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)

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 $6.7 \times 10^{23}$ addresses per m² 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)

<table>
<thead>
<tr>
<th>3</th>
<th>n</th>
<th>m</th>
<th>o</th>
<th>p</th>
<th>125-n-m-o-p</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>Registry</td>
<td>Provider</td>
<td>Subscriber</td>
<td>Subnet</td>
<td>Interface</td>
</tr>
</tbody>
</table>

**Provider-based global unicast address**

<table>
<thead>
<tr>
<th>10</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>1111111010</td>
<td>00 ... 00</td>
</tr>
</tbody>
</table>

**Link-local address**

<table>
<thead>
<tr>
<th>10</th>
<th>n</th>
<th>m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1111111010</td>
<td>00 ... 00</td>
<td></td>
</tr>
</tbody>
</table>

**Site-local address**

### IPv6 Address Formats (2)

<table>
<thead>
<tr>
<th>n</th>
<th>128-n</th>
</tr>
</thead>
</table>

**Subnet-router anycast address**

<table>
<thead>
<tr>
<th>8</th>
<th>4</th>
<th>4</th>
<th>112</th>
</tr>
</thead>
<tbody>
<tr>
<td>11111111</td>
<td>Flgs</td>
<td>Scop</td>
<td>Subnet Prefix</td>
</tr>
</tbody>
</table>

**Multicast address**

<table>
<thead>
<tr>
<th>n</th>
<th>128-n</th>
</tr>
</thead>
</table>

**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 Flags Scope Subnet Prefix
```

IPv6 Header (1)

```
0  4  8  16  24  31
Vers Prio  Flow Label
Payload Length Next Hdr Hop Limit

Source Address

Destination Address
```
### 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

Diagram:

- IP Header
- Ext Header 1
- Ext Header 2
- TCP Header
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
000 ... 000  IPv4 Address
```

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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**

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6bone Test Bed Overlaid on the Internet

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