Internet Network Protocols IPv4/ IPv6

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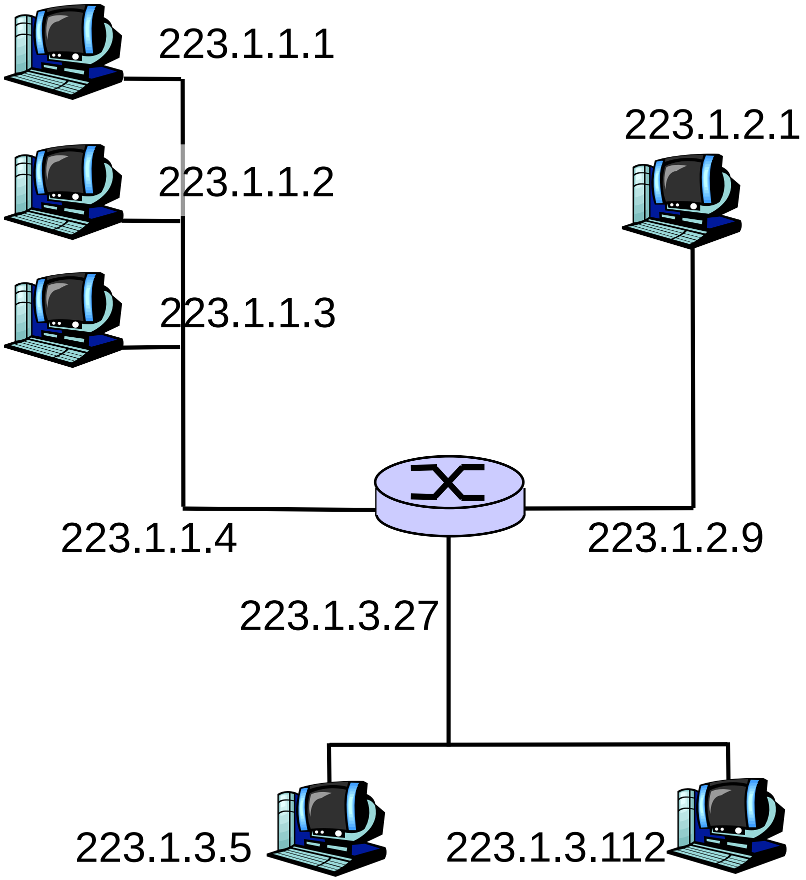
TCP/IP Illustrated, Volume 1, W. Richard Stevens
http://www.kohala.com/start

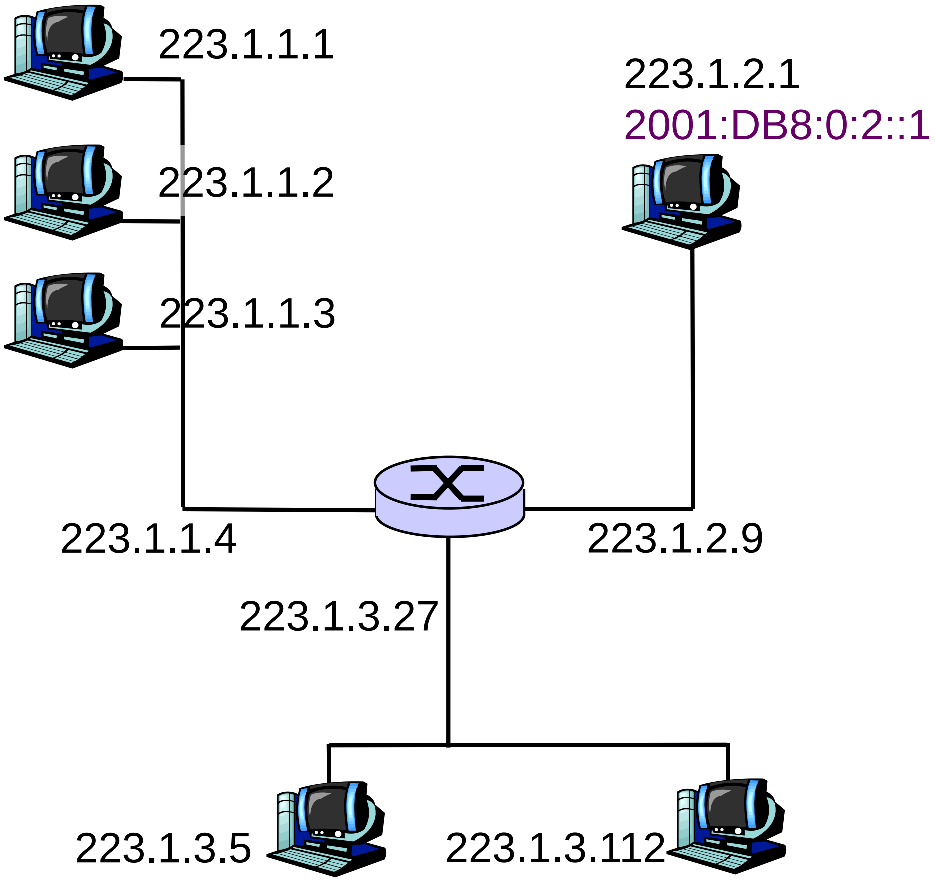
IP Interfaces

- IP address: identifier for host or router *interface*
  - IPv4: 32 bit long
  - IPv6: 128 bit long
- *Interface:* connects a host or router to a physical link
  - Routers typically have multiple interfaces
  - Host may have multiple interfaces
  - IP addresses are associated with interfaces, not hosts or routers



IPv4 Addressing

- IP address: Identifier for host or router *interface*
- IPv4 address:
  - 32 bit
  - written as 4x 8bit in decimal



223.1.1.1 = 11011111 00000001 00000001 00000001

223 1 1 1

IPv6 Motivation and History

- IPv4 address space is 32 bit
  - quite limited
- IPv4 was designed in the 1970ies
  - some requirements changed

Timeline:

1992 IETF begins discussion about IPv4 successor

1995 First IPv6 RFCs published

2000 50% of IPv4 address space assigned

2007 All major OS have IPv6 enabled by default

2011 IANA IPv4 assigned last IPv4 block
World IPv6 Day – Major sites test IPv6 for a day

2012 World IPv6 Launch Day – Major sites enable IPv6

IPv6 Addressing

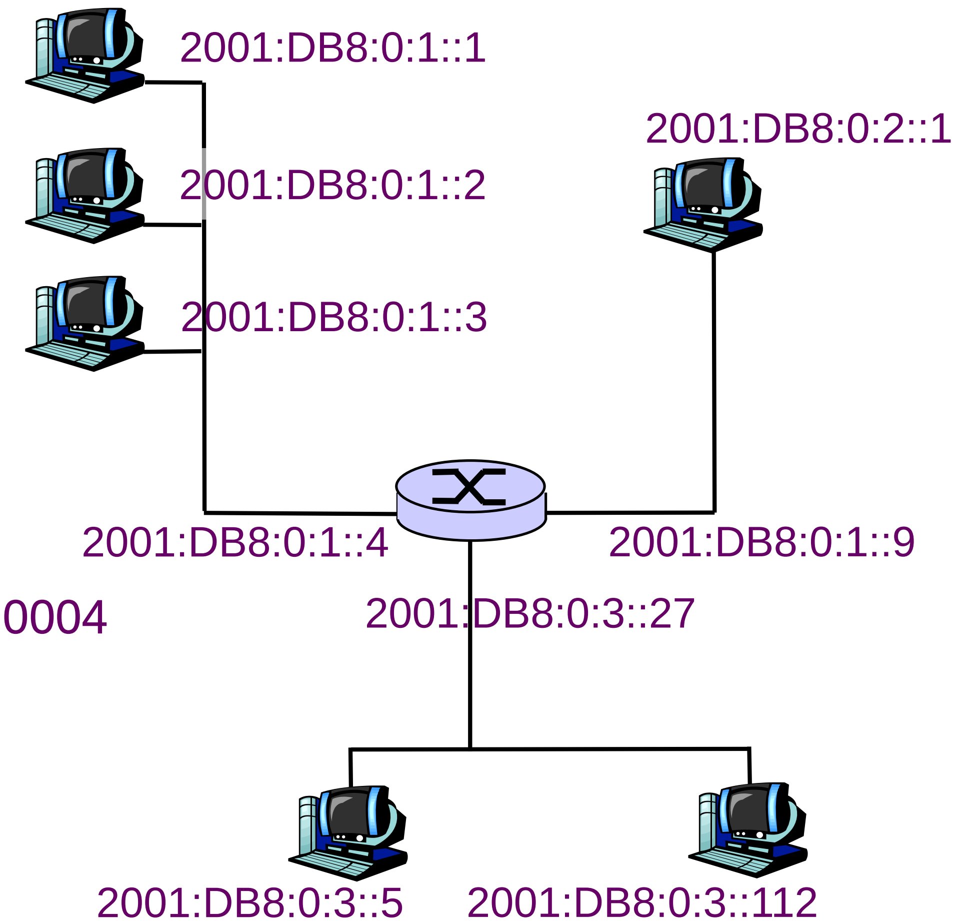
- IP address: Identifier for host or router *interface*
- IPv6 address: 128bit written as 8x 16bit in hex
  - Hextets are separated by colons

2001:0DB8:0000:0001:0000:0000:0000:0004

  - Leading zeros can be left out
  - Multiple “empty” (all zero) hextets can be abbreviated by a double-colon at one position

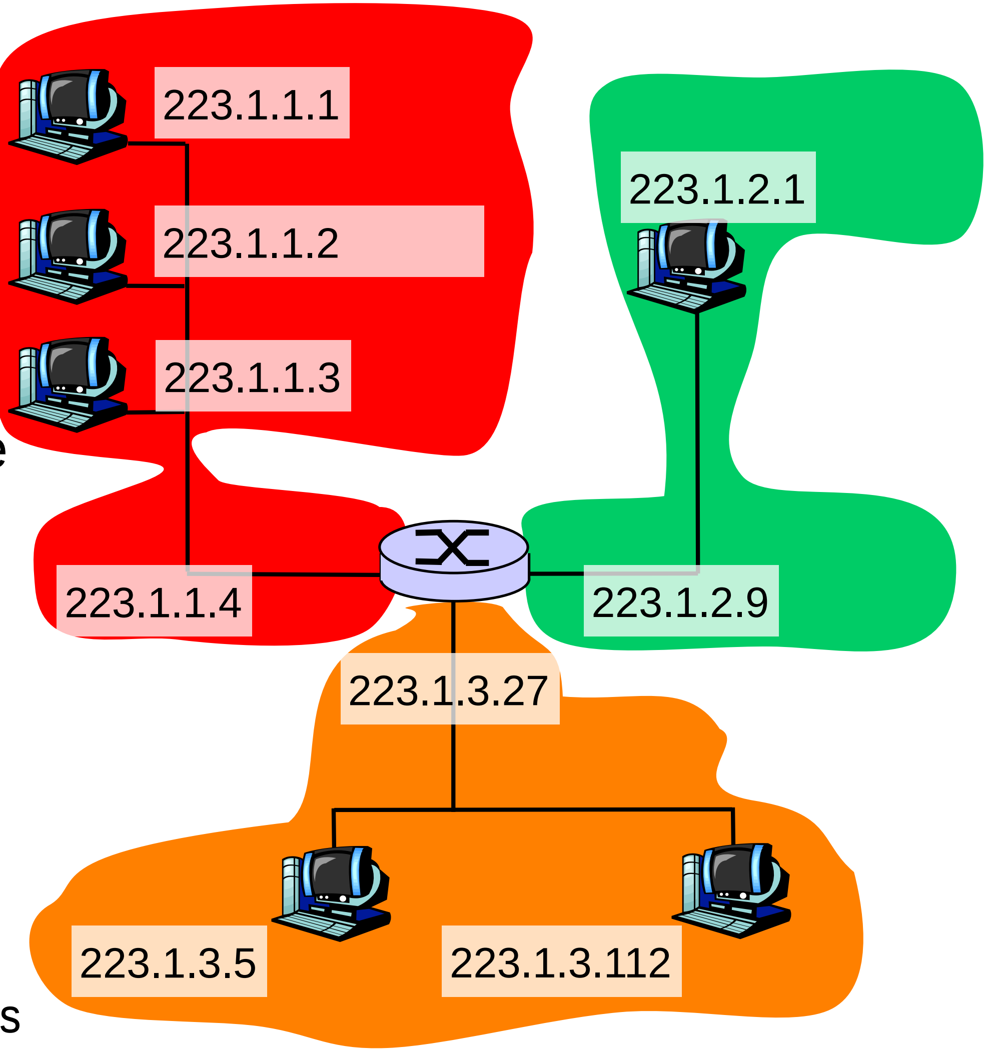
2001:DB8:0:1::4

shortening multiple times would lead to ambiguous addresses



IP Network

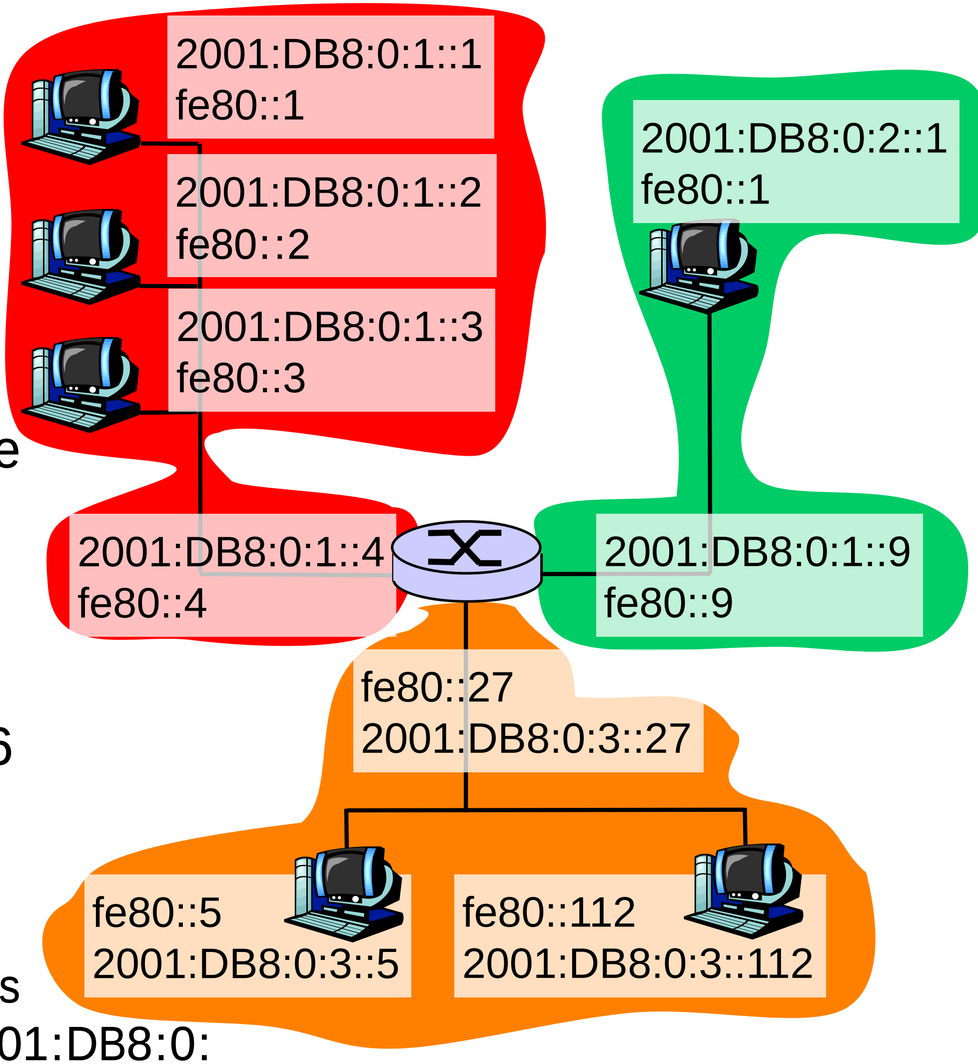
- *What's a network?*
  (from IP address perspective)
  - Can physically reach each other without intervening router
  - Device interfaces with same high order bits of their IP address



Network consisting of 3 IP networks
(for IP addresses starting with 223,
first 24 bits are network address)

IP Network (IPv6)

- *What's a network?*
  (from IP address perspective)
  - Can physically reach each other without intervening router
  - Device interfaces with same high order bits of their IP address
- What's different in IPv6?
  - Usually more than one IPv6 address per host
  - Special link-local network

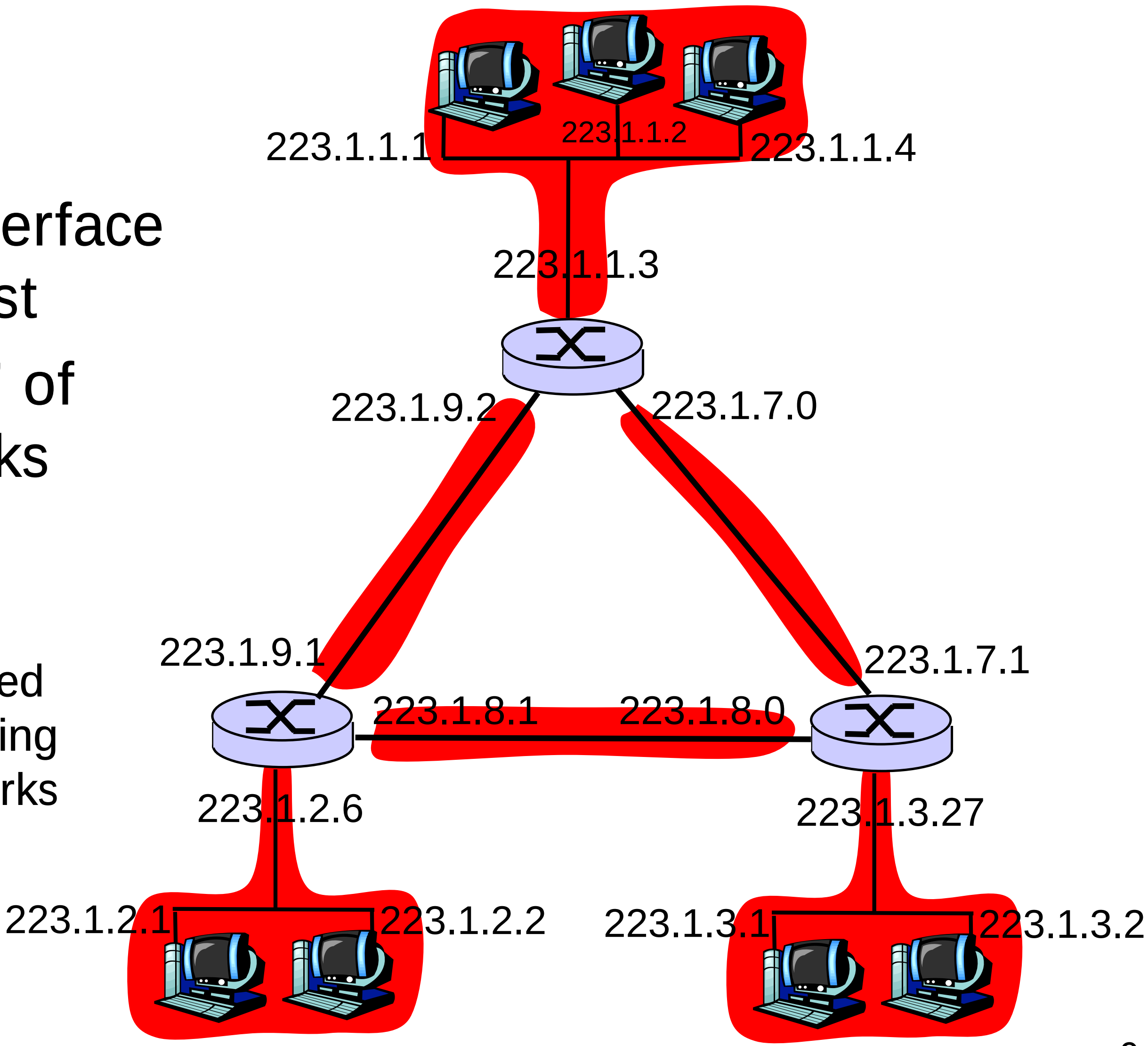


Network consisting of 3 IP networks
for IPv6 addresses starting with 2001:DB8:0:
the first 64 bits are network address and link-local-addresses starting with :fe80

IP Networks (top-down)

How to find the networks?

- Detach each interface from router, host
- Create "islands" of isolated networks



Interconnected system consisting of six networks

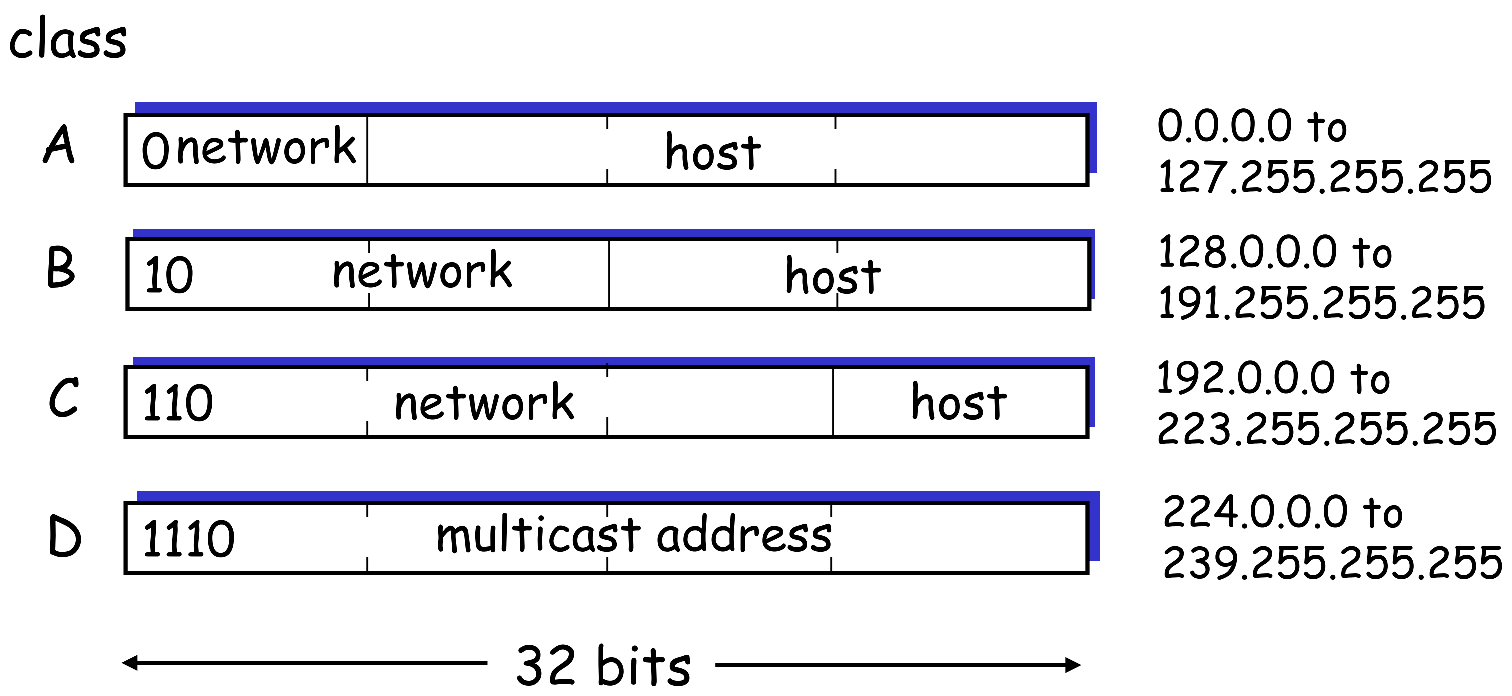
IP Subnetting

- Subnetting divides address space in
  - Network part referred to as prefix
  - Host address
- Address format (CIDR)
  - IPv4: a.b.c.d/m   200.23.16.0/24
  - IPv6: x:y:z::/m   2001:DB8:0:3::0/64
- m: Subnet portion of the address in # of bits; referred to as prefix length (bit representation==netmask)

11001000 00010111 00010000 00000000

200.23.16.0/24

IPv4 Classful Subnetting (deprecated)



Problem: Wastes IP address space

If you need more addresses than a class C network,

e.g. 256, you need to get at least a class B network (65536)

CIDR (current norm)

CIDR: Classless InterDomain Routing

- Subnet portion of address of arbitrary length
- Address format: a.b.c.d/x, where x is # bits in subnet portion of address

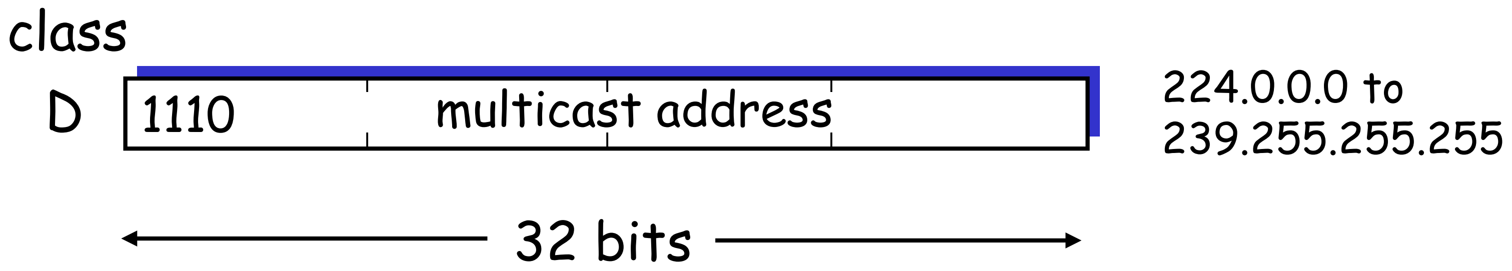
subnet part | host part

11001000 00010111 00010000 00000000

200.23.16.0/23

Special IP Address Ranges: IPv4

- Loopback 127.0.0.0/8
- Multicast 224.0.0.0/4



- Private ranges 10.0.0.0/8
  172.16.0.0/12
  192.168.0.0/16
- Link-Local 169.254.0.1/16

Special IP Address Ranges: IPv6

Loopback	::1/128
Global Unicast	2000::/3
Unique Local	FC00::/7
Multicast	FE00::/8
Link-Local Unicast	FE80::/10

Addresses for use in the Internet are Global Unicast and parts of Multicast.
Link-Local addresses are limited to a physical link (RFC3513).

Multicast Addresses

Addresses a group of hosts at once

- Useful for streaming and conferencing applications
- Heavily used in IPv6 for signaling

Only certain ranges usable as multicast

- IPv6: FE00::/8
- IPv4: 224.0.0.0/16

Link Local Addresses

Non-routable addresses

- Can only be used within a network
- Addresses not unique (!)
- Heavily used in IPv6 for local signaling

Address ranges used:

- 169.254.0.1/16 RFC 3927
- FE80::/10 RFC 4291

Private IP addresses

For local use only - not routable in the Internet

Private IPv4 addresses RFC 1918

- 10/8
- 172.16/12
- 192.168/16

Unique Local IPv6 Unicast addresses RFC 4193

- FC00::/7

How does a host get an IP addresses?

- Hard-coded by system admin

- DHCP / DHCPv6
  Dynamic Host Configuration Protocol
  - Request the address from a server
- IPv6 SLAAC
  Stateless Address Auto-Configuration
  - Router advertise the IPv6 prefix
  - Hosts add an Interface Identifier as Host-Part

IP Addresses Allocation Process

1. ICANN (Internet Corporation for Assigned Names and Numbers) gives IP address blocks to RIRs
2. RIRs (Regional Internet Registries), i.e. RIPE, ARIN, APNIC, LACNIC, AfriNIC assign addresses to LIRs
3. LIRs (Local Internet Registries) are larger Providers that assign addresses or address blocks to their customers

- IPv4 address space
  - None left in the ICANN pool since January 31st 2011,
  - Small blocks at a subset of the RIRs.
- IPv6 address space
  - Typical allocation for an LIR: /32
  - Typical allocation for a site: /48 – /56

IP Addresses Allocation Process

Q: What do I do if I don't have a public address?

A1: Recall private IP addresses

- 10/8 RFC 1918
- 172.16/12
- 192.168/16
- FC00::/7 RFC 4193

- Private use only – not routable in the Internet

A2: Recall link local addresses

- 169.254.0.1/16 RFC 3927
- FE80::/10 RFC 4291

- Local / single network use only – not routable

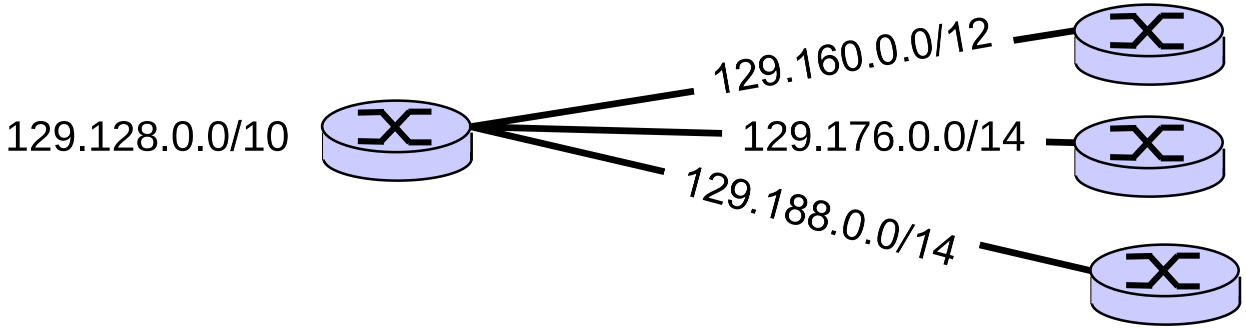
Hierarchical address structure

- Recall: CIDR

18 relevant bits

128.119.48.12/18 = 10000000 01110111 00110000 00001100

  - High order bits form the **prefix**
  - Once inside the network, can **subnet**: divide remaining bits
  - Subnet example:



Note: Picture shows prefix masks, not interface addrs!

- **Forwarding decision: Longest prefix match**

Forwarding vs. Routing

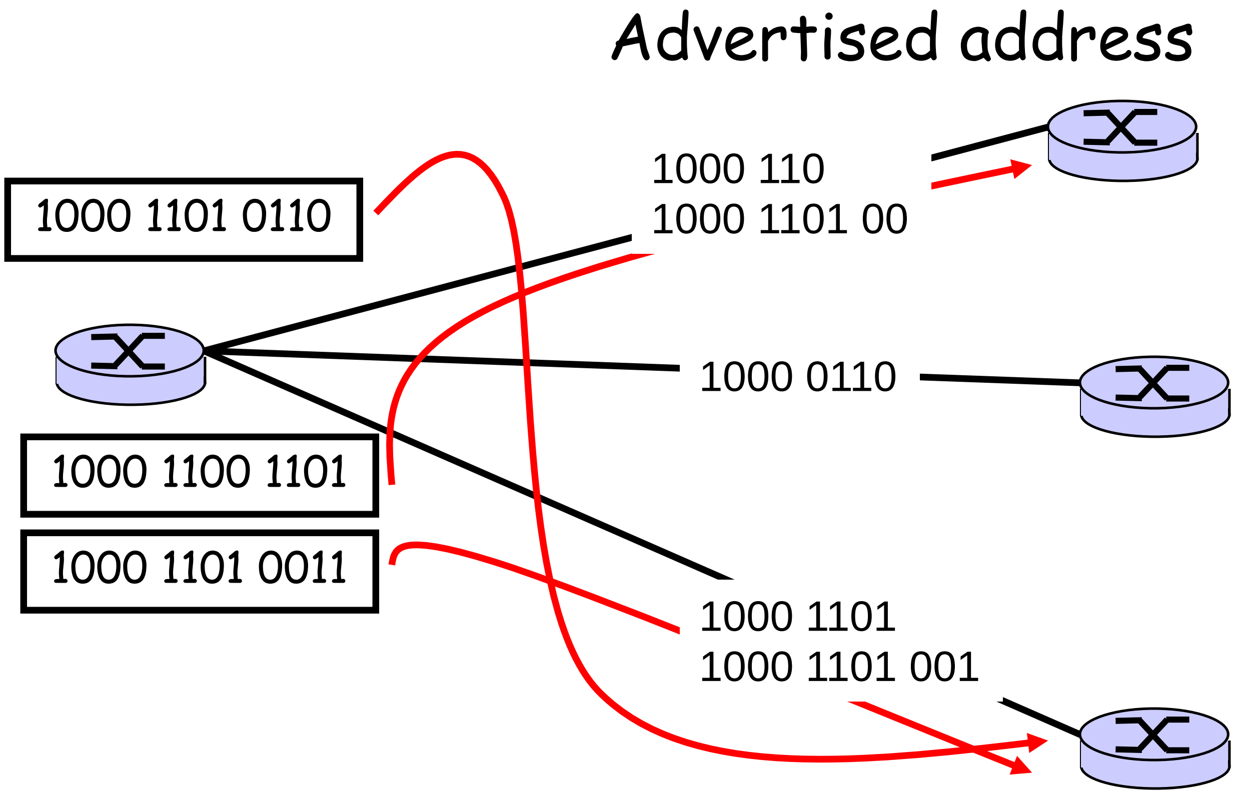
- Forwarding: Process of moving packets from input to output
  - The forwarding table
  - Information in the packet

- Routing: Process by which the forwarding table is built and maintained
  - One or more routing protocols
  - Procedures (algorithms) to convert routing info to forwarding table.

(More later ...)

Forwarding with CIDR

- Packet should be sent toward the interface with the **longest matching prefix**



Lookup: Longest Prefix Match

- Forwarding table:

  <Network>/<mask> <next-hop>
- IP Packets: destination IP address
  - Find next-hop via longest prefix match
- Example (IPv4):

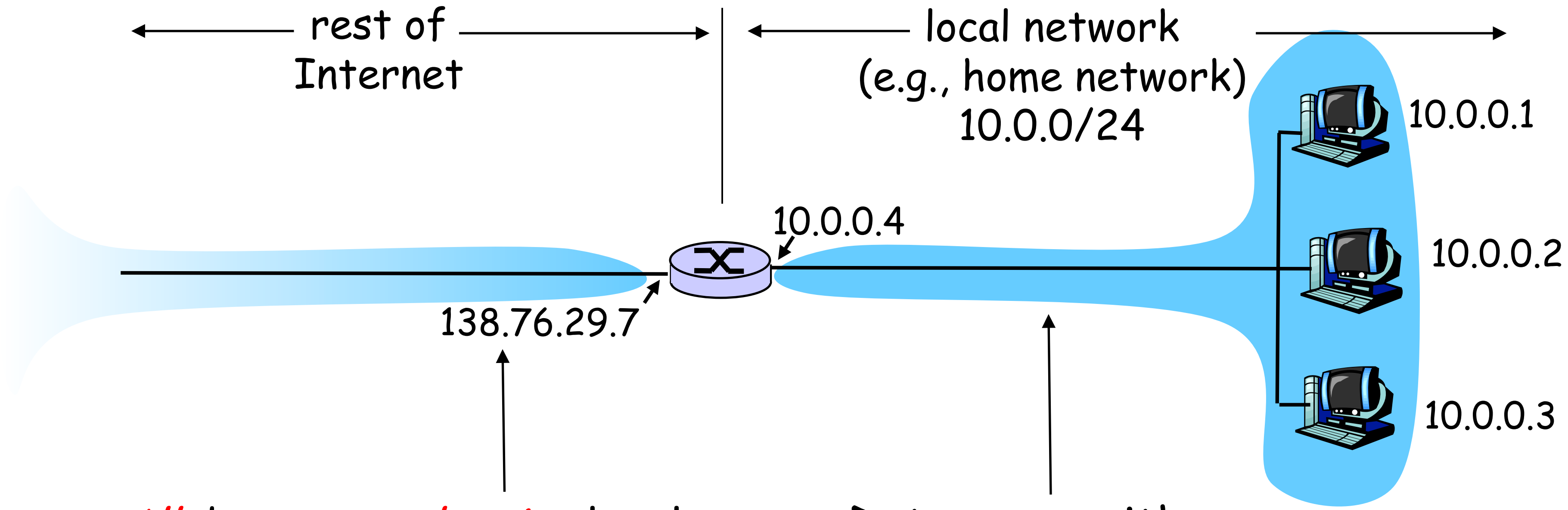
Forwarding table		Packets
134.96.252.0/24	A	134.96.252.200
134.96.0.0/16	C	134.96.254.2
134.96.240.0/20	B	134.96.239.200
134.96.252.192/28	B	134.97.239.200
134.96.252.128/28	A	134.96.252.191

NAT: Network address translation

Motivation: Local network uses just one IP address as far as outside world is concerned:

- Just one IP address for all devices
- Not needed range of addresses from ISP
- Work around for IPv4 exhaustion (carrier-grade NAT)

NAT: Network address translation (2.)



All datagrams *leaving* local network have same single source NAT IP address: 138.76.29.7, different source port numbers

Datagrams with source or destination in this network have 10.0.0/24 address for source, destination (as usual)

NAT: Network address translation (3.)

Motivation: Local network uses just one IP address as far as outside world is concerned:

- Range of addresses not needed from ISP: just one IP address for all devices
- Can change addresses of devices in local network without notifying outside world
- Can change ISP without changing addresses of devices in local network
- Devices inside local net not explicitly addressable, visible by outside world.

NAT: Network address translation (4.)

Implementation: NAT router must:

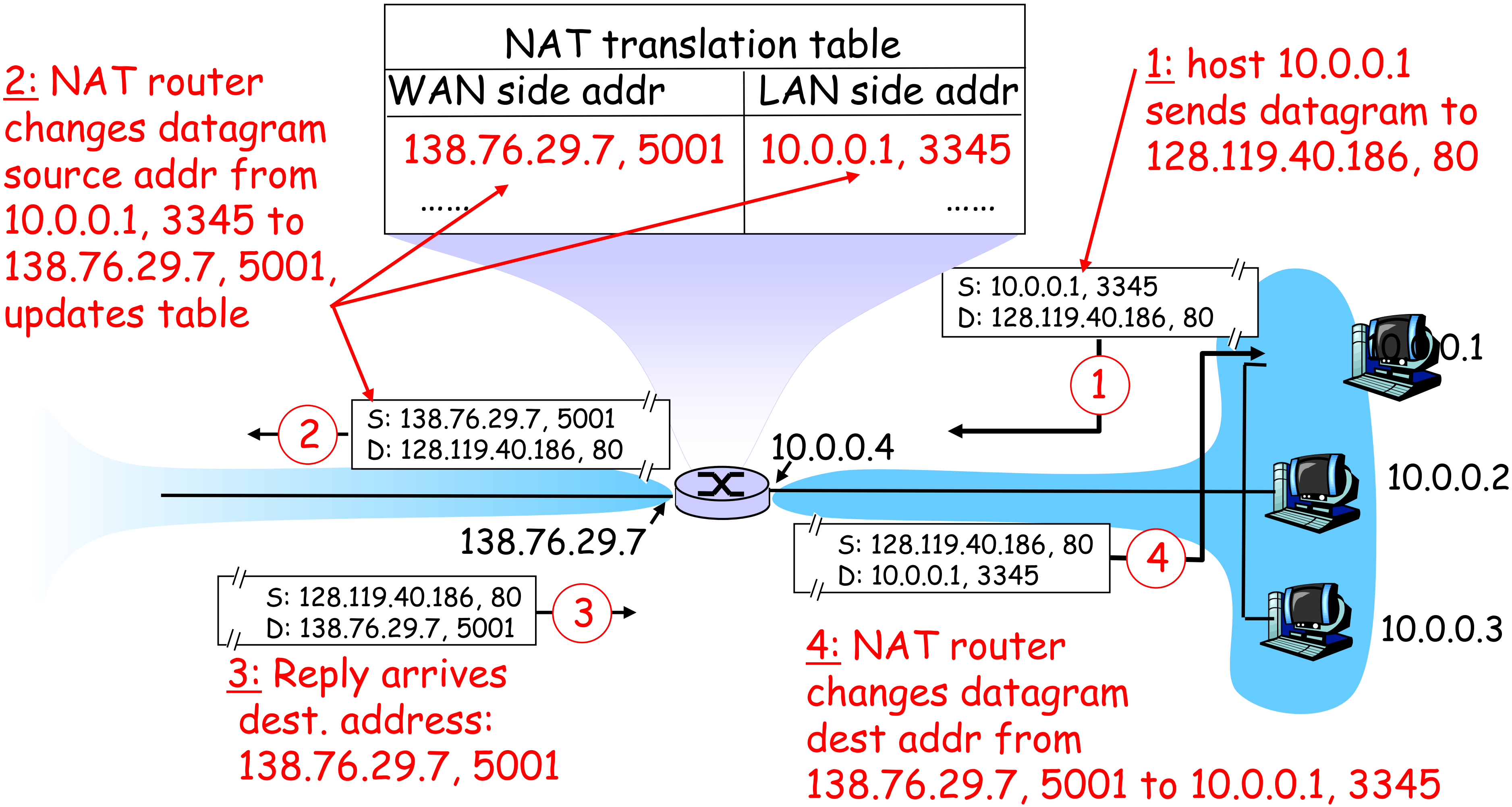
- *Outgoing datagrams: Replace* (source IP address, port #) of every outgoing datagram to (NAT IP address, new port #)

  . . . remote clients/servers will respond using (NAT IP address, new port #) as destination addr.

- *Remember (in NAT translation table)* every (source IP address, port #) to (NAT IP address, new port #) translation pair

- *Incoming datagrams: Replace* (NAT IP address, new port #) in dest fields of every incoming datagram with corresponding (source IP address, port #) stored in NAT table

NAT: Network address translation (5.)



NAT: Network address translation (6.)

- 16-bit port-number field
  - 60,000 simultaneous connections with a single LAN-side address!
- NAT is controversial
  - Routers should only process up to layer 3
  - Violates end-to-end argument
    - NAT possibility must be taken into account by app designers, e.g., P2P applications
  - Address shortage should instead be solved by IPv6