TCS 112: TELECOMMUNICATION AND NETWORKS I

University of Ilorin
Centre for Open & Distance Learning

CODL

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From the Vice Chancellor

Courseware remains the nerve centre of Open and Distance Learning. Whereas some institutions and tutors depend entirely on Open Educational Resources (OER), CODL at the University of Ilorin considers it necessary to develop its own materials. Rich as OERs are and widely as they are deployed for supporting online education, adding to them in content and quality by individuals and institutions guarantees progress. Doing it in-house as we have done at the University of Ilorin has brought the best out of the Course Development Team across Faculties in the University. Credit must be given to the team for prompt completion and delivery of assigned tasks in spite of their very busy schedules. The development of the courseware is similar in many ways to the experience of a pregnant woman eagerly looking forward to the D-day when she will put to bed. It is customary that families waiting for the arrival of a new baby usually do so with high hopes. This is the apt description of the eagerness of the University of Ilorin in seeing that the centre for open and distance learning [CODL] takes off. The Vice-Chancellor, Prof. Sulyman Age Abdulkareem, deserves every accolade for committing huge financial and material resources to the centre. This commitment, no doubt, boosted the efforts of the team. Careful attention to quality standards, ODL compliance and UNILORIN CODL House Style brought the best out from the course development team. Responses to quality assurance with respect to writing, subject matter content, language and instructional design by authors, reviewers, editors and designers, though painstaking, have yielded the course materials now made available primarily to CODL students as open resources. Aiming at a parity of standards and esteem with regular university programmes is usually an expectation from students on open and distance education programmes. The reason being that stakeholders hold the view that graduates of face-to-face teaching and learning are superior to those exposed to online education. CODL has the dual-mode mandate. This implies a combination of face-to-face with open and distance education. It is in the light of this that our centre has developed its courseware to combine the strength of both modes to bring out the best from the students. CODL students, other categories of students of the University of Ilorin and similar institutions will find the courseware to be their most dependable companion for the acquisition of knowledge, skills and competences in their respective courses and programmes. Activities, assessments, assignments, exercises, reports, discussions and projects amongst others at various points in the courseware are targeted at achieving the objectives of teaching and learning. The courseware is interactive and directly points the attention of students and users to key issues helpful to their particular learning. Students' understanding has been viewed as a necessary ingredient at every point. Each course has also been broken into modules and their component units in sequential order At this juncture, I must commend past directors of this great centre for their painstaking efforts at ensuring that it sees the light of the day. Prof. M. O. Yusuf, Prof. A. A. Fajonyomi and Prof. H. O. Owolabi shall always be remembered for doing their best during their respective tenures. May God continually be pleased with them, Aameen.

Bashiru,A.Omipidan

Director, CODL

Professor S. A. Abdulkareem
Vice Chancellor

Foreword

Courseware is the livewire of Open and Distance Learning. Whereas some institutions and tutors depend entirely on Open Educational Resources (OER), CODL at the University of Ilorin considered it necessary to develop its materials. Rich as OERs are and widely as they are deployed for supporting online education, adding to them in content and quality by individuals and institutions guarantees progress.

Pursuing this goal has brought the best out of the Course Development Team across Faculties in the University. Despite giving attention to competing assignments within their work setting, the team has created time and eventually delivered. The development of the courseware is similar in many ways to the experience of a pregnant mother eagerly looking forward to the delivery date.

As with the eagerness for a coming baby, great expectation pervaded the air from the University Administration, CODL, Faculty and the writers themselves. Careful attention to quality standards, ODL compliance and UNILORIN CODL House Style brought the best out from the course development team. Response to quality assurance with respect to writing, subject matter content, language and instructional design by the authors, reviewers, editors and designers, though painstaking, has yielded the course materials now made available primarily to CODL students as open resources.

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With this in mind, the Centre has developed its courseware to combine the strength of both modes to bring out the best from the students. CODL students and other categories of students of the University of Ilorin and similar institutions will find the courseware to be their most dependable companion for the acquisition of knowledge, skills and competences in the respective courses and programmes.

Activities, assessments, assignments, exercises, reports, discussions and projects at various points in the courseware are targeted at achieving the Outcomes of teaching ang learning. The courseware is interactive and directly points the attention of students and users to key issues helpful to their particular learning. The student's understanding has been viewed as a necessary ingredient at every point. Each course has also been broken into modules and their component units in an ordered sequence. In it all, developers look forward to successful completion by CODL students.

Courseware for the Bachelor of Science in Computer Science housed primarily in the Faculty of Communication and Information Science provide the foundational model for Open and Distance Learning in the Centre for Open and Distance Learning at the University of Ilorin.

Henry O. Owolabi
Director, CODL

INTRODUCTION

In this course, Computer Programming I, a harmattan semester course, I will introduce you to the concept of programming using one of the most popular programming language; C Language. Through this course, I will expose you to the fundamental syntax and structure of C language, focusing on major aspects of programming such as variables, data types, operators, expression, statement, control structures, functions, and composite types. In the journey through this course, I will help you to understand that this course provides solid foundation for learning programming languages.

Course Goal

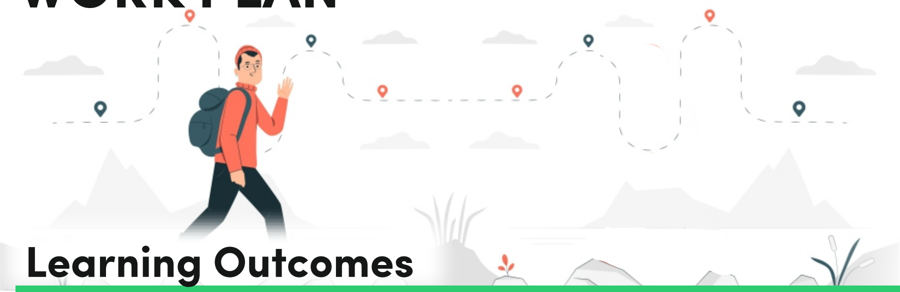
The course is designed to introduce students in the Physical Sciences and Engineering to the application of statistics in their discipline. This course is to intimate the students with the usefulness of statistics in their various field of studies. This course is to enlighten the student on the importance of statistics in carrying out researches in their various areas of study. This course is also to develop in students the ability to apply their knowledge and skills to the solution of theoretical and practical problems in Statistics.

Required for:

Course requirements

This is a compulsory course for students in Departments of Chemistry, Industrial Chemistry, Geology, Mathematics, Computer Science. Students are expected to participate in all the course activities and have minimum of 75% attendance to be able to write the final examination

WORK PLAN



Learning Outcomes

I.Understand the basics of telecommunication and networking.

II.Explain the mathematics of computing and data representation in computer systems.

Week 01

Week 02

V. Understand transmission impairments and list the various sources of impairments in communication channels.

VI.Explain modulation and multiplexing.

Week 03

Course Guide

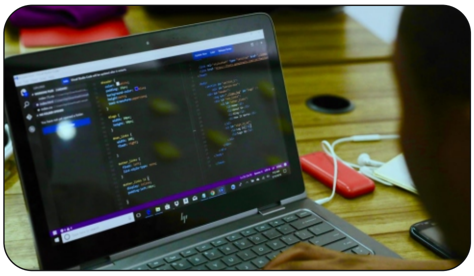
Module 1

MATHEMATICS OF COMPUTING AND DATA REPRESENTATION

Unit 1 Introduction to Data and Data Representation

Unit 2 Conversion Between Bases

Unit 3 Positional Numbering Systems



Module 2

FUNDAMENTALS OF NETWORKING

Unit 1 Introduction to networking

Unit 2 The Internet protocol

Unit 3 The Public Switched Telephone Network

Module 3

SWITCHING TECHNOLOGIES

Unit 1 Circuit Switched Networks

Unit 2 Packet Switching

Related Courses

CSC 112 – Introduction to Computer Science II

CSC 212 – Computer Programming II

CSC 233- Object-Oriented Programming (using JAVA)

Pre-requisite | **CSC 112** Introduction to Computer Science II

VII.Describe errors and list various approaches to error detection and correction in communication systems.

VIII.Explain the Public Switched Telephone Network and its principle of operation.

Week 04

IX.Understand optical fiber communication.

Week 05

Module 4

SIGNALS AND TRANSMISSION

Unit 1 The Communication System

Unit 2 Transmission Impairments

Unit 3 Error Detection And Correction

Module 5

MODULATION AND MULTIPLEXING

Unit 1 Modulation

Unit 2 Multiplexing

Module 6

OPTICAL FIBER COMMUNICATION

Unit 1 The Optical fiber cable

Unit 2 Optical Fiber Communication

Course Requirements

Requirements for success

The CODL Programme is designed for learners who are absent from the lecturer in time and space. Therefore, you should refer to your Student Handbook, available on the website and in hard copy form, to get information on the procedure of distance/e-learning. You can contact the CODL helpdesk which is available 24/7 for every of your enquiry.

Visit CODL virtual classroom on http://codllms.unilorin.edu.ng. Then, log in with your credentials and click on CSC 231. Download and read through the unit of instruction for each week before the scheduled time of interaction with the course tutor/facilitator. You should also download and watch the relevant video and listen to the podcast so that you will understand and follow the course facilitator.

At the scheduled time, you are expected to log in to the classroom for interaction. Self-assessment component of the courseware is available as exercises to help you learn and master the content you have gone through.

You are to answer the Tutor Marked Assignment (TMA) for each unit and submit for assessment

Embedded Support Devices

Support menus for guide and references

Throughout your interaction with this course material, you will notice some set of icons used for easier navigation of this course materials. We advise that you familiarize yourself with each of these icons as they will help you in no small ways in achieving success and easy completion of this course. Find in the table below, the complete icon set and their meaning.

		
Introduction	**Learning Outcomes**	**Main Content**

Summary	Tutor Marked Assignment	Self Assessment
Web Resources	Downloadable Resources	Discuss with Colleagues
References	Futher Reading	Self Exploration

Grading and Assessment

20%	20%	60%	100%
TMA	CA	Exam	Total

01 | Data representation
source: iStock.com

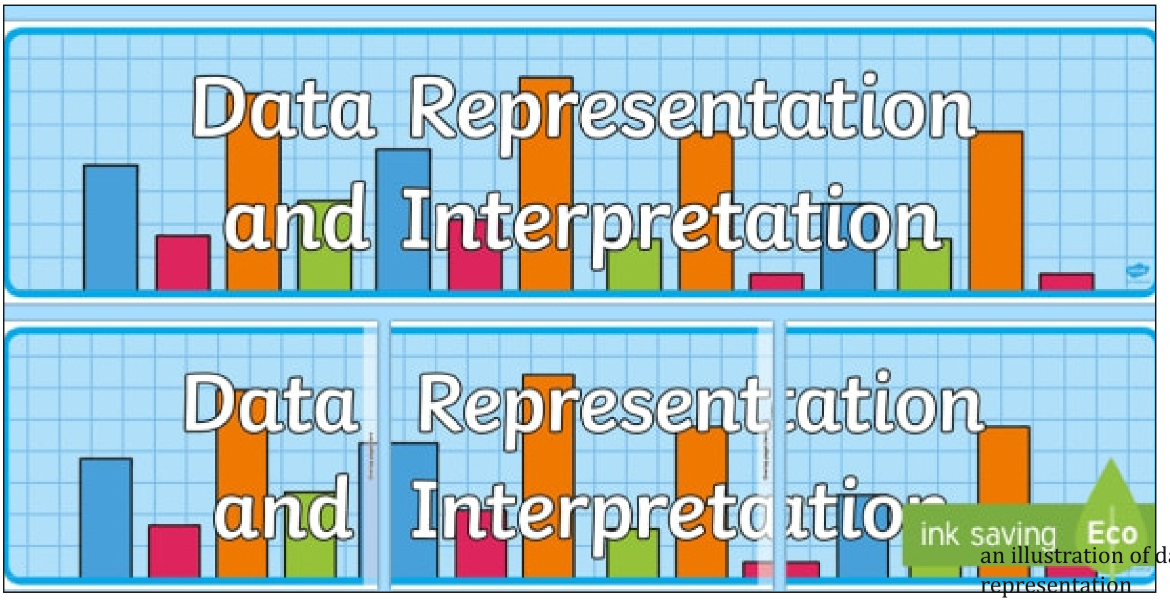
Module 1:

MATHEMATICS OF COMPUTING AND DATA REPRESENTATION

Unit 1 Introduction to Data and Data Representation

Unit 2 Conversion Between Bases

Unit 3 Positional Numbering Systems



an illustration of data representation
source: twinkl.com

UNIT 1

Introduction to Data and Data representation

Introduction

This unit will explain to you introduction to data representation and various ways of expressing information in computing

Learning Outcomes

1. Define data and list the various ways of data representation
2. Explain the importance of digitization in telecommunication
3. Explain the types of data representation
4. List the categories of the number system

Introduction to Data and Data Representation

8 mins

You are already familiar with Computer as a device that operate on input instructions to generate desired results as output. Data representation gives an insight into the way data can be represented in computer systems. Instructions, information, and other forms of data cannot be input directly into a computer using the conventional human language. For computers to understand anything input into it, they first need to be converted to a machine-readable format known as binary. Hence, it becomes very paramount to understand how data is handled in a computer system to produce human-understandable outputs.

Data

Data means anything that can be used to refer to people, events, things or ideas. It could be the name of a person, mobile number, or colors in a photograph. Information processed or stored by a computer isregarded as computer data. These pieces of information may be in different formats such as text documents, images, video clips other forms of data.

Data Representation

How data is stored, processed, and transmitted is referred to as data representation. Devices like computers, calculators, and mobile phones store data digitally for easy processing by the computer system. Figure 3.1 shows some of the devices used for data storage.

Figure 3.1: Data Representation

Representation of data in digital circuits

Fundamentally, representation of data in digital computers using the binary number system can be likened to that of switching on (high voltage) and off (low voltage) of an electric circuit. The electric circuit switch, when closed causes the bulb to light but when opened, the bulb goes off. Microprocessors and other electronic components consist of several lots of electronic circuits, the presence of high voltage in these circuits is represented by "1" while low voltage denotes '0'.

Representation of data on optical media

In optical media, the availability of light represents '1' while its unavailability is represented as '0'. This is the technology employed by optical devices in the reading and storage of data. The CD-ROM is a very good example of optical devices, the glittery part of the CD-ROM when observed using a powerful microscope, it will be observed that the surface contain very small holes known as pits while the surrounding areas are called land.

Digitization

2 mins

It may intrest you to know that digitalization is a process of converting information like text, numbers, images, or music, into digital data which can be processed or manipulated by computer devices. The language of the computer system is binary which operates using 0's and 1's which are known as binary digits.

Why binary?

The complexity of human natural languages has made it difficult for computers to directly understand them. Also, binary digits employ the use of digital devices that are more reliable, simple, and not as cumbersome as analog devices.

Types of data representation

5 mins

In this section, we will be looking into the various types of data representation that we have. Aside from numbers, the computer system operates on other forms of data such as alphabets, symbols, pictures, and sounds. Below are types of data representations.

Numeric data

Numbers that are used in arithmetic operations are referred to as numeric data. The basis for representing numeric data in digital devices is the binary number system also known as base 2. A number system is a set of symbols used to represent values derived from a common base or radix. It consists of only two digits: 0 and 1.

Categories of number systems

There are four major categories of number systems.

Decimal Number System

The word decimal is the Latin equivalence of deci which represents Ten (10). The decimal number system which is also referred to as base ten numbering system consists of ten digits ranging from 0 to 9.

Binary number system

The binary number system also known as base two number system makes use of only two digits ranging from 0 to 1 in the representation of data. In general, binary numbers are represented as X2 and have a place value which increases in factors of two.

Octal number system

The octal number system has eight digits ranging from 0 to 7 and place value of eight.

Hexadecimal number system

The hexadecimal system is also known as the base 16 number system and is made up of a combination of digits and letters. The letter part consists of digits ranging from 0 to 9 and letters A to F, where A, B, C, D, E, and F represent 10,11,12,13,14, and 15 in base ten respectively. The place value of hexadecimal numbers increases in factors of sixteen.

·Representation of symbols using coding schemes

Symbols can be represented using coding schemes, the type of coding scheme employed determines the number of bits per character. Some of the common coding schemes are discussed in this unit.

Binary Coded Decimal

Binary Coded Decimal (BCD) is a 4-bit code that can be used to represent numeric data only. For example, the BCD format of a number like 10 is 10102 while that of 9 can be represented as 10012. BCD iscommonly used in simple electronic devices such as calculators and microwaves that make use of Liquid Crystal Display (LCD) screens to process and display their numbers. A standard BCD, which is an improved format of BCD, has a 6-bit representation scheme which can represent non-numeric characters and allows 64 characters to be represented. For example, letter A can be represented as 1100012 using the standard Binary Coded Decimal.

Extended Binary Coded Decimal Interchange Code (EBCDIC)

Extended Binary Coded Decimal Interchange Code (EBCDIC) consists of an 8-bitcharacter-coding scheme used primarily on IBM computers. A total of 256 (i.e 28) characters can be coded using this scheme. For example, the symbolic representation of letter A using the Extended Binary Coded Decimal Interchange code is 110000012.

American Standard Code for Information Interchange (ASCII)

American standard code for information interchange (ASCII) is a 7-bit code ,which means that only 128 characters i.e. 27 can be represented. However, manufacturers have added an eight-bit to this coding scheme, which can now provide for 256 characters. This 8-bit coding scheme is regarded as an 8-bit American standard code for information interchange. The symbolic representation of letter A using this scheme is 10000012.

·Bits, Bytes, and Nibble.

These three terms (bits, bytes, nibble) are commonly used when referring to computer memory and data size. All of the data stored and transmitted by digital devices are encoded as bits. It is the basic unit of data or information in digital computers. Terminology related to bits and bytes is extensively used to describe storage capacity and network access speed. The word bit is an abbreviation for binary digit and can be further abbreviated as a lowercase b. A group of eight bits is called a byte and is usually abbreviated as an uppercase B, it is considered as the basic unit of measuring memory size in computer systems. A nibble is half a byte, which is known as a grouping of 4 bytes. When we have two or more bits, they make a word. Various conversions of bit and byte are given in table 3.1.

DBÅÇ	ABBREVIATION	CONVERSION
Bit	B	One binary digit
Byte	B	8 bits
Kilobit	Kb	1,024 or 210 bits
Kilobyte	KB	1,024 or 210 bytes
Megabit	Mb	1,048,576 or 220 bits
Megabyte	MB	1,048,576 or 220 bytes
Gigabit	Gb	230 bits
Gigabyte	GB	230 bytes
Terabyte	TB	240 bytes
Petabyte	PB	250 bytes
Exabyte	EB	260 bytes

Summary

In this unit, I have thought you the following:

- ·Computers store data in the form of bits, bytes, and words using the binary numbering system.
- ·Hexadecimal numbers are formed using four-bit groups known as nibbles.
- ·Error detecting and correcting codes are necessary because we can expect no transmission or storage medium to be completely error-free.
- ·Digitization is the process of converting information, such as text, numbers, photos, or music, into digital data which can be manipulated electronically.

Self-Assessment Questions

SAQ

- Define data and list 4 ways of representing data
- Explain why digitization important in telecommunication
- Discuss the types of data representation
- List the categories of the number system

Tutor Marked Assessment

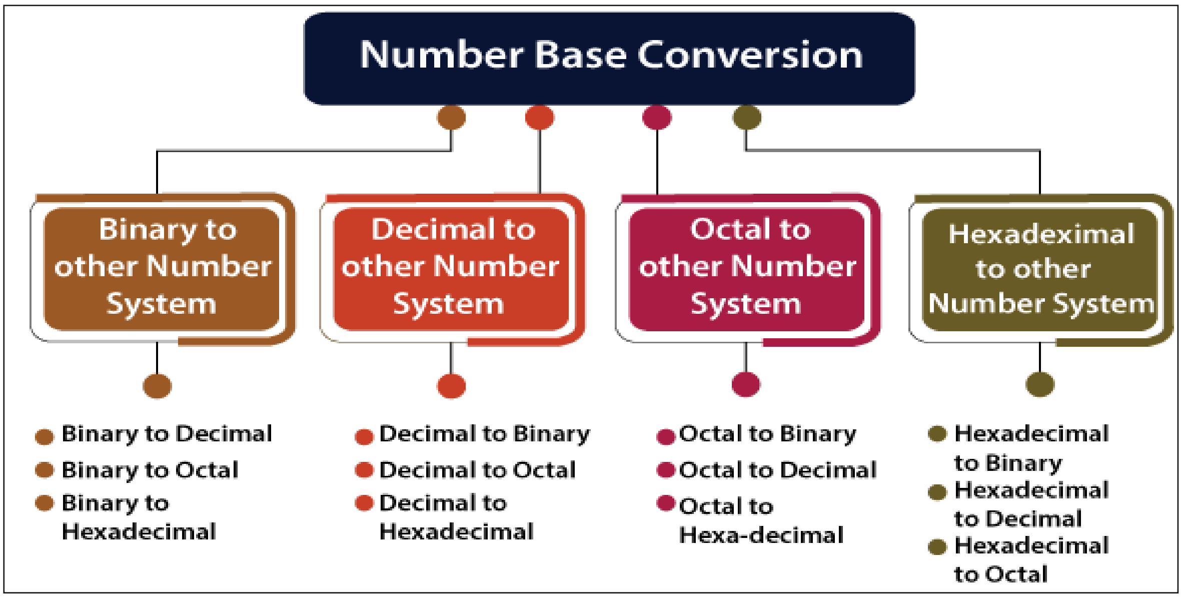
- ·Define the following terms:
- ·Data·Radix
- ·Digitization
- ·How are the following represented in a computer system;
- ·Number
- ·Data
- ·Text·
- Briefly differentiate between Bit, Byte, and Nibble.

Further Reading

- https://marketbusinessnews.com/telecommunications-definition-meaning/
- https://www.nap.edu/read/11711/chapter/3
- https://www.collinsdictionary.com/dictionary/english/telecommunications
- https://www.mitel.com/articles/history-telecommunication
- https://peda.net/kenya/css/subjects/computer-studies/form-three/driac2#

References

- Webster's Third International Dictionary, G&C Merriam Co., Springfield, MA, 1981.
- IEEE Standard Dictionary of Electrical and Electronic Terms, 6th ed., IEEE Std 100-1996, IEEE, New York, 1996
- Telecommunication Planning, ITT Laboratories of Spain, Madrid 1973.
- R. L. Freeman, Telecommunication System Engineering, 4th ed., Wiley, New York, 2004



source: javatpoint.com

UNIT 2

Conversion Between Bases

Introduction

This unit will explain to you introduction to data representation and various ways of expressing information in computing.

Learning Outcomes

1. Define data and list the various ways of data representation
2. Explain the importance of digitization in telecommunication
3. Explain the types of data representation
4. List the categories of the number system

CONVERSION FROM DECIMAL TO OTHER BASE SYSTEM

10 mins

If you are Converting from decimal to other bases, basically four stages are involved as follows:

Stage 1 – You are to divide the decimal by the value of the intended base (new base).

Stage 2 – The remainder from Stage 1 should be gotten as the rightmost digit (least significant digit) of the new base number.

Stage 3 – Then, divide the quotient of the former divide by the new base
.

Stage 4 – Write down the remainder from Stage 3 as the next digit (to the left direction) of the new base number.

Repeat stages 3 and 4, by noting down remainders from right to left, until the quotient becomes zero in stage 3. After going through the above steps, the last remainder obtained will be the Most Significant Digit (MSD) of the new base number.

Challenge 1:

Get the binary equivalence of the decimal number: 3910 To calculate the binary equivalence, the activities shown in Table 3.1 shall be performed.

ĊÇAĀÃ	Operation	Result	Remainder
Stage 1	39/ 2	19	1
Stage 2	19 / 2	9	1
Stage 3	9 / 2	4	1
Stage 4	4 / 2	2	0
Stage 5	2/ 2	1	0
Stage 6	1/2	0	1

Table 3.1: Conversion of 3910 to Binary.

As it is mentioned in Stages 2 and 4 above, the remainders should be arranged in the reverse order so that the first remainder gotten is written as the Least Significant Digit (LSD) and the last remainder is written as the Most Significant Digit (MSD).So from Table 3.1 above, the binary equivalence of 3910 is 1001112

CONVERSION FROM OTHER BASES TO DECIMAL

When you are converting from other bases to decimal, three stages are involved. Stage 1 – Determine the column (positional) value of each digit (this depends on the position of the digit and the base of the number system).

Stage 2 – Multiply the obtained column values (in Stage 1) by the digits in the corresponding columns.

Stage 3 – Add the products obtained in Stage 2. The total obtained after the addition is the equivalent value in decimal.

Challenge 2: Get the decimal equivalence of 1001112

Table 3.1 shows the steps involved in the conversion.

ĊÇAĀÃ	Binary Number	Decimal Number
Stage 1	100111_2	$((1 \times 2^5) + (0 \times 2^4) + (0\times 2^3) + (1 \times 2^2) + (1 \times 2^1) + (1 \times 2^0))_{10}$
Stage 2	100111_2	$(32 + 0 + 0 + 4+ 2 + 1)_{10}$
Stage 3	100111_2	39_{10}

Table 3.2: Conversion of 1001112 to decimal .

Hence the decimal equivalence of 1001112 is 3910

CONVERSION FROM OTHER BASE SYSTEM TO NON-DECIMAL SYSTEM

Here, we have two basic stages.

Stage 1 – Convert the number in whatever base to decimal (base 10).

Stage 2 – Convert the resulting decimal number to the new base.

Challenge 3

Convert 358 (Octal) to Binary

Stage 1 – Convert 258 to Decimal

ĊÇAĀÃ	Octal Number	Decimal Number
Stage 1	35_8	$((3\times 8^1) + (5 \times 8^0))_{10}$
Stage 2	35_8	$(24 + 5)_{10}$
Stage 3	35_8	29_{10}

Table 3.3: Conversion of 258 to decimal

Hence, the decimal equivalence of 258 is 29

Stage 2 – Convert 2910 to Binary

ĊÇAĀÃ	Operation	Result	Remainder
Stage 1	29/ 2	14	1
Stage 2	14/ 2	7	0
Stage 3	7 / 2	3	1
Stage 4	3 / 2	1	1
Stage 5	1 / 2	0	1

Table 3.3: Conversion of 2910 to Binary

So, the equivalence of 2910 in Binary is 111012

Thus, 358 (octal) is equal to 111012

Shortcut – Converting from Binary to Hexadecimal

Stages involved include:

Stage 1 – You are to divide the binary digits into groups of four (starting from the right).

Stage 2 – Then convert each group of four binary digits to one hexadecimal symbol.

Example

Binary Number – 111012

Calculating hexadecimal Equivalent –

ĊÇAĀÃ	Binary Number	Hexadecimal Number
Stage 1	11101_2	0001_2 1101_2
Stage 2	11101_2	1_{10} 13_{10}
Stage 3	11101_2	$1D_{16}$

Table 3.5: Shortcut method for converting Binary to Hexadecimal

Binary Number – 111012 = Hexadecimal Number – 1D16

Shortcut - Hexadecimal to Binary

Note that two stages are involved when converting Hexadecimal to Binary

Stage 1 – Convert each hexadecimal digit to a 4 digit binary number (the hexadecimal digits may be treated as decimal for this conversion).

Stage 2 – Combine all the resulting binary groups (of 4 digits each) into a single binary number.

Example

Hexadecimal Number – 1D16

Calculating Binary Equivalent –

3¥º ß•	Hexadecimal Number	Binary Number
Stage 1	$1D_{16}$	1_{10} 13_{10}
Stage$_T$ 2	$1D_{16}$	0001_2 1101_2
Stage 3	$1D_{16}$	00011101_2

Table 3.6: Shortcut method for converting Hexadecimal to Binary

Hexadecimal Number – 1D16 = Binary Number – 111012

Advantages of Binary Code

5 mins

Below are some of the advantages of binary code:

·They are used in computer applications.

·They are also suitable for digital communications.

·They are useful for the analysis and design of digital circuits.

·Since only Zer (0) & One (1) is being used, it is easy to implement.

Summary

In this unit, I have thought you the following:

- Conversion from one base to other base systems is possible but requires some basic steps to be followed to arrive at accurate answers.
- When converting from decimal to binary, the remainders need to be arranged on the reverse order so that the first remainder obtained is written as the LSD and the last remainder as MSD.
- When converting from Hexadecimal to Binary, you must first convert each of the hexadecimal digits to a 4 digit binary number.
- Binary codes have several advantages in computing, some of these advantages are:
  They are useful in digital communication and computer applications
- They can be used for the designing and analysis of digital circuits.
  The easy to implement.

Self-Assessment Questions

SAQ

- Convert 12110, 33310, and 24210 to Binary.
- Convert 101112,1111012 to Binary.
- What is the binary equivalence of 658
- List 4 advantages of Binary codes.

Tutor Marked Assessment

- In a tabular form, using both approaches learned in this unit, show how you would convert 6910 and 7910 to Binary.
- Convert 10111012 to binary, then in a tabular form, show how would convert your answer to octal.
- Why are binary codes important in computing

Further Reading

- https://marketbusinessnews.com/telecommunications-definition-meaning/
- https://www.nap.edu/read/11711/chapter/3
- https://www.collinsdictionary.com/dictionary/english/telecommunications
- https://www.mitel.com/articles/history-telecommunication
- https://peda.net/kenya/css/subjects/computer-studies/form-three/driac2#

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- Webster's Third International Dictionary, G&C Merriam Co., Springfield, MA, 1981.
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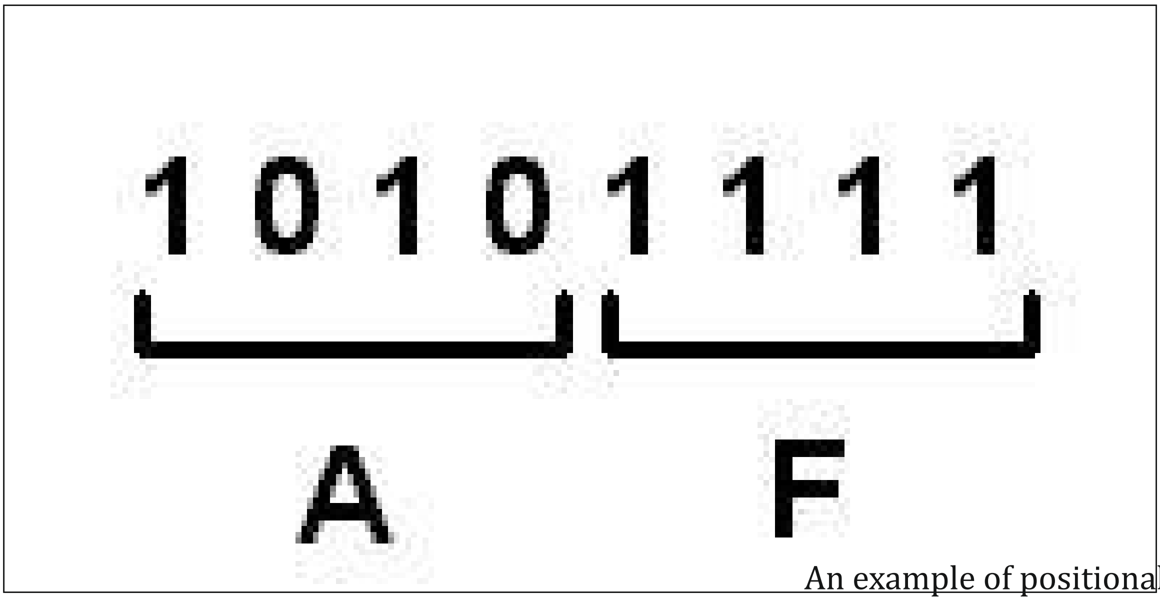


An example of positional numbering systems
source: danielmiessler.com

UNIT 3

Positional Numbering Systems

Introduction

In this unit you will be introduce to positional numbering systems, sign-magnitude, and background to binary complement systems.

Learning Outcomes

1. Express the idea behind positional numbering system
2. Calculate some basic sign-magnitude arithmetic
3. Express the binary system compliments and list the types of complements
4. Change numbers from 1's complement to 2's complement and vice-versa

Understanding the positional number system [SAQ 1]

4 mins

It will interest you to know that the idea behind positional numbering systems is that a numeric value is represented through increasing powers of a radix (or base). Below is the list of common radixes:

Decimal 0, 1, 2, 3, 4, 5, 6, 7, 8, 9

Binary 0, 1

Octal 0, 1, 2, 3, 4, 5, 6, 7

Hexadecimal 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F

GÑÑÓÒÖ MÕ	4-bit binary	Hexadecimal
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

Signed Magnitude

Note that a signed-magnitude number has a sign as its leftmost bit (also referred to as the high-order bit or the most significant bit) while the remaining bits represent the magnitude (or absolute value) of the numeric value.

Note: Numbers in brackets in the examples below are the decimal equivalent of the base 2 numbers. Binary Addition: 1+1=0 carry 1, 0+0=0, 0+1=1

Example 1:

Add 010011112 to 001000112 using signed-magnitude arithmetic.

010011112 (79) + 001000112 (35) = 011100102 (114)

You will notice that there is no overflow in this example

Example 2:

Add 010011112 to 011000112 using signed-magnitude arithmetic.

An overflow condition and the carry is discarded, resulting in an incorrect sum.

We obtain the erroneous result of

010011112 (79) + 011000112 (99) = 01100102 (50) instead of 101100102 (178)

Example 3:

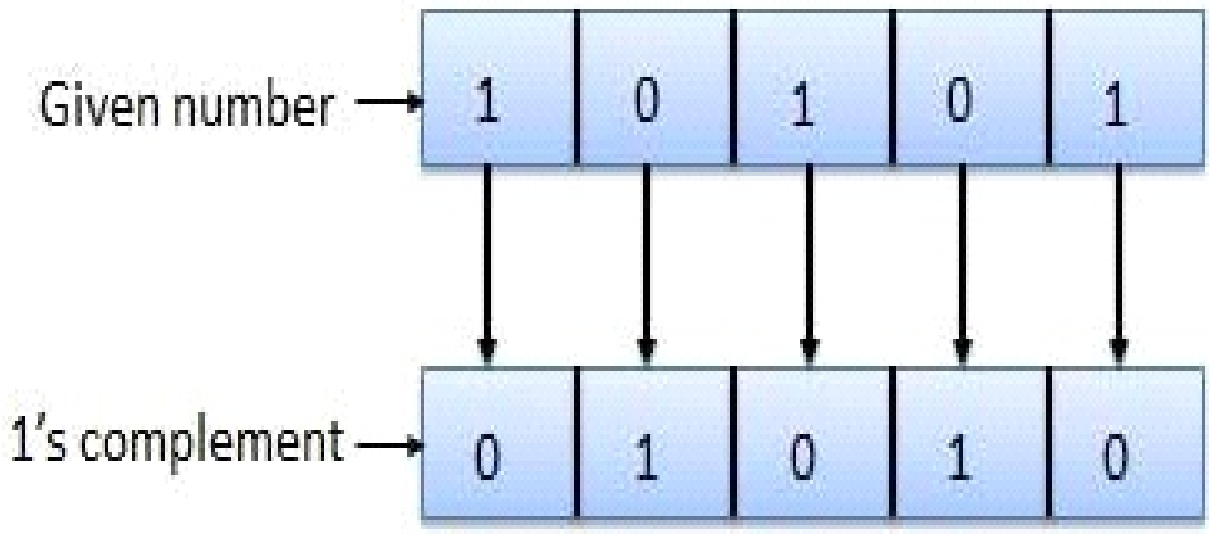
Subtract 010011112 from 011000112 using signed-magnitude arithmetic. We find 0110000112(99) - 010011112 (79) = 000101002 (20) in signed-magnitude representation.

Binary system complements

The binary system has base r = 2. The two types of complements for the binary system are 2's complementand 1's complement.

One's Complement

The 1's complement of a number could be obtained by changing all 1's to 0's and all 0's to 1's. This is known as taking complement or 1's complement. This sort of bit-flipping is very simple to implement in computer hardware.



An example of 1's Complement is as follows.

Example 4:

Express 2310 and -910 in 8-bit binary one's complement form.

2310 = + (000101112) = 000101112

-910 = - (000010012) = 111101102

The primary disadvantage of one's complement is that we still have two representations for zero:

00000000 and 11111111

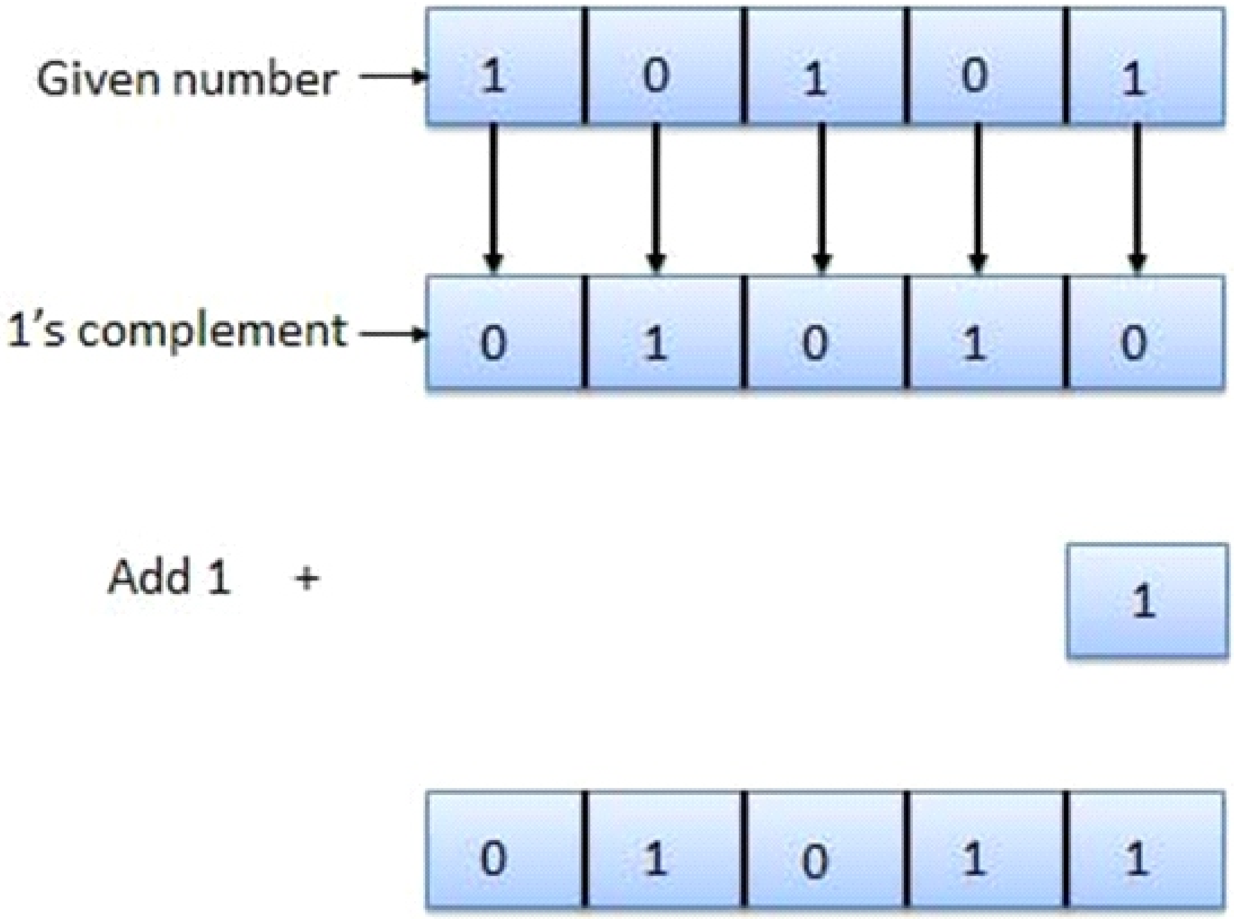
Two's Complement The 2's complement of binary number could be gotten by adding 1 to the Least Significant Bit (LSB)

of 1's complement of the number.

2's complement = 1's complement + 1

Note: You have to first find the 1's complement and then add 1

An example of 2's Complement is as follows.



Example 5:

Express 2310, -2310, and -910 in 8-bit binary two's complement form.

2310 = + (00010111_2) = 00010111_2

-2310 = - (00010111_2) = 11101000_2 + 1 = 11101001_2

-910 = - (00001001_2) = 11110110_2 + 1 = 11110111_2

Example 6:

Add 910 to -2310 using two's complement arithmetic.

000010012 (910) + 11101001_2 (-2310) = 11110010_2 (-1410)

00001001 <= Carries , 00001001_2 (9) , + 11101001_2 + (-23)

11110010_2 (-14)

Example 7:

Find the sum of 2310 and -910 in binary using two's complement arithmetic.
000101112 (2310) + 111101112 (-910) = 000011102 (1410)
11110111 <= Carries
000101112 (23)
+ 111101112 +(- 9)
000011102 (14)

Summary

In this unit, I have thought you the following:

- The common radix are decimal, binary, octal and hexadecimal numbers.
- A sign is appended to the left-most bit of a sign-magnitude and the remaining bits represent the magnitude or absolute value of the numeric value.
- The two types of binary system components are One's complement and Two's complement.
- One's complement of a number could be obtained by changing all 1's to 0's and all 0's to 1's while Two's complement is obtained by adding 1 to the LSB of 1's complement of the number.

Self-Assessment Questions

SAQ

- Explain the positional numbering system
- Describe a binary system complements?
- Explain the types of binary system complement.
- Express 2210, -2210, and -901 in 8-bit binary two's complement forms.

Tutor Marked Assessment

- Add 011011112 to 001010112 using signed-magnitude arithmetic.
- Subtract 010111112 from 011010112 using signed-magnitude. arithmetic ICS.
- Express 2110 and -911 in 8-bit binary one's complement form.
- Explain the binary system complement.

Further Reading

- https://marketbusinessnews.com/telecommunications-definition-meaning/
- https://www.nap.edu/read/11711/chapter/3
- https://www.collinsdictionary.com/dictionary/english/telecommunications
- https://www.mitel.com/articles/history-telecommunication
- https://peda.net/kenya/css/subjects/computer-studies/form-three/driac2#

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centre.
source: iStock.com

Module 2:
FUNDAMENTALS OF NETWORKING

Unit 1 Introduction to networking

Unit 2 The Internet protocol

Unit 3 The Public Switched Telephone Network

An illustration depicting
“Introduction to Networking”
source: edraak.org

UNIT 1

Introduction To Networking

Introduction

In this unit, you will be introduced to the concept of networking, elements, and components of a network.

Learning Outcomes

1. Explain what is meant by the term Networking
2. Discuss the elements of communication
3. Describe the components of a network
4. Explain the types of network

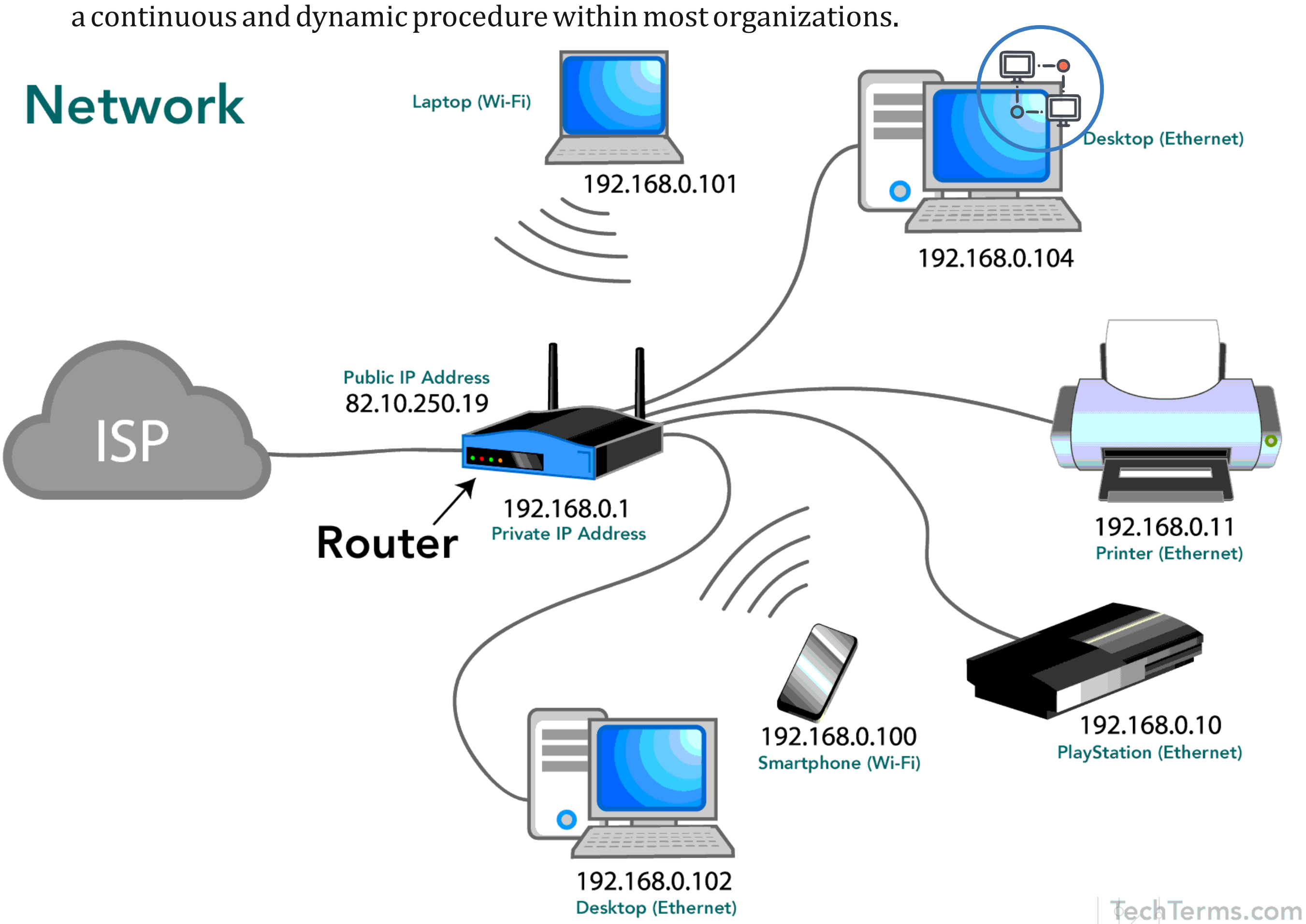
Main contents

2 mins

Networks have been playing a major role in the establishment of human communication over long distances. Over the decade, Electronic-mail (E-mail) has taken over from personal letters, handwritten and typed documents have become the word processing files, photographs have become fully digital, and phone calls have also been moving from analog to digital. The growth in size, diversity, and reliability of the computer networks has made it quite easy for it to transform into digital format and thus, enabled people to take advantage of the benefits of digital communications.

The following sections will focus on the platform for digital communication which is built upon the concepts and fundamentals of communication. These concepts are then applied to the media and devices which enables the fast transmission of data between end-users.

Networking as the word implies is the process of connecting two or more devices to share and manage resources. A network is designed in order to enable the successful sharing of information and resources between end-users. As the number of users, connection, and resources increases, the networks must be consistently improved to accommodate ever-changing growth and development while avoiding any decrease in the expected performance level. This process makes network architecture and designs a continuous and dynamic procedure within most organizations.



What is a network?

A computer network comprises a collection of different computers, printers, and many other devices that are connected with the primary aim of enabling communication within one another. Fig 1 gives a detailed example of a network implemented in a school consisting of a local area network (LAN) which are connecting computers, the internet, and various servers

The Elements of Communication [SAQ 2,3]

3 mins

Exchange of information between people passes through different communication methods. All these methods have three elements in common. Which are:

Message source, or sender: The source of messages are people, or electronic devices, that need to transmit a message to its desired destination.

Destination, or receiver of the message: The main function of the receiver is to collect the message and then interpret it.

Channel: A channel consists of the transmission media that provides the main pathway which allows smooth passage of message from source to destination. This model which allows the sending of messages through a transmission channel to the receiver also forms a basis of network communication between computers. The message is then encoded by the computers into binary signals before moving it across a cable or through a wireless media onto the receiver, which is must be fully aware of the protocols to follow to understand the original message.

Below is a diagrammatic representation of the elements of communication.

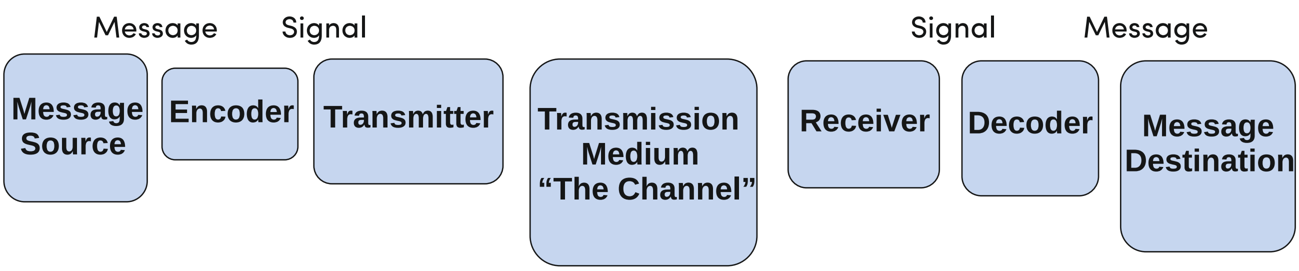


Figure 3.2: elements of communication

Components of the Network

Transmission path through which a message takes from source to destination can be as easy as a single cable connecting one computer to another or as complex and a network that generally covers the globe. This network infrastructure is the platform that supports our human network. It provides a stable and reliable channel over which our communications can occur. Media and Devices are the hardware or the physical elements of the network. Hardware is the visible component of the network which includes a laptop, a personal computer (PC), a switch, or the cable used in the connection of two or more devices. Occasionally, some components might not be so visible. In the case of wireless media, messages are transmitted through the airspace using invisible radio frequency or infrared waves. Services and processes are communication programs, called software, which is run on the networked devices. A network service provides information in response to a request. Services may include most of the network application many people use today such as web and e-mail hosting services. The functionality which moves and directs the messages through the network are been provided by its processes. Processes are less obvious to us but are critical and instrumental to the operation of networks.

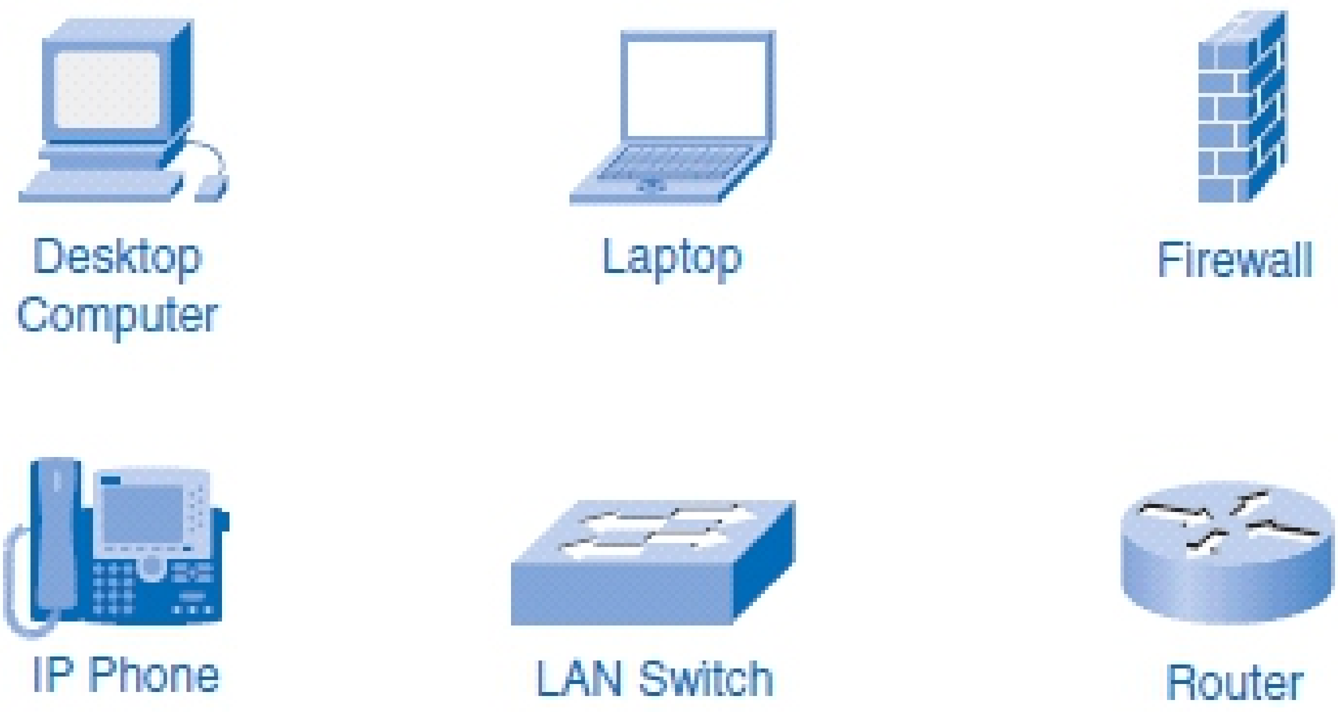


Figure 3.3: Components of the network

End Devices

An end device refers to a piece of device that is either at the source or the destination of a message on a communication network. A network user can see and touch an end device, which is mostly a computer. Another name given to the end device that sends or receives messages is a host. A host can be one of the different pieces of equipment performing a wide number of functions. Examples of ends device and hosts are listed as follows:

Computers, including workstations, laptops, and servers connected to a network

Network printers

Voice over Internet Protocol (VoIP) phones

Cameras on a network, including webcams and security cameras.

An end-user is one or a group of people using an end device. Although, not all end devices are usually operated by people, for example, end devices such as file servers are set up by people but perform their tasks on their own. A host such as servers is set to share and store information with other hosts called clients. Clients request information and services, like web pages and E-mail from servers, and servers reply to the requested information if they have validated the client. Host communicate with one another with the use of their unique address. The host address is a unique physical address used by hosts within a local-area network (LAN), and when there is a transmission of message from one host to the other, it uses the physical address of the destination device.

Intermediary devices and their roles on the network

End devices are the hosts that initiate communications and are also the ones that people are most familiar with. It is a complex task getting a message from the source to the destination because it encounters different intermediary devices along the way. Intermediary devices connect the individual hosts to the network and can also connect multiple individual networks to form an internetwork. Not all Intermediary devices are the same. Some work inside the LAN by performing different functions such as switching and others help in routing messages between networks.

Intermediary devices and their roles on the network

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Network Media

Communication between different networks is carried across a medium. Through the channel provided by the medium, the data is carried from a source to a destination. Below are the three (3) major types of media used in a network setup.

Copper

Fiber-optic cable

Wireless

Each aforementioned types of media have unique physical properties and distinct ways of encrypting messages.

Types of Networks

1 min

Networks can be categorized based on different attributes, be it operational or technical. For example, the size of connected users or devices, the technology implemented in the network, and so forth.However, one of the most used attributes in categorizing networks is the geographic area, where a network is labeled depending on the geographical area it covers. The five (5) most common types of networks in relation to geographic area from the smallest to the largest are:

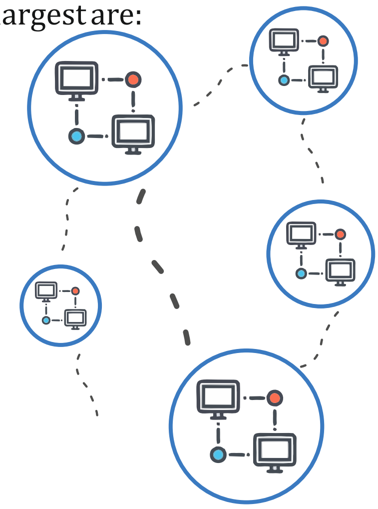
·Personal area networks (PANs).

·Local area networks (LANs).

·Campus area networks (CANs).

·Metropolitan area networks (MANs).

·Wide area networks (WANs).



Personal Area Networks (PANs)

PANs provides a network for areas as big as a home office or other personal workspaces. Individual networking devices within this range can be connected using wireless technologies.

Local Area Networks (LANs)

LANs provides network connections for some or all of the area within the range of a building. Most of the time, several workspace networking devices are connected to servers, switches, and other shared devices. A single LAN setup could provide a network to multiple groups, a department, or several devices in a single building. Both wireless and wired technologies can be used to connect LAN devices.

Campus Area Networks (CANs)

CANs can be achieved by connecting multiple LANs in different locations but close range together. Likewise here, connections between the building can be established employing both wireless and wired technologies together.

Metropolitan Area Networks (MANs)

MANs are created by linking the networks located in two or more sites within a city. Connections can be made using cabling or wireless technologies, with the use of optical fiber cable to link a customer's buildings to a facility operated by a telecommunications service provider.

Wide Area Networks (WANs)

WANs are created by linking the networks located at two or more sites over geographic distances which extends beyond the span of a single metropolitan area. These include links between cities, countries, and in the case of global WANs, continents.

The Internet: A Network of Networks

Over the years, LANs have changed the way people worked, but there is a limitation to the resources that can be provided within each network. Now workers who are not restricted to their own LAN can have access to other LANs on an internetwork. An internetwork is a collection of two or more LANs that are connected by WANs. Internetworks are interchangeably referred to as data networks or simply networks. The most popular internetwork is the Internet, which is generally open to public use. A term that is often confused with the Internet, an intranet, which is a private web of networks that are closed to the public but open for employees. For example, many companies use intranets to train and share company information across the globe to distant employees. Documents can be shared and projects are also managed securely over great distances on an intranet.

Summary

In this unit, I have thought you the following:

- The process of connecting several computer devices to manage and share resources is called Networking.
- The basic elements of a network are message source, destination, and channel.
- Computers, network printers, VoIP and cameras all form the components of a network.
- The types of networks are as follows:
  - Personal area networks (PANs).
  - Local area networks (LANs).
  - Campus area networks (CANs).
  - Metropolitan area networks (MANs).
  - Wide area networks (WANs).
- A collection of two or more LANs joined together by WANs is known as an internetwork and a popular example of the internetwork is the internet.
- A private web of networks closed to the public but open for employees to browse is referred to as an intranet.

Self-Assessment Questions

SAQ

- Explain what is meant by the term Networking
- List and explain the elements of communication
- Describe the components of a network
- Explain the types of network

Tutor Marked Assessment

- ·Define a network and list the basic elements of communication in a network
- Express what a network media is.
- Explain two types of network media
- Differentiate between LAN WAN and MAN
- Explain the following:
  ·Internet ·Internetwork ·Intranet

Further Reading

- https://marketbusinessnews.com/telecommunications-definition-meaning/
- https://www.nap.edu/read/11711/chapter/3
- https://www.collinsdictionary.com/dictionary/english/telecommunications
- https://www.mitel.com/articles/history-telecommunication
- https://peda.net/kenya/css/subjects/computer-studies/form-three/driac2#

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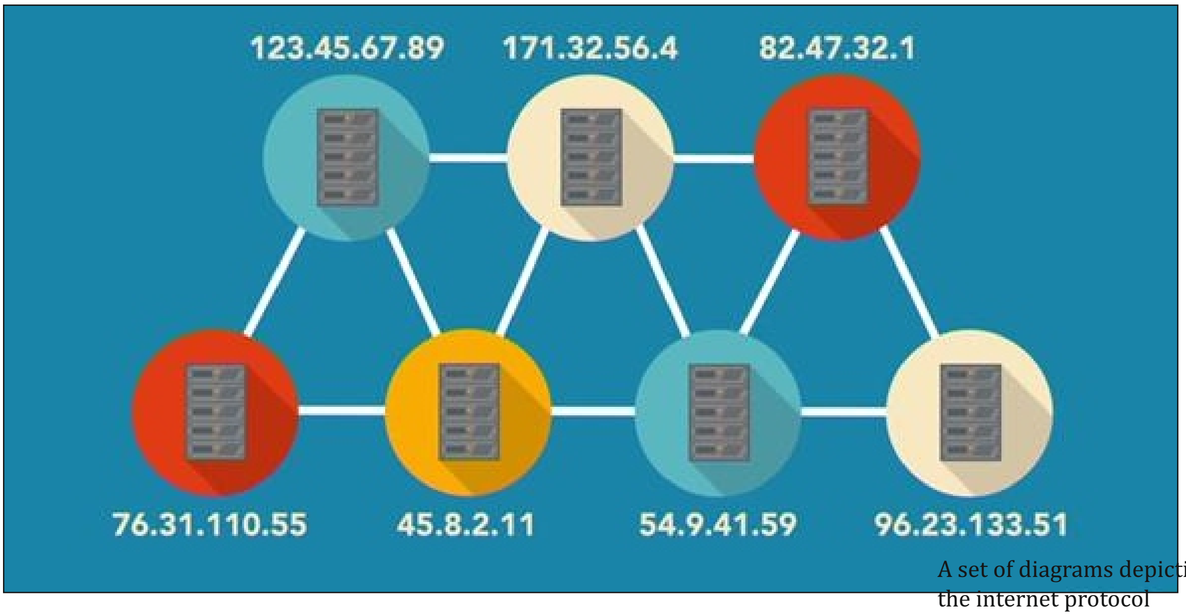
- Telecommunication Planning, ITT Laboratories of Spain, Madrid 1973.
- R. L. Freeman, Telecommunication System Engineering, 4th ed., Wiley, New York, 2004



A set of diagrams depicting the internet protocol
source: lynda.com

UNIT 2

The Internet Protocol

Introduction

In this unit, you will learn the concept of IP addresses in networking and how they work. The classes, types, and formats of IP addresses will also be introduced.

Learning Outcomes

1. Express what an IP address is and how it works on a network
2. Explain the types and classes of IP addresses
3. Express IP addresses using the bit-wise and decimal representations.

Introducing the IP Address [SAQ 1, 2, 3 & 4] 10 mins

IP stands for Internet Protocol and describes a set of requirements and standards for the creation and transmission of data packets, or datagrams, across the networks. The Internet Protocol (IP) is part of the Internet layer of the Internet protocol suite.

How IP works

It will interest you to know that IP is designed to work over a dynamic network. This means that IP must work without a monitor or central directory and it can not also rely on specific links or nodes existing. IP is a connectionless protocol which uses a datagram, every packet must contain the source IP address, destination IP address, and other needed data in the header for the message to be successfully delivered. These factors make IP an unreliable, best-effort delivery protocol. The protocol at the upper level will handle the error correction instead. These protocols include Transmission Control Protocol (TCP), which is a connection-oriented protocol, and User Datagram Protocol (UDP), which is a connectionless protocol.

Versions of IP

Basically, There are two versions of IP currently in use today, we have IPv4 and IPv6. The original IPv4 protocol is still in use today on both the internet and many other corporate networks. However, the IPv4 protocol only allowed for 232 addresses. This, at some certain point, will lead to the exhaustion of the addresses that will be allocated to the devices across the internet. In this unit, more emphasis will be put on Ipv4.

IPv4 addresses

Ipv4 addresses are 32-bit binary numbers, consisting of the two sub-addresses (identifiers) mentioned above which, specifically identify the network and the host to the network, with an imaginary boundary separating the two. An IP address is generally shown as 4 octets of numbers ranging from 0-255 which are represented in decimal form instead of the binary form. For example, the address168.212.226.204 represents the 32-bit binary number

10101000.11010100.11100010.11001100.

The binary number is important because that will determine which class of network the IP address belongs to. An IPv4 address is commonly expressed in dotted-decimal notation, with every eight bits (octet) represented by a number from one to 255, each separated by a dot. An example IPv4 address would look like this:

192.168.17.43

IPv4 addresses are comprised of two main parts. The first numbers in the address specify the network, while the latter numbers specify the specific host. A ***subnet mask*** specifies which part of an address is the network part, and which part addresses the specific host. A packet having the destination address that is not on the same network with the source address will be forwarded or routed to a suitable network. Once on the correct network, the host part of the address will determine which of the interface will packet get delivered to.

Subnet Masks

A single IP address can identify both a network and a unique interface on that network. A subnet mask can also be written in dotted-decimal notation and determines where the network part of an IP address ends, and also where the host portion of the address will begin. When expressed in binary form, any bit set to one means the corresponding bit in the IP address is part of the network address. All the bits set to zero marks the corresponding bits in the IP address as part of the host address. The bits marking the subnet mask must be consecutive ones. Most subnet masks start with 255. and continue until the network mask ends.

IP Classes

There are five classes of IP addresses depending on the size of the network and host addresses. The classes are listed below:

Class A

In a Class A network, the first eight bits, or the first dotted decimal, is the network part of the address, with the remaining part of the address being the host part of the address. There are 128 possible Class A networks. E.g: 2.134.213.2However, any address that begins with 127. is considered a loopback address. 0.0.0.0 to 127.0.0.0

Bit-wise representation of class A addresses

0. 0. 0.0=00000000.00000000.00000000.00000000

127.255.255.255=01111111.1111111.11111111.11111111

0nnnnnnn.hhhhhhhh.hhhhhhhh.hhhhhhhh

Note: n represents network part while H represents the host part

Class B

In a Class B network, the first 16 bits are the network part of the address. All Class B networks have their first bit set to 1 and the second bit set to 0. In dotted-decimal notation, that makes 128.0.0.0 to 191.255.0.0 as Class B networks. There are 16,384 possible Class B networks. E.g.: 135.58.24.17

Bit-wise representation of class B addresses

128. 0. 0. 0 = 10000000.00000000.00000000.00000000

191.255.255.25510111111.11111111.11111111.111111111

0nnnnnn.nnnnnnnn.hhhhhhhh.hhhhhh

Class C

In a Class C network, the first two bits are set to 1, and the third bit is set to 0. That makes the first 24 bits of the address the network address and the remainder as the host address. Class C network addresses range from 192.0.0.0 to 223.255.255.0. There are over 2 million possible Class C networks. E.g:192.168.178.1

Bit-wise representation of class C addresses

192. 0. 0. 0 = 11000000.00000000.00000000.00000000

223.255.255.255 =11011111.11111111.11111111.11111111

110nnnnn.nnnnnnnn.nnnnnnnn.hhhhhhh

Class D

Class D addresses are used for multicast applications. Unlike the previous classes, Class D is not used for "normal" networking operations. Class D addresses have their first three bits set to "1" and their fourth bit set to "0". Class D addresses are 32-bit network addresses, meaning that all the values within the range of 224.0.0.0 – 239.255.255.255 are used to uniquely identify multicast groups. There are no host addresses within the Class D address space since all the hosts within a group share the group's IP address for receiver purposes. E.g.:227.21.6.173Bit-wise representation of class D addresses 224. 0. 0. 0 = 11100000.00000000.00000000.00000000239.255.255.255 = 11101111.11111111.11111111.111111111110XXXX.XXXXXXXX.XXXXXXXX.XXXXXXXX

Class E

Class E networks are defined by having the first four network address bits as 1. That encompasses addresses from 240.0.0.0 to 255.255.255.255. While this class is reserved, its usage was never defined. As a result, most network implementations discard these addresses as illegal or undefined. The exception is 255.255.255.255, which is used as a broadcast address. E.g.:243.164.89.28

240. 0. 0. 0 = 11110000.00000000.00000000.00000000

255.255.255.255 = 11111111.11111111.11111111.11111111

1111XXXX.XXXXXXXX.XXXXXXXX.XXXXXXXX

Types of IP addresses

There are two basic types of addresses, which are:

·Private addresses

·Special addresses

Private addresses

Within the address space, certain networks are reserved for private networks. Packets from these networks are not routed across the public internet. This provides a way for private networks to use internal IP addresses without interfering with other networks. The private networks are

10.0.0.1 - 10.255.255.255

172.16.0.0 - 172.32.255.255

192.168.0.0 - 192.168.255.255

Special addresses

Some IPv4 addresses are set aside for specific uses:

□□ỳ□ỳ□ỳ□	Loopback address (the host's interface)
224.0.0.0	IP Multicast
255.255.255.255	Broadcast (sent to all interfaces on a network)

Summary

In this unit, I have thought you the following:

- Internet Protocol is used to describe a set of standards and requirements for creating and transmitting data packets across networks.
- IP is a connectionless protocol and thus, each message must contain the source IP address, destination IP address, and other data in the header to be successfully delivered.
- A subnet mask is used to determine where the network and host part of an IP address falls.
- IP addresses are divided into classes A, B, C, D, and E.

Self-Assessment Questions

SAQ

- Explain the term Internet Protocol Address
- Mention 2 types, and 5 classes of IP address
- Describe a subnet mask
- Discuss how IP addresses can be represent?

Tutor Marked Assessment

- Explain IP addresses and how they work in a network
- Mention two differences between the two classes of IP addresses.
- List two examples each of all the classes of IP address
- Explain the following:

  Private addresses

  Public addresses

  Subnet mask

Further Reading

- https://marketbusinessnews.com/telecommunications-definition-meaning/
- https://www.nap.edu/read/11711/chapter/3
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A public switched telephone
source: artstechnica.com

UNIT 3

The Public Switched Telephone Network (PSTN)

Introduction

In unit 1 you have learnt the concept of IP address in networking the classes, types and format of IP address. In this unit, you will learn about the Public Switched Telephone Network (PSTN)

Learning Outcomes

1. Explain the PSTN and write a brief history of it.
2. List some properties of the PSTN
3. Explain the major parts of the PSTN

Introduction to the Public Switched Telephone Network (PSTN)[SAQ 1, 2]

2 mins

Note that the PSTN operates similarly to the INTERNET of today by interconnecting nodes such as phones, switches, databases, and other end-user devices used for communication. These nodes play a vital role in establishing communication between two or more end-users. PSTN consists of several interconnected telephone lines owned by telecommunication operators. These operators offer services to end-users via dedicated or shared connections. The dedicated connection is usually leased and provides more efficiency as the communication line is exclusive to the user. However, the shared link is available to all other end users. This communication system can be wired or wireless. Wired communication involves the use of cables while wireless involves transmission over the air via electromagnetic waves. Early PSTN networks were purely analog and require the manual switching of end user's voice calls from one central office to another. Centralized switches are located at specific regions and allow for the transfer of calls from one region to another depending on the domain of the switch and the call. When two users need to communicate, user A dials user B's unique phone number, the intermediary switch between the two users helps to establish a dedicated connection (or line) between the users. With the advent of the internet, PSTN can now be used to establish internet connectivity by using a dial-up connection. i.e. internet data or packets were routed over telephone lines. However, it offers a slow data rate with a maximum of 56Kbps. The topology (the layout or arrangement of the nodes) of PSTN is mostly star-shaped and hierarchical. The star topology means all end-users need to be connected to one central endpoint which then manages the connection to other devices connected. For bulk communication, trunk lines are used to carry several simultaneous calls from one endpoint to another. To communicate between users, each user needs either an Area code (for users within the same locality) or Country code for international calls.

History of PSTN

Telephone commercialization began in the 1800s when telecommunication companies only offered analog communication, unlike the digital and IP-based communication that is obtainable today. In the late 1900s, the telephone networks expanded and more people started embracing the new technology. There was also a gradual shift from the analog means of communicating to digital. The PSTN used mostly analog cable lines made of copper as the medium for communication. These telephone lines were interconnected using switches to allow for seamlessly connectivity between users separated by distance. As new technologies such as fiber optics were introduced, PSTN services became increasingly digital with improved speed, connectivity, security, and reliability compared to the previous medium used for communication. Fiber optics cables offer communication to areas where copper could not be installed and covers a longer range of communication.

Some important facts about the PSTN

Below are some of the important facts about PSTN.

·It is an interconnection of telephone nodes likened to the internet of today

·It is also known as Plain Old Telephone Service (POTS)

·Alexander Graham Bell was given the patent for creating the first telephone

·PSTN networks are mostly owned by the government and private telecommunication operators.

·It helps to transmit Human Voice signals over a wired medium.

·It is an aggregation of circuit-switched networks of the world.

·Originally, it was an entirely analog network laid with copper cables and switches.

·Presently, most PSTN networks are digitized and comprise of a wide variety of communicating devices.

·The present PSTNs comprises of copper telephone lines, fiber optic cables, communication satellites, microwave transmission links, and undersea telephone lines. It can also be linked to cellular networks.

·The interconnection between the different parts of the telephone system is done by switching centers. This allows multiple telephone and cellular networks to communicate with each other.

·Present telephone systems are tightly coupled with WANs (wide area networks) and are used for both data and voice communications.

·The operation of PSTN networks follows the ITU-T standards.

When two nodes (computers) from the same company or organization and located close to each other need to communicate, it is often easiest just to run a cable between them.

LANs work this way, but with increasing distance especially when there are many computers to connect or the cables have to pass through a public road; the costs of running private cables are usually very high. Consequently, the network designers must rely on the existing telecommunication facilities. These facilities, especially the PSTN (Public Switched Telephone Network), were designed many years ago, with a completely different goal in mind: transmitting the human voice in a more-or-less recognizable form. Their suitability for use in computer-to-computer communication is often marginal at best, but the situation is rapidly changing with the introduction of fiber optics and digital technology.

MAJOR PARTS OF THE PSTN [SAQ 3]

2 mins

The telephone system was designed in a hierarchical topology comprising of several nodes including phones, switches, etc. End-users often have two telephone lines connected to the closest ***Central office*** spanning a distance of between 1 to 10km. These two telephone lines, when connected to the central office, form a loop often referred to as a ***Local loop***.

For example, in the US, there are about 22,000 end offices. End-users connect to their closest end office creating a loop. The loops are so enormous that if they are stretched out to form a straight line, they would reach the moon and back a thousand times. Connectivity between end-users within the same end office is quite simple as the switch just sets up a direct local connection between the local loops.

To connect end-users connected to different local office, a different approach is used. Each end office has several outgoing lines to one or more nearby switching centers, called Toll offices (or tandem offices if they are within the same local area). These lines are called toll connecting trunks. However, if both end-users' central offices happen to have a toll connecting trunk to the same toll office (a likely occurrence if they are relatively close by), the connection may be established within the toll office.

If the end-users do not have a toll office in common, the path will have to be established somewhere higher up in the hierarchy. Primary, sectional, and regional offices form a network by which the toll offices are connected. The toll, primary, sectional, and regional exchanges communicate with each other via high bandwidth inter-toll trunks (also called interoffice trunks). The number of different kinds of switching centers and their topology varies from country to country depending on the country's telephone density. A telephone network consisting only of telephones, end offices, switches, and toll offices is shown in figure 3.1.

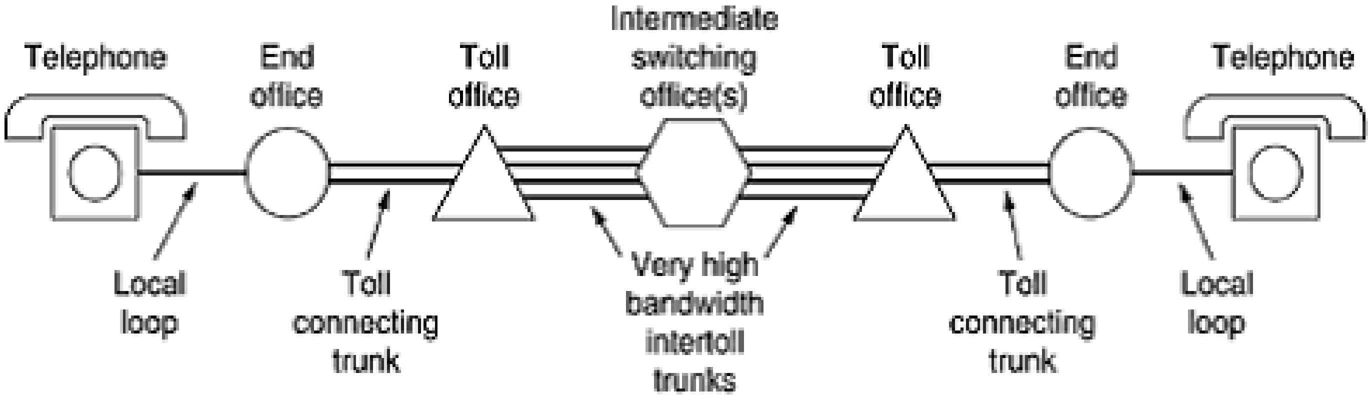

Figure 3.1: A typical circuit route for a medium-distance call.

The Telephone system, in summary, consists of three (3) major components. These are:

1. Local loops: analog twisted pairs going into houses and businesses.

2. Trunks: consists of fiber optics cables connecting the switching offices.

3. Switching offices: houses switches where calls are moved from one trunk to another.

PSTN and ISDN

The Integrated Services Digital Network (ISDN) was developed for the digital transmission of data and voice over ordinary phone lines and provides better voice quality than PSTN. The ISDN provides 128 Kbps as against the 56Kbps offered by PSTN. The integration of both voice and data on a single transmission line gives ISDN an edge over the conventional PSTN. The call connection establishment is faster and more reliable with ISDN than with PSTN.

PSTN and VoIP

Voice over IP (VoIP), also known as IP telephony, broadband telephony, or Internet telephony, means voice communication is transmitted over the internet or private Wide Area Network (WAN) service. VoIP eliminates the need for circuit-switched networks for phone calls. It uses codec (encoders/decoders) to turn audio into data packets, transmits them across an IP network, and turns the packets back into audio on the receiving end of the call.

Some of the advantages of VoIP over PSTN include lower network infrastructure costs, scalability, and availability of advanced features, such as unified communications and application integrations.

Summary

In this unit, I have thought you the following:

- A PSTN is a combination of telephone networks used worldwide that enables users to make landline telephone calls from one location to one another.
- The PSTN has several properties that make it more appropriate for voice communication
- The PSTN is made up of Local loops, trunks, and Switching offices.

Self-Assessment Questions

SAQ

- Discuss the PSTN
- Summarize on the history of PSTN
- Explain the major parts of the PSTN

Tutor Marked Assessment

- Expain term PSTN
- Summarize on the history of PSTN
- Explain 5 properties of the PSTN
- Define the following:
- Local loop
- Toll office
- ISDN
- VOIP

Further Reading

- https://marketbusinessnews.com/telecommunications-definition-meaning/
- https://www.nap.edu/read/11711/chapter/3
- https://www.collinsdictionary.com/dictionary/english/telecommunications
- https://www.mitel.com/articles/history-telecommunication
- https://peda.net/kenya/css/subjects/computer-studies/form-three/driac2#

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03 | A Satellite control centre.
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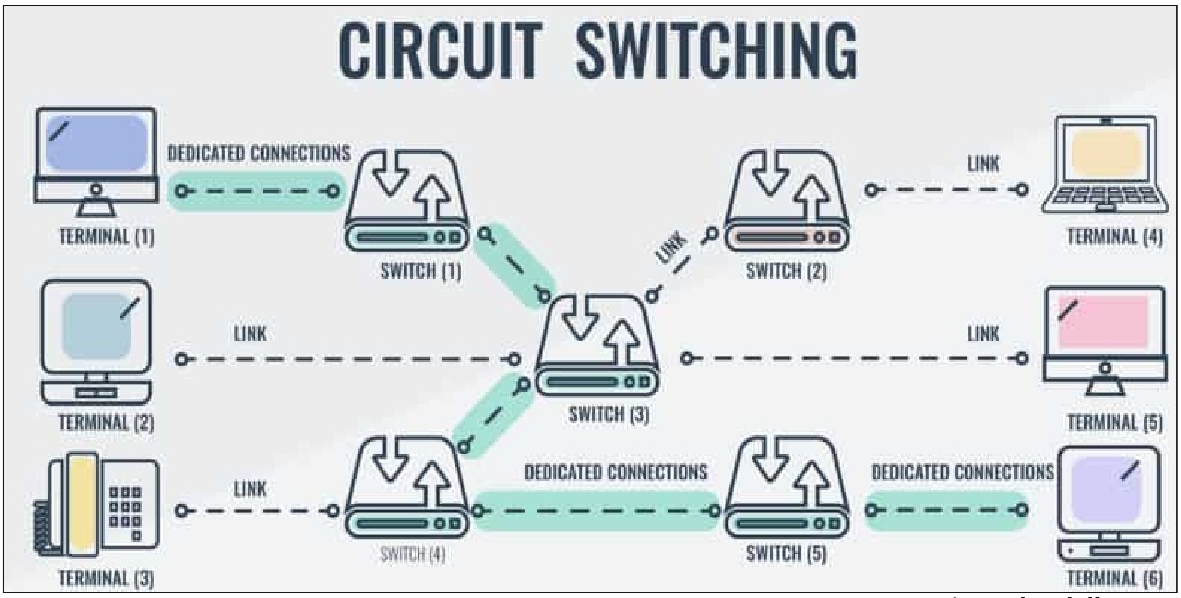
Module 3:
SWITCHING TECHNOLOGIES

Unit 1 Circuit Switched Networks

Unit 2 Packet Switching



A graphical illustration of circuit switching
source: comparitech.com

UNIT 1

Circuit Switched Networks

Introduction

In this unit, you will learn about the various techniques used to establish connections between user exchanges.

Learning Outcomes

1. Express why switching is needed in networks.
2. Explain the basic functions of switches.
3. Explain the types of switching.
4. Describe the basic steps involved in circuit establishment.

EVOLUTION OF TELEPHONE SWITCHING [SAQ 1, 2, 3]

10 mins

You are familiar with a telephone as a device that enables communication amongst two or more end-users over a short or long distance. The advent of telephones paved the way for end-users separated by a large geographical land map to communicate seamlessly as if they were within the same vicinity. However, for two end users to communicate, an intermediary mechanism is needed to facilitate their communication. This mechanism is often referred to as switching. Literally, switching means to change from one form to another. Telephone switching is the process of transferring an end-user-initiated call from one intermediary switch to another depending on the location and availability of the communication lines. This is done recursively until a suitable and free line or a suitable path to establish a call with another user is gotten. Telephone switches are intermediary devices that work in the background to connect two or more endpoints.

Telephone switching is a mechanism that automatically changes connection lines and finding the best and available path or route to send signals between two or more communicating devices. This mechanism is often abstracted from the end-user. When user A dials user B, the closest switch where user A is connected determines the most available path to get to user B. If there is no path, the switch transfers the connection request to another upper layer switch and the cycle continues until a path is established for communicating between the two users. Telephone switching could be analog or digital and can be operated either manually or automatically

In the early days of telephony, switching was done manually by human operators. Operators are always on duty to manually switch incoming calls from local to regional and international users as the case may be. This manual way of switching was inefficient as end-users often take turns before getting access to a free line. Another downside is the fact that each line is dedicated only to one connection at a time and there was no form of multiplexing. This form of switching was rather wasteful and inefficient as human operators were prone to errors.

Around the 19th century, automated electronic switches were invented. Although the mode of operation was analog, they were far more efficient than the manual switching. These switches were programmable but with little RAM, they could only hold little information in their Register. The register stores location-based information that quickly enables the transfer of a call from one endpoint (local, national, international) to another. Gateway switches were also introduced to allow for communication outside the local domain of local-based switches. The operation of these electronic switches was quite complex and required the services of only skilled operators.

From the late 20th century and up to date, the shift from the analog way of operation to digital made a positive impact on the switching world. Electronic signals can now be represented in digital form (i.e. ones and zeros). Digital Switches have become far more efficient, faster, and powerful. The advent of Very Large-Scale Integrated Circuitry (VLSI) allows for faster processing of electronic signals. Switches now have access to databases that allows for easy transfer of a call from one region to another. A telephone call can be established between two users within seconds irrespective of the distance. The hierarchical topology design of telephone switching allows for more efficient and secure routing of voice signals from one endpoint to another. Switches are now extremely smart and can accommodate two or more voice signals (or virtual lines) on the same communicating medium via a concept called multiplexing. These switches provided graphical user interfaces allowing for easier configuration and use compared to older switches.

Why Switching

It will interest you to know that a network is a set of interconnected computing devices. Whenever we have multiple devices, the problem of how to connect them to make one-to-one communication possible arises. One solution is to make a point-to-point connection between each pair of devices (a mesh topology) or between a central main device and every other device (a star topology). These methods, however, are inappropriate and wasteful when applied to a large number of networks. The number and length of the connectors require too much infrastructure to be economical, and the majority of those links would be inactive most times. Other topologies utilizing multipoint connections, like a bus connection, are not really encouraged because there's an increase in the distance between devices and the total number of devices beyond the capacities of the media and equipment.

A more preferred solution is switching. ***A switched network*** comprises a series of interlinked devices, called switches. Switches are devices capable of creating temporary connections between two or more devices connected to the switch. In a switched network, some of these nodes are connected to the end nodes (computers or telephones, for example). Others are used only for routing.

The basic function of Network Switches

One of the main functions performed by switches is to multiplex and de-multiplex data frames that belong to different computer-to-computer information transfer sessions and to determine the link(s) along which to forward any given data frame

This task is vital because a given physical link will usually be shared by several concurrent sessions between different devices. We break these functions into three problems, which are:

1. **Forwarding**: When a data frame arrives at a switch, the switch needs to process it, determine the correct outgoing link, and decide when to forward the frame on that link.

2. **Routing**: Each switch needs to somehow determine the topology of the network so that it can construct the data structures required for proper forwarding correctly. Routing can also be described as a process by which the switches in a network collaboratively compute the network topology, adapting to various kinds of failures. It does not occur on each data frame but happens in the "background".

3. **Resource allocation**: Switches allocate their resources by granting link access to different communication processes in progress.

Types of switching [SAQ 3]

1 min

You should know that switches are hardware and/or software devices that are used to connect two or more users temporarily. Message switching, circuit switching, and packet switching are the most important switching methods.

In a circuit-switched network, the frames do not carry any special information that tells the switches how to forward information unlike in packet-switched networks. The philosophical difference is more considerable: a circuit-switched network provides the abstraction of a dedicated link of some bit rate to the communicating devices or computers, whereas a packet-switched network does not. Of course, this dedicated link crosses multiple physical links and at least one switch, so the endpoints and switches must do some additional work to provide the illusion of a dedicated link. A packet-switched network, in contrast, provides no such illusion; once again, the endpoints and switches must do some work to provide good and effective communication service.

The workstations of the message switching systems are usually teleprinters. Delays are incurred in this switching, but calls are not lost as each message is queued for each link. Thus, a much higher link utilization is achieved. The main reason for the delay is that the system is designed to maximize the utilization of transmission links by lining up messages awaiting the use of a line. This switching is also called the store and forward switching. The circuit switching compiles connection between the telephones, telex networks, etc, and then exchanges information directly. If a subscriber or system to which connection to be made to has engaged with other connection, path setup cannot be made. Thus circuit switching is also referred to as a lost call system. Packet switching is the modified form of message switching. The packet switching system carries data from a terminal or computer as short packets of information to the needed destination.

This system is midway between message switching and circuit switching.

Circuit-Switched Networks [SAQ 4]

2 mins

A circuit-switched network consists of a set of switches connected by physical links. A connection between two stations is a dedicated path made of one or more links. Each connection however uses only one dedicated path on each link. Each link is normally divided into n channels by using frequency division multiplexing (FDM) or Time Division Multiplexing TDM. Circuit-switched networks require dedicated point-to-point connections during calls. The primary hardware for a circuit-switched network is the private branch exchange (PBX) system.

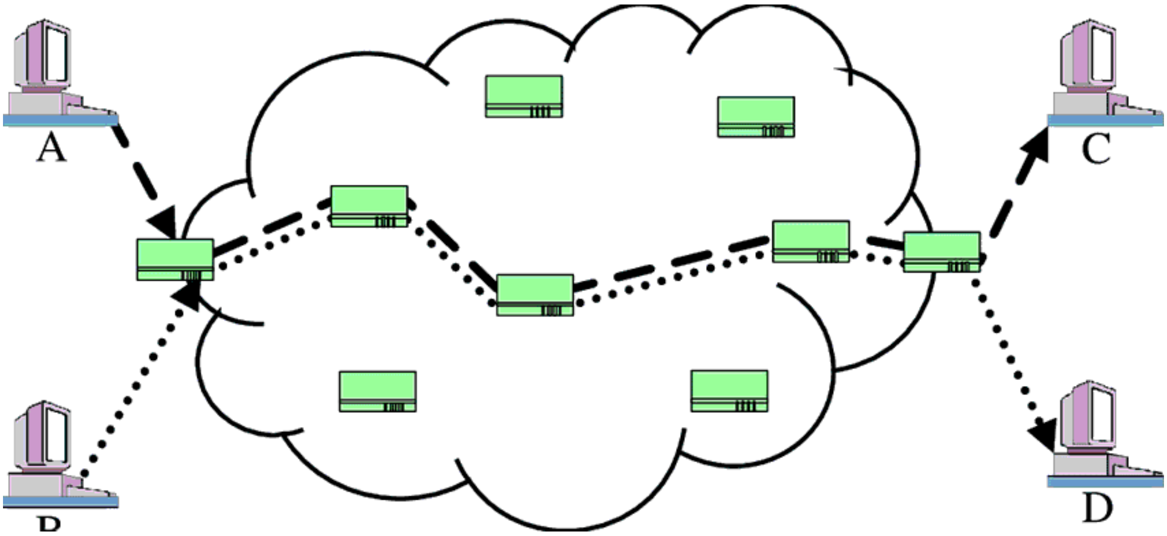


Figure 3.1: Circuit-switched network

Stages of circuit establishment

The actual communication in a circuit-switched network requires three phases: connection setup, data transfer, and connection teardown.

Setup Phase: A dedicated circuit (a combination of channels in links) needs to be established before the two parties can communicate .The end systems are mostly connected through dedicated lines to the switches, so connection setup means creating dedicated channels between the switches.

Data Transfer Phase: After the establishment of the dedicated circuit (channels), the two parties can transfer data.

Teardown Phase: When one of the devices needs to disconnect, a signal is sent to each switch to release the resources. Because the frames contain no information about where they should go, the setup phase needs to take care of this task, and also configure (reserve) any resources needed for the communication so that the illusion of a dedicated link is provided. The teardown phase is needed to release any reserved resources.

Advantages and Disadvantages of Circuit Switching

In discussing the circuit switching it is important for you to know that there are also some advantages and disadvantages involved.Circuit switching functions well for a network where the workload is relatively uniform, with all information sharing using the same capacity, and each transfer uses a constant bit rate (or near-constant bit rate). Telephony is the most compelling example of such a workload, where each digitized voice call might operate at 64 Kbits/s. Switching was invented first for the telephone network, well before computers were really in use, so this design choice makes a great deal of sense. The classical telephone network as well as the cellular telephone network in most countries still operate in this way, though telephony over the Internet is becoming increasingly popular and some of the network infrastructures of the classical telephone networks are moving toward packet switching.However, circuit-switching tends to waste link capacity if the workload has a variable bit rate, or if the frames arrive in bursts at a switch. Because a large number of computer applications make burst data patterns, we should consider a different link sharing strategy for computer networks. For applications that require a certain minimum bit rate, this approach might be reasonable, but even in that case a "busy tone" is the result.

The efficiency of a circuit-switched network

It can be stated that circuit-switched networks are not as effective as the other two types of networks because resources are allocated during the entire duration of the connection. These resources are unobtainable to other connections. In a telephone network, people normally end the communication when they have finished their conversation. In computer networks, however, a computer can be connected to another computer even if there is no activity for a long time. Allowing resources to be dedicated in this case means that other connections are deprived.

Delay in circuit-switched networks

The delay in this type of network is minimal, although a circuit-switched network normally has low efficiency. During data transfer, the data are not delayed at each switch since the resources are allocated for the duration of the connection.

Summary

In this unit, I have thought you the following:

- ·A better solution that guarantees effective communication when we have multiple devices connected is to employ a switching technique.
- Switches are devices capable of creating temporary connections between two or more devices linked to the switch.
- The three basic functions of network switches are:
  Forwarding
  Routing
  Resource allocation
- The basic types of switching are
  Packet switching
  Circuit switching
  Message switching
- In circuit switching, three steps involved are
  Setup phase
  Data transfer phase
  Teardown phase

Self-Assessment Questions

SAQ

- Express why a switching required in networks
- Explain the basic functions of switches
- List the types of switching.
- Explain the types of switching.
- Explain the basic steps involved in circuit establishment.

Tutor Marked Assessment

- Describe a switched network
- Explain the following as related to switching
- Forwarding - Routing - Resource allocation
- Describe a circuit switching?
- List the advantages and disadvantages of circuit switching

Further Reading

- https://marketbusinessnews.com/telecommunications-definition-meaning/
- https://www.nap.edu/read/11711/chapter/3
- https://www.collinsdictionary.com/dictionary/english/telecommunications
- https://www.mitel.com/articles/history-telecommunication
- https://peda.net/kenya/css/subjects/computer-studies/form-three/driac2#

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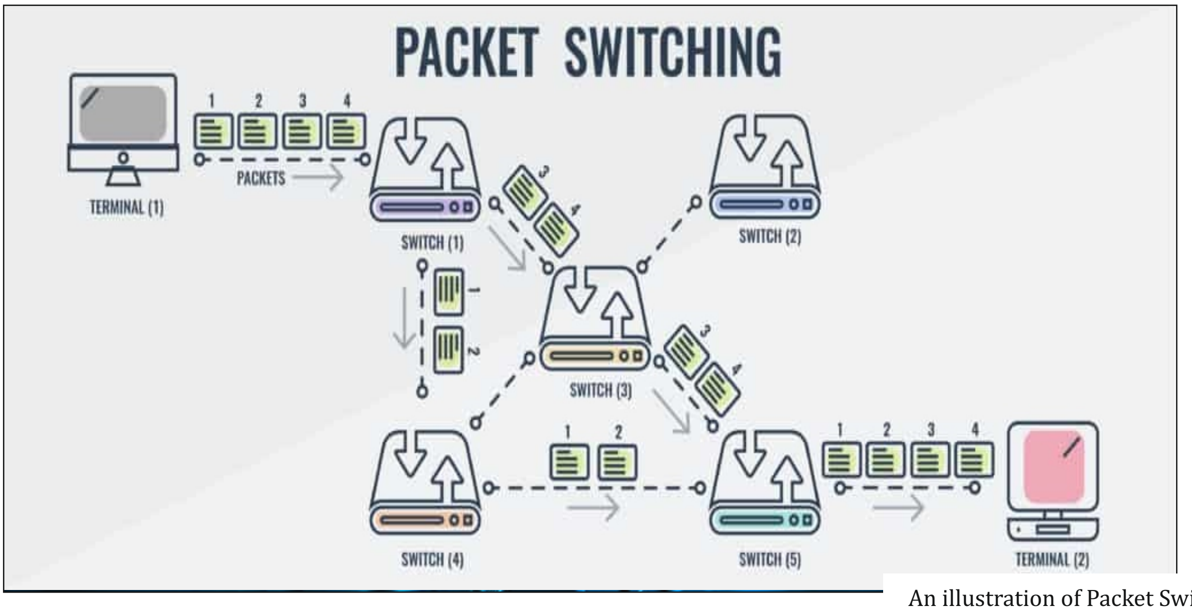
- Telecommunication Planning, ITT Laboratories of Spain, Madrid 1973.
- R. L. Freeman, Telecommunication System Engineering, 4th ed., Wiley, New York, 2004



An illustration of Packet Switching
source: comparitech.com

UNIT 2

Packet Switching

Introduction

In unit 1 you have have been introduced to what switching network is. In this unit, you will be learning two other switching technologies; packet switching and circuit switching.

Learning Outcomes

1. Define packet switching
2. List the advantages of packet switching technology
3. Differentiate between circuit switching and packet switching
4. Define message switching

10 mins

Introduction to packet switching [SAQ 1, 2, 3& 4]

You have learnt that Switches are devices capable of creating temporary connections between two or more devices connected to the switch. To tackle the inadequacies of circuit-switched networks, packet switching was introduced to give room for individual sender to transfer data at any time while also allowing the link to be shared. In packet switching, a little bit of information that tells the concerned switch how the data is to be forwarded is added to each frame of data. This information is added in the form of a packet header and the resulting frame is called a packet. In the most common form of packet switching, the header of each packet contains the address of the destination, which distinctively identifies the destination of data. The switches use this information to process and forward each packet. Packets usually also include the sender's address to help the receiver send messages back to the sender. Unlike the circuit-switched network, the packet-switched networks are powered by computer servers.

The purpose of the switch is to use the destination address as a key forwarding parameter and perform a lookup on a data structure called a routing table. This lookup returns an outgoing link to forward the packet on its way toward the intended destination.

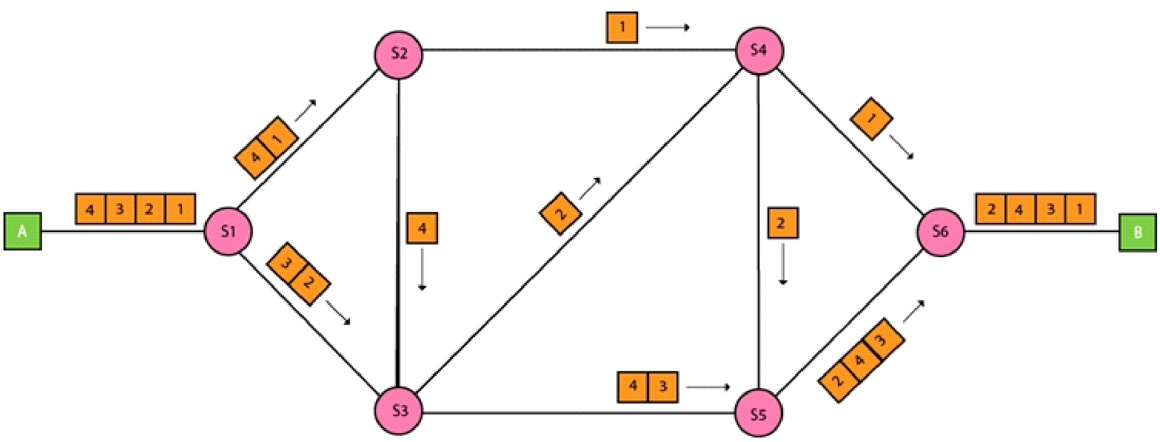


Figure 3.1: Packet-switched network

Advantages of packet switching

Do you know that a typical application of packet switching could be found in Statistical Multiplexing. Packet switching does not give the illusion of a dedicated link to any pair of communicating endpoints, but it has a few things going for it, some of which are as follows:

1. It doesn't waste the capacity of any link because each switch can send any packet available to it that needs to use that link.

2. It does not require any setup or pulldown phases and so can be used even for small transfers without any overhead.

3. It can provide variable data rates to different communications essentially as it is needed.

Circuit Switching vs Packet Switching

It may interest you to know that a circuit switching and packet switching are different in many ways. To start with, circuit switching requires that a circuit be set up end to end before communication begins. Packet switching does not require any initial setup. The first packet can just be sent whenever it is ready.

The result of the connection setup with circuit switching is the reservation of bandwidth from the sender to the receiver. All packets follow this route. Among other properties, having all packets follow the same channel ***means that they cannot arrive out of order***. With packet switching, there is no route, so different packets can follow a different route, depending on network conditions at the time they are sent, so ***they may arrive out of order***.

Packet switching is more ***fault permissive*** than circuit switching, in fact, that is why it was created. If a switch goes down, all of the circuits using it are terminated and no more traffic can be sent on any of them. With packet switching, packets can be routed around dead switches. Setting up a route in advance also opens up the likelihood of reserving bandwidth in advance. If ***bandwidth is reserved***, then when a packet arrives, it can be sent out immediately over the reserved bandwidth. With packet switching, no bandwidth is reserved, so packets may have to wait their turn to be passed on.

Packet switching uses ***store-and-forward*** transmission. A packet is accumulated in a router's memory, then passed on to the next router. With circuit switching, the bits just flow through the wire repeatedly. ***The store-and-forward technique adds delay.***

Another difference is that circuit switching is completely ***transparent***. The sender and receiver can use any bit rate, format, or framing method they want to. The carrier does not know or care. With packet switching, the carrier determines the basic parameters

Message Switching

You should know that a message switching is an alternative switching approach. No physical path is established in advance between the sender and receiver when this form of switching is used. Instead, when the sender has a block of data to be sent, it is stored in the first switching office (i.e., router) and then forwarded later, one hop at a time. Each block is received in its totality, checked for errors, and then resent over the channel. Message switching was adopted by the first electromechanical telecommunication systems used message switching, namely, for telegrams. The message was punched on paper tape (off-line) at the sending office, and then read in and transmitted over a communication line to the next office along the way, where it was punched out on paper tape. An operator there tore the tape off and read it in on one of the many tape readers, one reader per outgoing trunk. Such a switching office was called a torn tape office.

Summary

In this unit, I have thought you the following:

- Contrary to what is obtainable in circuit switching, in packet-based networks, the message gets broken into small data packets that seek out the most efficient route as circuits become available.
- Packet switching has several advantages
- In message switching, no physical path is established in advance between the sender and receiver.

Self-Assessment Questions

SAQ

- Define packet switching
- Explain the advantages of packet switching
- List the differences between circuit switching and packet switching
- Express what is meant by message switching

Tutor Marked Assessment

- Describe packet switching and when you think it should be implemented in networks.
- List 3 advantages of packet switching
- List 4 differences between circuit switching and packet switching
- Explain when a message switching should be deployed in a network

Further Reading

- https://marketbusinessnews.com/telecommunications-definition-meaning/
- https://www.nap.edu/read/11711/chapter/3
- https://www.collinsdictionary.com/dictionary/english/telecommunications
- https://www.mitel.com/articles/history-telecommunication
- https://peda.net/kenya/css/subjects/computer-studies/form-three/driac2#

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- Telecommunication Planning, ITT Laboratories of Spain, Madrid 1973.
- R. L. Freeman, Telecommunication System Engineering, 4th ed., Wiley, New York, 2004

04 | A row of signal transmitting satellites
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Module 4:
SIGNALS AND TRANSMISSION

Unit 1 The Communication System

Unit 2 Transmission Impairments

Unit 3 Error Detection And Correction

A satellite communication system
source: a-read.com

UNIT 1

The Communication System

Introduction

This unit will introduce you to the basic components of the communication system and analog/digital signals

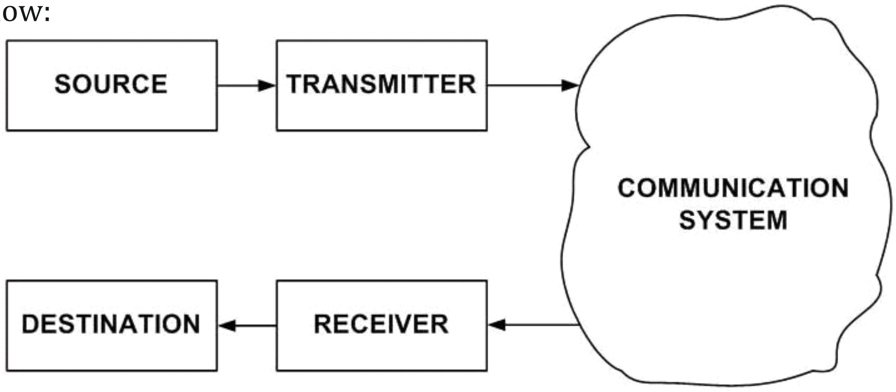
Learning Outcomes

1. Express the basic components of a communication system
2. Differentiate between data and signal
3. Explain analog signals and digital signals
4. Explain baseband and broadband signals
5. Differentiate between discrete and periodic signals

Basic Components of A Communication System [SAQ 1,2]

2 mins

You should note that a typical communication system consists of 5 basic components as shown below:



Source: Source is where the data is originated. Typically it is a computer, but it can be any other electronic equipment such as video, telephone handset, camera, etc, which can generate data for transmission to some destinations. **Transmitter:** As its well known that data cannot be sent in its native or raw form, so it is necessary to convert it into a signal. This is performed with the help of a transmitter such as a modem . **Communication Medium:** The signal can be sent to the receiving ends through a communication medium, which could be a coaxial cable, a simple twisted-pair of wire optical fiber, or a wireless communication system. **Receiver:** The receiver receives the signal and converts it back to the data before sending it to the destination. The data that the destination receives may not be identical to that of the originally sent data, because of the corruption or loss of data in the transmission process. **Destination:** Destination is where the data is absorbed. Again, it can be a computer system, a television set, a telephone handset, and so on.

Data

Data refers to information that conveys some meaning based on some mutually agreed up rules or conventions between a sender and a receiver and today it varies in forms such as text, video, audio, graphics, and animation. Data can be of two types; analog and digital. Analog data take on continuous values on some interval. Typical examples of analog data are voice and video. The data that is achieved from the real world with the help of transducers are continuous-valued or analog. On the other hand, digital data take on discrete or non-continuous values. Text or character strings can be considered as examples of digital data. Characters are represented by suitable codes, e.g. ASCII code, where each character is represented by a 7-bit code.

Signal

It is the electrical, electronic, or optical representation of data, which can be sent through a communication medium. Stated in mathematical terms, a signal is merely a function of the data. For example, a microphone converts voice data into a voice signal, which can be sent over a pair of wire. Analog signals are continuous-valued; digital signals are discrete-valued. The independent variable of the signal could be time (speech, for example), space (images), or the integers (denoting the sequencing of letters and numbers in the football score).

Basic signal types [SAQ 4, 5]

1 min

You should have it at the back of your mind that a telecommunications media carry two basic types of signals, ·Analog signals and ·Digital signals.

In addition to being represented by an analog signal, data can also be represented by a digital signal. Most digital signals are aperiodic and thus, frequency or period is not appropriate. Two new terms, bit rate (instead of frequency) and bit interval (instead of period) are used to describe digital signals. The bit rate is the number of bit intervals per second. This means that the bit rate is the number of bits sent in one second, usually expressed in bits per second (bps). while The bit interval is the time required to send one single bit. **Analog signals** are continuous waves that transmit information by changing the forms of the waves. Analog signals have two parameters, amplitude, and frequency. For example, voice and all sound are analog, travelling to human ears in the form of waves. The higher the waves (or amplitude), the louder the sound; the more closely packed the waves, the higher the frequency or pitch. Radio, telephones, and recording equipment historically transmit and receive analog signals, but they are beginning to change to digital signals.

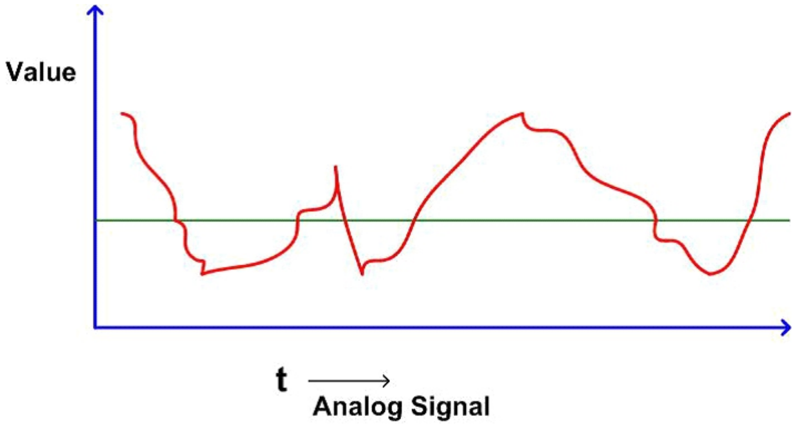


Figure 3.2: Analog signal

Digital signals do not have the form of wave or shape that is found in analog. Rather, they are discrete pulses that are either 0 or 1, on or off or true or false. This quality allows them to convey information in a binary form that can be interpreted by computers. Computers typically cannot distinguish whether an analog wave is in an "on" mode or an "off" mode.

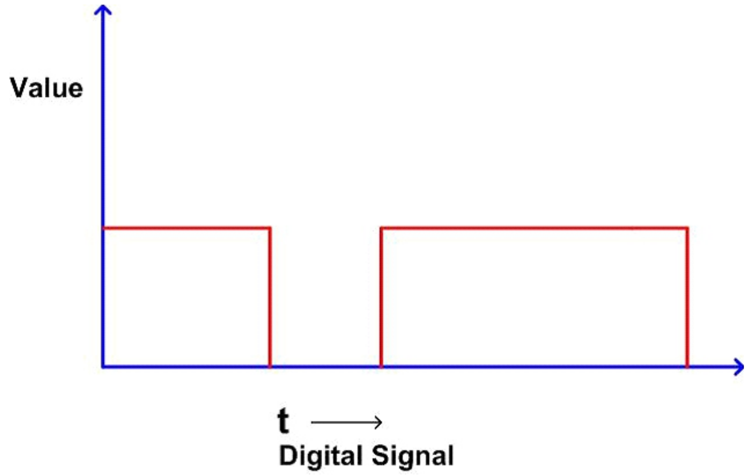


Figure 3.2: Digital signal

Signal Characteristics – A signal can be represented as a function of time, i.e. it differs with time. However, it can be also expressed as a function of frequency, i.e. a signal can be considered as a composition of different frequency components. Thus, a signal has both the frequency domain and time-domain representation.

Time-domain concepts – A periodic signal is characterized by the following three parameters. **Amplitude:** It is the value of the signal at different instants of time. It is measured in volts. **Frequency:** It is inverse of the period (T), i.e. f = 1/T. The unit of frequency is cycles per second or Hertz (Hz). **Phase:** It gives a measure of the relative position in time of two signals within a single period. It is represented by φ in degrees or radian. A sine wave, the most fundamental periodic signal, can be completely characterized by its amplitude, frequency, and phase.

Baseband and Broadband Signals – Depending on some type of typical signal formats or modulation schemes, a few terminologies developed to classify different types of signals. So, we can have either baseband or broadband signalling. ***Base-band*** is defined as one that uses digital signaling, which is inserted in the transmission channel as voltage pulses. On the other hand, ***broadband*** systems are those, which use analog signaling to transmit information using a carrier of high frequency. In baseband LANs, the entire frequency spectrum of the medium is being used for transmission and hence the FDM frequency division multiplexing cannot be used. Signals inserted at a point propagates in both the directions, hence transmission is bi-directional. Baseband systems extend only to limited distances because at a higher frequency, the attenuation of the signal is most pronounced and the pulses blur out, causing the large distance communication impractical. Since broadband systems use analog signaling, frequency division multiplexing is possible, where the frequency spectrum of the cable is divided into several sections of bandwidth. These separate channels can support different types of signals of various frequency ranges to travel in the same instance. Unlike base-band, broadband is a unidirectional medium where the signal inserted into the media propagates in only one direction.

Two data paths are required, which are connected at a point in the network called headend. All the stations transmit towards the headend on one path and the signals received at the headend are propagated through the second path.

Summary

In this unit, I have thought you the following:

- The five basic components of a communication system are source, transmitter, medium, destination, and receiver.
- The two basic types of signals are analog and digital signals
- A periodic signal is characterized by amplitude, frequency, and phase.

Self-Assessment Questions

SAQ

- List and explain the basic components of a communication system
- Define: Data - Signal
- Explain what is analog signals
- Explain what is digital signals
- Define baseband and broadband signals.

Tutor Marked Assessment

- Explain the following as related to a communication system:
  Transmitter
  Medium
  Receiver
  Destination
- What are the characteristics of a periodic signal
- Define
  Data
  Signal
  Broadband signals
  Baseband signals

Further Reading

- https://marketbusinessnews.com/telecommunications-definition-meaning/
- https://www.nap.edu/read/11711/chapter/3
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- https://www.mitel.com/articles/history-telecommunication
- https://peda.net/kenya/css/subjects/computer-studies/form-three/driac2#

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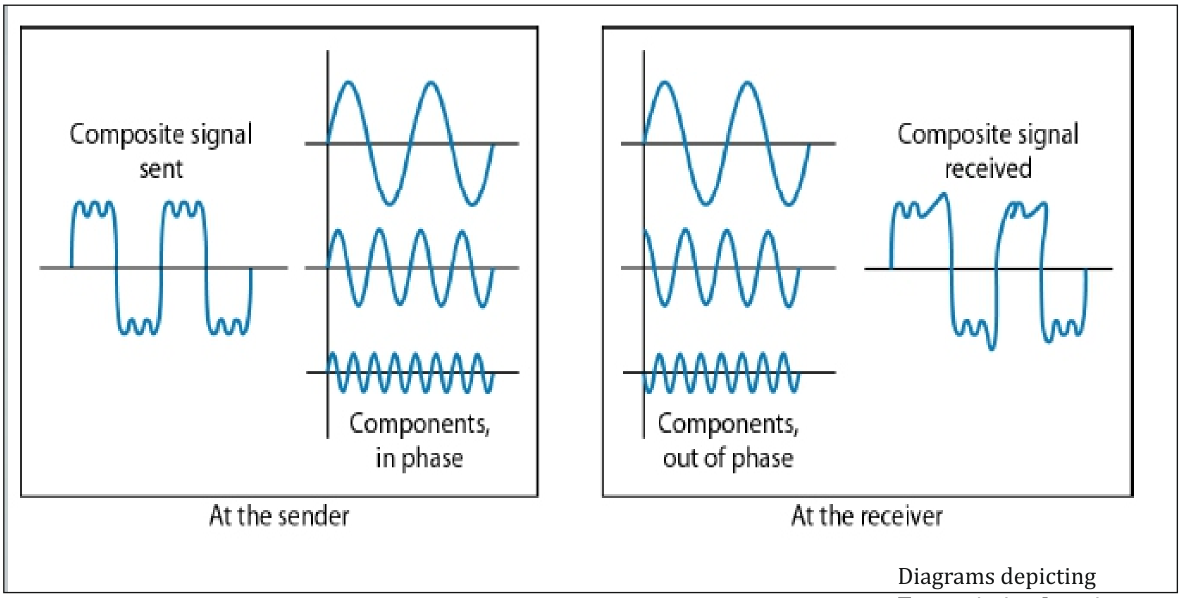
- Telecommunication Planning, ITT Laboratories of Spain, Madrid 1973.
- R. L. Freeman, Telecommunication System Engineering, 4th ed., Wiley, New York, 2004



Diagrams depicting
Transmission Impairments
source: freeitnetworking.blogspot.com

UNIT 2

Transmission Impairments

Introduction

In this chapter, you will be introduced to transmission impairments, causes, and how to measure attenuation.

Learning Outcomes

1. Define transmission impairments
2. List the causes of impairments
3. Explain the causes of impairments
4. Describe how to measure attenuation

Introduction [SAQ 1, 2, 3 & 4]

1 min

It may interest you to know that signals travel through a defective transmission media. The defection causes signal impairment (degradation in quality). If the transmission media were infallible, the receiver could receive the same signal that the transmitter sent. But communication lines are usually not perfect, so the received signal is not the same as the transmitted signal. This means that the signal at the beginning of the medium is not the same as the signal at the end of the medium i.e. what is sent is not what is received. For analog signals, these impairments cause degradation of signal quality. For digital signals, bit errors are introduced: 0 bit is been altered to 1 bit or otherwise.

Causes of Transmission Impairments

The major causes of impairments are:

Attenuation

Delay Distortion

Noise

Attenuation

Did you know that the amplitude of a signal reduces as the signal travels through the transmission medium (signal strength falls off with distance). This is known as Attenuation. When a signal, simple or composite, travels over a medium, it loses some of its energy in overcoming the resistance of the medium. That is why a wire carrying electric signals gets warm, if not hot, after a while. Some of the electrical energy in the signal is converted to heat. To compensate for this loss, amplifiers or repeaters are inserted at intervals along the medium to improve the received signal level as close as to its original level (i.e. to overcome the loss). Figure 3.1 below shows the effect of attenuation and amplification.

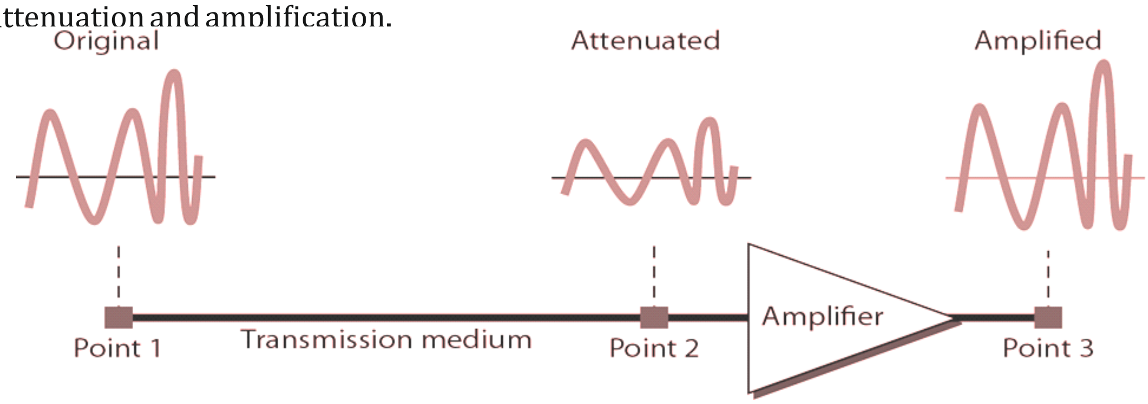


Figure 3.1: Illustration of attenuation

Measurement of Attenuation

To show that a signal has lost or gained strength, the unit of "decibel" is used. Decibel (dB) measures the relative strengths of two signals or one signal at two different points. The decibel gives a positive value when the signal is amplified but negative if attenuated.

The formular for computing decibel (dB) is :

dB= 10log P2/P1

Where P1 and P2 are the powers of a signal at points 1 and 2, respectively.

Example 1: If a signal moves through a transmission medium and has its power reduced by half. Compute the attenuation.

Solution

Since the power was reduced by half, it implies P2 is (1/2)P1.

Thus, we compute the attenuation (loss of power) as follows:

10log P2/P1 = 10log0.5P1/P1 = 10log 0.5 = 10 (-0.3) = -3dB

Interpretation: This implies that a loss of 3 dB (-3 dB) is equal to losing one-half the power.

Example 2: A signal has its power increased by 100 times while traveling through an amplifier, Calculate the gain in power.

Solution

This means that P2 = 100P1.

In this case, the amplification (gain of power) can be calculated as

Since P2 = 100P1

Then, 10log P2/P1 = 10log 100P1/P1 = 10log 100 = 10x2 = 20 dB

Note: One of the reasons that decibel is used to measure signal strength is that dB numbers can be added or subtracted when we are measuring several points instead of just two.

Example 3

Figure 3.2 shows a signal that travels from point 1 to point 4. Calculate the value of dB.

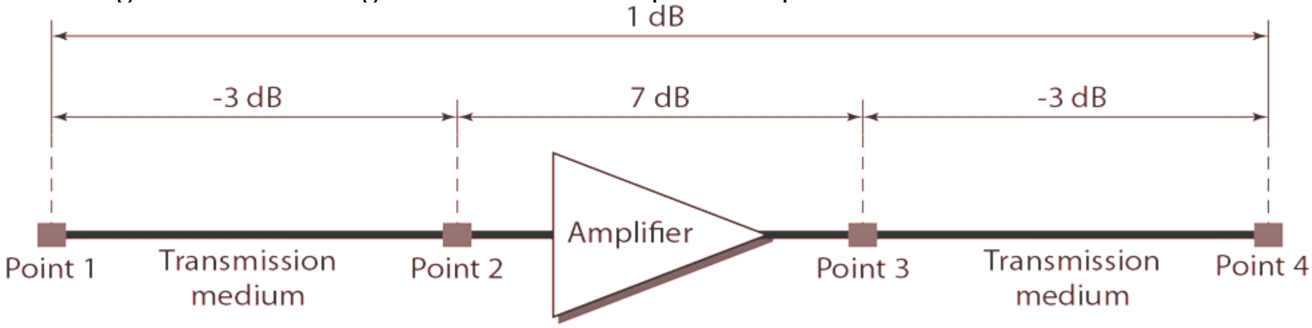


Figure 3.2: Movement of a signal between 4 points

Solution

In this case, the decibel value can be calculated by summing up all values of attenuation and amplification.

Thus,

dB = -3+7-3 = 1dB

Delay Distortion

Did you know that a delay distortion is a phenomenon peculiar to guided transmission media such as copper wire, coaxial cable, twisted pairs, etc. The distortion is caused by the fact that the velocity of propagation of a signal through a medium varies with frequency. A signal consisting of several frequencies will have its components arrive at the receiver at different times; therefore different components arrive with different delays at the receiver. This simply shows that the signals have different phases at the receiver than they did at the source. In digital data transmission, some signal components of the one-bit position will spill over into other bit positions, causing inter-symbol interference, which limits maximum bit rate transmission.

Noise

Noise on the other hand, is refer to as unwanted signals that are inserted into the real signal during transmission, in other words, it is the additional undesired signals inserted between transmitter and receiver. Noise can be divided into four different categories, namely: Thermal noise, Inter-modulation noise, Crosstalk, and Impulse noise.

Thermal Noise

Thermal noise is the random motion of electrons in a wire which generates an extra signal not originally sent by the transmitter. This is uniformly distributed across the frequency spectrum and hence, it is present in all electronic devices and transmission media. It is a function of temperature. This noise cannot be completely destroyed and it is also referred to as white noise.

Inter-modulation Noise

This noise appears when two signals of different frequencies share the same communication medium, due to the nonlinearity of the transmitters, this produces signals that are sum, difference, or multiples of original frequencies (f1+f2, f1-f2, f1f2). They are undesired components and need to be filtered out.

Crosstalk

Crosstalk is the effect a wire has on the other, it occurs when a signal from one wire is picked up by another. It is the unwanted coupling between signal paths. This coupling is common in telephone networks and as a result, we hear other people's conversations in the background.

Impulse Noise

This is a non-continuous noise, consisting of irregular pulses or noise spikes (a signal with high amplitude and short duration) that come from power lines, lightning, communication system faults, and so on. The figure below illustrates the effect of noise on a signal.

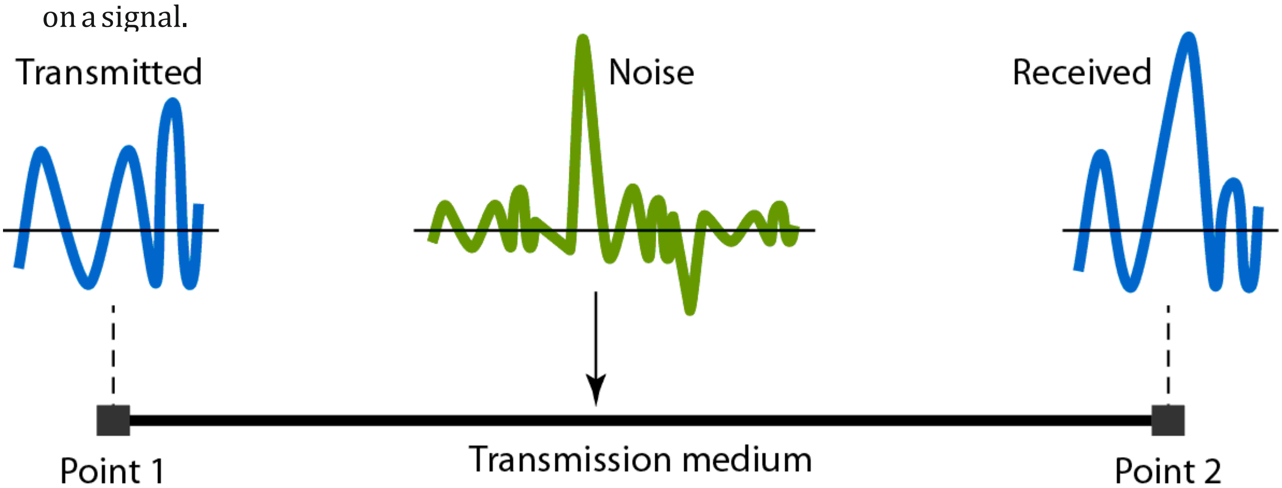


Figure 3.3: Effect of noise on the signal

Signal to Noise Ratio (SNR)

it will interest you to note that SNR is a parameter used to determine the value of how much noise is present in a signal. It is the ratio of what is required (signal power) to what is not required (noise power). A high SNR means the signal is less corrupted by noise while a low SNR means the signal is more corrupted by noise. Typically measured at the receiver to process the signal and eliminate undesired noise, it is usually given in dB and referred to as SNR_{dB}. It is expressed as:

SNR = ***Signal Power / Noise Power***

$$(SNR)_{dB} = 10\log \frac{\textit{Signal Power}}{\textit{Noise Power}}$$

Example 4: If the power of a signal is 10 mW and the power of the noise is 1 μW; Calculate the SNR and SNRdB?

Solution

The values of SNR and SNRdB can be calculated as follows:

SNR = signal power/ noise power = 10mW/1μW = 10,000

(SNR)dB = 10 log 10,000 = 40

Example 5: Calculate the values of SNR and SNRdB for a noiseless channel

Solution

Note that for a noiseless channel, the noise power is zero.

SNR = signal power/ noise power = signal power/0 = ∞

(SNR)dB = 10log ∞ = ∞

You should note that in an ideal situation, we can never achieve a noiseless channel.

Summary

In this unit, I have thought you the following:

- ·The medium through which signals travel is imperfect and there occurs a degradation in signal quality as it passes from source to destination.
- Three major causes of impairments are attenuation, delay distortion, and noise.
- The level of noise present in the transmitted signal can be measured through the SNR.

Self-Assessment Questions

SAQ

- Define transmission impairments
- List the causes of impairments
- Explain the causes of impairments
- Describe how to measure attenuation

Tutor Marked Assessment

- Explain the term " Transmission impairments"
- List the various types of transmission impairments discussed in this unit.
- Why is it needed to convert from analog to digital signal? briefly explain the following:
- Attenuation -Delay Distortion -Noise
- The power of a signal is 15 mW and the power of the noise is 0.5 µW; what are the values of SNR and SNRdB?

Further Reading

- https://marketbusinessnews.com/telecommunications-definition-meaning/
- https://www.nap.edu/read/11711/chapter/3
- https://www.collinsdictionary.com/dictionary/english/telecommunications
- https://www.mitel.com/articles/history-telecommunication
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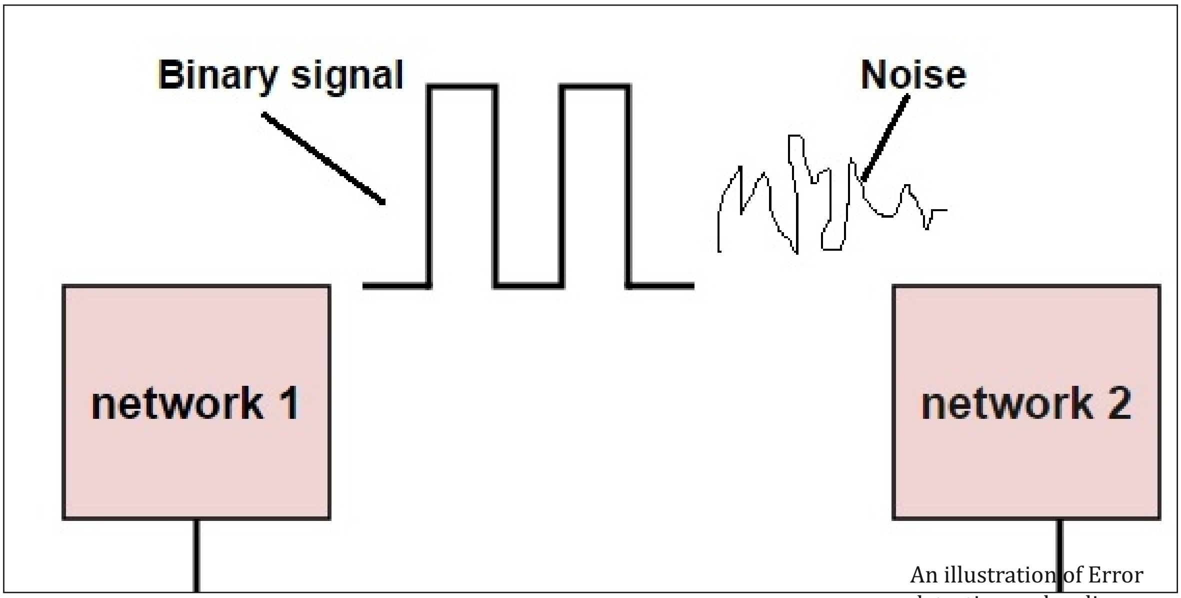
- R. L. Freeman, Telecommunication System Engineering, 4th ed., Wiley, New York, 2004



An illustration of Error detection and coding
source: electromicshub.org

UNIT 3

Error Detection And Correction

Introduction

In this chapter, you will be introduced to error detection, error correction and why we need them.

Learning Outcomes

1. Define the term transmission error
2. Explain the need for error-detecting codes
3. Explain parity Checking of Error Detection

Introduction [SAQ1, 2, & 3]

7 mins

As it was discussed in PSTN, the telephone system has three parts: the switches, the interoffice trunks, and the local loops. The first two are now almost entirely digital in most developed countries. The local loops are still analog twisted copper pairs. While errors are rare on the digital components, they are still common on the local loops. Furthermore, wireless communication is becoming more common, and the error rates here are worse than on the interoffice fiber trunks. Consequently, transmission errors cannot be totally eradicated, they are going to be with us for many years to come. We just need to learn how to deal with them.

What is Error?

An Error is a condition when the output information does not match with the input information. During transmission, digital signals suffer from noise that can introduce errors in the binary bits travelling from one system to another. That means a 0 bit may change to 1 or vise-versa.

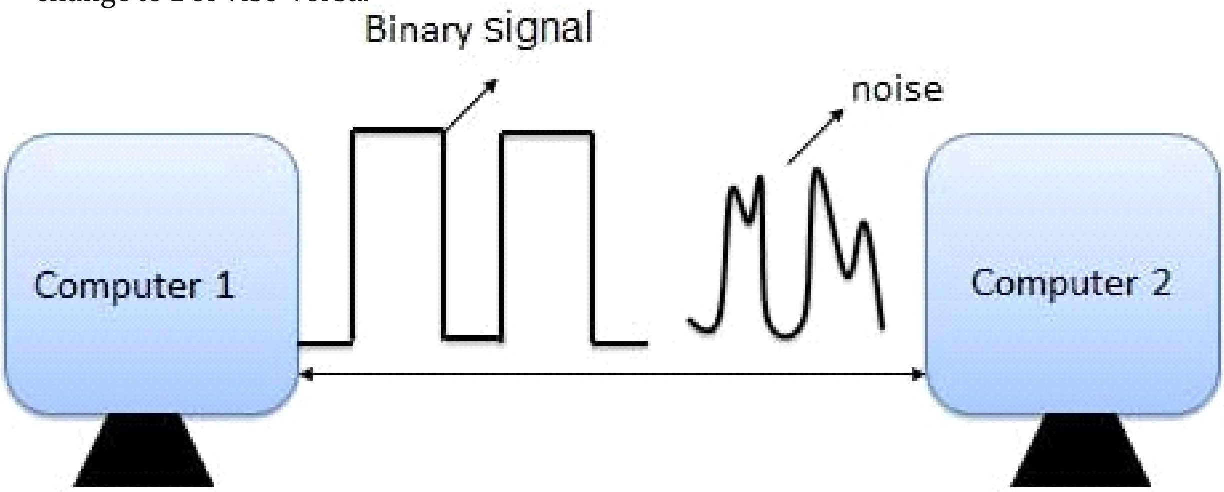


Figure 3.1: Error in transmission

Error-Detecting codes

Whenever a message is transmitted, it may get scrambled by noise or data may get corrupted. To avoid this, we use error-detecting codes which are additional data added to a given digital message to help us detect if an error occurred during transmission of the message. A simple example of an error-detecting code is the parity check.

Error-Correcting codes

Along with the error-detecting code, we can also pass some data to figure out the original message from the corrupt message that we received. This type of code is called an error-correcting code. Error-correcting codes also deploy the same strategy as error-detecting codes but additionally, such codes also detect the exact location of the corrupt bit.

In error-correcting codes, parity check has a simple way to detect errors along with a sophisticated mechanism to determine the corrupt bit location. Once the corrupt bit is located, its value is reverted (from 0 to 1 or 1 to 0) to get the original message.

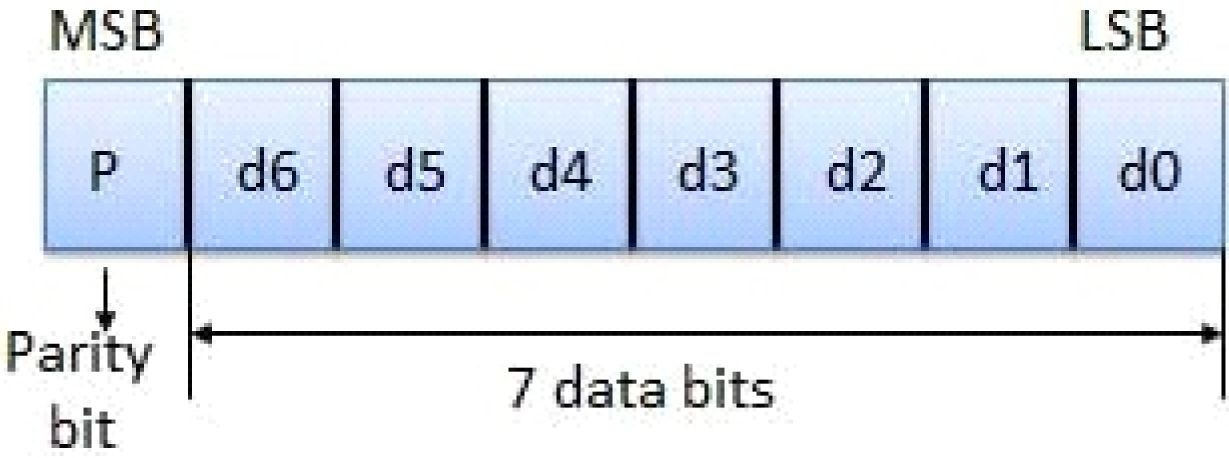
How to Detect and Correct Errors?

To detect and correct the errors, additional bits are added to the data bits at the time of transmission. ·The additional bits are called parity bits. They allow detection or correction of the errors.

·The data bits along with the parity bits form a code word.

Parity Checking of Error Detection

It is the simplest technique for detecting and correcting errors. The Most Significant Bit (MSB) of an 8-bits word is used as the parity bit and the remaining 7 bits are used as data or message bits. The parity of 8-bits transmitted word can be either even parity or odd parity.



Even parity : Even parity means the number of 1's in the given word including the parity bit should be even.

Odd parity : Odd parity simply means the number of 1's in the given word including the parity bit should be odd.

Use of Parity Bit

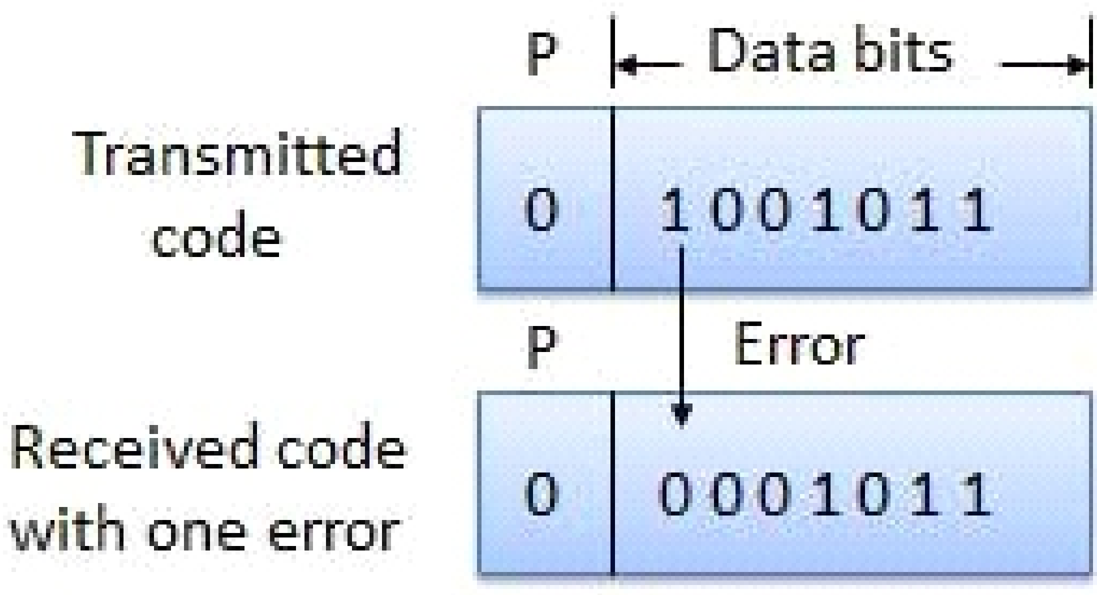
You should note that the parity bit can be set to 0 and 1 depending on the type of the parity required.

·For even parity, this bit is set to 1 or 0 such that the number of "1 bit" in the entire word is even.

·For odd parity, this bit is set to 1 or 0 such that the number of "1 bit" in the entire word is odd.

How Does Error Detection Take Place?

Similarly, parity checking at the receiver can detect the presence of an error if the parity of the receiver signal is different from the expected parity. That means if it is known that the parity of the transmitted signal is always going to be "even" and if the received signal has odd parity, then the receiver can conclude that the received signal is not correct. If an error is detected, then the receiver will ignore the received byte and request for retransmission of the same byte to the transmitter.



Error-Correcting Codes

Network designers have developed two basic strategies for dealing with errors. One way is to include enough redundant information along with each block of data sent, to enable the receiver to deduce what the transmitted data must have been. The other way is to include only enough redundancy to allow the receiver to deduce that an error occurred, but not which error, and allow it to request for retransmission. The former strategy uses error-correcting codes and the latter uses ***error-detecting codes***. The use of ***error-correcting codes*** is often referred to as ***forward error correction (FEC)***.

Choosing an error code

Each of the error management techniques has different functions depending on the transmission channel. On highly reliable channels, such as fiber, it is cheaper to use an error detecting code and just retransmit the occasional block found to be faulty.

However, on channels such as wireless links that are prone to many errors, it is better to add enough redundancy to each block for the receiver to be able to figure out what the original block was, rather than relying on a re- transmission, which itself may be in error.

Handling Transmission Errors

To understand how errors can be handled, it is necessary to look closely at what an error really is. Normally, a frame consists of m data (i.e., message) bits and r redundant, or check, bits. Let the total length be n (i.e., n = m+ r). An n-bit unit containing data and check bits is often referred to as an n-bit ***codeword***.

Given any two codewords, say, 10001001 and 10110001, it is possible to determine how many corresponding bits differ. In this case, 3 bits differ. To determine how many bits differ, just exclusive OR (XOR) the two codewords and count the number of 1 bit in the result. **For example:**

10001001

10110001

____

00111000

The number of bit positions in which two codewords differ is called the Hamming distance "d". Its significance is that if two codewords are a hamming distance d apart, it will require d single-bit errors to convert one into the other. In most data transmission applications, all 2m possible data messages are legal, but due to the way the check bits are computed, not all of the 2n possible codewords are used. Given the algorithm for computing the check bits, it is possible to construct a complete list of the legal codewords, and from this list find the two codewords whose Hamming distance is minimum. This distance is the Hamming distance of the complete code.

NOTE: The error-detecting and error-correcting properties of a code depend on its Hamming distance.

Detecting Errors

To detect 'd' errors, you need a distance 'd + 1' code because with such code there is no way that 'd' single-bit errors can change a valid codeword into another valid codeword. When the receiver sees an invalid codeword, it can tell that a transmission error has occurred. Similarly, to correct d errors, you need a distance 2d + 1 code because that way the legal codewords are so far apart that even with 'd' changes, the original codeword is still closer than any other codeword, so it can be uniquely determined.

As a simple example of an error-detecting code, consider a code in which a single parity bit is appended to the data. The parity bit is chosen so that the number of 1 bit in the codeword is even (or odd).

Example: when 1011010 is sent in even parity, a bit is added to the end to make it 10110100. With odd parity, 1011010 becomes10110101. A code with a single parity bit has a distance 2 since any single-bit error produces a codeword with the wrong parity. It can be used to detect single errors.

Example: for an error-correcting code, consider a code with only four valid codewords:

0000000000, 0000011111, 1111100000, and 1111111111

This code has a distance 5, which means that it can correct double errors. If the codeword 0000000111 arrives, the receiver knows that the original must have been 0000011111. If, however, a triple error changes 0000000000 into 0000000111, the error will not be corrected properly.

Correcting burst errors with Hamming code

Hamming codes can only correct single errors. However, there is a trick that can be used to permit Hamming codes to correct burst errors. A sequence of k consecutive codewords is arranged as a matrix, one codeword per row. Normally, the data would be transmitted one codeword at a time, from left to right. To correct burst errors, the data should be transmitted one column at a time, starting with the leftmost column,

Error-Detecting Codes

Error-correcting codes are widely used on wireless links, which are known to be very noisy and error-prone when compared to copper wire or optical fibers. Without error-correcting codes, it would be hard to get anything through. However, over copper wire or fiber, the error rate is much lower, so error detection and retransmission is usually more efficient for dealing with the occasional error.

Example: Consider a channel on which errors are isolated and the error rate is 10-6 per bit. Let the block size be 1000 bits. To provide error correction for 1000-bit blocks, 10 check bits are needed; a megabit of data would require 10,000 check bits. To merely detect a block with a single 1-bit error, one parity bit per block will suffice. Once every 1000 blocks, an extra block (1001 bits) will have to be transmitted. The total overhead for the error detection +retransmission method is only 2001 bits per megabit of data, versus 10,000 bits for hamming code.

Summary

In this unit, I have thought you the following:

- Error is a condition in transmission when the sent information does not match with the received information.
- Error-correcting codes are used to figure out the original message from the message received in error.

  Parity checking is the simplest technique for detecting and correcting errors and can detect the presence of an error if the parity of the receiver signal is different from the expected parity.
- The number of bit positions in which two codewords differ is called the Hamming distance "d".

Self-Assessment Questions

SAQ

- Define the term transmission error
- Explain the need for error-detecting codes
- Explain parity Checking of Error Detection

Tutor Marked Assessment

- Define the following
- Error

  Parity bit

  Hamming distance
- List 2 differences between error detecting and error-correcting codes
- Briefly explain the function of hamming distance in error detection

Further Reading

- https://marketbusinessnews.com/telecommunications-definition-meaning/
- https://www.nap.edu/read/11711/chapter/3
- https://www.collinsdictionary.com/dictionary/english/telecommunications
- https://www.mitel.com/articles/history-telecommunication
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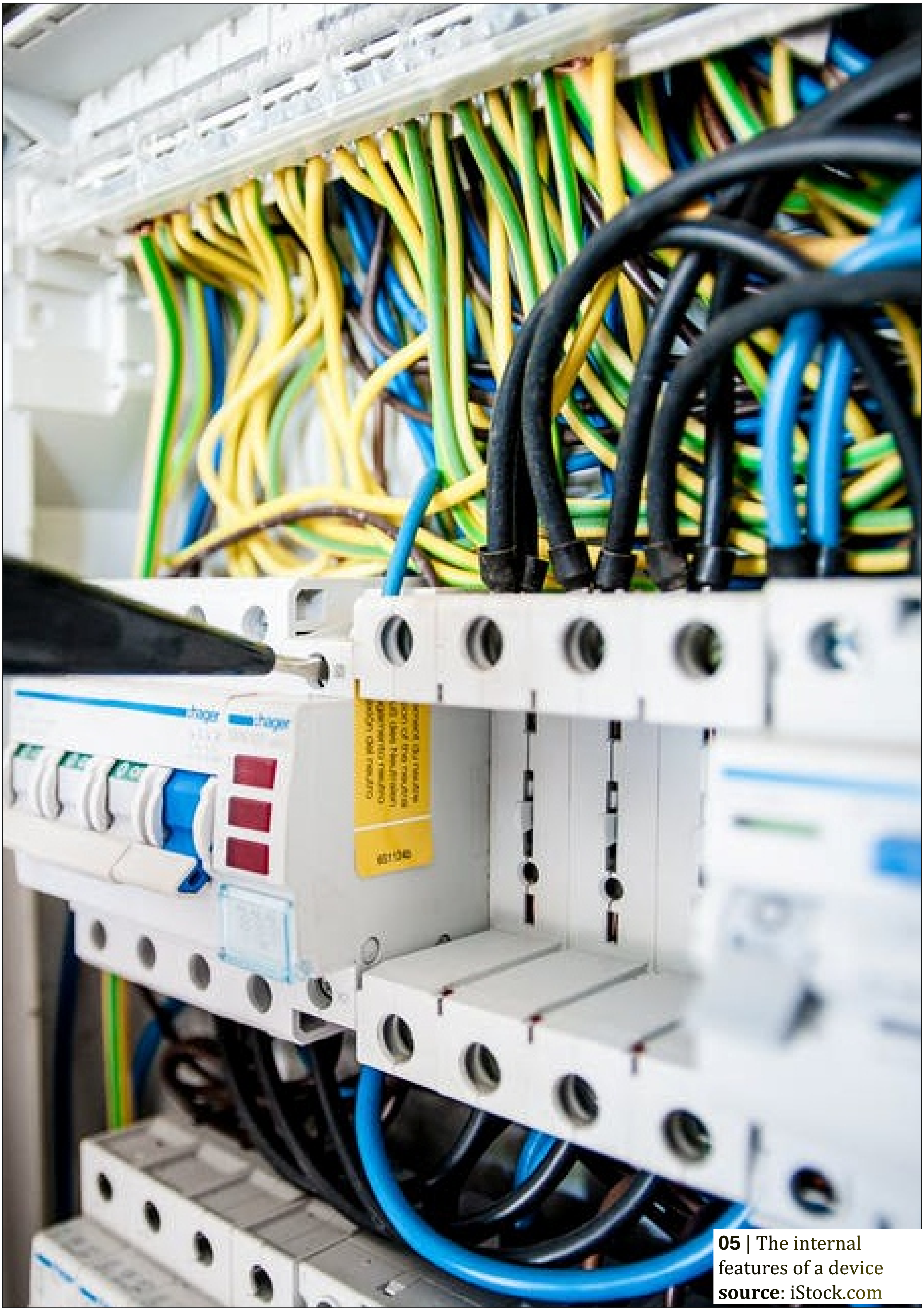


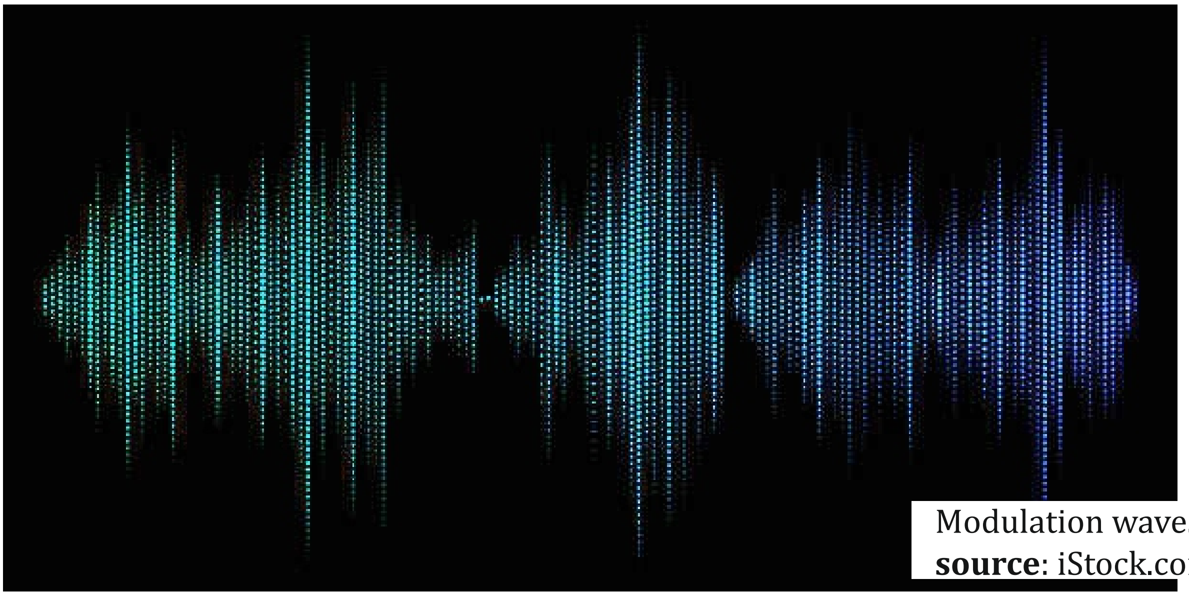
05 | The internal features of a device
source: iStock.com

Module 5:

MODULATION AND MULTIPLEXING

Unit 1: Modulation

Unit 2: Multiplexting



Modulation waves
source: iStock.com

UNIT 1

Modulation

Introduction

In this unit, you will be introduced to the concept of modulation in data transmission.

Learning Outcomes

1. Define modulation
2. List the types of modulation
3. Define analog and digital modulation
4. List advantages of modulation

Why Modulation? [SAQ 1]

1 min

Did you know that a radio carrier is generated at the transmitting side of the telecommunication link during transmission. A radio frequency is characterized by the generated carrier. This single radio frequency carries no valuable information (such as voice, data, or image) for the user.

The two vital motivating reasons for modulation are matching the transmission characteristics of the medium, and considerations of strength and antenna size, which affect portability. The second moment is the craving to multiplex or share, a communication medium among many concurrently active users.

What is Modulation?

Modulation simply means an operation based on the instantaneous amplitude of the baseband signal/modulating signal with varying amplitude or frequency or phase of the carrier signal. The IEEE describes modulation as "a process whereby certain characteristics of a wave, often called the carrier, are varied or selected by a modulating function."

Modulation is the method of imposing or impinging the carrier's useful information, and demodulation is the recuperation of that information from the carrier at the removal end near the destination user.

Types of Modulation [SAQ 2, 3]

5 mins

You should note that there are basically two types of modulation, which are:

·The Analog modulation

·Digital modulations.

Analog modulation: This deals with the voice, video, and normal waves of baseband signals.

Digital modulation: Deals with bitstreams or symbols from computing devices as baseband signals.

Below is the diagram showing the types of modulations and further the subtypes of analog and digital modulations:

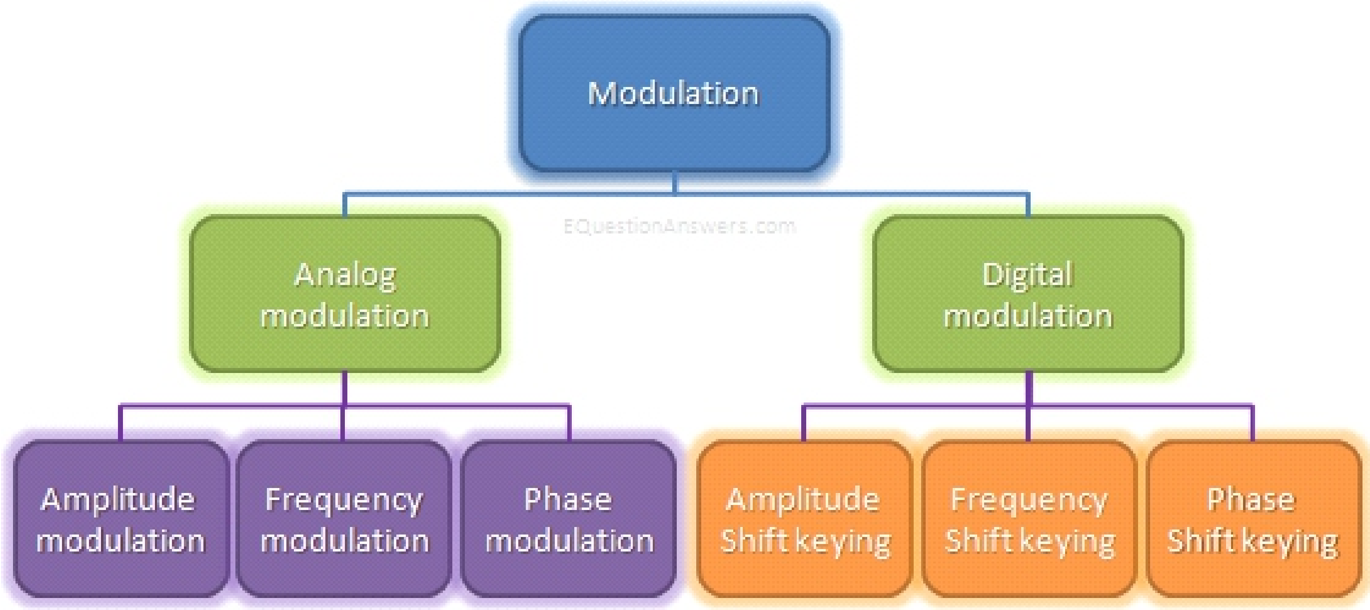


Figure 3.2: Amplitude modulation

ANALOG MODULATION

5 mins

Analog modulation can be described as the process of transferring analog low-frequency baseband signals over a higher frequency carrier signal such as a radio frequency band, like an audio or TV signal. For this modulation, the baseband signal is always analog. A carrier signal amplitude, frequency, and phase have three properties, so there are three basic types of analog modulations.

1.Amplitude Modulation (AM)

2.Frequency Modulation (FM)

3.Phase modulation (PM)

Amplitude Modulation (AM)

The process of varying the instantaneous amplitude of the carrier signal accordingly with the instantaneous amplitude of the message signal is termed Amplitude modulation or AM. It is when a carrier is varied with amplitude in accordance with the formation baseband signal.

Advantages of AM

·AM is the simplest type of modulation.

·The hardware design of both transmitter and receiver is very simple and less cost-effective.

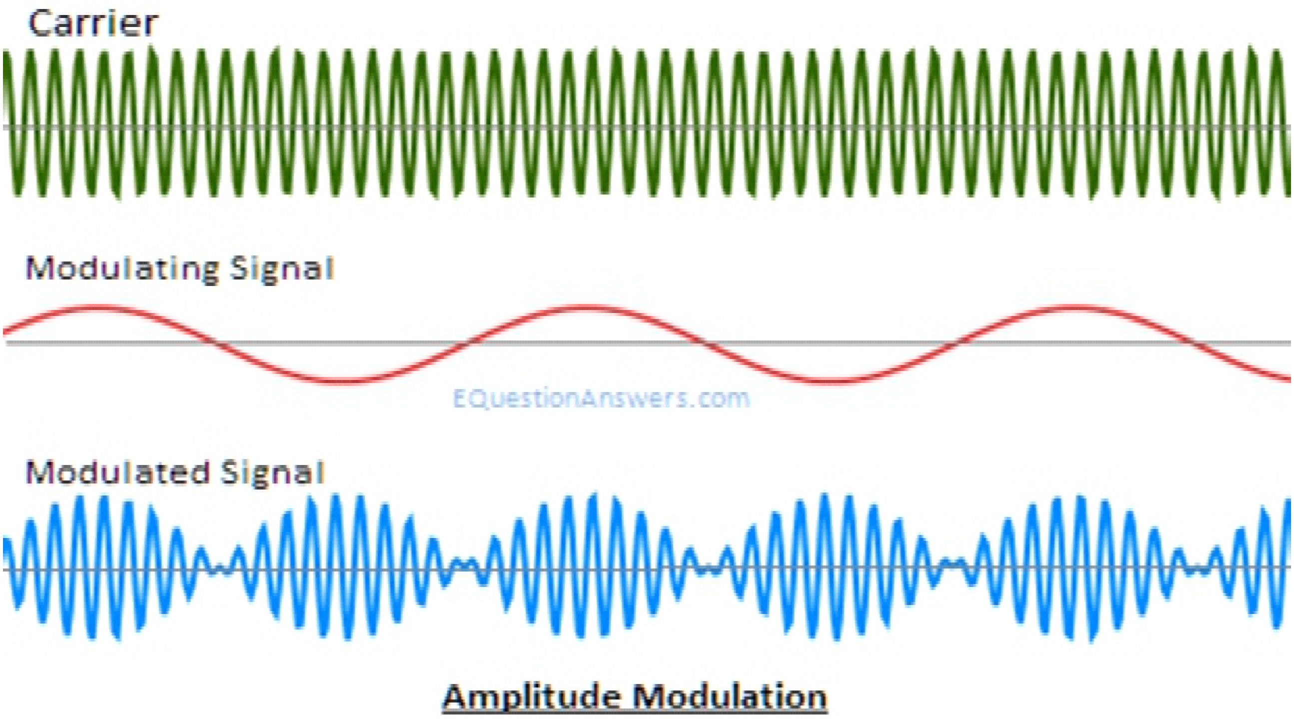


Figure 3.2: Amplitude modulation

Disadvantages of AM

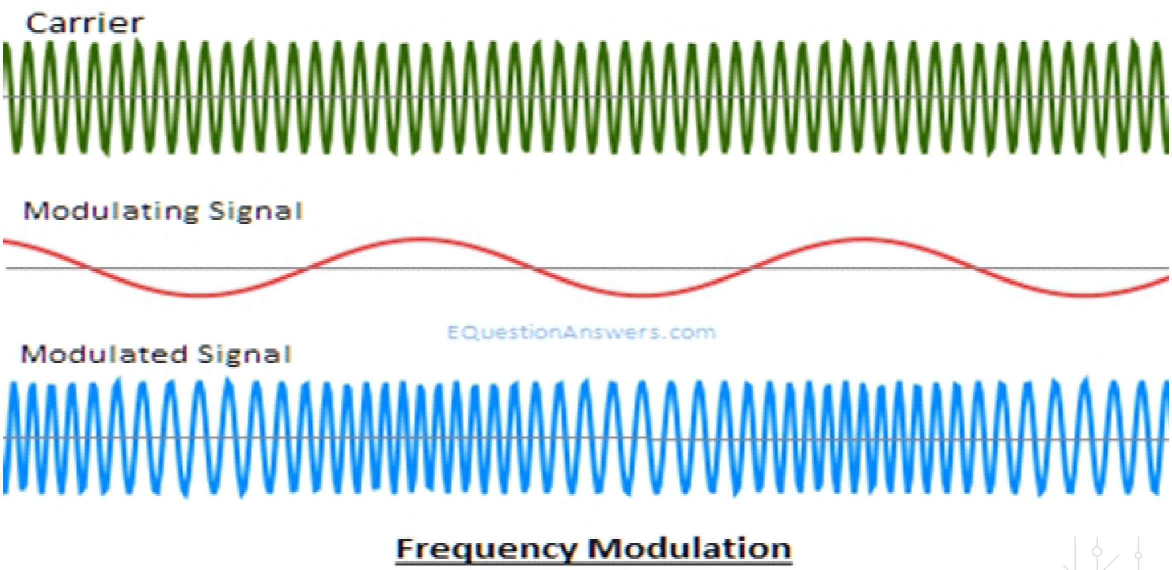
·It is very susceptible to noise.

Applications of AM

·AM radio broadcast is an example

Frequency Modulation (FM)

FM or Frequency modulation is the process of varying the instantaneous frequency of the Carrier signal accordingly with the instantaneous amplitude of the message signal.



Advantages of FM

·Modulation and demodulation do not catch any channel noise.

Disadvantages of FM

·Unlike Amplitude modulation (AM), the Circuit needed for FM modulation and demodulation is a bit complicated.

Application of FM

·FM radio broadcast is an example

Phase Modulation (PM)

The process of varying the instantaneous phase of the carrier signal appropriately with the instantaneous amplitude of the message signal is referred to as PM or Phase modulation.

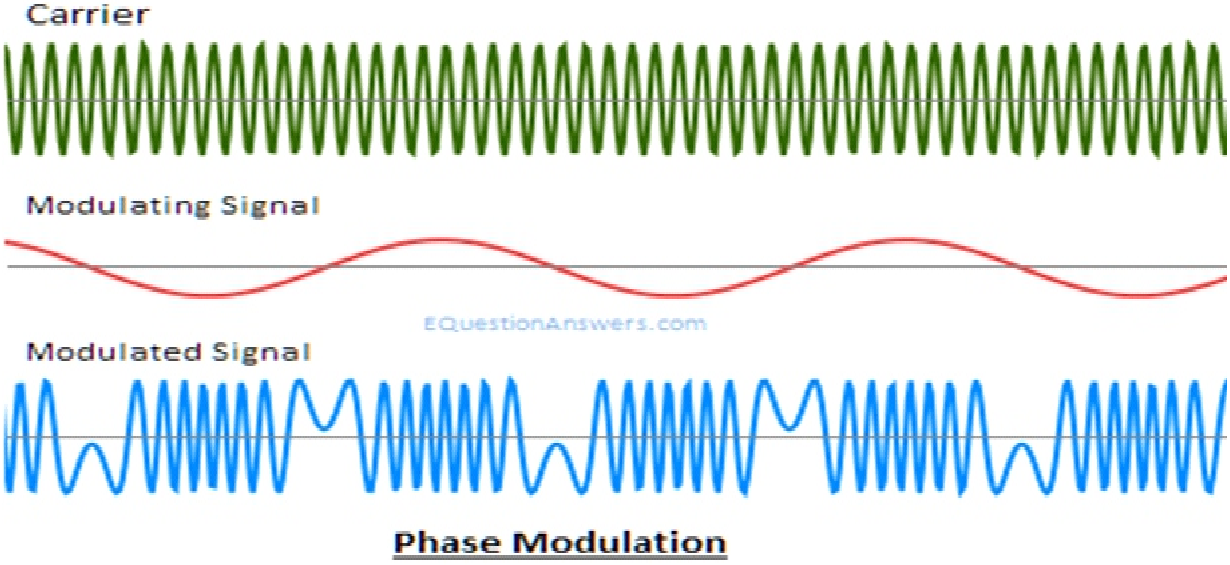


Figure 3.3: Phase modulation

PM Advantage

·Modulation and demodulation do not catch any channel noise.

PM Disadvantages

·The circuit needed for PM modulation and demodulation is a bit complicated than AM and FM

Application PM

·Satellite communication.

DIGITAL MODULATION

You should know that a digital modulation is of discrete amplitude level which is somehow similar to the analog modulation except for baseband signal. It has only two levels, either high or logic 1 or low or logic 0 for the binary signal. The modulation scheme consists essentially of three types.

·ASK or Amplitude shift Key

·FSK or Frequency shift key

·PSK or Phase shift key

Amplitude shift Key (ASK)

When the instantaneous amplitude of the carrier signal varied in proportion to message m(t), we have the modulated carrier m(t)coswct, where the carrier signal is coswct. Since the information is an On-Off digital signal, the output will also be an On-Off signal where the carrier is present if the information is 1 and the carrier is absent when information is 0. So this modulation method is known as On-Off Keying (OOK) or amplitude shift key.

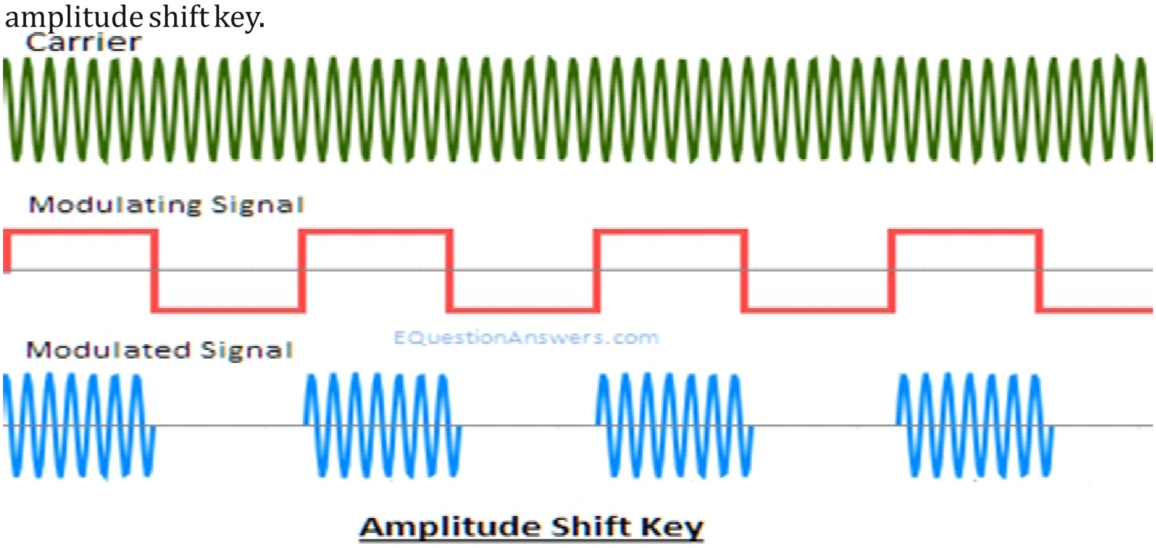


Figure 3.4: Amplitude shift keying

Application:

The following are stages involved in application process

·Used in our infrared remote controls

·Used in fiber optical transmitter and receiver.

Frequency Shift Key (FSK)

When transmitting data by changing the carrier's instantaneous frequency, we have the frequency shift key main scenario. There are two predefined frequency wc1 and wc2 in this modulation carrier. When information bit 1 is transmitted, the carrier with wc1 i.e. coswc1 is used and when information bit is 0 is transmitted, carrier with wc0 i.e. coswc0 is used.

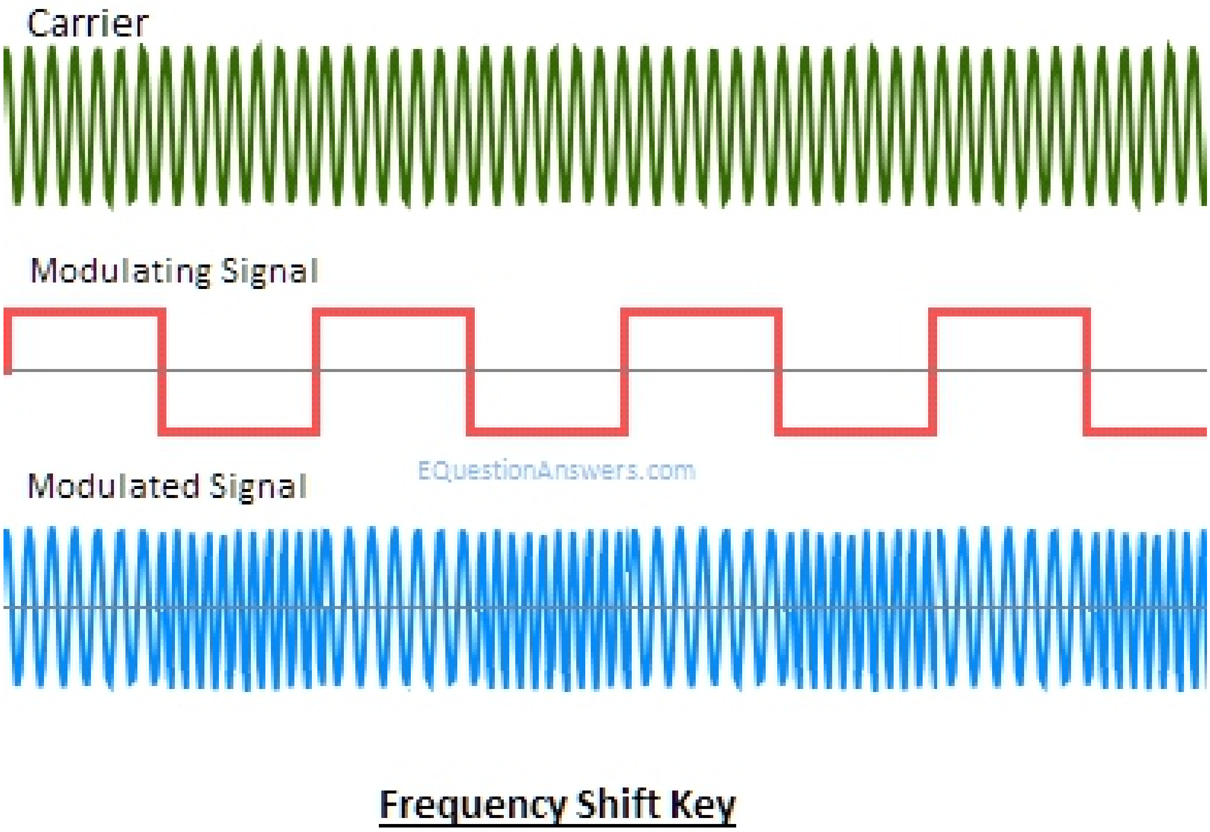


Figure 3.5: frequency shift key

Application:

·In Many modems, FSK was used in telemetry systems

Phase shift key (PSK)

For this modulation, the carrier's instant phase is shifted. When transmitting in phase the baseband signal m(t) =1 while during out of phase transmission, m(t)=0. If phase shift is accomplished in 4 different quadrants, then 2bit of information can be sent at once. This scheme is a special case of PSK modulation known as QPSK or Quadrature Phase Shift Key.

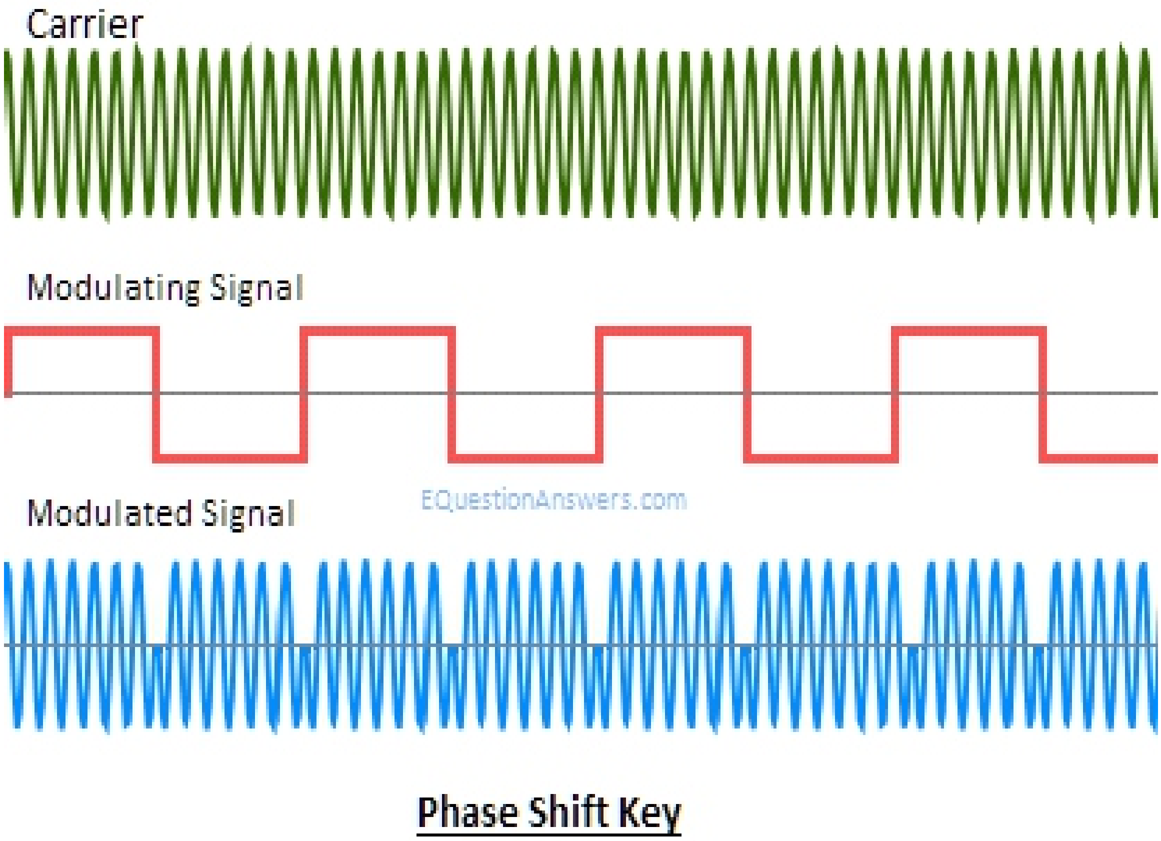


Figure 3.6: Phase shift keying

Application:

·Used in our ADSL broadband modem

·Used in satellite transmission

·Used in our mobiles

Summary

In this unit, I have thought you the following:

- The basic reasons for modulation are to match the transmission characteristics of the medium, and considerations of power and antenna size. Modulation is the process of imposing or impinging that useful information on the carrier and demodulation is the recovery of that information from the carrier at the distant end near the destination user.
- There are two types of modulation; analog and digital.

  Analog modulation deals with voice, video, and regular waves of baseband signals. While digital modulations deals with bit streams or symbols from computing devices as base band signals.

Self-Assessment Questions

SAQ

- Define modulation
- List the various types of modulation
- Define the following:

  Analog modulation

  Digital modulation

  Phase modulation

Tutor Marked Assessment

- Briefly explain the concept of modulation
- List and briefly explain three types of modulation

  Define:
- Amplitude modulation

  Frequency modulation
- Phase modulation
- Further Reading

Further Reading

- https://marketbusinessnews.com/telecommunications-definition-meaning/
- https://www.nap.edu/read/11711/chapter/3
- https://www.collinsdictionary.com/dictionary/english/telecommunications
- https://www.mitel.com/articles/history-telecommunication
- https://peda.net/kenya/css/subjects/computer-studies/form-three/driac2#

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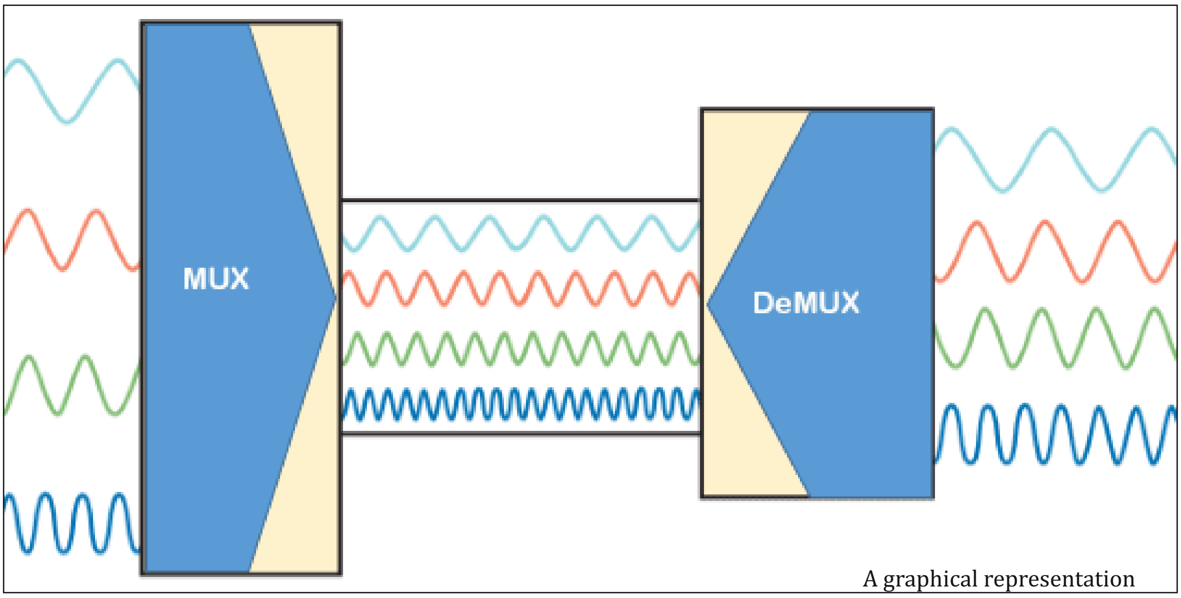
- Telecommunication Planning, ITT Laboratories of Spain, Madrid 1973.
- R. L. Freeman, Telecommunication System Engineering, 4th ed., Wiley, New York, 2004



A graphical representation of multiplexting
source: computernetworkingnotes.com

UNIT 2

Multiplexing

Introduction

In this unit, you will learn the concepts of multiplexing in telecommunication.

Learning Outcomes

1. Define multiplexing
2. List the various types of multiplexing
3. Define modulation

What is Multiplexing?[SAQ 1, 2]

5 mins

It will interest you to know that multiplexing was first introduced telephony by combining many signals together and sent over a single cable . The multiplexing process divides a communication channel into several logical channels, each allotting for a different message signal or a data stream to be transferred. A multiplexing device can be called as a MUX. The reverse process is called demultiplexing, i.e., extracting the number of channels from one, which is done at the receiver. The tool which doing demultiplexing is called as DEMUX. In the telecommunications industries, infrastructure cost plays a vital role. It essentially costs the same amount of money to install and maintain a high-bandwidth trunk as a low bandwidth trunk between two switching offices (i.e. it costs to dig the trench and not the copper wire or optical fiber). Telephone companies have therefore developed elaborate schemes to multiplex many conversations over a single physical trunk or connection. Multiplexing is the process of combining multiple signals over a shared medium, into one signal. If these signals are analogous, the process is called analog multiplexing otherwise it is called digital multiplexing.

Types of Multiplexers

There are essentially two types of multiplexers, analog and digital. They are further broken down into FDM, WDM, and TDM. The figure below gives a good idea of that classification.

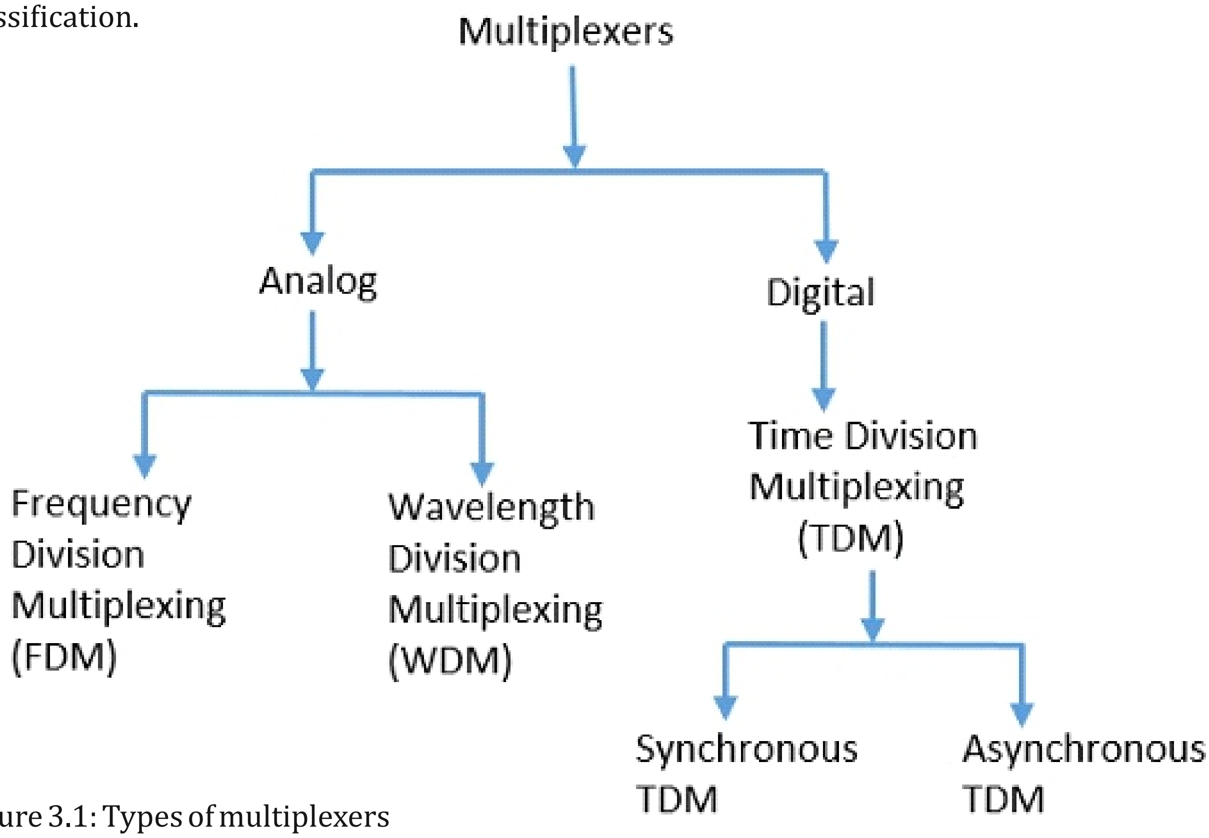


Figure 3.1: Types of multiplexers

There are many types of techniques for multiplexing. Of all of them, we have the major types with general classification, mentioned in the figure above. Let's take an individual look at them.

ANALOG MULTIPLEXING –

The analog technique of multiplexing involves signals that are similar. The analog signals are multiplexed by frequency (FDM) or wavelength (WDM), respectively.

Frequency Division Multiplexing (FDM) –

The most commonly used technique in analog multiplexing is the Frequency Division Multiplexing (FDM). This technique uses different frequencies to combine data streams as a single signal for transmitting them on a communication medium. A typical scenario is a conventional TV transmitter, which uses FDM to send a variety of channels through a single cable.

Wavelength Multiplexing Multiplexing (WDM)--

Wavelength Division Multiplexing (WDM) is an analog technique, in which the light spectrum transmits several data streams of various wavelengths. When the wavelength increases, the signal frequency decreases. A prism that can transform various wavelengths into one line can be used at MUX output and DEMUX input. An example of WDM technique is the combination of multiple wavelengths into a single communication light in optical communication.

DIGITAL MULTIPLEXING–

You should know that the term digital describes the bits of discrete information. Therefore the available data is in the form of discrete frames or packets.

Time Division Multiplexing (TDM) –

For TDM, the time frame is broken down into slots. This technique is used to transmit a signal over a single channel of communication, by assigning one slot for each packet. Of all TDM types, Synchronous and Asynchronous TDM are the main ones.

Synchronous TDM–

The Input is attached to a frame in Synchronous TDM. When the number of connections is 'n' then the frame is split into 'n' time slots. Every input line is allocated one slot. In this technique, the sampling rate is common for all signals, and hence the same clock input is given. The MUX allocates the same slot to each device at all times

Asynchronous TDM–

The sampling rate for each of the signals in Asynchronous TDM is different, and no specific clock is required. When the allocated device transmits nothing for a while and sits idle, instead, unlike synchronous, the period is allocated to another device. This TDM method is used in networks with Asynchronous Transfer Mode.

DE-MULTIPLEXER

De-multiplexers are used to connect to multiple destinations from a single source. Multiplexing is the reverse of that operation. As previously mentioned, it is mainly used on the receivers. There are several programs at DEMUX. It's used in messaging devices in the receivers. It is used in computers in the arithmetic and logical unit to provide power and relay data, etc. Demultiplexers are used as parallel converters in series form. At regular intervals, the serial data is provided as input to DEMUX, and a counter is attached to it to control the de-multiplexer output. All multiplexers and de-multiplexers play a significant role in communication networks, particularly in the parts of the transmitter and the receiver.

Summary

In this unit, I have thought you the following:

- Modulation is the process of imposing or impinging that useful information on the carrier, and demodulation is the recovery of that information from the carrier at the distant end near the destination user.
- There are three basic forms of modulation:
  Amplitude modulation (AM)
  Frequency modulation (FM)
  Phase modulation (PM).
- Multiplexing schemes can be divided into two basic categories:
  FDM (Frequency Division Multiplexing) and
  TDM (Time Division Multiplexing)

Self-Assessment Questions

SAQ

- Define :
- Modulation
- Multiplexing
- Carrier
- With an appropriate diagram, describe FDM and TDM

Tutor Marked Assessment

- Differentiate between Amplitude, frequency and phase modulation
- Give three advantages of multiplexing
- Define modulation according to the IEEE.

Further Reading

- https://marketbusinessnews.com/telecommunications-definition-meaning/
- https://www.nap.edu/read/11711/chapter/3
- https://www.collinsdictionary.com/dictionary/english/telecommunications
- https://www.mitel.com/articles/history-telecommunication
- https://peda.net/kenya/css/subjects/computer-studies/form-three/driac2#

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- Telecommunication Planning, ITT Laboratories of Spain, Madrid 1973.
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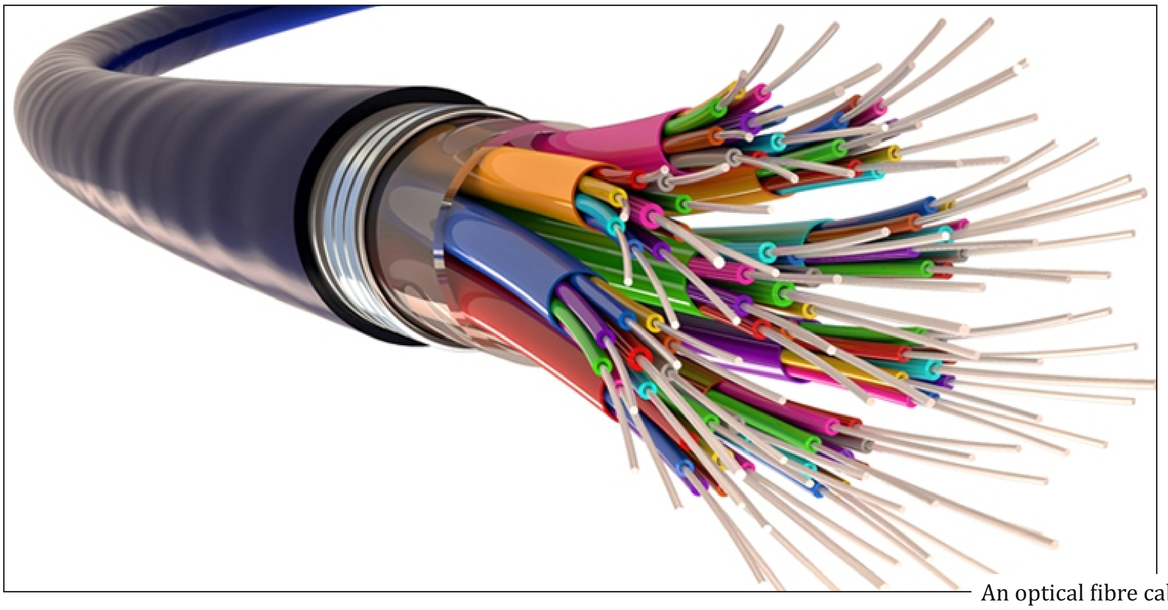
06 | Communication analysis using a Laptop.
source: iStock.com

Module 6:

SIGNALS AND TRANSMISSION

Unit 1: The Optical fiber cable

Unit 2: Optical Fiber Communication



An optical fibre cable
source: mctvohio.com

UNIT 1

The Optical Fiber Cable

Introduction

In this unit, you will be introduced to the basics of optical fiber communication.

Learning Outcomes

1. Define fiber optic cable
2. List and explain the parts of an optical fiber
3. List the components of an optical fiber
4. List the types of optical fiber

1 min

Transmission of Light through Fiber [SAQ 1]

Note that an optical fibers are made of glass, which, in turn, is made from sand, an inexpensive raw material available in limitless amounts. Ancient Egyptians were known as glassmakers, but their glass had to be no more than 1mm thick or the light could not shine through .Glass that is transparent enough to be useful for windows was developed during the Renaissance. Modern optical fibers glass used is so transparent that if the oceans were full of it instead of water, the sea bed would be as visible from the surface as the ground is from an airplane on a clear day.

Fiber Optics

An optical fiber can be understood as a dielectric waveguide, which operates at optical frequencies. The device or a tube, if bent or if terminated to radiate energy, is called a waveguide, in general. Unlike the coaxial, twisted-pair cables and wireless transmissions, the introduction of fiber-optics transmission has provided nearly infinite bandwidth, low loss, and outstanding performance in the communication system.

Light sources in Optical fiber

Two kinds of light sources are typically used to do the signaling in optical communication. These are:

LEDs (Light Emitting Diodes) and

Semi-conductor lasers.

They have different properties and can be tuned in wavelength by inserting Fabry-Perot or Mach-Zehnder interferometers between the source and the fiber. Fabry-Perot interferometers are simple resonant cavities consisting of two parallel mirrors. The light is incident perpendicular to the mirrors. The length of the cavity selects out those wavelengths that fit inside an integral number of times. Mach-Zehnder interferometers separate the light into two beams. The two beams travel at slightly different distances. They are recombined at the end and are in phase for only certain wavelengths.

Parts of a Fiber [SAQ 2, 3& 3]

3 mins

The most commonly used optical fiber is a single solid di-electric cylinder of radius a and index of refraction n1. The figure 3.1 explains the parts of an optical fiber.

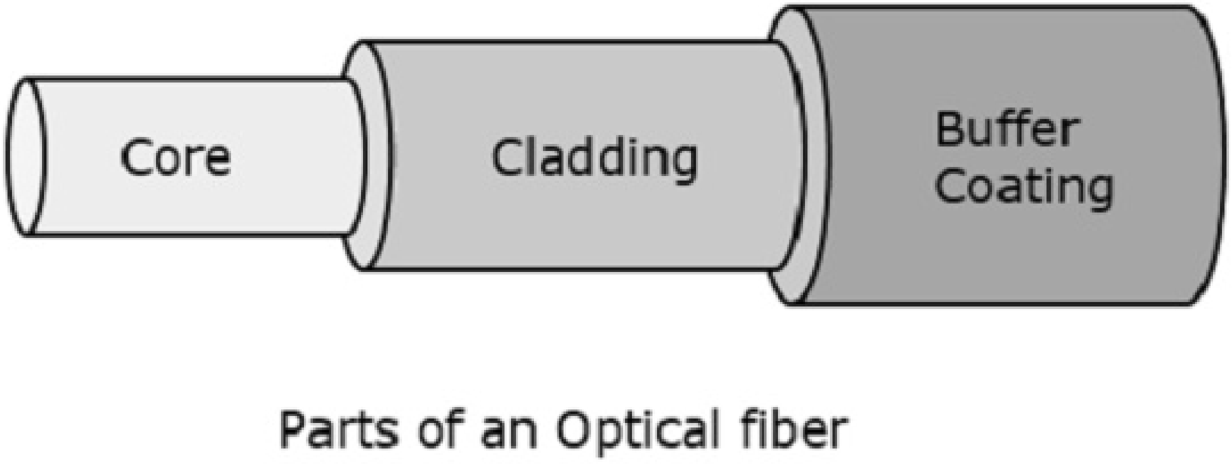


Figure 3.1: Parts of an optical fiber

This cylinder is known as the Core of the fiber. A solid dielectric material surrounds the core, which is known as Cladding. The cladding has a refractive index n2 which is less than n1.

Advantages of Cladding

Below are some of the advantages of cladding.

·It reduces scattering losses.

·Adds mechanical strength to the fiber.

·Protects the core from absorbing unwanted surface contaminants.

Components of the optical fiber

An optical transmission system has three key components which are:

·The light source,

·The transmission medium, and

·The detector.

Conventionally, a pulse of light indicates a 1 bit and the absence of light indicates a 0 bit.

The transmission medium is an ultra-thin fiber of glass. 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, we can obtain a unidirectional data transmission system that accepts an electrical signal, converts and transmits it by light pulses, and then reconverts the output to an electrical signal at the receiving end.The core is enclosed by a glass cladding with a lower refraction index than the core, to keep all the light in the core. Next comes a thin plastic jacket to protect the cladding.

Fibers are typically grouped in bundles, protected by an outer sheath. These fibers can be connected in three different ways. First, the connectors can be terminated and plugged into fiber sockets. Connectors lose about 10 to 20 percent of the light but make reconfiguration of systems easy. Second, they can be spliced mechanically. Mechanical splices just lay the two carefully-cut ends next to each other in a special sleeve and clamp them in place. Alignment can be improved by passing light through the junction and then making small adjustments to maximize the signal. Mechanical splices take trained personnel about 5 minutes and result in a 10 percent light loss.

Third, two pieces of fiber can be fused (melted) to form a solid connection.

A fusion splice is almost as good as a single drawn fiber, but even here, a small amount of attenuation occurs. For all three kinds of splices, reflections can occur at the point of the splice, and the reflected energy can interfere with the signal.

Types of Optical Fibers

Dependent upon the material composition of the core, there are two types of fibers used commonly. They are:

·**Step-index fiber :** The refractive index of the core is constant throughout and undergoes an abrupt change (or step) at the cladding boundary.

·**Graded-index fiber :** The core refractive index is made to vary as a function of the radial distance from the center of the fiber.

Both of these are further divided into :

·**Single-mode fiber –** These are excited with a laser.

·**Multi-mode fiber –** These are excited with LED.

Summary

In this unit, I have thought you the following:

- ·Fiber optic cable is a type of guided communication media which is made of glass and transmits signals with the speed of light
- The optical fiber consist of three basic components, namely:
  Light source
  Transmission medium and
  Detector
- The main types of optical fiber are
  Step-index fiber
  Graded-index fiber

Self-Assessment Questions

SAQ

- Define fiber optic cable
- List and explain the parts of an optical fiber
- List the components of optical fiber
- Mention the types of optical fiber

Tutor Marked Assessment

- List and explain the sources of light in optical fiber
- Explain the following as related to optical fiber:
  Waveguide
  Mechanical slice
  Fusion slice
- Differentiate between step-index fiber and graded-index fiber

Further Reading

- https://marketbusinessnews.com/telecommunications-definition-meaning/
- https://www.nap.edu/read/11711/chapter/3
- https://www.collinsdictionary.com/dictionary/english/telecommunications
- https://www.mitel.com/articles/history-telecommunication
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- Telecommunication Planning, ITT Laboratories of Spain, Madrid 1973.
- R. L. Freeman, Telecommunication System Engineering, 4th ed., Wiley, New York, 2004

A guide to fibre optic internet
source: iStock.com

UNIT 2

The Optical Fiber Communication

Introduction

In the previous unit you have learnt the basics of optical fiber communication, in this unit, you will be introduced to the concept of optical fiber in communication

Learning Outcomes

1. List the elements of an optical fiber
2. List differences between fiber optics and copper wire
3. List the functional advantages of optical fiber
4. List physical advantages of optical fiber

Optical Fiber Communication [SAQ 1, 2, 3, 4]

5 mins

It will intrest you to note that the communication system of fiber optics is well understood by studying the parts and sections of it. The major elements of an optical fiber communication system are shown in the following figure

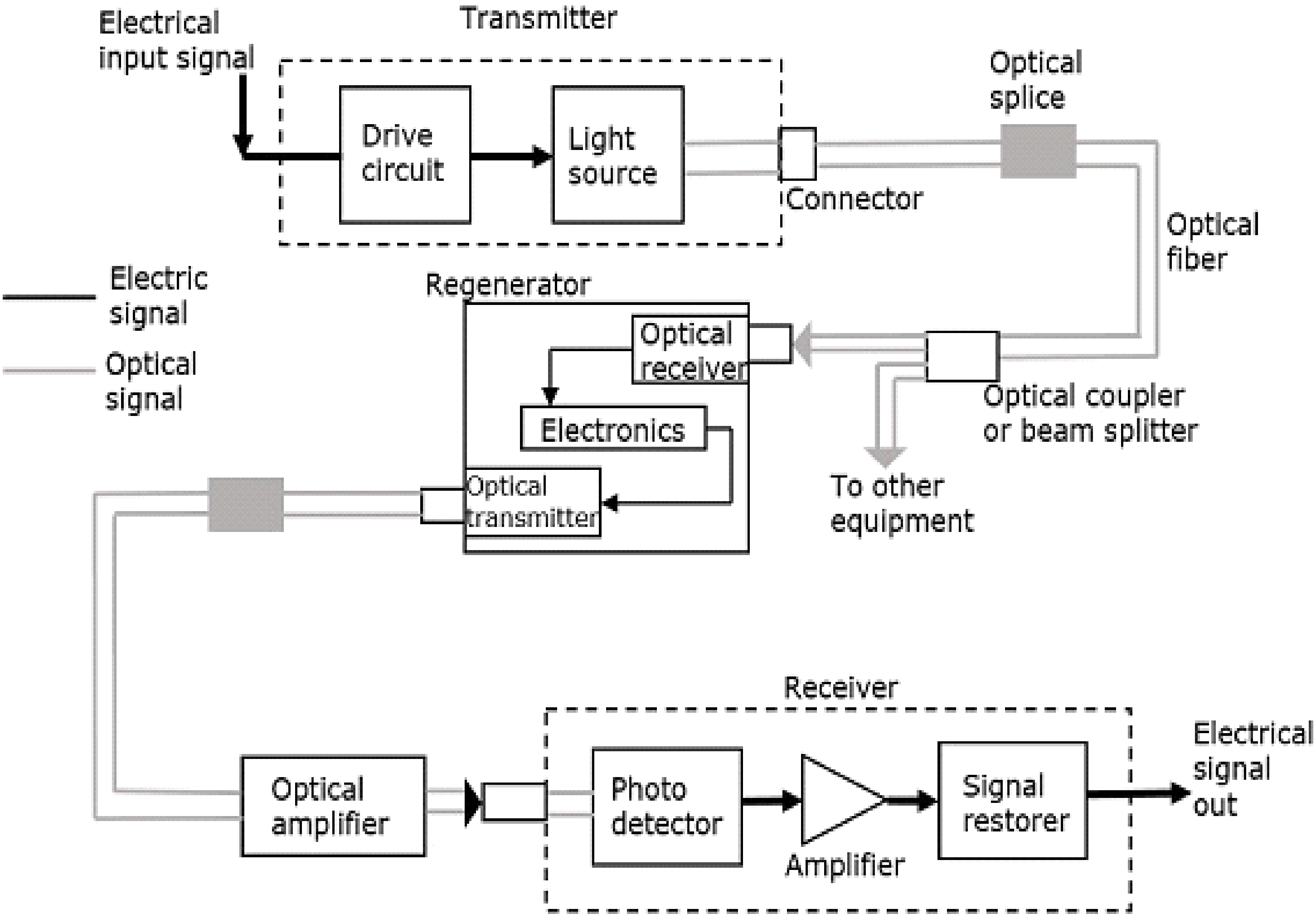

Figure 3.1: major elements of an optical fiber communication

The basic components are the light signal transmitter, the optical fiber, and the photo-detecting receiver. The additional elements such as fiber and cable splicers and connectors, regenerators, beam splitters, and optical amplifiers are employed to improve the performance of the communication system.

Fiber Optic Networks

Fiber optics can be used for LANs as well as for long-haul transmission, although connecting through it is more complex than connecting to an Ethernet.

Comparison of Fiber Optics and Copper Wire

It is instructive to compare fiber to copper. Fiber has many advantages. To start with, it can handle much higher bandwidths than copper. This alone would make it very useful in high-end networks. Due to the low attenuation, repeaters are needed only about every 50 km on long lines, unlike every 5 km for copper, a substantial cost saving. Fiber also has the advantage of not being affected by power surges, electromagnetic interference, or power failures. Nor is it affected by corrosive chemicals. Also, fiber is much lighter than copper, One thousand twisted pairs of 1 km long, weighs 8000 kg. Two fibers have more capacity and weigh only 100 kg, which greatly reduces the need for expensive mechanical support systems that must be maintained. For new routes, fiber is preferred due to its much lower installation cost. Finally, fibers do not leak light and are quite difficult to tap. These properties give fiber excellent security against potential wiretappers. On the other side, fiber is a new technology requiring special skills that only a few engineers have, and fibers can be damaged easily if not carefully bent. Since the optical transmission is inherently unidirectional, two-way communication requires either two fibers or two frequency bands on one fiber. Finally, fiber interfaces cost more than electrical interfaces. The electromagnetic energy travels through it in the form of light. The light propagation, along a waveguide, can be described in terms of a set of guided electromagnetic waves, called modes of the waveguide.

Advantages of Optical Fiber

The functional advantages of optical fibers are –

·The transmission bandwidth of the fiber optic cables is higher than the metal cables.

·The data transmission amount is higher in fiber optic cables.

The power loss is very low and hence helps in long-distance transmissions.

·Fiber optic cables provide high security and cannot be tapped.

·Fiber optic cables provide a more secure way for data transmission.

·Fiber optic cables are immune to electromagnetic interference.

·These are not affected by electrical noise.

Physical Advantages

The physical advantages of fiber optic cables are listed below:

·The capacity of these cables is much higher than copper wire cables.

·Though the capacity is higher, the size of the cable doesn't increase as it does in the copper wire cabling system.

·The space occupied by these cables is much less.

·The weight of these FOC cables is much lighter than the copper ones.

·Since these cables are di-electric, no spark hazards are present.

·These cables are more corrosion resistant than copper cables, as they are bent easily and are flexible.

·The raw material for the manufacture of fiber optic cables is glass, which is cheaper than copper.

·Fiber optic cables last longer than copper cables.

Disadvantages

Although fiber optics offer many advantages, they have the following drawbacks –

·Though fiber optic cables last longer, the installation cost is high.

·The number of repeaters is to be increased with distance.

·They are fragile if not enclosed in a plastic sheath. Hence, more protection is needed than copper ones.

Applications of Fiber Optics

The optical fibers have many applications. Some of them are as follows –

·Used in telephone systems

·Used in sub-marine cable networks

·Used in data link for computer networks, CATV Systems

·Used in CCTV surveillance cameras

·Used for connecting fire, police, and other emergency services.

·Used in hospitals, schools, and traffic management systems.

·They have many industrial uses and also used for heavy-duty constructions.

Summary

In this unit, I have thought you the following:

- Optical fiber consists of several components that make it perform better than other physical transmission media.
- The optical fiber cable has several advantages over copper wire
- Optical fiber has several applications such as in telephone systems, CCTV surveillance, and many other industrial applications.

Self-Assessment Questions

SAQ

- List the elements of an optical fiber
- List differences between fiber optics and copper wire
- List the functional advantages of optical fiber
- List physical advantages of optical fibe

Tutor Marked Assessment

- List and explain the elements of an optical fiber
- Explain the differences between fiber optics and copper wire
- List 4 functional advantages of optical fiber
- List 4 physical advantages of optical fiber

Further Reading

- https://marketbusinessnews.com/telecommunications-definition-meaning/
- https://www.nap.edu/read/11711/chapter/3
- https://www.collinsdictionary.com/dictionary/english/telecommunications
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