Reference Models

- OSI reference model :
  - Although the protocols associated with the OSI model are rarely used any more, the model itself is actually quite general and still valid.
- TCP/IP reference model :
  - The model itself is not of much use but the protocols are widely used.

Reference Models(cont.)

The OSI Reference Model

- Designed in 1983 based on a proposal developed by the International Standards Organization (ISO).
- Revised in 1995, then after, the model is called the ISO **OSI (Open Systems Interconnection)**.
- Deals with connecting open systems (systems that are open for communication with other systems).
- Based on **seven layers**.

Reference Models(cont.)

The OSI Reference Model

Principles :

- Layers created where different abstraction needed.
- 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.

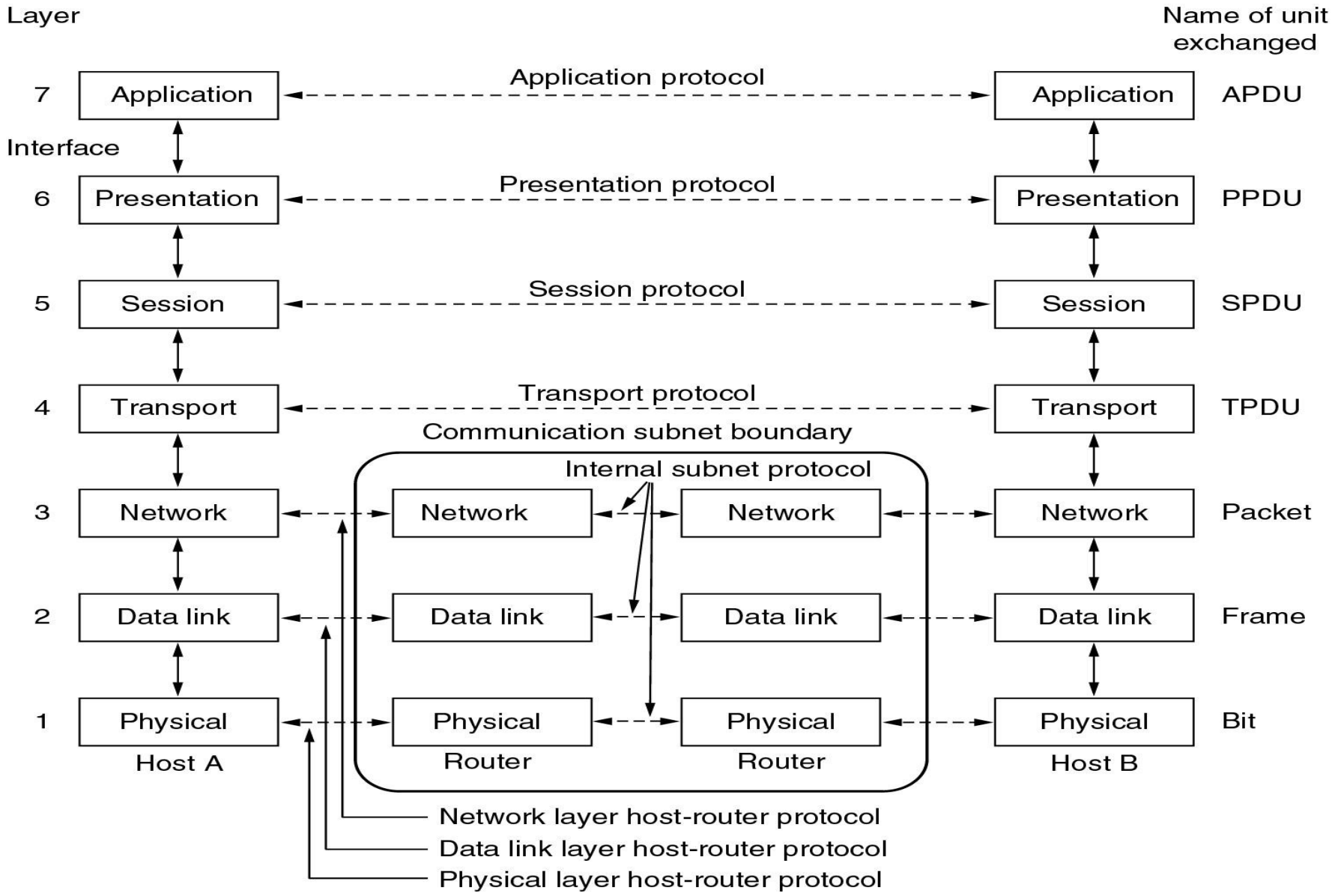
Layers :

1. Physical Layer
2. Data Link Layer
3. Network Layer
4. Transport Layer
5. Session Layer
6. Presentation Layer
7. Application Layer

Reference Models(cont.)

The OSI Reference Model

Structure of
OSI reference model.



Reference Models(cont.)

The OSI Reference Model

Physical Layer:

- Concerned with transmitting raw bits over a communication channel.
- Converts data from the upper layers into '1's and '0's for transmission over media.
- Defines how data is encoded onto the media to transmit the data.
- Defined on this layer: Cable standards, wireless standards, and fiber optic standards.
- Copper wiring, fiber optic cable, radio frequencies, anything that can be used to transmit data is defined on the Physical layer of the OSI Model.

Design issues :

- Ensuring that when one side sends a 1 – bit of information it is received as 1-bit (not as 0-bit or 2-or more- bits).
- What type of signal should be used to represent "1" and "0"?
- How many nano seconds a bit lasts?
- Whether transmission can occur simultaneously in both direction?
- How many pins the network connector has?
- What each pin is used for?

Reference Models(cont.)

The OSI Reference Model

Data Link Layer:

- Transforms the raw data bits to a data frame (few hundred/thousand bits)
- Responsible for sequential transmission of frames from node to node or computer to computer
- In reliable service the receiver confirms correct receipt of each frame by sending back an *acknowledgment frame*.
- Protocols defined include Ethernet Protocol and Point-to-Point Protocol (PPP)
- Two sub layers: Logical Link Control (LLC) and the Media Access Control (MAC)
  - Logical Link Control (LLC)
    - –Flow control, Error control
  - Media Access Control (MAC)
    - –Determines which computer has access to the network media at any given time
    - –Determines where one frame ends and the next one starts, called frame synchronization

Reference Models(cont.)

The OSI Reference Model

Network Layer:

- Controls the operation of the subnet.
- Responsible for moving (or routing) packets (data) from one end of the network to the other, called *end-to-end communications.*
- Determines how packets to be *routed* from source (in one network) to destination (in another network).
  - *Static table (rarely changed)*
  - *Dynamic table (Often changed to avoid failed components) : Route can be determined at the start of each conversion (or) new route for each packet depending on network load.*
- Responsible for congestion handling : If too many packets are present in the subnet at the same time, they will get in each other's way forming bottlenecks.
- Deals with quality of service (i.e. jitter, transit time, delay etc.)
- Handles the issues raised due to different physical addresses of machines belonging to different networks.

Reference Models(cont.)

The OSI Reference Model

Network Layer types :

In datagram networks

- Provides both routing and data forwarding

In connection-oriented network

- Separate data plane and control plane
- Data plane only forwards and schedules data (touches every byte)
- Control plane responsible for routing, call establishment, call-teardown (doesn't touch data bytes)

In Internet

- Network layer is provided by Internet Protocol
- Found in all **end-systems** and **intermediate systems**
- Packet-forwarding, routing, scheduling
- Unique IP addresses

Reference Models(cont.)

The OSI Reference Model

Transport Layer:

- Accepts data from higher levels and splits it into smaller segments that can be sent to network layer.
- Also, reassembles data segments into data for the use of higher layers.
- Puts segments in correct order (called sequencing), so they can be reassembled in correct order at destination.
- Concerned with the reliability of the transport of sent data.
- May use a *connection-oriented protocol* such as TCP to ensure destination has received segments.
- May use a *connectionless protocol* such as UDP to send segments without assurance of delivery.
- It is a true end-to-end layer; it carries data all the way form the source to the destination.
    - In the lower layers (i.e. 1 to 3), the protocols are between each machine and its immediate neighbours (may be routers), and not between the ultimate source and destination machines.

Reference Models(cont.)

The OSI Reference Model

Session Layer:

- Allows users on different machines to establish *sessions* between them.
- Services:

  Dialog control - Keeping track of whose turn is it to transmit

  Token management – Preventing two parties from attempting the same critical operation simultaneously

  Synchronization – Check pointing long transmissions to allow them to pick up form where they left off in the event of a crash and subsequent recovery.
- Establishes, manages, and terminates connections
- Provides duplex, half-duplex, or simplex communications between devices
- Internet – doesn’t have a standard session layer

Reference Models(cont.)

The OSI Reference Model

Presentation Layer:

- Concerned with the syntax and semantics of the information transmitted.
- Since different computer may deal with different data representations a standard encoding is done, thus handles three primary tasks:

  –Translation , –Compression , –Encryption

  Ex : ASCII
- Internet

  –no standard presentation layer

Application Layer:

- Contains all services or protocols needed by application software or operating system to communicate on the network

  Example : **HTTP (Hyper Text Transfer Protocol**), which is the basis for the World Wide Web.

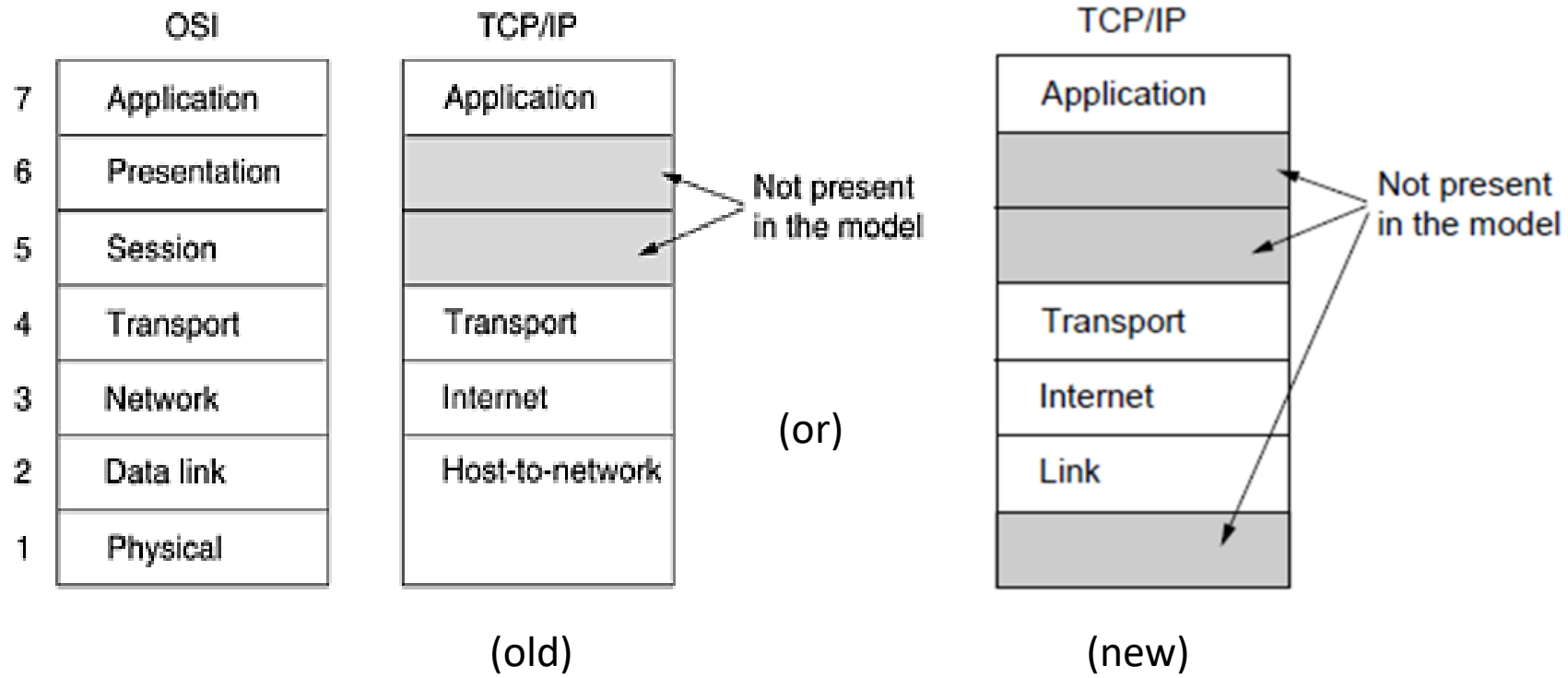
Reference Models(cont.)

The TCP/IP Reference Model

- Proposed earlier to OSI model.
- Used in **ARPANET**(grandparent of all wide area computer) and it's successor **the internet**
  (Also used in private networks)
- Designed to support/interconnect different types of network (e.g. interconnection of radio network and computer network).
- Four protocol layers :
  - Host-to-network/link
  - **Internet**
  - **Transport**
  - **Application**
- Design criteria:
  - Network be able to survive loss of subnet hardware without existing conversations being broken off.
  - Applications with divergent requirements were supported ranging from file transfer to real-time speech transmission.

Reference Models(cont.)

The TCP/IP Reference Model



Note :

When TCP/IP is compared to OSI it can be seen that the host-to-network layer is equivalent to the combination of physical and data link layer. Also, the internet layer is equivalent to the network layer, and the application layer is roughly doing the job of the session, presentation, and application layers

Reference Models(cont.)

The TCP/IP Reference Model

Link Layer :

- Describes what links such as serial lines and classic Ethernet must do to meet the needs of this connectionless internet layer.
- It is not actual layer in the classical sense of the term rather is an interface between hosts and transmission links.

Internet Layer :

- Permit hosts to inject packets into any network and have them travel independently to the destination (potentially on a different network).
- The packets may arrive in a completely random order from the original and the higher layer must rearrange them – if in-order of delivery is desired.

  (An analogy example : Letters dropped in the post box in sequence may not reach in the same sequence)
- Defines an official packet format and protocol called IP (Internet Protocol).
- Packet routing is a major issue and IP has not proven effective at avoiding congestion.

Reference Models(cont.)

The TCP/IP Reference Model

Transport Layer :

- Allow peer entities on the source and destination hosts to carry on a conversation.
- Uses either of the two types of transport protocol (i.e. TCP and UDP).

TCP(Transmission Control Protocol) :

- A reliable connection-oriented protocol.
- Allows a byte stream originating on one machine to be delivered without error on any other machine in the internet.
- It fragments the incoming byte stream into discrete messages and passes each one on to the internet layer.
- At the destination, the receiving TCP process reassembles the received messages into the output stream.
- TCP also handles flow control to make sure a fast sender cannot swamp a slow receiver with more messages than it can handle.

UDP(User Datagram Protocol):

- An unreliable, connectionless protocol for applications that do not want sequencing or flow control and wish to provide their own.
- Also widely used for one-shot, client-server-type request-reply queries and applications in which prompt delivery is more important than accurate delivery, such as transmitting speech or video.

Reference Models(cont.)

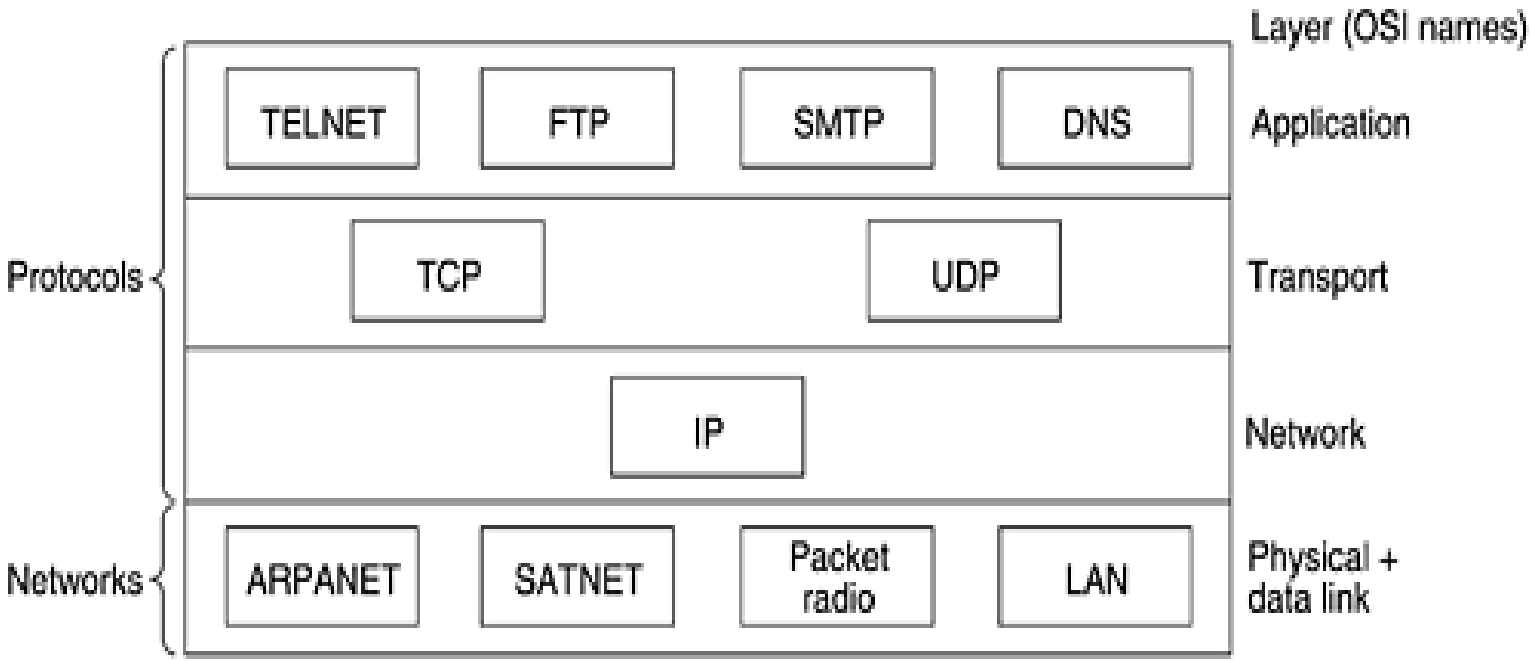
The TCP/IP Reference Model

Application Layer :

- Define the rules when implementing specific network applications.
- Applications simply include any session and presentation functions that they require.
- Rely on the underlying layers to provide accurate and efficient data delivery.
- Typical protocols:
  - FTP – File Transfer Protocol (For file transfer)
  - Telnet – Remote terminal protocol (For remote login on any other computer on the network)
  - SMTP – Simple Mail Transfer Protocol (For mail transfer)
  - HTTP – Hypertext Transfer Protocol (For Web browsing)

Reference Models(cont.)

The TCP/IP Reference Model



Protocols and networks in the TCP/IP model initially

Reference Models(cont.)

A Comparison of the OSI and TCP/IP Reference Models

Similarities :

1. Both lie on the concept of a stack of independent protocols.
2. Functionality of the layers is roughly similar (for example in both models, the layers above transport are application-oriented users of the transport service).

Differences :

OSI reference model	TCP/IP reference model
Uses 7 different layers.	Uses 4 different layers.
Supports both connectionless & connection oriented service in the network layer but only connection oriented service in transport layer.	Supports only connectionless service in the network layer but both connectionless & connection oriented service in transport layer.
Clearly distincts service, interface & protocol.	Doesn't clearly distinguish service, interface & protocol.
Protocols are better hidden and can be replaced relatively easily as the technology changes.	Protocols are not hidden and can not be replaced easily as the technology changes (e.g. Replacing IP with a different protocol is virtually impossible).
The reference model was devised before the corresponding protocols were invented.	The protocols came first, and the model was really just a description of the existing protocols since the protocols fit perfectly.

Example networks

The computer networks that are functioning in the current scenario are associated with so many attributes like size, technology, goals etc.

- Internet
  - ARPANET
  - NSFNET
- Connection oriented network : ATM
- Ethernet
- Wireless LANs: 802.11

Example networks (cont.)

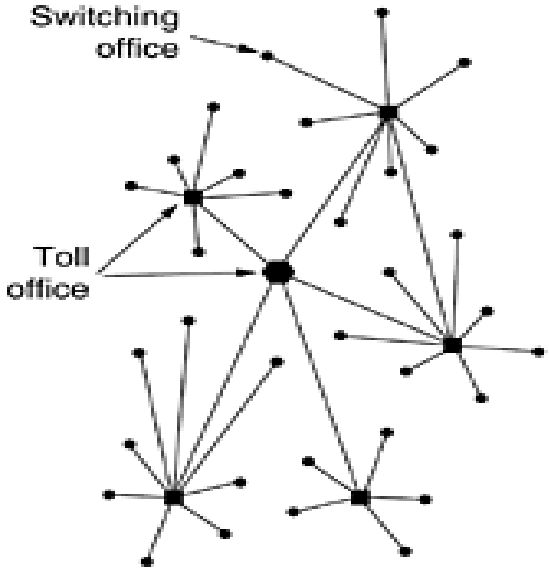
The Internet

- Never be considered as a single network rather than a vast collection of different networks that use certain common protocols and provide certain common services.
- Not planned by anyone and not controlled by anyone.
- Revolutionized many aspects of our daily lives.
- People use internet for various reasons.
- History :
  - ARPANET
  - NSFNET

Example networks (cont.)

ARPANET

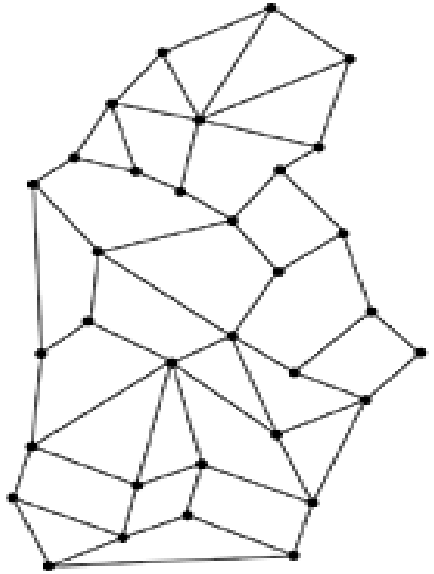
- Started with the want from DoD in late 1950 to develop a command-and-control network.
- In the beginning uses the base of existing public telephone network.
- Issue : Structure is vulnerable (i.e. destroy of toll offices fragments the system into isolated islands).



Structure of the telephone system

- Around 1960 the DoD awarded a contract to the RAND Corporation.
- Paul Baran, proposed the incorporation of digital packet switching technology in a highly distributed and fault tolerant system.

(Idea was dismissed)



Baran's proposed distributed switching system

Example networks (cont.)

ARPANET

- Following several years, **ARPA (Advanced Research Projects Agency)** is created to find the solution related to design of the command and control network.
- In 1967, Lary Roberts (director of ARPA) presented an idea (Wesley clark) in the form of paper related to building of a packet switched subnet, where each host has it's own router.
- Following to this, the practical implementation of a network is determined by Roberts with a name **ARPANET**.
- A consulting firm named BBN had contracted to make practical implementation of ARPANET.
  - Built subnet
  - Wrote the subnet software
  - Transmission line leased from telephone companies.

Example networks (cont.)

ARPANET

Concept :

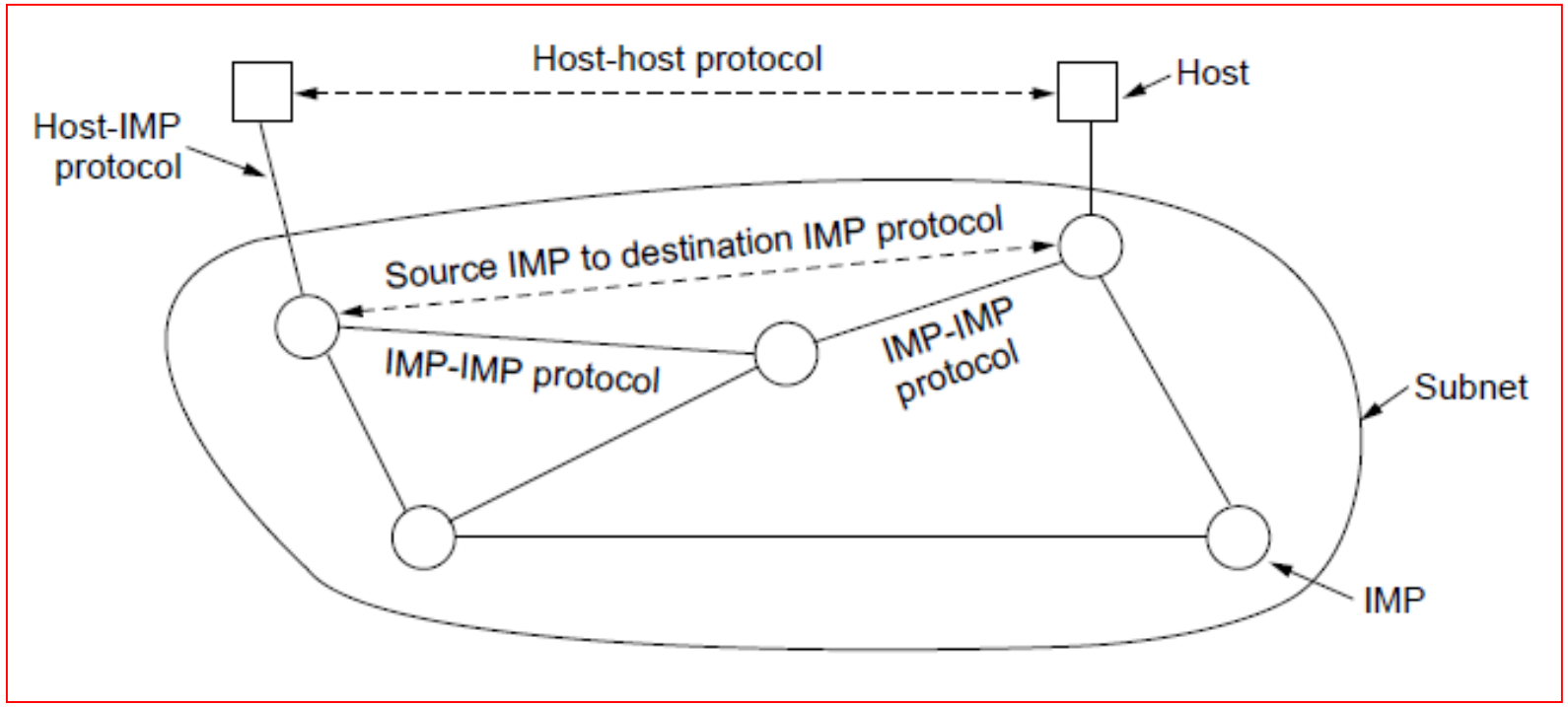
- Subnet consists of minicomputers called **IMPs (Interface Message Processors).**
- 56-kbps transmission lines.
- Each IMP connected to at least two other IMPs.
- Datagram subnet (if some lines and IMPs were destroyed, messages could be automatically rerouted along alternative paths).
- Each node consists of an IMP and a host, in the same room, connected by a short wire.
- A host can send messages of up to 8063 bits to its IMP.
- IMPs break these up into packets of at most 1008 bits and forward them independently toward the destination.
- Each packet was received in its entirety before being forwarded.
- Store-and-forward packet-switching network.

Example networks (cont.)

ARPANET

Software :

- Subnet software : required at the IMP end of the host-IMP connection
  - IMP-IMP protocol
  - Source IMP to destination IMP protocol
- Host software : Required at the host end of the host-IMP connection
  - Host-host protocol
  - Application software



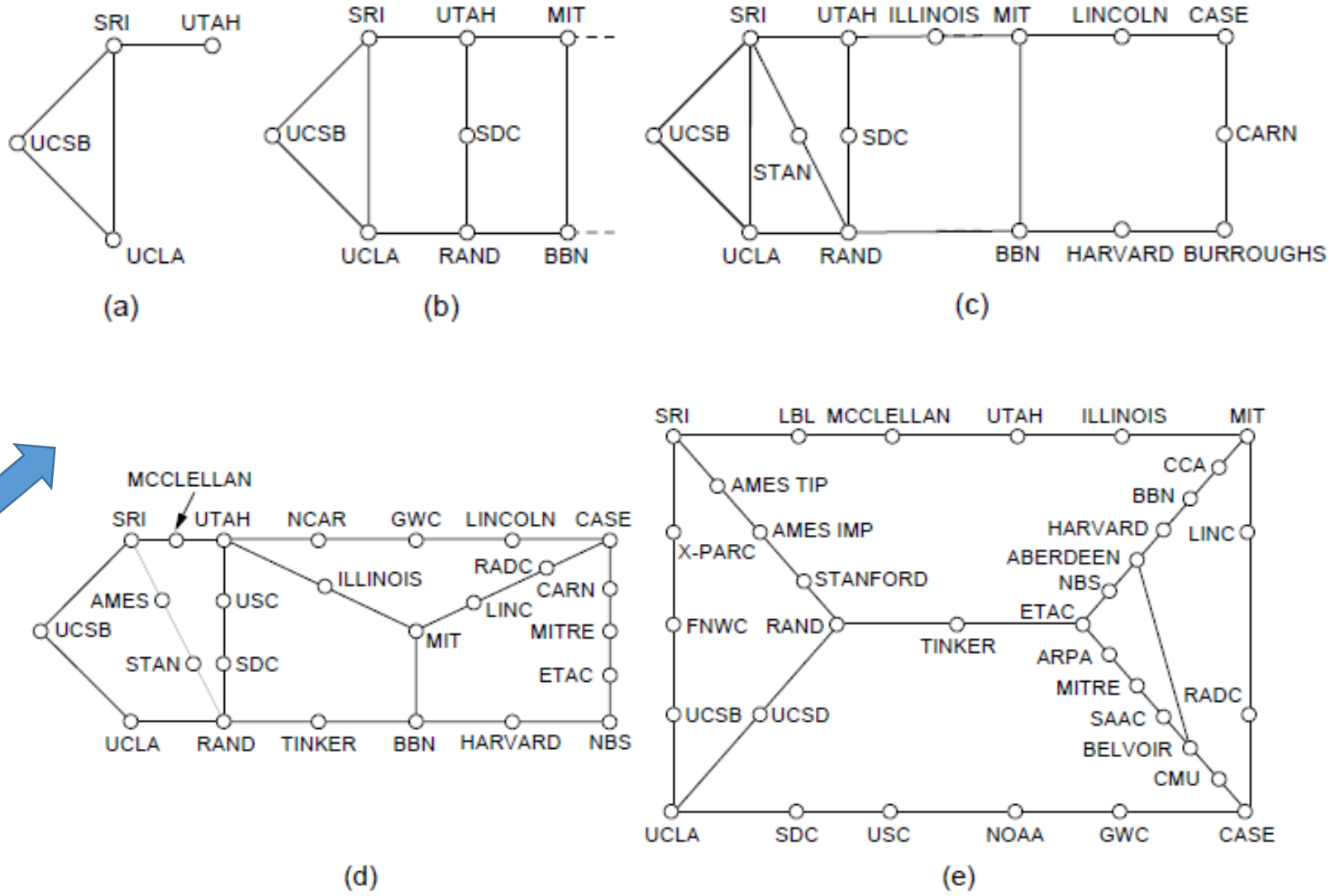
The original ARPANET design

Example networks (cont.)

ARPANET

Growth :

- An experimental network implemented in December 1969 with four nodes: at UCLA, UCSB, SRI, and the University of Utah. (a)
- Installation of more IMPs make the ARPANET to grew rapidly. (b), (c), (d), (e)



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

Example networks (cont.)

ARPANET

Use of TCP/IP :

- ARPANET protocols were not suitable for running over multiple networks.
- Leads to invention and implementation of **TCP/IP**.
- In 1980s, many additional networks, especially LANs, were connected to the ARPANET.

Use of DNS :

- Increase in scale of network → Difficulty in identifying hosts
- Development of **DNS (Domain Name system).**
- Host names mapped to IP addresses.
- DNS is still used in internet.

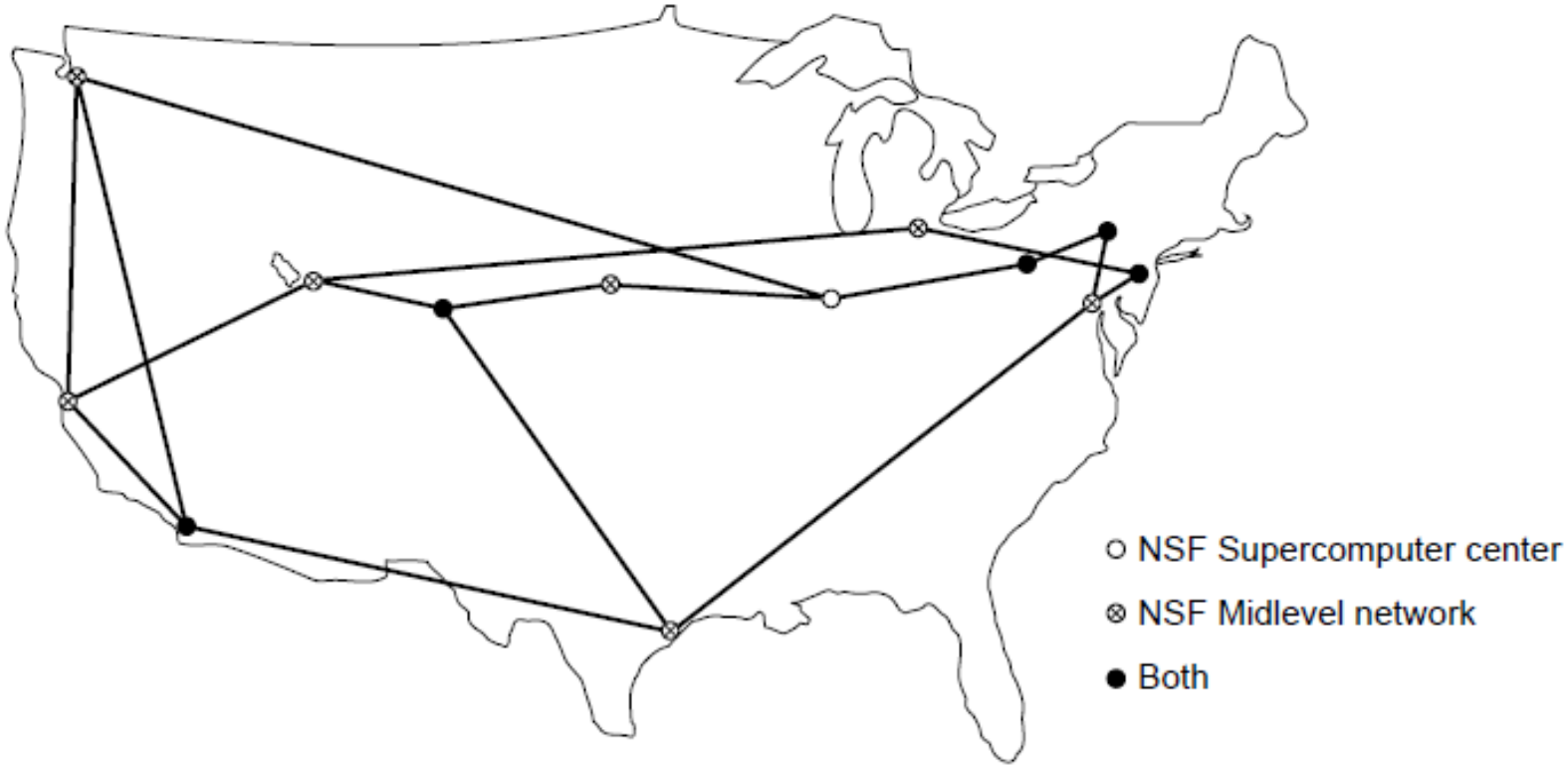
Example networks (cont.)

NSFNET

- Late 1970's : NSF (the U.S. National Science Foundation) had taken a response to design a successor to the ARPANET.
- Open to all university research groups.
- Initial step to built a backbone network to connect its six supercomputer centres.
- Each supercomputer was attached with a microcomputer called a **fuzzball**.
- **Fuzzballs** were connected with 56-kbps leased lines and formed the subnet.
- TCP/IP was used from the beginning.
- Regional networks also connected to the backbone getting the financial support from NSF.
  - Allow users at thousands of universities, research labs, libraries, and museums to access any of the supercomputers and to communicate with one another.
- Combined structure of backbone and regional networks named as **NSFNET**.
- **NSFNET** was also connected with ARPANET through link between fuzzball and IMP.

Example networks (cont.)

NSFNET



The NSFNET backbone in 1988

Example networks (cont.)

NSFNET

NSFNET to ANSNET:

- By 1990s version 2 backbone designed and implemented with the use of fiber channel to provide a speed of 1.5 Mbps.
- NSF with non government organizations forms **ANS (Advanced Networks and Services).**
- In 1990s, ANS took over the NSFNET and renamed it **ANSNET** with a speed 45 Mbps.

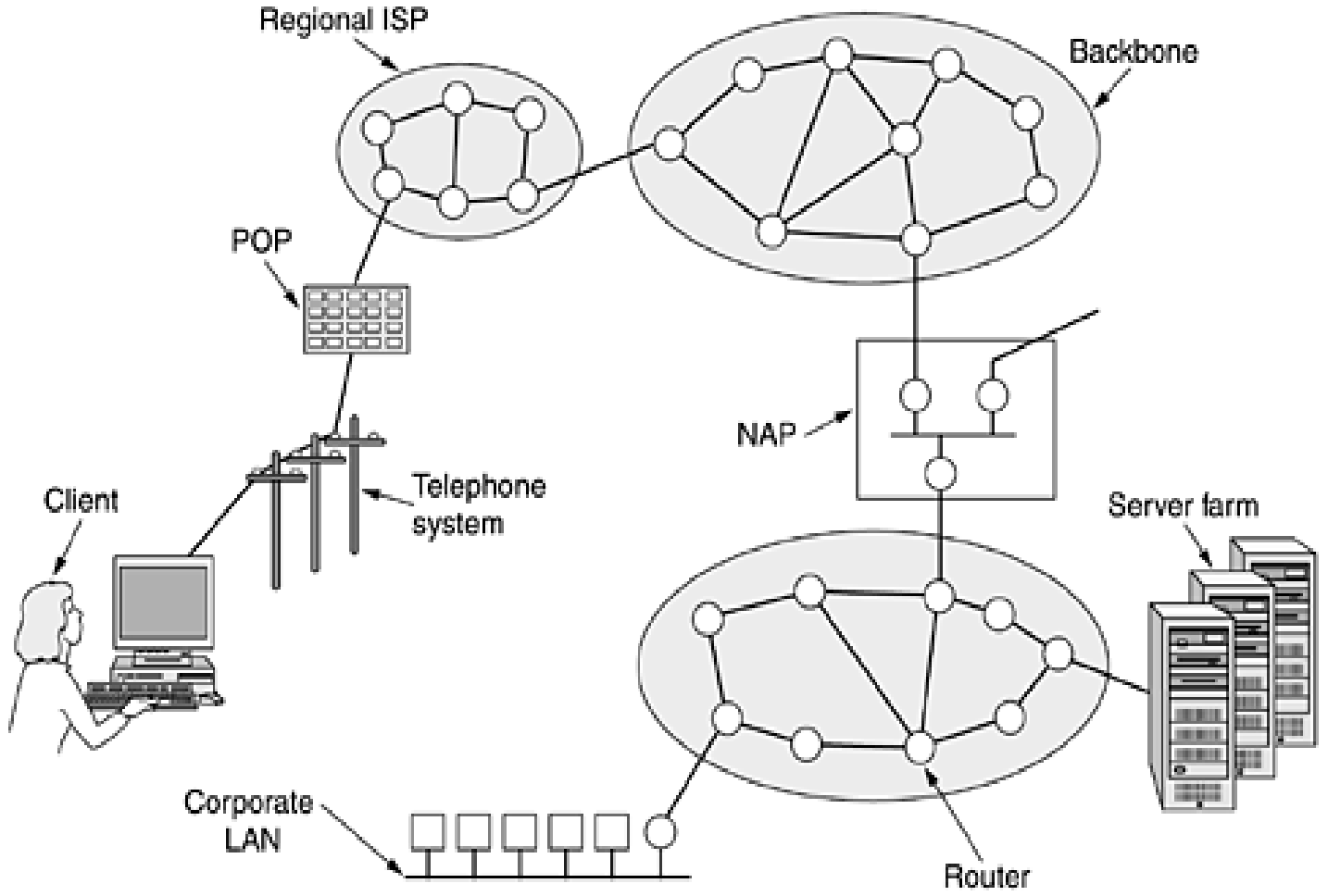
NAP (Network Access Point):

- Four different network operators get contract from NSF to set up **NAPs** for providing communication service between regional networks.
- Network operators also provide backbone service to regional networks.
- A packet originating on any regional network had a choice of backbone carriers to get from its NAP to the destination's NAP.
- More than one backbone like competitive structure came into action.

Example networks (cont.)

Architecture of the Internet

- Client machine gets connected to Regional ISP through POP centre.
  - Dial up service (for telecom company as ISP).
  - Direct cable (ISP other than telecom company).
- ISP's regional network consists of interconnected routers in cities.
- If destination host served by same ISP, then packet delivered to destination host, else forwarded to ISP's backbone operator.
  - If destination host directly connected to backbone, then Packet delivered to host, else forwarded to other ISP regional network/ other backbone (through NAP).
- Packet delivered to host.



Overview of the Internet

Example networks (cont.)

Internet usage

Definition :

A machine is on the Internet if it runs the TCP/IP protocol stack, has an IP address, and can send IP packets to all the other machines on the Internet.

1970 – early 1990 : The Internet and its predecessors had four main applications.

- E-mail.
- News.
- Remote login.
- File transfer.

- Until the early 1990s, the Internet was largely populated by academic, government, and industrial researchers.
- **WWW (World Wide Web)** changed all that and brought millions of new, non-academic users to the net.
- Together with the **browser,** the WWW made it possible for a site to set up a number of pages of information with embedded links between pages.
  - For example, many companies have a home page with entries pointing to other pages for product information, price lists, customer support and more.
- With the facility available in home, the network character has taken the shape of public utility.

Example networks (cont.)

Connection-Oriented Network: ATM

- Telephone companies were supporting the connection-oriented network because of two reasons:
  1) Quality of service
  2) Billing
- **X.25** (1970s) and **frame delay** (1980s) : works on synchronous transmission characteristics.
- In early 1990s, **ATM (Asynchronous Transfer Mode)** network designed to work with asynchronous transmission system.
- Merging of voice, data, cable television and many more signals into a single integrated system that could do everything for everyone.
- Initially not happened due to bad timing, technology and implementation, however later on, found to be successful.

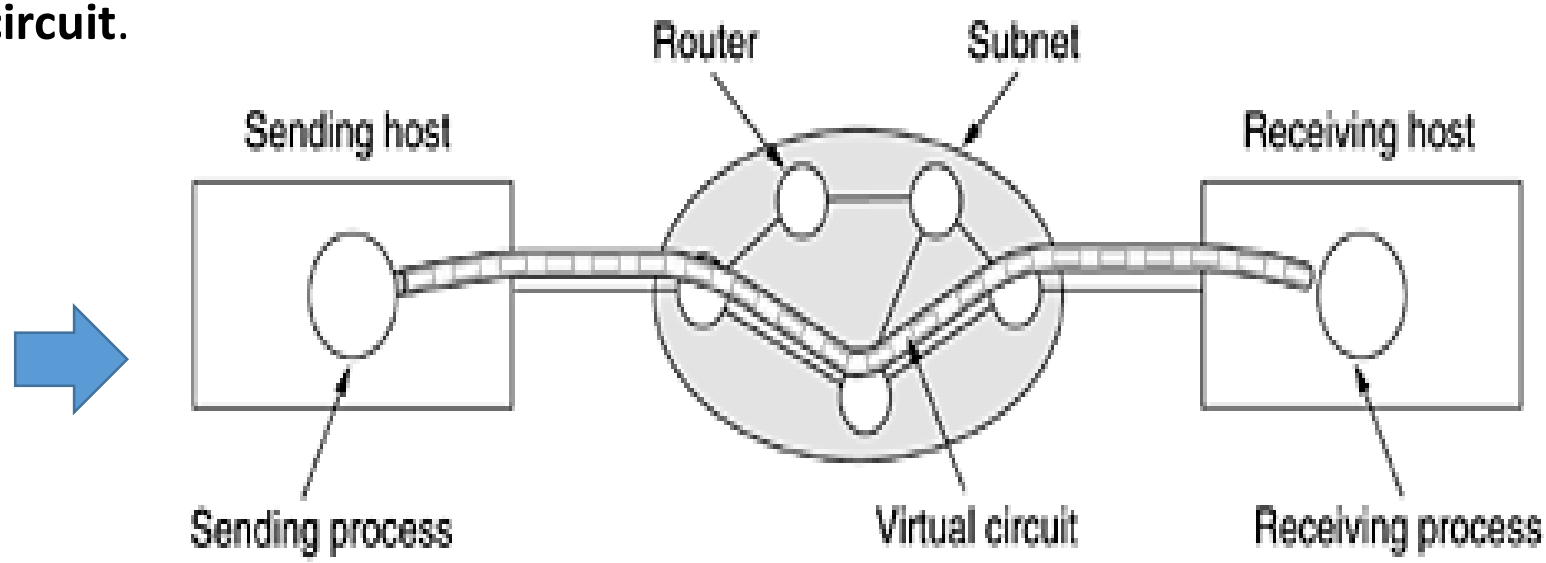
Example networks (cont.)

Connection-Oriented Network: ATM

ATM Virtual Circuits:

- Set up packet transmission prior to sending of data from source host to destination host.
- Routers in the path followed by set up packet make an entry to their routing table indicating path information till the end of the data transmission.
- Connection between two hosts through subnet/routers van be temporary/permanent and is referred as **ATM virtual circuit**.

A virtual circuit in ATM network



Example networks (cont.)

Connection-Oriented Network: ATM

Connection identifier, ATM cell, Information flow

- Each connection, temporary or permanent, has a unique **connection identifier**.
- The information in ATM is transmitted in the form of small, fixed-size packets called **cells**.
- The cells are 53 bytes long, of which 5 bytes are header and 48 bytes are payload.

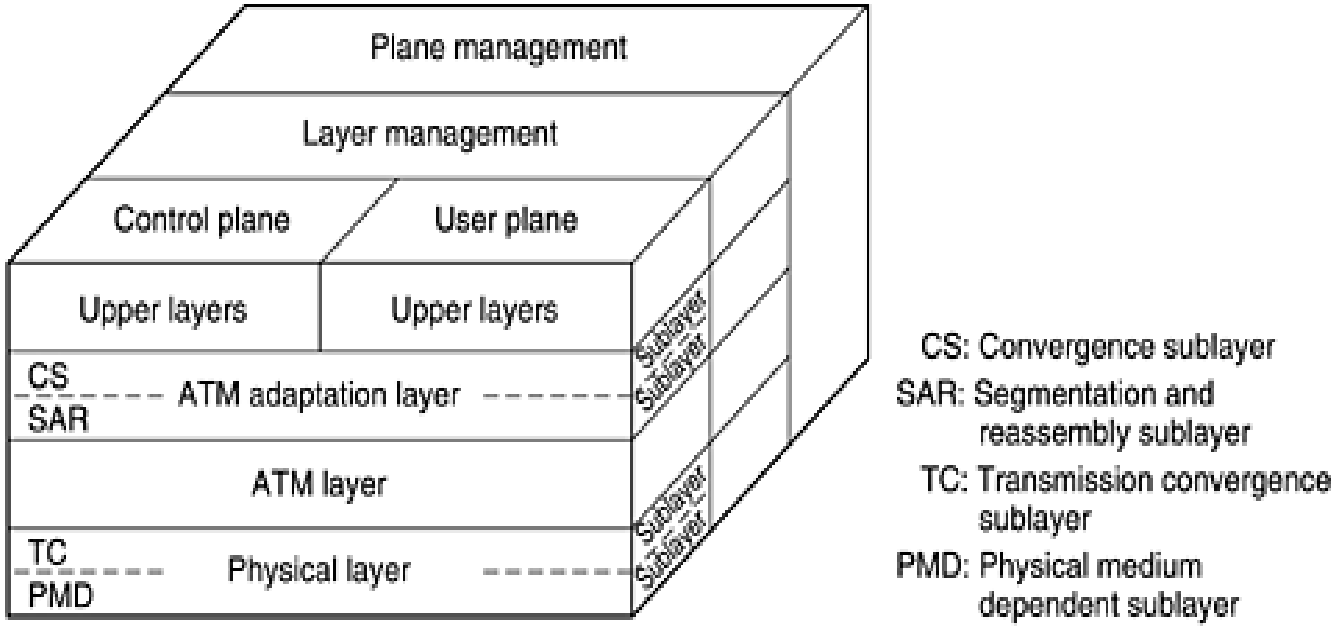
An ATM cell

- Part of the header is the connection identifier to identify the source and destination host for a packet.
- Helps the router to know how to route each incoming cell.
- Cells transmitted in a sequence order.
- Most common speeds for ATM networks are 155 Mbps and 622 Mbps.

Example networks (cont.)

The ATM Reference Model

- ATM has its own reference model, different from the OSI model and also different from the TCP/IP model.
- Three layers, the physical, ATM, and ATM adaptation layers with a flexibility for an user defined upper layer(s) above that.



The ATM reference model

Example networks (cont.)

The ATM Reference Model

Physical layer :

- Deals with the physical medium: voltages, bit timing, and various other issues.
- No specific rules for the cells regarding the chose of transmission medium.
- ATM cells can be sent on a wire or fibre by themselves.
- ATM cells can also be packaged inside the payload of other carrier systems.
- Two sub layers.

- PMD (Physical Medium Dependent) sub layer:

  - Make the bits on and off to move through transmission medium (say cable)/carrier.
  - Handles the bit timing.
  - For different carriers and cables, this layer will be different.

- TC (Transmission Convergence) sub layer:

  - Converts the cells into bit stream in transmitting end and the reverse in receiving end.
  - Handles all the issues related to telling where cells begin and end in the bit stream.

Example networks (cont.)

The ATM Reference Model

ATM layer :

- Deals with cells and cell transport.
- Defines the layout of a cell and tells what the header files mean.
- Deals with establishment and release of virtual circuits.
- Handles congestion control issues.

ATM adaption layer :

- Allow users to send packets larger than a cell.
- The ATM interface segments these packets, transmits to lower layer.
- Reassembles the segments (if any) at the other end.
- Two sub layers.

- SAR (Segmentation And Reassembly) sub layer:

  - Breaks up packets into cells on the transmission side and puts them back together again at the destination.

- CS (Convergence Sub layer):

  - Handles different kinds of services to different applications (e.g., file transfer and video on demand have different requirements concerning error handling, timing, etc.).

Example networks (cont.)

The ATM Reference Model

User defined upper layer :

- User plane deals with data transport, flow control, error correction, and other user functions.
- Control plane is concerned with connection management.
- Layer and plane management functions relate to resource management and interlayer coordination.

Example networks (cont.)

The ATM Reference Model

ATM layer	ATM sublayer	Functionality
AAL	CS	Providing the standard interface (convergence)
	SAR	Segmentation and reassembly
ATM		Flow control Cell header generation/extraction Virtual circuit/path management Cell multiplexing/demultiplexing
Physical	TC	Cell rate decoupling Header checksum generation and verification Cell generation Packing/unpacking cells from the enclosing envelope Frame generation
	PMD	Bit timing Physical network access

The ATM layers and sub layers, and their functions

Example networks (cont.)

Ethernet

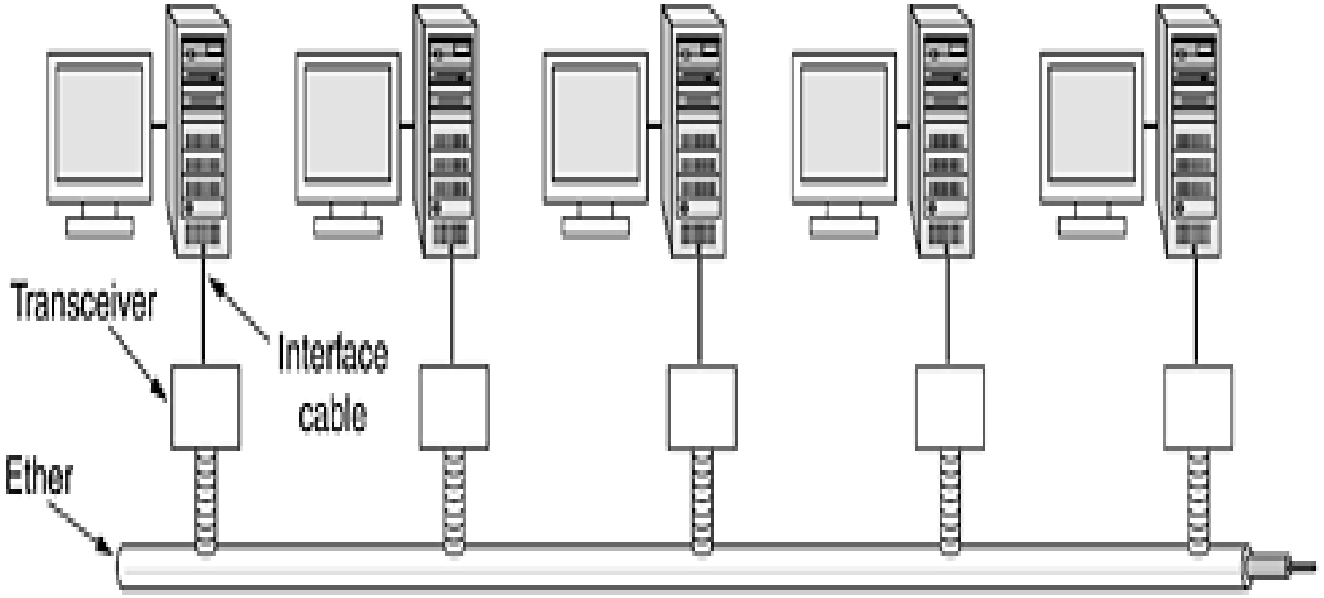
- Most popular local area network.
- Implemented in Xerox PARC (Palo alto Research centre) in 1976.
- Named after the ***luminiferous ether***, through which electromagnetic radiation was once thought to propagate.
- Considered as a suceeder to ALOHANET.
- Uses thick coaxial cable (the ether) as transmission medium.
- Cable length : 2.5 km

  (Repeaters at every 500m)
- 256 machines can be connected.
- Speed : 2.94 Mbps.

- Prior to Ethernet (in 1970s)
- Uses short range radio devices.
- Communication between user terminals through central computer.
- Uses two frequencies.
  1. Upstream (user terminal to central computer)
  2. Downstream (Central computer to user terminal).
- Worked fine with low traffic.
- Poor performance with heavy traffic in upstream.

Example networks (cont.)

Ethernet



Architecture of the original Ethernet

Example networks (cont.)

Ethernet

Advantage of Ethernet over ALOHANET :

- Before transmitting, a computer first listened to the cable to see if someone else was already transmitting.
- If so, the computer held back and wait until the current transmission finished.
- Avoids interfering with existing transmissions, giving a much higher efficiency.
- (ALOHANET : Not possible to sense the transmission line.)
- Still a possibility of simultaneous transmission ?
- Can be resolved with random wait time which can be doubled if still collision chance is there.

Example networks (cont.)

Ethernet

Ethernet as IEEE standard :

- Following to success in implementation of Ethernet the speed enhanced to 10 Mbps in 1978.
- In 1983, considered as **IEEE 802.3** standard.
- In the due course of time with the improvement in technology it provides higher speed (100 Mbps).

Other IEEE standards for LAN : IEEE 802.4, IEEE 802.5

- **802.4** : Token bus introduced by General motors, BUS topology
- **802.5** : Token ring introduced by IBM, RING topology
- **Token** : A short packet and is used to make a turn for a computer being allowable for transmission of its data.
- A computer could only send if it possessed the token, thus avoiding collisions.
- In due course of time 802.4 has vanished from sight .
- 802.5 had its existence and still in use at some IBM site (popular in the name **IBM token ring).**

In the war of LAN, Ethernet has taken the highest utility in compare to others like token bus and token ring.

Example networks (cont.)

Wireless LANs: 802.11

- To equip both the office and the notebook computers with short-range radio transmitters and receivers and to allow them to communicate.
- **Issue in the beginning : Some systems faces problem because of technical incompatibility between devices.**

  Example: A computer equipped with a brand X radio could not work in a room equipped with a brand Y base station.
- **Issue solved through standardisation of Wireless LAN (IEEE 802.11).**
- Popular in the term **WIFI**.

Example networks (cont.)

Wireless LANs: 802.11

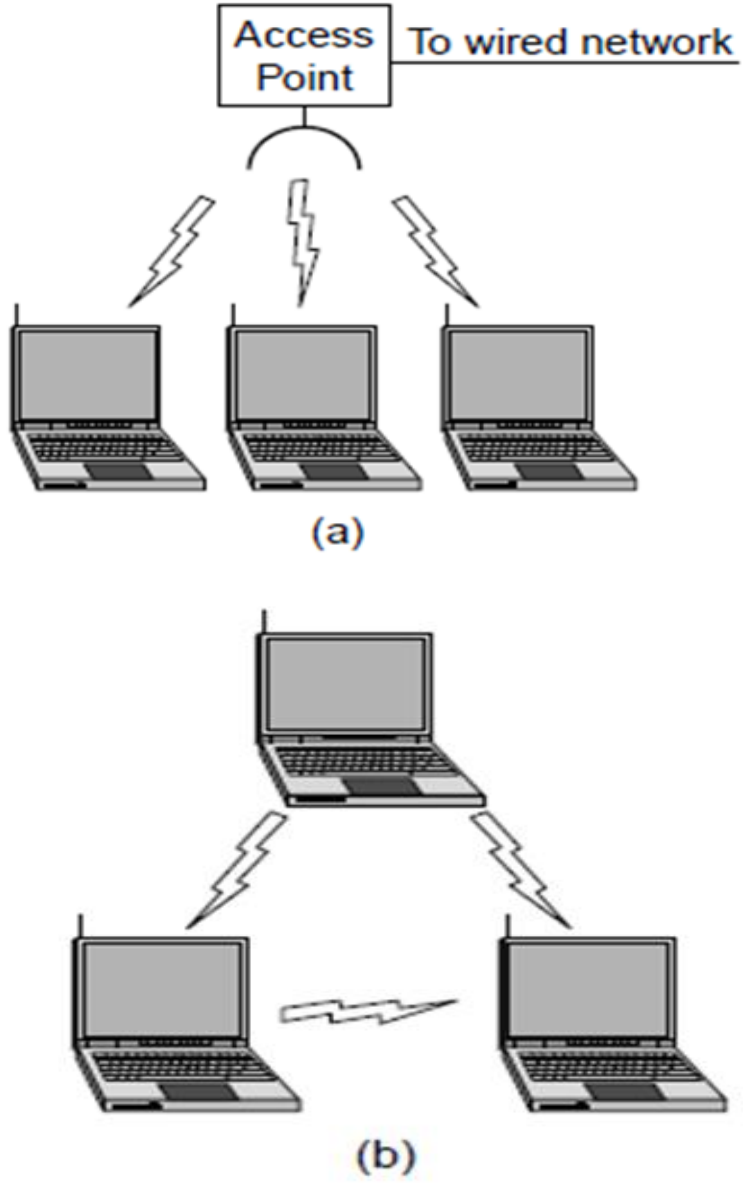
The proposed standard had to work in two modes:

(a) In the presence of a base station.

- All communication was to go through the base station, called an **access point**.

(b) In the absence of a base station.

- The computers would just send to one another directly.
- This mode is now sometimes called **ad hoc networking**.



Example networks (cont.)

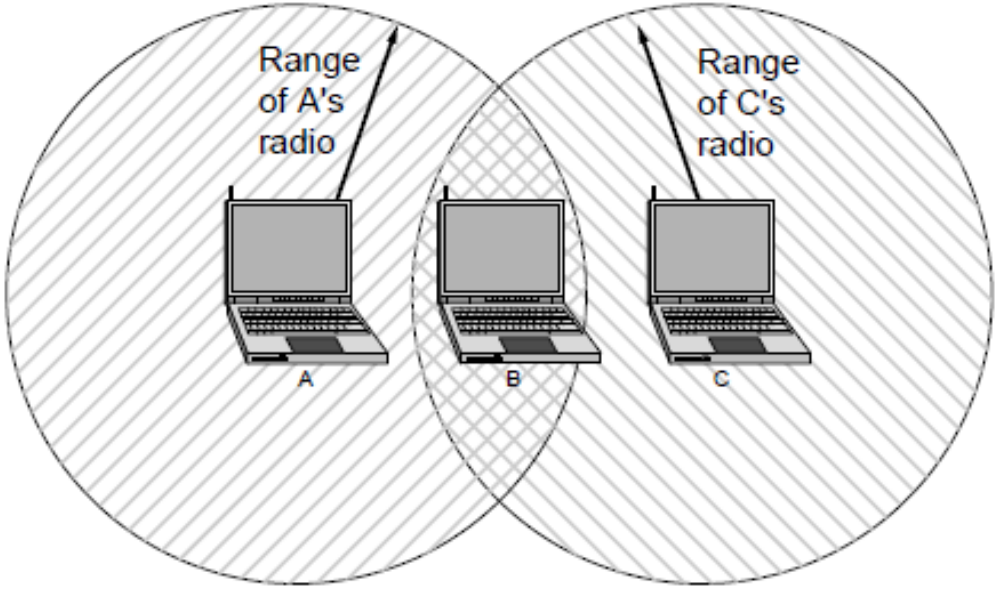
Problems encountered during implementation of Wireless LANs: 802.11

Carrier sense before transmission :

- Though works in Ethernet to avoid simultaneous transmission may not work always in 802.11.

Example :

Let’s assume that computer A is transmitting to computer B, but the radio range of A's transmitter is too short to reach computer C. If C wants to transmit to B it can listen to the ether before starting, but the fact that it does not hear anything does not mean that its transmission will succeed.



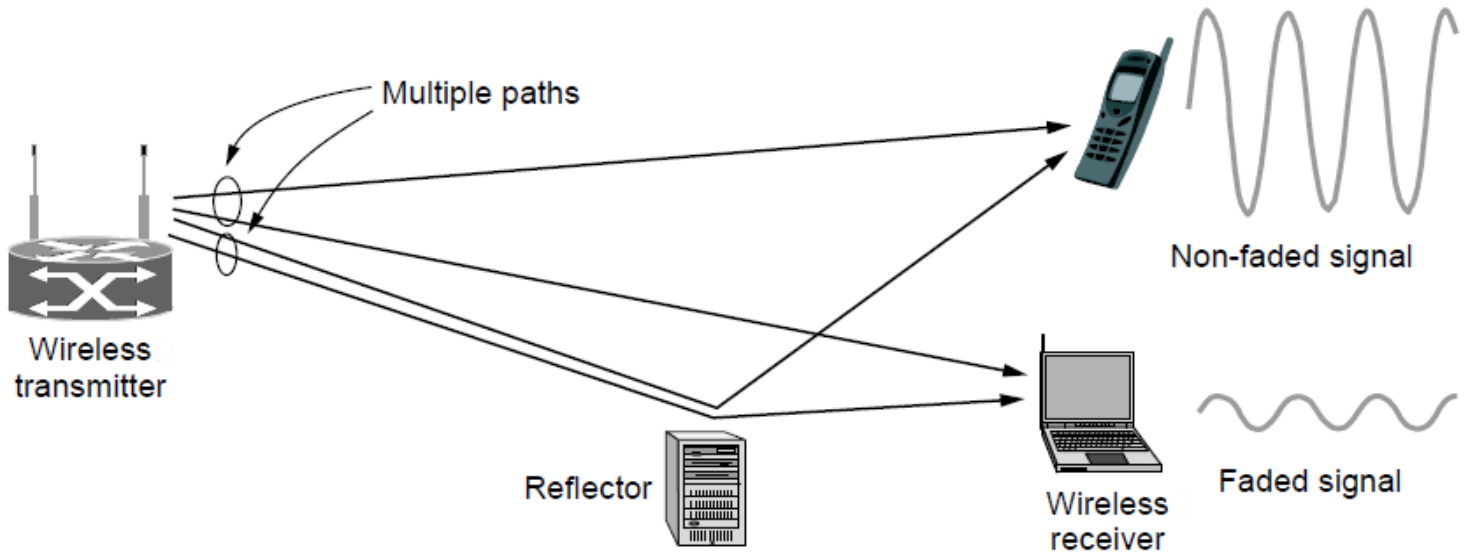
The range of a single radio may not cover the entire system

Example networks (cont.)

Problems encountered during implementation of Wireless LANs: 802.11

Multipath fading:

- A radio signal can be reflected off solid objects.
- Same signal may be received multiple times (along multiple paths).
- May lead to interference what is called **multipath fading**.



Example networks (cont.)

Problems encountered during implementation of Wireless LANs: 802.11

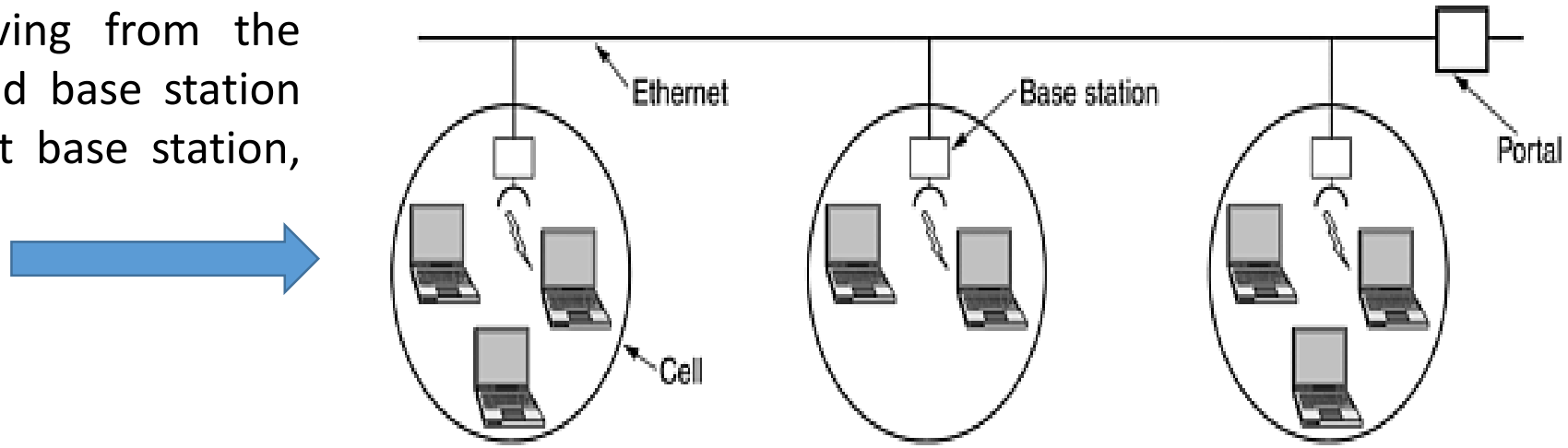
Compatibility with software :

- Software is not aware of mobility of computer system compatible with other device.

Example :
Many word processors have a list of printers that users can choose from to print a file. When the computer on which the word processor runs is taken into a new environment, the built-in list of printers becomes invalid.

Hand off:

- A notebook computer moving from the range of one ceiling-mounted base station into the range of a different base station, requires hand off.



A multi-cell 802.11 network

Example networks (cont.)

Versions of 802.11

Though the problem cited earlier were solved in the due course of time dissatisfaction lies among users with speed.

- The initial standard (i.e. 802.11 in 1997) ran at either 1 Mbps or 2 Mbps.

  (Frequency hopping and signal spreading technology)

- **802.11a** and **802.11b** (1999)

802.11a : Speed up to 54 Mbps (wider frequency band **)**

802.11b : 11 Mbps (same frequency band as 802.11 but different modulation technique**)**

Besides these 802.11g (2003) is also used currently in some networks that employs OFDM transmission.