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# IP Next Generation (IPv6)

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Limitations of current Internet Protocol (IP)

How many addresses do we need?

Pv6 Addressing

Pv6 header format

Pv6 features

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# IP Addresses

**Example:** 164.107.134.5

= 1010 0100 : 0110 1011 : 1000 0110 : 0000 0101

= A4:6B:86:05 (32 bits)

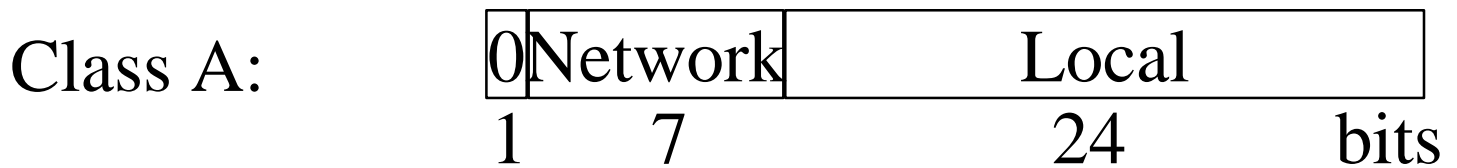
Maximum number of address =  $2^{32} = 4$  Billion

Class A Networks: 15 Million nodes

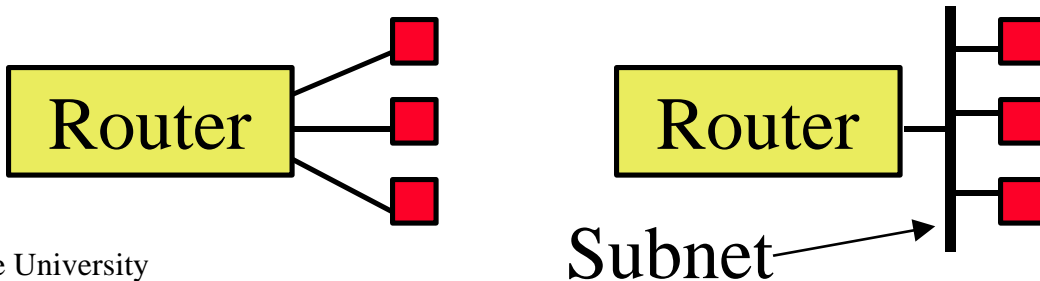
Class B Networks: 64,000 nodes or less

Class C Networks: 250 nodes or less

# IP Address



Local = Subnet + Host (Variable length)



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## 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.

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## 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

IPng Requirements  $\Rightarrow 10^{12}$  end systems and  $10^9$

networks. Desirable  $10^{12}$  to  $10^{15}$  networks

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## Address Size

H Ratio =  $\log_{10}(\text{number of objects})/\text{available bits}$

$2^n$  objects with  $n$  bits: H-Ratio =  $\log_{10}2 = 0.30103$

French telephone moved from 8 to 9 digits at  $10^7$  households  $\Rightarrow H = 0.26$  (assuming 3.3 bits/digit)

US telephone expanded area codes with  $10^8$  subscribers  $\Rightarrow H = 0.24$

SITA expanded 7-character address at 64k nodes  $\Rightarrow H = 0.14$  (assuming 5 bits/char)

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

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## 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  $10^6/\mu\text{s}$ , it would take 20 years

Expected to support  $8 \times 10^{17}$  to  $2 \times 10^{33}$  addresses

$\times 10^{17} \Rightarrow 1,564$  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

5% of the space is unassigned

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## Colon-Hex Notation

**Dot-Decimal:** 127.23.45.88

**Colon-Hex:**

FEDC:0000:0000:0000:3243:0000:0000:ABCD

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

# Initial IPv6 Prefix Allocation

location	Prefix	Allocation	Prefix
reserved	0000 0000	Unassigned	101
unassigned	0000 0001	Unassigned	110
SLAP	0000 001	Unassigned	1110
X	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

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## 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

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## Multicast Addresses

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

T = 0  $\Rightarrow$  Permanent (well-known) multicast address

1  $\Rightarrow$  Transient

Scope: 1 Node-local, 2 Link-local, 5 Site-local,  
8 Organization-local, E Global

Predefined: 1  $\Rightarrow$  All nodes, 2  $\Rightarrow$  Routers,

1:0  $\Rightarrow$  DHCP servers

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## Multicast Addresses (Cont)

- Example: 43  $\Rightarrow$  Network Time Protocol Servers
- q FF01::43  $\Rightarrow$  All NTP servers on this node
  - q FF02::43  $\Rightarrow$  All NTP servers on this link
  - q FF05::43  $\Rightarrow$  All NTP servers in this site
  - q FF08::43  $\Rightarrow$  All NTP servers in this organization
  - q FF0F::43  $\Rightarrow$  All NTP servers in the Internet

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# Header

IPv6:

Version	Priority	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	

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# 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 Encapsulation)
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

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## 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.

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

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# Extension Headers

Base Header	Extension Header 1	...	Extension Header $n$	Data
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Most extension headers are examined only at destination

Routing: Loose or tight source routing

Fragmentation: All IPv6 routers can carry 536 Byte payload

Authentication

Security Encapsulation: Confidentiality

Top-by-Hop Option

Destination Options:

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## Extension Header (Cont)

Only Base Header:

Base Header [ext = TCP	TCP Segment
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Only Base Header and One Extension Header:

Base Header [ext = TCP	Route Header Next = TCP	TCP Segment
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Only Base Header and Two Extension Headers:

Base Header [ext = TCP	Route Header Next = Auth	Auth Header Next = TCP	TCP Segment
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# Routing Header

Next Header	Routing Type	Num. Address	Next Address
Reserved	Strict/Loose bit mask		
Address 1			
Address 2			
Address n			

Strict  $\Rightarrow$  Discard if Address[Next-Address]  $\neq$  neighbor

Type = 0  $\Rightarrow$  Current source routing

Type > 0  $\Rightarrow$  Policy based routing (later)

New Functionality: Provider selection, Host mobility

Auto-readdressing (route to new address)

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# Provider Selection

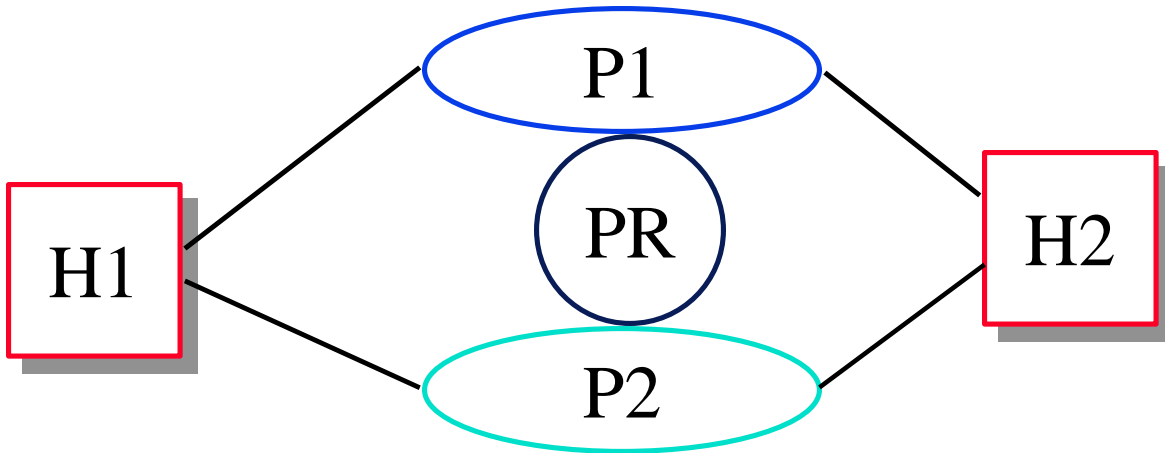
Possible using routing extension header

Source specified intermediate systems

No preference: H1, H2

P1 Preferred: H1, P1, H2

H1 becomes Mobile: H1, PR, P1, H2



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# IPv6 Features

Larger addresses

Flexible header format

Improved options

Support for resource allocation

Provision for protocol extension

Built-in Security:

Both authentication and confidentiality

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# Address Autoconfiguration

Allows plug and play

BOOTP and DHCP are used in IPv4

DHCPng will be used with IPv6

Two Methods: Stateless and Stateful

Stateless:

- q A system uses link-local address as source and multicasts to "All routers on this link"
- q Router replies and provides all the needed prefix info

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## Address Autoconfiguration (Cont)

- q All prefixes have a associated lifetime
- q System can use link-local address permanently if no router

Stateful:

- q Problem w stateless: Anyone can connect
- q Routers ask the new system to go DHCP server (1 setting managed configuration bit)
- q System multicasts to "All DHCP servers"
- q DHCP server assigns an address

# Transition Mechanisms

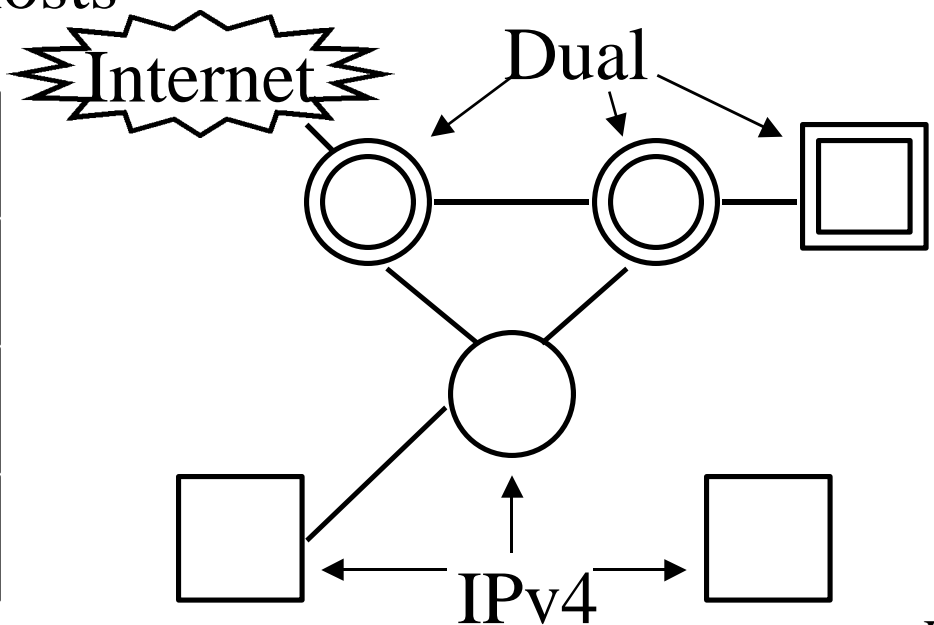
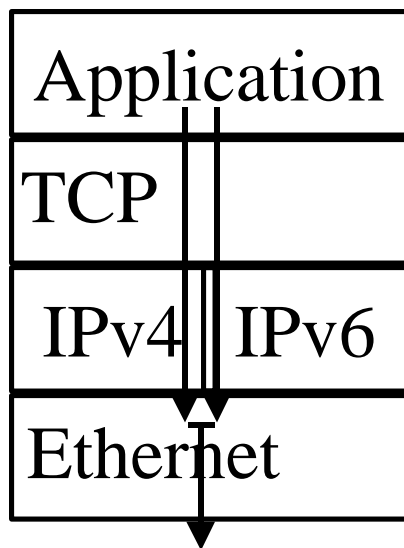
Dual-IP Hosts, Routers, Name servers

Tunneling IPv6 over IPv4

Hosts and Routers can be gradually upgraded to IPv6

It is better (though not required) to upgrade routers

before upgrading hosts



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## 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  $\Rightarrow$  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

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# Implementations

4.4-lite BSD by US Naval Research Laboratory

UNIX, OPEN-VMS by DEC

DOS/WINDOWS by FTP Software

HP-UX SICS (Swedish Institute of Comp. Science)

Linux

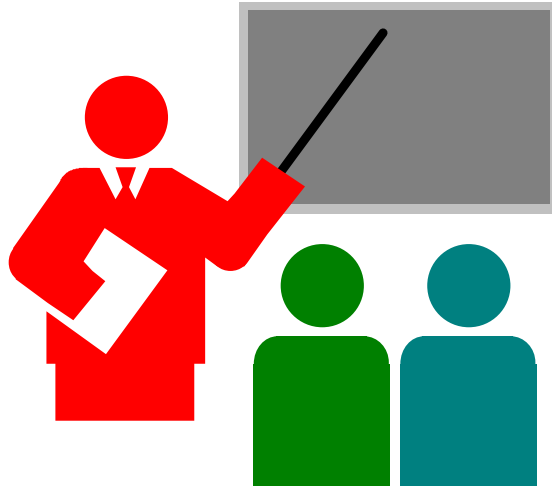
NetBSD by INRIA Rocquencourt

Solaris 2 by Sun

Streams by Mentat

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# Summary



Pv6 uses 128-bit addresses

allows provider-based, site-local, link-local, multicast addresses

fixed header size. Extension headers instead of options

allows auto-configuration

dual-IP router and host implementations for transition