National University of Computer & Emerging Sciences

CS 3001 - COMPUTER NETWORKS

Lecture 10

Chapter 2

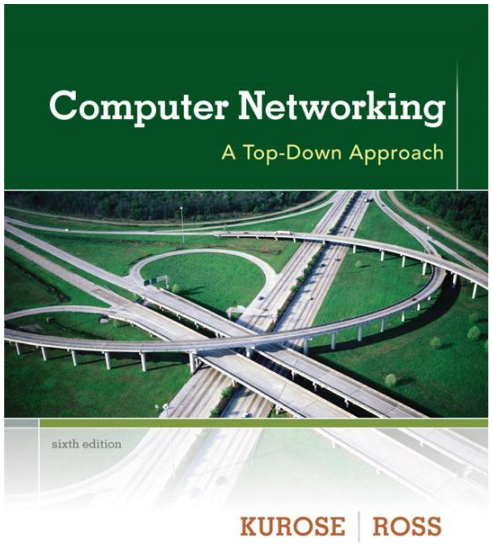
22nd September, 2022

Nauman Moazzam Hayat

nauman.moazzam@lhr.nu.edu.pk

Office Hours: 02:30 pm till 06:00 pm (Every Tuesday & Thursday)

Chapter 2
Application Layer



A note on the use of these ppt slides:

We're making these slides freely available to all (faculty, students, readers). They're in PowerPoint form so you see the animations; and can add, modify, and delete slides (including this one) and slide content to suit your needs. They obviously represent a *lot* of work on our part. In return for use, we only ask the following:

- If you use these slides (e.g., in a class) that you mention their source (after all, we'd like people to use our book!)
- If you post any slides on a www site, that you note that they are adapted from (or perhaps identical to) our slides, and note our copyright of this material.

Thanks and enjoy! JFK/KWR

Computer Networking: A Top Down Approach
6th edition
Jim Kurose, Keith Ross
Addison-Wesley
March 2012

Chapter 2: outline

2.1 principles of network applications
- app architectures
- app requirements

2.2 Web and HTTP

2.3 FTP

2.4 electronic mail
- SMTP, POP3, IMAP

2.5 DNS

2.6 P2P applications

2.7 socket programming with UDP and TCP

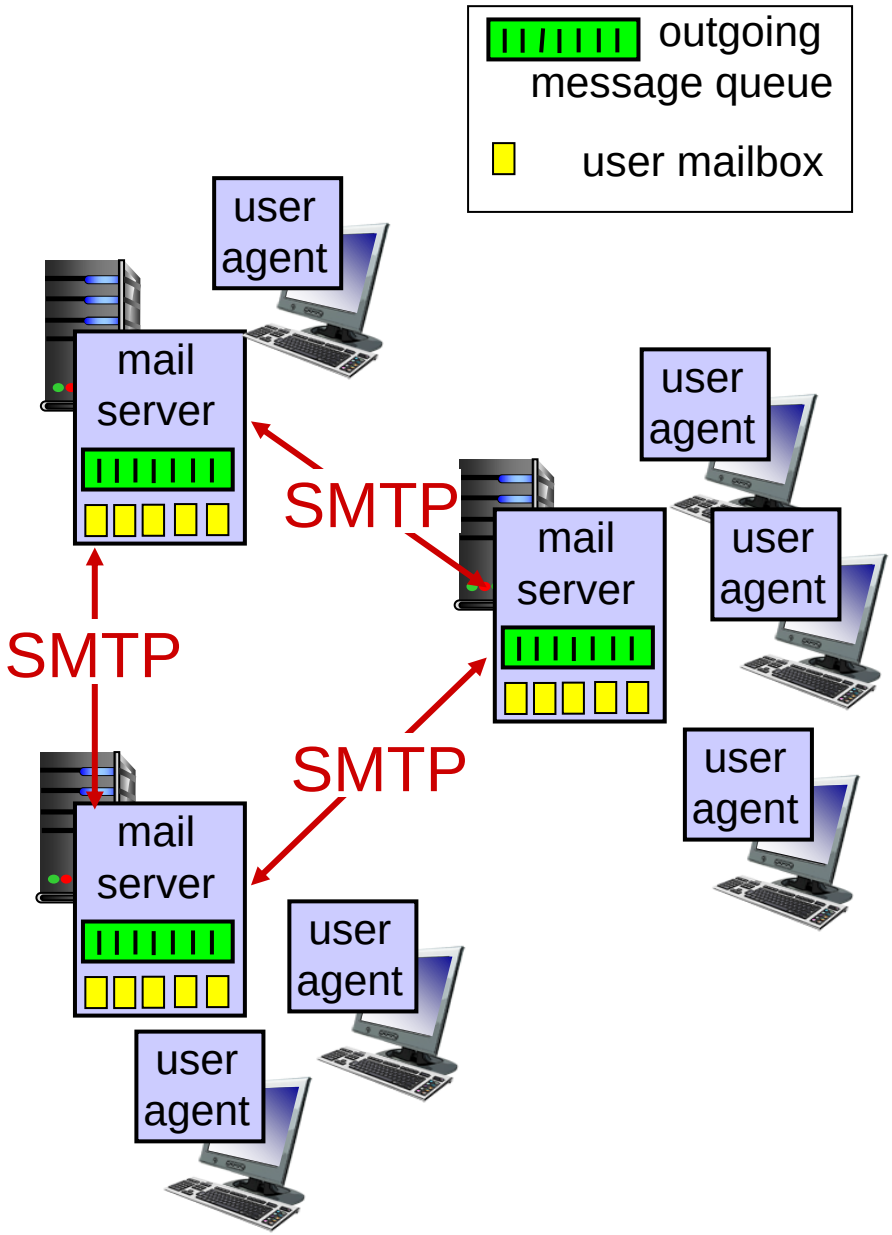
Electronic mail

Three major components:

- user agents
- mail servers
- simple mail transfer protocol: SMTP

User Agent

- a.k.a. "mail reader"
- composing, editing, reading mail messages
- e.g., Outlook, Thunderbird, iPhone mail client
- outgoing, incoming messages stored on server

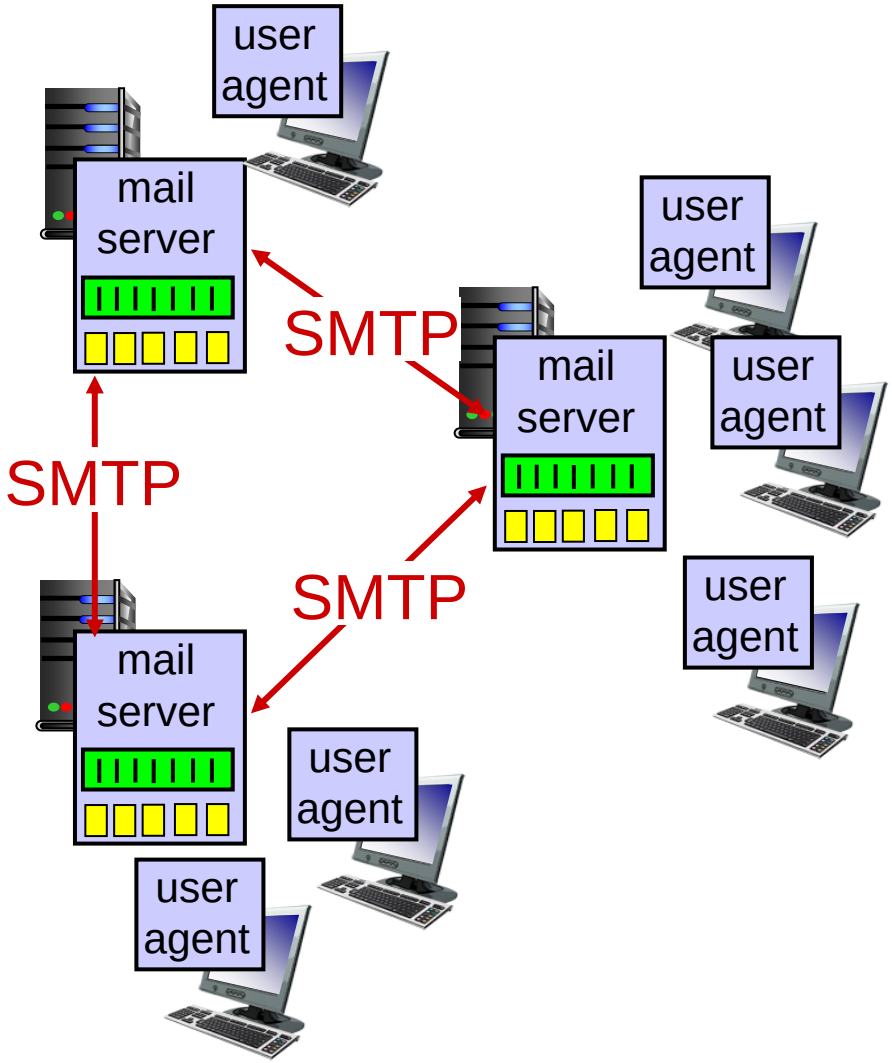


Electronic mail: mail servers

mail servers:

- *message queue* of outgoing (to be sent) mail messages
- *mailbox* contains incoming messages for user

- *SMTP protocol* between mail servers to send email messages
  - client: sending mail server
  - "server": receiving mail server

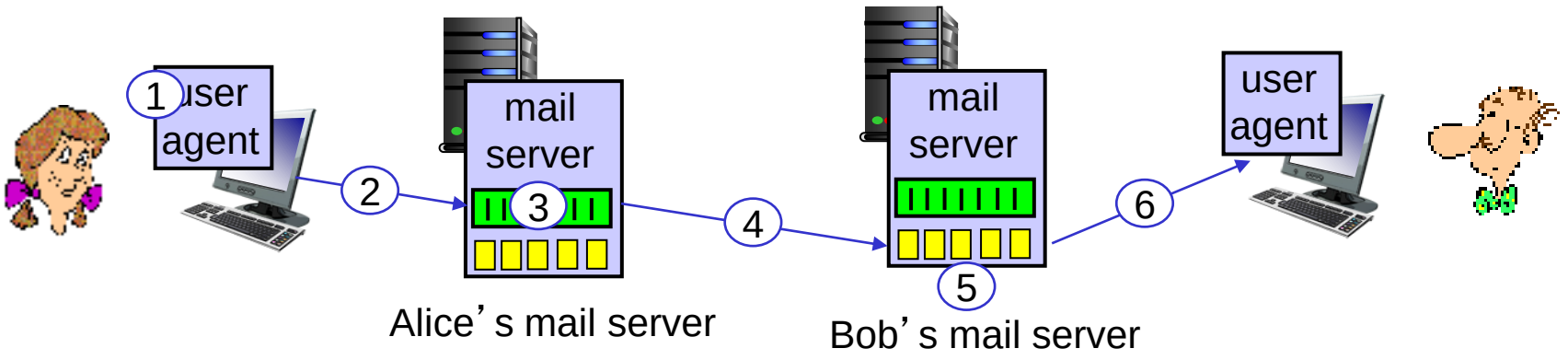


Electronic Mail: SMTP [RFC 2821]

- Client / Server
- uses TCP to reliably transfer email message from client to server, port 25
- direct transfer: sending server to receiving server
- three phases of transfer
  - handshaking (greeting)
  - transfer of messages (persistent TCP, many messages over the same TCP connection can be sent.)
  - closure
- command/response interaction (like HTTP, FTP)
  - commands: ASCII text
  - response: status code and phrase
- messages must be in 7-bit ASCI

Scenario: Alice sends message to Bob

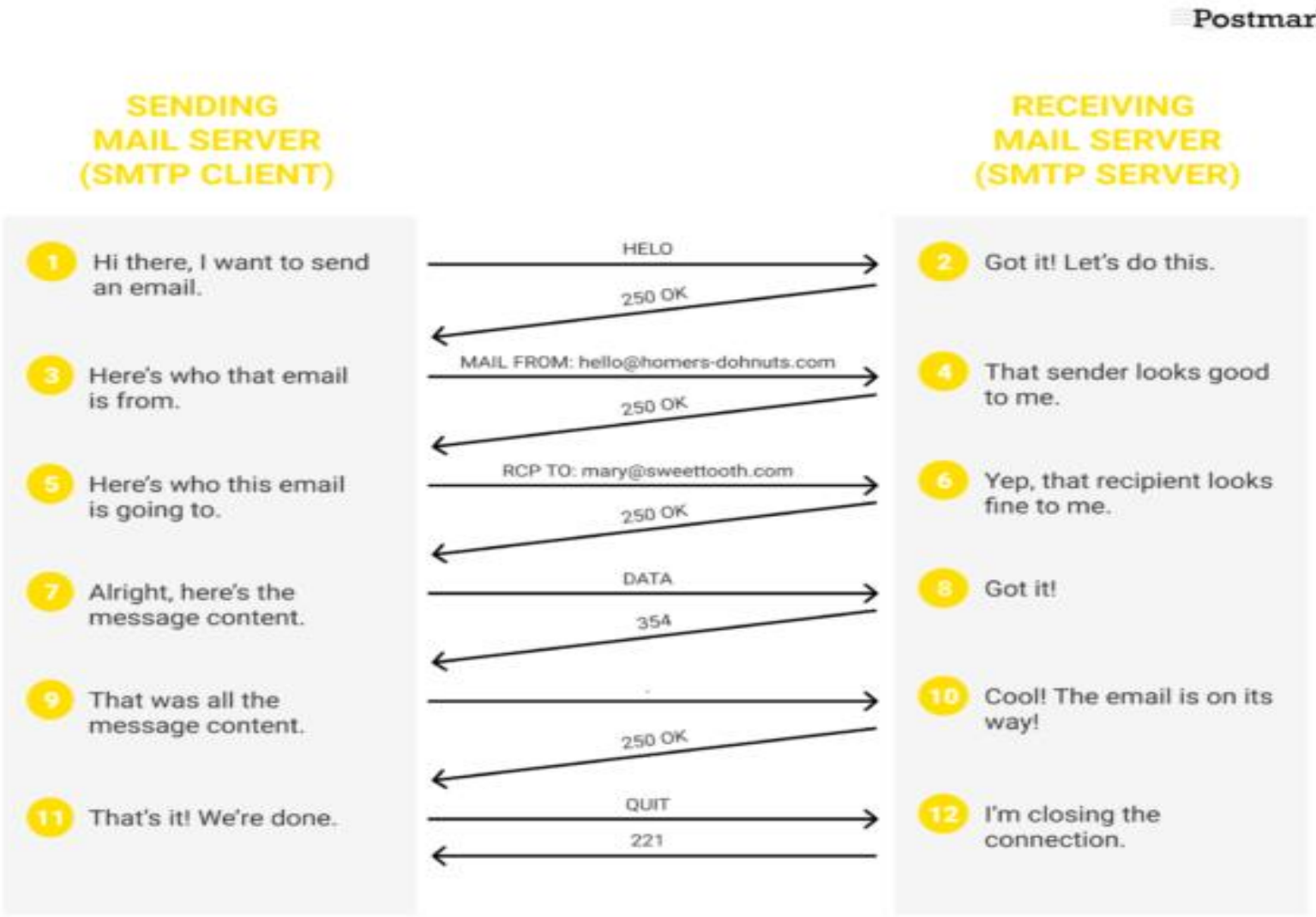
1) Alice uses UA to compose message "to" `bob@someschool.edu`
2) Alice's UA sends message to her mail server; message placed in message queue
3) client side of SMTP opens TCP connection with Bob's mail server
4) SMTP client sends Alice's message over the TCP connection
5) Bob's mail server places the message in Bob's mailbox
6) Bob invokes his user agent to read message



Sample SMTP interaction

```
S: 220 hamburger.edu
C: HELO crepes.fr
S: 250  Hello crepes.fr, pleased to meet you
C: MAIL FROM: <alice@crepes.fr>
S: 250 alice@crepes.fr... Sender ok
C: RCPT TO: <bob@hamburger.edu>
S: 250 bob@hamburger.edu ... Recipient ok
C: DATA
S: 354 Enter mail, end with "." on a line by itself
C: Do you like ketchup?
C: How about pickles?
C: .
S: 250 Message accepted for delivery
C: QUIT
S: 221 hamburger.edu closing connection
```

SMTP Interaction



Try SMTP interaction for yourself:

- **`telnet servername 25`**
- see 220 reply from server
- enter HELO/EHLO, MAIL FROM, RCPT TO, DATA, QUIT commands

above lets you send email without using email client (reader)

SMTP: final words

- SMTP uses persistent TCP connections
- SMTP requires message (header & body) to be in 7-bit ASCII
- SMTP server uses `CRLF.CRLF` to determine end of message
- **MIME**: Multipurpose Internet Mail Extensions: is an internet standard that extends the format of email to support non text attachments as well as text that non-ASCII

comparison with HTTP:

- HTTP: pull
- SMTP: push
- both have ASCII command/response interaction, status codes
- HTTP: each object encapsulated in its own response msg
- SMTP: multiple objects sent in multipart msg

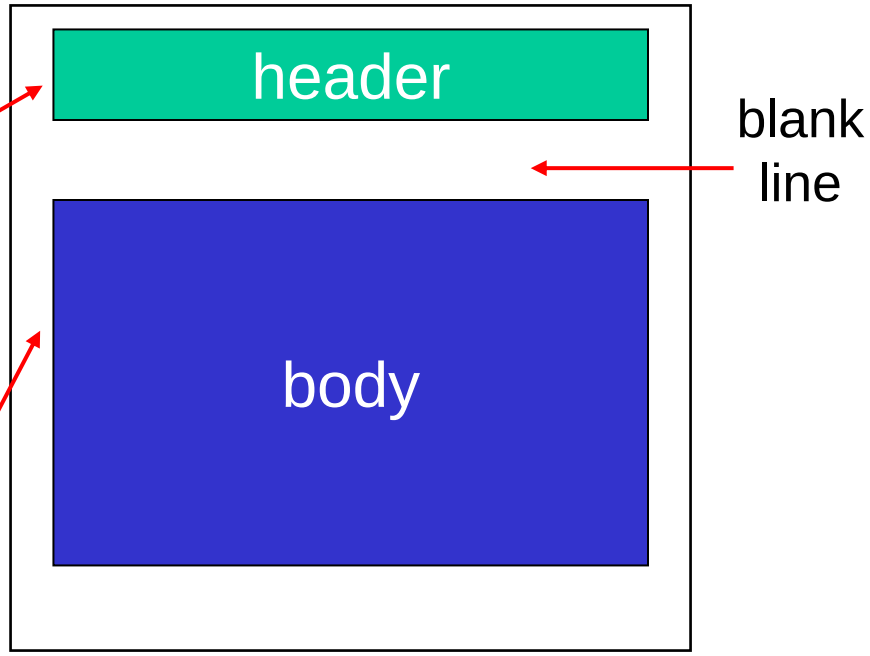
Mail message format

SMTP: protocol for exchanging email msgs

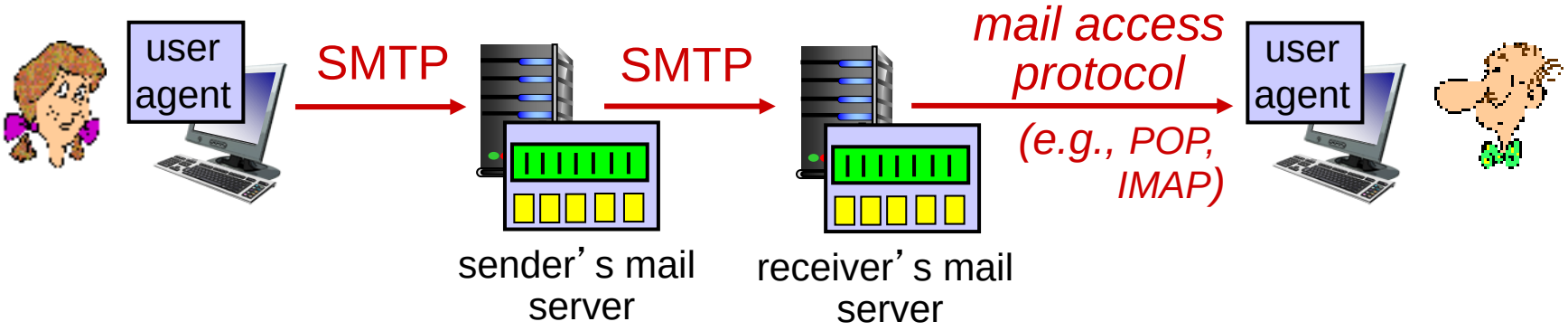
RFC 822: standard for text message format:

- header lines, e.g.,
  - To:
  - From:
  - Subject:

  different from SMTP MAIL FROM, RCPT TO: commands! (The commands in SMTP were part of the SMTP handshaking protocol; the header lines examined in this section are part of the mail message itself)
- Body: the "message"
  - ASCII characters only



Mail access protocols



- SMTP: delivery/storage to receiver's server
- mail access protocol: retrieval from receiver's server
  - POP: Post Office Protocol [RFC 1939]: authorization, download
  - IMAP: Internet Mail Access Protocol [RFC 1730]: more features, including manipulation of stored msgs on server
  - HTTP: gmail, Hotmail, Yahoo! Mail, etc.

POP3 protocol

authorization phase

- client commands:
  - **`user`**: declare username
  - **`pass`**: password
- server responses
  - **`+OK`**
  - **`-ERR`**

transaction phase, client:

- **`list`**: list message numbers
- **`retr`**: retrieve message by number
- **`dele`**: delete
- **`quit`**

```
S: +OK POP3 server ready
C: user bob
S: +OK
C: pass hungry
S: +OK user successfully logged on
```

```
C: list
S: 1 498
S: 2 912
S: .
C: retr 1
S: <message 1 contents>
S: .
C: dele 1
C: retr 2
S: <message 1 contents>
S: .
C: dele 2
C: quit
S: +OK POP3 server signing off
```

POP3 (more) and IMAP

more about POP3

- previous example uses POP3 "download and delete" mode
  - Bob cannot re-read e-mail if he changes client
- POP3 "download-and-keep": copies of messages on different clients
- POP3 is stateless across sessions

IMAP

- keeps all messages in one place: at recipient mail server
- allows user to organize messages in folders
- keeps user state across sessions:
  - names of folders and mappings between message IDs and folder name

The difference between IMAP and POP is that IMAP uses a cloud server so emails can be authenticated and categorized by any device. Many email users prefer IMAP to POP because of the convenience and efficiency.

Chapter 2

Assignement # 2 (Chapter – 2)

- *2nd Assignment will be uploaded on Google Classroom after the lecture in the Stream Section, on 22nd September, 2022*
- *Due Date: Tuesday, 4th Ocotober 2022 (During the lecture)*
- *Hard copy of the handwritten assignment to be submitted directly to the Instructor during the lecture.*
- *Submit the Assignment allotted for your own section only*
- *Please read all the instructions carefully in the uploaded Assignment document, follow & submit accordingly*

Chapter 3: Transport Layer

our goals:

- understand principles behind transport layer services:
  - multiplexing, demultiplexing
  - reliable data transfer
  - flow control
  - congestion control
- learn about Internet transport layer protocols:
  - UDP: connectionless transport
  - TCP: connection-oriented reliable 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

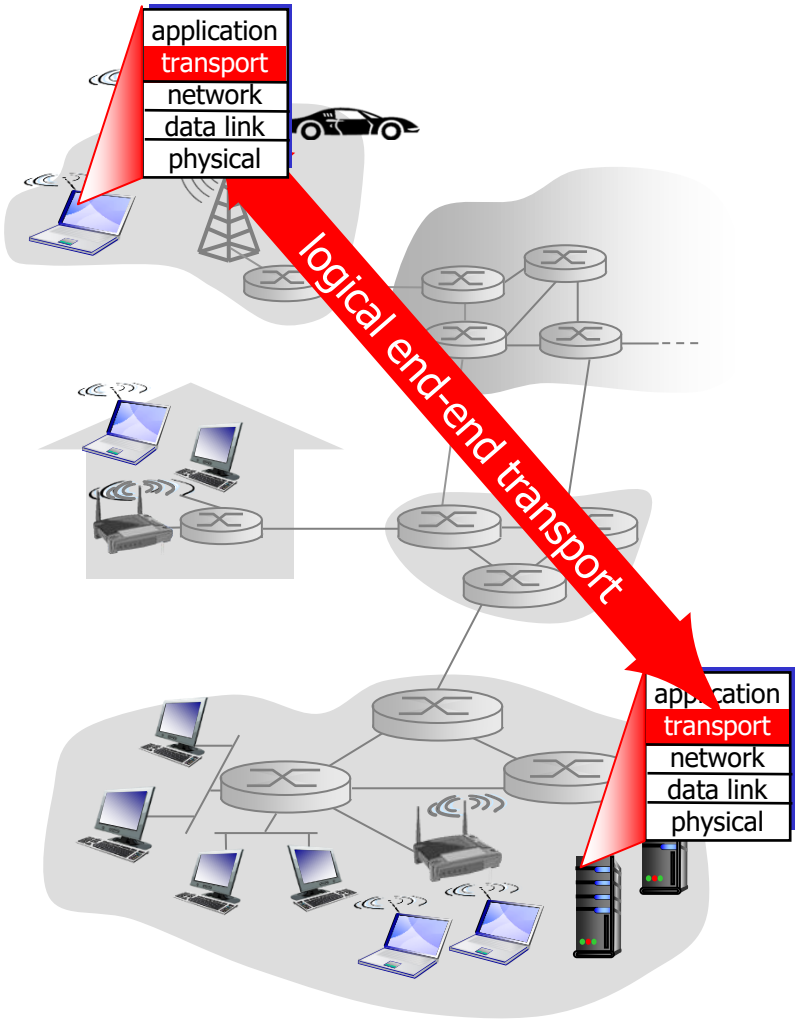
- segment structure
- reliable data transfer
- flow control
- connection management

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, SCTP etc…



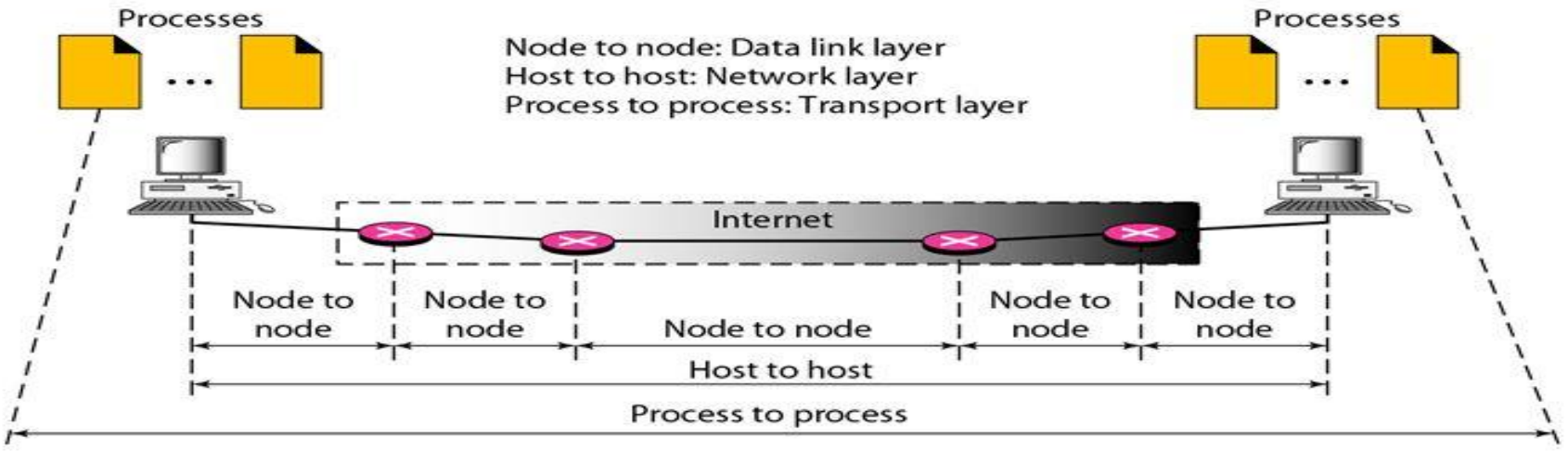
Transport Layer vs Network Layer & Data Link Layer

- The Data Link Layer is responsible for delivery of frames between two neighboring nodes over a link. This can be called node-to-node delivery.

- The network layer is responsible for delivery of datagrams between two hosts. This can be called host-to-host delivery.

Communication on the Internet is not defined as the exchange of data between two nodes or between two hosts. Real communication takes place between two processes.

- The Transport Layer is responsible for the process-to-process delivery.



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:

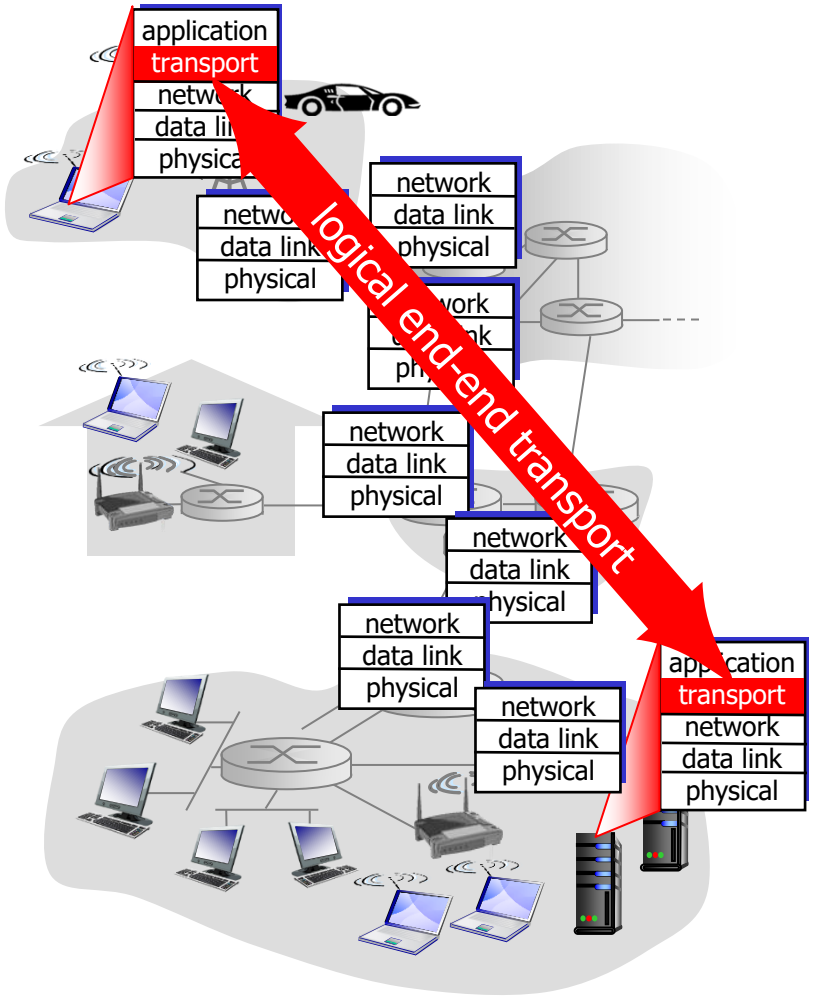
- hosts = houses
- processes = kids
- app messages = letters in envelopes
- transport protocol = Ann and Bill who demux to in-house siblings
- network-layer protocol = postal service

Functions of Transport Protocols

- Functions of the transport layer protocols include:
  - Provide for Process-to-Process communications. To accomplish this task, Port Numbers are used to identify the process, at both the client and at the server side
  - Provide for end-to-end Error Checking (both TCP and UDP), Error Control and Flow and Congestion control (only TCP)
  - TCP is a reliable protocol, UDP is an unreliable Protocol
- Neither TCP nor UDP provides for "Guaranteed Delay" or Guaranteed Bandwidth"

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



Midterm I