CISC 7332X T6
Overview of Computer Networks

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Acknowledgement

- These slides are a minor revision of the slides provided by the publisher and the authors of the textbook

Outline

- Network applications
- Application requirements
  - Bandwidth and latency
- Network hardware and classification by scale
- Network software
  - Protocols and services

Applications

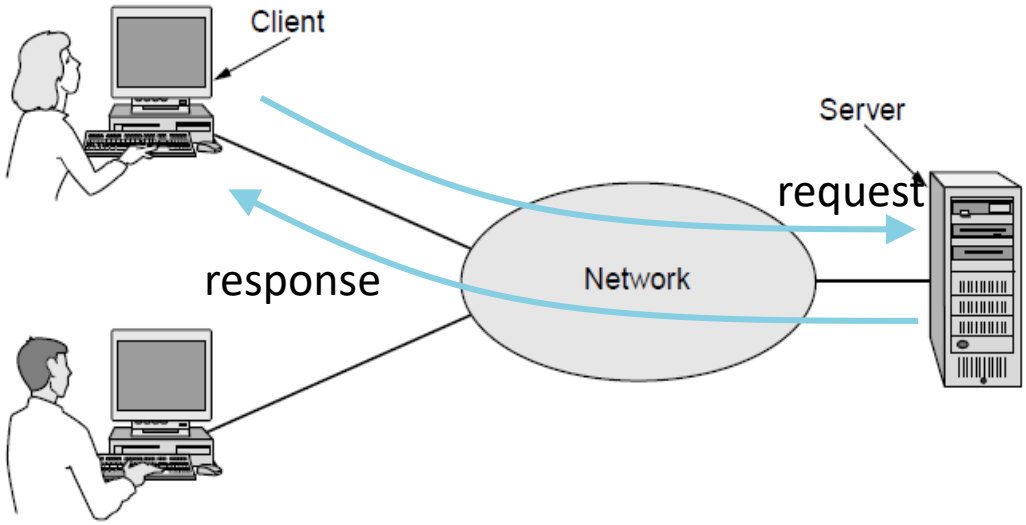
- A collection of autonomous computers form a computer network
- Many applications
  - Business applications
  - Home applications
  - Mobile users

Business Applications

- Organizations use computers and computer networks for
  - resource sharing
  - communication
  - typically, with a client-server model

Client-Server Model

- Client and server
- Request and response

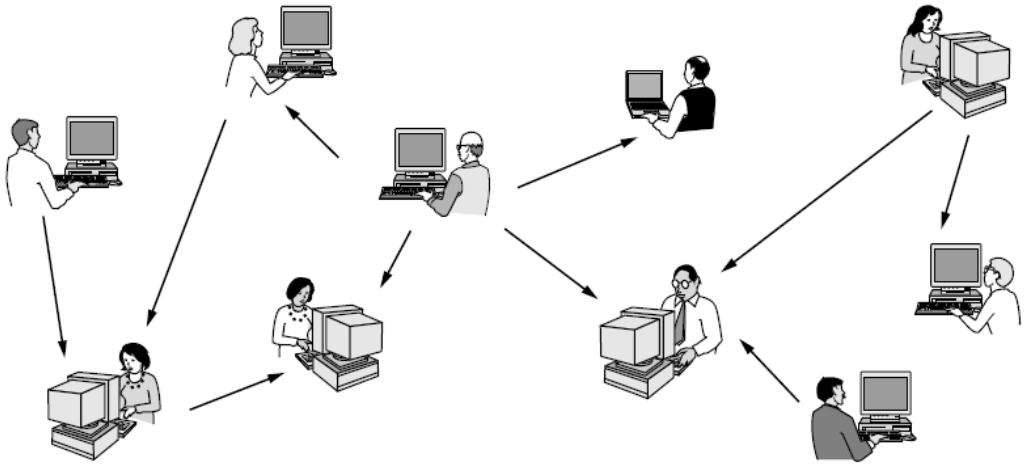


Home Applications

- Many networked devices at a home
  - such as, computers, TVs
  - connected to the Internet by cable, DSL, Fiber Optic, or wireless
- Home users communicate, e.g., social networks, consume content, e.g., video, and transact, e.g., auctions
- Some application use the peer-to-peer model in which there are no fixed clients and servers

Peer-to-Peer Model

- No fixed division into clients and servers



Mobile Users

- Tablets, laptops, and smart phones are popular devices
  - WiFi hotspots
  - 2G/3G/4G/5G cellular provide wireless connectivity.
- Mobile users communicate, e.g., voice and texts, consume content, e.g., video and Web, and use sensors, e.g., GPS.
- Wireless and mobile are related but different

Wireless and Mobile

- Wireless ≠ Mobile

Wireless	Mobile	Typical applications
No	No	Desktop computers in offices
No	Yes	A notebook computer used in a hotel room
Yes	No	Networks in unwired buildings
Yes	Yes	Store inventory with a handheld computer

Cloud and Fog Computing

- Cloud computing
  - Elastic and on-demand resource sharing
  - Typically, a network application
- Fog computing or edge computing
  - Off-loading computation to network edge nodes
  - Typically, a part of a computer network

Social Issues

- Social issues arise from use of computers and computer networks
  - Network neutrality
    - No network restrictions?
  - Content ownership
    - e.g., DMCA takedowns
  - Anonymity and censorship
  - Privacy
    - e.g., Web tracking and profiling
  - Theft
    - e.g., botnets and phishing

Application Requirements

- Applications may demand different network performance

Network Performance

- There are many performance metrics and criteria
  - Bandwidth
    - How many bits/second does a network can transport?
    - bps (1 bit/second), kbps (10^3 bits/second), Mbps (10^6 bits/second), Gbps (10^9 bits/second)
  - Latency (or delay)
    - How many seconds does it take for the firsts bit to get from the client to the server?

Bandwidth, Data Rate and Throughput

- Bandwidth is an overloaded term
  - See https://en.wikipedia.org/wiki/Bandwidth
  - Context matters
  - In this lecture: the rate of data transfer
    - Bit rate (design property)
    - Throughput (based on measurement)

Data

- Data
  - Bits and bytes
    - Notation: b for bits, B for bytes, but context matters
  - Today 1 byte ≡ 8 bits
  - KB, MB, GB, TB, PB …
    - Powers of 2's: K = 2^{10}, M = 2^{20}, G = 2^{30}, T = 2^{40} , P = 2^{50}

Bandwidth

- data / time
- Bits / second or bps
- Kbps, Mbps, Gbps …
  - Powers of 10's: K = 10^3, M = 10^6, G = 10^9

Latency (or Delay)

- Latency comes from many sources
  - Propagation delay
    - It takes time for a signal to travel a distance
      - Distance / speed
  - Processing delay
  - Queuing delay

Exercise 01b-1: Question 23 in Page 87

- An image is 1600 x 1200 pixels with 3 bytes/pixel. Assume the image is uncompressed. How long does it take to transmit it over the following network channels, respectively,
  - a 56-kbps modem channel?
  - a 1-Mbps modem channel? (on your own)
  - a 10-Mbps Ethernet? (on your own)
  - a 100-Mbps Ethernet? (on your own)

Exercise 01b-2: Question 6 in Page 86

- A client-server system uses a satellite network, with the satellite at a height of 40,000 km. What is the best-case delay in response to a request?

Questions

- Applications of computer networks
- Client-server and peer-to-peer models
- Social issues
- Application requirements
  - Bandwidth and latency

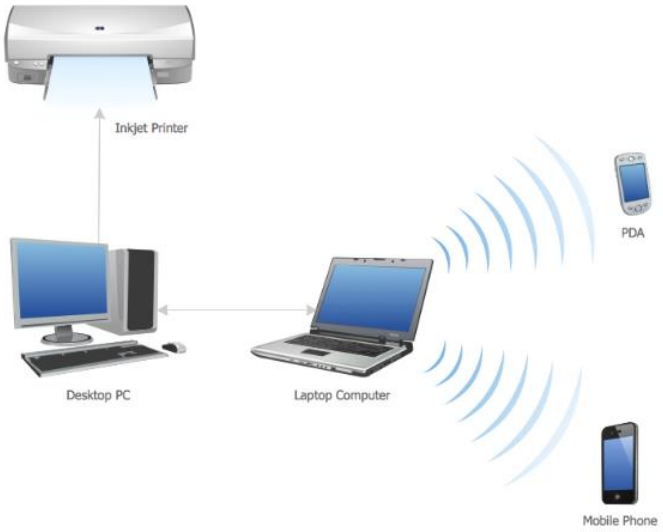
Network Hardware

- Networks can be classified by their scale

Scale	**Type**
Vicinity	PAN (Personal Area Network)
Building	LAN (Local Area Network)
City	MAN (Metropolitan Area Network)
Country	WAN (Wide Area Network)
Planet	The Internet (network of all networks)

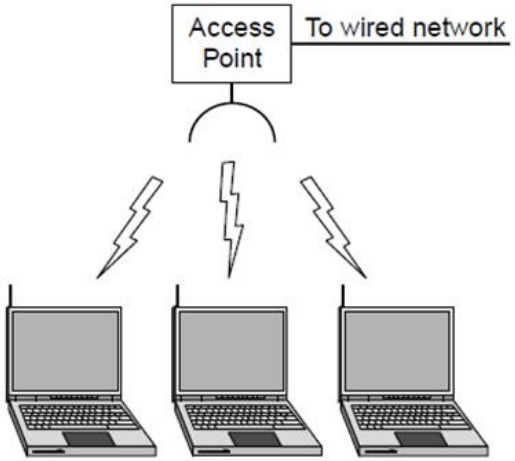
Personal Area Network

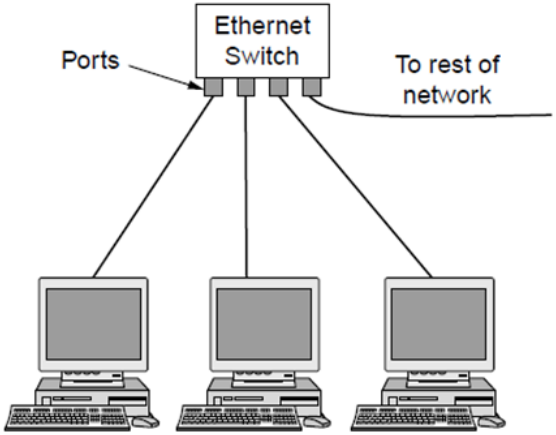
- PAN: connect devices over the range of a person
  - Example of a Bluetooth (wireless) PAN:



Local Area Network

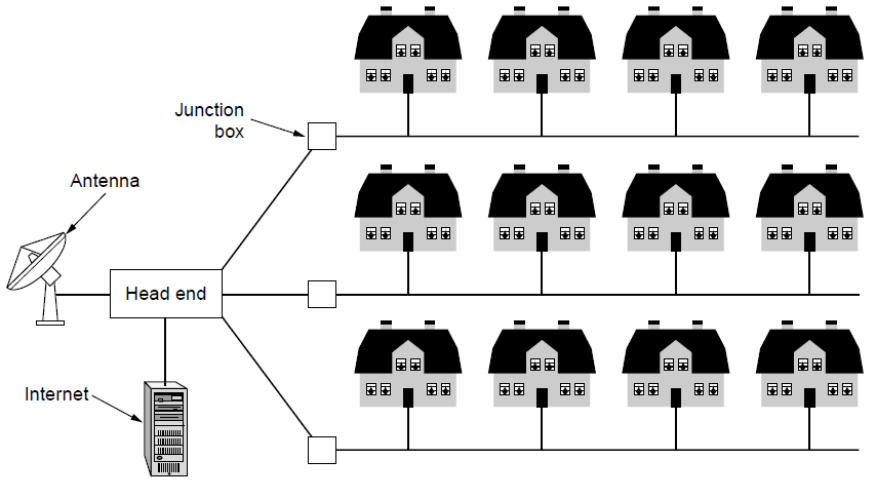
- LAN: connect devices in a home or office building, also called enterprise network
- Examples: IEEE 802.11 wireless LAN and 802.3 Ethernet LAN





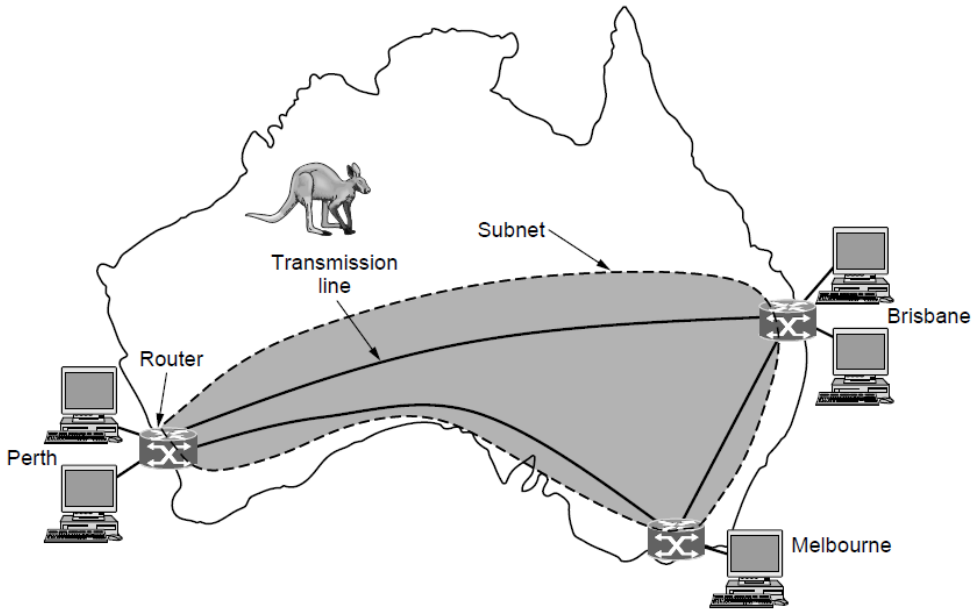
Metropolitan Area Network

- MAN: Connect devices over a metropolitan area
- Example MAN based on cable TV



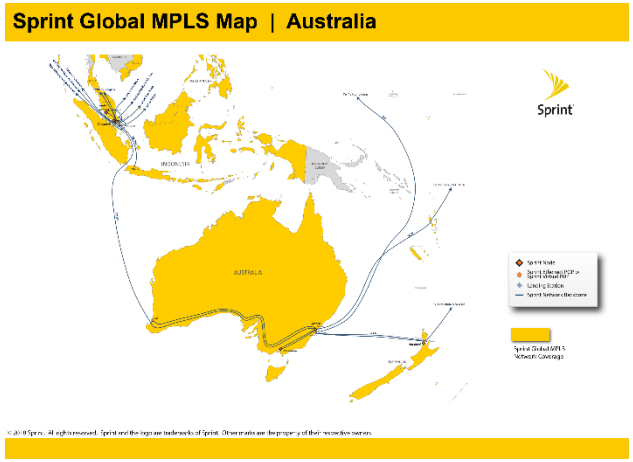
Wide Area Network

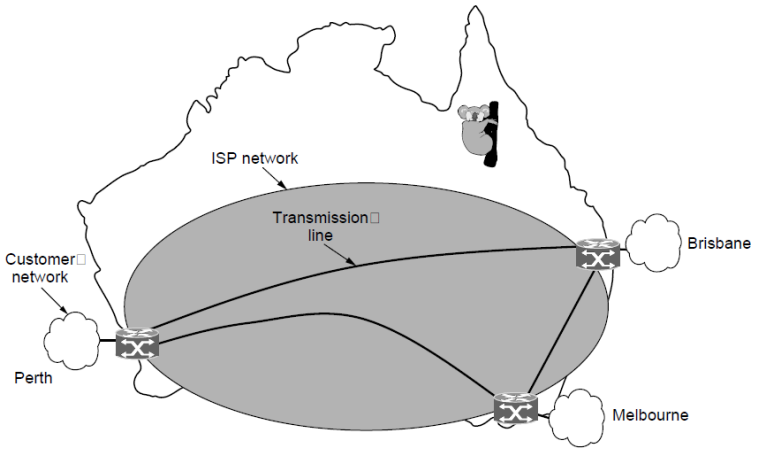
- WAN: connect devices over a country
- Example WAN connecting three branch offices



ISP Network

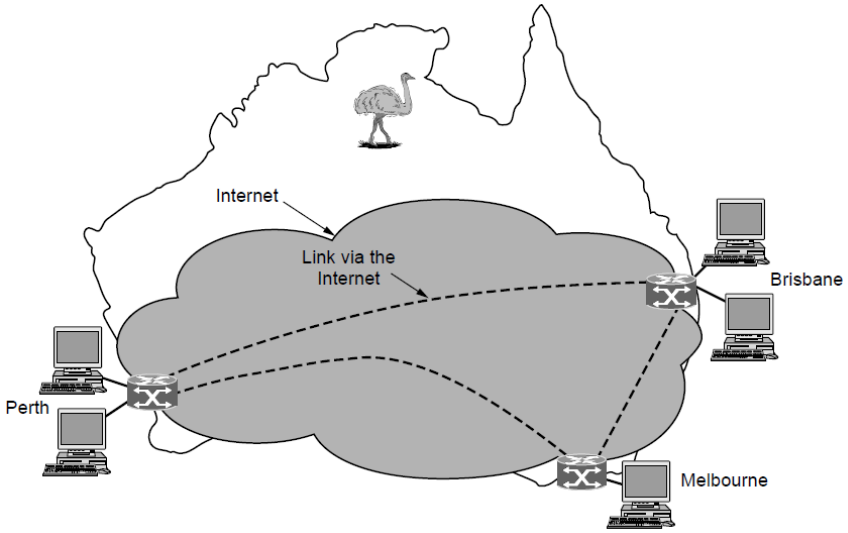
- An ISP (Internet Service Provider) network is also a WAN.
- Customers buy connectivity from the ISP to use it.





WAN and VPN

- A VPN (Virtual Private Network) is a WAN built from virtual links that run on top of the Internet



Internetworks

- A network of networks
- Example: the Internet, a global internetworks formed by many autonomous networks

Networks by Scale

Interprocessor distance	Processors located in the same area
~ 1 m	Square meter
~ 10 m	Room
~ 100 m	Building
~ 1 km	Campus
~ 10 km	City
~ 100 km	Country
~ 1,000 km	Continent
~ 10,000 km	Planet

Personal Area Network

Local Area Network

Metropolitan Area Network

Wide Area Network

The Internet

Questions?

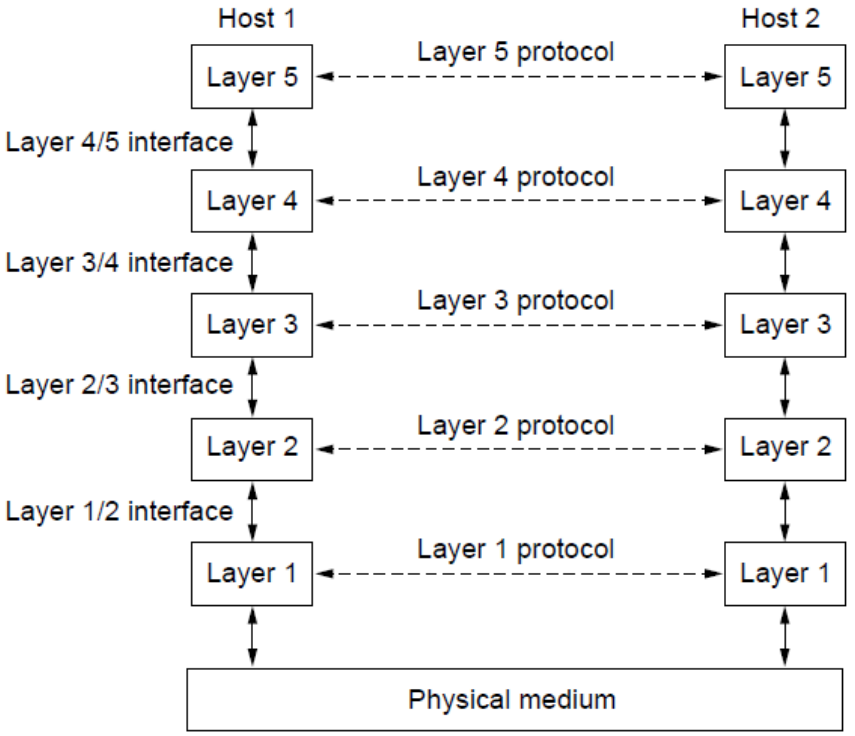
- Network by scale
  - PAN
  - LAN
  - MAN
  - WAN
  - The Internet

Network Software

- Protocol layers
- Design issues for the layers
- Connection-oriented vs. connectionless service
- Service primitives
- Relationship of services to protocols

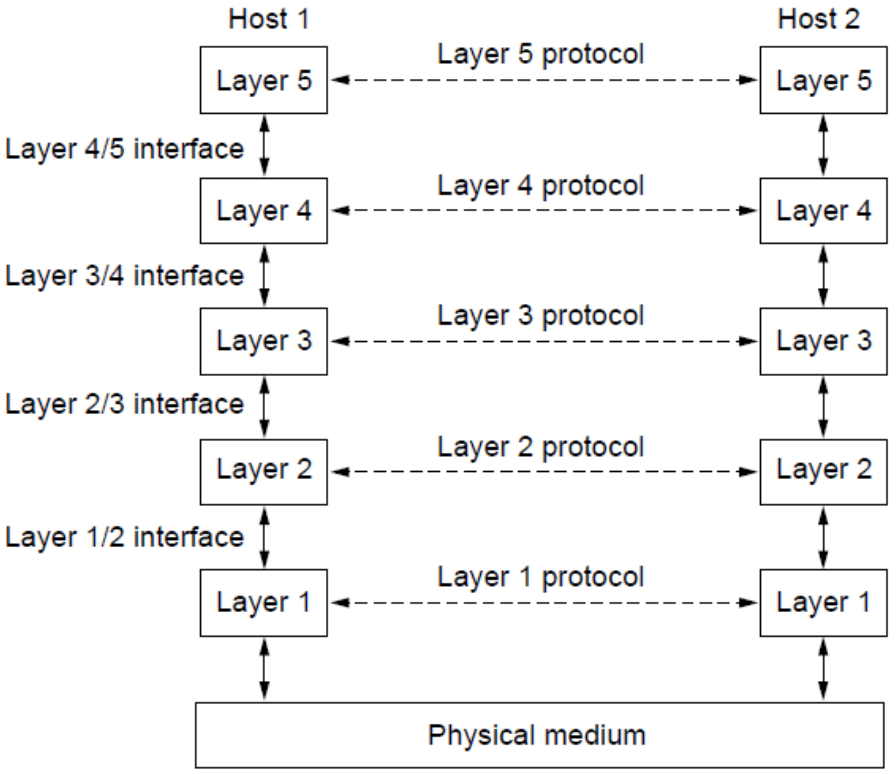
Protocol Layers

- main structuring method used to divide up network functionality.



Protocol Layers: Services and Peer Interfaces

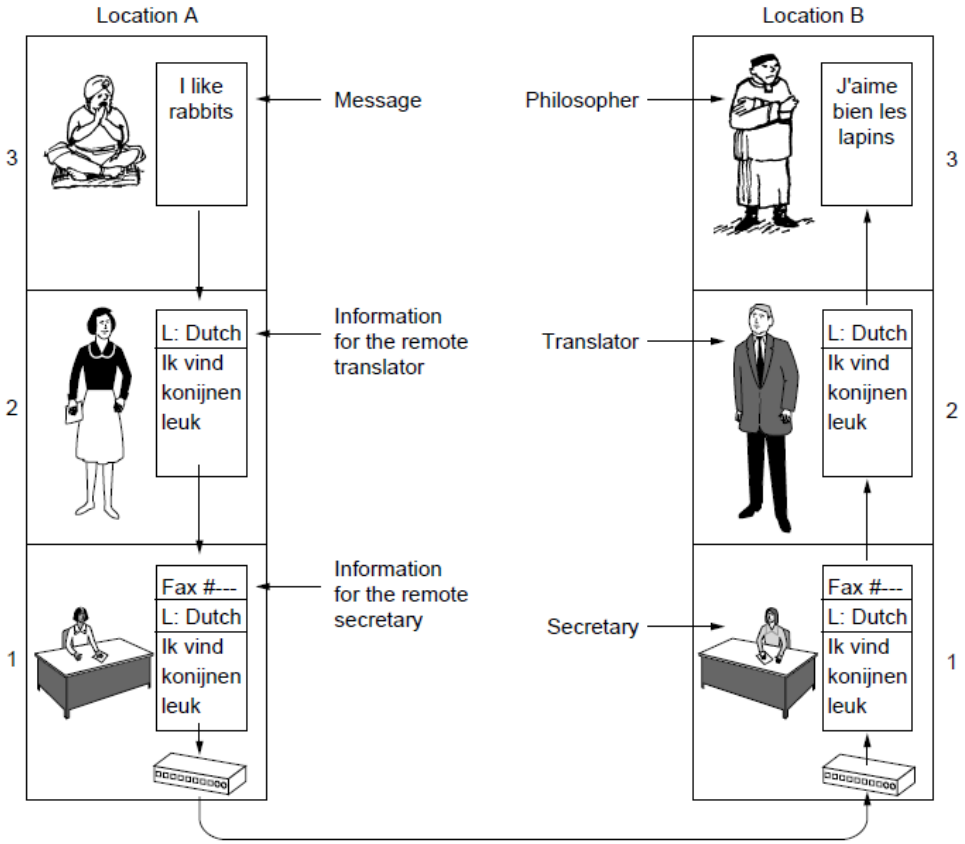
- Each protocol instance talks virtually to its peer
- Each layer communicates only by using the one below
- Lower layer services are accessed by an interface
- At bottom, messages are carried by the medium



Protocol Layers: An Analogy

- Example
  - the philosopher-translator-secretary architecture
  - Each protocol at different layers serves a different purpose

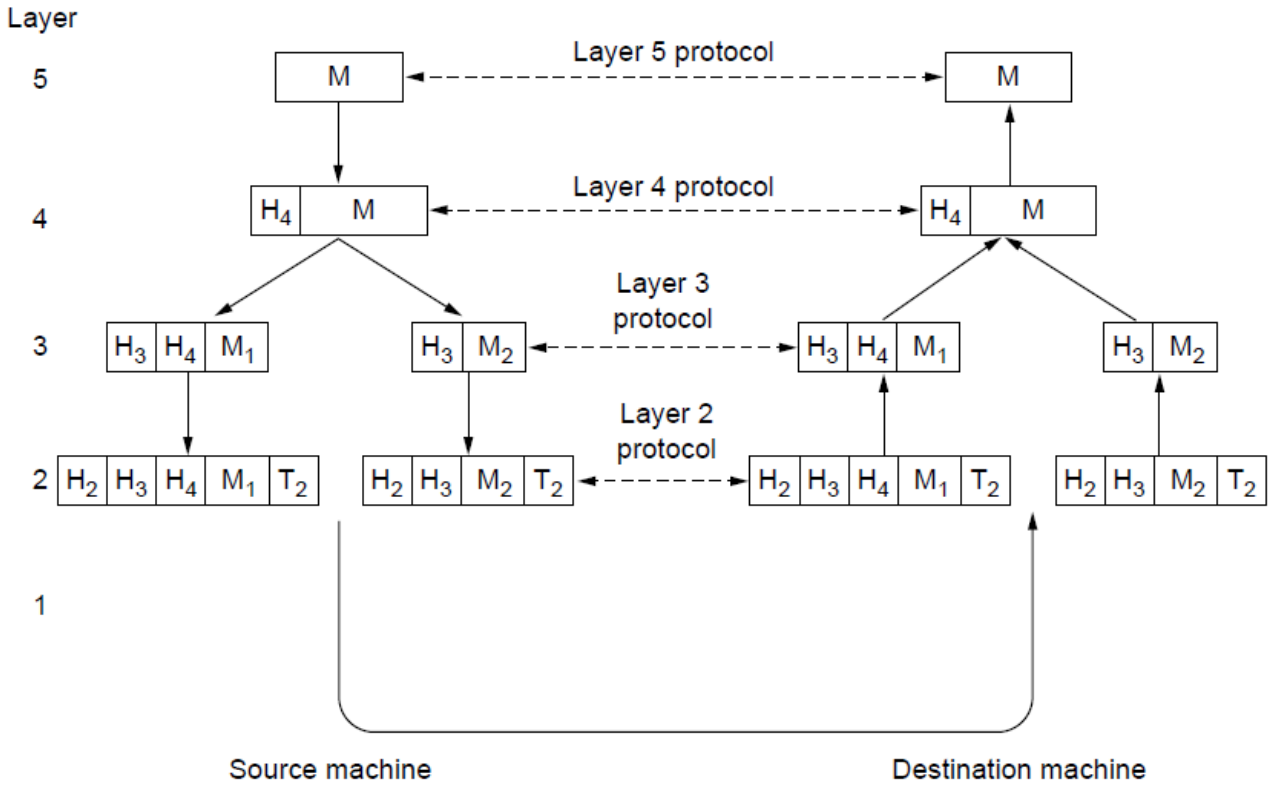
Philosopher-translator-secretary Architecture



Protocol Layers: Message and Message Header

- Each lower layer adds its own header (with control information) to the message to transmit and removes it on receive
- Layers may also split and join messages.

Protocol Layers, Messages and Message Headers



Design Issues for the Layers

- Each layer solves a particular problem but must include mechanisms to address a set of recurring design issues

Layers and Common Issues

- Important issues and layers

Issue	**Example mechanisms at different layers**
Reliability despite failures	Codes for error detection/correction (§3.2, 3.3) Routing around failures (§5.2)
Network growth and evolution	Addressing (§5.6) and naming (§7.1) Protocol layering (§1.3)
Allocation of resources like bandwidth	Multiple access (§4.2) Congestion control (§5.3, 6.3)
Security against various threats	Confidentiality of messages (§8.2, 8.6) Authentication of communicating parties (§8.7)

Connection-Oriented and Connectionless

- Two common abstractions of network services
- Service provided by a layer may be kinds of either:
  - Connection-oriented, must be set up for ongoing use (and torn down after use), e.g., phone call
  - Connectionless, messages are handled separately, e.g., postal delivery

Network Service Types and Examples

- Connection-oriented vs. connectionless services and examples

	Service	Example
Connection-oriented	Reliable message stream	Sequence of pages
	Reliable byte stream	Movie download
	Unreliable connection	Voice over IP
Connection-less	Unreliable datagram	Electronic junk mail
	Acknowledged datagram	Text messaging
	Request-reply	Database query

Network Service Primitives

- A service is provided to the layer above as primitives
- Hypothetical example of service primitives that may provide a reliable byte stream (connection-oriented) service

Connection-Oriented Service: Example

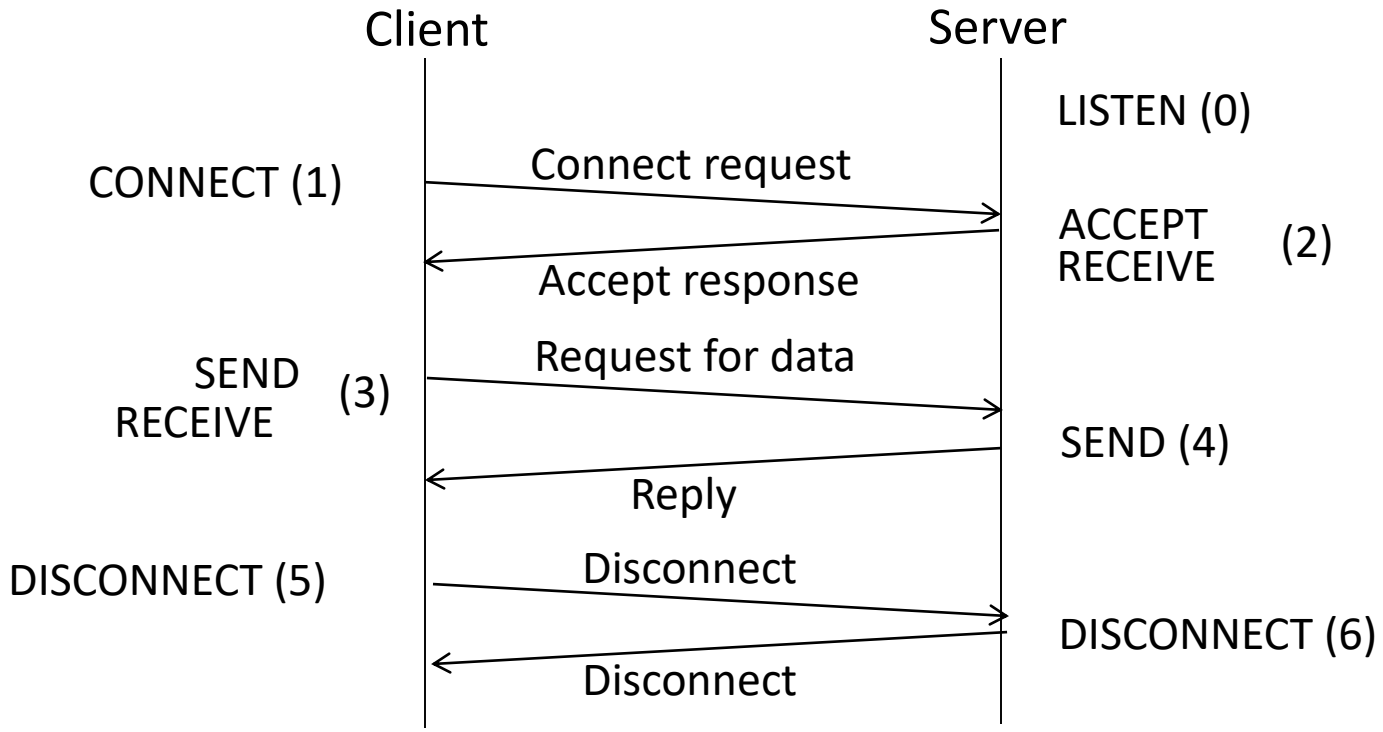
- A list of service primitives commonly provided by connection-oriented network services

Primitive	Meaning
LISTEN	Block waiting for an incoming connection
CONNECT	Establish a connection with a waiting peer
ACCEPT	Accept an incoming connection from a peer
RECEIVE	Block waiting for an incoming message
SEND	Send a message to the peer
DISCONNECT	Terminate a connection

Use of Service Primitives: Example

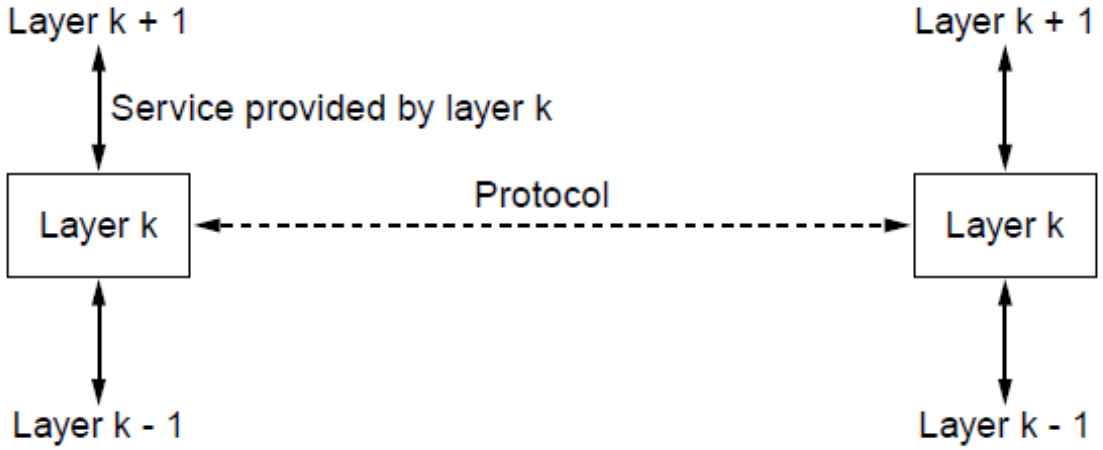
- Those primitives may be used for a client-server interaction

A Hypothetical Example



Relationship of Services to Protocols

- A layer provides a service to the one above (vertical)
- A layer talks to its peer using a protocol (horizontal)



Questions

- Protocol
- Protocol layers
- Services and protocols
- Service primitives