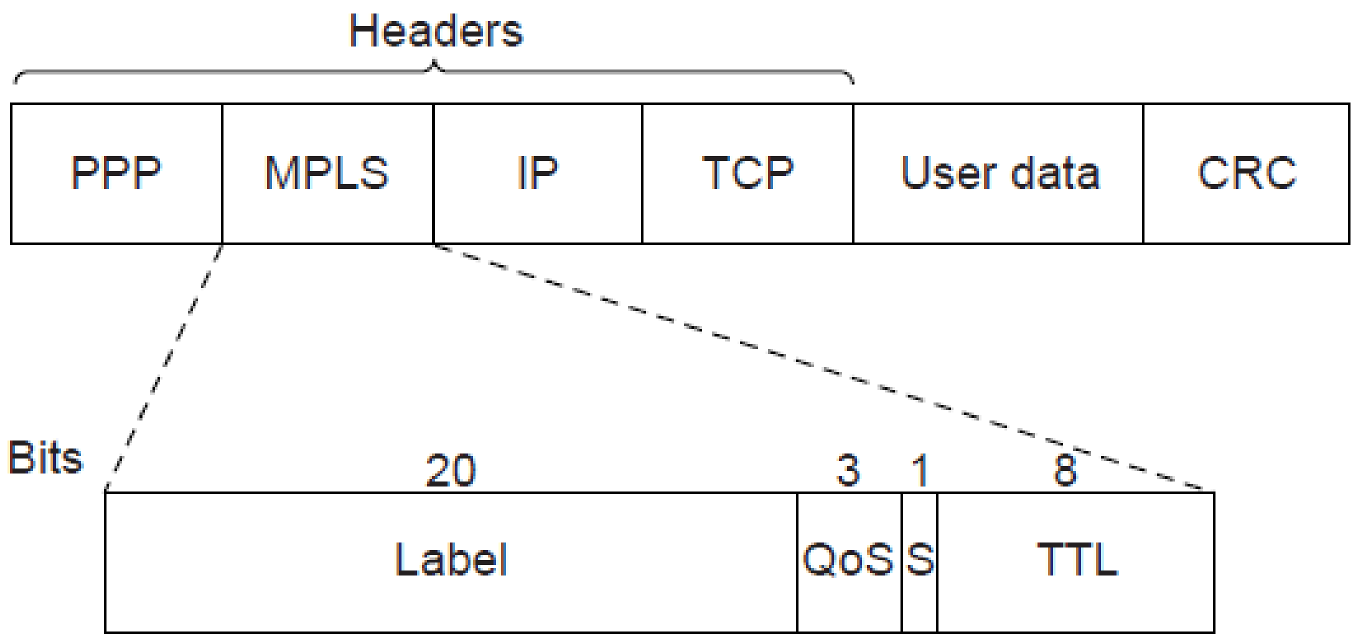
Frame	Source IP	Source Eth.	Destination IP	Destination Eth.
Host 1 to 2, on CS net	IP1	E1	IP2	E2
Host 1 to 4, on CS net	IP1	E1	IP4	E3
Host 1 to 4, on EE net	IP1	E4	IP4	E6

Dynamic Host Configuration Protocol

Operation of DHCP.

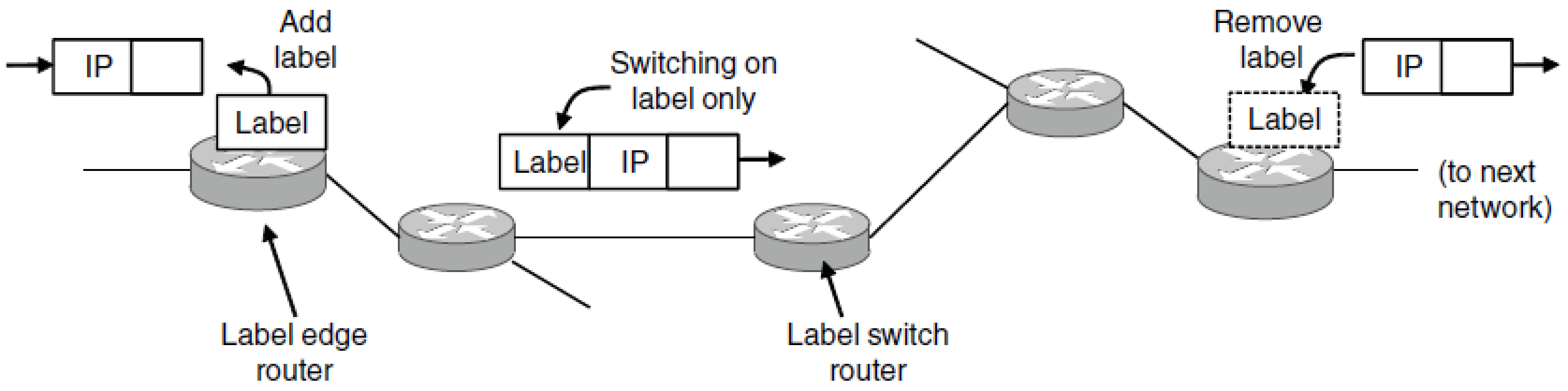


Label Switching and MPLS (1)



Transmitting a TCP segment using IP, MPLS, and PPP.

Label Switching and MPLS (2)

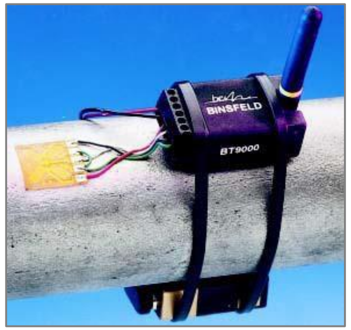


Forwarding an IP packet through an MPLS network

What is IPv6

- Also known as IPng (next generation)
- A new version of the Internet Protocol
  - Primarily designed to extend address space
  - Enhancements and new features

What IP is touching



Why is IPv6 Here

- IPv6 provides a platform for new Internet functionality that will be needed in the immediate future, and provide flexibility for further growth and expansion.

Features of IPv6

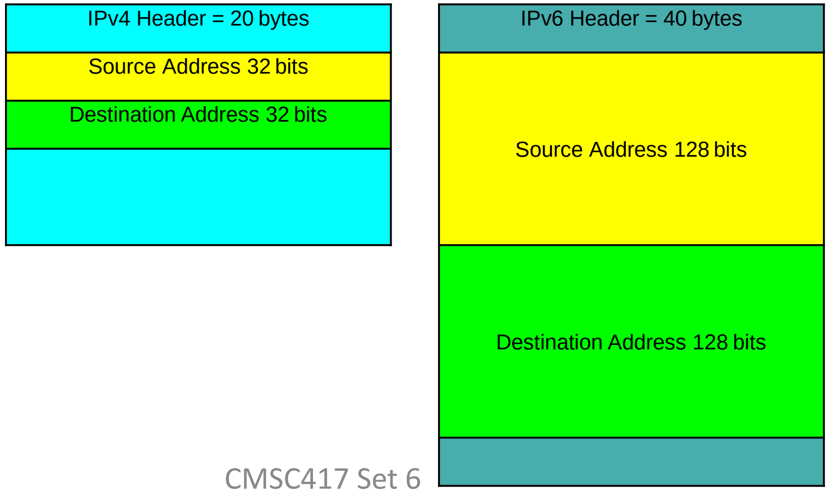
- Addressing
- Header
- Security
- Privacy
- Autoconfiguration
- Routing
- Quality of Service

Features of IPv6

- Expanded addressing and routing capabilities
  - 128-bit addresses
  - Multicast routing is now scalable with “scope” field
  - Defined usage of “Anycast” addressing

Features of IPv6

- Simplified header format
  - Some IPv4 fields dropped or made optional
  - IPv6 packet header only twice the size of v4 header, even though address is four times a v4 address



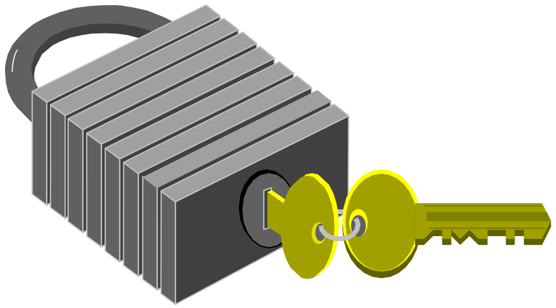
Features of IPv6

- Extension headers
  - “Options” are now placed in separate headers
  - “Options” are now any length
  - Router doesn’t have to look at most “Options”*

* except the hop-by-hop options

Features of IPv6

- Authentication and Privacy
  - Basic **required** support for authentication and data integrity
  - Basic support for Payload encryption
  - Support for Header and payload encryption

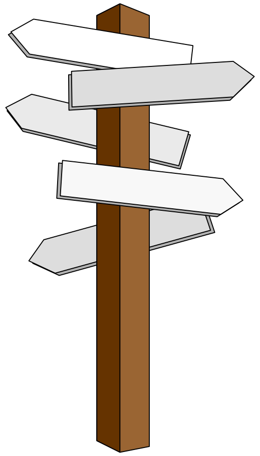


Features of IPv6

- Auto-configuration
  - Self-configuring nodes for local links
  - Auto-configuration for site links
  - Stateless uses “Router Advertisement”
    - Cost savings
    - Home market potential
  - Stateful uses “DHCPv6”
    - Centralized management
    - New “v6” features

Features of IPv6

- Source Routing
  - Support for Source Demand Routing Protocol (SDRP)
  - Sender can specify packet route
  - Destination can return packet via same route



Features of IPv6

- Route Aggregation
  - Address Hierarchy
  - Deployed in “Groups”
  - Defined in RFC 2374

Features of IPv6

- Quality of Service/Class of Service
  - (flow labels)
  - New 20 bit field for labeling traffic “flows”
  - Continued support for current IPv4 standards

Features of IPv6

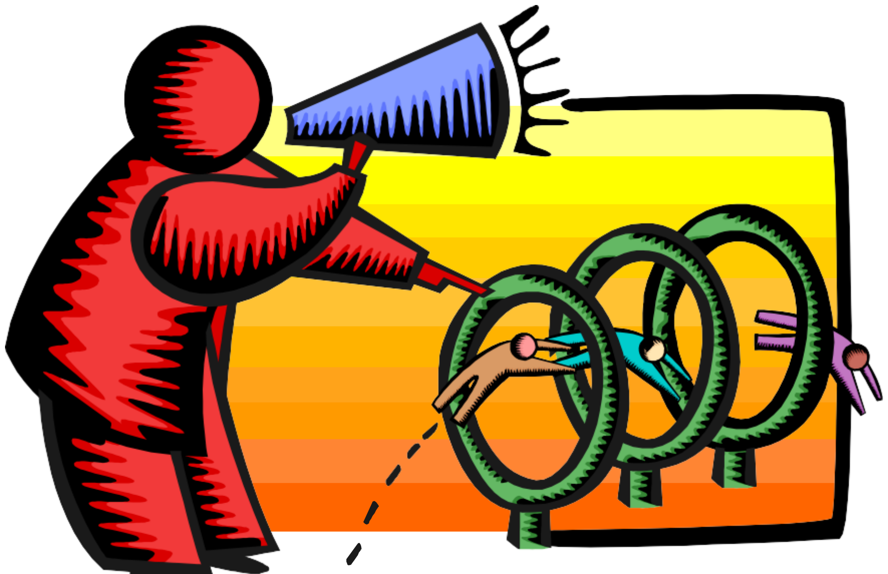
- Transition technologies
  - Required by RFC 1726
  - Various methodologies exist today
    - IPv6 Relays and Gateways (6to4) RFC 3056
    - Tunnels (automatic and manual)
      - – Broker RFC3053
    - NAT-PT   RFC 2766
    - and many others...

IPv6 versus IPv4

- • IPv4 addresses 2^{32} = 4,294,967,296
- IPv6 addresses 2^{128} =
  - 340,282,366,920,938,463,463,374,607,431,768,211,456
- 340 undecillion –US, 340 sextillion-UK
- • 79,228,162,514,264,337,593,543,950,33
  - times more v6 addresses than v4
- If IP addresses weighed one gram each
  - IPv4 = 1/7th of the Empire State Building
  - IPv6 = 56 billion(US) earths

IPv6 versus IPv4

- No Broadcast in IPv6
  - Replaced by Multicast
  - Multicast scope provides flexibility



IPv6 versus IPv4

- Uncontrolled fragmentation in IPv4
  - Only a source node can fragment IPv6
  - Limits packet size to minimum MTU in path (Maximum Transmission Unit)

IPv6 versus IPv4

- Extension Headers
  - – Supports multiple headers including upper layer headers. Provides for future enhancements.

IPv6 versus IPv4

- Other features inherent to IPv6
  - Security encryption
  - Header encryption
  - Sender authentication
  - Privacy

IPv6 Specifications

IPv6 specifications

- IPv6 - RFC 2460
- IPv6 Neighbor Discovery – RFC 2461
- IPv6 Auto Configuration – RFC 2462

RFC 2460

- IPv6 Terminology
- IPv6 Packet Header
- IPv6 Addressing
- IPv6 Header Extensions

IPv6 Terminology

- Node – A device that implements IPv6.
  - A node can be a host or a router
  - A node can be an entertainment system
  - A node can be a smart phone
  - A sensor node



IPv6 Terminology

- Router – A node that forwards IPv6 packets not explicitly addressed to itself.
  - Routers operate at the Network Layer
  - Routers use metrics to determine optimal paths which network traffic should be forwarded

IPv6 Terminology

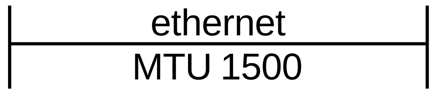
- Host – Any node that is not a router
  - A host can be your computer at home
  - A host can be your smart phone or tablet

IPv6 Terminology

- Upper Layer – A protocol layer immediately above IPv6.
  - TCP/UDP
  - ICMP
  - OSPF
  - And many more…

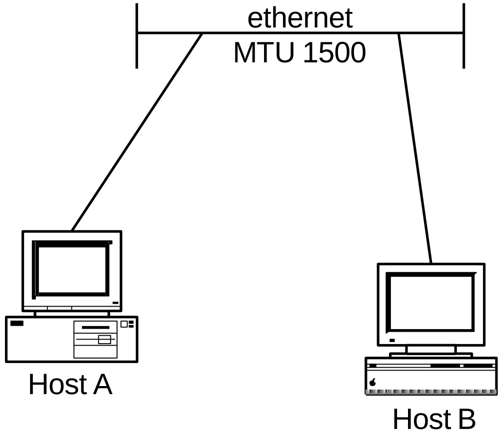
IPv6 Terminology

- Link – A communication facility or medium over which nodes can communicate at the Data Link Layer.
  - Ethernet
  - Token ring
  - Frame relay
  - A “tunnel”
  - And many more…



IPv6 Terminology

- Neighbors – Nodes attached to the same link.
  - 2 PC's on a hub can be neighbors
  - Hosts and routers can be neighbors



IPv6 Terminology

- Interface – A node’s attachment to a link.
  - A Network Interface Card (NIC) is an interface
  - A node can have more than one interface
  - Routers often have multiple interfaces
  - A PC’s dial-up adapter is an interface

IPv6 Terminology

- Address – An IPv6-layer identifier for an interface or a set of interfaces.
  - 128-bit address
  - Prefix represented by /nn bits
  - New address structure (to be discussed)

3ffe:80f0:ffff:1::202/64

IPv6 Addressing

- eight groups of four hexadecimal digits,
  - each group representing 16 bits (two octets).
  - The groups are separated by colons (:).

2001:0db8:85a3:0000:0000:8a2e:0370:7334

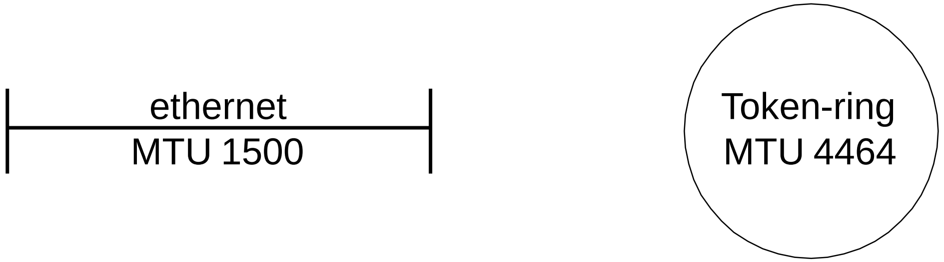
- Simplifications
  - Leading zeroes in a group may be omitted.
- 2001:db8:85a3:0:0:8a2e:370:7334
  - One consecutive group of zero value may be replaced with a single empty group using two consecutive colons (::).
- 2001:db8:85a3::8a2e:370:7334

IPv6 Terminology

- Packet – An IPv6 header plus payload.
  - Cannot be larger than the “Path MTU”*
  - Includes header and header extensions
  - Delivered in frames

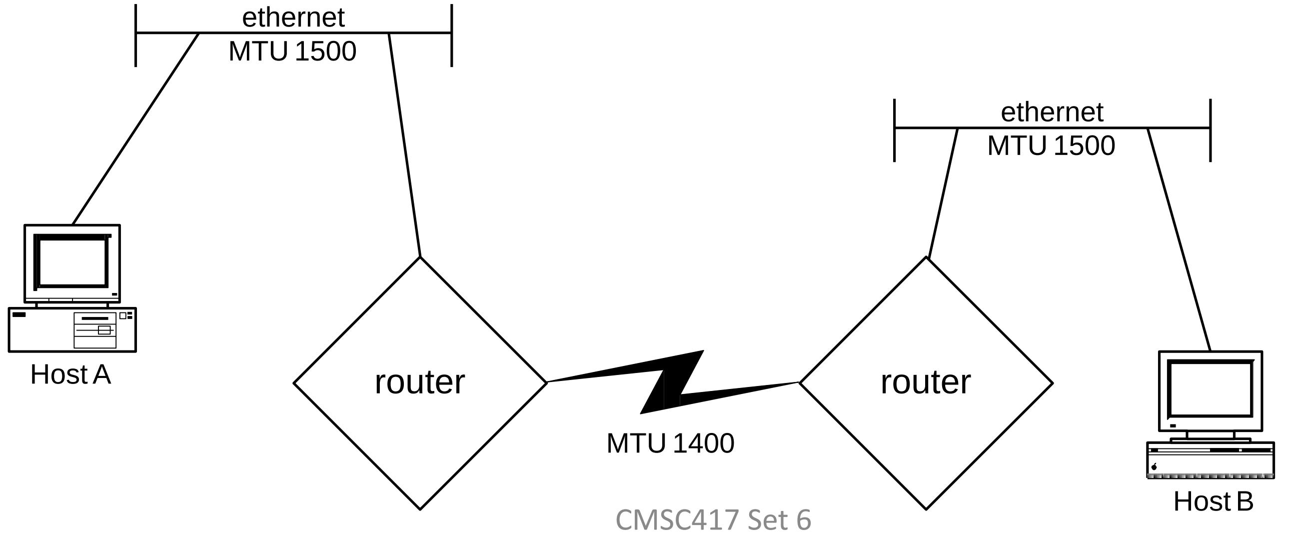
IPv6 Terminology

- Link MTU – The maximum transmission unit, or packet size, given in octets, that can be conveyed in one piece over a link.
  - MTU – Maximum Transmission Unit
  - Ethernet MTU is 1500 octets
  - 4mb Token Ring MTU is 4464 octets



IPv6 Terminology

- Path MTU – The minimum link MTU of all the links in a path between a source node and a destination node.
  – The smallest MTU in a network path



IPv6 Packet Header

IPv6 Packet

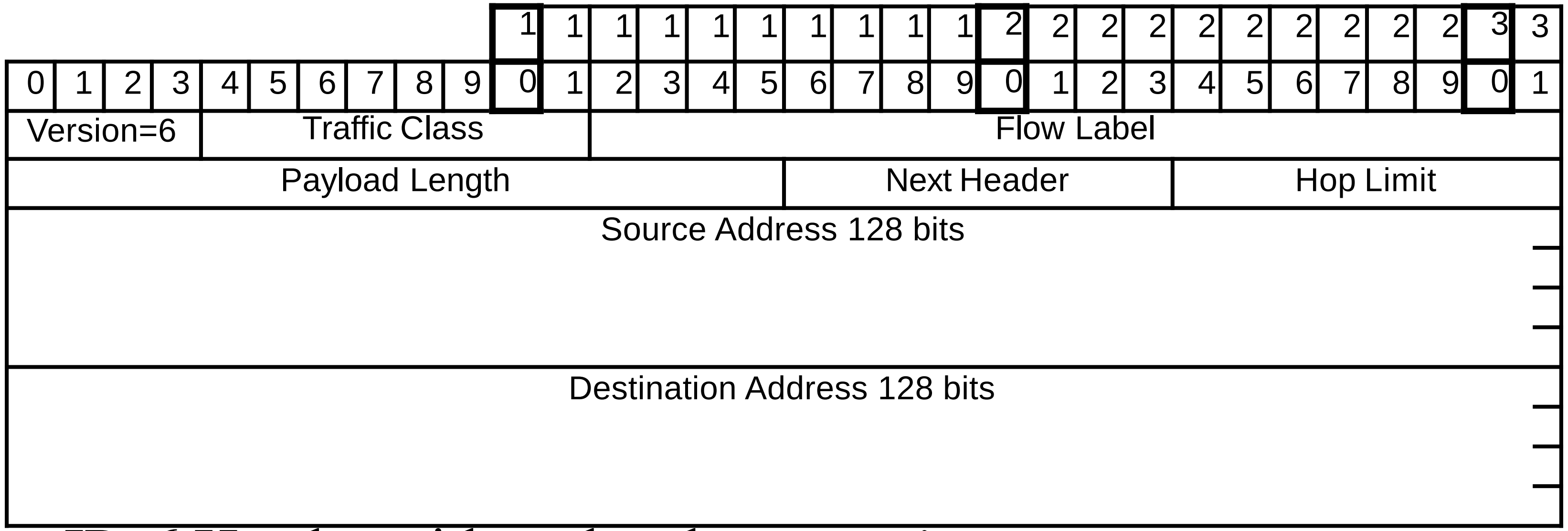
- Similar to IPv4
- No options with padding
- New fields
- Is only 2x length even though address is 4x

IPv6 Packet Header

- Compare to IPv4 header

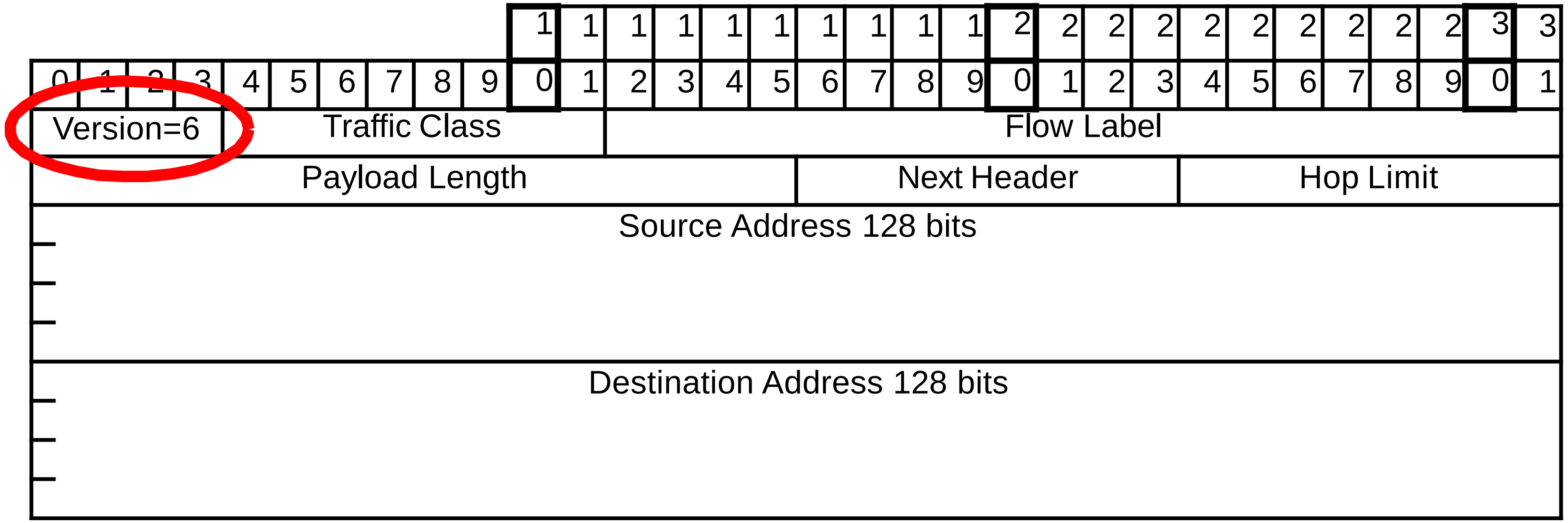
<table>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>3</td><td>3</td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td></tr>
<tr><td colspan="4">Version=4</td><td colspan="4">IHL</td><td colspan="8">Type of Service</td><td colspan="16">Total Length</td></tr>
<tr><td colspan="16">Identifier</td><td colspan="3">Flags</td><td colspan="13">Fragment Offset</td></tr>
<tr><td colspan="8">Time to Live</td><td colspan="8">Protocol</td><td colspan="16">Header Checksum</td></tr>
<tr><td colspan="32">Source Address</td></tr>
<tr><td colspan="32">Destination Address</td></tr>
<tr><td colspan="32">Options + Padding</td></tr>
</table>

IPv6 Packet Header



- IPv6 Header with no header extensions
- Carried in frames
- 8 fields

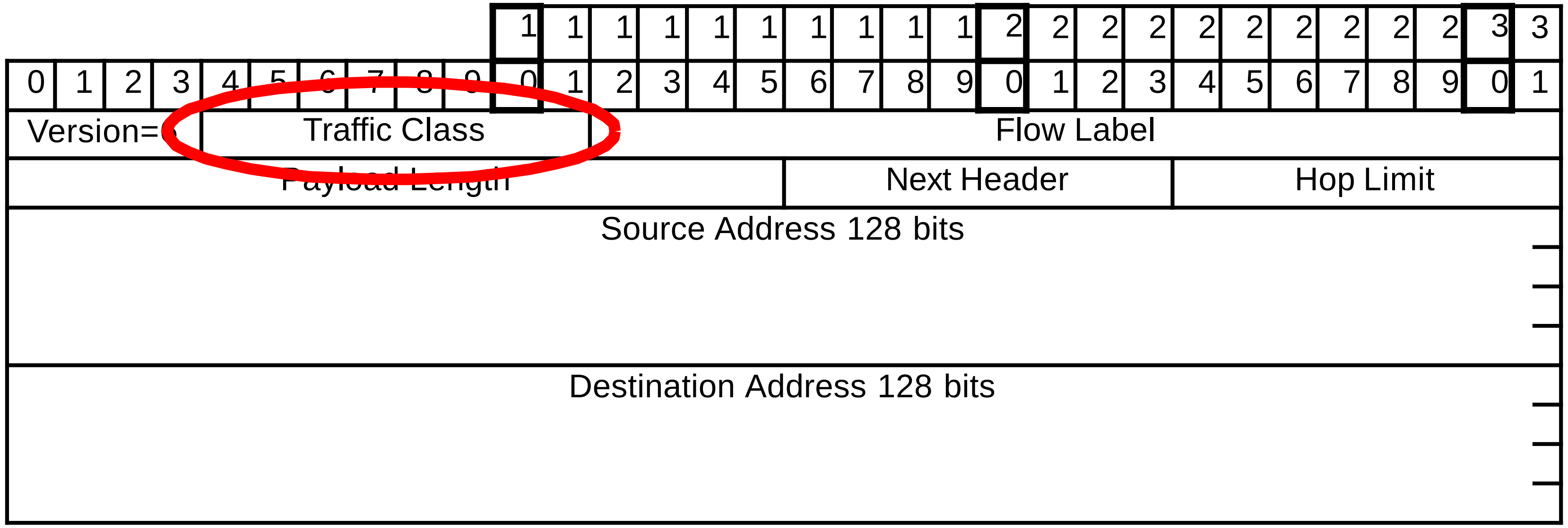
IPv6 Packet Header



- Version – 4 bits – Identifies the version of IP protocol
  - 0100 (4) for IPv4
  - 0110 (6) for IPv6

V4

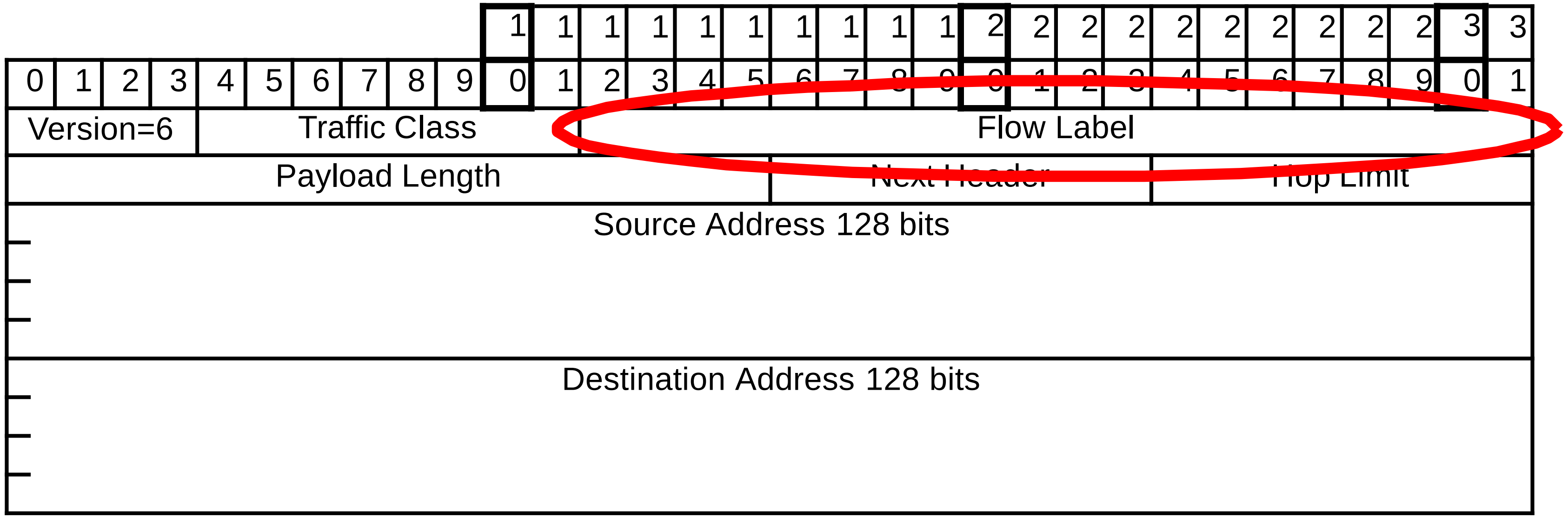
IPv6 Packet Header



- Traffic Class – 8 bits – Allows originating nodes and/or routers to distinguish between different classes or priorities of IPv6 packets
    - QoS is an example implementation
    - RSVP uses Traffic Class

V4

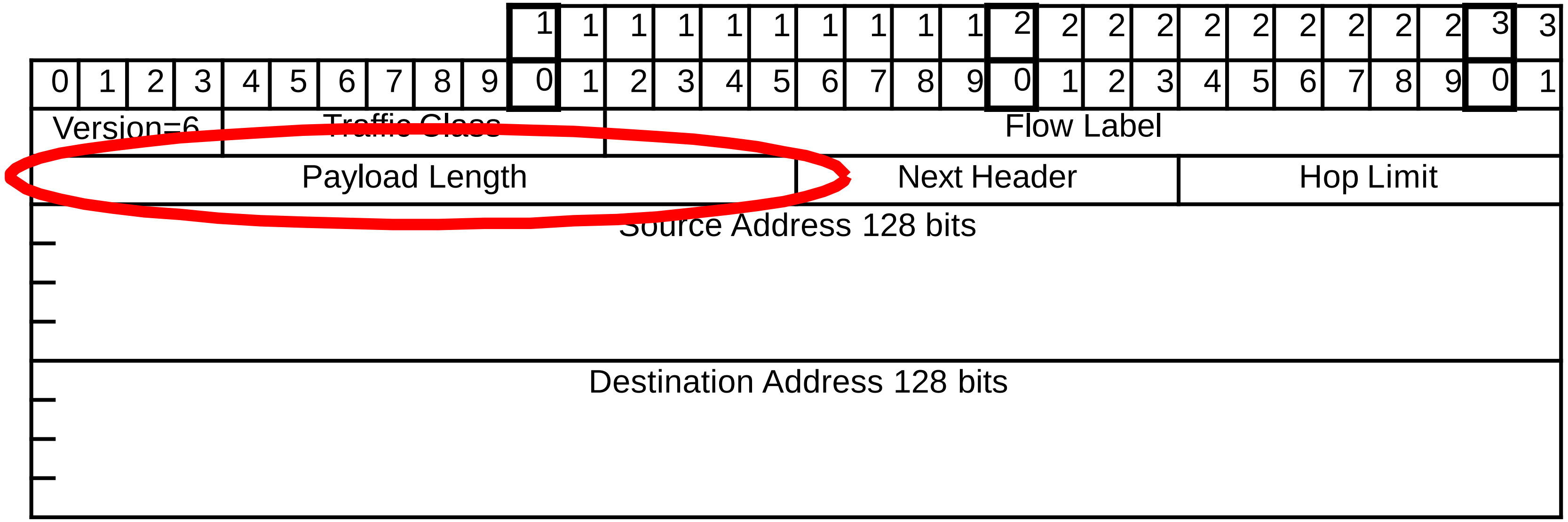
IPv6 Packet Header



- Flow Label – 20 bits – Used to “label” a flow of traffic.
    - May be used to request special handling
    - RFC 1809 “Using the Flow Label Field in IPv6”

V4

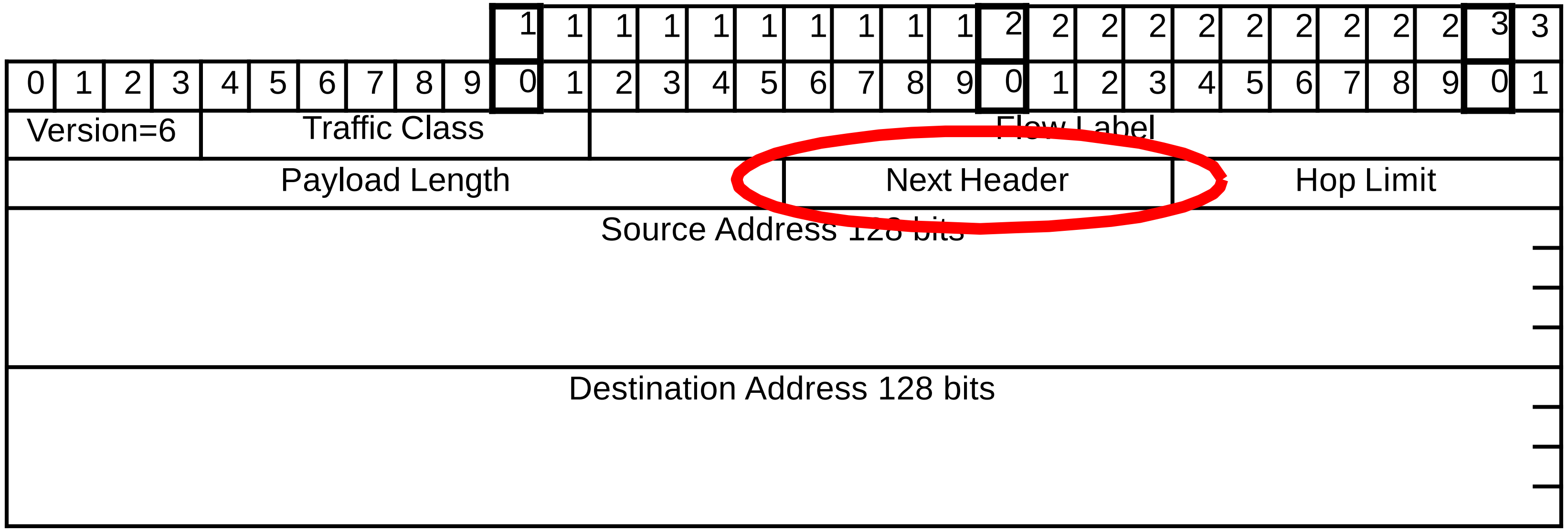
IPv6 Packet Header



- Payload Length – 16 bits – Length, in octets, of the payload
  - Payload is balance of IPv6 packet following header
  - Extension headers are part of payload
  - Jumbo Payloads*

V4

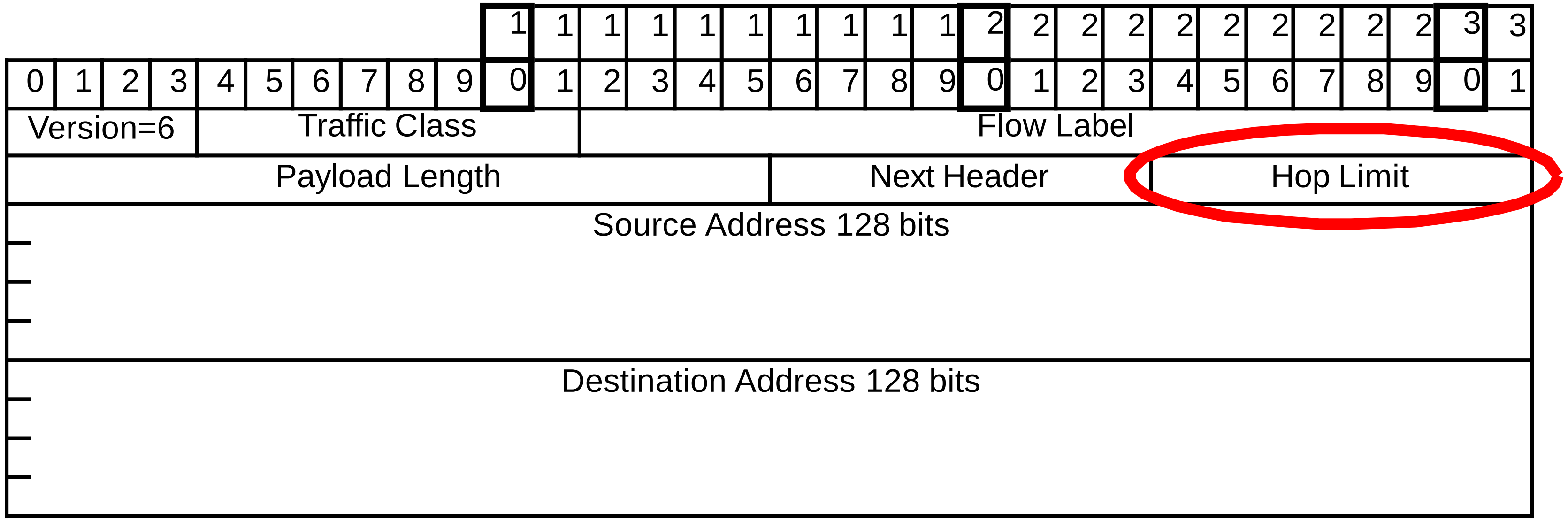
IPv6 Packet Header



- Next Header – 8 bits – Identifies the "extension" header immediately following
    - Packet may have zero, one, or more extension headers
    - Extension header order is important*

V4

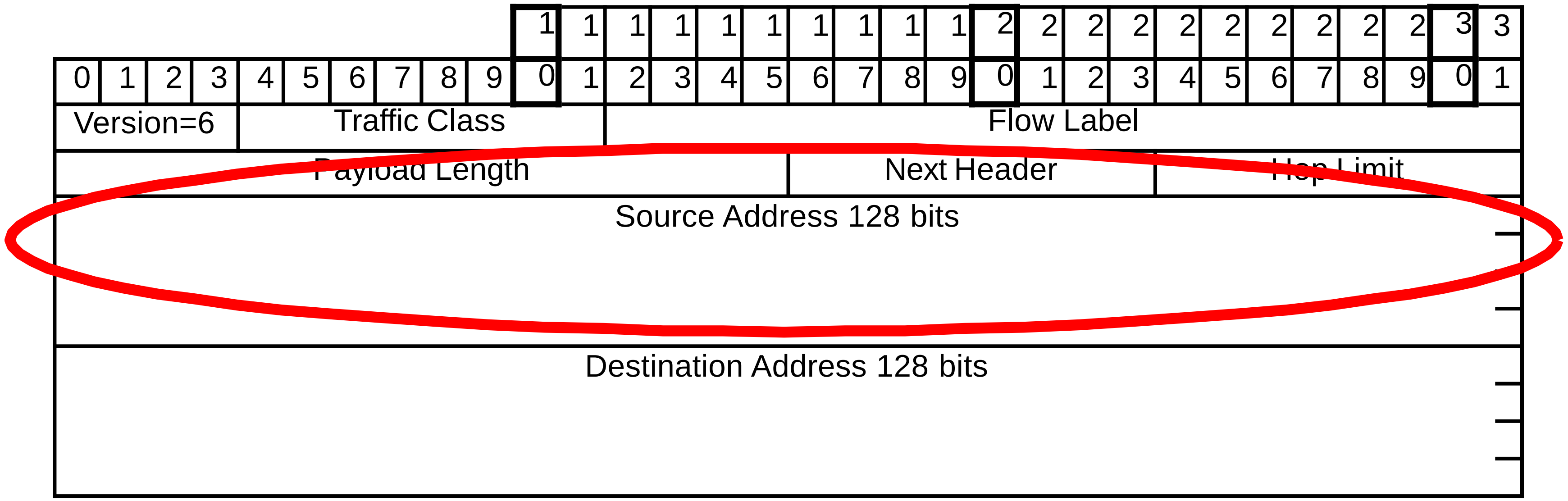
IPv6 Packet Header



- Hop Limit – 8 bits – Maximum number of **hops** an IPv6 packet can be forwarded.
    - Similar to IPv4 TTL, but NOT time
    - Decremented by each node on path

V4

IPv6 Packet Header



- Source Address – 128-bits
  - versus IPv4 32-bit

V4

IPv6 Packet Header

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<tr><td colspan="4">Version=6</td><td colspan="8">Traffic Class</td><td colspan="20">Flow Label</td></tr>
<tr><td colspan="16">Payload Length</td><td colspan="8">Next Header</td><td colspan="8">Hop Limit</td></tr>
<tr><td colspan="32">Source Address 128 bits</td></tr>
<tr><td colspan="32">Destination Address 128 bits</td></tr>
</table>

- Destination Address – 128-bits
  - versus IPv4 32-bit

V4

IPv6 Extension Headers

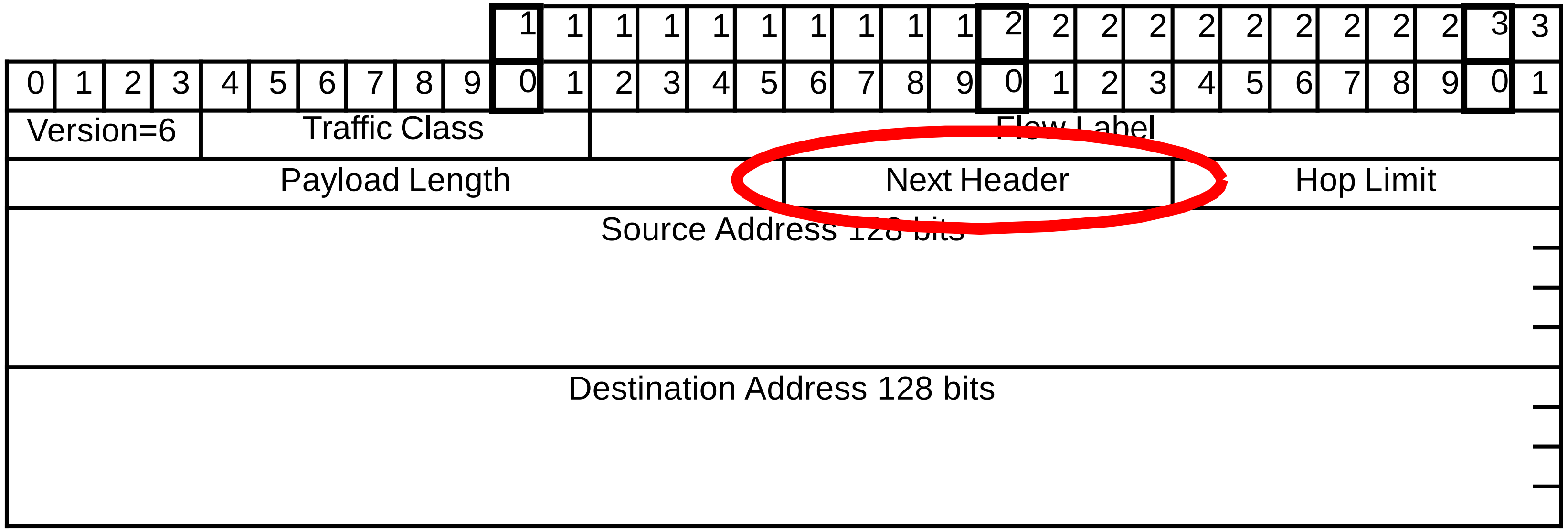
IPv6 Extension Headers

- What are Extension Headers?
- How are they identified in the IPv6 Header?
- Extension Header Order
- Extension Header Specifics

IPv6 Extension Headers

- Upper layer headers and options
  - Not examined by nodes on path
  - Allows flexibility

IPv6 Extension Headers



- Next Header – 8 bits – Identifies the "extension" header immediately following
  - Packet may have zero, one, or more extension headers
  - Extension header order is important*

IPv6 Extension Headers

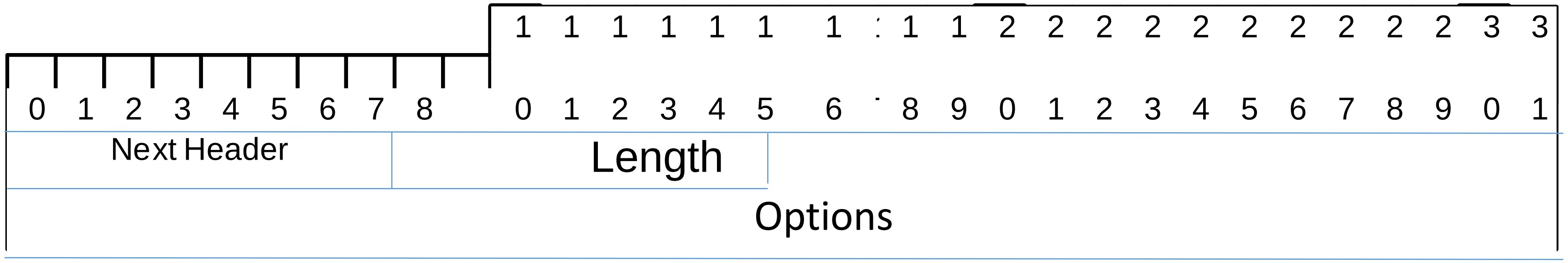
- IPv6 Header
- Hop-by-Hop
- Routing Header
- Fragment Header
- Authentication Header
- Encapsulating Security Payload
- Upper Layer protocol

IPv6 Extension Headers

- 0 – Hop-by-Hop Options – RFC 2460
  - Must be first header extension
  - Examined by every node on a delivery path
  - Supports Jumbo payload >65535 <4 billion
  - Cannot use Jumbo with Fragment
  - Only one allowed per packet

IPv6 Extension Headers

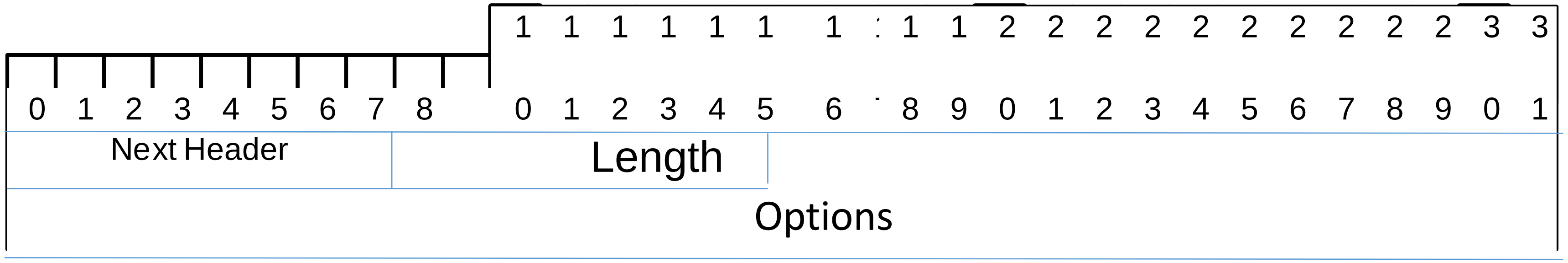
Example Hop-by-Hop Extension Header



- Next Header field identifies the header immediately following.
- Header Extension Length identifies the length of the hop-by-hop extension header, in octets, not including the first 8 octets.

IPv6 Extension Headers

Example Hop-by-Hop Extension Header



• Options - Variable-length field, of length such that the complete Hop-by-Hop Options header is an integer multiple of 8 octets long. Contains one or more TLV-encoded options. (type-length-value)

IPv6 Extension Headers

Example Hop-by-Hop Extension Header -continued

										1	1	1	1	1	1	
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	
Option Type								Option Length								Option Data

- TLV field is used in Hop-by-Hop header and Destination header.

IPv6 Extension Headers

- 1 – ICMPv4
  - Continued support for ICMPv4
  - New header for ICMPv6
  - Internet Control Message Protocol

IPv6 Extension Headers

- 6 – TCP – Transmission Control Protocol
  - Provides reliable delivery
  - Upper Layer header

IPv6 Extension Headers

- 17 – UDP – User Datagram Protocol
  - Unreliable delivery
  - Upper Layer header

IPv6 Extension Headers

- 43 – Routing Options – RFC 2460
  - Lists one or more IPv6 nodes to be "visited" on the way to a packets destination
  - Not looked at by each node on path

IPv6 Extension Headers

- 44 – Fragmentation Options – RFC 2460
  - Only the source node can fragment a packet in IPv6
  - Expected that packets sent are no larger than path-MTU

IPv6 Extension Headers

- 50 – Encapsulating Security Payload – RFC 2406
  - Provides Encryption security
  - Confidentiality
  - Data origin Authentication
  - Connectionless integrity

IPv6 Extension Headers

- 51 – Authentication Options – RFC 2402
  - Provides connectionless integrity
  - Data origin Authentication

IPv6 Extension Headers

- 58 – ICMPv6 – RFC 2463
  - ICMPv6 is used by IPv6 nodes to report errors encountered in processing packets
  - Is an integral part of IPv6 and MUST be fully implemented by every IPv6 node
  - Used for Neighbor Discovery

IPv6 Extension Headers

- 59 – No next header – RFC 2460
  - There will be no Extension Header following this header

IPv6 Extension Headers

- 60 - Destination Options – RFC 2460
  - – Used to carry optional information for the Destination

IPv6 Extension Headers