COMPUTER NETWORKS

Chapter 01

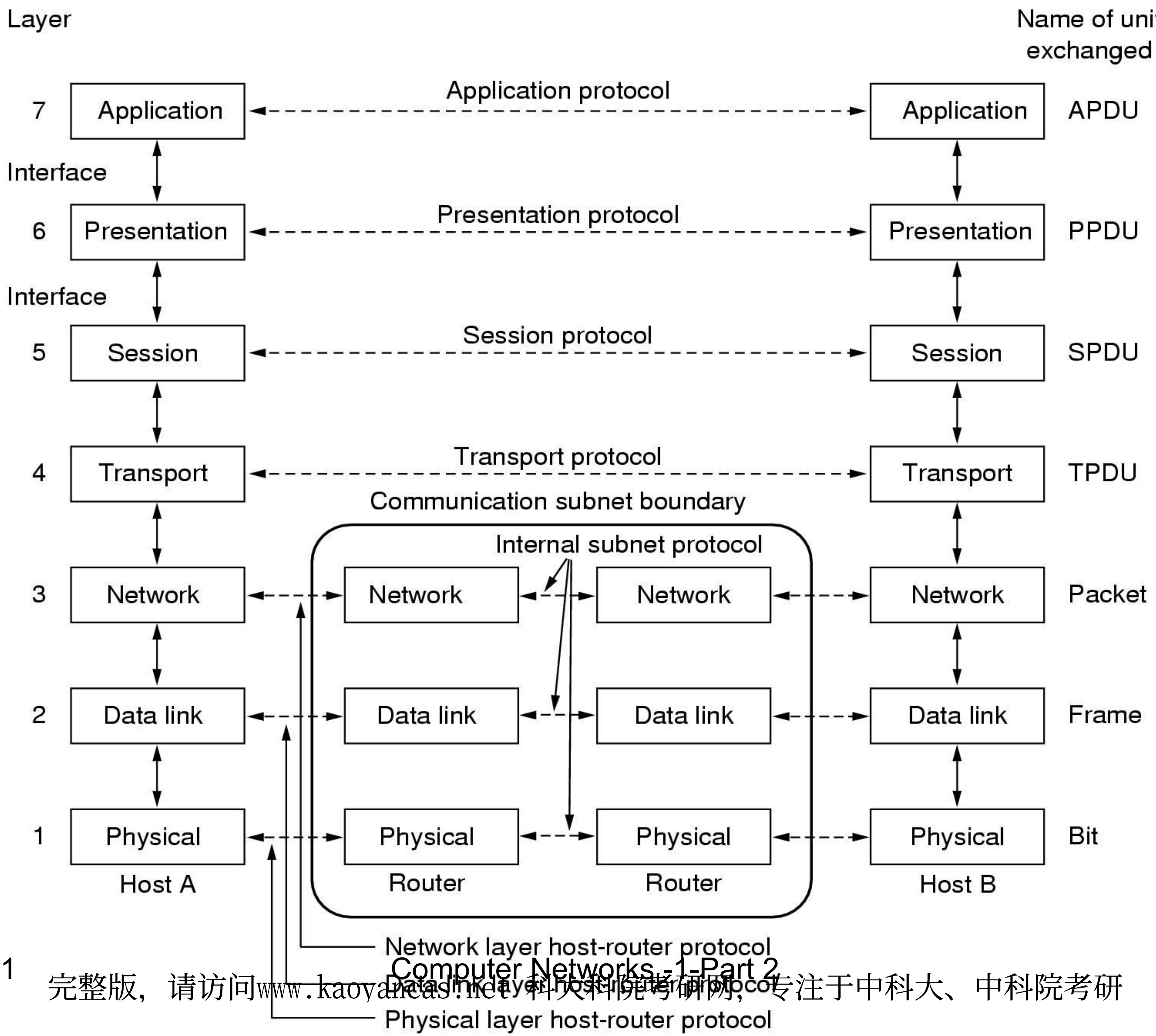
Introduction (2)

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 and electrical issues:
  - **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

OSI 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

OSI Session and Presentation Layers

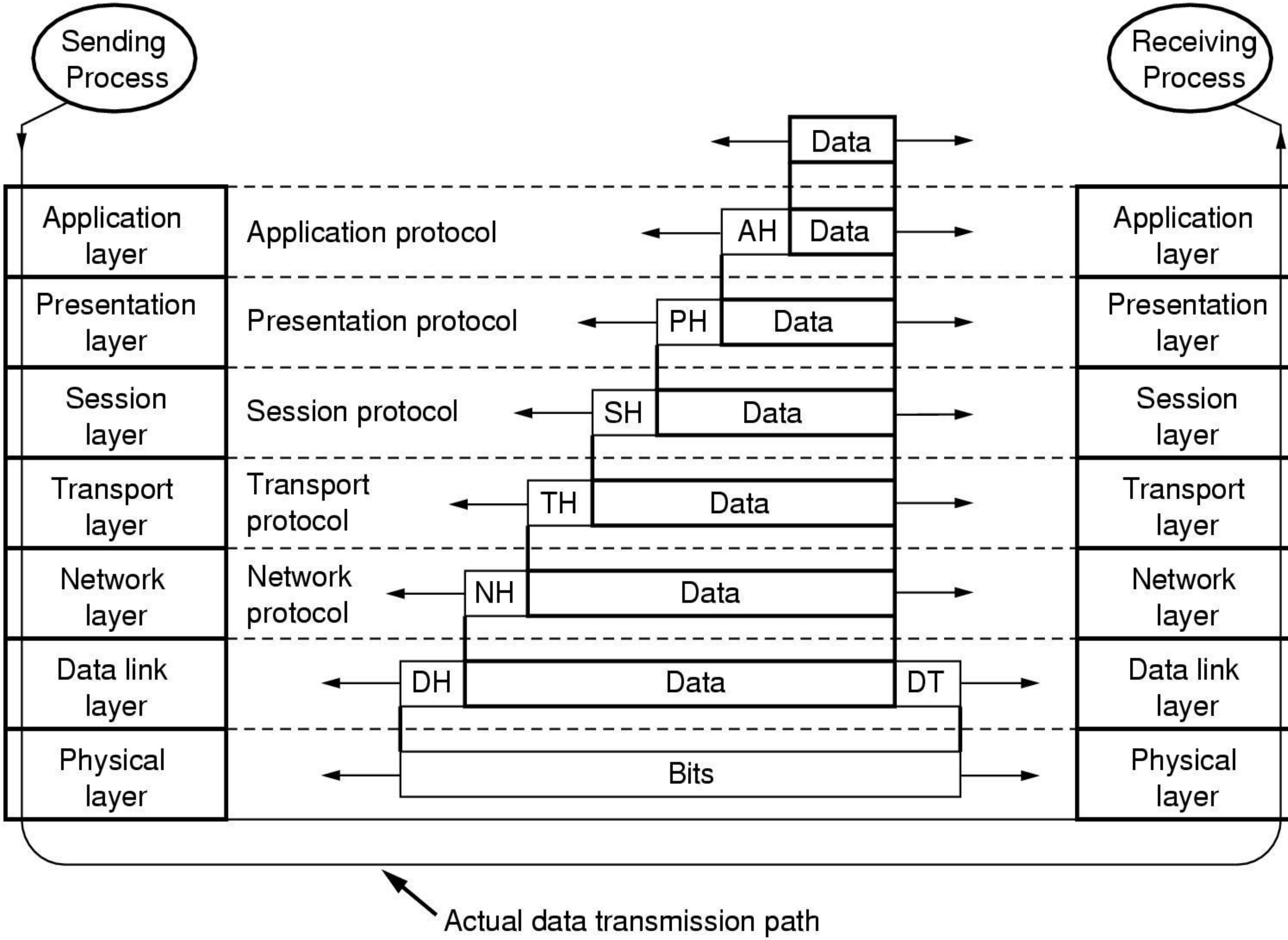
- **Session:** The dumbest one (and ill-defined) tells how applications can set up “long-lasting” communications, offers various services, including dialog control, token management, synchronization.
- **Presentation:** Describes everything that is needed to exchange data in a platform-independent way, concerned with the syntax and semantics of the information transmitted.
- Example: think of byte ordering in different computers, or passing “binary” data through e-mail

The Application Layer

Essence: Contains the rest

- **Traditional:** Name services (DNS), security, e-mail(SMTP), News (NNTP), Web (HTTP)
- **Modern:** All types of **middleware protocols** to support **distributed systems**:
  - New transfer protocols for object systems like Java (RMI), CORBA (IIOP), DCOM (propriety)
  - Special protocols to handle replication, fault tolerance, caching, data persistence, etc.
- **High-level protocols:** Special application-level protocols for e-commerce, banking, EDI, etc.

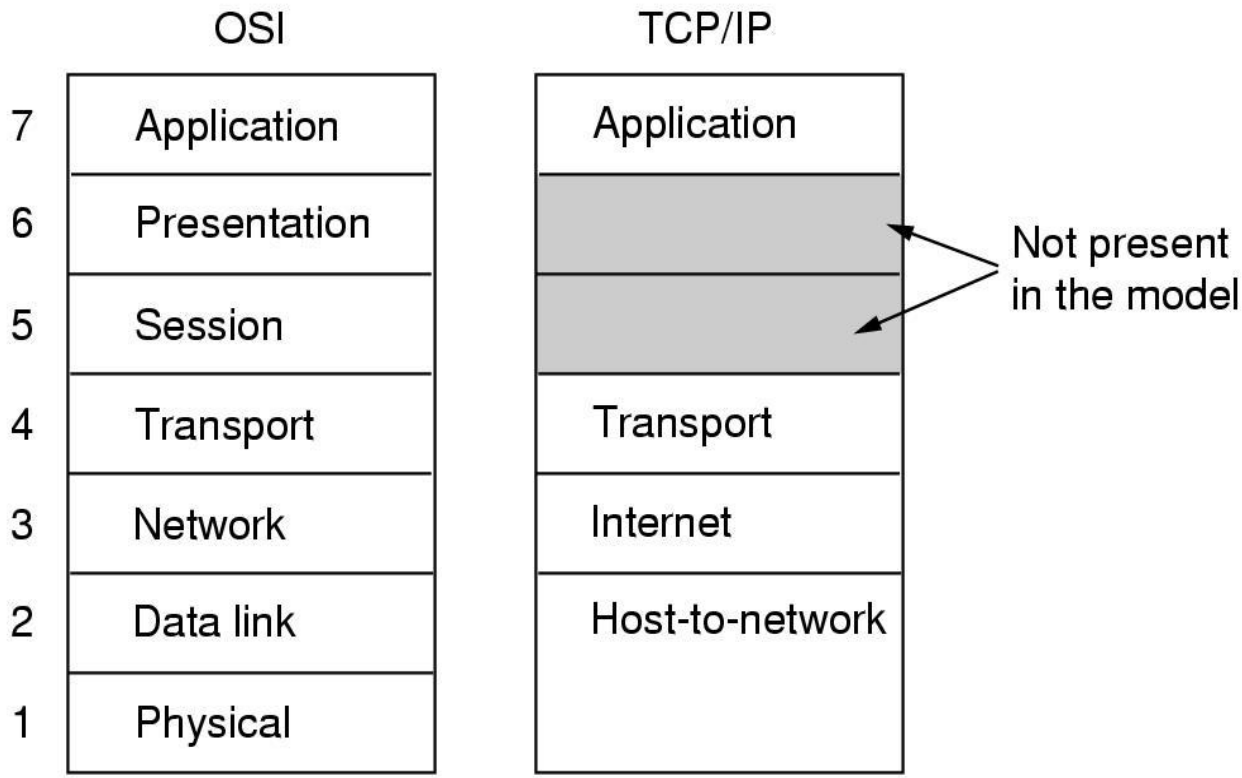
Data Transmission in the OSI Model

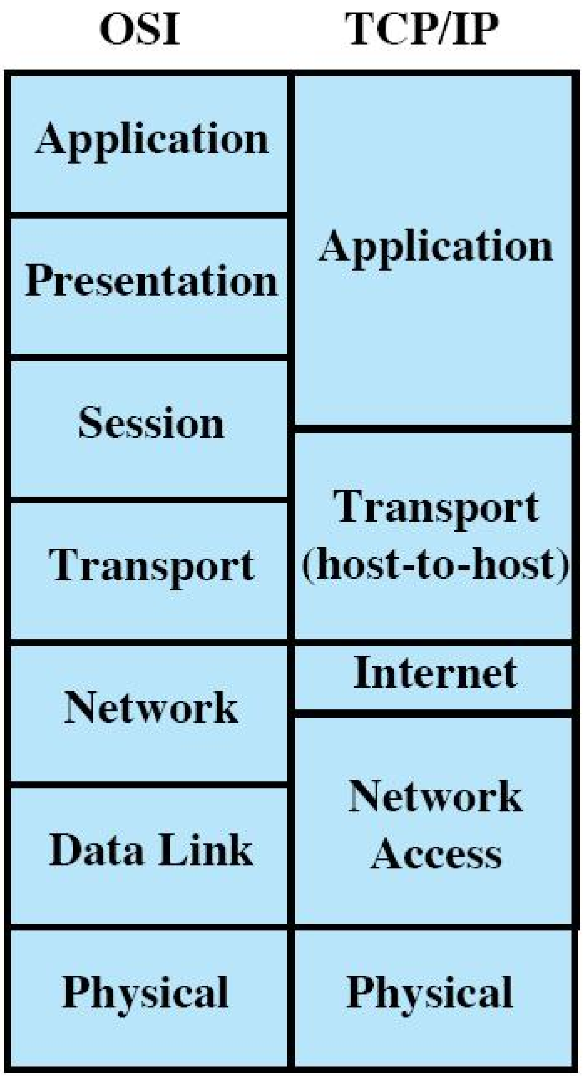


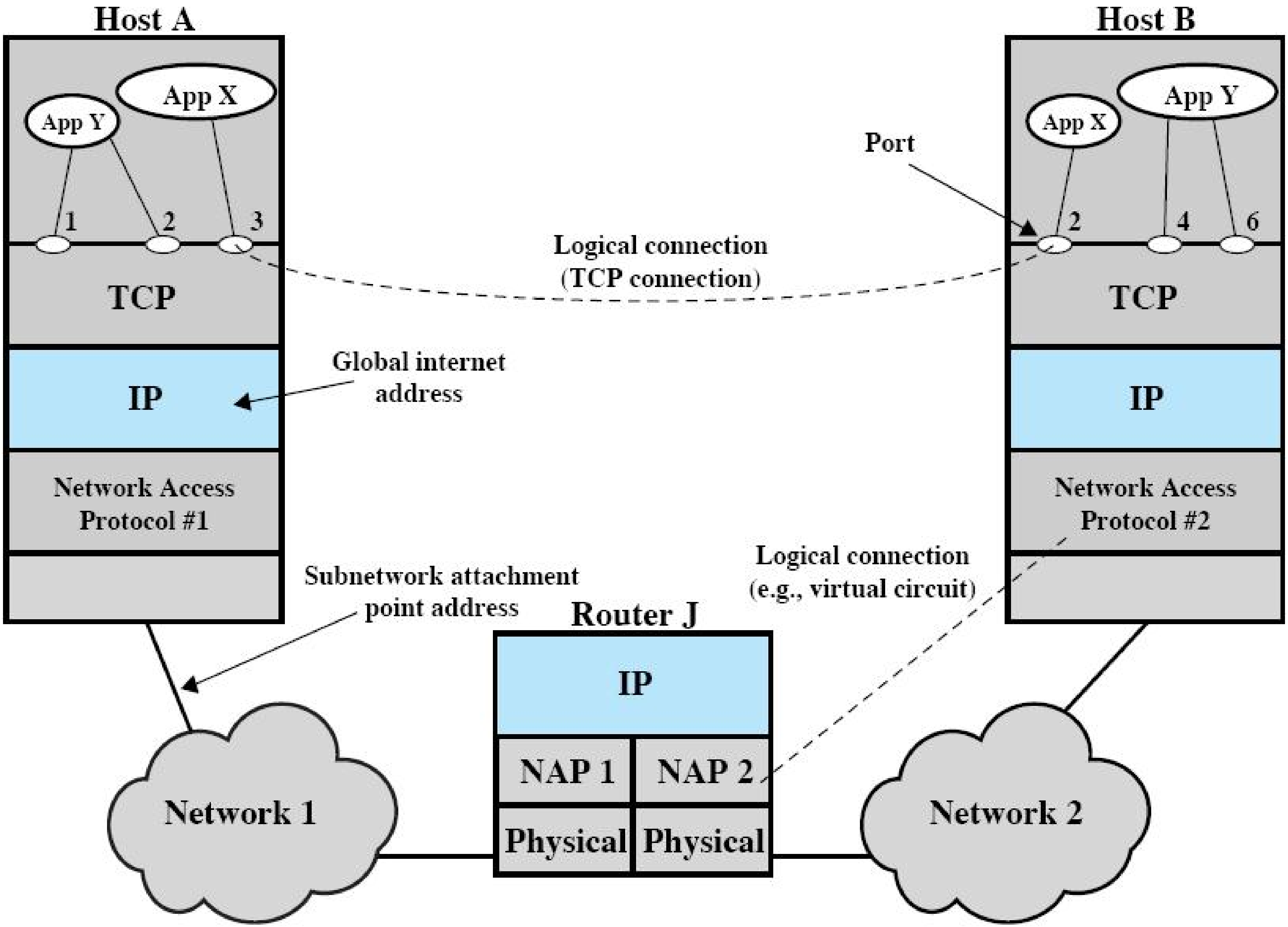
1.4.2 The TCP/IP Reference Model

- 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)





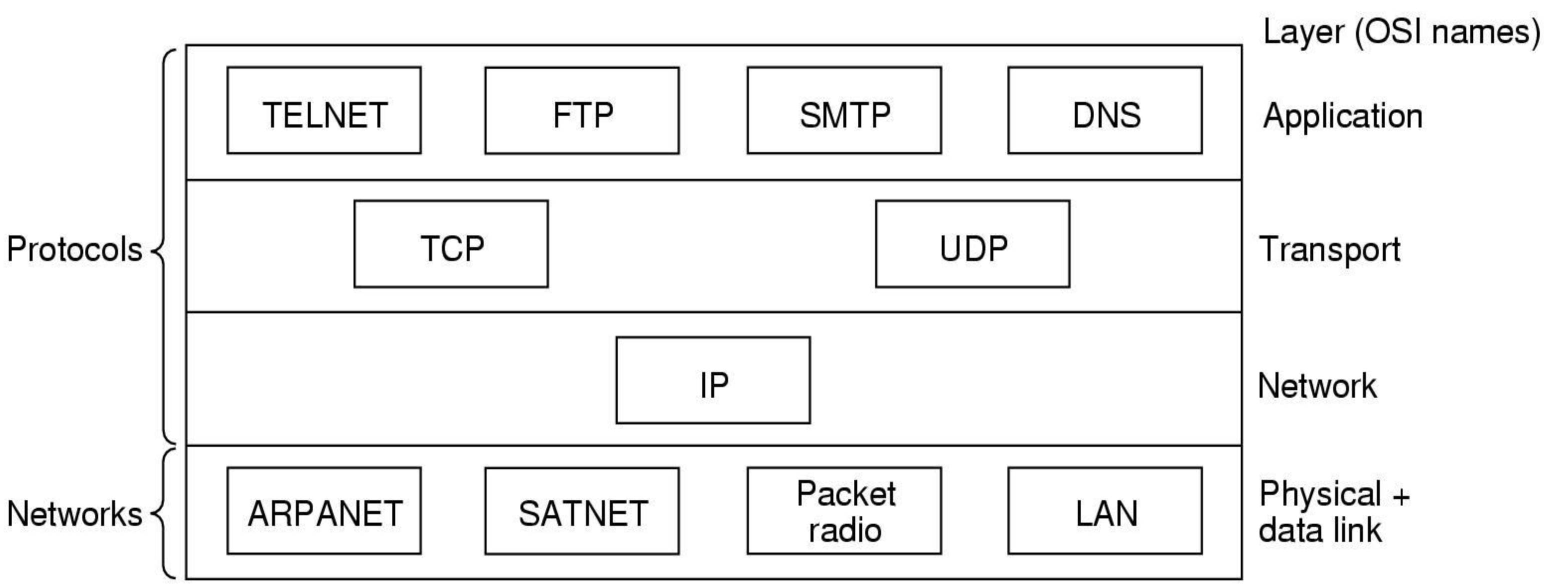

Host A
App Y
App X
1
2
3
TCP
IP
Network Access
Protocol #1
Host B
App X
App Y
2
4
6
TCP
IP
Network Access
Protocol #2
Port
Logical connection
(TCP connection)
Global internet
address
Subnetwork attachment
point address
Logical connection
(e.g., virtual circuit)
Router J
IP
NAP 1
NAP 2
Physical
Physical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



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)

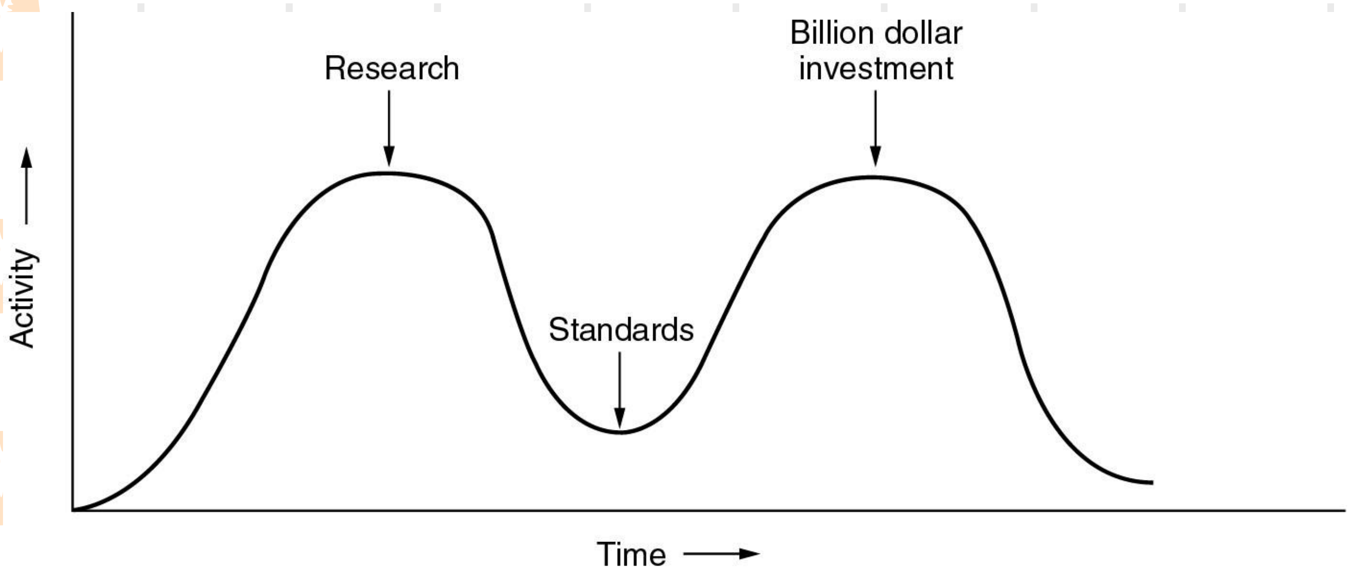
- The Application Layer
  - Contains all the higher-level protocols: Telnet, FTP, SMTP, DNS, HTTP, …
- The Host-Network Layer
  - The TCP/IP reference model does not really say much about what happens here, except to point out that the host has to connect to the network using some protocol so it can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

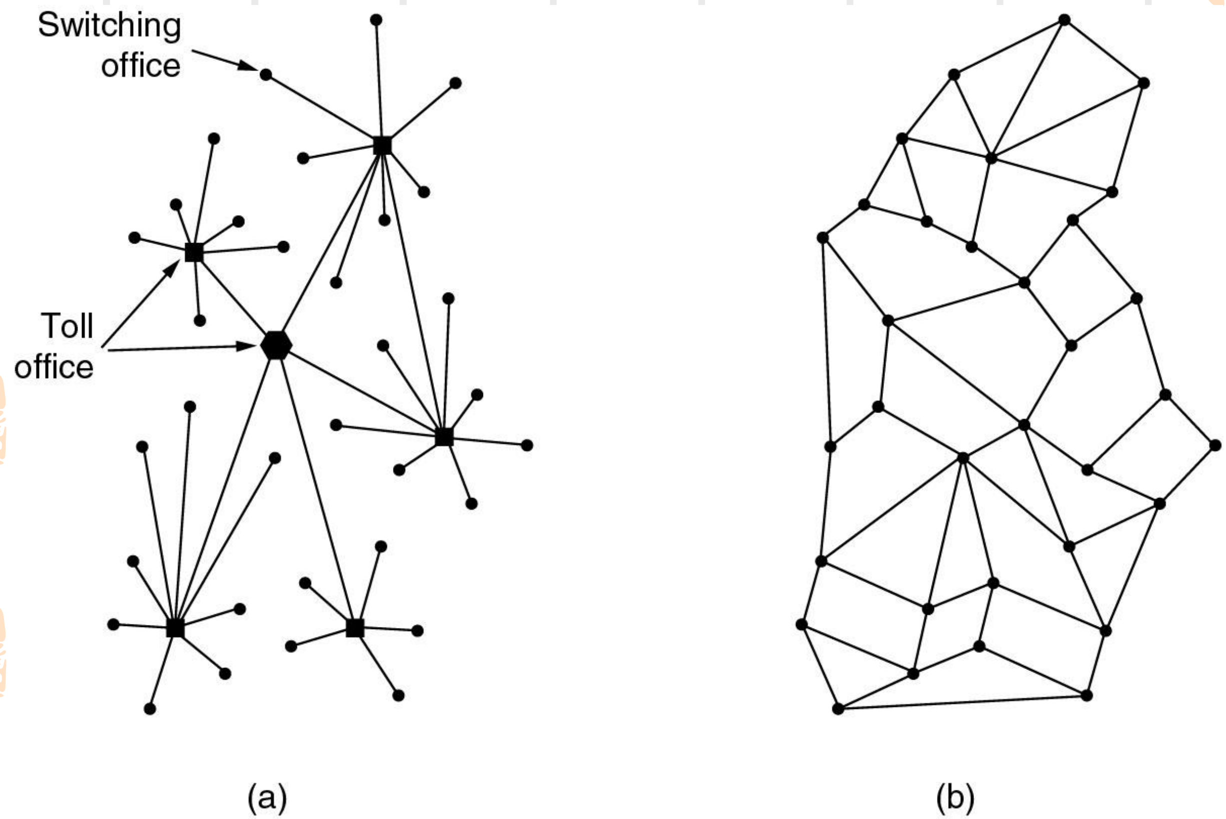
- Novell Netware

Layer			
Application	SAP	File server	. . .
Transport	NCP		SPX
Network	IPX		
Data link	Ethernet	Token ring	ARCnet
Physical	Ethernet	Token ring	ARCnet

- The ARPAnet

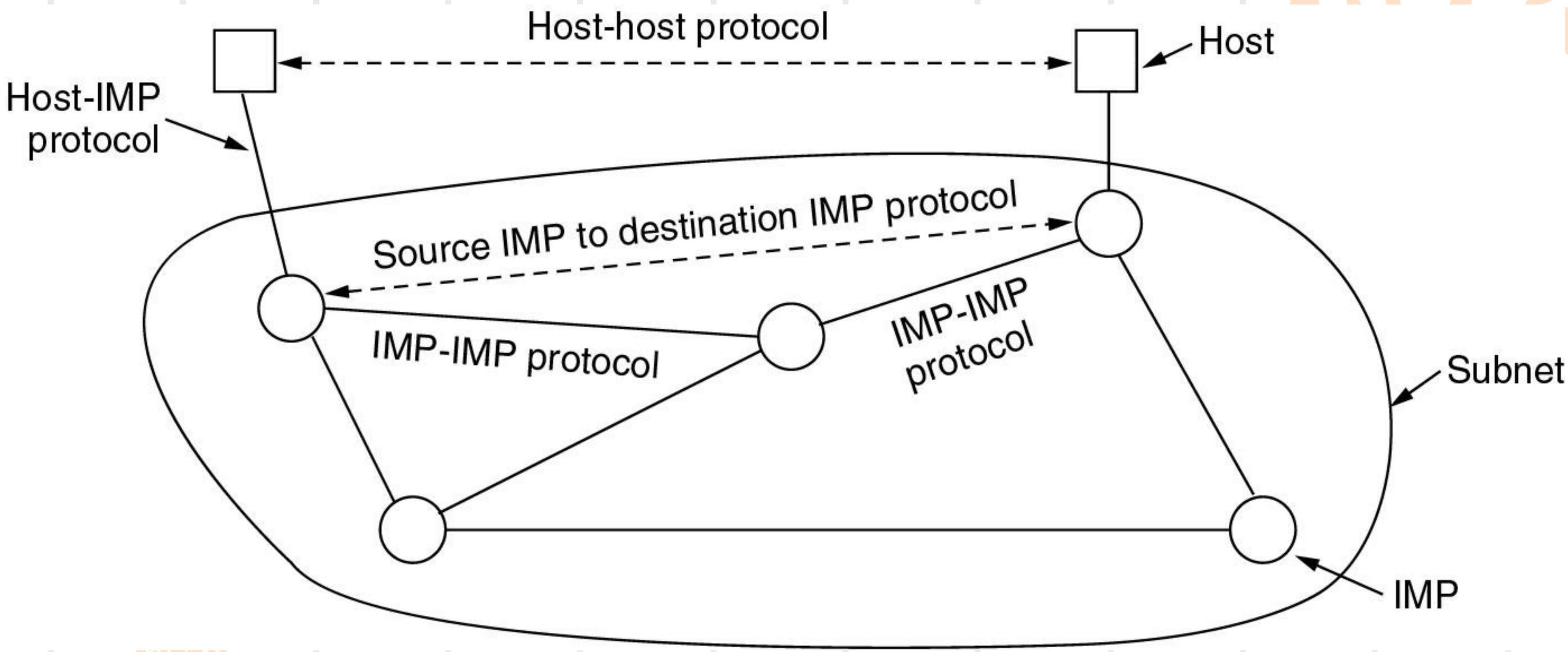
1.5.1 The Internet

The ARPANET



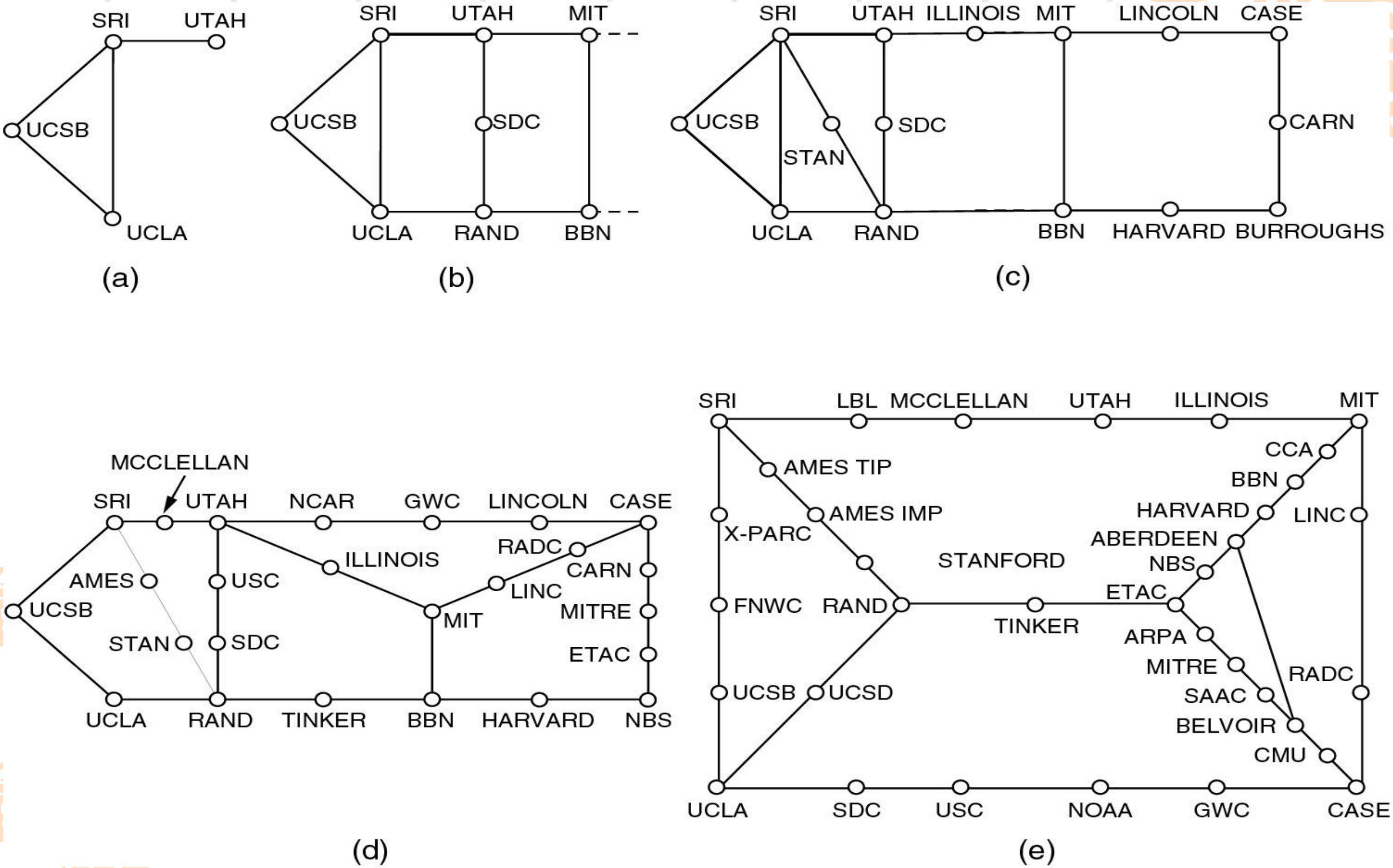
(a) Structure of the telephone system.
(b) Baran's proposed distributed switching system.

The ARPANET (2)



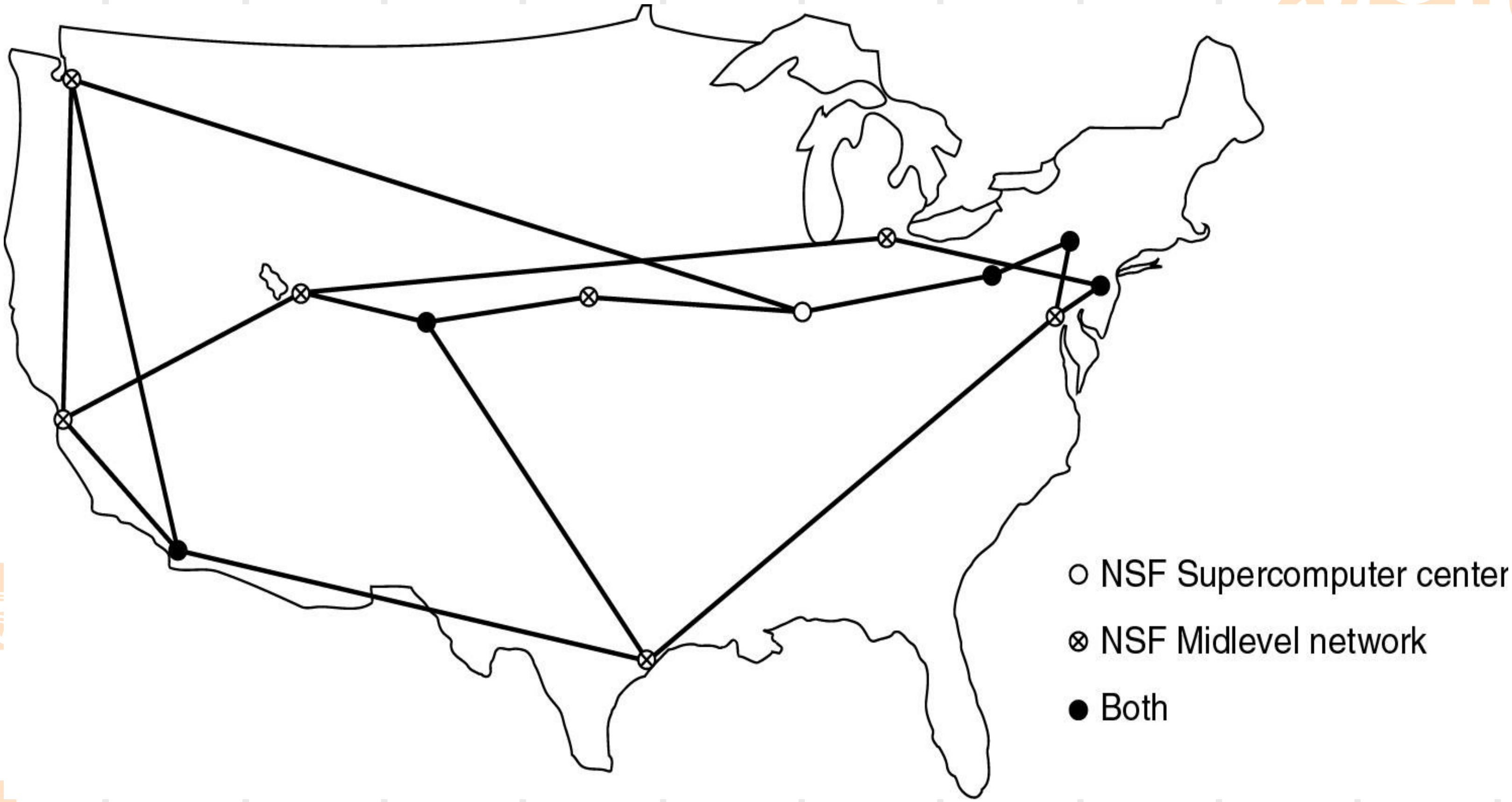
The original ARPANET design.

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

Architecture of the Internet

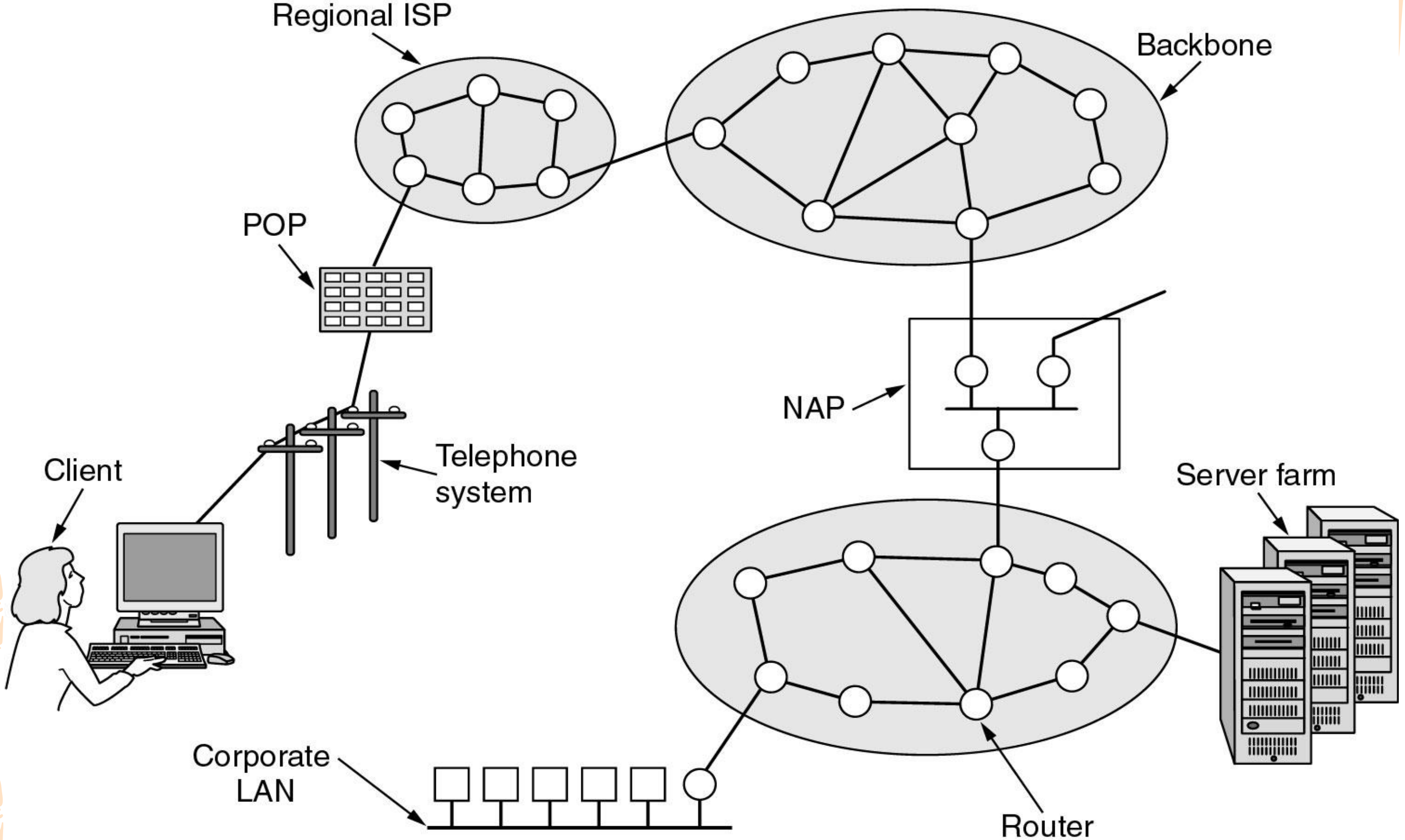


Fig. 1.29 Overview of the Internet.

ATM Virtual Circuits

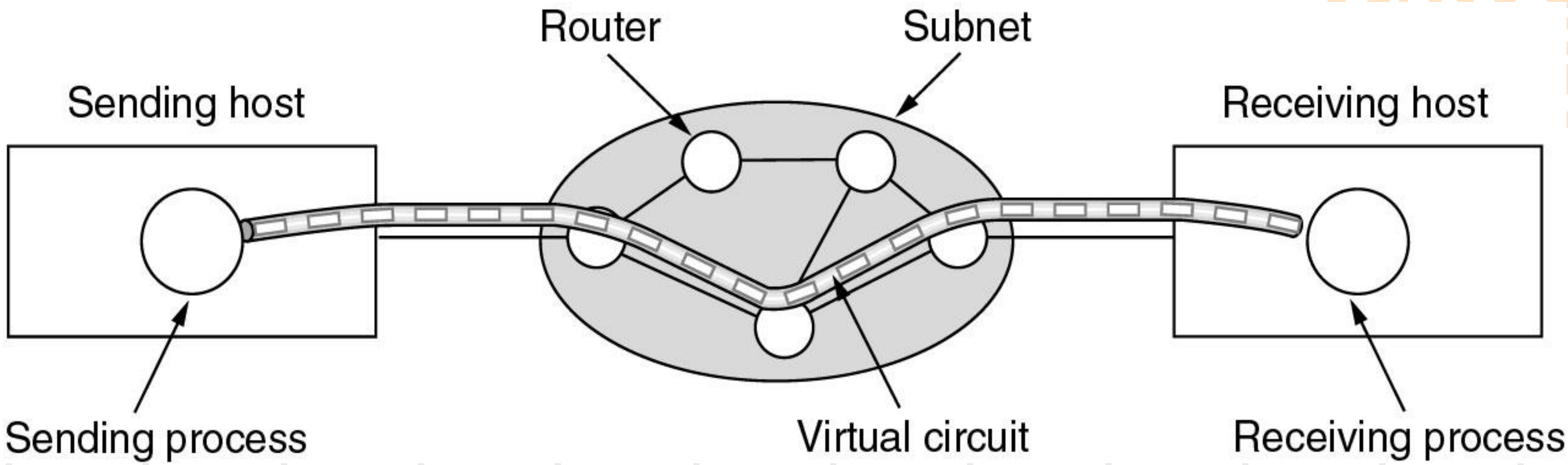


Fig. 1.30 A virtual circuit.

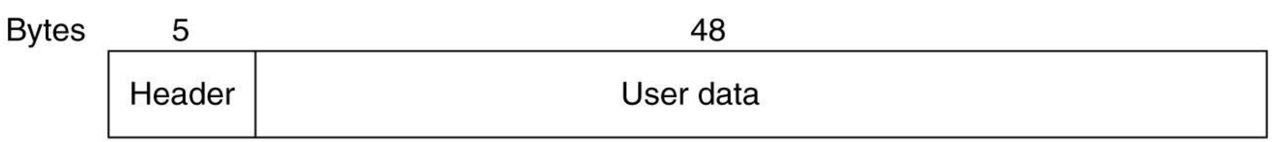
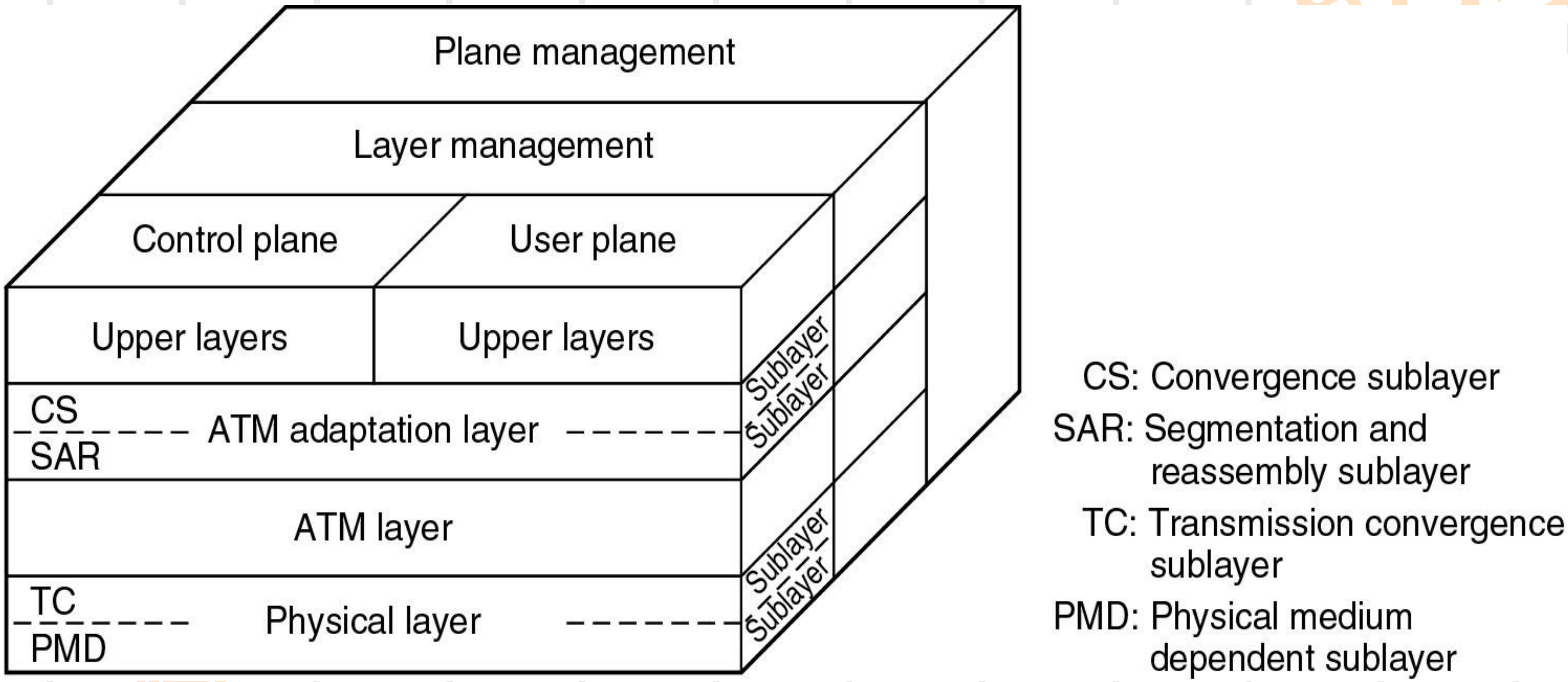


Fig. 1.31 An ATM cell.

The ATM Reference Model



The ATM reference model.

The ATM Reference Model (2)

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

The ATM layers and sublayers and their functions.

1.5.3 Ethernet

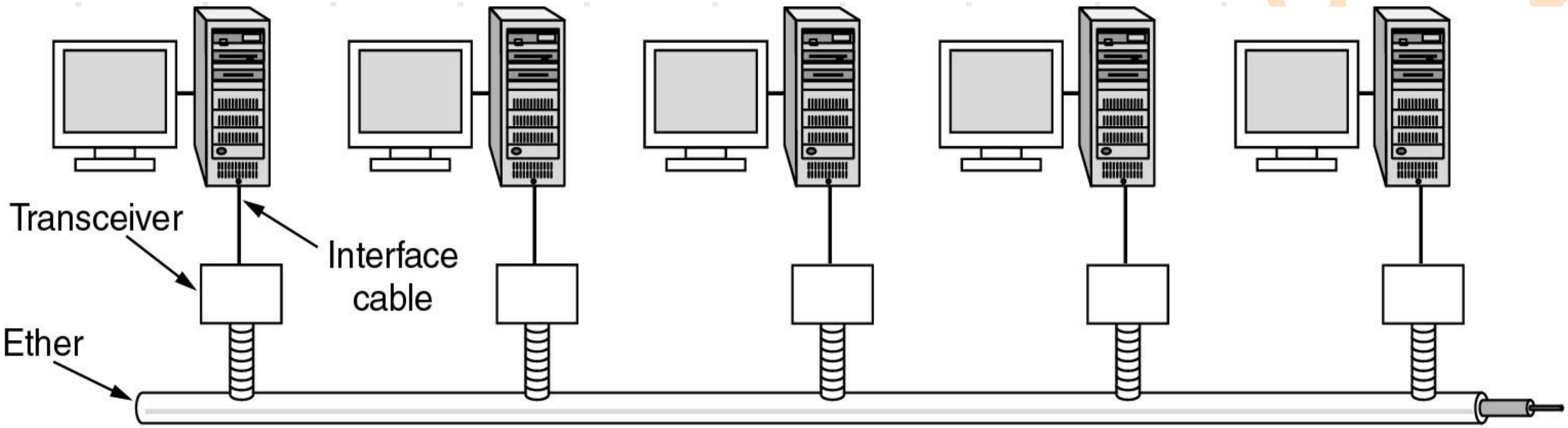
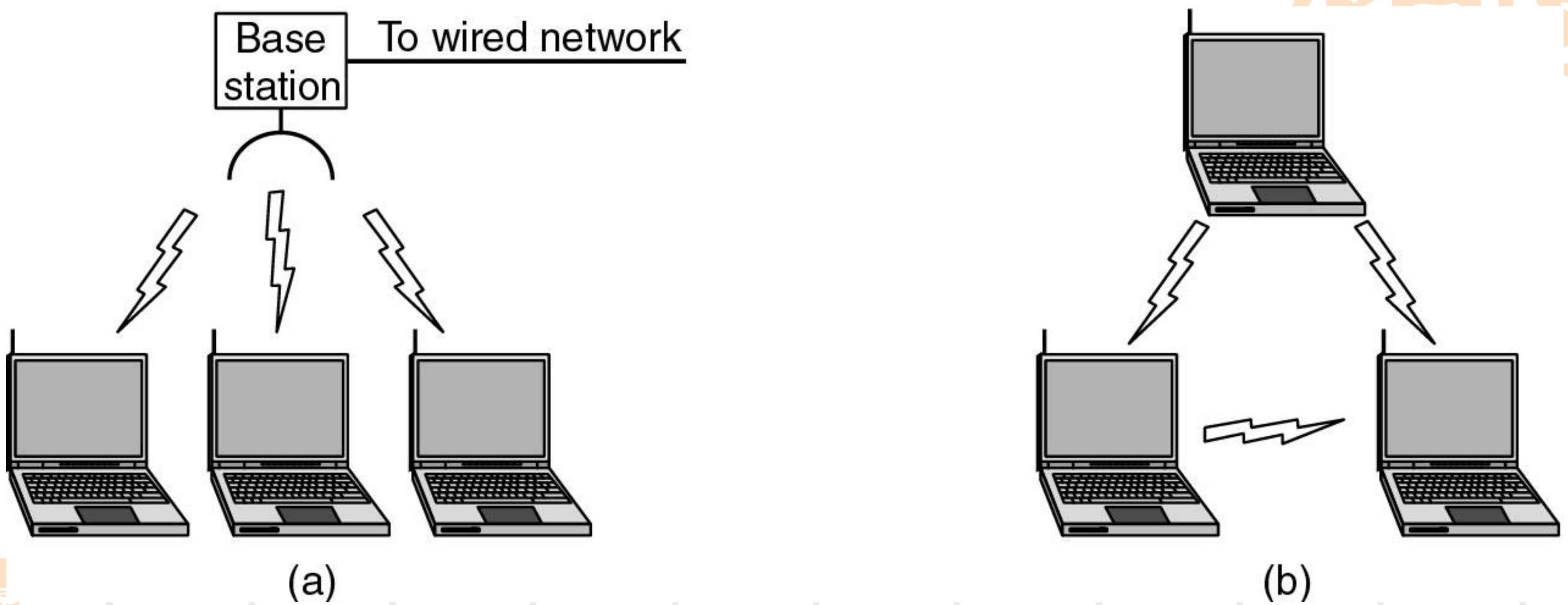


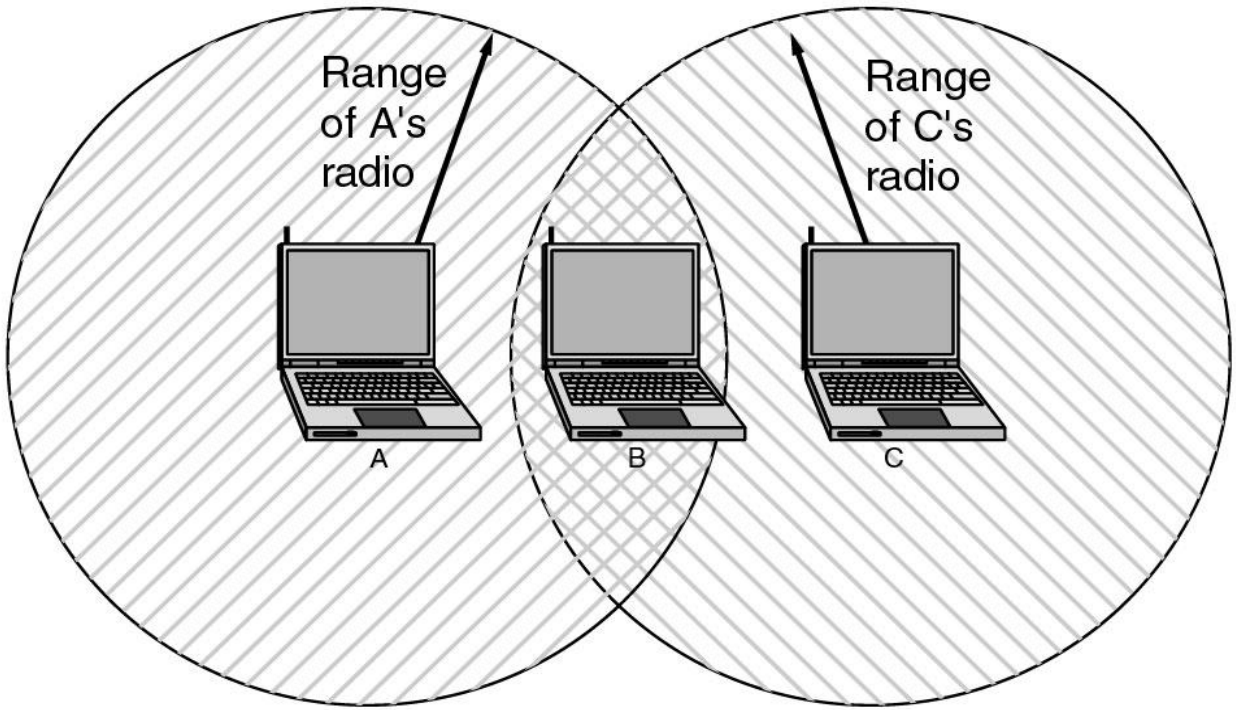
Fig. 1.34 Architecture of the original Ethernet.

1.5.4 Wireless LANs: 802.11



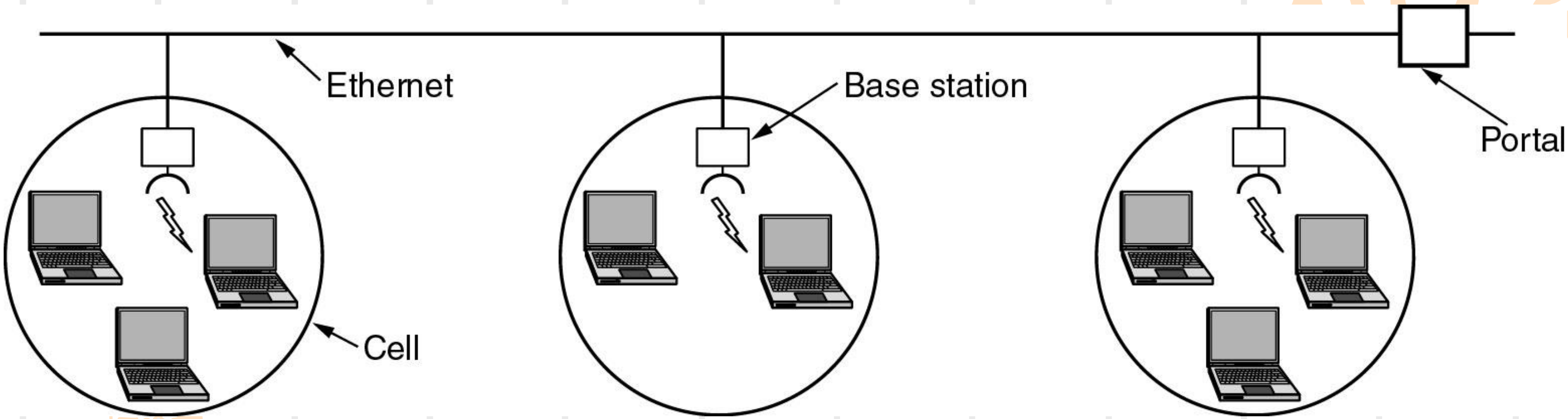
(a) Wireless networking with a base station.
(b) Ad hoc networking.

Wireless LANs (2)



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

Wireless LANs (3)



A multicell 802.11 network.

1.6 Network Standardization

- Who’s Who in the Telecommunications World
- Who’s Who in the International Standards World
- Who’s Who in the Internet Standards World

ITU

- Main sectors
  - Radio communications
  - Telecommunications Standardization
  - Development
- Classes of Members
  - National governments
  - Sector members
  - Associate members
  - Regulatory agencies

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.

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}	0.000000000000000001	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

Fig. 1-39. The principal metric prefixes.

Carrier Data Communication Services

- **Observation:** As long as carriers rule the world (i.e.they have the cables), and competition increases, carriers will increase and improve their data communication services for the public:
- **SMDS:** Switched Multimegabit Data Service primarily intended to connect a number of LANs through long-haul networks (owned by the carrier)

Carrier Data Communication Services

- **X.25:** The OSI network protocol (also covering datalink and physical layer), intended to offer a *data* network on top of an (existing) cable infrastructure. Pretty old.
- **Frame relay:** Extremely simple facility that allows a customer to hire a single high-bandwidth link. There is hardly any support for error detection, routing, flow control, etc.

Broadband ISDN

- **Observation:** The carriers are getting too many networks to maintain, and are missing one important type (i.e. those owned by cable-TVs)
- **Solution:** Let's invent a completely new network that should integrate data and telephony, and should be able to accommodate a large range of bandwidth requirements.

Broadband ISDN (2)

- **Problem:** How do you implement a network that can handle 622 Mbps?
  - Use small fixed-sized **cells** instead of relatively large packets and frames (that can also vary in length): this allow you to build low-latency switches
  - Do the least you can (i.e., don’t provide too many services): let the applications handle it all

ATM for B-ISDN

- **Solution:** Asynchronous Transfer Mode (ATM), by which cells of 53 bytes (!) are sent along **virtual circuits** from sender to destination.
- **Observation:** This model does not fit into OSI's layered approach: B-ISDN assumes there's a separate signaling network to setup a connection

Assignments

- Chapter 01

  Please see separate sheet.