Internet Protocol Version 6 (IPv6)

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These slides are available on-line at:

http://www.cse.wustl.edu/~jain/cse473-05/

- Limitations of IPv4 Addressing
- IPv6 Enhancements
- IPv6 Addresses
- IP v6 Header
- IPv6 Extension Headers

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: 254 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 ⇒ 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 will be served by 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
- IPv6 Requirements $\Rightarrow 10^{12}$ end systems and 10^9 networks. Desirable 10^{12} to 10^{15} networks

IPv6 Enhancements

1. Expanded address space: 128 bit
2. Address auto-configuration: Dynamic assignment
3. Increased addressing flexibility: Anycast + Multicast
4. Improved option mechanism: Extension Headers
   - Improved speed and simplified router processing
5. Support for resource allocation
   - Replaces type of service
   - Labeling of packets to particular traffic flow

IPv6 Addresses

- 128-bit long. Fixed size
- $2^{128} = 3.4\times10^{38}$ addresses
  $\Rightarrow 665\times10^{21}$ 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
  $8\times10^{17} \Rightarrow$ 1,564 address per sq. m
- Allows multiple interfaces per host.
- Allows multiple addresses per interface
- Allows unicast, multicast, anycast
- Allows provider based, site-local, link-local

Colon-Hex Notation

- **Dot-Decimal**: 127.23.45.88
- **Colon-Hex:**
  FEDC:0000:0000:0000:3243:0000:0000:ABCD
  - Can skip leading zeros of each word
  - Can skip one sequence of zero words, e.g.,
    FEDC::3243:0000:0000:ABCD
    ::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:BA23:0007::/50

Local-Use Addresses

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

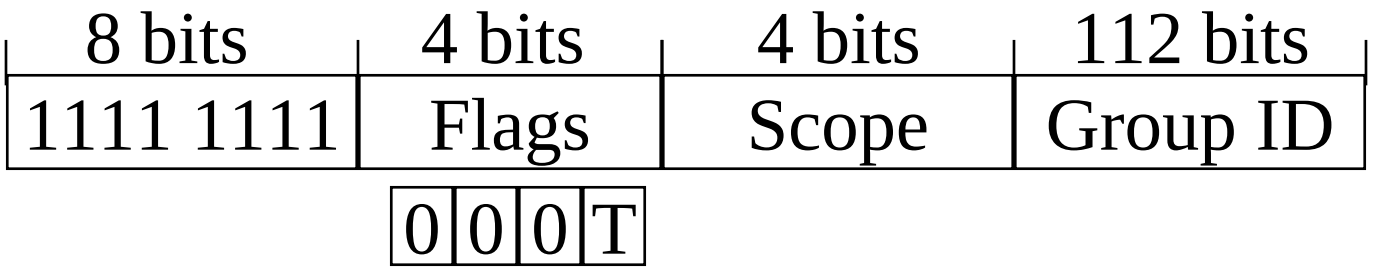
10 bits	n bits	118-n
1111 1110 10	0	Interface ID

  - 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



- T = 0 ⇒ Permanent (well-known) multicast address, 1 ⇒ Transient
- Scope: 1 Node-local, 2 Link-local, 5 Site-local, 8 Organization-local, E Global
- Predefined: 1 ⇒ All nodes, 2 ⇒ Routers, 1:0 ⇒ DHCP servers

Multicast Addresses (Cont)

- Example: 43 ⇒ Network Time Protocol 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 organization
  - FF0E::43 ⇒ All NTP servers in the Internet

Header

- IPv6:

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

- IPv4:

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

IP v6 Header

- Version: 6
- Traffic Class: Classes or priorities of packet
- Flow Label: Used by hosts requesting special handling
- Payload length: Includes all extension headers + data
- Next Header: Extension header or next layer up
- Source Address
- Destination address

Protocol and Header Types

Decimal	Keyword	Header Type
	HBH	Hop-by-hop (IPv6)
1	ICMP	Internet Control Message (IPv4)
2	IGMP	Internet Group Management (IPv4)
2	ICMP	Internet Control Message (IPv6)
3	GGP	Gateway-to-Gateway
4	IP	IP in IP (IPv4 Encaptulation)
5	ST	Stream
6	TCP	
17	UDP	
29	ISO-TP4	
43	RH	Routing Header (IPv6)
44	FS	Fragmentation Header (IPv6)
45	IDRP	Interdomain Routing
51	AH	Authentication header (IPv6)
52	ESP	Encrypted Security Payload
59	Null	No next header
60	ISO-IP	CLNP
88	IGRP	
89	OSPF	Open Shortest Path First

IPv6 vs IPv4

- 1995 vs 1975
- IPv6 only twice the size of IPv4 header
- Only version number has the same position and meaning as in IPv4
- Removed: header length, type of service, identification, flags, fragment offset, header checksum
- Datagram length replaced by payload length
- Protocol type replaced by next header
- Time to live replaced by hop limit
- Added: Priority and flow label
- All fixed size fields.

IPv6 vs IPv4 (Cont)

- No optional fields. Replaced by extension headers.
- 8-bit hop limit = 255 hops max (Limits looping)
- Next Header = 6 (TCP), 17 (UDP),

Extension Headers

Most extension headers are examined only at destination

1. Hop-by-Hop Options
2. Fragmentation: All IPv6 routers can carry 536 Byte payload
3. Routing: Loose or tight source routing
4. Destination Options

Extension Header (Cont)

- Only Base Header:

Base Header Next = TCP	TCP Segment

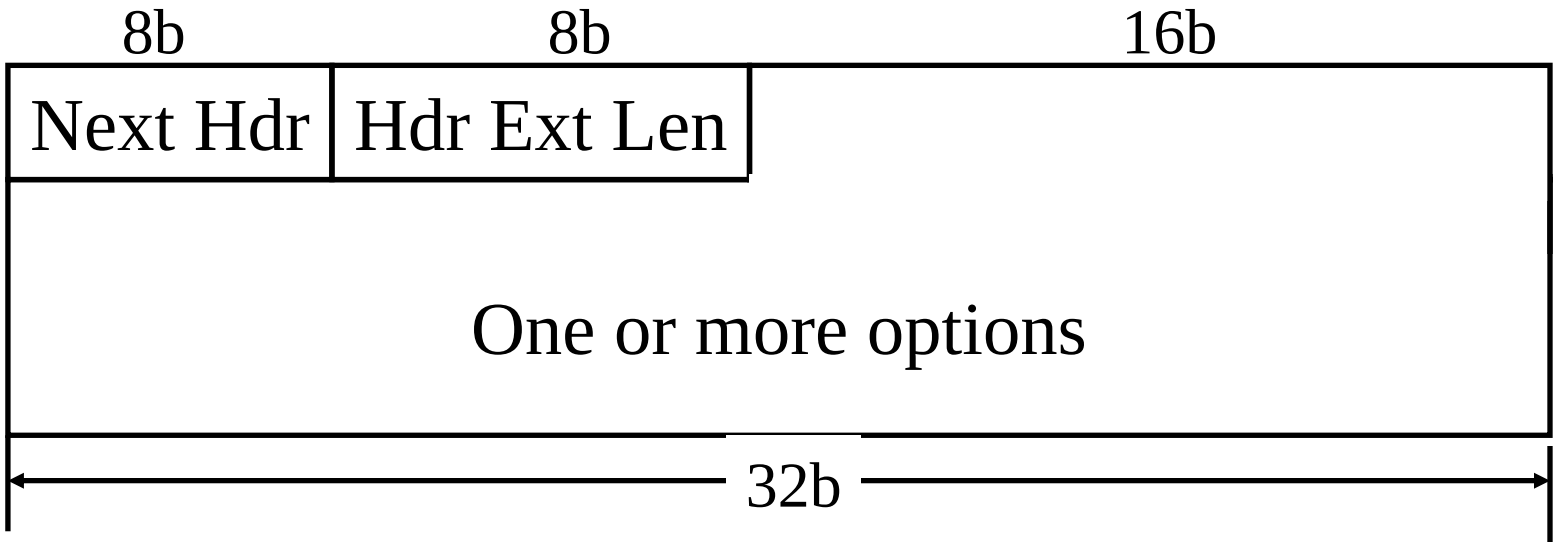
- Only Base Header and One Extension Header:

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

- Only Base Header and Two Extension Headers:

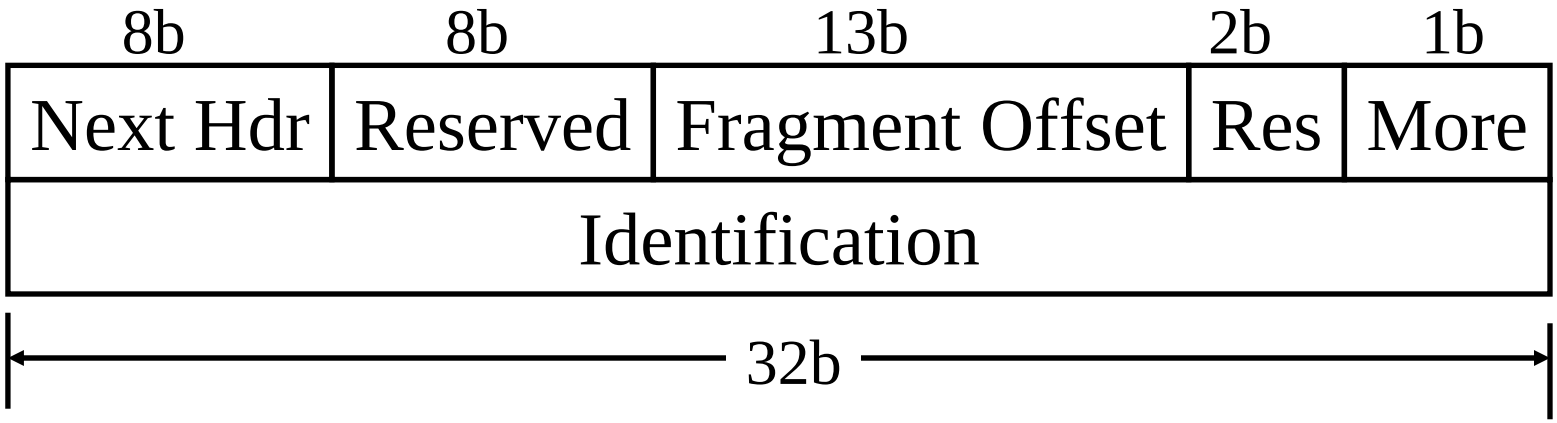
Base Header Next = Hop	Hop Header Next = Routing	Routing Header Next = TCP	TCP Segment

Hop-by-hop Options Header



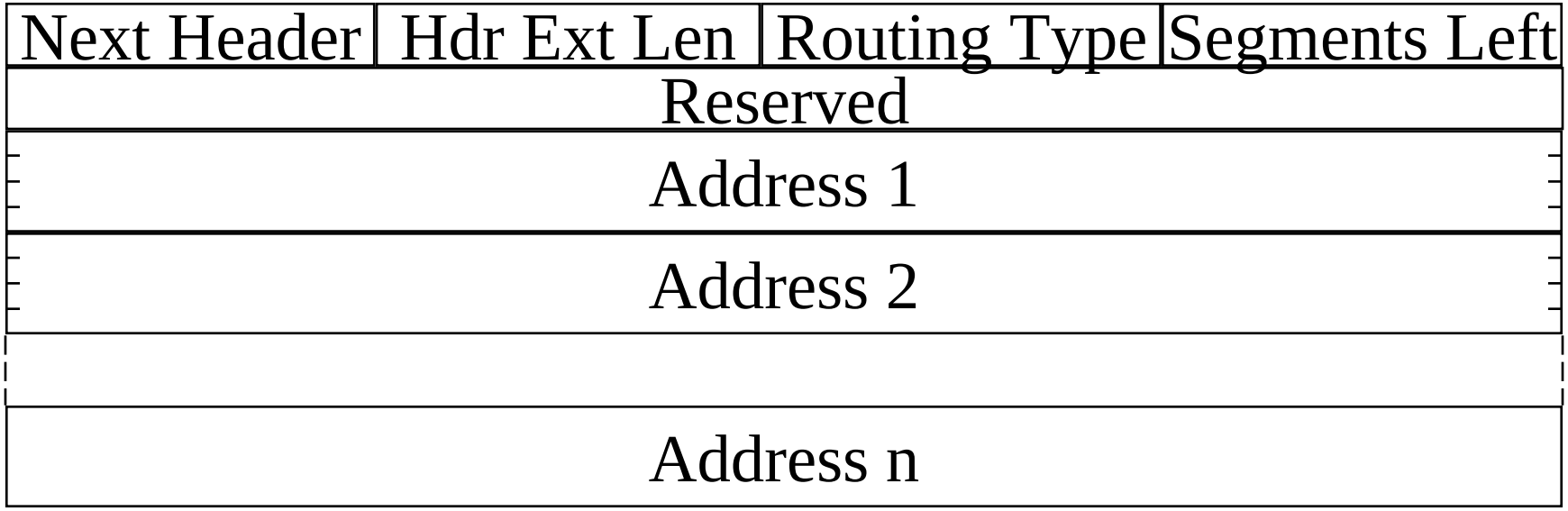
- Jumbo payload: Over 2^{16} = 65,535 octets
- Router alert
  - Contents of packet is of interest to router
  - Provides support for RSVP

Fragmentation Header



- Fragmentation only allowed at source
- No fragmentation at intermediate routers
- Node must perform path discovery to find smallest MTU of intermediate networks
- Source fragments to match MTU
- Otherwise limit to 1280 octets

Routing Header

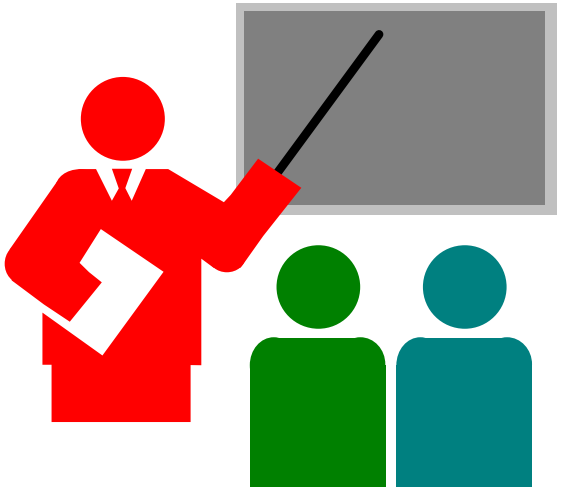


- Strict ⇒ Discard if Address[Next-Address] ≠ neighbor
- Type = 0 ⇒ Loose source routing
- IPv6 Destination Address = Next Address
- Segments Left: Number of route segments remaining
- IPv6 Dest Adr and Segments left are updated as each address specified in the list is reached

Destination Options

- Same format as Hop-by-Hop options header

Summary



1. IPv6 uses 128-bit addresses
2. Allows site-local, link-local, multicast, anycast addresses
3. Fixed header size. Extension headers instead of options
4. Hop-by-hop options, fragmentation, routing, destination options headers

Reading Assignment

- Read Section 18.5 of Stallings's 7th edition