Need for a New IP

- Current IP (IP version 4)
  - Scaling problems
    - Internet growth is exhausting IP address space
    - Routing structure is flat (almost), not hierarchical
  - Weak or no support for new applications
    - Multicast
    - Mobility
    - High capacity networks
    - Device control
- How to transition to a new version without a complete Internet “restart”?

Classless Inter-Domain Routing -- CIDR

- Short-term solution IP address shortage
  - Improves utilization of IPv4 address space
    - Network is too big for Class C (2^8 maximum)
    - Network is too small for Class B (2^{16} maximum)
  - Does require router modifications
- Consolidates arbitrary blocks of contiguous Class C addresses
  - Consolidate 263.234.0.0-263.234.7.0
  - Router advertises route to 263.234.0 with network mask 255.255.248.0 (high 21 bits)
- Defined in RFC 1519

IPv6 or IPng -- IP: The Next Generation

- **IPv6 is proposed standard to replace IPv4**
- **References**
  - **Defined in RFC 1883 (with aspects in other RFCs)**
  - **S. O. Bradner and A. Mankin, *IPng: Internet Protocol Next Generation*, Addison-Wesley, 1996**
  - ☞ **W. Stallings, "IPv6: The New Internet Protocol," *IEEE Communications Magazine*, vol. 34, no. 7, pp. 96-108, July 1996.**

IPv6 Features (1)

- **Header format simplification**
  - **Removed some IPv4 fields to simplify per packet processing**
  - **Fragmentation is not allowed**
  - **Header size doubles from IPv4 (but addresses are four times longer)**
- **Uses extension headers -- there are no option fields in the IPv6 header**
  - **More efficient forwarding**
  - **Allows longer options**
  - **Supports introduction of new options**

IPv6 Features (2)

- Expanded routing and addressing capabilities
  - Host addresses are 128 bits in IPv6 (32 bits in IPv4)
    - More hosts for Internet growth -- about 6.7×10^{23} addresses per m^2 of the Earth's surface
    - More hierarchy for smaller routing tables
    - Simpler autoconfiguration of addresses
  - "Anycast" addresses
    - Single address for a group of nodes
    - Delivery to just one of the nodes
  - Scope field for multicast addresses
  - Support for other protocols (IPX, NSAP)

IPv6 Features (3)

- Quality of service
  - Field to label packets as belonging to a particular traffic flow
  - Allows special handling, e.g. for real-time traffic
- Security extensions
  - Authentication
  - Data integrity
  - Confidentiality
- Interoperates with IPv4

IPv6 Addressing (1)

- One or more IPv6 addresses can be assigned to an *interface*
- Three types of addresses
  - Unicast -- single interface
  - Anycast -- delivered to one out of a set of interfaces
  - Multicast -- delivered to all out of a set of interfaces
- An additional address type for automatic tunneling for transition from IPv4 to IPv6

IPv6 Addressing (2)

- Three types of unicast addresses
  - Provider-based global unicast address
    - Allows universal addressing
    - Coordinated through Internet service provider
  - Link-local address
    - Used within a single link or subnetwork
    - Cannot be (and are not) routed beyond the local link or subnet
    - Allow private network addresses
  - Site-local address
    - For local use, but formatted to enable conversion to a global unicast address

IPv6 Address Formats (1)

3	*n*	*m*	*o*	*p*	*125-n-m-o-p*
010	Registry	Provider	Subscriber	Subnet	Interface

Provider-based global unicast address

10	*n*	*118-n*
1111111010	00 … 00	Interface

Link-local address

10	*n*	*m*	*118-n-m*
1111111010	00 … 00	Subnet	Interface

Site-local address

IPv6 Address Formats (2)

n	*128-n*
Subnet Prefix	00 … 00

Subnet-router anycast address

8	*4*	*4*	*112*
11111111	Flgs	Scop	Subnet Prefix

Multicast address

n	*128-n*
Subnet Prefix	00 … 00

Subnet-router anycast address

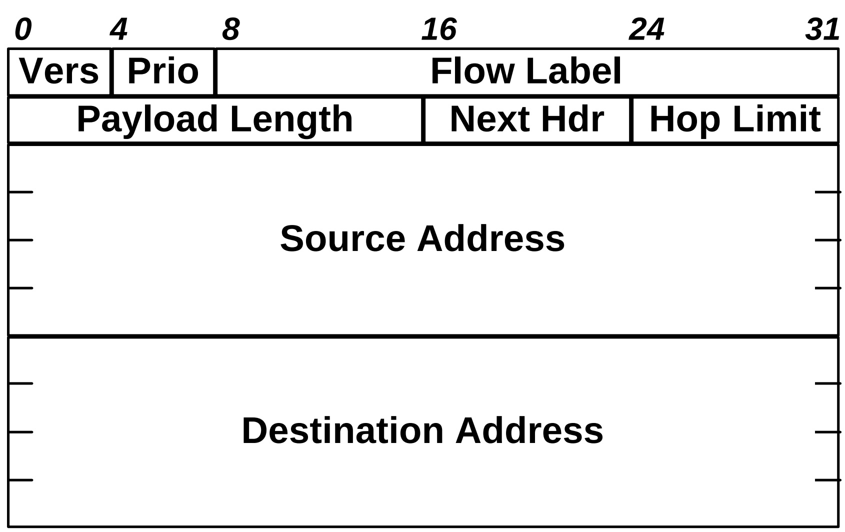
Multicasting

- A multicast address is directed to a predefined set of interfaces
- Flags (only T currently defined)
  - T=0: Well-known address
  - T=1: Transient multicast address
- Scope limits the scope of the multicast
  - For example, to site, organization, or global

8	*4*	*4*	*112*
11111111	Flgs	Scop	Subnet Prefix

Multicast address

IPv6 Header (1)



IPv6 Header (2)

- Version (Vers): Internet Protocol version, = 6 (4 bits)
- Priority (Prio): Priority value (4 bits)
- Flow Label: Flow label (24 bits)
- Payload Length: Length of payload, does not include header in bytes (16 bits)
  - Zero value indicates that payload length is carried in a “Jumbo Payload” hop-by-hop option

IPv6 Header (3)

- Next Header (Next Hdr): Identifies type of header immediately following the IPv6 header (8 bits)
  - Same values as the IPv4 Protocol field
  - Enables “extension headers”
- Hop Limit: Maximum hops allowed (8 bits)
  - Decremented by 1 by each node that forwards the packet
  - Packet is discarded if Hop Limit is decremented to zero
  - Similar to IPv4 TTL field

IPv6 Header (4)

- Source Address: Address of the packet originator (128 bits)
- Destination Address: Address of the intended recipient of the packet (128 bits)
  - Addressed node may possibly not be the ultimate recipient if a Routing header is present

Priority

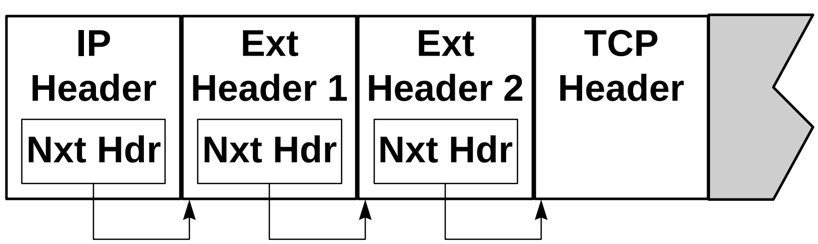
- Priority field indicates a 1-bit priority type (class) and a 3-bit relative priority
- There are two classes of relative priorities
  - Congestion-controlled traffic (e.g. TCP)
  - Non-congestion-controlled traffic
- Relative priority indicates the willingness of a router to discard the packet
  - Multimedia -- give audio a higher priority than video
  - Data -- give attended bulk transfers (HTTP) a higher priority than filler traffic (USENET)

Flows

- Flow label field plus source address identify a flow
- All traffic in a flow may be given special treatment, such as real-time delivery of interactive video traffic
- Meaning of the flow must be negotiated in advance, for example using a control protocol

Extension Headers (1)

- Cleans up option fields from IPv6
  - Simplifies header processing
  - Only the hop-by-hop extension header is examined by intermediate nodes



Extension Headers (2)

- Hop-by-hop header
  - Indicates options that are to be invoked at each intermediate node (router)
  - Used to specify length of “jumbo payloads” that are over 2^{16} = 65,536 bytes
- Destination options header
  - Processed by specified destination (and, perhaps, subsequent destinations specified by a routing header)

Extension Headers (3)

- Routing header
  - Allows source routing -- the source node specifies a route as a sequence of destination addresses
  - Receiver uses the reverse routing to return packets to the original sender
  - Supports mobility
    - Mobile sender determines route
    - Return traffic follows route, without having to know about mobility
    - Session (e.g. TCP connection) does not need to be discontinued

Extension Headers (4)

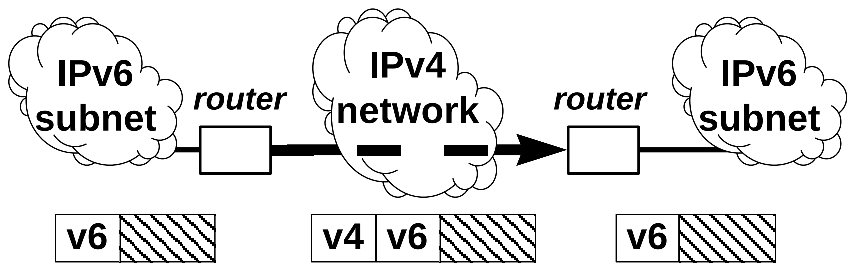
- Fragment header
  - IPv6 header does not support fragments
  - Sender must restrict packets to 576 bytes or use fragment header
    - Sender discovers the smallest *link* Maximum Transport Unit (MTU) on the path
    - Uses this *path* MTU to size the fragments
  - Algorithm is the same as for IPv4
- Authentication header
- Encapsulating security payload header
  - Supports privacy

Transition Approach

- Transition
  - A HUGE undertaking
  - Must be planned for and inherently supported
- New nodes support both IPv4 and IPv6
- Same transport layer and applications above both IPs
- Provides complete interoperability with IPv4
- Everything works IPv4/IPv6 nodes

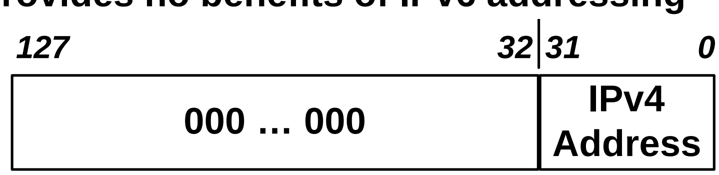
Initial Topology for Transition

- Initial IPv6 topology built by “tunneling” over IPv4
- Tunnels may be configured or automatic
  - Embedded IPv4 address allow automatic address resolution in automatic tunneling



Addresses for Automatic Tunneling

- Nodes use their 32-bit IPv4 addresses
- Facilitates transition
  - Automatic tunneling extracts IPv4 address from IPv6 address field
  - Configured tunnels require predefined translation tables
- Provides no benefits of IPv6 addressing

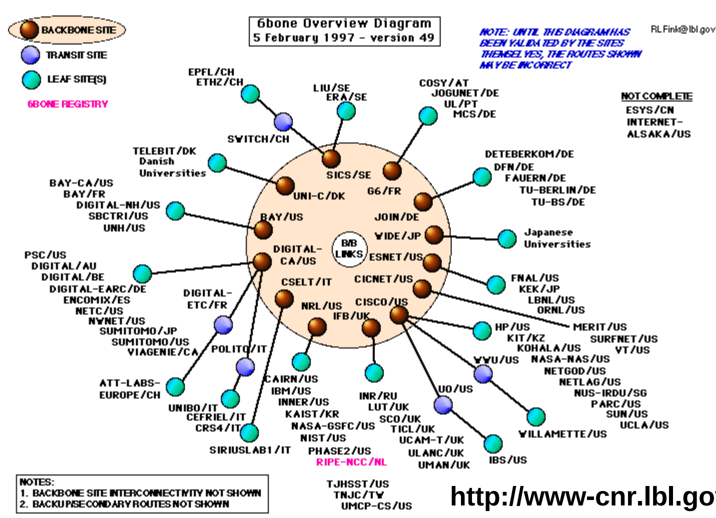


IPv6 Address

When Will IPv6 Happen?

- IPv6 status
  - Testing is underway
  - Test implementations are available
    - 4.4-lite BSD, BSDI/OS, Digital UNIX, WIN95, DOS, Windows, HP-UX, Linux, NetBSD, Novell, SCO, Solaris 2, Streams
    - 3Com, Bay Networks, Cisco, Telebit, Penril and Ipsilon routers
- IPv4 and IPv6 can co-exist

6bone Test Bed Overlaid on the Internet



http://www-cnr.lbl.gov/6bone/