

DATA COMMUNICATION NETWORKING

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Course Book & Slides:

Computer Networking, A Top-Down Approach
By: Kurose, Ross

Course Overview

- **Basics of Computer Networks**
 - Internet & Protocol Stack
 - Application Layer
 - Transport Layer
 - **Network Layer**
 - Data Link Layer
- **Advanced Topics**
 - Case Studies of Computer Networks
 - Internet Applications
 - Network Management
 - Network Security

IP Addressing

- **IP address**

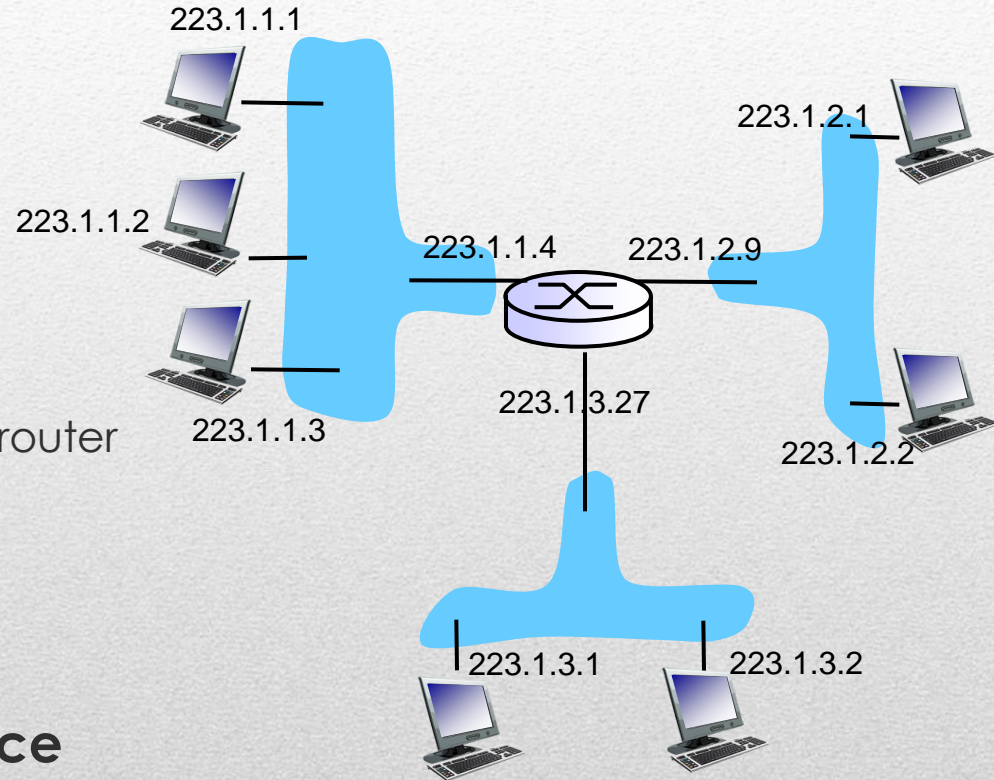
- 32 bit identifier
 - Host
 - Router

- **Interface**

- Connection between host or router and physical link
 - Routers: multiple interfaces
 - Hosts: 1-2 interfaces

- **IP address for each interface**

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



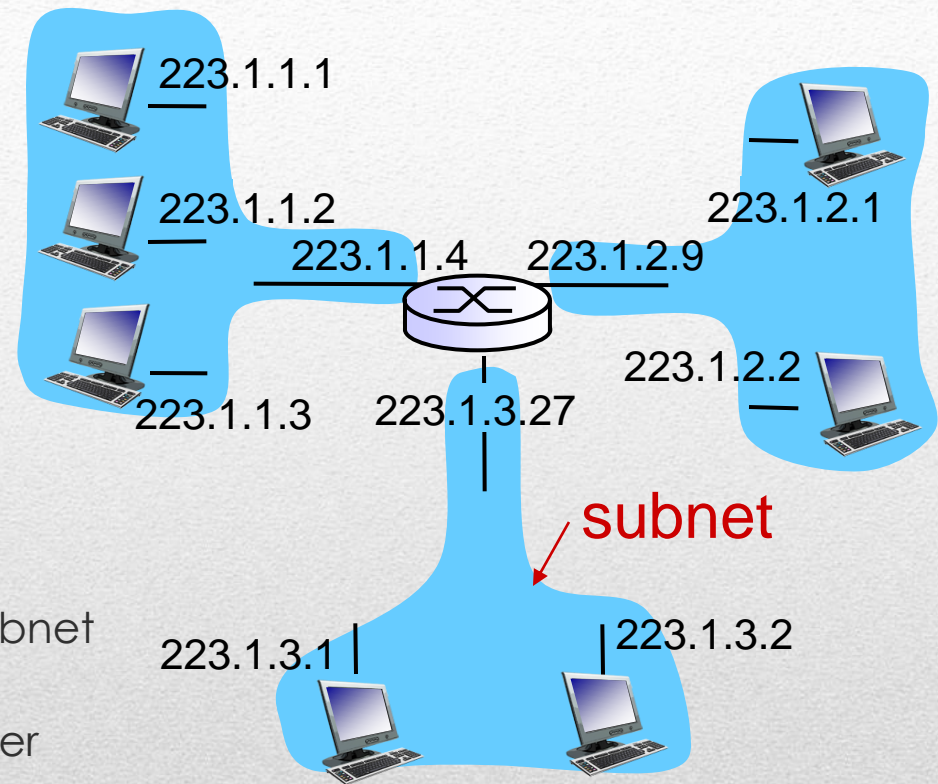
Subnets

- **IP address**

- High order bits: Subnet
- Low order bits: Host

- **Subnet**

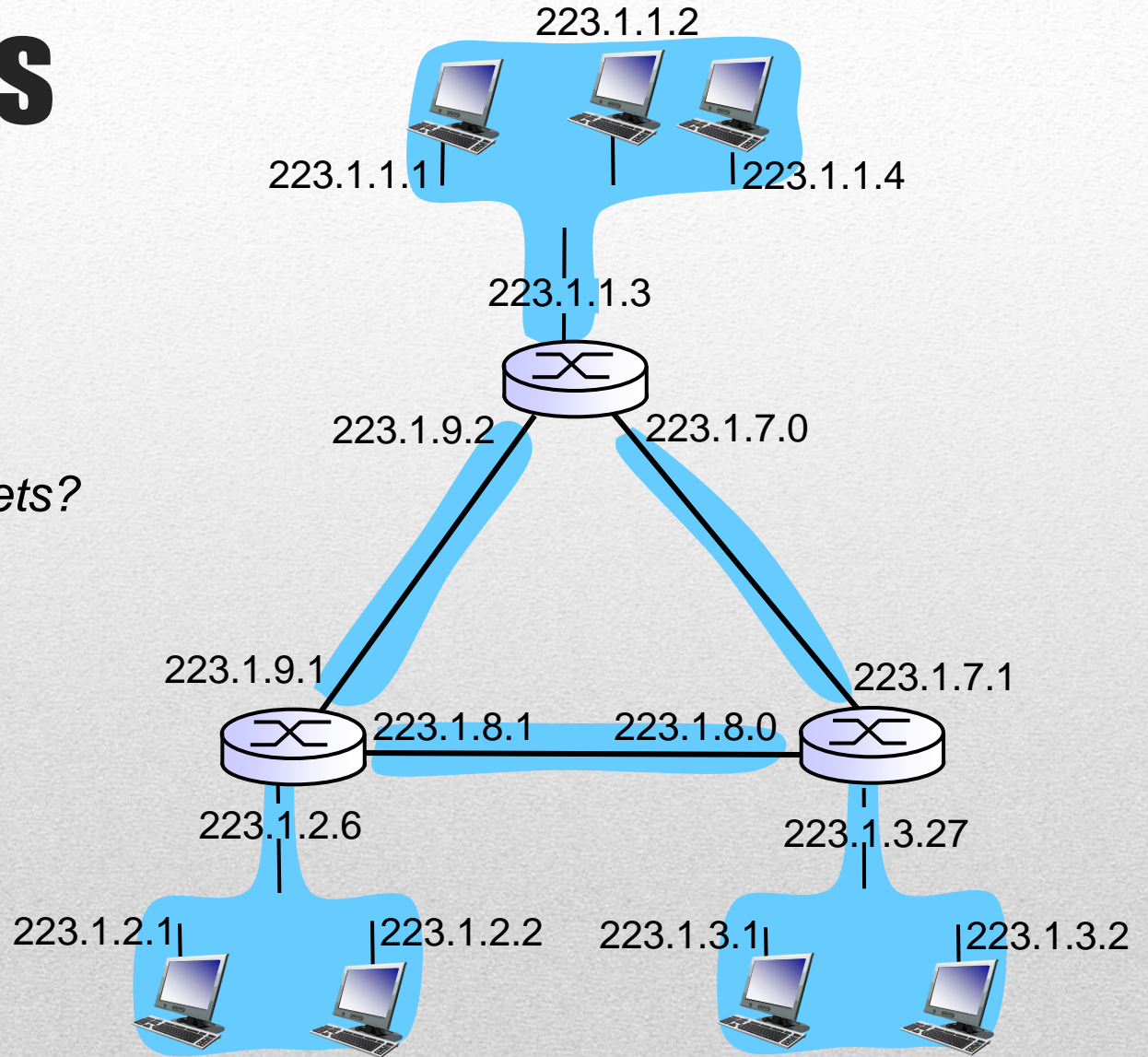
- Device interfaces with same subnet part of the IP address
- Can physically reach each other without intervening router



network consisting of 3 subnets

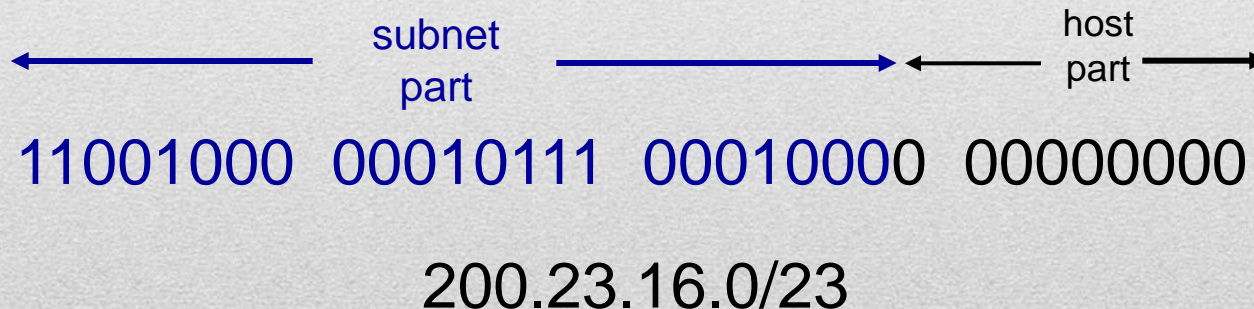
Subnets

How many subnets?



IP Addressing CIDR

- **Classless Inter Domain Routing**
 - Subnet portion of arbitrary length
 - a.b.c.d/x
 - X subnet portion of the address



Getting an IP Address

- **Hard-coded**

- **Windows:** control-panel → network → configuration → tcp/ip → properties
- **UNIX:** /etc/rc.config

- **DHCP: Dynamic Host Configuration Protocol**

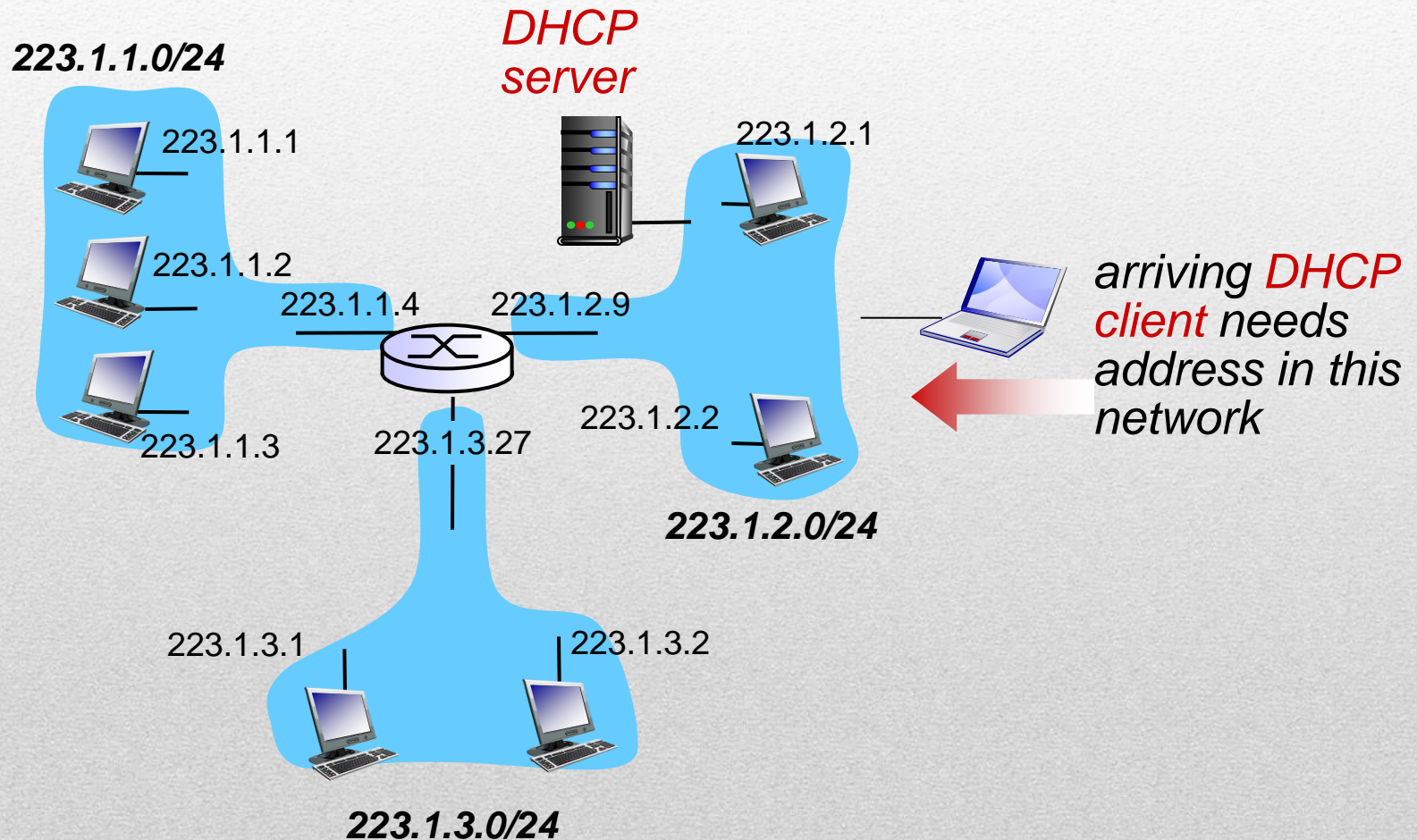
- Dynamically get address from the server
- Plug and play

DHCP

Goal: Allow host to dynamically obtain its IP address from network server when it joins network

- Can renew its lease on address in use
- Allows reuse of addresses (only hold address while connected/“on”)
- Support for mobile users who want to join network (more shortly)
- **DHCP overview**
 - Host broadcasts “DHCP discover” message [optional]
 - DHCP server responds with “DHCP offer” message [optional]
 - Host requests IP address: “DHCP request” message
 - DHCP server sends address: “DHCP ACK” message

DHCP



DHCP

Client-Server Communication

DHCP server: 223.1.2.5



DHCP discover

```
src : 0.0.0.0, 68
dest.: 255.255.255.255,67
yiaddr: 0.0.0.0
transaction ID: 654
```

arriving
client



DHCP offer

```
src: 223.1.2.5, 67
dest: 255.255.255.255, 68
yiaddr: 223.1.2.4
transaction ID: 654
lifetime: 3600 secs
```

DHCP request

```
src: 0.0.0.0, 68
dest.: 255.255.255.255, 67
yiaddr: 223.1.2.4
transaction ID: 655
lifetime: 3600 secs
```

DHCP ACK

```
src: 223.1.2.5, 67
dest: 255.255.255.255, 68
yiaddr: 223.1.2.4
transaction ID: 655
lifetime: 3600 secs
```

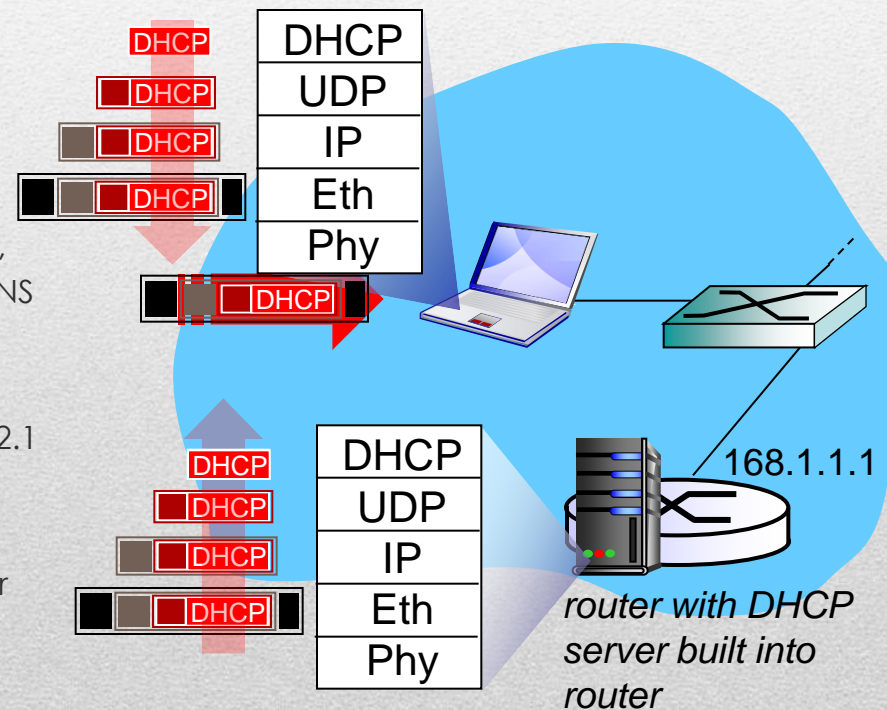
DHCP

More than IP addresses

- Address of first-hop router for client
- Name and IP address of DNS server
- Network mask
 - Indicating network vs. host portion of address

Example

- Connecting laptop needs its IP address, address of first-hop router, address of DNS server: use DHCP
- DHCP request encapsulated in UDP, encapsulated in IP, encapsulated in 802.1 Ethernet
- Ethernet frame broadcast (dest: FFFFFFFFFF) on LAN, received at router running DHCP server
- Ethernet demuxed to IP demuxed, UDP demuxed to DHCP



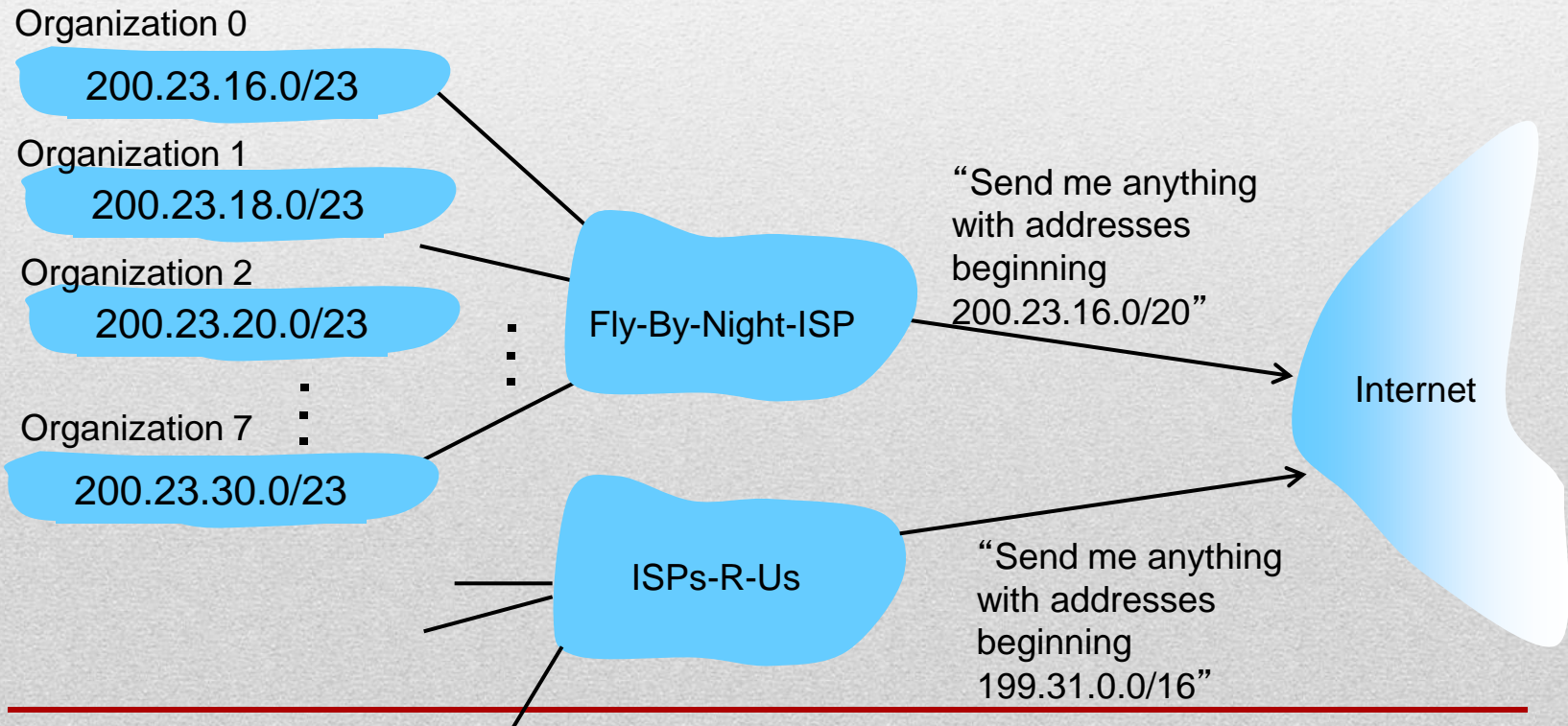
IP Addresses

- How does network get subnet part of the IP address?
 - Gets allocated portion of its provider ISP's address
 - Network Security

ISP's block	<u>11001000</u>	<u>00010111</u>	<u>00010000</u>	00000000	200.23.16.0/20
Organization 0	<u>11001000</u>	<u>00010111</u>	<u>00010000</u>	00000000	200.23.16.0/23
Organization 1	<u>11001000</u>	<u>00010111</u>	<u>00010010</u>	00000000	200.23.18.0/23
Organization 2	<u>11001000</u>	<u>00010111</u>	<u>00010100</u>	00000000	200.23.20.0/23
...	
Organization 7	<u>11001000</u>	<u>00010111</u>	<u>00011110</u>	00000000	200.23.30.0/23

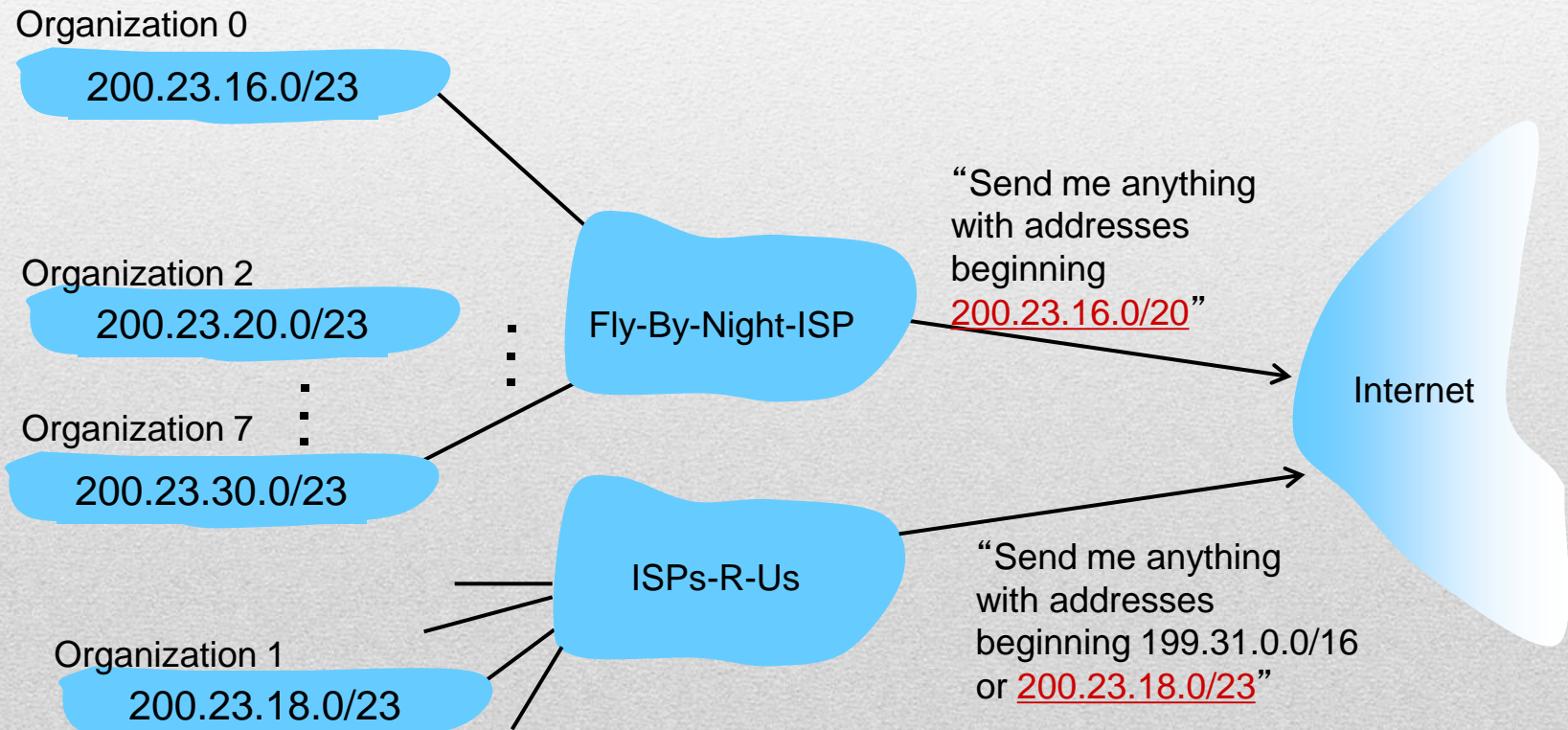
Hierarchical Addressing: Route Aggregation

Hierarchical addressing allows efficient advertisement of routing information



Hierarchical Addressing

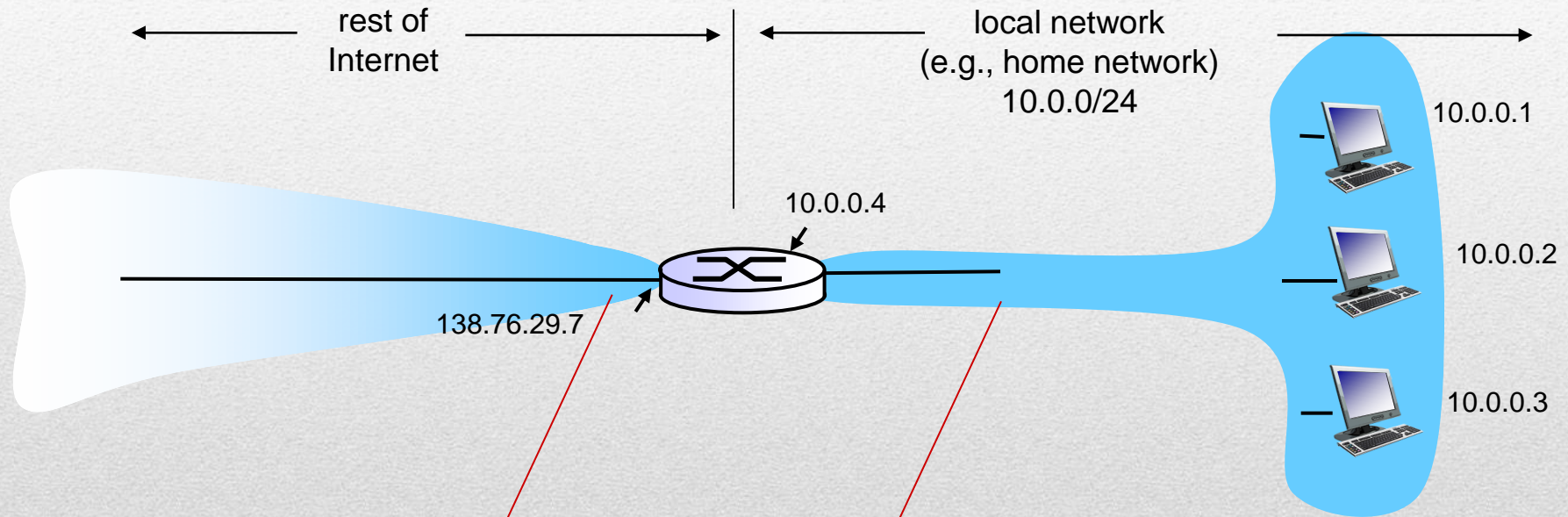
ISPs-R-U's has a more specific route to Organization 1



IP Addressing

- **How does an ISP get block of addresses?**
 - ICANN: Internet Corporation for Assigned Names and Numbers
 - <http://www.icann.org>
 - Allocates addresses
 - Manages DNS
 - Assigns domain names, resolves disputes

Network Address Translation



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)

Network Address Translation

- **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

Network Address Translation

- **NAT Router Implementation**

- 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 address

- NAT Table

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

- Incoming Datagrams

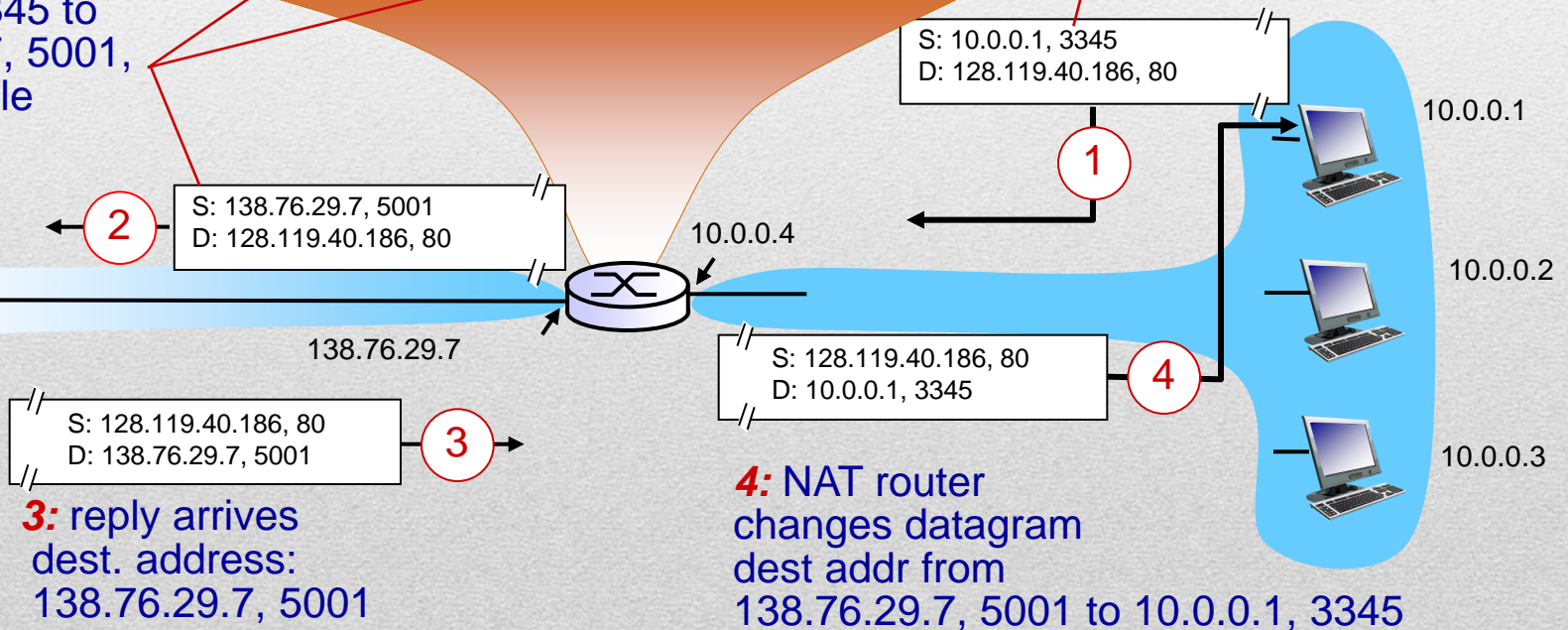
- Replace (NAT IP address, new port #) in destination fields of every incoming datagram with corresponding (source IP address, port #) stored in NAT table

Network Address Translation

NAT translation table	
WAN side addr	LAN side addr
138.76.29.7, 5001	10.0.0.1, 3345
.....

2: NAT router changes datagram source addr from 10.0.0.1, 3345 to 138.76.29.7, 5001, updates table

1: host 10.0.0.1 sends datagram to 128.119.40.186, 80



Network Address Translation

- **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

Network Address Translation

Client wants to connect to server with address 10.0.0.1

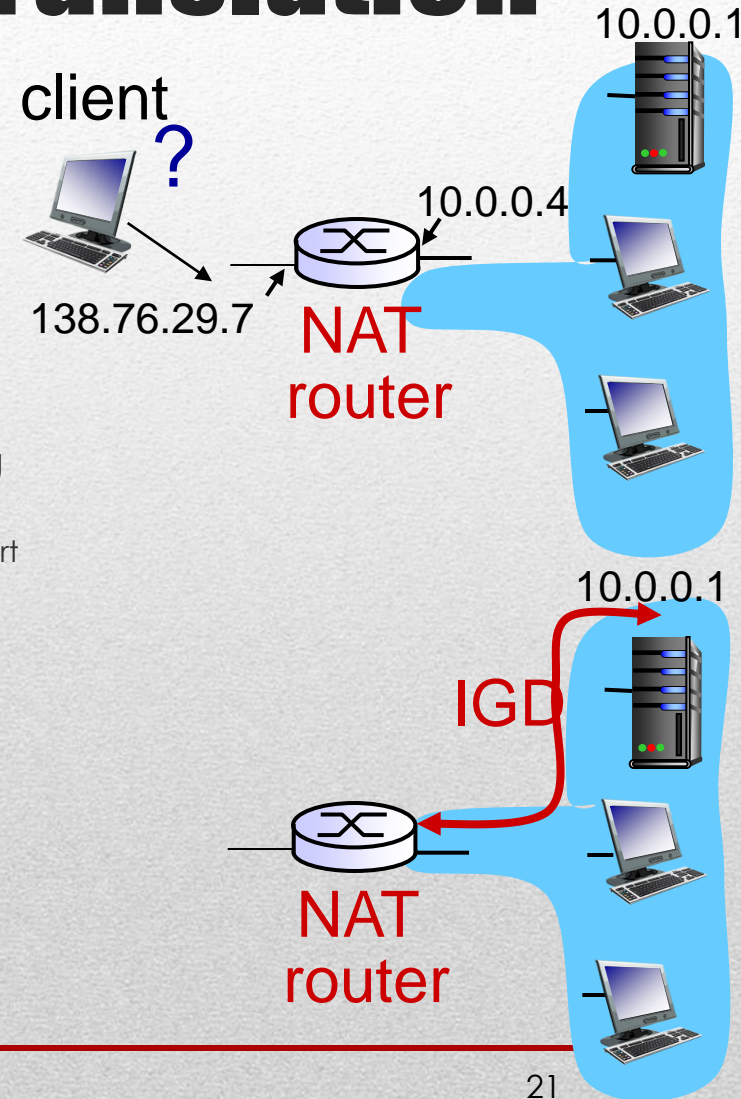
- Server address 10.0.0.1 local to LAN
- Only one externally visible NATed address: 138.76.29.7

Solution 1: statically configure NAT to forward incoming connection requests at given port to server

- e.g., (138.76.29.7, port 2500) always forwarded to 10.0.0.1 port 25000

Solution 2: Universal Plug and Play (UPnP) Internet Gateway Device (IGD) Protocol. Allows NATed host

- Learn public IP address (138.76.29.7)
- Add/remove port mappings (with lease times)
- i.e., automate static NAT port map configuration



Network Address Translation

Solution 3: relaying (used in Skype)

- NATed client establishes connection to relay
- external client connects to relay
- relay bridges packets between to connections

