IPv6

A short introduction to IPv6

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Agenda

- Do we really need IPv6?
  - A bit of history
  - New features
  - Why do we need IPv6
- IPv6 Addressing
  - Address space
  - Types, Notation and Prefix
- IPv6 Structure
  - Header structure
  - Fields in header
  - Extension Headers
- Benefits (conclusion)

Do we really need IPv6?

A bit of history…

- IETF began developing IPv6 early 1990
- RFC 1752 “The recommendation for IP Next Generation Protocol”
- IESG approved IPv6 recommendation, proposed Standard on Nov. 17, 1994
- RFC 1883, “Internet Protocol, Version 6 (IPv6) Specification,” published in 1995
- IPv6 protocols became an IETF Draft Standard on August 10, 1998
- Finally RFC 2460 published to obsolete RFC 1883

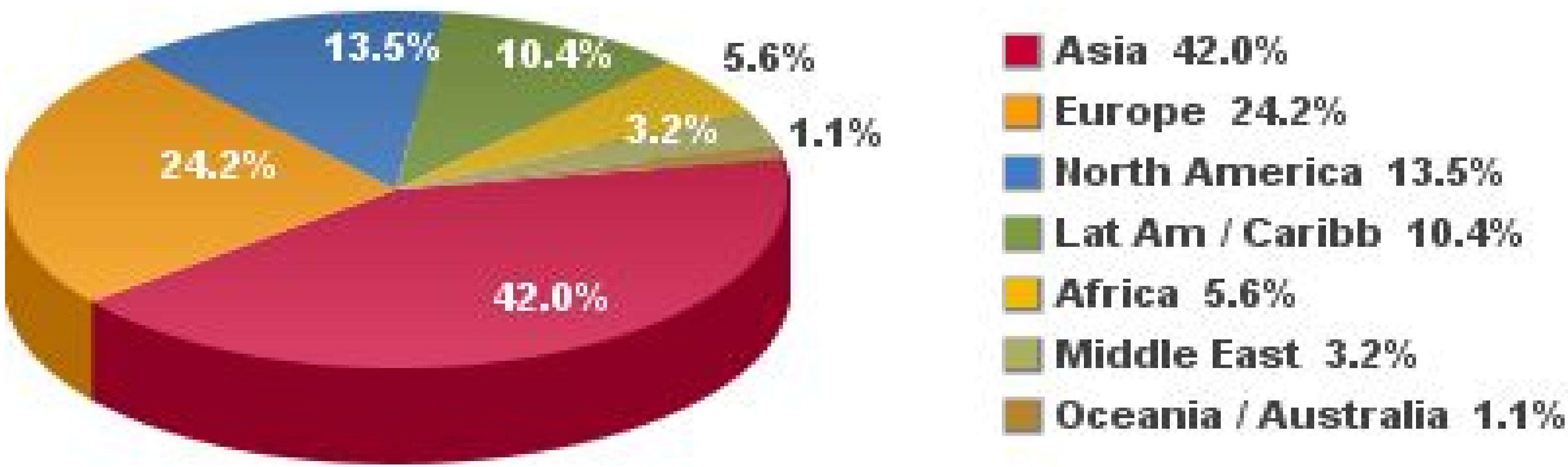
Do we really need IPv6?

Why do we need IPv6…

- DoD heavily involved in the creation of Internet gets to keep most of it!
- North America controls ~57% of IPv4 address space
- The rest of world has the remaining 43% of IPv4 addresses space
- The point is: ~5% of the world controls ~57% of IPv4 address space
- Given the growth of Internet users throughout the world; IPv4 is not enough.

Do we really need IPv6?

Internet Users in the World
Distribution by World Regions - 2010



Source: Internet World Stats - www.internetworldstats.com/stats.htm
Basis: 1,966,514,816 Internet users on June 30, 2010

Do we really need IPv6?

New features

- Extended address space; from 32 bits to 128 bits
- Auto-configuration; Devices ask for network prefix, use its MAC address to create a valid global IP
- Simpler header format; fixed length, 40 bytes: two 16 bytes for source/Dest address and 8 bytes for others
- Improved support for options; Unlike IPv4, IPv6 carries options in extension headers and only inserted as needed
  - Extensions per base specification describes six headers: Hop-by-Hop Options, Routing, Fragment, Destination Options, Authentication and Encrypted Security Payload

Do we really need IPv6?

Why do we need IPv6… Verdict

- To accommodate the growth of Internet users
- To accommodate the need for consumer electronics connectivity requirements
- The growth of wireless industries demand more IPs than IPv4 can ever afford.
- The automotive industry will be utilizing ~20 IP addresses per vehicle
- To connect all Things; The Internet of Things/Everythings

IPv6 Addressing

Address Space

- IPv6 addressing architecture is defined in RFC 4291 which obsoletes RFC 3513
- 128-bit address with a max of 2^128 addresses available; that is 340-undecillion
- IPv6 allows for 2^45 network IDs; 35,184,372,088,832 with a /48 prefix (missing three bits are 001 to signify global unicast addresses)
- Each of these networks can be divided into 2^16 subnets using remaining 16 bits of prefix

IPv6 Addressing

IPv6 Address categories

- Unicast; One-to-one communication
  - Global unicast; prefix: 2000::/3
  - Link-local unicast; prefix: fe80::/10
  - Unique Local Address; prefix fc00::/7
- Multicast; One-to-many communication
  - Prefix: FF00::/8
- Anycast; An address configured in multiple locations

IPv6 Addressing

Address Notation

- IPv6 address is 128 bits (16 bytes), divided into eight 16-bit hex blocks separated by colons

  2001:0DB8:0000:0000:0202:B3FF:FE1E:8329
- Leading zeros in a 16-bit block can be skipped

  2001:DB8:0:0:202:B3FF:FE1E:8329
- Double colon can replace consecutive zeros or leading/trailing zeros

  2001:DB8::202:B3FF:FE1E:8329

Note: Double colon can appear ONLY once in an address

IPv6 Addressing

Prefix Notation

- The prefix is contained in the leftmost fields of an IPv6 address
- Prefix is used for routing purposes, stated in CIDR notation
- Format of prefix: ***prefix/length***
  2001:db8:4c4c:0002:0000:0000:0000:0002
  2001:db8:4c4c::/48
- Prefix can contain subnet prefix as well
  2001:db8:4c4c:2::/64

IPv6 Addressing

IPv6 Global Unicast example:

Global Prefix 48 bits	Subnet 16 bits	Interface ID 64 bits

In Hex:

2001:4860:800f	:0000:	0000:0000:0000:0067

1. IPv6 address written in Hex, divided into eight pairs of two byte block
2. Each pair contains four hex digits
3. Interface ID can be auto-generated using EUI-64 identifier
4. Others: Teredo, Documentation, 6to4

IPv6 Addressing

Link-local Unicast address example:

Link-local Prefix 10bits	54 bits	Interface ID 64 bits

In Hex:

fe80	::	123a:456b

Characteristics:

1. Unique global prefix
2. Eliminates address conflicts when connecting private networks
3. Independent of ISP
4. Can be used for internal communication

IPv6 Addressing

Multicast address:

Link-local Prefix 8bits	Flags 4 bits	Scope 4 bits	Group Identifier 112 bits

Flags: 0RPT, high order bit zero and reserved

- R-flag: R=0 Rendezvous point not embedded
- R-flag: R=1 Rendezvous point embedded — RFC 3956

- P-flag: P=0 Multicast address without prefix information
- P-flag: P=1 Multicast address based on network prefix — RFC 3306

- T-flag: T=0 Well known Multicast address
- T-flag: T=1 Temporary Multicast address — RFC 4291

IPv6 Addressing

Multicast address continued…

Link-local Prefix 8bits	Flags 4 bits	Scope 4 bits	Group Identifier 112 bits

Scopes:

Value	Description
0,3,F	Reserved
1	Interface-local scope
2	Link-local scope
4	Admin-local scope
5	Site-local scope
6,7	Unassigned
8	Organizational-local scope
9,A,B,C, D	Unassigned
E	Global scope

IPv6 Addressing

Selected Well-Known Multicast address

Source: http://www.iana.org/assignments/ipv6-multicast-addresses

Scope	Address	Description
Interface-local scope	FF01:0:0:0:0:0:0:1	All-nodes address
	FF01:0:0:0:0:0:0:2	All-routers address
Link-local scope	FF02:0:0:0:0:0:0:1	All-nodes address
	FF02:0:0:0:0:0:0:2	All-routers address
	FF02:0:0:0:0:0:1:2	All DHCP agents
	FF02:0:0:0:0:0:0:9	RIP routers
	FF02:0:0:0:0:0:0:A	EIGRP routers
	FF02:0:0:0:0:0:0:5	OSPFIGP
	FF02:0:0:0:0:0:0:6	OSPFIGP designated routers
Site-local scope	FF05:0:0:0:0:0:0:2	All-routers address
	FF05:0:0:0:0:0:1:3	All DHCP servers

IPv6 Addressing

Solicited-Node Multicast Address

- Every node must join this multicast address
- Used in Neighbor Discovery
- Specified in RFC 4291
- Resolves MAC address by sending Neighbor Solicitation message to solicited-node multicast address
- Only nodes registered to this multicast address will inspect the packet
- Address formed as follows:
  - Take low-order 24 bits of IPv6 address
  - Append to the well-known prefix
  - Prefix: FF02:0:0:0:0:1:FF00::/104

IPv6 Addressing

Anycast Address

- Provides redundancy and load balancing where a service is provided by multiple hosts
- Not specific to IPv6; RFC 1546 in 1993
- Mainly created to be used in DNS and HTTP
- No special prefix assigned
- Anycast addresses are part of the Global unicast address range
- Examples: 6to4 relay anycast address; RFC3068 and Mobile IPv6 specifications

IPv6 Addressing

IPv6 Types Examples

Prefix	Description	IPv4 Equivalent
::/128	Unspecified: May be used as source address when host is initializing	0.0.0.0
::1/128	Loopback: used when a host is communicating with itself	127.0.0.1
fc00::/7 fdf8:f53b:82e4::54	Unique Local Address (ULA): Reserved for local use; may not be unique and therefore are not routed	10.0.0.0/8 172.16.0.0/12 192.168.0.0/16
fe80::/10 fe80::201:3ff:fe27:1171	Link-Local Address: used on single link, not routed and does not have to be unique	169.254.0.0/16
2001:db8::/32 2001:db8:8:4::3	Documentation: used in examples an documentation, never used as source/des.	192.0.2.0/24 192.51.100.0/24 203.0.113.0/24
2000::/3	Global Unicast: Addresses allocated to sites	141.117.233.251
ff00::/8 Ff01:0:0:0:0:0:0:2	Multicast: To identify multicast groups	224.0.0.0/24

IPv6 Addressing

Extended Unique Identifier (EUI-64)

	0	8	16	24	32	40
48-bit IEEE MAC Address	00	:01	:03	:27	:11	:71
	00000000:00000001:00000011:00100111:00010001:01110001					

Bit 48 marks the end.

	0	8	16	24	32	40	48	56
1.	00000000	00000001	00000011			00100111	00010001	01110001
2.	00000000	00000001	00000011	11111111	11111110	00100111	00010001	01110001
3.	00000010	00000001	00000011	11111111	11111110	00100111	00010001	01110001
4.	02	01	03	ff	fe	27	11	71

Bit 64 marks the end.

5.	fe80::201:3ff:fe:27:1171

1. Split MAC address
2. Insert “FFFE” in the middle
3. Change bit 7 to “1”
4. Modified MAC address in EUI-64 in hex
5. IPv6 address with EUI-64 modifier

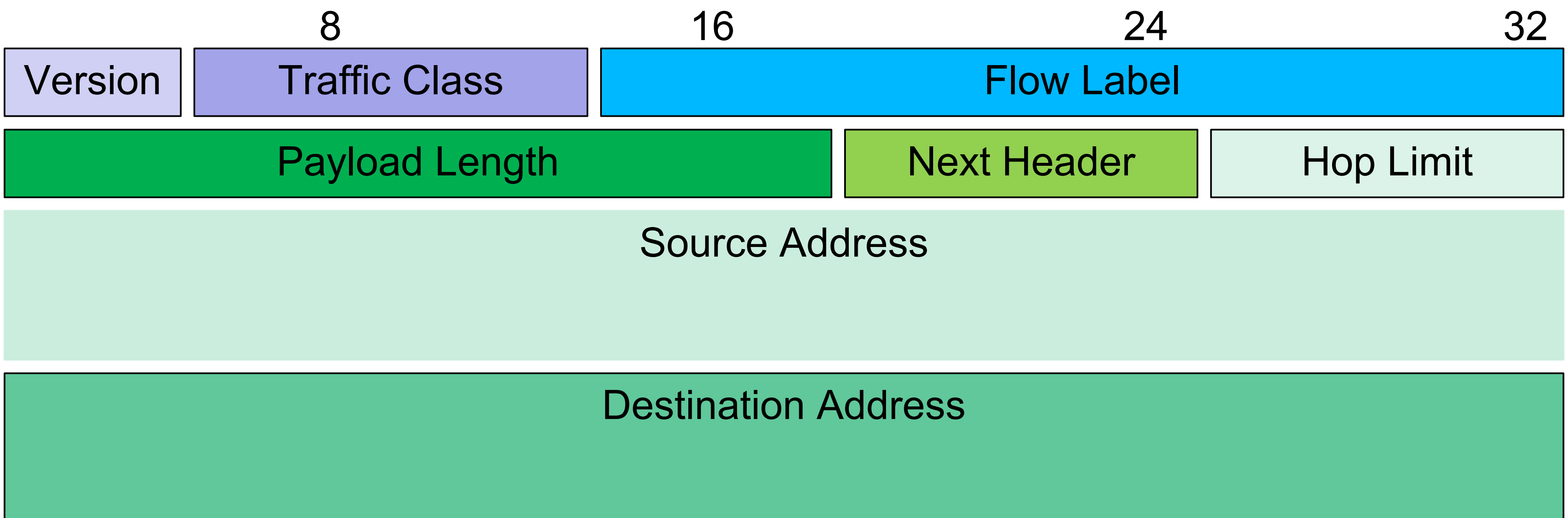
IPv6 Structure

IPv6 header structure specified in RFC2460

- Fixed length of 40 bytes
- Source and Destination field each use 16 bytes (128 bits)
- Only eight bytes are used for general header information
- IPv6 header is much simpler than IPv4 header
- More efficient processing due to simpler header and more flexible in extending the protocol for future needs

IPv6 Structure

IPv6 Protocol header



Version : 4 bits, set to 6
Traffic Class: 8 bits, A DSCP value for QoS
Flow Label : 20 bits, identifies unique flow
Payload Length: 16 bits, length of payload in bytes
Next Header: 8 bits, extension/header/protocol that follows
Hop Limit: 8 bits, similar to TTL in Pv4
Source/Destination Addresses: 128 bits each

IPv6 Structure

Fields removed from IPv4

- **Header Length field removed since IPv6 header is fixed**
- **Identification removed since fragmentation is not done by routers**
- **Flags and Fragment Offset, no more fragmentation by routers**
  - Who is fragmenting packets now?
  - In IPv6, hosts learns Path MTU through Path MTU Discovery
  - Hosts use Extension header to handle frags
  - Routers along the way do not fragment packets any more!
- **Header Checksum, to improve processing speed by routers, no need to check and update header checksums!**

IPv6 Structure

Selected IPv6 Next Header (1 byte) Values

Value	Description *Source: http://www.iana.org/assignments/protocol-numbers*
0	In an IPv4 header: reserved and not used In an IPv6 header: Hop-by-Hop Option Header follows
1	ICMPv4
2	IGMPv4
4	IPv4
6	TCP
8	EGP
17	UDP
44	Fragmentation header
58	ICMPv6
59	No Next Header for IPv6
60	Destination Options header
88	EIGRP
89	OSPF

IPv6 Structure

IPv6 Extensions

- IPv4 header may contain options that will extend the header from a minimum of 20 bytes up to 60 bytes
  - These options were rarely used due to performance issues
- IPv6 solves this performance issue by separating IPv6 header from options
  - Options go in Extension headers and inserted into packet if needed
- The separation of basic header from option makes IPv6 simpler and improves processing time
- An IPv6 packet can contain zero or more Extension header
- Extension header go between IPv6 header and upper-layer headers
- If Extension header is Hop-by-Hop Options header, extension must be the first in the chain of extensions and every node along way must process the packet.

IPv6 Structure

IPv6 Extension Headers

Header	Description
Hop-By-Hop Options (0)	RFC 2460: carries optional information that must be processed by all nodes along the way. Ex. Router Alert, RSVP, Multicast Listener Discovery (MLD)
Routing (43)	RFC 2460: lists one or more nodes that should be used along the way
Fragment (44)	RFC 2460: IPv6 host will use this extension to indicate fragmented packet
Destination Options (60)	RFC 2460: Optional information processed by destination node only, can appear more than once
Authentication Options (AH, 51)	RFC 2402: Used for Header Authentication
Encrypted Security Payload (ESP, 50)	RFC 2406: Used for encrypted data; secure communication

IPv6 Benefits

IPv6	IPv4
Auto-configuration makes network management much simpler	Network must be configured using a DHCP server
Direct addressing due to much bigger address space	Limited number of IPs and widespread of NAT to compensate for lack of IP addresses
340 undecillion or trillion trillion trillion addresses	4.2 billion addresses
New platform for future innovations due to its scalability and flexibility	IPv4 designed as a transport/communication medium and no scalability or flexibility is provided by protocol
Improved security as IPSEC is built in the protocol	Security is an add-on using applications, was not designed to be secure
Simpler more efficient header to promote routing speed (fixed length header)	Inefficient due to extraneous header fields (variable length header)

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