IPv6: An Introduction

Outline

- Problems with IPv4
- Basic IPv6 Protocol
- IPv6 features
  - Auto-configuration, QoS, Security, Mobility
- Transition Plans

Internet Protocol

Transports a datagram from source host to destination, possibly via several intermediate nodes (“routers”)

Service is:

- *Unreliable:* Losses, duplicates, out-of-order delivery
- *Best effort:* Packets not discarded capriciously, delivery failure not necessarily reported
- *Connectionless:* Each packet is treated independently

IP Datagram Header

<table>
<tr><th>0</th><th>4</th><th>8</th><th>16</th><th>19 … 31</th></tr>
<tr><td>VERS</td><td>HLEN</td><td>TOS</td><td colspan="2">TOTAL LENGTH</td></tr>
<tr><td colspan="3">IDENTIFICATION</td><td>FLAG</td><td>FRAGMENT OFFSET</td></tr>
<tr><td colspan="2">TTL</td><td>PROTOCOL</td><td colspan="2">CHECKSUM</td></tr>
<tr><td colspan="5">SOURCE ADDRESS</td></tr>
<tr><td colspan="5">DESTINATION ADDRESS</td></tr>
<tr><td colspan="5">OPTIONS (if any) + PADDING</td></tr>
</table>

Problems with IPv4: Limited Address Space

- IPv4 has 32 bit addresses.
- Flat addressing (only netid + hostid with "fixed" boundaries)
- Results in inefficient use of address space.
- Class B addresses are almost over.
- Addresses will exhaust in the next 5 years.
- IPv4 is victim of its own success.

Problems with IPv4: Routing Table Explosion

- IP does not permit route aggregation
  (limited supernetting possible with new routers)
- Mostly only class C addresses remain
- Number of networks is increasing very fast
  (number of routes to be advertised goes up)
- Very high routing overhead
  - lot more memory needed for routing table
  - lot more bandwidth to pass routing information
  - lot more processing needed to compute routes

Problems with IPv4: Header Limitations

- Maximum header length is 60 octets.
  (Restricts options)
- Maximum packet length is 64K octets.
  (Do we need more than that ?)
- ID for fragments is 16 bits. Repeats every 65537th packet.
  (Will two packets in the network have same ID?)
- Variable size header.
  (Slower processing at routers.)
- No ordering of options.
  (All routers need to look at all options.)

Problems with IPv4: Other Limitations

- Lack of quality-of-service support.
  - Only an 8-bit ToS field, which is hardly used.
  - Problem for multimedia services.
- No support for security at IP layer.
- Mobility support is limited.

IP Address Extension

- Strict monitoring of IP address assignment
- Private IP addresses for intranets
  - Only class C or a part of class C to an organization
  - Encourage use of proxy services
    - Application level proxies
    - Network Address Translation (NAT)
- Remaining class A addresses may use CIDR
- Reserved addresses may be assigned

But these will only postpone address exhaustion.

They do not address problems like QoS, mobility, security.

IPng Criteria

- At least 10^9 networks, 10^{12} end-systems
- Datagram service (best effort delivery)
- Independent of physical layer technologies
- Robust (routing) in presence of failures
- Flexible topology (e.g., dual-homed nets)
- Better routing structures (e.g., aggregation)
- High performance (fast switching)
- Support for multicasting

IPng Criteria

- Support for mobile nodes
- Support for quality-of-service
- Provide security at IP layer
- Extensible
- Auto-configuration (plug-and--play)
- Straight-forward transition plan from IPv4
- Minimal changes to upper layer protocols

IPv6: Distinctive Features

- Header format simplification
- Expanded routing and addressing capabilities
- Improved support for extensions and options
- Flow labeling (for QoS) capability
- Auto-configuration and Neighbour discovery
- Authentication and privacy capabilities
- Simple transition from IPv4

IPv6 Header Format

0 4 12 16 24 31

<table>
<tr><td>Vers</td><td>Traffic Class</td><td colspan="3">Flow Label</td></tr>
<tr><td colspan="3">Payload Length</td><td>Next Header</td><td>Hop Limit</td></tr>
<tr><td colspan="5">Source Address</td></tr>
<tr><td colspan="5">Destination Address</td></tr>
</table>

IPv6 Header Fields

- Version number (4-bit field)

  The value is always 6.
- Flow label (20-bit field)

  Used to label packets requesting special handling by routers.
- Traffic class (8-bit field)

  Used to mark classes of traffic.
- Payload length (16-bit field)

  Length of the packet following the IPv6 header, in octets.
- Next header (8-bit field)

  The type of header immediately following the IPv6 header.

IPv6 Header Fields

- Hop limit (8-bit field)

  Decremented by 1 by each node that forwards the packet.

  Packet discarded if hop limit is decremented to zero.

- Source Address (128-bit field)

  An address of the initial sender of the packet.

- Destination Address (128-bit field)

  An address of the intended recipient of the packet. May not be the ultimate recipient, if Routing Header is present.

Header Changes from IPv4

- Longer address - 32 bits → 128 bits
- Fragmentation field moved to separate header
- Header checksum removed
- Header length removed (fixed length header)
- Length field excludes IPv6 header
- Time to live → Hop limit
- Protocol → Next header
- 64-bit field alignment
- TOS replaced by flow label, traffic class

Extension Headers

- Less used functions moved to extension headers.
- Only present when needed.
- Processed only by node identified in IPv6 destination field.

  => much lower overhead than IPv4 options

  Exception: Hop-by-Hop option header
- Eliminated IPv4's 40-byte limit on options
- Currently defined extension headers: Hop-by-hop, Routing, Fragment, Authentication, Privacy, End-to-end.
- Order of extension headers in a packet is defined.
- Headers are aligned on 8-byte boundaries.

Address Types

Unicast	Address for a single interface.
Multicast	Identifier for a set of interfaces.
	Packet is sent to *all* these interfaces.
Anycast	Identifier for a set of interfaces.
	Packet is sent to the *nearest* one.

Text Representation of Addresses

- HEX in blocks of 16 bits

  BC84 : 25C2 : 0000 : 0000 : 0000 : 55AB : 5521 : 0018
- leading zero suppression

  BC84 : 25C2 : 0 : 0 :55AB : 5521 : 18
- Compressed format removes strings of **0**s

  BC84 : 25C2 :: 55AB : 5521 : 18

  :: can appear only once in an address.

  can also be used to compress leading or trailing **0**s
- Mixed Notation (X:X:X:X:X:X:d.d.d.d)

  e.g., ::144.16.162.21

IPv6 Addresses

- 128-bit addresses
- Multiple addresses can be assigned to an interface
- Provider-based hierarchy to be used in the beginning
- Addresses should have 64-bit interface IDs in EUI-64 format
- Following special addresses are defined :
  - IPv4-mapped
  - IPv4-compatible
  - link-local
  - site-local

Unicast Addresses Examples

- **Global Aggregate Address**

3	13	32	16	64 bits
FP	TLA	NLA	SLA	Interface ID
	Public Topology		Site Topology	Interface Identifier

- **Link local address**

10 bits	54 bits	64 bits
1111111010	0	Interface ID

- **Site-local address**

10 bits	38 bits	16 bits	64 bits
1111111011	0	subnet ID	Interface ID

Multicast Address

8 bits	4	4	112 bits
11111111	flags	scope	Group ID

Flags	000T	3 bits reserved
	T= 0	permanent
	T= 1	transient
Scope	2	link-local
	5	site-local
	8	org-local
	E	global

Permanent groups are formed independent of scope.

IPv6 Routing

- Hierarchical addresses are to be used.
- Initially only provider-based hierarchy will be used.
- Longest prefix match routing to be used.
  (Same as IPv4 routing under CIDR.)
- OSPF, RIP, IDRP, ISIS, etc., will continue as is
  (except 128-bit addresses).
- Easy renumbering should be possible.
- Provider selection possible with *anycast* groups.

QoS Capabilities

- Protocol aids QoS support, not provide it.
- Flow labels
  - To identify packets needing same quality-of-service
  - 20-bit label decided by source
  - Flow classifier: Flow label + Source/Destination addresses
  - Zero if no special requirement
  - Uniformly distributed between 1 and FFFFFF
- Traffic class
  - 8-bit value
  - Routers allowed to modify this field

IPv6: Security Issues

- Provision for
  - Authentication header
    - Guarantees authenticity and integrity of data
  - Encryption header
    - Ensures confidentiality and privacy
- Encryption modes:
  - Transport mode
  - Tunnel mode
- Independent of key management algorithm.
- Security implementation is mandatory requirement in IPv6.

Mobility Support in IPv6

- Mobile computers are becoming commonplace.
- Mobile IPv6 allows a node to move from one link to another without changing the address.
- Movement can be heterogeneous, i.e., node can move from an Ethernet link to a cellular packet network.
- Mobility support in IPv6 is more efficient than mobility support in IPv4.
- There are also proposals for supporting micro-mobility.