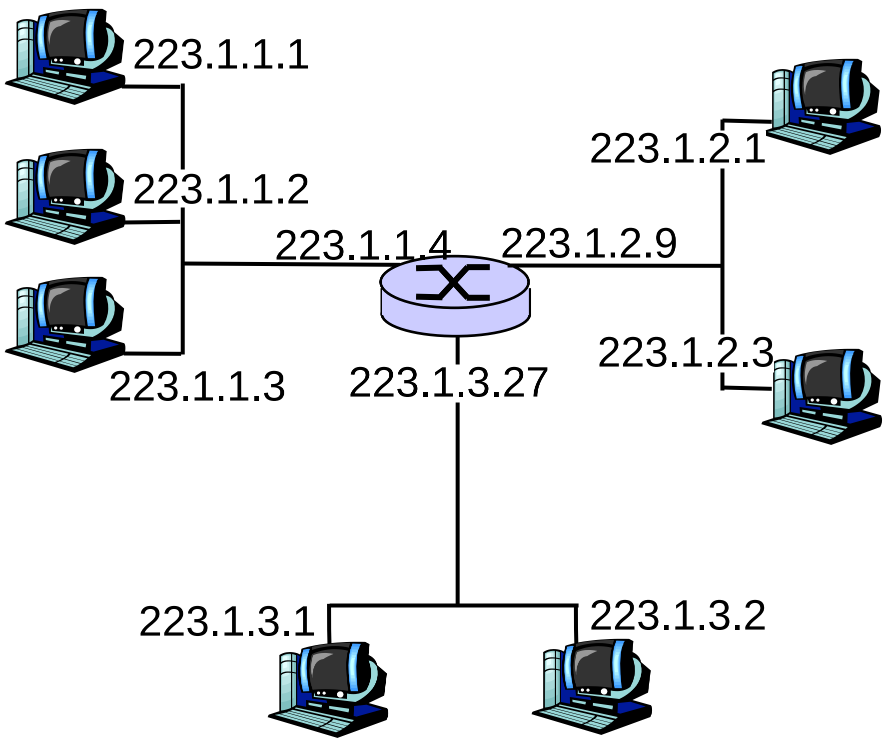
IP addressing

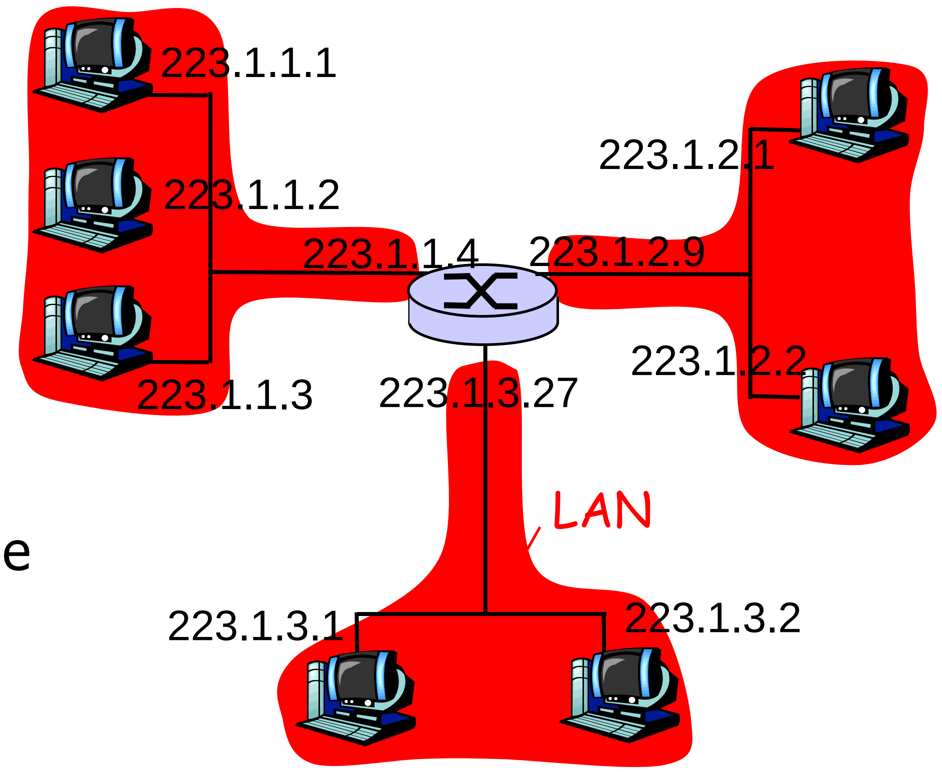
- IP address: 32-bit identifier for host, router *interface*
- *Interface:* Connection between host, router and physical link
  - routers typically have multiple interfaces
  - host may have multiple interfaces
  - IP addresses associated with interface, not host, router



$$223.1.1.1 = \underbrace{11011111}_{223}\ \underbrace{00000001}_{1}\ \underbrace{00000001}_{1}\ \underbrace{00000001}_{1}$$

IP addressing (2)

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

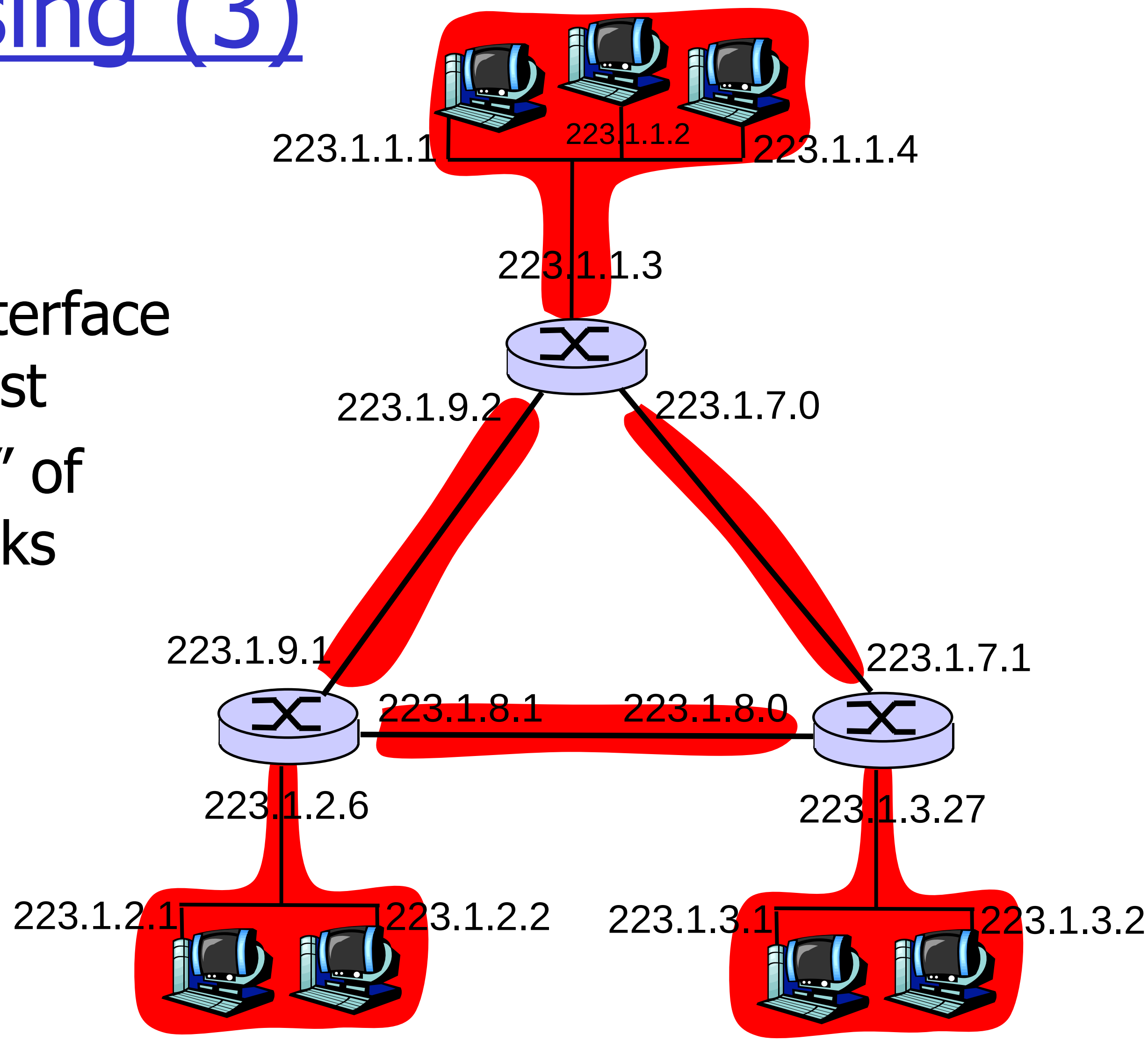


Network consisting of 3 IP networks (for IP addresses starting with 223, first 24 bits are network address)

IP addressing (3)

How to find the networks?

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



Interconnected system consisting of six networks

IP networks: Subnets

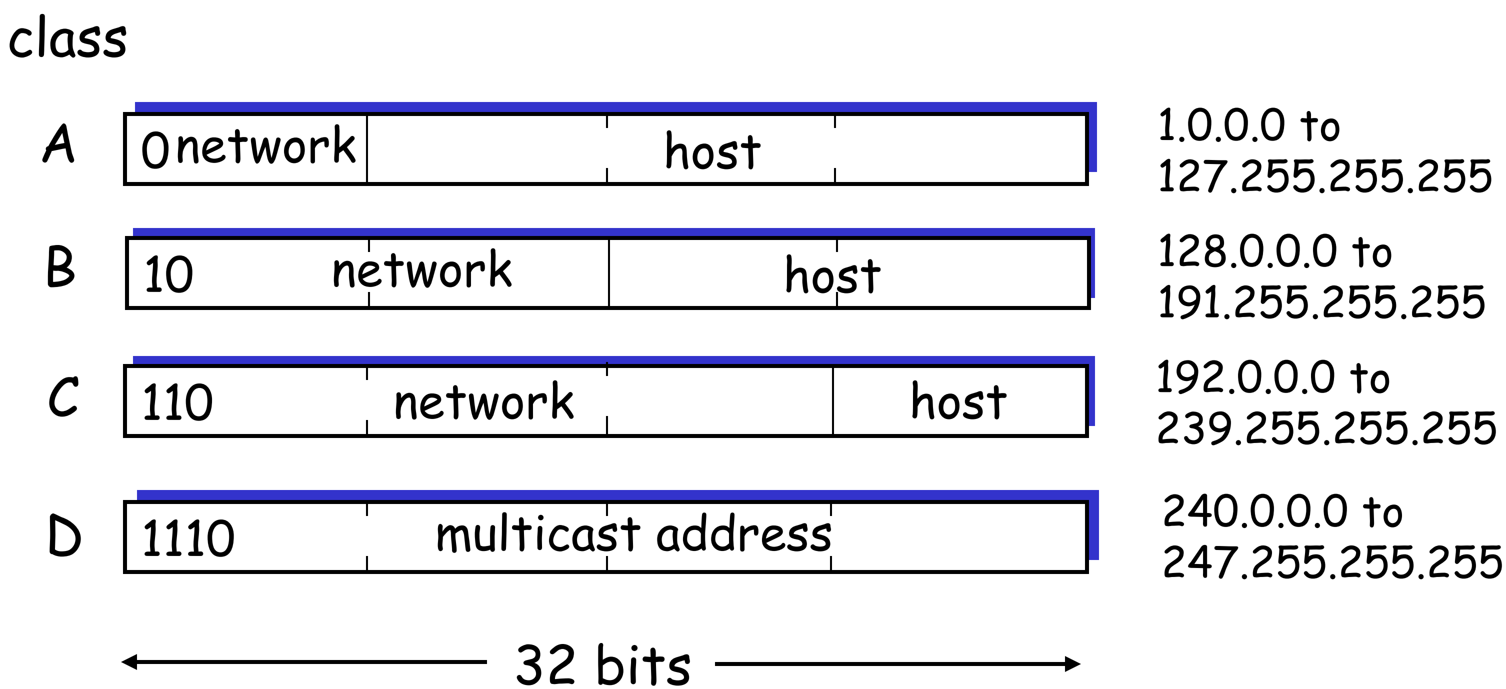
- Sub divide address space
  - network part
  - host address
- Address format: a.b.c.d/x, where x is # bits in subnet portion of address

subnet part | host part

11001000 00010111 00010000 00000000

200.23.16.0/24

Fixed subnetting (classful)



Address management

- Problem: We are running out of networks
- Solution (a):
  Subnetting: E.g., Class B Host field (16 bits) is subdivided into <subnet;host> fields
- Solution (b):
  CIDR (Classless Inter Domain Routing)

CIDR

CIDR: Classless InterDomain Routing

- Motivation
  - Class A is too large, Class C is too small
  - Everyone had a Class B address!!!

- Solution:
  - Sites are given contiguous blocks of class-C addresses (256 addresses each) and a mask or parts of former class A/B networks.

CIDR (2.)

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

IP addresses: How to get one?

Q: How does *host* get IP address?

- Hard-coded by system admin in a file
  - Wintel: Control Panel → Network → Configuration → TCP/IP → Properties
  - UNIX: /etc/rc.config
- DHCP: Dynamic Host Configuration Protocol: dynamically get address from as server
  - "Plug-and-play"
- IP / Subnets allocated by provider (RIPE/ARIN/…)

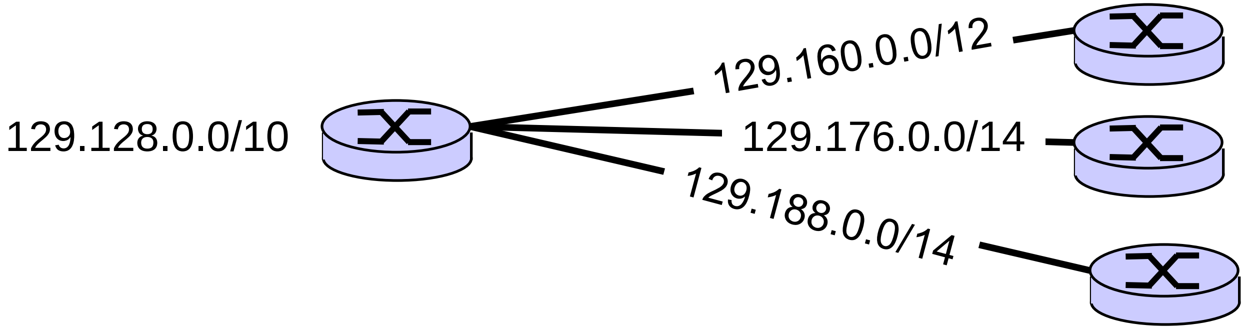
Hierarchical address structure

- 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

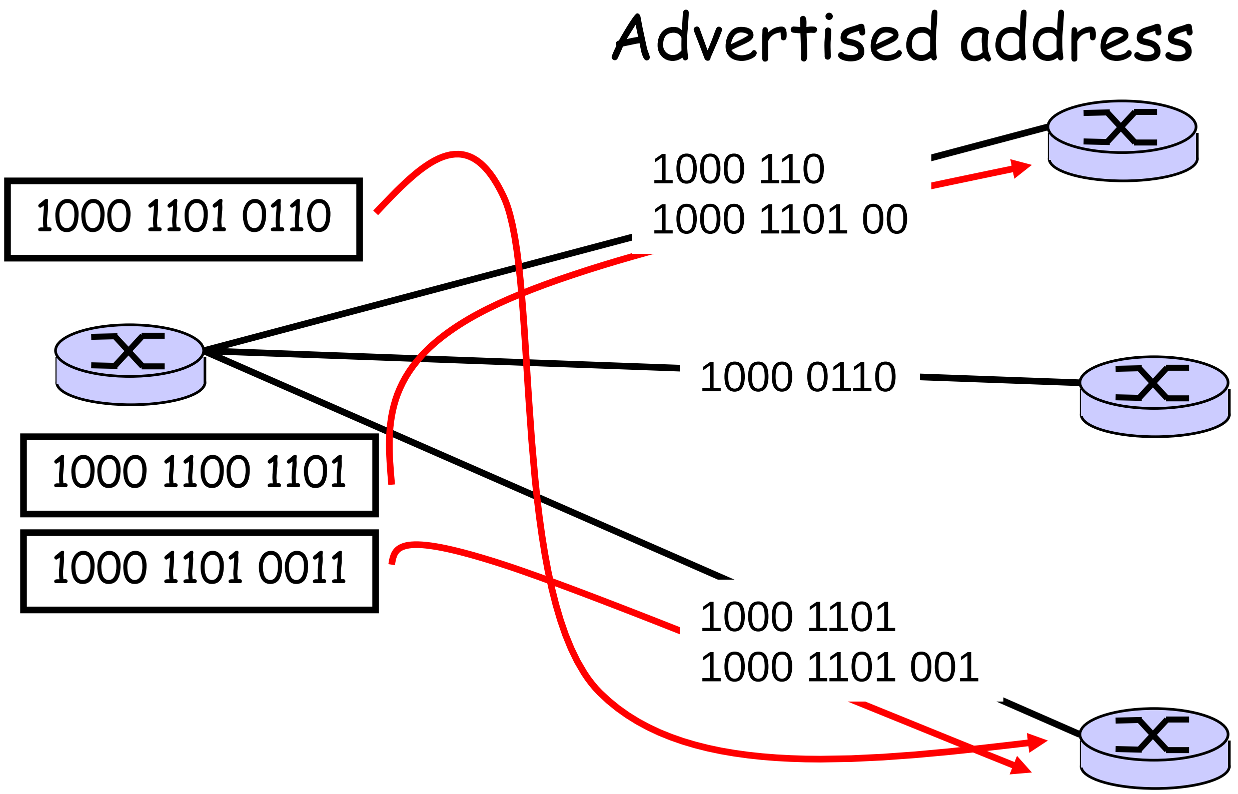
- Forwarding: the process of moving packets from input to output
  - The forwarding table
  - Information in the packet

- 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:

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

IP addressing: The last word ...

Q: How does an ISP get block of addresses?

A: ICANN: Internet Corporation for Assigned Names and Numbers

- allocates addresses
- manages DNS
- assigns domain names, resolves disputes

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

A: Private IP addresses (RFC 1918)

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

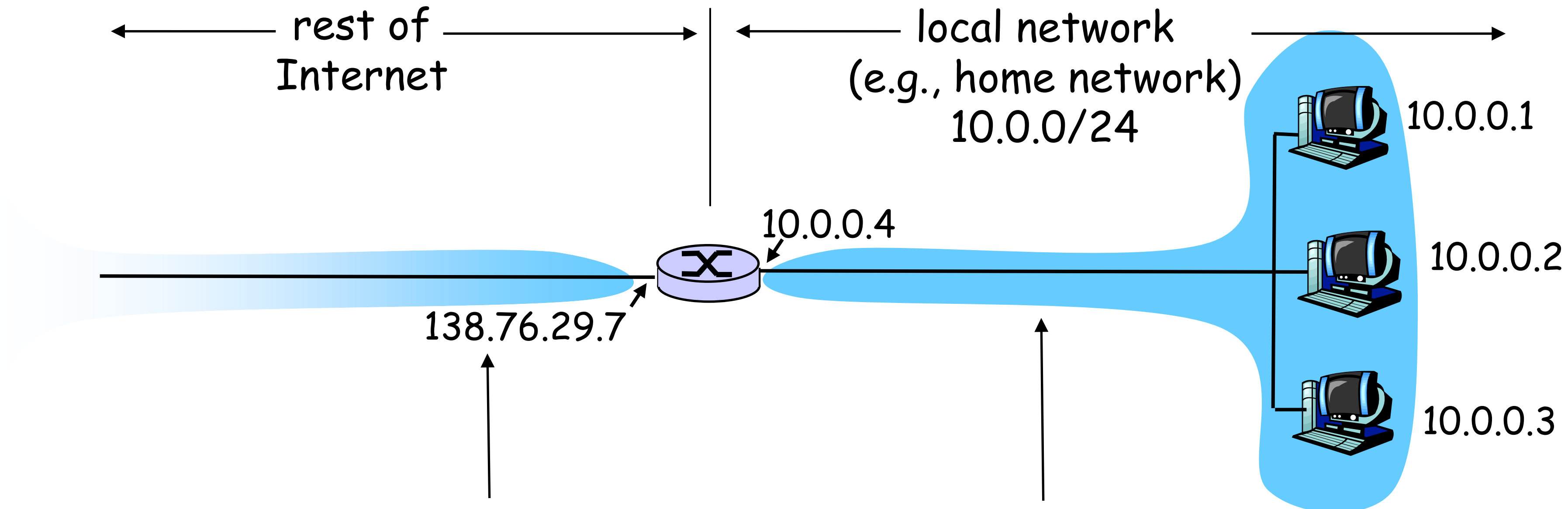
- Private use only – not routable in the Internet

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

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 (a security plus).

NAT: Network address translation (4.)

Implementation: NAT router must:

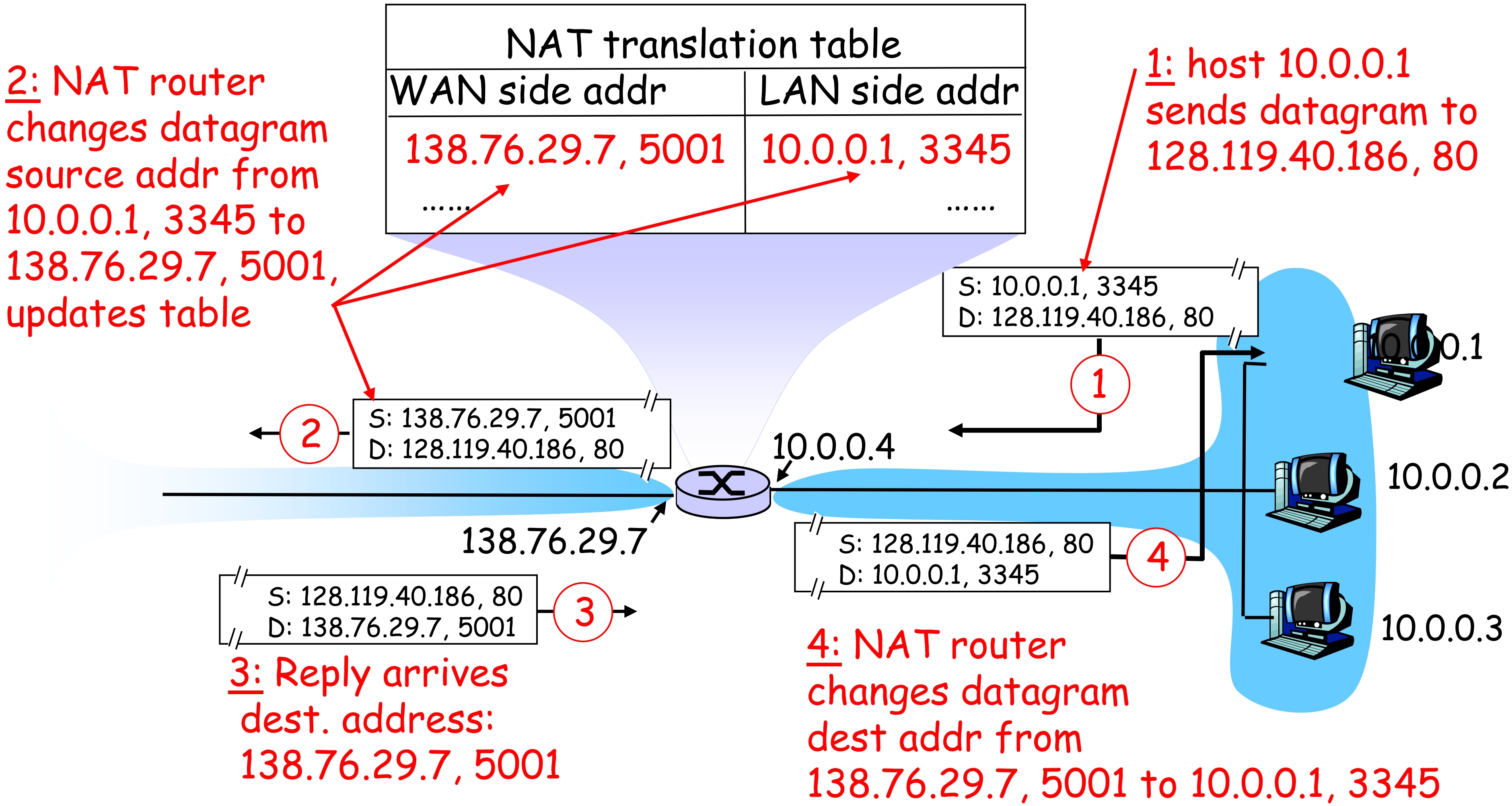
- *Outgoing datagrams: Replace* (source IP address, port #) of every outgoing datagram to (NAT IP address, new port #)

  . . . 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