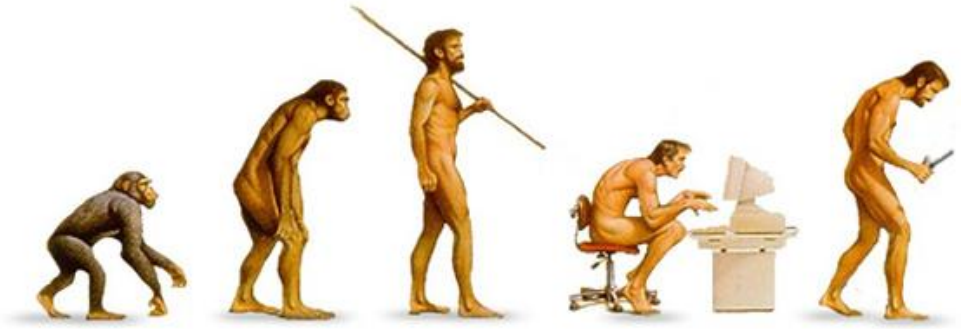
Introduction

Chapter 1

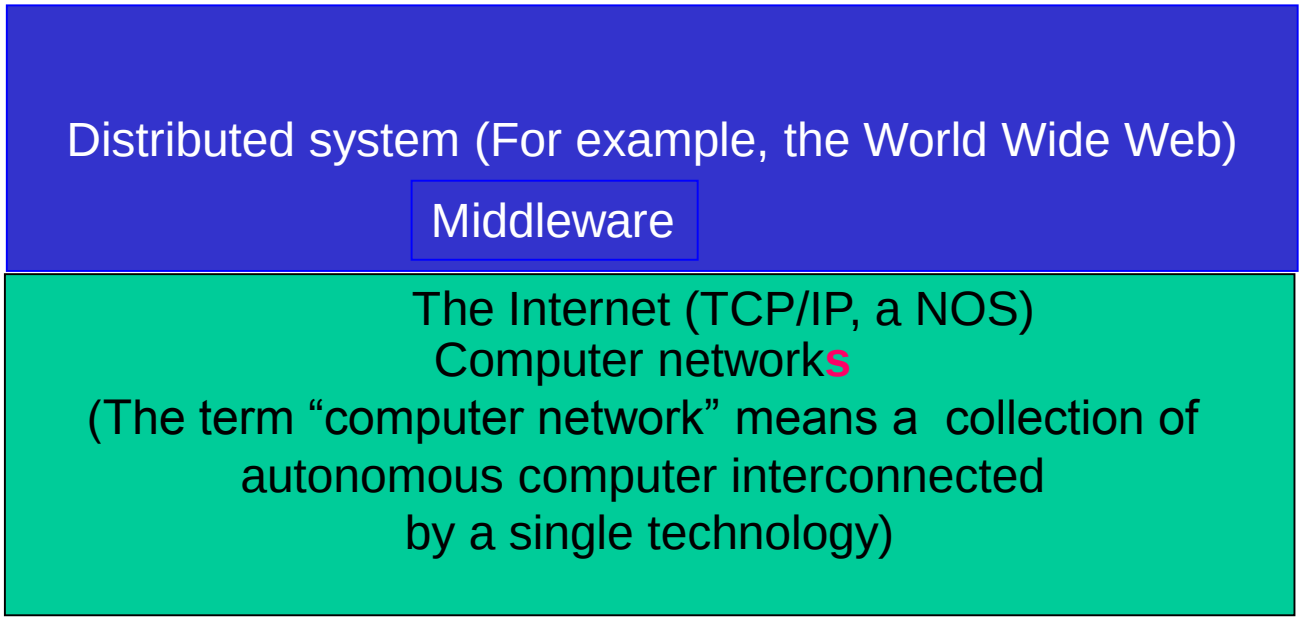
Key technology in history

a) The past three centuries:
   - The 18th: the great mechanical systems and the Industrial Revolution
   - The 19th: the steam engine
   - The 20th: Information gathering, processing, and distribution
     - Telephone networks, radio, television, computer, communication satellites, the Internet, …

b) The 21st century:
   - Convergence
   - ……



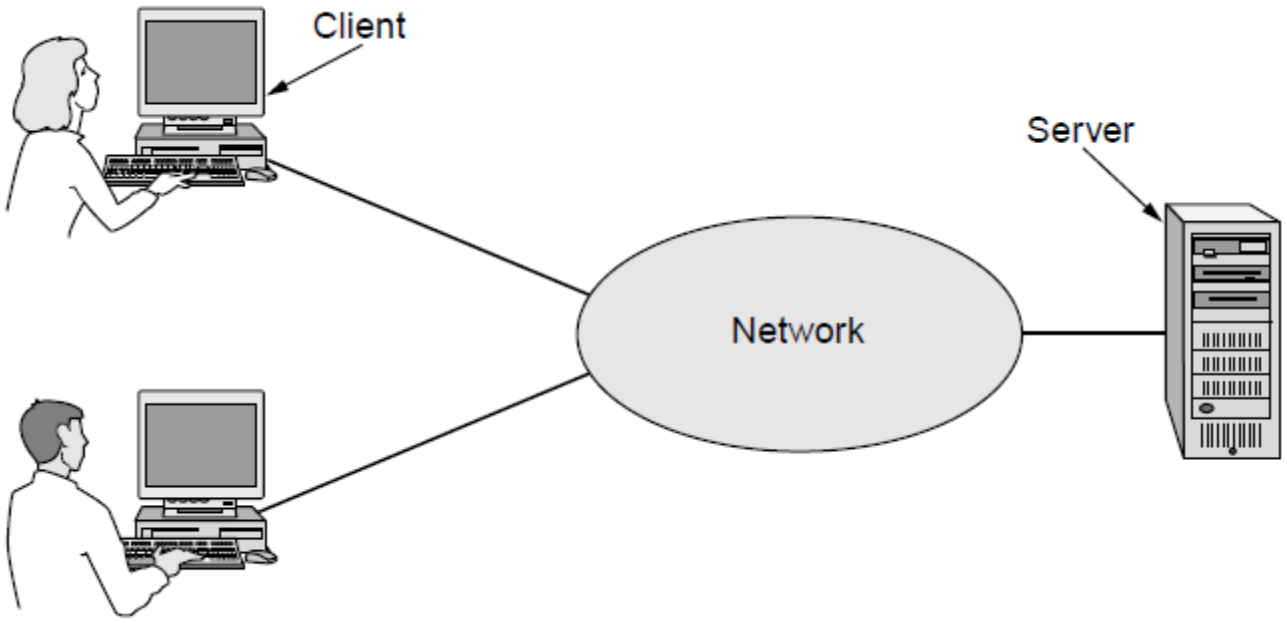
Computer networks and distributed system



Uses of Computer Networks

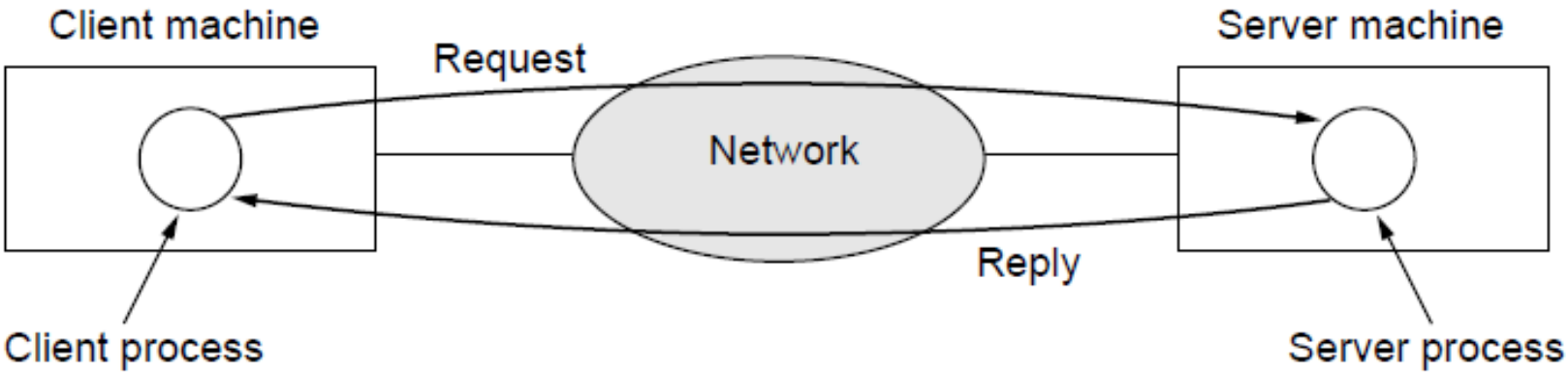
- Business Applications
  - Resource sharing
  - Communication medium: email, IP telephony or VoIP, Video, desktop sharing, …
  - E-commerce
- Home Applications
  - Internet access
  - Peer-to-peer communication(e.g., email)
  - Person-to-person communication, instant messaging, twitter,
  - Social networks: Facebook
  - Wiki, a collaborative Web site
  - E-commerce
  - Entertainment: music (e.g., MP3), radio, DVD-quality movies, television (e.g. IPTV), game playing
  - Ubiquitous computing, power-line networks, RFID
- Mobile Users
- Social Issues

Business Applications (1)



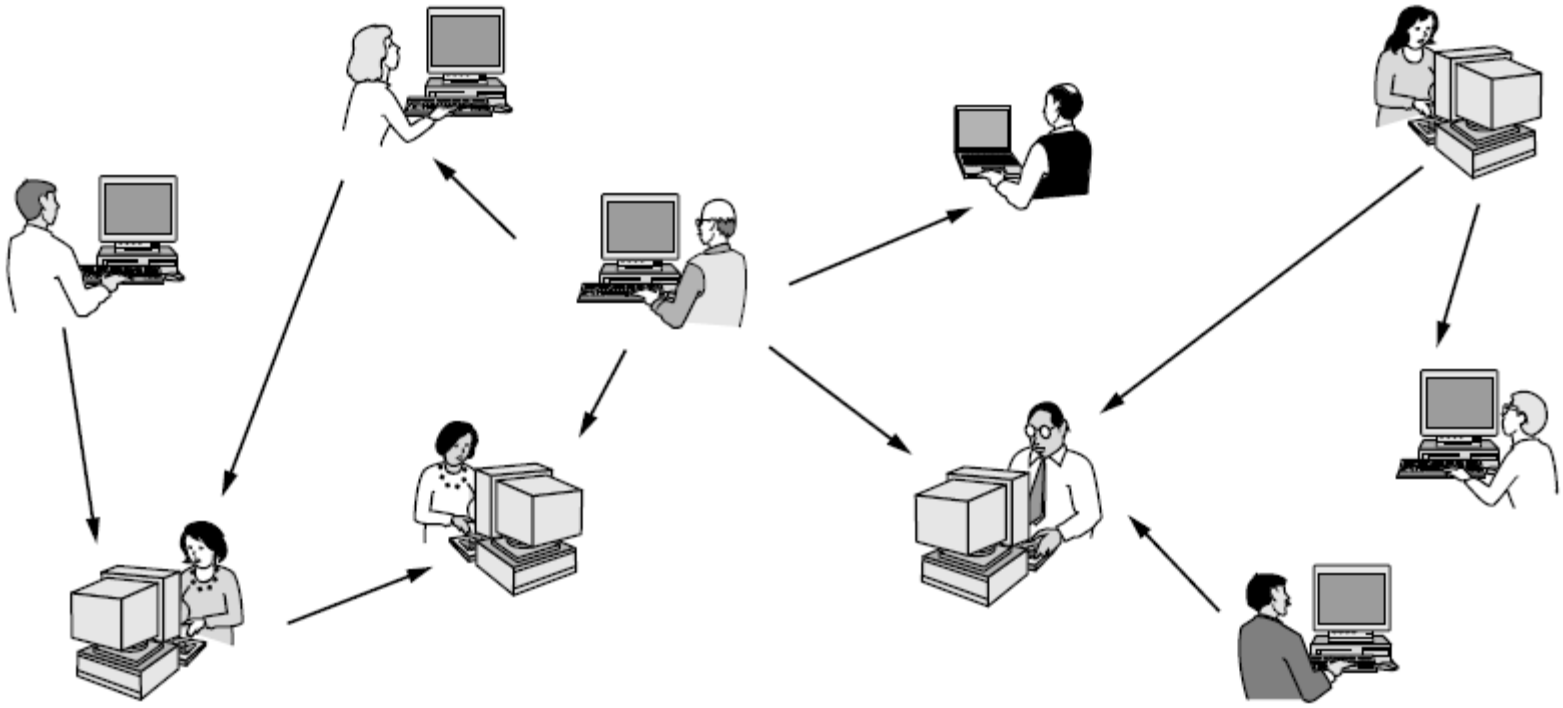
A network with two clients and one server

Business Applications (2)



The client-server model involves requests and replies

Home Applications (1)



In a peer-to-peer system there are no fixed clients and servers.

Home Applications (2)

Tag	Full name	Example
B2C	Business-to-consumer	Ordering books online
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 online
P2P	Peer-to-peer	Music sharing

Some forms of e-commerce

Mobile Users

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

Combinations of wireless networks and mobile computing

Mobile Users

- Issues : connectivity and coverage
- Applications or services:
  - Cellular networks
  - Wireless hotspots, e.g. IEEE 802.11(WiFi)
  - Text messaging or texting (or Short Message Service, SMS)
  - GPS-enabled phone or car
  - m-commerce
  - Sensor networks
  - Wearable computers (e.g., pacemaker)

Social Issues

- Network neutrality
- Digital Millennium Copyright Act (DMCA)
- Profiling users
  - Cookies
  - Location privacy
  - Electrical junk mail (spam)
- Phishing

Classify computer networks

- Transmission technology
  - Point-to-point links
    - Unicasting, for exactly one sender and exactly one receiver
  - Broadcast links
    - Unicasting
    - Multicasting
    - Broadcasting
- Scale
  - …. next

Network Hardware (1)

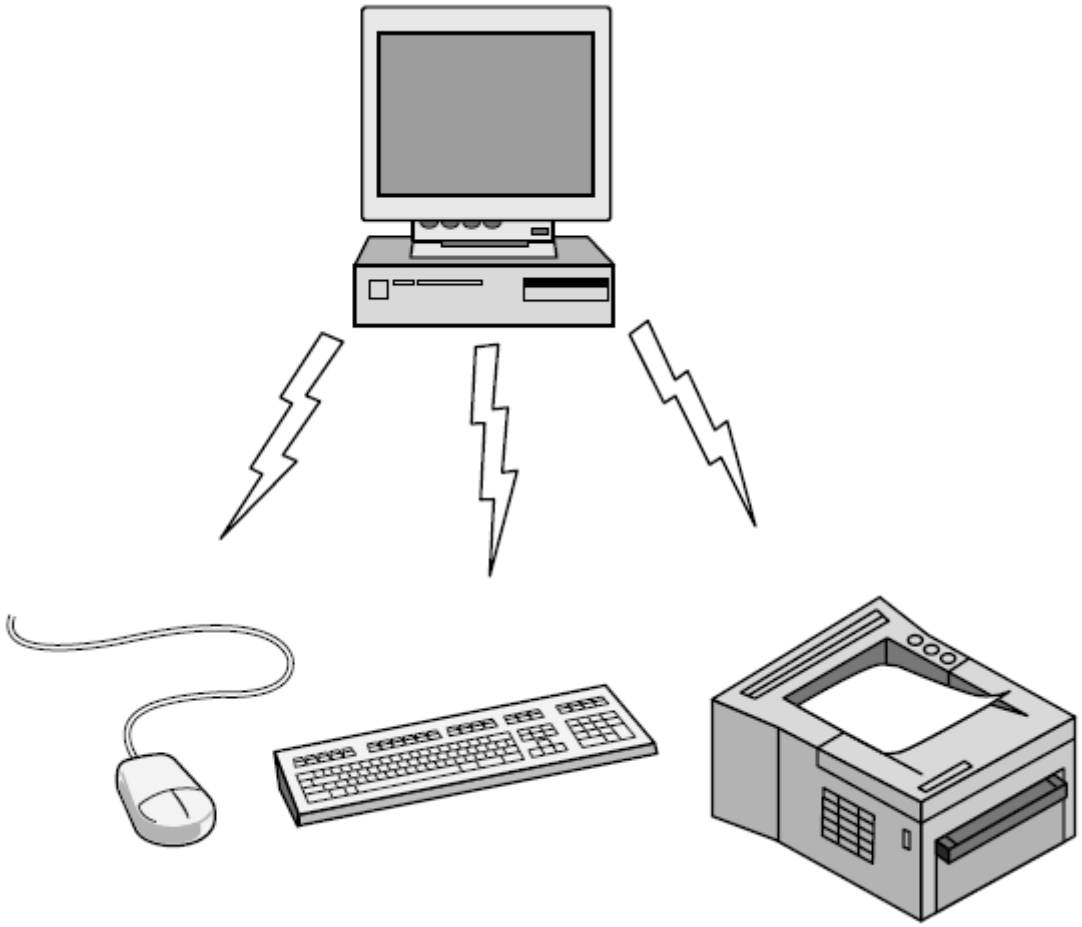
- Personal area networks
- Local area networks
- Metropolitan area networks
- Wide are networks
- The internet

Network Hardware (2)

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

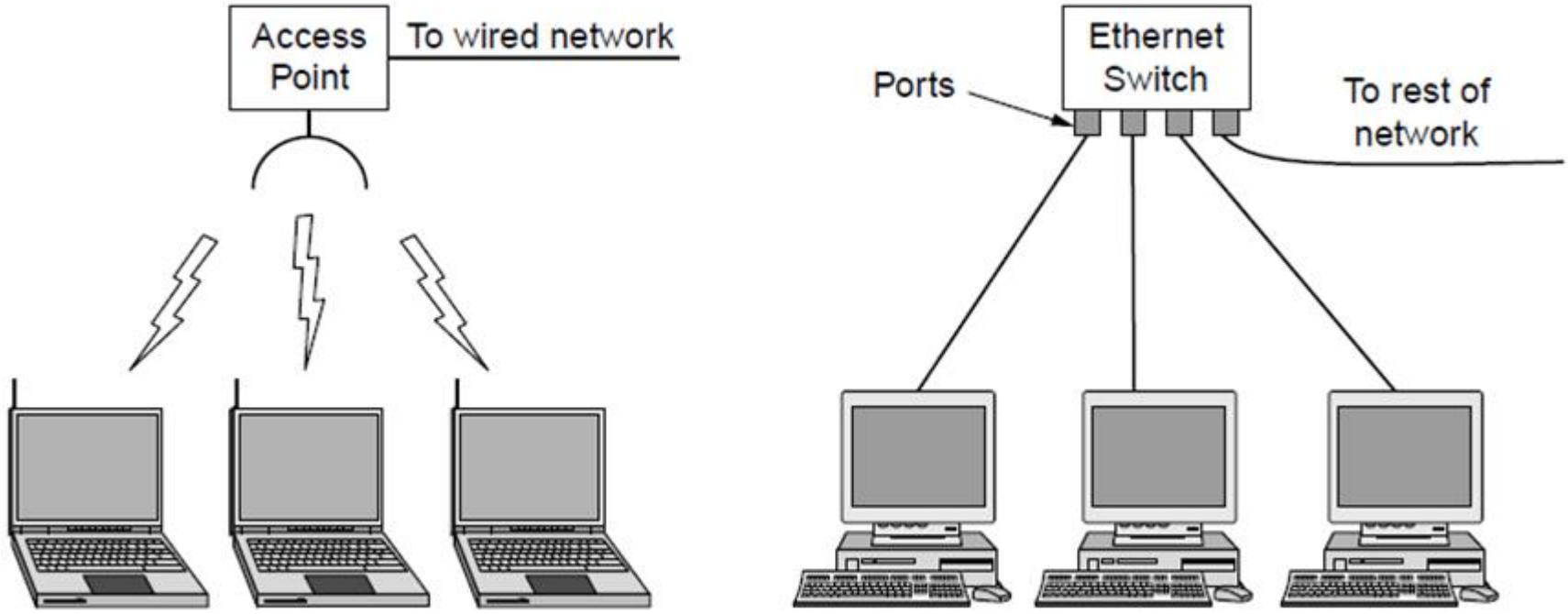
Classification of interconnected processors by scale.

Personal Area Network



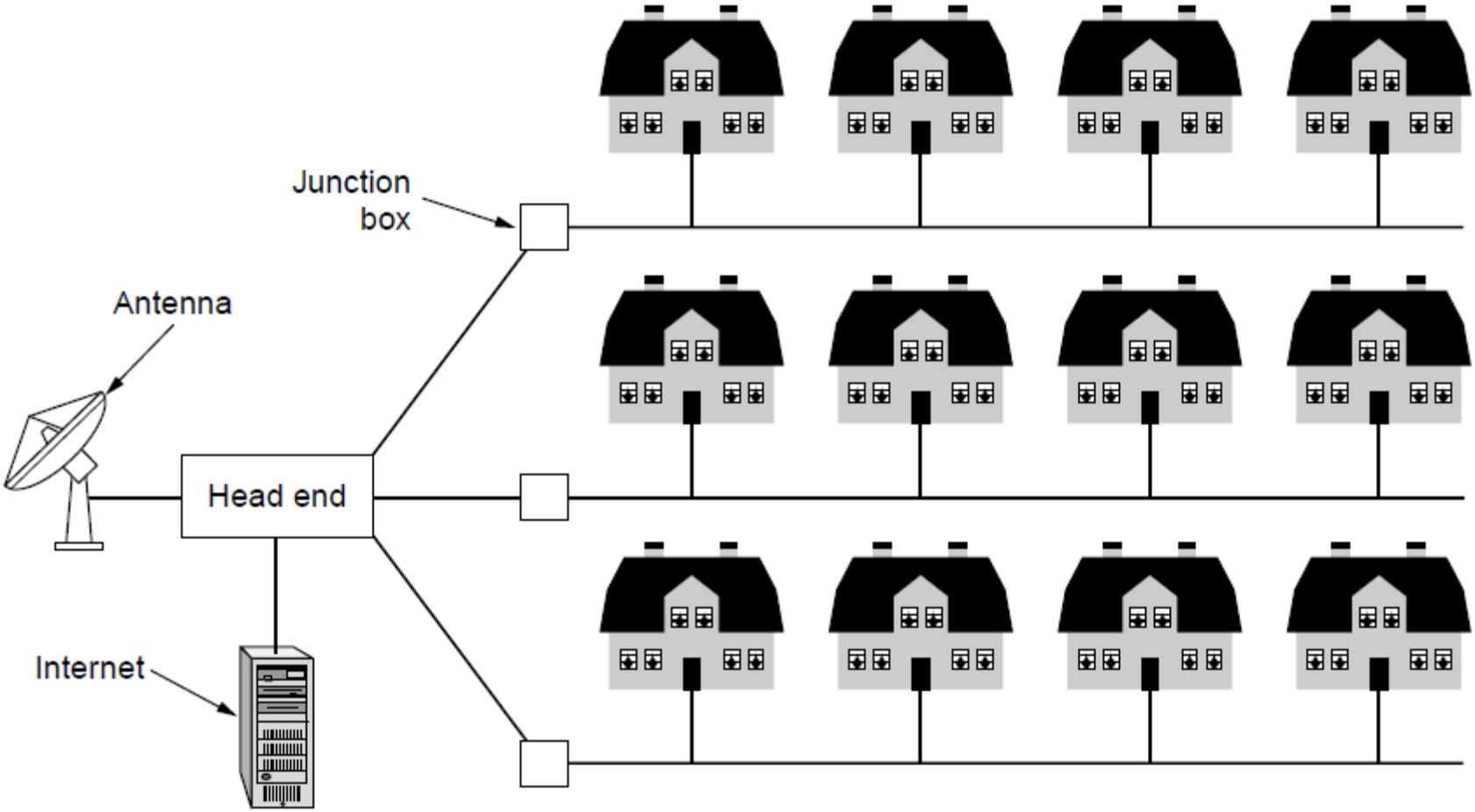
Bluetooth PAN configuration

Local Area Networks



Wireless and wired LANs. (a) 802.11. (b) Switched Ethernet.

Metropolitan Area Networks



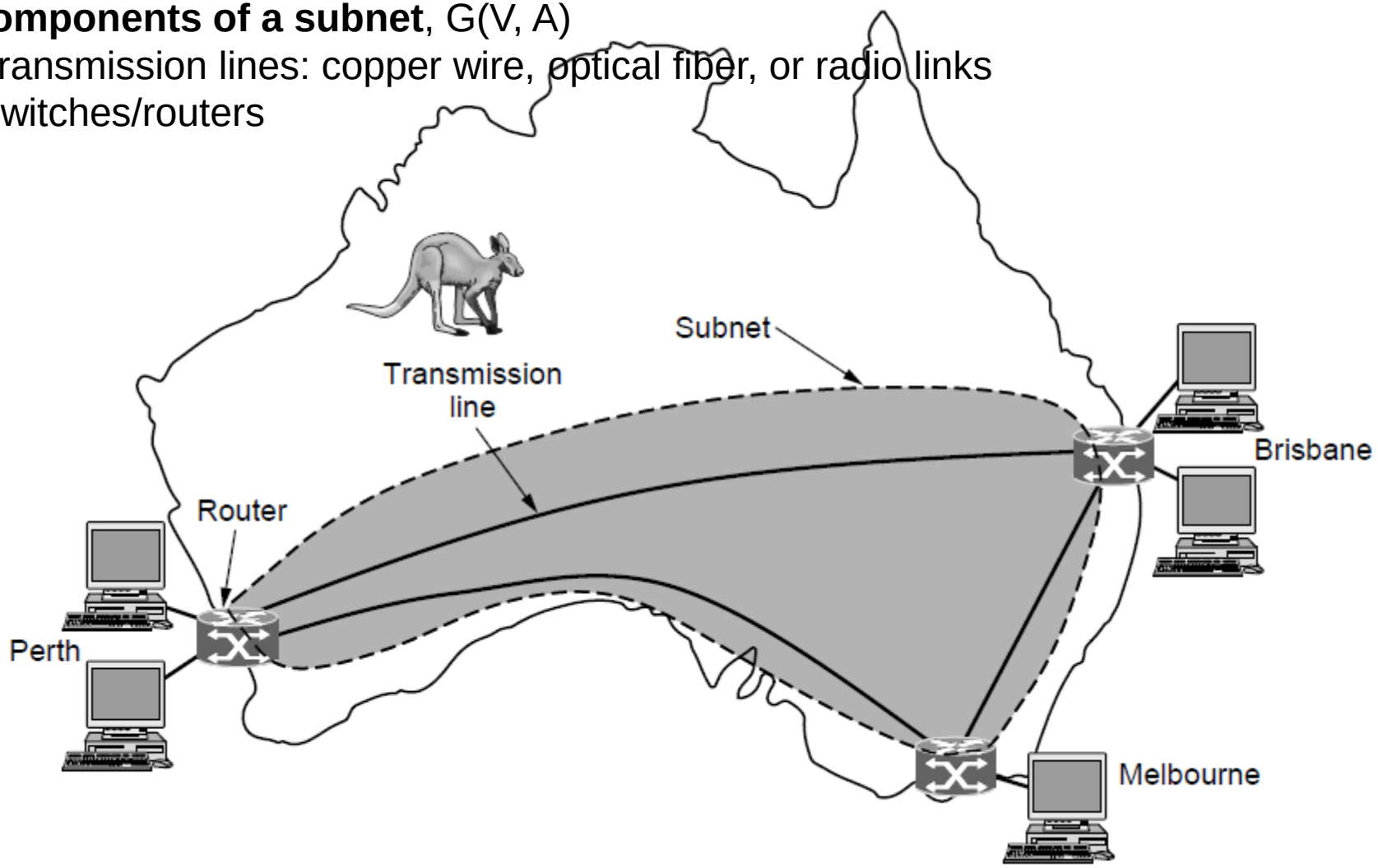
A metropolitan area network based on cable TV.

(WiMAX, IEEE 802.16, another MAN)

Wide Area Networks (1)

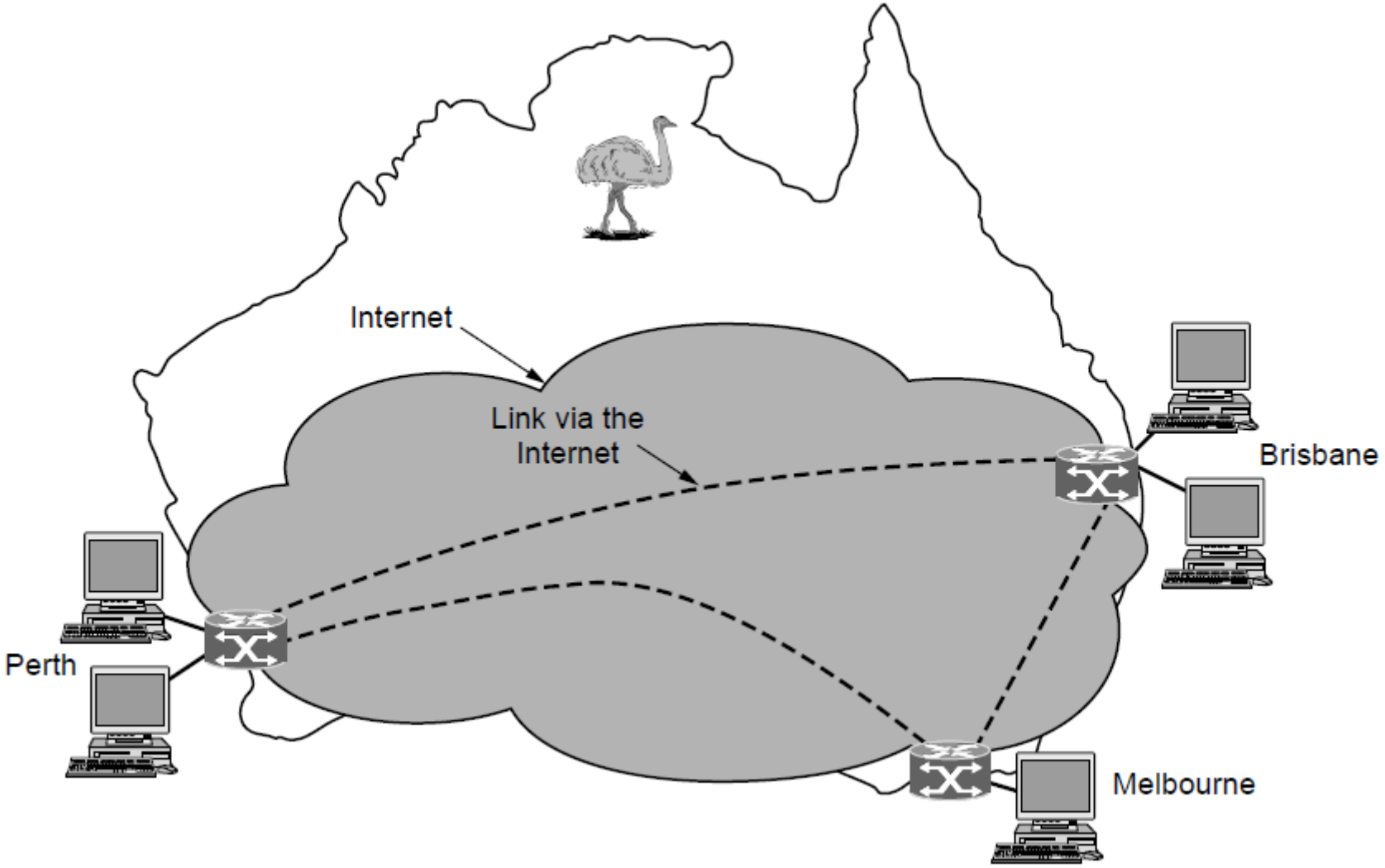
Components of a subnet, G(V, A)

- Transmission lines: copper wire, optical fiber, or radio links
- Switches/routers



WAN that connects three branch offices in Australia

Wide Area Networks (2)



WAN using a virtual private network.

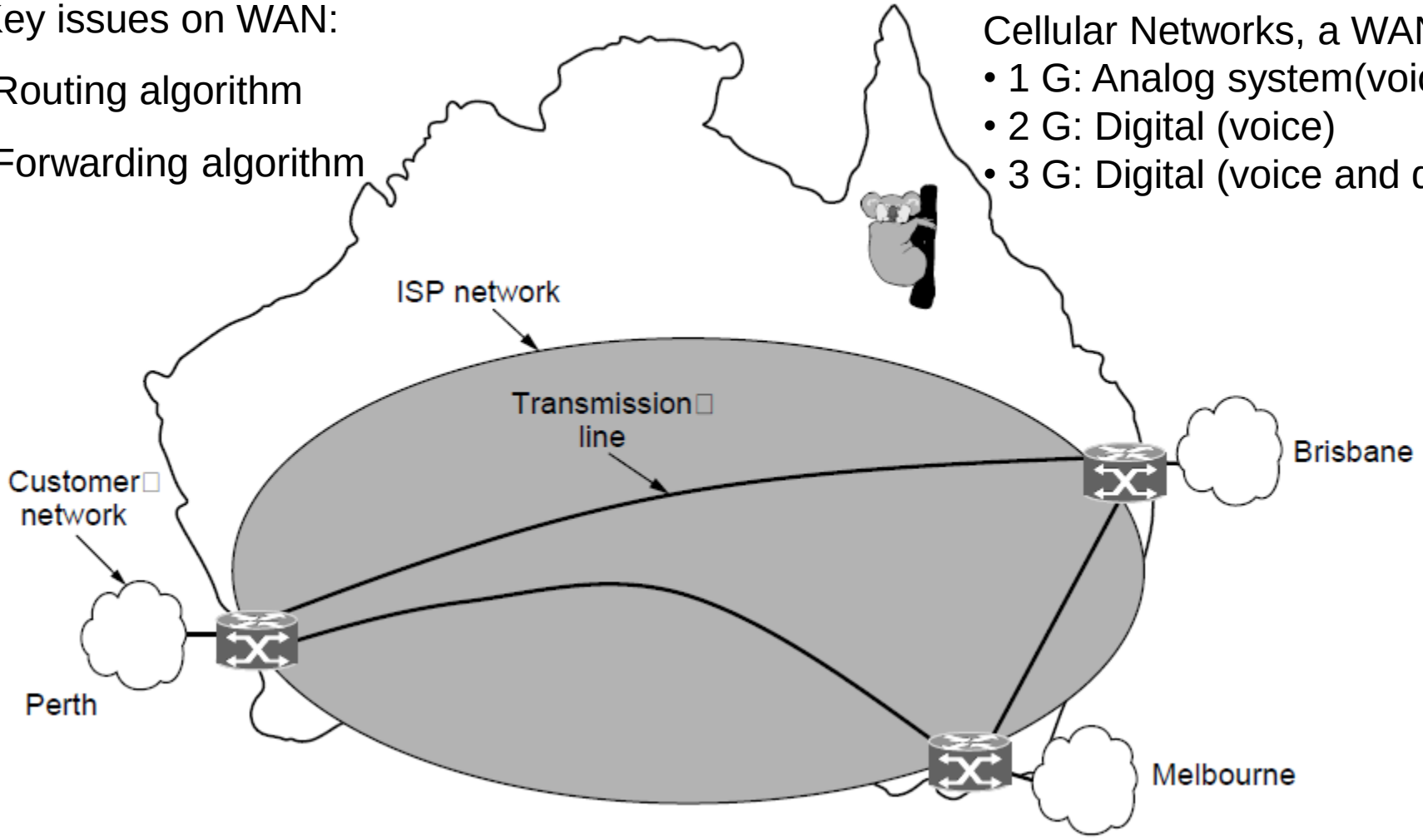
Wide Area Networks (3)

Key issues on WAN:

•Routing algorithm

•Forwarding algorithm

Cellular Networks, a WAN
- 1 G: Analog system(voice)
- 2 G: Digital (voice)
- 3 G: Digital (voice and data)

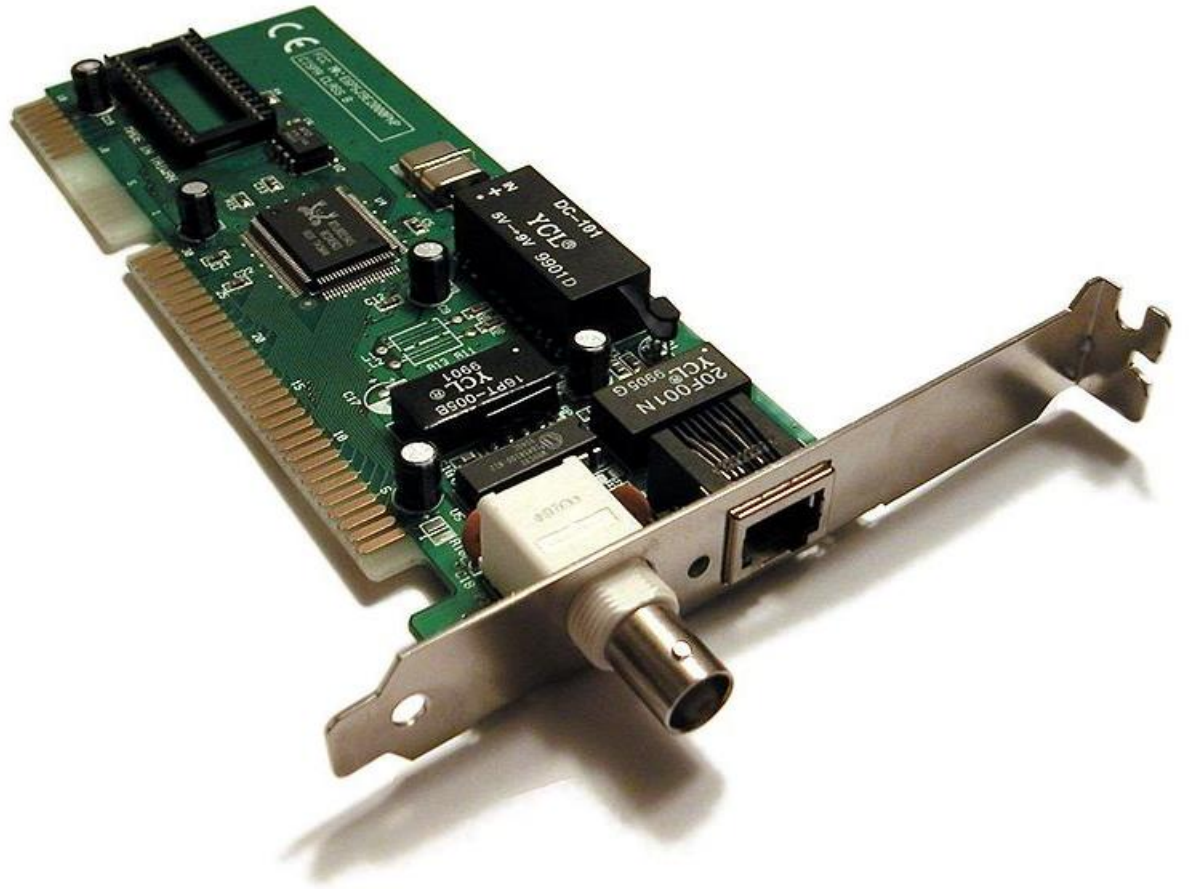


WAN using an ISP network.

internet

a) Little agreement over Terminology
   - Subnet
   - Network
   - Internetwork, (via gateway/router)

A Network interface card (NIC)



Ethernet NIC

Category 5 cable and RJ 49 connector

Wireless access point

Routers

Network Software

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

Protocol Hierarchies

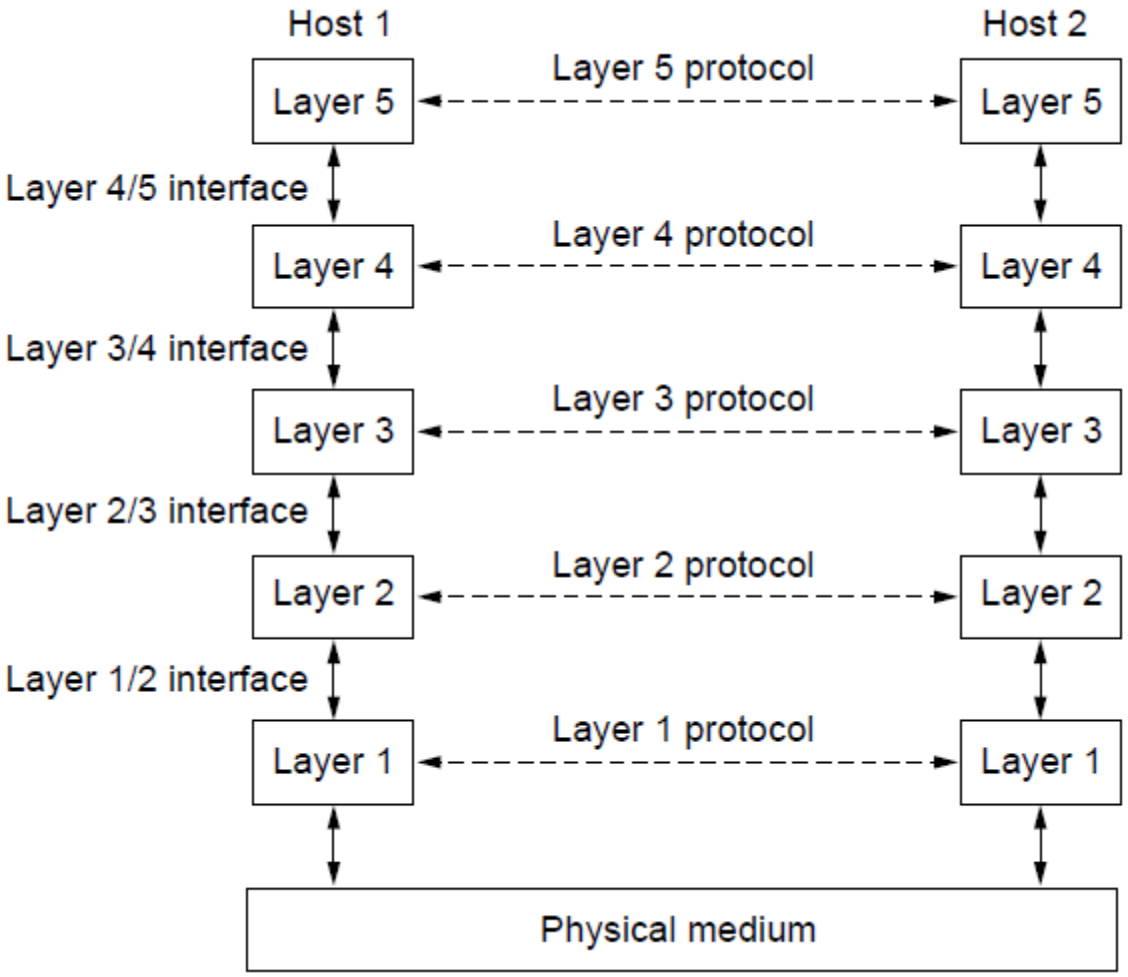
a) Layers/levels:
   - The number, the name, the contents, and the functions of each layer ?
     - The purpose of each layer is to offer certain service to the higher layer while shielding those layers from how the offered services are implemented.
       - Information hiding, abstract data types, data encapsulation, and OO programming

b) Protocols
   - An agreement between the communicating parties on how communication is to proceed.
     - Peer, entity

c) Interface, between each pair of adjacent layers
   - Primitive operations and services for the upper layers

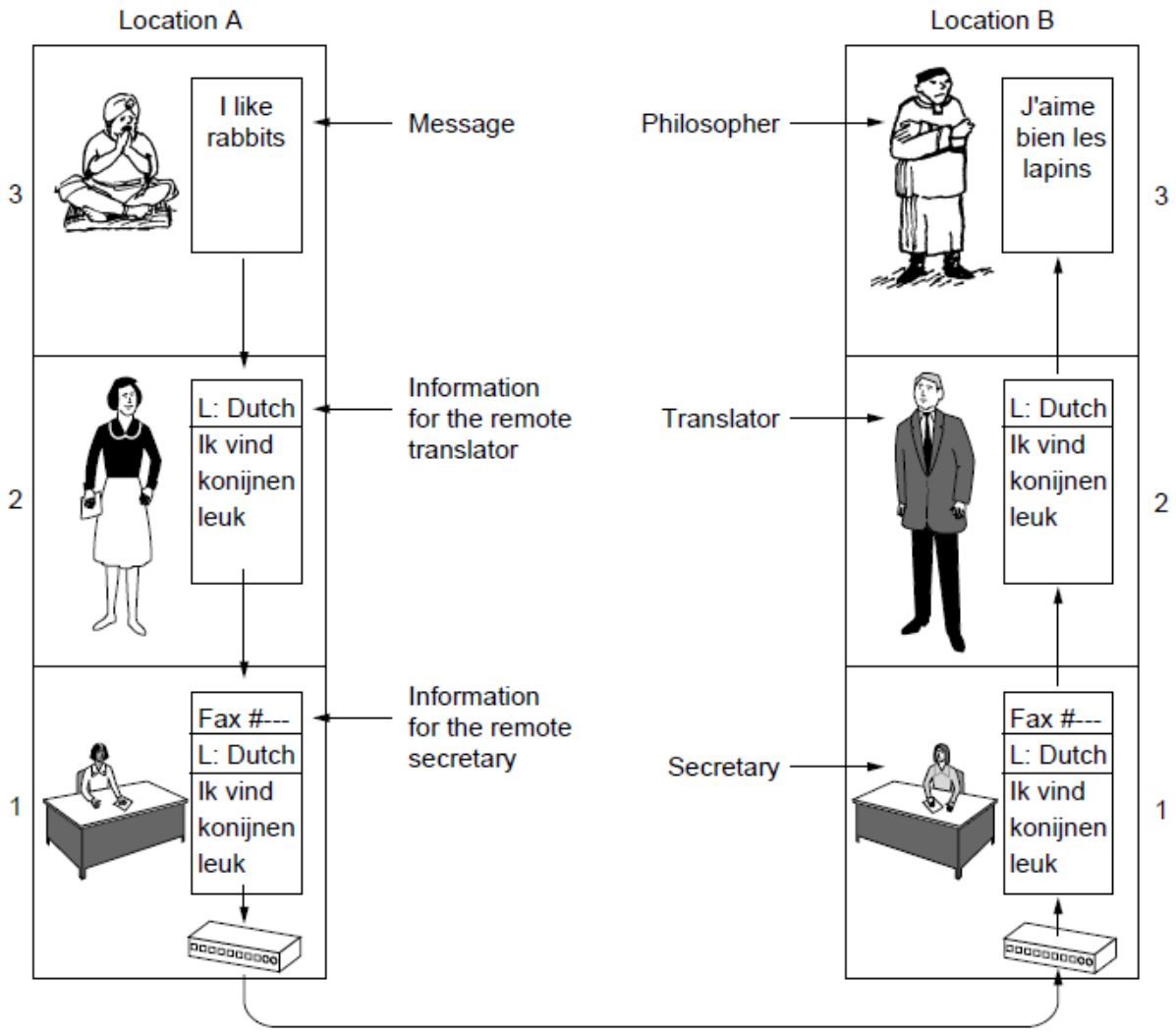
A set of layers and protocols is called a **network architecture**. ← Specification

Protocol Hierarchies (1)



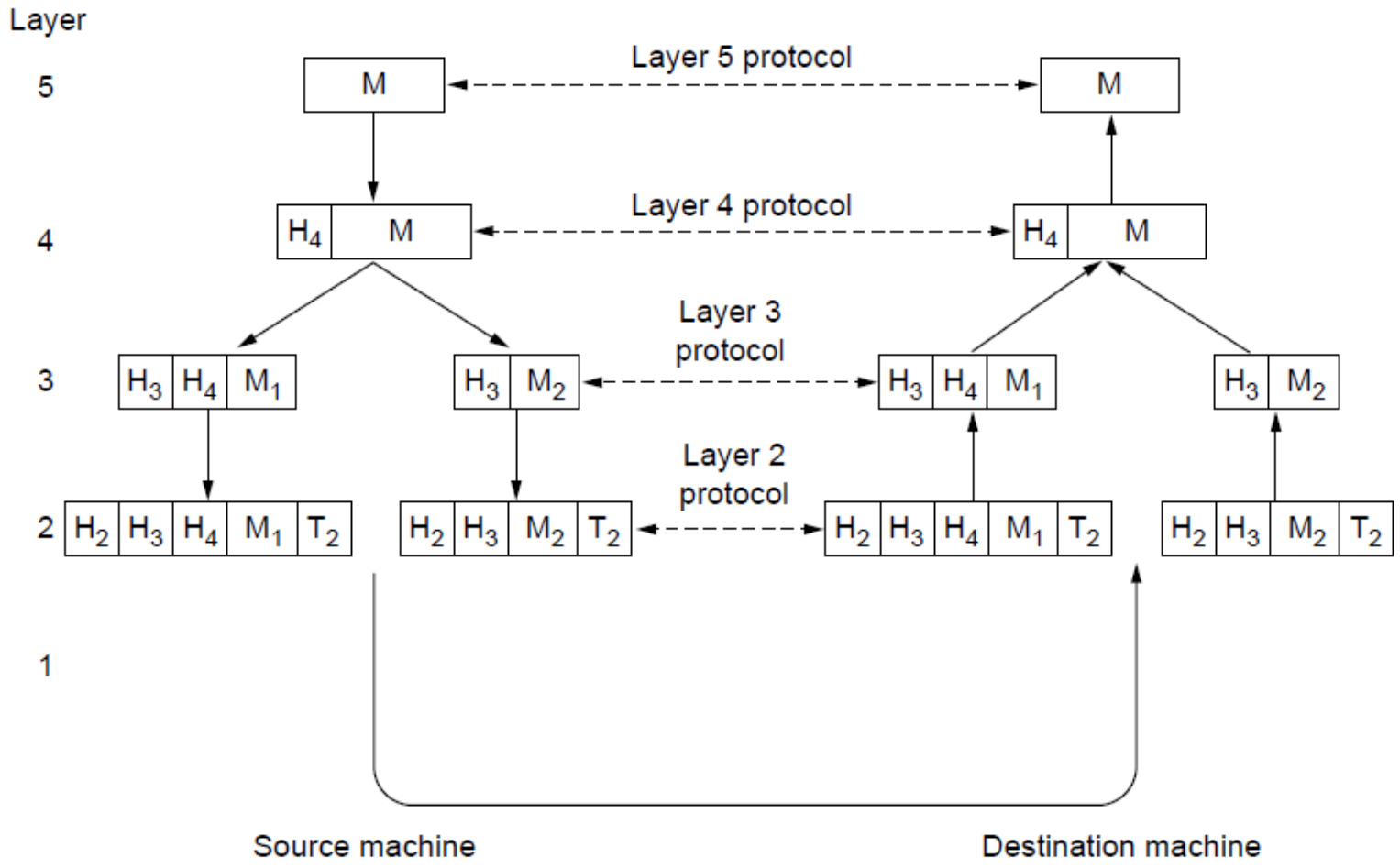
Layers, protocols, and interfaces.

Protocol Hierarchies (2)



The philosopher-translator-secretary architecture

Protocol Hierarchies (3)



Example information flow supporting virtual communication in layer 5.

Design issues for each layers

- Reliability
  - Error detection← at lower or higher layers
  - Error correction ← at lower or higher layers
  - Finding a working path through a network ← routing
- On the evolution of the network→ internetworking
  - Protocol layering, addressing or naming, fragmentation, numbering,..
  - Scalable
- Resource allocation/sharing
  - Statistical multiplexing
  - Flow control
    - keep a faster senders from swamping a slower receiver with data
  - Congestion/overloading ← congestion control
- QoS, quality of service
- Secure
  - Eavesdropping ↔ *Confidentiality*
  - *Authentication*
  - *Integrity*

Connection-Oriented Versus Connectionless Service

- **Connection-oriented** service is modeled after the telephone system.
  - Establish a connection, use the connection, and release the connection.
  - Negotiation for parameters during the phase of connection establishment: maximum message size, QoS requirements, etc.
  - A “circuit”
- **Connectionless** service is modeled after the postal office.
  - Store-and-forward switching
  - Cut-throughput switching
- Reliability
  - Message sequences
  - Byte streams

Connection-Oriented Versus Connectionless Service

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

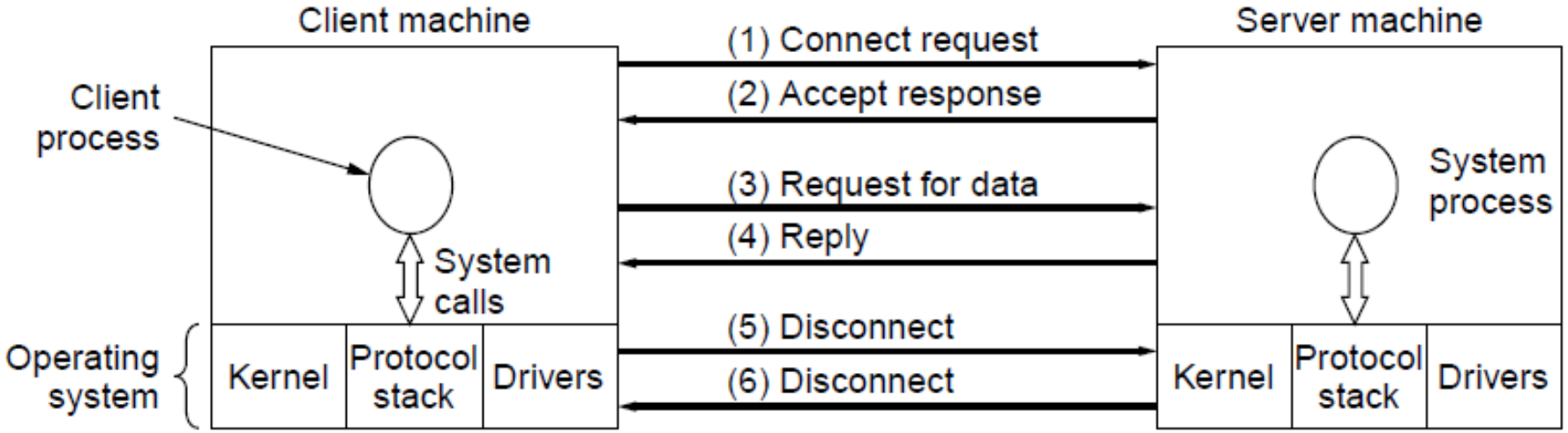
Six different types of service.

Service Primitives (1)

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

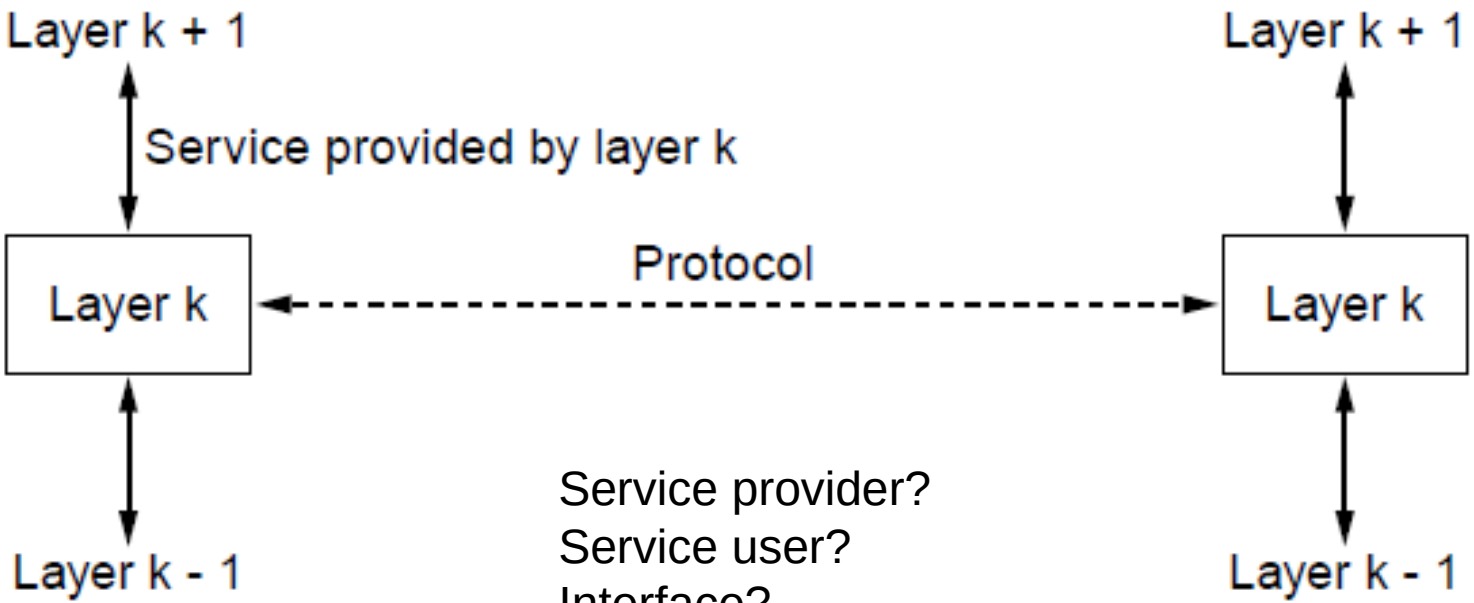
Six service primitives that provide a simple connection-oriented service

Service Primitives (2)



A simple client-server interaction using acknowledged datagrams.

The Relationship of Services to Protocols



The relationship between a service and a protocol.

Reference Models

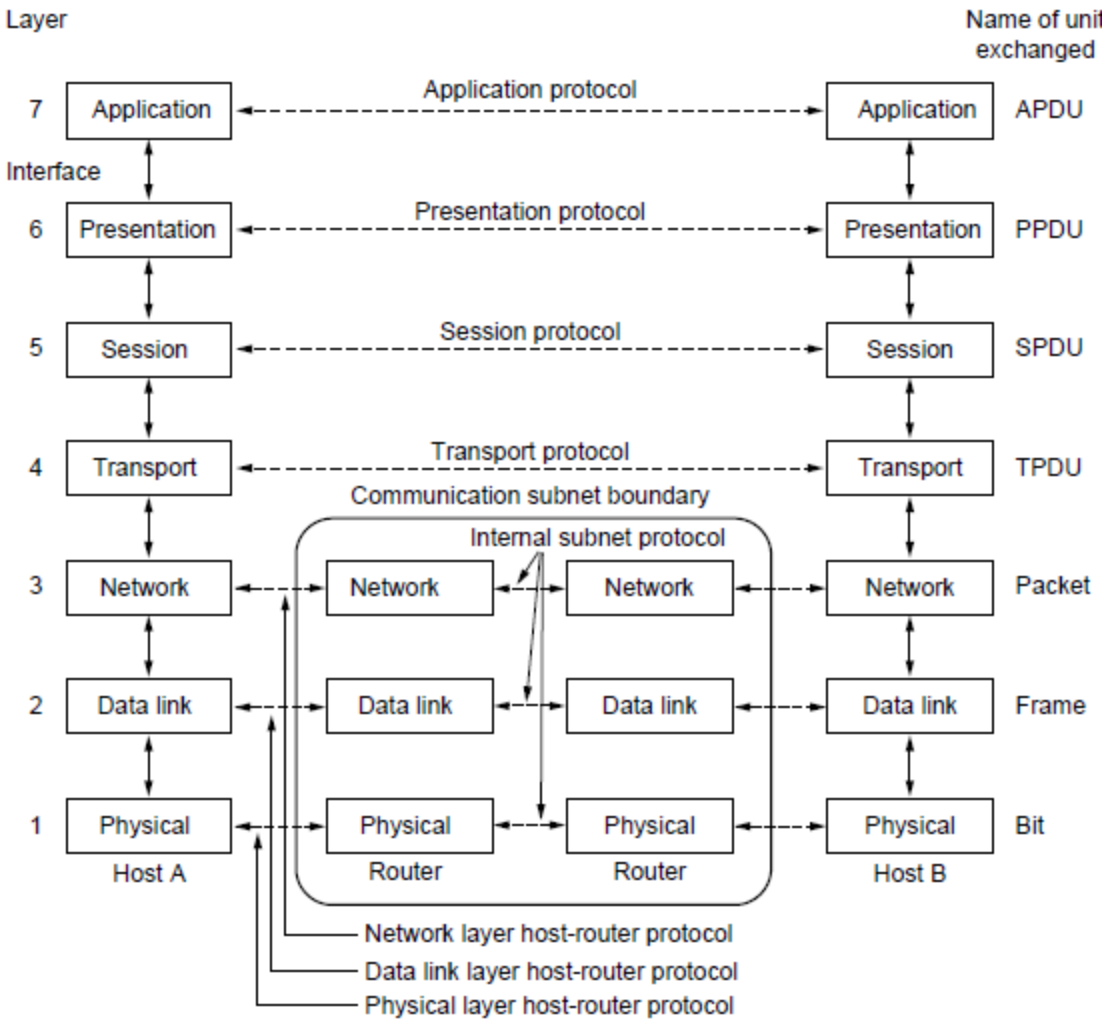
- OSI reference model
- TCP/IP reference model
- Model used for this text
- Comparison of OSI and TCP/IP
- Critique of OSI model and protocols
- Critique of TCP/IP model

The OSI Reference Model

Principles for the seven layers

- Layers created for different abstractions
- Each layer performs well-defined function
- Function of layer chosen with definition of international standard protocols in mind
- Minimize information flow across interfaces between boundaries
- Number of layers optimum

The OSI Reference Model



The OSI reference model

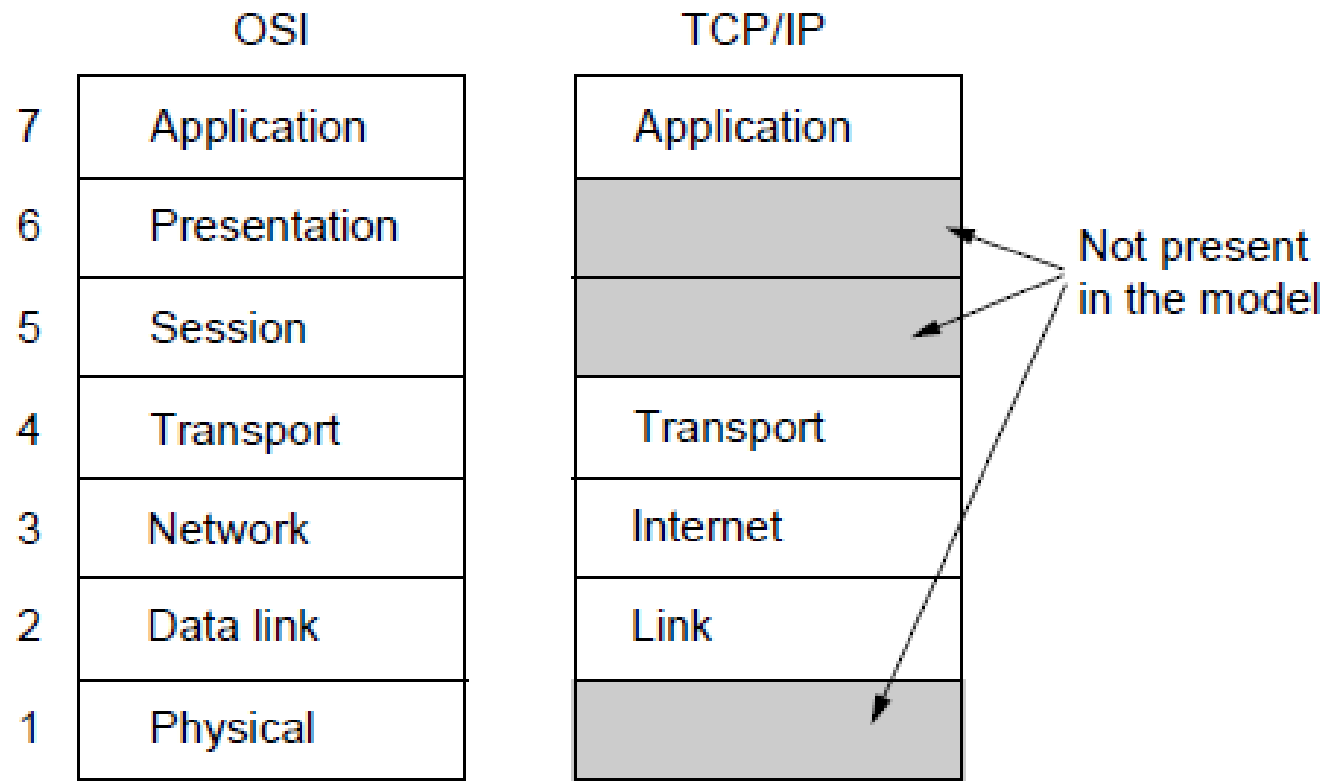
OSI Reference Model Layers

- Physical layer
  - Deal with mechanical, electrical, timing interfaces, and physical transmission medium.
- Data link layer
  - Framing, flow control and error control
  - Medium access control (MAC)
- Network layer
- Transport layer
  - A true end-to-end layer
- Session layer
- Presentation layer
- Application layer

The TCP/IP Reference Model Layers

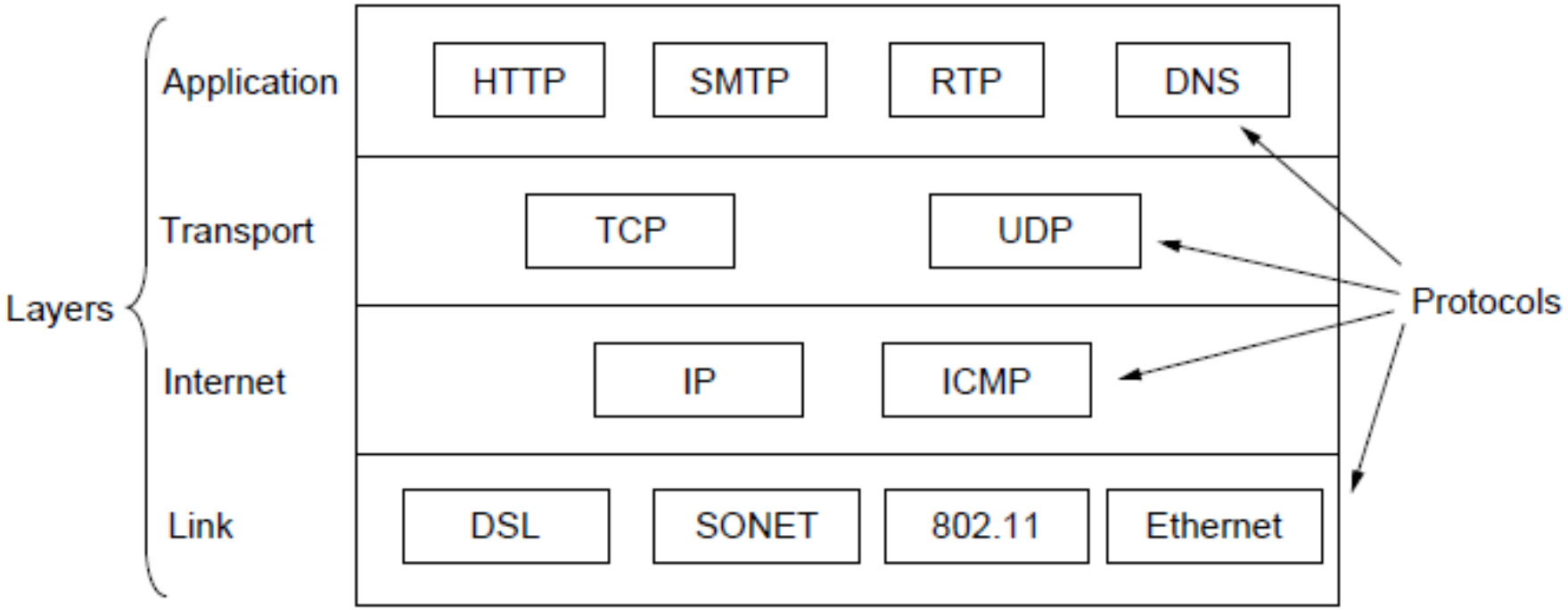
- Link layer
  - (Actually, an interface specification)
- Internet layer
- Transport layer
- Application layer

The TCP/IP Reference Model (1)



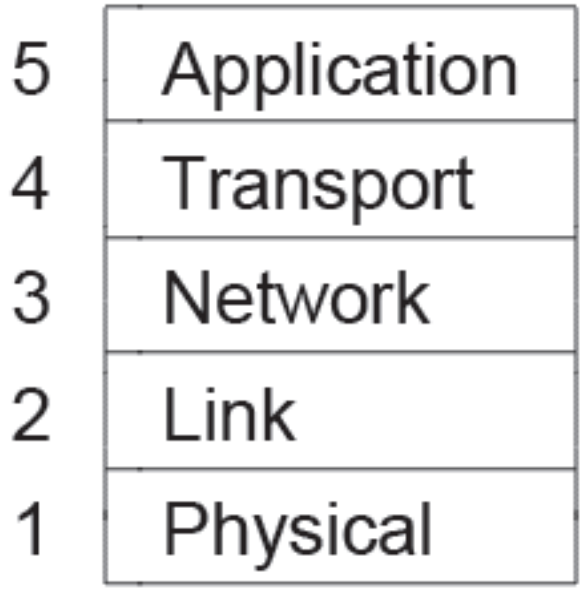
The TCP/IP reference model

The TCP/IP Reference Model (2)



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

The Model Used in this Book



The reference model used in this book.

Comparison of the OSI and TCP/IP Reference Models

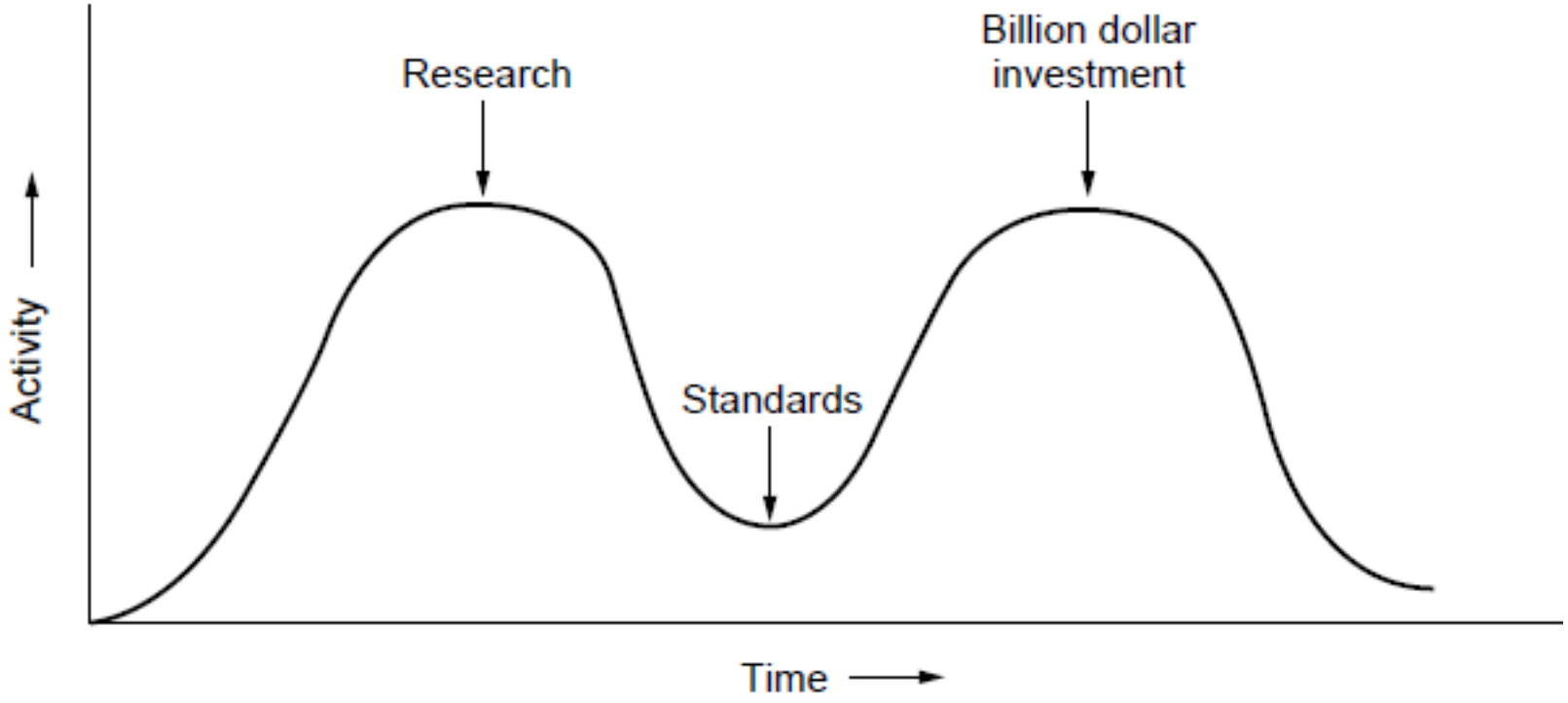
Concepts central to OSI model

- Services
- Interfaces
- Protocols

Critique of the OSI Model and Protocols

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

OSI Model Bad Timing

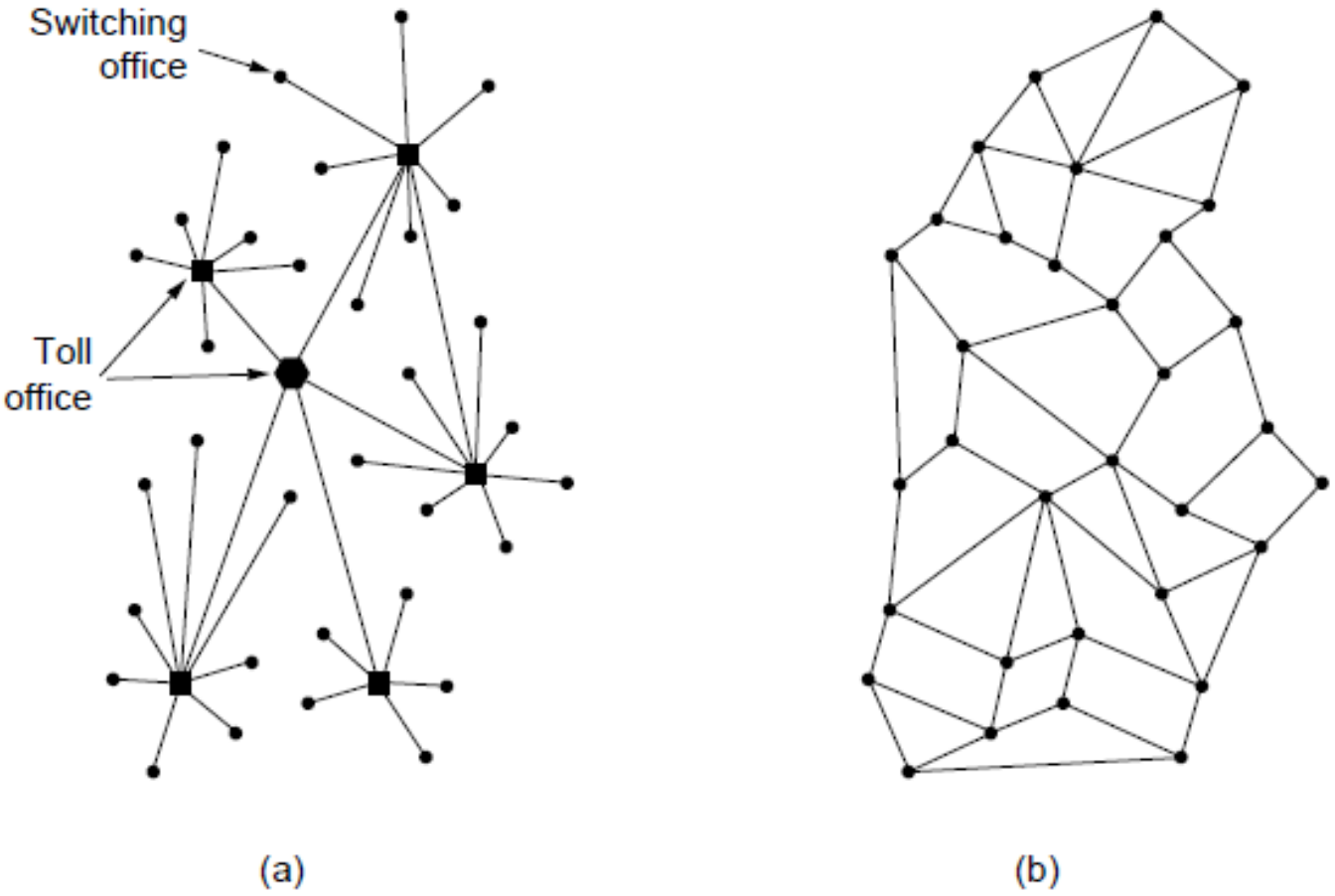


The apocalypse of the two elephants.

Example Networks

- Internet
- ARPANET
- NSFNET
- Third-generation mobile phone networks
- Wireless LANs: 802.11
- RFID and sensor networks

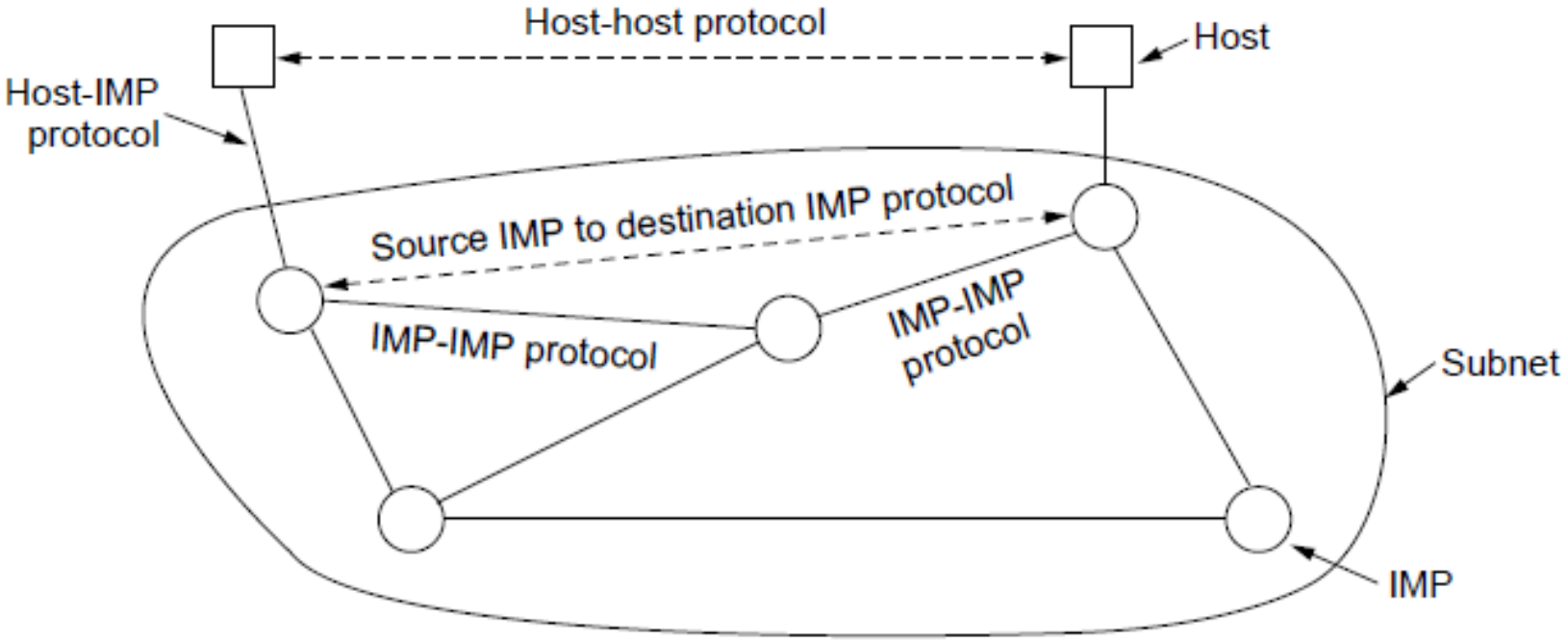
The ARPANET (1)



a) Structure of the telephone system.

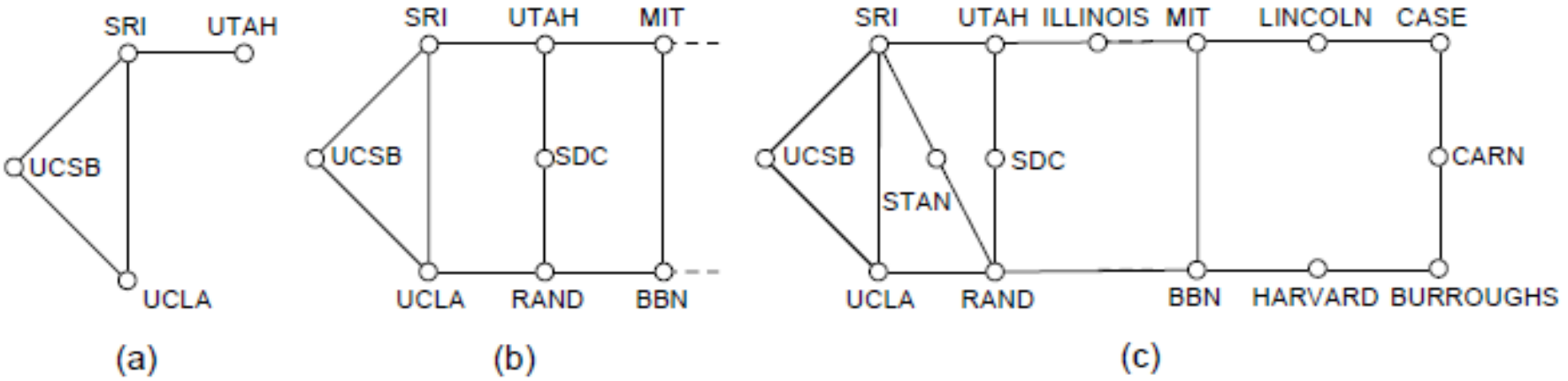
b) Baran's proposed distributed switching system.

The ARPANET (2)



The original ARPANET design

The ARPANET (3)



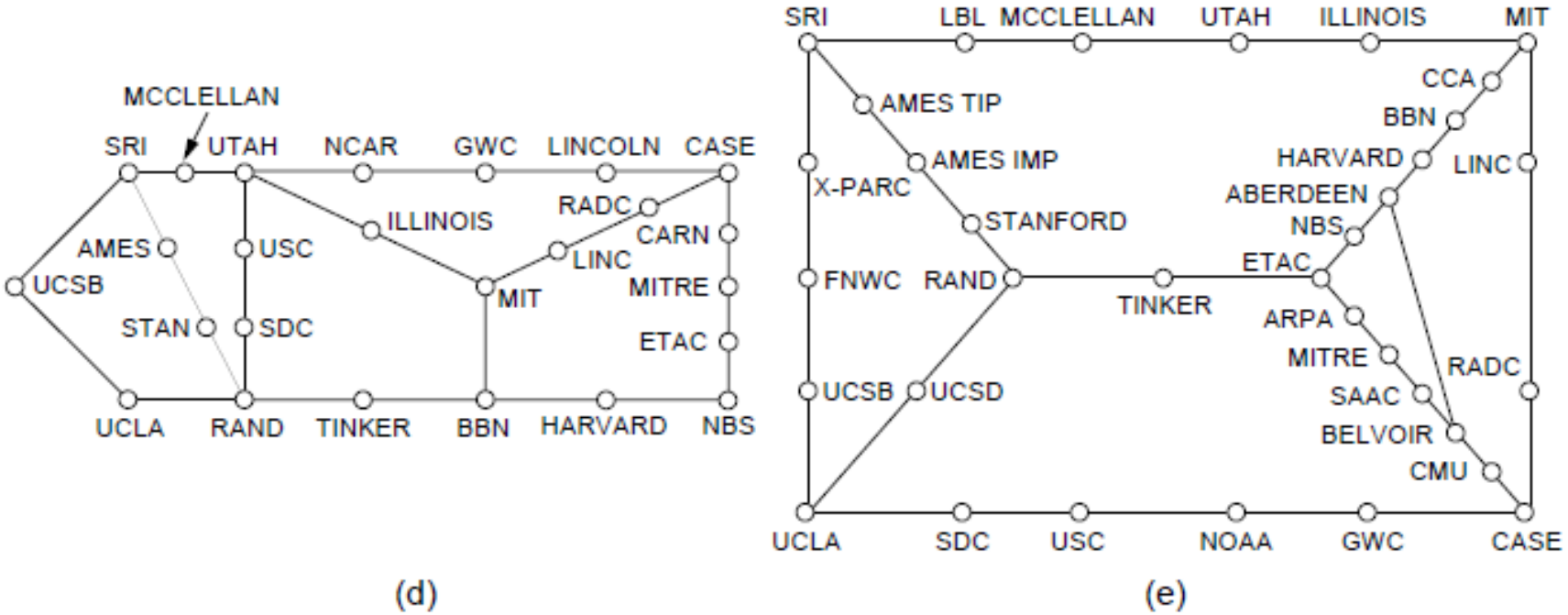
Growth of the ARPANET.

a) December 1969.

b) July 1970.

c) March 1971.

The ARPANET (4)

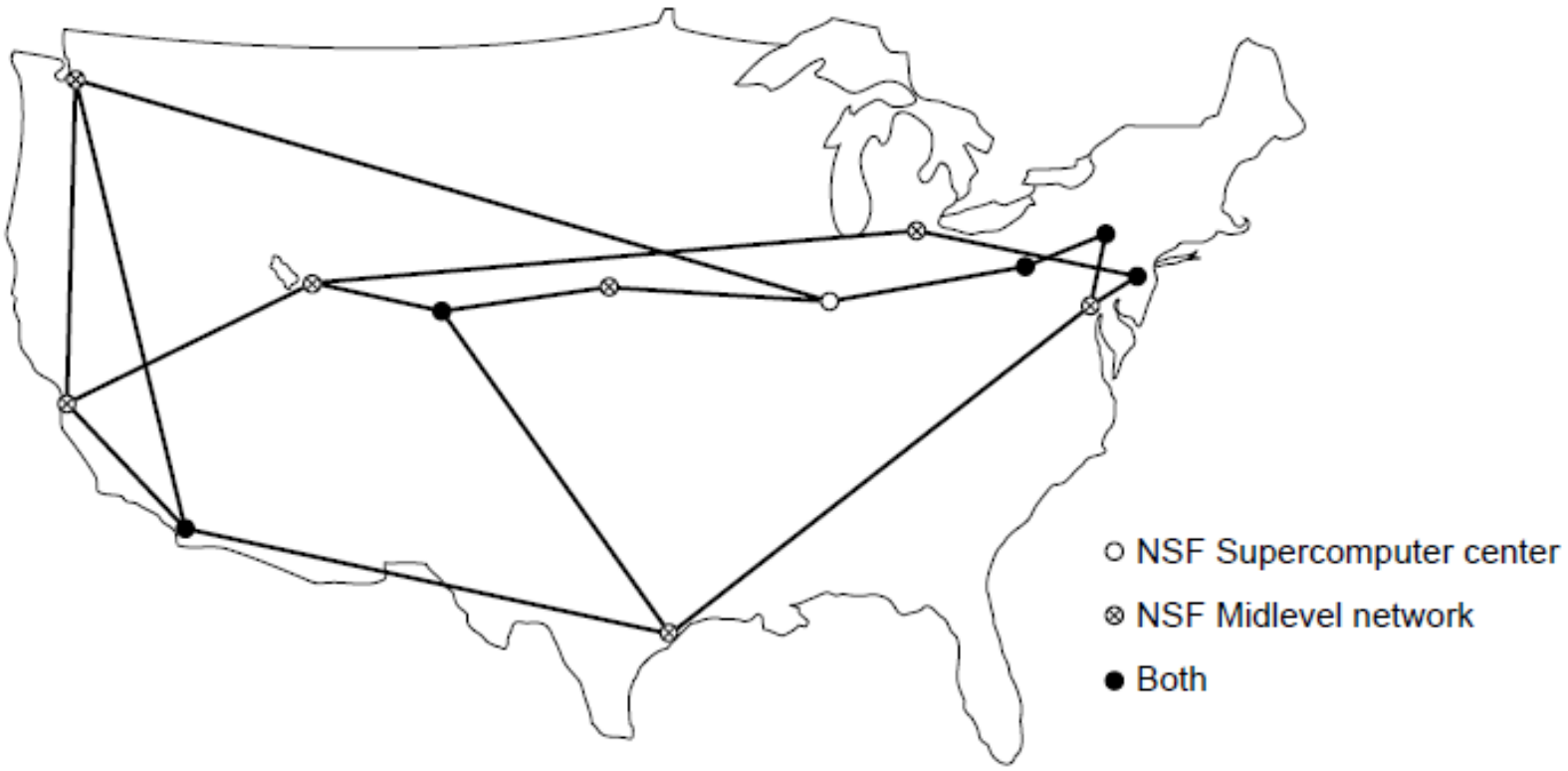


Growth of the ARPANET.

d) April 1972.

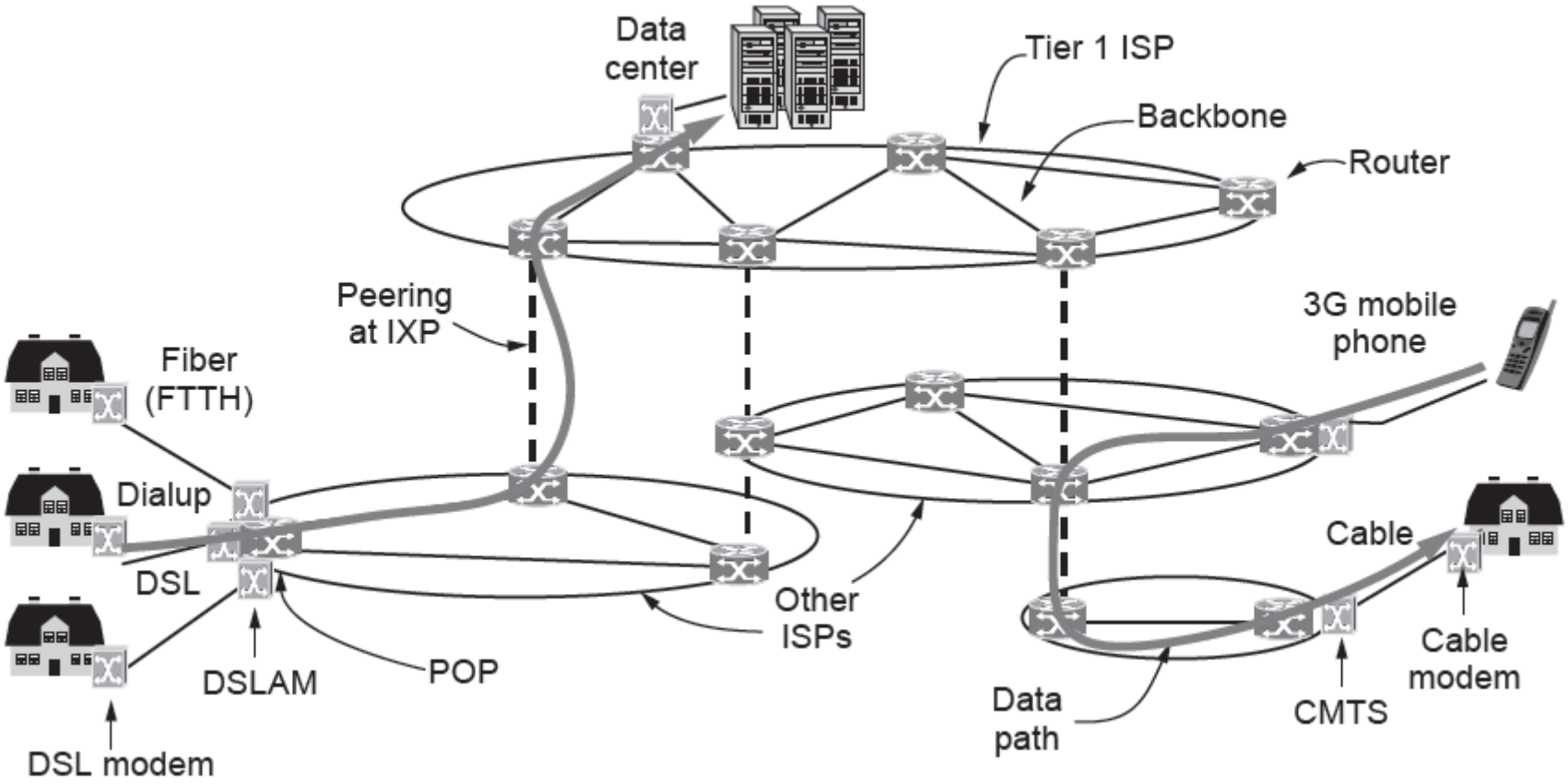
e) September 1972.

NSFNET



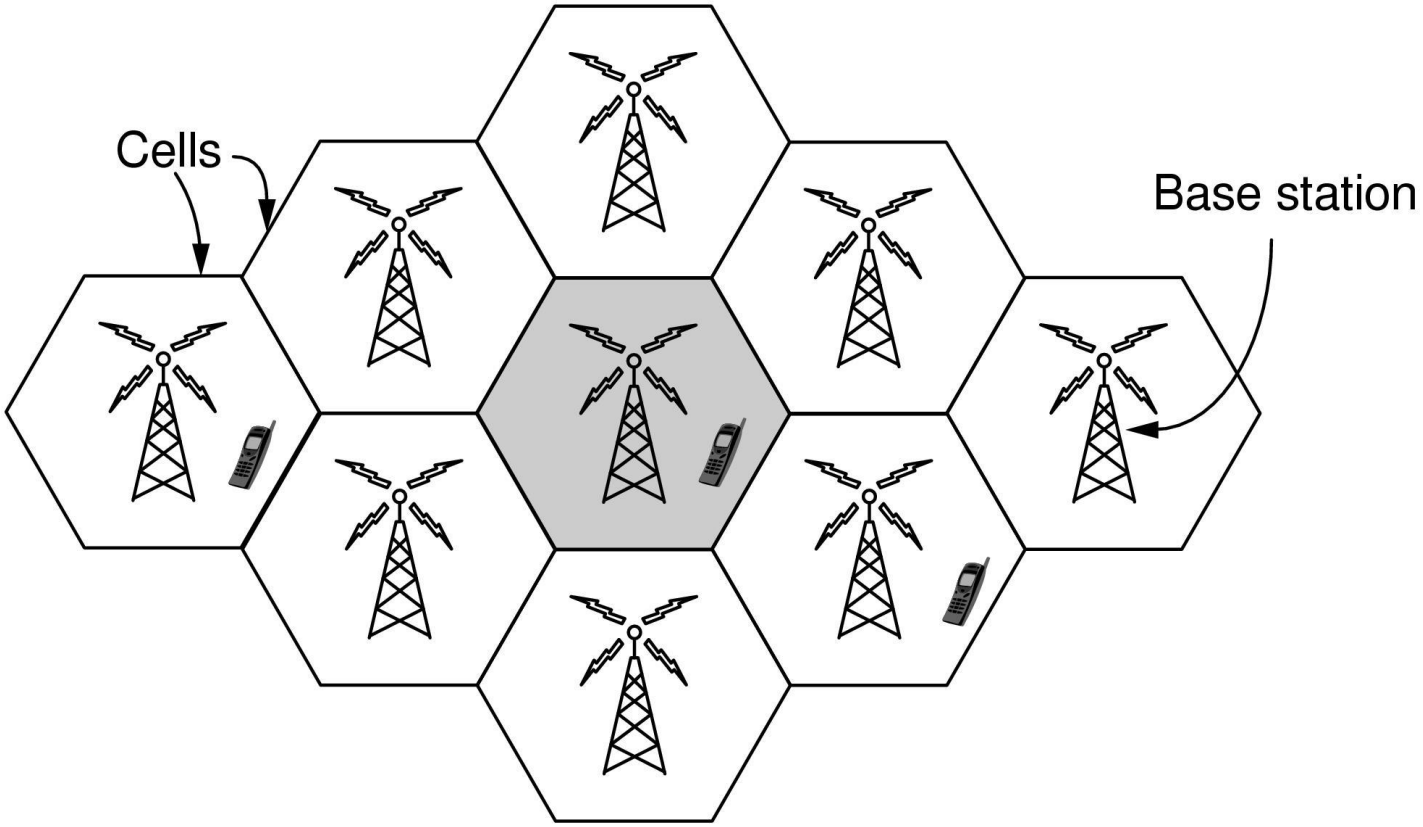
The NSFNET backbone in 1988.

Architecture of the Internet



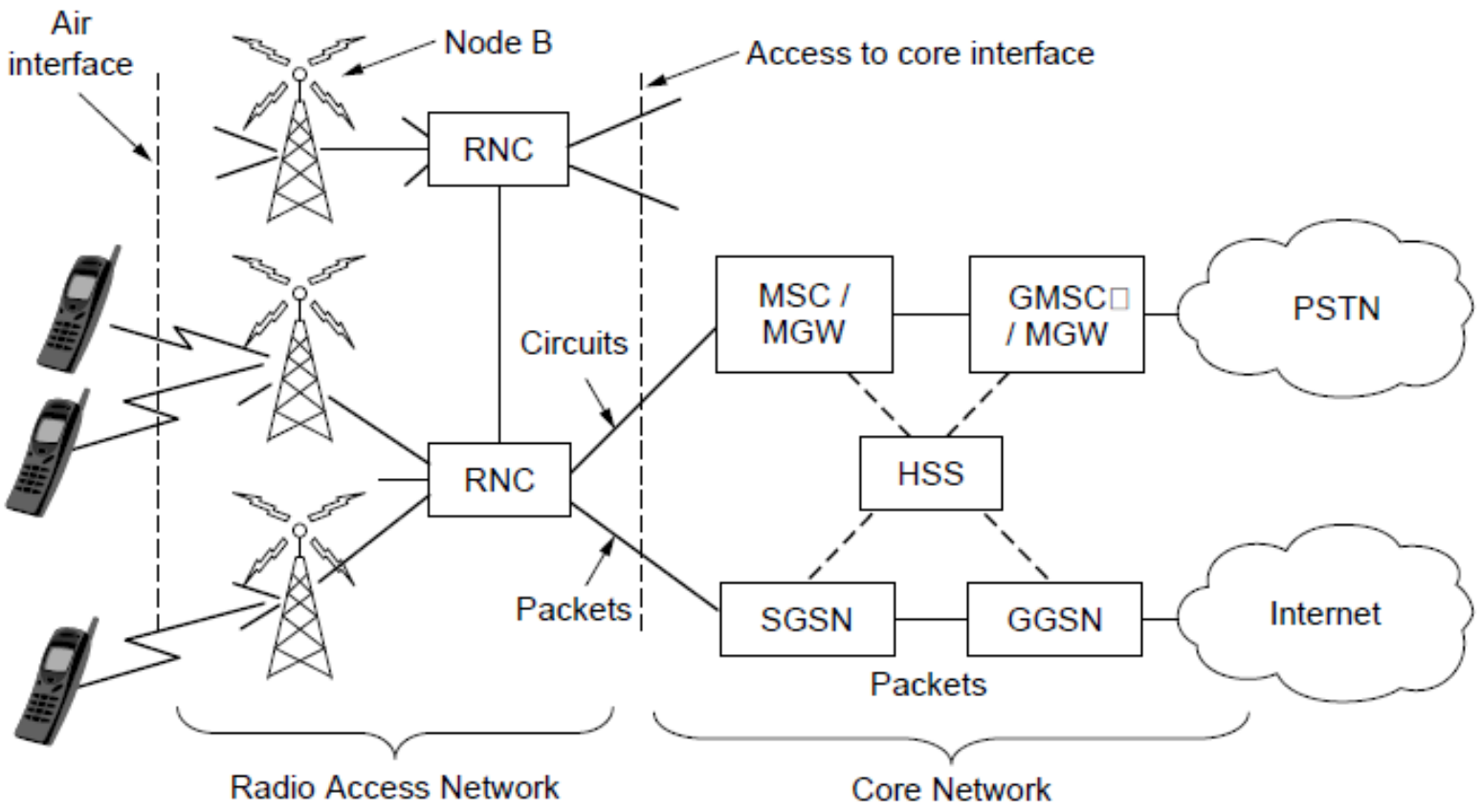
Overview of the Internet architecture

Third-Generation Mobile Phone Networks (1)



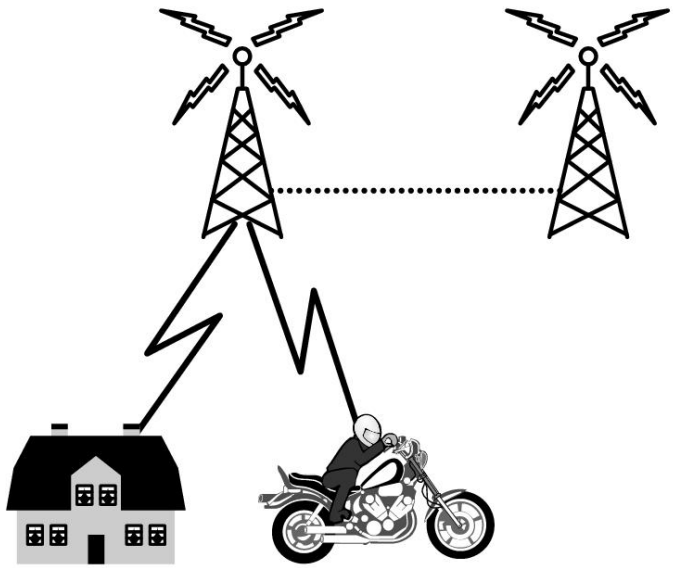
Cellular design of mobile phone networks

Third-Generation Mobile Phone Networks (2)



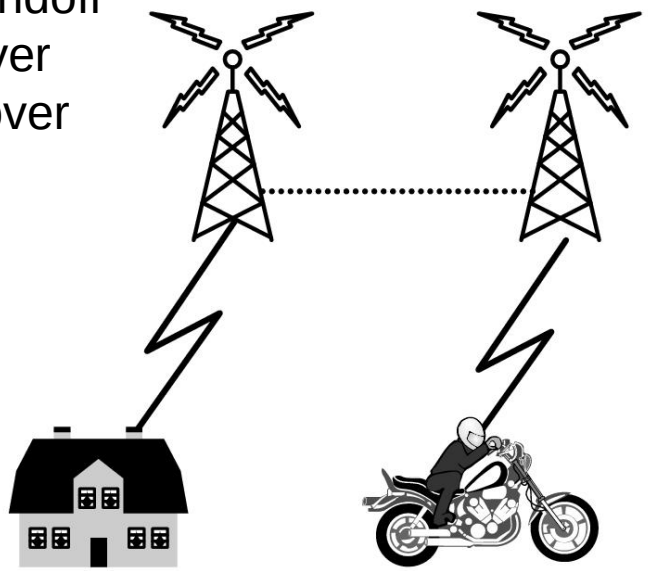
Architecture of the UMTS 3G mobile phone network.

Third-Generation Mobile Phone Networks (3)



(a)

Handover/handoff
- Soft handover
- Hard handover
- …



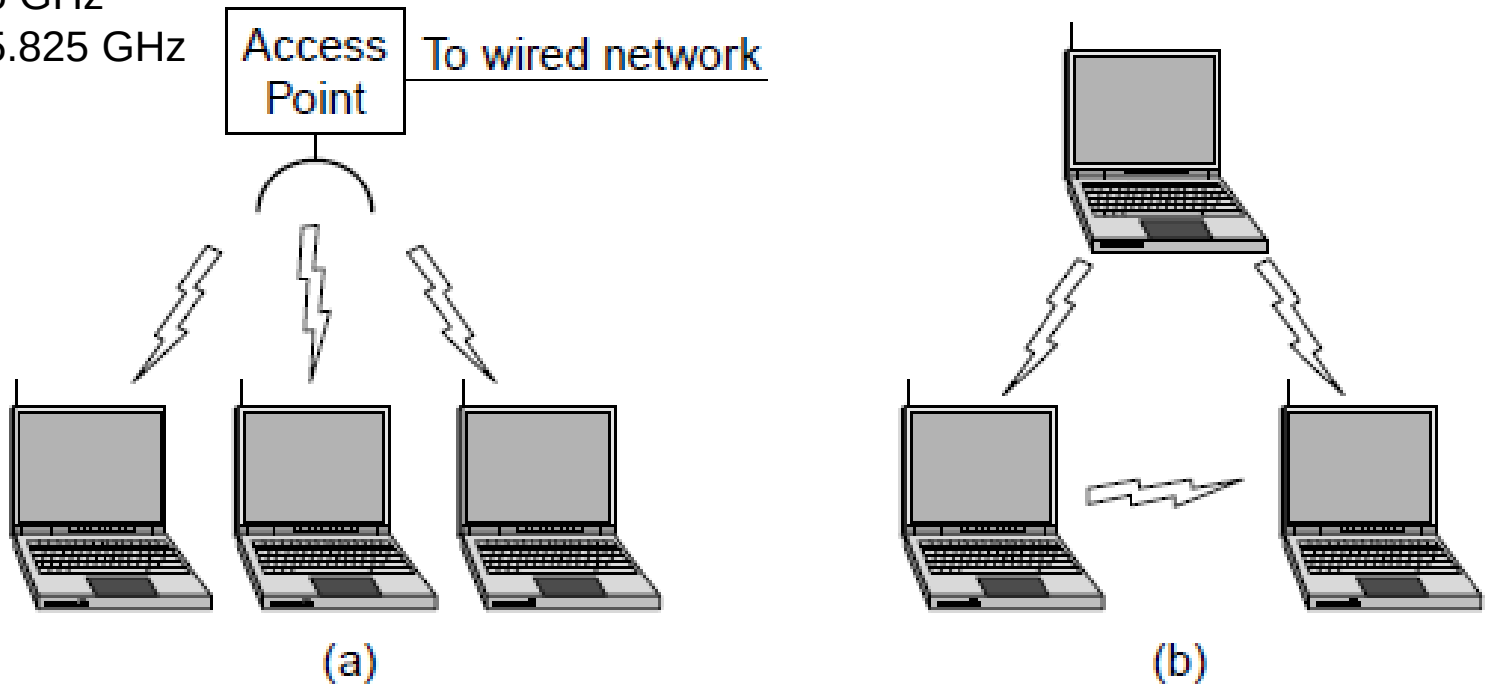
(b)

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

Wireless LANs: 802.11 (1)

Unlicensed ISM bands:

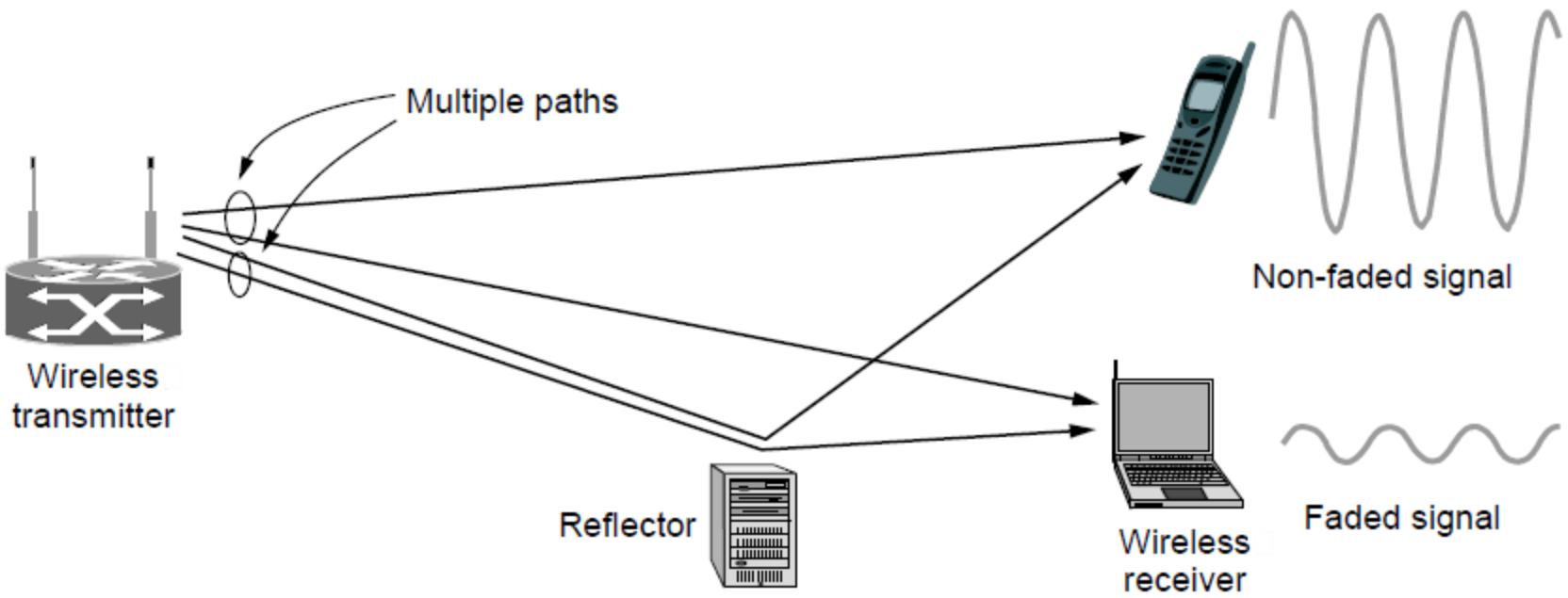
- 902-928 MHz
- 2.4 -2.5 GHz
- 5.725-5.825 GHz



(a) Wireless network with an access point.

(b) Ad hoc network.

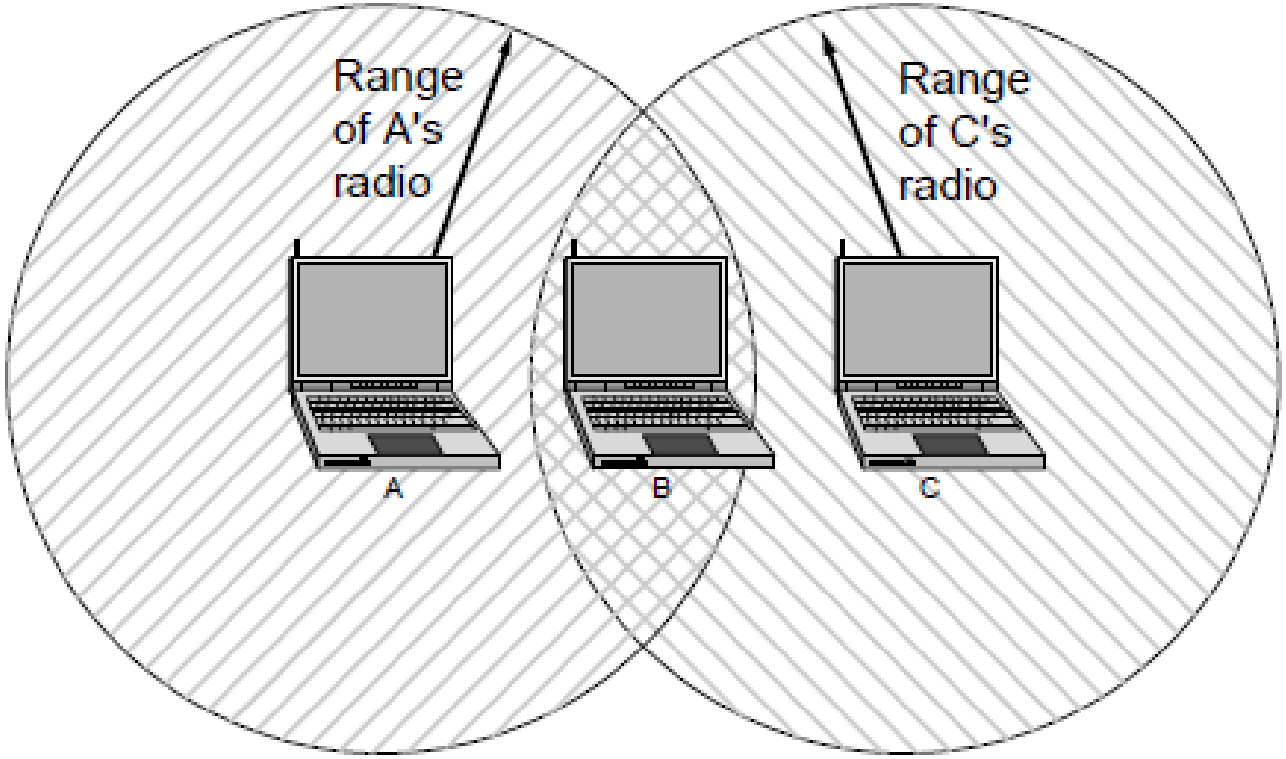
Wireless LANs: 802.11 (2)



Multipath fading

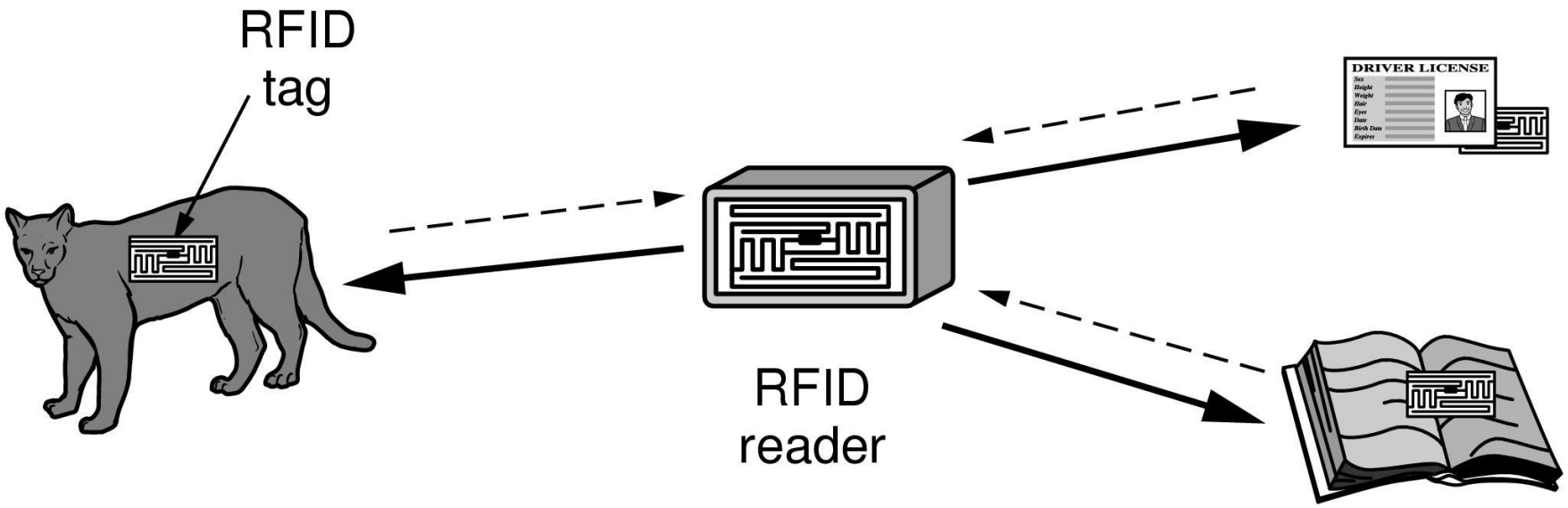
Solution: diversity in time, space, or freq.

Wireless LANs: 802.11 (3)



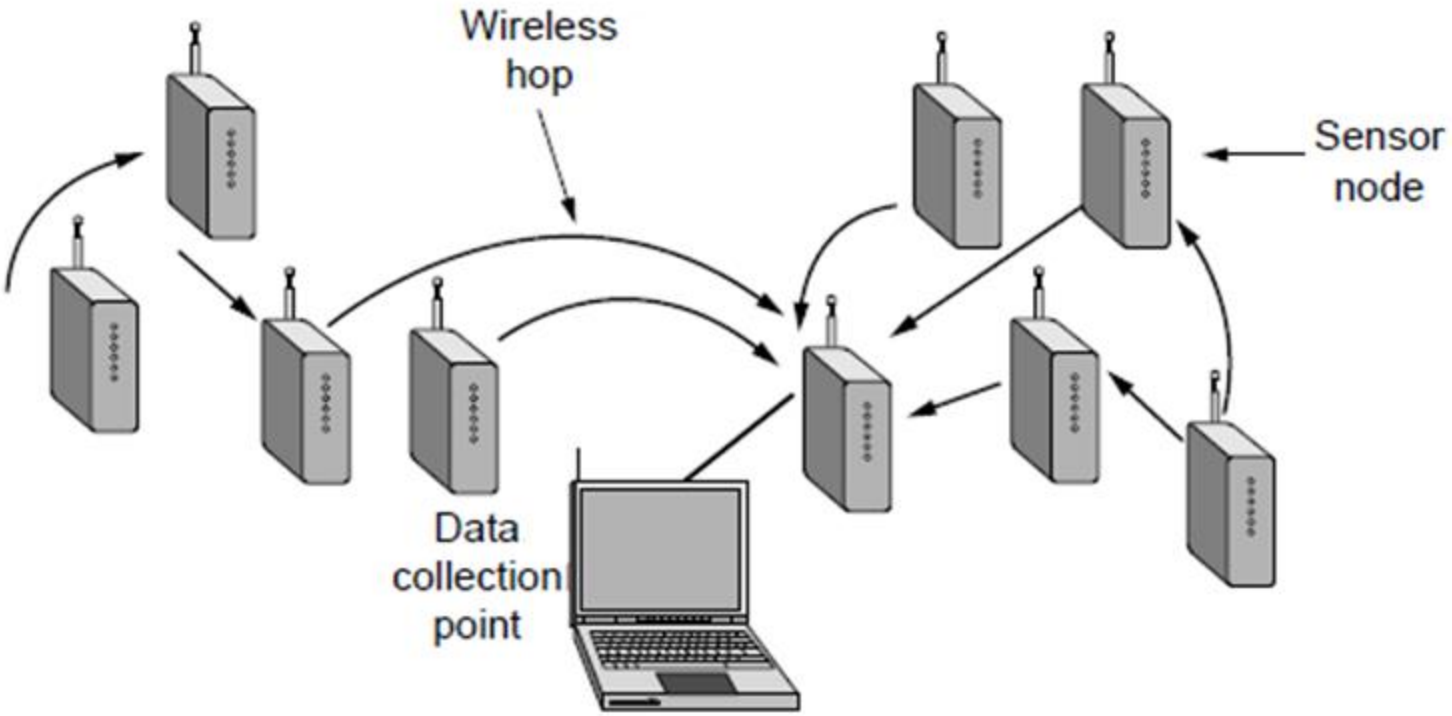
The range of a single radio may not cover the entire system.

RFID and Sensor Networks (1)



RFID used to network everyday objects.

RFID and Sensor Networks (2)



Multihop topology of a sensor network

Network Standardization

- Who's Who in telecommunications
- Who's Who in international standards
- Who's Who in internet standards

Who's Who in International Standards (1)

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 (WiFi)
802.12 ↓	Demand priority (Hewlett-Packard's AnyLAN)

The 802 working groups. The important ones are marked with *. The ones marked with ↓ are hibernating. The one marked with † gave up and disbanded itself.

Who's Who in International Standards (2)

802.13	Unlucky number; nobody wanted it
802.14 ↓	Cable modems (defunct: an industry consortium got there first)
802.15 *	Personal area networks (Bluetooth, Zigbee)
802.16 *	Broadband wireless (WiMAX)
802.17	Resilient packet ring
802.18	Technical advisory group on radio regulatory issues
802.19	Technical advisory group on coexistence of all these standards
802.20	Mobile broadband wireless (similar to 802.16e)
802.21	Media independent handoff (for roaming over technologies)
802.22	Wireless regional area network

The 802 working groups. The important ones are marked with *.

The ones marked with ↓ are hibernating. The one marked with † gave up and disbanded itself.

Metric Units (1)

Exp.	Explicit	Prefix
10^{-3}	0.001	milli
10^{-6}	0.000001	micro
10^{-9}	0.000000001	nano
10^{-12}	0.000000000001	pico
10^{-15}	0.000000000000001	femto
10^{-18}	0.000000000000000001	atto
10^{-21}	0.000000000000000000001	zepto
10^{-24}	0.000000000000000000000001	yocto

The principal metric prefixes

Metric Units (2)

Exp.	Explicit	Prefix
10^3	1,000	Kilo
10^6	1,000,000	Mega
10^9	1,000,000,000	Giga
10^{12}	1,000,000,000,000	Tera
10^{15}	1,000,000,000,000,000	Peta
10^{18}	1,000,000,000,000,000,000	Exa
10^{21}	1,000,000,000,000,000,000,000	Zetta
10^{24}	1,000,000,000,000,000,000,000,000	Yotta

The principal metric prefixes

End

Chapter 1