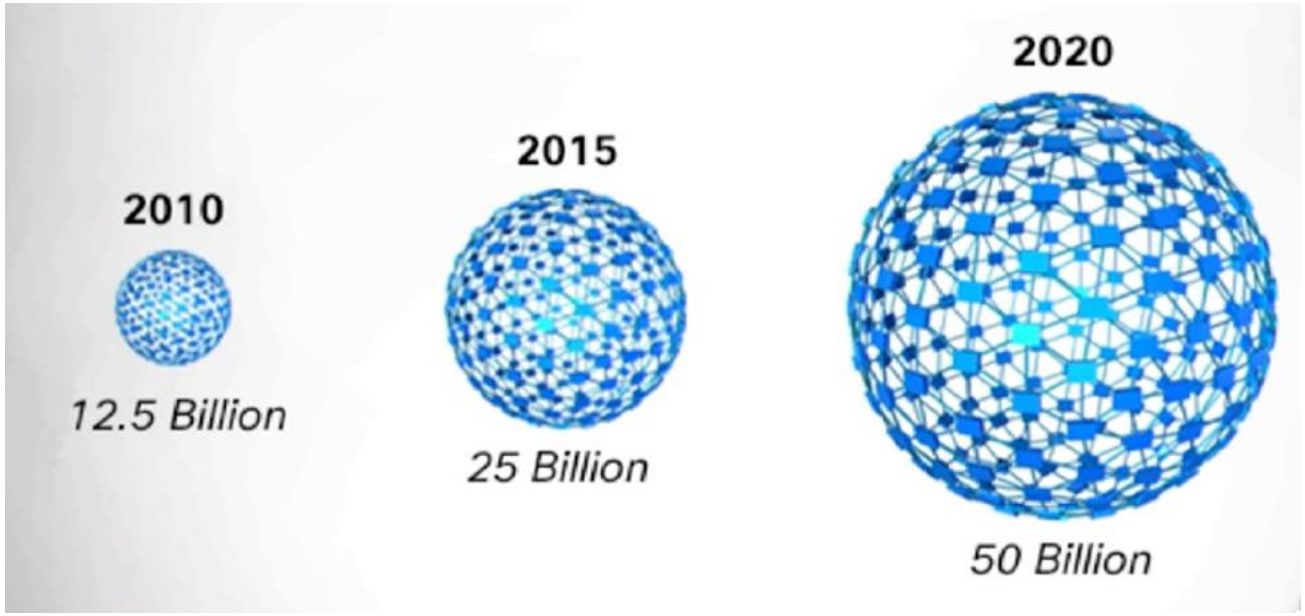
IPv6 Addressing

CSCI 101

IPv6

- 1990s - addressing limitations of IPv4
- 1994 Internet Engineering Task Force (IETF)



IPv4 vs IPv6

IPv4:

- Running out of IP addresses (Class A and B waste lots of hosts)
- IPv4 IPSec optional
- IPv4 supports unicast (1-1), broadcast (1-all), multicast (1-many)

IPv6:

- IPv6 uses 128-bit addresses (3.4×10^{38})
- IPv6: IPSec support is mandatory (it's optional in IPv4)
- IPv6: supports unicast, multicast, and anycast (one to nearest), does not use broadcast.

IPv4: 192.168.0.1 IPv6: 2001:odb8:85a3:0000:0000:8a2e:0370:7334
2001:odb8:85a3::8a2e:0370:7334

Solutions

- NAT (network address translation) – last 25 years!
- Run both IPv4 and IPv6 (dual-stack configuration)
- Time: IPv4 imbedded, many legacy systems (time is needed to ensure compatibility)

IPv4 vs IPv6

192.168.32.152

32 Bit

Octets separated by “.”

2001:0db8:0000:0000:a111:b222:c333:abcd

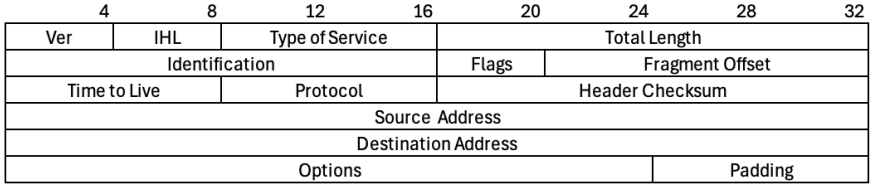
128 bit

Hextets* separated by “:”

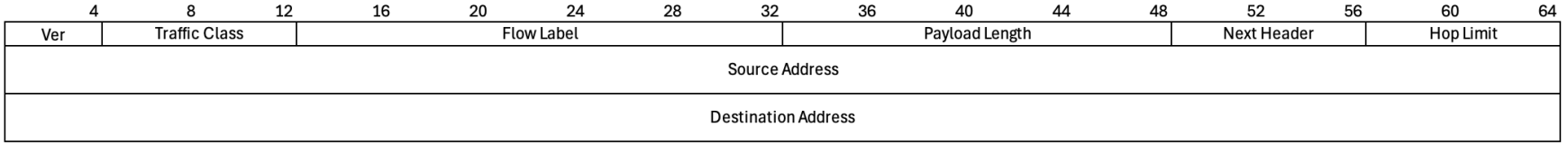
*Hexidecimal: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f

IPv4 : IPv6

IPv4



IPv6



Feature	IPv4	IPv6
Version	4	6
Header Length	Variable (20-60 bytes)	Fixed (40 bytes)
Address Length	32-bit	128-bit
Traffic Class / TOS	Type of Service (TOS) (8 bits)	Traffic Class (8 bits)
Flow Label		Flow Label (20 bits)
Payload Length	Total Length (16 bits)	Payload Length (16 bits)
Next Header	Protocol (8 bits)	Next Header (8 bits)
Hop Limit / TTL	Time to Live (TTL) (8 bits)	Hop Limit (8 bits)
Fragmentation	Identification (16 bits), Flags (3 bits), Fragment Offset (13 bits)	Fragmentation handled by extension header

Feature	IPv4	IPv6
Checksum	Header Checksum (16 bits)	
Source Address	Source Address (32 bits)	Source Address (128 bits)
Destination Address	Destination Address (32 bits)	Destination Address (128 bits)
Options / Extensions	Options (variable length)	Uses extension headers
Padding	Ensures the header is a multiple of 32 bits	
Simplified Processing	More complex due to variable header length and options	Simplified processing due to fewer fields and fixed header size
Security	Optional protocols like IPsec	IPsec support is mandatory

Key Differences

	IPv4	IPv6
Address Space	32-bit addresses	128-bit addresses
Header Length	Variable (20-60 bytes)	Fixed (40 bytes)
Fragmentation Handling	Routers and sending hosts	Sending hosts only, via Fragment extension header
Header Checksum	Includes a header checksum	No header checksum
Options and Extensions	Included within the header	Uses separate extension headers
Flow Label Field	No equivalent	Includes a Flow Label field
Security	Handled by optional protocols like IPsec	IPsec support is mandatory
Processing Efficiency	More complex header processing	Simplified header processing

IPv6 Address Space

- IPv6: 128-bit address (2^{128}) That's a lot.
  (6.65×10^{23} per square meter on earth*)

- IPv6 Address Types (single host has multiple addresses assigned, each serving specific function)
  - Unicast (1:1)
  - Multicast (1:M)
  - Anycast (1:nearest)

- Address Notation
  - user lower case
  - 16-bit blocks (leading 0 in 16 bit block can be dropped)
  - :: can replace largest number of consecutive zeros, once in an address

  2001:0db8:0000:0000:0056:abcd:0000:1234
  2001:db8::56:abcd:0:1234

- IPv4 mixed environment:

  IPv4: 192.168.1.2
  IPv6: ::192.168.1.2
  or ::c0a8:2 (hex)

- Prefix length replaces subnet mask
  - think CIDR: IPv6 Address /prefix length

* Hagen, S (2014) IPv6 Essentials, 6th Ed, O'Reilly Media, Inc

IPv6 Address Breakdown

2001:0DB8:0000:0000:A222:B333:0000:ABCD /64

Global Prefix: 2001:DB8:0000 ISP provided Public Address

Subnet: 0000 set by local network admin

Interface ID: A222:B333:0000:ABCD

Global prefix + Subnet: /64

In class: Activity 1

A) Expand the following IPv6 Addresses

1. 2001:db8::1
2. fe80::
3. ::ffff:c00a:2ff
4. 2001:0db8:0:0:0:0:1428:57ab
5. ::1

B) Compress the following IPv6 Addresses

1. 2001:0db8:0000:0000:0000:0000:0000:0001
2. fe80:0000:0000:0000:0202:b3ff:fe1e:8329
3. 0000:0000:0000:0000:0000:0000:0000:0001
4. 2001:0db8:0000:0042:0000:8a2e:0370:7334
5. 0000:0000:0000:0000:0000:ffff:c00a:02ff

Activity 1 (continued)

C) Given the following IPv6 addresses and prefix lengths, identify the subnet prefix:

1. 2001:0db8:85a3:0000:0000:8a2e:0370:7334/64
2. 2001:0db8:abcd:1234:5678:9abc:def0:1234/48
3. fe80:0000:0000:0000:0202:b3ff:fe1e:8329/128
4. 2001:0db8:abcd:0012:0000:0000:0000:0001/56

D) For the following IPv6 addresses and prefix lengths, identify the network portion and the host portion:

1. 2001:0db8:85a3:0000:0000:8a2e:0370:7334/64
2. 2001:0db8:abcd:1234:5678:9abc:def0:1234/48
3. fe80:0000:0000:0000:0202:b3ff:fe1e:8329/64
4. 2001:0db8:abcd:0012:3456:789a:bcde:f012/56

Subnetting IPv6: Example

Given an IPv6 address and subnet prefix, create two subnets. Determine the Network Addresses

IPv6 Address: 2001:0db8:85a3::

Subnet Prefix: /64

Solution

Step 1: Understand the Problem

We have an IPv6 address with a /64 prefix.

Subdividing this into 2 networks means increasing the prefix length by 1 bit (from /64 to /65).

Step 2: Subnet the IPv6 Address

When dividing a /64 network into two /65 networks:

The first /65 network will have the first bit of the 65th position as 0.

The second /65 network will have the first bit of the 65th position as 1.

Step 3: Determine Network Addresses

Network 1:

Network Address: 2001:0db8:85a3:: (first 65th bit = 0)

Prefix: /65

Network 2:

Network Address: 2001:0db8:85a3:8000:: (first 65th bit = 1)

Prefix: /65

Remember:

IPv6 is 128 bits

Every segment has 16 bits

Subnetting IPv6:

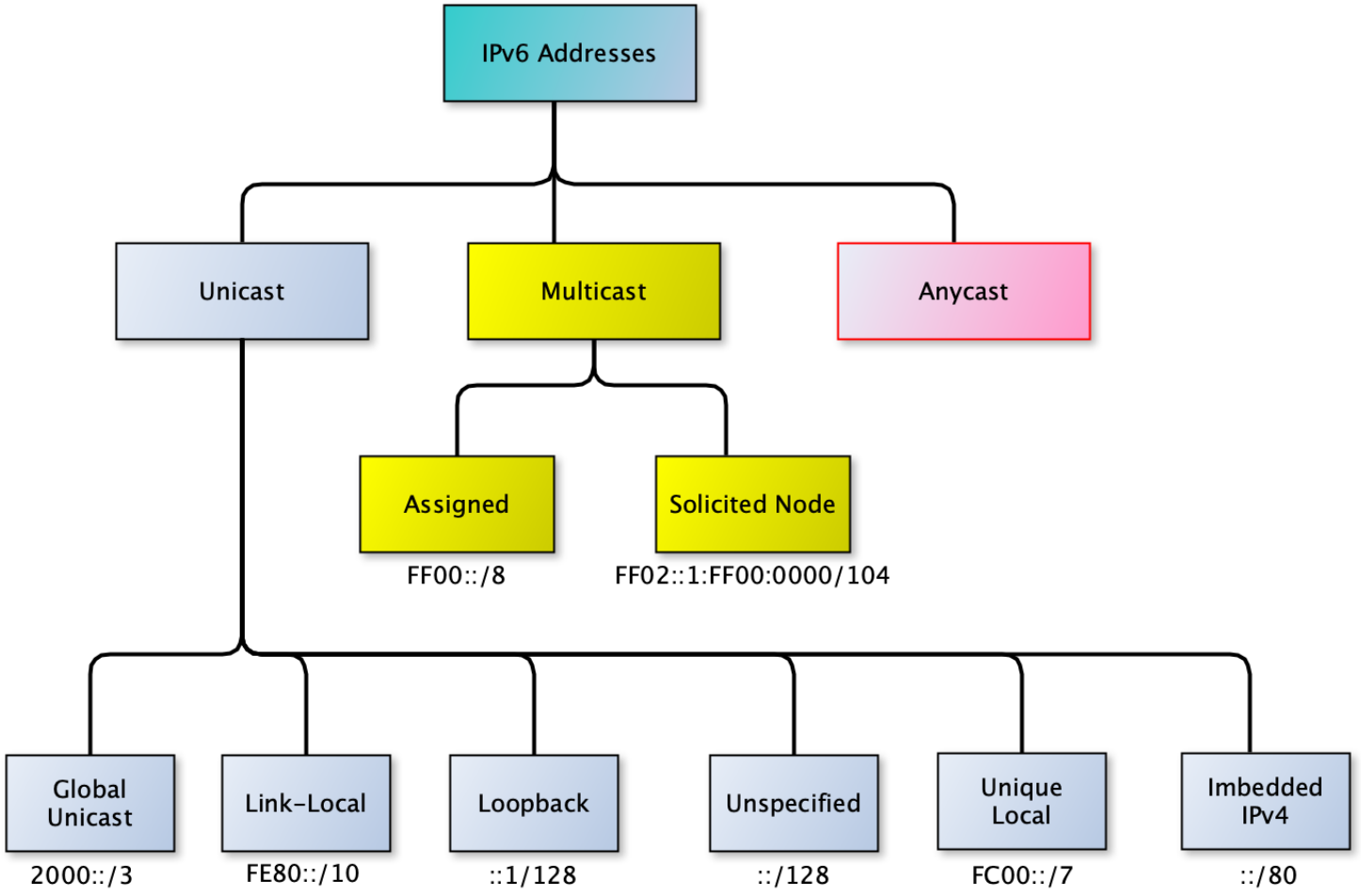
Given an IPv6 address and subnet prefix:

- Create two subnets.
- Determine the Network Addresses

Problem 1: IPv6 Address: 3001:abcd:ef01:: /56

Problem 2: IPv6 Address: 2400:dead:beef:: /48

IPv6 Addresses



IPv6 Addressing

- Autoconfiguration:
  - On boot, network prefix from IPv6 router on link
  - Using network prefix, autoconfigures valid global IP using MAC or private random number
- Elimination of NAT: larger address space means no shortage of addresses
- Enhanced IPSec:
  - Seamlessly integrated into IPv6 protocol stack
  - No NAT issues (secure end-to-end communication
  - Standardization means improved interoperability between vendors

In class: Activity 2

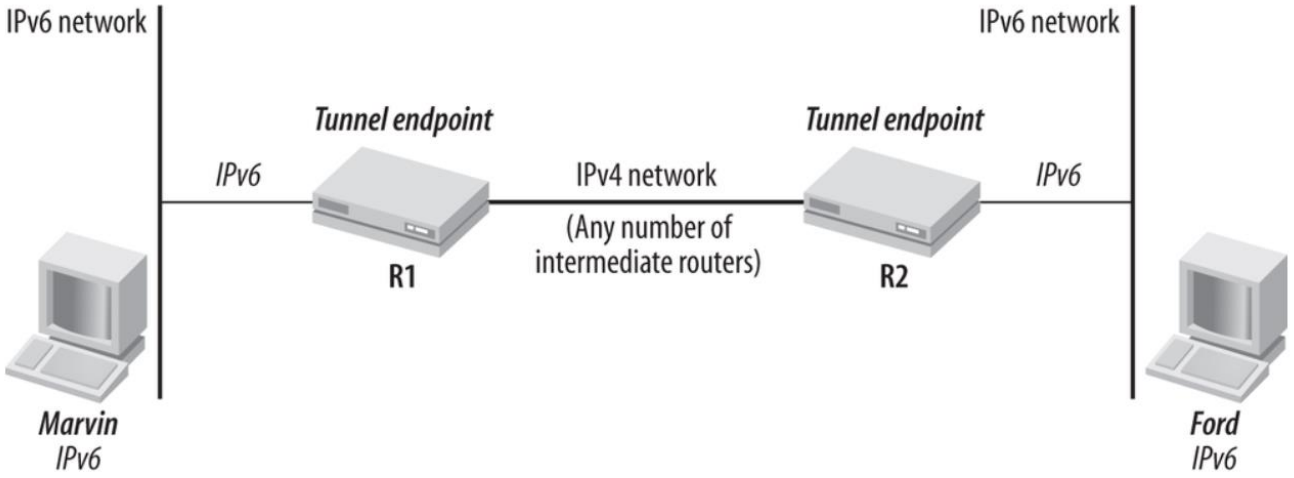
- View IPv6 configuration (ipconfig /all or ifconfig)
- Identify link-local address and global address
- Ping local IPv6 host:
- Ping 2001:4860:4860:8888
- Ping classmate’s IPv6 address

Moving to IPv6: Transitions

- Dual-Stack: IPv6/IPv4 node – provides complete support for both protocol versions
  - IPv6 only (IPv4 disabled)
  - IPv4 only (IPv6 disabled)
  - Dual Stack mode (both enabled)

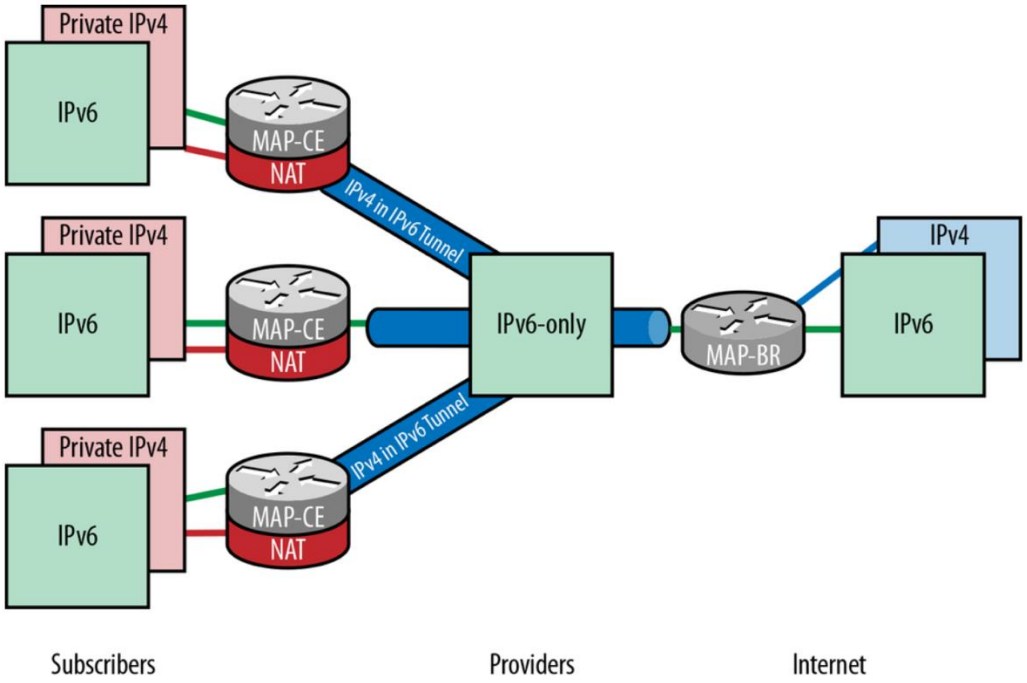
Moving to IPv6: Transitions

- Tunneling: Encapsulating IPv6 traffic in IPv4 packets and routing through IPv4 infrastructure



Moving to IPv6: Transitions

- NAT:
  - Temp fix (hiding multiple private addresses behind one public address)



Troubleshooting IPv6 Issues

Common IPv6 Connectivity Issues

- **Dual-stack implementation problems:** timeouts, poor connectivity, slow connections
- **Incomplete IPv6 configuration:** everything there?
- **lack of IPv6 support in applications / devices**: Update hardware and software . . .
- **IPv6 Address Assignment:** issues with SLAA or DHCPv6 (incorrect or inconsistent address assignment
- **DNS Resolution Issues:** DNS servers not configured to resolve IPv6 addresses (AAAA records)
- **Transition Mechanisms Issues (6to4, NAT64):** transition between IPv4 and IPv6 can introduce latency or fail:

Troubleshooting IPv6 Issues

Using Windows Troubleshooter for IPv6

- Verify IPv6 Configuration: ipconfig/all
- Ping IPv6 Address: ping ::1, gateway, external address
- Check Windows firewall: is IPv6 traffic allowed?
- Check DNS Settings: nslookup –query <hostname>
- Check for software Conflicts: Temporarily disable third-party firewalls, antivirus software