IP Next Generation (IPv6)

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- Limitations of current Internet Protocol (IP)
- How many addresses do we need?
- IPv6 Addressing
- IPv6 header format
- IPv6 features: routing flexibility, plug-n-play, multicast support, flows

IP Addresses

- **Example**: 164.107.134.5
  = 1010 0100 : 0110 1011 : 1000 0110 : 0000 0101
  = A4:6B:86:05 (32 bits)
- Maximum number of address = 2^{32} = 4 Billion
- Class A Networks: 15 Million nodes
- Class B Networks: 64,000 nodes or less
- Class C Networks: 250 nodes or less

IP Address Format

- Three all-zero network numbers are reserved
- 127 Class A + 16,381 Class B + 2,097,151 Class C networks = 2,113,659 networks total
- Class B is most popular.
- 20% of Class B were assigned by 7/90 and doubling every 14 months $\Rightarrow$ Will exhaust by 3/94
- Question: Estimate how big will you become?
  Answer: More than 256!
  Class C is too small. Class B is just right.

How Many Addresses?

- 10 Billion people by 2020
- Each person has more than one computer
- Assuming 100 computers per person $\Rightarrow 10^{12}$ computers
- More addresses may be required since
  - Multiple interfaces per node
  - Multiple addresses per interface
  - Some believe 2^6 to 2^8 addresses per host
- Safety margin $\Rightarrow 10^{15}$ addresses
- *IPng Requirements Þ 10^{12} end systems and 10^9 networks. Desirable 10^{12} to 10^{15} networks*

How big an address space ?

- H Ratio = $\log_{10}$(# of objects)/available bits
- 2^n objects with n bits: H-Ratio = $\log_{10}2$ = 0.30103
- French telephone moved from 8 to 9 digits at 10^7 households $\Rightarrow$ H = 0.26 (~3.3 bits/digit)
- US telephone expanded area codes with 10^8 subscribers $\Rightarrow$ H = 0.24
- Physics/space science net stopped at 15000 nodes using 16-bit addresses $\Rightarrow$ H = 0.26
- 3 Million Internet hosts currently using 32-bit addresses $\Rightarrow$ H = 0.20 $\Rightarrow$ A few more years to go

IPv6 Addresses

- 128-bit long. Fixed size
- $2^{128} = 3.4 \times 10^{38}$ addresses
  $\Rightarrow 665 \times 10^{21}$ addresses per sq. m of earth surface
- If assigned at the rate of $10^6/\mu s$, it would take 20 years
- Expected to support 8×10^{17} to 2×10^{33} addresses
  $8 \times 10^{17} \Rightarrow$ 1,564 address per sq. m

IPv6 Addresses (Continued)

- Allows multiple interfaces per host.
- Allows multiple addresses per interface
- Allows unicast, multicast, anycast
- Allows provider based, site-local, link-local
- 85% of the space is unassigned

Colon-Hex Notation

- **Dot-Decimal**: 127.23.45.88
- **<u>Colon-Hex:</u>**
  FEDC:0000:0000:0000:3243:0000:0000:ABCD
  - Can skip leading zeros of each word
  - Can skip <u>one</u> sequence of zero words, e.g.,
    FEDC::3243:0000:0000:ABCD *or*
    ::3243:0000:0000:ABCD
  - Can leave the last 32 bits in dot-decimal, e.g.,
    ::127.23.45.88
  - Can specify a prefix by /length, e.g.,
    2345:BA23:7::/40

Header

- <u>IPv6</u>:

Version	Class	Flow Label
Payload Length	Next Header	Hop Limit
Source Address		
Destination Address		

- <u>IPv4:</u>

Version	IHL	Type of Service	Total Length
Identification		Flags	Fragment Offset
Time to Live	Protocol	Header Checksum	
Source Address			
Destination Address			
Options			Padding

IPv6 vs IPv4

- IPv6 only twice the size of IPv4 header
- Only version number has the same position and meaning as in IPv4
- ***Removed***:
  - Header length, fragmentation fields (identification, flags, fragment offset), header checksum
- ***Replaced***:
  - Datagram length by payload length
  - Protocol type by next header
  - Time to live by hop limit
  - Type of service by "class" octet
- ***Added***: flow label
- All fixed size fields.

IPv6 vs IPv4 (Continued)

- No optional fields. Replaced by extension headers.
  - <u>Idea:</u> avoid unnecessary processing by intermediate routers while not sacrificing the flexibility possible due to options
  - Next Header = 6 (TCP), 17 (UDP), etc

Extension Headers

Base Header	Extension Header 1	…	Extension Header *n*	Data

- Most extension headers are examined only at destination
- Routing: Loose or tight source routing
- Fragmentation: All IPv6 routers can carry 536 Byte payload
- Authentication
- Hop-by-Hop Options
- Destination Options:

Extension Header (Continued)

- Only Base Header:

Base Header Next = TCP	TCP Segment

- Only Base Header and One Extension Header:

Base Header Next = TCP	Route Header Next = TCP	TCP Segment

- Only Base Header and Two Extension Headers:

Base Header Next = TCP	Route Header Next = Auth	Auth Header Next = TCP	TCP Segment

Fragmentation

- Routers cannot fragment. Only source hosts can.
  ⇒ Need path MTU discovery or tunneling
- Fragmentation requires an extension header
- Payload is divided into pieces
- A new base header is created for each fragment

	← Part 1 → | … | ← Part n →	
Base Header	Data	
New Base Header	Frag. 1 Header	Part 1
New Base Header	Frag. 2 Header	Part 2
New Base Header	Frag. n Header	Part n

IPv6 Addressing and Routing

- Aggregatable Global Unicast Addresses
- Link-local and Site-local addresses
- Multicast and Anycast support
- Provider-based inter-domain routing & IDRP

Initial IPv6 Prefix Allocation

Allocation	Prefix	Allocation	Prefix
Reserved	0000 0000	Unassigned	101
Unassigned	0000 0001	Unassigned	110
NSAP	0000 001	Unassigned	1110
IPX	0000 010	Unassigned	1111 0
Unassigned	0000 011	Unassigned	1111 10
Unassigned	0000 1	Unassigned	1111 110
Unassigned	0001	Unassigned	1111 1110
Unassigned	001	Unassigned	1111 1110 0
Provider-based*	010	Link-Local	1111 1110 10
Unassigned	011	Site-Local	1111 1110 11
Geographic	100	Multicast	1111 1111

*Has been renamed as "Aggregatable global unicast"

Aggregatable Global Unicast Addresses

- Address allocation:"provider-based" plan
- Format: TLA + NLA + SLA + 64-bit interface ID
- TLA = "Top level aggregator." (13 bits)
  - Ranges of TLA values allocated to various registries
  - For "backbone" providers or "exchange points"

Aggregatable Global Unicast Addresses (Continued)

- NLA = "Next Level Aggregator" (32 bits)
  - Second tier provider and a subscriber
  - More levels of hierarchy possible within NLA
- SLA = "Site level aggregator" = 16 bits for link
  - Renumbering after change of provider => change the TLA and NLA. But have same SLA & I/f ID

Aggregatable Global Unicast Addresses (Continued)

- Interface ID = 64 bits
  - Will be based on IEEE EUI-64 format
  - An extension of the IEEE 802 (48 bit) format.
  - Possible to derive the IEEE EUI-64 equivalent of current IEEE 802 addresses
  - Along with neighbor discovery procedures, obviates need for ARP.

Local-Use Addresses

- Link Local: Not forwarded outside the link, FE:80::xxx

10 bits	n bits	118-n
1111 1110 10	0	Interface ID

- Site Local: Not forwarded outside the site, FE:C0::xxx

10 bits	n bits	m bits	118-n-m bits
1111 1110 11	0	Subnet ID	Interface ID

- Provides plug and play

Multicast Addresses

8 bits	4 bits	4 bits	112 bits
1111 1111	Flags	Scope	Group ID
	0 0 0 T		

- All routers recognize this format
  - all routers can route multicast packets.
  - Also IGMP part of ICMPv6 => required.
  - I.e. IPv6 supports native multicast
- Flags: T = 0 ⇒ Permanent (well-known) multicast address, 1 ⇒ Transient

Multicast Addresses (Continued)

- Scope: 1 Node-local, 2 Link-local, 5 Site-local, 8 Organization-local, E Global => routers reqd to honor this.
- Predefined: 1 ⇒ All nodes, 2 ⇒ Routers, 1:0 ⇒ DHCP servers

Multicast & Anycast

- Scoping. Eg: 43 ⇒ NTP Servers
  - FF01::43 ⇒ All NTP servers on this node
  - FF02::43 ⇒ All NTP servers on this link
  - FF05::43 ⇒ All NTP servers in this site
  - FF08::43 ⇒ All NTP servers in this org.
  - FF0F::43 ⇒ All NTP servers in the Internet
- Structure of Group ID:
  - First 80 bits = zero (to avoid risk of group collision, because IP multicast mapping uses only 32 bits)

Address *Auto-configuration*

- Allows plug and play
- BOOTP and DHCP are used in IPv4
- DHCPng will be used with IPv6
- Two Methods: Stateless and Stateful
- Stateless:
  - A system uses *link-local* address as source and multicasts to "All routers on this link"
  - Router replies and provides all the needed prefix info

Address Auto-configuration (Continued)

  - All prefixes have a associated *lifetime*
  - System can use link-local address permanently if no router
- Stateful:
  - Problem w stateless: Anyone can connect
  - Routers ask the new system to go DHCP server (by setting managed configuration bit)
  - System multicasts to "All DHCP servers"
  - DHCP server assigns an address

ICMPv6: Neighbor Discovery

- ICMPv6 combines regular ICMP, ARP, Router discovery and IGMP.
- The “neighbor discovery” is a generalization of ARP & router discovery.
- Source maintains several caches:
  - destination cache: dest -> neighbor mapping
  - neighbor cache: neighbor IPv6 -> link address
  - prefix cache: prefixes learnt from router advertisements
  - router cache: router IPv6 addresses

Neighbor Discovery (Continued)

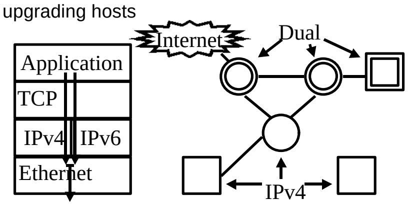
- Old destination => look up destination cache
- If new destination, match the prefix cache. If match => destination local!
- Else select a router from router cache, use it as the next-hop (neighbor).
  - Add this neighbor address to the destination cache
- Solicitation-advertisement model:
  - Multicast solicitation for neighbor media address if unavailable in neighbor cache
  - Neighbor advertisement message sent to soliciting station.

Real-Time/QoS Support

- Flow label and the “class” octet field
- Flow = sequence of packets from a single source to a particular (unicast/multicast) destinations requiring special handling by intermediate routers
  - Class field can simplify packet classification (data-plane support for QoS)
  - “Class” field assignments being worked upon by differentiated services group at IETF

Transition Mechanisms

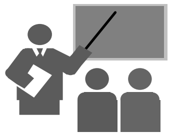
- Dual-IP Hosts, Routers, Name servers
- Tunneling IPv6 over IPv4
- Nodes can be partially upgraded to IPv6
- It is better (though not required) to upgrade routers before upgrading hosts



Application Issues

- Most application protocols will have to be upgraded: FTP, SMTP, Telnet, Rlogin
- 27 of 51 Full Internet standards, 6 of 20 draft standards, 25 of 130 proposed standards will be revised for IPv6
- No checksum ⇒ checksum at upper layer is mandatory, even in UDP
- non-IETF standards: X-Open, Kerberos, ... will be updated
- Should be able to request and receive new DNS records

Summary



- IPv6 uses 128-bit addresses
- Allows provider-based, site-local, link-local, multicast, anycast addresses
- Fixed header size. Extension headers instead of options for provider selection, security etc
- Allows auto-configuration
- Dual-IP router and host implementations for transition