L1: Introduction

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Acknowledgements

- Some pictures used in this presentation were obtained from the Internet
- The instructor used the following references
  - Larry L. Peterson and Bruce S. Davie, Computer Networks: A Systems Approach, 5th Edition, Elsevier, 2011
  - Andrew S. Tanenbaum, Computer Networks, 5th Edition, Prentice-Hall, 2010
  - James F. Kurose and Keith W. Ross, Computer Networking: A Top-Down Approach, 5th Ed., Addison Wesley, 2009
  - Larry L. Peterson's (http://www.cs.princeton.edu/~llp/) Computer Networks class web site

Lecture Outline

- About the class
- Network building blocks
- Laying and architecture

Course Overview by Topics

- Foundation
  - Layering
  - Topology design
  - Internet architecture
  - Bandwidth and latency
- Links and simple networking
  - Classes of links and physical media
  - Encoding
  - Framing
  - Error detection and correction
  - Case studies
- Internetworking
  - Switching and bridging
  - Basic internetworking
  - Routing
  - Implementation and performance
- Advanced internetworking
  - Interdomain routing
  - IPv6
- End-to-End protocols
  - Simple demultiplexer
  - Reliable byte stream
- Congestion control and resource allocation
- Network security
- Network analysis
  - Probabilistic modeling
  - Computer simulation
- Software and applications

Textbook

- Required textbook: Computer Networks: A Systems Approach (5th edition), by Larry Peterson and Bruce Davie

- 1 Foundation
- 2 Getting Connected
- 3 Internetworking
- 4 Advanced networking
- 5 End-to-end protocols
- 6 Congestion control and resource allocation
- 7 End-to-end data
- 8 Network security
- 9 Applications

Requirement

- Class participation
  - Attendance
  - Discussion
  - In-class exercises
- Review after class
  - Lecture nodes/slides
  - Read relevant sections in the textbook
- Assignments
  - Homework
  - Labs
  - Project
  - Presentations
- Exams and Quizzes
  - Midterm
  - Final

Open Discussion

- What is the Class for?

What is the Class for?

- Focus on the ***designers*** of future products and protocols
  - To understand underlying principles of networking
- Exposure for the network administrators and application developers

Systems Approach

- What are the ways that a user can get connected to a larger network? (Connectivity)
- How do we grow networks in size? (Scalability)
- What are the ways to allow different network products and protocols to coexist on the same network? (Heterogeneity)
- How do we manager resources on the network and satisfy requirements of different users? (Resource management and congestion control)
- How do we keep data transmitted over networks secure? (Network security)
- ……

System Approach

- Building and designing networks
  - Foundation: basic concepts
  - Direct link network
    - Nodes and links
  - Grow network
    - Direct link network → switched network → internetworks
      - The Internet is an internetwork
  - Network applications and security

Foundation

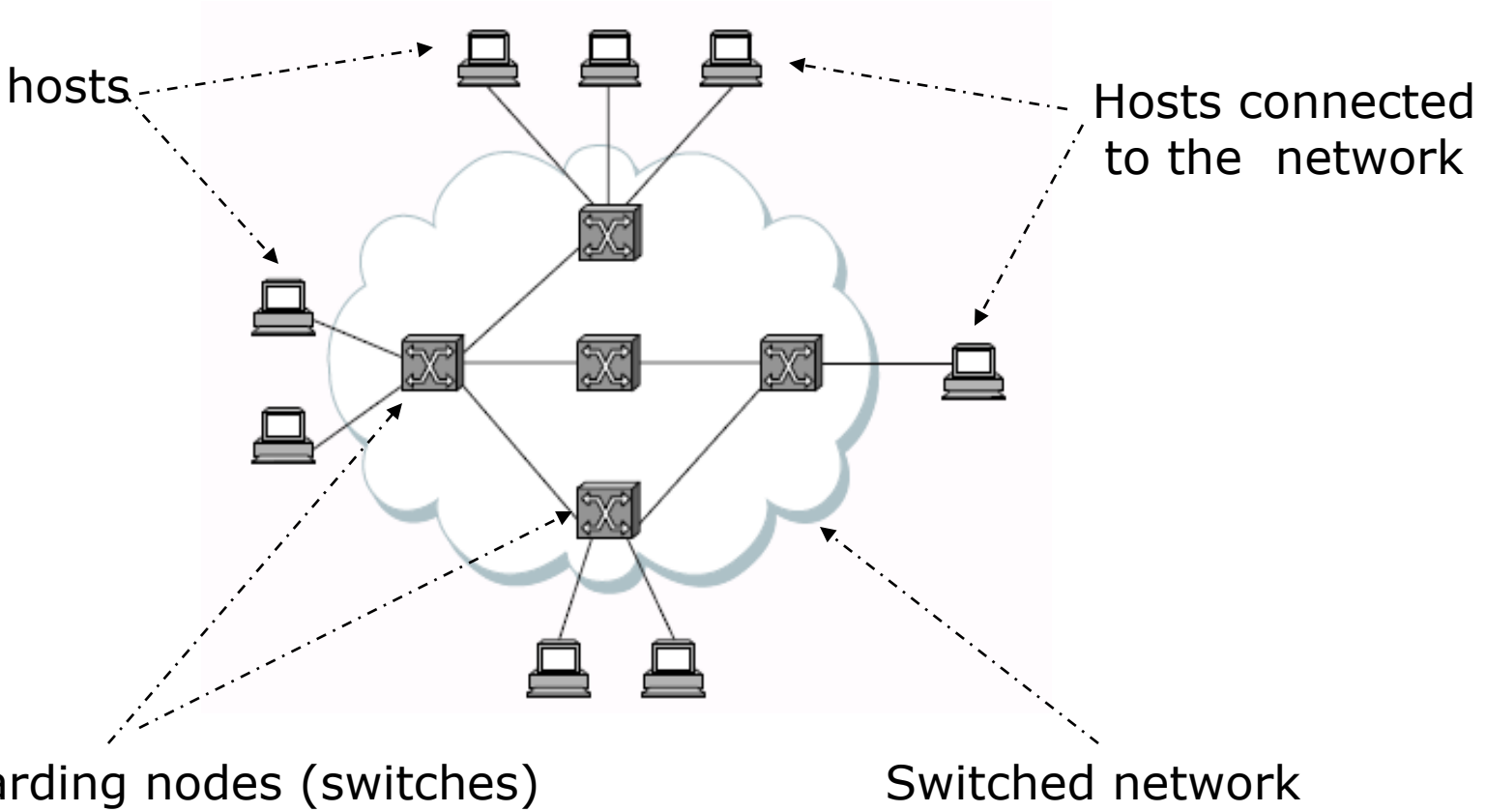
- Topics
  - Cover primarily section 1.3
  - Computer network concept
  - Network architecture
    - Layering and Protocols
    - Internet Architecture
- Reading assignment
  - Chapter 1 (section 1.1, 1.2, and 1.3)

What is a ***Computer*** Network?

- Built primarily from ***general-purpose*** programmable hardware
- Optimized for carrying many ***different types of data***
- Support a wide, and ever-growing, range of ***applications***.

A Network Consisting of Nodes and Links

Nodes can be indirectly connected!



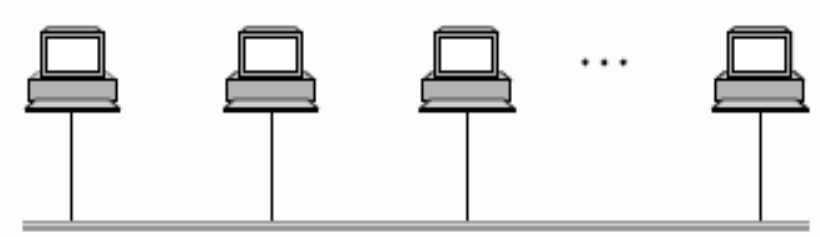
Nodes and Links

- Nodes: personal computers, server computers, special-purpose hardware …
- Links:
  - Physical media
    - Coax cable, optical fiber, twisted-pair network cable, wireless (EM radiation, acoustic waves, …) …
  - Connection type
    - Point-to-point
    - Multiple access

Direct Link Networks

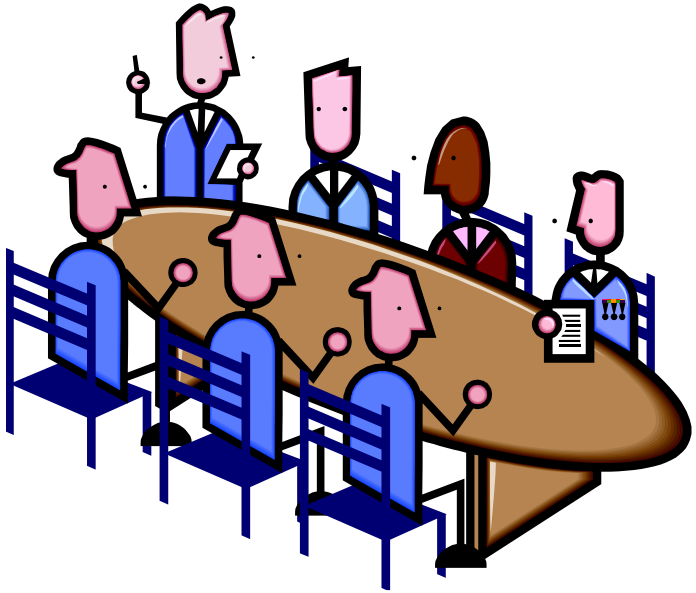
- Point-to-point networks
- Multiple access networks

Point-to-point link



Multiple access link

Direct Link Networks: Two Types of Links

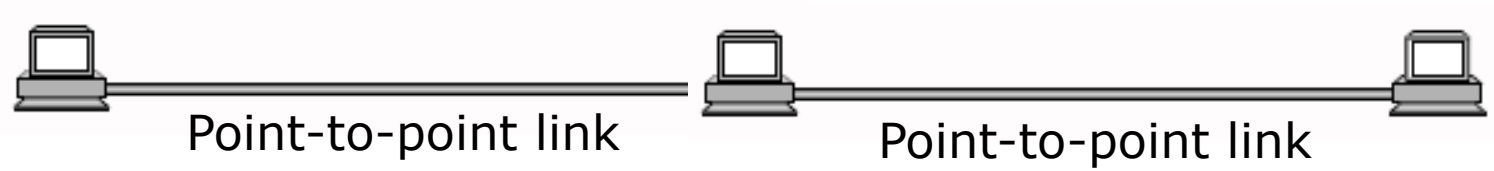


Direct Link Networks: Advantage and Disadvantages

- What are their *advantage and disadvantage* between point-to-point and multiple access networks?

Grow Network in Size

- Direct link networks are small
- How to grow networks in size?
  - Switched networks: a network of networks connected by network switches
  - A network switch (forwarding node) is a node with two or more links
    - Forward messages from one network to other networks



Switched Networks

- Circuit-switched networks
  - Carry bit-streams
    - Establishes a dedicated circuit across a sequence of links between source node and destination node
    - Allows the source node to send a stream of bits across this circuit to a destination node.
  - e.g.: original telephone network
- Packet-switched networks
  - Store-and-forward messages
    - Receive: each node in a store-and-forward network first receives a complete packet over some link
    - Store: stores the packet in its internal memory
    - Forward: forwards the complete packet to the next node.
  - e.g.: Internet

Identifying Nodes

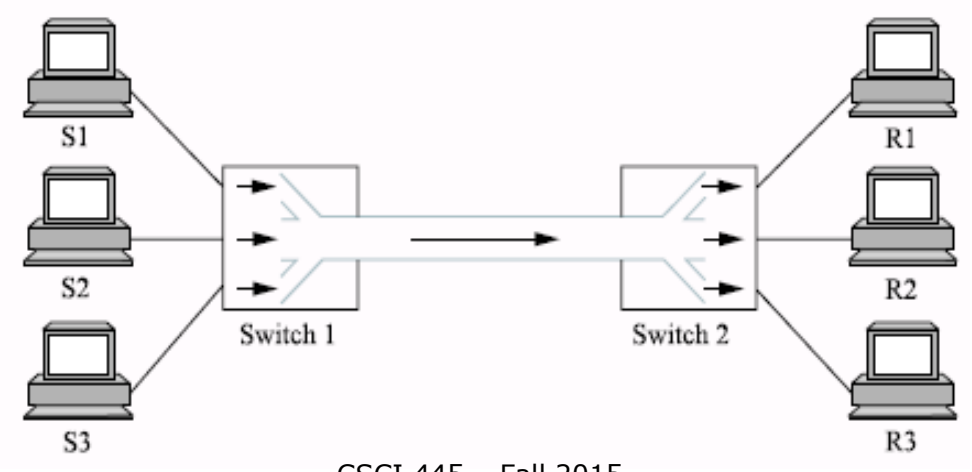
- When networks grow, there is a need to identify and differentiate different nodes and to forward messages to a or a set of nodes
- Addressing and routing

Addressing and Routing

- Address: byte-string that identifies a node
  - Usually unique
- Routing: process of finding ways to forward messages to the destination nodes based on its address
- Type of addresses
  - Unicast: node-specific
  - Broadcast: all nodes on the network
  - Multicast: some subset of nodes on the network

Multiplexing

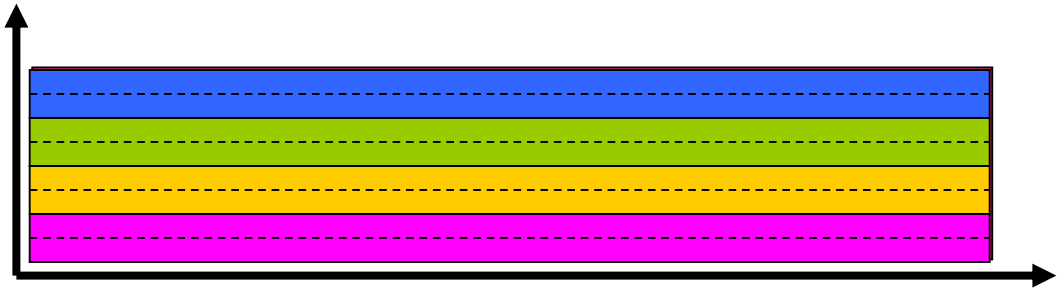
- A system resource is shared among multiple users
- Examples:
  - Time-division multiplexing (TDM)
  - Frequency-division multiplexing (FDM)



FDM and TDM

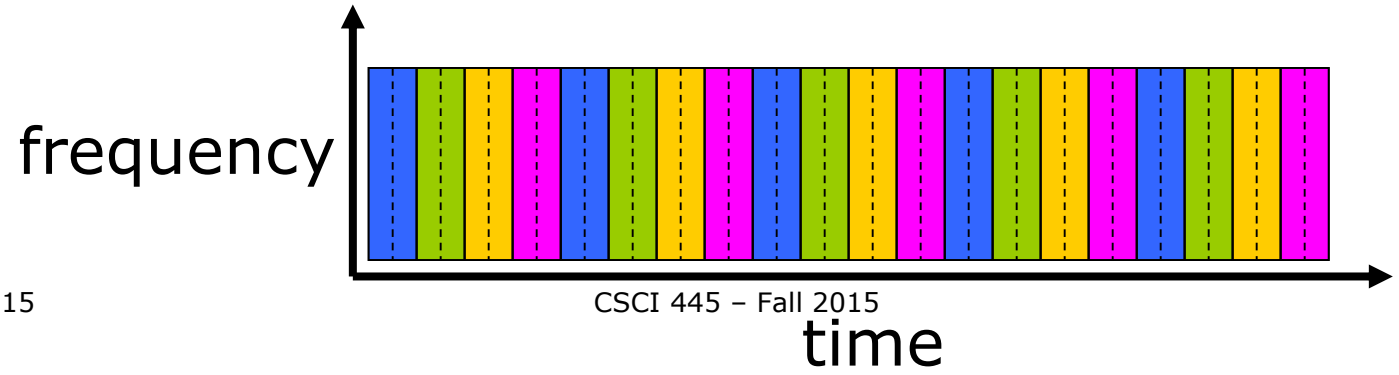
Example:

4 users



FDM

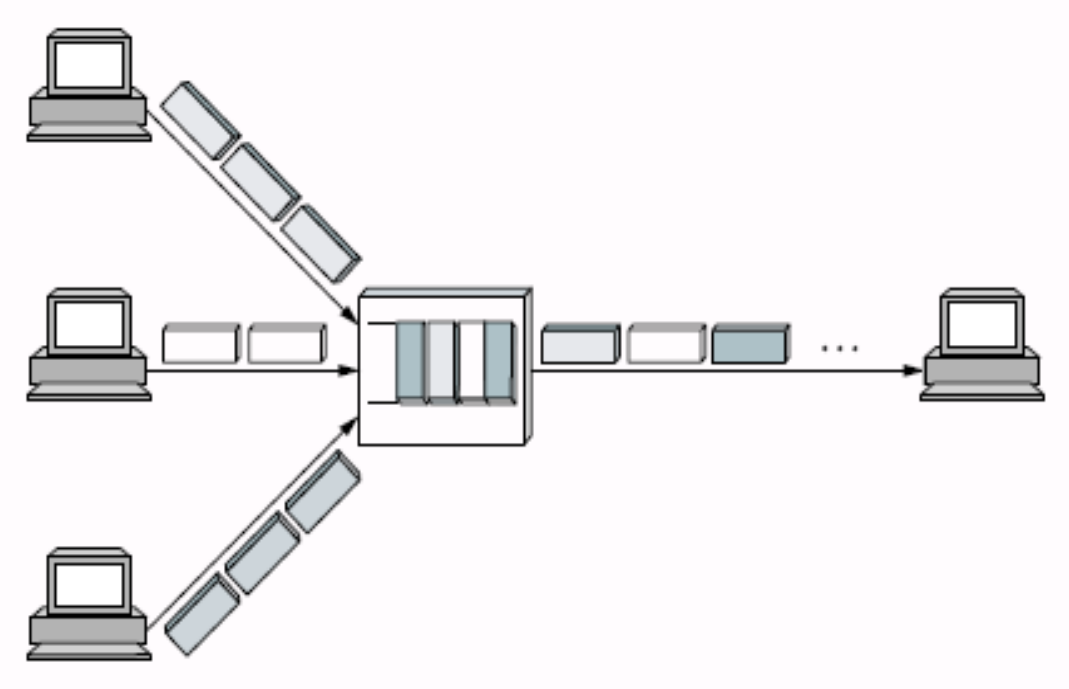
TDM



Static and Statistical Multiplexing

- Static Multiplexing
  - Examples: TDM and FDM
  - Limitations
    - If one flow does not have any data to send, its share of physical link (time quantum or frequency) remains idle
    - The maximum number of flows is fixed and known ahead of time
- Statistical Multiplexing
  - On-demand time-division
  - Schedule link on a per-packet basis
  - Packages from different sources interleaved on link
  - Buffer packets that are contending for the link
  - Congestion: Buffer (queue) overflow

An Example of Multiplexing



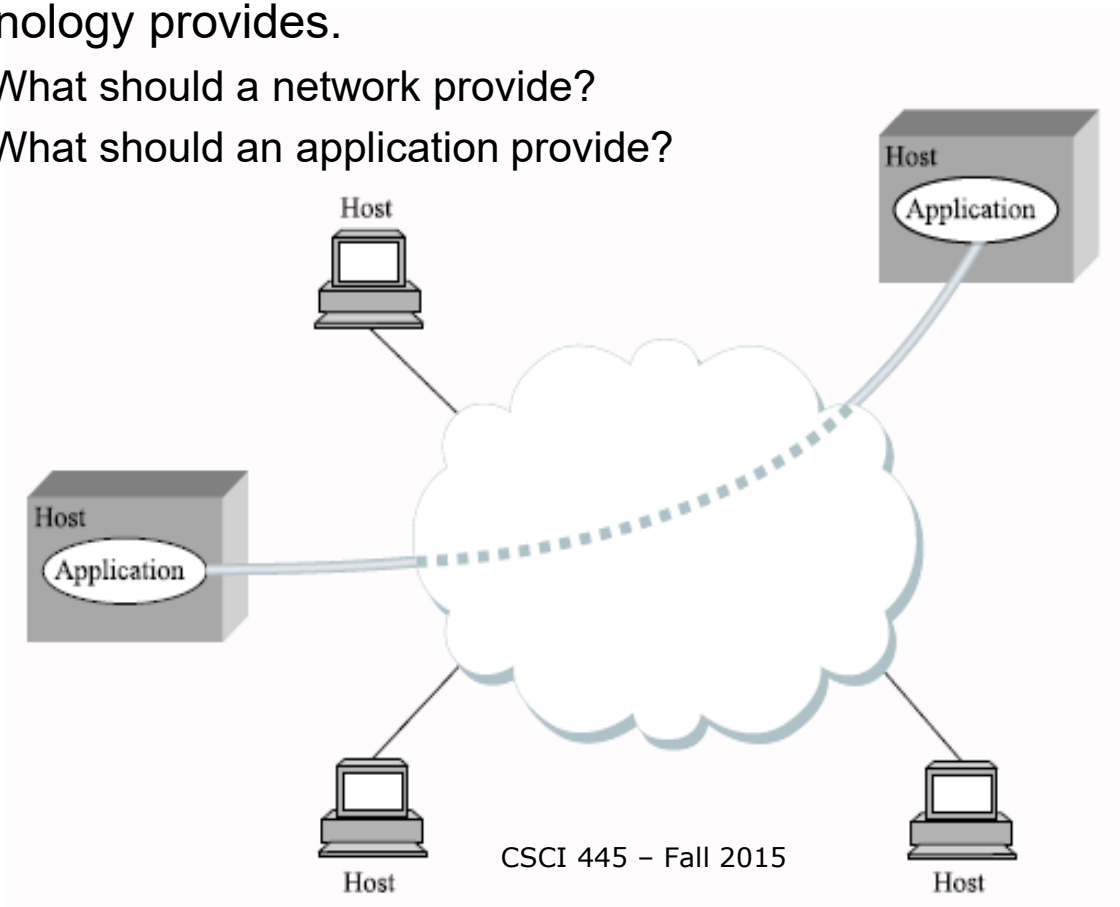
A switch multiplexing packets from multiple sources onto one shared link.

Statistical Multiplexing: Challenges

- Fairly allocating link capacity to different flows
- Dealing with congestion
- Ensuring quality of service

Inter-Process Communication (1)

- Turn host-to-host connectivity into process-to-process communication
- Fill gap between what applications expect and what the underlying technology provides.
  - What should a network provide?
  - What should an application provide?



Inter-Process Communication (2)

- Examples of IPC Abstractions

Request/reply-based
- Distributed file systems
- Web access

Stream-based
- Video: sequence of frames
- Video application
  - On-demand video
  - Video conference

Things can go wrong!

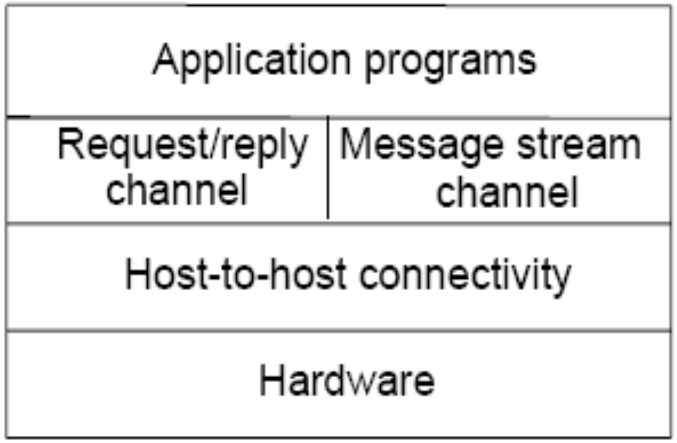
- Network failures:
  - Bit-level errors (electrical interference, e.g., lightning)
  - Packet-level errors (congestion)
  - Link and node failures (cable is cut, computers crashes)
- Other related issues
  - Messages/packets are delayed
  - Messages/packets are delivered out of order
  - Third parties eavesdrop

Protocols

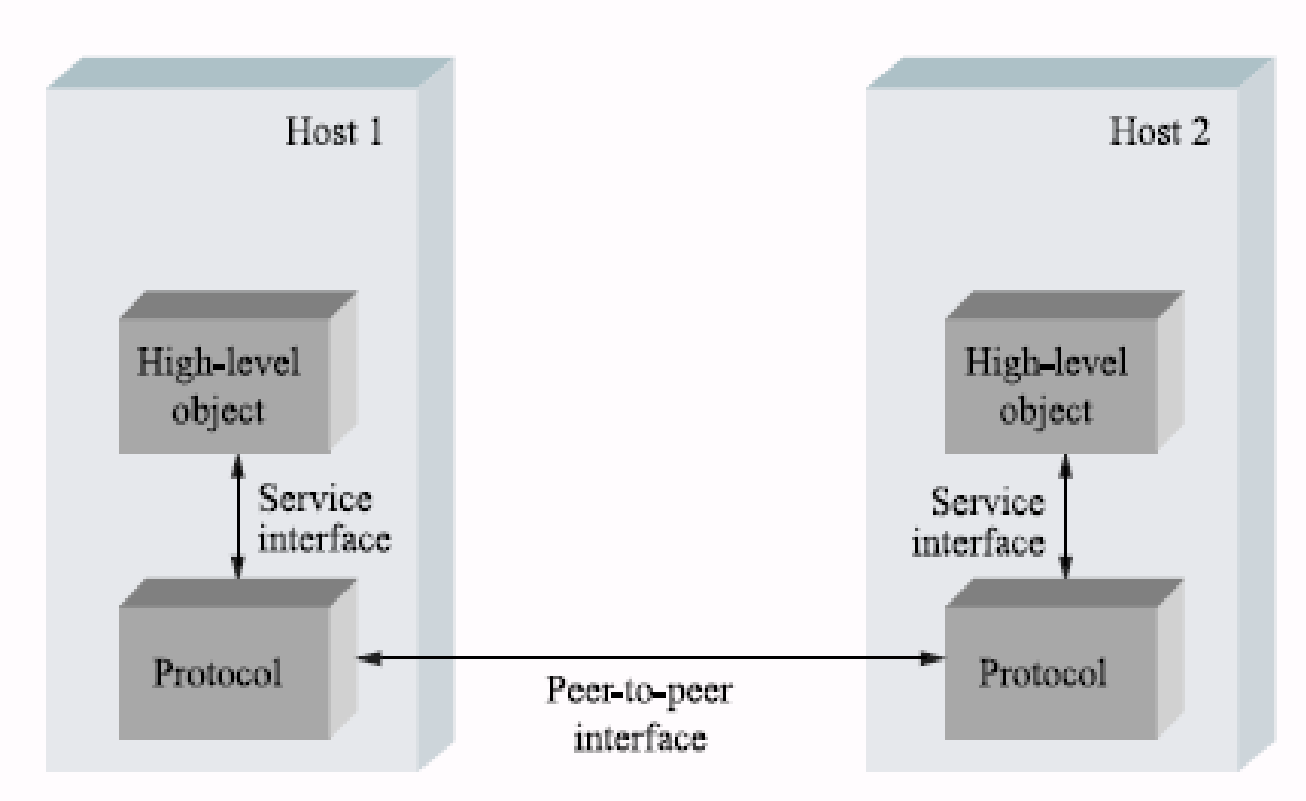
- Well-defined procedure that runs on multiple parties
- A set of rules and conventions
- Two interface
  - Service interface: operations on this protocol
  - Peer-to-peer interface: message exchanged with peer
- Building blocks for a network architecture
- Term “protocol” is overloaded
  - Specification of peer-to-peer interface
  - Module that implements this interface

Layered Architecture

- Network Architecture
  - A structured set of protocols that implement the exchange of information between computers/parties
- Use **abstractions** to hide complexity
- Abstraction naturally leads to layering
- Alternative abstractions at each laver



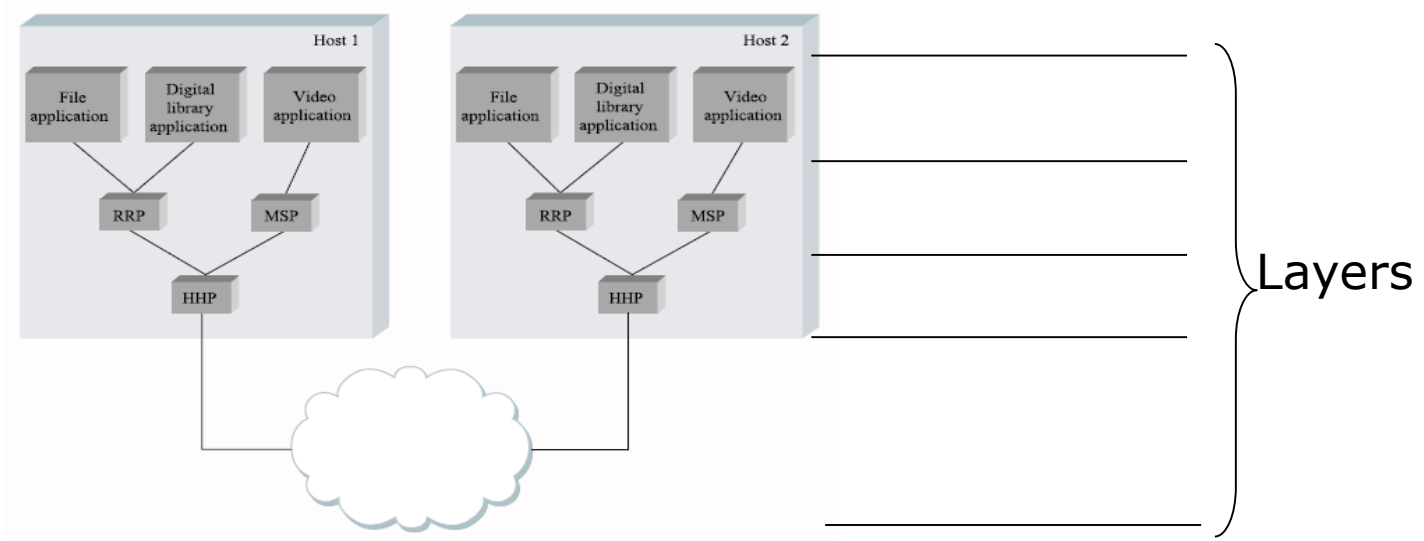
Service and Peer Interfaces



Service and peer interfaces

Example of Protocol Machinery

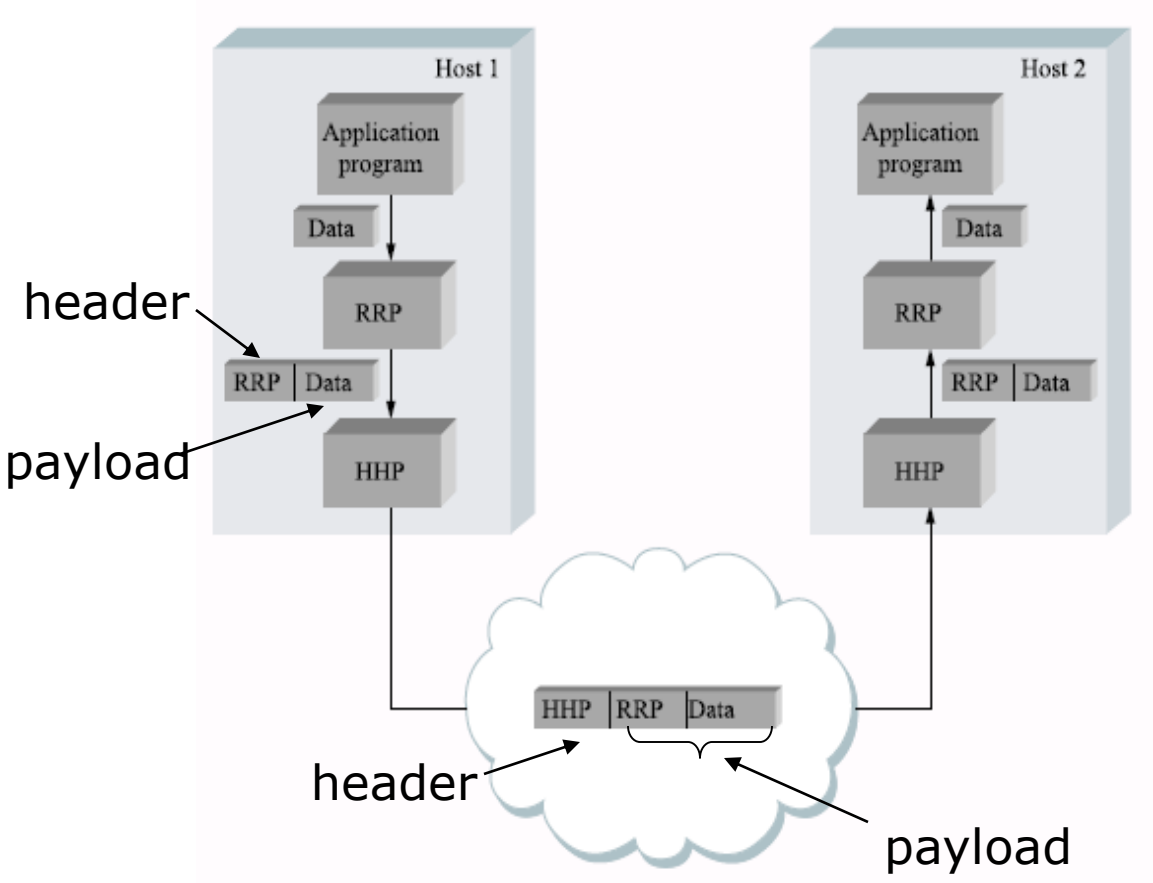
- Most peer-to-peer communication is indirect
- Peer-to-peer is directly only at hardware level



Service are grouped in a hierarchy of layers, which provide service interface
Layer N protocols only use *services* provided by layer N-1
Layer N protocols only provide *services* to layer N+1
Q: does layer N needs to know the inner-working of layer N-1 or layer N+1?

Encapsulation and Multiplexing/Demultiplexing

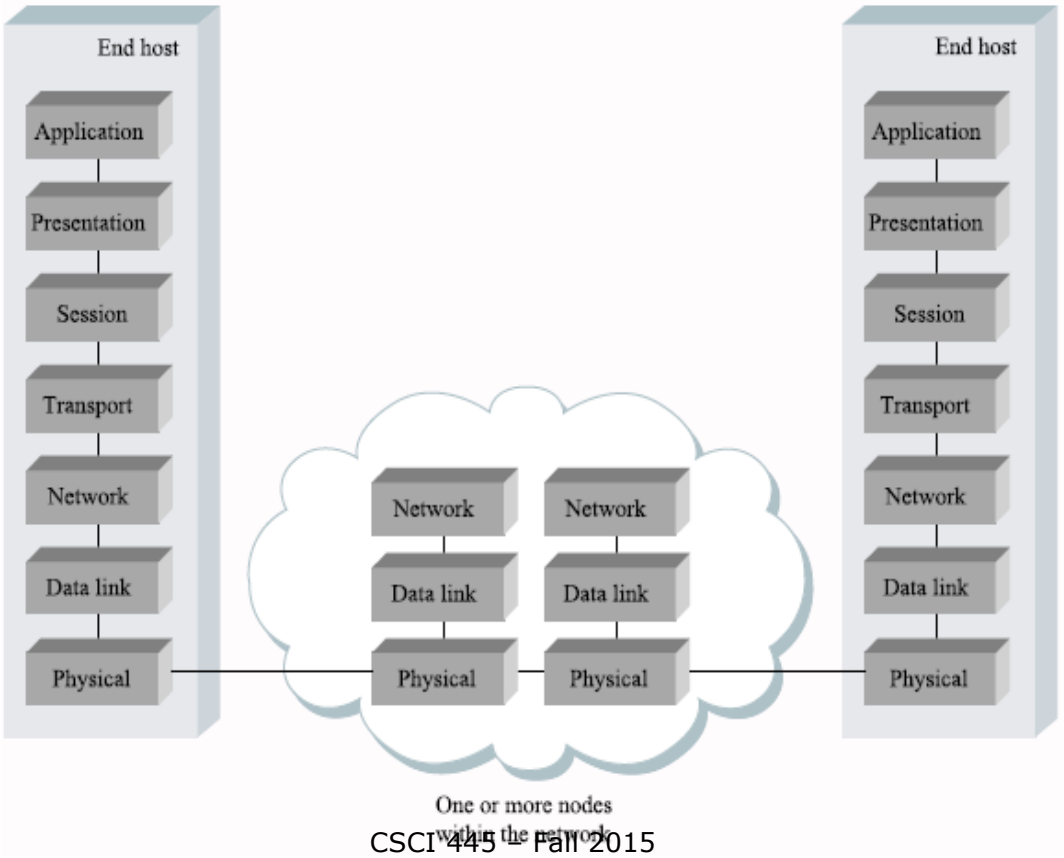
- *Header can have demultiplexing key*



High-level messages are encapsulated inside of low-level messages

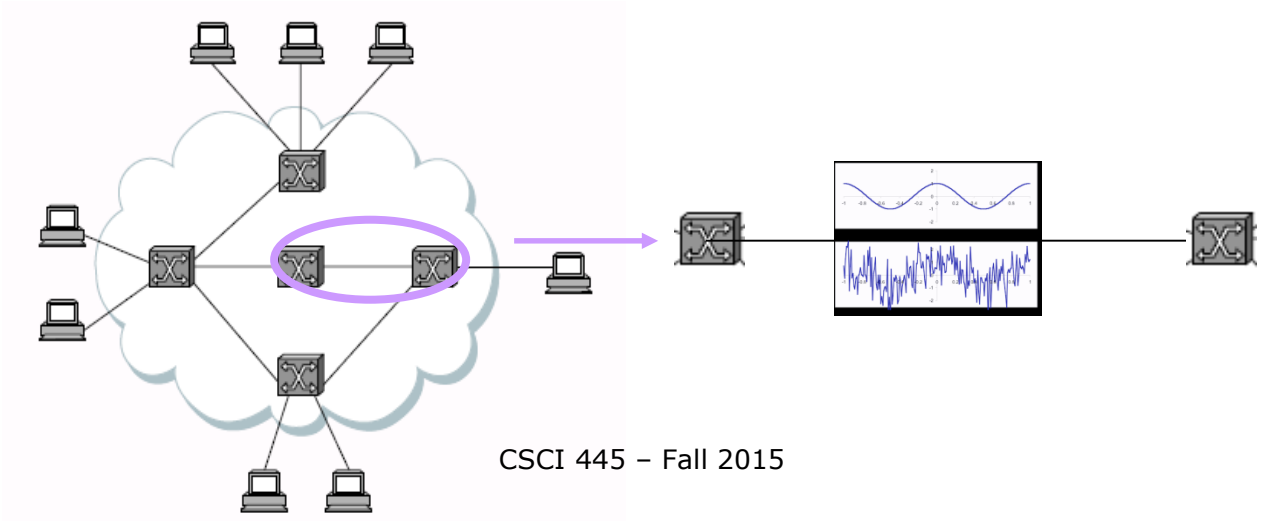
OSI (Open System Interconnection) Architecture

- Defined by ISO. Used as a reference model



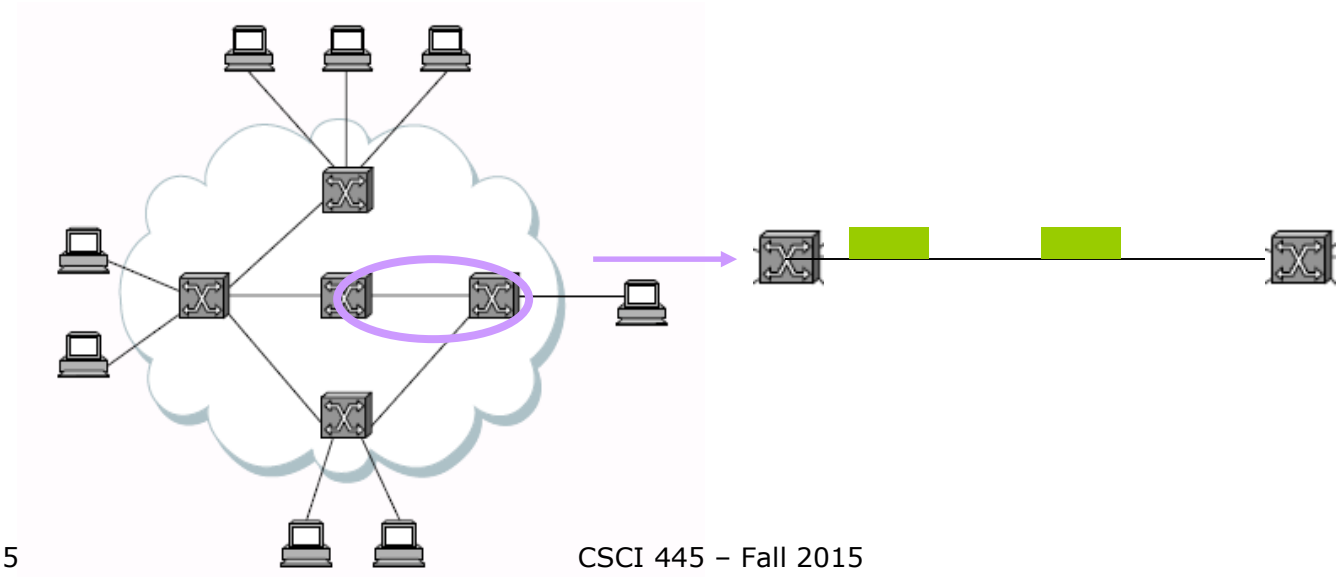
OSI: Physical Layer (Layer 1)

- Converts bits into physical signals such as electrical, optical, acoustic signals …
- Transmits these signals over the hardware communication medium such as twisted pair cable, coaxial cable, fiber optics, open/free space, water …



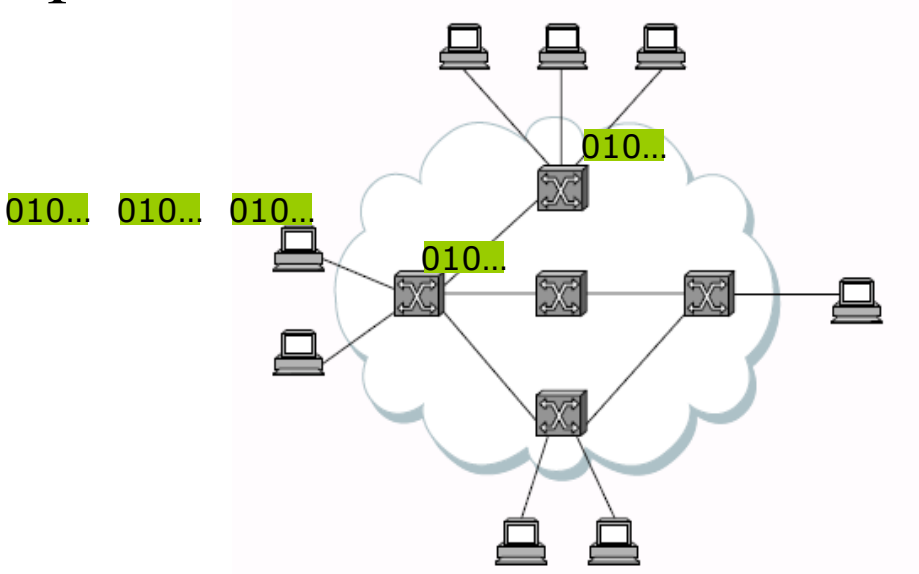
OSI: Data Link Layer (Layer 2)

- Reliably transfers data frames over a link
- Performs synchronization, error control, and flow control
- Example: Point-to-Point Protocol (PPP)



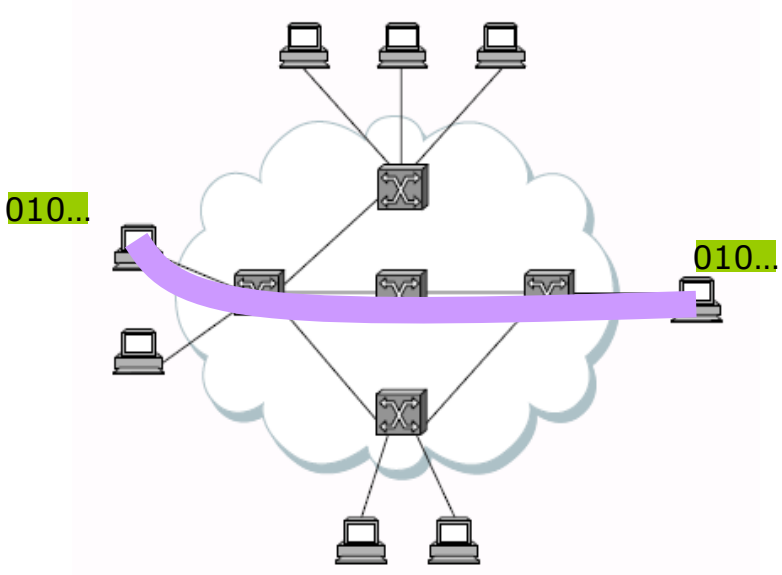
OSI: Network Layer (Layer 3)

- Moves packets inside the network
- Performs routing, addressing, switching, congestion control
- Example: Internet Protocol (IP)



OSI: Transportation Layer (Layer 4)

- Controls delivery of data between hosts
- Connection management, error control, flow control, multiplexing
- Example: Transmission Control Protocol (TCP) and User Datagram Protocol (UDP)



OSI: Session Layer (Layer 5)

- Support dialog between application programs
- Session management, synchronization
- Example: Remote-Procedure-Call (RPC)

OSI: Presentation Layer (Layer 6)

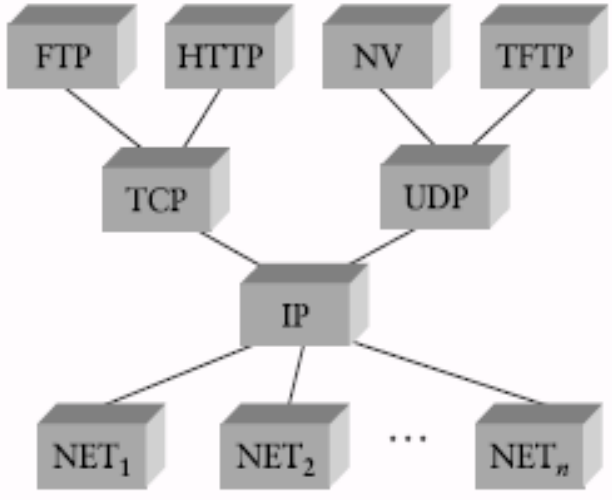
- Data conversion into application format
- Encryption and decryption
- Example: Secure Sockets Layer (SSL)

OSI: Application Layer (Layer 7)

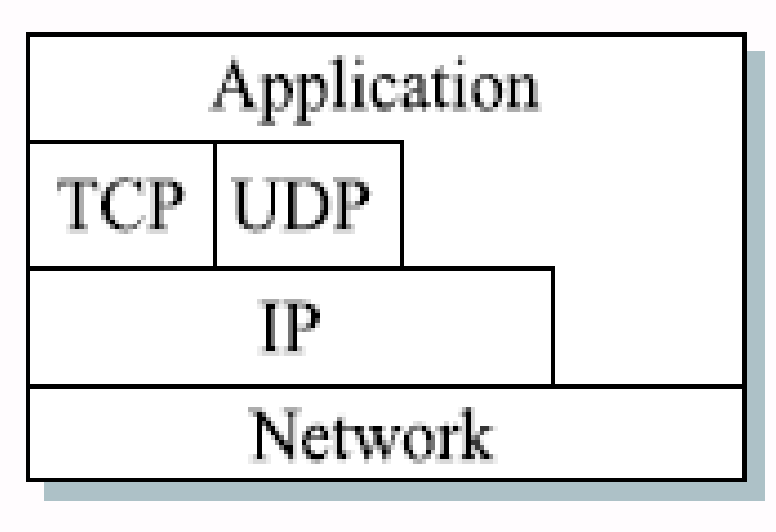
- Provides network access to application programs
- Application specific
- Example: File Transfer, Electronic Mail

Internet (TCP/IP) Architecture

- Defined Internet Engineering Task Force (IETF)

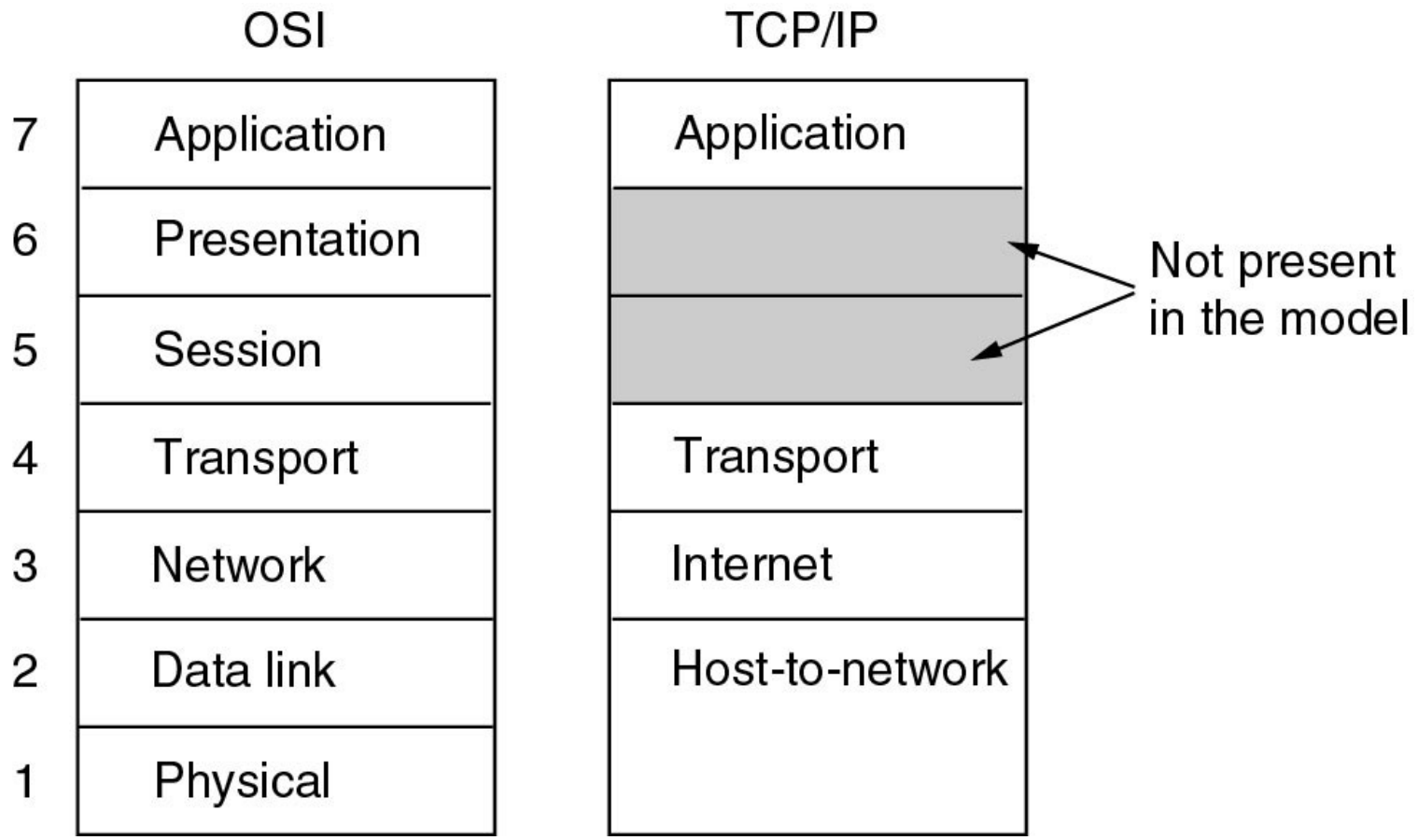


Internet protocol graph.



Internet architecture.

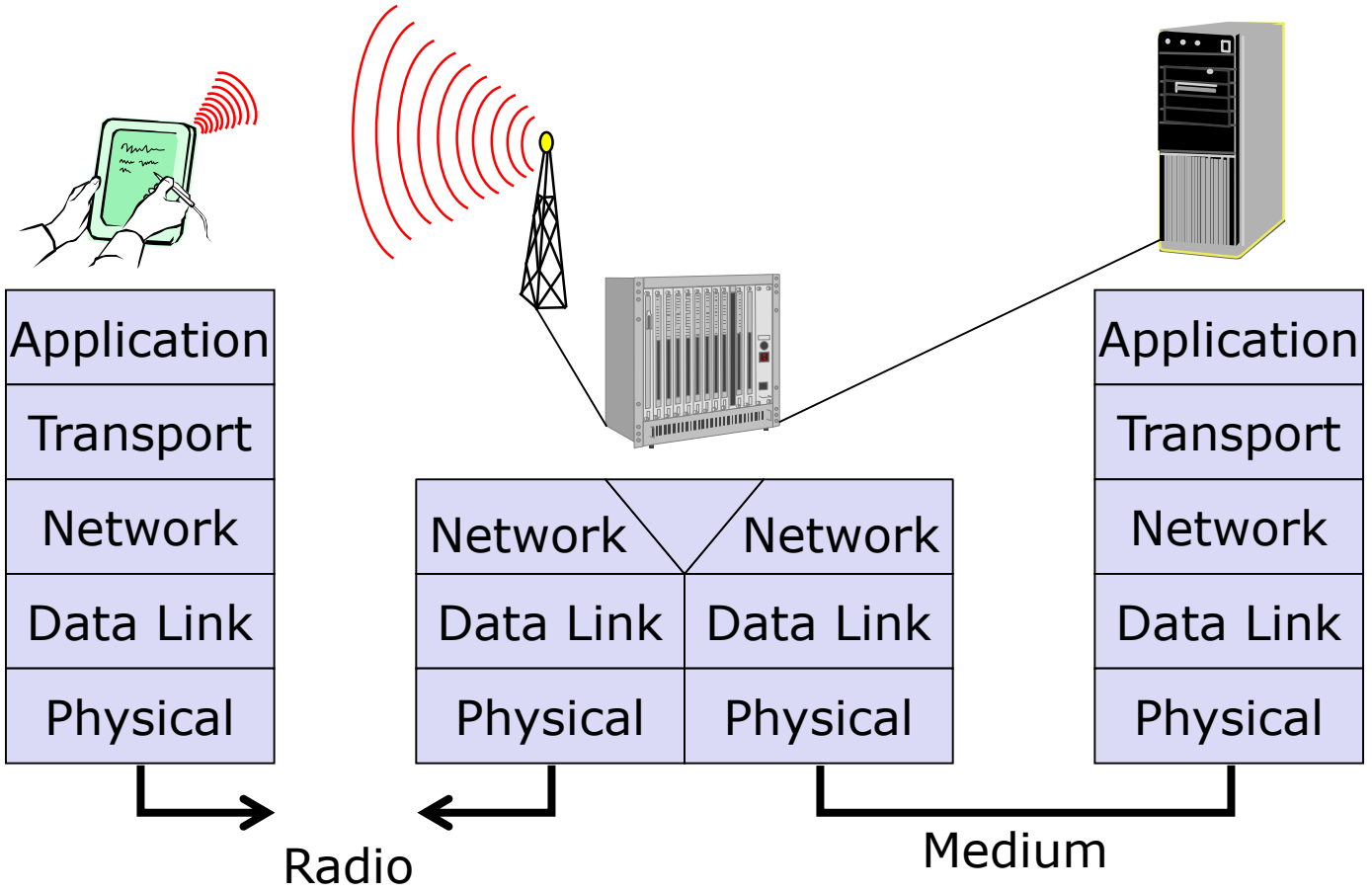
OSI and Internet Architectures



Key Characteristics of Internet Architecture

- Layering is not strict
- Hourglass design with IP as focal point
- Protocol specification + 1 (preferable 2) representative implementation

The Layered Reference Model



Often we need to implement a function across multiple layers.

Summary

- What is a computer network?
- Basic requirements
  - General purpose
  - Cost-effective network sharing
  - Fair network link allocation
  - Robust connectivity
- Layered architecture
- *Question:*
  - *How is the performance (see next lecture)?*

Additional Reading Assignment

- Leonard Kleinrock, An Early History of Internet, IEEE Communications Magazine, Vol. 48, No. 8, pp. 26-36, Available: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5534584