SCS 2205
Computer Networks I

Introduction

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Who am I?

I am Ajantha Atukorale

- Did my undergraduate @ University of Colombo ('91- '95)
- Joined the Academic staff as a Demonstrator/ Temp. Assistant Lecturer in '96 and Became a Lecturer in 1997
- Went for my PhD in 1997 and returned to Sri Lanka in 2001
- Became a Senior Lecturer in 2002
- Subject Lecturer for Computer Systems (YR 1), Computer Networks I (YR 2), Network & System Administration (YR 3)
- Currently holding the post of Head/CIS & Deputy Director
- Research Interests: Artificial Neural Networks, Pattern Recognition, Computer Networks, Big Data Analytics

Objectives

This course will introduce the fundamental concepts in the design and implementation of computer communication networks and their protocols. By the end of this course, students should be able to:

- Explain the fundamentals of data transmission
- Understand and explain the underlying network concepts
- Display an understanding of the process used to design a computer network for various sized systems
- Analyse the structure of TCP/IP based networks and to investigate approaches used in modern integrated networks
- Explain the most common communication network standards used in industry

Course Contents

- Introduction to Data Communication: Waves & Signals, Digital Communication, Channel Effects on Transmission and Multiplexing
- Data Rate in Channels, Modulation and Data Encoding
- Communication Modes, Transmission Modes, Synchronization and Switched Communications
- Transmission Media, Last Mile Access Technologies
- Computer Networks: Topologies, Types and Layered Architectures
- LAN Architectures, Channel Access Methods: CSMA, CSMA/CD, Ethernet
- Networking Devices: Hubs, Switches, Routers, Structure of the Internet, TCP/IP Protocol Suite

Course Contents

- IP Addressing, Sub-netting/ Super-netting and Routing
- IP Multicasting, Introduction to IPv6
- IP Support Protocols, Transport Layer Protocols
- Application Layer Protocols

Course Delivery - 2020

SCS 2105 Course Delivery Schedule - 2020

Lec. No	Topics(s)	Lecturer	Assignment
1	Data Communication	Dr. Nalin	
2	Data Communication	Dr. Nalin	
3	Data Communication	Dr. Nalin	Ass - 1
4	Introduction to LAN and Layered Architechtures	Ajantha	
5	Physical Media and Networking Devices	Ajantha	
6	Designing Networks	Ajantha	
7	Layer 2 and Ethernet	Ajantha	
8	APR and RARP Protocols	Ajantha	Ass - 2
9	Leyer 3 - IP Header in detail & IP Fragmentation	Ajantha	
10	IP Addressing	Rangana	
11	IP Addressing (Cont) and NAT	Rangana	
12	ICMP Protocol and IP Routing	Rangana	Ass - 3
13	IPv6 and IPv4/IPv6 Coexistance	Ajantha	
14	Layer 4 - UDP/TCP Header in detail	Dr. Nalin	
15	Layer 7 - DNS/HTTP Applications	Ajantha	
	Instructors		
	Coordinator :- Mr. Tharindu		
	Instructors :- Ms. Anjalee, Ms. Dushani, Mr. Isuru		

Recommended Reading

- Computer Networks (3rd Edition), Andrew S. Tanenbaum, Prentice Hall, 1996.
- Data and Computer Communications (6th Edition), William Stallings, Prentice Hall, 2000.
- Internetworking with TCP/IP (3rd Edition), D.E. Comer, Prentice Hall, 1995.
- Data Communications, Computer Networks and Open Systems (4th Edition), Fred Halsall, Addison-Wesley, 1995.
- Internet RFCs, Magazine Articles & Product White-papers.

Computer Networks ➔ Bunch of Acronyms !!!

Who's Who?

- In the Telecommunication World
- Legal status of world's telcos – varies considerably from country to country
- Common carriers – provides communication services to the public
- Tariff – their offerings & prices
- PTT – Post Telegraph & Telephone (National authority or a branch of the Gov.)
- ITU – International Telecommunication Union, many European Govs formed this in 1865. In 1947 ITU became an agency of the UN. (ITU-R, ITU-T, ITU-D ie. Radiocom, Telecom, Development Sectors)
- The standards are called "Recommendations"

Who's Who? (Contd.)

- In the International Standards World
- ISO – International Standards Organization ('46), members ANSI, BSI, AFNOR, etc.
- Tech-Committee (TC) ➔ Sub-Committee (SC) ➔ Working-Groups (WG) (Volunteers)

  Committee Draft ➔ Draft Intl. Stand. ➔ **International Standard**
- ANSI – a private non-Govt, non-profit Org. ANSI standards are frequently adopted by ISO as international standards!!
- IEEE - Institute of Electrical and Electronic Engineers, largest professional Org in the world. Major player in the standards world today.
- IEEE 802 standard for LANs (ISO 8802)
- Internet Society (ISOC) – by people interested in the Internet. Comparable to IEEE

  (Activity: IEEE vs ISOC discussion)

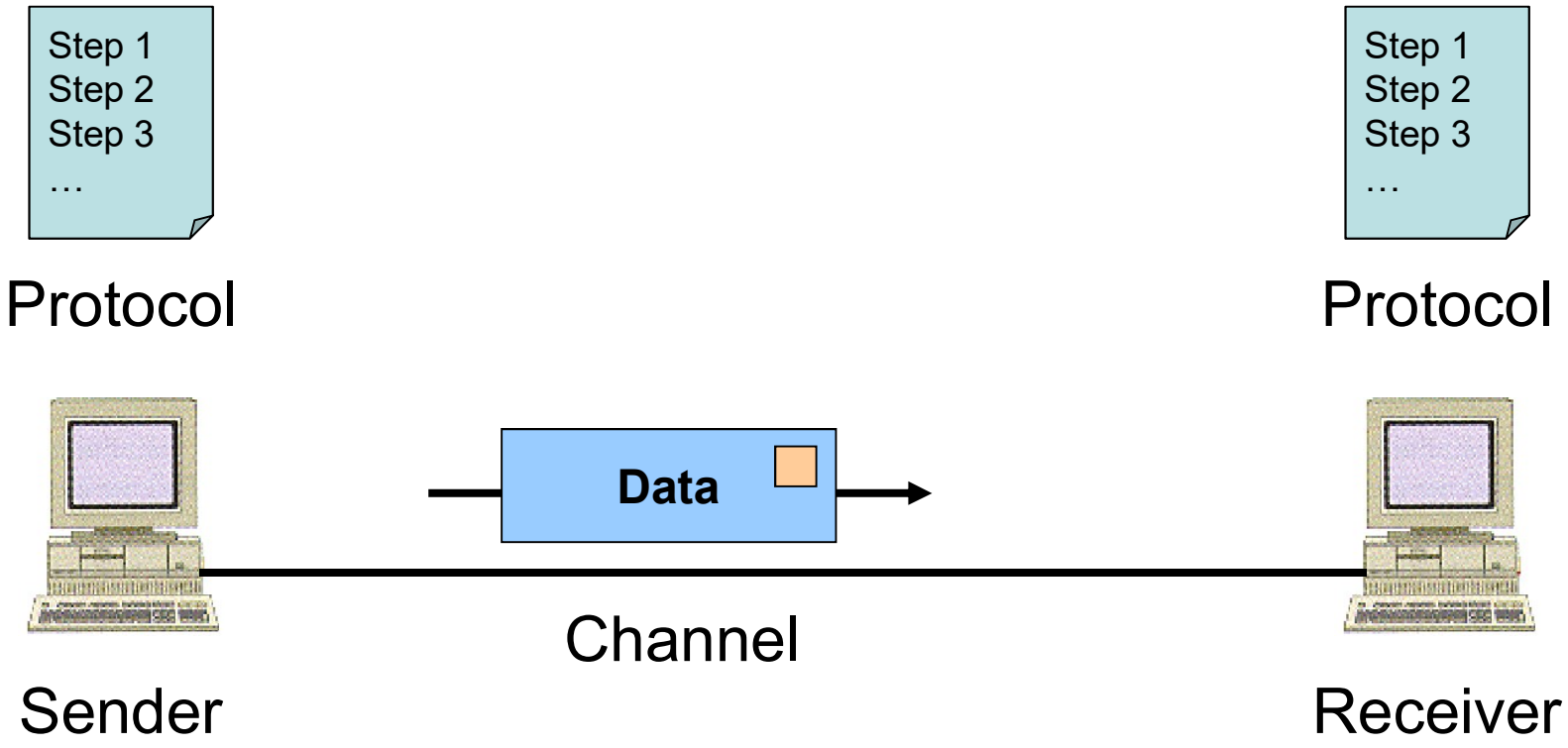
International Standards

The new 802.11ax standard (High Efficiency or HE specification) aims to provide better spectral efficiency, capacity, and coverage in dense deployment scenarios as well as outdoor environments, with a goal to improve the average throughput per station by at least 4x compared to 802.11ac. Let's look at five new features in 802.11ax that enable these improvements.

Note: This white paper is only available for download in the United States, Canada and Latin America.

Download White Paper

Data Communication System Components



Protocol is set of rules that shiuld follow by sender and reciever

Requirements for Communication

- Basic Requirements for Successful Communication
  - Two or more parties (Sender & Receiver)
  - Communication medium (Channel)
  - Use of compatible standards (Protocols)

- For data communication to occur, the communicating devices must be part of a **communication system** made up of a combination of **hardware** and **software.**

Characteristics of Data Communication System

- Delivery
  - The system must deliver data to the correct destination. Data must be received by the intended device or user and only by that device or user.
- Accuracy
  - The system must deliver data accurately. The data that had been altered in transmission and left uncorrected are unusable.
- Timelines
  - The system must deliver data in a timely manner. Data delivered late are useless. Timely deliver means delivering data as they are transmitted, in the same order they are sent, and without significant delay.

security

Sending Data from Source to Destination

- Data is **encoded** and transmitted as signals in the transmission media.
- Based on the bit pattern of data, the sending side generates a **signal** on the selected transmission medium and then this signal propagates to the receiving end.
- The receiving side extracts data from this signal and reproduce in its original format.

data has two types analog and digital

How Signals are Generated

- A signal is generated by changing the **strength** (or any other property) of a particular form of **energy** with respect to time on a suitable medium.

- Form of energy used can be **Electrical**, **Light** or **Electromagnetic**.

fiber optics

radio signal

- The medium used can be **Copper**, **Optical Fiber** or **Free Space**.

MEDIA TYPES

Physical Media

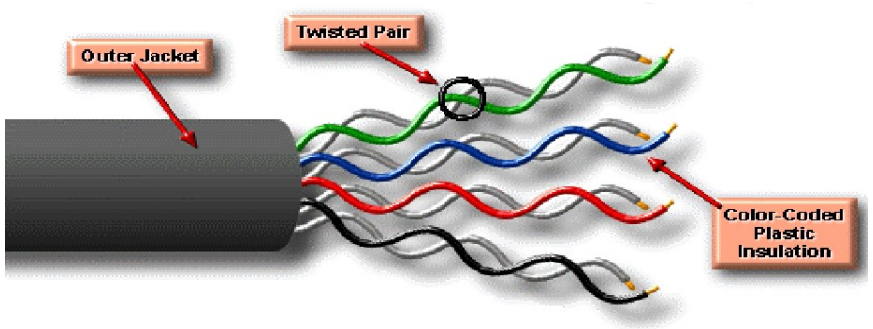
- Properties – Bandwidth, Delay, Cost, Ease of installation & maintenance, etc.
- Media
  - Guided (wire-line)
  - Unguided (wireless) - signal is always analog
- Characteristics and quality determined by medium and signal
- For guided, the medium is more important
- For unguided, the bandwidth produced by the antenna is more important
- Key concerns - data rate and distance
- Design Factors – Bandwidth (Higher bandwidth gives higher data rate), Transmission impairments, Interference, Number of receivers

Guided Transmission Media

- Twisted Pair
- Coaxial cable
- Optical fiber

Twisted Pair (TP)

- Separately insulated
- Twisted together
- Often bundled into cables
- Often referred to as UTP
- Most common medium



Twisted Pair – Applications

- Telephone network

  Between house and local exchange (subscriber loop)
- Within buildings

  To private branch exchange (PBX)
- For local area networks (LAN)

  10Mbps to 10Gbps

Twisted Pair – Pros & Cons

- Cheap
- Easy to work with
- Low data rate compared to
- Short range

Twisted Pair – Characteristics

- Analog

  Amplifiers are used for long distances
- Digital

  Use either analog or digital signals, **repeaters** are used for long distances
- Limited distance
- Limited bandwidth
- Limited data rate
- Susceptible to interference and noise

Q1: What is the type of connector used in twisted pair?

RJ 25 RJ 45 Connector
RJ = registered jack

Unshielded and Shielded TP

- Unshielded Twisted Pair (UTP)
  - Ordinary telephone wire
  - Cheapest
  - Easiest to install
  - Suffers from external EM interference

- Shielded Twisted Pair (STP)
  - Metal braid or sheathing that reduces interference
  - Expensive than UTP
  - Harder to handle (thick, heavy)

UTP Categories

- Cat 3
  - up to 16MHz
  - 10Mbps Ethernet (802.3), Basic rate ISDN
  - Voice grade found in most offices (4 pairs)
  - Twist length of 7.5cm to 10cm
- Cat 4
  - up to 20MHz
  - 10Mbps Ethernet, 16Mbps Token Ring (802.5)
- Cat 5 /5e
  - up to 100MHz
  - Twist length 0.6cm to 0.85cm
  - 100Base TX 100Mbps, 155Mbps ATM

UTP Categories

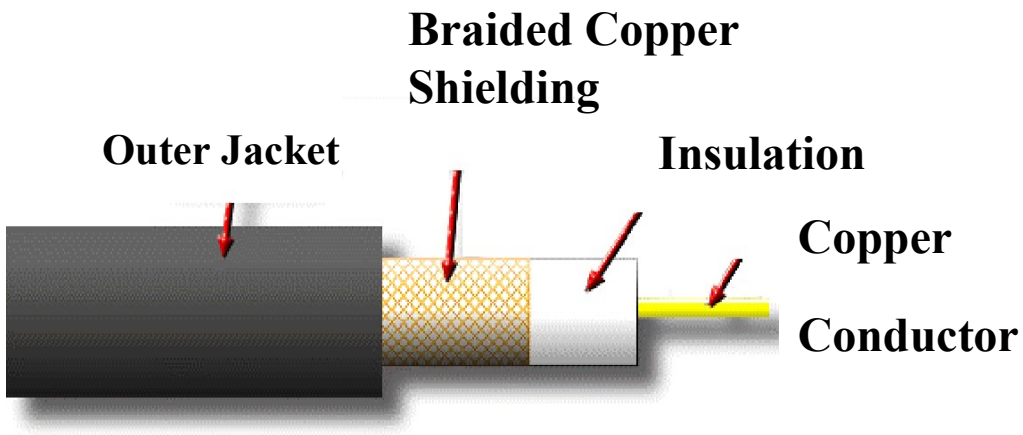
- Cat 6
  - up to 250MHz
  - 10GBase T
- Cat 7
  - up to 600MHz
  - 10GBase T (100m on copper)
  - Uses fully shielded cable

Name	Typical construction	Bandwidth	Applications	Notes
Level 1		0.4 MHz	Telephone and modem lines	Not described in EIA/TIA recommendations. Unsuitable for modern systems.[7]
Level 2		4 MHz	Older terminal systems, e.g. IBM 3270	Not described in EIA/TIA recommendations. Unsuitable for modern systems.[7]
Cat.3	UTP[8]	16 MHz[8]	10BASE-T and 100BASE-T4 Ethernet[8]	Described in EIA/TIA-568. Unsuitable for speeds above 16 Mbit/s. Now mainly for telephone cables[8]
Cat.4	UTP[8]	20 MHz[8]	16 Mbit/s[8] Token Ring	Not commonly used[8]
Cat.5	UTP[8]	100 MHz[8]	100BASE-TX & 1000BASE-T Ethernet[8]	Common in most current LANs[8]
Cat.5e	UTP[8]	100 MHz[8]	100BASE-TX & 1000BASE-T Ethernet[8]	Enhanced Cat5. Same construction as Cat5, but with better testing standards.
Cat.6	UTP[8]	250 MHz[8]	10GBASE-T Ethernet	Most commonly installed cable in Finland according to the 2002 standard. SFS-EN 50173-1
Cat.6a	U/FTP, F/UTP	500 MHz	10GBASE-T Ethernet	Adds outer shielding. ISO/IEC 11801:2002 Amendment 2.
Cat.7	F/FTP, S/FTP	600 MHz	Telephone, CCTV, 1000BASE-TX in the same cable. 10GBASE-T Ethernet.	Fully shielded cable. ISO/IEC 11801 2nd Ed.
Cat.7a	F/FTP, S/FTP	1000 MHz	Telephone, CATV, 1000BASE-TX in the same cable. 10GBASE-T Ethernet.	Uses all four pairs. ISO/IEC 11801 2nd Ed. Am. 2.
Cat.8.1	F/UTP	1600-2000 MHz	Telephone, CATV, 1000BASE-TX in the same cable. 40GBASE-T Ethernet.	In development.
Cat.8.2	F/FTP, S/FTP	1600-2000 MHz	Telephone, CATV, 1000BASE-TX in the same cable. 40GBASE-T Ethernet.	In development.

http://en.wikipedia.org/wiki/Twisted_pair

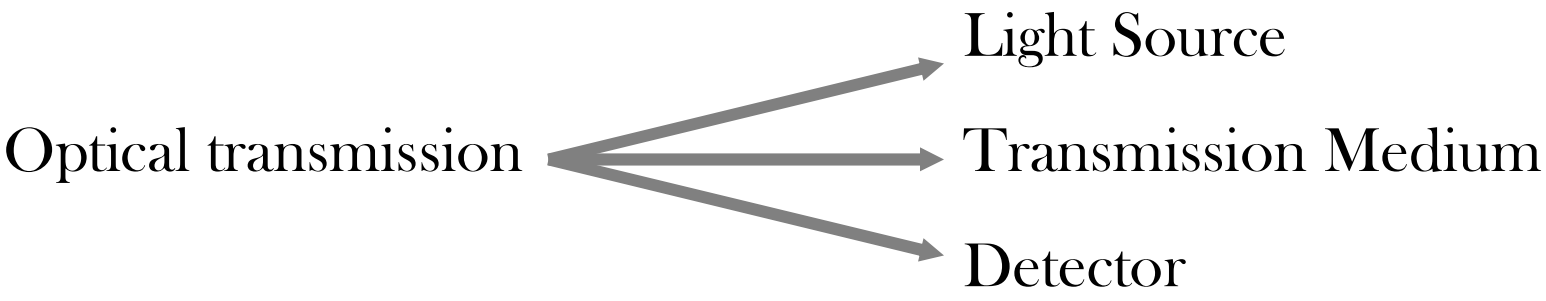
Coaxial Cable

- 50 ohm – digital trans.
- 75 ohm – analog trans.
- Television distribution
  - Ariel to TV
  - Cable TV



- Long distance telephone transmission
  - Can carry 10,000 voice calls simultaneously
  - Being replaced by fiber optic
- Slow Local area networks

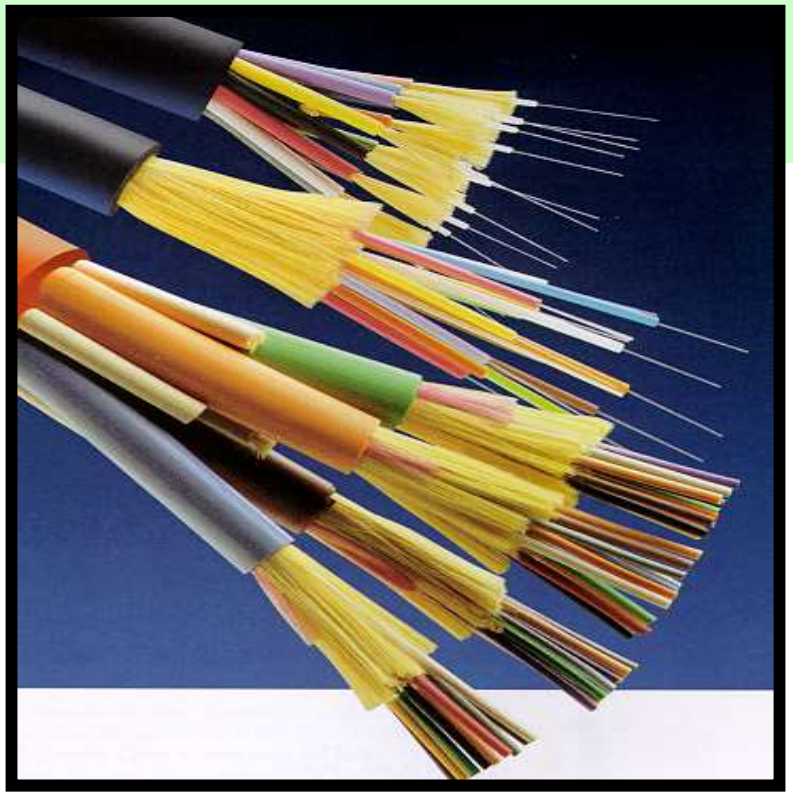
Optical Fiber



Benefits:

- Greater capacity : data rates of hundreds of Gbps
- Smaller size & weight
- Lower attenuation
- Electromagnetic isolation
- Greater repeater spacing

Optical Fiber (Cond)



Applications:

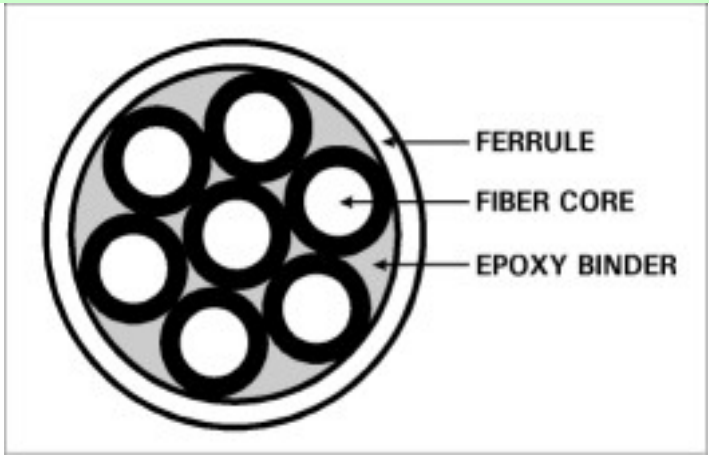
- Long-haul trunks
- Rural exchange trunks
- LANs

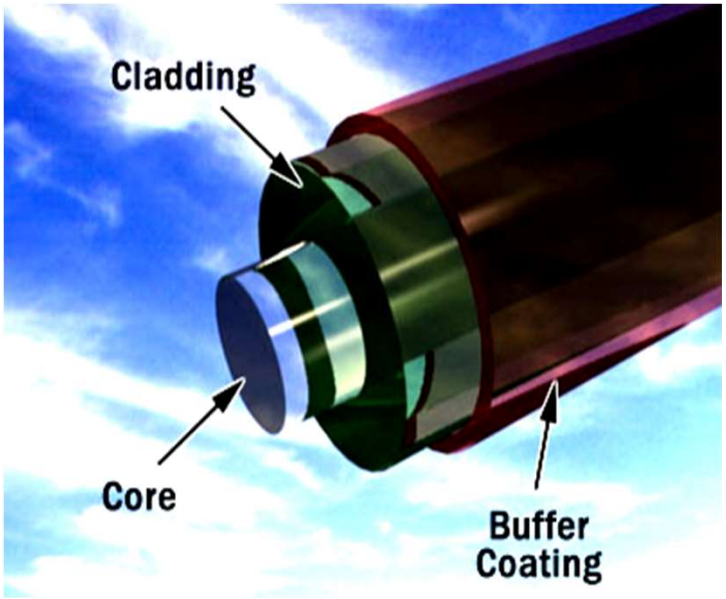
Characteristics:

- Act as wave guide for 10^{14} to 10^{15} Hz
  Athorakthakirana and drusha warnawaliya
  - Portions of infrared and visible spectrum
- Single-mode – light only propagates in straight lines without bouncing, expensive, but can be used for long distance, core 8-10 microns
- Multi-mode – many different rays will be bouncing around at different angles, core 50-65 microns (Cladding ~125 microns)

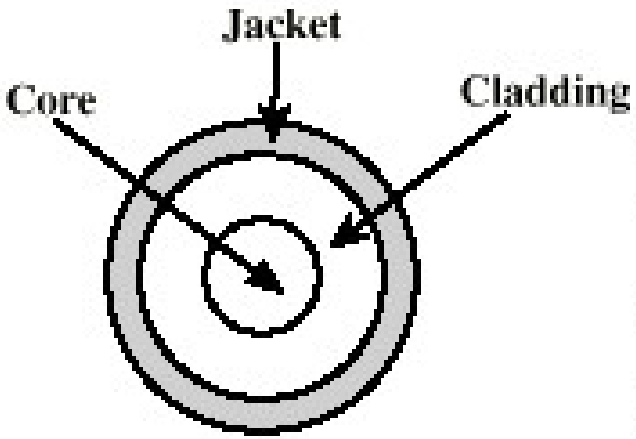
Optical Fiber (Cond)

- Silica based glass or plastic filaments are spun and packed into bundles of several hundreds or thousands. Bundles may be put together as rods or ribbons and sheets.
- These bundles are flexible and can be twisted and contorted to conduct light
- The thin glass center of the fibre where the light travels is called the "**core**".
- The outer optical material surrounding the core that reflects the light back into the core is called the "**cladding**".
- In order to protect the optical surface from moisture and damage, it is coated with a layer of buffer coating.

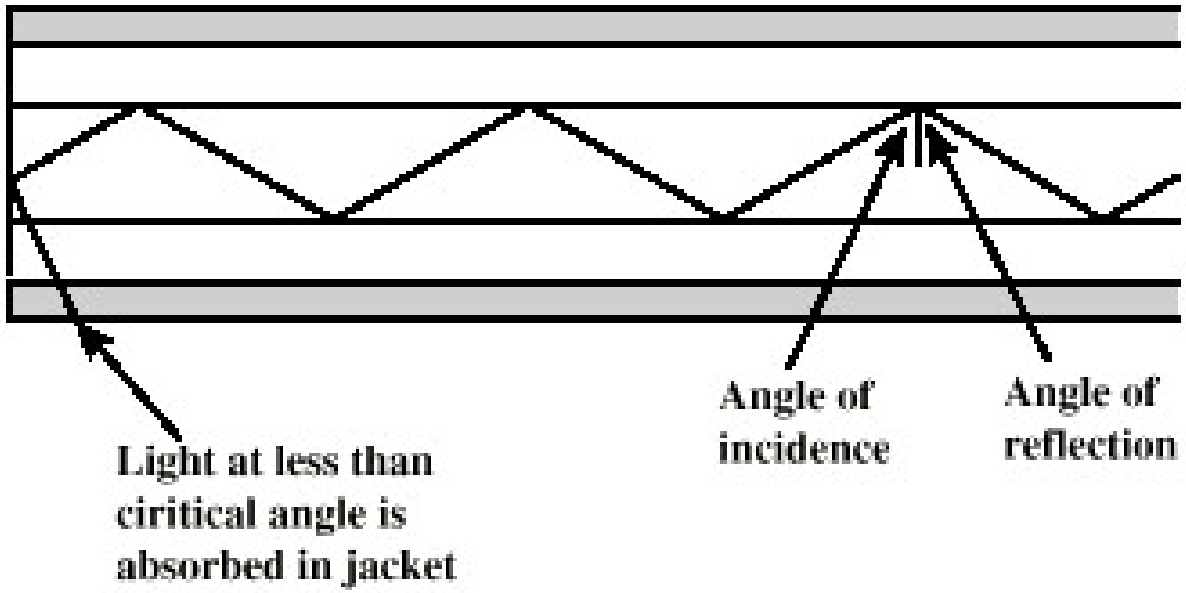




Optical Fiber (Cond)

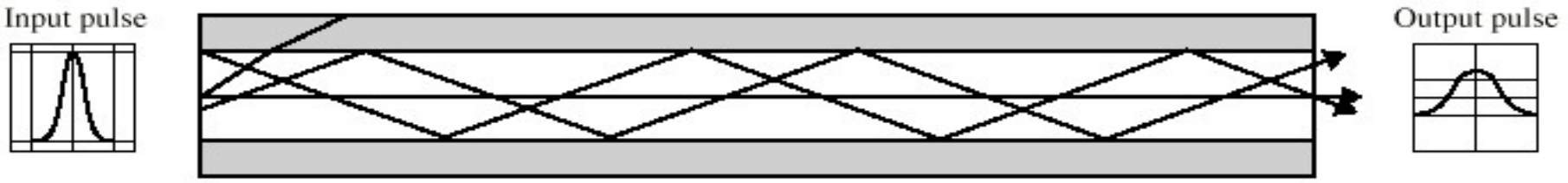


—Glass or plastic core
—Laser or light emitting diode
—Specially designed jacket
—Small size and weight

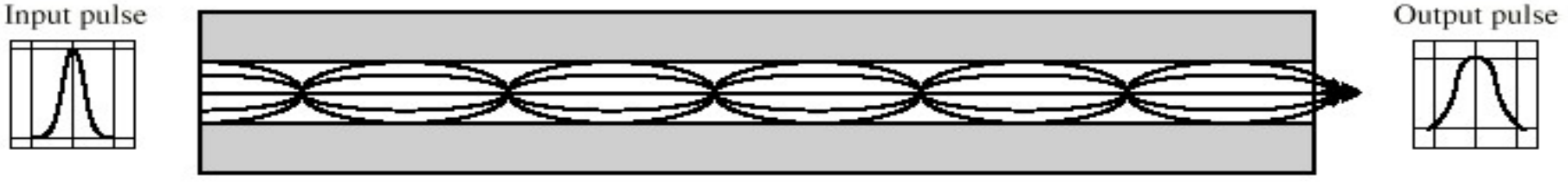


Optical Fiber Transmission

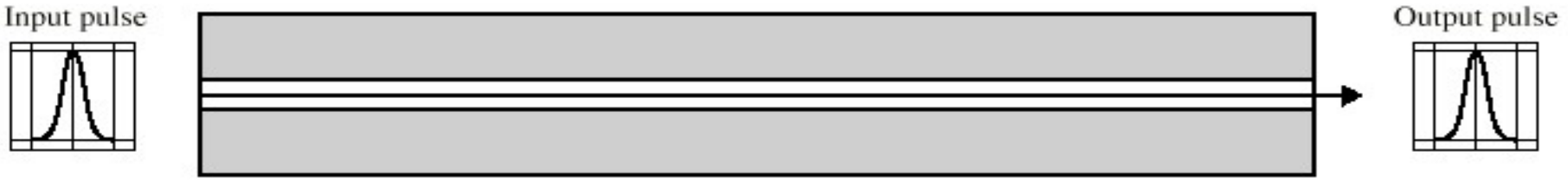
Modes



(a) Step-index multimode



(b) Graded-index multimode



(c) Single mode

Optical Fiber

Optical Fiber (Cond)

Ways of connecting fibers:

- Can terminate and plugged into fiber socket (10% - 20% light loss)
- Spliced manually, lay the two ends next to each other in a special sleeve and clamp them, take less time (10% light loss)
- Fused (melted) to form a solid connection (very less loss)

Light source comparison:

Item	**LED**	**Laser**
Data Rate	Low	High
Mode	Multi-mode	Multi/Single-mode
Distance	Short	Long
Lifetime	Long	Short
Temp. Sensitivity	Minor	Substantial
Cost	Low	Expensive

Optical Fiber (Cond)

Fiber has many advantages compared to Copper wire:

- Higher Bandwidth
- Low attenuation
- Not affected by electromagnetic interferences
- Not affected by corrosive chemicals
- Lighter in weight
- Secured from wire-tappers
- Do not induce high voltages when lightening takes place

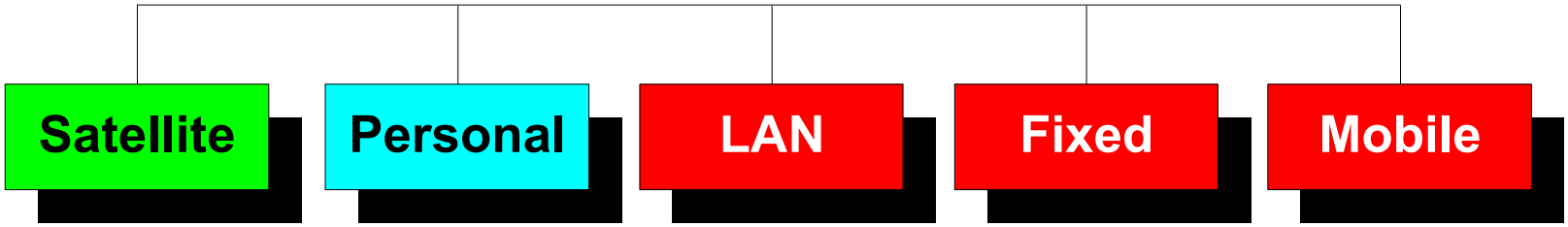
The disadvantages are:

- Expensive, but now the prices are nearing the other alternatives
- Skilled people are needed for the cabling
- Making joints is expensive
- Must be physically protected against damages

Wireless Transmission

- Unguided media
- Transmission and reception via antenna
- Directional
  - Focused beam
  - Careful alignment required
- Omni-directional
  - Signal spreads in all directions
  - Can be received by many antennae

Wireless Categorization



LEO
MEO
GSO

Bluetooth
IEEE 802.15
Zigbee

IEEE 802.11
HomeRF
WiFi

LMDS
MMDS
PtoP µWave

1G Analog Cellular
2G Digital Cell/PCS
2.5G (GPRS/EDGE)
3G
4G
5G

Last Mile Technologies

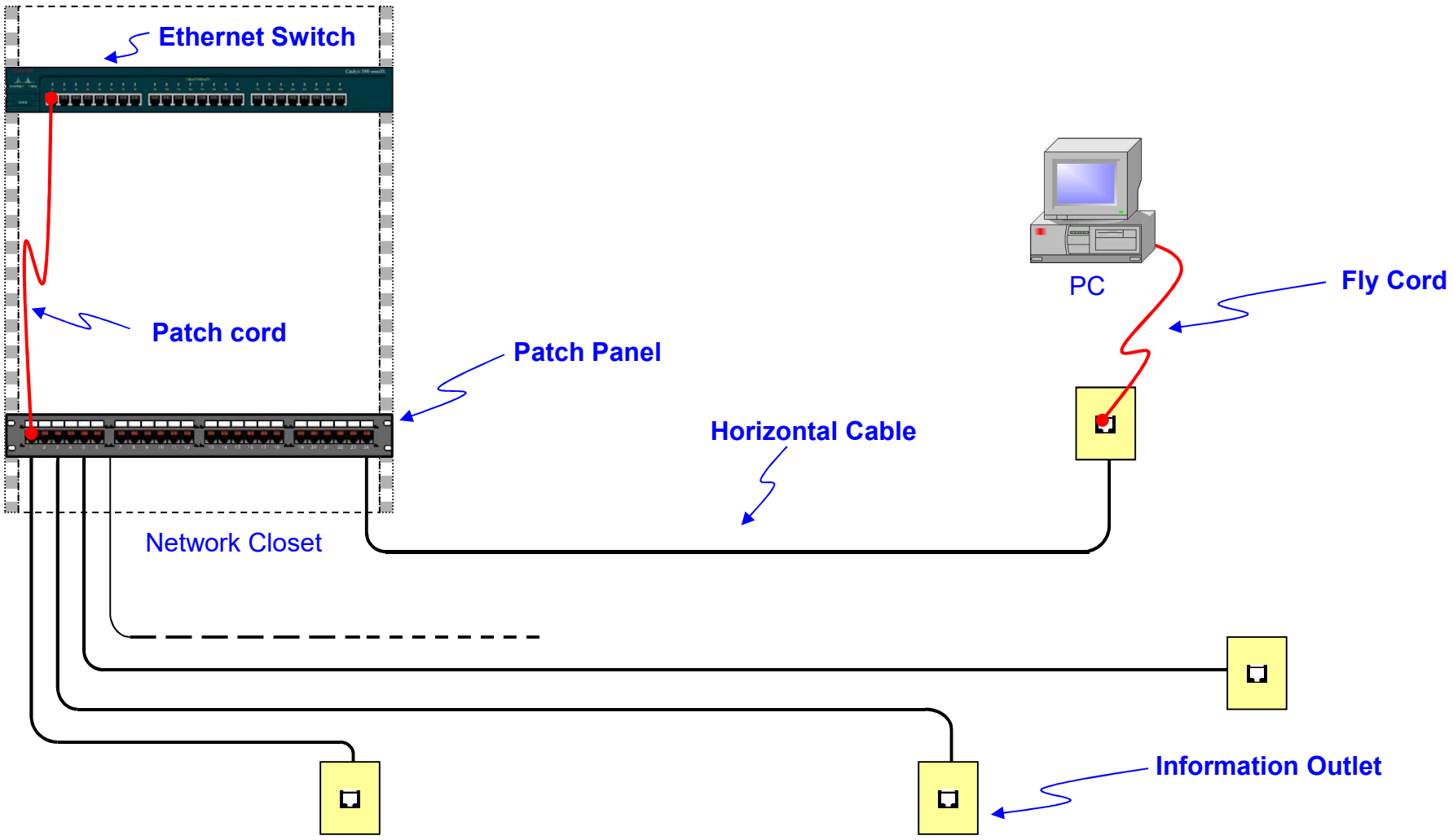
Last-mile technology is any telecommunications technology that carries signals from the broad telecommunication backbone along the relatively short distance (hence, the "last mile") to and from the home or business.

Today, last-mile technologies include:

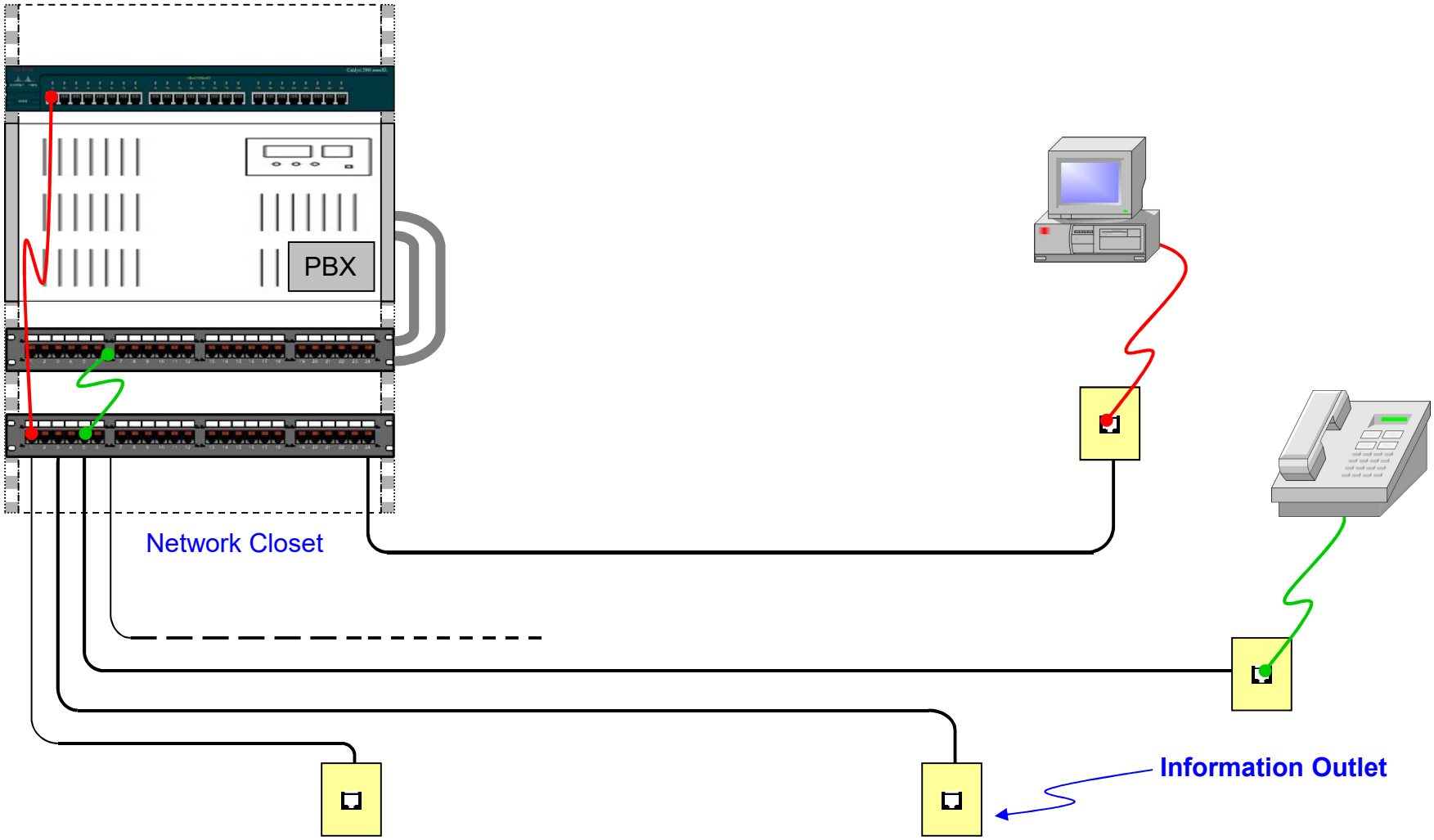
- Plain old telephone systems (POTS) **(Obsolete)**
- ISDN, a somewhat faster technology than regular phone service **(Obsolete)**
- Digital Subscriber Line (DSL) over existing telephone twisted pair lines
- Cable and the cable modem for data, using the same installed coaxial cable that already is used for television **(Obsolete)**
- Wireless
- Optical fiber and its transmission technologies
- What is FTTH?

Structured Cabling System

SCS - Ethernet Application



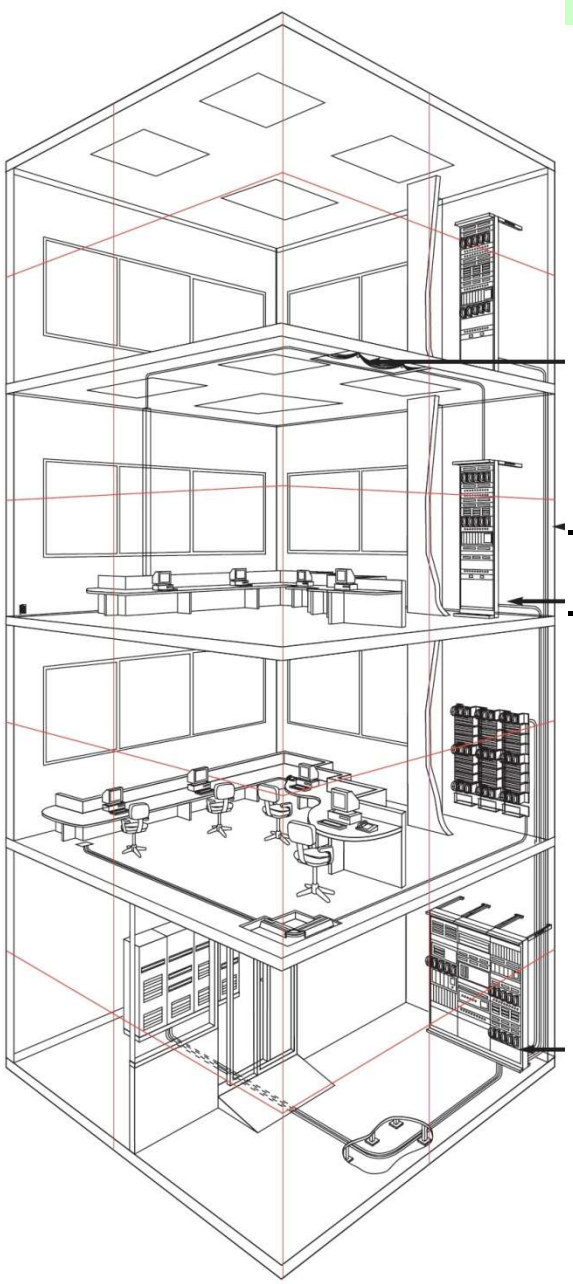
SCS – Voice Application



Benefits of a Structured Cabling

- Structured Cabling makes it easy to add, move, change and re-site individual employees or complete department's communications equipment.
- Support data and traditional voice; no need for multiple cabling systems in a building
- No downtime when reconnecting equipment
- Multiple conventional cable plants are expensive to maintain and upgrade compared to a Structured Cabling System
- Independent of protocols and networking technologies
- Covers current & future requirements
- Allows total flexibility

Design Concept



HORIZONTAL CABLING
Horizontal Cabling is the sub-section of the cabling system from the workstation outlet to the FD/IDF.

BACKBONE
Backbone cabling provides the main feeder cable in a system. It can be either 'vertical style' in which it runs vertically between floors in a building, connecting FD/IDF's to the BD, or 'campus style' in which it connects several BD's in separate buildings in one centralized location.

FLOOR DISTRIBUTOR (FD) OR INTERMEDIATE DISTRIBUTION FRAME (IDF)
The FD/IDF accommodates all of the cross connect facilities to interconnect work stations to active LAN equipment (also located in the FD/IDF enclosure), and backbone cabling to centralized processing equipment installed elsewhere.

BUILDING DISTRIBUTOR (BD) OR MAIN DISTRIBUTION FRAME (MDF)
The BD, provides a means of centralized processing and switching systems to the vertical backbone cabling.

Standards are for…

- Structured Cabling System Design
- Categories of connectors and cable
- Class of Channels
- Correct installation procedures
- Testing guidelines

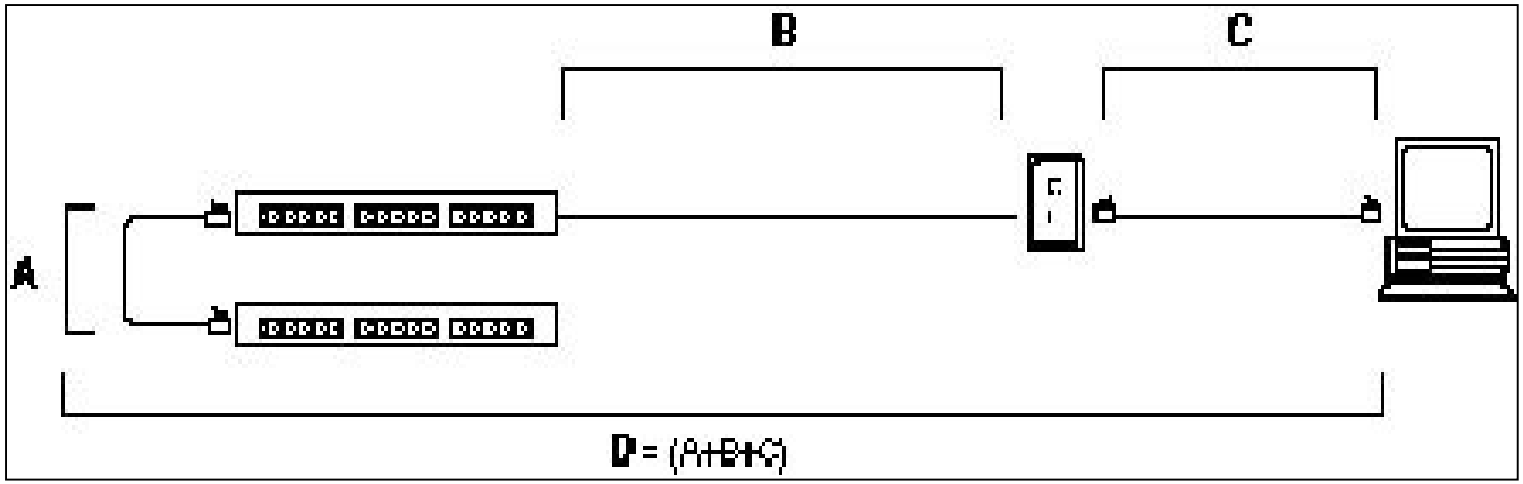
Standard Organizations

- IEEE – Institution of Electrical and Electronic Engineers
- ISO – International Standards Organization
- ANSI/EIA/TIA – American National Standards Institute / Electrical Industries Association/Telecommunication Industries Association
  - Consortium of manufacturers, vendors, users and other interested parties responsible for the family of standards associated with design, installation and use of structured Cabling Systems.

IEEE Standards

	Data Rate	Media	Distance
10 Base-2	10 Mbps	Copper Coaxial	200 m
10 Base-5	10 Mbps	Copper Coaxial	500 m
10 Base-T	10 Mbps	Copper UTP	100 m
100 Base-TX	100 Mbps	Copper UTP	100 m
100 Base-FX	100 Mbps	62.5/50 µm MM Fiber 9/10 µm SM Fiber	2 km 10 km
1000 Base-TX	1000 Mbps	Copper UTP	100 m
1000 Base-SX	1000 Mbps	62.5 µm MM Fiber 50 µm MM Fiber	220 m 550 m
1000 Base-LX	1000 Mbps	50 µm MM Fiber 9/10 µm SM Fiber	550 m 5 km
1000 Base-LH	1000 Mbps	62.5/50 µm MM Fiber 9/10 µm SM Fiber	550 m 10 km
1000 Base-ZX	1000 Mbps	9/10 µm SM Fiber Dispersion Shifted Fiber	70 km 100 km

Recommended Lengths



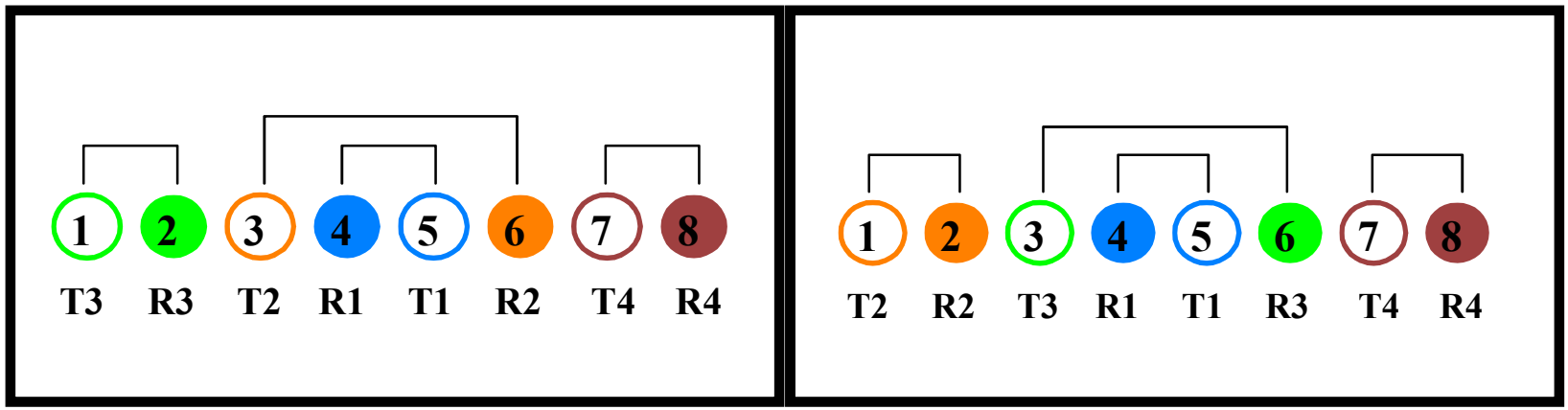
- A + C = 10m (combined)
- B = 90m (Permanent Link)
- D = 100m (Channel Link)

UTP Color Coding

- To distinguish between pairs, they are colored each pair has designated Tip and Ring conductors. Pair 1 can therefore be designated T1 and R1. Both UTP & STP conform to this standard
  - T1 - White Blue/Blue White - R1
  - T2 - White Orange/Orange White - R2
  - T3 - White Green/Green White - R3
  - T4 - White Brown/Brown White - R4

Wiring Sequences

- 568A
  - International ISDN standard
  - Pairs 2 & 3 are transposed from 568B.
  - Pairs 1 & 2 USOC compatible
- 568B
  - Most widely specified sequence. Also Known as 258A
  - Same as 568A but pairs 2 & 3 are transposed



Types of Pathways

- Conduit
  - Used in environments where required by code or maximum protection of the cable is desired or required. Typically constructed of one of the following:
    - Rigid metal conduit
    - Rigid PVC
    - Flexible
- Under Floor
  - Under floor duct is either sealed inslab floor or in fill placed on top of slab (This added thickness to floor).
  - Cellular floor requires distribution cells located on lower level of system. Provides service to workstations. Separated by power and communication.
  - Raised floor consists of steel footings holding pedestals which support the raised floor.
- Suspended Ceiling
  - Most common and cost effective pathway for running cable.


MOD-TAP
IDC PATCHING
MOD-TAP
FIBER DISTRIBUTION
KATT PD5

End of Lecture

Any Questions?