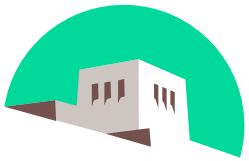
Chapter 1: Introduction

Computer Networks

Maccabe

Computer Science Department
The University of New Mexico



August 2002

Topics

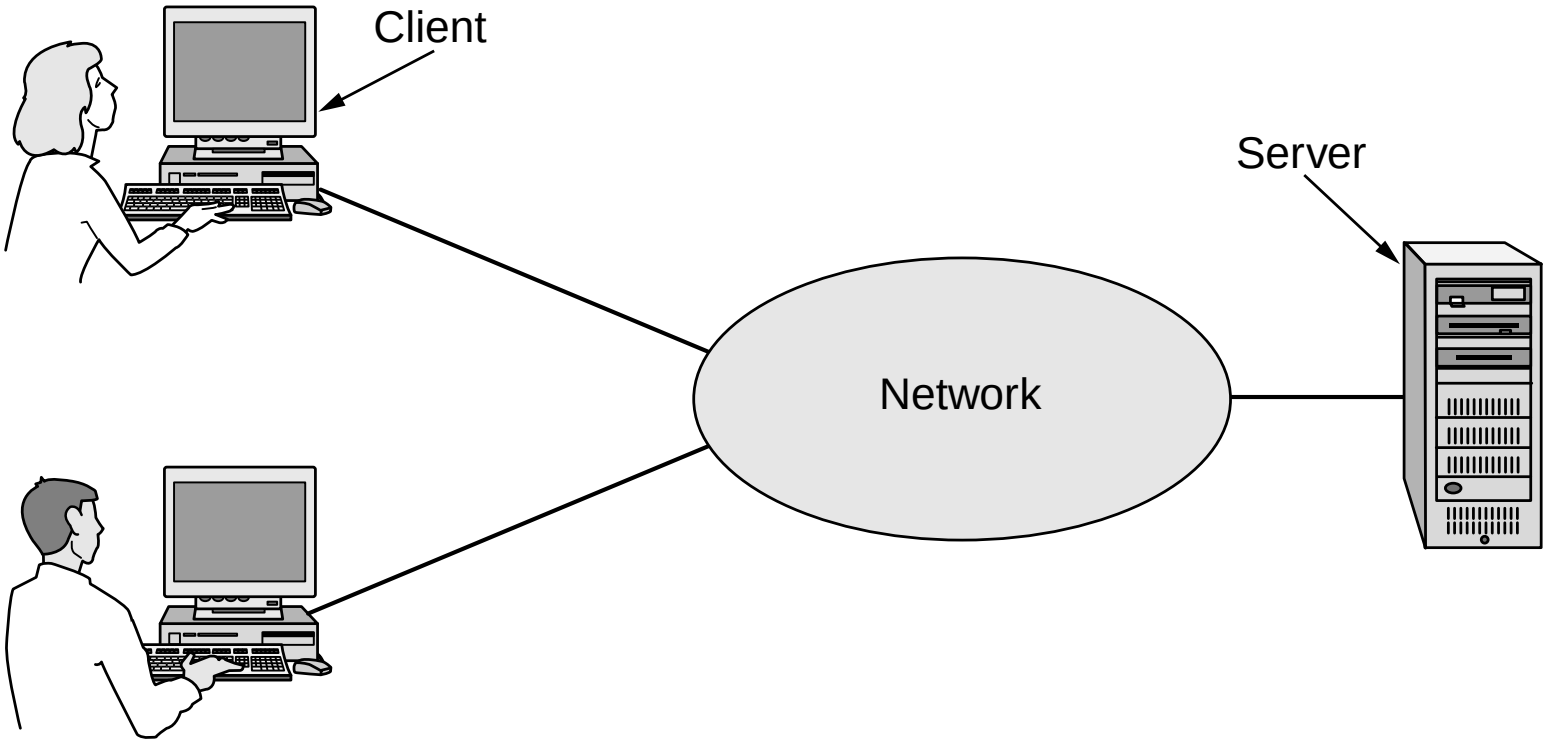
- Uses of Computer Networks
- Network Hardware
- Network Software
- Reference Models
- Example Networks
- Network Standardization

Uses of Computer Networks

- Business Applications
- Home Applications
- Mobile Users
- Social Issues

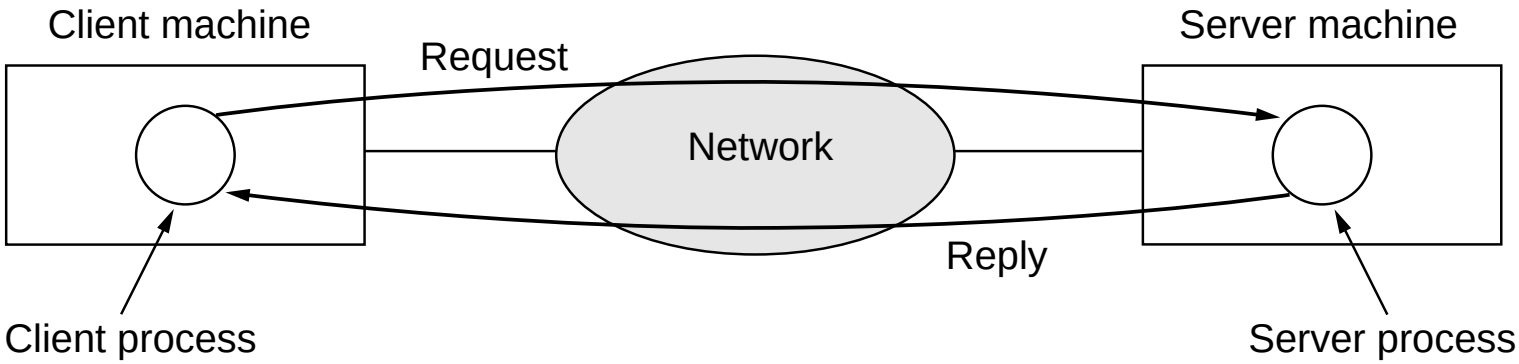
Business Applications

A network with two clients and one server



Business Applications (2)

The client-server model involves requests and replies

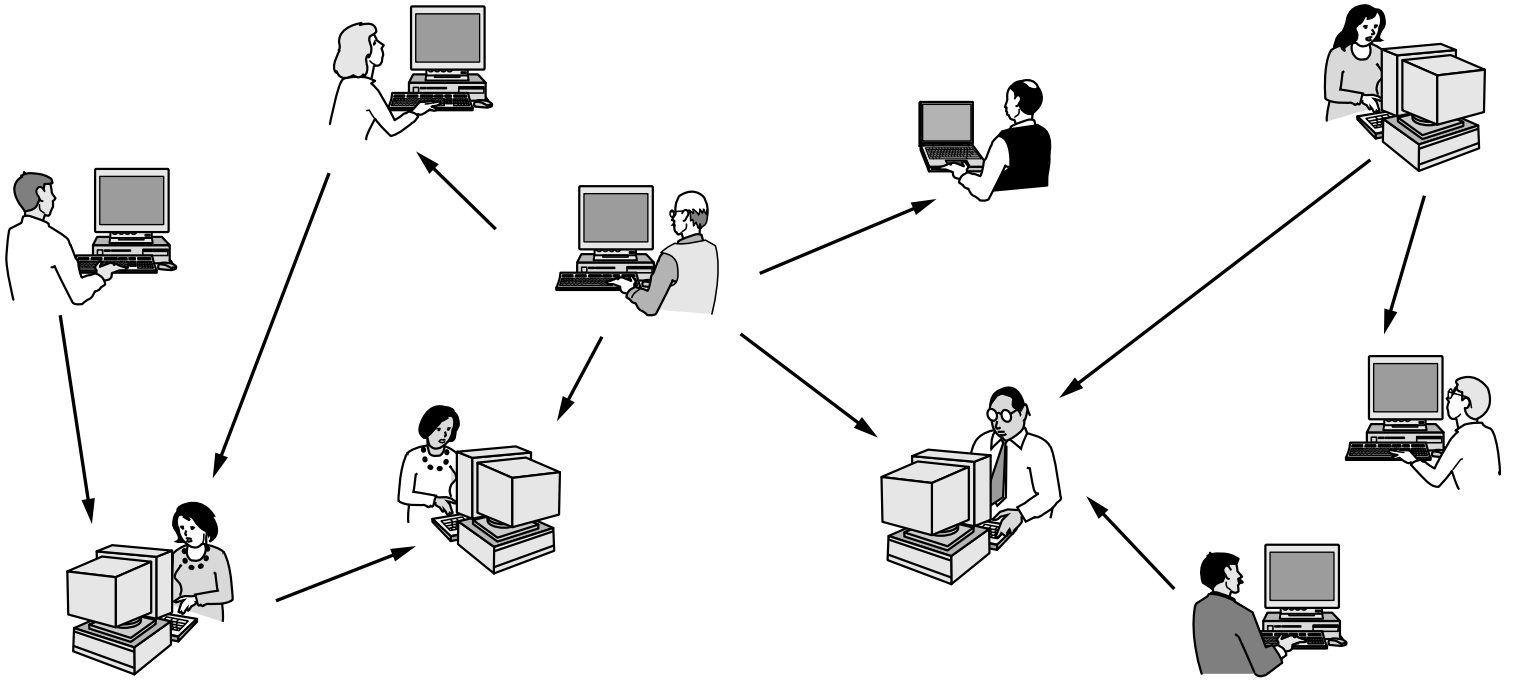


Home Applications

- Access to remote information
- Person-to-person communication
- Interactive entertainment
- Electronic commerce

Home Applications
Peer-to-Peer Networks

No fixed clients and servers



Home Applications
Examples of E-commerce

Tag	Full name	Example
B2C	Business-to-consumer	Ordering books on-line
B2B	Business-to-business	Car manufacturer ordering tires from supplier
G2C	Government-to-consumer	Government distributing tax forms electronically
C2C	Consumer-to-consumer	Auctioning second-hand products on line
P2P	Peer-to-peer	File sharing

Mobile Network Users

Wireless	Mobile	Applications
No	No	Desktop computers in offices
No	Yes	A notebook computer used in a hotel room
Yes	No	Networks in older, unwired buildings
Yes	Yes	Portable office; PDA for store inventory

Social Issues

- No problem when primary use is technical
- suing ISP for content available
- businesses versus employees (email content)
- government versus citizen (Carnivore – email)
- cookies
- spam
- good (easier communication) and bad (easier flow of sensitive information)

Topics

- Uses of Computer Networks
- Network Hardware
- Network Software
- Reference Models
- Example Networks
- Network Standardization

Network Hardware

- Local Area Networks
- Metropolitan Area Networks
- Wide Area Networks
- Wireless Networks
- Home Networks
- Internetworks

Broadcast Networks

Types of transmission technology

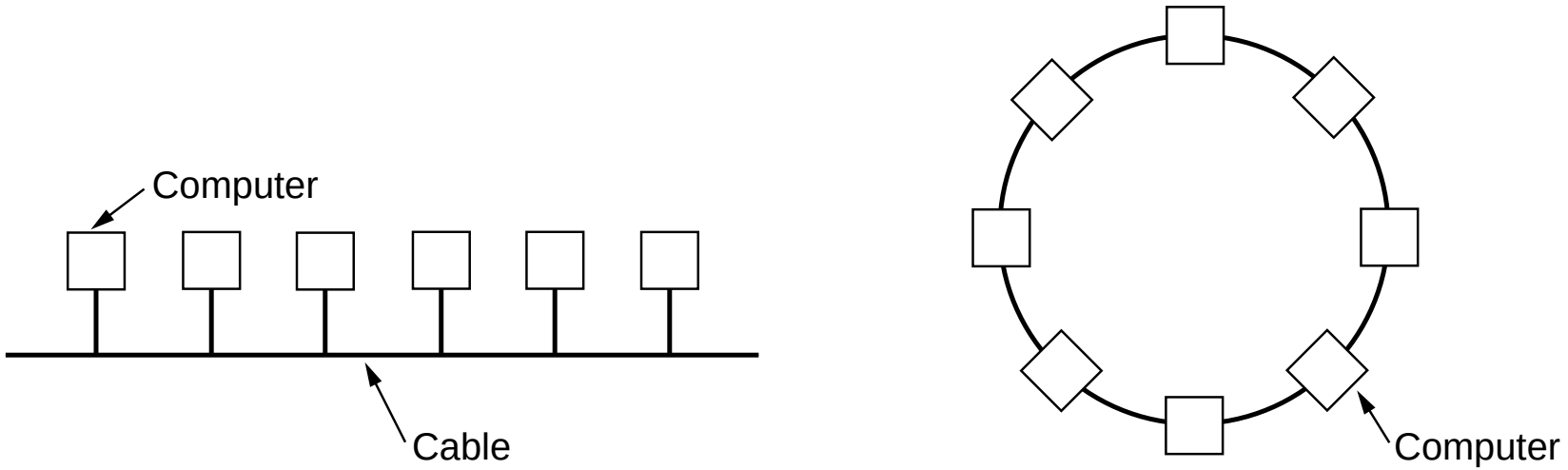
- Broadcast links
- Point-to-point links

Broadcast Networks(2)

Classification based on scale

Interprocessor distance	Processors located in same	Example
1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

Local Area Networks



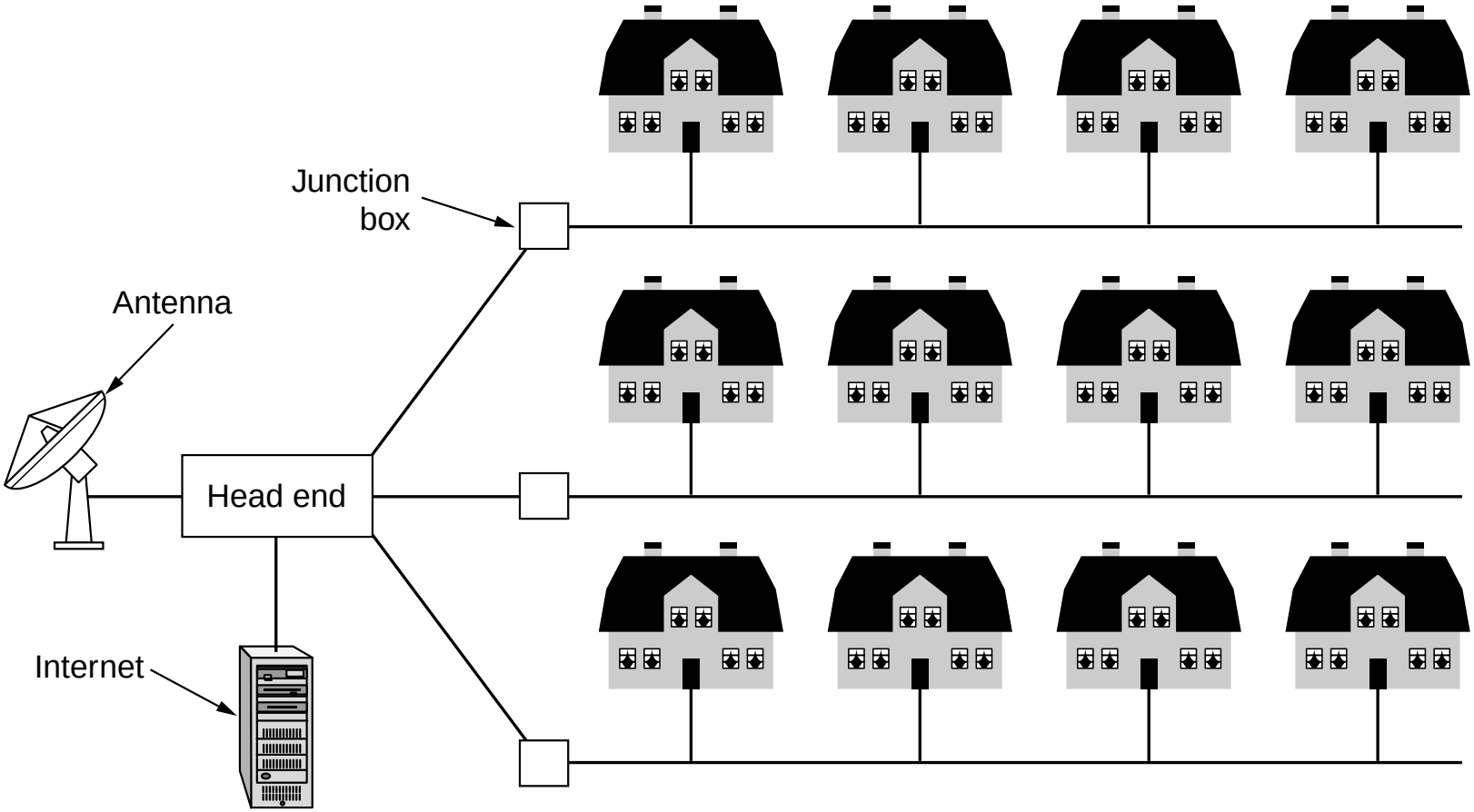
(a) (b)

Two types of broadcast networks

- (a) bus
- (b) ring

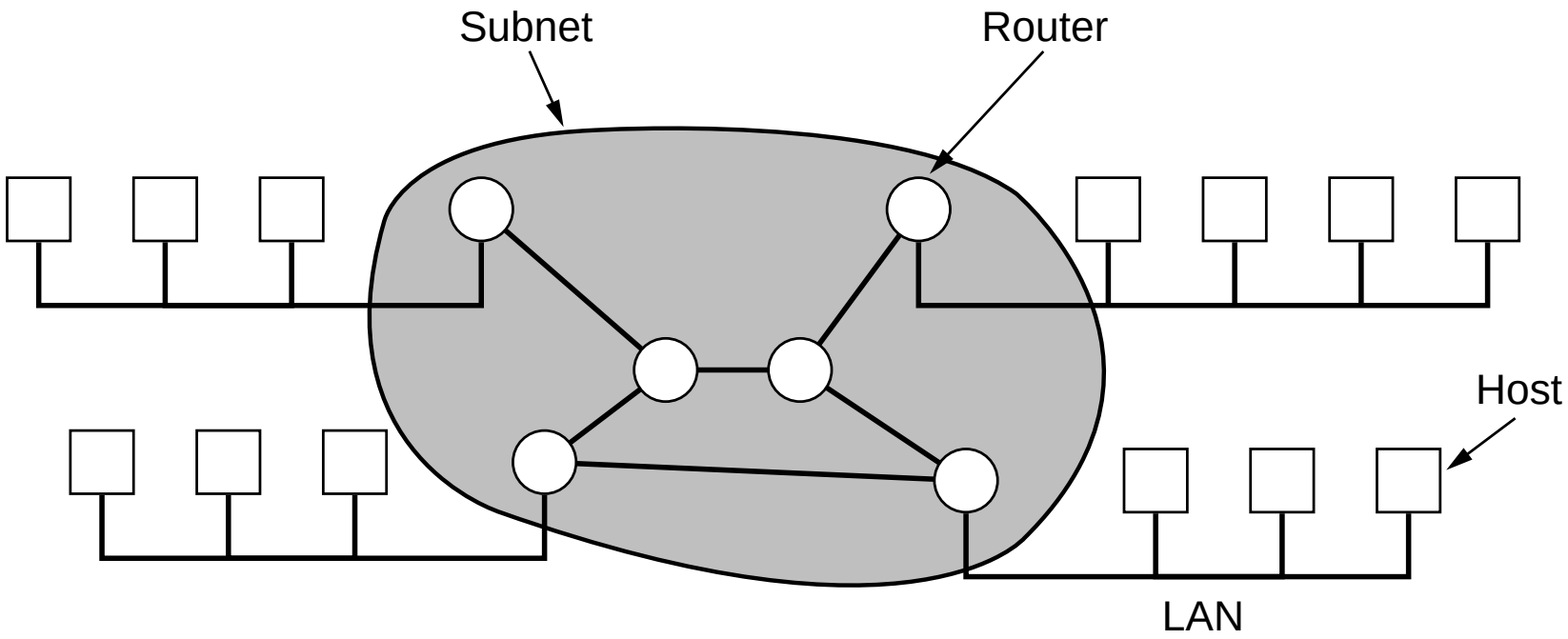
Metropolitan Networks

A metropolitan area network based on cable TV



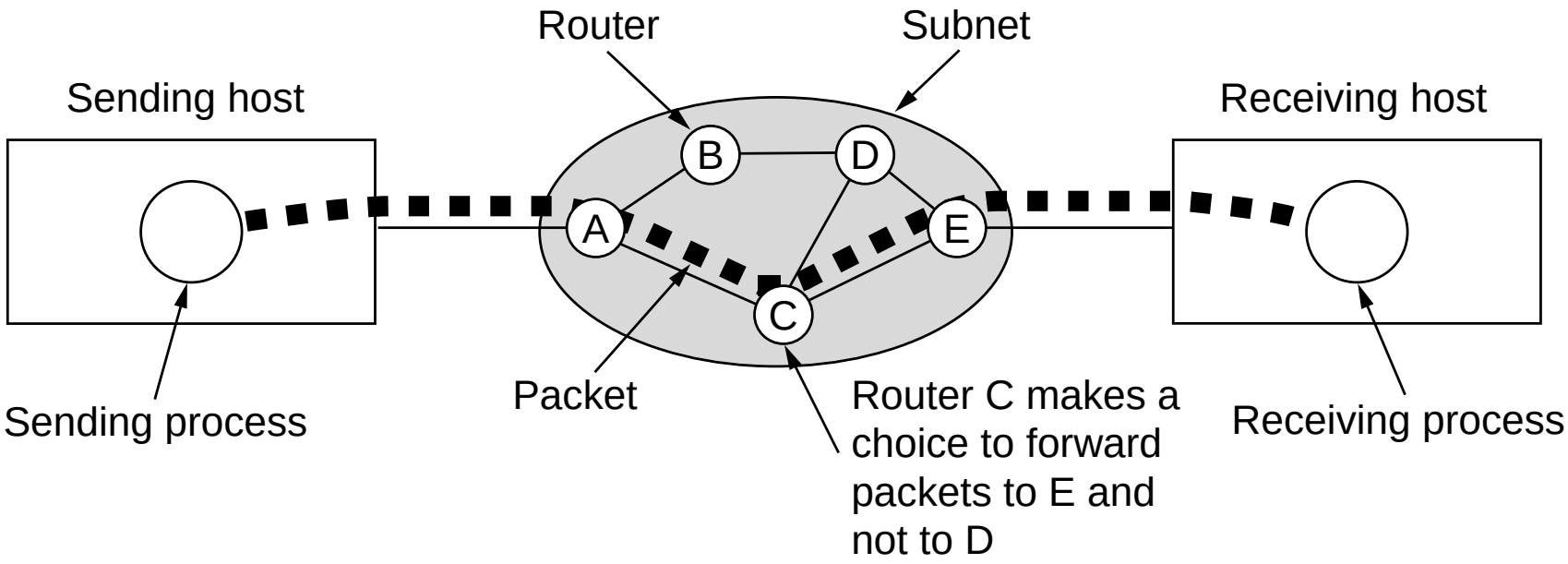
Wide Area Networks

Relation between hosts on LANs and the subnet



Wide Area Networks (2)

Stream of packets from sender to receiver

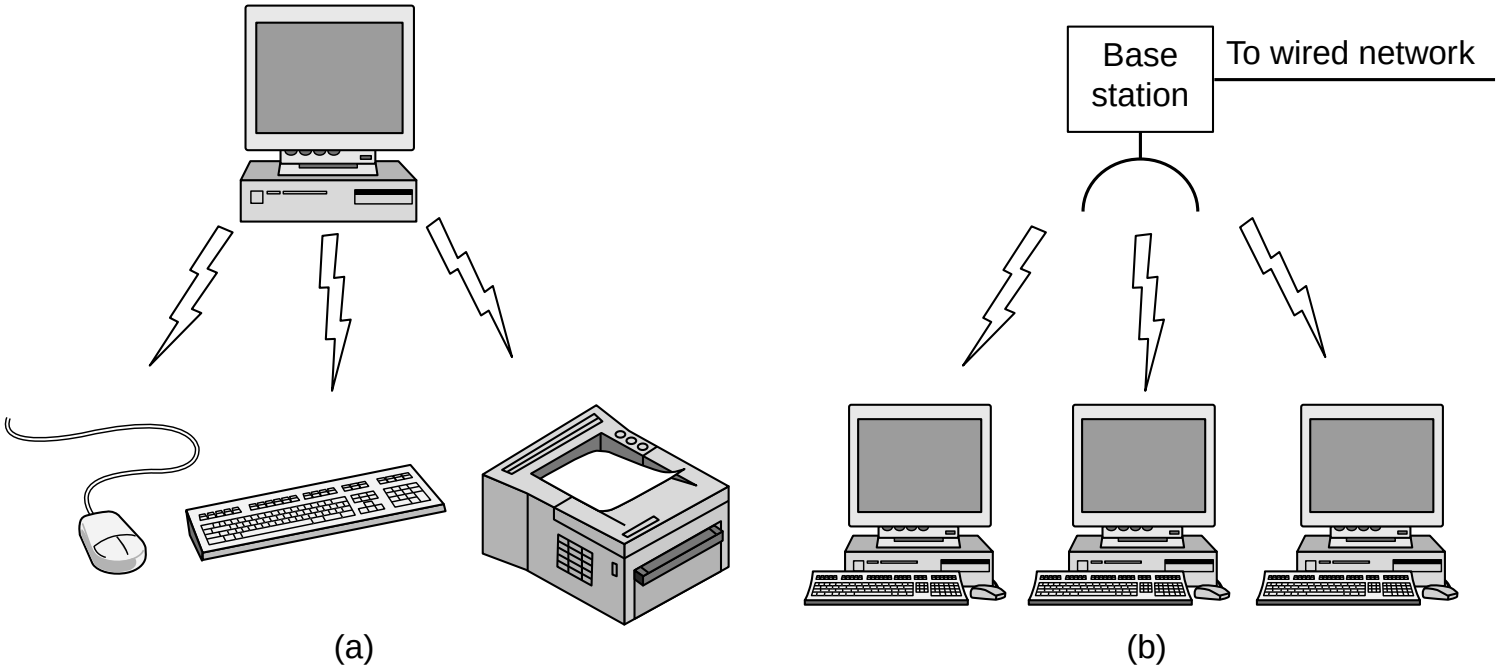


Wireless Networks

Categories of wireless networks:

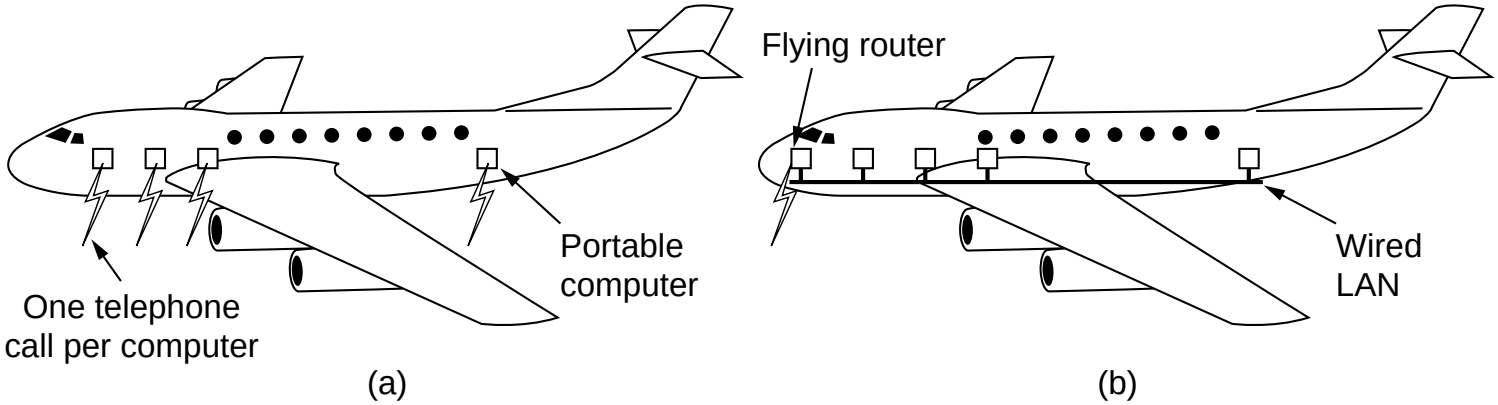
- System interconnection
- Wireless LANs
- Wireless WANs

Wireless Networks (2)



- (a) bluetooth configuration
- (b) wireless LAN

Wireless Networks (3)



- (a) individual mobile computers
- (b) a flying LAN

Home Network Categories

- Computers (desktop PC, PDA, shared peripherals)
- Entertainment (TV, DVD, VCR, camera, stereo, MP3)
- Telecomm (telephone, cell phone, intercom, FAX)
- Appliances (microwave, fridge, clock, furnace)
- Telemetry (utility, burglar alarm, babycam)

Topics

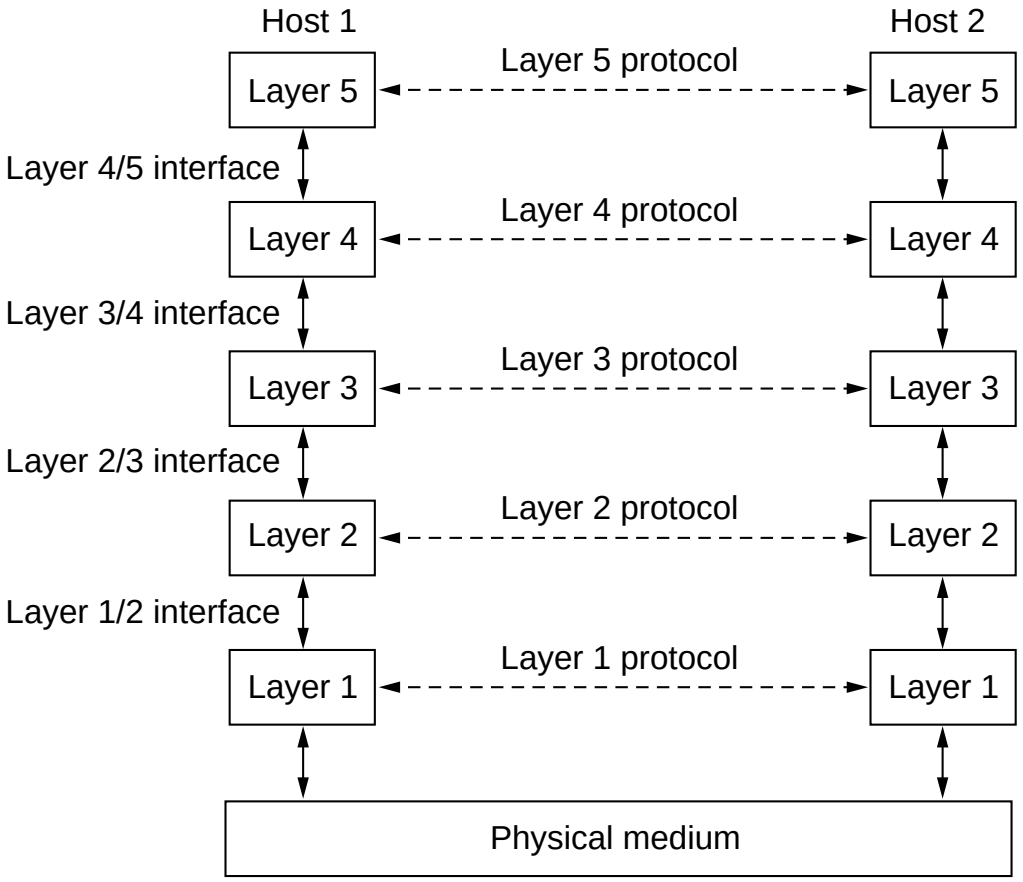
- Uses of Computer Networks
- Network Hardware
- Network Software
- Reference Models
- Example Networks
- Network Standardization

Network Software

- Protocol Hierarchies
- Design Issues for the Layers
- Connection-Oriented and Connectionless Services
- Service Primitives
- The Relationship of Services to Protocols

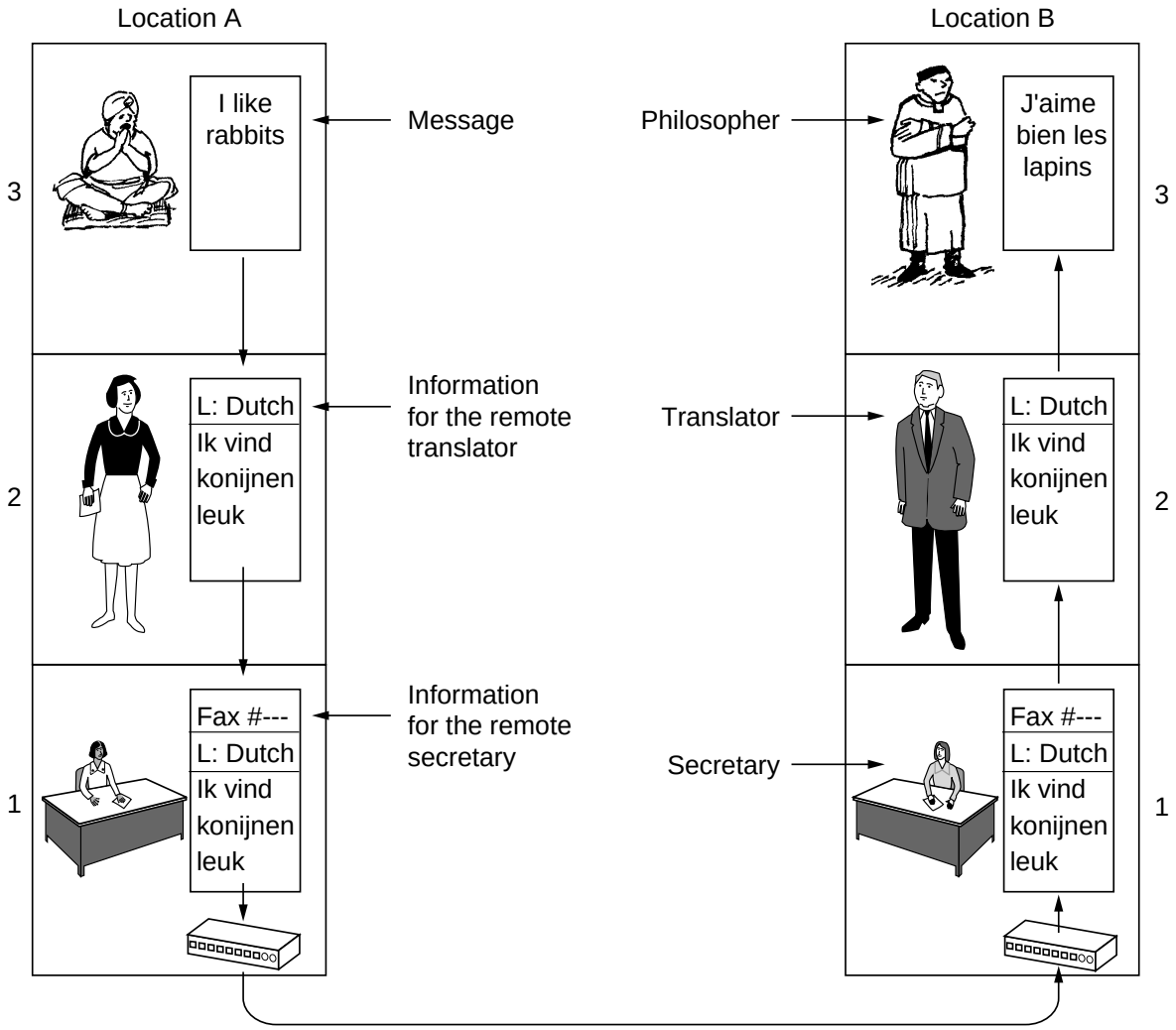
Network Software
Protocol Hierarchies

Layers, Protocols, and Interfaces



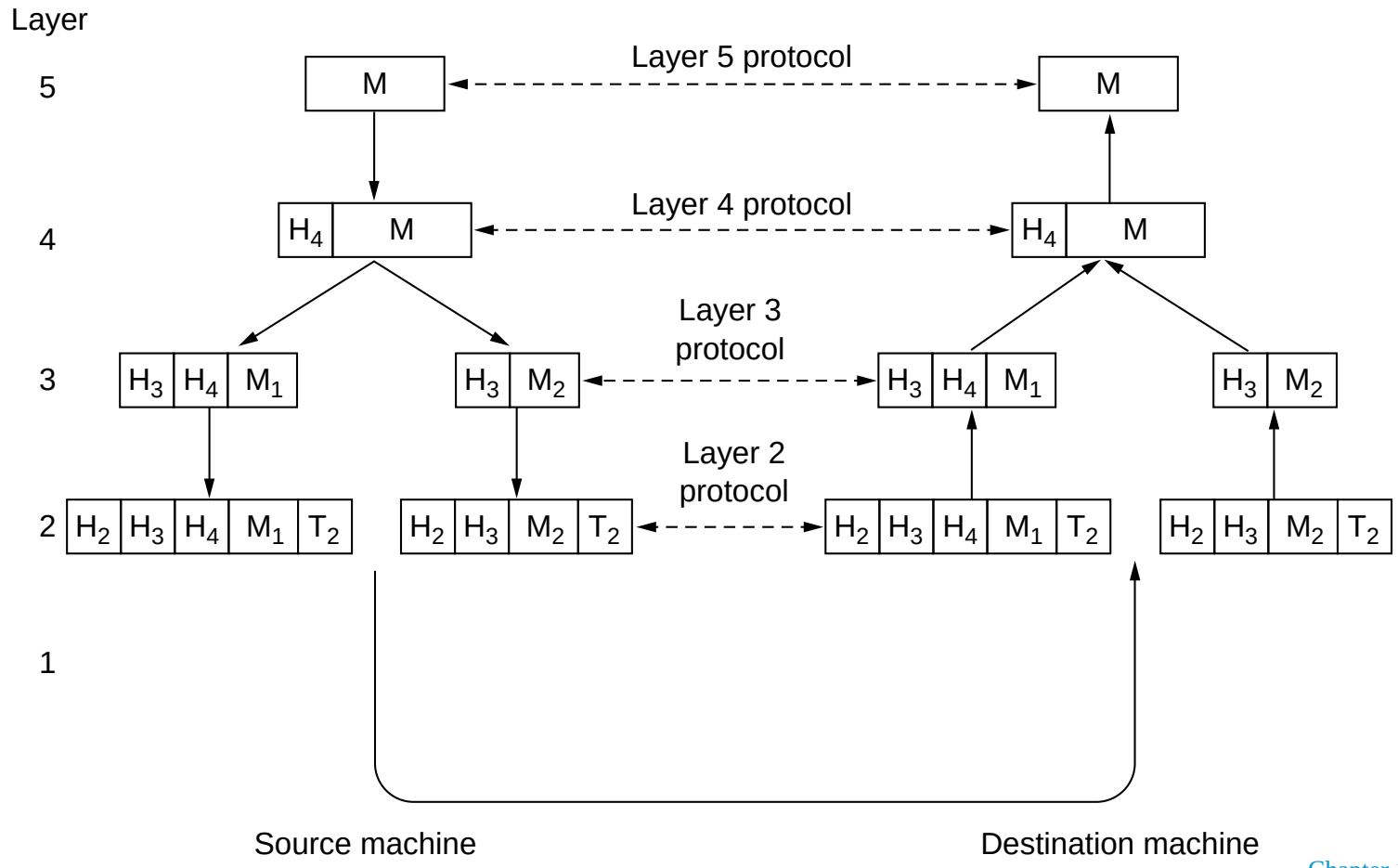
Protocol Hierarchies(2)

Philosopher-translator-secretary architecture



Protocol Hierarchies(3)

Example information flow supporting virtual communication in layer 5



Design Issues for the Layers

- Addressing
- Error control
- Flow control
- Multiplexing
- Routing

Connection-Oriented and Connectionless Services

	Service	Example
Connection-oriented	Reliable message stream	Sequence of pages
	Reliable byte stream	Remote login
	Unreliable connection	Digitized voice
Connection-less	Unreliable datagram	Electronic junk mail
	Acknowledged datagram	Registered mail
	Request-reply	Database query

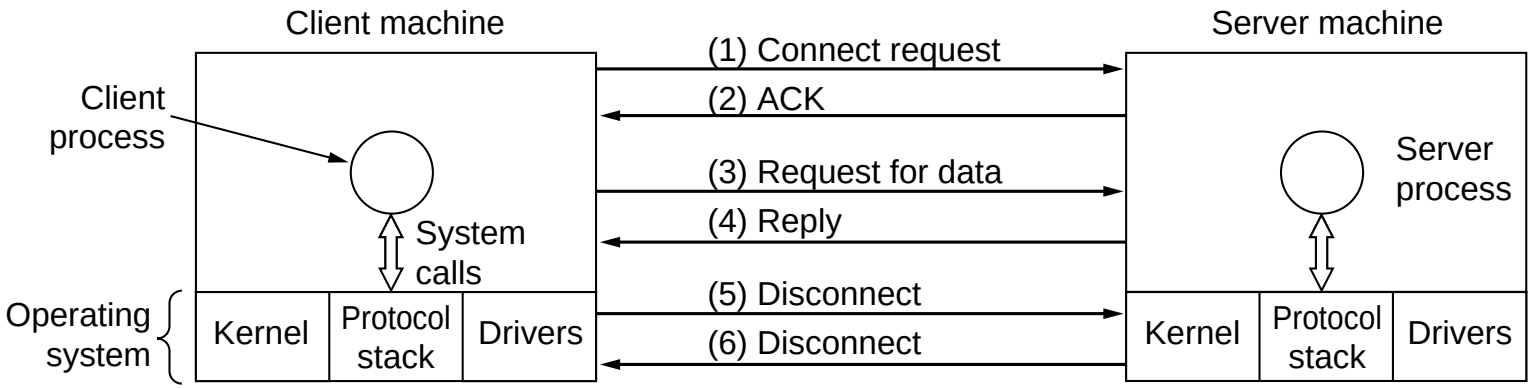
Service Primitives

Five service primitives for implementing a simple connection-oriented service

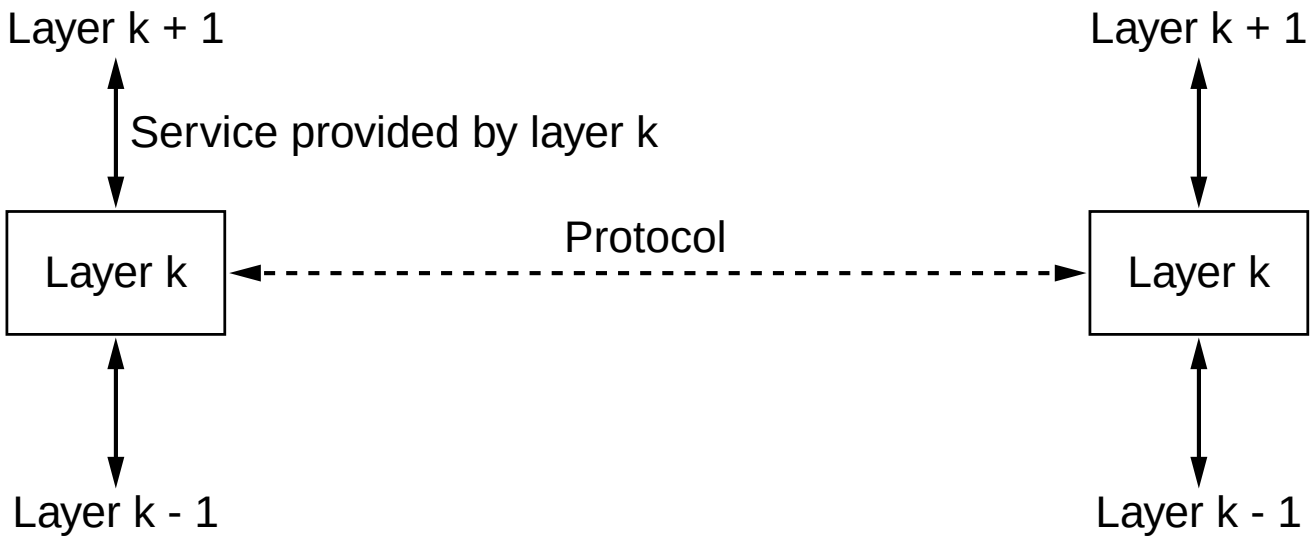
Primitive	Meaning
LISTEN	Block waiting for an incoming connection
CONNECT	Establish a connection with a waiting peer
RECEIVE	Block waiting for an incoming message
SEND	Send a message to the peer
DISCONNECT	Terminate a connection

Service Primitives (2)

Packets sent in a simple client-server interaction on a connection-oriented network



Relationship Between Services and Protocols



Topics

- Uses of Computer Networks
- Network Hardware
- Network Software
- Reference Models
- Example Networks
- Network Standardization

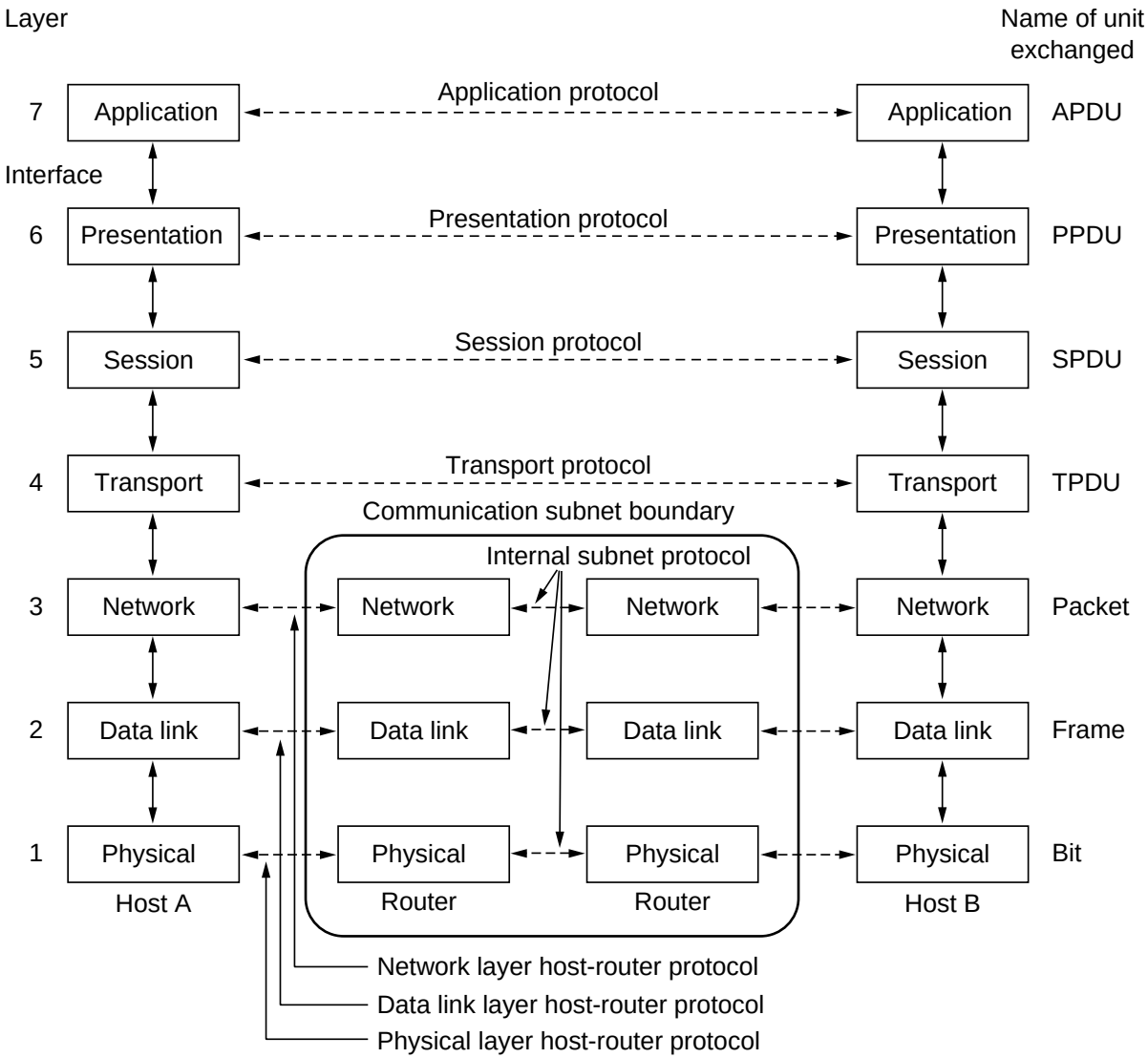
Reference Models

- The OSI (Open Standards Interconnection) Reference Model
- The TCP/IP Reference Model
- A Comparison of OSI and TCP/IP
- A Critique of the OSI Model and Protocols
- A Critique of the TCP/IP Reference Model

OSI Layering Principles

- Layers should be created where different abstraction is needed.
- Each layer performs a well defined function
- The function of each layer should be chosen with an eye toward defining an international standard.
- The layer boundaries should be chosen to minimize the information flow across boundaries.
- The number of layers should be large enough that distinct functions need not be thrown together in the same layer out of necessity and small enough that the architecture does not become unwieldy.

Reference Models
OSI



OSI Layers

Application applications, e.g., HTTP

Presentation syntax and semantics of information (encoding)

Session dialog control, token management, synchronization

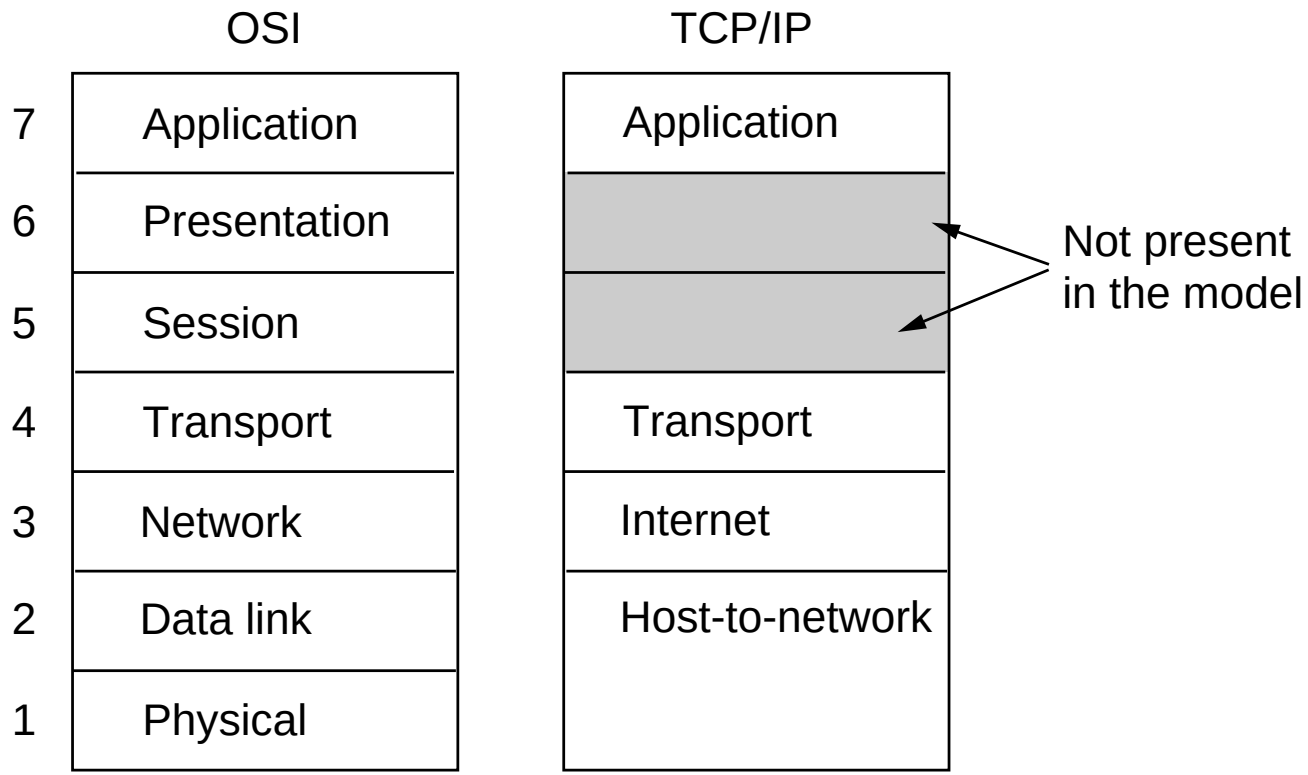
Transport packetization

Network packet routing

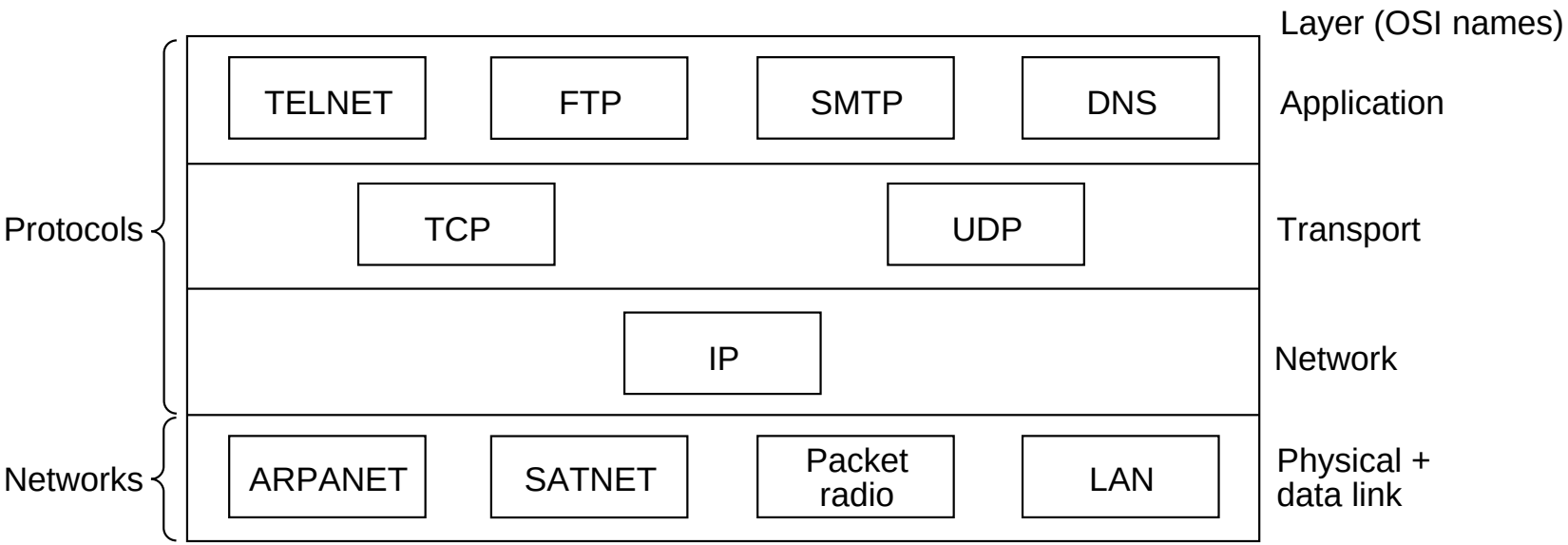
Data Link free of undetected transmission errors

Physical moving bits

Reference Models (2)
TCP and OSI



Network Models (3)
Protocols and Networks in TCP/IP



Comparing the OSI and TCP/IP Models

Concepts central to the OSI model:

- Services
- Interfaces
- Protocols

Nice, layered design.

TCP/IP is a collection of protocols; services and interfaces are an afterthought.

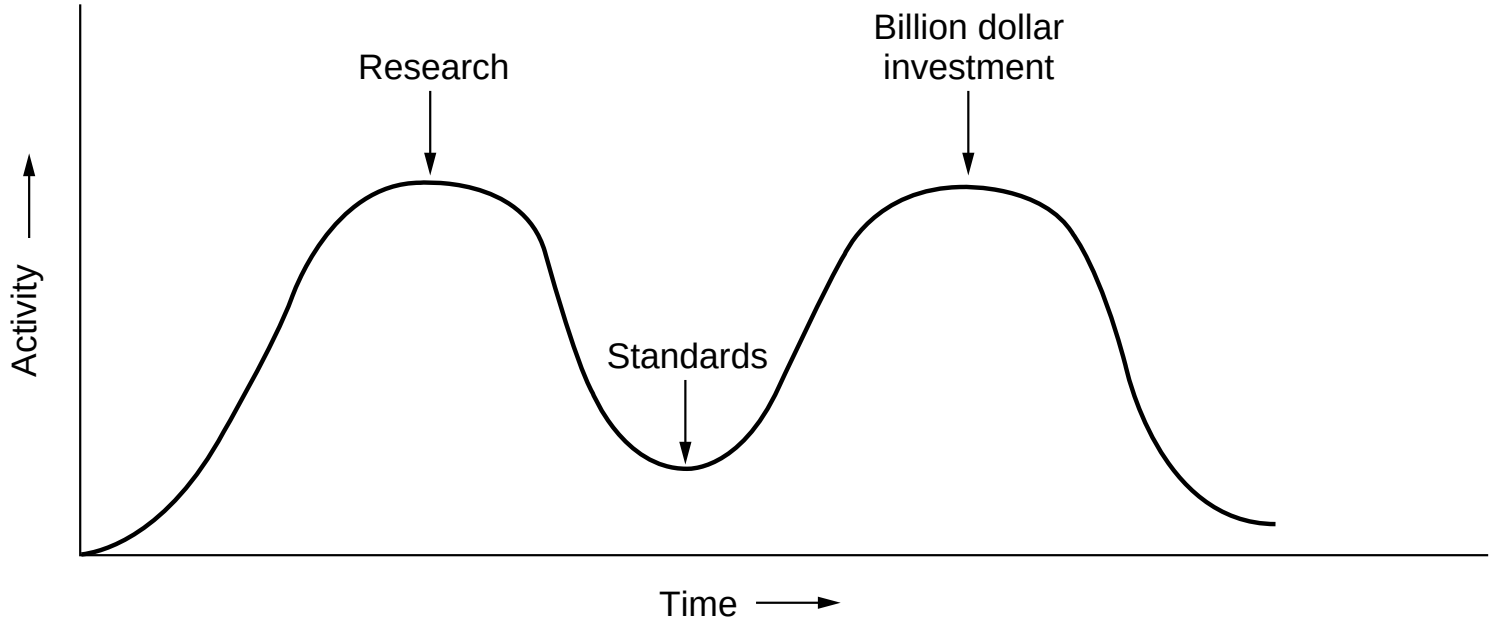
A Critique of the OSI Model and Protocols

Why OSI did not take over the world:

- Bad timing
  - TCP/IP forced shortened standardization period
- Bad technology
  - layers are more political than technical
  - documentation is overly complex
  - error and flow control duplicated in multiple layers
- Bad implementations
  - complexity lead to poor implementations
- Bad politics
  - TCP/IP == Unix, Unix good
  - OSI == committee, committee bad

Bad Timing

David Clark's apocalypse of the two elephants



Timing of standards is critical:

- too early – research is incomplete
- too little time and they get crushed

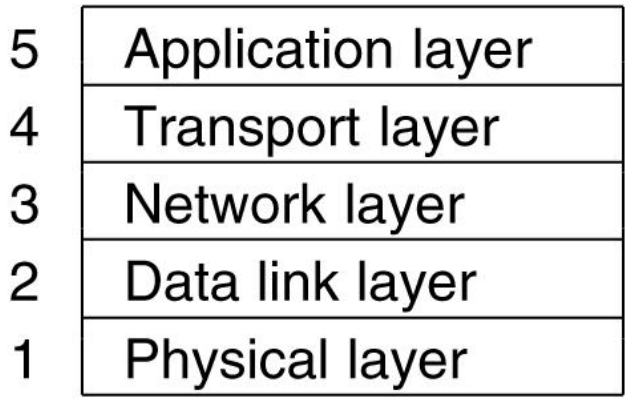
OSI standards got crushed

A Critique of the TCP/IP Reference Models

Problems:

- service, interface and protocol not distinguished
- not a general model
- host-to-network “layer” not really a layer
- no mention of physical and data link layers
- minor protocols deeply entrenched, hard to replace

Hybrid Model



Topics

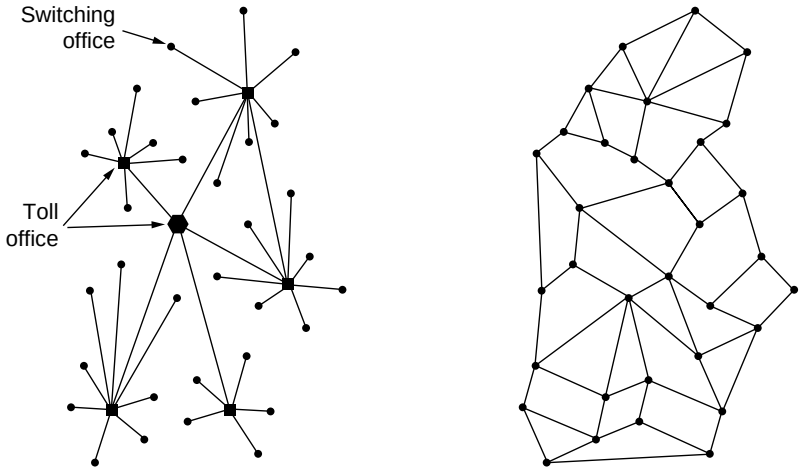
- Uses of Computer Networks
- Network Hardware
- Network Software
- Reference Models
- Example Networks
- Network Standardization

Example Networks

- Internet
- Connection-oriented networks:
  - X.25, Frame Relay, and ATM
- Ethernet
- Wireless LANs: 802.11b

The ARPANET

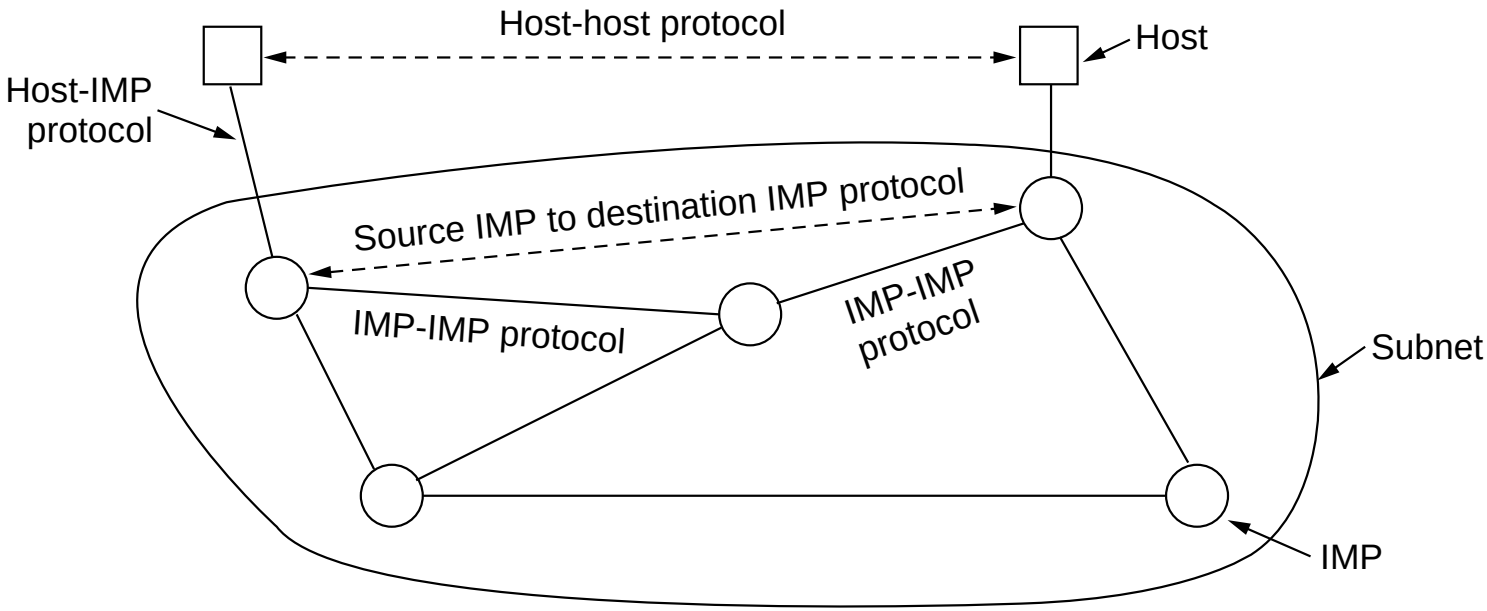
- (D)ARPA – (Defense) Advanced Research Projects Agency
- A command and control network that could survive nuclear war
- Network structure



(a) the telephone network

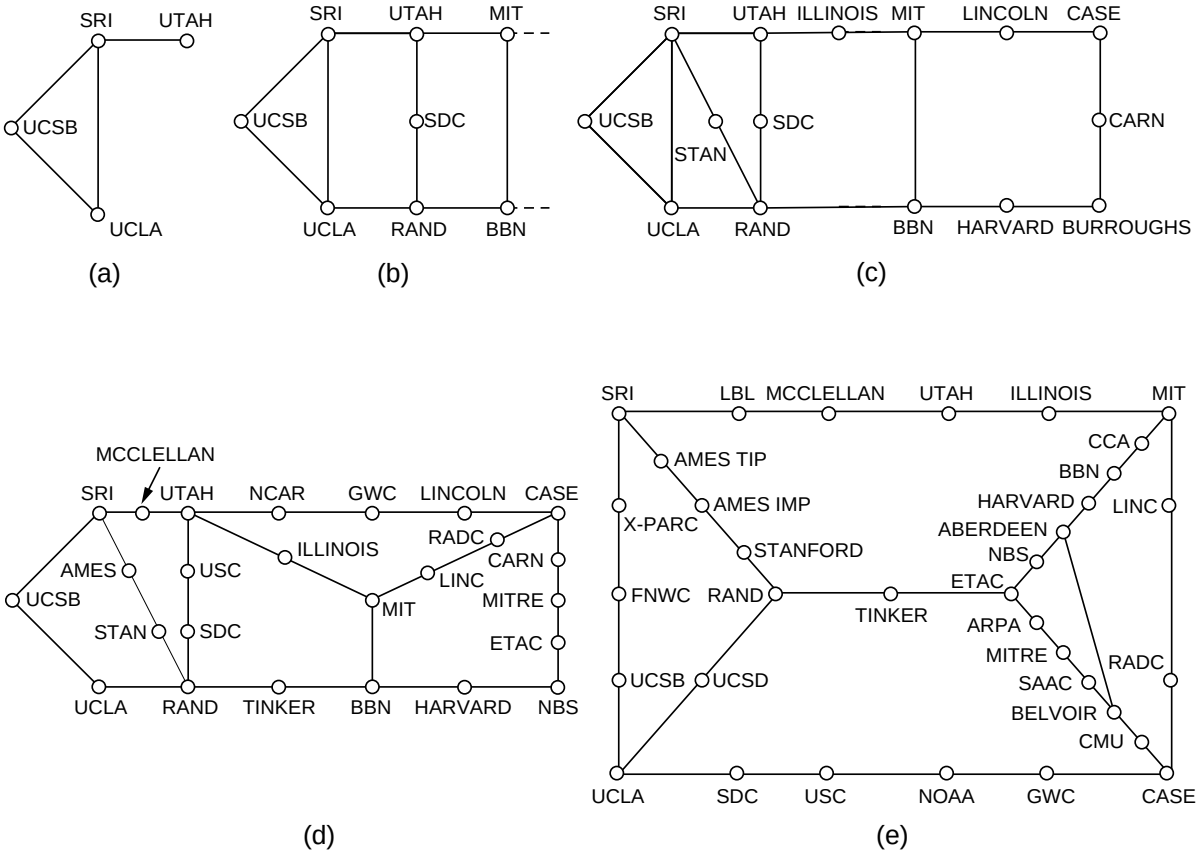
(b) Baran's proposed distributed switching network

The ARPANET Original Design



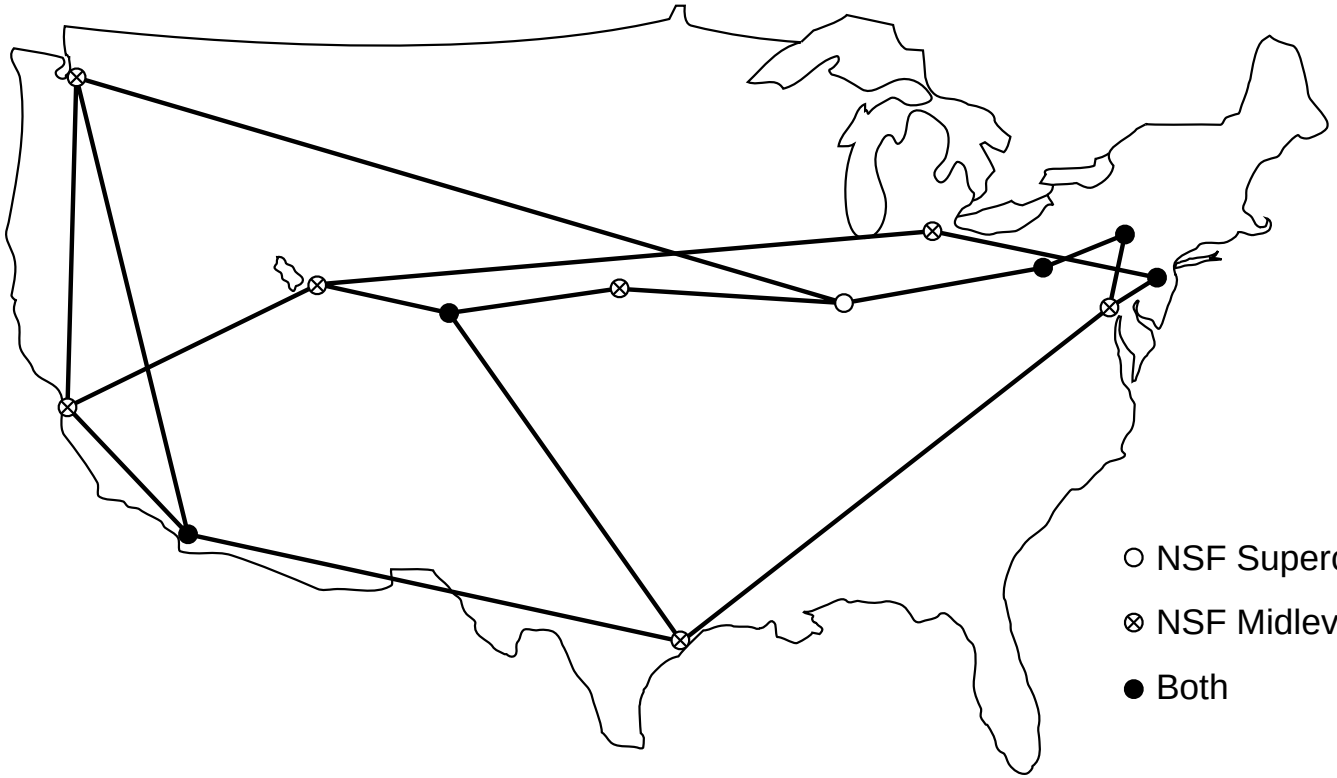
- IMP – Interface Message Processors
- Host-IMP pairs
- IMP-IMP software (56kbs, leased lines)
- Host-IMP software

Growth of the ARPANET



(a) December 1969, (b) July 1970, (c) March 1972, (d) April 1972, (e) September 1972

NFSNET
1988 Backbone

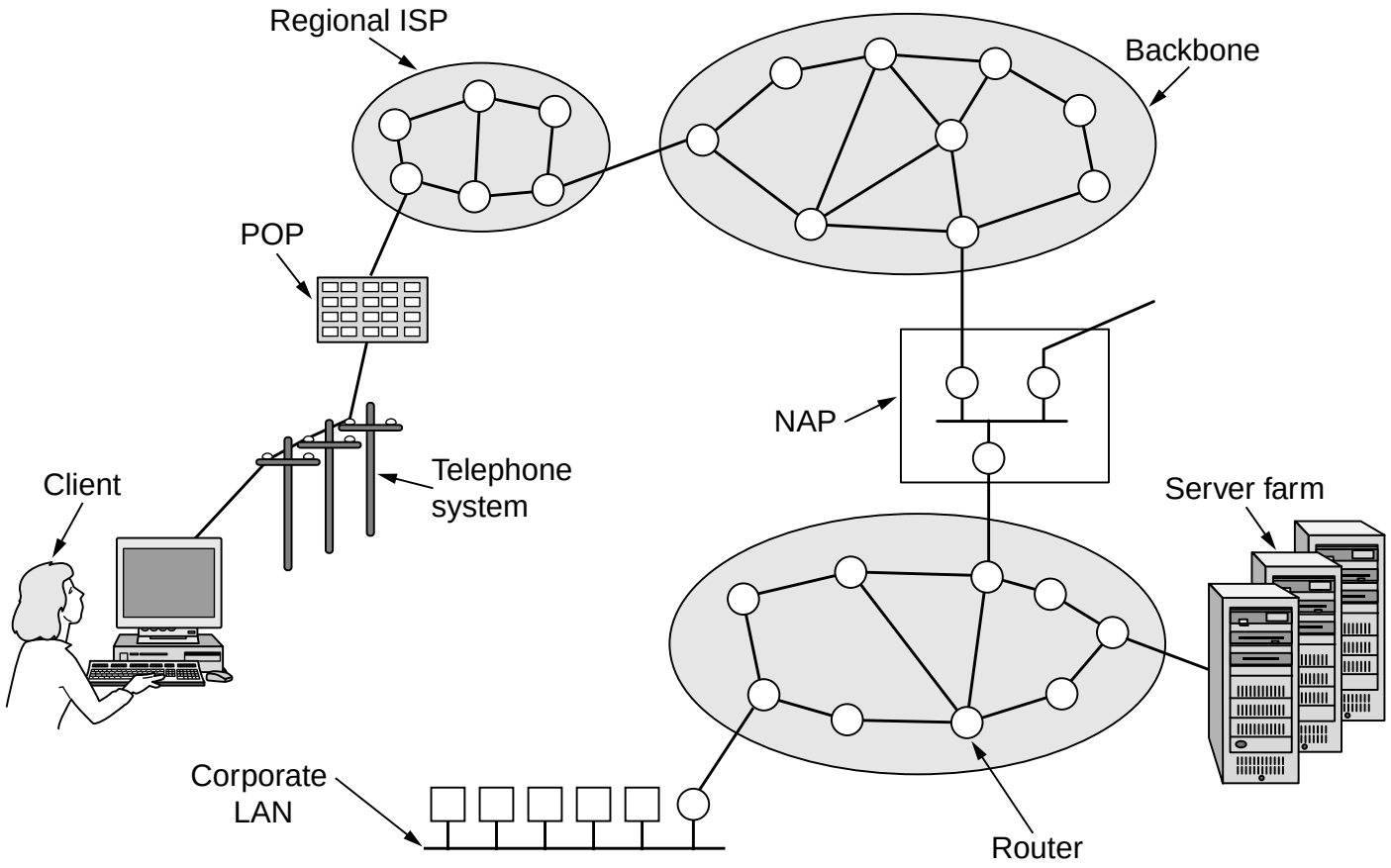


Internet Usage

Traditional applications (1970–1990)

- Email
- News
- Remote login
- File transfer

Architecture of the Internet



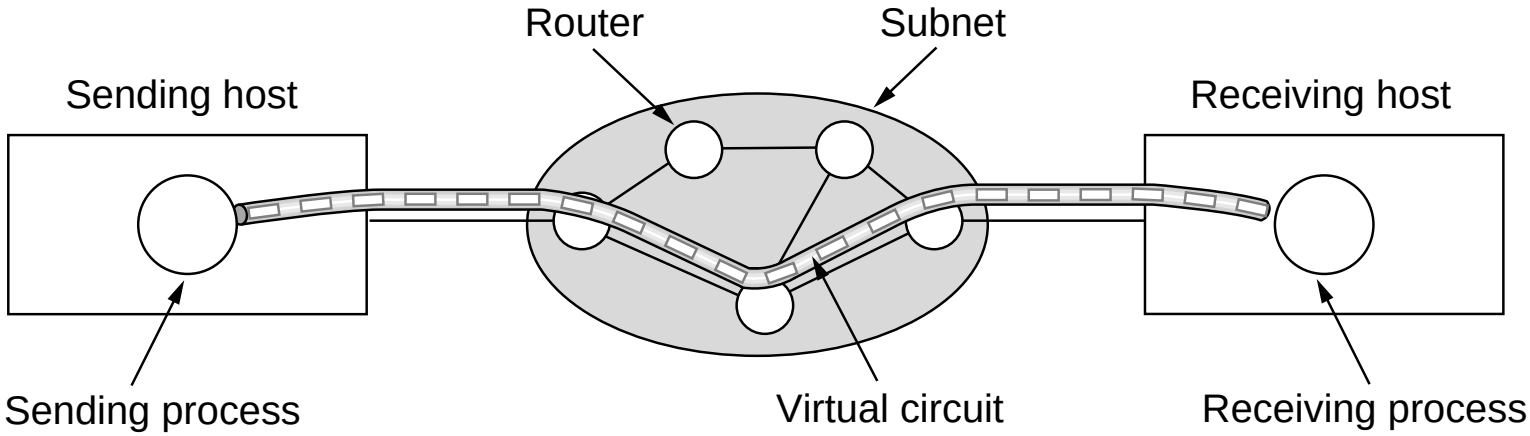
Connection-Oriented Networks

X.25, Frame Relay, and ATM

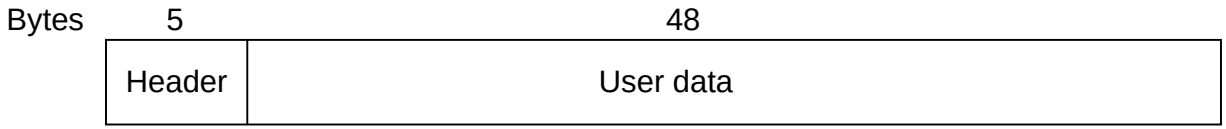
- −Multiple routes (nuclear war)
- −Connection setup
- +Quality of Service
- +Billing

ATM

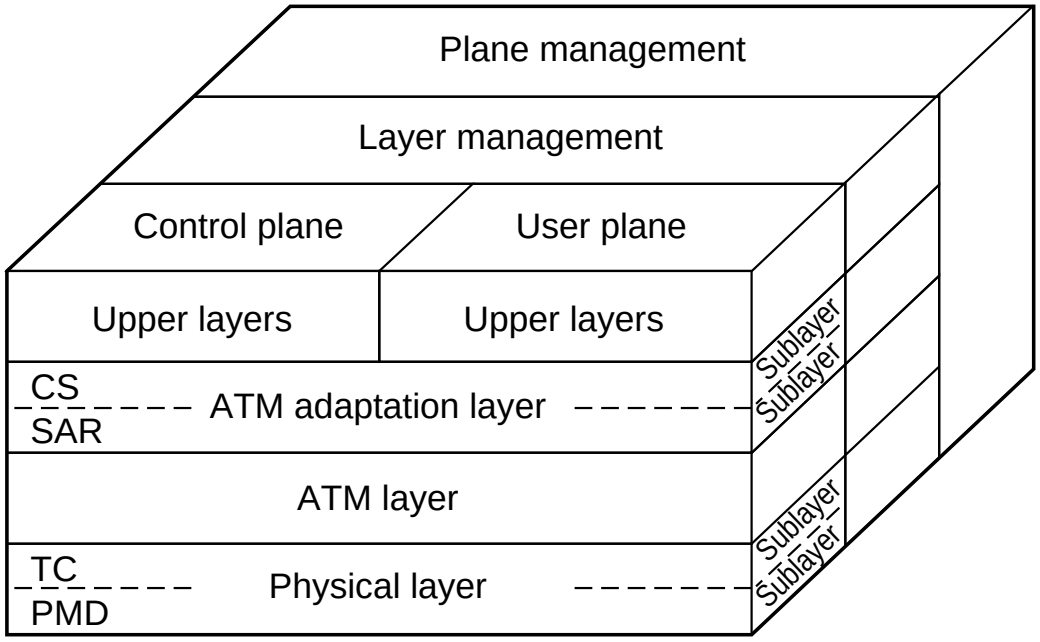
- Virtual circuits



- Fixed sized cells (easier to route)



ATM Reference Model



CS: Convergence sublayer
SAR: Segmentation and reassembly sublayer
TC: Transmission convergence sublayer
PMD: Physical medium dependent sublayer

- user plane: data transport, flow control, error correction
- control plane: connection management

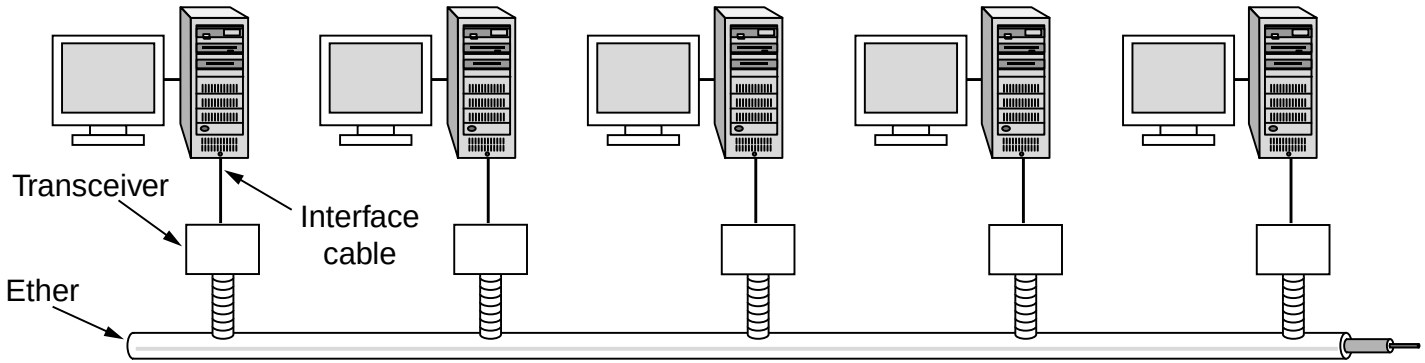
ATM Layers and Sublayers

OSI layer	ATM layer	ATM sublayer	Functionality
3/4	AAL	CS	Providing the standard interface (convergence)
		SAR	Segmentation and reassembly
2/3	ATM		Flow control Cell header generation/extraction Virtual circuit/path management Cell multiplexing/demultiplexing
2	Physical	TC	Cell rate decoupling Header checksum generation and verification Cell generation Packing/unpacking cells from the enclosing envelope Frame generation
1		PMD	Bit timing Physical network access

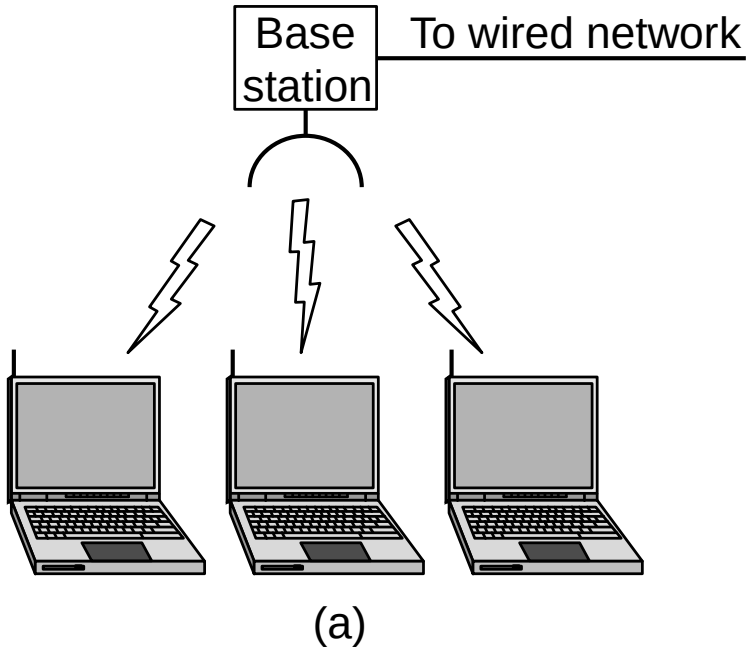
Ethernet

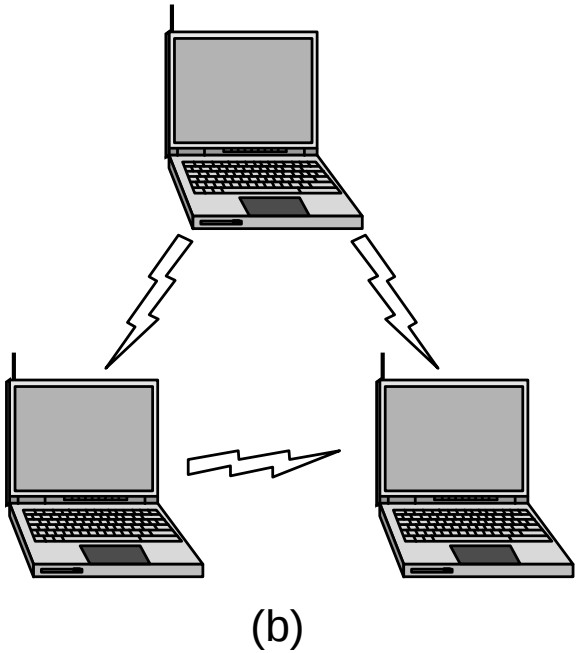
- ALOHANET

- Original Ethernet



Wireless LANs



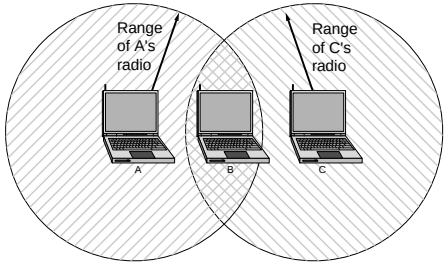


(a) Using a base station

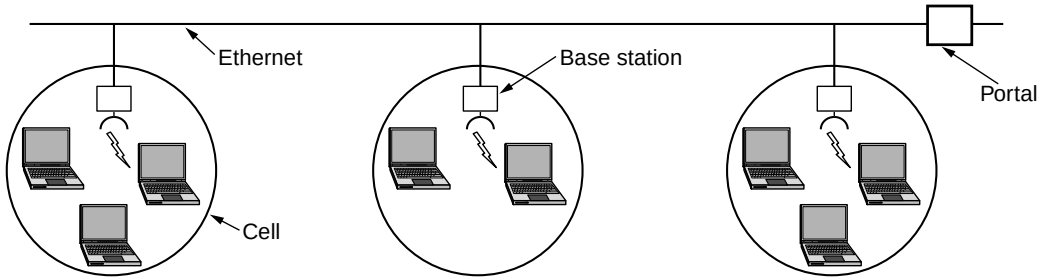
(b) ad-hoc networking

Wireless LANs Issues

- listen before send



  - limited radio range
  - obstructions
- multipath fading (reflections, multiple receipts)
- mobility in higher level software (e.g., printers)
- base station handoff (multi-cell networks)



Topics

- Uses of Computer Networks
- Network Hardware
- Network Software
- Reference Models
- Example Networks
- Network Standardization

Network Standardization

- De facto
- De jure
- Interoperability
- Who’s who in the International Standards World
- Who’s who in the Internet Standards World

Telecommunications

- AT & T breakup lead to 1500 phone companies
- Nationalized PTT (Post, Telegraph & Telephone)
- move toward privatization of PTTs
- ITU (International Telecommunication Union)
  - Main Sectors
    - Radiocommunications (ITU-R)
    - Telecommunications Standardization (ITU-T, CCITT)
    - Development (ITU-D)
  - Classes of Members
    - National governments
    - Sector members
    - Associate members
    - Regulatory agencies

International Standards

- ISO – International Standards Organization
- ANSI – American National Standards Institute
- NIST – National Institute of Standards and Technology
- IEEE – Institute of Electrical and Electronic Engineers

IEEE 802 Standards

Number	Topic
802.1	Overview and architecture of LANs
802.2 ↓	Logical link control
802.3 *	Ethernet
802.4 ↓	Token bus (was briefly used in manufacturing plants)
802.5	Token ring (IBM's entry into the LAN world)
802.6 ↓	Dual queue dual bus (early metropolitan area network)
802.7 ↓	Technical advisory group on broadband technologies
802.8 †	Technical advisory group on fiber optic technologies
802.9 ↓	Isochronous LANs (for real-time applications)
802.10 ↓	Virtual LANs and security
802.11 *	Wireless LANs
802.12 ↓	Demand priority (Hewlett-Packard's AnyLAN)
802.13	Unlucky number. Nobody wanted it
802.14 ↓	Cable modems (defunct: an industry consortium got there first)
802.15 *	Personal area networks (Bluetooth)
802.16 *	Broadband wireless
802.17	Resilient packet ring

(*) Important standards, (↓) Hibernating, (†) Gave up

Internet Standards

- IAB – Internet Architecture Board
- RFC – Request For Comment
- IRTF – Internet Research Task Force
- IETF – Internet Engineering Task Force

Metric Units

Exp.	Explicit	Prefix	Exp.	Explicit	Prefix
10^{-3}	0.001	milli	10^{3}	1,000	Kilo
10^{-6}	0.000001	micro	10^{6}	1,000,000	Mega
10^{-9}	0.000000001	nano	10^{9}	1,000,000,000	Giga
10^{-12}	0.000000000001	pico	10^{12}	1,000,000,000,000	Tera
10^{-15}	0.000000000000001	femto	10^{15}	1,000,000,000,000,000	Peta
10^{-18}	0.000000000000000001	atto	10^{18}	1,000,000,000,000,000,000	Exa
10^{-21}	0.000000000000000000001	zepto	10^{21}	1,000,000,000,000,000,000,000	Zetta
10^{-24}	0.000000000000000000000001	yocto	10^{24}	,000,000,000,000,000,000,000	Yotta