IPng (IPv6)

Motivation
Currently: mainly servers, workstations, SLIP/PPP
Address space exhaustion + new uses:

- permanently attached home computers (CATV)
- game consoles
- mobile terminals (PDAs)
- embedded controllers (light switches)

新IP fix other problems
CLNP considered (variable-length addresses!), but not chosen
Address Space

- 32 bits ➔ $4 \cdot 10^9$ hosts, but can’t number sequentially
- 128 bits instead of 32 bits ➔
  340,282,366,920,938,463,463,374,607,431,768,211,456 ($3 \cdot 10^{38}$) hosts
  or 665,570,793,348,866,943,898,599 hosts/m² of earth surface
- hierarchical assignment ➔ inefficiency ➔ only $8 \cdot 10^{17}$ to $2 \cdot 10^{33}$
  addresses if similar to telephones, etc.
- write addresses hex, with zero suppression:
  4123::ACD9:4571:D5:F3:7

IPv6 Packet Header

<table>
<thead>
<tr>
<th>flow-controlled</th>
<th>8</th>
<th>16</th>
<th>24</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>version (6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>prio.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>flow label</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>payload length</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>next header</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>hop limit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

source address

destination address
IPv6 Packet Header

<table>
<thead>
<tr>
<th>IPv4</th>
<th>IPv6</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-byte addresses</td>
<td>16-byte addresses</td>
</tr>
<tr>
<td>final destination</td>
<td>intermediate destination</td>
</tr>
<tr>
<td>precedence, TOS field</td>
<td>flow id, priority</td>
</tr>
<tr>
<td>header length, total length</td>
<td>payload length</td>
</tr>
<tr>
<td>( \leq 44 ) bytes options</td>
<td>“unlimited”</td>
</tr>
<tr>
<td>options</td>
<td>options ∈ header extensions</td>
</tr>
<tr>
<td>router fragmentation</td>
<td>e-e fragmentation</td>
</tr>
<tr>
<td>header checksum</td>
<td>–</td>
</tr>
<tr>
<td>higher-layer protocol</td>
<td>next header type</td>
</tr>
<tr>
<td>TTL time-based</td>
<td>TTL hops only</td>
</tr>
<tr>
<td>20 bytes fixed header</td>
<td>40 bytes</td>
</tr>
</tbody>
</table>

IPv6 Packet Structure

- next header can be IPv4 “tunneling”
- header extension: hop-by-hop options (HH0), routing, fragment, destination options (DO)
- DO, HHO: type-length-value TLV options
- HHO:
  - looked at by each node, immediately after header
  - jumbo payload option (32 bits)
- routing header:
  - fixed header may not contain final address if routing header!
– mixed loose/strict source route (bitmask)
– swap destination address and next address from routing header

• fragment header: like IPv4 (32 bit identification, offset, more fragments flag)
• explicit MTU message rather than try-until-fit

IPv6 Flows

• explicit and implicit state
• router may cache based on flow identifier
• implicit state discarded after < 6 seconds
• priority ranges:
  – congestion controlled (TCP) drop priority
  – not controlled (UDP; fixed-bandwidth services)
    0 uncharacterized traffic
    1 filler traffic (netnews)
    2 unattended data transfer (email)
    4 attended bulk transfer (ftp, nfs)
    6 interactive traffic (telnet, X)
    7 internet control traffic (routing, network management)
**Address Assignment**

Administrative and topological:

- 0000 0000 IPv4 addresses 1/256
- 0000 0001 reserved 1/256
- 0000 001 NSAP addresses 1/128
- 0000 010 IPX addresses 1/128
- 0000 011 reserved 1/128
- 0000 1 reserved 3/128
- 0001 reserved 1/16
- 001 reserved 1/16
- 010 provider-based 1/8
- 011 reserved 1/8
- 100 geographic 1/8

... 1111 1111 scoped multicast 1/256

<table>
<thead>
<tr>
<th>010</th>
<th>continent</th>
<th>16</th>
<th>8</th>
<th>24</th>
<th>8</th>
<th>64</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>provider ID</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>country</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>provider ID</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>subscriber ID</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>subnet ID</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>intra-subscriber ID</td>
<td></td>
<td>48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>node ID (Ethernet address)</td>
<td>48</td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

**Security**

- authentication: insure that packet comes from right source ➔ prevent “address spoofing”
- encryption: insure privacy (DES)
Transition

- cannot have flag day
- transition period may last decade or more
- dual-stack → IPv6 can send IPv4
- IPv4 address range
- DNS servers need to understand IPv6 addresses
- avoid translation, use IPv6-in-IPv4 tunneling
- use IPv6 on same Ethernet
- end-to-end tunnel or concatenated tunnels

UDP
UDP Services

- datagram (like IP)
- protocol identifier 17
- unreliable - discarded by network or host (without notification)
- demultiplexing by process (not host)
- each datagram received by one process (“socket”) only
- no connection setup
- to answer: reverse source-destination ports
- also: audio, video, multicast

UDP Header

<table>
<thead>
<tr>
<th>0</th>
<th>16</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-bit source port number</td>
<td>16-bit destination port number</td>
<td></td>
</tr>
<tr>
<td>16-bit UDP length</td>
<td>16-bit UDP checksum</td>
<td></td>
</tr>
<tr>
<td>data (if any)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**port**: “TSAP” - identifies process sending/receiving datagram

**length**: including header (IP length ≠ redundant)

**checksum**: across *pseudo-header*, UDP header, data for end-to-end reliability
### UDP Checksum Computation

<table>
<thead>
<tr>
<th>32-bit source IP address</th>
<th>32-bit destination IP address</th>
</tr>
</thead>
<tbody>
<tr>
<td>zero</td>
<td>8-bit protocol (17)</td>
</tr>
<tr>
<td>16-bit source port number</td>
<td>16-bit destination port number</td>
</tr>
<tr>
<td>16-bit UDP length</td>
<td>16-bit UDP checksum</td>
</tr>
</tbody>
</table>

- checksum may be turned off for better performance *at your peril*
- similar for IPng (but mandatory – why?)

#### UDP Port Numbers

- `< 512`: reserved for particular services (one per host)
- `512 ... 1023`: privileged port (Unix superuser only)
- `1023 ... 65536`: available for applications

7  echo
9  discard
19 character generator
37  time
53  domain name service
123 Network Time Protocol (NTP)