CSC 458/2209 – Computer Networks

Handout # 2:
Course Logistics and Introduction

Professor Yashar Ganjali

Department of Computer Science

University of Toronto

yganjali@cs.toronto.edu

http://www.cs.toronto.edu/~yganjali

Today

- Outline
  - What this course is about
- Logistics
  - Course structure, assignments, evaluation
  - What is expected from you
  - What you can expect from this course
- Review
  - Simple example – mail vs. FTP
- Foundations and basic concepts

What is This Course About?

- Undergrad course; can be taken by grads
- Computer networks
  - Basics: Layers, naming, and addressing, network (socket) programming, packet switching, routing, congestion control, …
  - Advanced networking: HTTP, web, peer-to-peer, routers and switches, security, multimedia, online social networks, software-defined networking, …
- Theory vs. Practice
  - CSC 358: foundation and theory
  - CSC 458: advanced networking and network programming

Logistics – Prerequisites, Readings

- Prerequisites
  - Algorithms
  - Basic probability theory
  - Strong background in *C* programming and Unix environment

- CSC 358 is not a prerequisite.

- Readings
  - Will be posted on course schedule web page
  - Read before class

Logistics – Textbooks

- Textbook
  - *“Computer Networks: A Systems Approach”,* (5th Edition), Peterson, Davie, 2011
- Recommended books
  - “*UNIX Network Programming, Volume I: The Sockets Networking API*”, W. Richard Stevens, Bill Fenner, and Andrew M. Rudoff, 3rd edition, 2003
  - “*TCP/IP Illustrated, Volume 1: The Protocols*”, W. Richard Stevens, 1993

Logistics – Hours, Web, Announcements

- Office hours
  - L0101, and L0201:
    - Tue. 3-4 PM, Thu. 3-4 PM, Bahen 5238,
    - Or by appointment
  - L5101
    - Please check with your instructor

- Course web page

  http://www.cs.toronto.edu/~yganjali/courses/csc458/

- Please check the class web page, and the bulletin board regularly for announcements.

Logistics – Sections

- This course is offered in three sections
  - L0101: Thu 1-3PM, SS1087, Y. Ganjali
  - L0201: Tue. 1-3PM, SS1071, Y. Ganjali
  - L5101: Tue. 6-8PM, BA1200, J. Lim
- Might have slight differences in content
  - Assignments and exams are coordinated

Logistics – Teaching Assistants

- Shiva Ketabi
  - shketabi@cs.toronto.edu
- Joseph Wahba
  - joseph.wahba@mail.utoronto.ca
- Sajad Shirali-Shahreza
  - shirali@cs.toronto.edu
- Saeed Arezoumand
  - saeed.arezoumand@gmail.com
- Pegah Abed-Esfahani
  - pegah.abed73@gmail.com
- Yinan Liu
  - yinan@ece.toronto.edu
- Hongbo Fan
  - fhb1992@gmail.com
- Hao WANG
  - haowang@ece.utoronto.ca

Logistics – TA hours, Tutorials

- Check class web page for office hours.

- Tutorials and discussion session
  - L0101: Fri. 11-12PM, SS1087
  - L0201: Fri. 1-2PM, SS1071
  - L0501: Tue. 8-9PM, BA1200

- First tutorial:
  - L0101 and L0201 this Friday
  - Section L0501 next Tue.

Logistics – Mailing List, Bulletin Board

- Bulletin board
  - We will use Piazza for announcements and Q&A
    - Sign up link on class web site
  - Post any questions related to the course.
  - Check previous posts before asking a question.
  - We guarantee to respond within 48 hours.

- Class mailing list
  - Based on e-mail address you have defined on ROSI/ACORN.
  - The TAs and I will use this list for announcements only.
  - Do not send e-mails to this list!

Logistics – Grading

- Grading for undergraduate AND graduate students
  - Assignments: 50%
    - Problem sets: 20%
    - Programming: 30%
  - Midterm exam: 20% - In class
    - L0101: Oct. 27^{th}
    - L0201: Oct. 25^{th}
    - L0501: Oct. 25^{th}
  - Final exam: 30% - TBA

- Please note that grading is the same for graduate and undergraduate students this year.

Logistics - Deadlines

- Assignment deadlines
  - One free late submission of 24 hours
    - Use on assignment of your choice
    - E-mail TAs before the deadline
  - 10% deduction for each day late
    - Up to 20%
    - Assignment not accepted after two days

Logistics – Programming Assignments

- To be completed in groups of three students.

- You can submit your assignment during a 7-10 day period before the deadline
  - And have the results of basic tests back
  - Your last submission before the deadline will be marked

- Socket Programming
- MiniNet
  - Your very own virtual network!
  - You will create and program your own network
  - VM available on CDF machines
  - More detail on this later.

- This is a *heavy* course, but *manageable*!

Logistics – Academic Integrity

- Academic Integrity
  - All submissions must present original, independent work.
  - We take academic offenses very seriously.
  - Please read
    - Handout # 1 (course information sheet)
    - “Guideline for avoiding plagiarism”
    - http://www.cs.toronto.edu/~fpitt/documents/plagiarism.html
    - “Advice about academic offenses”
    - http://www.cs.toronto.edu/~clarke/acoffences/

Logistics - Accessibility

- Accessibility Needs
  - The University of Toronto is committed to accessibility. If you require accommodations or have any accessibility concerns, please visit http://studentlife.utoronto.ca/accessibility as soon as possible.

Acknowledgements

- Special thanks to:
  - Nick McKeown from Stanford University
  - Jennifer Rexford from Princeton University
  - David Wetherall from University of Washington
  - Nick Feamster from Georgia Tech

Quick Survey

- Have you taken CSC358 before?
- Have you taken any networking course?
- Are you familiar with
  - Socket programming?
  - Ethernet, framing, encoding, error detection/correction?
  - UDP, TCP and congestion control?
  - DNS, SNMP, BGP?
  - BitTorrent?
  - Voice and video over IP?
  - Control plane vs. data path?
  - Network security?
  - Software-defined networking?

Questions?

What else do you want to know about this course?

Announcement

- First tutorial
  - L0101 and L0201, Friday, Sep. 16th
  - L5101, Tue. Sep 20th

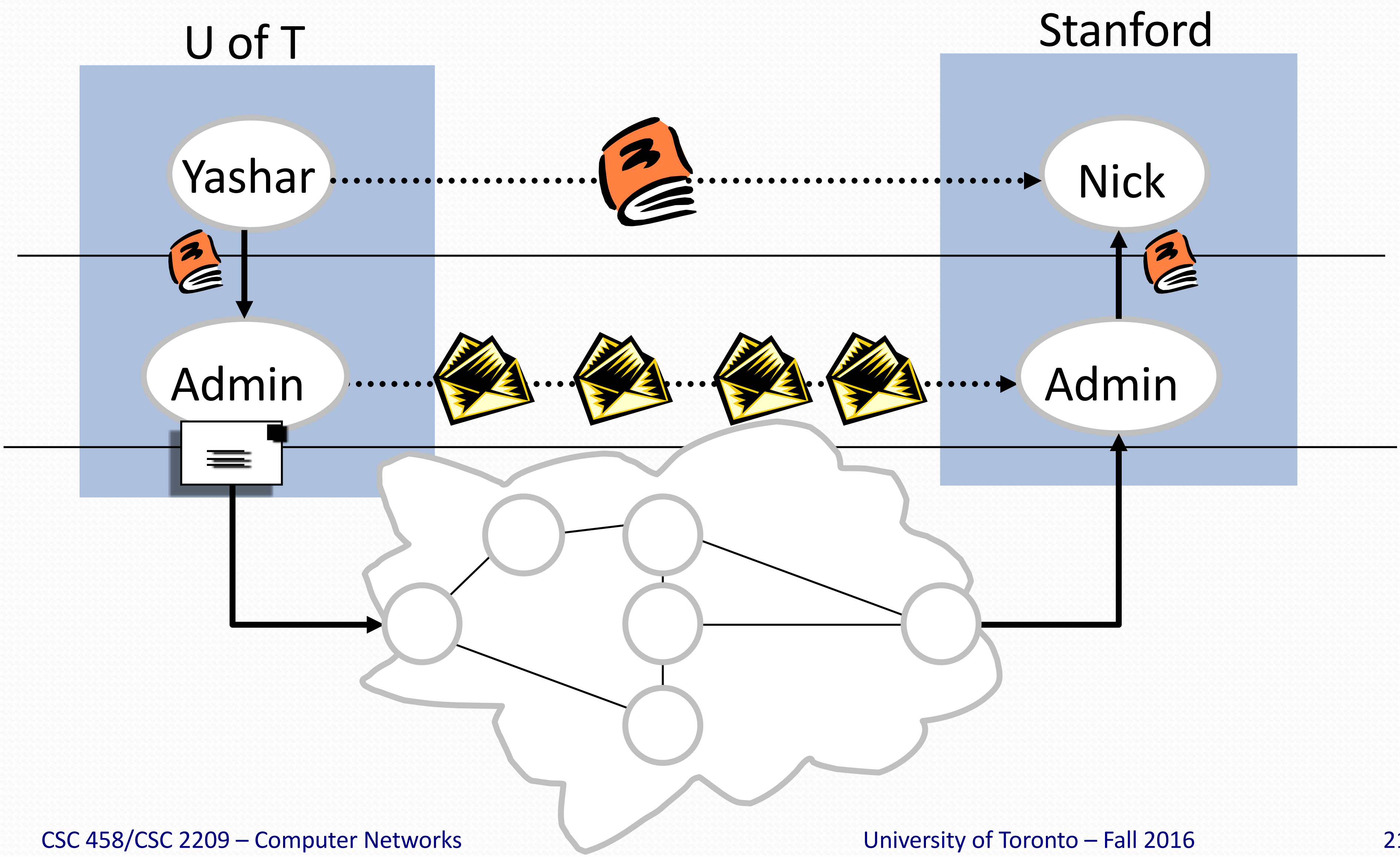
- Covers *socket programming*

- You'll need this information for your first programming assignment, which will be posted next week.

Let’s Begin

- An introduction to the mail system
- An introduction to the Internet

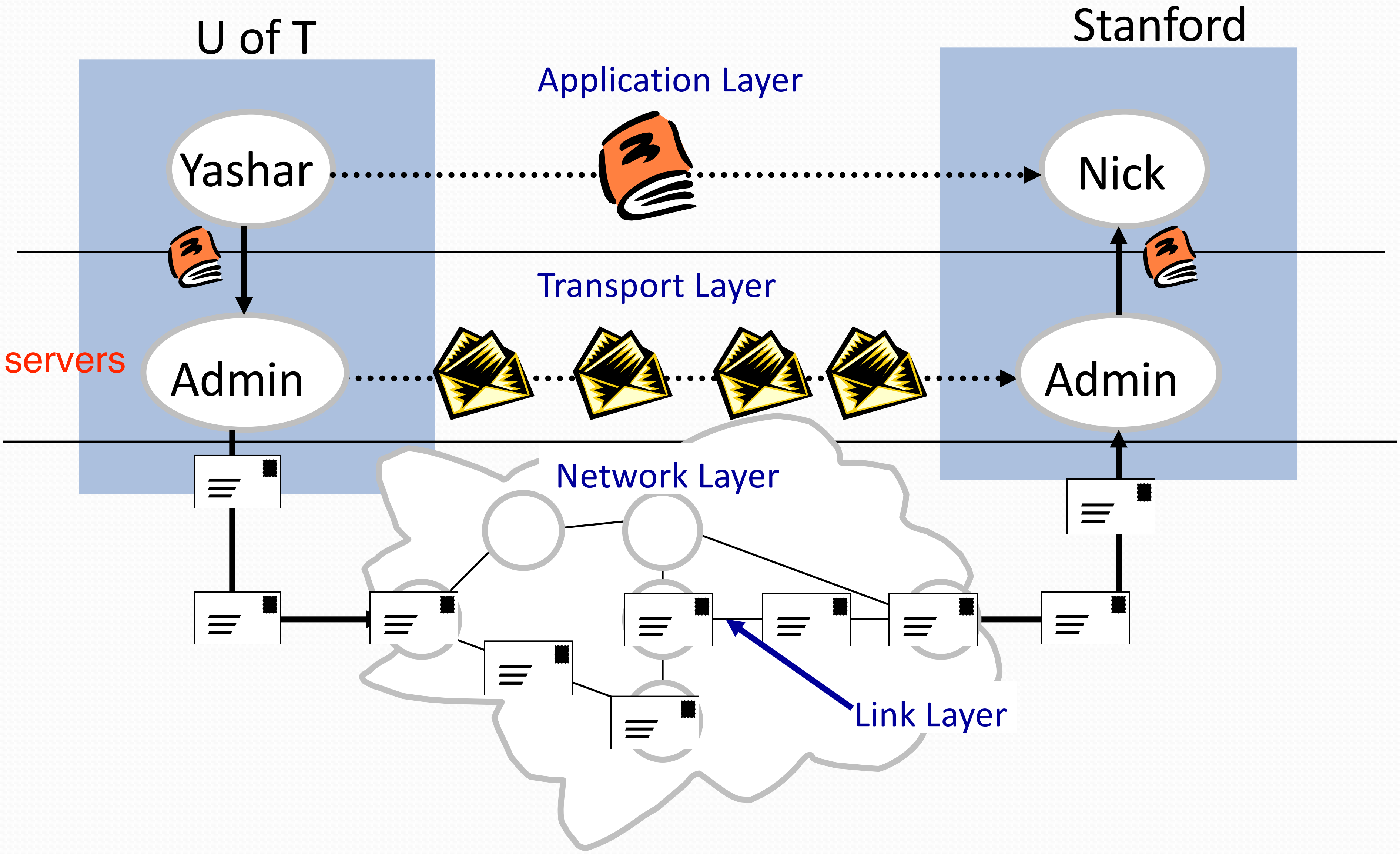
An Introduction to the Mail System



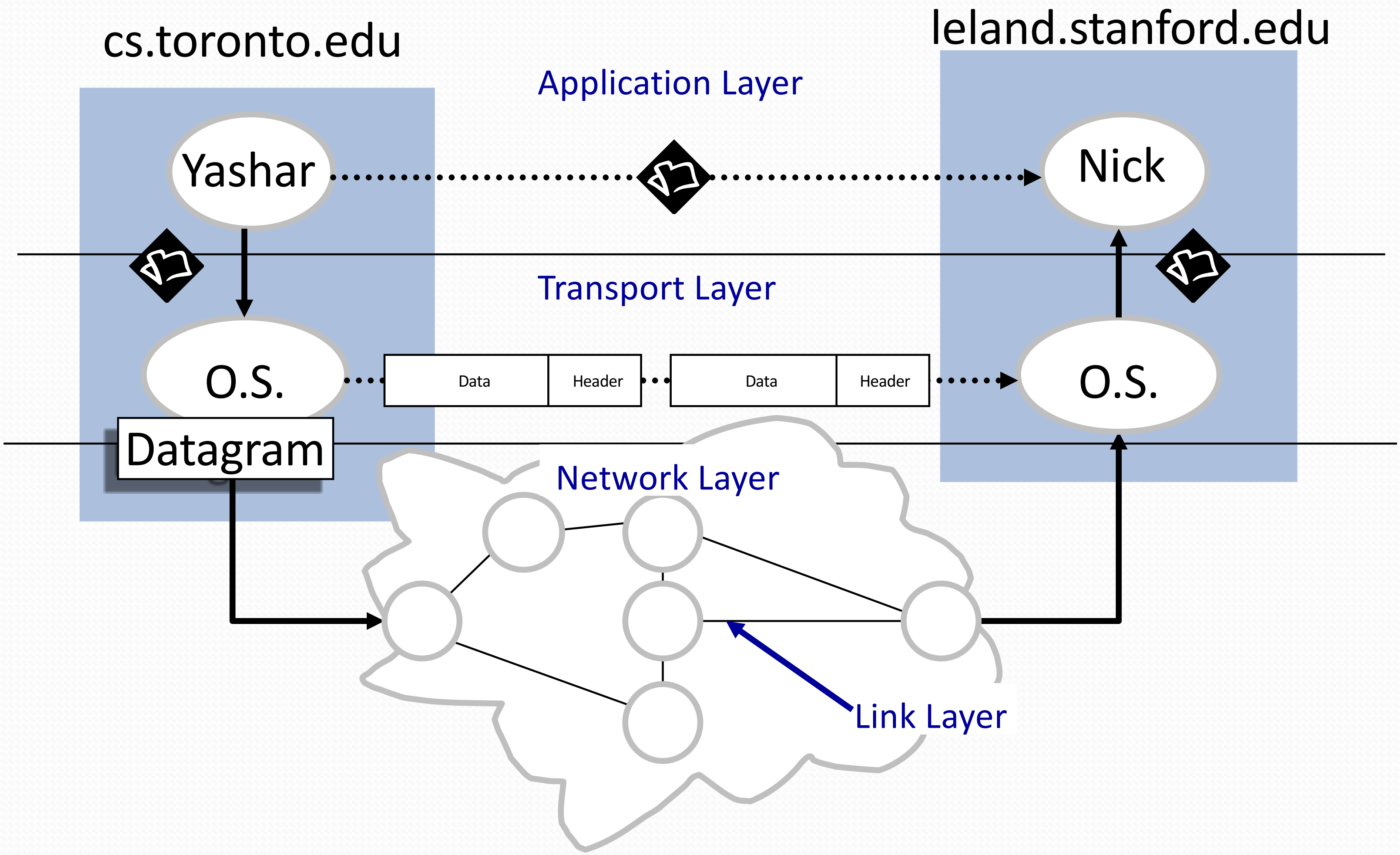
Characteristics of the Mail System

- Each envelope is individually routed.
- No time guarantee for delivery.
- No guarantee of delivery in sequence.
- No guarantee of delivery at all! resend
  - Things get lost
  - How can we acknowledge delivery?
  - Retransmission
    - How to determine when to retransmit? Timeout?
    - Need local copies of contents of each envelope.
    - How long to keep each copy.
    - What if an acknowledgement is lost?

An Introduction to the Mail System



An Introduction to the Internet



Characteristics of the Internet

- Each packet is individually routed.
- No time guarantee for delivery.
- No guarantee of delivery in sequence.
- No guarantee of delivery at all!
  - Things get lost
  - Acknowledgements
  - Retransmission
    - How to determine when to retransmit? Timeout?
    - Need local copies of contents of each packet.
    - How long to keep each copy?
    - What if an acknowledgement is lost?

Characteristics of the Internet – Cont'd

- No guarantee of integrity of data.
- Packets can be fragmented. chopping packets into smaller pieces
- Packets may be duplicated.

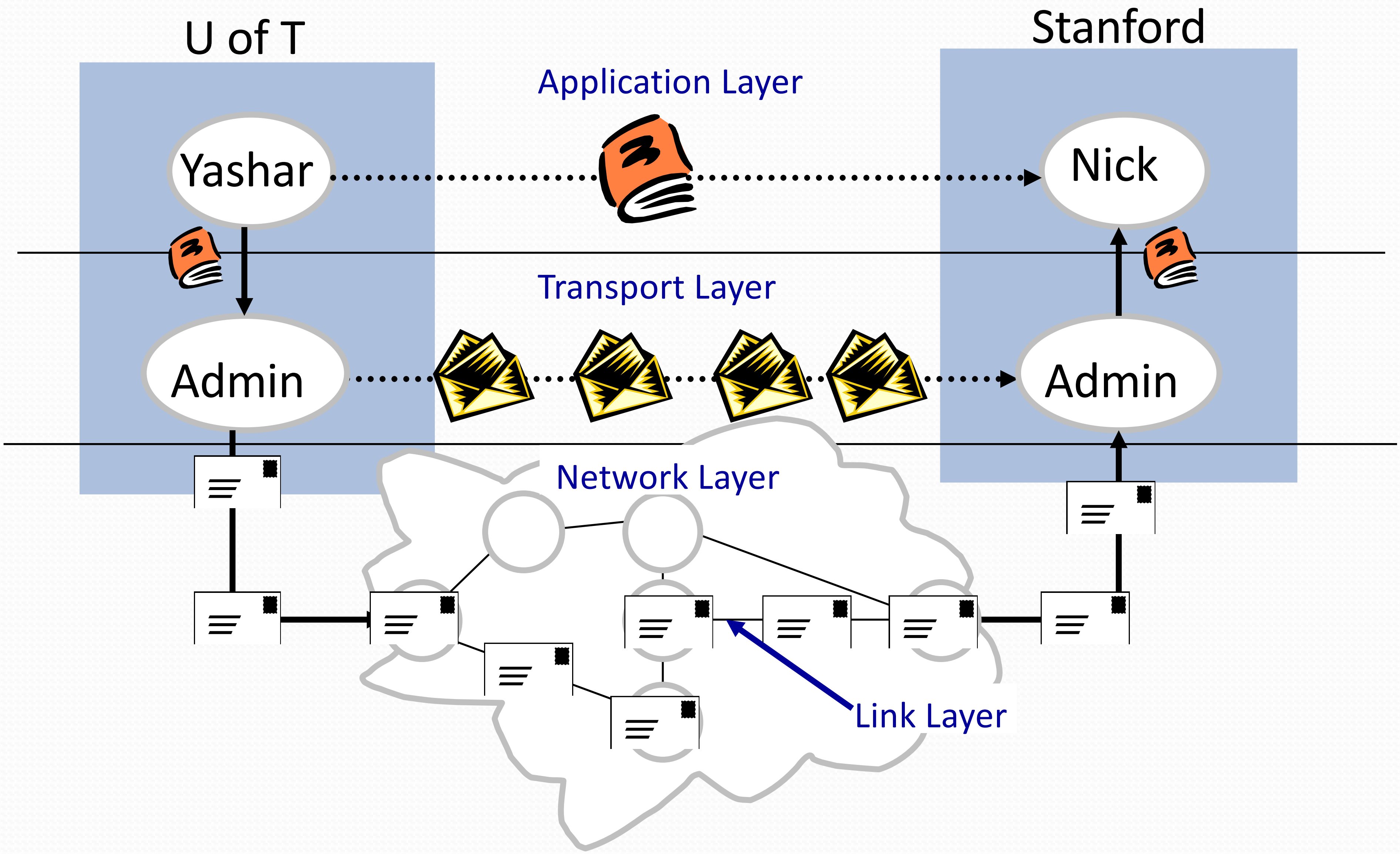
sender thought receiver did not receive, but did receive

- delay in sending packet
- delay in Ack

Layering in the Internet

- Transport Layer
  - Provides reliable, in-sequence delivery of data from end-to-end on behalf of application.
- Network Layer
  - Provides "best-effort", but unreliable, delivery of datagrams.
- Link Layer
  - Carries data over (usually) point-to-point links between hosts and routers; or between routers and routers.

An Introduction to the Mail System



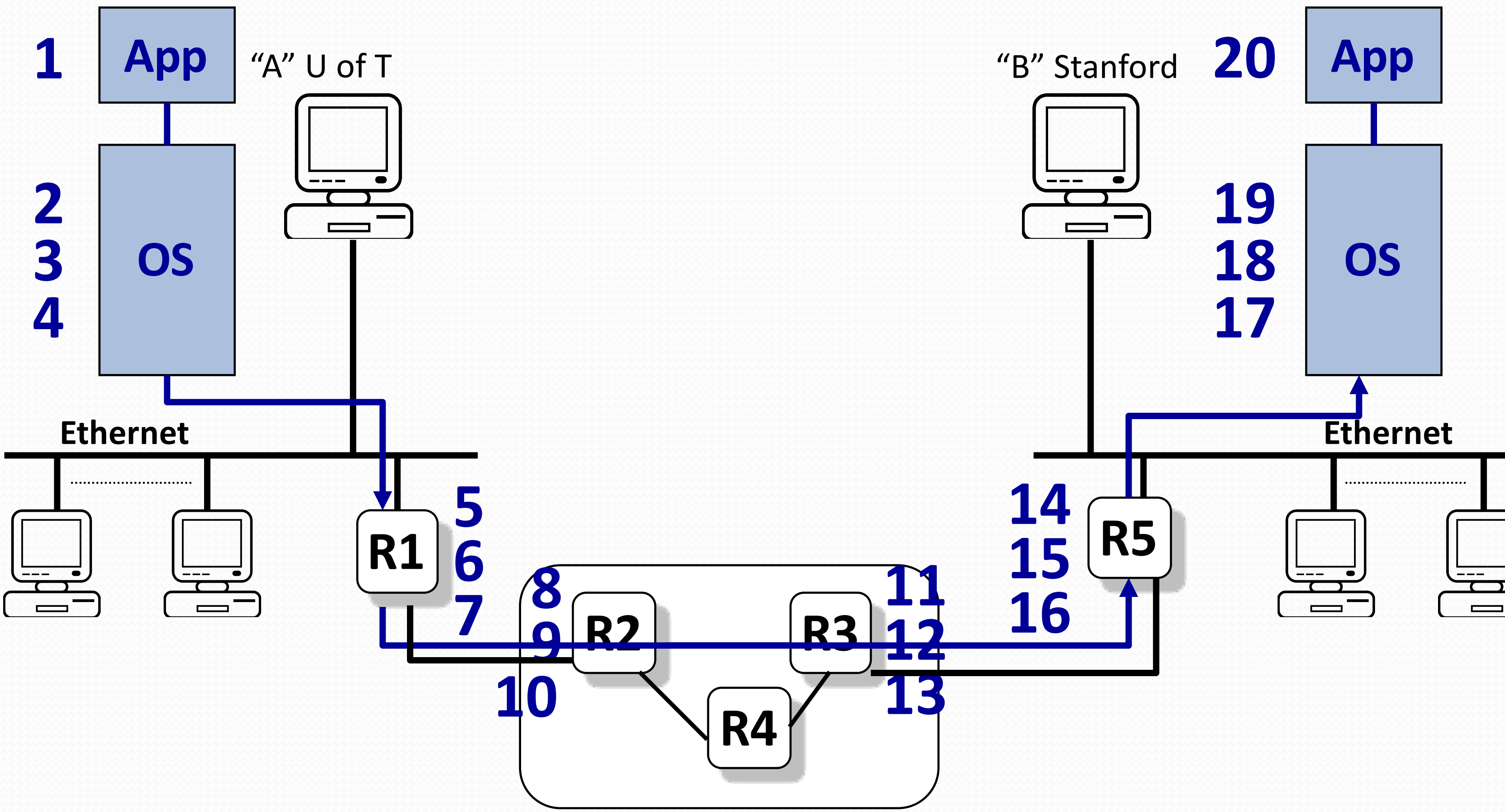
Some Questions About the Mail System

- How many sorting offices are needed and where should they be located?
- How much sorting capacity is needed?
  - Should we allocate for Mother's Day?
- How can we guarantee timely delivery?
  - What prevents delay guarantees?
  - Or delay variation guarantees?
- How do we protect against fraudulent mail deliverers, or fraudulent senders?

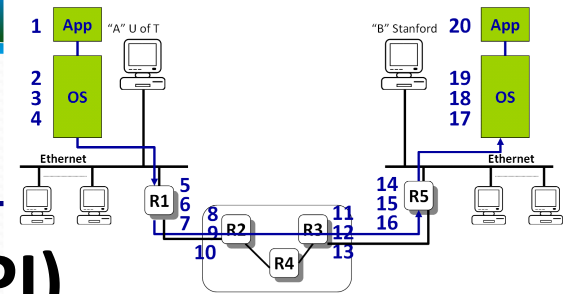
Outline – Foundations & Basic Concepts

- A detailed FTP example dropbox
- Layering
- Packet switching and circuit switching

Example: FTP over the Internet Using TCP/IP and Ethernet



In the Sending Host



1. Application-Programming Interface (API)

- Application requests TCP connection with "B"

reliable data delivery but maybe slow

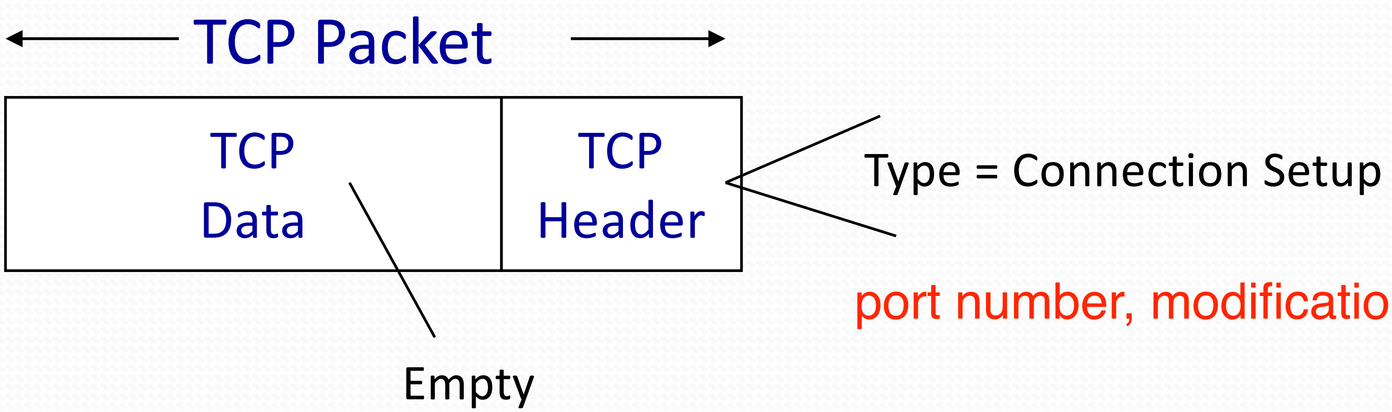
2. Transmission Control Protocol (TCP)

- Creates TCP "Connection setup" packet

2 host agrees with params on conenction

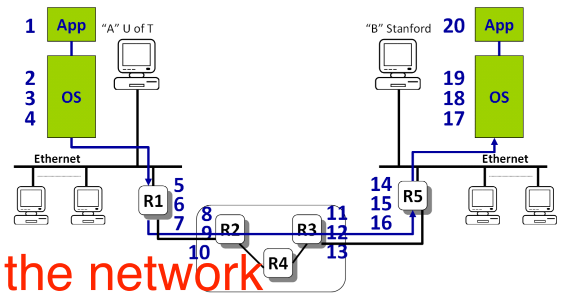
- TCP requests IP packet to be sent to "B"

A request



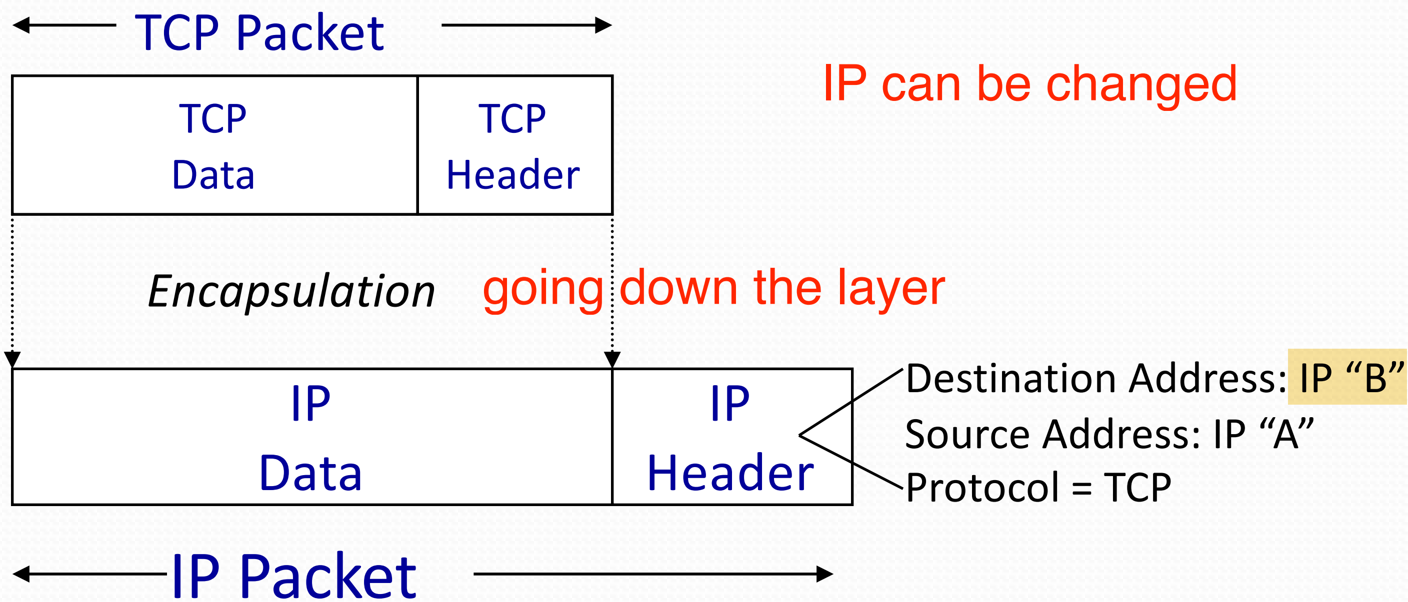
port number, modification time...

In the Sending Host – Cont'd



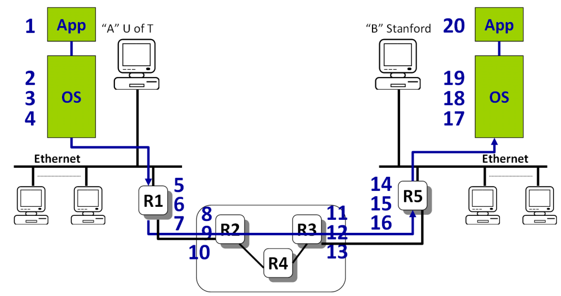
3. Internet Protocol (IP) use to distinguish hosts in the network

- Creates IP packet with correct addresses.
- IP requests packet to be sent to router.



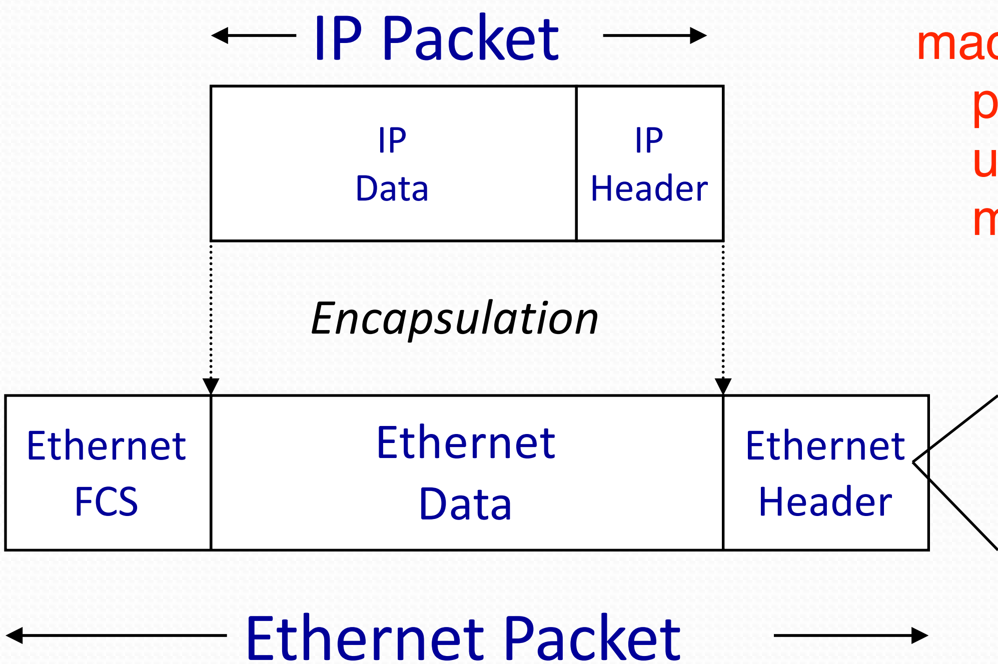
IP can be changed

In the Sending Host – Cont’d



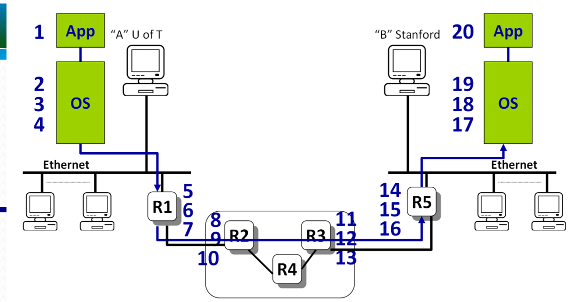
4. Link (“MAC” or Ethernet) Protocol

- Creates MAC frame with Frame Check Sequence (FCS).
- Wait for Access to the line.
- MAC requests PHY to send each bit of the frame.



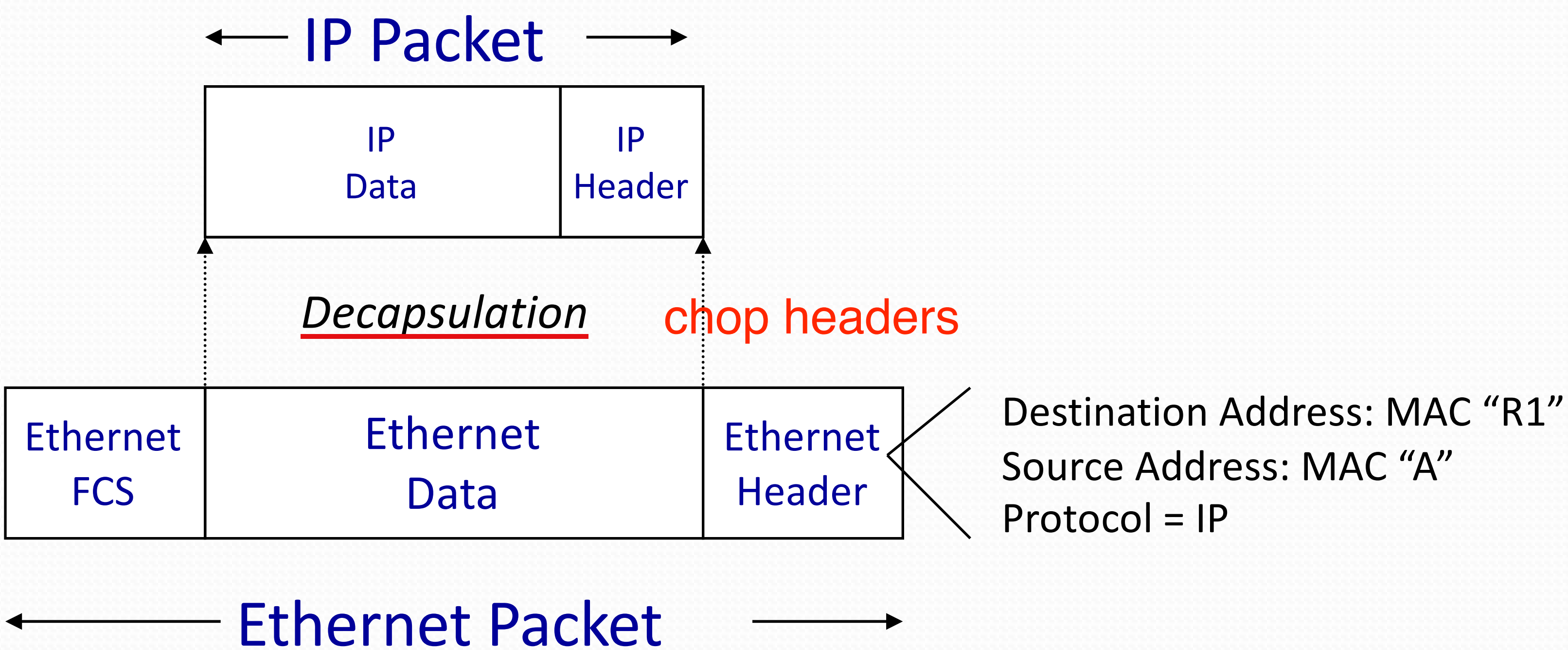
mac address:
physical address
unique for every device
might not be easy to change

In Router R1

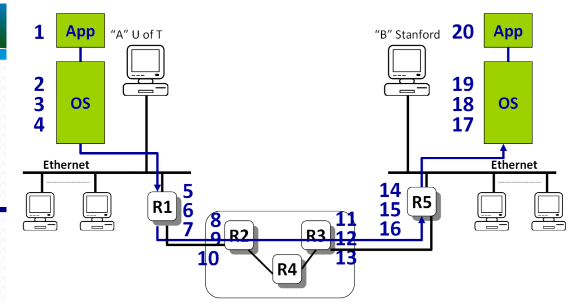


5. Link (“MAC” or Ethernet) Protocol

- Accept MAC frame, check address and Frame Check Sequence (FCS).
- Pass data to IP Protocol.



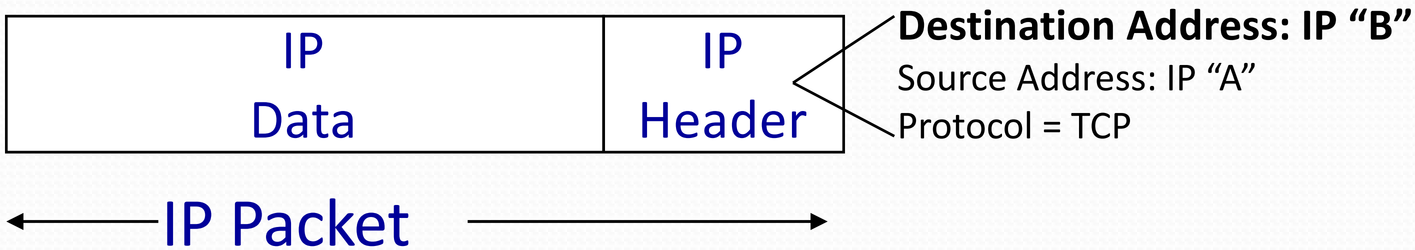
In Router R1



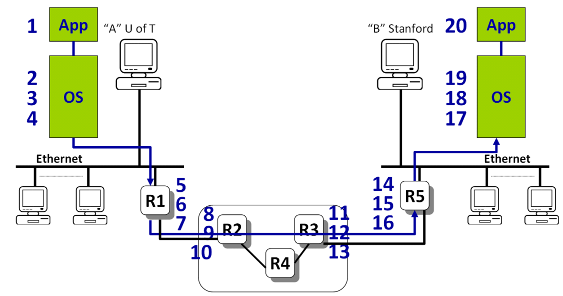
6. Internet Protocol (IP)

- Use IP destination address to decide where to send packet next ("next-hop routing").
- Request Link Protocol to transmit packet.

the same ip though



In Router R1



7. Link ("MAC" or Ethernet) Protocol

- Creates MAC frame with Frame Check Sequence (FCS).
- Wait for Access to the line.
- MAC requests PHY to send each bit of the frame.

← IP Packet →

IP Data	IP Header

Encapsulation

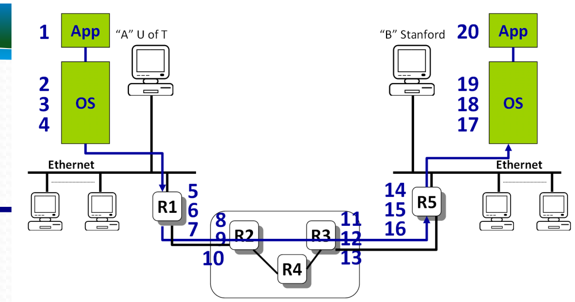
mac address changes as packet cross network

Ethernet FCS	Ethernet Data	Ethernet Header

Destination Address: **MAC "R2"**
Source Address: **MAC "R1"**
Protocol = IP

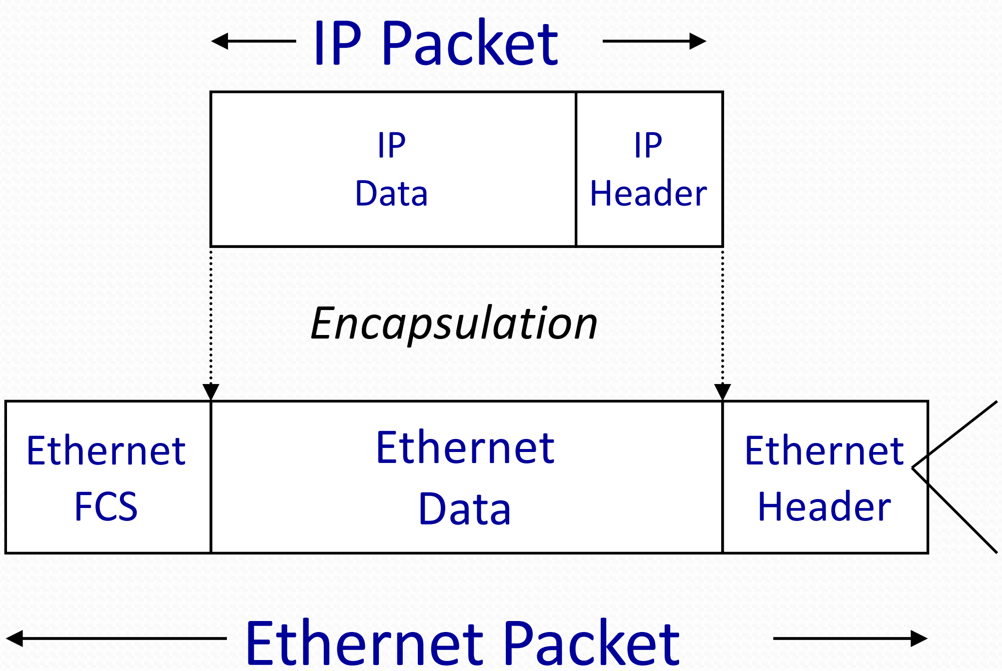
← Ethernet Packet →

In Router R5



16. Link ("MAC" or Ethernet) Protocol

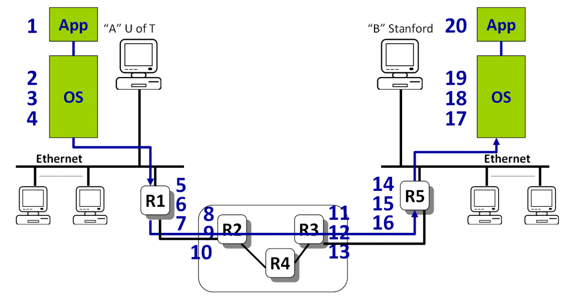
- Creates MAC frame with Frame Check Sequence (FCS).
- Wait for Access to the line.
- MAC requests PHY to send each bit of the frame.



the final link

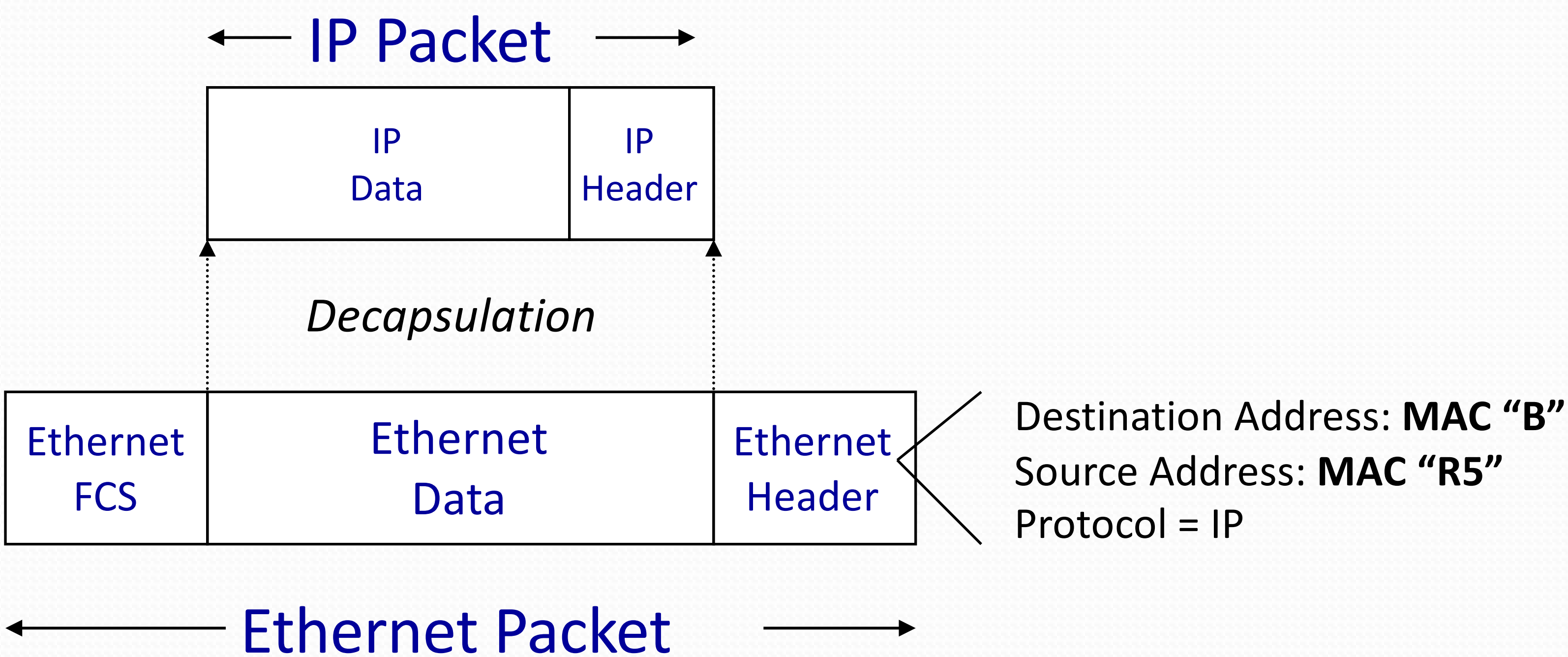
Destination Address: **MAC "B"**
Source Address: **MAC "R5"**
Protocol = IP

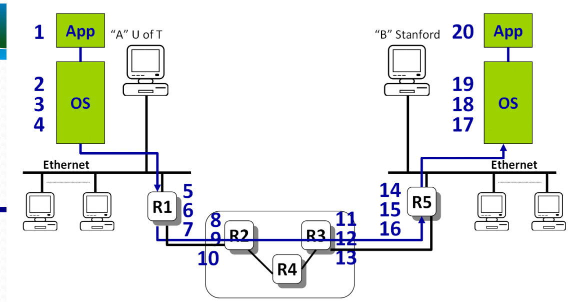
In the Receiving Host



17. Link ("MAC" or Ethernet) Protocol

- Accept MAC frame, check address and Frame Check Sequence (FCS).
- Pass data to IP Protocol.

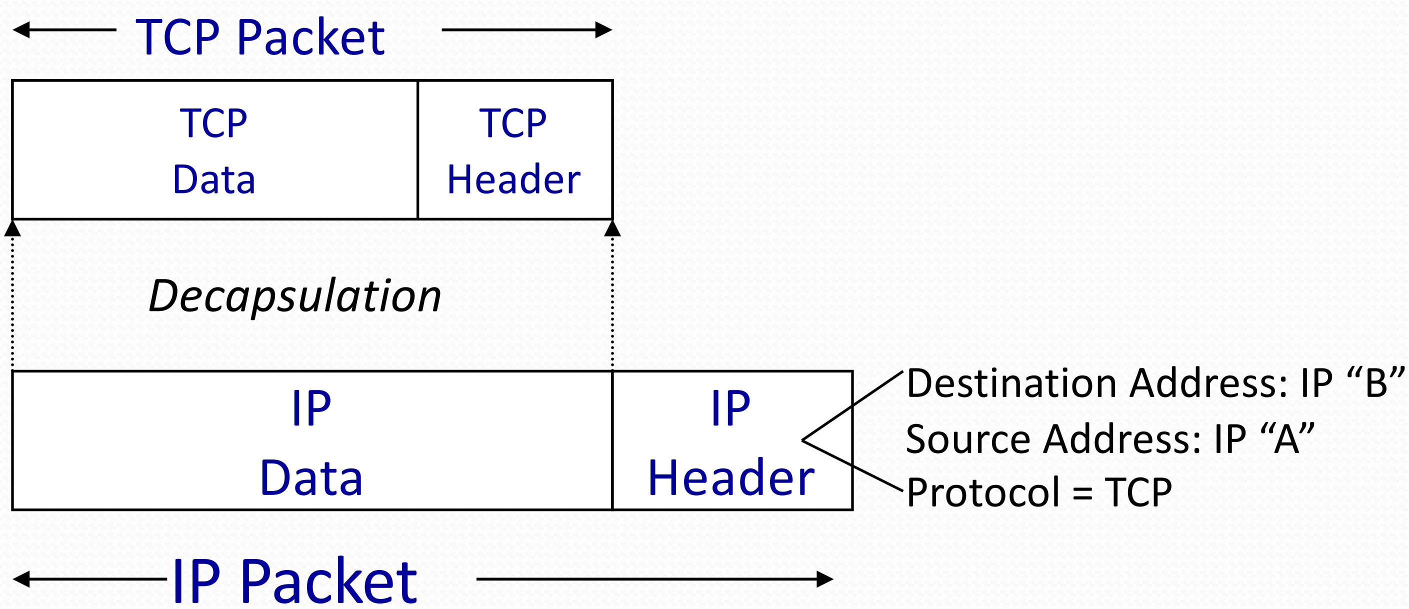


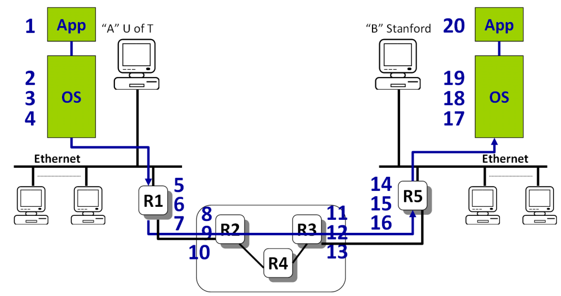


In the Receiving Host - Cont'd

18. Internet Protocol (IP)

- Verify IP address.
- Extract/decapsulate TCP packet from IP packet.
- Pass TCP packet to TCP Protocol.





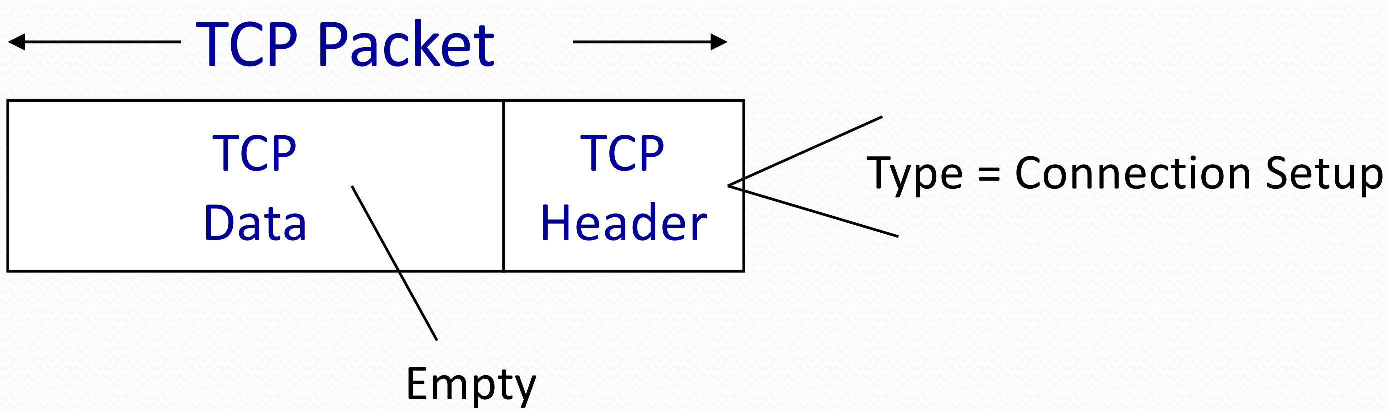
In the Receiving Host - Cont'd

19. Transmission Control Protocol (TCP)

- Accepts TCP "Connection setup" packet
- Establishes connection by sending "Ack".

20. Application-Programming Interface (API)

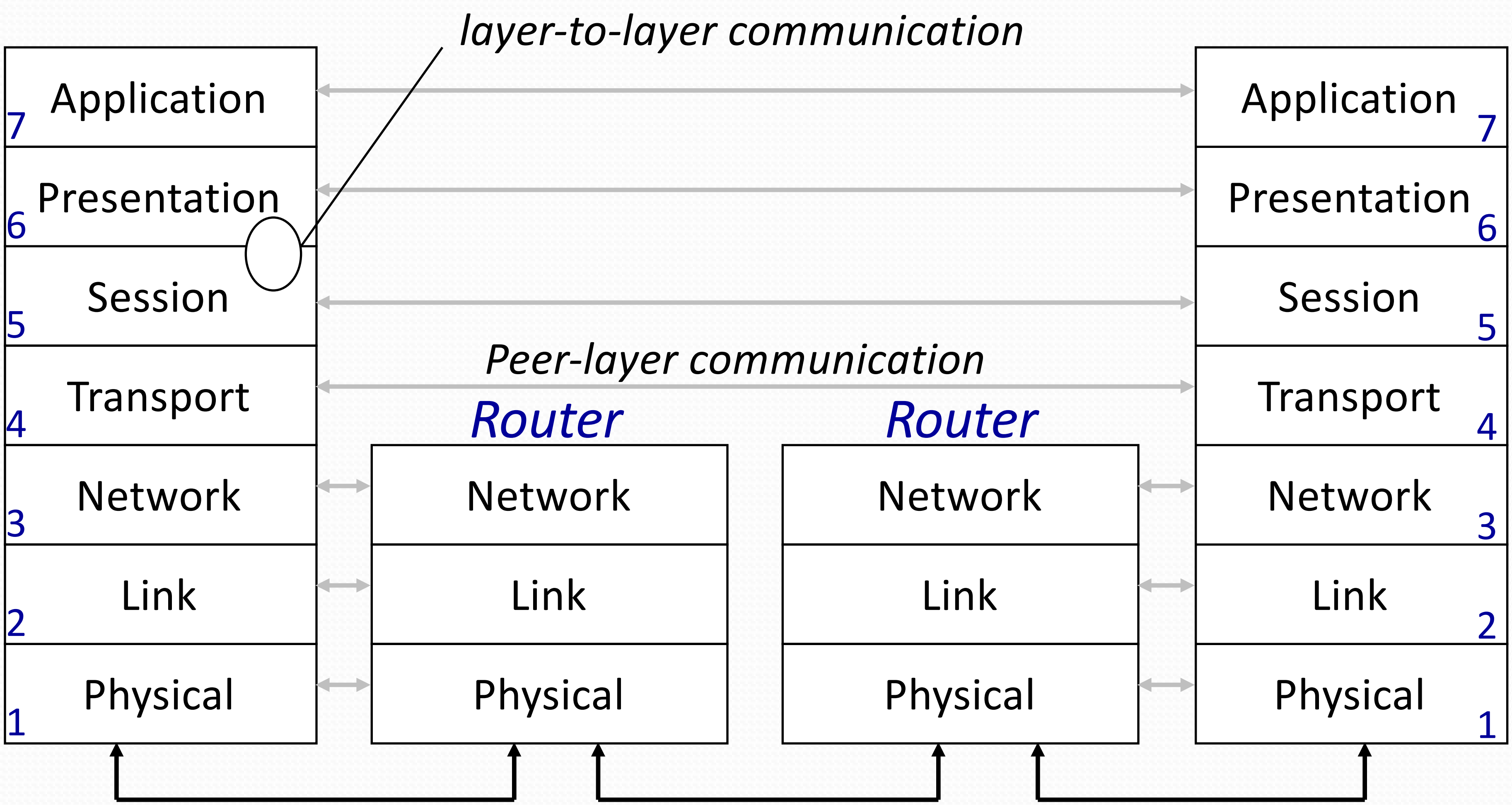
- Application receives request for TCP connection with "A".



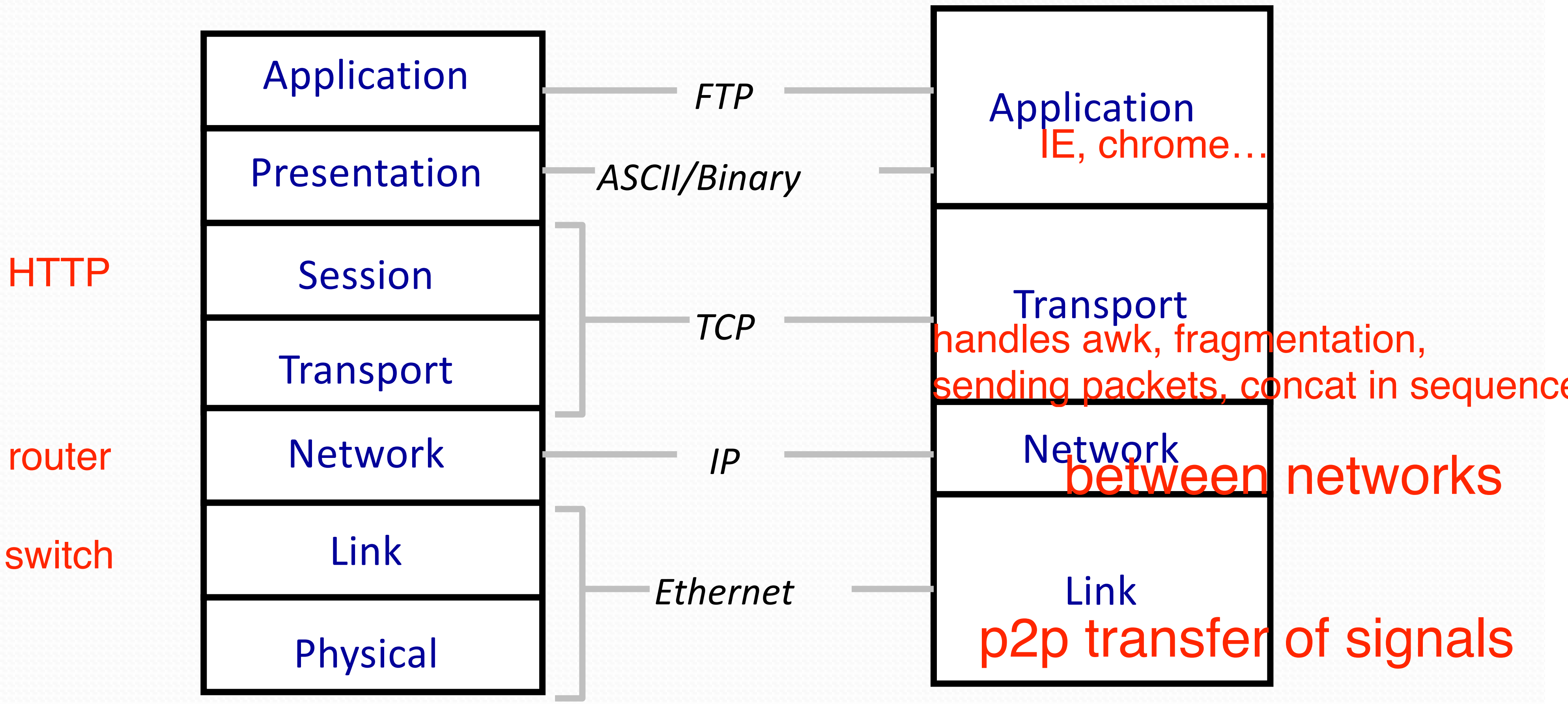
Outline – Foundations & Basic Concepts

- A detailed FTP example
- Layering
- Packet switching and circuit switching

Layering – *The OSI Model*



Layering – *Our FTP Example*



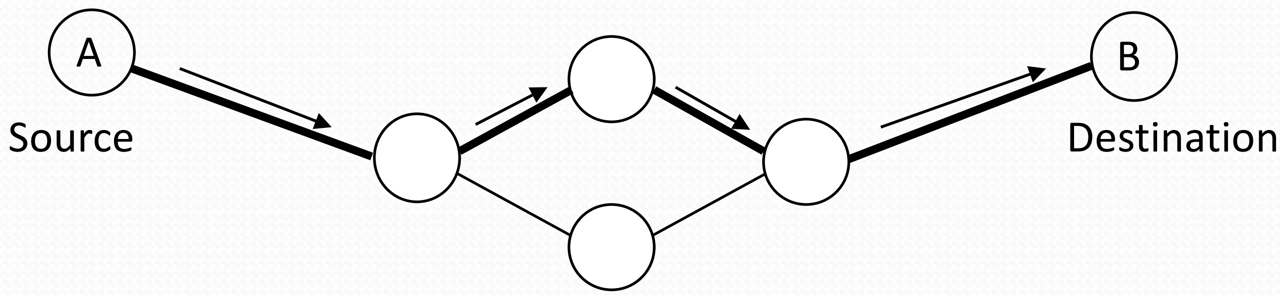
The 7-layer OSI Model

The 4-layer Internet model

Outline – Foundations & Basic Concepts

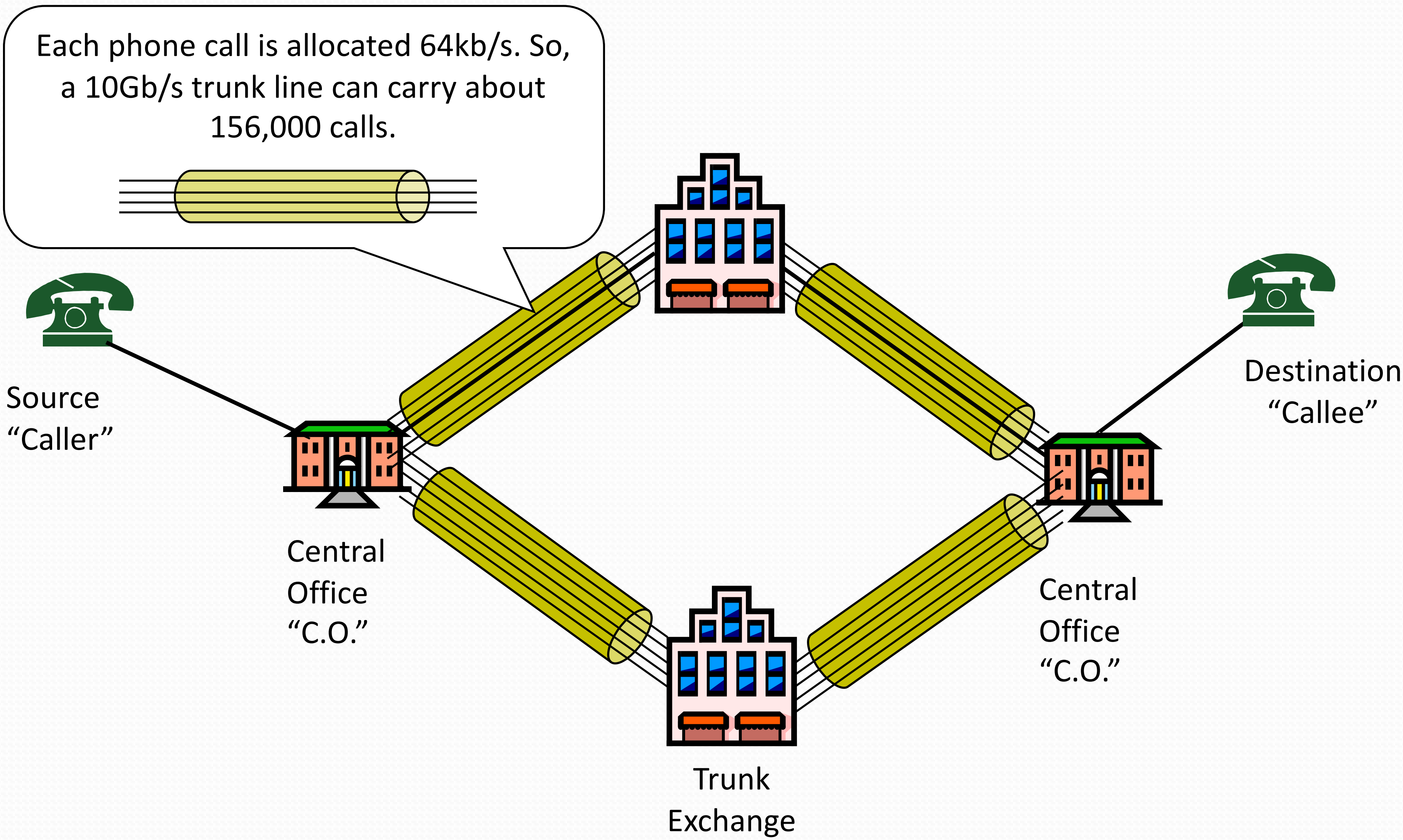
- A detailed FTP example
- Layering
- Packet switching and circuit switching

Circuit Switching

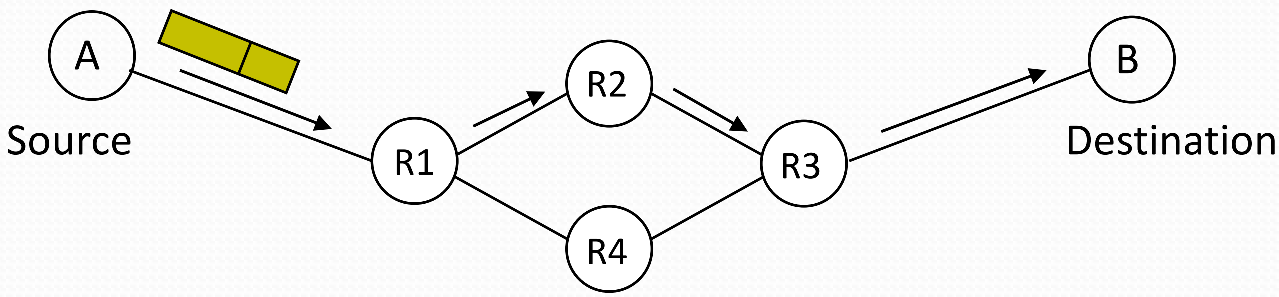


- It's the method used by the telephone network.
- A call has three phases:
  - Establish circuit from end-to-end ("dialing"),
  - Communicate,
  - Close circuit ("tear down").
- Originally, a circuit was an end-to-end physical wire.
- Nowadays, a circuit is like a virtual private wire: each call has its own private, guaranteed data rate from end-to-end.

Circuit Switching – *Telephone Network*



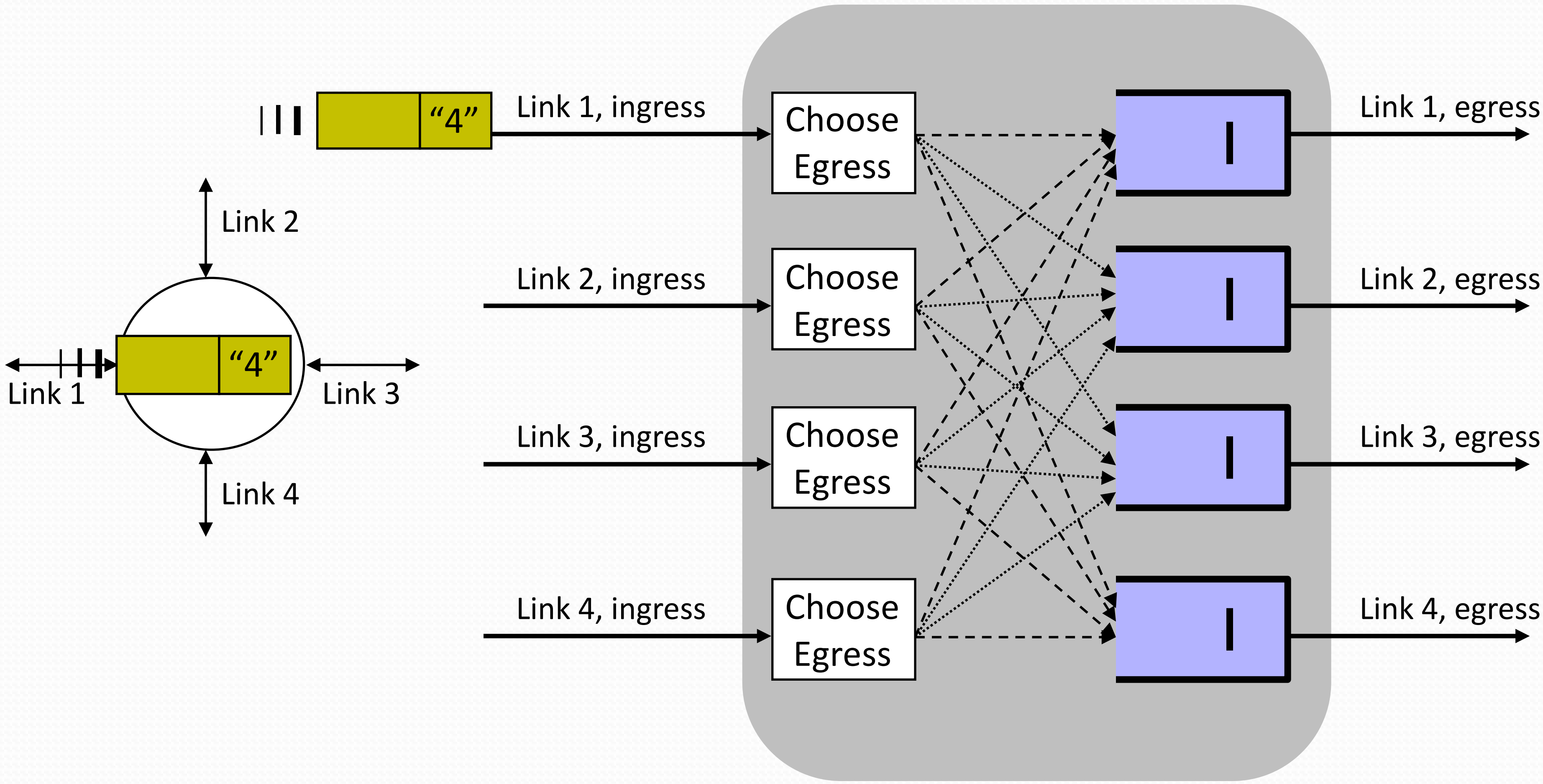
Packet Switching



- It's the method used by the Internet.
- Each packet is individually routed packet-by-packet, using the router's local routing table.
- The routers maintain no per-flow state.
- Different packets may take different paths.
- Several packets may arrive for the same output link at the same time, therefore a packet switch has buffers.

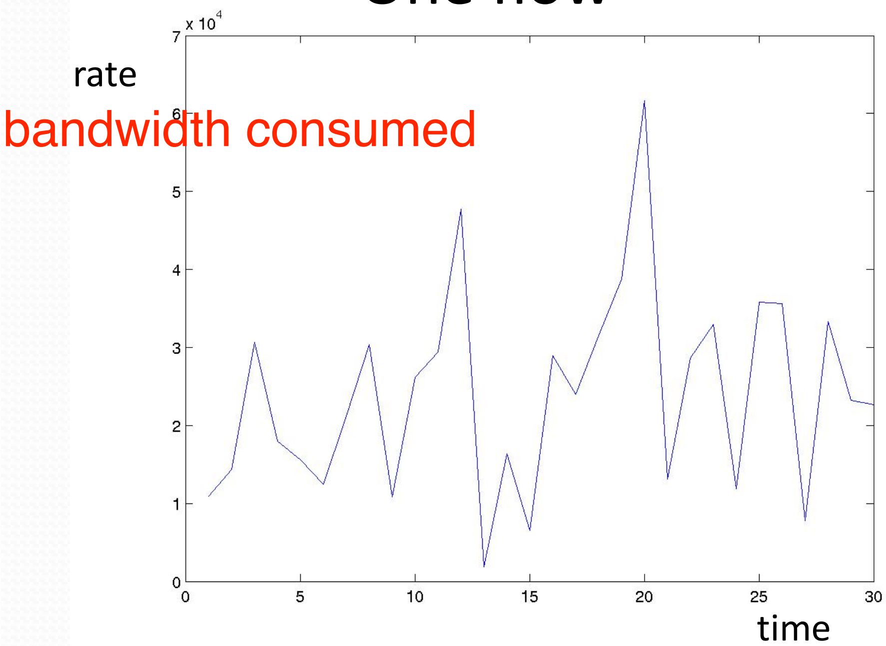
have to store in buffers if line is busy

Packet Switching – *Simple Router Model*

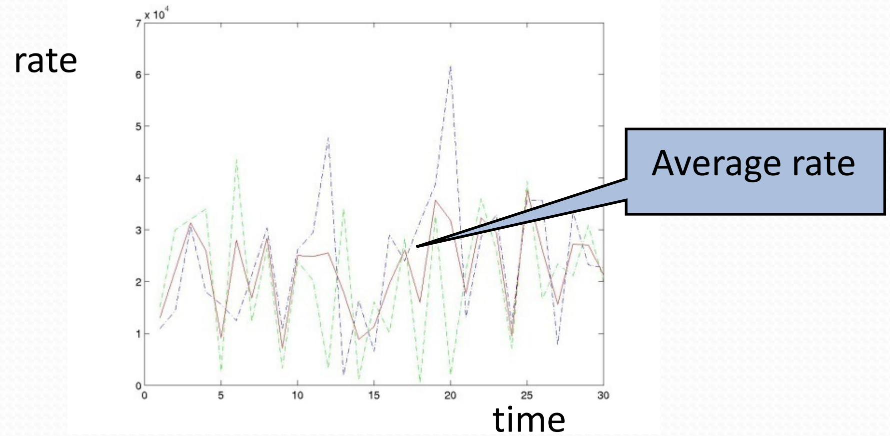


Statistical Multiplexing – *Basic Idea*

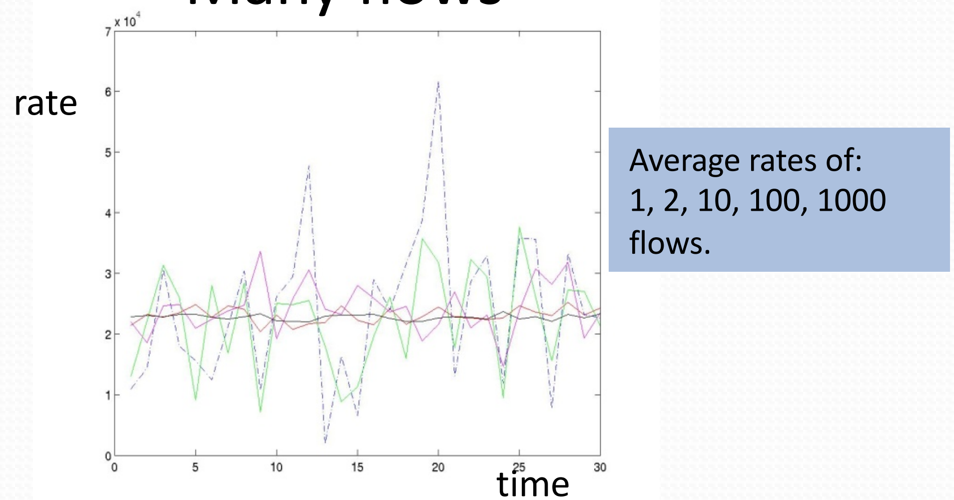
One flow



Two flows

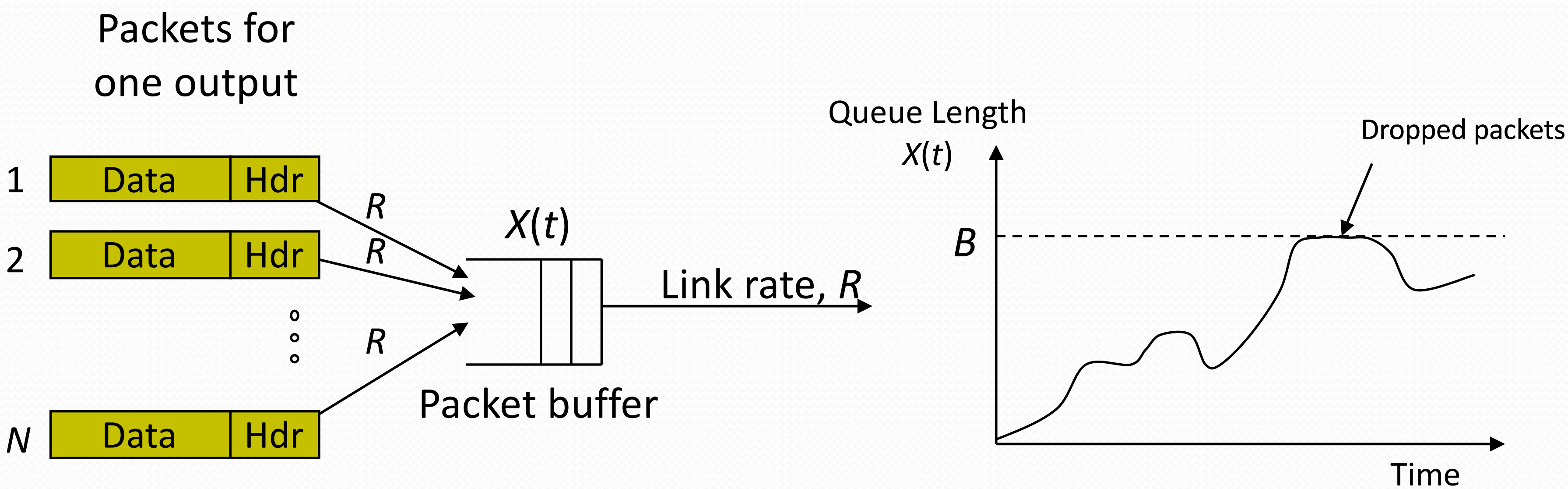


Many flows



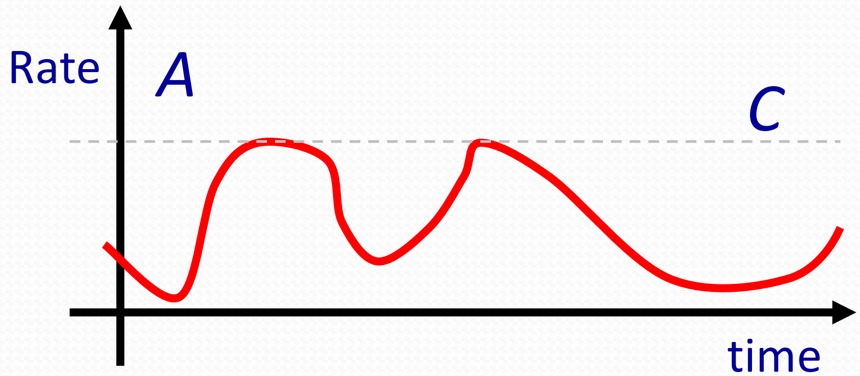
- Network traffic is bursty.
  i.e. the rate changes frequently.
- Peaks from independent flows generally occur at different times.
- Conclusion: The more flows we have, the smoother the traffic.

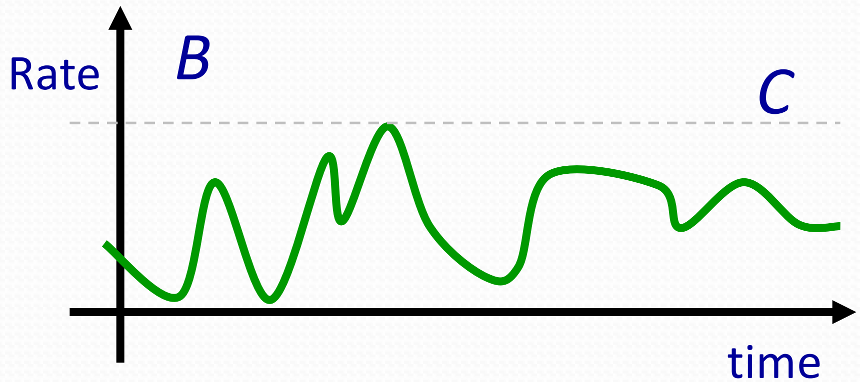
Packet Switching – *Statistical Multiplexing*

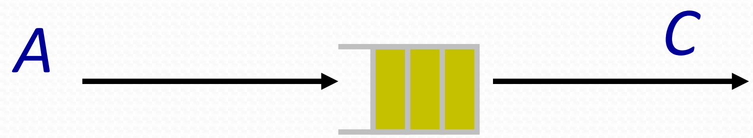


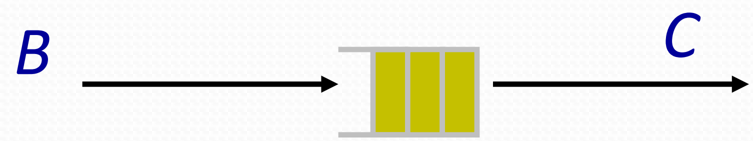
- Because the buffer absorbs temporary bursts, the egress link need not operate at rate *N.R*.
- But the buffer has finite size, *B*, so losses will occur.

Statistical Multiplexing

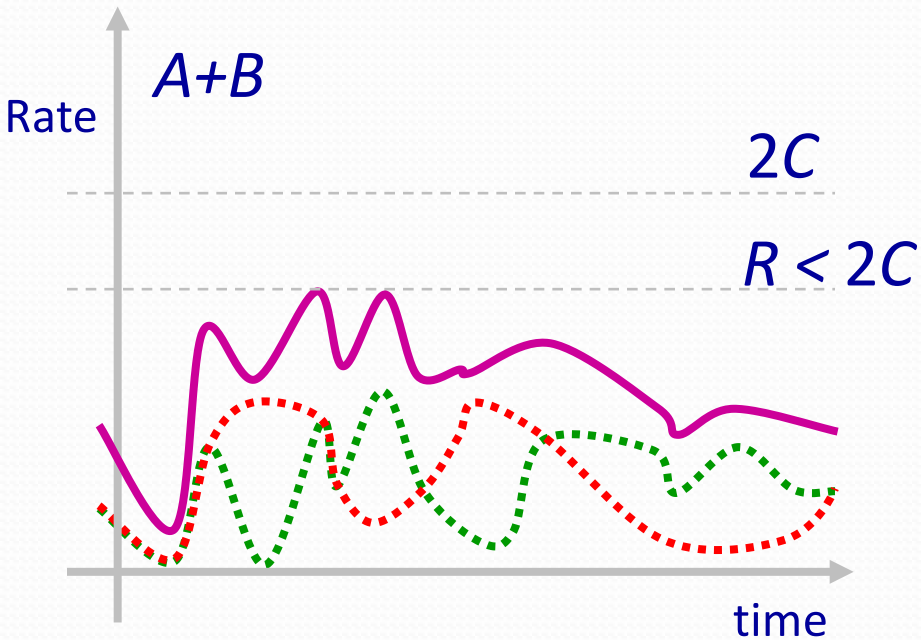


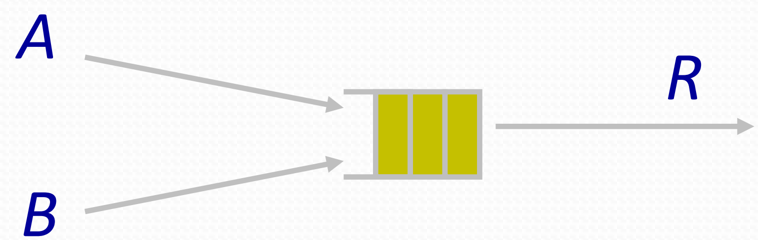






Statistical Multiplexing Gain





Statistical multiplexing gain = $2C/R$

Other definitions of SMG: The ratio of rates that give rise to a particular queue occupancy, or particular loss probability.

Why Packet Switching in the Internet?

- Efficient use of expensive links:
  - The links are assumed to be expensive and scarce.
  - Packet switching allows many, bursty flows to share the same link efficiently.
  - “Circuit switching is rarely used for data networks, ... because of very inefficient use of the links” - Gallager
- Resilience to failure of links & routers:
  - “For high reliability, ... [the Internet] was to be a datagram subnet, so if some lines and [routers] were destroyed, messages could be ... rerouted” - Tanenbaum

Final Comments, Discussion

- Is layering the best approach?
  - Simplifies design
  - Yet, limited and inflexible

since protocols maybe introduce overheads, speed, timely delivery

- Best effort service
  - Made the rapid growth of the Internet possible
  - Makes providing any guarantees very difficult
- Packet switching
  - Enables statistical multiplexing
  - We need extremely fast routers
- Routing
  - How does a router know which output port to send the packet to?