CHAPTER 1 INTRODUCTION

- 1.1 Network Usage
- 1.2 Network Hardware
- 1.3 Network Software
- 1.4 Network Models
- 1.5 Network Examples
- 1.6 Network Standardization

NETWORK USAGE

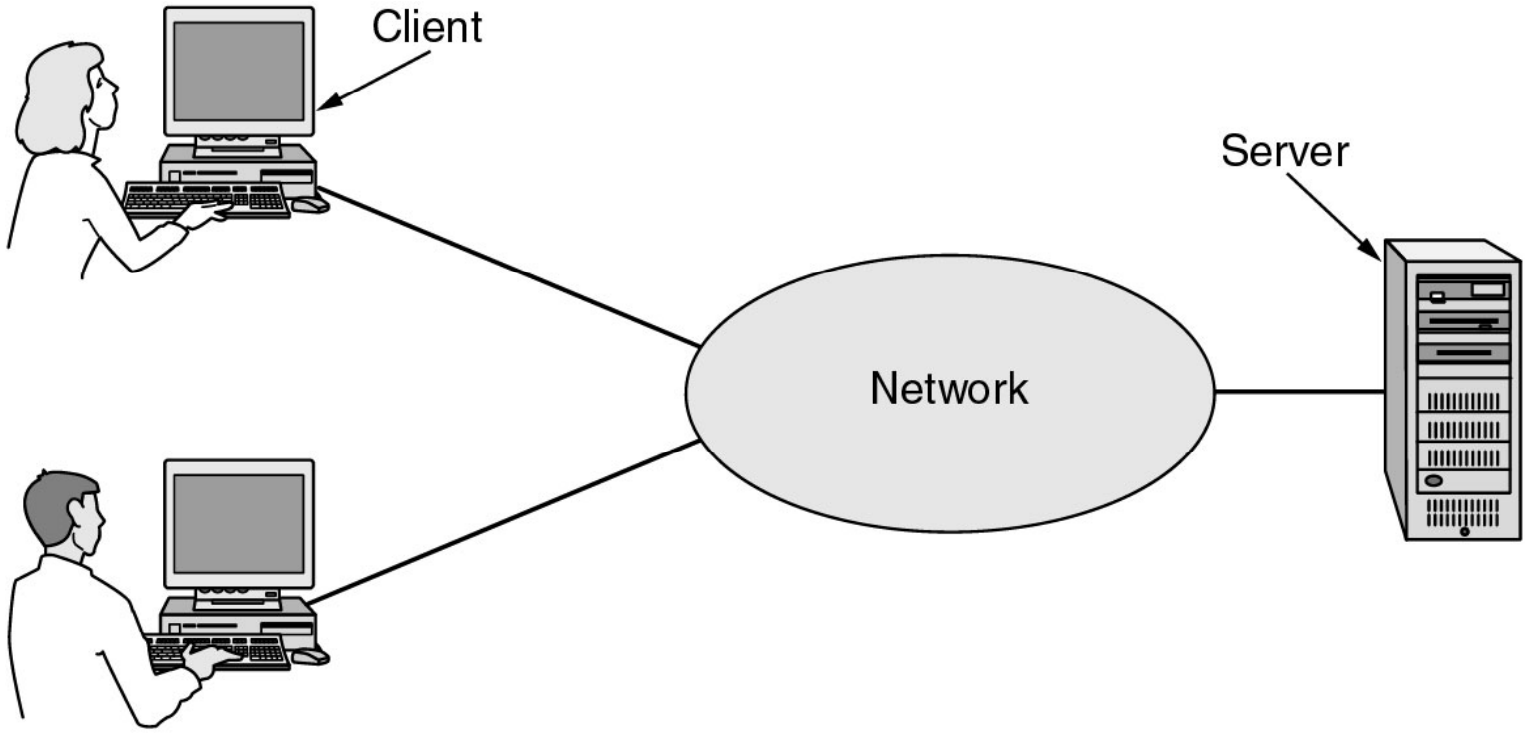
- In the old days, computer systems were highly centralized.
- Now, a large number of autonomous (自治) computers are interconnected to do the job → Computer network (计算机网络) → Distributed systems (分布式系统).
- Computer network v.s. distributed system
  - Computer network: a collection of autonomous computers interconnected by a single technology.
  - Distributed systems: a collection of autonomous computers appears to its users as a single coherent system. Coherence, model, implementation (middleware).
  - Examples: The Internet is not a single network but a network of networks. The Web is a distributed system that runs on top the of the Internet.

Network Usage

- Business applications
- Home applications
- Mobile applications
- Social issues

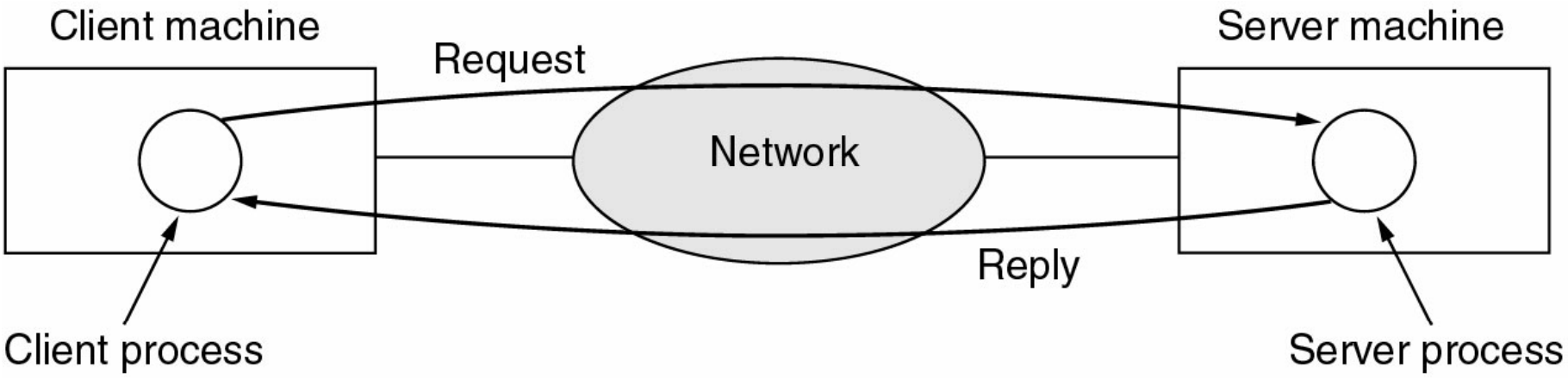
Network Usage: Business applications

- Resource sharing (资源共享): To make all programs, equipment, and especially data available to anyone on the network without regard to the physical location of the resource and the user. “距离不是问题”



Network Usage: Business applications

The client-server model involves requests and replies.



Network Usage: Business applications

- Communication (通信): To provide a powerful communication medium among widely separated employees.
  - Email,
  - BBS,
  - Video conferencing (QQ, MSN).
- E-commerce (电子商务):
  - B2B,
  - B2C.

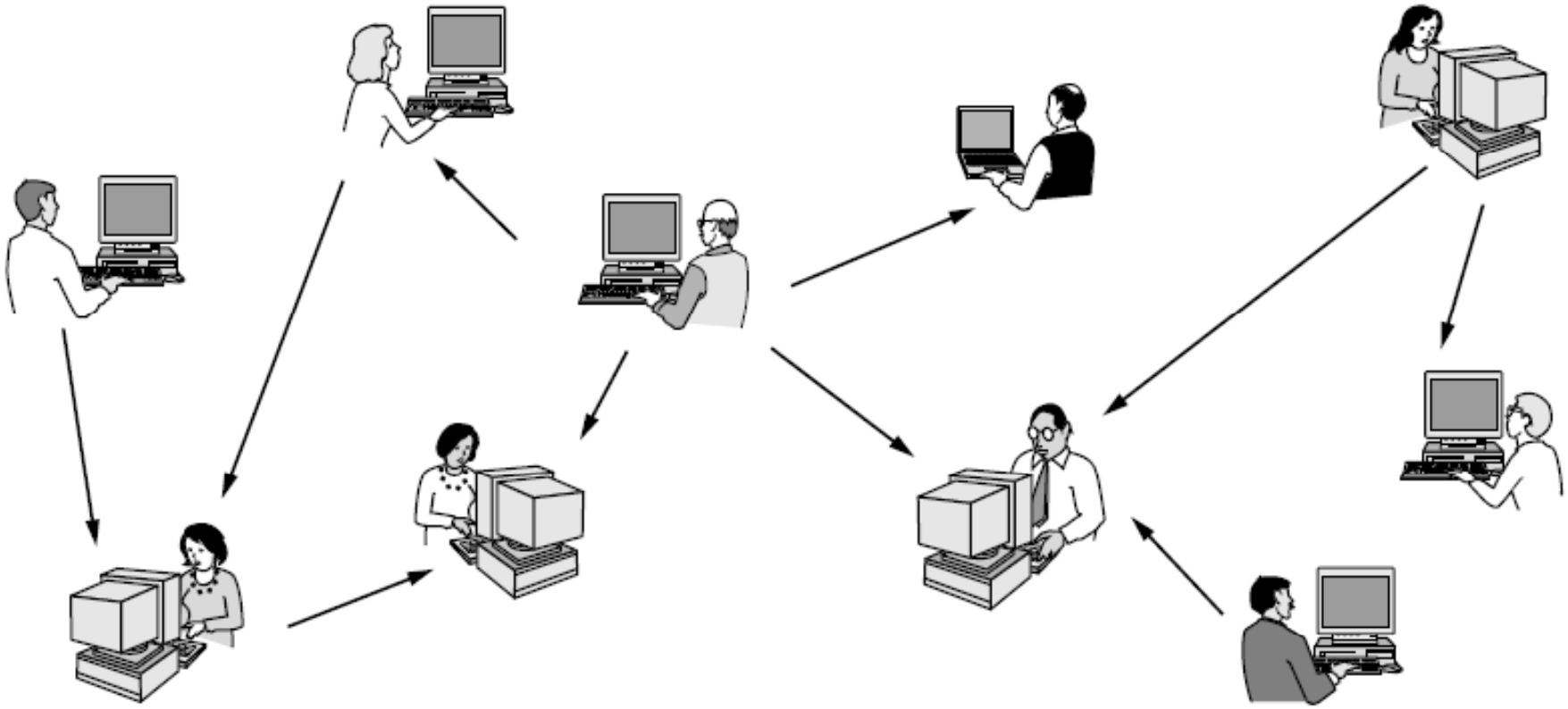
Network Usage: Home applications

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

Network Usage: Home applications

In a peer-to-peer model,

there are no fixed clients and servers.



Network Usage: Home applications

- Access to remote information
  - Access to remote financial institutions.
  - Access to on-line and personalized newspapers.
  - Access to information systems like the WWW, which contains information about the arts, business, cooking, government, health, history, hobbies, recreation, science, sports, travel, and
    - too many other topics to even mention.
    - (Some better left unmentioned)

Network Usage: Home applications

- Person-to-person communication
  - Email
  - Instant messaging: chat room
  - Using the Internet to carry telephone calls, video phone, and Internet radio (YouTube)
  - Facebook, MSN, QQ, BBS
  - Wiki (Wikipedia)
  - Tele-learning

Network Usage: Home applications

Electronic 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

Network Usage: Home applications

- Interactive entertainment
  - VOD (video on demand) (视频点播), interactive films and interactive TVs.
  - Network game playing
  - Maybe a brand new industry based on computer networking and entertainment
- Ubiquitous computing (普适计算)
  - Computing is embedded into everyday life
  - Power-line networks
  - RFID

Network Usage: Mobile applications

- Portable office
- Important for drivers
- Important to military
- M-apps: m-commerce, m-learning, …

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

Network Usage: Social issues

- Contents on newsgroup or BBS
- Employee rights versus employer rights
- Government versus citizen's rights
- Profiling
- Anonymous messages
- Along with the good comes the bad. Life seems to be like that.
  - Junk email
  - Ill-informed, misleading, or downright wrong info.
  - Identity theft

NETWORK HARDWARE

- Network classification:
  - Transmission technology
    - Broadcast networks
    - Point-to-point networks
  - Scale
    - Local area networks (LANs)
    - Metropolitan area networks (MANs not Men)
    - Wide area networks (WANs)
    - Inter-networks (internet vs. Internet)

Network Hardware: Transmission

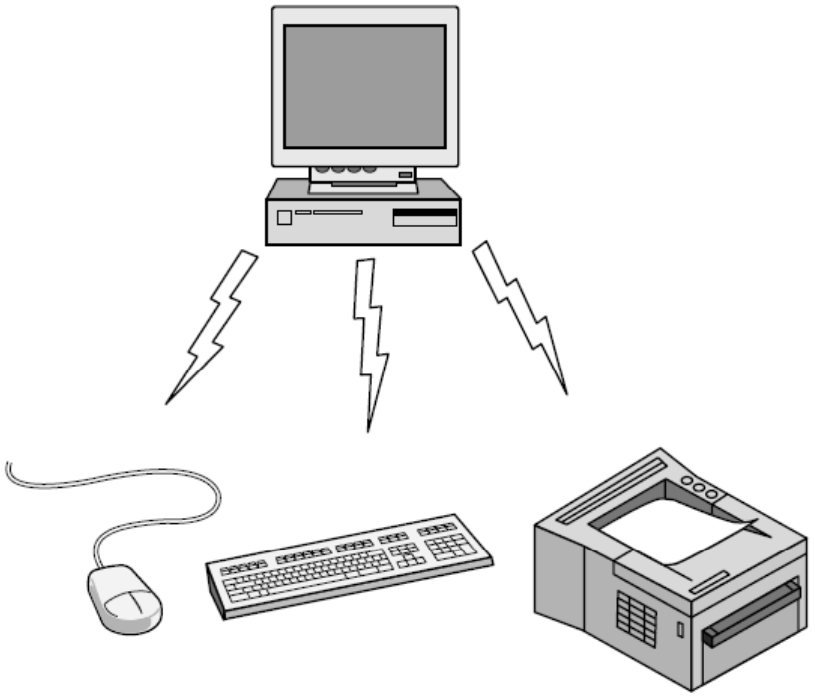
- Broadcast networks (广播式网络): broadcast networks have a single communication channel that is shared by all the machines on the network. There are three addressing possibilities:
  - Unicasting (单播),
  - Broadcasting（广播）,
  - Multicasting （组播）.
- Point-to-point networks (点到点网络): point-to-point networks have many communication connections between individual pairs of machines.

Network Hardware: 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

Network Hardware: PAN (个人局域网)

- PANs (Personal Area Networks) let device communicate over the range of a person.
- To connect a Bluetooth mouse a Bluetooth keyboard, a Bluetooth Printer with a computer.
- To connect a Bluetooth earphone with a mobile phone
- To use RFID to communicate with goods.



Network Hardware: LAN (局域网)

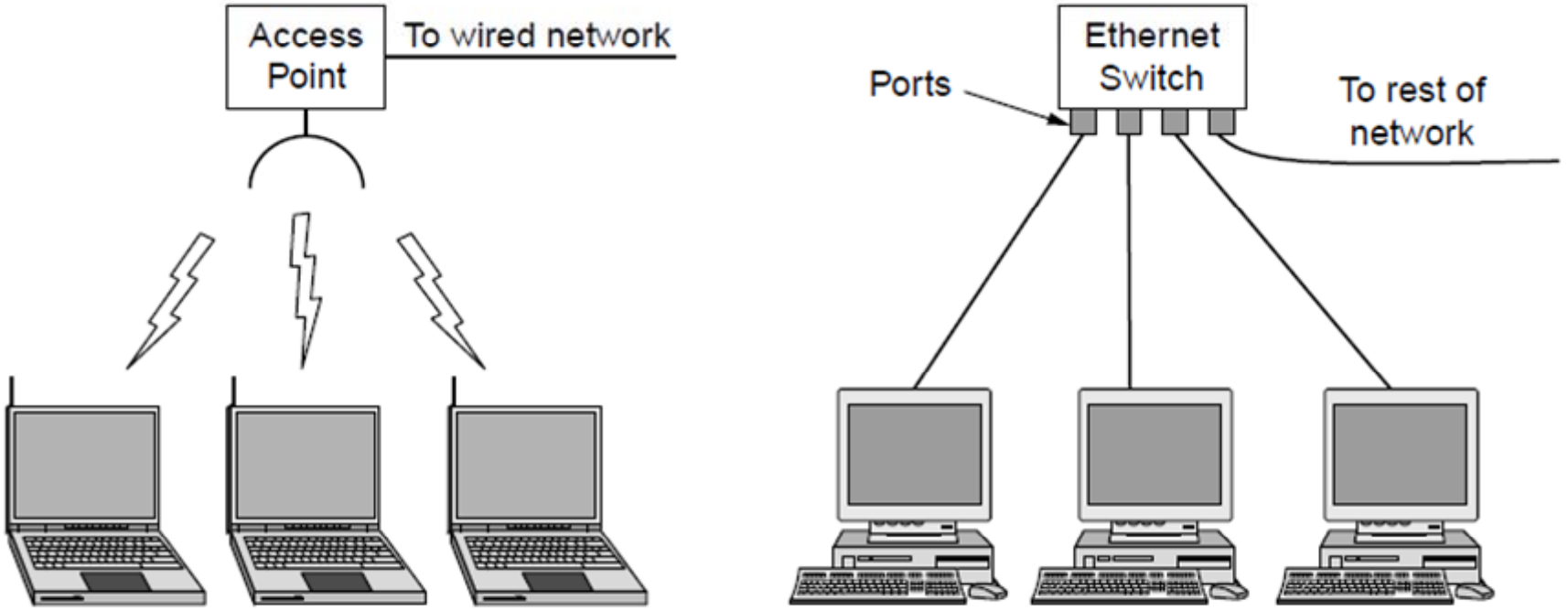
- LANs are privately-owned networks within a single building or campus of up to a few kilometers in size.
- LAN characteristics
  - The size is restricted → The worst-case transmission time is bounded and known in advance → Certain designs are possible and network management can be simplified.
  - Transmission technology →high speed → 10Gpbs
  - Topology (physical and local): Bus, Ring, Star (Hub)

Network Hardware: LAN

Wireless and wired LANs.

(a) 802.11.

(b) Switched Ethernet.



Network Hardware: LAN

- Broadcast networks can be further divided into static and dynamic, depending on how the channel is allocated.
  - A typical static allocation would be to divide time into discrete intervals and use a round-robin algorithm, allowing each machine to broadcast only when its time slot comes up.
  - Dynamic allocation methods for a common channel are
    - either centralized (A single entity determines who goes next)
    - or decentralized. (Many algorithms are designed to bring order out of the potential chaos.)

Network Hardware: LAN

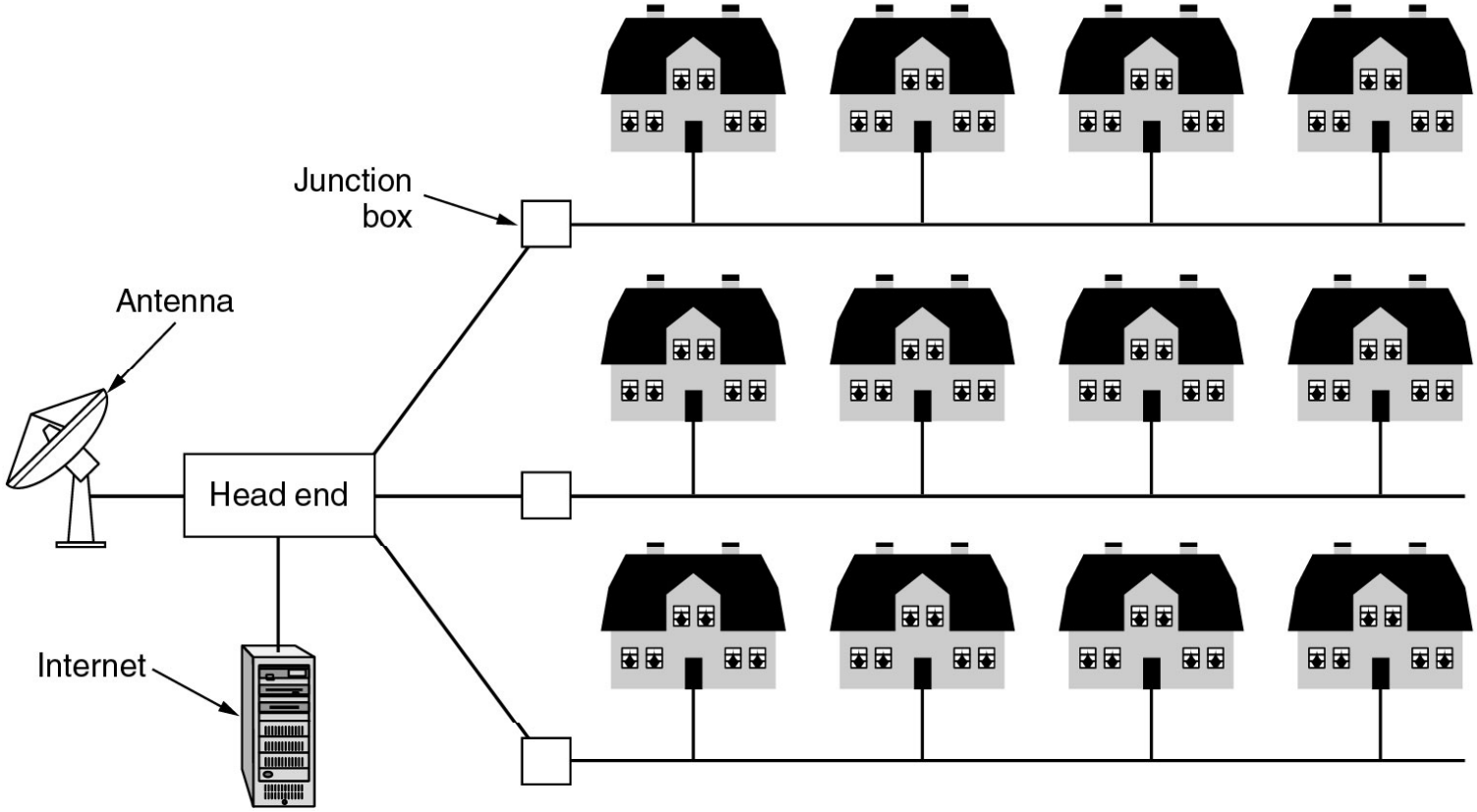
- Many home devices are capable of being networked:
  - Computers (desktop PC, PDA, shared peripherals)
  - Entertainment (TV, DVD, VCR, camera, stereo, MP3)
  - Telecommunications (telephone, cell phone, intercom, fax)
  - Appliances (microwave, fridge, clock, furnace, airco)
  - Telemetry (utility meter, burglar alarm, babycam).
- Requirements: easy to install, foolproof in operation, low price, sufficient capacity, to be expandable, secure and reliable.

Network Hardware: MAN (城域网)

- A metropolitan area work, or, MAN (plural: MANs, not MEN) is basically a bigger version of a LAN and normally uses similar technology.
- Examples
  - One reason for distinguishing MANs as a special category is that a standard has been adopted for them. It is called DQDB (Distributed Queue Dual Bus) (分布式队列双总线) .
  - A MAN can be based on cable TV (See the next slide)
  - IEEE 802.16 (WiMAX)
- A key aspect of MAN is that there is a broadcast medium to which all the computers are attached.

Network Hardware: MAN

A metropolitan area network based on cable TV.

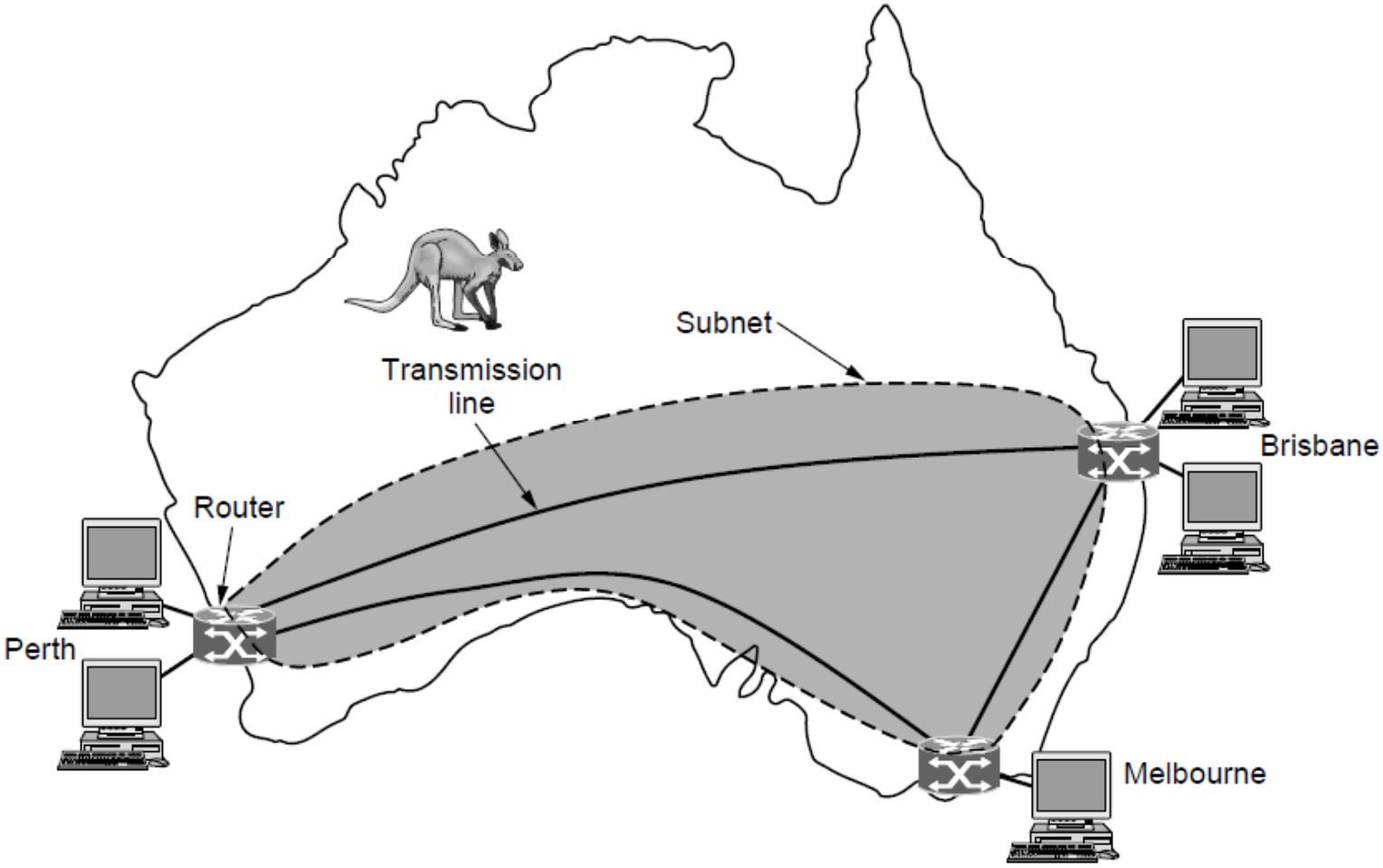


Network Hardware: WAN (广域网)

- A WAN consists of a collection of machines intended for running user programs (hosts, end systems) and a pure communication subnet(subnet)
- The subnet consists of two distinct components:
  - Transmission lines (also called circuits, channels, or trunks) move bits between machines.
  - Switching elements (packet switching nodes, intermediate system, data switching exchanges, routers) are specialized computers used to connect three or more transmission lines. When data arrive on an incoming line, the switching element must choose an outgoing line to forward them on.

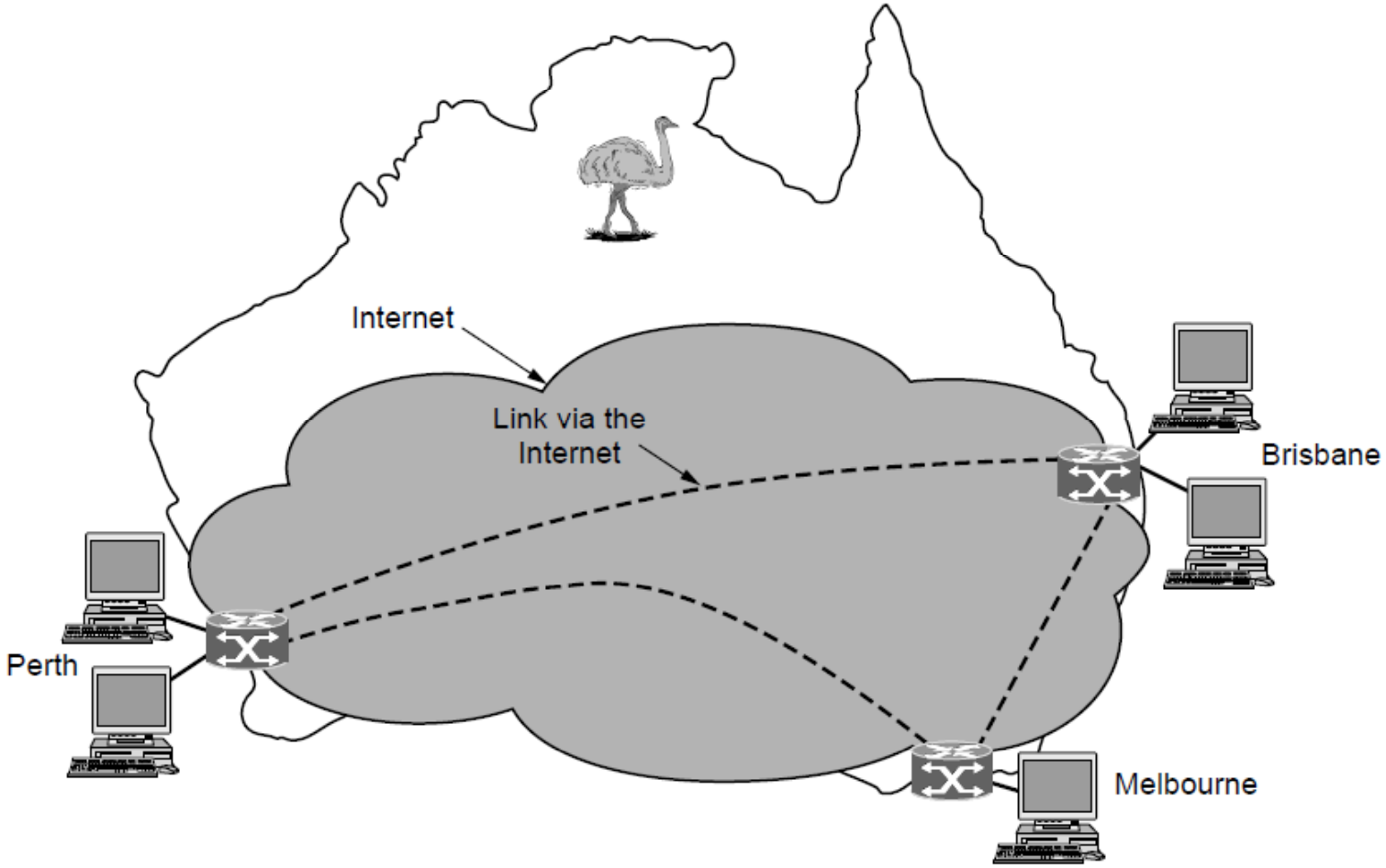
Network Hardware: WAN

WAN that connects three branch offices in Australia



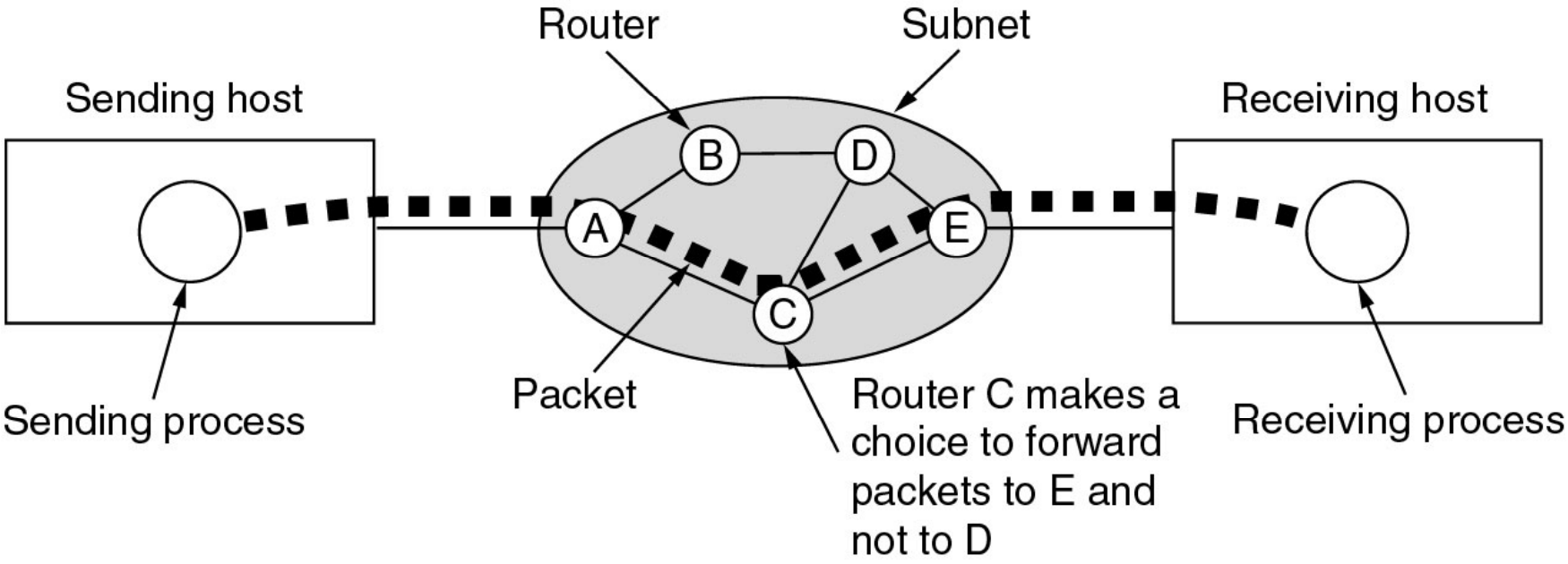
Network Hardware: WAN

WAN using a virtual private network.



Network Hardware: WAN

A stream of packets from sender to receiver.



Network Hardware: Internet (互联网)

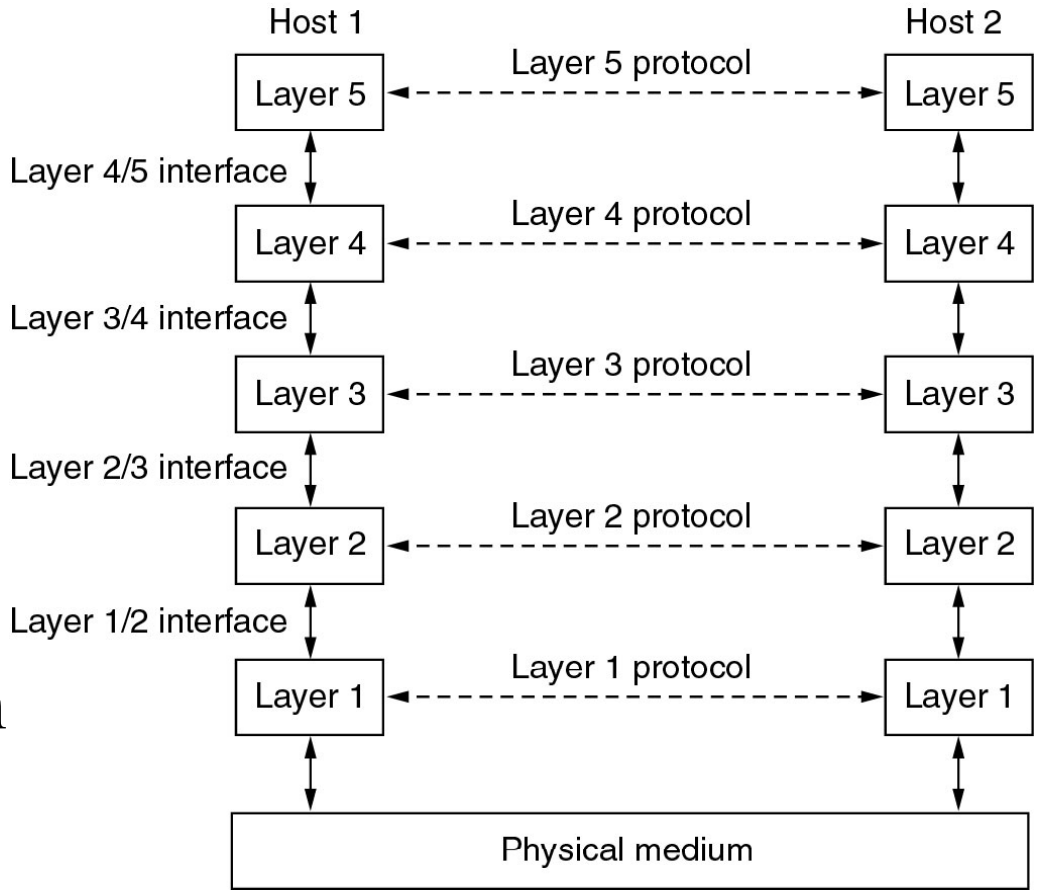
- An internetwork or just internet is a collection of interconnected networks. (internet vs Internet)
- A common form of internet is a collection of LANs connected by a WAN.
- Differences among WANs, subnets, networks, and internetworks.
  - WAN = subnet + hosts
  - Subnet + hosts → WAN →network
  - Cable + hosts → LAN →network
  - Many interconnected networks → internetworks.
    - Different owners
    - Different technologies.

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.
  - The number of layers
  - The name of each layer
  - The function of each layer
  - The content of each layer



Network Software: Protocol hierarchies

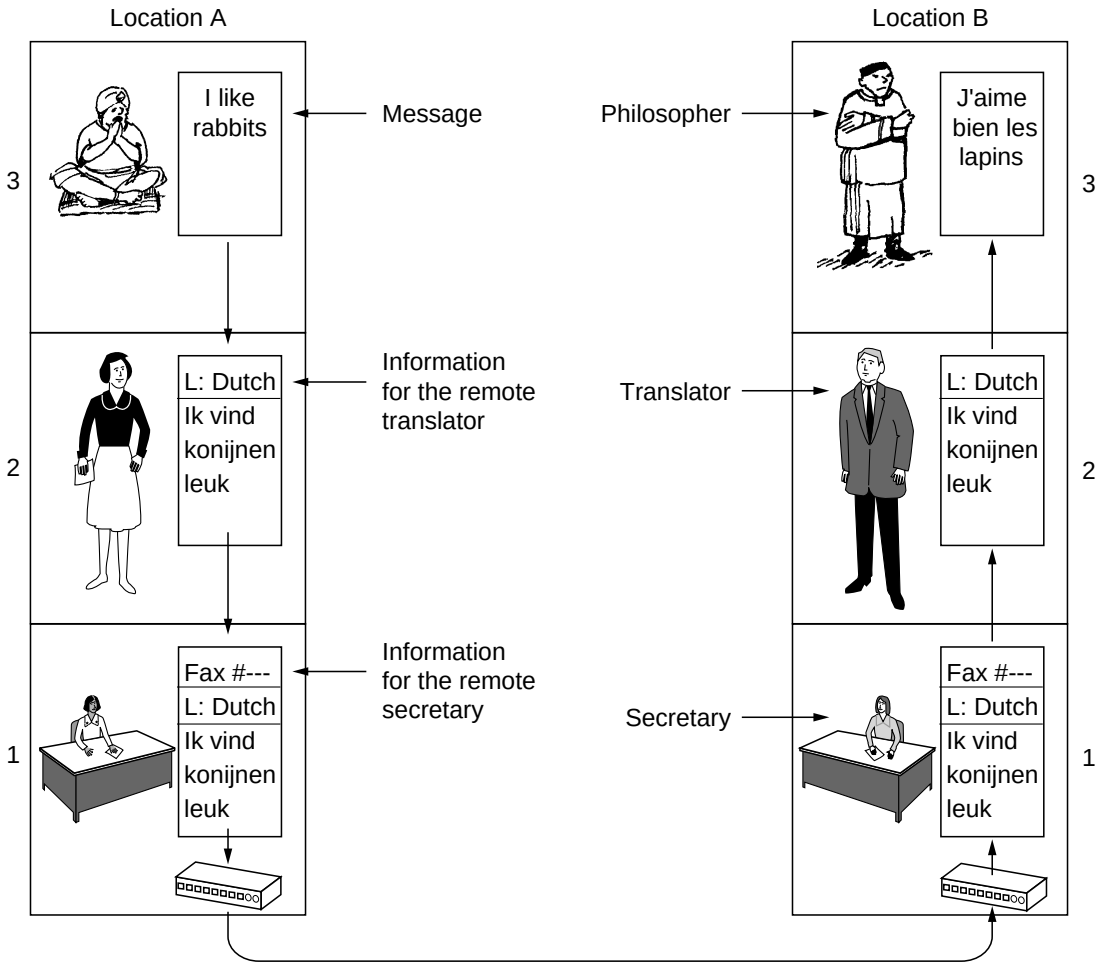
- A **protocol** (协议) is an agreement between the communicating parties on how communication is to proceed.
- The **peers** (对等实体) are the entities comprising the corresponding layers on different machines. The peers may be OS kernel, processes, hardware devices, or even human beings. It is the peers that communicate by using the protocol.
- Communication: actual and virtual.
- Service interfaces:
  - The interface defines which primitive operations and services the lower layer makes available to the upper one.
  - It is common that different hosts use different implementations.

Network Software: Protocol hierarchies

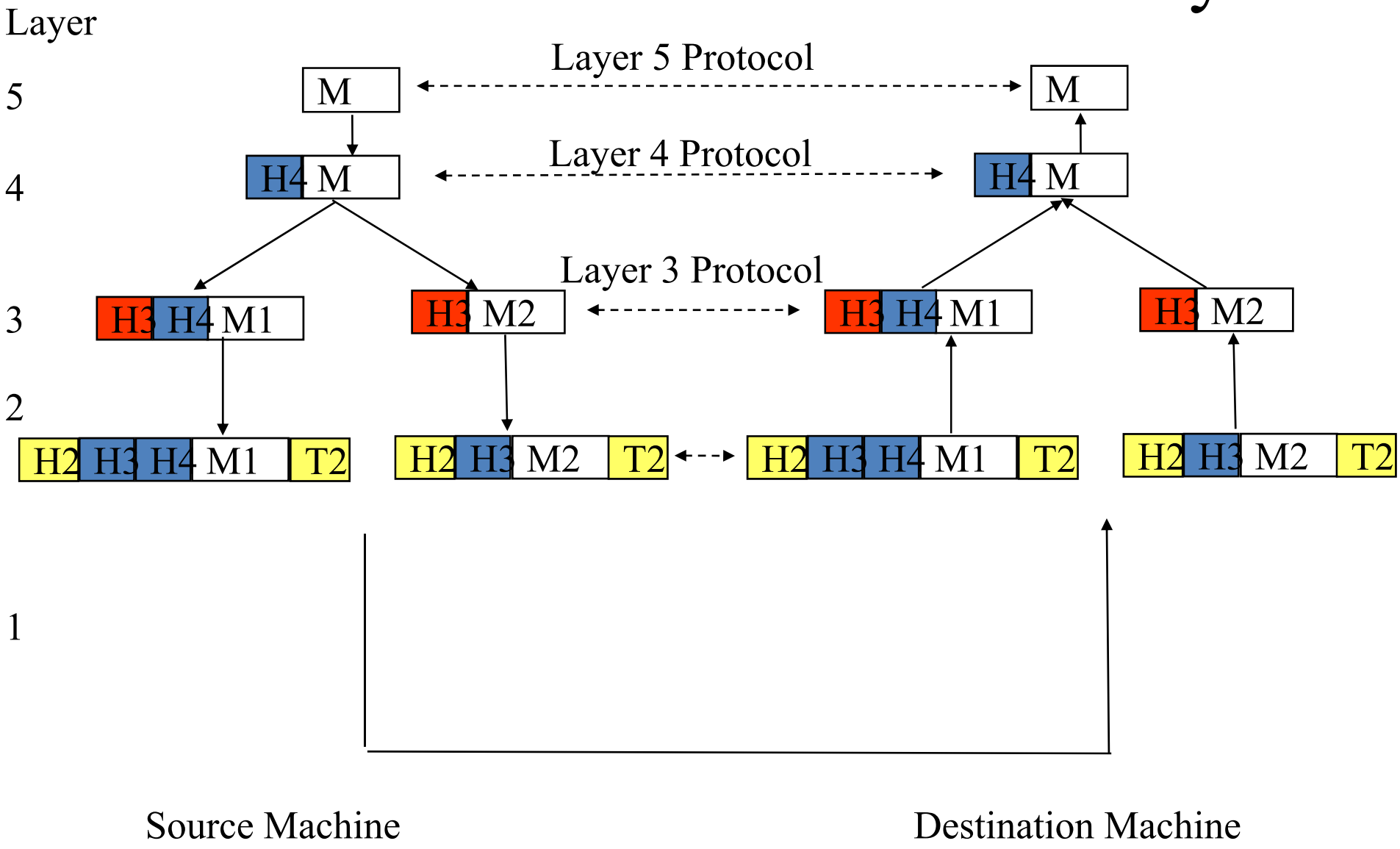
- A set of layers and protocols is called **a network architecture.**
- A list of protocols used by a certain system, one protocol per layer, is called **a protocol stack**.
- The subjects of network architectures, protocol stack, and the protocol themselves are the principal topics of computer networks.

Network Software: Protocol hierarchies

The philosopher-translator-secretary architecture.



Virtual Communication in Peer Layer



Network Software: Layer design issues

- Addressing
- Channel control
  - simplex/duplex,
  - data channel/control channel
- Error control: Detection / correction
- Flow control: not to drown the poor receiver
- Disassembling / reassembling
- Multiplexing / demultiplexing
- Routing

Network Software: Service issues

- Two main types:
  - Connection-oriented service (面向连接的服务)
  - Connectionless service (无连接的服务)
- QoS (Quality of service) （服务质量）

	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

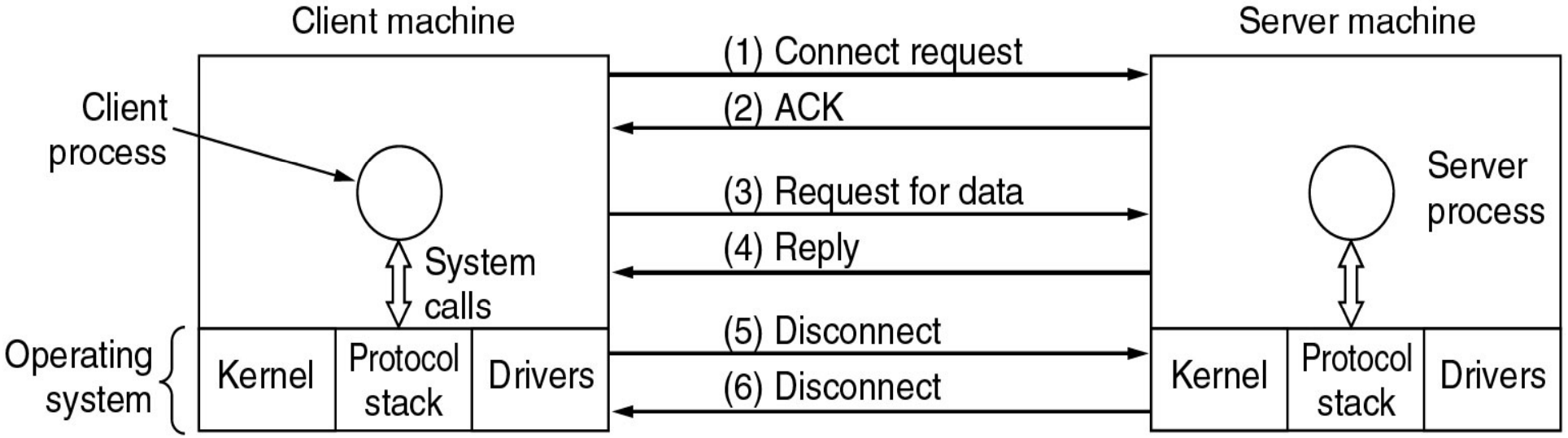
Network Software: Service primitives

Five service primitives for implementing a simple connection-oriented service.

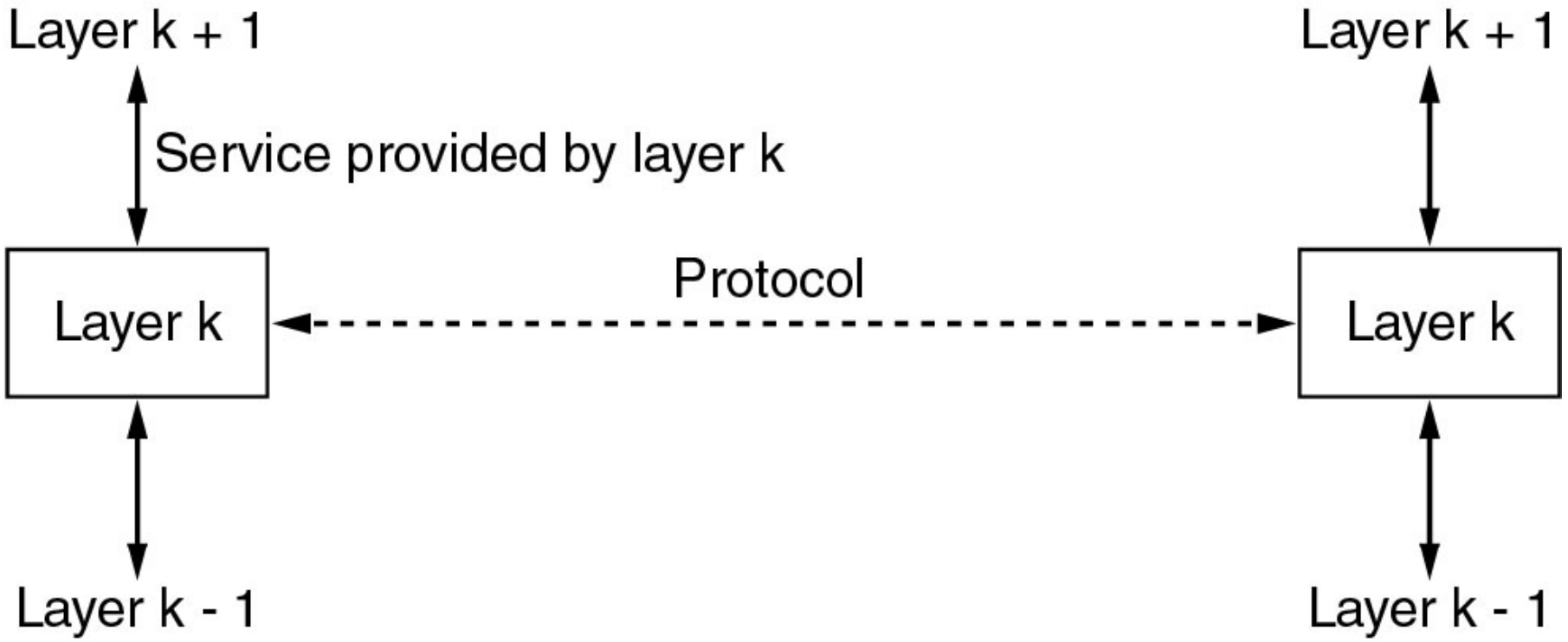
Primitive	Meaning
LISTEN	Block waiting for an incoming connection
CONNECT	Establish a connection with a waiting peer
RECEIVE	Block waiting for an incoming message
SEND	Send a message to the peer
DISCONNECT	Terminate a connection

Network Software: Service primitives

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



Network Software: Services / protocols



Network Software: Services / protocols

- **A service** is a set of primitives (operations) that a layer provides to the layer above it.

- **A protocol** is a set of rules governing the format and meaning of the packets, or messages that are exchanged by the peer entities within a layer.

Network Software: Services / protocols

- An analogy with programming languages
  - A service is like an abstract data type or an object in an object-oriented language. It defines the operations that can be performed on an object but does not specify how these operations are implemented.
  - A protocol relates to the implementation of the service and as such is not visible to the user of the service.
- An analogy with programming
  - A service
  - A interface (C++, C#, Java)
  - A protocol

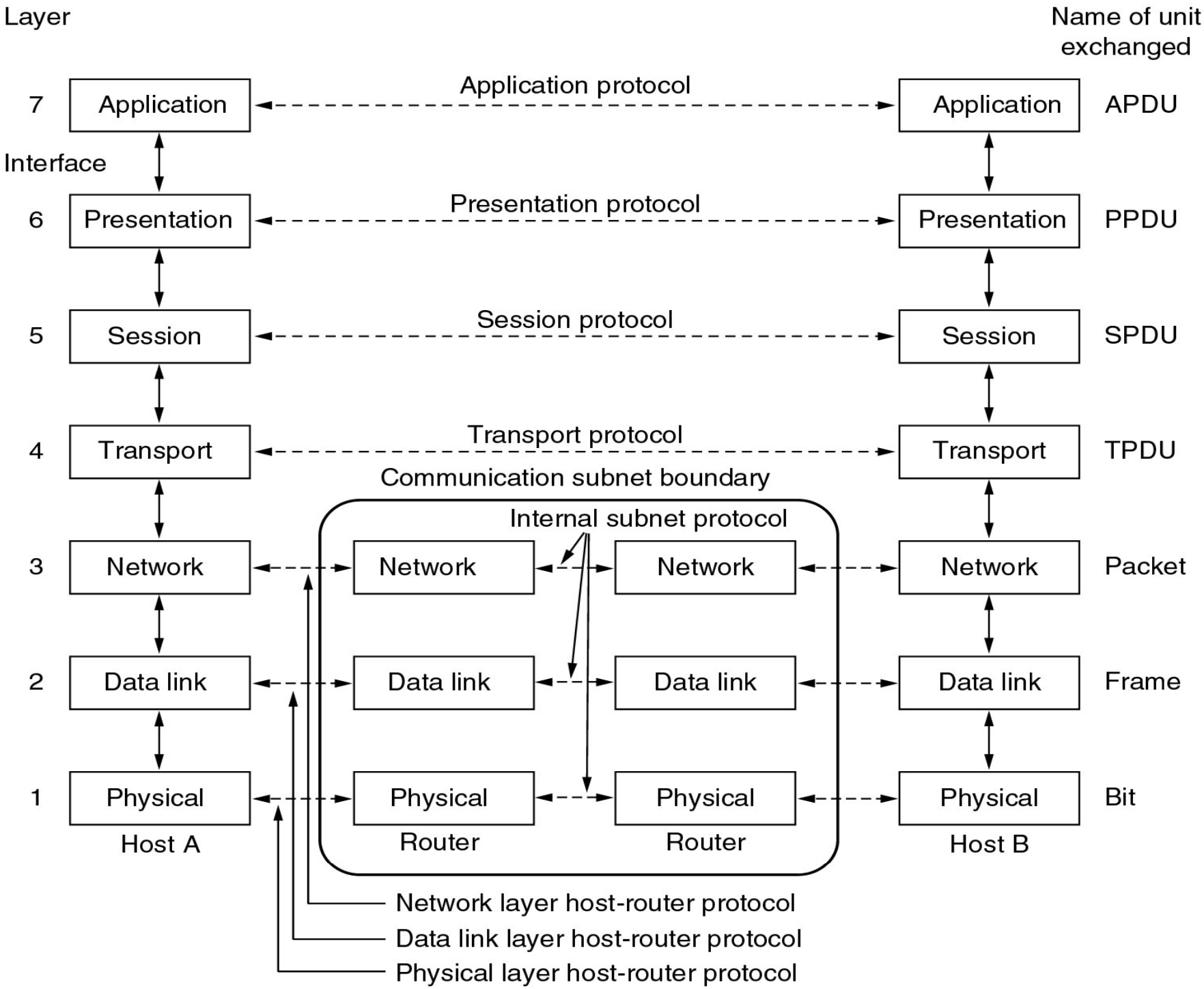
REFERENCE MODELS

- The OSI 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

Reference models: The OSI reference model

Design principles

1. A layer should be created where a ***different abstraction*** is needed.
2. Each layer should perform a ***well-defined function***.
3. The function of each layer should be chosen with an eye toward ***defining internationally standardized protocols***.
4. ***The layer boundaries*** should be chosen to minimize the information flow across the interfaces.
5. ***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 (笨拙).


Layer
Name of unit exchanged
7
Application
Application protocol
Application
APDU
Interface
6
Presentation
Presentation protocol
Presentation
PPDU
5
Session
Session protocol
Session
SPDU
4
Transport
Transport protocol
Transport
TPDU
Communication subnet boundary
Internal subnet protocol
3
Network
Network
Network
Network
Packet
2
Data link
Data link
Data link
Data link
Frame
1
Physical
Physical
Physical
Physical
Bit
Host A
Router
Router
Host B
Network layer host-router protocol
Data link layer host-router protocol
Physical layer host-router protocol

Reference models: The OSI reference model

Physical layer (物理层): Concerned with transmitting raw bits over a communication channel. The design issues deal with mechanical, electrical, and timing interfaces, and the physical transmission medium. Some typical questions:

- how many volts should be used to ***represent*** a 1 and how many for a 0, how many microseconds a bit lasts,
- whether transmission may proceed simultaneously in both ***directions***,
- how the initial ***connection*** is established and how it is torn down when both sides are finished,
- how many pins the network ***connector*** has and what each pin is used for.

Reference models: The OSI reference model

Data link layer (数据链路层): This layer is to take a raw transmission facility and transform it into a line that appears free of undetected transmission errors to the network layer. The design issues are:

- Framing: how to create and recognize ***frame boundaries***,
- Error detection, recovery: how to solve the problems caused by ***damaged, lost, and duplicate frames***,
- Flow control: how to keep a fast transmitter from ***drowning*** a slow receiver in data,
- MAC: how to control access to the ***shared channel*** (for broadcast networks).

Reference models: The OSI reference model

Network layer(网络层) : This layer is concerned with controlling the operation of the subnet. The design issues:

- how to ***route packets*** from source to destination:
- how to ***control congestion***.
- how to ***connect heterogeneous networks*** (different addressing, different maximum packet size, different protocols).

Reference models: The OSI reference model

Transport layer (传输层): To accept data from the session layer, split it up info smaller units if need be, pass these to the network layer, and ensure that the pieces all arrive correctly at the other end.

The design issues:

- Multiplexing: how to make the multiplexing transparent to the session layer,
- how to determine what types of service to provide the session layer,
- how to tell which messages belongs to which connection,
- how to regulate the flow of information.

Reference models: The OSI reference model

Session layer (会话层) : To allow users on different machines to establish sessions between them.

The design issues are:

- how to manage dialog control,
- how to manage token,
- how to synchronize different sessions.

Reference models: The OSI reference model

Presentation layer (表示层): The presentation layer is concerned with the syntax and semantics of the information transmitted.

The design issues are:

- how to encode data in a standard agreed upon way,
- how to efficiently convert from the representation used inside the computer to the network standard representation and back.
- Big endian (most sig. appear first/smallest addr) vs. little endian

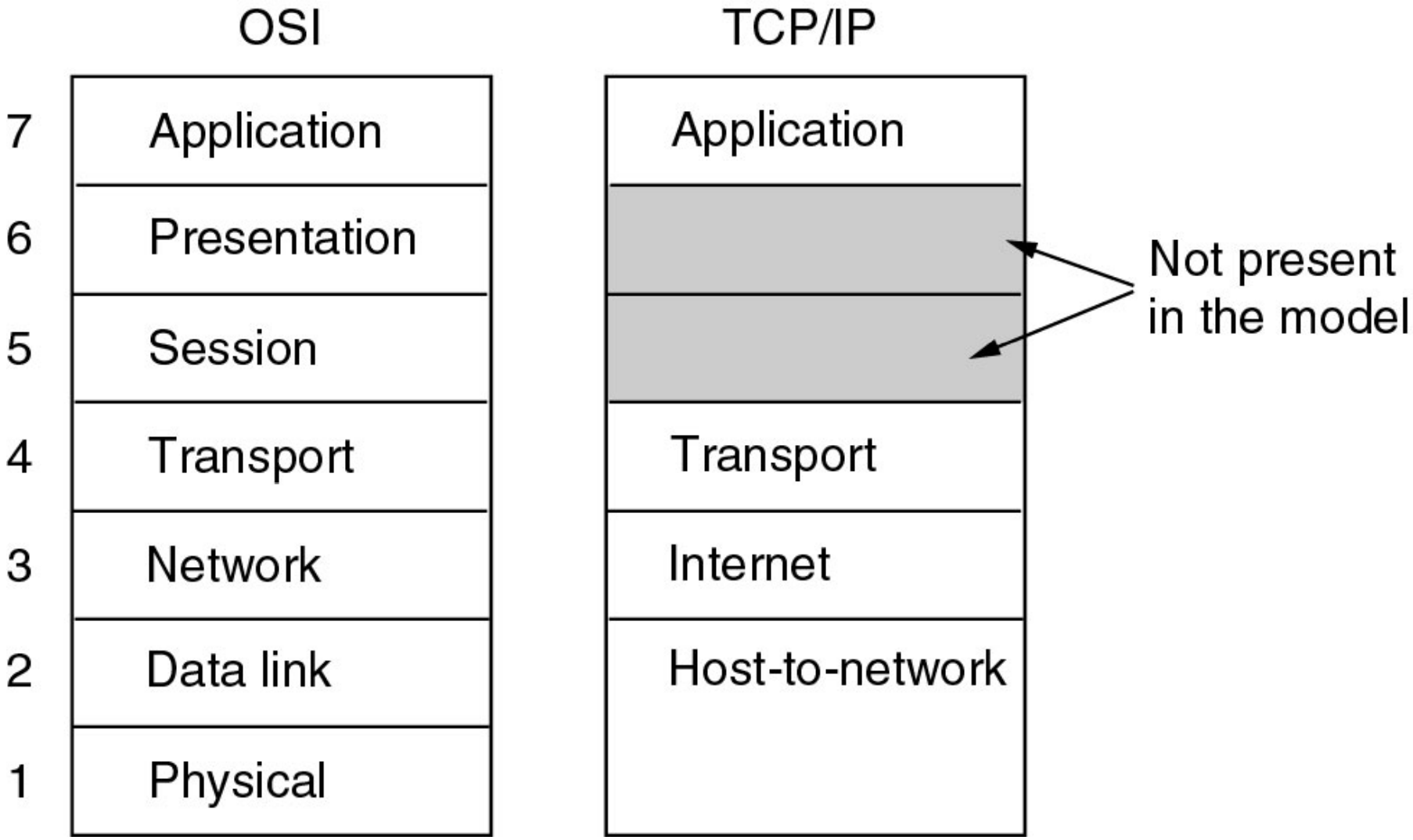
Reference models: The OSI reference model

Application layer(应用层): This layer contains a variety of protocols that are commonly needed.

Some application layer protocols:

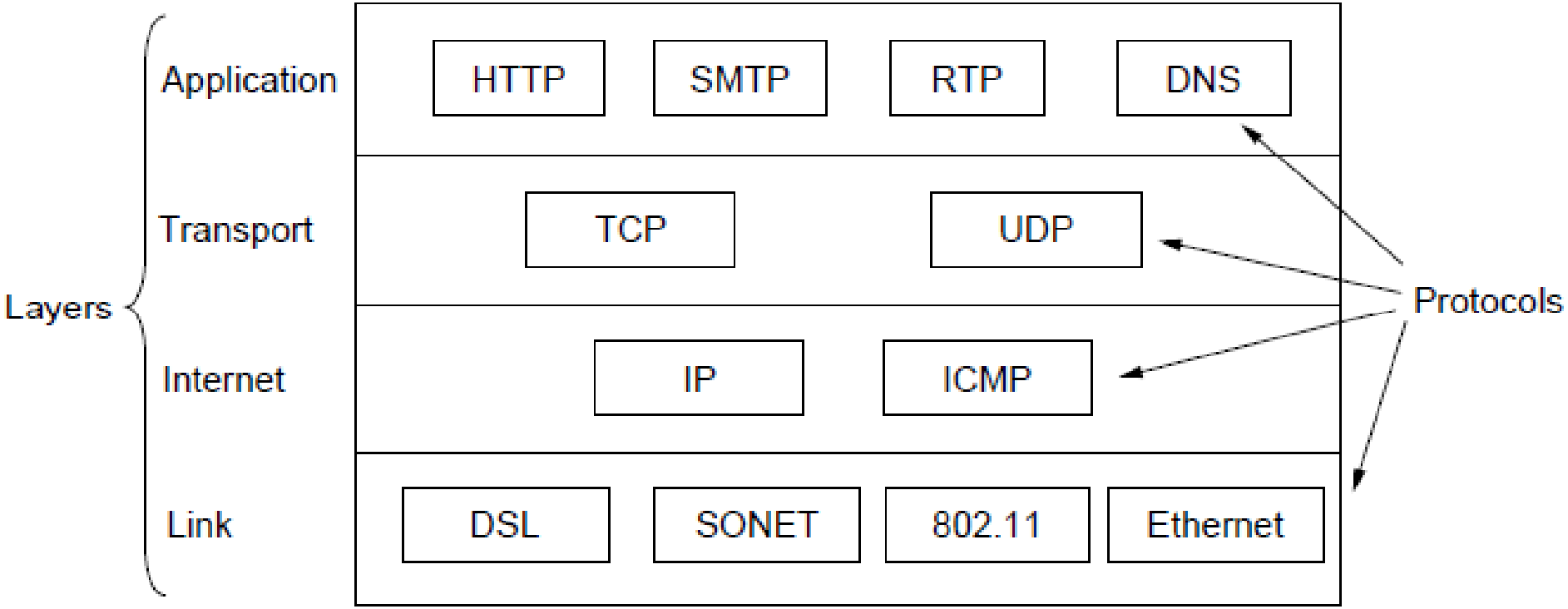
- http (WWW)
- telnet (network virtual terminal)
- ftp (file transfer protocol)
- DNS
- DHCP
- SMTP
- POP.

Reference models: The TCP/IP reference model



Reference models: The TCP/IP reference model

The TCP/IP reference model with some protocols we will study



Reference models: The TCP/IP reference model

Host-to-network layer

- The host has to connect to the network using some protocol so it can send packets to it.
- The protocol is not defined and varies from host to host and network to network.
- Books and papers about the the TCP/IP model rarely discuss it.
- Possible connections
  - LAN → router → Internet
  - Dial-up → router → Internet
  - ADSL → router → Internet

Reference models: The TCP/IP reference model

Internet layer

- Its job is to permit hosts to inject packets into any network and have them travel independently to the destination (potentially on a different network).
- The internet layer defines an official packet format and protocol called IP (Internet Protocol).
- Some issues
  - Packet routing
  - Avoiding congestion
  - QoS

Reference models: The TCP/IP reference model

Transport Layer

- It is designed to allow peer entities on the source and destination hosts to carry on a conversation.
- Two end-end transport protocols
  - TCP: a reliable connection-oriented protocol
  - UDP: an unreliable, connectionless protocol

Reference models: The TCP/IP reference model

Application layer

- It contains all the higher-level protocols
- Some examples
  - HTTP
  - FTP
  - TFTP
  - SMTP
  - POP
  - DNS
  - NNTP
  - DHCP

Reference models: Comparison

Similarities for the OSI and TCP/IP reference models

- Protocol stack
- Layer functionality
- End-end service provider vs. end-end service user

Differences for the OSI and TCP/IP reference models

- Services/interfaces/protocols
  - The OSI makes the distinction explicit
  - The TCP/IP model did not originally clearly distinguish them

Reference models: Comparison

Differences for the OSI and TCP/IP reference models

- Which comes first? (Models/protocols):
  - OSI model first while TCP protocol first.
- 7 layer / 4 layers; Network, transport, application layers common; the rest different.
- Connection-oriented vs and connectionless comm.
  - OSI: Connection-oriented and connectionless communication in network layer
    connection-oriented in transport layer
  - TCP: connectionless communication in network layer
    connection-oriented and connectionless communication in transport layer.

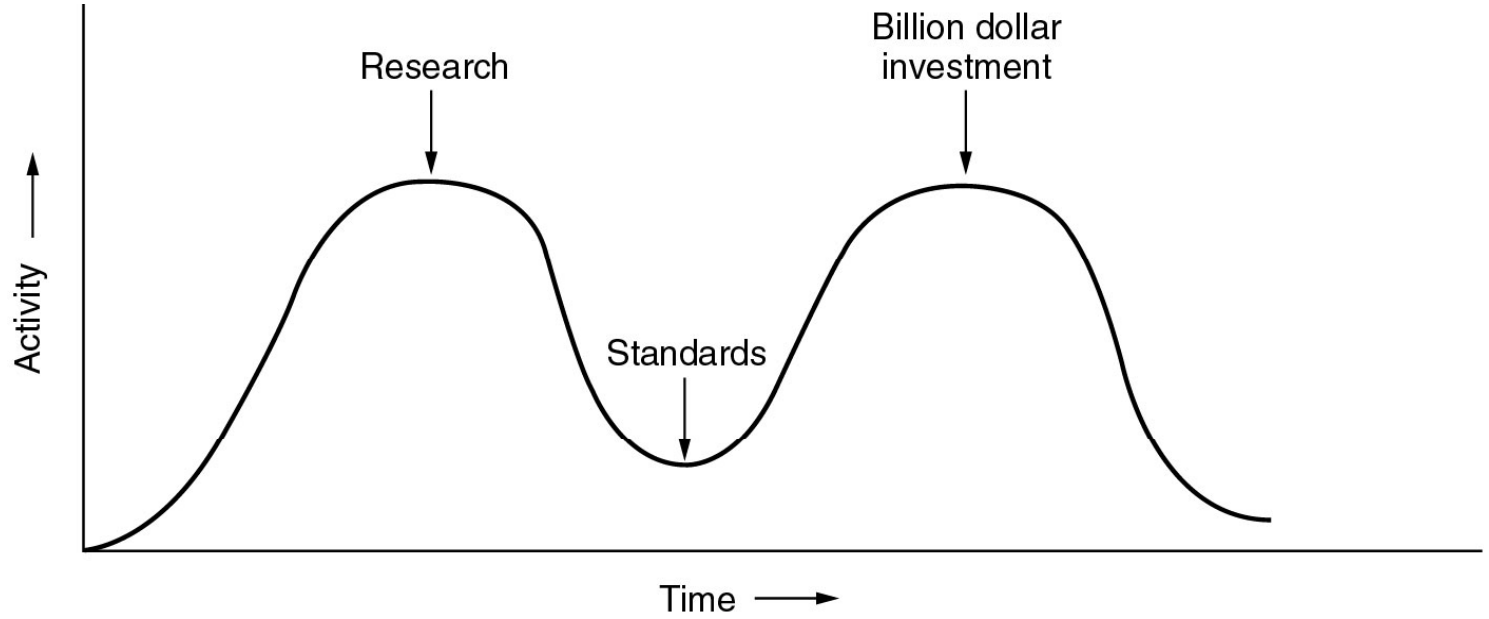
Reference models: A critique of the OSI model and protocols

Why OSI did not take over the world

- Bad timing
- Bad technology
- Bad implementations
- Bad politics

Reference models: A critique of the OSI model and protocols

- Bad timing
  - The time at which a standard is established is absolutely critical to its success.
  - The first elephant represents a burst of research activity.
  - The second elephant represents the billion-dollar wave of investment hits.



Reference models: A critique of the OSI model and protocols

- Bad technology: Both the model and the protocols are flawed, extraordinarily complex, difficult to implement and inefficient in operation.
- Bad implementation: The initial implementations were huge, unwieldy, and slow.
- Bad politics: The OSI model was thought to be the creature of government bureaucrats.

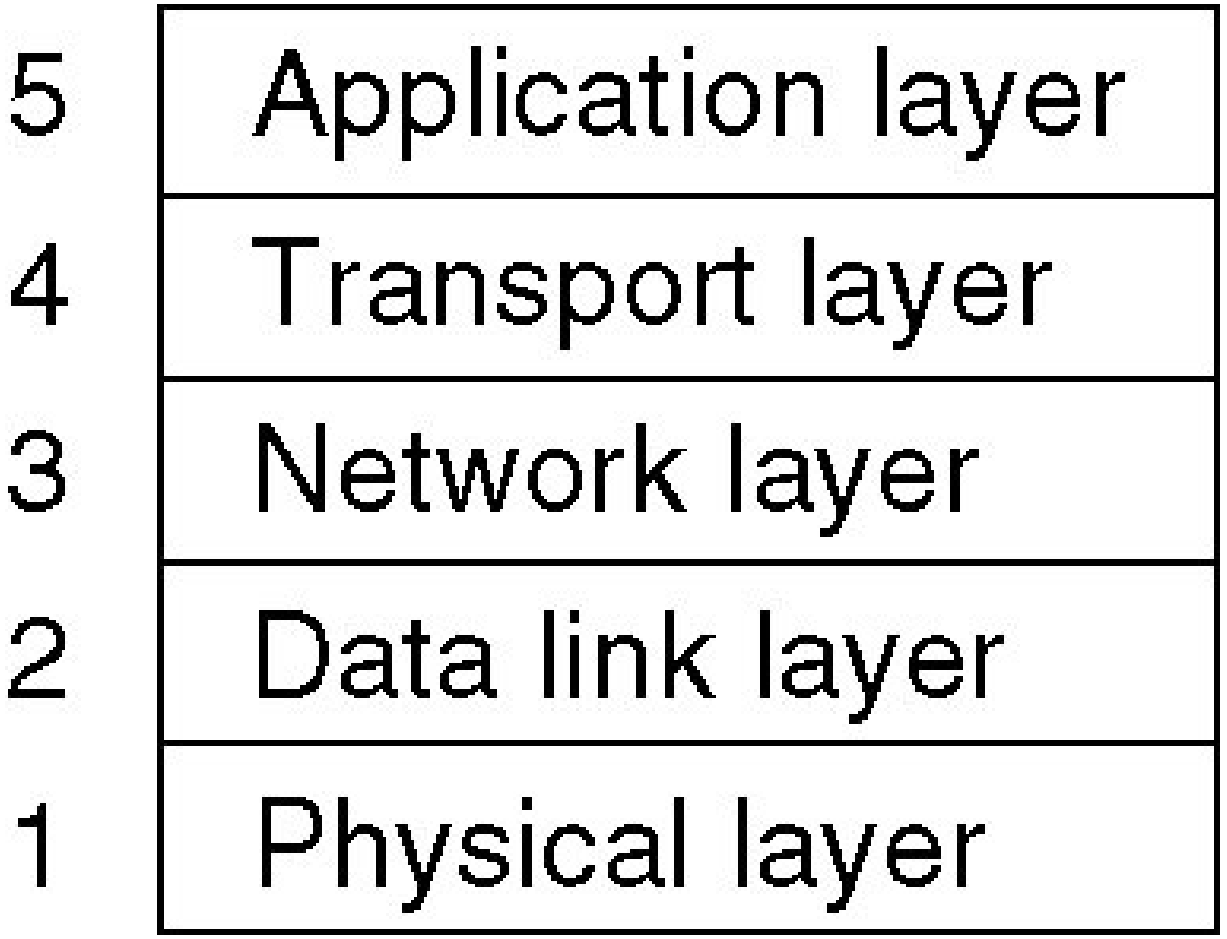
Reference models:
A critique of the TCP/IP model and protocols

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

REFERENCE MODELS

The hybrid reference model



EXAMPLE NETWORKS

- The Internet
- Wireless LANs: 802:11
- Third-generation mobile phone networks
- RFID and sensor networks

Example networks: The Internet

- The ARPANET
- NSFNET
- Internet usage
- Architecture of the Internet

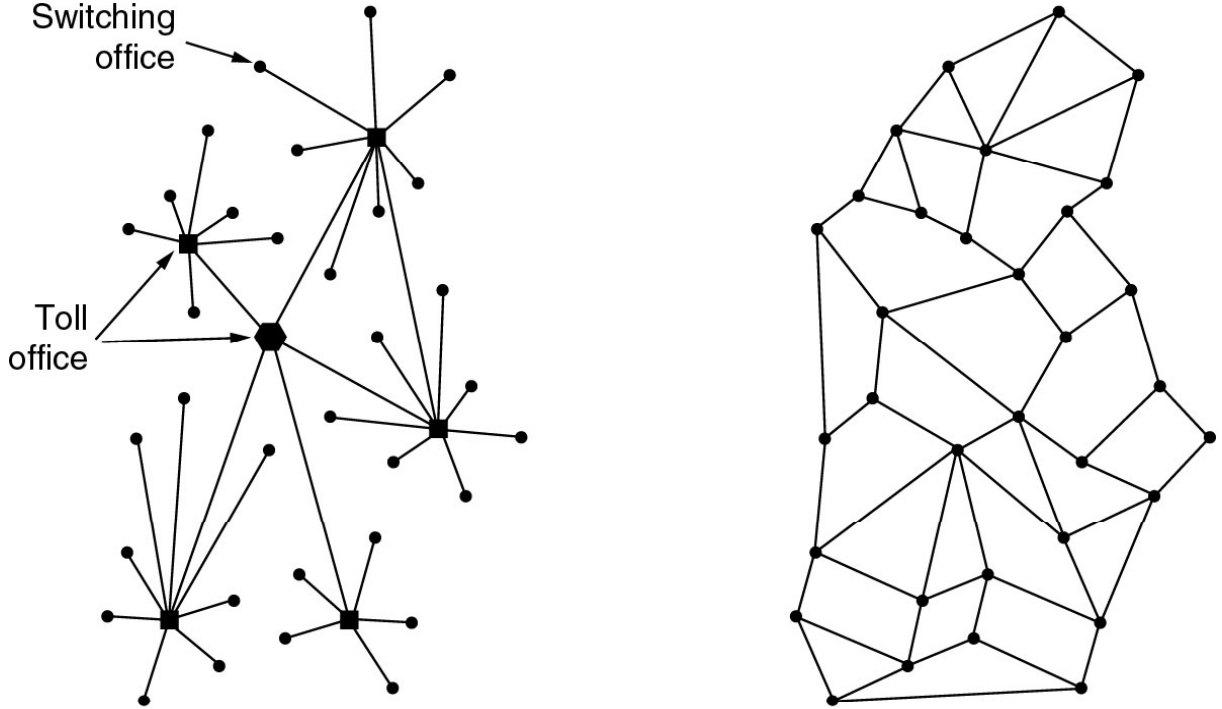
Example networks: The Internet: ARPANET

- In the late 1950s (at the height of the Cold War), the DoD wanted a command-and-control network that could survive a nuclear war.
- Around 1960, the DoD awarded a contract to the RAND Cooperation to find a solution.
  - **Paul Baran** came up with the highly distributed and fault-tolerant design.
  - Baran wrote several reports for the DoD describing his ideas in detail
  - Officials liked the concept and asked AT&T to build a prototype
  - **AT&T** dismissed Baran's ideas out of hand.

Example networks: The Internet: ARPANET

(a) Structure of the telephone system.

(b) Baran's proposed distributed switching system.

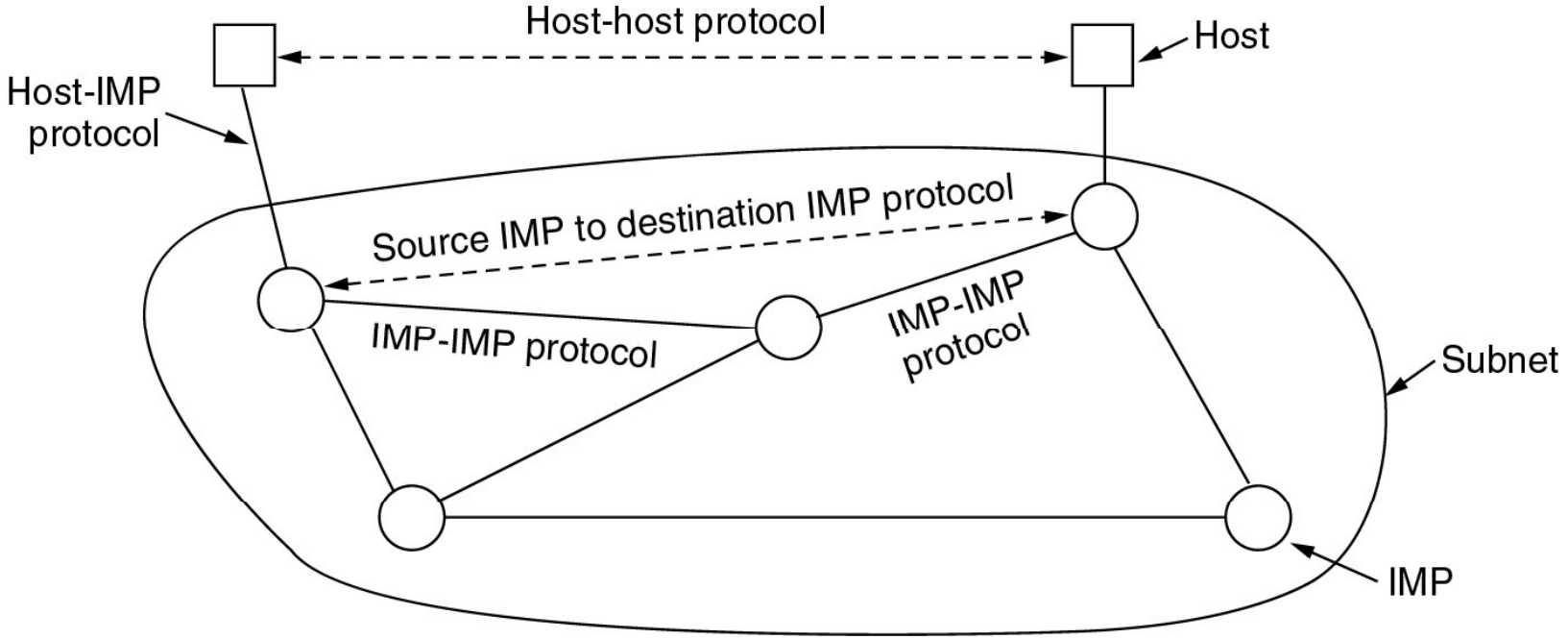


Example networks: The Internet: ARPANET

- In 1967, the attention of ARPA's then director, **Larry Roberts**, turned to networking.
- At the SOSP held in Gatlinburg, Tennessee in late 1967, Larry Roberts presented a somewhat vague paper about his idea.
- Another paper described a similar system that had not only been designed but actually implemented under the direction of **Donald Davies** at the National Physical Laboratory in England.
- Roberts came back and determined to build what later became known as the ARPANET.

Example networks: The Internet: ARPANET

- The original design ARPANET
  - The subnet would consist of minicomputers called IMP (Interface Message Processors) connected by 56-kbps transmission lines.
  - Hosts would be connected IMPs by short wires.

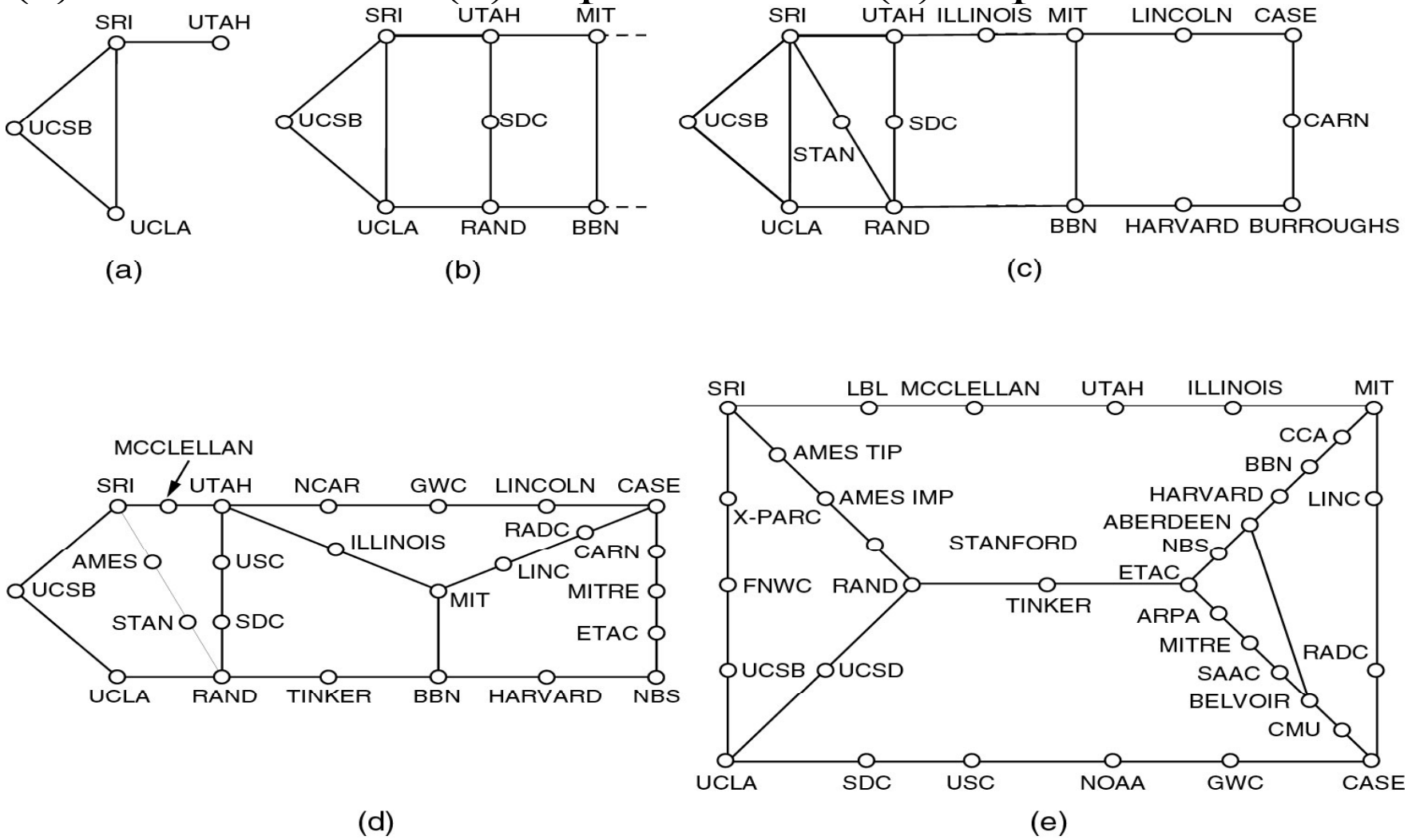


Example networks: The Internet: ARPANET

- In December 1968, ARPA selected and awarded BBN (a consulting firm in Cambridge, Massachusetts) a contract to build the subnet and write the subnet software.
- In the summer of 1969, Roberts convened a meeting of network researchers, mostly graduate students, at Snowbird, Utah.
  - No network expert and no grand design.
  - The graduate students had to figure out what to do on their own.
- In December 1969, an experimental network went on the air with four nodes: at UCLA, UCSB, SRI, and the University of Utah.

Example networks: The Internet: ARPANET

Growth of the ARPANET: (a) December 1969. (b) July 1970. (c) March 1971. (d) April 1972. (e) September 1972.



Example networks: The Internet: ARPANET

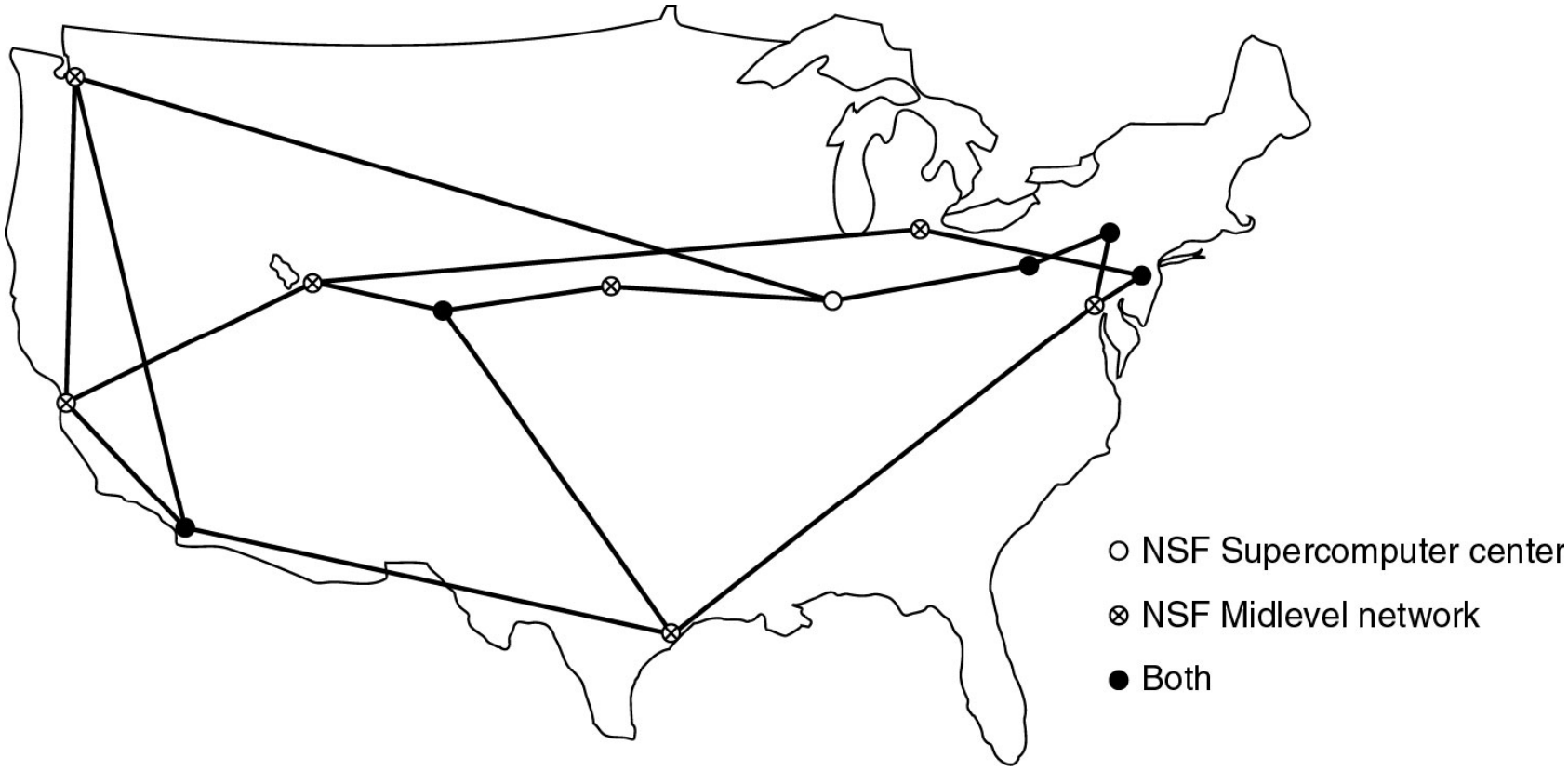
- In 1974, the TCP/IP model (and its protocols) was invented.
- BSD Unix + TCP/IP
- During the 1980s, additional networks, especially LANs were connected to the ARPANET.
- DNS (Domain Name System) was created to organize machines into domains and map host names onto IP addresses.
- For more protocols, see RFC.

Example networks: The Internet: NSFNET

- By the late 1970s, NSF saw the enormous impact the ARPANET was having on university research, allowing scientists across the country to share data and collaborate on research projects.
- NSFNET
  - One backbone network that connected six NSF super computer centers.
  - About 20 regional networks that connected to the backbone
  - ARPNET and NSFNET connected at CMU.

Example networks: The Internet: NSFNET

The NSFNET backbone in 1988.



Example networks: The Internet: NSFNET

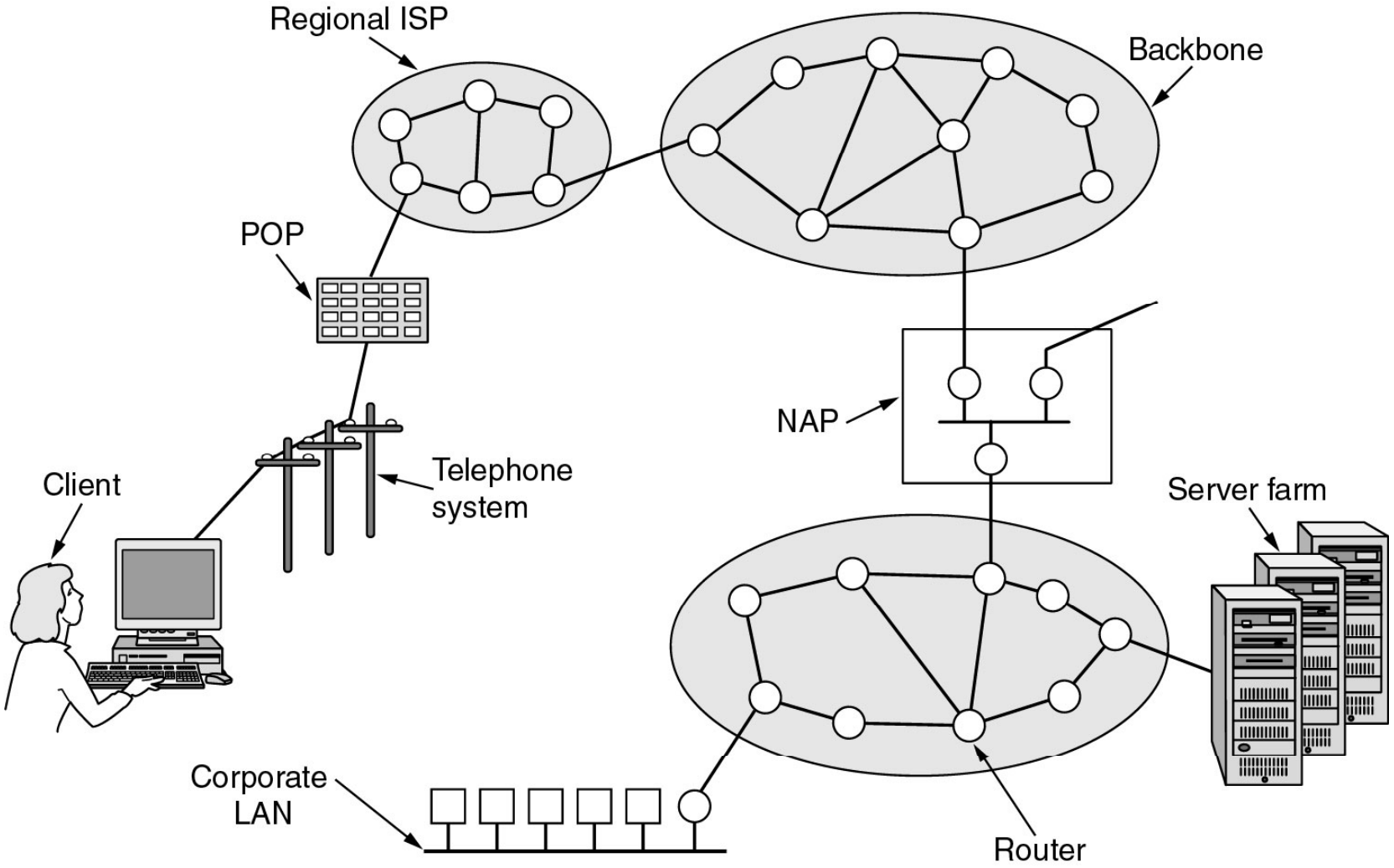
- NSFNET grew
  - 56kbps
    - NSFNET was overloaded from the word go.
  - 448kbps
    - Soon overwhelmed.
  - 1.5Mbps
  - 45Mbps (ANSNET, Advanced Networks and Services)
  - NSFNET → HEAVEN → many different commercial network operators

Example networks: The Internet: Usage

- On January 1, 1983, the TCP/IP became the only official protocol.
- Up until the early 1990s, the applications : email, news, remote login, file transfer.
- WWW (Tim Berners-Lee) and Internet.

Example networks: The Internet: The architecture

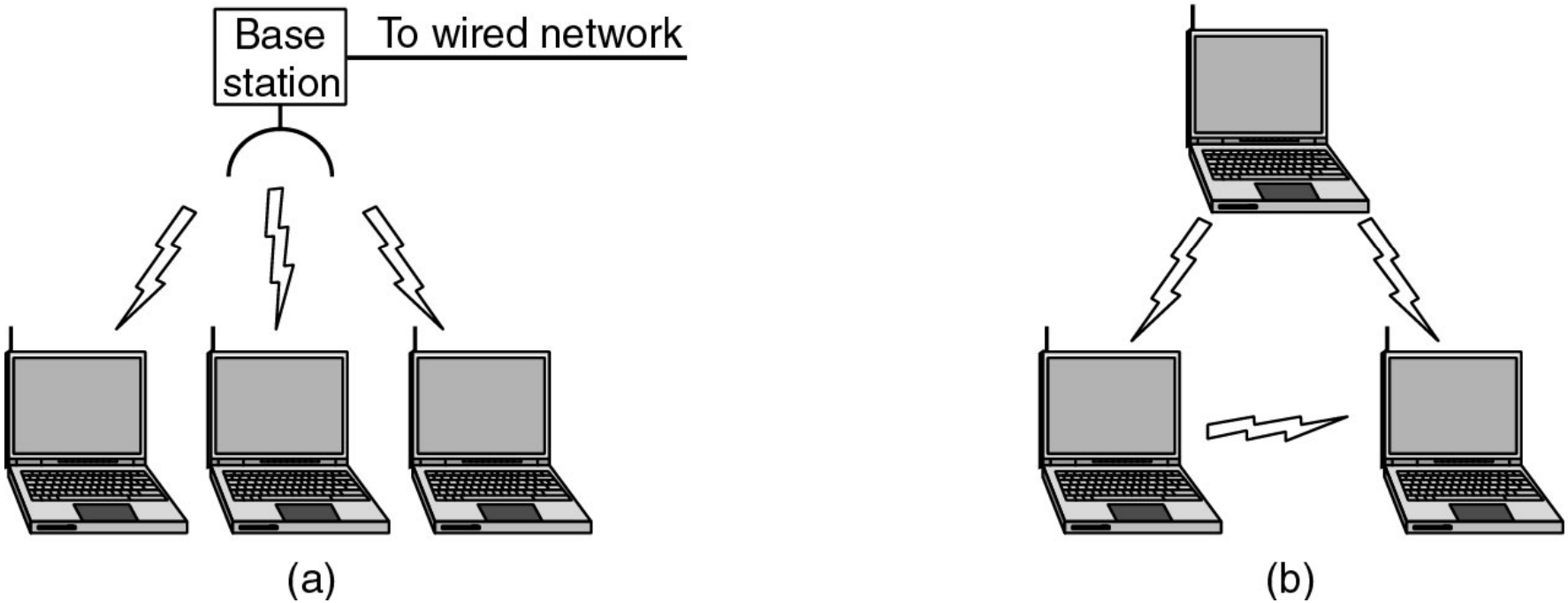
Overview of the Internet.



Example networks: Wireless LAN

(a) Wireless networking with a base station.

(b) Ad hoc networking.

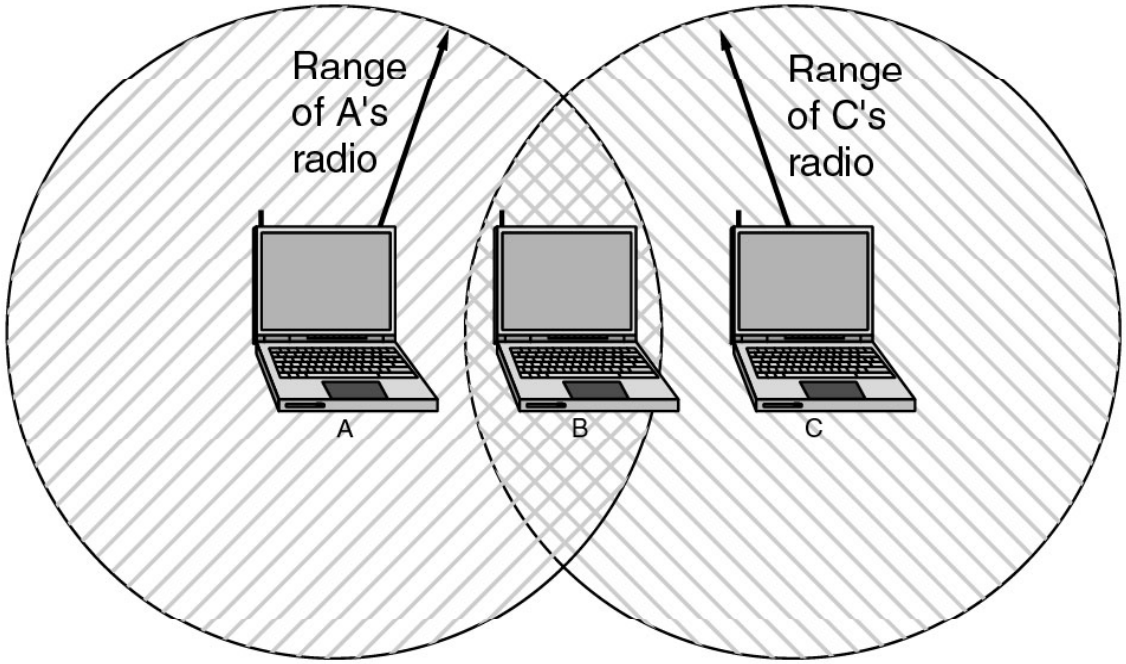


Example networks: Wireless LAN

- Problems
  - The hidden station problem and the exposed station problem (see the next slide)
  - Multipath fading
  - A great deal of software is not aware of mobility.
  - Move away from the ceiling-mounted base station (see the next slide).

Example networks: Wireless LAN

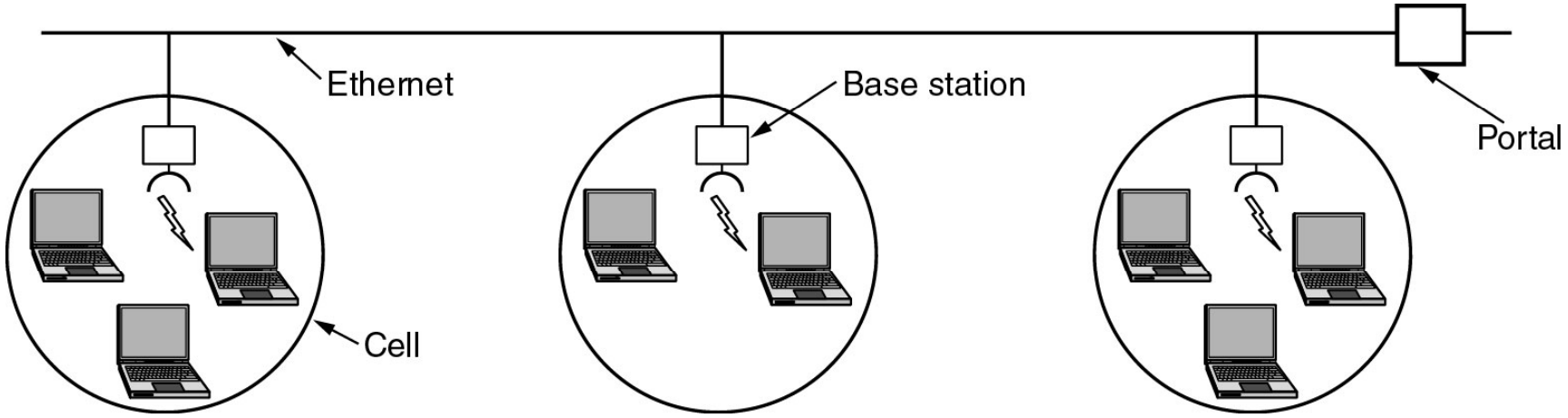
Hidden terminal: the range of a single radio may not cover the entire system



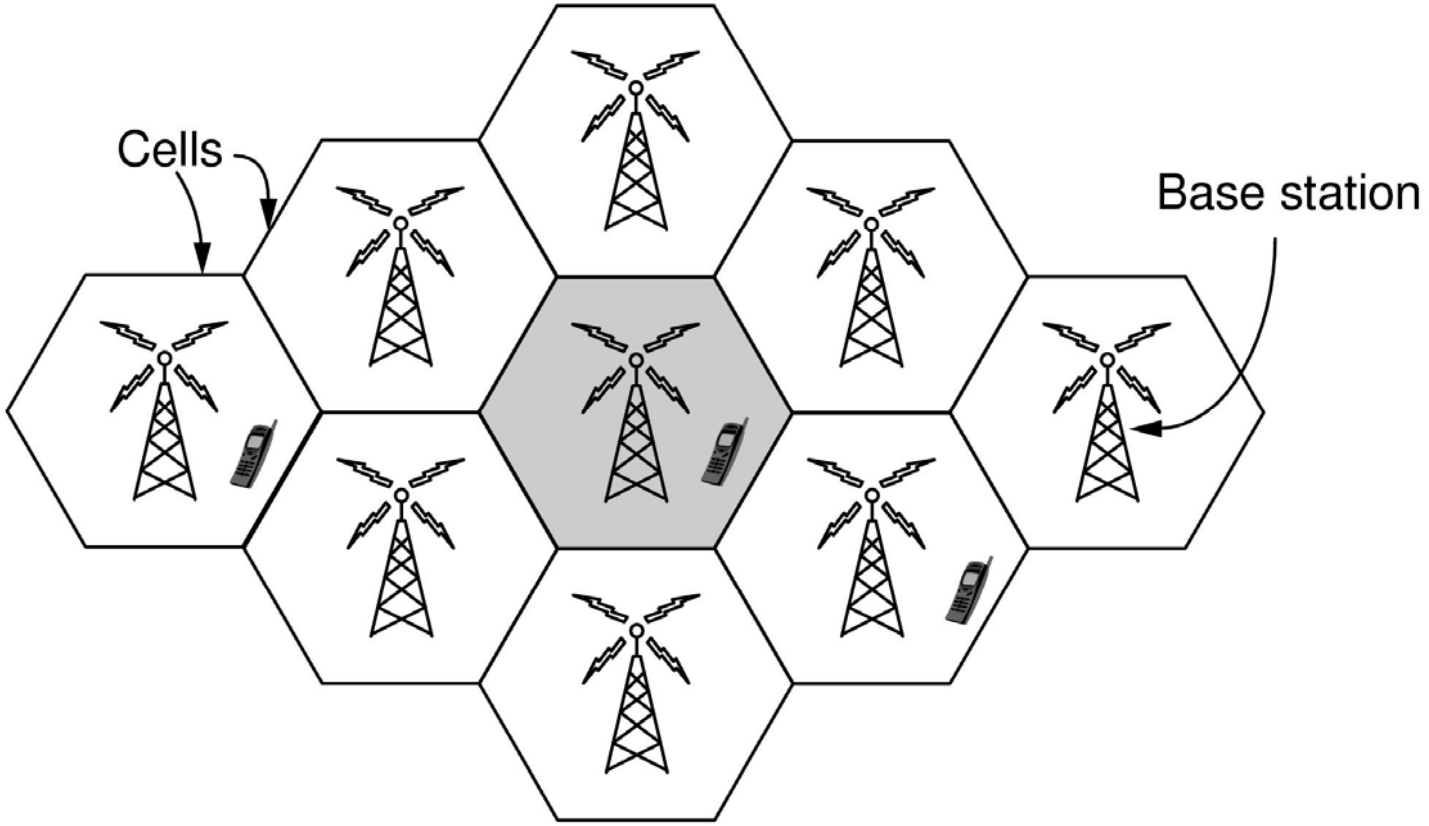
Example networks: Wireless LAN

A multicell 802.11 network.

- In 1997 → 802.11 2Mbps
- In 1999 →11Mbps, 54Mbps

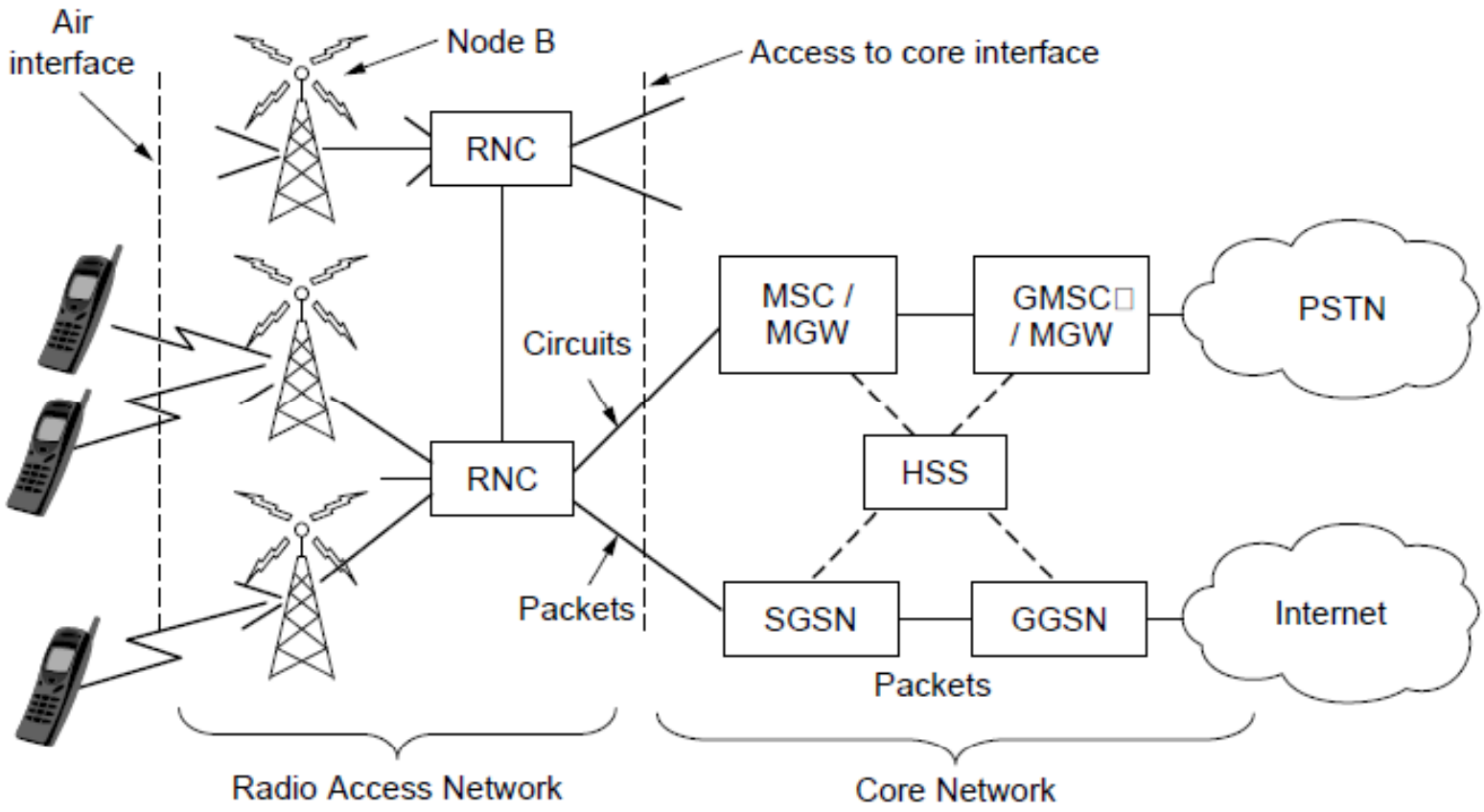


Third-Generation Mobile Phone Networks (1)



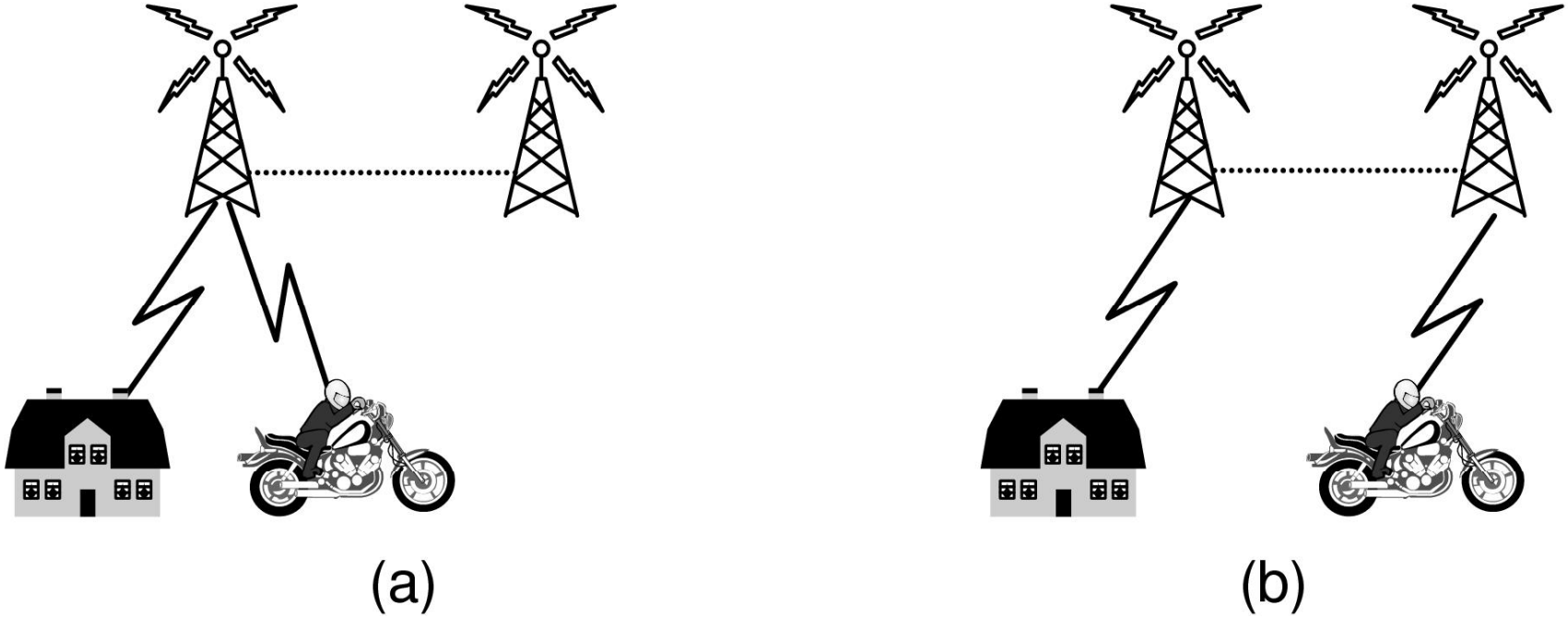
- Cellular design of mobile phone networks

Third-Generation Mobile Phone Networks (2)



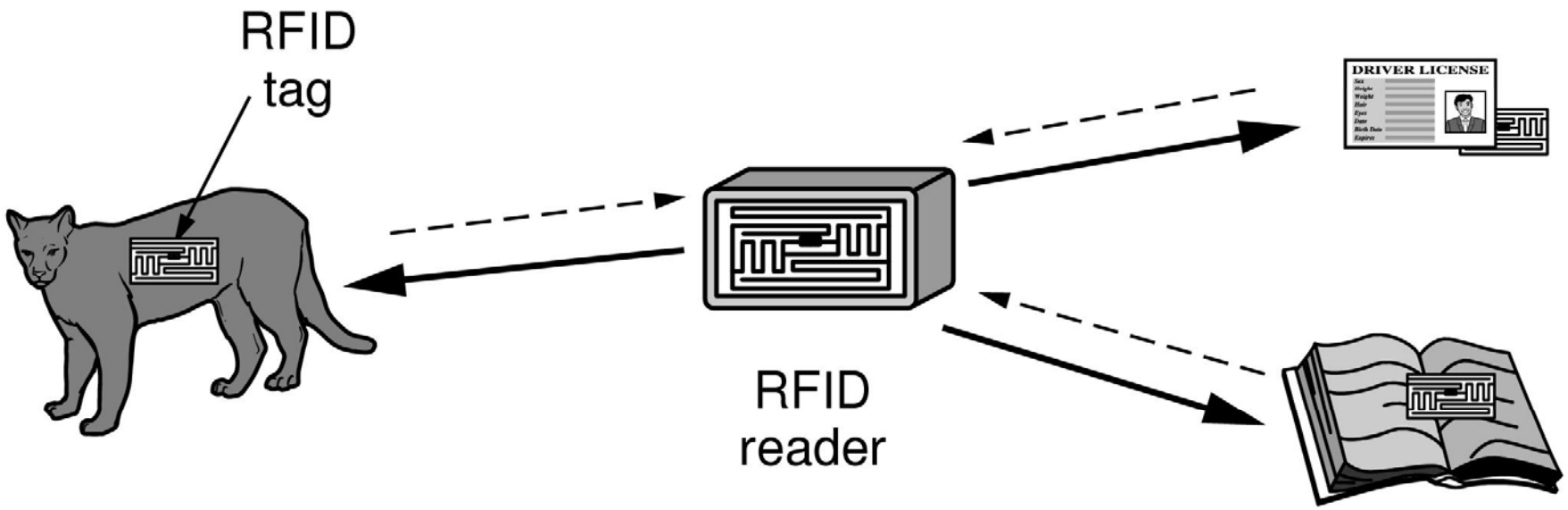
- Architecture of the UMTS 3G mobile phone network.

Third-Generation Mobile Phone Networks (3)



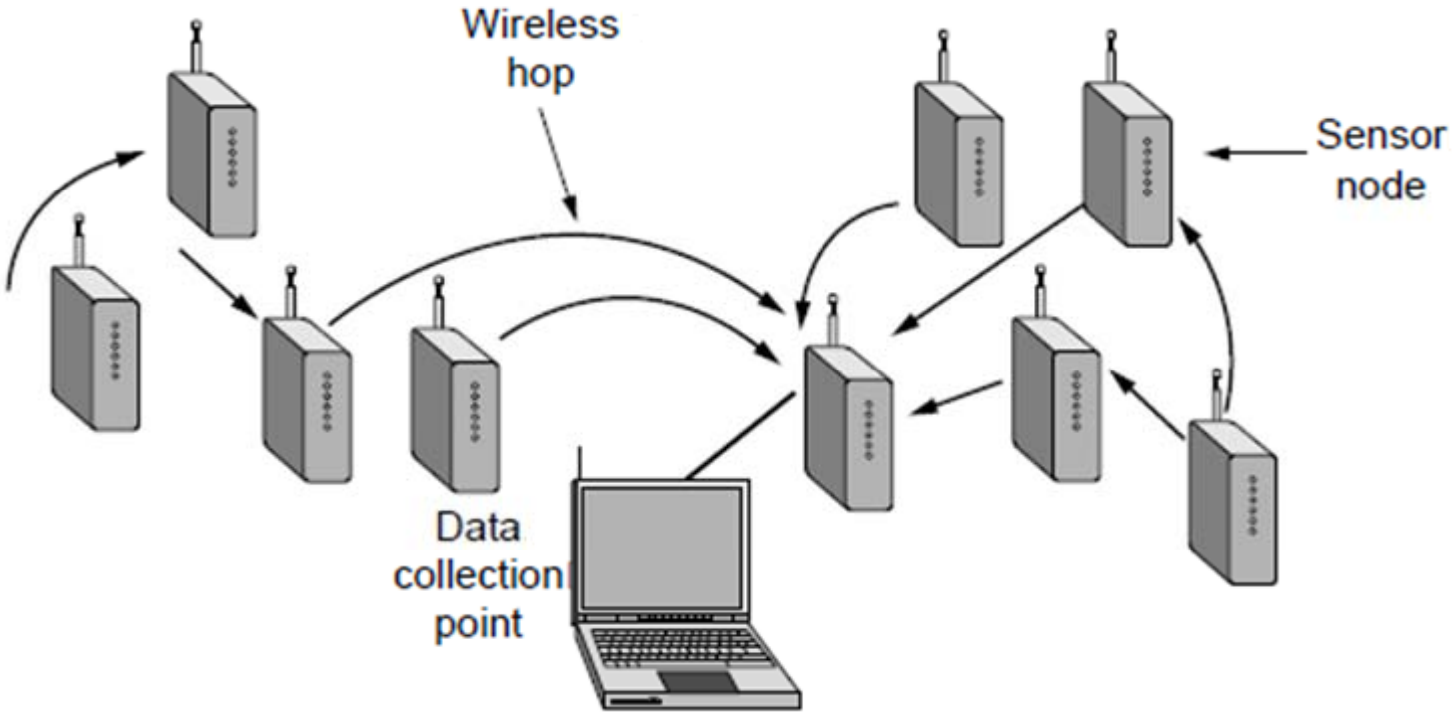
- Mobile phone handover (a) before, (b) after.

RFID and Sensor Networks (1)



- RFID used to network everyday objects.

RFID and Sensor Networks (2)



- Multihop topology of a sensor network

NETWORK STANDARDIZATION

- Why standardization?
  - Many network vendors and suppliers exist, each with its own ideas of how things should be done. Without coordination, there would be complete chaos, and users would get nothing done. The only way out is to agree on some network standards.
  - Standards increase the market for products adhering to the standard
- Standards fall into two categories:
  - De facto (Latin “from the fact”):
    - PC for small office and home / Unix for the CS
  - De jure (Latin “by law”)

Network standardization: ITU

- International Telecommunications Union
- Main sectors
  - Radiocommunications (ITU-R)
  - *Telecommunications Standardization (ITU-T)*
  - Development (ITU-D)

Network standardization: ISO

- ISO (International Standards Organization, International Organization of Standardization)
- Members
  - Volunteers
  - ANSI, IEEE, NIST

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

Network standardization: Internet

- In 1983, IAB (Internet Activities Board)
- Later, IAB(Internet Architecture Board)
- In 1989, IAB → IRTF + IETF
  - IRTF (Internet Research Task Force)
  - IETF (Intern Engineering Task Force)
    - Originated by DARPA for TCP/IP protocol development
    - Request for Comments (RFC)
    - E.g., www.ietf.org/rfc/rfc0793.txt = TCP

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}	1,000,000,000,000,000,000,000,000	Yotta

Computer Network: Outline

- Chapter 1: Introduction
- Chapter 2: The Physical Layer
- Chapter 3: The Data Link Layer
- Chapter 4: The Medium Access Control Sublayer
- Chapter 5: The Network Layer
- Chapter 6: The Transport Layer
- Chapter 7: The Application Layer
- Chapter 8: Network Security
- (Summary)

Homework

1. Imagine that you have trained your St. Bernard, Bernie, to carry a box of three 8-mm tapes instead of a flask of brandy. (When your disk fills up, you consider that an emergency.) These tapes each contain 7 gigabytes. The dog can travel to your side, wherever you may be, at 18 km/hour. For what range of distances does Bernie have a higher data rate than a transmission line whose data rate (excluding overhead) is 150 Mbps? How does your answer change if (i) Bernie's speed is doubled; (ii) each tape capacity is doubled; (iii) the data rate of the transmission line is doubled.

5. A factor in the delay of a store-and-forward packet-switching system is how long it takes to store and forward a packet through a switch. If switching time is 10 μsec, is this likely to be a major factor in the response of a client-server system where the client is in New York and the server is in California? Assume the propagation speed in copper and fiber to be 2/3 the speed of light in vacuum.

10. What are two reasons for using layered protocols? What is one possible disadvantage of using layered protocols?

15. In some networks, the data link layer handles transmission errors by requesting that damaged frames be retransmitted. If the probability of a frame's being damaged is p, what is the mean number of transmissions required to send a frame? Assume that acknowledgements are never lost.

17. What is the main difference between TCP and UDP?

22. How long was a bit in the original 802.3 standard in meters? Use a transmission speed of 10 Mbps and assume the propagation speed in coax is 2/3 the speed of light in vacuum.

25. List two advantages and two disadvantages of having international standards for network protocols.

30. What are the disadvantages of using small, fixed-length cells in ATM?