ECSE-4670: Computer Communication Networks (CCN)

Introduction

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Adapted in part from S.Keshav (Cornell), Peterson (Uarizona)

- Syllabus, administratrivia
- Networking: An Overview of Ideas and Issues

Who's Who

- **Instructors:**
  - Shiv Kalyanaraman; kalyas ; x8979
  - Biplab Sikdar; sikdab ; x6664
- **Course secretary:** (on-campus)
  - Jeanne Denue-Grady: JEC 6049 ; x6313
- **PDE/RSVP Point-of-contact:**
  - Kari Lewick; CII 4011; x2347
- **TAs:**
  - G.Liu, H. Yang, Y. Pei (PDE), S. Raghunath (PDE)

Web Resources

- WebCT Course Web Site:
  - http://webct.rpi.edu
  - (backup) http://www.ecse.rpi.edu/Homepages/shivkuma/teaching/fall2001/index.html
- WebCT: bulletin board, video streams, homework drop-box etc
- Text book Web Site: http://www.awl.com/kurose-ross

Course Description Highlights

- Syllabus:
  - Networking layers: application, transport, network, link
    - Issues: application models, multiplexing, reliability, flow/congestion control, error detection/correction, multiple access etc
  - Network Modeling: Elementary probability, queuing theory, analysis of a router queue, network of queues, LAN performance

Course Description Highlights (Continued)

- Lectures
- Informal quizzes: Every two weeks
- WebCT bulletin board: Post your questions! TAs monitor it daily.
- WebCT: Grades, papers, RFCs, Internet drafts…
- 2 Labs: Transport/Network layers {20 pts}
- 6 Homeworks: {30 pts}
- 3 exams: 15 pts, 15 pts, 20 pts: {50pts}

Prerequisites

- Background in **elementary probability**
  - *Probability for Engineering Applications, ECSE-4500, Discrete structures, CSCI-4320, or Modeling and Analysis of Uncertainity, ENGR-2600*
- Knowledge of **basic computer organization**
  - *ECSE-2660 Computer Architecture, Networks and Operating Systems or CSCI-2500 Computer Organization*
- **C programming** knowledge
- If you do not have the required prerequisites, you must drop the course and take it later (next year).

Still trying to get into the course ?

- Do you have the pre-requisites ?
- Please submit course add form to course secretary: Jeanne, JEC 6049 by tomorrow (Wed, Aug 29th), noon time (12 pm).
- Depending upon the number of people who drop the class, space available, TA resources available, we will add more students.
  - Decisions to be emailed to you by Jeanne.
  - Make sure you mention your email address to her.

Answers to FAQ

- All homeworks & labs due at the beginning of the class indicated on the course calendar
  - Up to one late submission: no penalty
  - Beyond that 10% penalty: only if submitted before solutions are posted.
- Exams are open-book and extremely time limited.
- Exams consist of design qns, numerical, true-false, and short answer questions.

Answers to FAQ

- Focus will be on conceptual understanding, and problem-solving skill.

- Labs are based upon the programming assignments suggested in chap 3 and 4 of the textbook
- Informal quizzes will be given for your benefit once in 2-3 weeks to recap/test recently covered material and reading assignments. No grading.

Information, Computers, Networks

- Information: anything that is represented in *bits*
  - *Form* (can be represented as bits) vs
  - *Substance* (cannot be represented as bits)
- Properties:
  - Infinitely replicable
  - Computers can "*manipulate*" information
  - Networks create "*access*" to information

Networks

- Potential of networking:
  - move bits *everywhere*, *cheaply*, and with desired *performance characteristics*
  - *Break the space barrier for information*
- Network provides "connectivity"

What is "*Connectivity*" ?

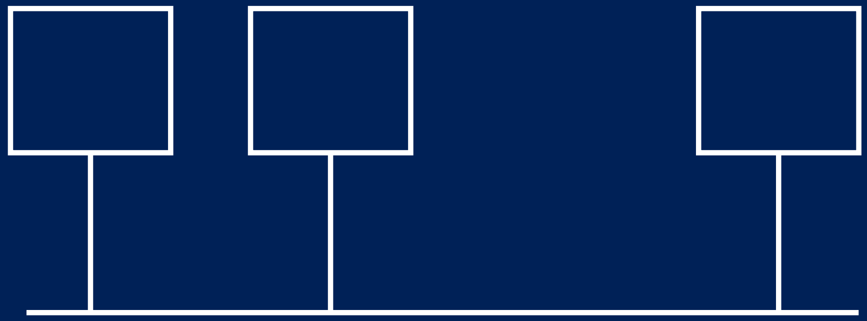
- Direct or indirect access to every other node in the network
- Connectivity is the magic needed to communicate if you do not have a direct pt-pt physical link.
  - *Tradeoff: Performance characteristics worse than true physical link!*

Connectivity.

- Building Blocks
  - links: coax cable, optical fiber...
  - nodes: general-purpose workstations...

- *Direct* connectivity:
  - <u>point-to-point</u>

  - <u>multiple access</u>



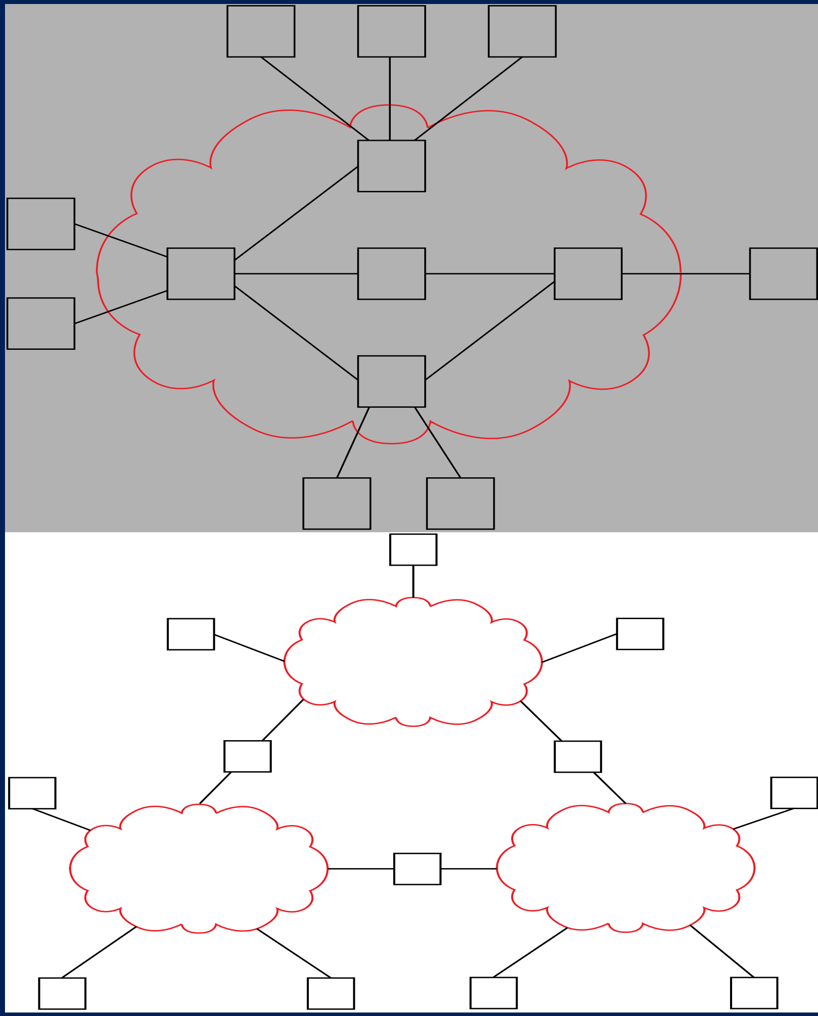
Connectivity..

- *Indirect* Connectivity
  - switched networks

    => *switches*

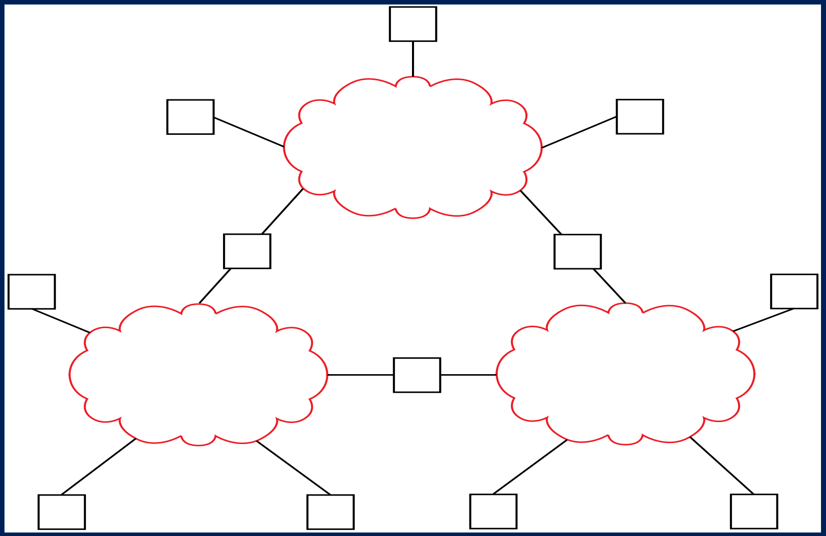
  - inter-networks

    => *routers*



Connectivity …

- Internet:
  - *Best-effort*
    (no performance guarantees)
  - *Packet-by-packet*



- A pt-pt physical link:
  - *Always-connected*
  - *Fixed bandwidth*
  - *Fixed delay*
  - *Zero-jitter*

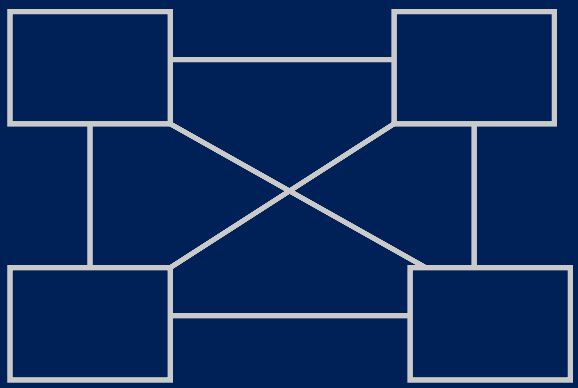
Point-to-Point Connectivity

- **Physical** layer: coding, modulation etc
- **Link** layer needed if the:
  - link is shared between apps (**framing, medium access control, multiplexing**)
  - link is unreliable (**reliability**)
  - link is used sporadically and traffic can flood receivers (**flow control**)
- ***No need for protocol concepts*** like addressing, names, routers, hubs, forwarding, filtering …

Connecting N users: *Directly* ...

- ***Bus***: broadcast, collisions, media access control
- ***Full mesh***: Cost vs simplicity

Bus



Full mesh

- **Address concept** needed if we want the receiver *alone* to consume the packet!

List of Problems (so far)

- Topologies
- Framing
- Error control
- Flow control
- Multiple access
  - How to share a wire

How to build Scalable Networks?

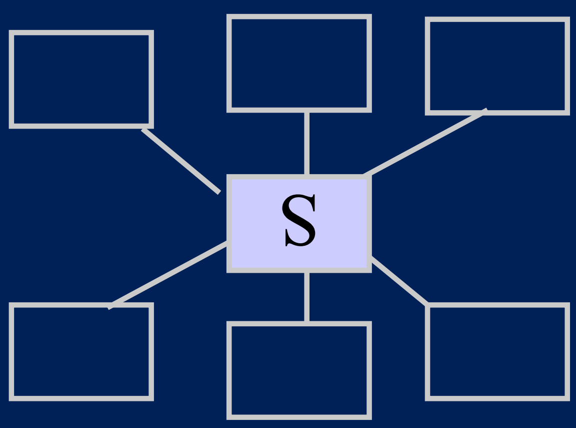
- <u>Scaling:</u> system allows the increase of a key parameter. Eg: let N increase…
  - *<u>Inefficiency limits scaling</u>* …
- Direct connectivity is *<u>inefficient</u>* & hence does not scale
  - Mesh: *inefficient* in terms of # of links
  - Bus architecture: 1 expensive link, N cheap links. *Inefficient* in bandwidth use

Filtering, forwarding …

- **Filtering**: choose a subset of elements from a set
  - *Filtering is the key to efficiency & scaling*
- **Forwarding**: actually sending packets to a filtered subset of link/node(s)
  - Packet sent to one link/node => efficient
- **Solution:** Build nodes which filter/forward and connect indirectly => "switches" & "routers"

Connecting N users: *Indirectly*

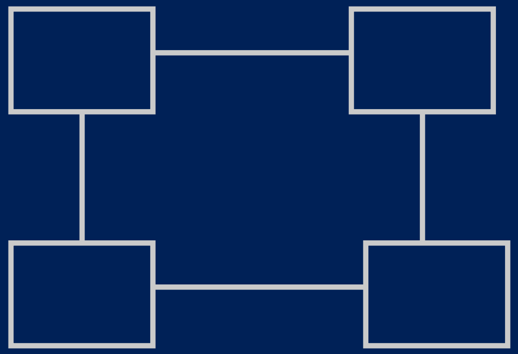
- Star: One-hop path to any node, reliability, forwarding function
- "Switch" S can filter and forward!
  - Switch may forward multiple pkts in parallel for additional efficiency!



Star

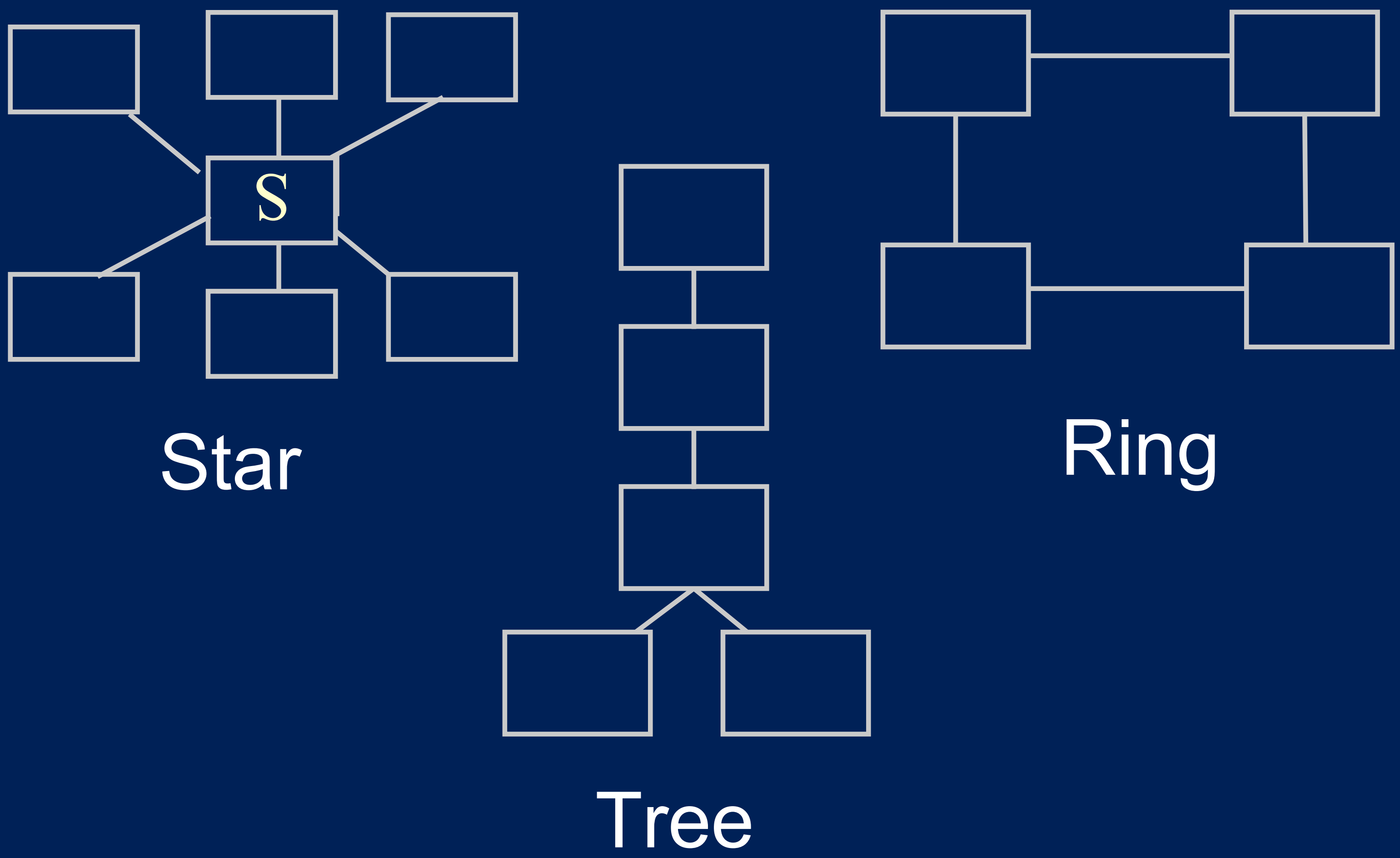
Connecting N users: *Indirectly* …

- Ring: Reliability to link failure, near-minimal links
- All nodes do "forwarding" and "filtering"

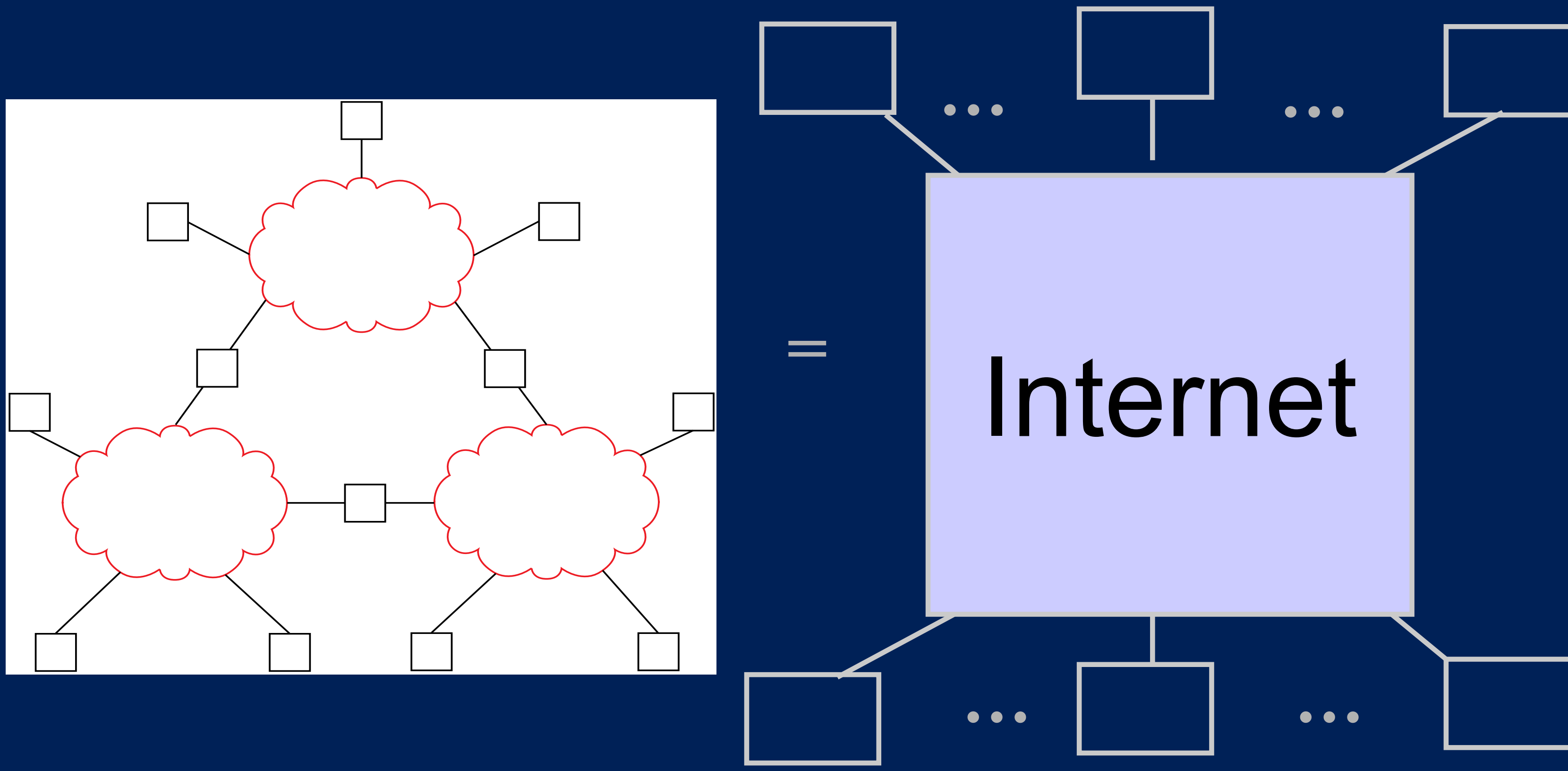


Ring

Topologies: Indirect Connectivity



Inter-Networks: *Networks of Networks*



Our goal is to design this black box on the right

Inter-Networks: Networks of Networks

- Internetworking involves two fundamental problems: *heterogeneity and scale*
- Concepts:
  - Translation, overlays, address & name resolution, fragmentation: to handle ***heterogeneity***
  - Hierarchical addressing, routing, naming, address allocation, congestion control: to handle ***scaling***
- Covered in more detail in "Internet Protocols“ course

Additions to Problem List

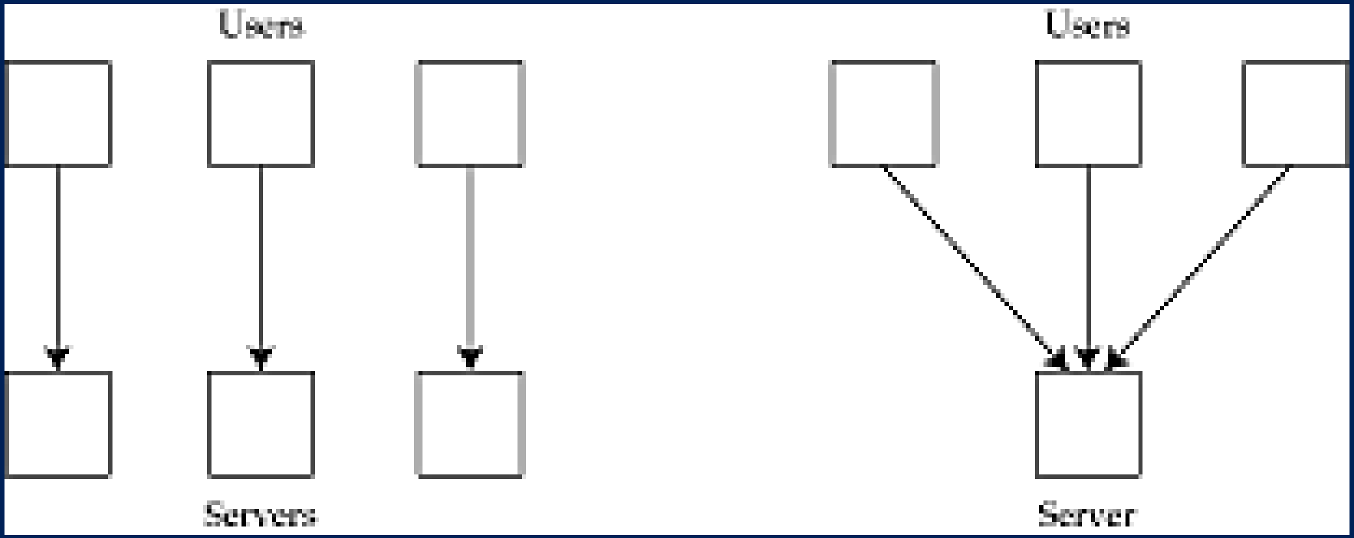
- Fragmentation
- Switching, bridging, routing
- Naming, addressing
- Congestion control, traffic management
- Reliability

How to do system design ?

- **Eg goal: Design an Inter-network…**
- ***Resources:***
  - Space
  - Time
  - Computation
  - Money
  - Labor
- **Design:** *tradeoff cheaper resources against expensive ones to meet goals.*

Building blocks: *Multiplexing*

- **Multiplexing = sharing**
  - Trades time and space for money
  - *Cost*: waiting time, buffer space & packet loss
  - *Gain*: Money => Overall system costs less

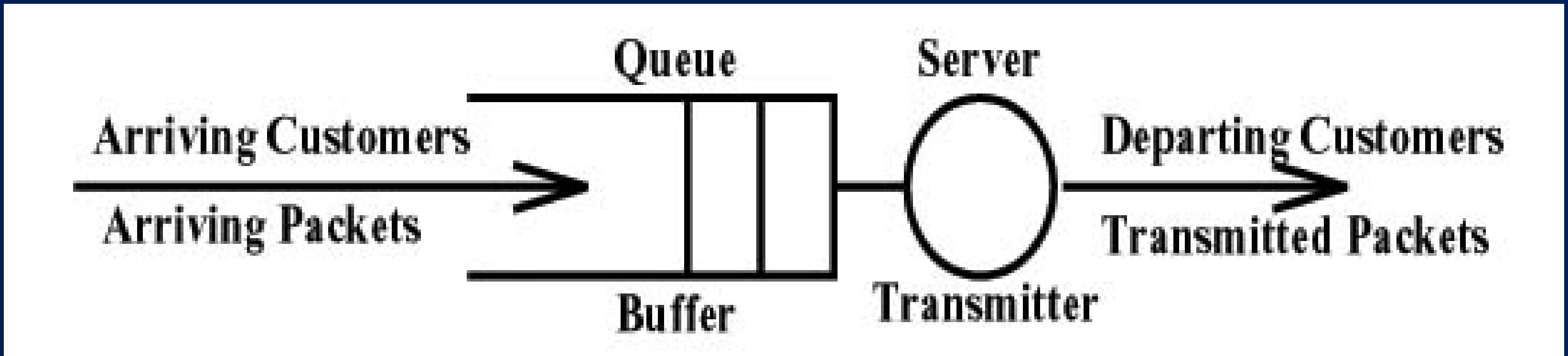


Statistical Multiplexing

- Reduce resource requirements by ***exploiting statistical knowledge*** of the system.
  - Eg: average rate <= service rate <= peak rate
  - If service rate < average rate, then system becomes **unstable**!!
    - First design to ensure system stability!!
  - Then, for a stable multiplexed system:
    - ***Gain*** = peak rate/service rate.
    - ***Cost***: buffering, queuing delays, losses.

Stability of a Multiplexed System

Average Input Rate > Average Output Rate => system is unstable!



How to ensure stability ?

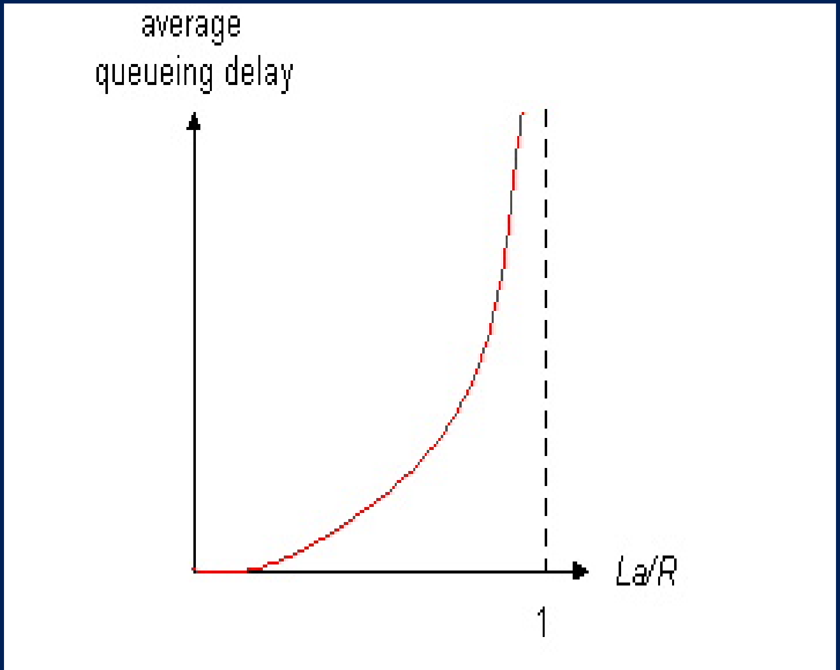
1. Reserve enough capacity so that demand is less than reserved capacity
2. Dynamically detect overload and adapt either the demand or capacity to resolve overload

What’s a performance *tradeoff* ?

- A situation where you cannot get something for nothing!
- Also known as a zero-sum game.

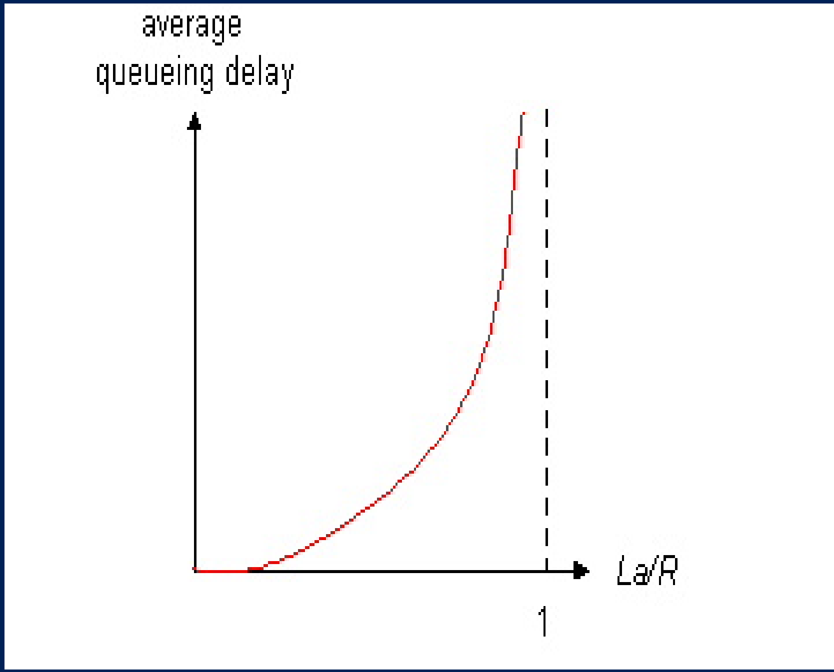
- R=link bandwidth (bps)
- L=packet length (bits)
- a=average packet arrival rate

Traffic intensity = La/R



What's a performance *tradeoff* ?

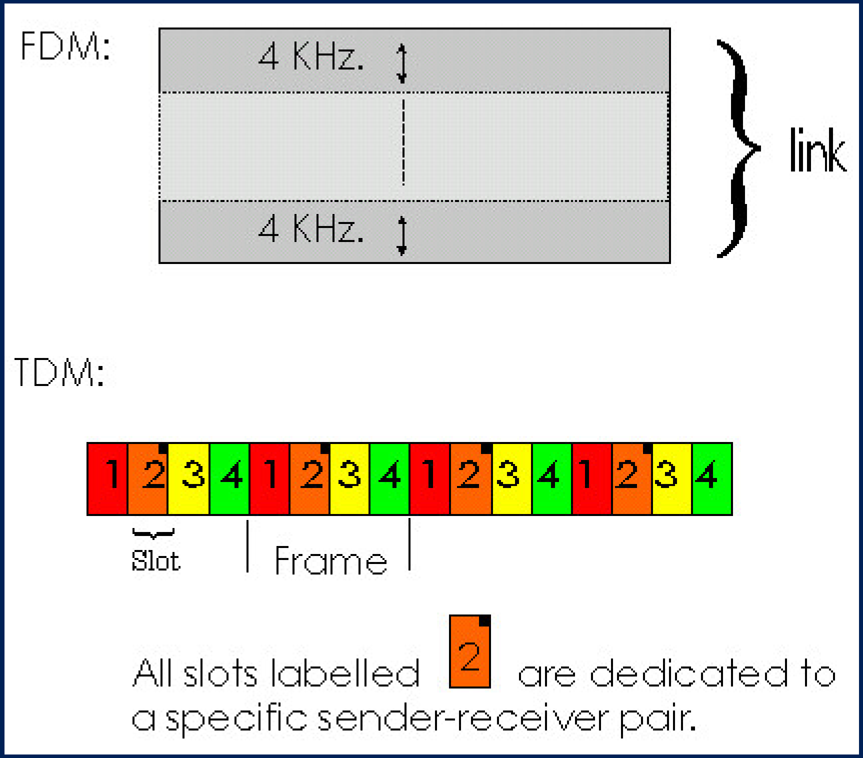
- **La/R ~ 0: average queuing delay small**
- **La/R -> 1: delays become large**
- **La/R > 1: average delay infinite (*service degrades unboundedly => instability*)!**



Example Design: *Circuit-Switching*

Circuit-switching: A form of multiplexing

- Divide link bandwidth into "pieces"
- Reserve pieces on successive links and tie them together to form a "*circuit*"
- Map traffic into the reserved circuits
- Resources wasted if unused: *expensive*.



- Mapping can be done without "headers".
- Everything inferred from timing.

Example Design: *Packet-Switching*

Packet-switching: Another form of multiplexing:

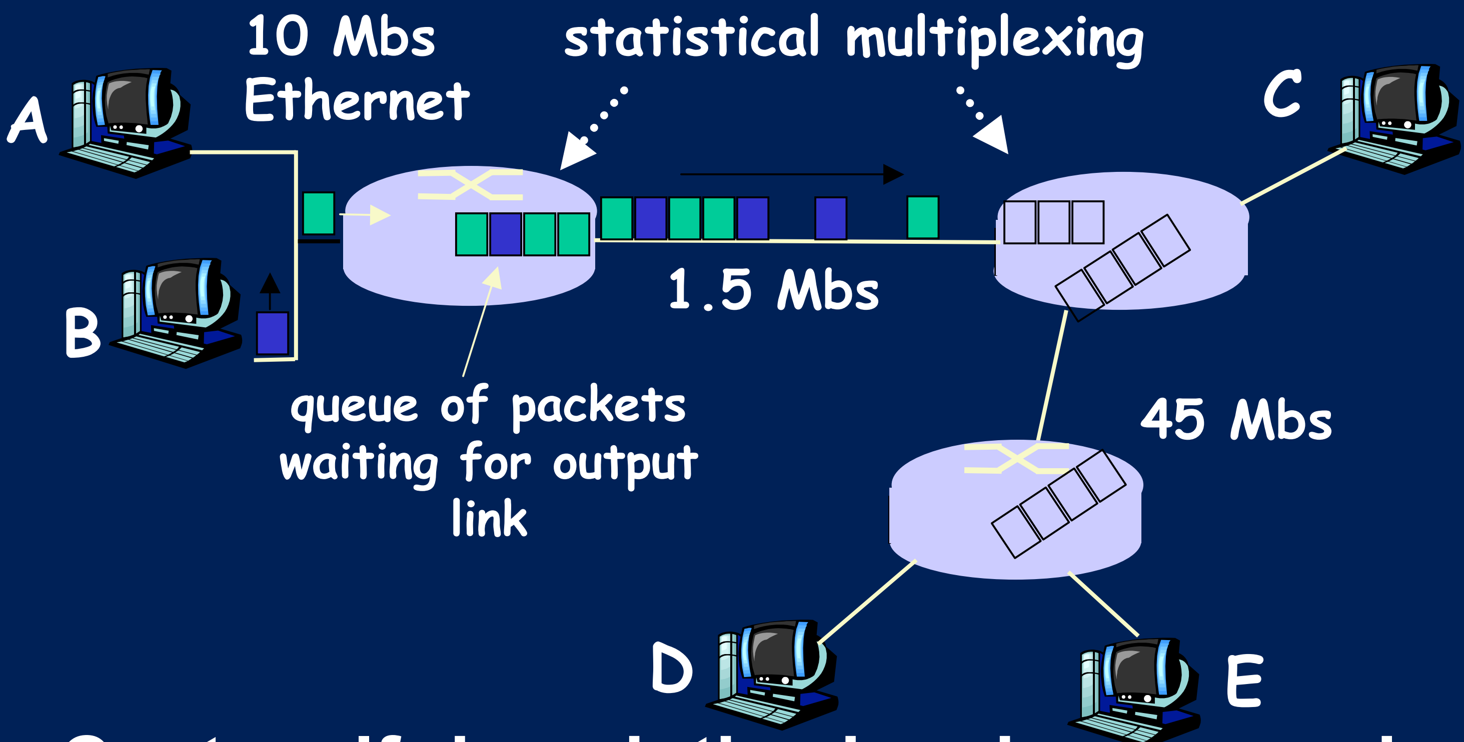
- Chop up data (not links!) into "packets"
  - Packets: data + meta-data (header)
- "Switch" packets at intermediate nodes
  - *Store-and-forward* if bandwidth is not immediately available.

Bandwidth division into "pieces"

Dedicated allocation

Resource reservation

Packet Switching



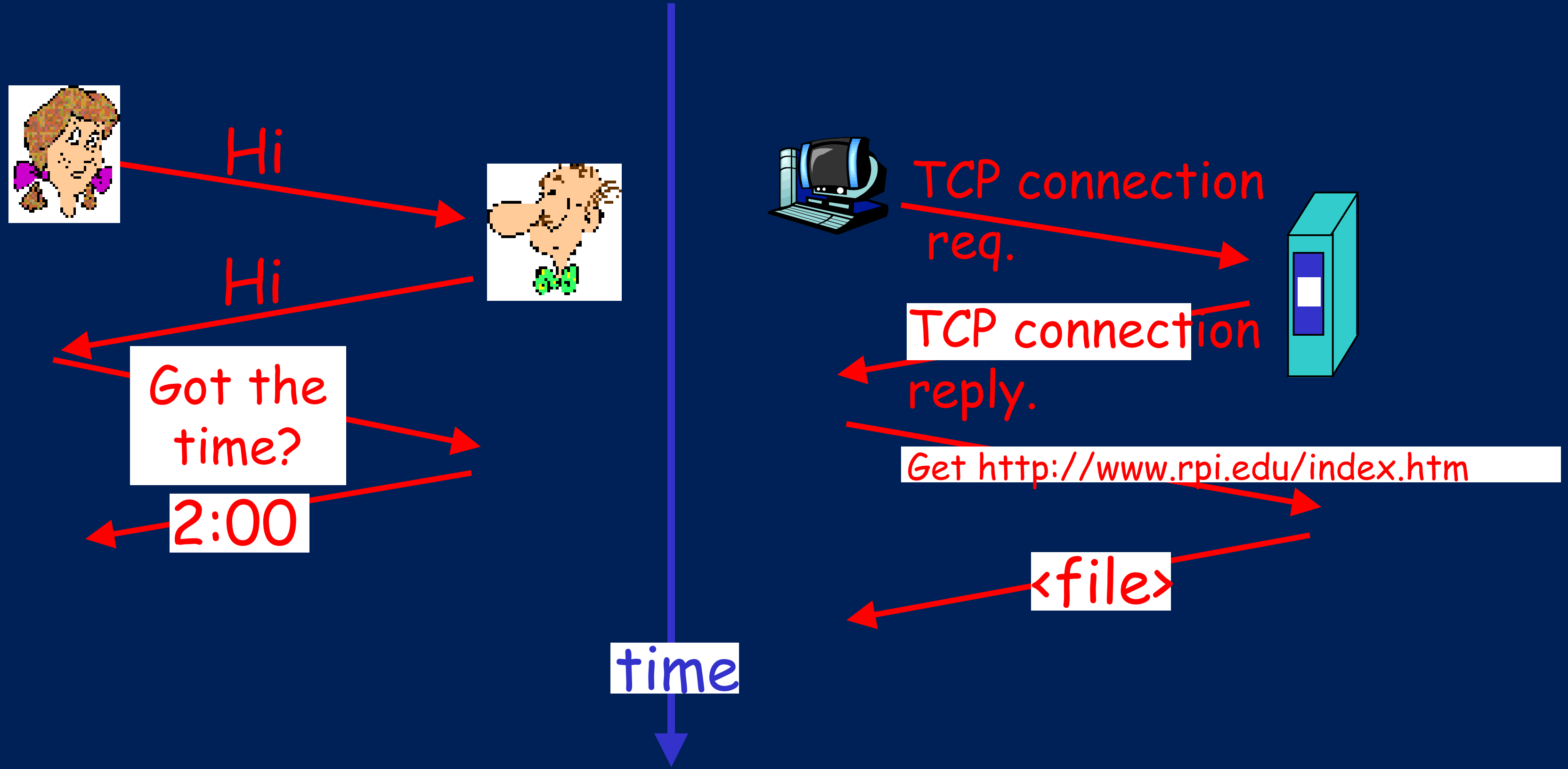
- Cost: self-descriptive header per-packet, buffering and delays for applications.
- Need to either reserve resources or dynamically detect/adapt to overload for stability

Summary of System Design Ideas

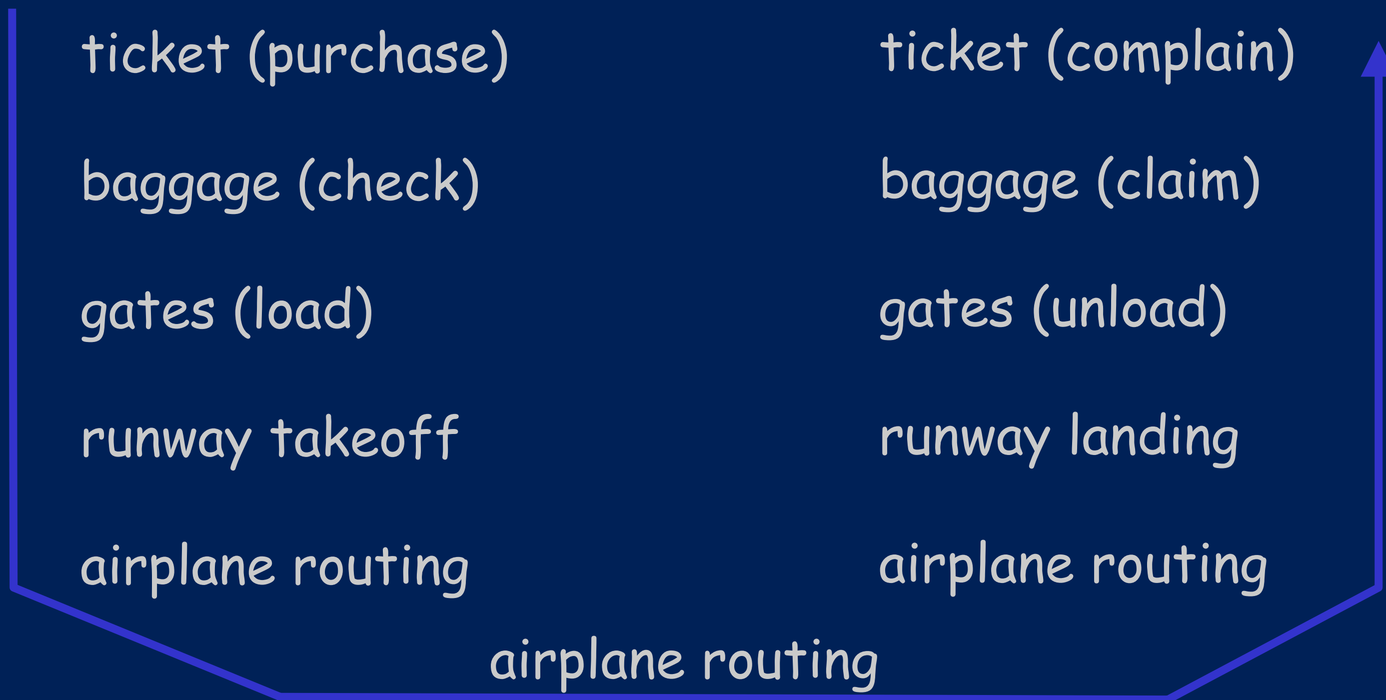
- Multiplexing
- Statistical Multiplexing
- Stability and performance tradeoffs
- Circuit switching
- Packet switching

What are protocols ?

- Networking software is organized as ***protocols***
- Eg: Human protocol vs network protocol:



Analogy: Organization of air travel



- **Protocols: a series of functions performed at different locations**

Organization of air travel: *a different view*

Layers: each layer implements a *service*

- **via its own internal-layer actions**
- **relying on services provided by layer below**

Layered air travel: *services*

Counter-to-counter delivery of person+bags

baggage-claim-to-baggage-claim delivery

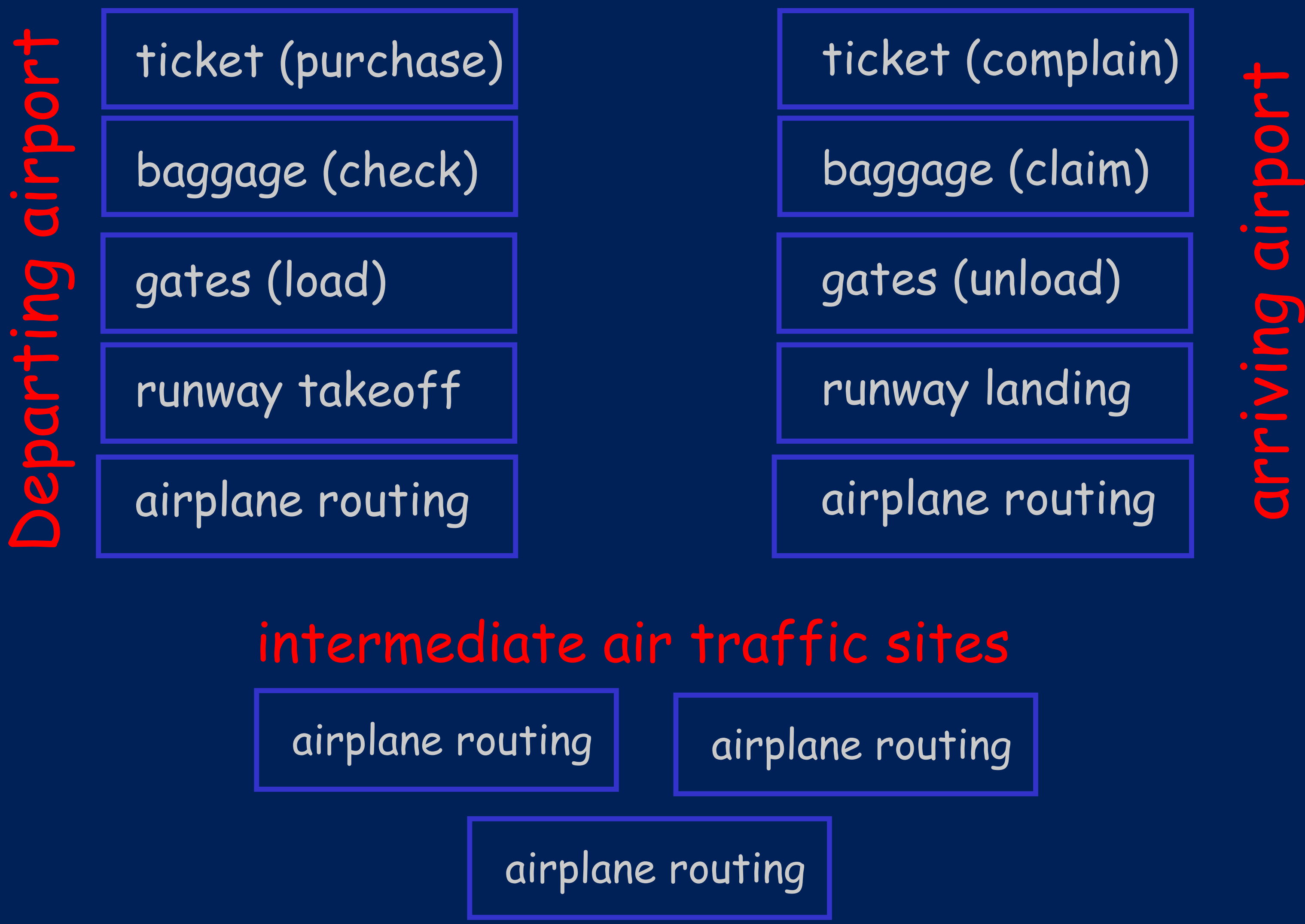
people transfer: loading gate to arrival gate

runway-to-runway delivery of plane

airplane routing from source to destination

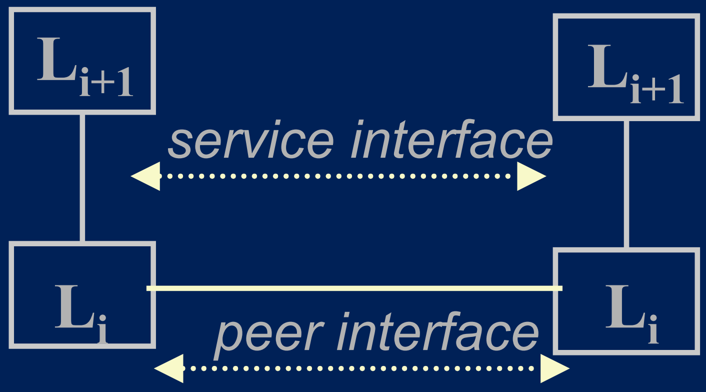
Similarly, we organize network protocols into a bunch of layers!

Distributed implementation of layers

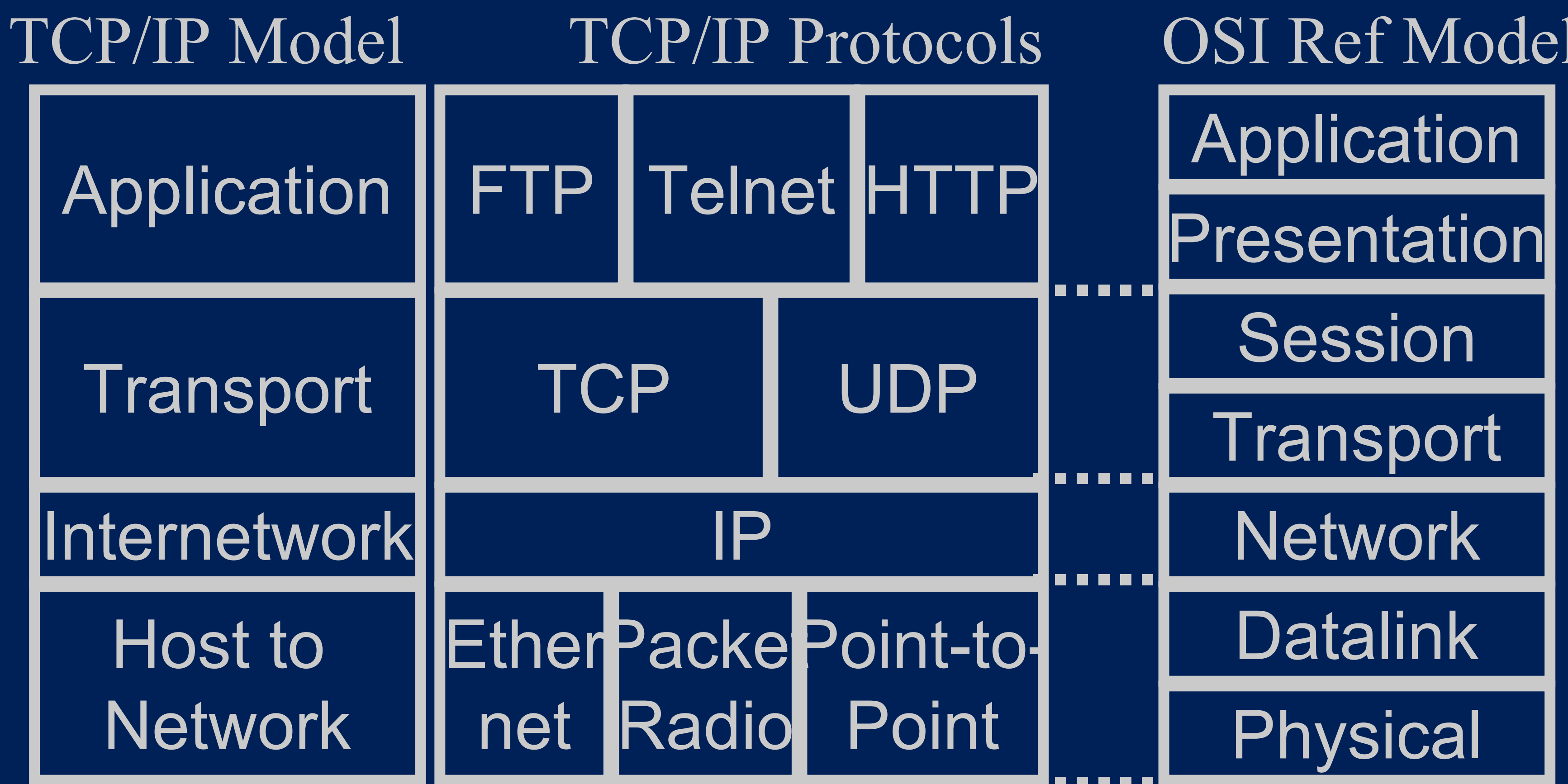


Protocol Implementations

- Are building blocks of a network architecture
- Each protocol object has two different interfaces
  - *service interface*: defines operations on this protocol
  - *peer-to-peer interface*: defines messages exchanged with peer



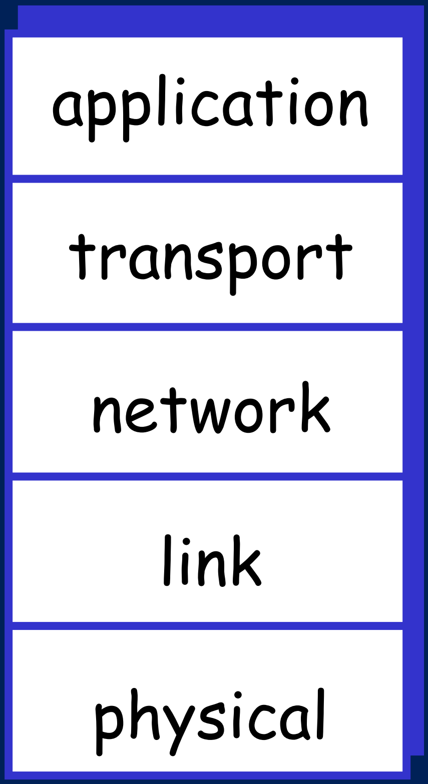
Reference Models for Layering



"Top-down" approach means we will first learn the application layer and then learn about lower layers

Internet protocol stack

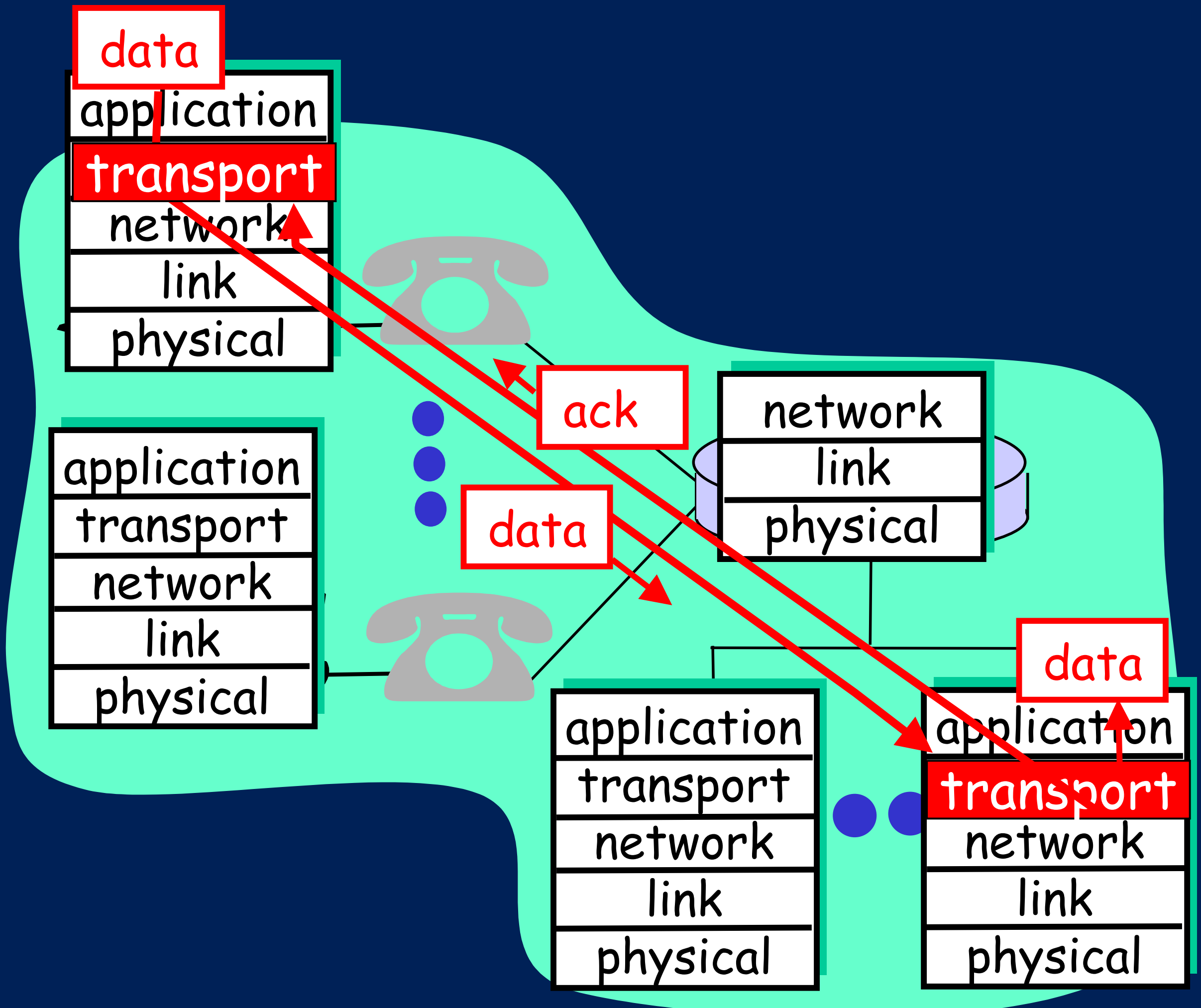
- **application:** supporting network applications
  - ftp, smtp, http
- **transport:** host-host data transfer
  - tcp, udp
- **network:** routing of datagrams from source to destination
  - ip, routing protocols
- **link:** data transfer between neighboring network elements
  - ppp, ethernet
- **physical:** bits "on the wire"



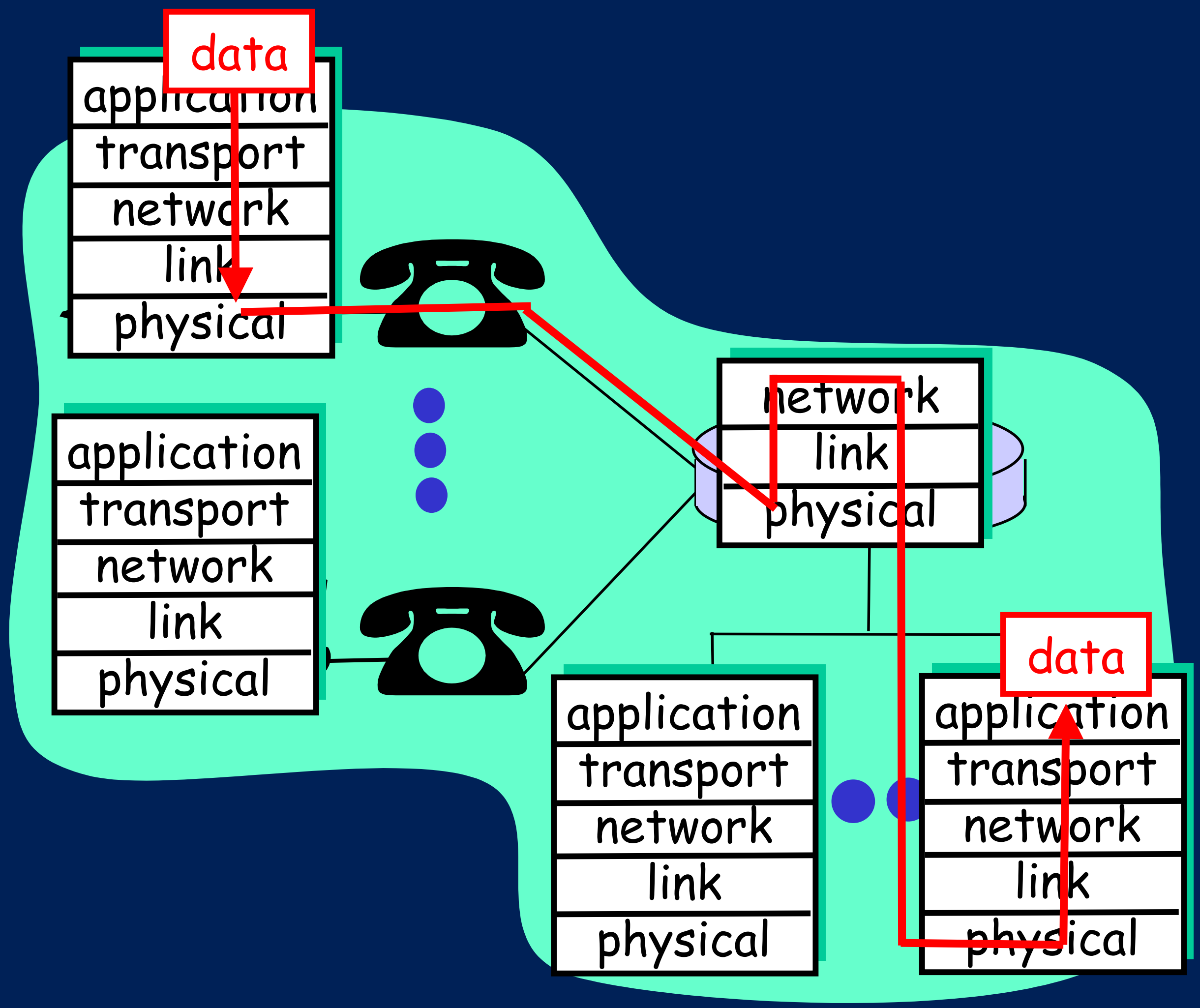
Layering: ***logical*** communication

E.g.: transport

- take data from app
- add addressing, reliability check info to form "datagram"
- send datagram to peer
- wait for peer to ack receipt
- analogy: post office



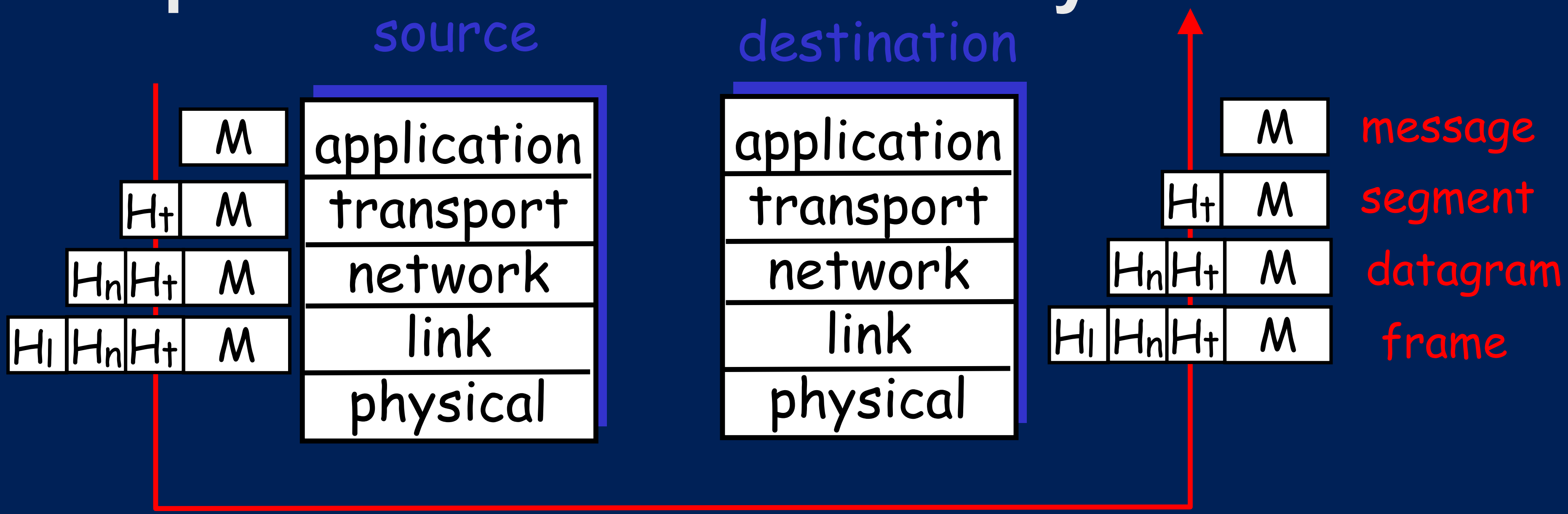
Layering: ***physical*** communication



Protocol layering and data

Each layer takes data from above

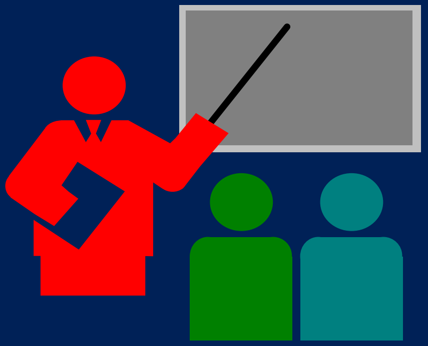
- **adds header** information to create new data unit (“**encapsulation**”)
- passes new data unit to layer below



Design Perspectives

- *Network users:* **services that their *applications need*, e.g., guarantee that each message it sends will be delivered without error within a certain amount of time**
- *Network designers:* ***cost-effective design* e.g., that network resources are efficiently utilized and fairly allocated to different users**
- *Network providers:* **system that is easy to *administer and manage* e.g., that faults can be easily isolated and it is easy to account for usage**

Summary



- Administratrivia
- Networks, connectivity, topologies …
- Pot Pourri of networking concepts and problems to be explored in this course ...