Example Networks

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- The subject of computer networking covers many different kinds of networks, large and small, well known and less well known. They have different goals, scales, and technologies.
- The computer networks that are functioning in the current scenario are associated with so many attributes like size, technology, goals etc.
- Some examples : Internet, ATM (Asynchronous Transfer Mode), Ethernet, IEEE 802.11

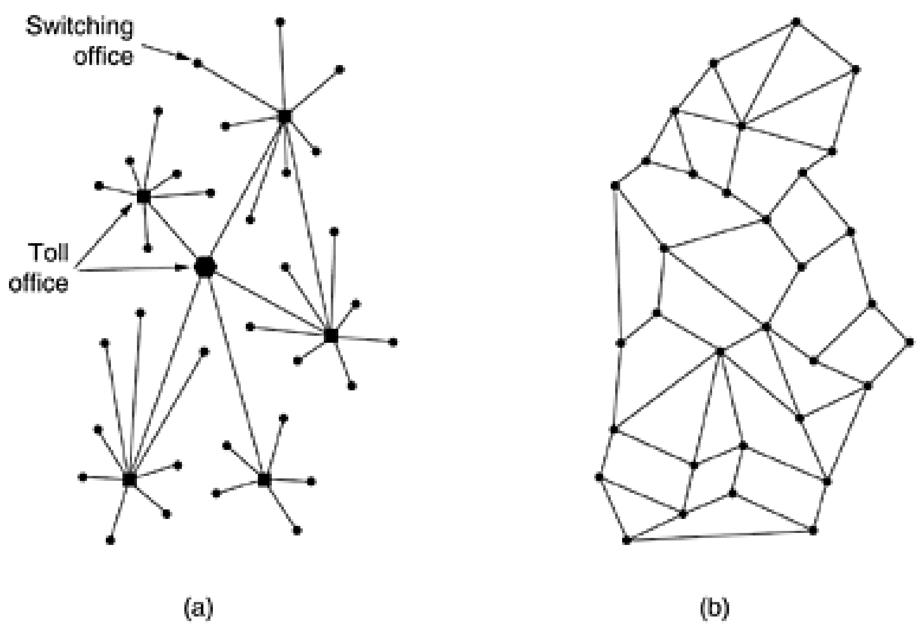
The Internet

- To introduce the internet the first statement which holds true is that internet has revolutionized many aspects of our daily lives. People use internet for various reasons, if accounted it may be more than our knowledge.
- The Internet is not a network at all, but a vast collection of different networks that use certain common protocols and provide certain common services.
- It is an unusual system in that it was not planned by anyone and is not controlled by anyone.

The ARPANET (Advanced Research Projects Agency Network)

- The history started with the want from DoD (***DEPARTMENT OF DEFENSE)*** in late 1950 .
- The work started using the base of existing public telephone network.
- The vulnerability of the system was that the destruction of a few key toll offices could fragment the system into many isolated islands.

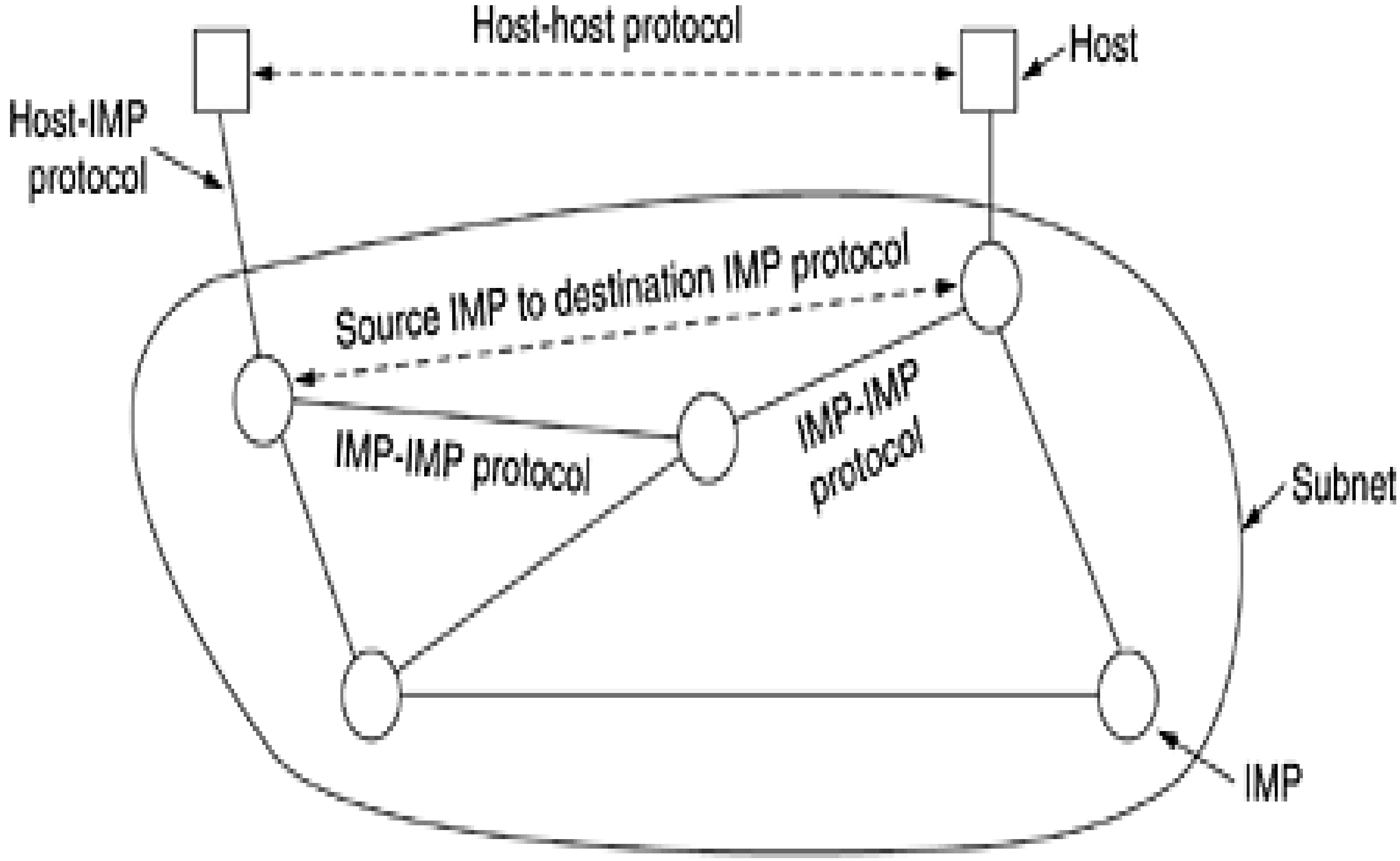
(a) Structure of the telephone system. (b) Baran's proposed distributed switching system.



The ARPANET

- Around 1960, the DoD awarded a contract to the RAND Corporation to find a solution. One of its employees, Paul Baran, proposed the incorporation of digital packet switching technology in a higly distributed and fault tolerant system
- However due to lack of support from the biggest and richest corporation AT&T, the idea was dismissed.
- Following several years, with the interest of U.S., 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 bouhght the idea suggested by Wesley clark related to building of a packet switched subnet, where each host has it's own router: with a name **ARPANET**

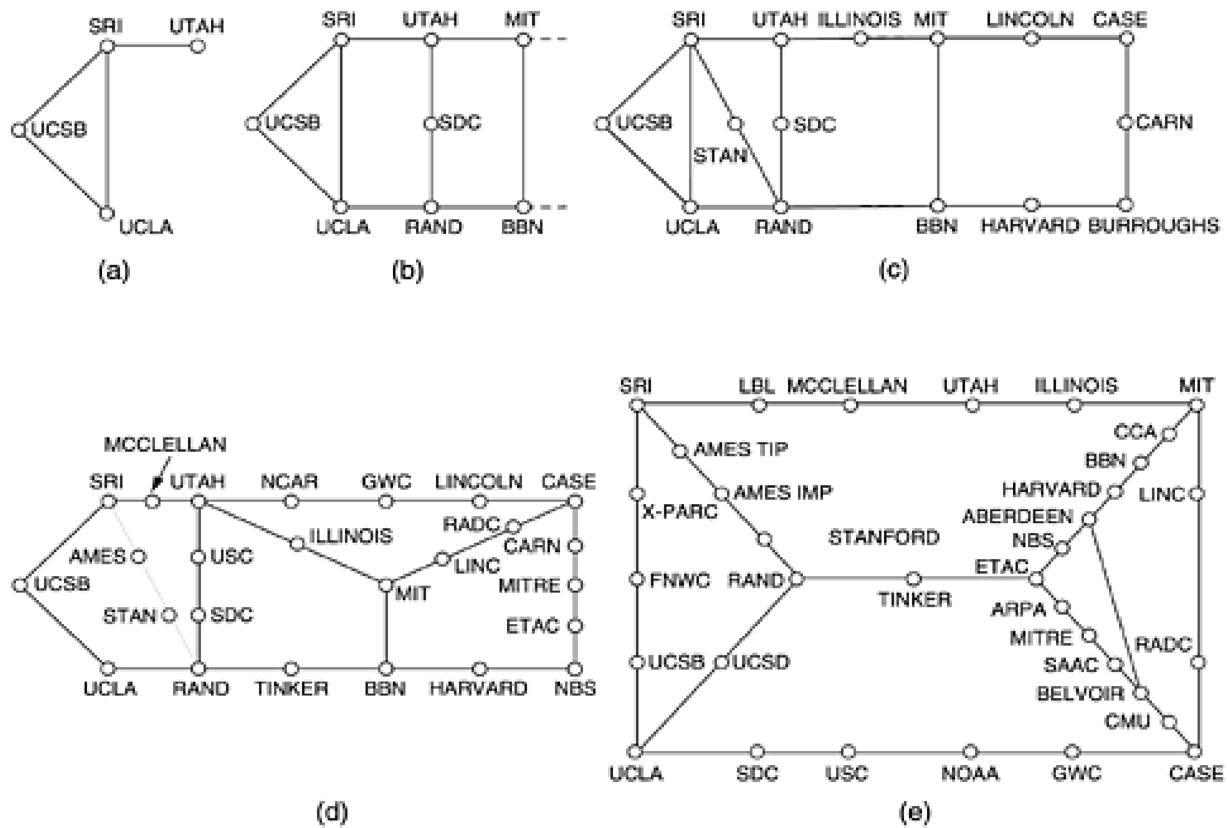
The original ARPANET design



- In ARPANET, the subnet consists of minicomputers called **IMPs (Interface Message Processors)** connected by 56-kbps transmission lines.
- For high reliability, each IMP connected to at least two other IMPs.
- The subnet was to be a datagram subnet, so if some lines and IMPs were destroyed, messages could be automatically rerouted along alternative paths. Each node of the network was to consist of an IMP and a host, in the same room, connected by a short wire.
- A host could send messages of up to 8063 bits to its IMP, which would then 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, so the subnet was the first electronic store-and-forward packet-switching network.
- The IMPs were interconnected by 56-kbps lines. The 56kbps lines were also leased from telephone companies.

- The software was split into two parts: subnet and host.
- The subnet software consisted of the IMP end of the host-IMP connection, the IMP-IMP protocol, and a source IMP to destination IMP protocol designed to improve reliability.
- Outside the subnet, software was also needed, namely, the host end of the host-IMP connection, the host-host protocol, and the application software.
- An experimental network went on the air in December 1969 with four nodes: at UCLA, UCSB, SRI, and the University of Utah.
- The network grew quickly as more IMPs were delivered and installed; it soon spanned the United States. Further, with installation of more IMPs the network grew quickly.

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

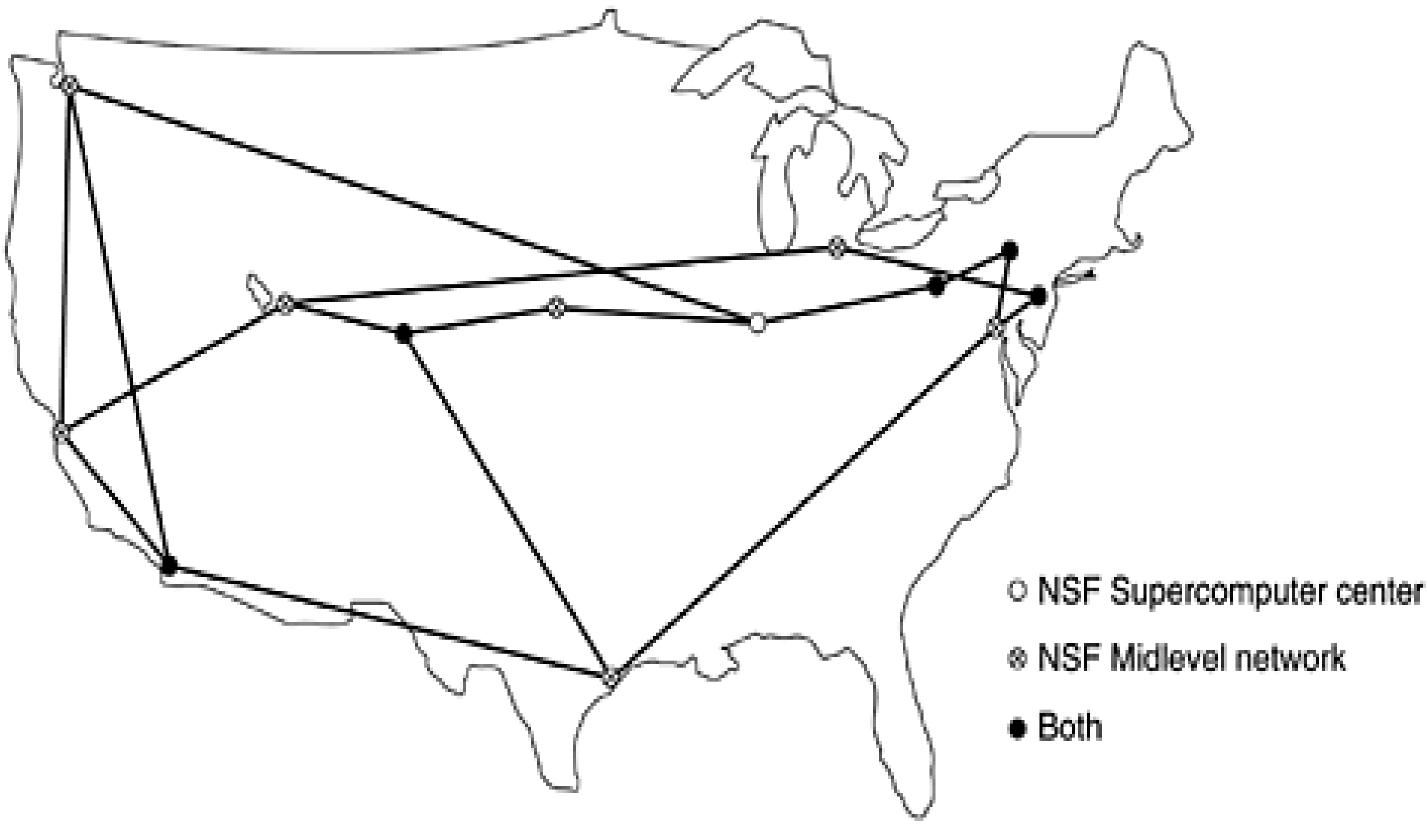


- During that period it was found that ARPANET protocols were not suitable for running over multiple networks. Further research on this leads to the invention of TCP/IP protocol which was specifically designed to handle communication over internetworks.
- Furthermore, with TCP/IP, it was easy for the LANs to connect to the ARPANET. During the 1980s, many additional networks, especially LANs, were connected to the ARPANET.
- However, As the scale increased, finding hosts became increasingly expensive, so **DNS (Domain Name System)** was created to organize machines into domains and map host names onto IP addresses.

NSFNET

- In the late 1970’s to facilitate the research on network issues, NSF (the U.S. National Science Foundation) had taken a response to design a successor to the ARPANET that would be open to all university research groups.
- NSF decided to build a backbone network to connect its six supercomputer centers where in each supercomputer was attached with a microcomputer called a **fuzzball**.
- The fuzzballs were connected with 56-kbps leased lines and formed the subnet.
- The software technology was different however: the fuzzballs spoke TCP/IP right from the start, making it the first TCP/IP WAN.
- NSF also funded some regional networks that connected to the backbone to allow users at thousands of universities, research labs, libraries, and museums to access any of the supercomputers and to communicate with one another.
- The complete network, including the backbone and the regional networks, was called **NSFNET .** Further, It connected to the ARPANET through a link between an IMP and a fuzzball.

The NSFNET backbone in 1988



- Following to instantaneous success of NSFNET, the NSF started using the fiber optic channels at 448 kbps to provide the version 2 backbone. Further, by 1990, the second backbone was upgraded to 1.5 Mbps.
- Later on, looking at the inability in financial support from governemnet, NSF encouraged few non government organizations (one of which is IBM) to form a non profit corporation, **ANS (Advanced Networks and Services),** as the first step along the road to commercialization.
- In 1990, ANS took over NSFNET and upgraded the 1.5-Mbps links to 45 Mbps to form **ANSNET**, which after a running 5 years sold to America Online. But by then, various companies were offering commercial IP service.
- In the due course of time, to ease the transition and make sure every regional network could communicate with every other regional network, NSF awarded contracts to four different network operators to establish a **NAP (Network Access Point)**.

- Every network operator had provided backbone service to the NSF regional networks as well as to connect to all the NAPs.
- In terms of technical it means that a packet originating on any regional network had a choice of backbone carriers to get from its NAP to the destination's NAP.
- During the 1990s, many other countries and regions also built national research networks, often patterned on the ARPANET and NSFNET.
- These included EuropaNET and EBONE in Europe, which started out with 2-Mbps lines and then upgraded to 34-Mbps lines.

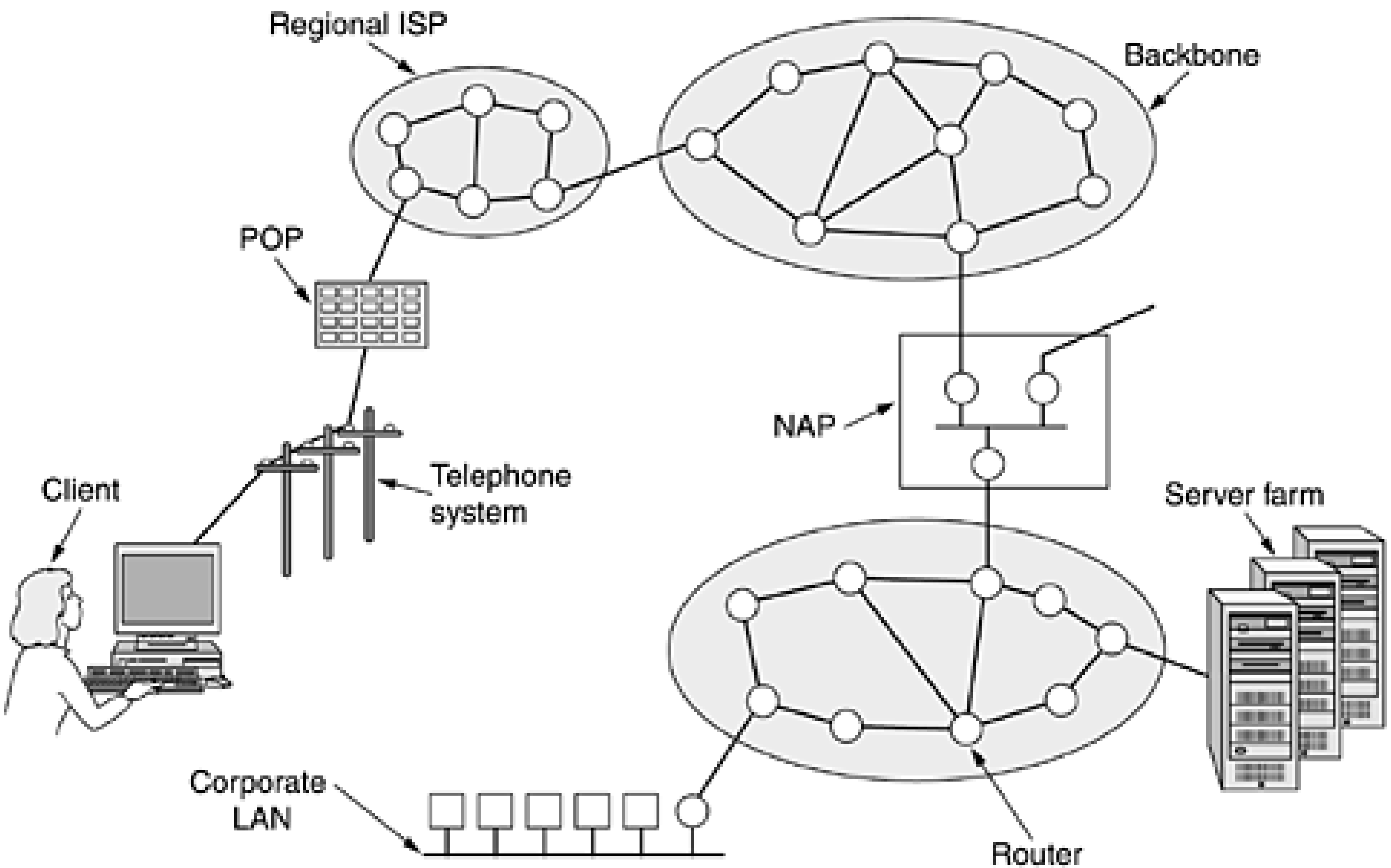
Internet Usage:

- The number of networks, machines, and users connected to the ARPANET grew rapidly after TCP/IP became the only official protocol on January 1, 1983.
- When NSFNET and the ARPANET were interconnected, the growth became exponential. Many regional networks joined up, and connections were made to networks in Canada, Europe, and the Pacific.
- Sometime in the mid-1980s, people began viewing the collection of networks as an internet, and later as the Internet.
- The glue that holds the Internet together is the TCP/IP reference model and TCP/IP protocol stack. TCP/IP makes universal service possible.
- **What does it actually mean to be on the Internet?** The definition is that 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.

- However, the issue is clouded somewhat by the fact that millions of personal computers can call up an Internet service provider using a modem, be assigned a temporary IP address, and send IP packets to other Internet hosts.
- Traditionally (meaning 1970 to about 1990), the Internet and its predecessors had four main applications: **E-mail. News. Remote login. File transfer.**
- Up until the early 1990s, the Internet was largely populated by academic, government, and industrial researchers. One new application, the **WWW (World Wide Web)** changed all that and brought millions of new, nonacademic users to the net.
- In the due course of time, numerous other kinds of pages have come into existence through WWW
- During 1990s the ISPs (Internet Service Providers) made the facility available.

Architecture of the Internet:

- **Figure. Overview of the Internet.**



- Let us assume client calls his or her ISP over a dial-up telephone line.
- The modem is a card within the PC that converts the digital signals the computer produces to analog signals that can pass unhindered over the telephone system.
- These signals are transferred to the ISP's **POP (Point of Presence),** where they are removed from the telephone system and injected into the ISP's regional network.
- The ISP's regional network consists of interconnected routers in the various cities the ISP serves. If the packet is destined for a host served directly by the ISP, the packet is delivered to the host. Otherwise, it is handed over to the **ISP's backbone operator**.
- If a packet given to the backbone is destined for an ISP or company served by the backbone, it is sent to the closest router and handed off there.
- To allow packets to hop between backbones, all the major backbones connect at the **NAPs (Network Access Point).**
- A Network Access Point was a public network exchange facility where Internet service providers connected with one another in peering arrangements.

Connection-Oriented Networks: ATM (Asynchronous Transfer Mode)

- In connectionless design every packet is routed independently of every other packet. As a consequence, if some routers go down during a session, no harm is done as long as the system can reconfigure itself dynamically so that subsequent packets can find some route to the destination, even if it is different from that which previous packets used.
- The connection-oriented camp comes from the world of telephone companies. In the telephone system, a caller must dial the called party's number and wait for a connection before talking or sending data. This connection setup establishes a route through the telephone system that is maintained until the call is terminated. All words or packets follow the same route.
- If a line or switch on the path goes down, the call is aborted.
- Why do the telephone companies like it then? There are two reasons:
    - Quality of service.
    - Billing.

- connection-oriented networks
  - X.25 and Frame Relay
  - ATM (Asynchronous Transfer Mode)
- The word synchronous refers to things happening at the same time. Synchronous transmission is defined as the process by which data or a signal is transferred from one application system or device to another at constant periods or intervals, usually monitored by a clock. This means that the transmitting and receiving systems send and receive data at the same rate or speed.
- In the case of asynchronous transmission, the data or signals being transmitted and received are not done in synchronization. The time interval between the sending and receiving devices enable transmission and reception at their own pace. This means the data sending transmitter may not be at the same rate as the data receptor. This mode of transmission is not monitored by the same rate and the transmission is said to be asynchronous.
- Transmission in synchronous mode closely tied to a clock and ATM is not.

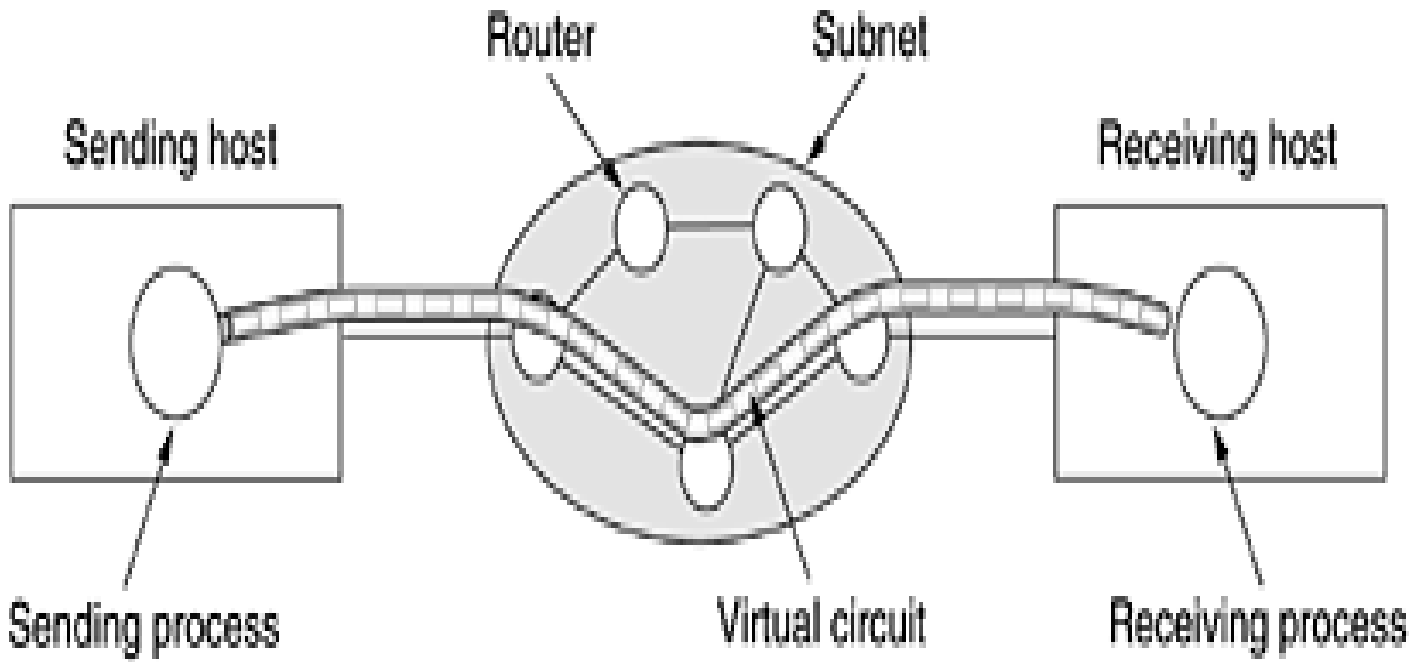
X.25 and Frame Relay

- The initial connection-oriented networks implemented in 1970s (i.e. **X.25**) and later on in 1980s (i.e **frame delay**) usually works with synchronous transmsion characteristics.
- **To use X.25**, a computer first established a connection to the remote computer, that is, placed a telephone call. This connection was given a connection number to be used in data transfer packets.
- **Frame relay** : it is a connection-oriented network with no error control and no flow control. Because it was connection-oriented, packets were delivered in order

Asynchronous Transfer Mode (ATM)

- connection-oriented network developed to work with an asynchrous transmission sytem. This network is named as **ATM (Asynchronous Transfer Mode)** network.
- ATM was designed in the early 1990s. The main aim of this network is to solve all the world's networking and telecommunications problems by merging voice, data, cable television, telex, telegraph, connected by strings and everything else into a single integrated system that could do everything for everyone.
- However, this was not happened at that time due to bad timing, technology and implementation. Later on, it was found to be successful and being widely used within the telephone system for moving IP packets.
- ATM was much more successful than OSI, and it is now widely used deep within the telephone system, often for moving IP packets.

ATM Virtual Circuits:

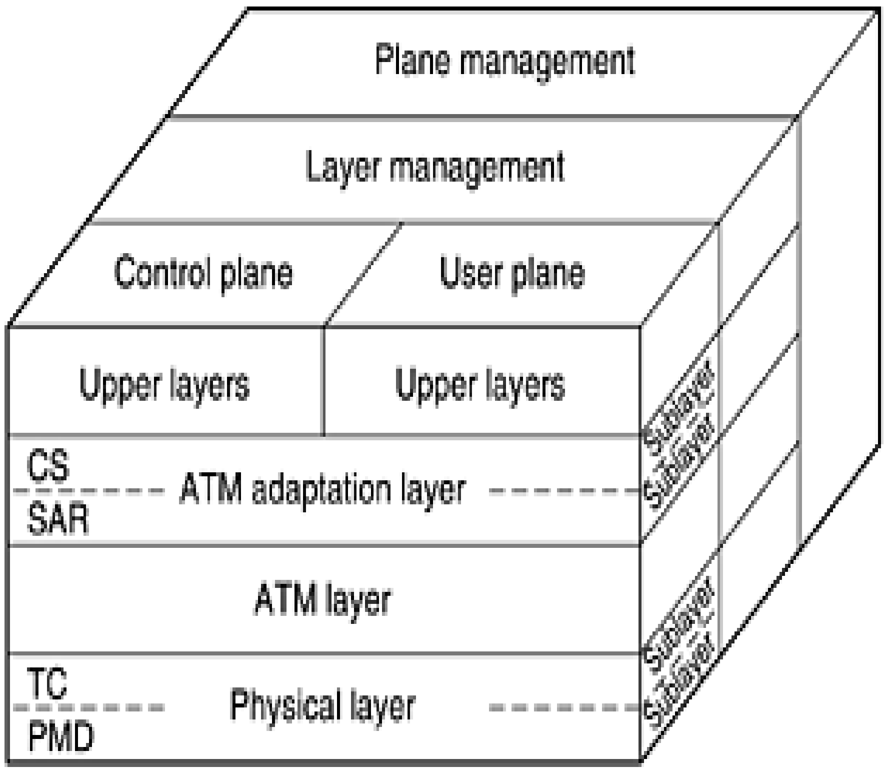


- Since ATM networks are connection-oriented, sending data requires first sending a packet to set up the connection.
- Connections are often called virtual circuits, in analogy with the physical circuits used within the telephone system.
- Most ATM networks also support permanent virtual circuits, which are permanent connections between two (distant) hosts. They are similar to leased lines in the telephone world.
- Each connection, temporary or permanent, has a unique connection identifier.
- Once a connection has been established, either side can begin transmitting data. The basic idea behind ATM is to transmit all information in small, fixed-size packets called cells.
- ATM Cell

- The cells are 53 bytes long, of which 5 bytes are header and 48 bytes are user data.
- Part of the header is the connection identifier, so the sending and receiving hosts and all the intermediate routers can tell which cells belong to which connections. This information allows each router to know how to route each incoming cell.
- Cell routing is done in hardware, at high speed. In fact, the main argument for having fixed-size cells is that it is easy to build hardware routers to handle short, fixed-length cells.
- Variable-length IP packets have to be routed by software, which is a slower process.

- Another plus of ATM is that the hardware can be set up to copy one incoming cell to multiple output lines, a property that is required for handling a television program that is being broadcast to many receivers. Finally, small cells do not block any line for very long, which makes guaranteeing quality of service easier.
- All cells follow the same route to the destination. Cell delivery is not guaranteed, but their order is. If cells 1 and 2 are sent in that order, then if both arrive, they will arrive in that order, never first 2 then 1. But either or both of them can be lost along the way.
- It is up to higher protocol levels to recover from lost cells.
- ATM networks are organized like traditional WANs, with lines and switches (routers). The most common speeds for ATM networks are 155 Mbps and 622 Mbps, although higher speeds are also supported.

The ATM Reference Model:



CS: Convergence sublayer
SAR: Segmentation and reassembly sublayer
TC: Transmission convergence sublayer
PMD: Physical medium dependent sublayer

- ATM has its own reference model, different from the OSI model and also different from the TCP/IP model.
- It consists of three layers, the physical, ATM, and ATM adaptation layers, plus whatever users want to put on top of that (layers with a flexibility for an user defined upper layer(s) above that).

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 fiber by themselves.

ATM layer :

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

ATM adaption layer (AAL) :

- 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.

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.

The ATM layers and sublayers, and their functions.

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

PMD (Physical Medium Dependent) sublayer:

- 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) sublayer:

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

SAR (Segmentation And Reassembly) sublayer:

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

CS (Convergence Sublayer):

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

Ethernet

- Both the Internet and ATM were designed for wide area networking. However, many companies, universities, and other organizations have large numbers of computers that must be connected. This need gave rise to the local area network.
- It is the most popular local area network which was developed and implemented in Xerox PARC (Palo alto Research center) in 1976. Prior to this the concept of interconnecting the computers was available, where the communication was taking place through short range radio devices. Such a network was implemented by University of Hawaii in 1970s and was named as ALOHANET.
- In ALOHANET a number of user terminals were connected to a central computer. The communication between each user terminal and central computer was taking place in two frequencies: **upstream (to the central computer) and downstream (from the central computer).**

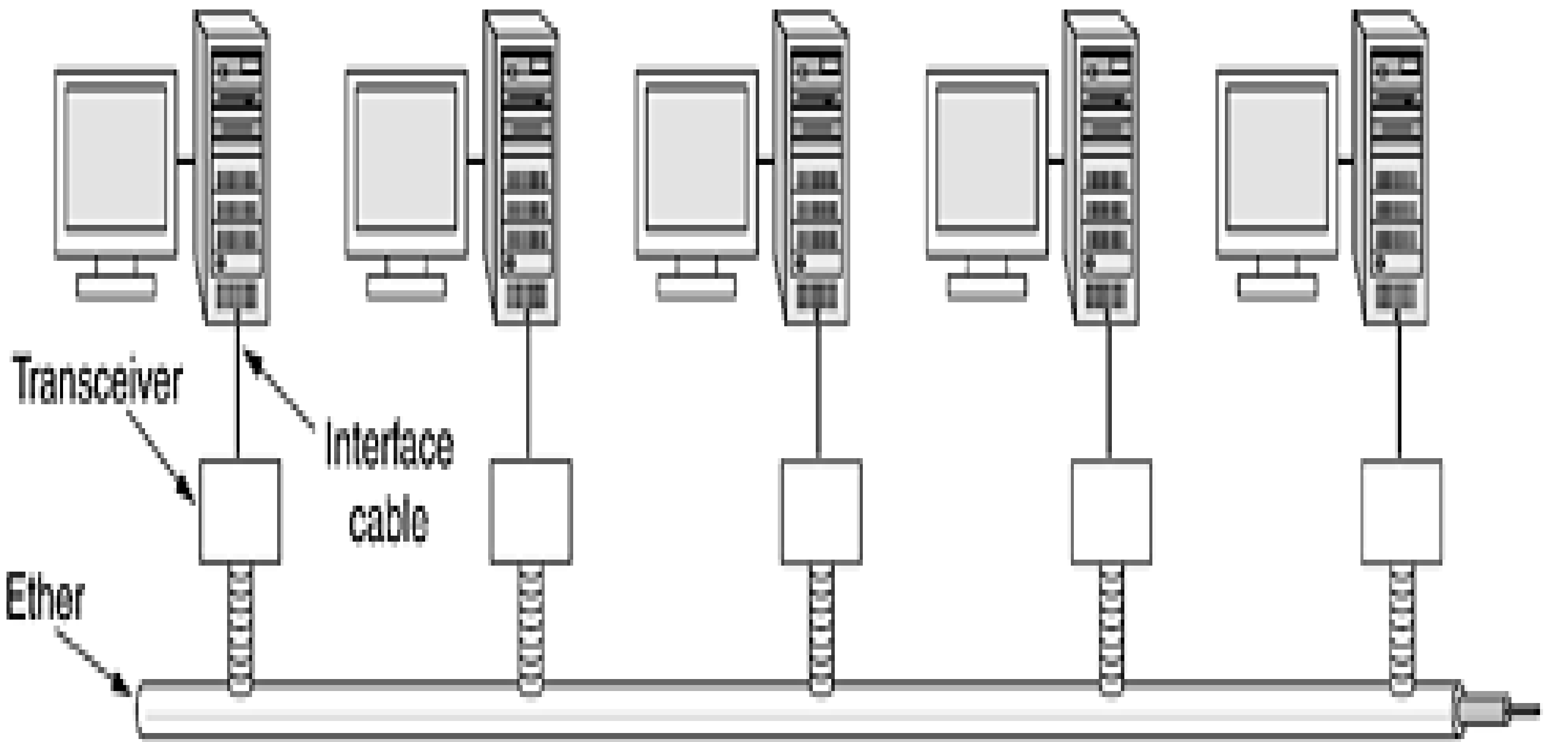
Ethernet

- When the user wanted to contact the computer, it just transmitted a packet containing the data in the upstream channel. If no one else was transmitting at that instant, the packet probably got through and was acknowledged on the downstream channel.
- This system worked fairly well under conditions of low traffic but bogged down badly when the upstream traffic was heavy because contention in upstream channel.

- **Ethernet** was named after the *luminiferous ether*, through which electromagnetic radiation was once thought to propagate. This network was developed after ALOHANET with a difference that in **Ethernet the transmission medium was not the vacuum but a thick coaxial cable (the ether).**
- The coaxial cable is up to 2.5 k long (with repeaters at every 500meters).
- Up to 256 machines could be attached to the system via transceivers screwed onto the cable. A cable with multiple machines attached to it in parallel is called a multidrop cable. The system ran at 2.94 Mbps.

- Ethernet had a major improvement 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 until the current transmission finished. Doing so avoided interfering with existing transmissions, giving a much higher efficiency.
- ALOHANET did not work like this because it was impossible for a terminal on one island to sense the transmission of a terminal on a distant island. With a single cable, this problem does not exist.

Architecture of the original Ethernet



- Despite the computer listening before transmitting, a problem still arises: what happens if two or more computers all wait until the current transmission completes and then all start at once?
- The Xerox Ethernet was so successful that DEC, Intel, and Xerox drew up a standard in 1978 for a 10-Mbps Ethernet, called the DIX standard. With two minor changes, the DIX standard became the **IEEE 802.3** standard in 1983.
- Ethernet continued to develop and is still developing. New versions at 100 Mbps, 1000 Mbps, and still higher have come out. Also the cabling has improved, and switching and other features have been added.
- Ethernet (**IEEE 802.3**) is not the only LAN standard. The committee also standardized a token bus (**802.4**) and a token ring (**802.5**).

- The term **token** is nothing but a short packet and is used to make a turn for a computer being allowable for transmission of its data. Thus it was taken that a computer could only send if it possessed the token, thus avoiding collisions.
- Similarly, IBM had its own favorite: its proprietary token ring. The token was passed around the ring and whichever computer held the token was allowed to transmit before putting the token back on the ring.
- However, in due course of time 802.4 has vanished from sight but 802.5 had its existence and still in use at some IBM site (popular in the name **IBM token ring)**.
- However in the war of LAN, Ethernet has taken the highest utility in compare to others like token bus and token ring.

Wireless LANs: 802.11

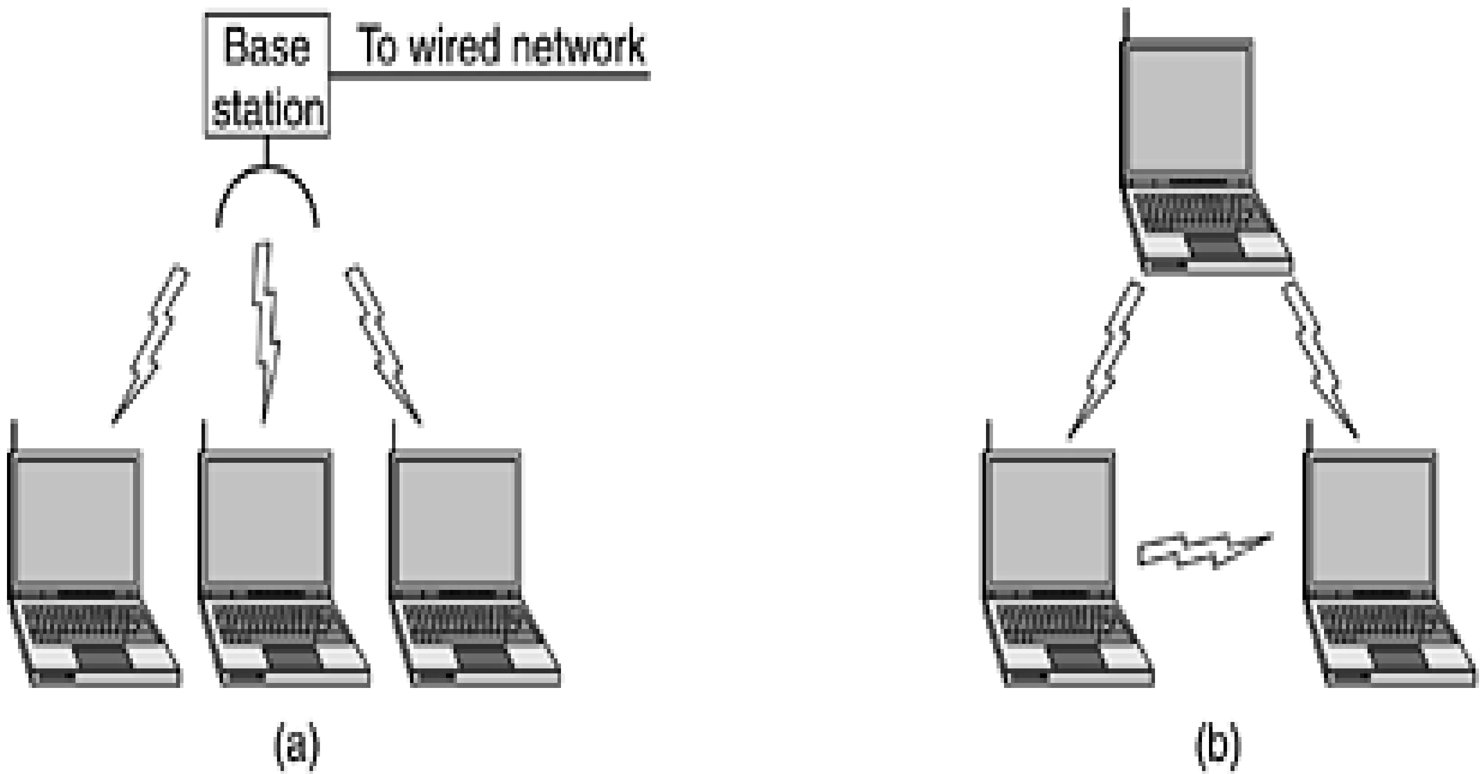
- The idea of Wireless LAN was developed when it was thought of to equip both the office and the notebook computers with short-range radio transmitters and receivers and to allow them to communicate.
- The most practical approach is to equip both the office and the notebook computers with short-range radio transmitters and receivers to allow them to communicate.
- But during its implementation some systems faces problem because technical incompatibility between devices. For example a computer equipped with a brand X radio could not work in a room equipped with a brand Y base station.
- To short out this issue, the industry decided that a wireless LAN standard might be a good idea, so the IEEE committee that standardized the wired LANs was given the task of drawing up a wireless LAN standard.

- The standard it came up with was named 802.11. A common name for it is WiFi.
- The proposed standard had to work in two modes:

1. **In the presence of a base station:** all communication was to go through the base station, called an **access point** in 802.11 terminology.
2. **In the absence of a base station :** the computers would just send to one another directly. This mode is now sometimes called **adhoc networking**.

The two modes are illustrated in fig.

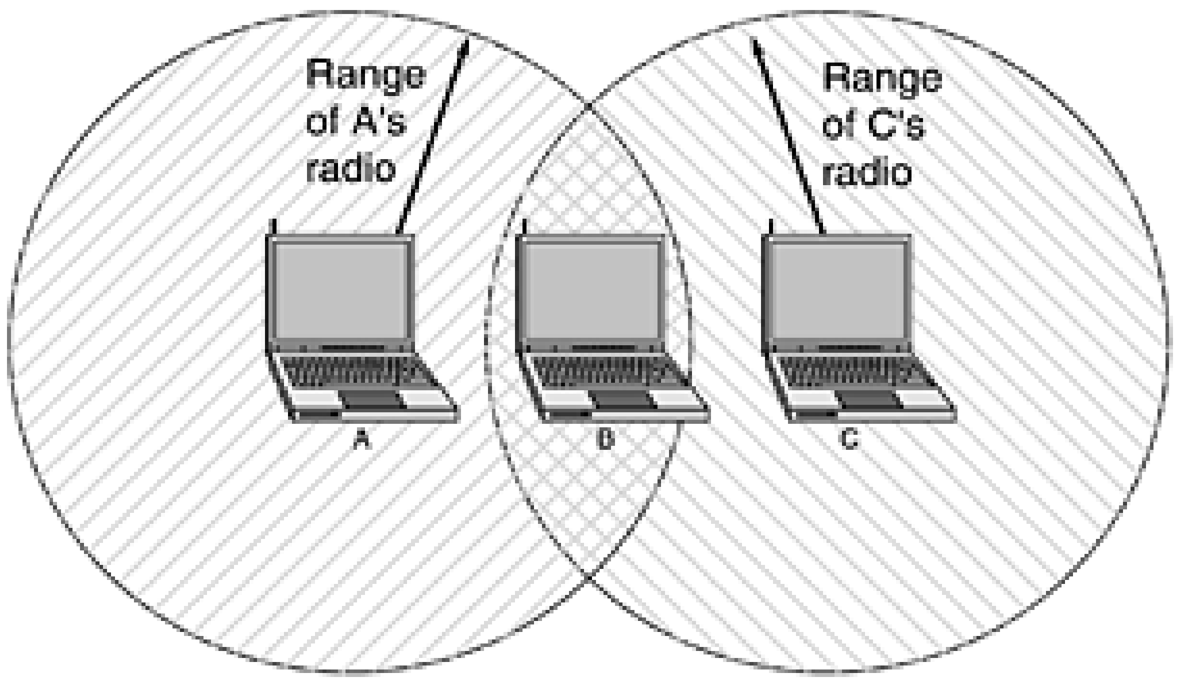
Figure. (a) Wireless networking with a base station. (b) Ad hoc networking.



- In particular, some of the many challenges that had to be met were:
  - finding a suitable frequency band that was available, preferably worldwide;
  - dealing with the fact that radio signals have a finite range;
  - ensuring that users' privacy was maintained;
  - taking limited battery life into account;
  - worrying about human safety (do radio waves cause cancer?);
  - understanding the implications of computer mobility;
  - building a system with enough bandwidth to be economically viable.

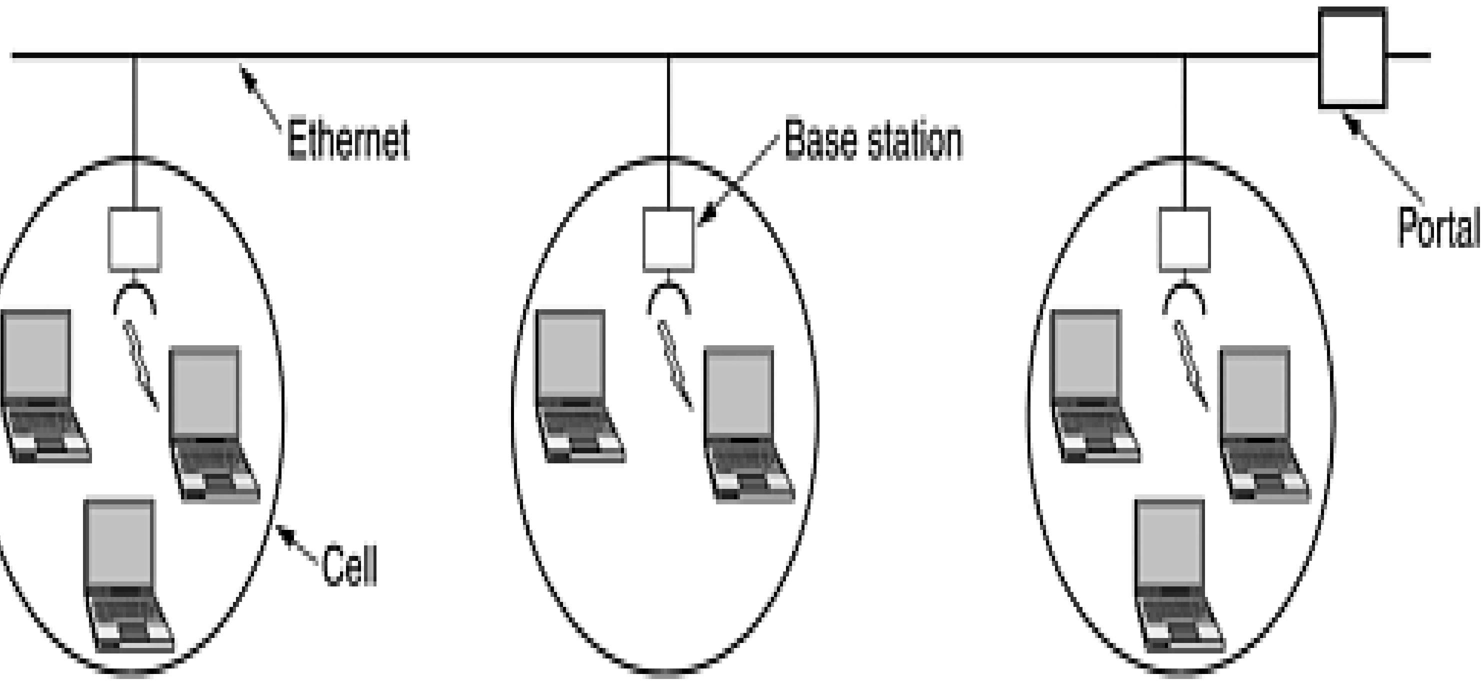
- At the time the standardization process started (mid-1990s), Ethernet had already come to dominate local area networking, so the committee decided to make 802.11 compatible with Ethernet above the data link layer.
- In particular, it should be possible to send an IP packet over the wireless LAN the same way a wired computer sent an IP packet over Ethernet. Nevertheless, in the physical and data link layers, several inherent differences with Ethernet exist and had to be dealt with by the standard.
- Though Wireless LAN had come up as a substitute of Ethernet but suffered from certain problems found out after installation.
- <u>First,</u> a computer on Ethernet always listens to the ether before transmitting. Only if the ether is idle does the computer begin transmitting. With wireless LANs, that idea does not work so well.

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



- The second problem that had to be solved is that a radio signal can be reflected off solid objects, so it may be received multiple times (along multiple paths). This interference results in what is called **multipath fading.**
- The third problem is that a great deal of software is not aware of mobility.
- The fourth problem is that if a notebook computer is moved away from the ceiling-mounted base station it is using and into the range of a different base station, some way of handing it off is needed.
- Although this problem occurs with cellular telephones, it does not occur with Ethernet and needed to be solved.
- The network consists of multiple cells, each with its own base station, but with the base stations connected by Ethernet.
- From the outside, the entire system should look like a single Ethernet. The connection between the 802.11 system and the outside world is called a portal.

A multicell 802.11 network.



- After some work, the committee came up with a standard in 1997 that addressed these and other concerns. The wireless LAN it described ran at either **1 Mbps or 2 Mbps**.
- A split developed within the committee, resulting in two new standards in 1999.
  - The **802.11a** standard uses a wider frequency band and runs at speeds up to **54 Mbps**.
  - The **802.11b** standard uses the same frequency band as 802.11, but uses a different modulation technique to achieve **11 Mbps**.
- In the current scenario, the 802.11 is being widely used in organizations like airports, railway stations, hotels, shopping malls, and universities so far as the computational ability and internet access is conecerned.

QUIZ