CS 3251- Computer Networks I: Transport Layer

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Lecture 07
9/10/13

Announcements

- Project 1 - Due Thursday at 5pm.
    - Please submit your tarball to T-Square.
    - Remember to include the results requested on the website.
- Homework 2 will be posted within 24 hours.
- Project 2 will be posted soon.
    - Due 10/8/13
    - Please check the website.
    - This one is going to take some time...

Last Time...

- Sockets programming API
  - Calls return -1 in error.
  - TCP and UDP look different.
    - Remember, there is no *connect()* in UDP - just start sending (and hope that it gets there).
  - Much of this code is reusable!
  - Take a look at the details of *pthread_create()* - you will need this going forward.

Chapter 3: Transport Layer

Our goals:

- understand principles behind transport layer services:
  - multiplexing/ demultiplexing
  - reliable data transfer
  - flow control
  - congestion control

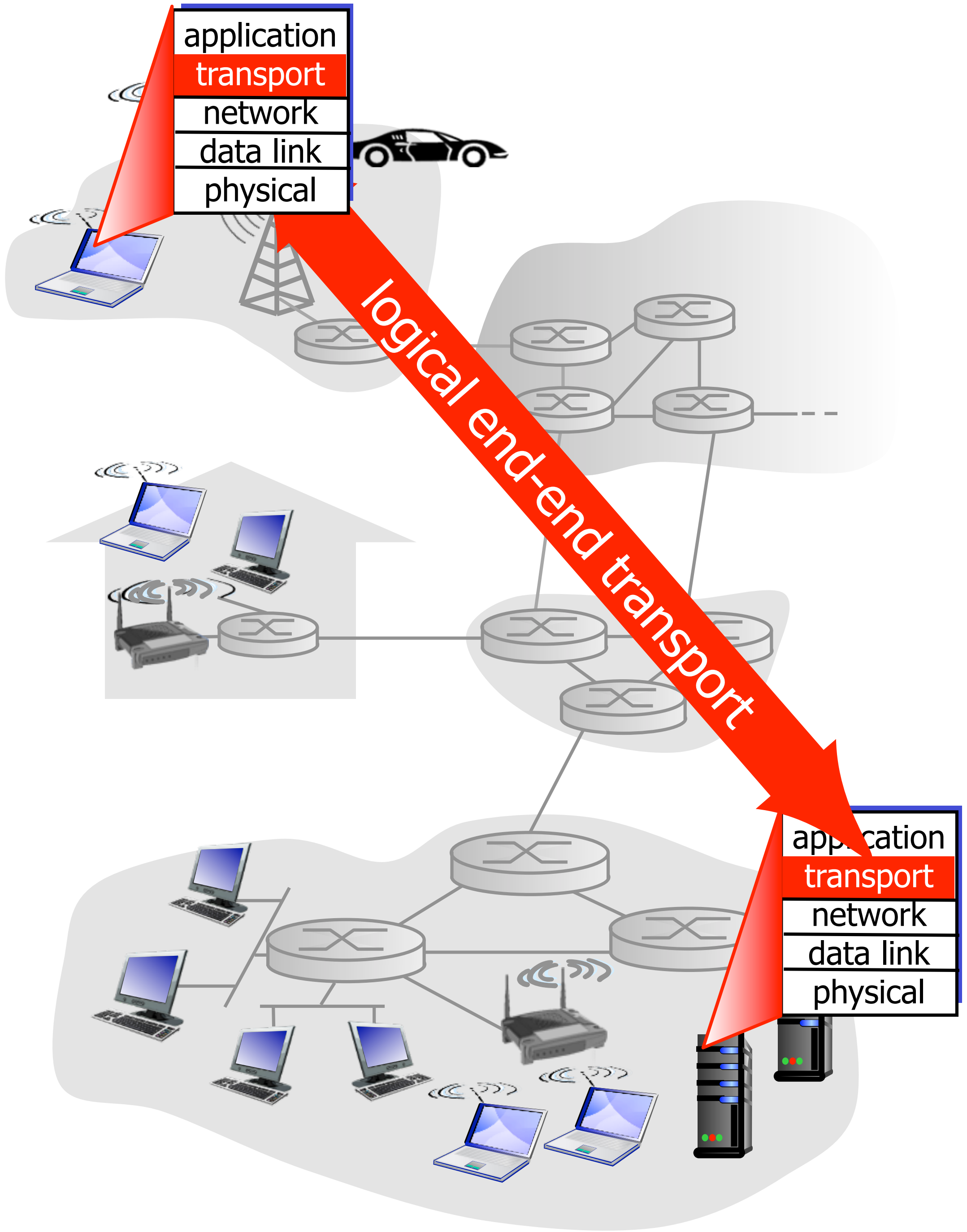
- learn about transport layer protocols in the Internet:
  - UDP: connectionless transport
  - TCP: connection-oriented transport
  - TCP congestion control

Chapter 3 Outline

- 3.1 Transport-layer services
- 3.2 Multiplexing and demultiplexing
- 3.3 Connectionless transport: UDP
- 3.4 Principles of reliable data transfer
- 3.5 Connection-oriented transport: TCP
  - segment structure
  - reliable data transfer
  - flow control
  - connection management
- 3.6 Principles of congestion control
- 3.7 TCP congestion control

Transport services and protocols

- provide *logical communication* between app processes running on different hosts
- transport protocols run in end systems
  - send side: breaks app messages into *segments*, passes to network layer
  - rcv side: reassembles segments into messages, passes to app layer
- more than one transport protocol available to apps
  - Internet: TCP and UDP



Transport vs. Network layer

- network layer: logical communication between hosts
- transport layer: logical communication between processes
  - relies on, enhances, network layer services

Household analogy:

12 kids in Ann's house sending letters to 12 kids in Bill's house:

hosts = houses

processes = kids

app messages = letters in envelopes

transport protocol = Ann and Bill who demux to in-house siblings

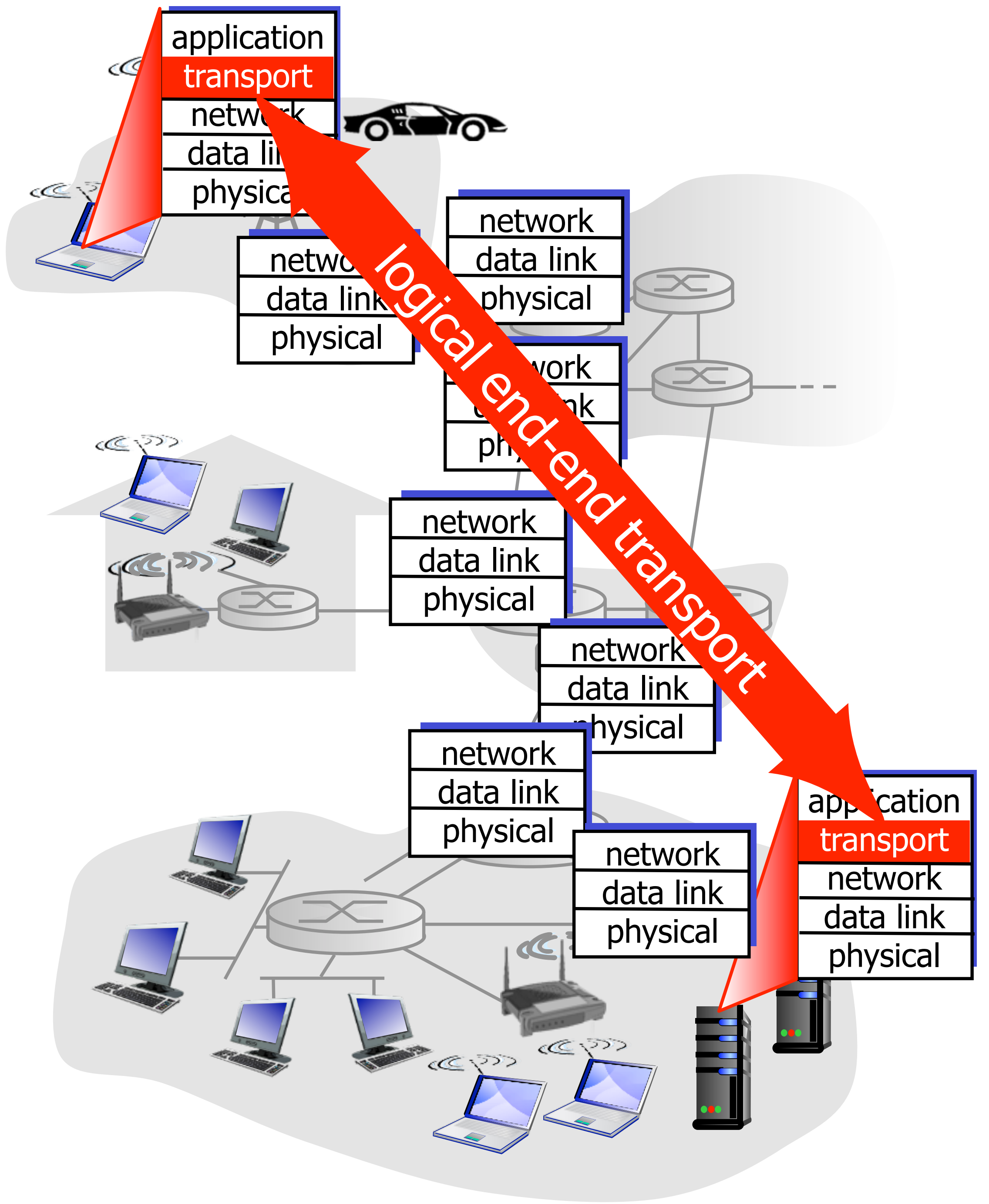
network-layer protocol = postal service

Layers of Networks?

- You can view each layer that we have discussed thus far as an abstract network:
    - Application Layer Networks: P2P, Social Networks, etc
    - Transport Layer Networks: Communicating processes
    - Network Layer Networks: Networks of Hosts
    - Link Layer Networks: One-Hop Networks
    - Physical Layer Networks: Wires

Internet transport-layer protocols

- reliable, in-order delivery (TCP)
  - congestion control
  - flow control
  - connection setup
- unreliable, unordered delivery: UDP
  - no-frills extension of “best-effort” IP
- services not available:
  - delay guarantees
  - bandwidth guarantees



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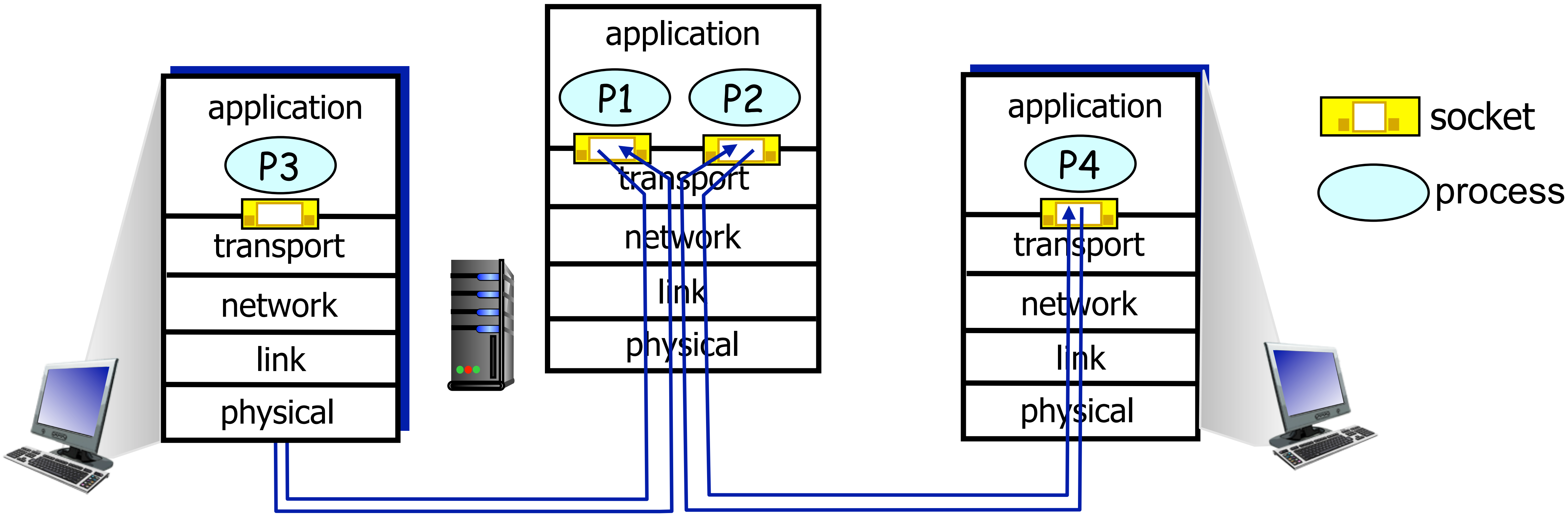
Multiplexing/demultiplexing

Multiplexing at send host:

handle data from multiple sockets, add transport header (later used for demultiplexing)

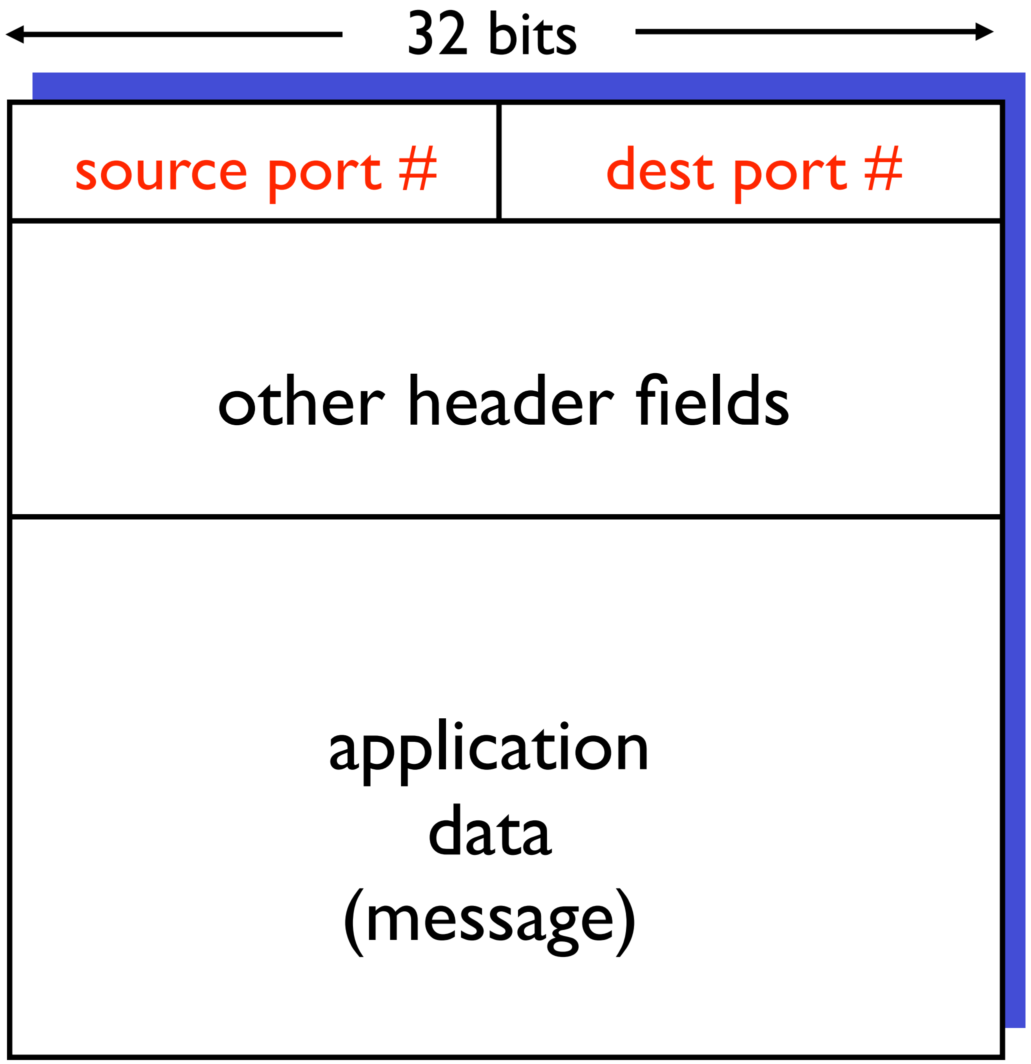
Demultiplexing at rcv host:

delivering received segments to correct socket



How demultiplexing works

- host receives IP datagrams
    - each datagram has source IP address, destination IP address
    - each datagram carries one transport-layer segment
    - each segment has source, destination port number
- host uses *IP addresses* & *port numbers* to direct segment to appropriate socket



TCP/UDP segment format

Connectionless demultiplexing

- Create sockets with port numbers:

```
addr1.sin_port = htons(12534);

addr2.sin_port = htons(12535);
```

- UDP socket identified by two-tuple:

(dest IP address, dest port number)

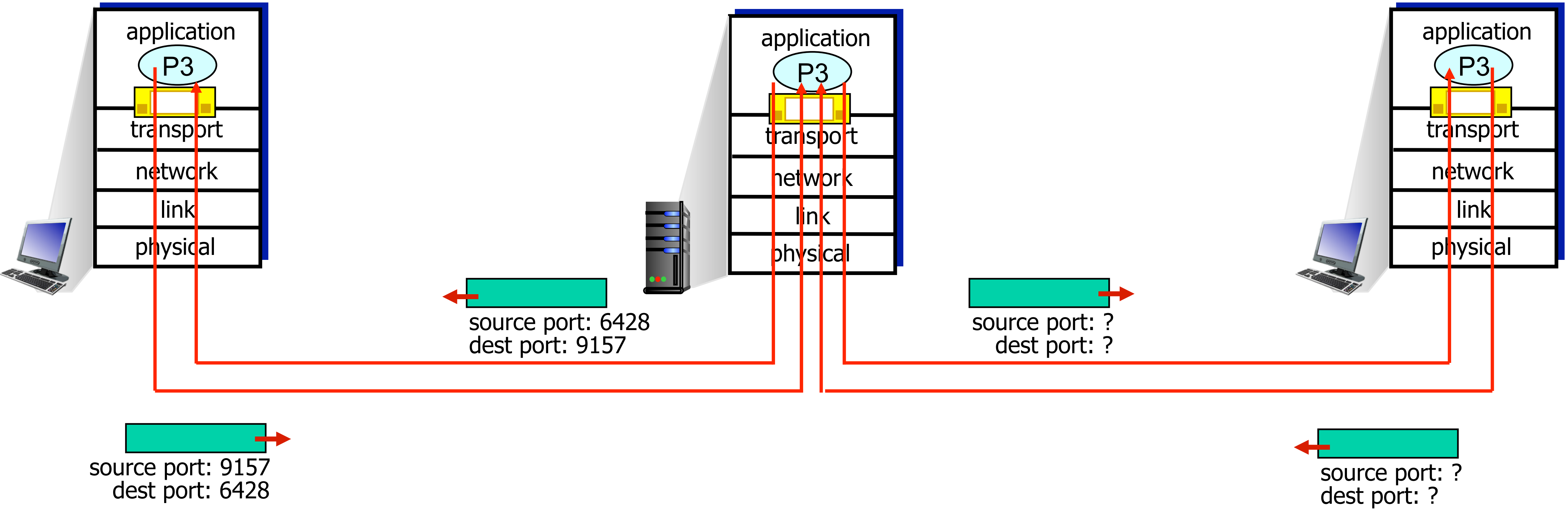
- When host receives UDP segment:
  - checks destination port number in segment
  - directs UDP segment to socket with that port number
- IP datagrams with different source IP addresses and/or source port numbers directed to same socket

Connectionless demux (cont)

```
DatagramSocket
 mySocket2 = new
 DatagramSocket
 (9157);
```

```
DatagramSocket
 serverSocket = new
 DatagramSocket
 (6428);
```

```
DatagramSocket
 mySocket1 = new
 DatagramSocket
 (5775);
```



source port: 6428
dest port: 9157

source port: ?
dest port: ?

source port: 9157
dest port: 6428

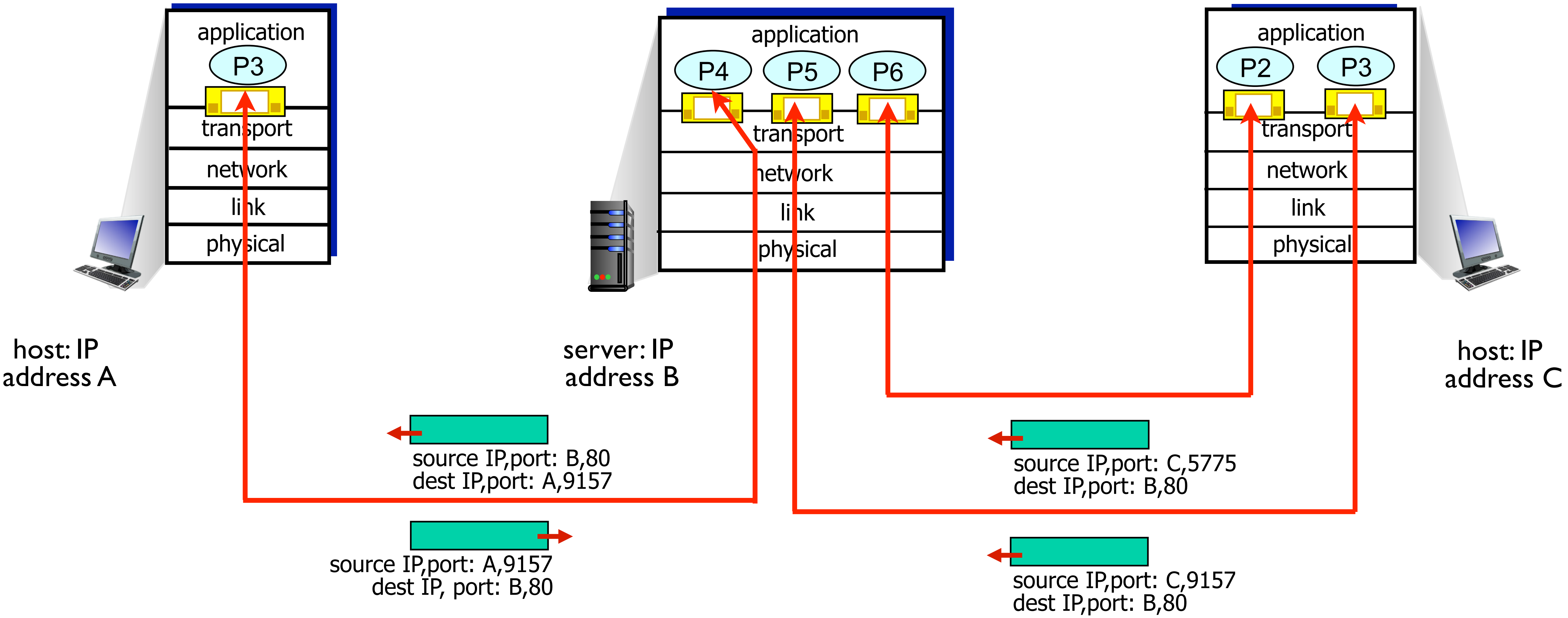
source port: ?
dest port: ?

Connection-oriented demux

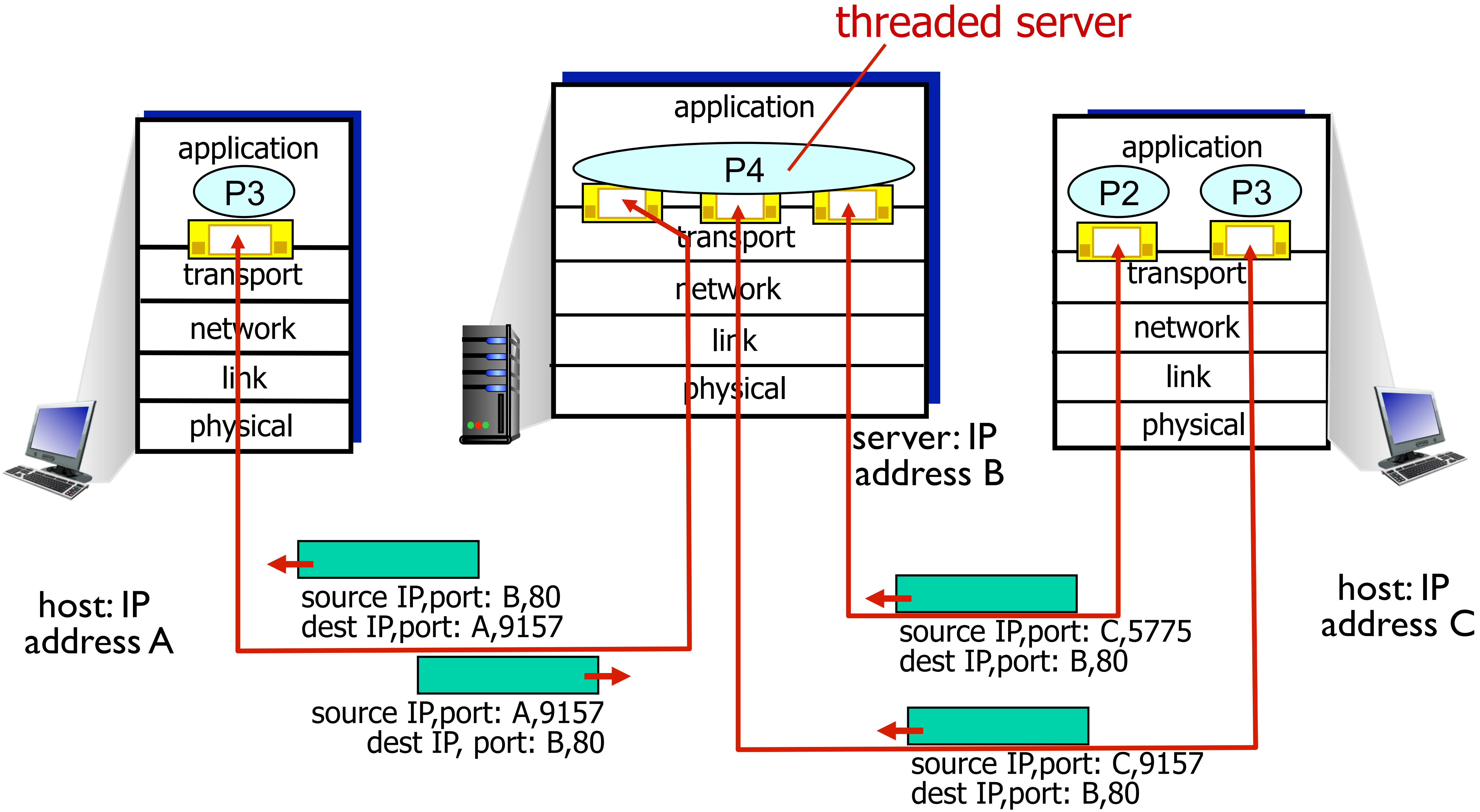
- TCP socket identified by 4-tuple:
  - source IP address
  - source port number
  - dest IP address
  - dest port number
- recv host uses all four values to direct segment to appropriate socket

- Server host may support many simultaneous TCP sockets:
  - each socket identified by its own 4-tuple
- Web servers have different sockets for each connecting client
  - non-persistent HTTP will have different socket for each request

Connection-oriented demux (cont)



Connection-oriented demux: Threaded Web Server



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UDP: User Datagram Protocol [RFC 768]

- "no frills," "bare bones" Internet transport protocol
- "best effort" service, UDP segments may be:
  - lost
  - delivered out of order to app
- connectionless:
  - no handshaking between UDP sender, receiver
  - each UDP segment handled independently of others

Why is there a UDP?

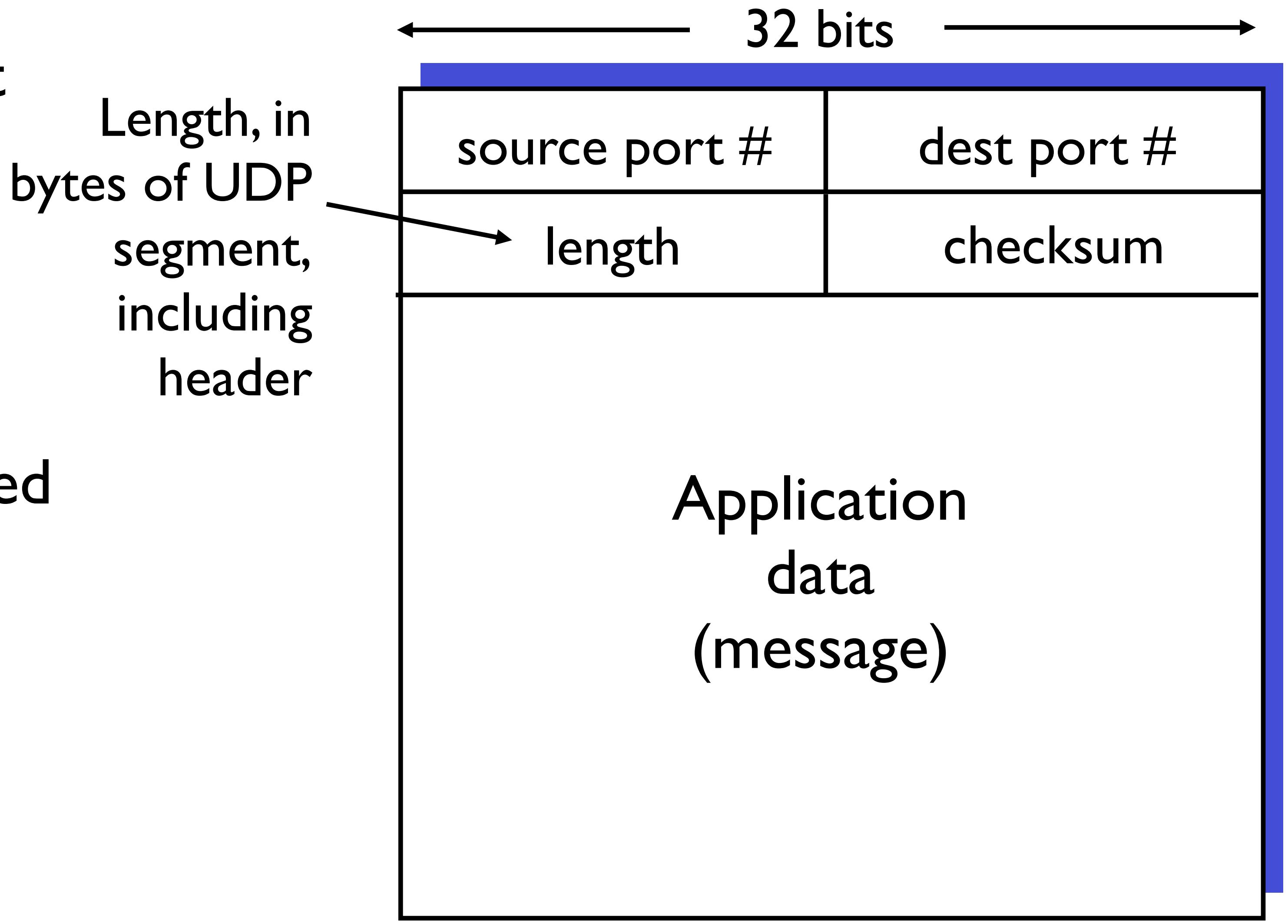
- no connection establishment (which can add delay)
- simple: no connection state at sender, receiver
- small segment header
- no congestion control: UDP can blast away as fast as desired

UDP Applications:

- streaming multimedia apps (loss tolerant, rate sensitive)
- DNS
- SNMP

UDP: more

- no connection establishment (which can add delay)
- simple: no connection state at sender, receiver
- small header size
- no congestion control: UDP can blast away as fast as desired


32 bits
Length, in bytes of UDP segment, including header
source port #
dest port #
length
checksum
Application data (message)

UDP segment format

UDP checksum

Goal: detect "errors" (e.g., flipped bits) in transmitted segment

Sender:

- treat segment contents as sequence of 16-bit integers
- checksum: addition (1's complement sum) of segment contents
  - How is this different than 2's complement?
- sender puts checksum value into UDP checksum field

Receiver:

- compute checksum of received segment
- check if computed checksum equals checksum field value:
  - NO - error detected
  - YES - no error detected. But maybe errors nonetheless? More later ....

Internet Checksum Example

- Note
    - When adding numbers, a carryout from the most significant bit needs to be added to the result
- Example: add two 16-bit integers

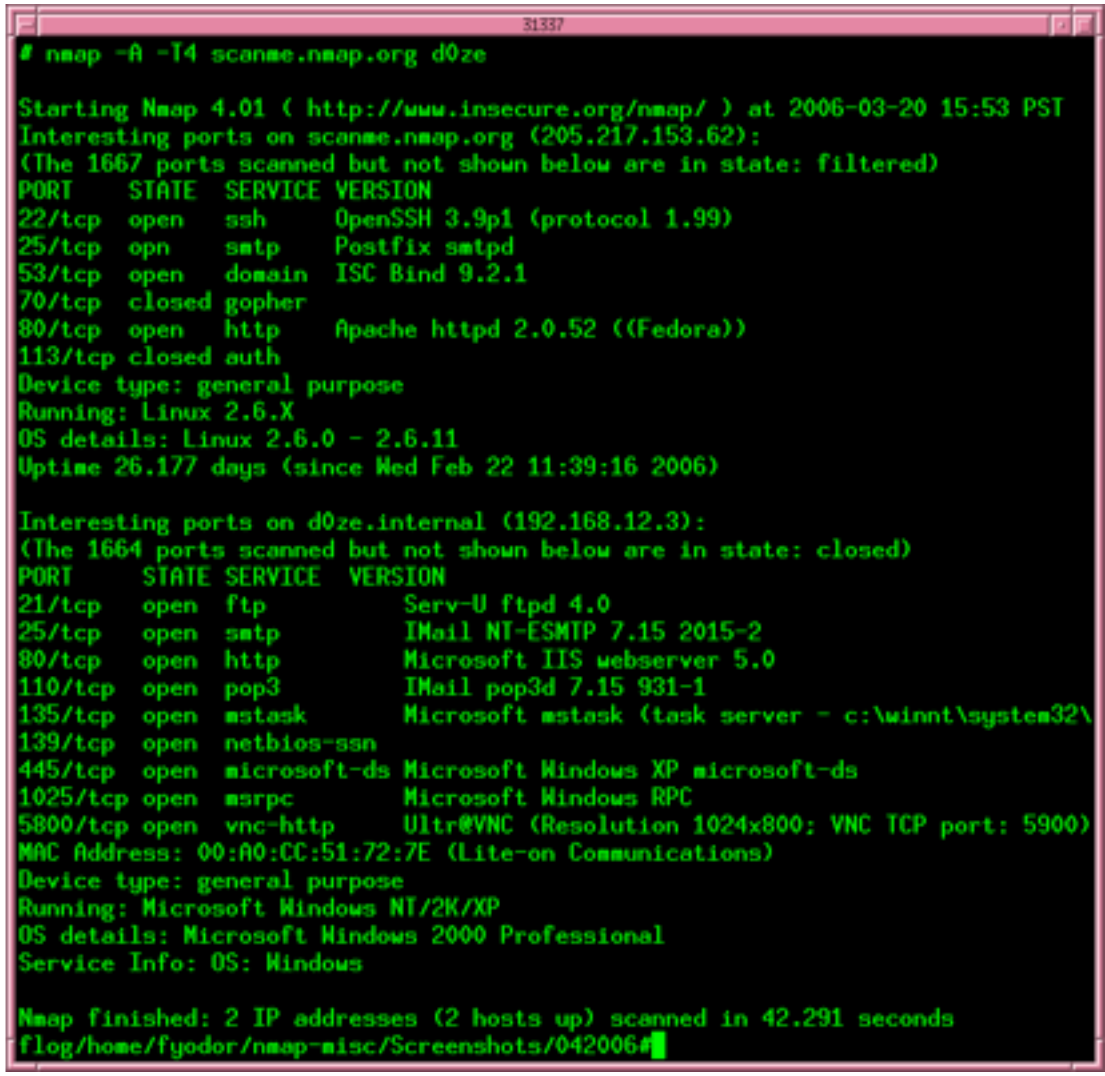
		1	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0
		1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
wraparound	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1
sum		1	0	1	1	1	0	1	1	1	0	1	1	1	1	0	0
checksum		0	1	0	0	0	1	0	0	0	1	0	0	0	0	1	1

Port Scanning

- Technique used by black- and white-hat communities alike.
- Attempts to connect to a large number (usually all) of ports on a machine.
    - Successful responses mean that a process is running.
    - If you know what processes are running, you will be able to select the right exploit to launch.
    - Most firewalls offer some protection against this.
- This is happening *all the time* on the Internet.
    - The bad guys are constantly looking for a way in...

Port Scanning Tools

- *nmap* is the most popular tool for port scanning.
  - ...and it is free...
- By seeing which ports are active, nmap can tell a lot about your machine.
  - For instance, what OS you are running...
- Do not run this on the GaTech network.
  - Most admins will automatically shut you down if you do...



```
# nmap -A -T4 scanme.nmap.org d0ze

Starting Nmap 4.01 ( http://www.insecure.org/nmap/ ) at 2006-03-20 15:53 PST
Interesting ports on scanme.nmap.org (205.217.153.62):
(The 1667 ports scanned but not shown below are in state: filtered)
PORT     STATE  SERVICE VERSION
22/tcp   open   ssh     OpenSSH 3.9p1 (protocol 1.99)
25/tcp   opn    smtp    Postfix smtpd
53/tcp   open   domain  ISC Bind 9.2.1
70/tcp   closed gopher
80/tcp   open   http    Apache httpd 2.0.52 ((Fedora))
113/tcp  closed auth
Device type: general purpose
Running: Linux 2.6.X
OS details: Linux 2.6.0 - 2.6.11
Uptime 26.177 days (since Wed Feb 22 11:39:16 2006)

Interesting ports on d0ze.internal (192.168.12.3):
(The 1664 ports scanned but not shown below are in state: closed)
PORT     STATE SERVICE      VERSION
21/tcp   open  ftp          Serv-U ftpd 4.0
25/tcp   open  smtp         IMail NT-ESMTP 7.15 2015-2
80/tcp   open  http         Microsoft IIS webserver 5.0
110/tcp  open  pop3         IMail pop3d 7.15 931-1
135/tcp  open  mstask       Microsoft mstask (task server - c:\winnt\system32\
139/tcp  open  netbios-ssn
445/tcp  open  microsoft-ds Microsoft Windows XP microsoft-ds
1025/tcp open  msrpc        Microsoft Windows RPC
5800/tcp open  vnc-http     Ultr@VNC (Resolution 1024x800; VNC TCP port: 5900)
MAC Address: 00:A0:CC:51:72:7E (Lite-on Communications)
Device type: general purpose
Running: Microsoft Windows NT/2K/XP
OS details: Microsoft Windows 2000 Professional
Service Info: OS: Windows

Nmap finished: 2 IP addresses (2 hosts up) scanned in 42.291 seconds
flog/home/fyodor/nmap-misc/Screenshots/042006#
```

Next Time

- Project 1 due on Thursday!
    - T-Square by 5pm EDT (sharp, 15% deducted per day, starting at 5pm TODAY)
- Read Section 3.4 for Tuesday...
    - Lots of important information here...
- Project 2 details coming soon...
    - This project will take a *significant* amount of effort - *get ready*.