Computer Networks

UNIT-1

M S Kumar Reddy
CSE, SVEC

Course Objectives

- CO 1: Illustrate fundamentals of networks, Reference Models and Transmission Media. (K2)
- CO 2: Demonstrate Error Detection & Correction and Data Link Layer protocols. (K3)
- CO 3: Illustrate the protocols of MAC sublayer and Channelization. (K2)
- CO 4: Utilize connection and connectionless services and Apply Routing and Congestion Control Algorithms. (K3)
- CO 5: Explain Transport Layer and Application Layer protocols. (K2)

UNIT-1

Introduction

- What is Computer Network?
- Applications
- Network Hardware
- **Network Types: WAN, LAN, MAN.**
- **Network Topologies: Mesh, Bus, Star, Ring, and Hybrid.**
- Network Software
- **The OSI Reference Model**
- **The TCP/IP Reference Model**

Physical Layer

- **Introduction to Guided Media**
  - **Twisted-pair cable**
  - **Coaxial cable**
  - **Fiber optic cable**
- **introduction about unguided media**

What is CN?

A **computer network** refers to a collection of **computers** that are linked together, enabling them to share information with each other.

Applications

- **Business Applications**
  - Resource Sharing
  - Emails
  - VPNs
  - E-Commerce
- **Home Applications**
  - TV
  - Smart Homes (IoT)
  - Facebook, Twitter, etc.
- **Mobile Applications**
  - GPS
  - Smart Phones
  - Wearable Devices

Network Hardware

- Participants
  - Connecting Devices
    - Hubs, Switches, Routers, Modems, etc.
  - Communication Medium
    - Wired, Wireless
  - Edge Devices
    - PCs, Laptops, Servers, Sensors, Printers, etc.

INTERNET

- By the early 1990s, the interconnection of various commercial networks and organizations (such as ARPANET, NSFNET, EuropaNET, EBONE, and others) signified the onset of the **modern Internet.**
- The structure of the Internet is characterized by a multilevel architecture.

INTERNET (Cont.)

- A computer establishes connection with an **Internet Service Provider**.
- One typical method of connecting to an ISP involves using your home's phone line through a **DSL** (**Digital Subscriber Line**) **modem**.
- DSL provides a higher bandwidth option to utilize the local telephone line compared to transmitting data over a standard voice call (Dial-up).

INTERNET (Cont.)

- Another method is to send signals over the cable TV system.
- But these two are slower, Up to few Mbps.
- Now we are communicating at greater speed like 10 to 100 Mbps because of **FTTH (Fiber to the Home).**

What Happens in an **Internet Minut**

5312 petabytes
of data transferred

2025

4.3 milli
Video vie

233 million
Emails sent

110,000
New appsts

233 million
Emails sent

443 million
Spent online

10.5 million
Mobile app downlodds

420,000
Mobile app downloads

520,000
New posts

6.2 million
Search queries

And Future Growth is Staggering

By 2030
700 million
people will

35 billion
IoT events
every minute

By 2030
700 million people
will live in the metaverse

MSKR

200.33.210.250
207.205.230.105
207.205.230.110
207.205.230.128
207.205.230.123
207.205.249.112
207.205.230.117
207.205.230.102
207.205.230.174
207.205.230.134
207.205.230.118
207.205.249.117
207.205.230.126
207.205.230.169
207.205.230.155
207.205.249.101

MSKR

Network Types

- The criteria of distinguishing one type of network from another is difficult and sometimes confusing. We use a few criteria such as size, geographical coverage, and ownership to make this distinction.
- Based on the size/geographical coverage a network will be falling under different categories.

Network Types (PAN)

- **PANs** (**Personal Area Networks**) let devices communicate over the range of a person.
  - Wired
  - Wireless
    - Bluetooth
    - RFID

Network Types (LAN)

- A **LAN (Local Area Network)** is a privately owned network that operates within and nearby a single building like a home, office or factory.
- When LANs are used by companies, they are called **enterprise networks**.
- Wired LANs: Generally uses coper wires, Older ones operate at 100Mbps to 1Gbps, newer can operate upto 10Gbps.
- Wireless LANs are very popular these days that uses: **AP** (**Access Point**), **wireless router**, or **base station,** usually operates at 11 to 100 Mbps.

a. LAN with a common cable (past)

b. LAN with a switch (today)

Network Types (MAN)

- A **MAN (Metropolitan Area Network)** covers a city. Ex: Cable Network.
- In this figure we see both television signals and Internet being fed into the centralized **cable headen** for subsequent distribution to people's homes.
- Recent developments in high-speed wireless Internet access have resulted in another MAN, called **WiMAX.**

Network Types (WAN)

- A **WAN** (**Wide Area Network**) spans a large geographical area, often a country or continent.
- A LAN interconnects hosts; a WAN interconnects connecting devices such as switches, routers, or modems.
- a WAN is normally created and run by communication companies and leased by an organization that uses it.
- A point-to-point WAN is a network that connects two communicating devices through a transmission media (cable or air).
- Switched WAN is a combination of several point-to-point WANs that are connected by switches.
- **switches**, are specialized computers that connect two or more transmission lines.

Network Types (WAN)

Network Types (WAN)

Network Types (WAN)

Network Types (WAN)

Network Topologies

- ***Network Topology*** refers to the way in which a network is laid out physically.
- Two or more devices connect to a link; two or more links form a topology.
- The topology of a network is the geometric representation of the relationship of all the links and linking devices (usually called ***nodes***) to one another.
- There are four basic topologies possible:
  - Mesh
  - Star
  - Bus
  - ring

Network Topologies (Cont.)

- ***Mesh Topology***
  - Every device has a dedicated point-to-point link to every other device.
  - To create a fully connected mesh network with *n* nodes, we need ***n* (*n* – 1) / 2** duplex-mode links.
  - To accommodate that many links, every device on the network must have *n* – 1 input/output (I/O) ports to be connected to the other *n* – 1 stations.
  - Advantages: No traffic problems, Robust i.e., Failure of one link or node will not effect others, Privacy and Security, & fault identification and isolation is easy.
  - Disadvantages: installation and reconnection are difficult, the sheer bulk of the wiring can be greater than the available space, the hardware required to connect each link.

Network Topologies (Cont.)

- ***Star Topology***
  - Each device has a dedicated point-to-point link only to a central controller, usually called a ***hub***.
  - *Advantages:* Less expensive than a mesh topology, easy to install and reconfigure, robustness in terms of links, and easy fault identification and isolation.
  - Disadvantages: Dependency of the whole topology on one single point, the hub, more cabling is required in a star than in some other topologies (such as ring or bus).

Network Topologies (Cont.)

- ***Bus Topology***
  - Unlike the preceding topologies a **bus topology** is multipoint. One long cable acts as a **back** link all the devices in a network. Nodes are connected to the bus cable by drop lines and tap
  - Advantages: Ease of installation, less cabling than mesh or star topologies.
  - Disadvantages: difficult reconnection and fault isolation, difficult to ad devices, Signal reflection at the taps can cause degradation in quality, that can be contr limiting the number and spacing of devices connected to a given length of cable and a break in the bus cable stops all transmission.

Network Topologies (Cont.)

- ***Ring Topology***
  - each device has a dedicated point-to-point connection with only the two devices on either side of it. A signal is passed along the ring in one direction, from device to device, until it reaches its destination. Uses tokens to control the medium access.
  - Advantages: Relatively easy to install and reconfigure, Easy fault identification and isolation.
  - Disadvantages: Unidirectional traffic, break in a link will bring down the entire network.

Which Topology Wins?

Topology	Performance	Reliability	Cost	Scalability	Fault Tolerance
Mesh	High (dedicated links)	Very High (redundancy)	Very High	Poor	Excellent
Star	Moderate (hub is key)	Good (unless hub fails)	Moderate	Good	Good (except hub)
Bus	Moderate (shared cable)	Poor (single cable)	Low	Poor	Poor
Ring	Moderate	Fair	Moderate	Poor	Poor (break affects all)

Network Software: Protocol Hierarchy

- Protocol
  - An agreement between the communicating parties on how communication is to proceed.

    Or
  - Set of rules that governs the communication.
- Network Service
  - An application that provides data storage, manipulation, presentation, communication or other capability.
  - Examples: Normal Web Service, Secured Web Service, E-Mail, File server, Remote login, instant messaging, video conferencing, video broadcasting, VoIP Calls, Gaming, IoT,
- Any service will be provided by clearly following a set of rules i.e. Protocols.

Protocol Hierarchy (Cont..)

- Network software is designed as a stack of layers, where every layer will have a set of protocols that does certain task.
- Imaging a network service as a simple program
  - Takes input from the user
  - Does some magic on it (process)
  - But instead of normal output, the program generates electrical/electro-magnetic/light signal as output.
- So if the program is a continuous program (Single Layer) then we need different programs to provide different services from first to last step.
  - It is like multiple programs created without using Modules/Functions that need to do all the tasks from taking input to generating signals.

Protocol Hierarchy (Cont..)

- Drawback with single layer is:
  - Design Complexity is Very High
- Instead, if we combine all the programs into one and divide the program using function/modules to eliminate repeated coding.

- As shown here one such program is capable of providing 4x3x6=72 different types of services.
- Hence, the network software is a layered architecture with multiple protocols in each layer.
- Every layer will provide some service to above layer. (Taking input from above layer, processing it and giving it to bellow layer).

Protocol Hierarchy (Cont..)

Protocol Hierarchy (Cont..)

- This layered concept provides information hiding, abstract data types, data encapsulation like in OOPs.
- The entities comprising the corresponding layers on different machines are called **peers**.
- A set of layers and protocols is called a **network architecture**.

Protocol Hierarchy (Cont..)

- When data moves from top layer to bottom headers will be added.
- When data moves from bottom layer to top headers will be removed.

Design Issues

- Reliability – Error Control Mechanisms in 2 different layers in two levels.
- Routing – 1 Layer Completely Dedicated
- Addressing and Naming – Diff layers use their diff type of addressing for different levels of communication.
- Scalability
- Flow Control
- Congestion Control
- QoS in Real-time Services

Connection-oriented vs Connection-less

- Layers can offer two different types of service to the layers above them.
- **Connection-oriented** service is modeled after the telephone system.
  - **Negotiation:** Maximum message size, QoS level required, other Issues.
  - Addressing in the begining only.
- **connectionless** service is modeled after the postal system.
  - No need of negotiation.
  - Addressing in every message.
- Reliable (Ack) and Unreliable (No-Ack) Services

	Service	Example
Connection-oriented	Reliable message stream	Sequence of pag
	Reliable byte stream	Movie download
	Unreliable connection	Voice over IP
Connection-less	Unreliable datagram	Electronic junk m
	Acknowledged datagram	Text messaging
	Request-reply	Database query

Relationship between Services and Protocols

- Service (Layers)
  - A *service* is a set of primitives (operations) that a layer provides to the layer above it.
  - The service defines what operations the layer is prepared to perform on behalf of its users, but it says nothing at all about how these operations are implemented.
  - A service relates to an interface between two layers, with the lower layer being the service provider and the upper layer being the service user.
- Protocol
  - Entities use protocols to implement their service definitions.
  - They are free to change their protocols at will, provided they do not change the service visible to their users.

Reference Models

- **OSI Reference Model**
  - Developed in response of a International Standard Organisation's (ISO) proposal in 1993 & revised in1995.
  - Not used anymore but layers model is quite general and valid.
- TCP/IP Reference Model
  - Designed for ARPANET(Universities and DARPA) for support different types of communications via the network in 1974 & redefined and standardised in1988
  - Model was not clearly defined but the protocols are widely used.
- The current Internet is successor of ARPANET hence continued using TCP/IP.

OSI Reference Model

- ISO-OSI: International Standards Organization – Open System Interconnection

OSI Reference Model(Cont.)

- So why 7 layers? The principles behind the coming up with 7 are
  - 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 with an eye toward 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 need not be thrown together in the same layer out of necessity and small enough that the architecture does not become unwieldy.
- Note that the OSI model itself is not a network architecture because it does not specify the exact services and protocols to be used in each layer. It just tells what each layer should do.

OSI Reference Model(Cont.)

OSI Reference Model(Cont.)

- **Physical Layer**: Concerned with transmitting raw bits over a communication channel.
  - To do so, take cares of
    - What electrical signals should be used to represent a 1 and a 0
    - How many nanoseconds a bit lasts
    - whether transmission may proceed simultaneously in both directions
    - How the initial connection is established
    - How the connection was closed once done
    - How many pins the network connector has? and what is purpose of each pin
  - These design issues largely deal with mechanical, electrical, and timing interfaces, as well as the physical transmission medium, which lies below the physical layer.

OSI Reference Model(Cont.)

OSI Reference Model(Cont.)

- **Data Link Layer**: Transform a raw transmission facility into a line that appears free of undetected transmission errors.
  - DLL will achieve this by
    - having the sender break up the input data into **data frames** and transmitting them sequentially**.**
    - Make the receiving device send an acknowledgement in reliable services.
  - Also make sure that a fast receiver will not overrun a slow receiver.
  - In case of broadcasting channels (multi-point), also decides, who can access and transmit (Medium Access Control).
  - Uses physical (MAC) Address for delivery of information to next node (node-to-node delivery).

OSI Reference Model(Cont.)

OSI Reference Model(Cont.)

- **Network Layer**
  - Controls the operation of a subnet
  - Takes care of “Routing” from host to host that are in different networks (host-to-host delivery).
  - Uses logical (IP) address for identifying and delivering to a node in the network.

OSI Reference Model(Cont.)

OSI Reference Model(Cont.)

- **Transport Layer**
  - Accepts data from above it, split it up into smaller units if need be, pass these to the network layer, and ensure that the pieces all arrive correctly at the other end.
  - Provides two types of services, selects which service to provide based on need.
    - Connection-oriented service
    - Connection-less service
  - Uses port address to identify communicating processes on both ends (process-to-process delivery)
  - A true end-to-end delivery of information.

OSI Reference Model(Cont.)

OSI Reference Model(Cont.)

Different Applications	Electronic Mail	HTML Page	Internet Chat
Port	110	80	531

OSI Reference Model(Cont.)

- The physical layer, data link layer, and network layer are N/W dependent layers. They deliver of information from the current device to the next device with the corresponding layer access.
- Where as the remaining 4 layers will be there in only end devices normally, they will work in the perspective of source to destination(end-to-end).

OSI Reference Model(Cont.)

- **Session Layer**
  - Allows users on different machines to establish **sessions** between them
  - Sessions offer various services
    - Dialogue Control: Who’s turn is it to communicate.
    - Token management: Prevention of simultaneous access of same operation (like deadlocks)
    - Synchronization

OSI Reference Model(Cont.)

- **Presentation Layer**
  - Concerned with the syntax and semantics of the information transmitted
  - To make it possible for computers with different internal data representations to communicate.
  - Defines and uses higher level abstract data structures and encoding mechanisms.

OSI Reference Model(Cont.)

- **Application Layer**
  - Contains a variety of protocols that are commonly needed by users.
  - Provides a systematic and easy way for users to get a network service.

TCP/IP Reference Model

- Named after the two major protocols TCP (Transport Layer) and IP (Internet Layer).

TCP/IP Reference Model (Cont.)

- **Link Layer**
  - An interface between hosts and transmission links.
- **Internet Layer**
  - Its job is to permit hosts to inject IP packets into any network and have them travel independently to the destination and delivered (potentially on a different network).
  - The internet layer defines an official packet format and protocol called **IP** (**Internet Protocol**), plus a companion protocol called **ICMP** (**Internet Control Message Protocol**) that helps it function.
  - Routing
  - Uses IP addresses (Logical address) to do host-to-host delivery.

TCP/IP Reference Model (Cont.)

- **Transport Layer**
  - It is designed to allow peer entities on the source and destination hosts to carry on a conversation, just as in the OSI transport layer.
  - Segments data received from above layer and gives them to internet layer.
  - Uses two protocols to provide process-to-process communication in two ways
    - TCP
      - Reliable Connection-Oriented Protocol
      - Sends information as stream of bytes.
      - Error Control, Flow Control

TCP/IP Reference Model (Cont.)

- UDP
  - Unreliable Connectionless Protocol
  - Not provides Error Control, Flow Control.
  - For services that need prompt delivery: Video or Speech Communication

TCP/IP Reference Model (Cont.)

- **Application Layer**
  - Applications in TCP/IP simply include any session and presentation functions that they require.
  - Contain all the high level protocols like
    - TELNET: Remote Access
    - FTP: File Transferring
    - SMTP: Electronic Mails
    - HTTP: Web Service

TCP/IP Reference Model (Cont.)

Layers in the TCP/ Protocol Suite

OSI vs TCP/IP

- **Similarities**
  - Based upon layered architecture.
  - In both models, the layers above transport layer are application-oriented users of the transport service.

OSI vs TCP/IP

- **Differences**
  - OSI model is a generic model that is based upon functionalities of each layer. TCP/IP model is a protocol-oriented standard.
  - OSI model distinguishes the three concepts, namely, services, interfaces, and protocols. TCP/IP does not have a clear distinction between these three.
  - OSI model gives guidelines on how communication needs to be done, while TCP/IP define standards on which the Internet was developed. So, TCP/IP is a more practical model.
  - In OSI, the model was developed first and then the protocols in each layer were developed. In the TCP/IP suite, the reverse is true.
  - The OSI has seven layers while the TCP/IP has four layers.

Physical Layer

Physical Layer

Physical Layer

- **Representation of Bits:** Data in this layer consists of stream of bits. The bits must be encoded into signals for transmission. It defines the type of encoding i.e. how 0's and are changed to signal.
- **Data Rate:** This layer defines the rate of transmission which is the number of bits per second.
- **Synchronization:** It deals with the synchronization of the transmitter and receiver. Th sender and receiver are synchronized at bit level.
- **Interface:** The physical layer defines the transmission interface between devices and transmission medium.

Physical Layer

- **Line Configuration:** This layer connects devices with the medium: Point to Point configuration and Multipoint configuration.
- **Topologies:** Devices must be connected using the following topologies: Mesh, Star, Ring and Bus.
- **Transmission Modes:** Physical Layer defines the direction of transmission between two devices: Simplex, Half Duplex, Full Duplex.
- Deals with baseband and broadband transmission.

Periodi Analog Signals

a. A signal with a frequency of 12 Hz

b. A signal with a frequency of 6 Hz

a. A signal with high peak amplitude

b. A signal with low peak amplitude

$$f = \frac{1}{T} \quad \text{and} \quad T = \frac{1}{f}$$

Frequency and period are the inverse of each other.

Periodi
Analog
Signals

Three sine waves with the same amplitude and frequency, but different phases

Fourier Analysis

- In the early 19th century, the French mathematician Jean-Baptiste Fourier proved that any reasonably behaved periodic function, *g*(*t*) with period *T,* can be constructed as the sum of a (possibly infinite) number of sines and cosines.
- where *f* = 1/*T* is the fundamental frequency, *an* and *bn* are the sine and cosine amplitudes of the *n*th **harmonics** (terms), and *c* is a constant. Such a decomposition is called a **Fourier series**.

$$g(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2\pi nft) + \sum_{n=1}^{\infty} b$$

$$a_n = \frac{2}{T}\int_0^T g(t)\sin(2\pi nft)\,dt$$

$$b_n = \frac{2}{T}\int_0^T g(t)\cos(2\pi nft)\,dt$$

$$c = \frac{2}{T}\int_0^T g(t)\,dt$$

Fourier Analysis

As shown in the figure, a square wave can be approximated by combining 3 sine waves (3-harmonics) at 3 frequencies.

A composite periodic signal

Decomposition of a composite periodic signal in the time and frequency domains

Fourier Analysis

The bandwidth of a composite signal is the difference between the highest and the lowest frequencies contained in that signal.

Digital Signals

Digital Signals

- **Bit Rate**: The **bit rate** is the number of bits sent in 1s, expressed in **bits per second (bps)**
- **Bit Length:** The **bit length** is the distance one bit occupies on the transmissi medium.
- Based on Fourier analysis, a digital signal is a composite analog signal. The bandwidth is infinite, as you may have guessed.
- Since a digital signals carry infinite number of frequencies and since there is carrier that is available to carry all the frequencies, using Fourier analysis onl proration of the frequency harmonics will be used.

Transmission Impairment

- **Attenuation:** When a signal, simple or composite, travels through a medium, it loses som energy in overcoming the resistance of the medium. (DB)
- **Distortion:** The signal changes its form or shape, as the signal is a composite of r frequencies, each frequency may react differently to the medium(Like light travelling thr prism.).
- **Noise:** Several types of noise, such as thermal noise, induced noise, crosstalk, and impulse may corrupt the signal.

Data Rate

- A very important consideration in data communications is how fast we can send data, bits per second, over a channel. Data rate depends on three factors:
  - The bandwidth available
  - The level of the signals we use
  - The quality of the channel (the level of noise)

- **Noiseless Channel: Nyquist Bit Rate**

$$\text{BitRate} = 2 \times \text{bandwidth} \times \log_2 L$$

- **Noisy Channel: Shannon Capacity**

$$\text{Capacity} = \text{bandwidth} \times \log_2(1 + S$$

$$\text{SNR}_{\text{dB}} = 10 \log_{10}\text{SNR} \longrightarrow \text{SNR} = 10^{\text{SNR}_{\text{dB}}/10}$$

Data Rate

- Consider a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with two signal levels. The maximum bit rate can be calculated as

$$\text{BitRate} = 2 \times 3000 \times \log_2 2 =$$

- Consider the same noiseless channel transmitting a signal with four signal levels. The maximum bit rate can be calculated as

$$\text{BitRate} = 2 \times 3000 \times \log_2 4 = 1$$

- We need to send 265 kbps over a noiseless channel with a bandwidth of 20 kHz. How many signal levels do we need?

$$265{,}000 = 2 \times 20{,}000 \times \log$$
$$\log_2 L = 6.625$$
$$L = 2^{6.625}$$
$$= 98.7 \text{ levels}$$

Data Rate

- We have a channel with a 1-MHz bandwidth. The SNR for this channel is 63. What are th maximum bit rate?

$$
\begin{aligned}
C &= B \log_2(1 + \text{SNR}) \\
&= 10^6 \log_2(1 + 63) \\
&= 10^6 \log_2 64 \\
&= 6 \text{ Mbps}
\end{aligned}
$$

FIGURE 8-25 On a coaxial cable, data travels through a copper wire. This illustration shows computers networked together with coaxial cable.

FIGURE 8-24 A twisted-pair cable consists of one or more twisted-pair wires. Each twisted-pair wire usually is color coded for identification.

FIGURE 8-26 A fiber-optic cable consists of hair-thin strands of g
plastic that carry data as pulses of light.

Transmission Medium

- A **transmission medium** can be broadly defined as anything that can carry information from a source to a destination.

Guided Medium/Media

- A signal traveling along any of these media is directed and contained by the physical limits of the medium.
- It guides signal through solid physical path.
- Three major guided media
  - Twisted-Pair
    - Unshielded Twisted-Pair (UTP)
    - Shielded Twisted-Pair (STP)
  - Coaxial Cables
  - Fiber-Optic Cables

Twisted-Pairs

- A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together, as shown in Figure.
- By twisting the pairs, a balance is maintained by nullifying the noise/interference.
- Twisting also nullify the magnetic field generated, so the wire radiates less effectively. Hence reduces cross talks.

Unshielded vs Shielded

The most common twisted-pair cable used in communications is referred to as ***unshielded twisted-pair*** **(UTP).** IBM has also produced a version of twisted-pair cable for its use, called ***shielded twisted-pair*** **(STP).** STP cable has a metal foil or braided mesh covering that encases each pair of insulated conductors.

Twisted-Pairs

Category	*Specification*	*Data Rate (Mbps)*	*Use*
1	Unshielded twisted-pair used in telephone	< 0.1	Telephor
2	Unshielded twisted-pair originally used in T lines	2	T-1 lines
3	Improved CAT 2 used in LANs	10	LANs
4	Improved CAT 3 used in Token Ring networks	20	LANs
5	Cable wire is normally 24 AWG with a jacket and outside sheath	100	LANs
5E	An extension to category 5 that includes extra features to minimize the crosstalk and electromagnetic interference	125	LANs
6	A new category with matched components coming from the same manufacturer. The cable must be tested at a 200-Mbps data rate.	200	LANs
7	Sometimes called *SSTP (shielded screen twisted-pair)*. Each pair is individually wrapped in a helical metallic foil followed by a metallic foil shield in addition to the outside sheath. The shield decreases the effect of crosstalk and increases the data rate.	600	LANs

Twisted-Pair Connecters

The RJ45 is a keyed connector, meaning the connector can be inserted in only one way.

RJ-45 Female

RJ-45 Male

Coaxial Cable

- Coaxial cable (or *coax*) carries signals of higher frequency ranges than those in twisted-pair cable, in part because the two media are constructed quite differently.
- Coax has a central core conductor of solid or stranded wire (usually copper) enclosed in an insulating sheath, which is, in turn, encased in an outer conductor of metal foil, braid, or a combination of the two.
- The outer metallic wrapping serves both as a shield against noise and as the second conductor, which completes the circuit.
- Two kinds of coaxial cable are widely used. One kind, 50-ohm cable, is commonly used when it is intended for digital transmission from the start. The other kind, 75-ohm cable, is commonly used for analog transmission and cable television.

Coaxial Cable

Fiber-Optic Cable

- A fiber-optic cable is made of glass or plastic and transmits signals in the form of light.
- Working Principle:
  - If a ray of light traveling through one substance sudde enters another substance (of a different density), the r changes direction. In that case, if the **angle of inciden** less than the **critical angle,** the ray **refracts** and move closer to the surface. If the angle of incidence is equal critical angle, the light bends along the interface. If the is greater than the critical angle, the ray **reflects** (mak turn)

Fiber-Optic Cable

Optical fibers use reflection to guide light through a ch
A glass or plastic **core** is surrounded by a **cladding**
dense glass or plastic. The difference in density of th
materials must be such that a beam of light moving th
the core is reflected off the cladding instead of
refracted into it.

Fiber-Optic Cable

Current technology supports two modes (multimode ar
single mode) for propagating light along optical channe
each requiring fiber with different physical characterist
Multimode can be implemented in two forms: step-inde
graded-index.

Fiber-Optic Cable

- Single-mode uses step-index fiber and a highly focused source of light that limits beams to a sm range of angles, all close to the horizontal. The **single-mode fiber** itself is manufactured with a much smaller diameter than that of multimode fiber, and with substantially lower density (index refraction). The decrease in density results in a critical angle that is close enough to 90° to make propagation of beams almost horizontal.
- In **multimode step-index fiber,** the density of th core remains constant from the center to the ed
- **In multimode graded-index fiber,** decreases th distortion of the signal through the cable.

Fiber-Optic Cable

Type	*Core (μm)*	*Cladding (μm)*	*Mode*
50/125	50.0	125	Multimode, graded index
62.5/125	62.5	125	Multimode, graded index
100/125	100.0	125	Multimode, graded index
7/125	7.0	125	Single mode

There are three types of connectors for fib
optic cables. The **subscriber channel (SC
connector** is used for cable TV. It uses a
push/pull locking system. The **straight-ti
(ST) connector** is used for connecting cabl
networking devices. A Mechanical Transfe
Registered **Jack** (**MT-RJ**) is a **connector** us
for two fibers.

Fiber-Optic Cable

Advantages

- Higher bandwidth.
- Less signal attenuation.
- Resistance to corrosive materials
- Light weight.
- Greater immunity to tapping.

Disadvantages

- Installation and maintenance.
- Unidirectional light propagation.
- Cost.

Applications

- Twisted-Pair
  - Used in telephone lines to provide voice and data channels.
  - The DSL lines that are used by the telephone companies to provide high-data-rate.
  - Local-area networks, such as 10Base-T and 100Base-T, also use twisted-pair cables.
- Coax
  - Coaxial cable was widely used in analog telephone networks where a single coaxial network could carry 10,000 voice signals.
  - Later it was used in digital telephone networks where a single coaxial cable could carry digital data up to 600 Mbps.
  - Used in traditional Ethernet LANs
  - Now a days mostly used in TV communication.
- Optical-Fibers
  - Used in backbone networks because its wide bandwidth is cost-effective.
  - In some TV communications.

10 HZ
100 HZ
1 kHZ
10 kHZ
100 kHZ
1 MHZ
10 MHZ
100 MHZ
1 GHZ
10 GHZ
100 GHZ
1 THZ
10 THZ
100 THZ
10^{15} HZ
10^{16} HZ
10^{17} HZ
10^{18} HZ
10^{19} HZ
10^{20} HZ
10^{21} HZ
10^{22} HZ
10^{23} HZ
VLF
LF
MF
HF
VHF
UHF
SHF
EHF
INFRARED
VISIBLE
ULTRAVIOLET
X-RAY
GAMMA-RAY
COSMIC-RAY
Radio Spectrum
Optical Spectrum
3 KHz
300 GHz

Unguided Medium(Wireless)

Unguided medium transport electromagnetic waves without usi physical conductor. This type of communication is often referred to ***wireless communication*.**

Unlike guided transmission mediu unguided, signals are normally bro through free space and thus are av to anyone who has a device capabl receiving them.

f (Hz) 10^0 10^2 10^4 10^6 10^8 10^{10} 10^{12} 10^{14} 10^{16} 10^{18} 10^{20} 10^{22} 10^{24}
Radio
Microwave
Infrared
UV
X-ray
Gamma ray
Visible light
f (Hz) 10^4 10^5 10^6 10^7 10^8 10^9 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16}
Twisted pair
Coax
Satellite
Terrestrial microwave
Fiber optics
Maritime
AM radio
FM radio
TV
Band
LF
MF
HF
VHF
UHF
SHF
EHF
THF

Backgrou

Background

AN ANTENNA – USUALLY 1/2 WAVELENGTH LONG

Background

- We can divide wireless transmission into three broad groups: radio waves, microwaves, and infrared waves.
- The section of the electromagnetic spectrum defined as radio waves and microwaves is divided into eight ranges, called *bands,* each regulated by government authorities. These bands are rated from *very low frequency* (VLF) to *extremely high frequency* (EHF).

Band	*Range*	*Propagation*	*Applic*
very low frequency (VLF)	3–30 kHz	Ground	Long-range r navigation
low frequency (LF)	30–300 kHz	Ground	Radio beacor navigational
middle frequency (MF)	300 kHz–3 MHz	Sky	AM radio
high frequency (HF)	3–30 MHz	Sky	Citizens bane ship/aircraft
very high frequency (VHF)	30–300 MHz	Sky and line-of-sight	VHF TV, FM
ultrahigh frequency (UHF)	300 MHz–3 GHz	Line-of-sight	UHF TV, cell paging, satel
superhigh frequency (SF)	3–30 GHz	Line-of-sight	Satellite
extremely high frequency (EHF)	30–300 GHz	Line-of-sight	Radar, satelli

Wireless Propagation

Radio Waves (3kHz-1GHz)

- Although there is no clear-cut demarcation between radio waves and microwaves, however, the behavior of the waves, rather than the frequencies, is a better criterion for classification.
  - Adv: Radio waves, for the most part, are omnidirectional. When an antenna transmits radio waves, they are propagated in all directions.
  - Disadv: The radio waves transmitted by one antenna are susceptible to interference by another antenna that may send signals using the same frequency or band.

Radio Waves (3kHz-1GHz)

- Radio waves, particularly those waves that propagate in the sky mode, can travel long distances. This makes radio waves a good candidate for long-distance broadcasting such as AM radio.
- Radio waves, particularly those of low and medium frequencies, can penetrate walls.
- The radio wave band is relatively narrow, just under 1 GHz.

Microwaves(1GHz-300Ghz)

- Microwaves are unidirectional.
- Microwave propagation is line-of-sight.
- Use of certain portions of the band requires permission from authorities.
- Disadv: Very high-frequency microwaves cannot penetrate walls.
- Adv: The microwave band is relatively wide, almost 299 GHz. Therefore wider sub-bands can be assigned, and a high data rate is possible.

a. Parabolic dish antenna b. Horn antenna

Infrared(300Ghz-400Thz)

- Used for short-range communication, can’t penetrate through walls.
- Not suitable for outside communication as the sun’s rays contain infrared waves that can interfere with the communication.

Applications

Radio Waves:

The omnidirectional characteristics of radio waves make them useful for multicasting, in which there is one sender but many receivers.

Ex: AM and FM radio, television, maritime radio, cordless phones, and paging.

Microwaves

Microwaves, due to their unidirectional properties, are very useful when unicast (one-to-one) communication is needed between the sender and the receiver.

Ex: Cellular phones, satellite networks, and wireless LANs.

Infrared

The infrared band, almost 4
THz, has an excellent potential for data transmission.

Ex: Communication betweer
devices such as keyboards, mice, PCs, printers, Mobiles using special ports.

One widely used application is in Remote Controllers.