IPv6 (4.3.5)

- Current version of IP - version 4 - is 20 years old
- IPv4 has shown remarkable ability to move to new technologies
- IETF has proposed entirely new version to address some specific problems

Success of IP

- IP has accommodated dramatic changes since original design
  - Basic principles still appropriate today
  - Many new types of hardware
  - Scale
- Scaling
  - Size - from a few tens to a few tens of millions of computers
  - Speed - from 56Kbps to 1Gbps
  - Increased frame size in hardware

Motivation for change

- Address space
  - 32 bit address space allows for over a million networks
  - But...most are Class C and too small for many organizations
  - $2^{24}$ Class B network addresses already almost exhausted (and exhaustion was first predicted to occur a couple of years ago)
- Type of service
  - Different applications have different requirements for delivery reliability and speed
  - Current IP has type of service that's not often implemented

Name and versions number

- Preliminary versions called IP - Next Generation (IPng)
- Several proposals all called IPng
- One was selected and uses next available version number (6)
- Result is IP version 6 (IPv6)

New features

- Address size - IPv6 addresses are 128bits
- Header format - entirely different
- Extension headers - Additional information stored in optional extension headers, followed by data
- Support for audio and video - flow labels and quality of service allow audio and video applications to establish appropriate connections
- Extensible - new features can be added more easily

IPv6 datagram format
IPv6 base header format

- Contains less information than IPv4 header
- NEXT HEADER points to first extension header
- FLOW LABEL used to associate datagrams belonging to a flow or communication between two applications
- Traffic class
- Specific path
- Routers use FLOW LABEL to forward datagrams along prearranged path

IPv4 datagram header format

<table>
<thead>
<tr>
<th>Field</th>
<th>Octets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version</td>
<td>4</td>
</tr>
<tr>
<td>Header Length</td>
<td>1</td>
</tr>
<tr>
<td>Total Length</td>
<td>2</td>
</tr>
<tr>
<td>Identification</td>
<td>8</td>
</tr>
<tr>
<td>Flags</td>
<td>3</td>
</tr>
<tr>
<td>Fragment Offset</td>
<td>11</td>
</tr>
<tr>
<td>Time to Live</td>
<td>16</td>
</tr>
<tr>
<td>Protocol</td>
<td>12</td>
</tr>
<tr>
<td>Header Checksum</td>
<td>16</td>
</tr>
<tr>
<td>Source Address</td>
<td>32</td>
</tr>
<tr>
<td>Destination Address</td>
<td>32</td>
</tr>
</tbody>
</table>

IPv6 NEXT HEADER

- Base Header
- TCP Data
- TCP Options

Parsing IPv6 headers

- Base header is fixed size - 40 octets
  - NEXT HEADER field in base header defines type of header
  - Extension headers appear at end of fixed-size base header
- Some extensions headers are variable sized
  - NEXT HEADER field in extension header defines type
  - HEADER LEN field gives size of extension header

Fragmentation

- Fragmentation information kept in separate extension header
- Each fragment has base header and (inserted) fragmentation header
- Entire datagram, including original header may be fragmented
Fragmentation

- IPv6 source (not intermediate routers) responsible for fragmentation
  - Routers simply drop datagrams larger than network MTU
  - Source must fragment datagram to reach destination
- Source determines path MTU
  - Smallest MTU on any network between source and destination
  - Fragments datagram to fit within that MTU
- Uses path MTU discovery
  - Source sends probe message of various sizes until destination reached
  - Must be dynamic - path may change during transmission of datagrams

Use of multiple headers

- Efficiency - header only as large as necessary
- Flexibility - can add new headers for new features
- Incremental development - can add processing for new features to testbed; other routers will skip those headers

IPv6 addressing

- 128-bit addresses
- Includes network prefix and host suffix
- No address classes - prefix/suffix boundary can fall anywhere
- Special types of addresses:
  - unicast - single destination computer
  - multicast - multiple destinations; possibly not at same site
  - cluster - collection of computers with same prefix; datagram is delivered to one out of cluster
- IPv4 broadcast flavors are subsets of multicast
- Cluster addressing allows for duplication of services

IPv6 address notation

- 128-bit addresses unwieldy in dotted decimal; requires 16 numbers
  - 105.220.136.100.255.255.255.0.18.128.140.10.255.255
- Groups of 16-bit numbers in hex separated by colons - colon hexadecimal (or colon hex)
  - 69DC:8864:FFFF:FFFF:0:1280:8C0A:FFFF
- Zero-compression - series of zeroes indicated by two colons
  - FF0C:0:0:0:0:0:0:B1
- IPv6 address with 96 leading zeros is interpreted to hold an IPv4 address
  - IPv4-compatible IPv6 address ::128:96.33.81
  - IPv4-mapped IPv6 address ::FFFF:128:96.33.81

Summary

- IPv4 basic abstractions have been very successful
- IPv6 carries forward many of those abstraction... but, all the details are changed
  - 128-bit addresses
  - Base and extension headers
  - Source does fragmentation
  - New types of addresses
  - Address notation