IPv6 - Introduction

Basics

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

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Brief History of the Internet*

- First node of DARPANET established 1969
- 1972 electronic mail (e-mail) was invented
- 1974 TCP/IP invented by Kahn/Cerf
- 1980-1994 massive growth in use of “networks” beyond Military/University
- 1991 World Wide Web developed
- 1993 Mosaic is released

*Source: www. netvalley.com

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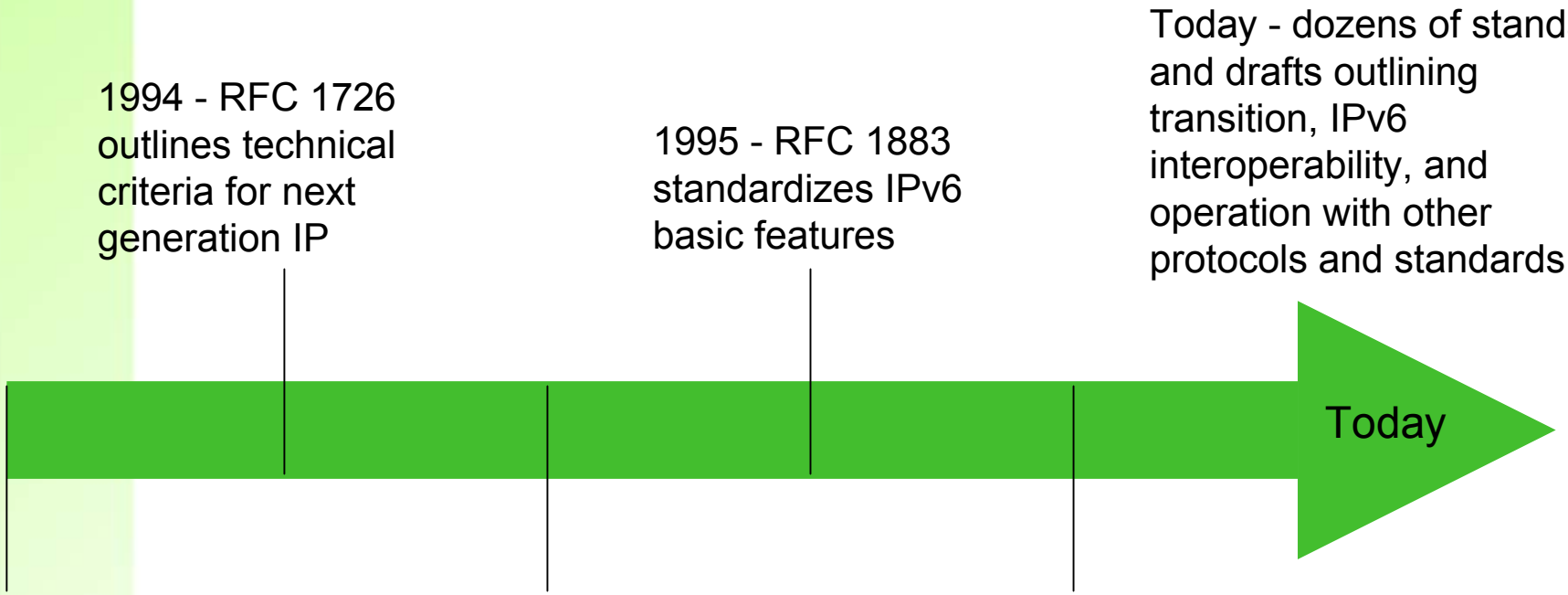
History of IPv6



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History of IPv6

- What happened to IPv5
  - Version 5 in IP header was assigned to ST protocol (a.k.a, Internet Streaming Protocol)
  - Experimental non-IP real-time streaming protocol
  - Never widely used
  - RFC 1819

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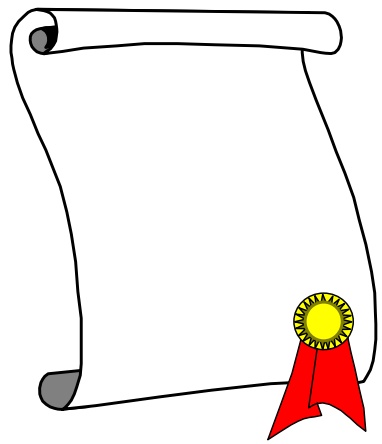
STANDARDS

- IP is based on publicly available standards
  - Published by Internet Engineering Task Force
    http://www.ietf.org
  - RFCs
    http://www.ietf.org/rfc.html
  - IETF Working Groups
    http://www.ietf.org/html.charters/wg-dir.html



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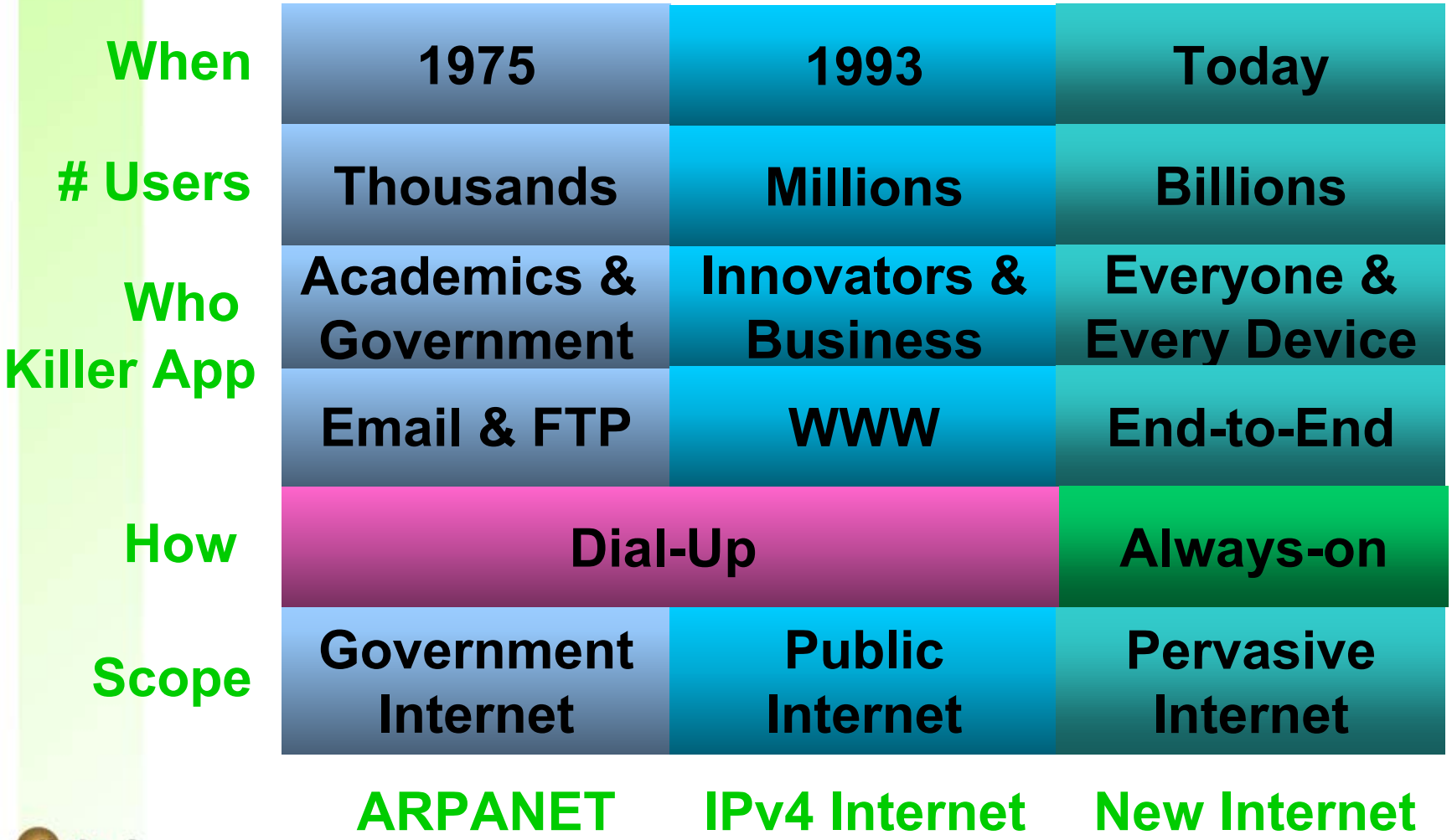
Internet Evolution



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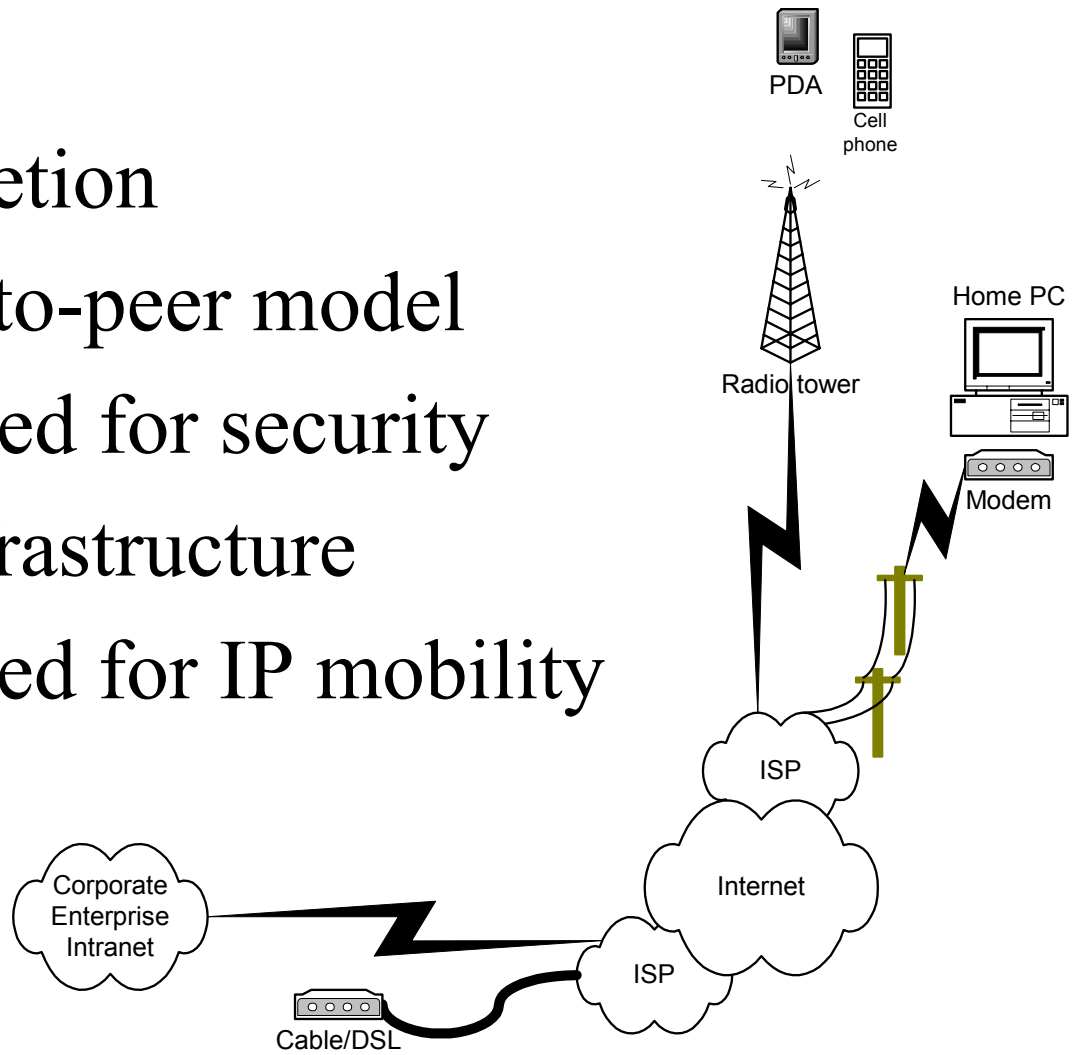
Challenges in Today's Internet

- Address depletion
- Loss of peer-to-peer model
- Increasing need for security
- Burdened Infrastructure
- Increasing need for IP mobility



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Challenges in Today's Internet

- Increased traffic flow
- New applications have specific delivery requirements
- Increasing need for security and information protection
- Varied usage of Internet requires continual "tweaking" of current Internet protocols

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Challenges in Today's Internet

- IPv4 growth and adoption phenomenal
  - Exhausting address space
  - Internet routing table very big
- IPv4 Lack of inherent features
  - Quality of Service (QoS)
  - Security
- IPv4 failings
  - Broadcast
  - Uncontrolled Packet Fragmentation

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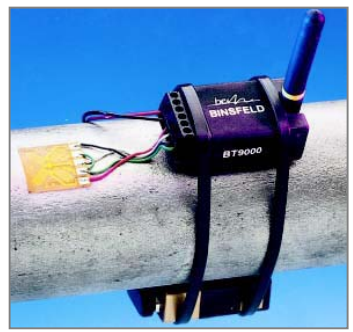
Challenges in Today's Internet

- QOS Issues
  - Multiple methods available
  - Non-uniformity across network boundaries
- Security
  - No uniformity, myriad methods
  - Multitude of methods for "hackers" to attack networks

Challenges in Today's Internet

- Mobility
  - Increasing number of wireless/mobile devices accessing Internet services
  - Inadequate support for IP mobility in devices (moving seamlessly from one network to another)
  - 3G & 4G initiatives, 802.11x, Bluetooth, UWB moving connectivity from wireline to wireless

What IP is touching



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Use of IP in Telecommunications

- Telecommunication carriers extending circuit usage with VoIP/VoDS.
  - July, 2002 Verizon announces move to VoATM
  - Feb, 2001 AT&T launches VoIP portfolio (Link)
  - Oct., 2001 Qwest announces it will replace all circuit switched telephony to VoIP (Link)
- Increasing number of mobile users accessing web-based services/applications

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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

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Features of IPv6

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

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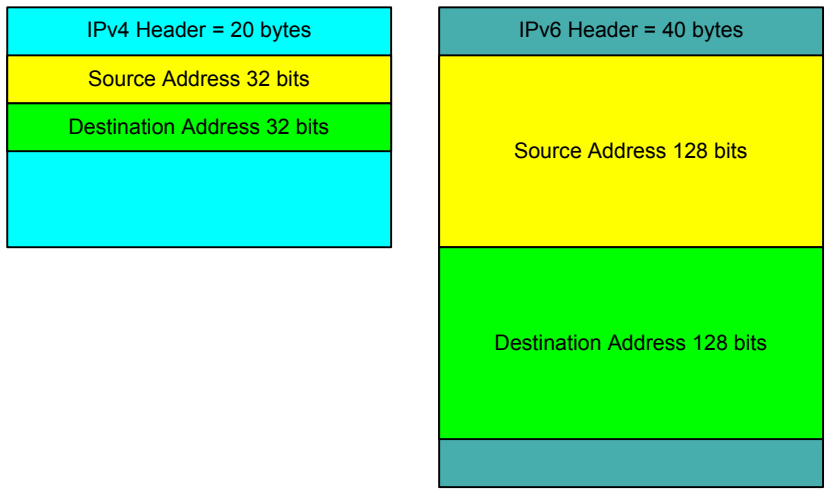
Features of IPv6

- 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



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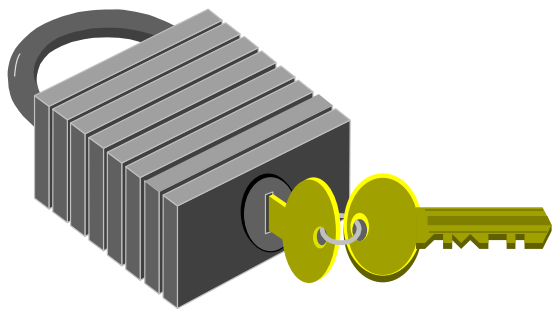
Features of IPv6

- 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



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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

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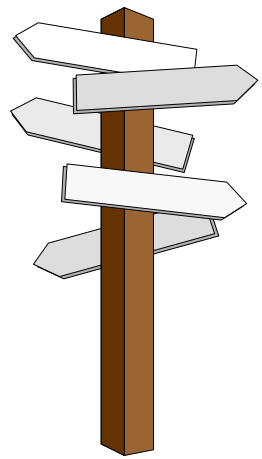
Features of IPv6

- 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 RFC 3053
    - 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
- 79,228,162,514,264,337,593,543,950,336 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

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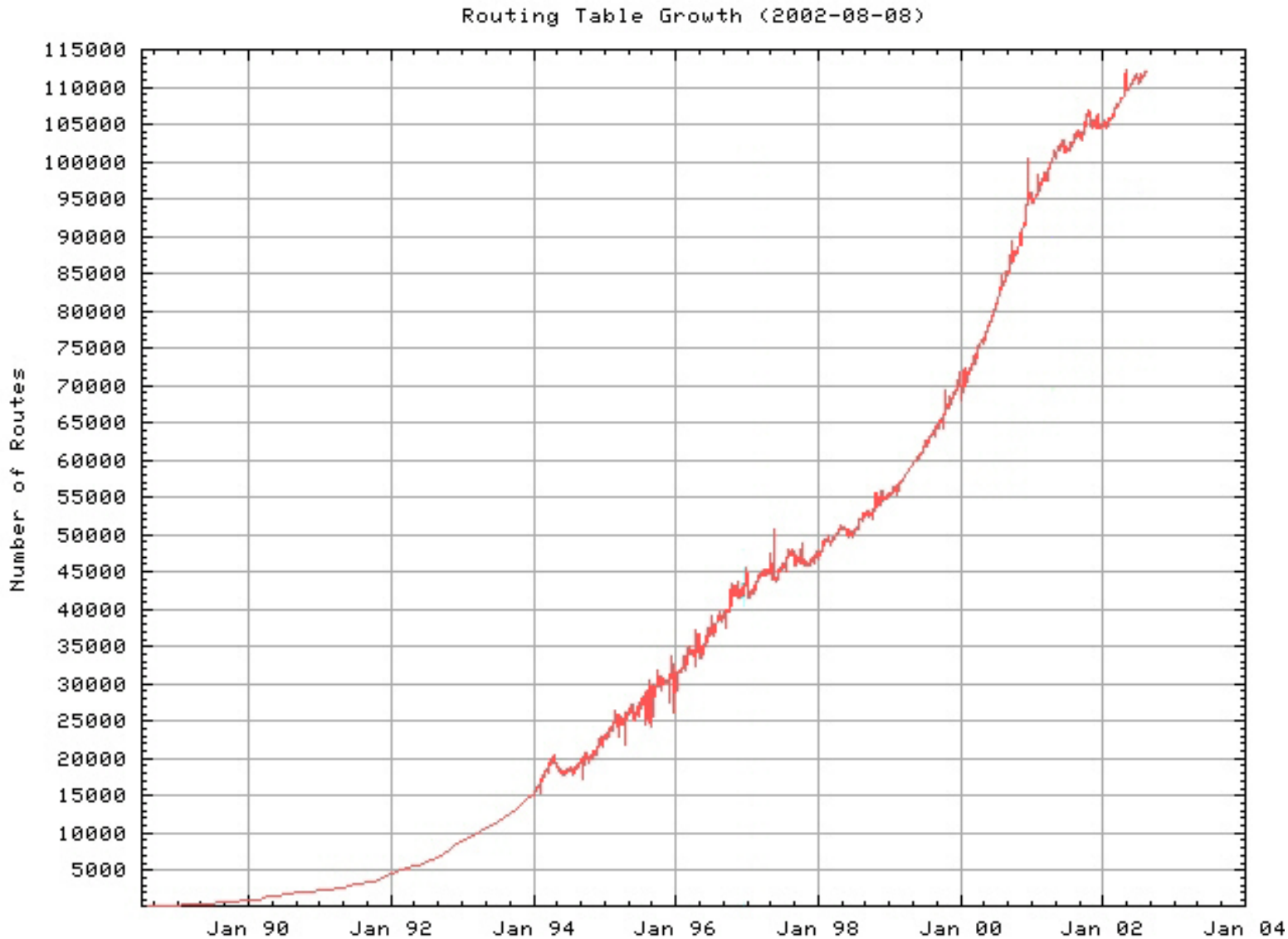
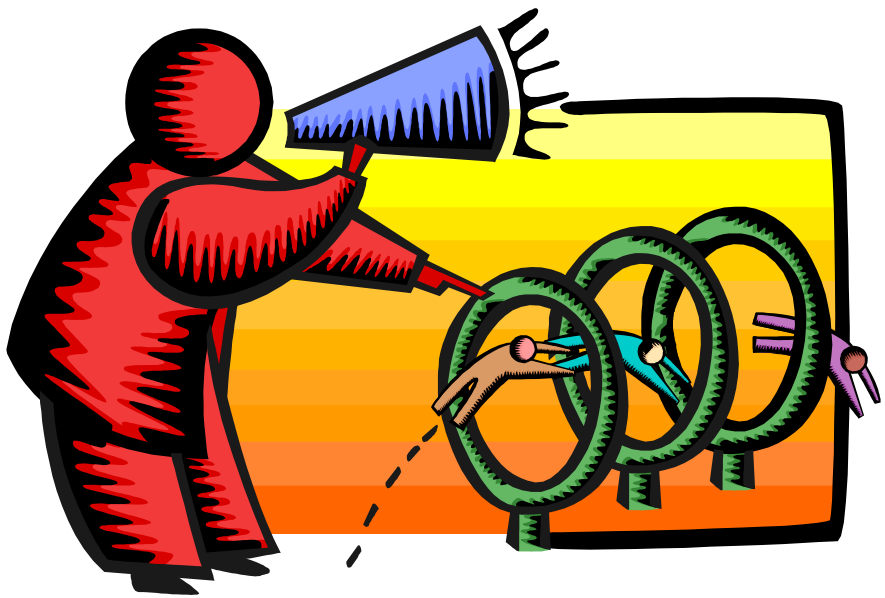
IPv6 versus IPv4 - CIDR



IPv6 versus IPv4

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



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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

IPv6 – RFC 2460

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 PDA or cell phone

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 cell phone or PDA

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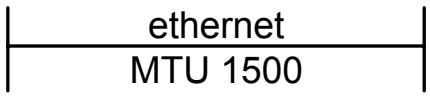
IPv6 Terminology

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

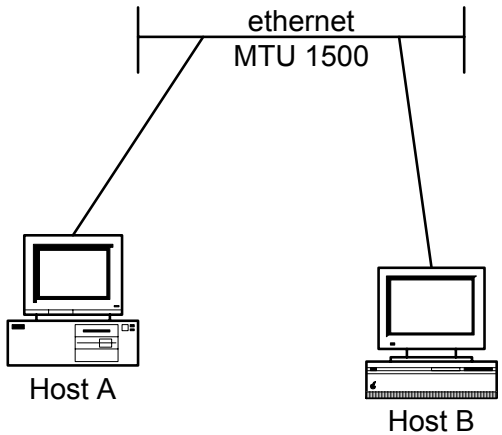
IPv6 Terminology

- 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



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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

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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

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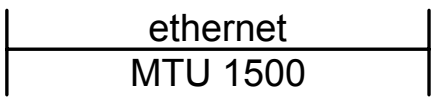
IPv6 Terminology

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

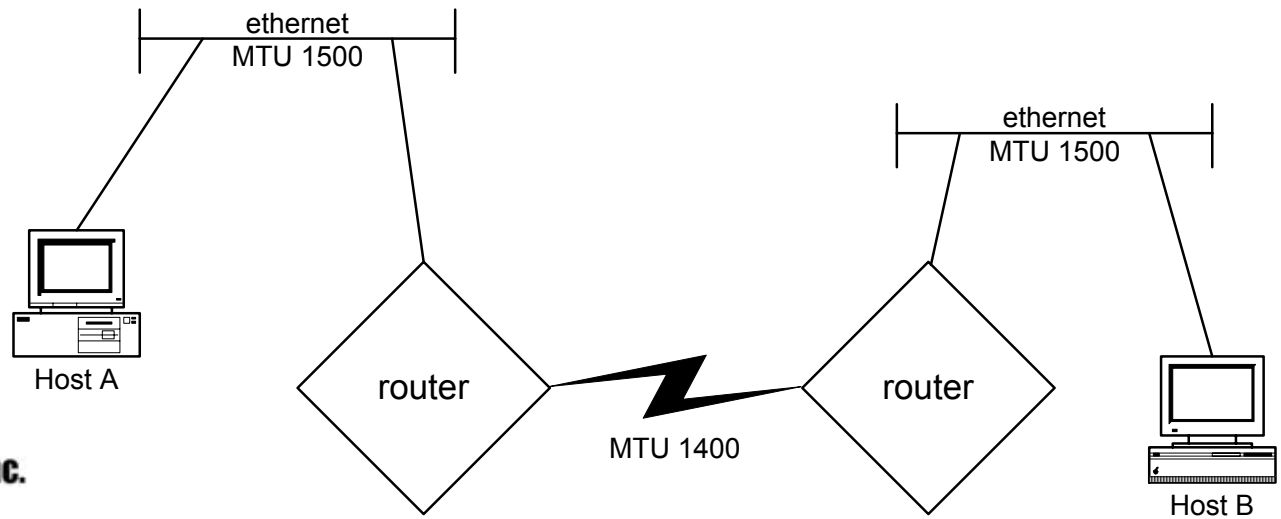
IPv6 Terminology

- 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

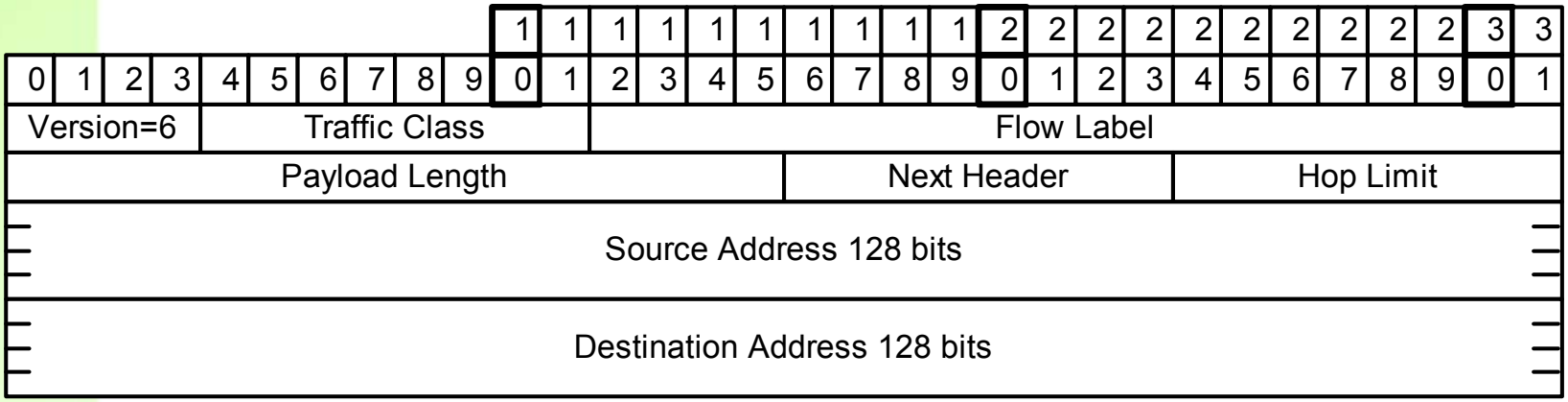
IPv6 Packet

- 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

IPv6 Packet Header



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

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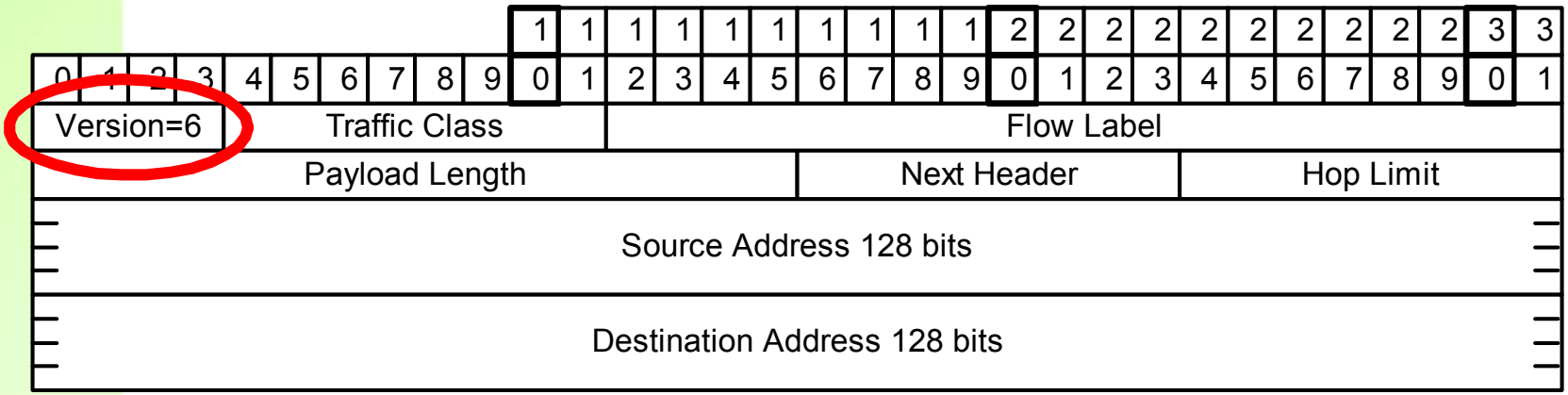
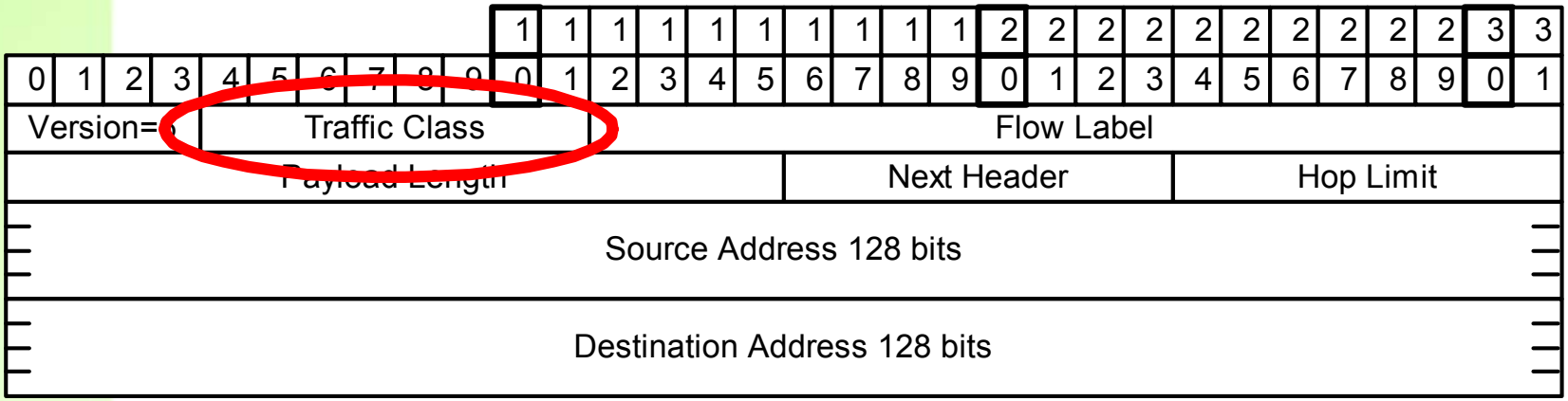
IPv6 Packet Header



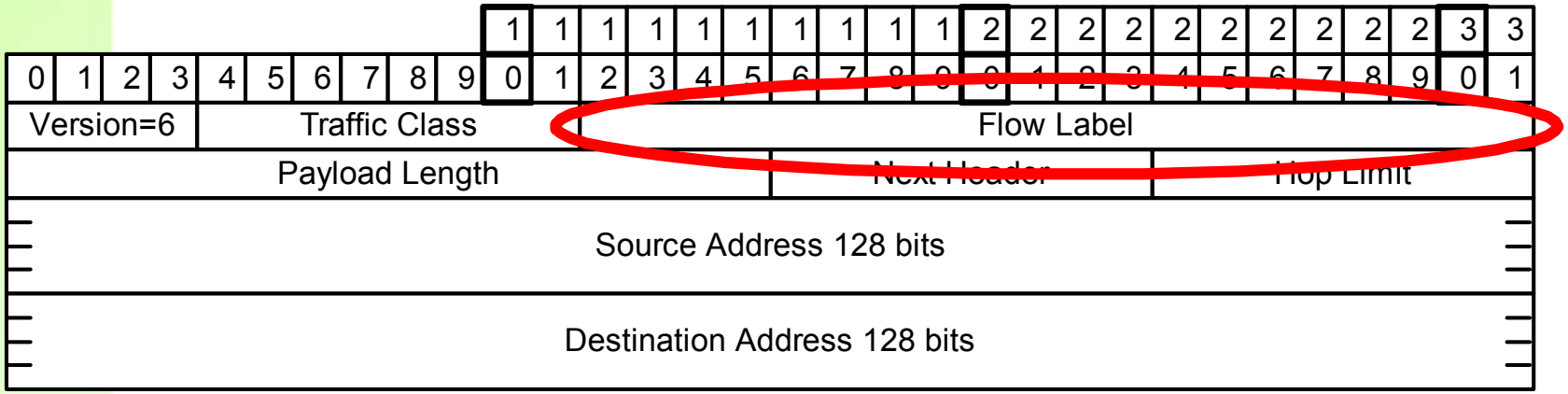
- Version – 4 bits – Identifies the version of IP protocol
  - 0100 (4) for IPv4
  - 0110 (6) for IPv6

IPv6 Packet Header



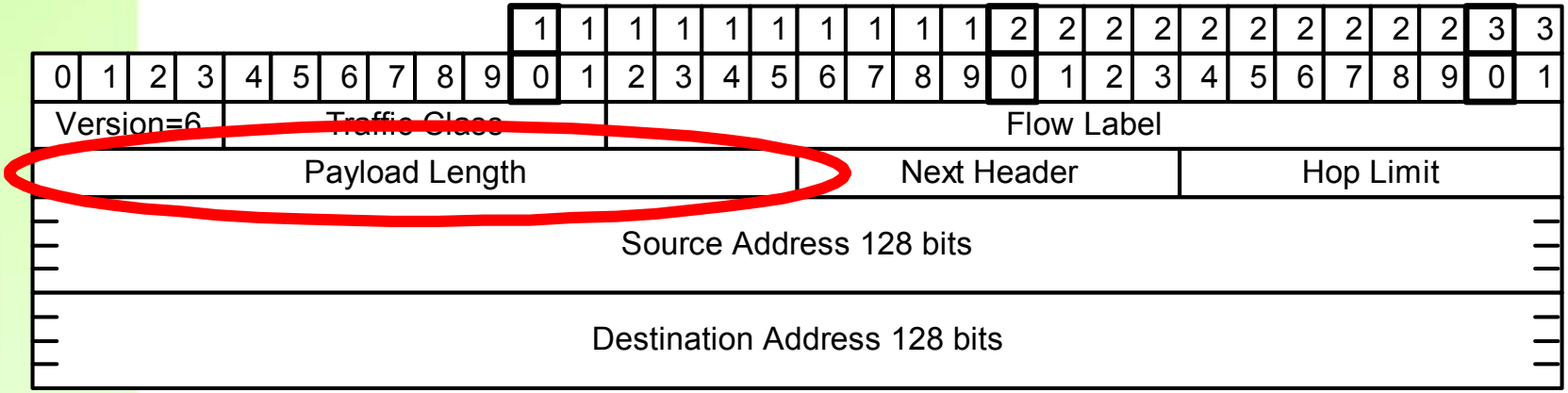
- Traffic Class – 8 bits – Allows originating nodes and/or routers to distinguish between different classes or priorities of IPv6 packets
  - QoS is an example implementation
  - RSVP uses Traffic Class

IPv6 Packet Header



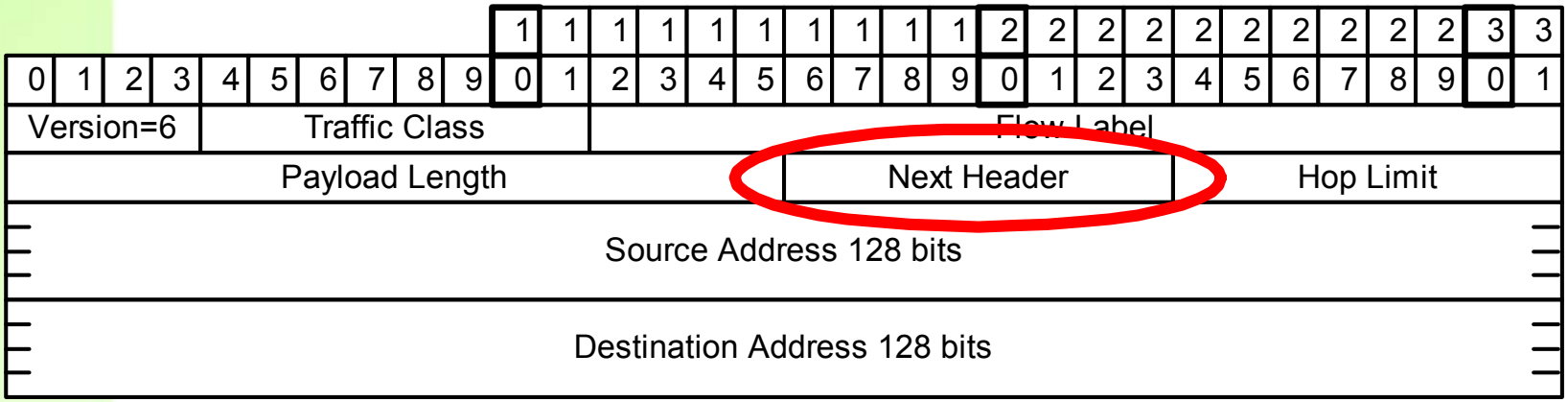
- Flow Label – 20 bits – Used to "label" a flow of traffic.
  - May be used to request special handling
  - RFC 1809 "Using the Flow Label Field in IPv6"

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*

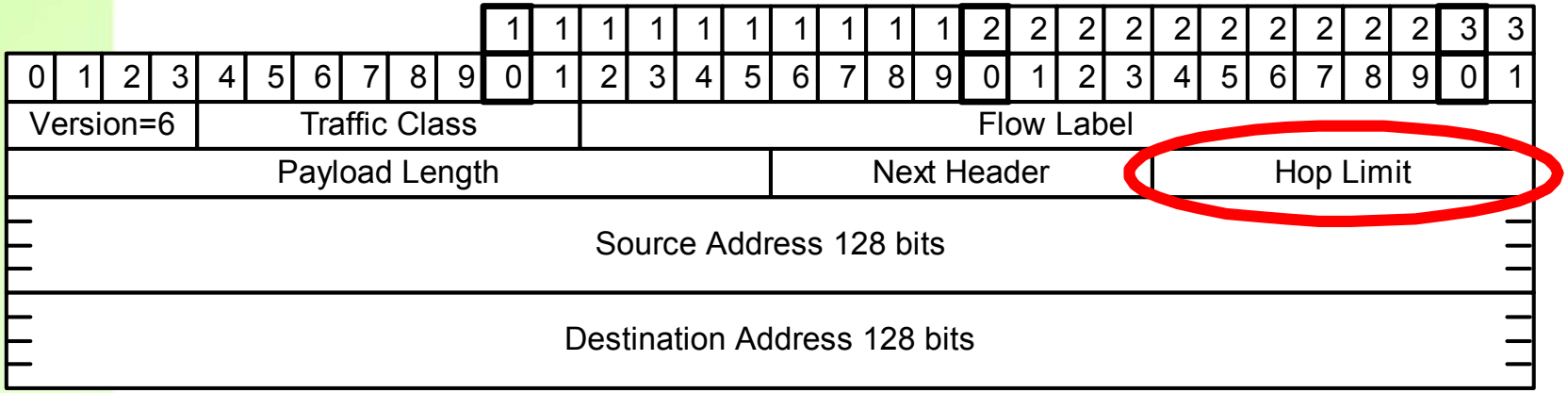
IPv6 Packet Header



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

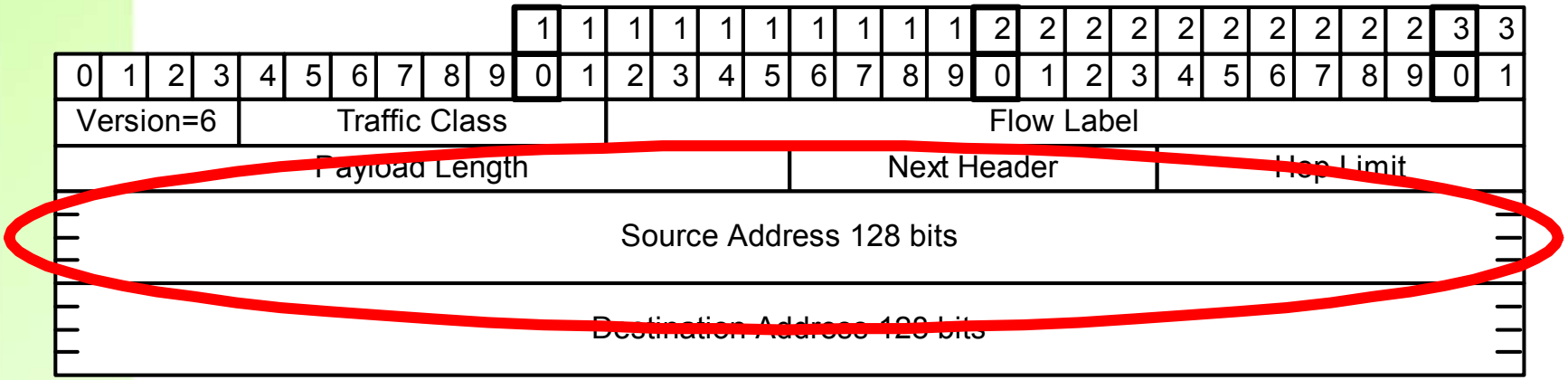
V4

IPv6 Packet Header



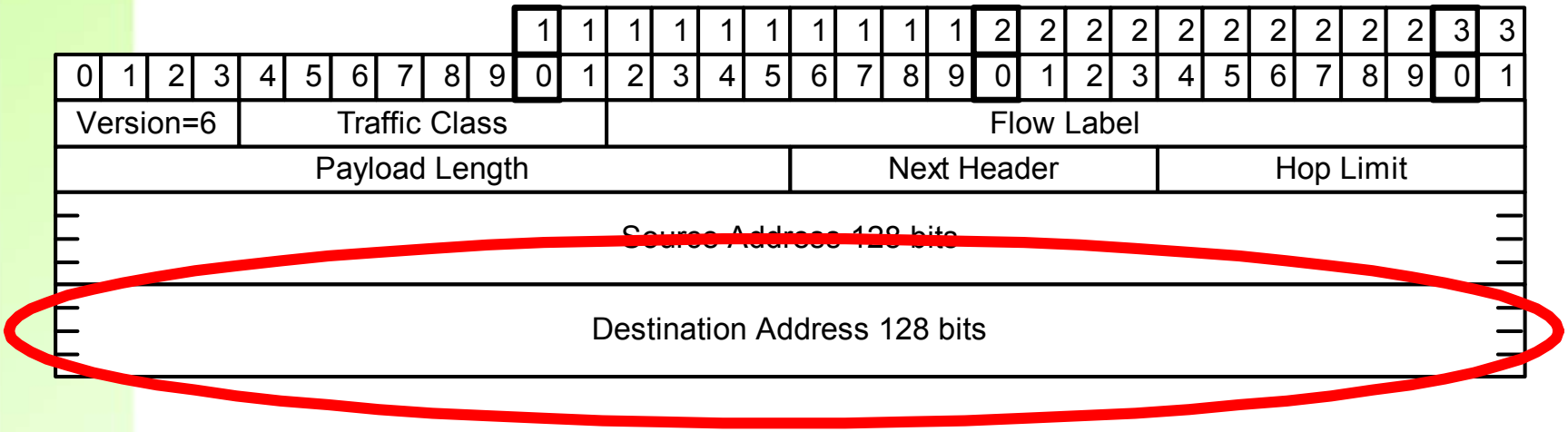
- Hop Limit – 8 bits – Maximum number of **hops** an IPv6 packet can be forwarded.
  - Similar to IPv4 TTL, but NOT time
  - Decremented by each node on path

IPv6 Packet Header



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

IPv6 Packet Header



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

IPv6 Extension Headers

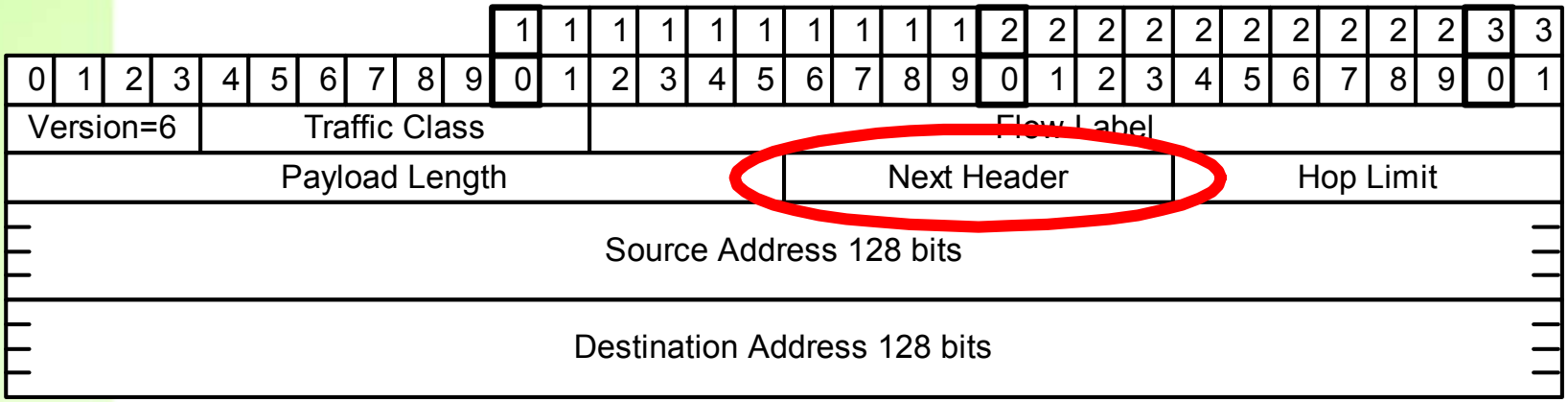
IPv6 Extension Headers

- 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

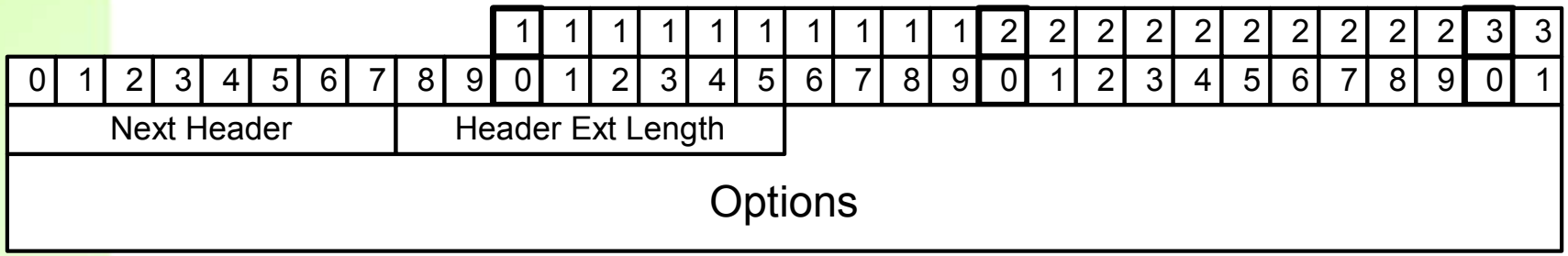
- IPv6 Header
- Hop-by-Hop
- Routing Header
- Fragment Header
- Authentication Header
- Encapsulating Security Payload
- Upper Layer protocol

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.

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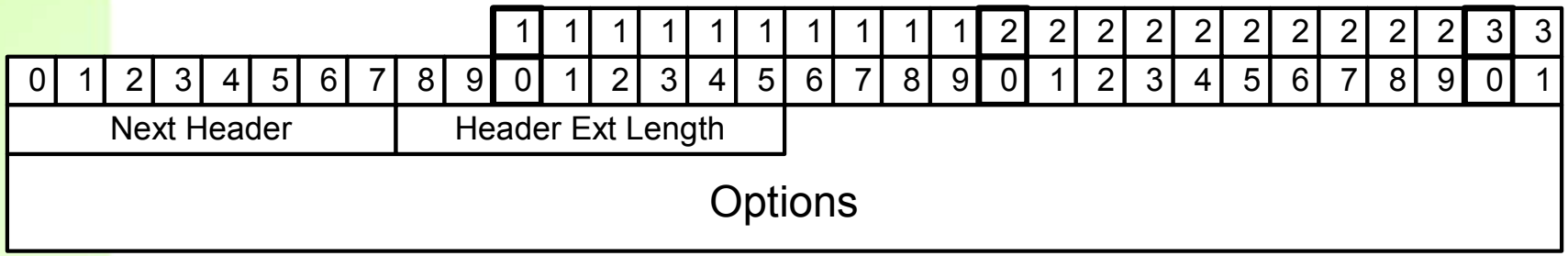
IPv6 Extension Headers

Example Hop-by-Hop Extension Header -continued



- 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)

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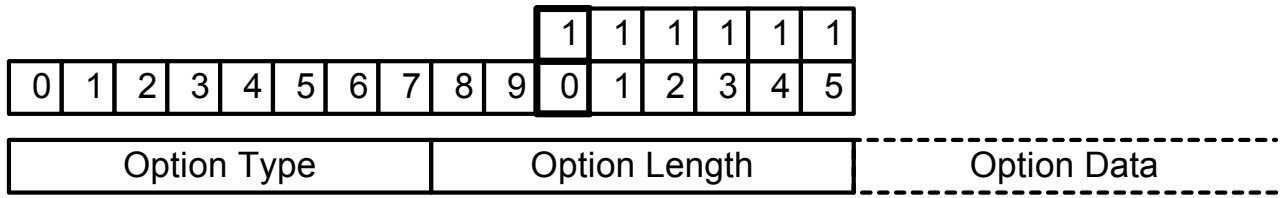
IPv6 Extension Headers

Example Hop-by-Hop Extension Header -continued



- 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

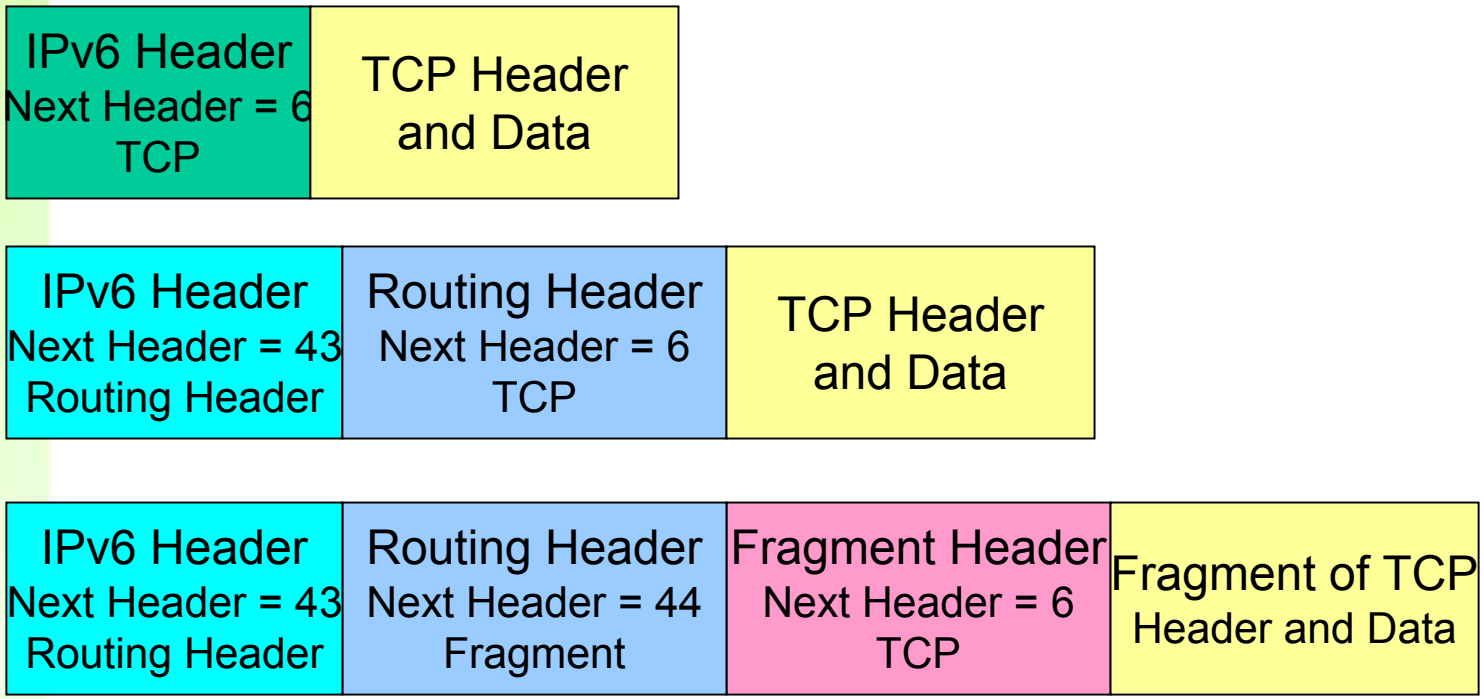
IPv6 Extension Headers

- 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



IPv6 Transition

IPv6 Transition

- Many transition mechanisms exist today!
  - Dual-Stack
  - Tunnels
    - Static/Manual
    - Automatic
  - Translation

IPv6 Today

IT Community Support

- IPv6 Supported by every major OS vendor
- Majority of network hardware manufacturers have IPv6 implementations
- Many core network services have support, particularly in the Open Source community
- Smart device manufacturers have already developed products that leverage v6

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OS Support for IPv6

- Current operating systems that have IPv6 support
  - HP-UX 11i
  - Linux (Redhat, Mandrake, Debian, SuSe)
  - BSD flavors (Free, Net, Open)
  - Sun Solaris 8 and 9
  - Windows 2000 and XP
  - IBM AIX (since release 4.3)

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OS Support for IPv6

- Implementations at various stages of maturity
  - Basic support to generate v6 packets
  - Basic support for some transition mechanisms
    - 6to4
    - 6in4 (tunnel)
  - Varying degree of support for more advanced features

IPv6 Hardware Support

- Currently most hardware implementations involve routing
  - Cisco, Juniper, Hitachi, Nortel, Ericsson, Nokia, NEC, Fujitsu, Yokogawa Electric, Allied Telesyn, etc.
- v6 support varies between software-based and hardware-based packet forwarding

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IPv6 Applications Support

- Number of v6 applications growing
- Services currently available:
  - DNS, some DHCPv6
  - Web (Server and browsers)
  - E-mail (server - client availability still missing)
  - Basic functions (FTP, Telnet, SSH, Ident, Whois, News)
- Commercial firewalls now available

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IPv6 Connectivity

- Being implemented globally
- Asia
  - NTT, IIJ, Singapore Telecom
- Europe
  - NTT (Europe), British Telecom, France Telecom
- USA
  - MCI vBNS, Hurricane Electric, Stealthnet, NTT (Verio)

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IPv6 networks available today

- 6bone
  - An IPv6 test network that began as the IETF IPNG project
  - Primarily tunneled via IPv4 Internet
  - Being deprecated in favor of production v6 Internet

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IPv6 organizations available today

- www.ipv6forum.net
- www.v6pc.jp
- www.ipv6-taskforce.org
- www.hs247.com
- www.ipv6.org

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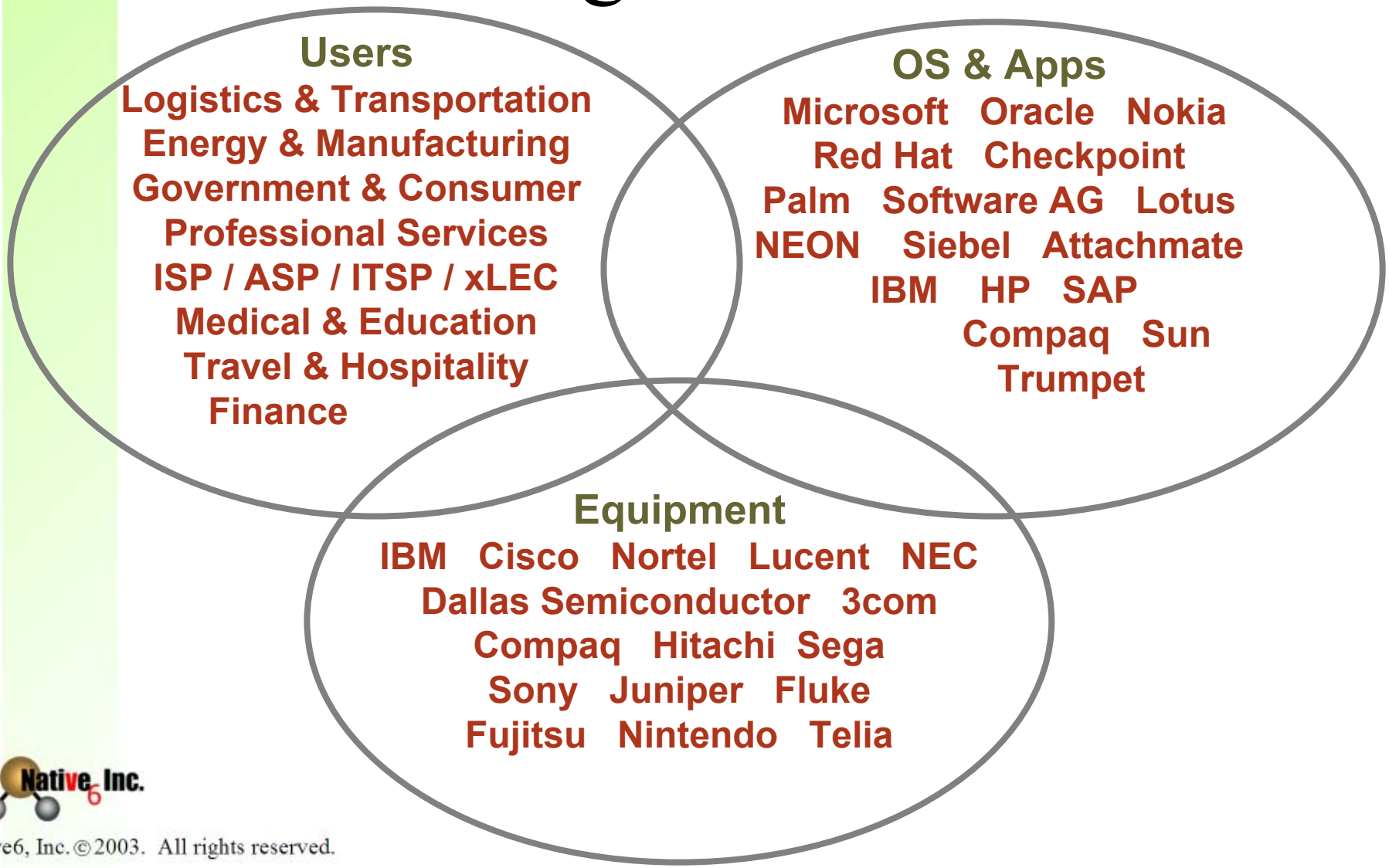
Making IPv6 Real



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