Lecture 1
An Introduction
(Computer Communication Networks)

CS 35201
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§1.0.0 Contents

The contents of this lecture have been composed from various resources including those listed at the reference section.

Reading List

- Chapter 1 Sections 1.1-1.5 of [Tanenbaum and Wetherall, 2011]

§1.0.0 Glossaries

E2E	End-to-End 43
IMP	Interface Message Processor 29
IP	Internet Protocol 18, 21
ISP	Internet Service Provider 7, 13
LAN	Local Area Network 18
OSI	Open Systems Interconnection 21, 26, 44
P2P	Peer-to-Peer 6, 43
QoS	Quality of Service 34
RFID	Radio Frequency Identification 27
TCP	Transport Control Protocol 21
WAN	Wide Area Network 11–13

§1.1.0 Computer Networks Applications I

Networks can be classified based on their application:

1. Business Applications
2. Home Applications
3. Mobile Users
4. Social networks

$\Rightarrow$ Other classifications based on their range, technology, etc. are possible

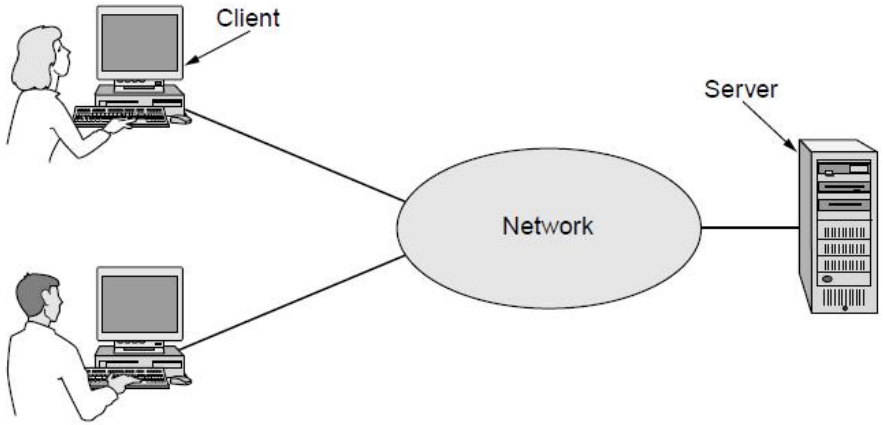
- Wired vs. wireless (1G, 2G, ..., 5G)
- LAN, MAN, WAN, ...
- Terrestrial, satellite, space, ...
- Cellular, ad hoc, sensor, mesh ..
- $\vdots$

§1.1.0 Computer Networks Applications II

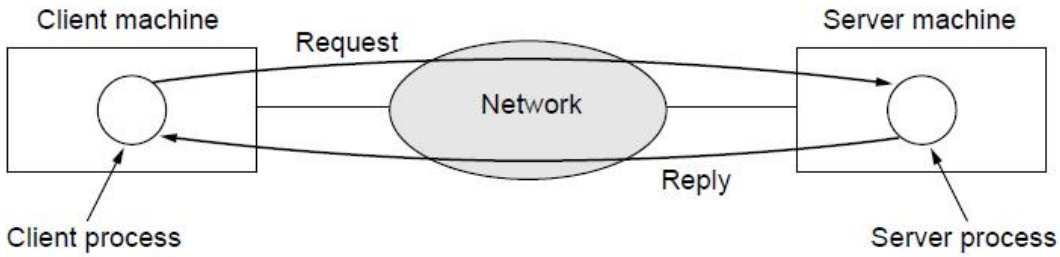
➥ *Classification Based on Applications*

1 Business Applications

Example 1: A network with two clients and one server



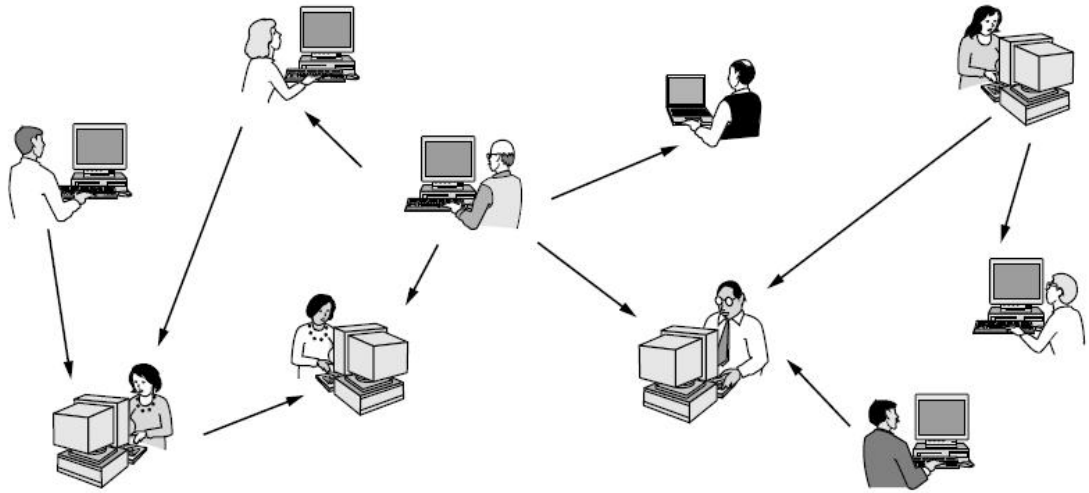
Example 2: The client-server model involves requests and replies



§1.1.0 Computer Networks Applications III

2 Home Applications

Example 1: In a Peer-to-Peer (P2P) system there are no fixed clients and servers



Example 2: Some forms of e-commerce

- Business-to-consumer ⇒ Ordering books online
- Business-to-business ⇒ Car manufacturer ordering tiers from supplier
- Government-to-consumer ⇒ IRS distributing tax forms electronically
- Consumer-to-consumer ⇒ Auctioning second-hand product on line
- Peer-to-peer ⇒ Music sharing

Homework 1.1 (Social Networking)

How do you classify social networking?

§1.1.0 Computer Networks Applications IV

3 Mobile Users ⇒ Mobility vs. Wireless ⇒ Not the same *Why?*

Example 1: Combinations of wireless networks and mobile computing

Wireless	Mobile	Typical applications
No	No	Desktop computer in offices
No	Yes	A notebook computer is used in a hotel room
Yes	No	Networks in unwired building
Yes	Yes	Store inventory with a handheld computer

4 Social networks
- Network neutrality
  - No restrictions by Internet Service Provider (ISP)/Governments on contents, sites, platforms, equipment and mode of communication
  - ISPs should not be able to play favorites with the content that goes over the network
- Digital Millennium Copyright Act
  - Treaties of the World Intellectual Property Organization (WIPO)
- Profiling users
  - Explicit digital representation of a person's identity ⇒ Linkedin
- Phishing
  - Criminally fraudulent process of attempting to acquire sensitive information such as usernames, passwords and credit card details by masquerading as a trustworthy entity in an electronic communication

§1.2.0 Computer Networks Hardware I

Networks can be classified based on their hardware:

1. Personal area networks
2. Local area networks
3. Metropolitan area networks
4. Wide are networks
5. The Internet

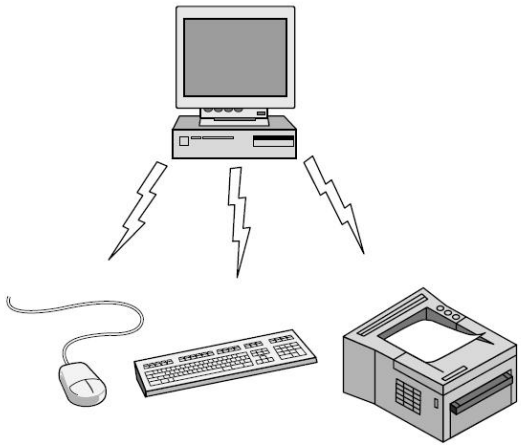
Interprocessor distance	Processors located in same	Example
1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

§1.2.0 Computer Networks Hardware II

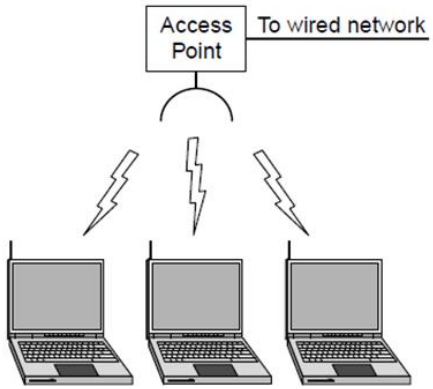
➥ *Classification Based on Hardware*

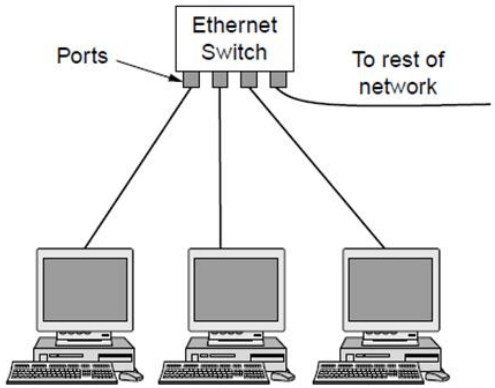
➥ *Classification of interconnected processors by scale*

1. Personal area networks ⇒ Bluetooth PAN configuration



2. Local area networks ⇒ 802.11 and Switched Ethernet





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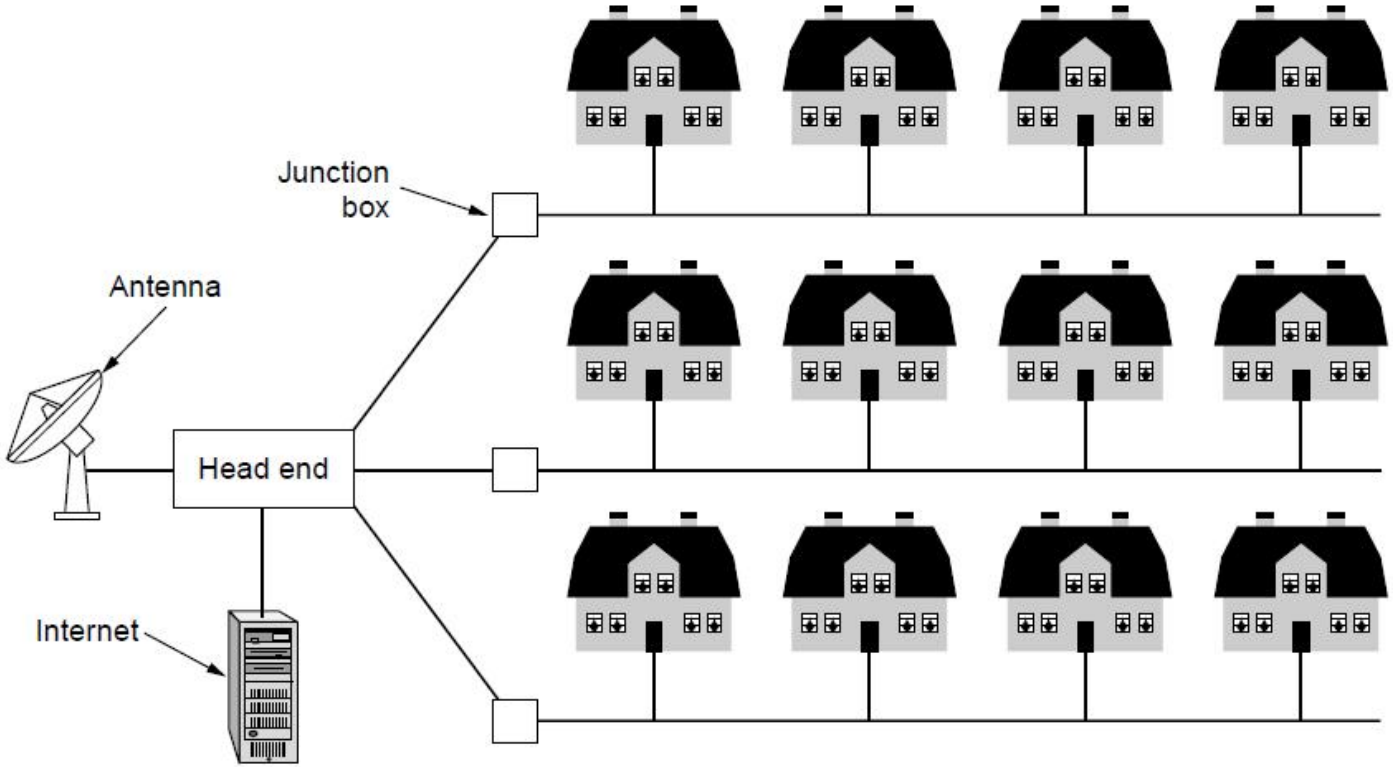
§1.2.0 Computer Networks Hardware III

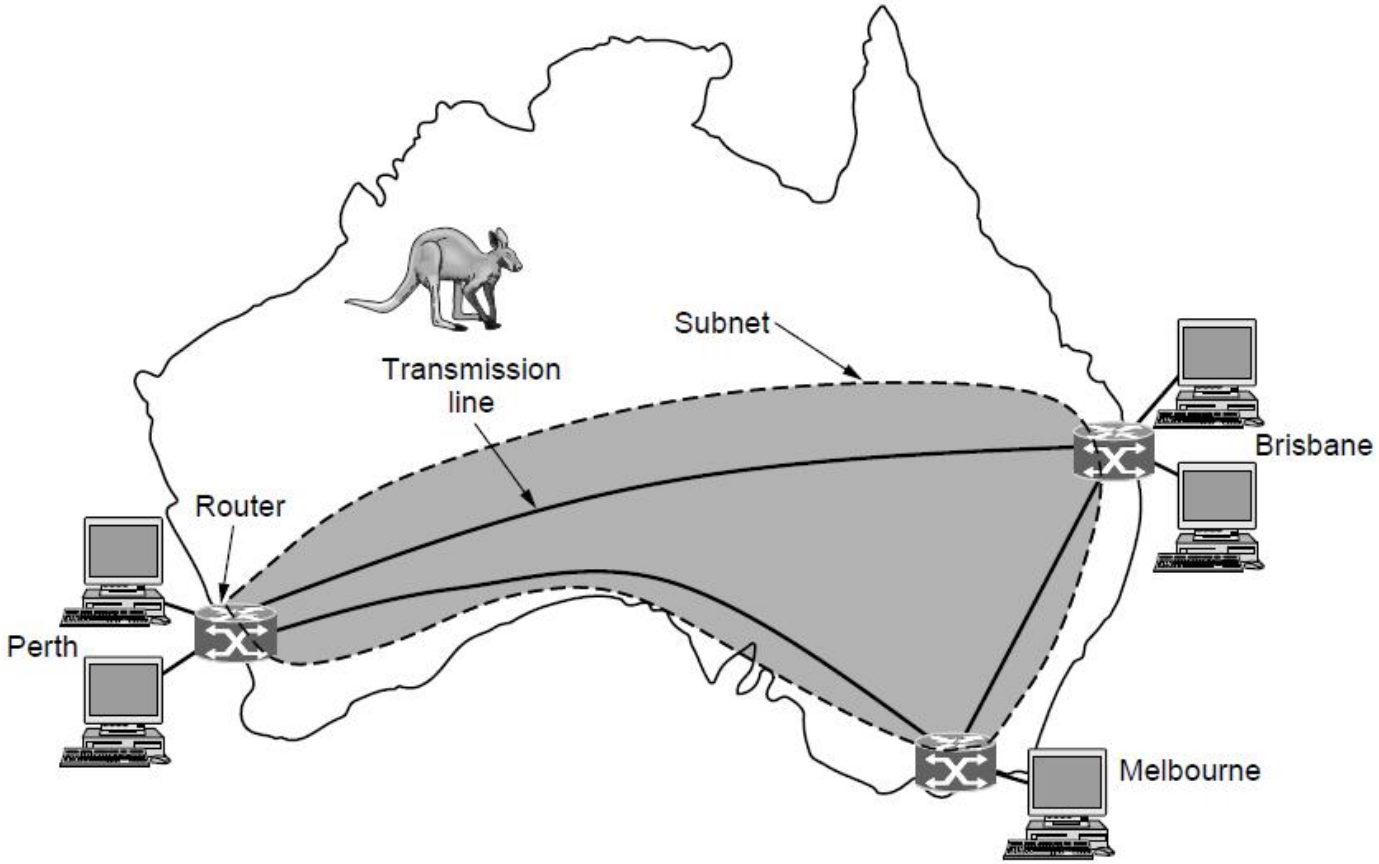
3 Metropolitan area networks ⇒ Based on cable TV



§1.2.0 Computer Networks Hardware IV

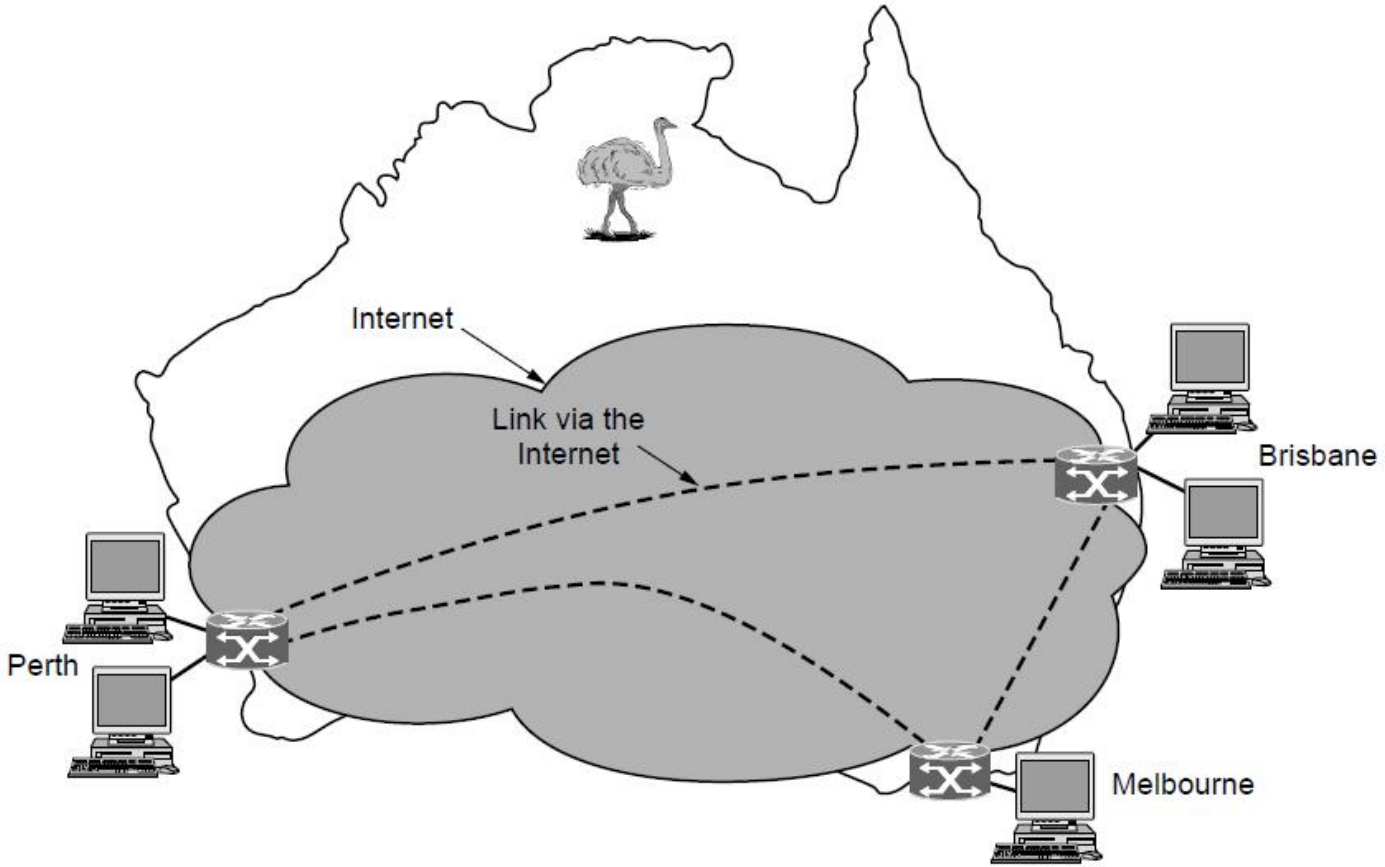
4 Wide Area Network (WAN)

Example 1: WAN that connects three branch offices in Australia



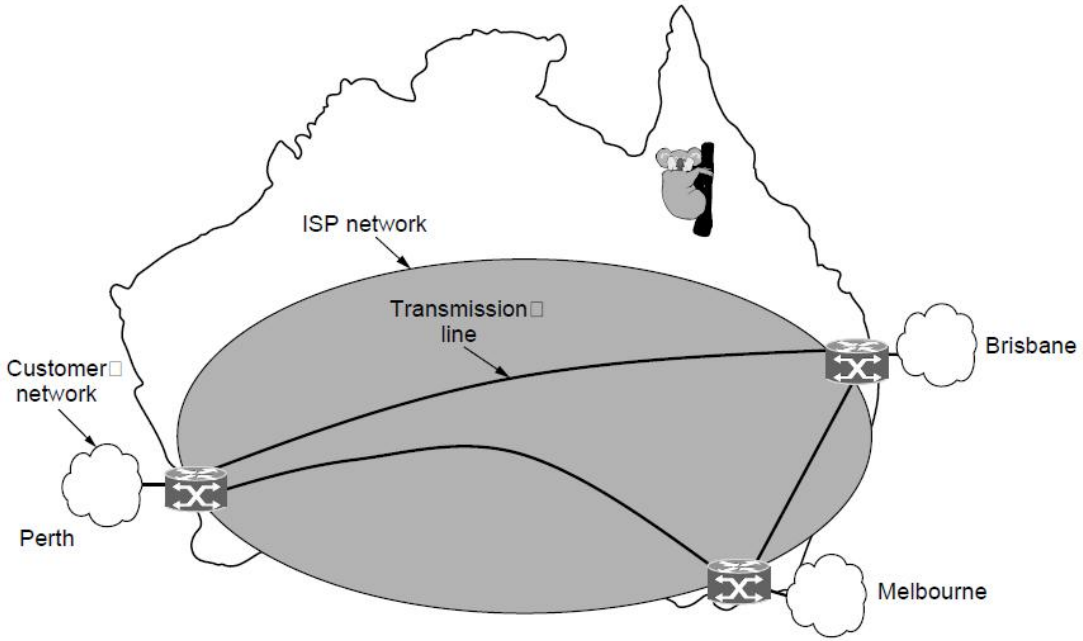
§1.2.0 Computer Networks Hardware V

Example 2: WAN using a virtual private network



§1.2.0 Computer Networks Hardware VI

Example 3: WAN using an ISP network



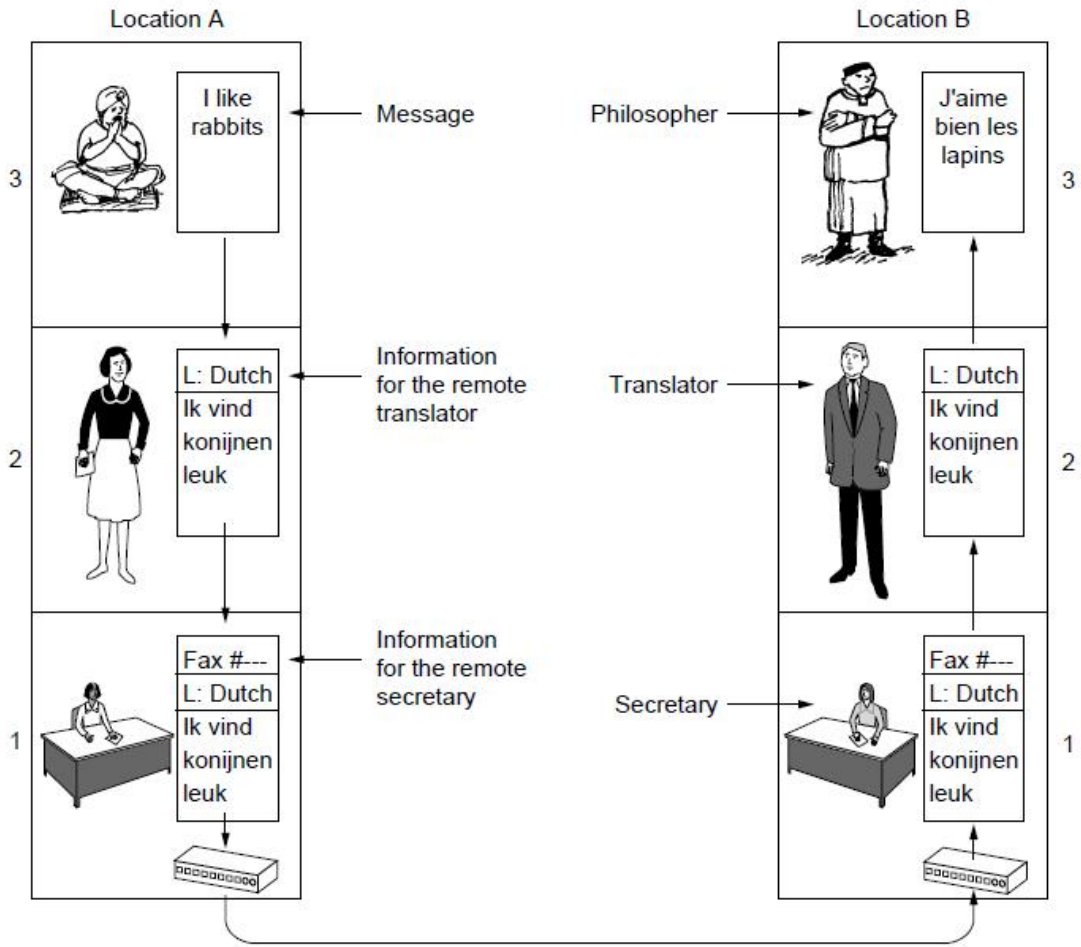
§1.3.0 Network Software I

Topics in Layered Architecture

1. Protocol hierarchies
2. Design issues for the layers
3. Connection-oriented versus connectionless service
4. Service primitives
5. Relationship of services to protocols

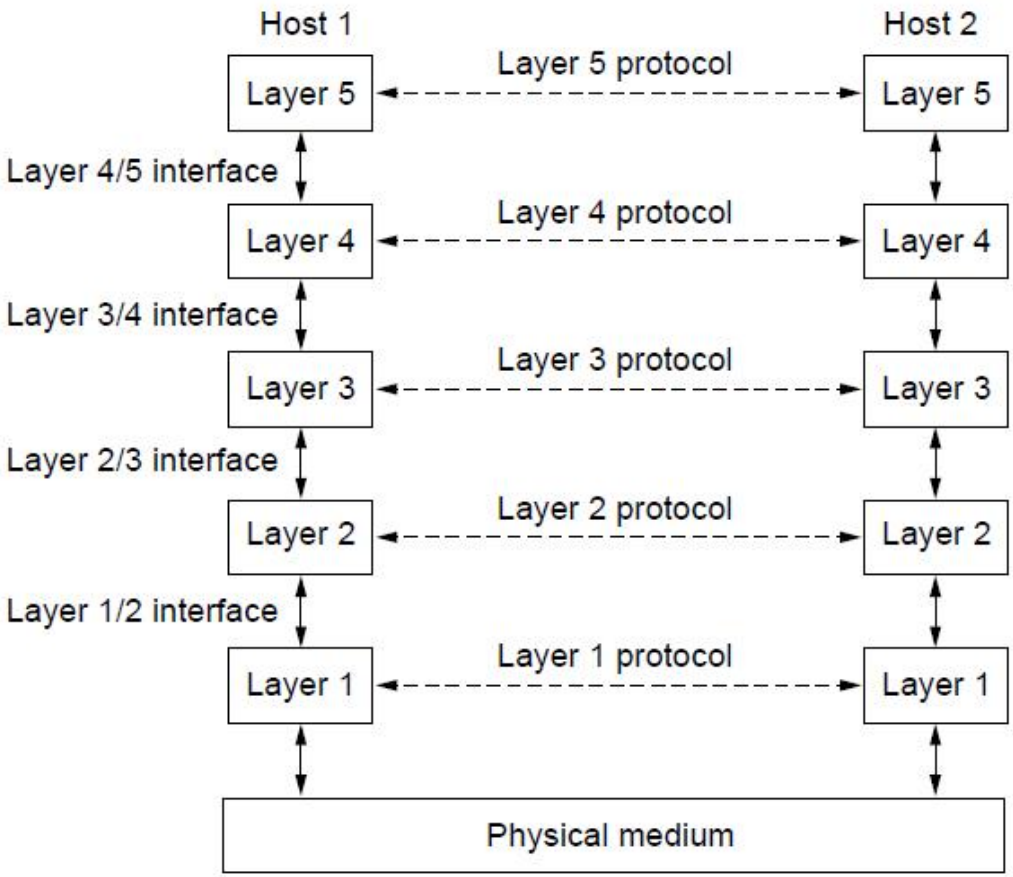
§1.3.0 Network Software II

Example 1.1 (The philosopher-translator-secretary architecture)



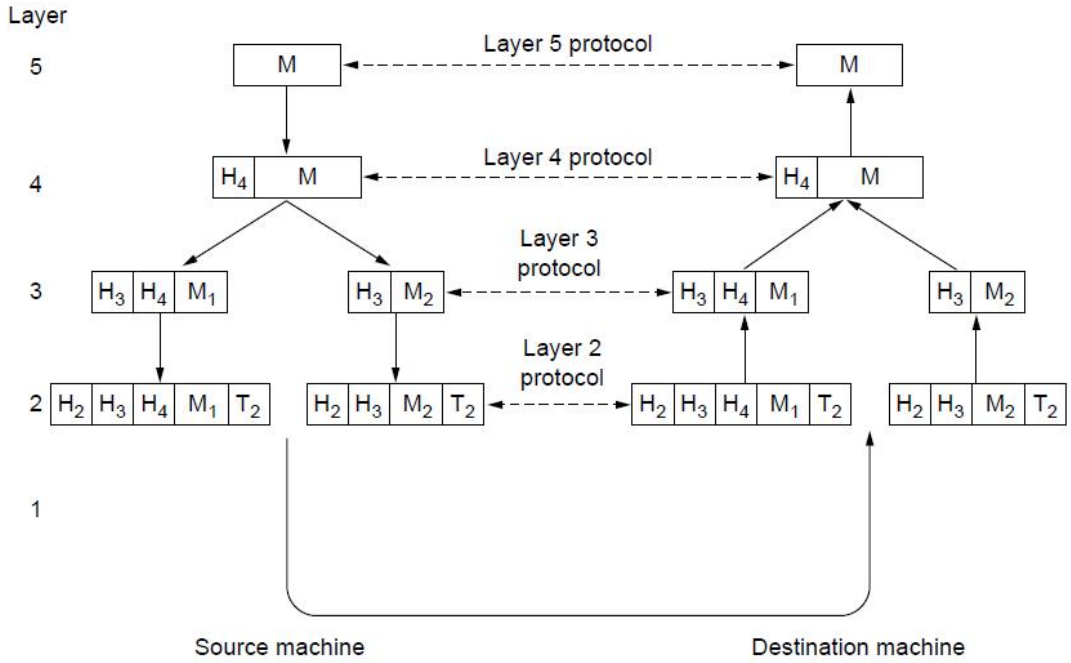
§1.3.0 Network Software III

1 Layers, protocols, and interfaces



§1.3.0 Network Software IV

2 Information flow supporting virtual communication in layer 5



- The more layers, the more overhead ⇓
- The more layers, the easier to design, mange, update ⇑

§1.4.0 Connection-Oriented vs. Connectionless Service

Types of services

	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*

➥ *Each can be implemented on each layer*

Homework 1.2

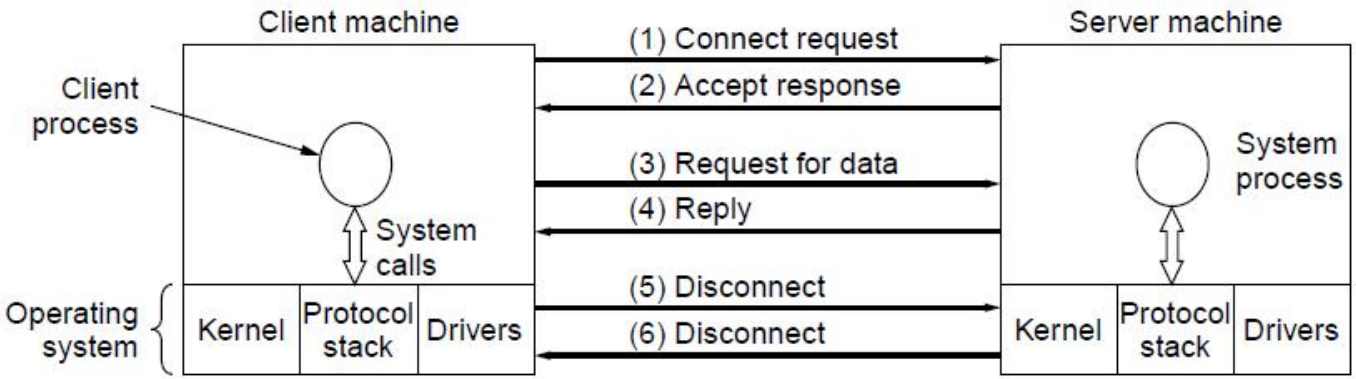
Explain how each service is performed by a Local Area Network (LAN) or Internet Protocol (IP)

§1.4.1 Service Primitives

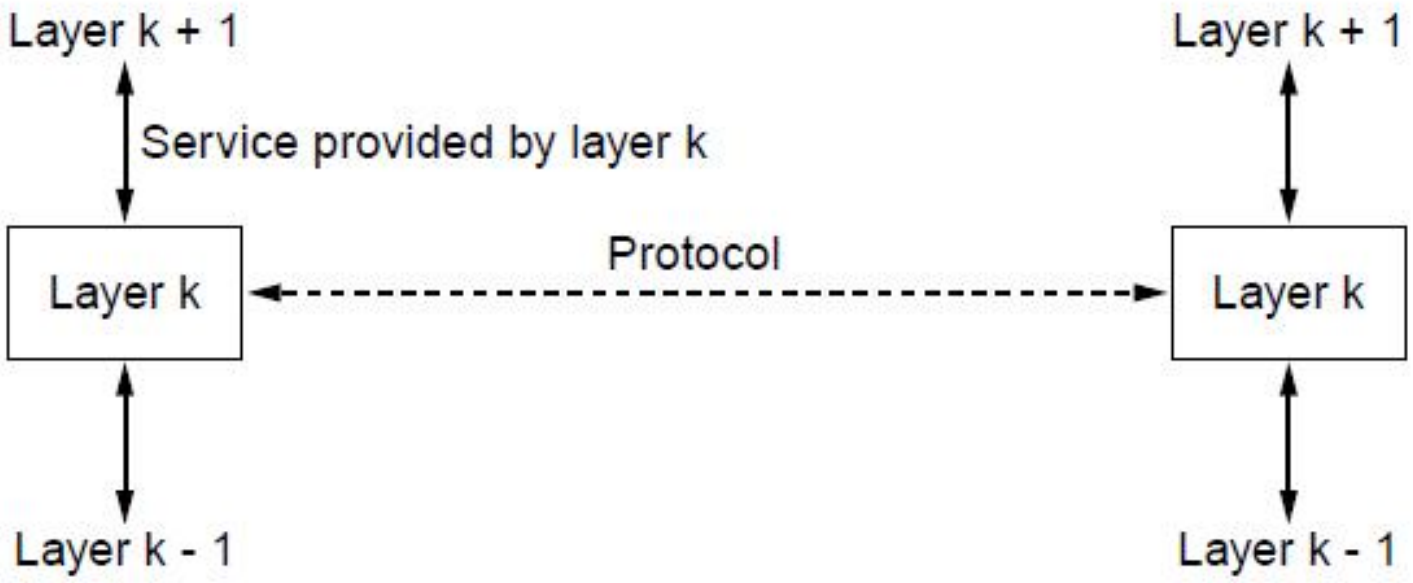
- Six service primitives that provide a simple connection-oriented service

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

- A simple client-server interaction using acknowledged datagrams



§1.4.2 The Relationship of Services to Protocols



➥ *The relationship between a service and a protocol*

- Layer ⇒ black box
- servicer ⇒ Input/output ⇒ depend on the direction ⇒ send/Receive

§1.5.0 Reference Models

➥ *Towards Standardization*

1. Open Systems Interconnection (OSI) reference model
2. Transport Control Protocol (TCP)/IP reference model

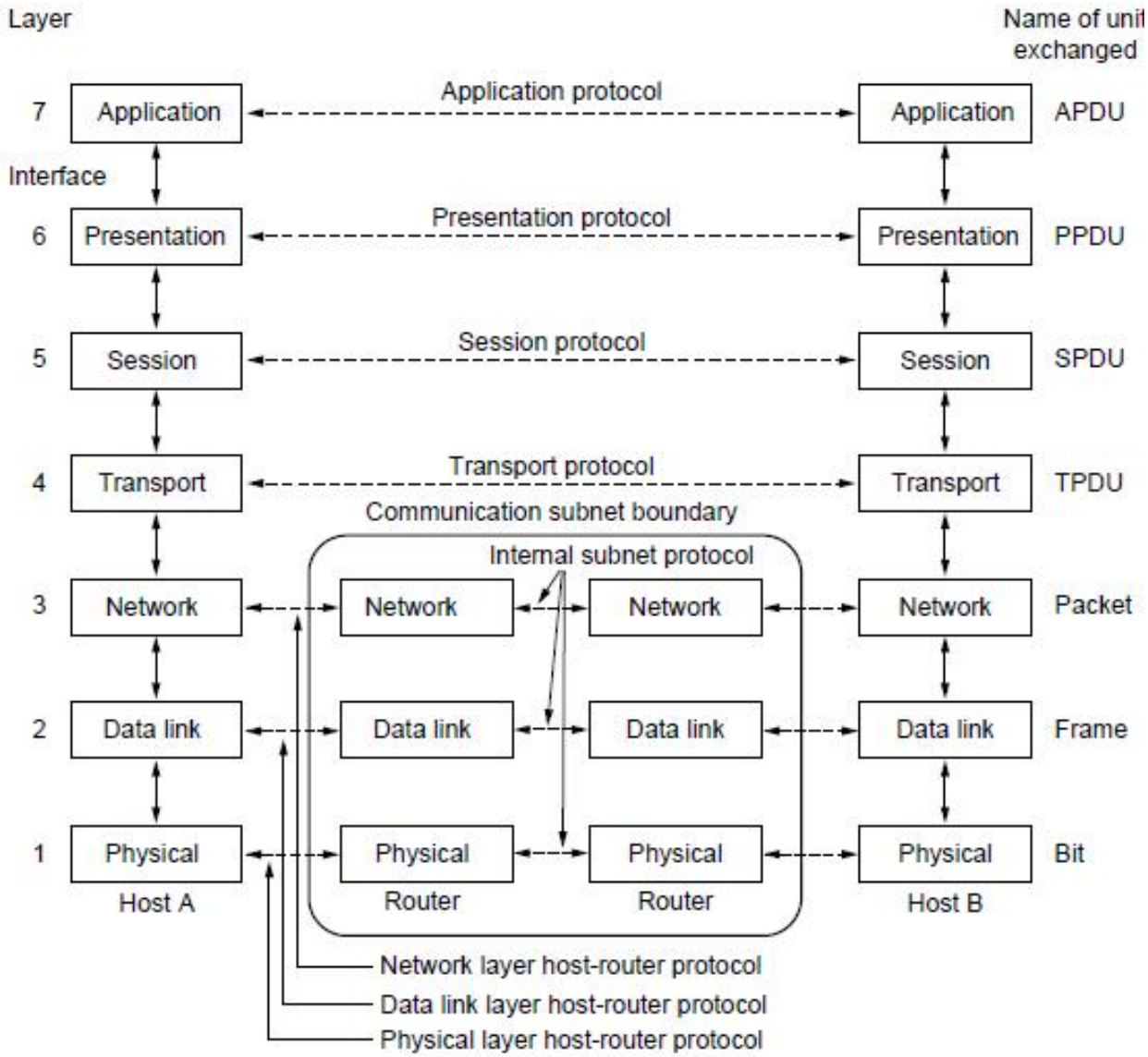
- Model used in the text
- Comparison of OSI and TCP/IP
  - Critique of OSI model and protocols
  - Critique of TCP/IP model

§1.6.0 The OSI Reference Model I

Principles for the seven layers

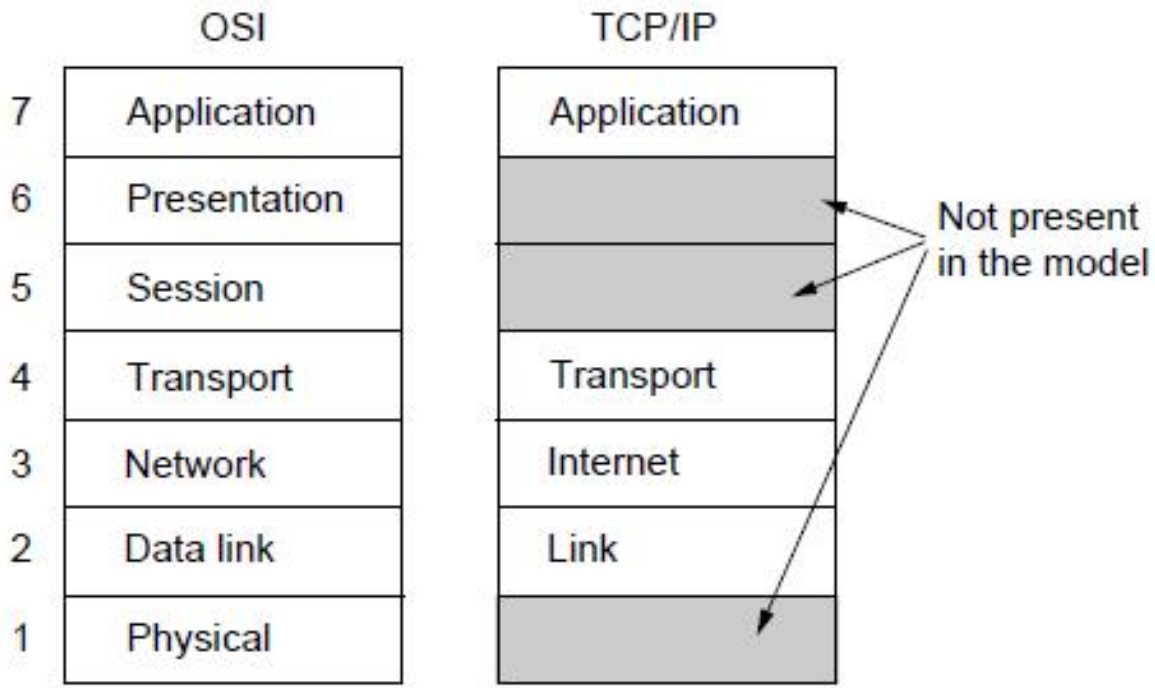
1. Layers are created for different abstractions
2. Each layer performs well-defined function(s)
3. The function of a layer is chosen with definition of international standard protocols in mind
4. Minimize information flow across interfaces between boundaries
5. Optimal number of layers

§1.6.0 The OSI Reference Model II

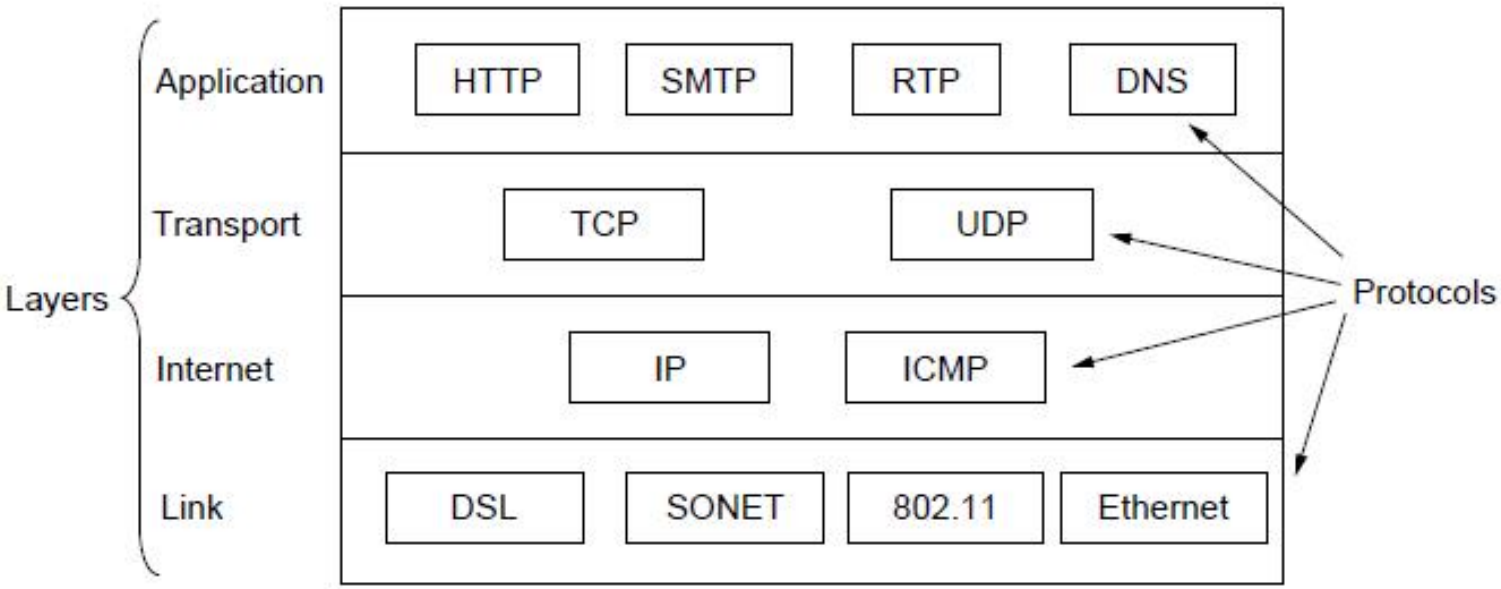


§1.7.0 TCP/IP Reference Model I

1. Link layer
2. Internet layer
3. Transport layer
4. Application layer

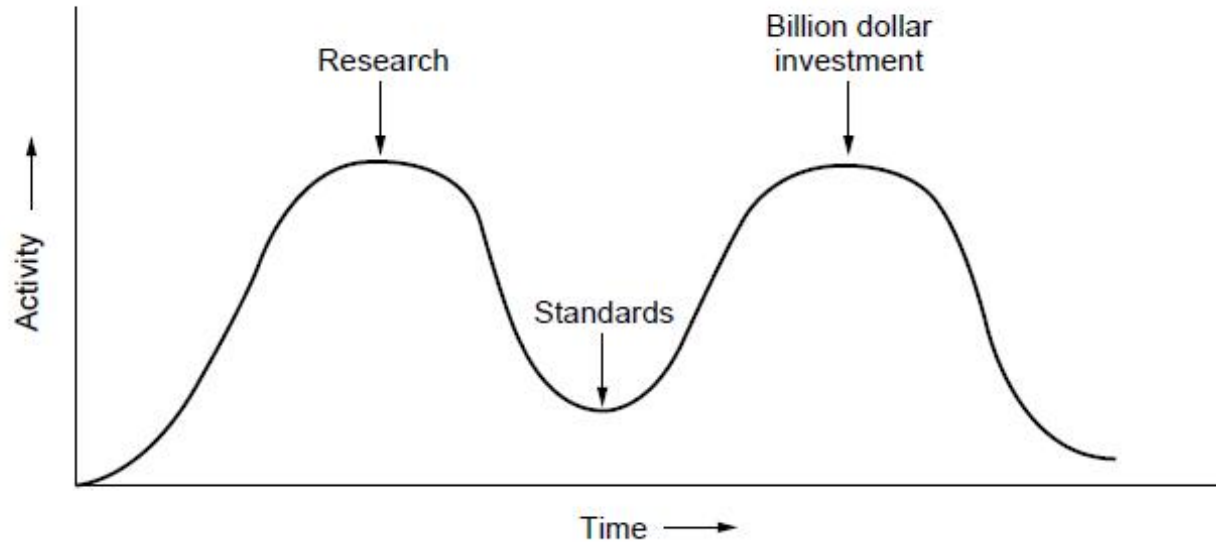


§1.7.0 TCP/IP Reference Model II



§1.7.1 OSI Concepts and Critiques

1. Concepts central to OSI model
   - Services
   - Interfaces
   - Protocols
2. Critique of the OSI Model and Protocols
   - Bad timin.
   - Bad technology
   - Bad implementations
   - Bad politics

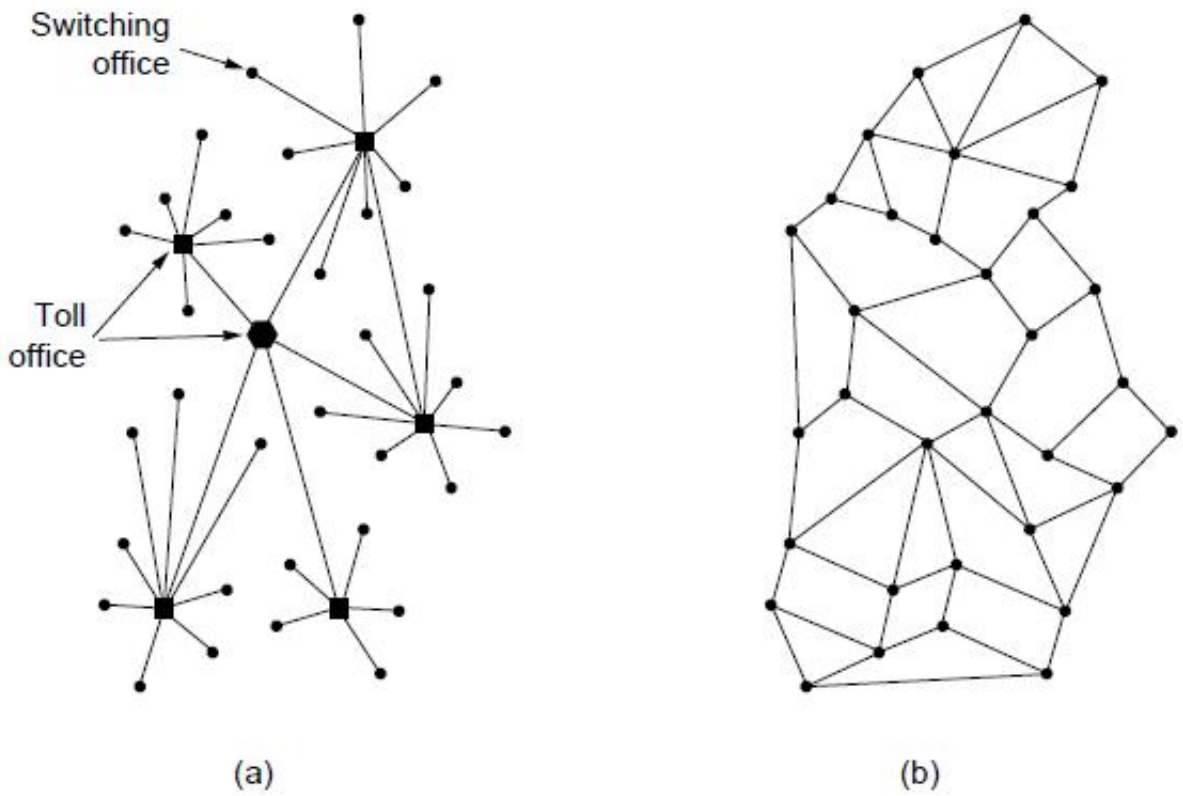


Bad Timing

§1.8.0 Network Examples

- Internet
- ARPANET
- NSFNET
- Third-generation mobile phone networks
- Wireless LANs: 802.11 (WiFI), 802.16(WiMax), 802.15 (Bluetooth)
- Radio Frequency Identification (RFID) and sensor networks

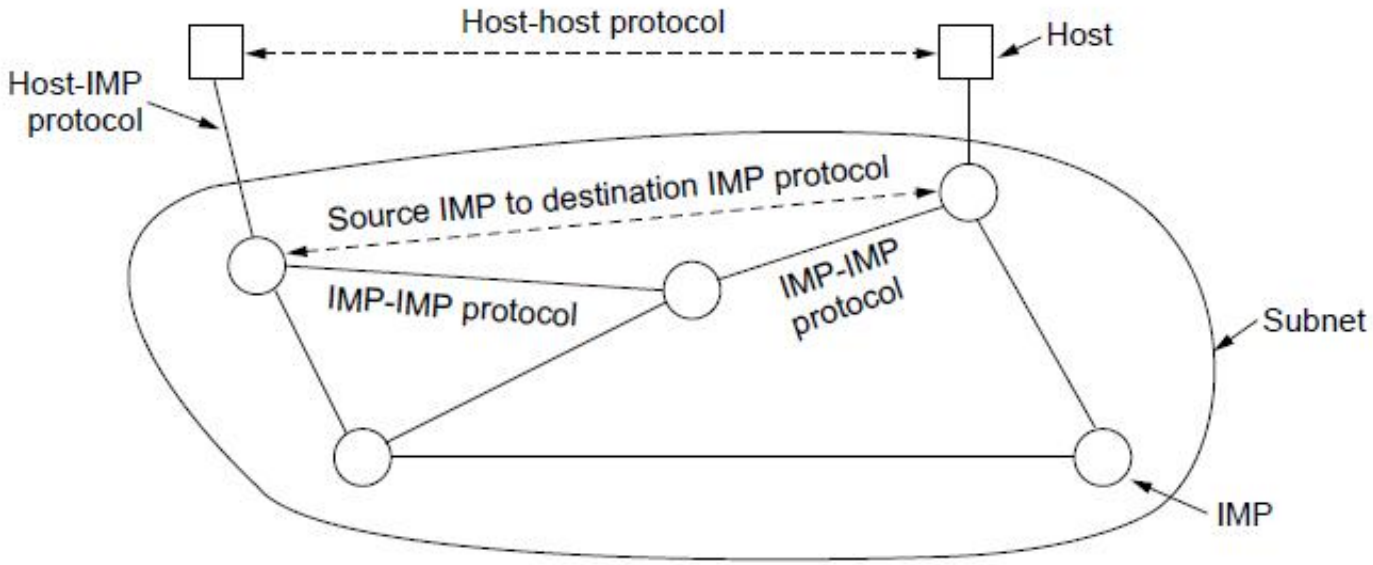
§1.8.1 ARPANET I



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

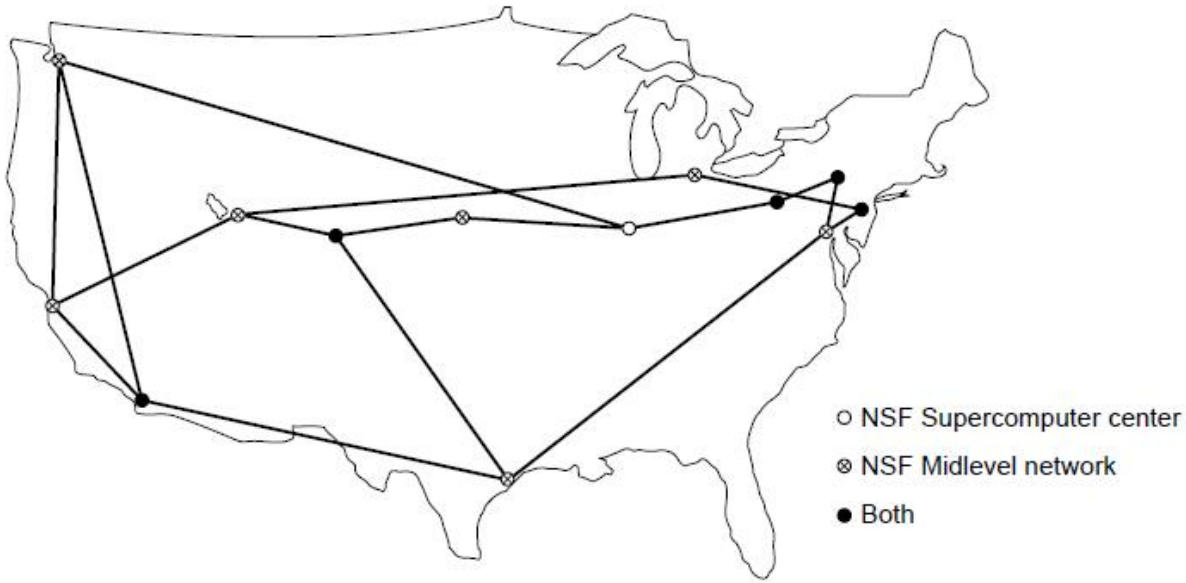
§1.8.1 ARPANET II

- The original ARPANET design



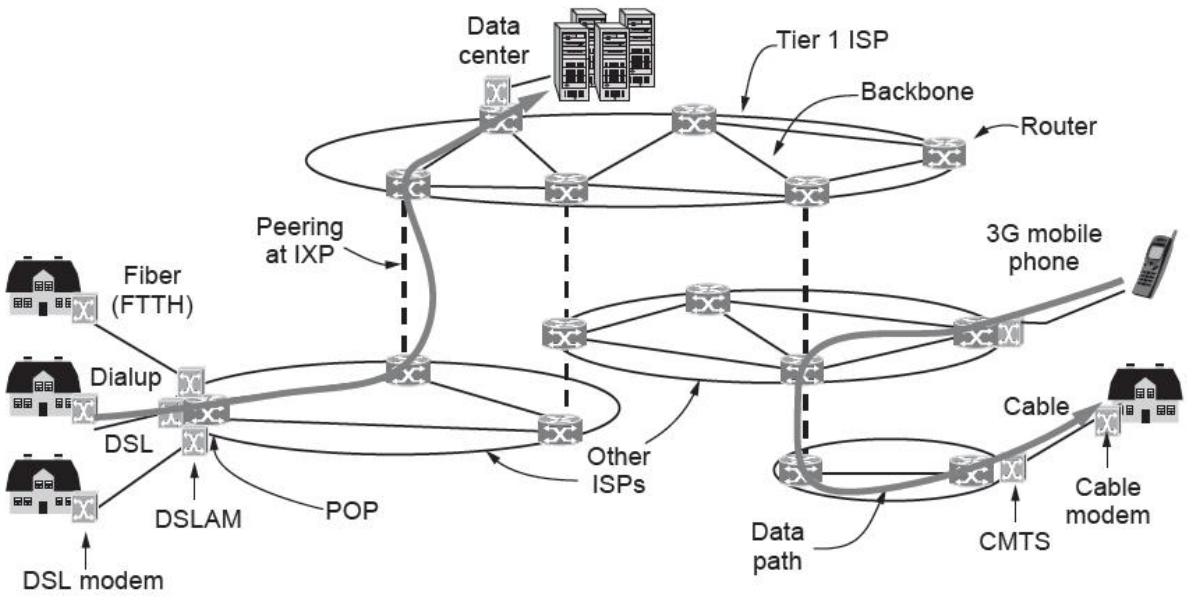
- Interface Message Processor (IMP) = Roter

§1.8.2 NSFNET



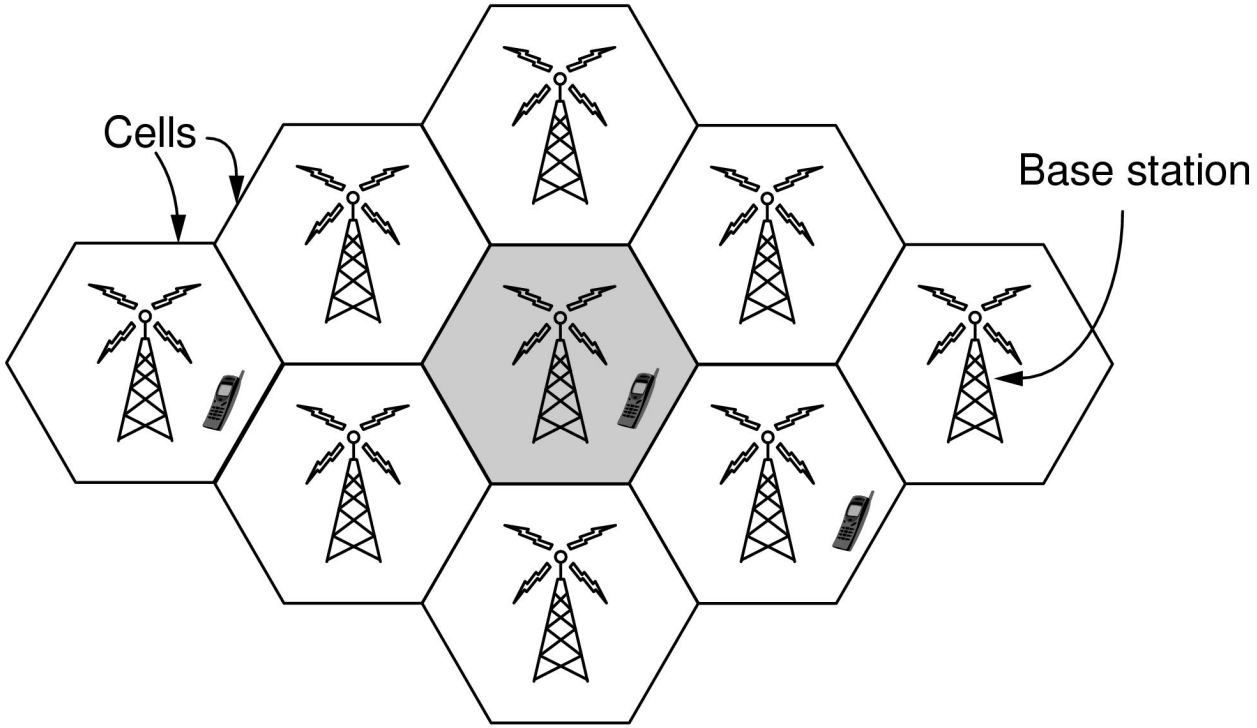
- The NSFNET backbone in 1988

§1.8.3 Architecture of the Internet

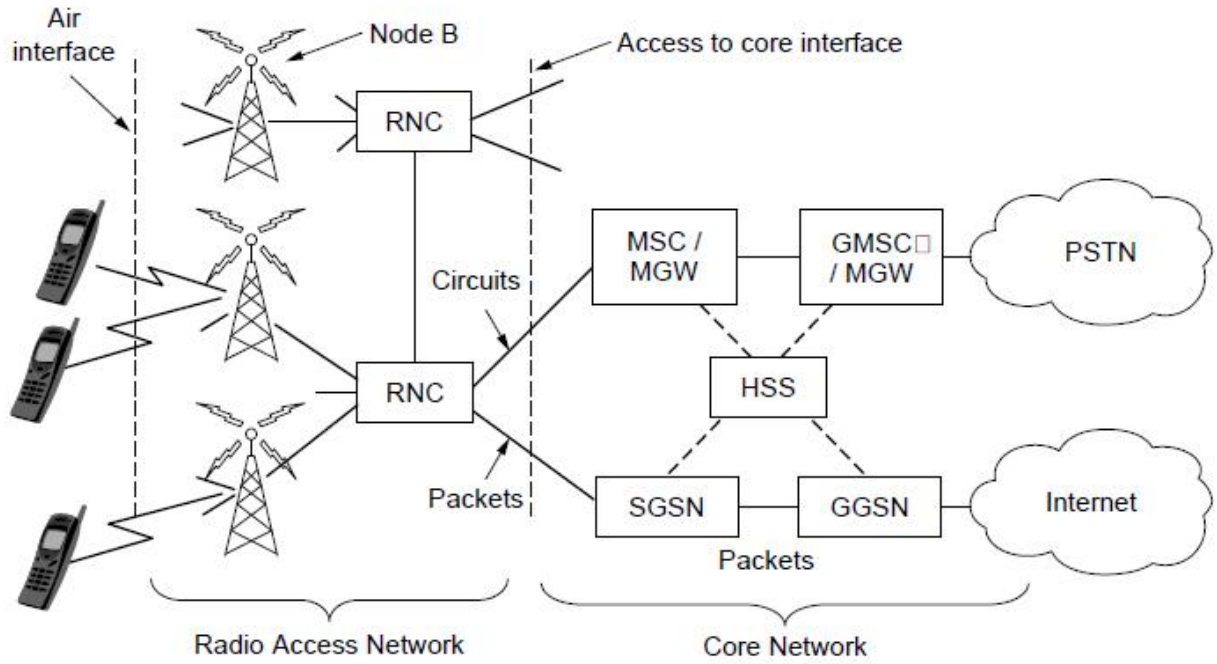


- Overview of the Internet architecture
  - DSLAM: Digital Subscriber Line Access Multiplexer
  - POP: Point of Presence
  - FTTH: Fiber to the Home
  - IXP: Internet eXchange Point
  - CMTS: Cable Modem Termination System

§1.8.4 Third-Generation Mobile Phone Networks I

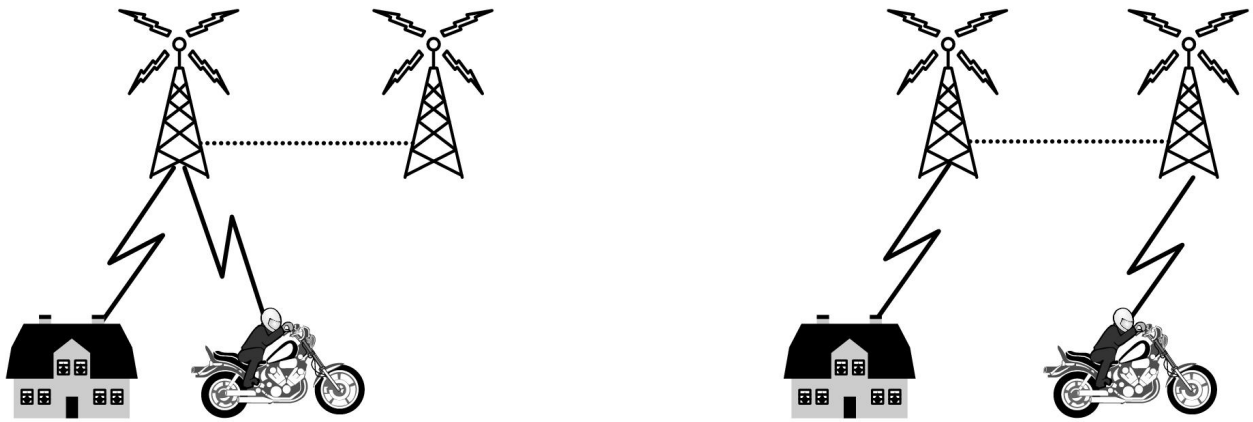


§1.8.4 Third-Generation Mobile Phone Networks II



- Architecture of the UMTS 3G mobile phone network
  - Cellular design of mobile phone networks
    - UMTS: Universal Mobile Telecommunication System
    - RNC: Radio Network Controller
    - GPRS: General Packet Radio Service
    - GGSN: Gateway GPRS Support Node
    - SGSN: Service GPRS Support Node
    - MGW: Media Gateway
    - GMSC: Gateway Mobile Switching Center
    - HSS: Home Subscriber Server

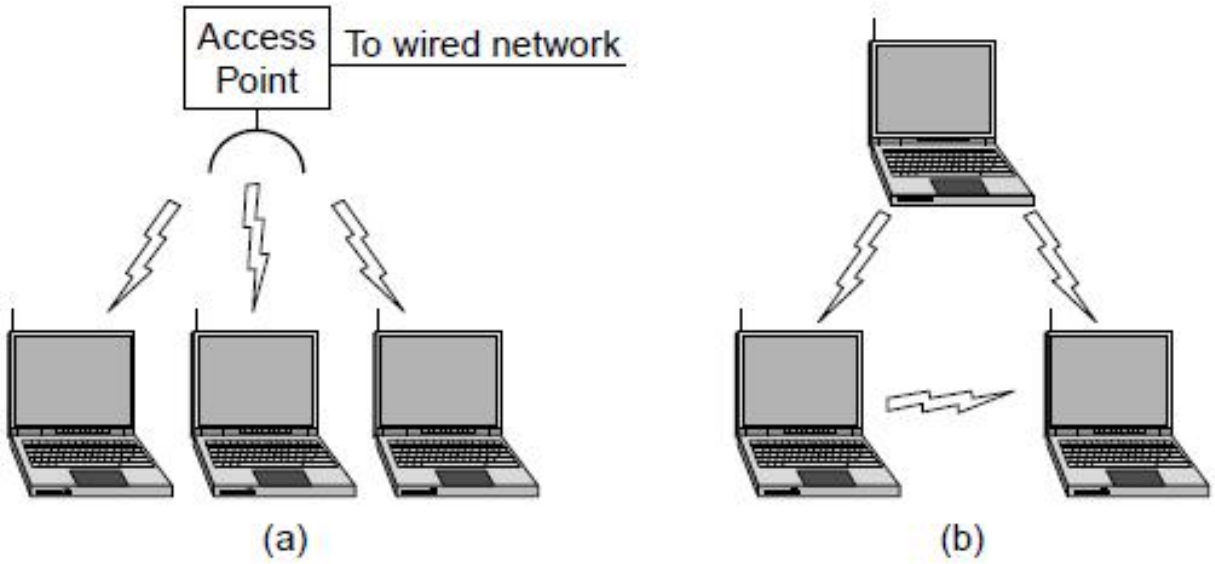
§1.8.4 Third-Generation Mobile Phone Networks III



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

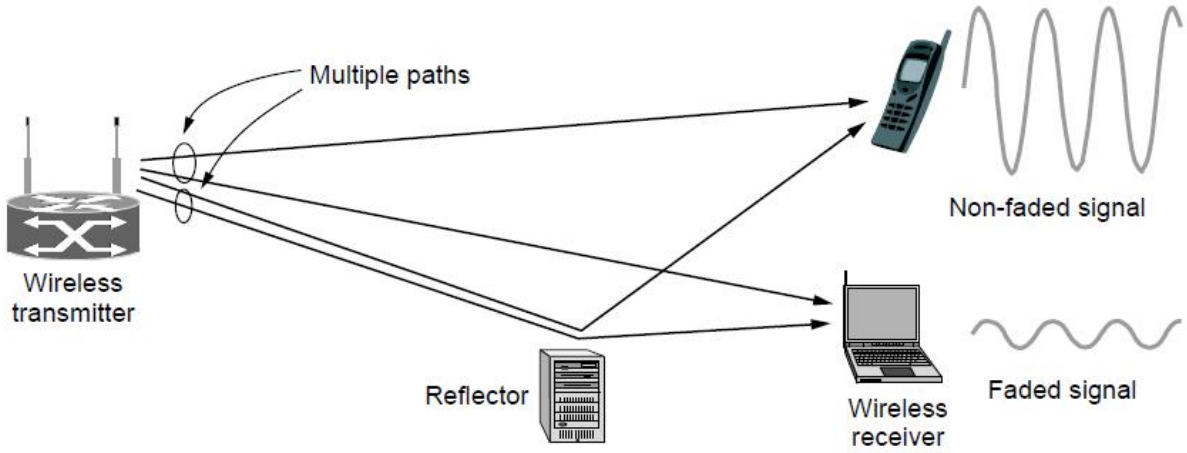
- 4th & 5th generations tried to improve
  - Transmission range
  - Better bit-rate (bandwidth)
  - Quality of Service (QoS)
  - Better security

§1.9.0 Wireless LAN's: IEEE 802.11x I



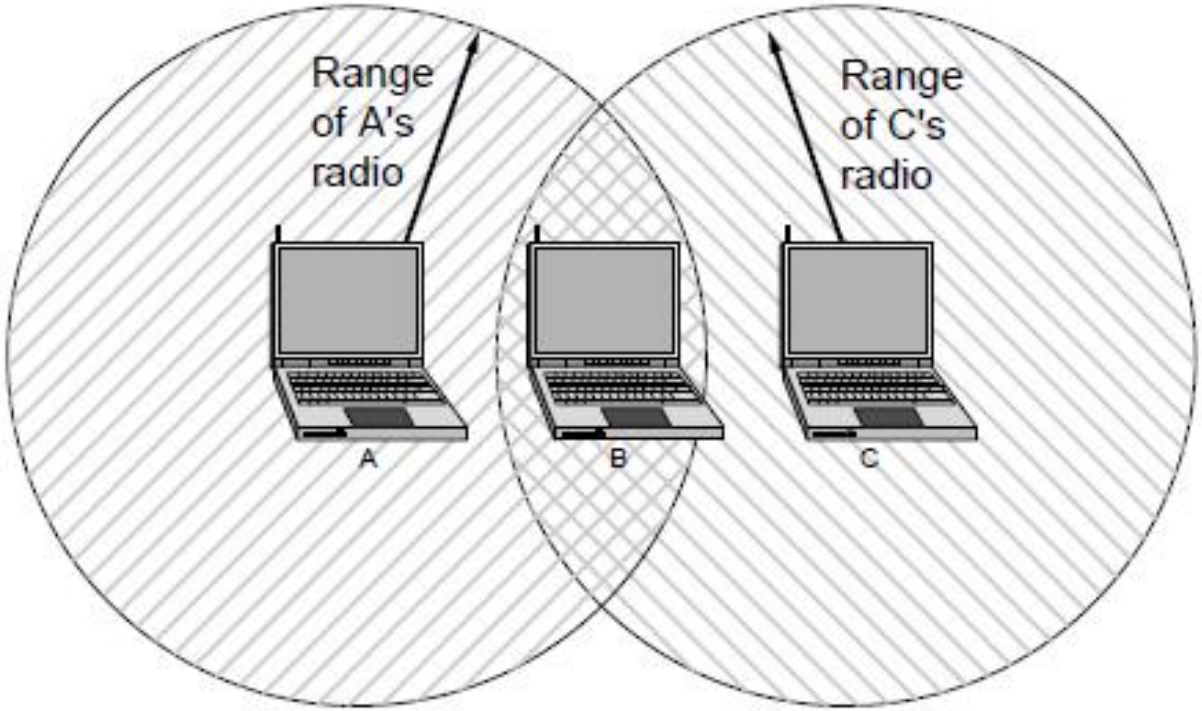
- Wireless network with an access point
- Ad hoc network

§1.9.0 Wireless LAN's: IEEE 802.11x II



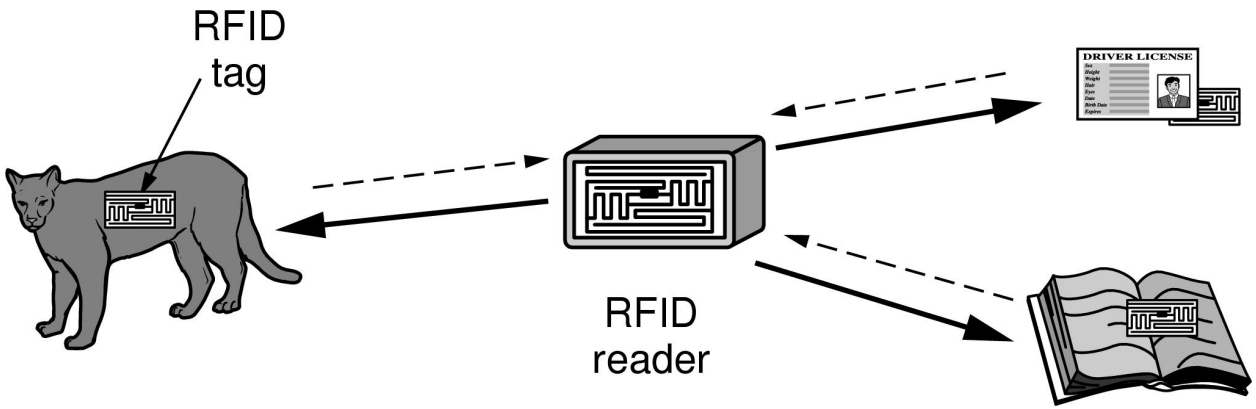
- The range of a single radio may not cover the entire system

§1.9.0 Wireless LAN's: IEEE 802.11x III



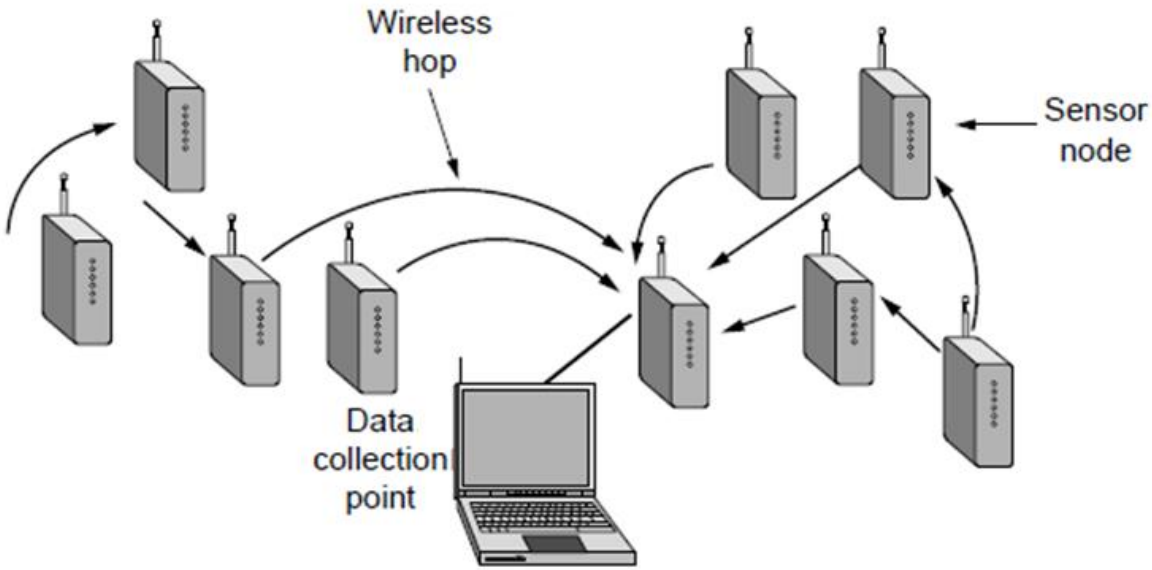
- The range of a single radio may not cover the entire system

§1.10.0 RFID and Sensor Networks I



- RFID used to network everyday objects

§1.10.0 RFID and Sensor Networks II



- Multihop topology of a sensor network

§1.11.0 Network Standardization I

- Who is who in telecommunications
- Who is who in international standards
- Who is who in Internet standards
- The 802 working groups

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 important ones are marked with *
- The ones marked with ↓ are hibernating
- The one marked with † gave up and disbanded itself

§1.11.0 Network Standardization II

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)
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802.10 ↓	Virtual LANs and security
802.11 *	Wireless LANs (WiFi)
802.12 ↓	Demand priority (Hewlett-Packard's AnyLAN)

§1.11.0 Network Standardization III

- Some wireless standards

Amendment	Description
802.11a	Physical Layer 5 GHz band
802.11b	Physical Layer 2.4 GHz band
802.11c	Bridging operations with roaming (802.11d)
802.11d	Roaming operations
802.11e	QoS to the MAC layer
802.11g	Physical Layer 2.4 GHz band
802.11h	Spectrum management
802.11i	Enhancing security
802.11j	4.9-5.0 GHz operation in Japan
802.11k	Radio resource measurements
802.11m	Maintenance of the standard
802.11n	MIMO antenna
802.11p	High mobility
802.11r	Fast roaming
802.11s	Mesh
802.11t	Testing WLAN Equipment
802.11u	Internetworking with other networks
802.11v	Network management
802.11w	Extension 802.11i; Enhancing security further
802.11y	3.65-3.7 GHz in theUS

§1.12.0 What's Next?

- Device-to-Device Communication ⇒ Chapter 2
- Point-to-Point (P2P) Communication (one hop communication) ⇒ Chapters 3 & 4
- End-to-End (E2E) Communication (multi hop communication) ⇒ Chapters 5 & 6

§1.13.0 Suggested Exercises From the Text

3 The performance of a client-server system is influenced by two network factors: the bandwidth of the network (how many bits/sec it can transport) and the latency (how many seconds it takes for the first bit to get from the client to the server). Give an example of a network that exhibits high bandwidth and high latency. Then give an example of one with low bandwidth and low latency.

4 Besides bandwidth and latency, what other parameter is needed to give a good characterization of the quality of service offered by a network used for digitized voice traffic?

13 What does ”negotiation” mean when discussing network protocols? Give an example.

16 A system has an n-layer protocol hierarchy. Applications generate messages of length M bytes. At each of the layers, an h-byte header is added. What fraction of the network bandwidth is filled with headers? 21. List two ways in which the OSI reference model and the TCP/IP reference model are the same. Now list two ways in which they differ.

20 When a file is transferred between two computers, two acknowledgment strategies are possible. In the first one, the file is chopped up into packets, which are individually acknowledged by the receiver, but the file transfer as a whole is not acknowledged. In the second one, the packets are not acknowledged individually, but the entire file is acknowledged when it arrives. Discuss these two approaches.

23 An image is 1024 x 768 pixels with 3 bytes/pixel. Assume the image is uncompressed. How long does it take to transmit it over a 56-kbps modem channel? Over a 1-Mbps cable modem? Over a 10-Mbps Ethernet? Over 100-Mbps Ethernet?

33 The ping program allows you to send a test packet to a given location and see how long it takes to get there and back. Try using ping to see how long it takes to get from your location to several known locations. From these data, plot the one-way transit time over the Internet as a function of distance. It is best to use universities since the location of their servers is known very accurately. For example, Berkeley.edu is in Berkeley, California, mit.edu is in Cambridge, Massachusetts, vu.nl is in Amsterdam, The Netherlands, www.usyd.edu.au is in Sydney, Australia, and www.uct.ac.za is in Cape Town, South Africa.

§1.14.0 References

[Tanenbaum and Wetherall, 2011] Tanenbaum, A. S. and Wetherall, D. J. (2011).
Computer Networks: 5th Edition.
Prentice Hall PTR.