UNIT-V

Data Communication Systems, Serial Data formats, encoded data formats, error detection and correction], information about microwave, information about microwave in communications, Satellite, Geosynchronous Satellites and optical fiber communication [Basic concept of light propagation, Fibre Cables, Optical fiber versus Metalic cable facilities, Light source, Optical Detectors, Fiber cable losses, SONET, ISDN, DSL.

5. Data Communication System 139-189

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Chapter

5 Data Communication System

5.1 Introduction

Data communication and networking are changing the way we do business and the way we live. Business decisions have to be made ever more quickly and the decision makers require immediate access to accurate information. Why wait a week for that report from Germany to arrive by mail when it could appear almost instantaneously through computer networks? Business today relies on computer networks and Internet works. But before we ask quickly we can get hooked up, we need to know how networks operate, what types of technologies are available and which design best fills which set of needs.

We all are acquainted with some sorts of communication in our day to day life. For communication of information and messages we use telephone and postal communication systems. Similarly data and information from one computer system can be transmitted to other systems across geographical areas. Thus data transmission is the movement of information using some standard methods. These methods include electrical signals carried along a conductor, optical signals along an optical fibers and electromagnetic areas.

Suppose a manager has to write several letters to various clients. First he has to use his PC and Word Processing package to prepare his letter. If the PC is connected to all the client's PCs through networking, he can send the letters to all the clients within minutes. Thus irrespective of geographical areas, if PCs are connected through communication channel, the data and information, computer files and any other program can be transmitted to other computer systems within seconds. The modern form of communication like e-mail and Internet is possible only because of computer networking.

The development of the personal computer brought about tremendous changes for business, industry, science and education. A similar revolution is occurring in data communications and networking. Technological advances are making it possible for communications links to carry more and faster signals.

Data Communications and networking are in their infancy. The goal is to be able to exchange data such as ext, audio and video.

5.2 Data Communications

When we communicate, we are sharing information. This can be local or remote. Between individuals, local communication usually occurs face to face, while remote communication takes place over distance. The term telecommunication, which includes telephony, telegraphy and television, means communication at a distance.

The word data refers to information presented in whatever form is agreed upon by the parties creating and using the data.

Data communication is the exchange of data between two devices via some form of transmission medium such as a wire cable. For data communication to occur, the communicating devices must be the part of a communication system made up of a combination of hardware and software. The effectiveness of a data communications system depends on three fundamental characteristics : delivery, accuracy and timeliness.

1. **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.
2. **Accuracy :** The system must deliver the data accurately. Data that have been altered in transmission and left uncorrected are unusable .
3. **Timeliness :** The System must deliver data in a timely manner. Data delivered late are useless. In the case of video and audio, timely delivery means delivering data as they are produced, and without significant delay. This kind of delivery is called real time transmission.

Components

A data communications system has five components :

1. **Message :** The message is the information to be communicated. It can consist of text numbers, pictures, sound or video or any combination of these.
2. **Sender :** The sender is the device that sends the data message. It can be a computer, workstation, telephone handset, video camera and so on.
3. **Receiver :** The receiver is the device that receives the message . It can be a computer, workstation, telephone hand set, television and so on.
4. **Medium :** The transmission medium is the physical path by which a message travels from sender to receiver. It could be a twisted - pair wire, coaxial cable, fiber optic table or radio waves.
5. **Protocol :** A protocol is a set of rules that governs data communications. It represents an agreement between the communicating devices. Without a protocols, two devices may be connected but not communicating, just as a person speaking French cannot be understood by a person who speaks only Japanese.

5.3 Communication Protocols

You may be wondering how do the computers send and receive data across communication links. The answer is data communication software. It is this software that enables us to communicate with other systems. The data communication software instructs computer systems and devices as to how exactly data is to be transferred from one place to another. The procedure of data transformation in the form of software is commonly called protocol.

The data transmission software or protocols perform the following functions for the efficient and error free transmission of data.

1. **Data sequencing:** A long message to be transmitted is broken into smaller packets of fixed size for error free data transmission.
2. **Data Routing:** It is the process of finding the most efficient route between source and destination before sending the data.
3. **Flow control:** All machines are not equally efficient in terms of speed. Hence the flow control regulates the process of sending data between fast sender and slow receiver.
4. **Error Control:** Error detecting and recovering is the one of the main function of communication software. It ensures that data are transmitted without any error.

5.4 Data Representation

Information today comes in different forms such as text, numbers, images, audio and video.

Text :

In data communication, text is represented as a bit pattern, a sequence of bits (0s or 1s). The number of bits in a pattern depends on the number of symbols in the language. For example, the English language uses 26 symbols (A,B, C….Z) to represent uppercase letters, 26 symbols (a, b, c …. z) lowercase letters, 10 symbols (0,1,2….9) to represent numeric character and symbols (; ?, :, …..!) to represent punctuation. Other symbols such as the blank, the new line and the tab are used for text alignment and readability

Different sets of bit patterns have been designed to represent text symbols. Each set is called a code and the process of representing symbols is called coding.

ASCII :

The American National Standards Institute (ANSI) developed a code called the American Standard Code for Information Interchange (ASCII). This code uses 7 bits for each symbol. This means 128(27) different symbols can be defined by this code. The full bit patterns for ASCII code are found

ASCII stands for American Standard Code for Information Interchange. Computers can only understand numbers, so an ASCII code is the numerical representation of a character such as 'a' or '@' or an action of some sort. ASCII was developed a long time ago and now the non-printing characters are rarely used for their original purpose. Below is the ASCII character table and this includes descriptions of the first 32 non-printing characters. ASCII was actually designed for use with teletypes and so the descriptions are somewhat obscure. If someone says they want your CV however in ASCII format, all this means is they want 'plain' text with no formatting such as tabs, bold or underscoring - the raw format that any computer can understand. This is usually so they can easily import the file into their own applications without issues. Notepad.exe creates ASCII text, or in MS Word you can save a file as 'text only'

Dec Hx Oct Char	Dec Hx Oct Html Chr	Dec Hx Oct Html Chr	Dec Hx Oct Html Chr
0 0 000 NUL (null)	32 20 040 Space	64 40 100 @ @	96 60 140 ` `
1 1 001 SOH (start of heading)	33 21 041 ! !	65 41 101 A A	97 61 141 a a
2 2 002 STX (start of text)	34 22 042 " "	66 42 102 B B	98 62 142 b b
3 3 003 ETX (end of text)	35 23 043 # #	67 43 103 C C	99 63 143 c c
4 4 004 EOT (end of transmission)	36 24 044 $ $	68 44 104 D D	100 64 144 d d
5 5 005 ENQ (enquiry)	37 25 045 % %	69 45 105 E E	101 65 145 e e
6 6 006 ACK (acknowledge)	38 26 046 & &	70 46 106 F F	102 66 146 f f
7 7 007 BEL (bell)	39 27 047 ' '	71 47 107 G G	103 67 147 g g
8 8 010 BS (backspace)	40 28 050 ((	72 48 110 H H	104 68 150 h h
9 9 011 TAB (horizontal tab)	41 29 051))	73 49 111 I I	105 69 151 i i
10 A 012 LF (NL line feed, new line)	42 2A 052 * *	74 4A 112 J J	106 6A 152 j j
11 B 013 VT (vertical tab)	43 2B 053 + +	75 4B 113 K K	107 6B 153 k k
12 C 014 FF (NP form feed, new page)	44 2C 054 , ,	76 4C 114 L L	108 6C 154 l l
13 D 015 CR (carriage return)	45 2D 055 - -	77 4D 115 M M	109 6D 155 m m
14 E 016 SO (shift out)	46 2E 056 . .	78 4E 116 N N	110 6E 156 n n
15 F 017 SI (shift in)	47 2F 057 / /	79 4F 117 O O	111 6F 157 o o
16 10 020 DLE (data link escape)	48 30 060 0 0	80 50 120 P P	112 70 160 p p
17 11 021 DC1 (device control 1)	49 31 061 1 1	81 51 121 Q Q	113 71 161 q q
18 12 022 DC2 (device control 2)	50 32 062 2 2	82 52 122 R R	114 72 162 r r
19 13 023 DC3 (device control 3)	51 33 063 3 3	83 53 123 S S	115 73 163 s s
20 14 024 DC4 (device control 4)	52 34 064 4 4	84 54 124 T T	116 74 164 t t
21 15 025 NAK (negative acknowledge)	53 35 065 5 5	85 55 125 U U	117 75 165 u u
22 16 026 SYN (synchronous idle)	54 36 066 6 6	86 56 126 V V	118 76 166 v v
23 17 027 ETB (end of trans. block)	55 37 067 7 7	87 57 127 W W	119 77 167 w w
24 18 030 CAN (cancel)	56 38 070 8 8	88 58 130 X X	120 78 170 x x
25 19 031 EM (end of medium)	57 39 071 9 9	89 59 131 Y Y	121 79 171 y y
26 1A 032 SUB (substitute)	58 3A 072 : :	90 5A 132 Z Z	122 7A 172 z z
27 1B 033 ESC (escape)	59 3B 073 ; ;	91 5B 133 [[	123 7B 173 { {
28 1C 034 FS (file separator)	60 3C 074 < <	92 5C 134 \ \	124 7C 174	|
29 1D 035 GS (group separator)	61 3D 075 = =	93 5D 135]]	125 7D 175 } }
30 1E 036 RS (record separator)	62 3E 076 > >	94 5E 136 ^ ^	126 7E 176 ~ ~
31 1F 037 US (unit separator)	63 3F 077 ? ?	95 5F 137 _ _	127 7F 177 &#127; DEL

Extended ASCII :

To make the size of each pattern 1 byte (8 bits), the ASCII bit pattern are augmented with an extra 0 at left. Now each pattern is exactly 1 byte of memory. In other words, in extended ASCII, the first pattern is 00000000 and the last one is 0111111.

Extended ASCII Codes

As people gradually required computers to understand additional characters and non-printing characters the ASCII set became restrictive. As with most technology, it took a while to get a single standard for these extra characters and hence there are few varying 'extended' sets. The most popular is presented below.

128	Ç	144	É	161	í	177	▒	193	┴	209	╤	225	ß	241	±
129	ü	145	æ	162	ó	178	▓	194	┬	210	╥	226	Γ	242	≥
130	é	146	Æ	163	ú	179	│	195	├	211	╙	227	π	243	≤
131	â	147	ô	164	ñ	180	┤	196	─	212	╘	228	Σ	244	⌠
132	ä	148	ö	165	Ñ	181	╡	197	┼	213	╒	229	σ	245	⌡
133	à	149	ò	166	ª	182	╢	198	╞	214	╓	230	µ	246	÷
134	å	150	û	167	º	183	╖	199	╟	215	╫	231	τ	247	≈
135	ç	151	ù	168	¿	184	╕	200	╚	216	╪	232	Φ	248	°
136	ê	152	_	169	_	185	╣	201	╔	217	┘	233	Θ	249	
137	ë	153	Ö	170	¬	186	║	202	╩	218	┌	234	Ω	250	
138	è	154	Ü	171	½	187	╗	203	╦	219	█	235	δ	251	√
139	ï	156	£	172	¼	188	╝	204	╠	220	▄	236	∞	252	_
140	î	157	¥	173	¡	189	╜	205	═	221	▌	237	φ	253	²
141	ì	158	_	174	«	190	╛	206	╬	222	▐	238	ε	254	■
142	Ä	159	ƒ	175	»	191	┐	207	╧	223	▀	239	∩	255	
143	Å	160	á	176	░	192	└	208	╨	224	α	240	≡		

Unicode :

The coalition of hardware and software manufacturers have designed a code called Unicode that uses 16 bits and can represent up to 65,536(216) symbols.

ISO :

The International organization For Standardization, known as ISO, has designed a code using a 32 bit pattern. This code can be represent up to 4,294,967,296(232) symbols, which is definitely enough to represent any symbol in the world today.

Numbers :

Numbers are also represented by using bit patterns. However a code such as ASCII is not used to represent numbers ; the number is directly converted to a binary numbers. The reason is to simplify mathematical operations on numbers.

Images :

Images today are also represented by bit patterns. However the mechanism is different. In its simpler form an image is divided into a matrix of pixels where each pixels is a small dot. The size of pixel depends on what is called the resolution. For example, an image can be divided into 1000 pixels into 1000 pixels or 10,000 pixels. In the second case, there is a better representation of the image but more memory is needed to store the image.

After an image is divided into the pixels, each pixel is assigned a bit pattern. The size and the value of pattern depend on the image. For an image made of only black and white dots, a 1 -bit pattern is enough to represent a pixel.

If an image is not made of pure white and pure black pixels, you can increase the size of the bit pattern to include gray scale. For example, to show four levels of gray scale you can use 2 bit patterns. A black pixel can be represented by 00 , a dark gray pixel by 01, a light gray pixel by 10 and a white pixel by 11.

To represent color images, each colored pixel is decomposed into three primary colors : red, green ,and blue(RGB). Then the intensity of each color is measured and a bit pattern is assigned to it. In other words , each pixel has three bit patterns : one to represent the intensity of the green color and one to represent the intensity of the blue color.

Audio :

Audio is representation of sound. Audio is by nature different from text, numbers, or images. It is continuous , not discrete. Even when we use a microphone to change voice3 or music to an electric signal, we create a continuous signal.

Video :

Video can be produced either as a continuous entity or it can be a combination of images, each a discrete entity, arranged to convey the idea of motion

Direction of Data Flow

Communication between two devices can be simplex, half duplex or full duplex.

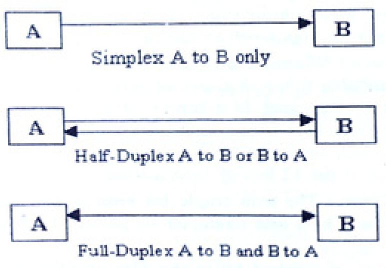


Fig. 1 :

Simplex :

In a Simplex mode, the communication is unidirectional as on away street. Only one of the two devices on a link can transmit the other can only receive.

Keyboards and traditional monitors are both examples of simplex devices. The keyboard can only introduce input, the monitor can only accept output.

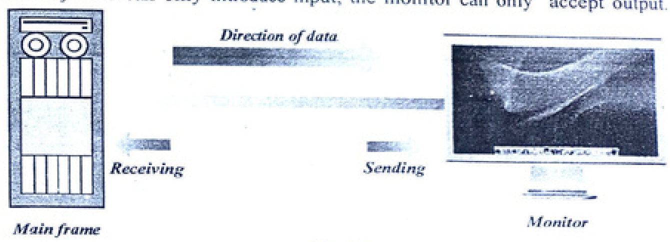


Fig. 2

Half Duplex:

In half - duplex mode, each station can both transmit and receive, but not at the same time. When one device is sending, the other can only receive and vice versa

The half duplex mode is like a one lane road with two directional traffic. While cars are traveling one direction, cars going the other way must wait. In a half duplex transmission, the entire capacity f a channel is taken over by whichever of the two devices is transmitting at the time. Walkie - talkies and CB radios are both half duplex systems

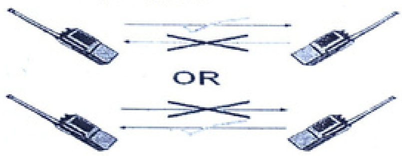


Fig. 3 : A simple illustration of a Half-duplex communication system

A half-duplex system provides for communication in both directions, but only one direction at a time (not simultaneously). Typically, once a party begins receiving a signal, it must wait for the transmitter to stop transmitting, before replying.

An example of a half-duplex system is a two-party system such as a "walkie-talkie" style two-way radio, wherein one must use "Over" or another previously designated command to indicate the end of transmission, and ensure that only one party transmits at a time, because both parties transmit on the same frequency.

A good analogy for a half-duplex system would be a one lane road with traffic controllers at each end. Traffic can flow in both directions, but only one direction at a time with this being regulated by the traffic controllers.

In automatically-run communications systems, such as two-way data-links, the time allocations for communications in a half-duplex system can be firmly controlled by the hardware. Thus, there is no waste of the channel for switching. For example, station A on one end of the data link could be allowed to transmit for exactly one second, and then station B on the other end could be allowed to transmit for exactly one second. And then this cycle repeats over and over again.

Full Duplex :

In full duplex mode both stations can transmit and receive simultaneously

Fig. 4 : A simple illustration of a full-duplex communication system.

The full duplex mode is like a two way street with traffic flowing in both directions at the same time. In a full duplex mode, signals going in either directions share the capacity of the link. This sharing can occur in two ways : Either the link must contain two physically separate transmission paths, one for sending and the other for receiving; or the capacity of the channel is divvied between signals traveling in both directions

One common example of full duplex mode is the telephone network. When two people are communicating by a telephone line, both can talk and listen at the same time

A full-duplex, or sometimes double-duplex system allows communication in both directions, and unlike half-duplex, allows this to happen simultaneously. Land-line telephone networks are full-duplex since they allow both callers to speak and be heard at the same time. A good analogy for a full-duplex system would be a two-lane road with one lane for each direction.

Examples: Telephone, Mobile Phone, etc.

Two way radios can be, for instance, designed as full-duplex systems, which transmit on one frequency and receive on a different frequency. This is also called frequency-division duplex. Frequency-division duplex systems can be extended to farther distances using pairs of simple repeater stations, because

the communications transmitted on any one frequency always travel in the same direction.

Full-duplex Ethernet connections work by making simultaneous use of two physical pairs of twisted cable (which are inside the jacket), where one pair is used for receiving packets and one pair is used for sending packets (two pairs per direction for some types of Ethernet), to a directly connected device. This effectively makes the cable itself a collision-free environment and doubles the maximum data capacity that can be supported by the connection.

There are several benefits to using full-duplex over half-duplex. First, time is not wasted since no frames need to be retransmitted as there are no collisions. Secondly, the full data capacity is available in both directions because the send and receive functions are separated. Third, stations (or nodes) do not have to wait until others complete their transmission since there is only one transmitter for each twisted pair.

Historically, some computer-based systems of the 1960s and 1970s required full-duplex facilities even for half-duplex operation, because their poll-and-response schemes could not tolerate the slight delays in reversing the direction of transmission in a half-duplex line.

Error Detection and Correction : Network must be able to transfer data from one device to another with acceptable accuracy. For most application, a system must guarantee that the data recevied are identical to data transmitted. Any time data are transmitted from one node to the next, they can become corrupted in passage. Many factors can after one or more bits of message. Some applications require a mechanism for detecting and correcting errors.

Data can be corrupted during transmission. Some applications require that errors be detected and corrected

Some application can tolerate a small level of error. For example, randam errors in audio or video transmission may be tolerable, but when we transfer text, we except a very high level of aceuncy.

Types of errors : Whenever bits flow from one point to another, tey are subject to unpredictable change because of interference. This interference can change the shape of the signal. In a single bit error, a 0 is changed to a 1 or a 1 to a 0. In a bust error, multiple bits are changed. For example, a 1/100 s burst of impulse noise on a transmission with a data rate of 1200 bps might change all or some o the 12 bits of information.

Single Bit Error : The term single bit error means that only 1 bit of a given data unit (such as a byte character or packet) is changed from 1 to 0 or from 0 to 1.

(In a single bit error, only 1 bit in the data unit has changed.)

Fig. 5 shows the effect of a single bit error an a data unit. To understand the impact of change, imagine that each group of 8 bits is an ASCII character with a 0 bit added to the left. In Fig. 1. 00000010 (ASCII STX) was sent, meaning start of text but 00001010 (ASCII LF) was recieved meaning line feed.

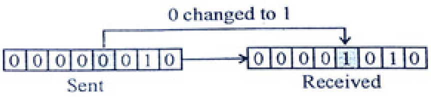


Fig. 5 : Single bit error

Single bit errors are the least likely type of error in serial data transmission. To understand why, imagine data sent at 1 Mbps. This means that each bit lasts only 1/1,000,000 s or 1μs. For a single bit error to occur, the noise must be have a duration of only 1 μs, which is very rare; noise normally last much longer than this.

Burst error-

The term burst error means that 2 or more bits in the data unit have changed from 1 to 0 or from 0 to 1.

Example 5.1 : The 4B/5B block coding discussed in Chapter 4 is a good example of thistype of coding. In this coding scheme, $k = 4$ and $n = 5$. As we saw, we have $2^k = 16$ datawords and $2^n = 32$ codewords. We saw that 16 out of 32 codewords are used for message transfer and the rest are either used for other puposes or unused.

5.5 Error Detection

How can errors be detected by using block ocding ? If the following two conditions are met, the receiver can detect a change in the original codeword.

1. The receiver has (or can find) a list of valid codewords.
2. The original codeword has changed to an invalid one.

Figure 6. shows the role of block coding in error detection.

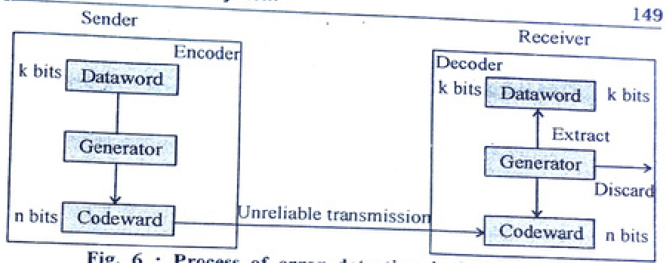


Fig. 6 : Process of error detection in block coding

The sender creates codewords out of datawords by using a generator that applied the rules and procedures of encoding (discussed later). Each code ward sent to the receiver may change during transmission. If the received codeward is the same as one of the valid code words, the word is accepted; the corresponding dataword is extracted for use. If the received codeword is not valid, it is discarded. However, if the codeword is corrupted during transmission but the receied word still matches a valid codeword, the error remains undetected. This type of coding can detect only single errors. Two or more errors may remain undetected.

Example 2 : Let us assume that $k = 2$ and $n = 3$. Thable 10.1 show the list of datawords and codewords. Later, we will see how to derived a codeward from a dataword.

Table 1 : A code for error detection (Example 10.2)

Data words	Code words
00	000
01	011
10	101
11	110

Assume the sender encodes the dataword 01 as 011 and sends it to the receiver. Consider the following cases :

1. The receiver receives 011. It is a valid codeword. The receiver extracts the dataword 01 from its.

2. The codeword is corrupted during trasmission, and 111 is received (the leftmost bit is corrupted). This is not a valid codeword and is discarded.

3. The codeword is corrupted during tranmission, and 000 is received (the right two bits are corrupted). This is a valid codeword. The receiver incorrectly extracts the dataword 00. Two corrupted bits have made the error undetectable.

An error-detecting code can detect only the types of errors for which it is designed; other types of errors may remain undetected.

Error Correction

As we said before, error correction is much more difficult than error detection. In error detection, the receiver needs to known only that the received codeword is invalid; in error correction the receiver needs to find (or guess) the original codeword sent. We can say that we need moe redundant bits for error correction than for error detection. Figure 10.7 shows the role of block coding in error correction. We can see that the idea is the same as error detection but the checker functions are must more complex.

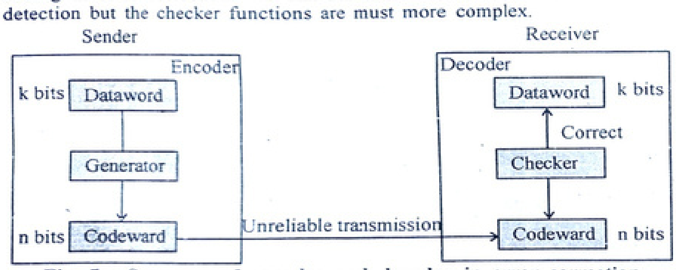


Fig. 7 : Structure of encoder and decoder in error correction

Example 3 : Let us add more redundant bits to Example 10.2 to see if the receiver can correct an error without knowing what was actually sent. We add 3 redundant bits to the 2-bit dataword to make 5-bit codewords. Again, later we will show how we chose the redundant bits. For the moment let us concentrate on the error correction concept. Table 10.2 shows the datawords and codewords.

Assume the dataword is 01. The sender consults the table (or uses an algorithm) to create the codeword 01011. The codeword is corrupted during transmission, and 01001 is received (error in the second bit from the right). first the receiver finds that the received codeword is not in the table. This means an error has occurred. (Detection must come before correction). The receiver, assuming that there is only 1 bit corruped, uses the following strategy to guess the correct dataword.

Data word	Code word
00	0000
01	01011
10	10101
11	11110

Table 2 : A code for error correction (Example 10.3)

1. Comparing the received codeword with the first codeword in the table (01001 versus 00000), the receiver decides that the first codeword is not the one that was sent because there are two different bits.

2. By the same reasoning, the original codeword cannot be the third or fourth one in the table.

3. The original codeword must be the second one in the table because this is the only one that differs from the received codeword by 1 bit. The receiver replaces 01001 with 01011 and consults the table to find the dataword 01.

Hamming Distance

One of the central concepts in coding for error control is the idea of the Hamming distance. The Hamming distance between two words (of the same size) is the number of differences between the corresponding bits. We show the hamming distance between two word x and y as d (x, y).

The Hamming distance can easily be found if we apply the XOR operation (⊕) on the two words and count the number of 1s in the result. Note that the Hamming distance is a value greater than zero.

The Hamming distance between two words is the number of differences between corresponding bits.

Example 4 :

Let us find the Hamming distance between two pairs of words.

1. The Hamming distance d(000, 011) is 2 because 000 ⊕ 01 is 011 (two 1s).

2. The Hamming distance d(10101, 11110) is 3 because 10101 ⊕ 11110 is 01011 (three 1s).

5.6 Minimum Hamming Distance

Although the concept of the Hamming distance is the central point in dealing with error detection and correction codes, the measurement that is used for designing a code is the minimum Hamming distance. In a set of words, the minimum Hamming distance is the smallest Hamming distance between all possible pairs. We use d_{min} to define the minimum Hamming distance in a coding scheme. To find this value, we find the Hamming distance between all words and select the smallest one.

The minimum Hamming distance is the smallest Hamming distance between all possible pairs in a set of words.

Example 5 : Find the minimum Hamming distance of the coding scheme in Table 1.

Solution : We fist find all Hamming distances.

d(000, 011) = 2 d(000, 101) = 2 d(000, 110) = 2 d(011, 101) = 2

d(011, 110) = 2 d(101, 110) = 2

The d_{min} in this case is 2.

Example 6 : Find the minimum Hamming distance of the coding scheme in Table 10.2.

Solution : We first all the Hamming distances.

d(00000, 0101) = 3 d(00000, 10101) = 3 d(00000, 11110) = 4

d(01011, 10101) = 4 d(01011, 11110) = 3 d(10101, 11110) = 3

The d_{min} in this case is 3.

Three Parameters

Before we continue with our discussion, we need to mention that any coding scheme needs to have at least three parameters; the codeword size n, the dataword size k, and the minimum Hamming distance d_{min}. A coding shceme C is writen as C(n, k) with a separate expression for d_{min}. For example, we can call our first coding scheme C(3, 2) with d_{min} = 2 and our second coding scheme C(5,2), with d_{min} = 3.

Hamming Distance and Error

Before we explore the criteria for error detection or correction, let us discuss the relationship between the Hamming distance and errors occuring during transmission. When a codeword is corrupted during transmission, the Hamming distance between te sent and received code words is the number of bits affected by the error. In othe words, the Hamming distance between the received codeword and the sent codeword is the number of bits that are corupted during transmission. for example, if the codeword 00000 is sent and 01101 is received, 3 bits are in error and the Hamming distance between the two is d(00000, 01101) = 3.

Minimum Distance for Error Detection

Now let us find the minimum Hamming distance in a code if we want to be able to detect up to s errors. If s errors occur during transmission, the Hamming distance between the sent codeword and received codeword is s. If our code is to detect up to s errors, the minimum distance between the valid codes must be s + 1, so that the received codeword does not match a valid codeword. In other words, if the minimum distance between all valid codewords is s + 1, the received codeword cannot be erroneously mistaken for another codeword. The sdistances are not enough (s + 1) for the receiver to accept it as valid. The error will be detected. We need to clarify a point here : Although a code with d_{min} = s + 1 may be able to detect more than s errors

in some special cases, only s or fewer erros are guaranteed to be detected.

> To guarantee the detection of up to s errors in all cases, the minimum Hamming distance in a block code must be d_{min} = s + 1.

Example 8 : The minimum Hamming distance for our first code scheme (Table 1) is 2. This code guarantees detection of only a single error. For example, if the third codeword (101) is sent and one error occurs, the received codeword does not match any valid codeword. If two errors occur, however, the received codeword may match a valid codeword and the errors are not detected.

Example 9 : Our-second block code scheme (Table 10.2) has d_{min} = 3. This code can detect up to two errors. Again, we see that when any of the valid codewords is sent, two errors create a codeword which is not in the table of valid codewords. The receiver cannot be fooled. However, some combinations of three errors change a valid codeword to another valid codeword. The receiver accepts the received codeword and the errors are undetected.

We can look at this geometrically. Let us assume that the sent codeword x is at the center of a circle with radius s. All other received codewords that are created by 1 to s errors are points inside the circle or on the perimeter of the circle. All other valid code words must be outside the circle, as shown in Figure 8.

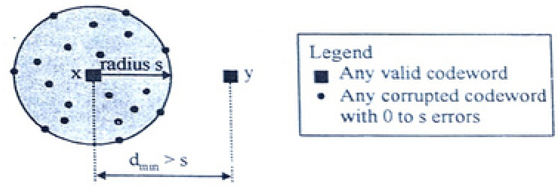


Fig. 8 : Geometric concept for finding dmin in error detection

In Figure 10.8 d_{min} must be an integer greater than s; that is d_{min} = s + 1.

Distance for Error Correction

Error correction is more complex than error detection; a decision is involved. When a received codeword is not a valid codeword, the receiver needs to decide which valid codeword was actually sent. The decision is based on the concept of territory, an exclusive area surrounding the codeword. Each valid codeword has its own territory.

We use a geometric approach to define each territory. We assume that each valid codeword has a circular territory with a radius of t and that the valid codeword is at the center. For example, suppose a codeword x is corrupted by t bits or less. Then this corrupted codeword is located either inside or on the perimeter of this circle. If the receiver receives a codeword that belongs to this territory,, it decides that the original codeword is the one at the center. Note that we assume that only up to t errors have occured; otherwise, the decision is wrong. Figure 9 shows this geometric interpretation. Some tets use a sphere to show the distance between all valid block codes.

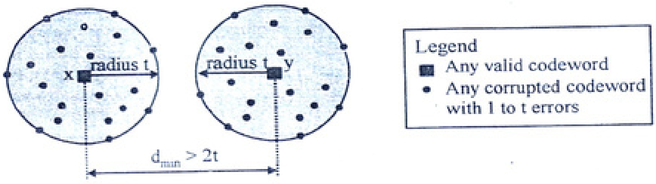


Fig. 9 : Geometric concept for Finding dmin in error correction

Example 9 : A code scheme has a Hamming distance d_{min} = 4. What is the error detection and correction capability of this scheme ?

Solution : This code guarantees the detection of up to three errors (s = 3), but it can correct up to one error. In other words, if this code is used for error correction, part of its capability is wasted. Error correction codes need to have an odd minimum distance (3, 5, 7,....).

5.7 Information about Microwave and Satellite Transmission:

For wireless transmission, transmission and reception are achieved by means of antenna. For transmission, the antenna radiates electromagnetic energy into the medium (usually air), and for reception, the antenna picks up electromagnetic waves from the surrounding medium. There are basically two types of configuration for wireless transmission: directional and omni directional. For the directional configuration, the transmitting antenna puts out a focused electromagnetic beam. Highly directional beams are possible at microwave frequencies (2-40 GHz). For omni directional case, the transmitted signals spreads out in all directions and can be received by many antennas.

Microwaves techniques expanded rapidly during world war II as a result of the need to produce radar equipment with improved resolution. The development of radio links using microwave frequencies was accelerated by

the introduction of the traveling wave amplifier, which was the first microwave valve to have the exceedingly desirable property of a high gain over extremely large percentage bandwidths.

5.8 Information about Microwave Communication:

As the need for wider bandwidth has become more prominent in recent years, UHF and SHF frequencies have been used to accommodate the expansion of telephone traffic and the added requirement of television. Modern microwave links are designed to transmit wide bands of modulation frequencies up to 10 MHz over distances of several thousand mile with the high standard of performance and reliability essential for national and international along range communication routes. At microwave frequencies, highly directional beams are possible, and microwave is quite suitable for point-to-point transmission. Microwave is also used for satellite communications.

S.No.	Band	Typical Services
1.	VLF (3 – 30 KHz)	World wide telegraphy
2.	LF(30 – 300 KHz)	Long distance point to point service, marine and navigational aids
3.	MF (300 – 3000 KHz)	Broadcasting, Navigation, Harbour Telephone etc.
4.	HF (3 – 30 MHz)	Beamed communication services eg. moderate and long distance communication of all types, short wave broadcasting to distant places.
	VHF (30 – 300 MHz)	Short distance communication, TV, Frequency modulation. Radar Aeroplane Navigation, Radio rely Telephony.
	UHF (300 – 3000 MHz)	Short distance communication, Radar relay system landing, Television. [Above 200 MHz are known as microwave frequencies]
	SHF (3000 – 30,000 MHz)	Radar, Radio and Television relay links, Satellite communication
	EHF (30,000 – 3000,000 MHz)	Experimental, Amateur, Government

Microwave communication can be attributed to the following advantages:

(1) High and flexible channel capacity from a few voice channels to several

television channels.

(2) Easy expansion in capacity.

(3) Easy and shorter installation time.

(4) Better adaptation to difficult terrains and natural barrier.

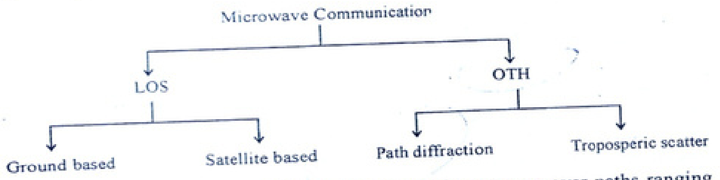
(5) Long range.

(6) Less expensive then wired system.

The cost of installation kilometers of cable, either underground or on poles as well as the cost of maintaining the wired infrastructure is avoided.

5.9 Microwave Communication:

Most of the microwave radio communication systems in use today fall into two main categories, namely. Line Of Sight (LOS) and Over The Horizon system (OTH)



The LOS systems use relatively low transmitter power over paths ranging from 10 to 50 mils in length per relay link for ground based communication system. LOS systems are also use high transmitter power upto 50 k watt or more for beyond the horizon paths from 50 to 700 miles in length per link, including path diffraction and tropospheric scatter modes of propagation. The prime advantage of OTH system over LOS microwave systems is that they provide reliable communication over distance of hundred miles without repeater stations. This feature is of considerable value when the intervening terrain is accessible only with difficulty or when sea crossing are involved.

Line of Sight System : Microwave communication systems with line of sight paths have assumed, in the last two decades, a position of considerable importance in the communication field. In many respects such systems are competitors to wire line and coaxial cable systems, Theoretically, a line of sight system can be extended over favorable terrain without natural barriers for rather long distances, for example, 3000 to 4000 miles, with many repeater stations and links in between. The distance to be covered by each link, however is limited to short distances in the range of 30 to 50 miles. The wide range of possible, applications extends, for example, from systems providing a small

number of telephone circuits to system providing several thousand telephone circuits or several television channels over distance of several thousand miles with the high standards of performance and reliability essential for national and internationals trunk circuits.

Over the Horizon : Forward scatter propagation or simply scatter propagation is of practical importance at VHF, UHF and microwaves UHF and microwaves signals were found to be propagated much beyond the light of sight propagation through the forward scattering in the tropospheric irregularities. It uses certain properties of troposphere and is also known as tropascatters as illustrated in fig. 3.32. This has also lead to the discovery of ionosphere scatter propagation for signals frequencies in the lower end of VHF band. Therefore in the recent years, it has been established that it is possible to achieve a very reliable communication over communication range of 160km to 1600km by using high power transmitter and high gain antennas i.e. reliable scatter propagation is possible in the VHF and UHF bands. The name scatter propagation or over the horizon is given to it due to mechanism involved in the phenomenon.

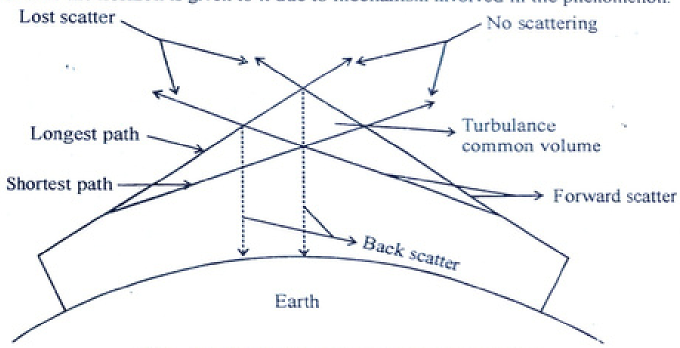


Fig. 10 :Tropospheric scatter propagation

In fact the physical mechanism is not yet completely known but there are two different theories involved in forward scatter propagation. The first mode is inospheric and is believed to be resulted from the scattering of radio waves from the lower layer of ionosphere. The second mode is tropospheric and is thought to be result of scattering from either blobs or fine iayers in the troposphere. Ionosphere scatter permits communication in the communication range of about 1000km to 200km at about 25 MHz to 60MHz. However, the importance of ionspheric scatter propagation decrease beyond 60 MHz, but at the same time tropospheric scatter propagation appears to be effective starting from 100MHz to at least 10GHz. Due to the greater attenuation of signals along the path, forward scatter propagation is mainly useful for point to point communication, radio or television relay links where it possible to use externally high gain antennas and high power transmitters.

In fig. 3.32 two directional (transmitting and receiving) antennas are so pointed that their beams intersect midway between them above the horizon. If one is UHF transmitting antenna and the other UHF receiving antenna then sufficient radio energy is directed towards in the receiving antenna to make this a useful communication system. The blobs of air masses or eddies in the troposphere, scatter radio waves due to turbulence and this happens when they are situated in the common volume facing transmitting and receiving antennas beams. When the wavelength is more (frequency low) than the eddies, the scattering may occur in all directions even some back scattering too. On the other hand, when the wavelength is small (frequency high) than the eddies, forward scattering dominates into the cone of angle X. The angle should be as small as possible. The best and typical used frequencies are centered on 900 MHz, 2000MHz, 5000MHz.

Satellite Communication :

A communication satellite is basically an electronic communication package placed in orbit around the earth. It is not originator of information to be transmitted, but a relay station for other sources. If a transmitting station on earth cannot communicate directly with one or more receiving stations because of line of sight restrictions, then satellite can be used. The transmitting station sends the information to the satellite which in turn retransmits it ti the receiving station. The satellite in this application is known repeater.

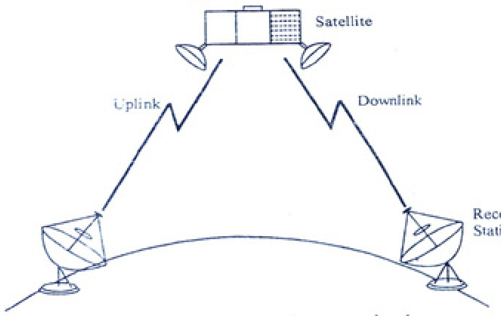


Fig. 11 :Satellite Communication

The above diagram shows the basic operation of communication satellite

The satellite contains a receiver which picks up the transmitted signal, amplifies it, and translates it to a new frequency. This new frequency is now transmitted to the receiving station on the earth. The original signal being transmitted from the earth station to the satellite is known as uplink and the retransmitted signal from satellite to the receiving stations in known as downlink beam can be broad, , covering a substantial fraction of the earth 's surface, or narrow, covering an area only hundred of kilometers in a diameters. This mode of operation is known as bent pipe. Even though the typical transponder has a wide bandwidth, it is only used with a single signal to minimize interference and improve communication reliability. However, a satellite would not be economical multiple transponders(12,24 or more) each operating at a different frequency. Each transponder represents an individual communication channel. Various multiplexing schemes are used so that each channel may carry multiple information transmissions.

Frequency Bands :

ITU has allocated certain frequency bands for satellite use on the basis of type of services and geographic regions in which earth stations are located. The C band was first designated for commercial satellite traffic. Two frequency ranges are assigned in it, one for downlink and other for uplink. To allow traffic to go both ways at the same time; two channels are required, one going each way. These bands are already over crowded because they are also used by the common carriers for terrestrial microwave links. The L and S bands were added by the international agreement in 2000. However , they are narrow and crowded.

Bank	Downlink	Uplink	Bandwidth	Problems
L	1.5 GHz	1.6 GHz	15 MHz	Low bandwidth, crowded
S	1.9 GHz	2.2 GHz	70 MHz	Low bandwidth, crowded
C	4.0 GHz	6.0 GHz	500 MHz	Terrestrial interface
Ku	11 GHz	14 GHz	50 MHz	Rain
Ka	20 GHz	30 GHz	3500 MHz	Rain, equipment cost

The next highest band available to commercial telecommunication carriers is the Ku(K under) band. This band is not congested and at these frequencies, satellite can be spaced as class as 1 degree. In this band rain in the main problem. Water is an excellent absorber of these short microwaves. Fortunately, heavy storms are usually localized, so using several widely separated around stations instead of just one overcomes the problem but at the price of extra antennas, extra cables and extra electronics to enables rapid switching between stations. Bandwidth has also been allocated in the Ka band for commercial satellite traffic, but the equipment needed to use it is still expensive. In addition to these commercial bands , many government and military bands also exist.

Applications

The communication satellite is a technological revolution as important as fiber optics. Among the most important applications for satellite are :

1. Television distribution
2. Long distance telephone transmission
3. Private business networks

1. Television distribution :- Because of their broadcast nature, satellite are well suited to television distribution and are being used extensively throughout the would for this purpose.

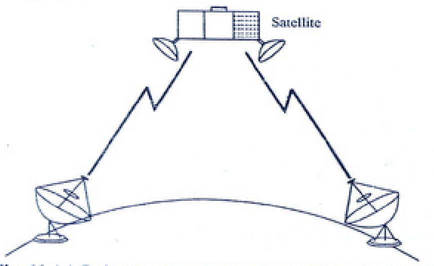


Fig. 11 (a) Point to point link via satellite microwave

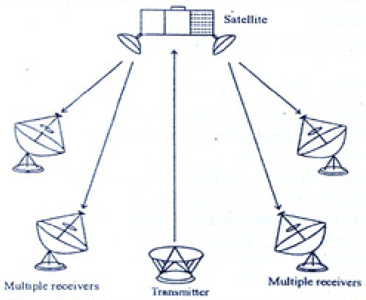


Fig. 11 (b) Broadcast link via satellite microwave

In its traditional use, a network provides programming from a central location. Programs are transmitted to the satellite and then broadcast down to a number of stations, which then distribute the programs to individual viewers. One network, the Public Broadcasting Service Channels, distribute its television programming almost exclusively by the use of satellite channels. Other commercial networks also make substantial use of satellite and cable television

systems are receiving an ever increasing proportion of their programming from satellites. The most recent application of satellite technology to television distribution is Direct Broadcast Satellite in which satellite video signals are transmitted directly to the home user. The dropping cost and size of receiving antennas have made DBS economically feasible and a number of channels are either already in service or in the planning stage.

2. Long distance telephone transmission :- Satellite transmission is also used for point to point trunks between telephone exchange offices in public telephone networks. It is the optimum medium for high usage international trunks and is competitive with terrestrial systems for many long distance international links.

3. Private business networks :- There are a number of business data applications for satellite. The satellite provider can divide the total capacity into a number of channels and base these channels to individual with the antennas at a number of sites can use a satellite channel for a private network. Traditionally , such applications have been quite expensive and limited to larger organizations with high volume requirements. A recent development is the very small aperture terminal system, which provides a low cost alternative figure show typical VSAT configuration. A number of subscriber stations are equipped with low cost VSAT antennas

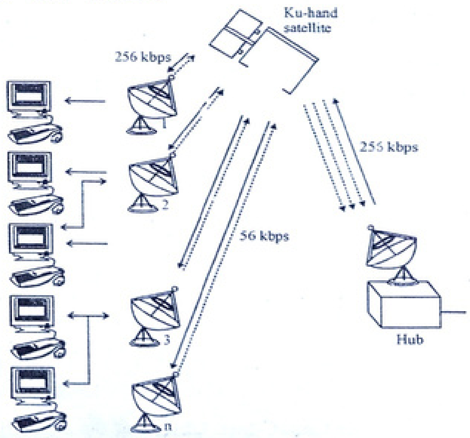


Fig. 12 :VSAT configuration

5.10 Satellite Communication

A satellite network uses a combination of nodes that provides communication between any points on the earth. Example of different nodes in the network is a satellite, an earth station, or an end-user terminal or a telephone. Satellite microwave systems transmit signals between directional parabolic antennas. Like terrestrial microwave systems, they use low frequency ranges usually at 4 to 6 GHz and 11 to 14 GHz and must be in line-of-sight. The main difference with terrestrial microwave systems is that satellite microwave systems can reach the most remote places on earth and communicate with mobile devices. A communication satellite is basically a big microwave repeater in the sky. It contains several transponders, which can receive from the earth station incoming weak signal, amplifies it into high power signal, and rebroadcasts at another frequency (to avoid interference with the incoming signal) to the receiving earth station. A typical satellite has 12-20 transponders with a 36-50 MHz bandwidth.

- Satellite microwave systems usually use low frequency ranges.
- The cost of building and launching a satellite is extremely expensive. Although satellite communications are expensive, the cost of cable (fiber optics) to cover the same distance may be even more expensive.
- Installation of satellites is extremely technical and difficult. The earth-based systems may require exact adjustments.
- Attenuation depends on frequency, power, antenna size and atmospheric conditions. High-frequency microwaves are more affected by rain and fog.
- Bandwidth capacity depends on the frequency used.
- Data rates are from 1 to 10Mbps.

VSATs (Very Small Aperture Terminals) are low-cost microstations used in satellite communication. These tiny terminals have 1 meter antennas and can put out about 1 watt power. In many VSAT systems, the microstations do not have enough power to communicate directly with another via satellite. Hub is a special ground station, with a large high-gain antenna which needed to relay traffic between VSATs. In this mode of operation, either the sender or the receiver has a large antenna and a powerful amplifier. There is a time delay of 540 m second between a transmitted and received signal for a VSAT system with a hub.

An artificial satellite need a path in which it travels around the earth is called orbit. Based on the location of the orbit, satellite can be divided into three categories:

1. GEO (Geosynchronous Earth Orbit). GEO is at the equatorial plane and resolves in phase with the earth.
2. LEO (Low-Earth Orbit). LEO satellite provides direct universal voice and data communications for handheld terminals and also provides universal broadband internet access.
3. MEO (Medium earth Orbit). MEO satellite provides time and location information for vehicles and ships.

GEO Satellite

Sending and receiving antennas must be in line-of-sight. For short time communication, a satellite can move faster and slower than the earth rotation. But for relay (constant) communication; the satellite must be move at the same speed as the earth so that it seems to remain fixed above a certain spot. Such satellites are called **geosynchronous.** The rotation period of geosynchronous satellite is same as the earth (rotation period is 23 hours 56 minutes 4.09 seconds). Only one orbit can be geosynchronous. This orbit is at equatorial plane and is 35,786 km above the equator.

To avoid interference geosynchronous satellites are spacing 2 degree in the 360 degree equatorial plane, as a result there can only be 180 geosynchronous communication satellites in the sky at once. To provide full global transmission, it takes minimum of three satellites to cover whole earth. Three satellites are spacing 120 degree from each other in geosynchronous orbit.

- It is capable of providing continuous and uninterrupted communication over the desired area.
- There is a time delay of 250 to 300 m second between a transmitted and received signal.
- Small areas near north and south poles are not covered in the communication range of the satellite.
- A costly launch vehicle is required.

MEO Satellite

MEO satellites are positioned between the two Van Allen belts. MEO satellites are located at altitudes between 5000 and 15,000 km. and a rotation period of 6 hours.

Global Positioning System (GPS) satellites are MEO satellites that provides time and location information for vehicles and ships. GPS has 24 satellites in six orbits, with each orbit hosting four satellites. A GPS receiver can tells the current position of a satellite and sends a signal to four satellites. It calculates your position on the earth.

LEO Satellite

LEO satellites are normally at altitude between 500 to 2000 km. LEO satellites have polar orbits. The satellite has a speed of 20,000 to 25,000 km/h with a rotation period of 90 to 120 min.

Iridium is designed to provide direct world wide voice and data communication using handheld terminals, a service similar to cellular telephony but on a global scale. The Iridium System has 66 satellites in six LEO orbits; each at an altitude of 750 km. Communication between two distant users requires relaying between several satellites. Globalstar system has 48 satellites in six polar orbits with each orbit hosting eight satellites. Communication between two distant users requires both satellites and earth stations, which means that ground stations can create more powerful signals.

Teledesic satellites are LEO satellites that will provide universal broadband Internet access. Teledesic has 288 satellites in 12 LEO orbits with each orbit hosting 24 satellites. The orbits are at an altitude of 1350 km.

Two frequencies are designed for each satellite to send and receive. Transmission from the earth to the satellite is called **uplink**. Transmission from the satellite to the earth is called **downlink**. Frequency bands for satellite communication are given in the following table.

Band	Bandwidth MHz	Uplink (GHz)	Downlink (GHz)	Problems
L	15	1.6	1.5	-
S	70	2.2	1.9	-
C	500	6	4	Terrestrial interference
Ku	500	14	11	Rain
Ka	3500	30	20	Rain; Expensive

Table Optical fiber versus mechanic cable

Twisted pair cable	Co-axial cable	Optical fiber
1. Transmission of signals takes place in the electrical form over the metallic conducting wires.	1. Transmission of signals takes place in the electrical form over the inner conductor of the cable	1. Signal transmission takes place in an optical forms over a glass fibre.
2. In this medium the noise immunity is low	2. Coaxial having higher noise immunity than twisted pair cable.	Optical fibre has highest noise immunity as the light rays are unaffected by the electrical noise.
3. Twisted pair cable can be affected due to external magnetic field.	3. Coaxial cable is less affected due to external magnetic field.	3. Not affected by the external magnetic field.
4. Cheapest medium	4. Moderate expensive	Expensive
5. Low Bandwidth	5. Moderately high bandwidth.	Very high bandwidth.
6. Attenuation is very high	6. Attenuation is low.	Attenuation is very low.
7. Installation is easy.	7. Installation is fairly easy.	8. Installation is difficult.

Optical Fiber :

In above articles, we have discussed conductive (metal) cables that transmit signals in the form of current. Optical fiber, on the other hand, is made of glass or plastic and transmits signals in the form of light. Transmission of light signal in optical fiber is based on the phenomenon of total internal reflection. An optical fiber cable has a cylindrical shape and consists of three concentric sections: the core, the cladding, and the jacket. The core is the innermost section and consists of one or more very thin strands or fibers made of glass or plastic. Its own cladding, a glass or plastic coating that has optical properties different from those of the core surrounds each fiber. The outermost layer, surrounding one or a bundle of gladded fibers, is the jacket. The jacket is composed of plastic and other material layered to protect against moisture, abrasion, crushing, and other environmental dangers.

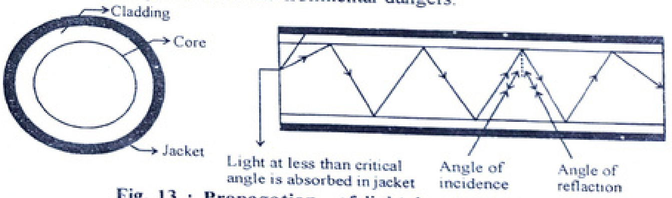
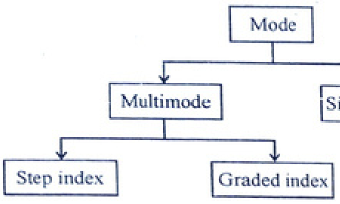


Fig. 13 : Propagation of light in optical fiber

Propagation Modes : There are two modes of propagation of light in optical fibers: multimode and single mode. Each mode require fiber with different characteristics. Multimode can implemented in two forms : step index or graded index.

(a) Multimode : Multimode is so named because multiple beams move through the core in different paths. How these beams move within the cable depends on the structure of the core.



(1) Multimode step index : In multimode step index fiber, the density of the core remains constant from the center to the edges. A beam of light moves through this constant density in a straight until it reaches the interface of the core and the cladding. At the interface, there is an abrupt change to a lower density that alters the angle of the beam's motion. The term step index refers to the suddenness of this change.

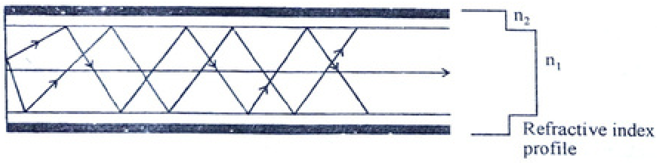


Fig. 14 :Propagation in Multimode step index fiber

The light ray traveling the straight path through the center and reaches the receiving end before the other rays, which follow a zigzag path. This difference in path length means that different beams arrive at the destination at different times. As these different beams are recombined at the receiver, they result in a signal that is no longer an exact replica of the signal that was transmitted. This is know as modal dispersion.

(2) Multimode graded index : Multimode graded index fiber decreases the distortion as compared to step index fiber. A graded index fiber is one with varying densities. Density is highest at the center of the core and decreases gradually to its lowest at the edge because light rays travel faster through the lower index of refraction, the light at the fiber core travels more slowly than the light nearer the surface. Therefore, both light rays arrive at exit point at almost the same time, thus reducing modal dispersion.

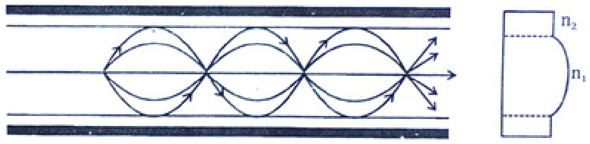


Fig. 15 : Propagation in Multimode graded- index fiber

Single mode : Single mode uses step index fiber and a highly focused source of light that limits beams to a small range of angles, all close to the horizontal. The single mode fiber is manufactured with a much smaller diameter than that of multimode fibers and with substantially lower density. In this case, Propagation of different beams is almost identical and delays are negligible. All of the beams arrive at the destination 'together' and can be recombined without distortion to the signal.

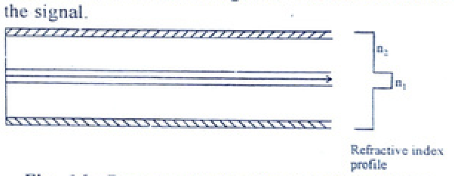


Fig. 16 :Propagation in Single Mode Fiber

Light sources for optical cable: As we have seen, the purpose of fiber optical cable is to contain and direct a beam of light from source to target. For transmission to occur. The sending device must be equipped with a light source and the receiving device with a photosensitive cell (called a photodiode) capable of translating the received light into current usable by a computer. The light source can be either a light emitting diode (LED) or an infection laser diode (ILD). LEDs are the cheaper source, but they provide unfocused light that strikes the boundaries of the channel at uncontrollable angles and diffuses over distance. For this reason. LEDs are limited to short distance use. Lasers, on the other hand, can be focused to a very narrow range allowing control over the angle of incidence. Laser signals preserve the character of the signal over considerable distances.

Advantages of optical Fiber :

(1) Greater capacity:

Spectrum location of fiber optical make it suitable for high data rate transmission. Data rates of 2Gbps over ten of kilometers can be supported.

(2) Smaller size and lighter weight :
Optical fibers are considerably thinner than coaxial cable or bundled twisted pair cable.

(3) Lower attenuation: Fiber optic transmission distance is significantly greater than that of other guided media. A signal can run for miles without requiring regeneration.

(4) Electromagnetic isolation: Optical fiber systems are not affected by external electromagnetic fields. Thus, the system is not vulnerable to interference with other equipment and thus providing a high degree of security from eaves dropping.

(5) Greater repeater spacing : Fewer repeaters means lower cost and fewer sources of error.

(6) Bit error rates of around one in 10 are typical compared with around one in 10 for coaxial cables. This increase data throughput by reducing the number of retransmissions or the amount of redundancy required for error correction.

(7) There is no risk of short circuits or electrical sparks which removes the need to line conduit (pipe through which liquid flow) with fire resistant material and makes fiber optical cable suitable for intrinsically safe applications such as in explosive atmosphere.

(8) Fiber optic cable is suitable for use over a wider temperature range.

(9) Fiber optic cable has a higher resistance to corrosive atmospheres and liquids than electrical cables.

(10) Raw materials for manufacturing glass are plentiful and costs are expected to reduce relative to the cost of metal cables.

(11) The operational life and mean time between failures of fiber optical cables are superior to electrical cables (This does not necessarily apply to conductors and light sources/detectors).

Disadvantages of optical fiber:

The main disadvantages of fiber optical cables are cost, installation/ maintenance, and fragility.

5.11 Light sources

1. Fiber Light Source for Fiber Networking Application In a fiber optic system, transmitter, optic fiber and receiver are necessary for data transmission. A light source plays a significant par in a telecommunication maintenance system. An optical light source that modulated by a suitable drive circuit in accordance with the signal is needed in the transmitter to accomplish the transmission work. Optical Light Source is a handheld optical light source, newly released in 2007. It can provide 1~7 wavelengths, 650/850/1300/1310/ 1490/1550/1625nm, output to satisfy specific requirements including the 650nm visible light source and the 1310/1550nm wavelengths for single mode fiber or the 850/1300nm wavelengths for multimode fiber, as well as other wavelengths according to customer's needs. An optical light source is used together with the optical power meter, they act as an economic and efficient solution for the fiber optic network works. An fiber light source is widely used in fiber networking application like Maintenance in Telecom Maintenance, CATV, Fiber Optic Lab Testing and other Fiber Optic Measurements. For high speed fiber optic communication systems, which operate at speed higher than 1 Gbit/s, the selection of light source is even more critical.

2. First, the selected fiber light source must be able to emit a wavelength corresponding to low loss window of the most common optic fiber material, fused silica, namely 1.3um and 1.5um windows. Second, the optical light source must have the high speed digital modulation ability. That is because with the current fiber optic communication systems reached operation speed up to 100Gb/ s, the optic light source is required to be modulated at speed in excess of 2.5Gb/s. Currently, two methods are developed to meet this requirements, one is to use a LiNbO3 external modulator, in which the light source is required to give steady power output, another is to directly modulate the light source at the speed desired. Lastly, the small spectral linewidth of the source is the third important characteristic of the light source, which significantly affects the magnitude of dispersion which is directly proportional to the linewidth of the source. Light sources of the fiber light source are offered in a variety of types. Basically there are two types of semiconductor light sources available for fiber optic communication - The LED sources and the laser sources. LED light source is a semiconductor diode with a p region and an n region. When the LED is forward biased, current flows through the LED. As current flows through the LED, the junction where the p and n regions meet emits random photons. This process is referred to as spontaneous emission. LEDs are also used in many other applications except fiber optic communication, such as aviation lighting, automotive lighting, and traffic signals, etc.

3. The laser is a semiconductor diode with a p and an n region which is similar with LED, but the difference is that, the laser has an optical cavity that contains the emitted photons with reflecting mirrors on each end of the diode. One of the reflecting mirror is only partially reflective. This mirror allows some of the photons to escape the optical cavity. The VCSEL(vertical-cavity surface-emitter laser) is the most popular laser source of high-speed networking, in which the semiconductor diode combines high bandwidth with low cost and is an ideal choice for the gigabit networking options. As one of the main suppliers of fiber light source in China, Ingellen provides both type of fiber optic light sources with different working wavelengths. These fiber optic light sources

features compact size, light weight, high stable output power and large display window and easy operation.

5.12 Optical Detectors

Detectors perform the opposite function of light emitters. They convert optical signals back into electrical impulses that are used by the receiving end of the fiber optic data, video, or audio link. The most common detector is the semiconductor photodiode, which produces current in response to incident light. Detectors operate based on the principle of the p-n junction. An incident photon striking the diode gives an electron in the valence band sufficient energy to move to the conduction band, creating a free electron and a hole. If the creation of these carriers occurs in a depleted region, the carriers will quickly separate and create a current. As they reach the edge of the depleted area, the electrical forces diminish and current ceases. While the p-n diodes are insufficient detectors for fiber optic systems, both PIN photodiodes and avalanche photodiode (APDs) are designed to compensate for the drawbacks of the p-n diode.

- Responsivity: Ratio of current output to light input. High responsivity equals high receiver sensitivity.
- Quantum Efficiency: Ratio of primary electron-hole pairs created by incident photons to the photons incident on the detector material.
- Capacitance: Dependent upon the active area of the device and the reverse voltage across the device.
- Response Time: Time needed for the photodiode to respond to optical inputs and produce and external current.

Response time can be affected by dark current, noise, linearity, backreflection, and edge effect Edge effect results from the fact that detectors only provide fast response in their center region. The outer region of the detector has a higher responsivity than the center region, which can cause problems when aligning the fiber to the detector. The higher responsivity may fool one into thinking they have aligned the fiber to the center region. Because response is much slower at the edge, this misalignment will reduce the response time of the detector.

PIN Photodiode

A p-n diode's deficiencies are related to the fact that the depletion area (active detection area) is small; many electron-hole pairs recombine before they can create a current in the external circuit. In the PIN photodiode, the depleted region is made as large as possible. A lightly doped intrinsic layer separates the more heavily doped p-types and n-types. The diode's name comes from the layering of these materials positive, intrinsic, negative - PIN.

Avalanche Photodiode (APD)

The avalanche photodiode (APD) operates as the primary carriers, the free electrons and holes created by absorbed photons, accelerate, gaining several electron Volts of kinetic energy. A collision of these fast carriers with neutral atoms causes the accelerated carriers to use some of their own energy to help the bound electrons break out of the valence shell. Free electron-hole pairs, called secondary carriers, appear. Collision ionization is the name for the process that creates these secondary carriers. As primary carriers create secondary carriers, the secondary carriers themselves accelerate and create new carriers. Collectively, this process is known as photomultiplication. Typical multiplication ranges in the tens and hundreds. For example, a multiplication factor of eighty means that, on average, eighty external electrons flow for every photon of light absorbed. APDs require high-voltage power supplies for their operation. The voltage can range from 30 or 70 Volts for InGaAs APDs to over 300 Volts for Si APDs. This adds circuit complexity. Also, APDs are very temperature sensitive, further complicating circuit requirements. In general, APDs are only useful for digital systems because they possess very poor linearity. Because of the added circuit complexity and the high voltages that the parts are subjected to, APDs are always less reliable than PIN detectors. This, added to the fact that at lower data rates, PIN detector-based receivers can almost match the performance of APD-based receivers, makes PIN detectors the first choice for most deployed low-speed systems. At multigigabit data rates, however, APDs rule supreme.

Table - Comparison of PIN Photodiodes and APDs

Parameter	PIN Photodiodes	APDs
Construction Materials	Si, Ge, InGaAs	Si, Ge, InGaAs
Bandwidth	DC to 40+ GHz	DC to 40+ GHz
Wavelength	0.6 to 1.8 µm	0.6 to 1.8 µm
Conversion Efficiency	0.5 to 1.0 Amps/Watt	0.5 to 100 Amps/Watt
Support Circuitry Required	None	High Voltage, Temperature Stabilization
Cost (Fiber Ready)	$1 to $500	$100to $2,000

5.13 Fiber Optics Cable

A Fiber optics cable is made of very fine fibers of glass or plastic that accepts and transports signals in the form of light. They consist of a glass core, roughly fifty micrometers in diameter, surrounded by a glass "optical cladding" giving an outside diameter of about 120 micrometers. They make use of TIR (Total Internal Reflection) to confine light within the core of the fiber.

Optical Fibers are optical waveguides. This means that wherever the fiber goes the light, which is confined to the core of the fiber, also goes. So optical fibers can be used to make light bend round corners. There are two types of bends macro-bend and micro-bend.

An optical transmission system has three components: the light source (LED or laser), the transmission medium (Fiber-optics cable) and the detector (Photodiode). A pulse of light indicates a 1 bit and the absence of light indicates a 0 bit. The detector generates an electrical pulse when light falls on it. By attaching a light source to one end of an optical fiber and a detector to the other end, a unidirectional data transmission system that accepts an electrical signal, converts to light pulse and transmits it. At the receiving end the incoming signal reconverts to an electrical signal.

The receiving end of an optical fiber consists of a photodiodes. The typical response time of a photodiode is 1nsec so data rates will be 1 Gbps. A pulse of light must carry enough energy to be detected.

Repeaters are needed only about 30km on long lines. The repeater convert the incoming light to an electrical signal, regenerated full strength if it has weakened and retransmitted as light.

There are two types of light sources for which fiber cables are available. These sources lights are:

1. Light Emitting Diodes (LEDs).
2. Light Amplification bi stimulated Emission Radiation (Lasers).

Item	LED	Semiconductor Laser
Data rate	Low	High
Mode	Multimode	Multimode or single mode
Distance	3 km	30 km
Lifetime	Long life	Short life
Temperature Sensitivity	Minor	Substantial
Cost	Low	Expensive

A single fiber has a glass or plastic core at the center through which the light propagates. In single-mode fibers, the core is 8 to 10 microns in diameter.

In multimode fibers, the core is 50 microns. The core is surrounded by a glass cladding with a lower index of refraction than the core, to keep all the light in the core. Its diameter is usually 125 microns. Although the cladding does not carry light, it is nevertheless an essential part of the fiber. The cladding is not just a mere covering. It keeps the value of the critical angle constant throughout the whole length of the fiber. For protection the cladding is covered in a thin plastic jacket. Its diameter is usually 250 microns. Fibers are usually grouped together in bundles protected by an outer sheath/jacket which is made of either PVC or Teflon. And it is provided for protection against moisture, abrasion, crushing and other environment dangers. In between the outer sheath and the plastic jacket are Kevlar strands to strengthen the cable. Kevlar is a strong material used in the fabrication of bulletproof vests. An optical fiber with its protection jacket may be typically 0.635 cm in diameter. Optical fibers are defined by the ratio of diameter of their core to the diameter of their cladding.

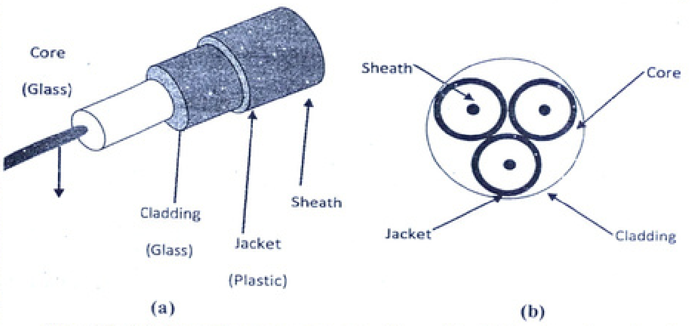


Fig. 17. (a) Side view of a single fiber. (b) End view of a sheath with three fibers

When the angle of indent is less than critical angle, the light is refracted and moves closer to the surface. If a light ray incident on the boundary at critical angle, the light bends along to the interface. If the angle is greater than the critical angle, the light ray reflected internally. However, if the diameter of core is reduced than the light ray can only moves in a straight line, without reflection.

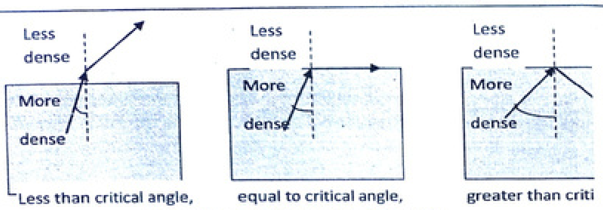


Fig. 18 Bending of a light ray

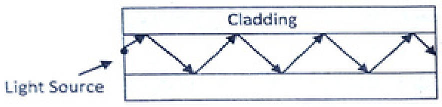


Fig. 19 : Optical Fibre

Propagation Modes

There are two types of modes for propagation of light along optical channel.

1. Multimode.
2. Single-Mode.

Multimode

In multimode fiber multiple rays from a light source (LED) moves through the core in different paths. In multimode fibers, the core is 50 to 100 microns in diameter and 125 microns cladding.

Multimode can be in two forms:

1. Step-index.
2. Graded-index.

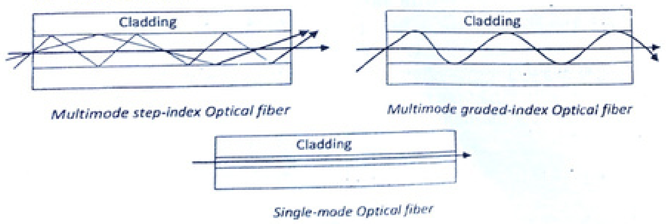


Fig. 20

Multimode Step-index

In multimode step-index propagation, the core density is constant and the light beam moves through this constant density in a straight line until it reaches the interface of the core and the cladding. The direction changes suddenly at the interface between the core and the cladding. The term step index refers to the suddenness of this change.

Multimode Graded-index

In multimode graded-index propagation, the core density decreased with distance from the center. Density is highest at the center of the core and lowest at the edge. As the index of refraction is related to density; this causes a curving of the light beams. The word index refers to the index of refraction.

Single-mode

In single-mode fiber as the core's diameter reduce, the light can moves in a straight line. As the core density is lower than multimode fiber, the critical angle that is close enough to 900, which make the propagation of beams almost straight. In this case, propagation of different beams is almost identical and delays are negligible. All the beams arrive at the destination together and can be recombined with little distortion to the signal. In single-mode fibers, the core is 8 to 10 microns in diameter and 125 microns cladding. Single-mode fiber uses an Injection Laser Diode (ILD) as a light source.

Type	Core(micron)	Cladding(micron)	Mode
50/125	50	125	Multimode Graded-index
62.5/125	62.5	125	Multimode Graded-index
100/125	100	125	Multimode Graded-index
7/125	7	125	Single-mode

- Fiber-optic cables are composed of glass or plastic inner core surrounding by cladding, all encased in an outside jacket.
- Fiber-optic cables transmit data signal in the form of light. The signal is propagated along the inner core by reflection
- Fiber-optic transmission is become popular due to its noise resistance, low attenuation and high bandwidth capabilities.
- In optical fibers signal propagation can be multimode (multiple beams from a light source) or single-mode (essentially one beam from a light source).
- In multimode step-index propagation, the core density is constant and the

light beam changes direction suddenly at the interface between the core and the cladding.

- In multimode graded-index propagation, the core density decreased with distance from the center. This causes a curving of the light beams.
- Fiber-optic cable is used in backbone networks, cable TV networks, Telecommunication, and Fast Ethernet networks.
- Mode of data transmission is half-duplex.
- An optical transmission system has three components: the light source (LED or laser), the transmission medium (Fiber-optics cable) and the detector (Photodiode).
- Used mainly for digital data. A pulse of light indicates a 1 bit and the absence of light indicates a 0 bit.
- The detector generates an electrical pulse when light falls on it.
- The repeater convert the incoming light to an electrical signal, regenerated full strength if it has weakened and retransmitted as light

Advantage of Fiber Optics

1. Fiber-optic cable carry signals with much less energy loss than twister cable or coaxial cable and with a much higher bandwidth. Hence the data rate data rate is also higher than other cables.
2. Fiber-optic cables are much lighter and thinner than copper cables with the same bandwidth. This means that much less space is required in underground cabling ducts. Also they are easier for installation engineers to handle.
3. Fiber-optic cables suffer less attenuation than other guided media because light beam traveling in the fiber. This means that fibers can carry more channels of information over longer distances and with fewer repeaters.
4. Fiber-optic cables are not affected by electromagnetic interference, power surges or power failure or corrosive chemicals in the air.
5. Fiber-optic cables cannot easily be tapped. It has more immunity to tapping than copper cables.
6. As fibers are very good dielectric, isolation coating is not required.
7. No electric connection is required between the sender and the receiver.
8. Fiber-optic cables are much more reliable than other cables. It can better stand environment condition, such as pollution, radiation etc. Its life longer in compare to copper wire.

Fiber Optics Losses

1. Fiber-optic cables and the interfaces are more expensive than other guided media.
2. Propagation of light is unidirectional. So two fibers are needed if we need bi-directional communication.

It is new technology, therefore only few trained mechanics are available. Optical fibers cannot be joined together as an easily as copper cable and requires additional training of personnel and expensive precision splicing and measurement equipment.

Guided media	Unguided media
Guided media transmit data in the form of electrical current or light.	Unguided media transmit data by electromagnetic wave through air.
Here the data is transmitted by metal or glass conductor.	Here the data is transmitted without used of any physical conductor.
Through guided media signal can travel according physical path.	Through unguided media signal can travel according to their propagation like ground propagation, sky propagation and line-of-sight propagation.
This type of media is generally used at low frequency data transmission.	This type of media is generally used for high frequency data transmission.
This type of media is used for generally short distance transmission.	This type of media is used for large distance transmission such as satellite.
Here the data transmission is private; only that the receiver can receive the data to which the cable is connected.	Here any one can receive transmitted data which have capable receiver to receive it.
In the case of guided media analog and digital transmission possible.	Only analog transmission happens.
It has lower bandwidth.	It has higher bandwidth than guided media.
Through this media signal can pass through least undesired external interference. It is protected from as much as possible from external interference.	In the case of unguided media external interference can cause serious effect to the signal.
Guided media include twisted-pair cable, coaxial cable and fiber-optic cable	Unguided media is wireless such as radio and lasers through the air.
It is a lower cost media such as twisted-pair or coaxial cable.	The media is high media as satellite is used or several high capable transmitter and receiver are used.

SONET

Synchronous optical networking (SONET) and Synchronous Digital Hierarchy (SDH), are two closely related multiplexing protocols for transferring multiple digital bit streams using lasers or light - emitting diodes (LEDs) over the same optical fiber. The method was developed to replace the Plesiochronous Dogital hierarchy (PDH) system for transporting larger amounts of telephone calls and data traffic over the same fiber wire without synchronization problems.

SONET and SDH were originally designed to transport circuit mode communications (eg. T1, T3) from a variety of different sources. The primary difficulty in doing this prior to SONET was that the synchronization source of these different circuits were different, meaning each circuit was actually operating at a slightly different rate and with different phase. SONET allowed for the simultaneous transport of many different circuits of differing origin within one single framing protocol. In a sense, then, SONET is not itself a communications protocol per se, but a transport protocol.

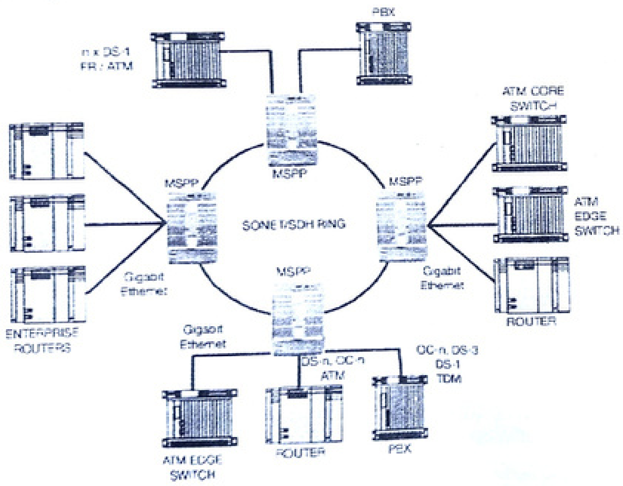


Fig. 21 :

Due to SONET's essential protocol neutrality and transport-oriented features, SONET was the obvious choice for transporting ATM (Asynchronous Transfer

Mode) frames, and so quickly evolved mapping structures and concatenated payload containers so as to transport ATM connections. In other words, for ATM (and eventually other protocols such as TCP/IP and Ethernet), the internal complex structure previously used to transport circuit-oriented connections is removed, and replaced with a large and concatenated frame (such as STS-3c) into which ATM frames, IP packets, or Ethernet is placed.

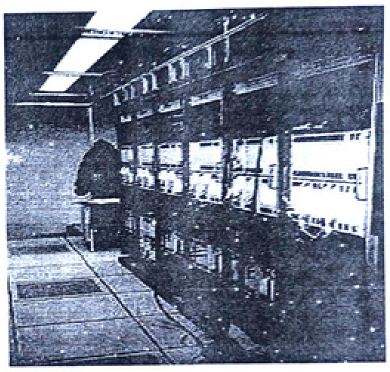


Fig. 22 :A rack of Alcatel STM-16 SDH Add Drop Multiplexors

Both SDH and SONET are widely used today: SONET in the U.S. and Canada and SDH in the rest of the world. Although the SONET standards were developed before SDH, their relative penetrations in the worldwide market dictate that SONET now is considered the variation.

The two protocols are standardized according to the following:

- **SDH or Synchronous Digital Hierarchy** standard developed by the International Telecommunication Union (ITU), documented in standard G.707 and its extension G.708
- **SONET or Synchronous Optical Networking** standard as defined by GR 253 CORE from Telcordia and T1.105 from American national Standards Institude

WaveLength Division Multiplexing -

In fiber - optic communications, **wavelength-division multiplexing (WDM)** is a technology which multiplexes multiple optical carrier signals on a single optical fiber by using different wavelengths (colours) of laser light to carry different signals. This allows for a multiplication in capacity, in addition to enabling bidirectional communications over one strand of fiber. This is a form of frequency division multiplexing (FDM) but is commonly called wavelength division multiplexing.

The term wavelength-division multiplexing is commonly applied to an optical carrier (which is typically described by its wavelength), whereas freqency - division multiplexing typically applies to a radio carrier (which is more often described by frequency). However, since wavelength and frequency are inversely proportional, and since radio and light are both forms of electromagnetic radiation, the two terms are equivalent in this context.

DWDM - Dense WaveLength Division Multiplexing

Dense Wavelength Division Multiplexing, or DWDM for short, refers originally to optical signals multiplexed within the 1550-nm band so as to leverage the capabilities (and cost) of erbium doped fiber amplifiers (EDFAs), which are effective for wavelengths between approximately 1525-1565 nm (C band), or 1570-1610 nm (L band). EDFAs were originally developed to replace SONET/SDH optical-electrical-optical (OEO) regenerators, which they have made practically obsolete. EDFAs can amplify any optical signal in their operating range, regardless of the modulated bit rate. In terms of multi-wavelength signals, so long as the EDFA has enough pump energy available to it, it can amplify as many optical signals as can be multiplexed into its amplification band (though signal densities are limited by choice of modulation format). EDFAs therefore allow a single-channel optical link to be upgraded in bit rate by replacing only equipment at the ends of the link, while retaining the existing EDFA or series of EDFAs through a long haul route. Furthermore, single-wavelength links using EDFAs can similarly be upgraded to WDM links at reasonable cost. The EDFAs cost is thus leveraged across as many channels as can be multiplexed into the 1550-nm band.

DWDM systems

At this stage, a basic DWDM system contains several main components:

1. A DWDM terminal multiplexer. The terminal multiplexer actually contains one wavelength converting transponder for each wavelength signal it will carry. The wavelength converting transponders receive the input optical signal (i.e., from a client-layer SONET/SDH or other signal), convert that signal into the electrical domain, and retransmit the signal using a 1550-nm band laser. (Early DWDM systems contained 4 or 8 wavelength converting transponders in the mid 1990s. By 2000 or so, commercial systems capable of carrying 128 signals were available.) The terminal mux also contains an optical multiplexer, which takes the various 1550-nm band signals and places them onto a single SMF-28 fiber. The terminal multiplexer may or may not also support a local EDFA for power amplification of the multi-wavelength optical signal.

2. An intermediate optical terminal, or Optical Add-drop multiplexer. This is a remote amplification site that amplifies the multi-wavelength signal that may have traversed up to 140 km or more before reaching the remote site. Optical diagnostics and telemetry are often extracted or inserted at such a site, to allow for localization of any fiber breaks or signal impairments. In more sophisticated systems (which are no longer point-to-point), several signals out of the multiwavelength signal may be removed and dropped locally.

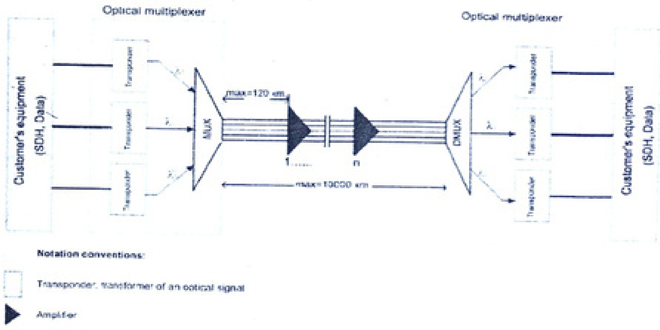


Fig. 23 :

3. A DWDM terminal demultiplexer. The terminal demultiplexer breaks the multi-wavelength signal back into individual signals and outputs them on separate fibers for client-layer systems (such as SONET/SDH) to detect. Originally, this demultiplexing was performed entirely passively, except for some telemetry, as most SONET systems can receive 1550-nm signals. However, in order to allow for transmission to remote client-layer systems (and to allow for digital domain signal integrity determination) such demultiplexed signals are usually sent to O/E/O output transponders prior to being relayed to their client-layer systems. Often, the functionality of output transponder has been integrated into that of input transponder, so that most commercial systems have transponders that support bi-directional interfaces on both their 1550-nm (i.e., internal) side, and external (i.e., client-facing) side. Transponders in some systems supporting 40 GHz nominal operation

may also perform forward error correction (FEC) via 'digital wrapper' technology, as described in the ITU - G.709 standard.

4. Optical Supervisory Channel (OSC). This is an additional wavelength usually outside the EDFA amplification band (at 1510nm, 1620nm, 1310nm or another proprietary wavelength). The OSC carries information about the multi-wavelength optical signal as well as remote conditions at the optical terminal or EDFA site. It is also normally used for remote software upgrades and user (i.e., network operator) Network Management information. It is the multi-wavelength analogue to SONET's DCC (or supervisory channel). ITU standards suggest that the OSC should utilize an OC-3 signal structure, though some vendors have opted to use 100 megabit Ethernet or another signal format. Unlike the 1550-nm band client signal-carrying wavelengths, the OSC is always terminated at intermediate amplifier sites, where it receives local information before retransmission.

The introduction of the ITU-T G.694.1 frequency grid in 2002 has made it asier to integrate WDM with older but more standard SONET/SDH systems. /DM wavelengths are positioned in a grid having exactly 100 GHz (about 8nm) spacing in optical frequency, with a reference frequency fixed at 193.10 Hz (1552.52nm). The main grid is placed inside the optical fiber amplifier andwidth, but can be extended to wider bandwidths. Today's DWDM systems se 50 GHz or even 25 GHz channel spacing for up to 160 channel operation.

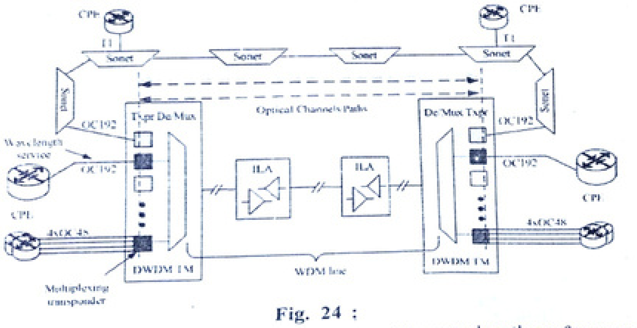


Fig. 24 :

DWDM systems have to maintain more stable wavelength or frequency an those needed for CWDM because of the closer spacing of the wavelengths. recision temperature control of laser transmitter is required in DWDM systems prevent "drift" off a very narrow frequency window of the order of a few Hz. In addition, since DWDM provides greater maximum capacity it tends to

be used at a higher level in the communications hierarchy than CWDM, for example on the Internet backbone and is therefore associated with higher modulation rates, thus creating a smaller market for DWDM devices with very high performance levels. These factors of smaller volume and higher performance result in DWDM systems typically being more expensive than CWDM.

Recent innovations in DWDM transport systems include pluggable and software-tunable transceiver modules capable of operating on 40 or 80 channels. This dramatically reduces the need for discrete spare pluggable modules, when a handful of pluggable devices can handle the full range of wavelengths.

ISDN -

Integrated Services Digital Network is a telephone system network. Prior to the ISDN, the phone system was viewed as a way to transport voice, with some special services available for data. The key feature of the ISDN is that it integrates speech and data on the same lines, adding features that were not available in the classic telephone system. There are several kinds of access interfaces to the ISDN defined: Basic Rate Interface (BRI), Primary Rate Interface (PRI) and Broadband-ISDN (B-ISDN).

ISDN is a circuit - switched telephone network system, that also provides access to packet switched networks, designed to allow digital transmission of voice and data over ordinary telephone copper wires, resulting in better voice quality than an analog phone. It offers circuit-switched connections (for either voice or data), and packet-switched connections (for data), in increments of 64 kbits/s. Another major market application is Internet access, where ISDN typically provides a maximum of 128 kbit/s in both upstream and downstream directions (which can be considered to be broadband speed, since it exceeds the narrowband speeds of standard analog 56k telephone lines). ISDN B-channels can be bonded to achieve a greater data rate, typically 3 or 4 BRIs (6 to 8 64 kbit/s channels) are bonded.

ISDN should not be mistaken for its use with a specific protocol, such as Q.931 whereby ISDN is employed as the transport, data-link and physical layers in the context of the OSI model. In a broad sense ISDN can be considered a suite of digital services existing on layers 1, 2, and 3 of the OSI model. ISDN is designed to provide access to voice and data services simultaneously.

However, common use has reduced ISDN to be limited to Q.931 and related protocols, which are a set of protocols for establishing and breaking circuit switched connections, and for advanced call features for the user. They were introduced in the late 1980s.

In a videoconference, ISDN provides simultaneous voice, video, and text transmission between individual desktop videoconferencing systems and group (room) videoconferencing systems.

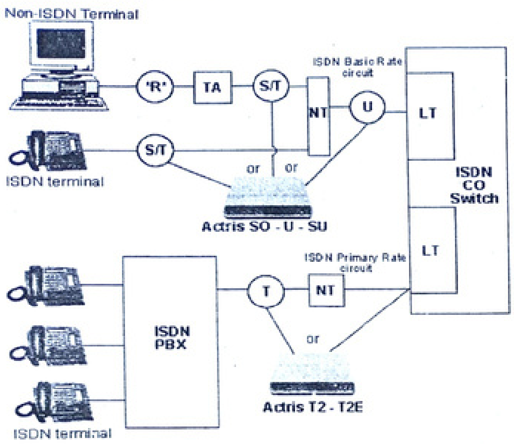


Fig. 25

Cable Modem System - A **cable modem** is a type of modem that rovides access to a data signal sent over the cable television infrastructure. :able modems are primarily used to deliver broadband Internet access in the prm of cable internet, taking advantage of the high bandwidth of a cable elevision network. They are commonly found in Australia, Canada, Europe, ;osta Rica, and the United States. In the USA alone there were 22.5 million able modem users during the first quarter of 2005, up from 17.4 million in the irst qı

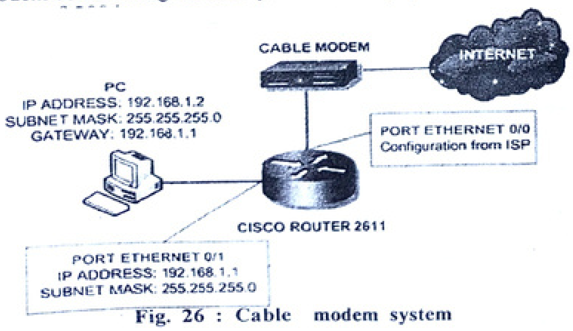


Fig. 26 : Cable modem system

In network topology, a cable modem is a network bridge that conforms to IEEE 802.1D for Ethernet networking (with some modifications). The cable modem bridges Ethernet frames between a customer LAN and the coax cable network.

With respect to the OSI model, a cable modem is a data link layer (or layer 2) forwarder.

A cable modem does support functionalities at other layers. In physical layer (or layer 1), the cable modem supports the Ethernet PHY on its LAN interface, and a DOCSIS defined cable-specific PHY on its HFC cable interface. It is to this cable-specific PHY that the name cable modem refers. In the network layer (or layer 3), the cable modem is an IP host in that it has its own IP address used by the network operator to manage and troubleshoot the device. In the transport layer (or layer 4) the cable modem supports UDP in association with its own IP address, and it supports filtering based on TCP and UDP port numbers to, for example, block forwarding of Net BIOS traffic out of the customer's LAN. In the application layer (layer 5 or layer 7), the cable modem supports certain protocols that are used for management and maintenance, notably DHCP, SNMP, and TFTP.

Some cable modem devices may incorporate a router along with the cable modem functionality, to provide the LAN with its own IP network addressing. From a data forwarding and network topology perspective, this router functionality is typically kept distinct from the cable modem functionality (at least logically) even though the two may share a single enclosure and appear as one unit. So, the cable modem function will have its own IP address and MAC address as will the router.

DSL - Digital Subscriber Line

DSL or **xDSL**, is a family of technologies that providesdigital data transmission over the wires of a local telephone network. DSL originally stood for **digital subscriber loop**, although in recent years, the term **digital subscriber line** has been widely adopted as a more marketing-friendly term for ADSL, which is the most popular version of consumer-ready DSL. DSL can be used at the same time and on the same telephone line with regular telephone, as it uses high frequency, while regular telephone uses low frequency.

Typically, the download speed of consumer DSL services ranges from 256 kilobits per second (kbit/s) to 24,000 kbit/s, depending on DSL technology, line conditions and service level implemented. Typically, upload speed is lower than download speed for Asymmetric Digital Subscriber Line (ADSL) and equal to download speed for the rarer Symmetric Digital Subscriber Line (SDSL).

Fig. 27 :A Digital Subscriber Line

Voice and data

DSL (VDSL) typically works by dividing the frequencies used in a single phone line into two primary "bands". The ISP data is carried over the high-frequency band (25 kHz and above) whereas the voice is carried over the lower-frequency band (4 kHz and below). The user typically installs a DSL filter on each phone. This filters out the high frequencies from the phone line, so that the phone only sends or receives the lower frequencies (the human voice). The DSL modem and the normal telephone equipment can be used simultaneously on the line without interference from each other.

Asymmetric Digital Subscriber Line

Asymmetric Digital Subscriber Line (ADSL) is a form of DSL, a data communications technology that enables faster data transmission over copper telephone lines than a conventional voiceband modem can provide. It does his by utilizing frequencies that are not used by a voice telephone call. A splitter - or microfilter - allows a single telephone connection to be used for both ADSL service and voice calls at the same time. Because phone lines vary in quality and were not originally engineered with DSL in mind, it can generally only be used over short distances, typically less than 4km.

At the telephone exchange the line generally terminates at a DSLAM where another frequency splitter separates the voice band signal for the conventional phone network. Data carried by the ADSL is typically routed over the telephone company's data network and eventually reaches a conventional internet network. In the UK under british Telecom the data network in question is its ATM network which in turn sends it to its IP network IP Colossus.

Very High Bitrate Digital Subscriber Line -

VDSL or **VHDSL** (Very High Bitrate DSL) is a DSL technology providing faster data transmission over a single flat untwisted or twisted pair of copper wires. These fast speeds mean that VDSL is capable of supporting high bandwidth applications such as HDTV, as well as telephone services (Voice over IP) and general Internet access, over a single connection. VDSL is deployed over existing wiring used for POTS (Plain Old Telephone Sevice) and lower-speed DSL connections. This standard was approved by ITU in November 2001.

Second-generation VDSL2 systems (ITU-T G.993.2 Approved in February 2006) utilize bandwidth of up to 30 MHz to provide data rates exceeding 100 Mbits/s simultaneously in both the upstream and downstream directions. The maximum available bit rate is achieved at a range of about 300 meters; performance degrades as the loop attenuation increases.

Currently, the standard VDSL uses up to 7 different frequency bands, which enables customization of data rate between upstream and downstream depending on the service offering and spectrum regulations. First generation VDSL standard specified both QAM (Quadrature amplitude modulation) and DMT (Discrete multi - Tone modulation.) In 2006, ITU-T standardized VDSL in recommendation G.993.2 which specified only DMT modulation for VDSL2

HDSL - High bit rate Digital Subscriber Line

High bit rate Digital Subscriber Line (HDSL) was the first DSL technology to use a higher frequency spectrum of copper, twisted pair cables. HDSL was developed in the USA, as a better technology for high-speed, synchronous circuits typically used to interconnect local exchange carrier systems, and also to carry high-speed corporate data links and voice channels, using T1 lines.

T-carrier circuits operate at 1.544 Mbits. These circuits were originally carried using a line code called Alternate Mark Inversion (AMI). Later the line code used was B8ZS. AMI did not have sufficient range, requiring the application of repaeters over long circuits. As with any wire circuit, they were subject to lightning and cable trouble such as inferior splices and backhoe fade. In troubleshooting these type of services, the *felt* frequency on each conductor is 772 kHz and the repeaters are usually spaced every mile to 1.2 miles depending on conductor gauge and the whim of the engineers.

As in classical T-carrier, HDSL has a positive and negative polarity to the side of the repeater. In splicing this type of service the telcos placed the low voltage side of the repeater cable together and then the High voltage side together in the splice. The telcos have a powering end to the circuit path and this gives the polarity and the repeaters are typically powered up to 130 volts dc. Usually if you see 130 voits there is trouble because the repeaters are running FULL power to try to compensate for the trouble. They require 60 milliamps and if they cannot get it they try to achieve it by raising the voltage.

The first attempts to use DSL technology to solve the problem were done in the USA, using the line code 2B1Q. This modulation allowed for a 784 kbits data rate over a single twisted pair cable. With two twisted pair cables, the full 1.544 Mbit/s was achieved. The new technology attracted the attention of the industry, but could not be directly used worldwide, due to the differences between the T1 and E1 standards. A new standard was then developed by the ITU for HDSL, using the CAP (Carrierless Amplitude Phase Modualtion) line code, that reached the maximum bandwidth of 2.0 Mbit/s using two pairs of copper.

HDSL gave the telcos a greater distance reach when delivering a T-1 circuit. It was marketed originally as a Non Repeated T-1, with a distance of 12k feet over 24 gauge cable. The cable gauge affects the distance. To allow for longer distances, a repeater can be used. The repeater actually terminates the circuit and regenerates the signal. Up to four repeaters can be used for a reach of 60k feet (about 20 km). This reduced the cost of maintenance when compared with AMI-based repeaters that had to be used at every 35 db of attenuation (about 1 mile).

HDSL can be used either at the T1 rate (1.544 Mbit/s) or the E1 rate (2 Mbit/s). Slower speeds are obtained by using multiples of 64 kbit/s channels, inside the T1/E1 frame. This is usually known as **channelized T1/E1**, and it's used to provide slow-speed data links to customers. In this case, the line rate is still the full T1/E1 rate, but the customer only gets the limited (64 multiple) data rate over the local serial interface. Unlike later ADSL, HDSL did not allow POTS at baseband.

HDSL gave way to two new technologies, called HDSL2 and SDSL. HDSL2 offers the same data rate over a single pair of copper; it also offers longer reach, and can work over copper of lower gauge or quality. SDSL is a multi-rate technology, offering speeds ranging from 192 kbit/s to 2.3 Mbit/s, using a single pair of copper. SDSL is used as a replacement (and in some cases, as a generic designation) for the entire HDSL family of protocols.

SMDS -

SMDS, which stands for **Switched Multi-megabit Data Services**, was a connectionless service used to connect LANs,MANs and WANs, and to exchange data. SMDS was based on the IEEE 802.6 DQDB standard. SMDS fragmented its datagrams into smaller "cells" for transport, and can be viewed as a technological precursor of ATM.

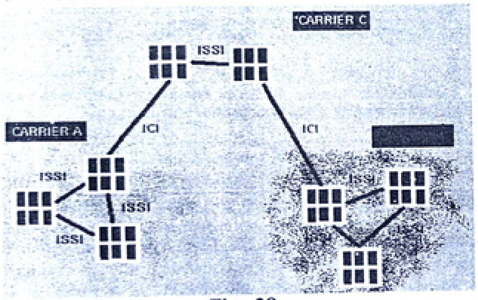


Fig. 28

Exercises

Very Short Questions [2 marks each]

1. What is data communication system ?
2. What is communicaiton protocols?
3. Explain direction of flow ?
4. What is data transmission ?
5. Explian Simplex, half duplex and full duplex.
6. What is error detection ?
7. How many types of errors ?
8. What is error correction ?

9. What is cable modem system ?
10. What is DWDM

Short Questions [4 marks each]

1. Explain data communication system
2. What is error detection and error cassetion.
3. Explain microwave communication.
4. What is sonet ? Explain

Long Questions [12 marks each]

1. What is data communication. Explain with diagram.
2. What is sonet ? Explain with diagram.
3. Explain optical fibre cable ? Give advantages and disadvantages.
4. What is sonet ? Explain satellite communication with diagram.
5. Explain error detection and error correction ?

2017
2018
2019
2020
2021

2017

1. what is Lan.
2. Define Network → 2019 → 2021
3. what is Bandwidth - ~~2017~~ ~~2020~~ - 2021
4. " " protocol
" " ~~Talent~~ Talnet
" " " MIME
" " " Multiplexing = 2020
" " " data communication
" " microwave
" " What do you mean SS7?

2019

(a) what is IP Add.
(b) what is various type of Network - 2022
(c) switch
(d) OSI physical layer
(e) MAC Add → 2021
(f) fiber otic cable
(g) SMTP?
(h) IPV6
(I) Ring topology

2020

(1) using Network advandg
(2) Network topology what mean
(3) data tramission mode
~~bandwidth~~
(4) Asynchronus and synchrous delay
TCP/IP 2021
DHCP - 2021
DNS → 2021

2021
(1) what is Link
(2) ~~Switch~~ Gateway
(3) SSL

topic's

TCP/IP

(1) protocol
(2) SMTP
(3) FTP
(4) HTTP
(5) DHCP
(6) SSL
(7) MIME
(8) error dection and collection
(9) circuit switch / pcket ?
(10) Data comunicat - A & S
(11) TCP / UDP
(12) Sonet
peer to peer process

OSI	TCP