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Semester: Autumn 2026

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ALLAMA IQBAL OPEN UNIVERSITY, ISLAMABAD

(Department of Computer Science)

Course: Data Communication & Networks (3584) • Level: Postgraduate

Semester: Autumn 2026

Assignment No. 1

Total Marks: 100 • Pass Marks: 50

SOLVED ASSIGNMENT GUIDE — For Study & Reference

Note: This guide is prepared for study and reference purposes only. Students are advised to read the relevant parts of the course book, understand the concepts, redraw the diagrams and work through the examples themselves, and then write the assignment in their own words. Copying this guide word for word is not recommended. No units are printed in the question booklet for this course, so none are shown on this title page.

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Question 1: Communication Model versus Communication Task; Communication Models (20 Marks)

Question as printed: What is the difference between a communication model and a communication task? Elaborate on different communication models in detail. (20)

Introduction

Data communication is the exchange of data between two devices through some form of transmission medium, such as a wire cable, optical fibre or radio waves. Before the details of any real system can be studied sensibly, the subject needs two organising ideas. The first is a

communication model: a simplified picture that names the main parts of any communication system and shows how data flows between them. The second is the list of communication tasks: the actual jobs that must be performed inside that system if the exchange is to be reliable, efficient and secure. Confusing the two ideas is a common examination mistake. A model tells us what the pieces are and how they are arranged; a task list tells us what work has to be done. This answer first separates the two ideas clearly, then explains the simplified communication model, Shannon's model and the more general model used in modern networking, together with the key communication tasks that arise from them.

The Difference Between a Communication Model and a Communication Task

A communication model is an abstract, simplified representation of a communication system. It identifies the essential components — typically a source, a transmitter, a transmission system or channel, a receiver and a destination — and the direction in which information moves between them. Its purpose is understanding and design: by reducing a complicated real system, such as a telephone network or a computer network, to a handful of blocks, the model lets engineers discuss, compare and improve systems without being lost in detail. A model is therefore descriptive and structural. It answers the question: what are the parts, and how are they connected?

A communication task, by contrast, is a function or activity that must actually be performed for communication to succeed. Tasks include generating a signal that can travel over the medium, synchronising sender and receiver, detecting and correcting errors, controlling the flow of data so a slow receiver is not overwhelmed, addressing and routing, security, and managing the

network. A task list is therefore functional and operational. It answers the question: what must be done, and done correctly, for the model to work in practice? One and the same model gives rise to many tasks, and the difficulty of those tasks grows as the transmission system between the two devices becomes more complex — for example, when the simple link of the basic model is replaced by a whole network.

Table 1: Communication model versus communication task

Aspect	Communication model	Communication task
Nature	Abstract, simplified diagram or framework	A concrete function or job to be performed
Question it answers	What are the parts and how are they arranged?	What work must be done for communication to succeed?
Examples	Source, transmitter, channel, receiver, destination; Shannon's model; OSI layers	Signal generation, synchronisation, error detection and correction, flow control, addressing, routing, security
Purpose	Understanding, comparison and system design	Correct, efficient and reliable operation
Level	Structural — the skeleton of the system	Operational — the activities running on that skeleton

A useful analogy is a road journey. The map showing the starting city, the roads and the destination is the model. Driving, refuelling, following signposts, avoiding collisions and repairing a puncture are the tasks. Neither replaces the other: the map is useless without the

tasks being performed, and the tasks cannot be organised sensibly without the map. In exactly the same way, the designer of a data communication system first fixes a model and then assigns every necessary task to some part of that model.

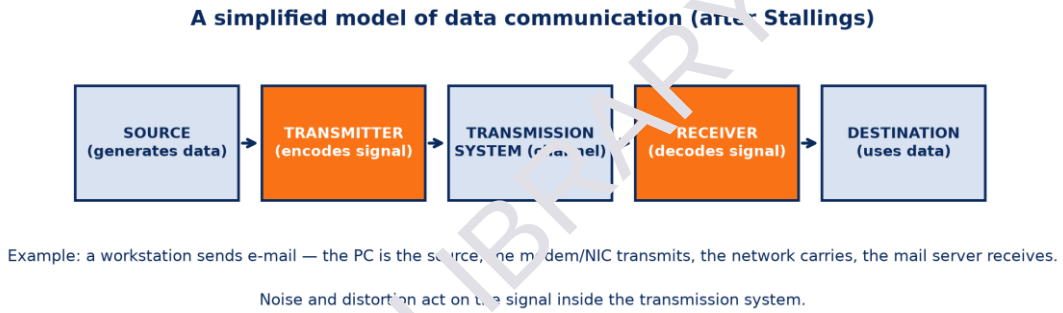

Figure 1: A simplified model of data communication: source, transmitter, transmission system, receiver and destination.

The Simplified Communication Model

The simplest useful model, presented in Stallings' Data and Computer Communications, contains five elements. The source generates the data to be transmitted; primary examples are telephones and personal computers. The transmitter transforms and encodes the information in such a way as to produce electromagnetic signals that can be transmitted across some sort of transmission system; a modem, which takes the digital data from a computer and produces an analogue signal for the telephone network, is the classic example. The transmission system can be a single transmission line or a complex network connecting source and destination. The receiver accepts the signal coming from the transmission system and converts it into a form that can be handled by the destination device. Finally, the destination takes the incoming data from the receiver. If a personal computer user wants to send an e-mail message to another

user, the sending PC is the source, its network interface or modem acts as transmitter, the network is the transmission system, the receiving mail server or PC performs the receiver's job, and the user who reads the message is the destination.

Two features of this simple model deserve emphasis. First, the transmitter and receiver are needed because the signal suitable for the source is rarely suitable for the medium: data inside a computer are digital and at low voltage, whereas a long line or a radio path needs a carefully shaped signal. Second, everything between the transmitter and the receiver — distance, noise, distortion and other users — is hidden inside the single block labelled transmission system. As that block grows from a short cable into a worldwide network, the tasks listed later in this answer multiply, but the five-part model itself still holds.

Shannon's Communication Model

Claude Shannon's 1948 model, developed at Bell Laboratories for telephony, is the ancestor of all later models and is still drawn in almost every textbook. Its elements are an information source, which selects the desired message out of many possible messages; a transmitter, which transforms the message into a signal suitable for the channel; the channel, the medium used to transmit the signal; a noise source, representing everything that distorts or adds to the signal on its way; a receiver, which reconstructs the message from the received signal; and a destination, the person or machine for whom the message is intended. Shannon's great contributions were to treat noise as a formal part of the model rather than as an afterthought, and to show mathematically that every channel has a capacity — a maximum rate, depending on its bandwidth and signal-to-noise ratio, at which information can be sent with arbitrarily few

errors. Warren Weaver later pointed out that the model also raises three levels of problem: the technical problem of accurate symbol transfer, the semantic problem of meaning, and the effectiveness problem of whether the received meaning produces the desired conduct. Data communication engineering concentrates mainly on the technical level, which is exactly the level the Shannon and Stallings models describe.

Other Models: Interactive, Transactional and Layered Models

Human-communication theorists extended Shannon's one-way picture in two directions that are also instructive for data networks. The interactive (or convergence) model adds a feedback path, so the receiver becomes a sender in turn and the two parties alternate roles; acknowledgements in data protocols are precisely this feedback made mechanical. The transactional model goes further: both parties send and receive simultaneously, and each message is shaped by context and by the parties' shared field of experience. Full-duplex data links, in which both ends transmit at the same time, behave in this transactional way.

For computer networks the most important elaboration of the basic model is the layered or protocol-architecture model, of which the OSI model in Question 3 is the best-known example. Instead of one transmitter block and one receiver block, each end is drawn as a stack of layers. Corresponding layers on the two machines are peers that communicate according to a protocol, while each layer uses the service of the layer below it. Layering does not contradict the simplified model; it refines the transmitter and receiver blocks so that the communication tasks can be allocated, one group per layer. A related refinement is the general model of a network itself, in which the transmission system is expanded into access networks and a core, with

switches and routers performing the routing task between the endpoints. Stallings also draws the model in a second, practical form — two PCs connected through a public telephone network or the Internet — to show that the same five blocks survive even when the transmission system is a shared public network used by millions of sources and destinations.

The Key Communication Tasks the Model Gives Rise To

Once the model is fixed, the tasks follow from asking, at each block and each interface, what can go wrong or what must be arranged. The standard list is as follows. Transmission system utilisation concerns making efficient use of facilities that are usually shared by many devices, using multiplexing and congestion control. Interfacing concerns the electrical, mechanical and functional rules by which a device connects to the transmission system. Signal generation concerns producing signals whose shape, strength and timing suit the medium and the data. Synchronisation requires the receiver to know when each signal element begins and ends, and when each block of data starts and finishes. Error detection and correction must cope with the noise that Shannon placed inside the model, using codes that reveal, and where possible repair, damaged bits. Flow control stops a fast sender overwhelming a slow receiver. Addressing and routing identify the intended destination among many, and choose a path through a network. Recovery restarts communication after a failure without losing or duplicating data. Message formatting agrees the format of the exchanged blocks. Security protects against unauthorised access, alteration and denial of service, and network management monitors, configures and repairs the whole system. Each of these tasks is examined in detail in later questions of these two assignments, which shows how a single short model generates the entire agenda of the subject.

Conclusion

To conclude, a communication model and a communication task are different kinds of idea. The model — whether the five-block simplified model, Shannon's noise-conscious model of 1948, the feedback-rich interactive and transactional models, or the layered protocol architecture — is the structural skeleton that names the parts and the flow between them. The tasks — signal generation, synchronisation, error control, flow control, addressing, routing, security and the rest — are the operational work that must be performed on that skeleton before any real message survives the journey. The examiner's distinction matters because good answers, and good systems, keep the two apart: draw the model first, then assign each task to the part of the model responsible for it.

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Question 2: Signals; Time Domain and Frequency Domain; Guided and Unguided Media (20 Marks)

Question as printed: Define signal? Differentiate between the time domain and the frequency domain. What is the difference between guided and unguided transmission media? (20)

Introduction

Everything a data communication system moves is carried by a signal. Data — the facts, text, numbers, pictures and sounds the users care about — cannot travel down a cable or through the air by themselves; they must first be encoded into a form suited to the medium, and that travelling form is the signal. How engineers describe signals, in the time domain or in the frequency domain, decides which properties of a signal they can see and control, while the

choice between guided and unguided media decides how the signal is physically carried. This answer defines a signal, contrasts the two domains carefully, and then distinguishes guided from unguided transmission media.

What Is a Signal?

A signal is a physical quantity — most commonly a voltage, a current, a pattern of light or an electromagnetic wave — that varies with time and is deliberately made to represent data. Formally, a signal can be written as a function of time, g(t), whose variations follow agreed rules so that the receiver, observing those variations, can recover the original data. Signals are analogue or digital. An analogue signal is a continuously varying electromagnetic wave that can be propagated over a variety of media; its amplitude, frequency and phase can take a continuous range of values, as in the human voice. A digital signal is a sequence of voltage (or light) pulses, each representing one or more bits, that can be transmitted only over certain media such as wire or fibre. Three characteristics describe a wave from which signals are built: amplitude, the height or strength of the wave; frequency, the number of cycles completed per second, measured in hertz; and phase, the position of the wave within its cycle. Changing any one of these in a controlled pattern is how data are impressed on a carrier, and a signal that repeats itself is periodic, with a period equal to the time for one cycle. The rate at which signal elements change is closely related to the data rate a channel can support, which is why signals, and not raw data, are the currency of the physical layer.

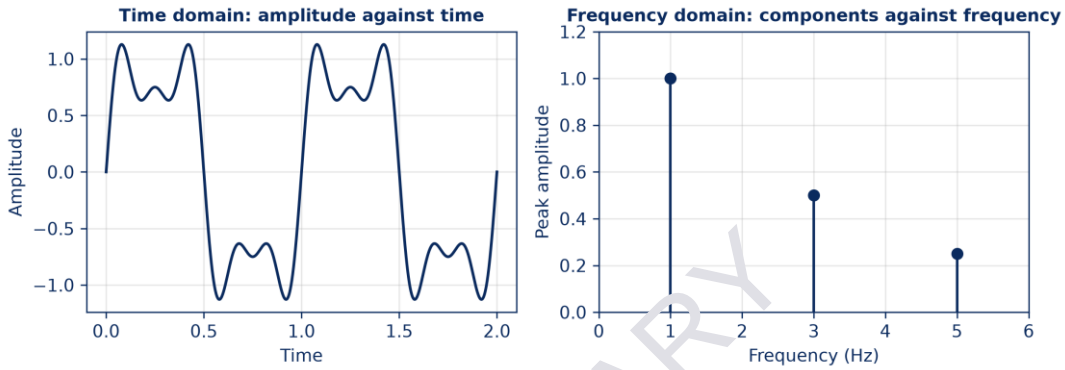

Figure 1: The same composite signal shown in the time domain (left) and the frequency domain (right).

Time Domain versus Frequency Domain

In the time-domain view, a signal is described by watching how its amplitude changes as time passes — exactly what an oscilloscope draws. This view answers questions such as: how strong is the signal at this instant, when does each pulse start and finish, and how long does one cycle last? Time-domain concepts include amplitude, period and phase, and the time-domain picture is the natural one for digital signalling, where the sequence of pulses in time is the message itself.

In the frequency-domain view, the same signal is described by listing the sine waves of different frequencies from which it is composed. The French mathematician Fourier showed that any periodic signal can be built by adding sine and cosine waves of different frequencies, amplitudes and phases, and that even non-periodic signals can be analysed in this way. Plotting the amplitude of each frequency component gives the signal's spectrum; the range of frequencies it occupies is its bandwidth. This view answers different questions: which frequencies must the channel pass undistorted, how much bandwidth does the signal need, and what happens if part of its spectrum is cut off? The two domains are not two different signals

but two descriptions of one signal. A square-wave digital pulse, innocent in the time domain, turns out in the frequency domain to contain components stretching to very high frequencies — which is why a channel of limited bandwidth rounds its corners and why bandwidth, a frequency-domain idea, limits the achievable data rate. Engineers constantly move between the two views, designing in whichever domain makes the problem clearer.

Table 1: Time domain versus frequency domain

Aspect	Time domain	Frequency domain
Signal shown as	Amplitude varying with time, g(t)	Amplitude (and phase) of each frequency component
Typical instrument / plot	Oscilloscope trace	Spectrum analyser plot / spectrum diagram
Key concepts	Amplitude, period, phase, pulse duration	Spectrum, bandwidth, fundamental frequency, harmonics
Natural for	Digital pulses, timing, synchronisation	Bandwidth limits, filtering, multiplexing, modulation
Question answered	What does the signal look like moment by moment?	Which frequencies does the signal contain, and how much bandwidth does it need?

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Guided and Unguided Transmission Media

Transmission media fall into two broad classes according to whether the signal is physically confined. In guided media, the electromagnetic waves are guided along a solid physical path: twisted-pair copper cable, coaxial cable and optical fibre are the standard examples, and Questions 4 of this assignment discusses the last two in detail. Because the path is made by the installer, its characteristics — length, material and quality — are controlled and predictable; capacity and distance depend on the medium itself, on interference picked up along the way, and on the number of receivers attached. Guided media dominate inside buildings and for fixed point-to-point links, where laying a cable is practical and where privacy and predictable performance matter.

In unguided media, usually called wireless, the waves are transmitted through the atmosphere, outer space or water but are not confined to any path. Antennas launch and capture the waves, and the properties of transmission are governed far more by the frequency band used than by the medium itself. Low-frequency signals radiate in all directions and follow the earth's surface; higher-frequency signals travel in straight lines, can be focused into narrow beams by dish antennas, and are blocked by obstacles and absorbed by rain. Terrestrial and satellite microwave, infrared and broadcast radio are unguided examples. Unguided transmission is the only choice when the endpoints move, when terrain makes cables impossible, or when one transmitter must reach many receivers at once, as in broadcasting and mobile telephony.

Table 2: Guided versus unguided transmission media

Feature	Guided media	Unguided media

Path of the signal	Confined to a physical cable or fibre	Radiated through free space, air or water
Examples	Twisted pair, coaxial cable, optical fibre	Terrestrial microwave, satellite microwave, broadcast radio, infrared
Direction	Point-to-point along the path (or multipoint on a shared cable)	Omnidirectional at low frequencies; focused beams at microwave frequencies
Control of quality	High – the medium is installed and owned	Lower — weather, obstacles and other users affect the path
Security	Better — access requires physical tapping	Weaker — anyone in range can receive; encryption is essential
Mobility / reach	Endpoints are fixed to the cable	Supports mobile users and very long or broadcast reach
Cost pattern	Cable and installation cost grow with distance	Tower, antenna and spectrum costs dominate

The contrast can be summarised in one sentence: in guided media the engineer builds the road, whereas in unguided media the engineer must share the open air. Each choice also interacts with the domain discussion above. A guided medium such as twisted pair passes only a limited band of frequencies, so its usable bandwidth shrinks as the cable lengthens, whereas an unguided microwave link is allocated a band by regulation and must fit its signal, using modulation, inside that band.

Conclusion

To conclude, a signal is the time-varying physical representation of data, described by amplitude, frequency and phase. The time domain shows that signal moment by moment and suits timing and pulse questions; the frequency domain decomposes it into its spectrum and suits bandwidth, filtering and multiplexing questions — two views of the same reality. Guided media confine the signal to a manufactured path with predictable, private behaviour, while unguided media radiate it through space, trading control for mobility and reach. Every later topic in data communication — modulation, multiplexing, media selection and error behaviour — is an application of these three distinctions.

Question 3: Protocols and the OSI Model, with an Example (20 Marks)

Question as printed: What is protocol? Explain the OSI stack model in detail with an example. (20)

Introduction

Two computers can exchange bits over a cable and still fail to communicate, just as two people can hear each other's voices and still fail to hold a conversation because they share no language. What turns raw transmission into communication is a protocol: the agreed rules that govern the exchange. Because a complete network involves too many rules for one monolithic design, the rules are organised into layers, and the most famous layered framework is the OSI (Open Systems Interconnection) model of the International Organization for Standardization. This answer defines a protocol and its elements, explains all seven OSI layers in detail, and then

traces one concrete example — sending and receiving through the layers — so that the abstract stack becomes a working story.

What Is a Protocol?

A protocol is a set of rules that governs data communication; it defines what is communicated, how it is communicated and when it is communicated. In data communication the term is used for the agreements between the corresponding (peer) entities at each layer of two communicating systems. Every protocol has three key elements. Syntax refers to the structure or format of the data — the order in which fields appear in a block, which bits are the address, which are control information and which are the payload. Semantics refers to the meaning of each section of bits: what a particular control code requests, what action the receiver must take, and how errors are to be reported. Timing refers to when data should be sent and how fast: it covers speed matching between a fast sender and a slow receiver, and sequencing, so that blocks arrive and are processed in the right order. A protocol is implemented in hardware, in software, or in a combination of both, and modern networks never rely on a single protocol: they use a protocol stack or suite, such as TCP/IP, in which each layer contributes its own protocol to one stage of the overall job. The key point for the examination is that communication succeeds only when both ends implement the same protocols — which is why standards bodies such as ISO, IEEE and the IETF matter so much.

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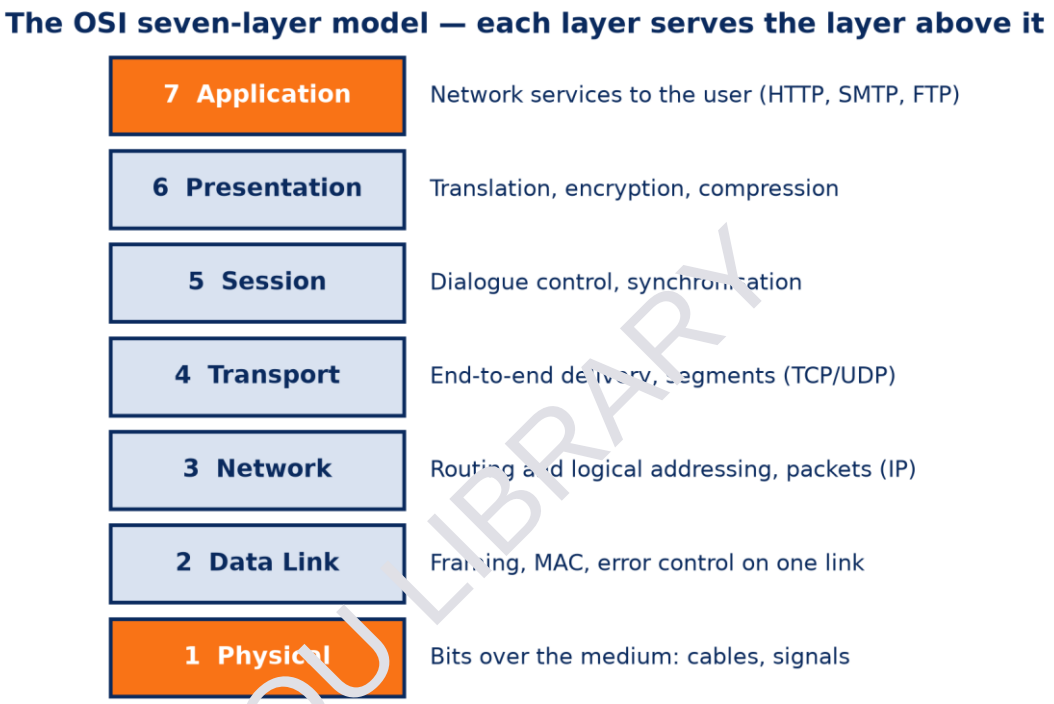

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Figure 1: The seven layers of the OSI model, from physical transmission to application services.

The OSI Model: Layer by Layer

The OSI model, published by ISO in the early 1980s, divides communication into seven layers. Within one system, each layer provides services to the layer above it and uses the services of the layer below; between two systems, each layer communicates logically with its peer layer on the other machine using that layer's protocol. As data pass down the sending stack, each layer typically adds its own header — the process of encapsulation — and the receiving stack removes the headers in the reverse order. The three lowest layers are often called the media or network-support layers, the top three the user-support layers, and the transport layer links the two groups.

Layer 1, the Physical layer, is responsible for transmitting the individual bits of a frame over the communication channel as raw signals. It defines the mechanical and electrical specifications of the interface and the transmission medium: connectors and pin assignments, voltages and light levels, data rate, synchronisation of bits, line configuration, physical topology and transmission mode (simplex, half-duplex or full-duplex). It has no knowledge of frames or addresses — it simply moves a stream of bits, and it is where the signals and media of Questions 2 and 4 live.

Layer 2, the Data Link layer, turns the unreliable bit pipe of layer 1 into a link that appears (nearly) error-free to the layer above. It organises bits into frames, adds physical (MAC) addressing so that a frame reaches the right device on the local link, performs error detection and often error correction for that single hop, controls the flow of frames between two directly connected devices, and — where the medium is shared — controls access to it through protocols such as CSMA/CD. Ethernet and PPP are data-link technologies, and switches and bridges are layer-2 devices.

Layer 3, the Network layer, is responsible for the delivery of individual packets from the original source to the final destination, possibly across many interconnected networks. It provides logical addressing (IP addresses in the TCP/IP world), and its central task is routing: choosing, hop by hop or end to end, the path each packet follows through routers. Where the data-link layer moves a frame across one link, the network layer moves a packet across the whole internetwork; routers are layer-3 devices.

Layer 4, the Transport layer, is responsible for process-to-process delivery of the entire message. It adds port numbers so data reach the correct application program, segments a long message at the sender and reassembles it at the receiver, and offers connection-oriented

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reliable service (as TCP does, with acknowledgements, retransmission, flow control and error control end to end) or a simpler connectionless service (as UDP does). It is the first truly end-to-end layer: intermediate routers do not participate in it.

Layer 5, the Session layer, establishes, manages and terminates the dialogue between two applications. It provides dialogue control (deciding whose turn it is to transmit, in half-duplex exchanges) and synchronisation, inserting checkpoints into a long transfer so that, after a failure, transmission resumes from the last checkpoint instead of from the beginning. Layer 6, the Presentation layer, is concerned with the syntax and semantics of the information exchanged: it translates between the format the application uses and a common network format, encrypts and decrypts data for security, and compresses data to reduce the number of bits that must travel. Layer 7, the Application layer, is the window through which users and application processes access the network: it provides services such as electronic mail (SMTP), file transfer (FTP), web access (HTTP), remote login and directory services, and it identifies communication partners and checks resource availability.

Table 1: The OSI layers at a glance

Layer	Name	Unit of data	Main responsibility	Example protocol / device
7	Application	Message / data	Services directly to users and applications	HTTP, SMTP, FTP
6	Presentation	Data	Translation, encryption,	TLS formatting, JPEG,

			compression	ASCII/Unicode conversion
5	Session	Data	Dialogue control and synchronisation checkpoints	Session management in RPC / NetBIOS
4	Transport	Segment	Process-to-process delivery, reliability	TCP, UDP
3	Network	Packet	Logical addressing and routing across networks	IP; routers
2	Data Link	Frame	Framing, MAC addressing, error control on one link	Ethernet; switches, bridges
1	Physical	Bit	Raw bit transmission over the medium	Cables, fibre, radio; hubs, repeaters

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An Example Through the Layers: Sending an E-mail / Opening a Web Page

Consider a student who writes an e-mail in a mail program and clicks Send. At the application layer the mail protocol (SMTP) formats the message with its headers — sender, recipient,

subject — and hands it down. The presentation layer ensures the text is in a character code the far end can read and may encrypt the connection's content; the session layer maintains the ongoing dialogue with the mail server. The transport layer (TCP) divides the message into segments, numbers them, and accepts responsibility for delivering every one, in order, re-sending any that are lost. The network layer (IP) wraps each segment into a packet addressed to the destination mail server and routes it across the Internet, through several routers, each making an independent forwarding decision. On every single hop, the data-link layer wraps the packet in a frame bearing the MAC address of the next device on that link and adds an error-check trailer; the physical layer then sends the frame's bits as pulses of light or voltage. At the destination the process runs in reverse: bits become frames, frames shed their headers layer by layer, TCP reassembles the message in order, and the recipient's mail application finally presents the identical message. Notice the peer logic: the sender's transport layer 'converses' with the receiver's transport layer through the segment headers, even though the segments physically travel up and down both stacks and across every intermediate link. This example also exposes the honest limitation of OSI: real Internet systems implement the TCP/IP suite, in which the session and presentation functions are usually absorbed into the application layer, but OSI remains the reference vocabulary in which all networking is taught and compared.

Conclusion

To conclude, a protocol is the rulebook — syntax, semantics and timing — that lets two entities communicate, and layering is how a large rulebook is divided into manageable chapters. The OSI model defines seven such layers, from the physical movement of bits, through framing, routing and end-to-end transport, up to dialogue management, data representation and user

services. The e-mail example shows the model at work: encapsulation on the way down, peer-to-peer logic across, and orderly unpacking on the way up. Even where practice follows TCP/IP rather than OSI itself, the seven-layer framework remains the standard map of where every protocol and every networking device belongs.

Question 4: Short Notes — Attenuation, Delay Distortion, Coaxial Cable, Optical Fiber (20 Marks)

Question as printed: Write a short note on each of the following: (20) (a) Attenuation (b) Delay distortion (c) Coaxial Cable (d) Optical Fiber

Introduction

This question joins the two sides of physical transmission. Attenuation and delay distortion are impairments — things the medium does to a signal that the engineer must measure and counteract. Coaxial cable and optical fibre are guided media — two of the physical paths built to carry signals while keeping those impairments tolerable. Each note below defines its topic, explains the underlying mechanism, and states the practical consequences for system design.

(a) Attenuation

Attenuation is the loss of signal strength (energy) as a signal travels through a transmission medium. Resistance in a copper conductor converts some of the signal's energy into heat, and in any medium the signal spreads and weakens with distance, so the received signal is always weaker than the transmitted one. The loss is measured in decibels (dB), a logarithmic unit: the attenuation in dB is ten times the logarithm of the ratio of transmitted power to received

power. A loss of 3 dB means roughly half the power has gone; 10 dB means only a tenth remains. Attenuation matters for three reasons. First, the received signal must remain strong enough to be detected above the noise — below that threshold, errors become unavoidable. Second, attenuation increases with frequency, so the high-frequency components of a signal are weakened more than the low ones, which distorts the signal's shape as well as its size. Third, it fixes the maximum useful length of a cable run. Two remedies are standard: amplifiers, which boost an analogue signal (and, unavoidably, the noise travelling with it), and repeaters, which receive a digital signal, regenerate clean fresh pulses from it, and retransmit those — which is why digital systems tolerate much longer distances. Equalisers are also used to compensate for the frequency-dependent part of the loss over a band, flattening the overall response.

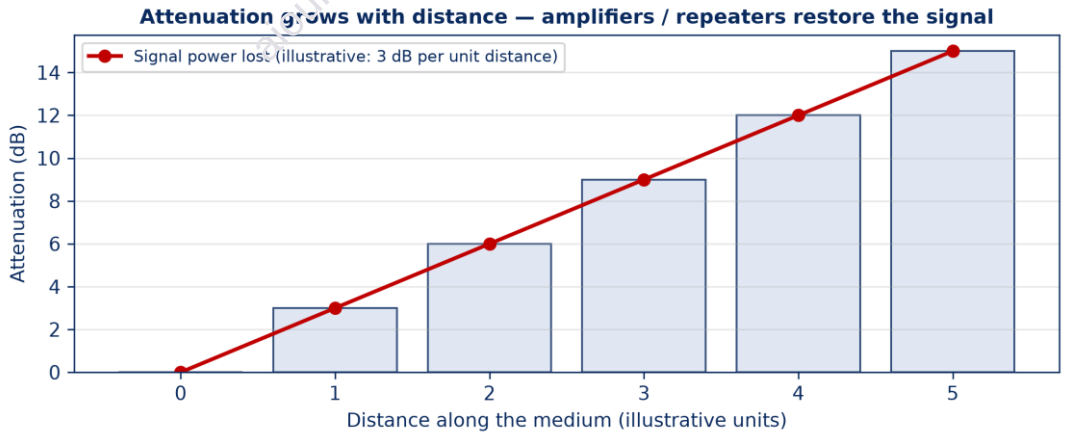

Figure 1: Attenuation increases steadily with distance; repeaters or amplifiers must intervene before the signal falls into the noise.

(b) Delay Distortion

Delay distortion (also called phase or envelope-delay distortion) occurs because the propagation velocity of a signal through a guided medium varies with frequency. The different frequency components of one signal therefore do not all arrive together: some are delayed more than others, so the components are received out of the phase relationship they had when transmitted, and the received waveform is distorted. The effect is most serious for digital data. A bit is represented by a pulse containing many frequency components; if those components arrive smeared out in time, the energy of one pulse spills into the time slot of the next, a phenomenon called intersymbol interference, and the receiver may read the wrong bit values. Delay distortion grows worse near the edges of a channel's usable band, where the delay-versus-frequency curve is least flat, and it is one of the factors that cap the maximum bit rate of a given cable: pushing more bits per second into the same band uses wider frequency ranges and invites exactly this smearing. In telephone and modem engineering the distortion is countered with equalisation — filters that deliberately delay the fast components so that all components are delayed by the same amount — and with line conditioning that guarantees a flatter delay characteristic across the band used.

(c) Coaxial Cable

Coaxial cable ('coax') consists of two conductors sharing a single common axis. The inner conductor, a solid or stranded copper wire, carries the signal; around it lies a layer of insulating dielectric; around that is the outer conductor, a braided copper mesh or foil that acts both as the return path and as a shield against external electromagnetic interference; and an outer

plastic jacket protects the whole assembly. Because the signal is enclosed by its own shield, coaxial cable can support much higher frequencies and data rates, with far less interference and crosstalk, than twisted pair of similar size, though it is bulkier and more expensive. Two families are traditional: baseband coax (50-ohm), once the standard medium of early Ethernet LANs (10BASE5 and 10BASE2), carrying one digital channel at a time; and broadband coax (75-ohm), used for decades by cable television, which divides its wide bandwidth by frequency-division multiplexing into many analogue channels. Modern uses include cable-TV distribution and cable-Internet access, CCTV, and short high-frequency equipment interconnects. Its honest limitations are bulk, cost relative to twisted pair, and the fact that, being copper, it still suffers attenuation that rises sharply with frequency and remains vulnerable over very long distances.

(d) Optical Fiber

Optical fibre transmits data not as electricity but as pulses of light. A fibre is a hair-thin strand of glass or plastic built in three concentric parts: the core, through which the light travels; the cladding, a layer of material with a lower refractive index that, by total internal reflection, keeps the light bouncing inside the core; and a protective buffer coating and jacket. At the sending end an electrical signal drives a light source — an LED for cheaper, shorter links or a laser diode for longer, faster ones — and at the receiving end a photodetector converts the returning light pulses back into an electrical signal. Fibres are used in three propagation modes: multimode step-index, multimode graded-index, in which many rays ('modes') take paths of different lengths, and single-mode, whose very narrow core admits essentially one path and so supports the highest rates over the longest distances — the mode of long-haul telecommunication backbones. The advantages are decisive: enormous bandwidth and data

rates, very low attenuation (allowing tens of kilometres between repeaters), immunity to electromagnetic interference and crosstalk, small size and light weight, and high security, since a fibre is very difficult to tap without detection. Its disadvantages are higher cost of the fibre and its connectors, the need for skilled splicing and alignment, and unidirectional transmission, so two strands are normally installed for full-duplex working. Fibre is today the default medium for network backbones, metropolitan and long-haul links, and increasingly for access networks in the form of fibre-to-the-home.

Table 1: Coaxial cable versus optical fiber

Feature	Coaxial cable	Optical fiber
Signal carried	Electrical (radio-frequency) energy on copper	Pulses of light in glass/plastic
Construction	Inner copper conductor, dielectric, braided shield, jacket	Core, cladding (total internal reflection), buffer/jacket
Interference	Shielded — good resistance, not immune	Immune to electromagnetic interference
Attenuation / distance	Moderate; rises steeply with frequency	Very low; tens of km between repeaters in single-mode
Bandwidth	High (hundreds of MHz class)	Very high (far beyond copper media)
Typical uses	Cable TV, cable Internet, CCTV, legacy Ethernet	Backbones, long-haul telecom, FTTH, high-speed data centres
Weakness	Bulk, copper limits, tap-able	Cost, fragile splicing, one-way per strand

Conclusion

In summary, attenuation is the progressive loss of signal power with distance, countered by amplifiers for analogue signals and regenerating repeaters for digital ones; delay distortion is the frequency-dependent delay that smears pulses into one another and limits bit rate. Coaxial cable answers these problems with a shielded copper construction that serves television and access networks well, while optical fibre answers them far more completely — light confined by total internal reflection gives huge bandwidth, low loss and immunity to interference — which is why fibre, despite its cost and handling demands, has become the medium of serious long-distance communication.

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Question 5: Digital Data versus Digital Signal; Terrestrial and Satellite Microwave (20 Marks)

Question as printed: Differentiate between digital data and digital signal? Also, explain terrestrial & Satellite Microwave in detail. (20)

Introduction

The final question of this assignment links a distinction of meaning with two wireless technologies. Digital data and digital signal sound alike but belong to different stages of a communication system: one is what the user produces, the other is what the medium carries. Getting the distinction right prevents a whole family of confusions — for example, the false belief that digital data can only travel as digital signals. Terrestrial microwave and satellite

microwave then show the unguided side of the subject: both send focused radio beams, but one hops between towers on the ground while the other relays through a satellite in orbit.

Digital Data versus Digital Signal

Digital data are data represented in discrete form: a finite set of values, most practically the binary digits 0 and 1 produced by computers, digital telephones, scanned documents and digitised media. Text stored as character codes, numbers in binary registers and the output of an analogue-to-digital converter are all digital data. Digital data exist as information — stored in memory, processed by programs — and they have no physical form of their own; to move, they must be encoded.

A digital signal is the physical encoding used to carry such data over a medium: a sequence of discrete, discontinuous voltage (or light) pulses, in which each signal element represents one or more bits. In the simplest encoding, one voltage level represents binary 0 and another represents binary 1. The signal, unlike the data, is a physical event in time: it has amplitude, duration and a rate of change (its signalling or baud rate), it suffers attenuation and noise on its journey, and it ceases to exist when transmission ends. Data are encoded into a digital signal by schemes such as NRZ, Manchester and differential Manchester, which differ in their synchronisation, bandwidth and error properties — a whole design topic that exists only because data and signal are different things.

The distinction is proved by the two cross-combinations. Digital data can be carried by an analogue signal: a modem converts computer data into tones for an analogue telephone line, and digital cable channels ride on analogue carriers. Analogue data can be carried by a digital

signal: the human voice is digitised by a codec in PCM (pulse code modulation) and then travels the telephone backbone as pulses. Data describe content; signals describe carriage. It also follows that their quality measures differ: digital data are judged by correctness and completeness, a digital signal by its levels, timing, noise margin and the bit error rate it sustains on a real medium. Their storage behaviour differs too – data persist in files, whereas a signal exists only while it is being transmitted, and must be regenerated by repeaters rather than amplified if its shape is to survive a long journey.

Table 1: Digital data versus digital signal

Aspect	Digital data	Digital signal
What it is	Information in discrete (binary) form	Physical pulses that encode and carry data
Exists where	In memory, files, processor registers	On the transmission medium, during transmission only
Form	Bits — 0s and 1s with agreed meaning (codes)	Voltage or light levels changing in time
Created by	Computers, digitisers (ADC), user input	Transmitter encoding the data (line coding)
Quality judged by	Correctness, completeness of the information	Noise margin, timing, bit error rate
On a long path	Stored and forwarded unchanged as content	Regenerated by repeaters to restore pulse shape
Counterpart	Can also be sent as an analogue signal (modem)	Can also carry analogue data after digitisation (PCM)

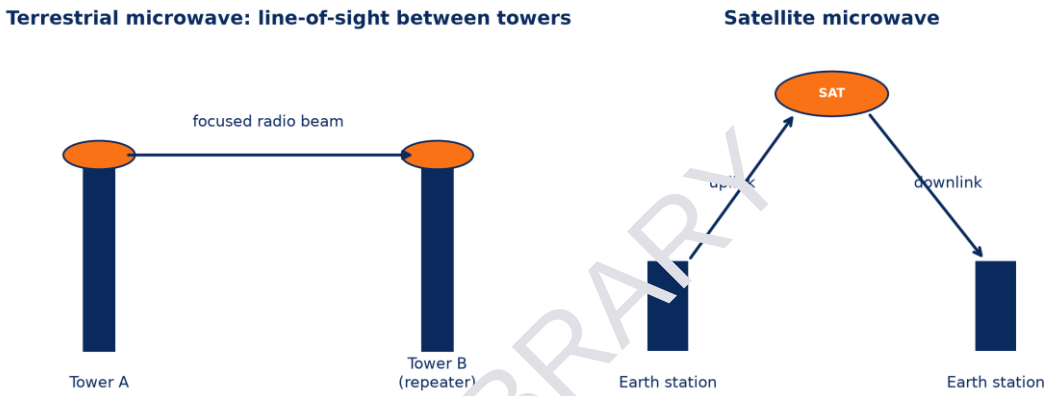

Figure 1: Terrestrial microwave hops between line-of-sight towers; satellite microwave relays through an orbiting transponder.

Terrestrial Microwave

Terrestrial microwave is a guided-by-geometry unguided system: it transmits a narrow, focused beam of radio waves, typically in the 2 to 40 GHz range, between parabolic dish antennas mounted on towers, rooftops or hills. Because microwaves at these frequencies travel in straight lines and cannot pass through obstacles, transmission is strictly line-of-sight: the two antennas must see each other, which limits a single hop to roughly 25–50 km depending on tower height and terrain, and long routes are built as chains of repeater towers, each receiving, amplifying (or regenerating) and retransmitting the beam to the next. The capacity of a microwave link is generous — its wide assigned bandwidth supports high data rates — and the system avoids the cost and delay of digging cable over difficult terrain, across rivers or between cities. Its weaknesses follow from the physics: the beam is absorbed and scattered by rain and fog (rain fade, worse at higher frequencies), can be refracted or reflected into multipath paths

that arrive out of phase, needs licensed spectrum and precise antenna alignment, and, being a beam in open air, can be intercepted, so encryption is prudent. Classic uses are long-haul telecommunication trunks (historically the backbone before fibre), cellular backhaul connecting base stations, links across water or mountains, and private enterprise links between buildings.

Satellite Microwave

Satellite microwave replaces the tower chain with a single relay in the sky. A communications satellite in geostationary orbit — about 35,786 km above the equator, orbiting at the same rate as the earth's rotation so that it appears fixed in the sky — carries transponders that receive a signal from an earth station on one frequency (the uplink, classically 6 GHz in the C band), amplify it, shift it to a different frequency and retransmit it (the downlink, classically 4 GHz) over a wide footprint covering a continent-sized area. Because the satellite simply relays between any earth stations inside its footprint, a satellite link behaves as a microwave link bent in the middle: point-to-point between two stations, or, more distinctively, as a broadcast medium in which one uplink is received by thousands of downlink stations, which is why satellite is natural for television distribution. The strengths are coverage and independence of terrain: oceans, deserts, mountains and disaster zones are all equally reachable, and the cost of a channel depends on distance hardly at all. The weaknesses are equally physical: the round trip of roughly 72,000 km introduces a propagation delay of about a quarter of a second, noticeable in voice conversation and demanding care in protocols; the signal spreads and weakens over the huge path, requiring sensitive antennas and error control; satellites are expensive to build and launch, have a working life of roughly 10–15 years, occupy regulated orbital slots and frequency bands, and their wide footprint makes encryption essential. Modern systems also

use lower orbits (LEO and MEO constellations) to cut delay for data services, trading the single fixed relay for fleets of fast-moving satellites and more complex hand-over.

Table 2: Terrestrial versus satellite microwave

Feature	Terrestrial microwave	Satellite microwave
Relay	Towers on the ground, hop by hop	Transponder on a satellite (usually geostationary)
Path	Line-of-sight, about 25–50 km per hop	Uplink + downlink, about 72,000 km round trip
Propagation delay	Tiny (microseconds per hop)	About 0.25–0.27 seconds round trip (GEO)
Coverage pattern	A chain along one route	A footprint covering up to a third of the earth
Broadcast ability	Essentially point-to-point	Natural broadcast / multicast to many earth stations
Main impairments	Rain fade, multipath, obstruction of the path	Huge path loss, delay, footprint interception
Cost pattern	Towers and land along the route	Satellite and launch dominate; distance-insensitive channels
Typical uses	Telecom trunks, cellular backhaul, inter-building links	TV distribution, remote/oceanic links, VSAT networks, disaster recovery

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Conclusion

To conclude, digital data are the discrete information a system exists to move, while a digital signal is the train of physical pulses that actually moves it — and the modem and PCM codec prove the two are independent choices. Of the two microwave systems, terrestrial microwave focuses its beam between nearby towers and repeats it hop by hop, giving high capacity with negligible delay along a fixed route, whereas satellite microwave lifts the relay into orbit, gaining continental coverage and true broadcast ability at the price of a quarter-second delay and an expensive space segment. Together they show the engineering pattern of this whole assignment: understand the signal, respect the medium, and choose the design whose strengths match the problem.

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