COMPUTER NETWORKS

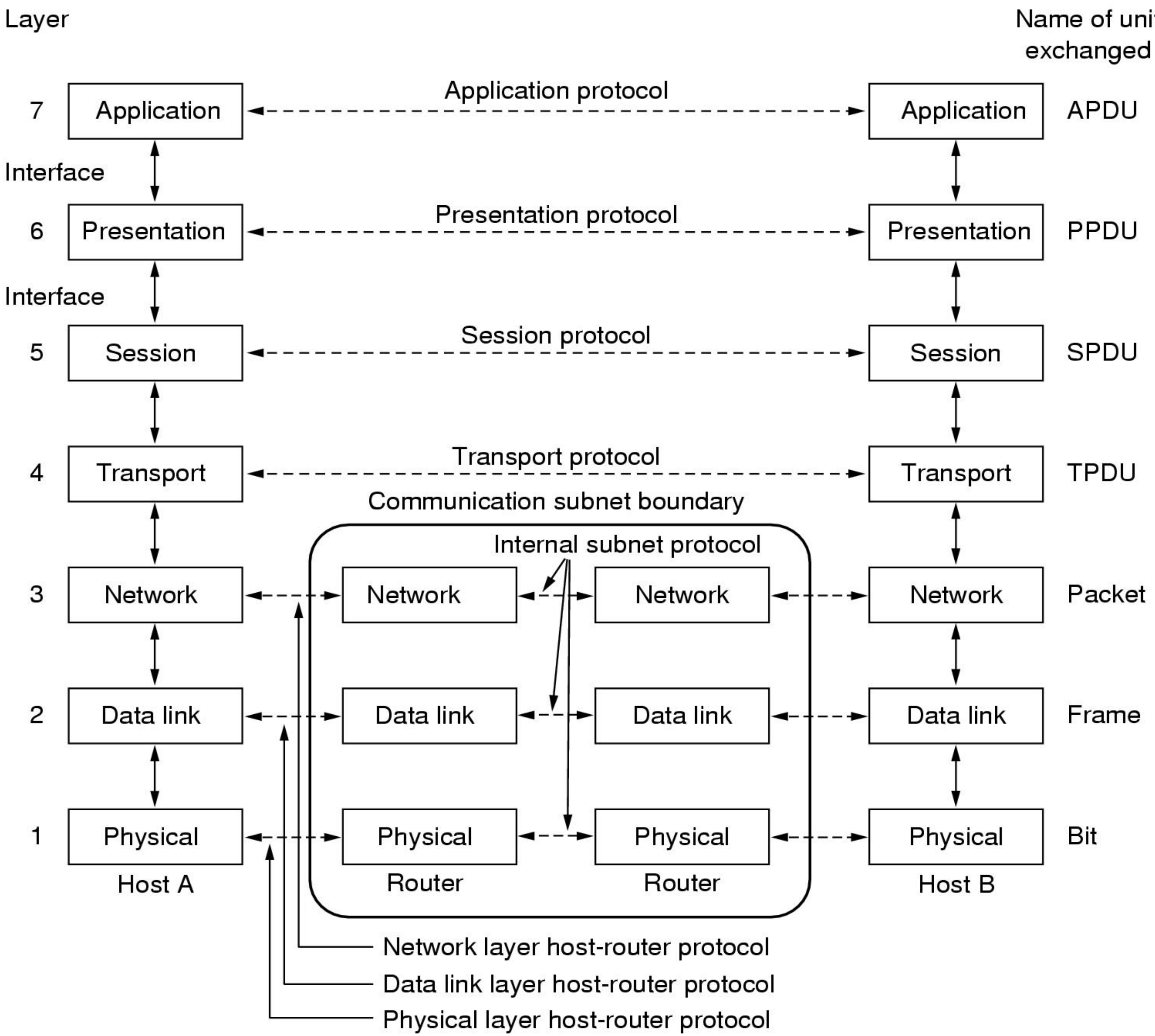
Chapter 01
Introduction (2)

1.4 Reference Models

1.4.1 OSI Reference Model

- 1983, International Standards Organization (ISO) proposed the “ISO OSI (Open Systems Interconnection) Reference Model”, OSI-rm
- The principles of layering
  - A layer should be created where a different abstraction is needed
  - Each layer should perform a well-defined function
  - The function of each layer should be chosen towards defining internationally standardized protocols
  - The layer boundaries should be chosen to minimize the information flow across the interfaces
  - The number of layers should be large enough that distinct functions and small enough that the architecture does not become unwieldy

The OSI Model



The Physical Layer

- **Essence:** Describes the transmission of raw bits in terms of mechanical, electrical, functional and timing interfaces issues:
  – Typical questions here are what electrical signals should be used to represent a 1 and a 0
  – How many nanoseconds a bit lasts
  – whether transmission may proceed simultaneously in both directions
  – how the initial connection is established
  – how it is torn down when both sides are finished
  – how many pins the network connector has
  – What each pin is used for.
  – **Example:** Connect two computers by means of a wire:
    - Setting -3V to -12V on the wire corresponds to a binary 1; +3V to +12V is a binary 0
    - The wire is not to be longer than 15 meters
    - You may change the voltage at most 20,000 times per second (**Question:** what's the transfer rate?)

The Data Link Layer

- **Data link layer** is to transform a raw transmission facility into a line that appears free of undetected transmission errors to the network layer
- **Observation:** We need to at least **detect bit transmission errors,** send bits in **frames** that add redundancy to detect something went wrong

Examples: Add a parity bit to every 7 transmitted bits: 1 says there were odd number of 1's; 0 says there were an even number of 1's

Add a checksum (cyclic redundancy check) that should match the bits before it

Also: Provide the mechanisms so that fast senders don't overwhelm slow receivers (flow control)

Bits	8	8	8	≥ 0	16	8
	0 1 1 1 1 1 1 0	Address	Control	Data	Checksum	0 1 1 1 1 1 1 0

Data Link Layer

- **Observation:** We also need to specify how a number of computers can **share** a common channel (e.g. wire), that is **medium access control sublayer** (MAC):

1. Specifies how one out of several competing senders, is eventually allowed exclusive access to the wire
2. Common approach 1: listen to each other; retreat when you hear someone else, and try again later
3. Common approach 2: wait your turn by passing a **token** between all stations

Well-known protocols: Ethernet, token ring, token bus, FDDI

The Network Layer

- **Essence:** Describes how routing (and congestion) is to be done. Mostly needed in subnets. Network layer controls subnet operations.

1. How do we find out which computers/routers are in the network?
2. How do we calculate the best route from A to B?
3. What happens when a computer/router goes down?
4. Should multicasting/broadcasting be supported?
5. What happens if a router becomes overloaded and starts dropping packets?
6. Can we detect and avoid “hot spots?”

The Transport Layer

- **Observation:** The transport layer is to accept data from above, split it up into smaller units if need be, pass these to network layer, and ensure that the pieces all arrive correctly at the other end. Generally offers connection-oriented as well as connectionless services, and varying degrees of reliability. This layer provides the actual network interface to *applications*

1. Often provides network interface through **sockets** (UNIX, Windows)
2. Allows to set up a connection to another application, and subsequently deliver data **reliably**, and in the order that it was **sent**
3. Often also support for **secure connections**
4. Also support for **datagrams**: unreliable message passing on a per-message basis

The Transport Layer

- The transport layer is a true end-to-end layer; it carries data all the way from the source to the destination.
- In other words, a program on the source machine carries on a conversation with a similar program on the destination machine, using the message headers and control messages.
- In the lower layers, each protocols is between a machine and its immediate neighbors, and not between the ultimate source and destination machines, which may be separated by many routers.
- The difference between layers 1 through 3, which are chained, and layers 4 through 7,which are end-to-end

OSI Session Layers

- The session layer allows users on different machines to establish **sessions** between them.
- Sessions offer various services, including **dialog control** (keeping track of whose turn it is to transmit), **token management** (preventing two parties from attempting the same critical operation simultaneously), and **synchronization** (checkpointing long transmissions to allow them to pick up from where they left off in the event of a crash and subsequent recovery).

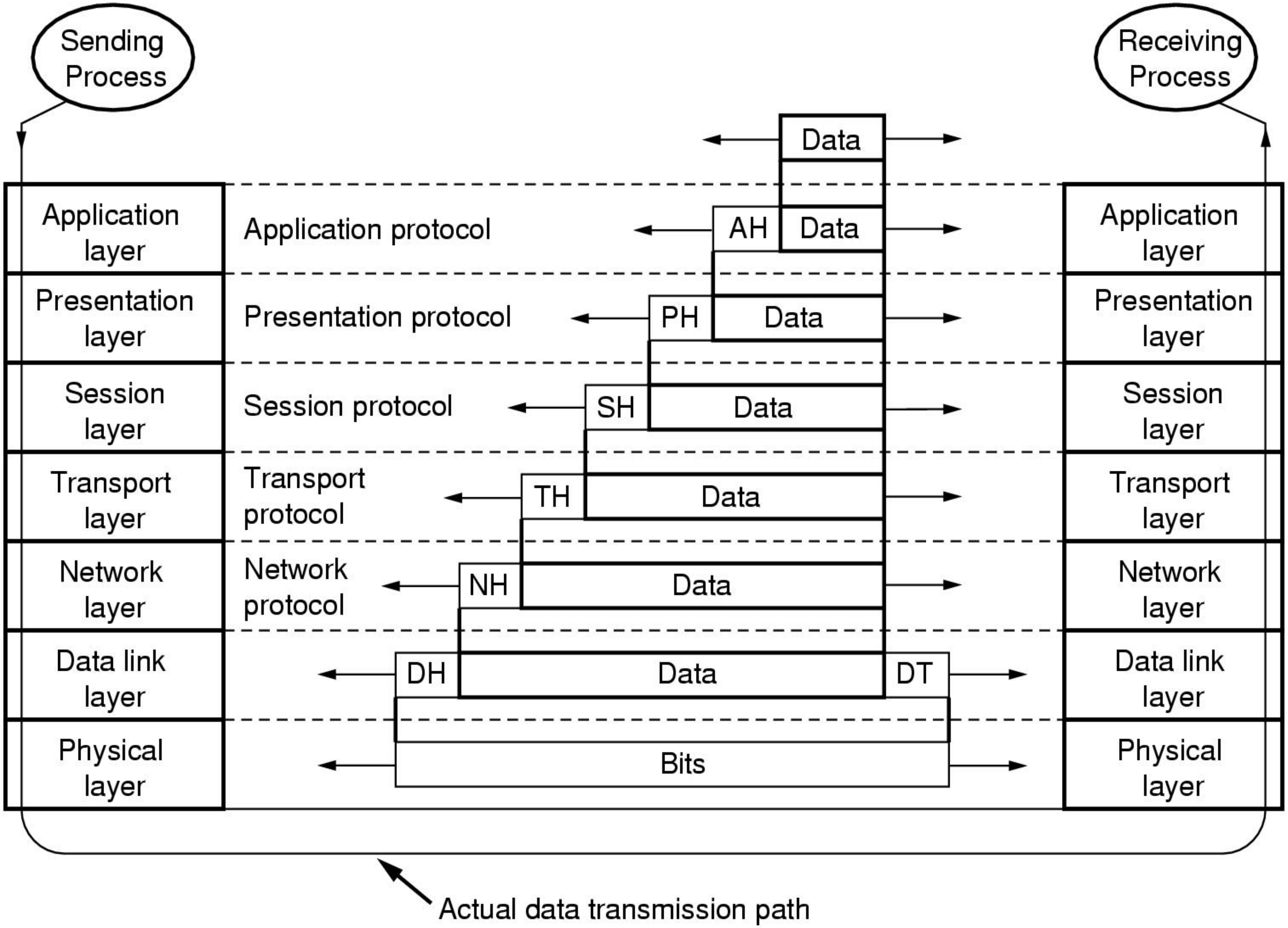
OSI Presentation Layers

- the **presentation layer** is concerned with the syntax and semantics of the information transmitted.
- In order to make it possible for computers with different internal data representations to communicate, the data structures to be exchanged can be defined in an abstract way, along with a standard encoding to be used "on the wire."
- The presentation layer manages these abstract data structures and allows higher-level data structures (e.g., banking records) to be defined and exchanged.

The Application Layer

- The **application layer** contains a variety of protocols that are commonly needed by users.
- One widely used application protocol is **HTTP** (**HyperText Transfer Protocol**), which is the basis for the World Wide Web. When a browser wants a Web page, it sends the name of the page it wants to the server hosting the page using HTTP. The server then sends the page back.
- Other application protocols are used for file transfer, electronic mail, and network news.

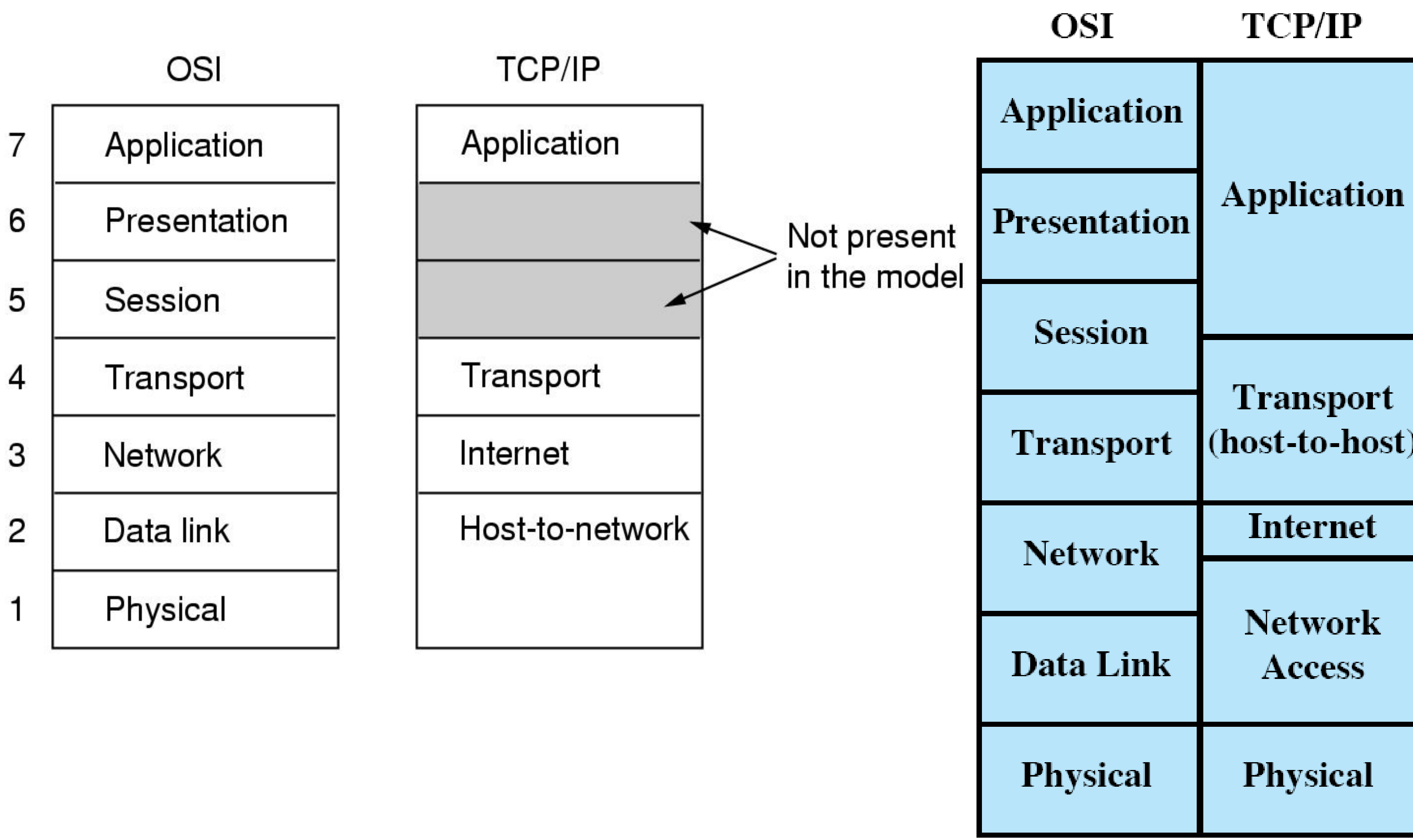
Data Transmission in the OSI Model

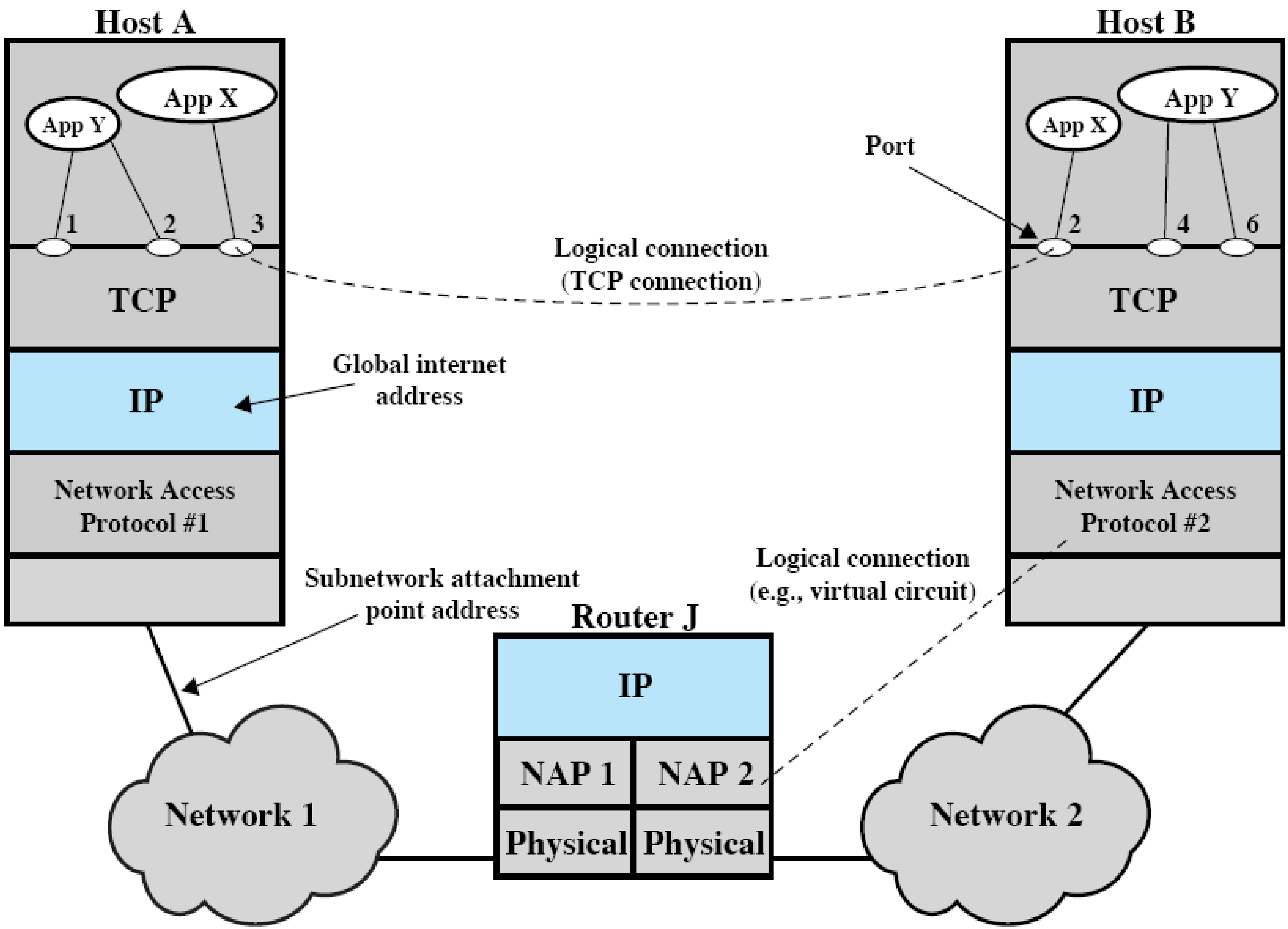


1.4.2 The TCP/IP Reference Model

- TCP/IP is a result of protocol research and development conducted on the experimental packet switched network, ARPANET, funded by the **Defense Advanced Research Projects Agency (DARPA),** and is generally referred to as the TCP/IP protocol suite.
- This protocol suite consists of a large collection of protocols that have been issued as Internet standards by the Internet Activities Board (IAB).
- There is no official TCP/IP protocol model. However, based on the protocol standards, we can organize the communication task for TCP/IP into four relatively independent layers, from bottom to top: host-to-network (physical layer+network access layer), internet layer, transport layer (host-to-host), application layer.

1.4.2 The TCP/IP Reference Model (2)





Host A
App Y
App X
1
2
3
TCP
IP
Global internet
address
Network Access
Protocol #1
Subnetwork attachment
point address
Host B
App X
App Y
Port
2
4
6
Logical connection
(TCP connection)
TCP
IP
Network Access
Protocol #2
Logical connection
(e.g., virtual circuit)
Router J
IP
NAP 1
NAP 2
Physical
Physical
Network 1
Network 2

1.4.2 The TCP/IP Reference Model (3)

- The bad thing is that TCP/IP did not make a clear distinction between services, interfaces, and protocols. That makes it much harder to re-implement certain layers.
- TCP/IP protocol suite is successful because

(1) it was *there* when needed (OSI implementations were terrible),

(2) freely distributed with the UNIX operating system.

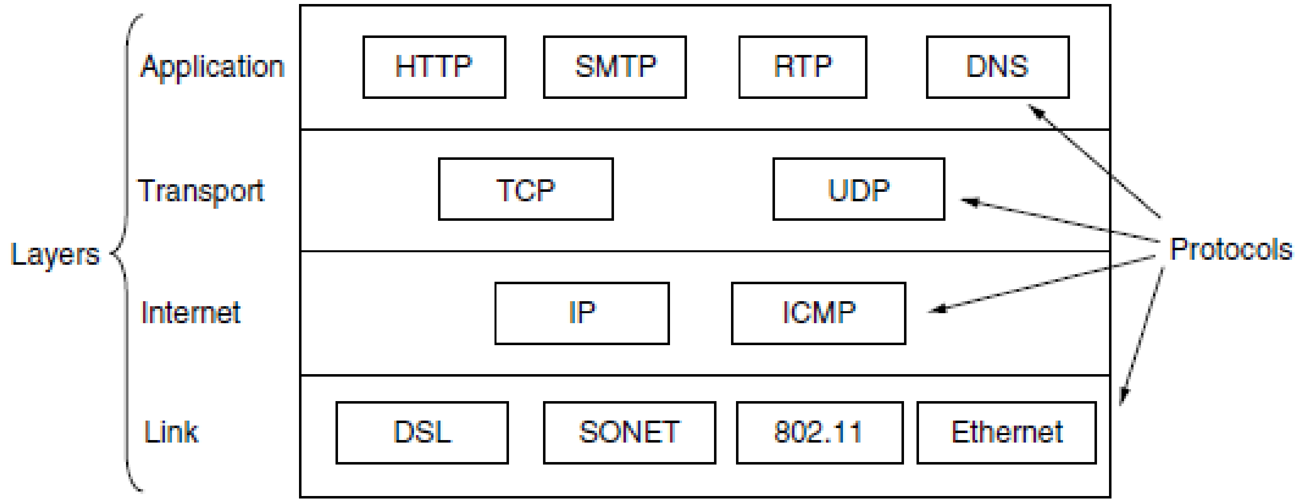


Figure 1-22. The TCP/IP model with some protocols we will study.

1.4.2 The TCP/IP Reference Model (4)

- The Internet Layer
  - A packet-switching network based on a connectionless internetwork layer, permits hosts to inject packets into any network and have them travel independently to the destination.
  - The internet layer defines an official packet format and protocol called IP (Internet Protocol), delivers IP packets where they are supposed to go.
- The Transport Layer
  - Allows peer entities on the source and destination hosts to carry on an conversation. TCP (Transmission Control Protocol) is a reliable connection-oriented protocol, while UDP (User Datagram Protocol) is an unreliable connectionless protocol.

1.4.2 The TCP/IP Reference Model (5)

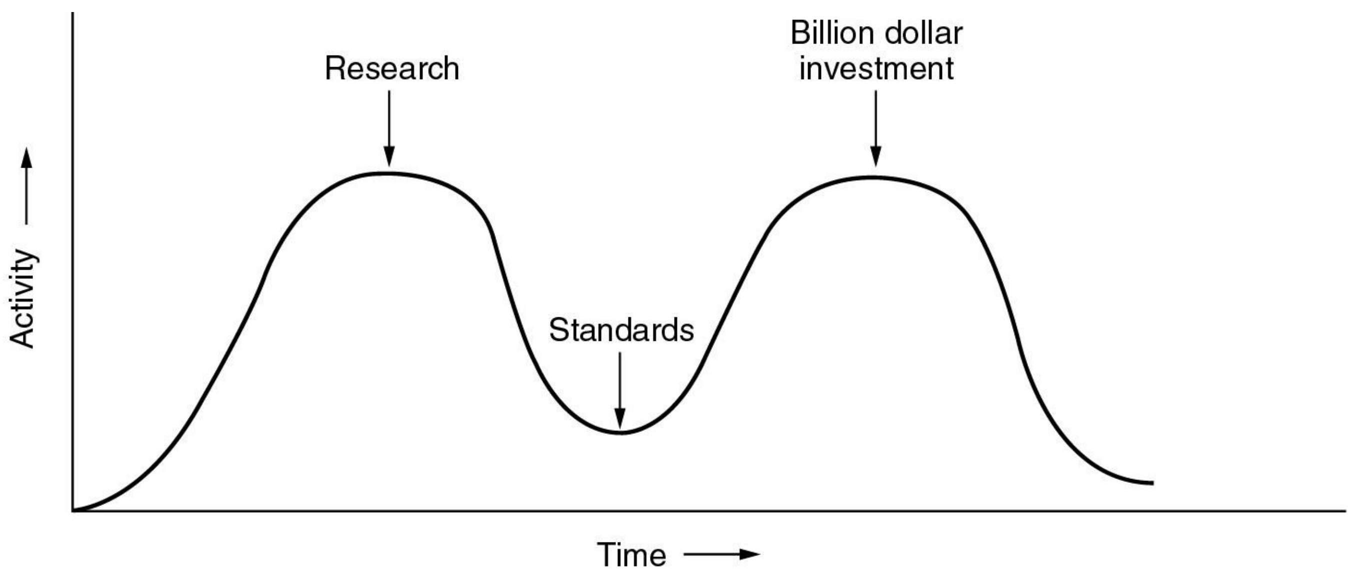
- The Application Layer
  - Contains all the higher-level protocols: Telnet, FTP, SMTP, DNS, HTTP, …
- The Host-Network Layer
  - The TCP/IP reference model does not really say much about what happens here, except to point out that the host has to connect to the network using some protocol so it can send IP packets to it. This protocol is not defined and varies from host to host and network to network.

1.4.3 Comparing OSI and TCP/IP Models

- Concepts central to the OSI model
  - Services
  - Interfaces
  - Protocols
- The TCP/IP model did not originally clearly distinguish between service, interface, and protocol.
- TCP/IP's protocols came first, and the model was really just a description of the existing protocols.
- Different numbers of layers
- Another difference is in the area of connectionless versus connection-oriented communication.

1.4.4 A Critique of the OSI Model and Protocols

- Why OSI did not take over the world
  - Bad timing (apocalypse of the two elephant)
  - Bad technology
  - Bad implementations
  - Bad politics



1.4.5 A Critique of the TCP/IP Reference Model

- 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
- The hybrid reference model to be used in this book.

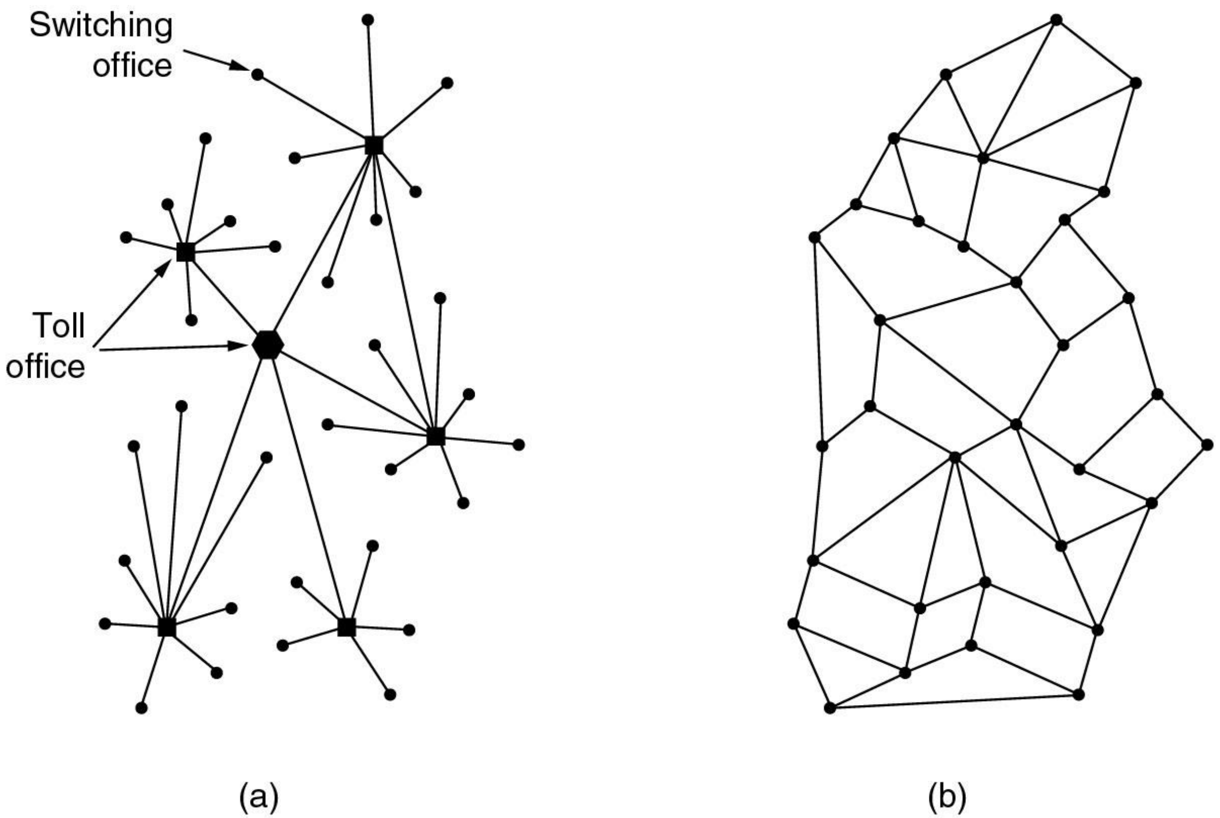
5	Application layer
4	Transport layer
3	Network layer
2	Data link layer
1	Physical layer

1.5 Example Networks

- We will start with the Internet, probably the best known network, and look at its history, evolution, and technology.
- Then we will consider the mobile phone network. Technically, it is quite different from the Internet, contrasting nicely with it.
- Next we will introduce IEEE 802.11, the dominant standard for wireless LANs.
- Finally, we will look at RFID and sensor networks, technologies that extend the reach of the network to include the physical world and everyday objects.

1.5.1 The Internet

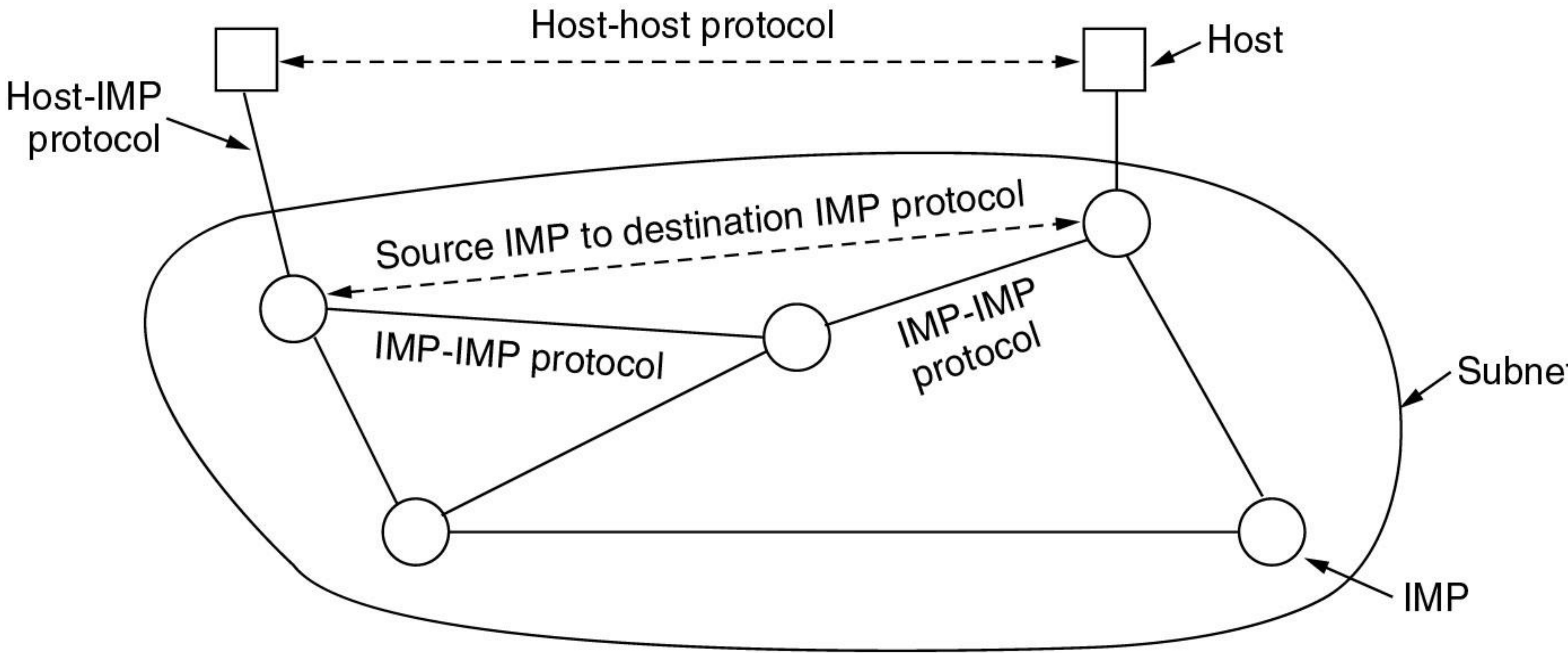
The ARPANET



(a) Structure of the telephone system.

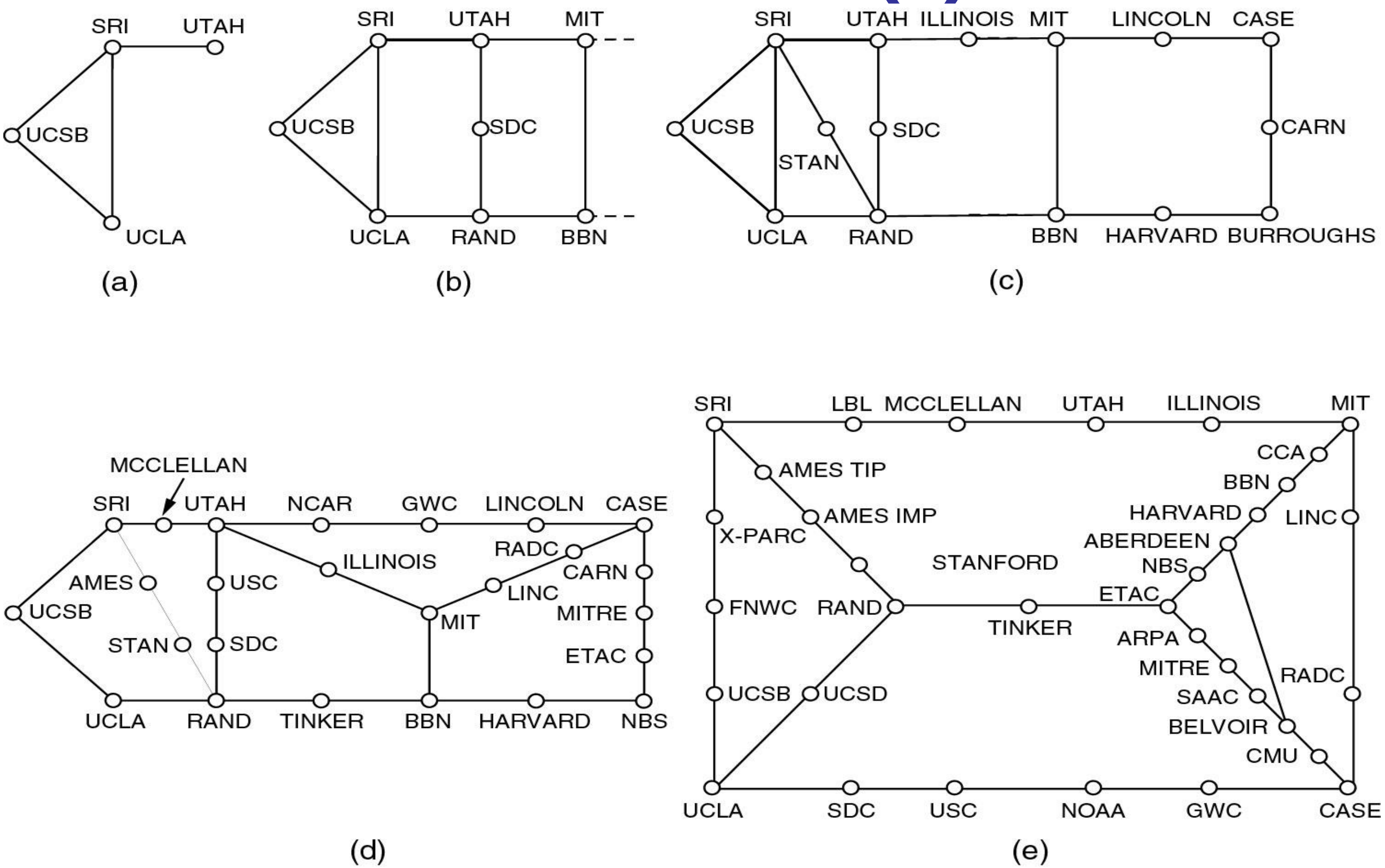
(b) Baran's proposed distributed switching system.

The ARPANET (2)



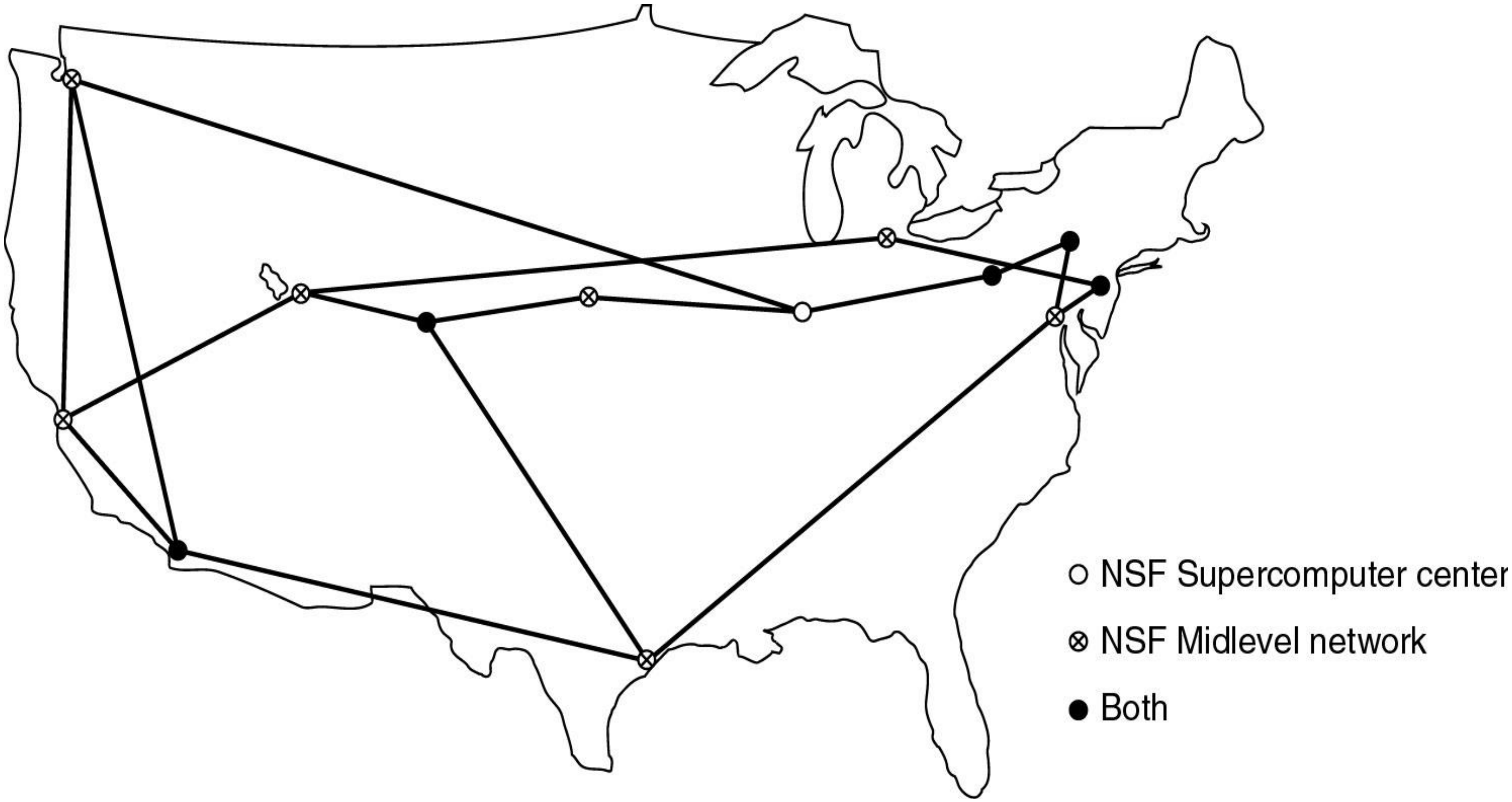
The original ARPANET design.

The ARPANET (3)



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

NSFNET



The NSFNET backbone in 1988.

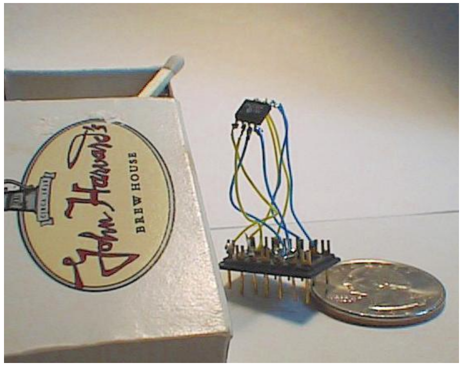
Internet Usage

- Traditional applications (1970 – 1990)
  - E-mail
  - News
  - Remote login
  - File transfer

“Cool” internet appliances

IP picture frame
http://www.ceiva.com/

Web-enabled toaster +
weather forecaster



World’s smallest web server
http://www-ccs.cs.umass.edu/~shri/iPic.html

Internet phones

Architecture of the Internet

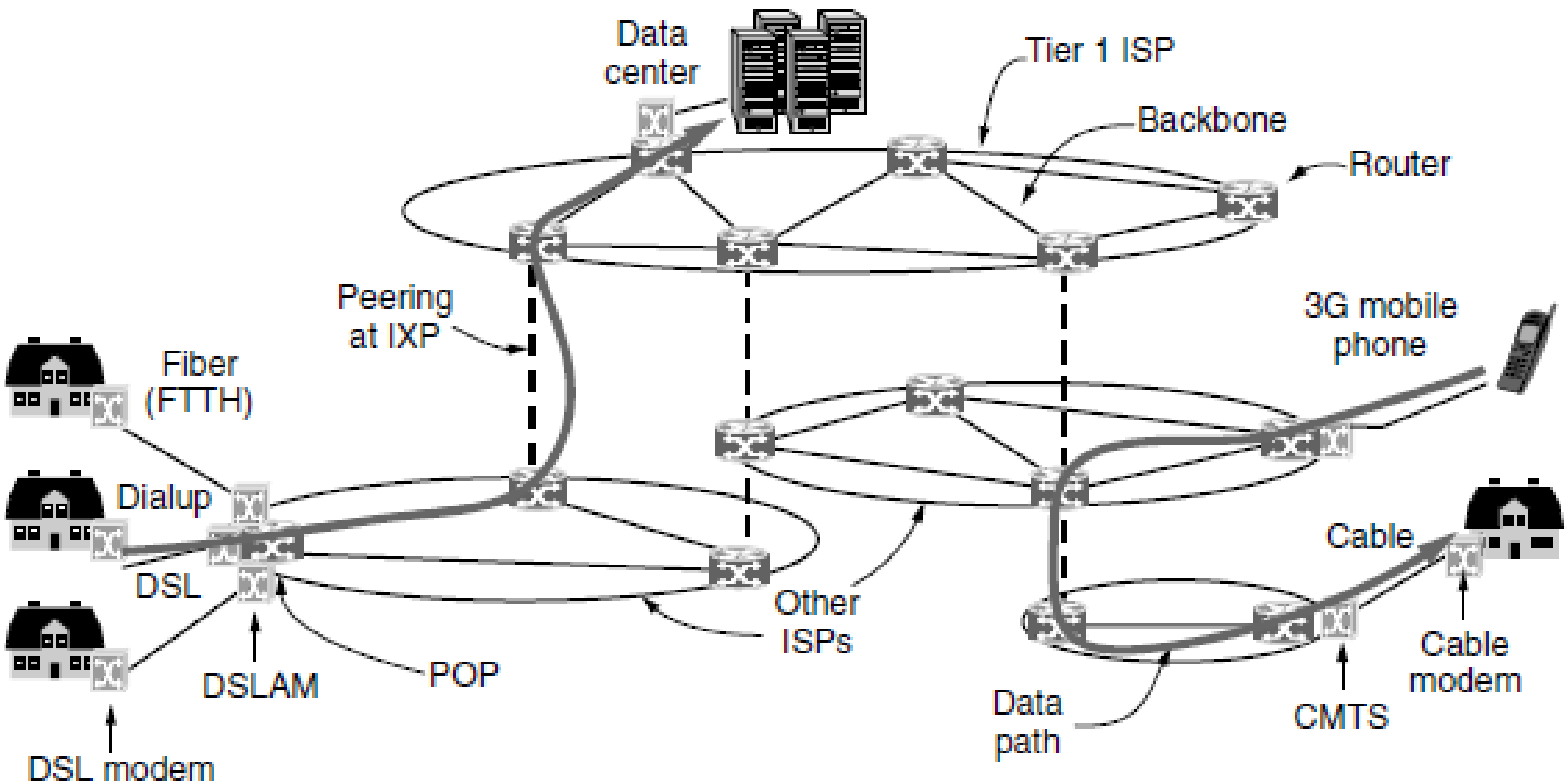
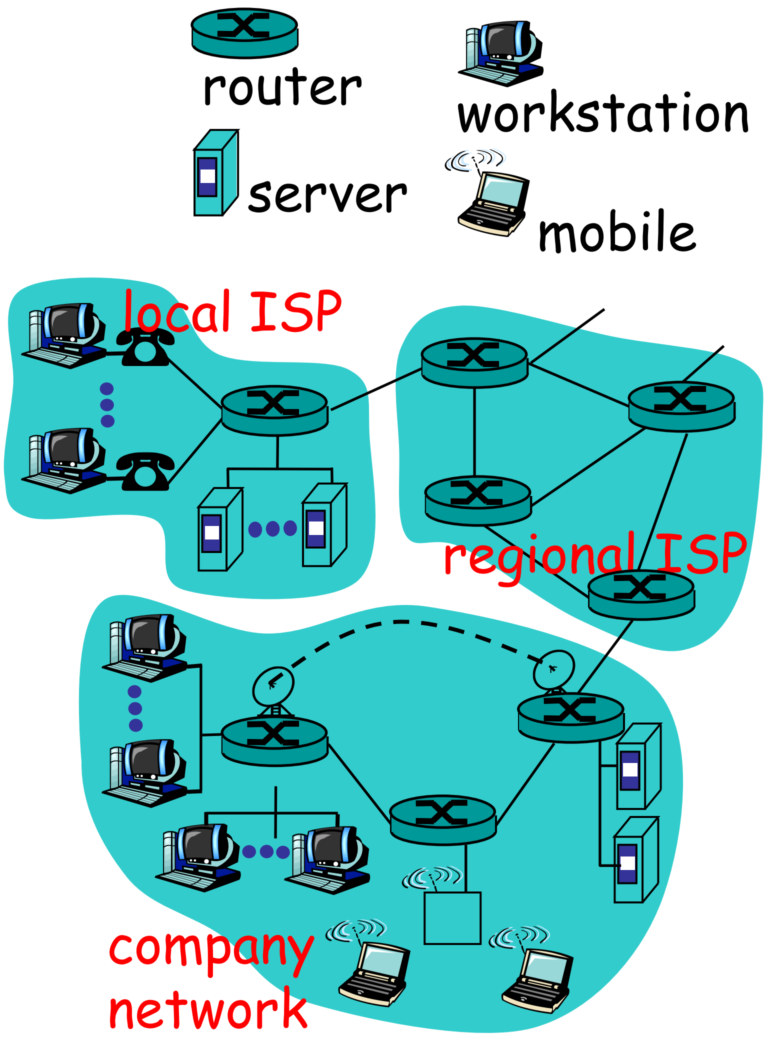


Figure 1-29. Overview of the Internet architecture.

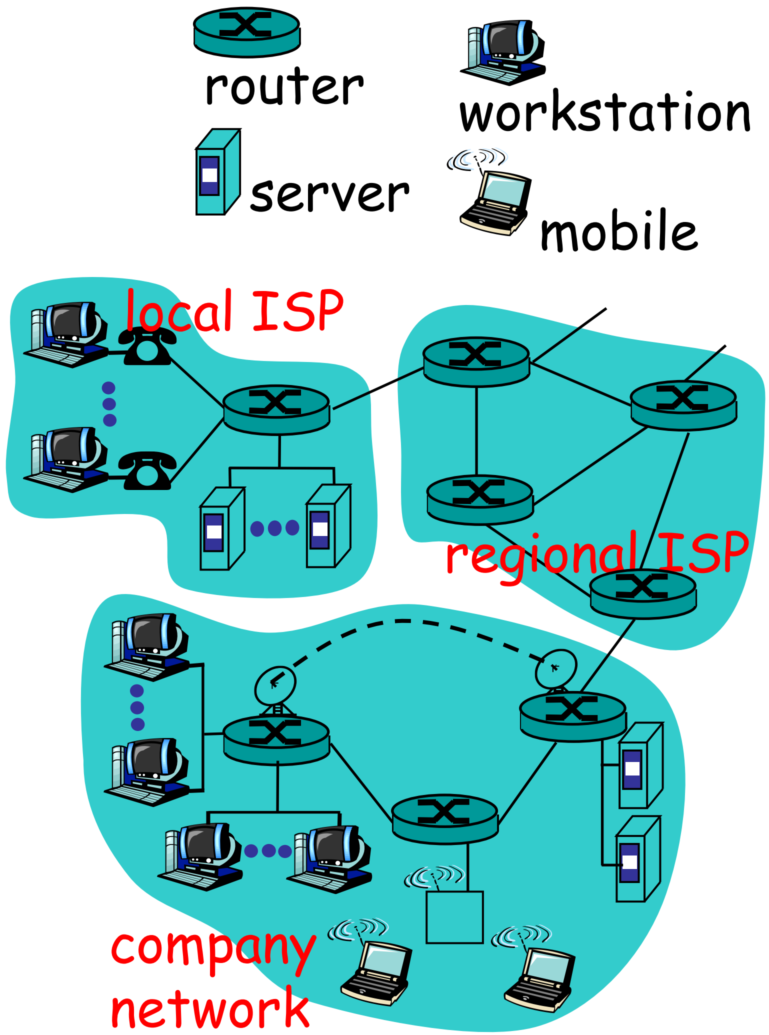
What's the Internet: detail view

- millions of connected computing devices: *hosts = end systems*
- running *network apps*
- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate = ***bandwidth***
- *routers:* forward packets (chunks of data)



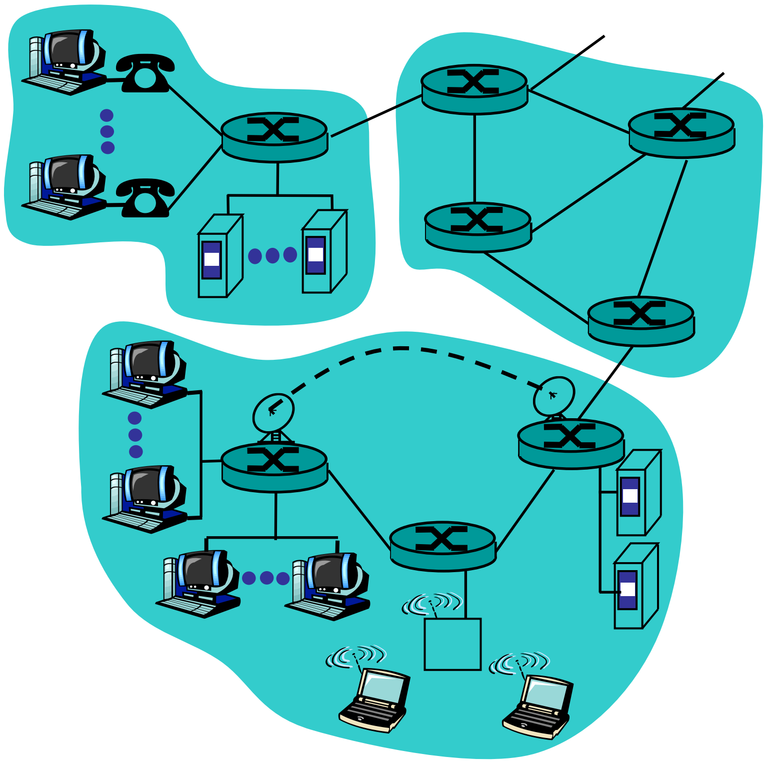
What's the Internet: detail view

- *protocols* control sending, receiving of msgs
  - e.g., TCP, IP, HTTP, FTP, PPP
- *Internet:* "network of networks"
  - loosely hierarchical
  - public Internet versus private intranet
- Internet standards
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force



What's the Internet: a service view

- communication *infrastructure* enables distributed applications:
  - Web, email, games, e-commerce, file sharing
- communication services provided to apps:
  - Connectionless unreliable
  - connection-oriented reliable



1.5.2 3G Mobile Phone Networks

- 3G network is based on spatial cells; each cell provides wireless service to mobiles within it via a base station

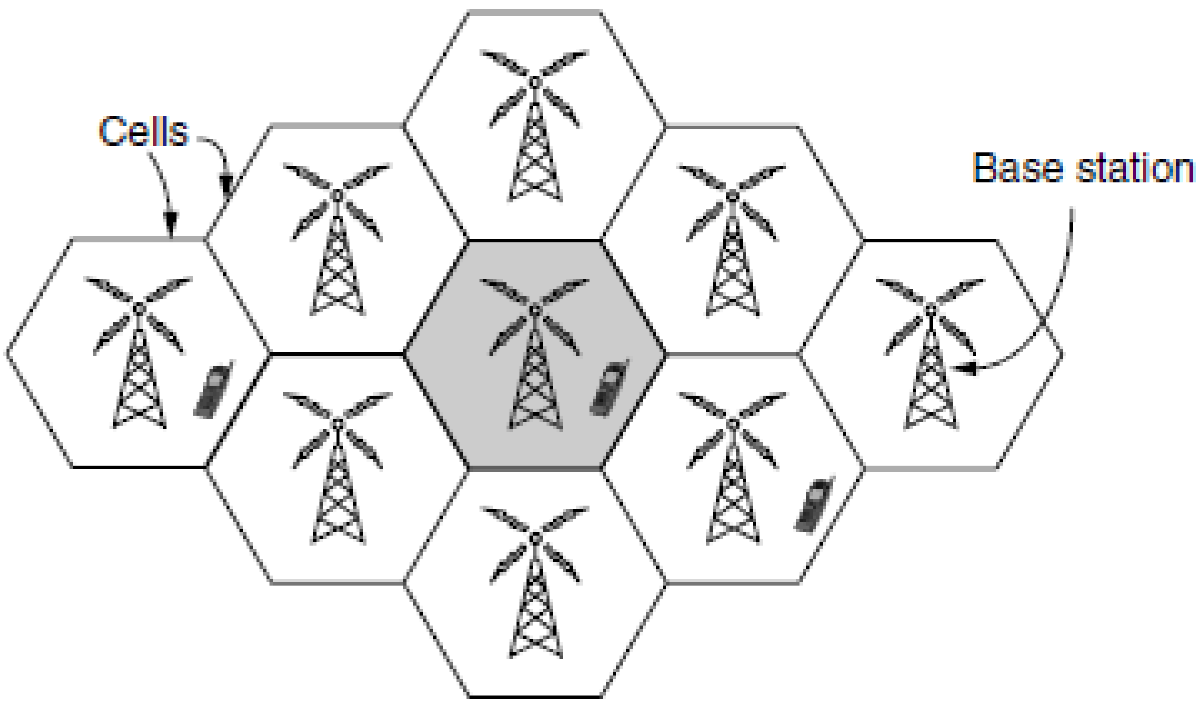


Figure 1-30. Cellular design of mobile phone networks.

3G Mobile Phone Networks

- Base stations connect to the core network to find other mobiles and send data to the phone network and Internet

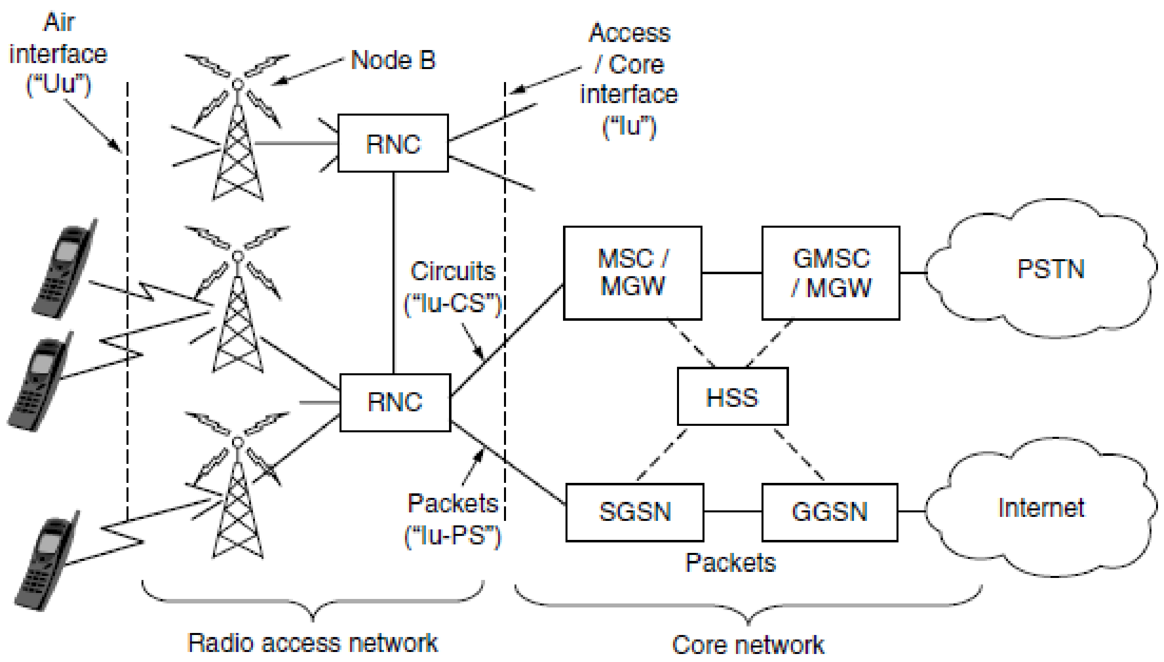


Figure 1-31. Architecture of the UMTS 3G mobile phone network.

3G Mobile Phone Networks

- As mobiles move, base stations hand them off from one cell to the next, and the network tracks their location

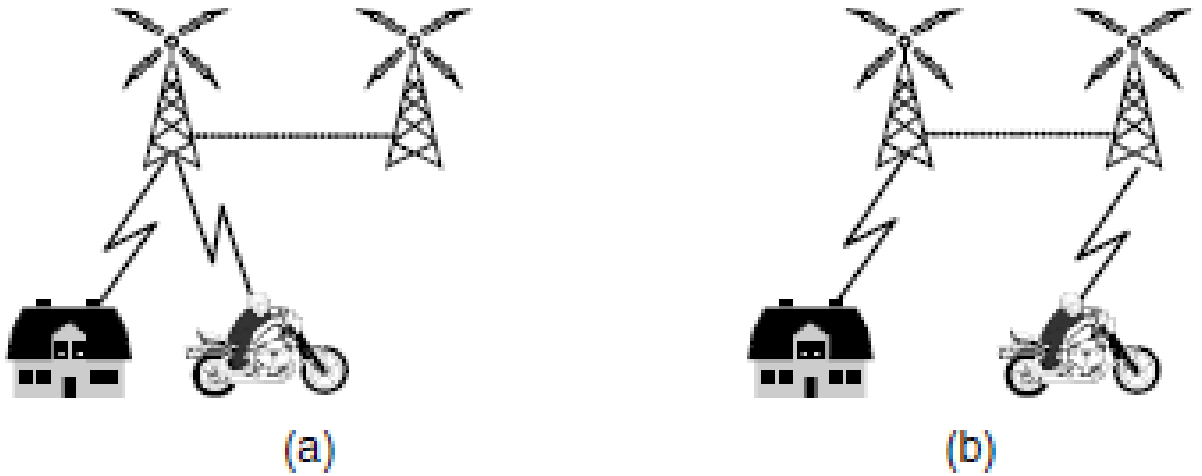


Figure 1-32. Mobile phone handover (a) before, (b) after.

1.5.3 Wireless LANs : 802.11

- In 802.11, clients communicate via an AP (Access Point) that is wired to the rest of the network.

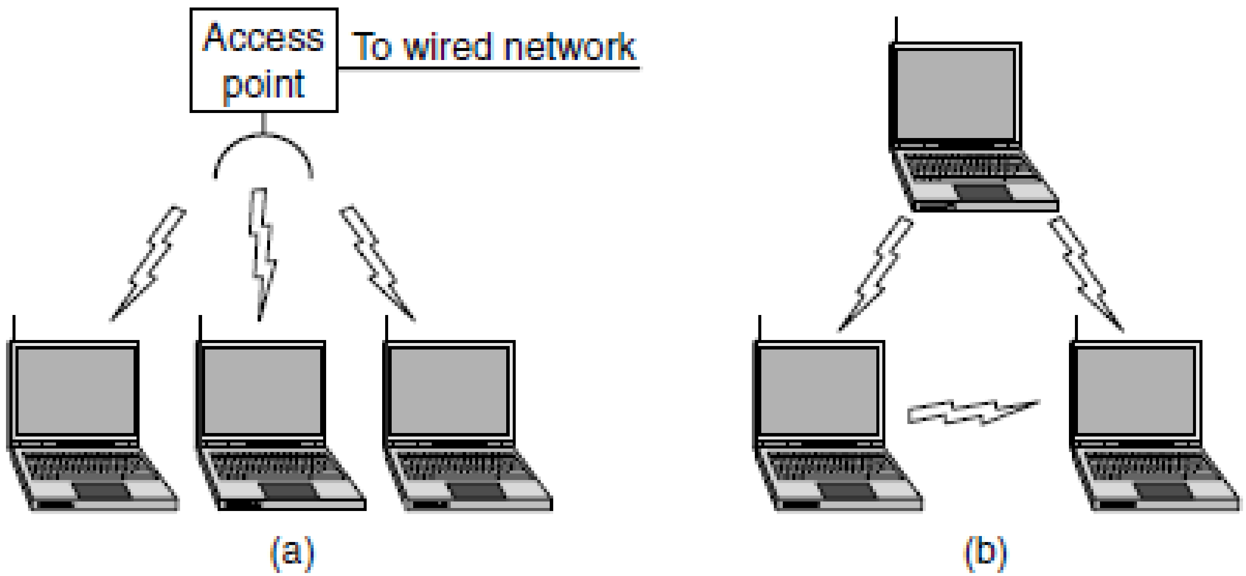


Figure 1-33. (a) Wireless network with an access point. (b) Ad hoc network.

Wireless LANs

- Signals in the 2.4GHz ISM band vary in strength due to many effects, such as multipath fading due to reflections
  - –requires complex transmission schemes, e.g., OFDM

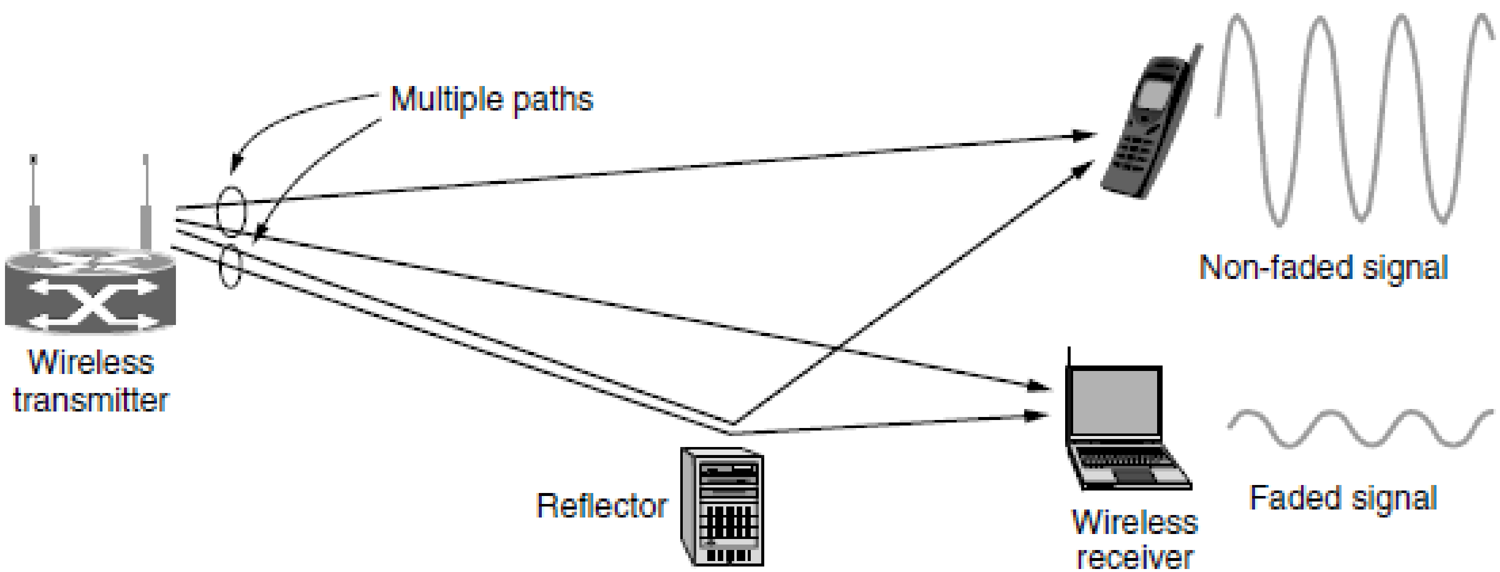
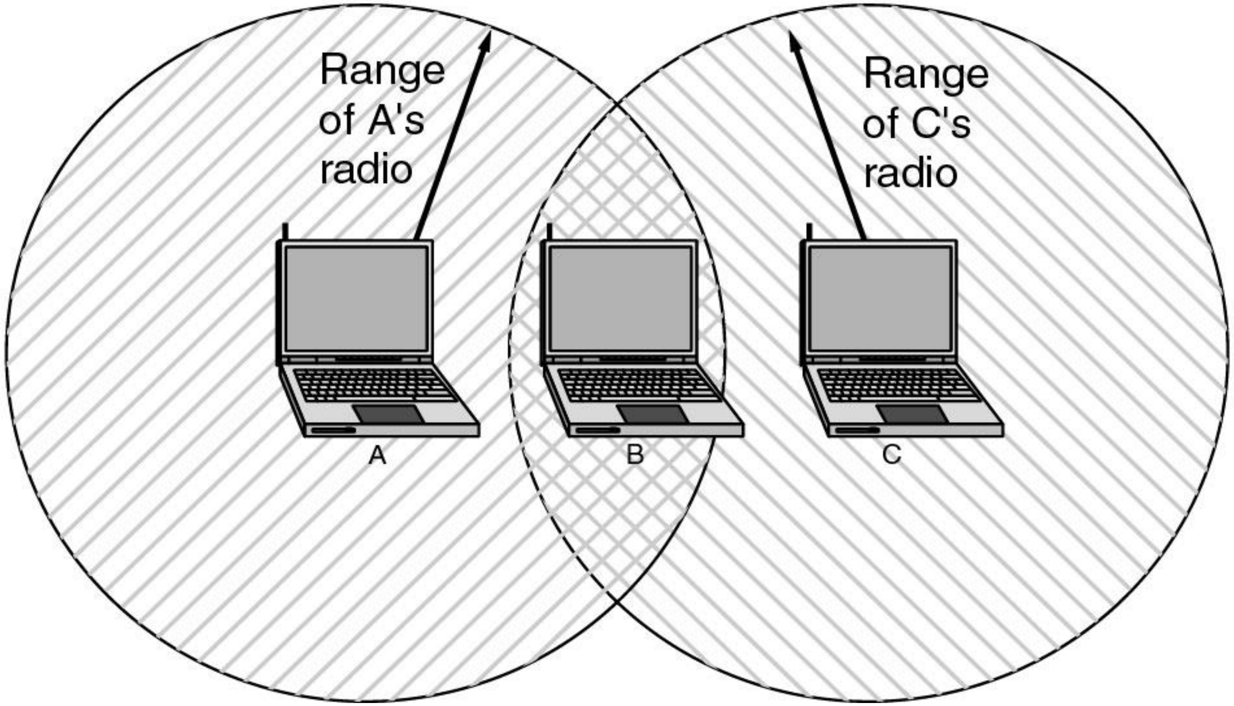


Figure 1-34. Multipath fading.

Wireless LANs

- Radio broadcasts interfere with each other, and radio ranges may incompletely overlap
  - –CSMA (Carrier Sense Multiple Access) designs are used



1.5.4 RFID and Sensor Networks

- Passive UHF RFID networks everyday objects:
  - Tags (stickers with not even a battery) are placed on objects
  - Readers send signals that the tags reflect to communicate

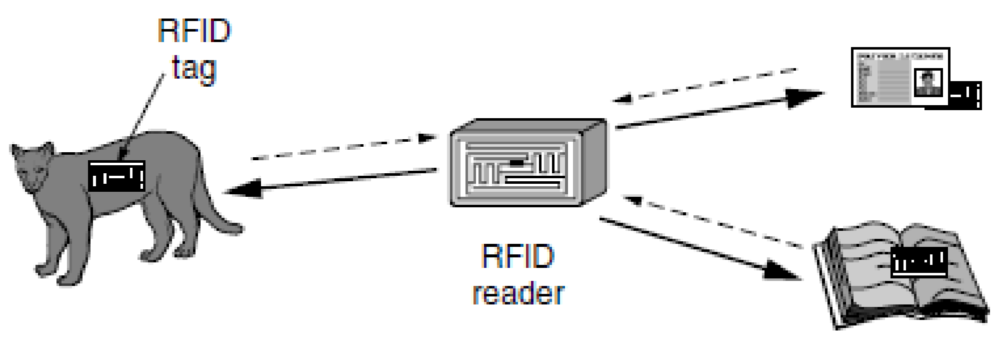


Figure 1-36. RFID used to network everyday objects.

RFID and Sensor Networks

- Sensor networks spread small devices over an area:
  - Devices send sensed data to collector via wireless hops

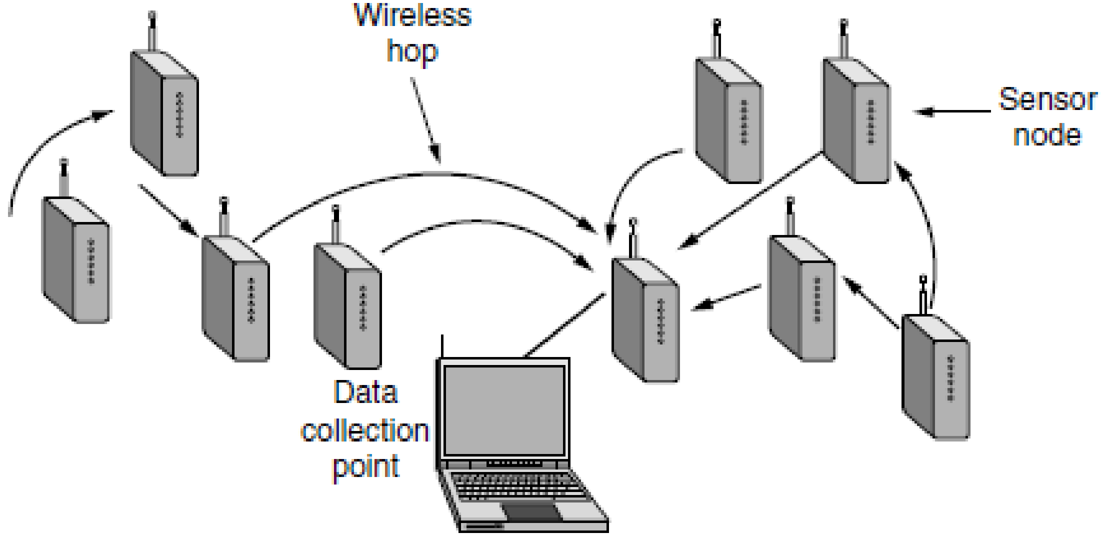


Figure 1-37. Multihop topology of a sensor network.

1.6 Network Standardization

- Standards fall into two categories: de facto and de jure.
- De facto (Latin for "from the fact") standards are those that have just happened, without any formal plan.
- De jure (Latin for "by law") standards, in contrast, are formal, legal standards adopted by some authorized standardization body.

Who's Who in the Telecommunications World

- **ITU**
  - **International Telecommunication Union**
- Telecommunications Standardization (ITU-T)
- From 1956 to 1993, ITU-T was known as CCITT, an acronym for its French name: Comité Consultatif International Télégraphique et Téléphonique

Who's Who in the International Standards World

- ISO (International Standards Organization)
- The U.S. representative in ISO is ANSI (American National Standards Institute)
- NIST (National Institute of Standards and Technology) is part of the U.S. Department of Commerce.
- IEEE (Institute of Electrical and Electronics 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

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

Who's Who in the Internet Standards World

- IAB (Internet Activities Board) , The meaning of the acronym "IAB" was later changed to Internet Architecture Board.
- a series of technical reports called RFCs (Request For Comments).
- IRTF (Internet Research Task Force)
- IETF (Internet Engineering Task Force)
- Internet Society was created, populated by people interested in the Internet.

1.7 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}	0.0000000000000000001	atto	10^{18}	1,000,000,000,000,000,000	Exa
10^{-21}	0.0000000000000000000001	zepto	10^{21}	1,000,000,000,000,000,000,000	Zetta
10^{-24}	0.0000000000000000000000001	yocto	10^{24}	1,000,000,000,000,000,000,000,000	Yotta

Fig. 1-39. The principal metric prefixes.

Assignments

- Chapter 01

  Please see separate sheet.