Digital & Data Communication (4343201) - Winter 2024 Solution

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Question 1(a) [3 marks]

Differentiate Basic modes of Communication: Broad casting communication and Point to Point Communication.

Solution

Table 1. Broadcasting vs Point-to-Point

Parameter	Broadcasting Communication	Point to Point Communication
Definition	One transmitter sends signals to multiple receivers simultaneously	One transmitter communicates with one specific receiver
Direction	Unidirectional (one-way)	Bidirectional (two-way)
Examples	TV, Radio, FM	Telephone, Mobile calls, Private networks
Privacy	Low (signal available to everyone in range)	High (dedicated connection between endpoints)
Efficiency	High for mass communication	Better for personal/private communication

- **Broadcasting**: Targeted at mass audience (One-to-Many).
- **Point-to-Point**: Targeted at specific individual (One-to-One).

Mnemonic

"BDPEC - Broadcasting Distributes to Public, Endpoints Connect in point-to-point"

Question 1(b) [4 marks]

Define: Bit Rate, Baud Rate, Bandwidth and Repeater Distance.

Solution

Table 2. Definitions

Term	Definition
Bit Rate	Number of binary bits transmitted per second (bps). Measures actual data transfer speed.
Baud Rate	Number of signal units or symbols transmitted per second. One symbol may contain multiple bits.
Bandwidth	Range of frequencies used by a signal, measured in Hertz (Hz). Determines maximum data capacity of a channel.
Repeater Distance	Maximum distance between repeaters in a communication system before signal degradation requires regeneration.

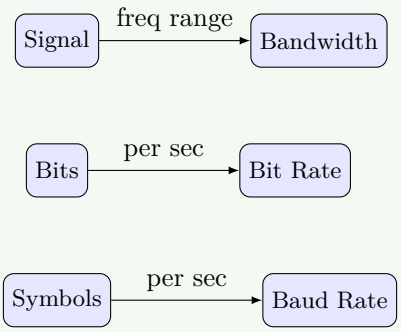


Figure 1. Communication Rate Concepts

Mnemonic

"BBRR - Better Bandwidth Requires Repeaters"

Question 1(c) [7 marks]

Draw the block diagram of digital communication system. Explain the functions of each block in brief. State advantages and disadvantages of it.

Solution

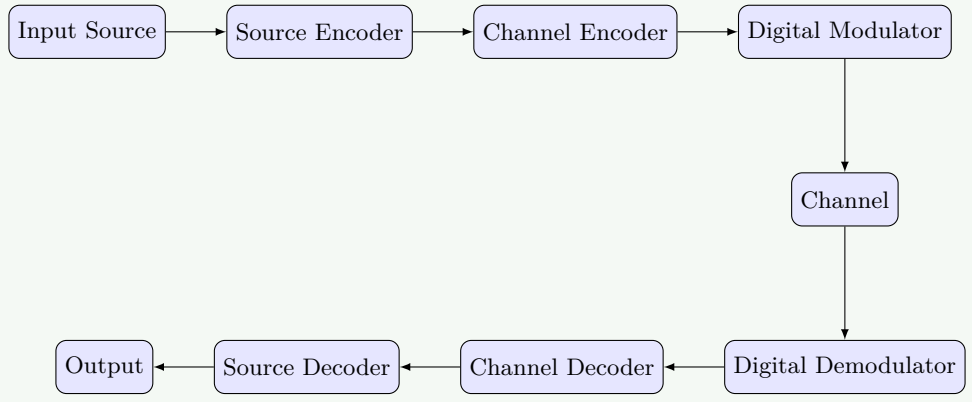


Figure 2. Digital Communication System

- **Source Encoder**: Converts analog signal to digital, removes redundancy, compresses data.
- **Channel Encoder**: Adds redundancy for error detection and correction.
- **Digital Modulator**: Converts digital data to suitable form for transmission (ASK, FSK, PSK).
- **Channel**: Medium through which signal travels (wired/wireless).
- **Digital Demodulator**: Extracts original digital data from received modulated signal.
- **Channel Decoder**: Detects and corrects errors using added redundancy.

- **Source Decoder**: Decompresses data and converts to original form.

Table 3. Advantages and Disadvantages

Advantages	Disadvantages
Better noise immunity	Requires more bandwidth
Easier signal regeneration	Complex implementation
Secure transmission possible	Synchronization required
Integration with computers	Quantization errors
Better quality for long distance	Higher cost for simple applications

Mnemonic

"SECDCSO - Secure Encoding Creates Digital Communication System Output"

Question 1(c OR) [7 marks]

Justify the needs of multiplexing techniques for digital communication. Draw and explain Time Division multiplexing technique in brief. Discuss its merits and demerits.

Solution

Need for Multiplexing:

Table 4. Need for Multiplexing

Need	Explanation
Channel Efficiency	Allows multiple signals on one channel, saving bandwidth
Cost Reduction	Reduces need for multiple transmission media
Infrastructure Utilization	Maximizes use of expensive infrastructure
Spectrum Conservation	Conserves limited frequency spectrum

Time Division Multiplexing (TDM):

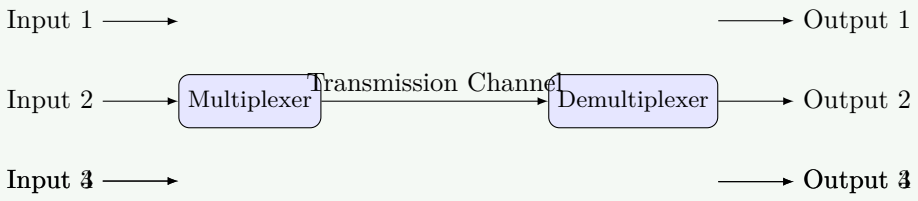


Figure 3. Time Division Multiplexing (TDM)

- **Working**: In TDM, each input signal gets a specific time slot. The multiplexer samples each input sequentially, combining them into a single high-speed data stream. At the receiver, signals are separated based on timing.

Table 5. Merits and Demerits

Merits	Demerits
Efficient bandwidth usage	Requires synchronization
No guard bands needed	Complex buffering required
No cross-talk	Timing issues can cause errors
Flexible allocation	Unused slots waste capacity
Digital implementation	Higher data rate than individual channels

Mnemonic

"TIME - Transmission Interleaves Multiple Endpoints"

Question 2(a) [3 marks]

Differentiate: Coherent and Non-Coherent Detection Technique.

Solution

Table 6. Coherent vs Non-Coherent Detection

Parameter	Coherent Detection	Non-Coherent Detection
Phase Information	Uses phase information	Ignores phase information
Local Oscillator	Required	Not required
Complexity	More complex	Simpler
Performance	Better noise immunity	Less efficient in noise
Implementation	Difficult	Easier
Applications	High-quality systems	Low-cost systems

Mnemonic

"PLCPIA - Phase Local Complex Performance Implementation Applications"

Question 2(b) [4 marks]

Sketch the ASK, FSK, PSK and QPSK waveform for the data sequence 101100110110.

Solution

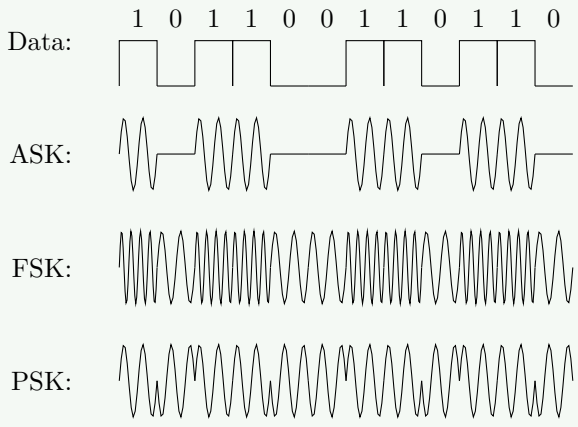


Figure 4. Modulation Waveforms

- **QPSK**: Represented by phase shifts of 0, 90, 180, 270 degrees for dibits (00, 01, 10, 11).

Mnemonic

"AFPQ - Amplitude Frequency Phase Quadrature"

Question 2(c) [7 marks]

Explain the principle of 16-QAM. Also explain constellation diagram and waveform for 16-QAM. Write its advantages and disadvantages.

Solution

Principle of 16-QAM: 16-QAM (Quadrature Amplitude Modulation) combines amplitude and phase modulation to transmit 4 bits per symbol. It uses 16 different combinations of amplitude and phase, allowing higher data rates in the same bandwidth.

Constellation Diagram:

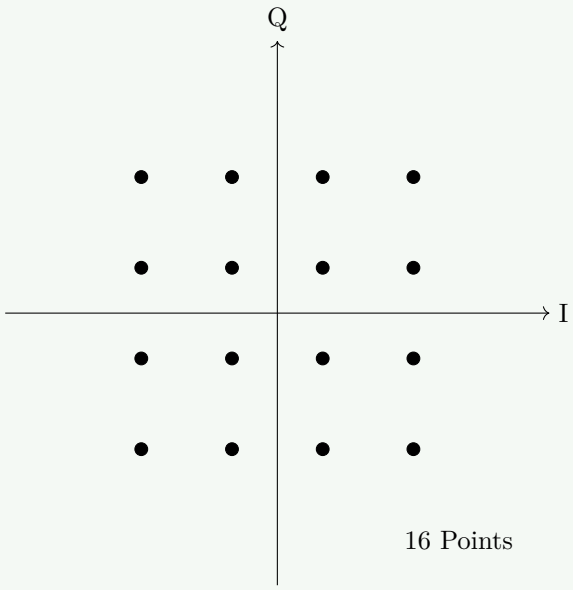


Figure 5. 16-QAM Constellation

Waveform: The 16-QAM waveform varies in both amplitude (4 levels) and phase (4 phases), creating 16 unique symbols. Each point represents 4 bits (0000 to 1111).

Table 7. Advantages and Disadvantages

Advantages	Disadvantages
High spectral efficiency	Sensitive to noise and interference
Higher data rate	Requires higher SNR
Bandwidth efficient	Complex implementation
Better use of channel capacity	Susceptible to amplitude distortion

Mnemonic

"SCHAP - Sixteen Combinations Have Amplitude and Phase"

Question 2(a OR) [3 marks]

Compare: ASK and PSK

Solution

Table 8. ASK vs PSK

Parameter	ASK (Amplitude Shift Keying)	PSK (Phase Shift Keying)
Modulation Parameter	Amplitude	Phase
Noise Immunity	Poor	Good
Power Efficiency	Less efficient	More efficient
Bandwidth Efficiency	Lower	Higher
Implementation	Simple	More complex
BER Performance	Higher error rate	Lower error rate

Mnemonic

"ANPBIP - Amplitude Noise Power Bandwidth Implementation Performance"

Question 2(b OR) [4 marks]

Draw the block diagram of BPSK modulator and demodulator.

Solution

BPSK Modulator:

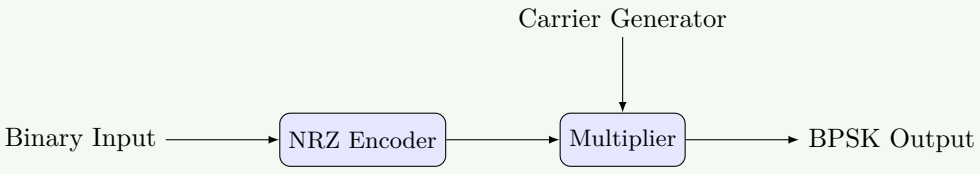


Figure 6. BPSK Modulator

BPSK Demodulator:

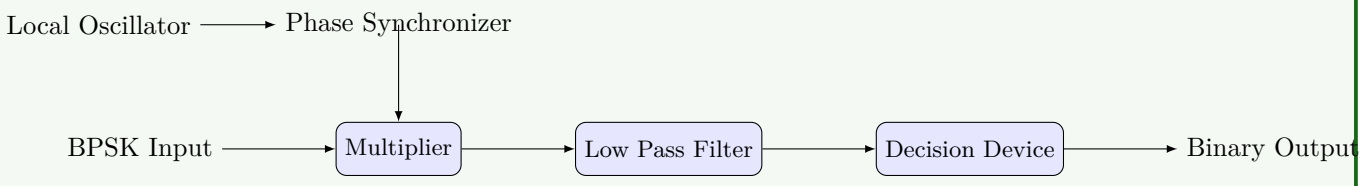


Figure 7. BPSK Demodulator

Mnemonic

"MNECO - Modulation Needs Encoding, Carriers, Oscillators"

Question 2(c OR) [7 marks]

Explain QPSK generation and detection with the help of block diagram and waveform. Discuss its advantages and disadvantages.

Solution

QPSK Generation Block Diagram:

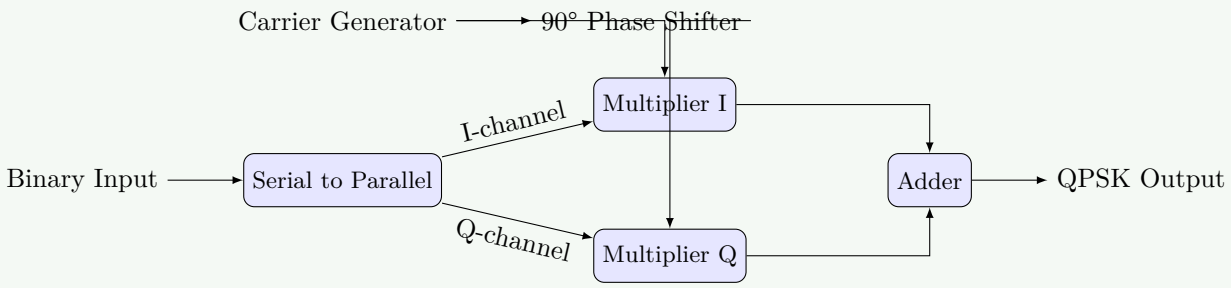


Figure 8. QPSK Generation

QPSK Detection Block Diagram:

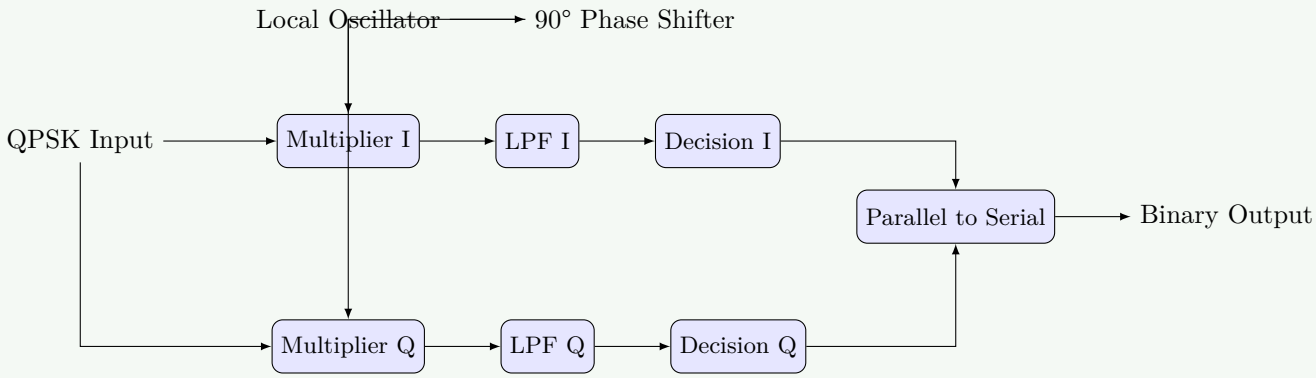


Figure 9. QPSK Detection

- **QPSK Waveform**: Each symbol in QPSK represents 2 bits, with 4 possible phase states (0°, 90°, 180°, 270°).

Table 9. Advantages and Disadvantages

Advantages	Disadvantages
Twice the data rate of BPSK	More complex implementation
Same bandwidth as BPSK	Sensitive to phase errors
Good noise immunity	Requires carrier recovery
Spectral efficiency	More complex synchronization

Mnemonic

"PACE - Phase Alteration Carries Extra data"

Question 3(a) [3 marks]

State the features of RS-422.

Solution

Table 10. Features of RS-422

Features of RS-422
Differential signaling for noise immunity
Maximum data rate of 10 Mbps
Maximum cable length of 1200 meters
Multi-drop capability (1 driver, up to 10 receivers)
Balanced transmission line
Higher noise immunity than RS-232

Mnemonic

"DMMBHN - Differential Maximum Multi-drop Balanced Higher Noise-immunity"

Question 3(b) [4 marks]

Define: Entropy, Information, Mutual Information and Probability.

Solution

Table 11. Definitions

Term	Definition
Entropy	Measure of uncertainty or randomness in a message source, calculated as $H(X) = -\sum p(x) \log_2 p(x)$
Information	Reduction in uncertainty when a message is received, measured in bits
Mutual Information	Measure of dependency between two random variables, indicating how much information one variable contains about the other
Probability	Mathematical measure of likelihood that an event will occur, ranging from 0 (impossible) to 1 (certain)

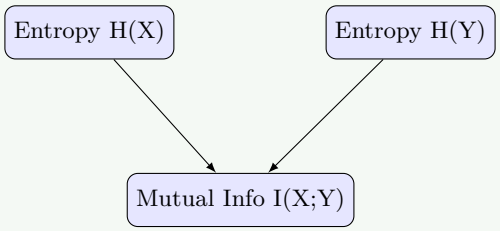


Figure 10. Information Theory Concepts

Mnemonic

"EIMP - Entropy Information Measures Probability"

Question 3(c) [7 marks]

Explain Huffman Code and Shannon-Fano code with suitable example.

Solution

Huffman Code: Huffman coding assigns variable-length codes to symbols based on their frequencies, with shorter codes for more frequent symbols.
Example:

Table 12. Huffman Example

Symbol	Frequency	Huffman Code
A	45%	0
B	25%	10
C	15%	110
D	10%	1110
E	5%	1111

Huffman Tree:

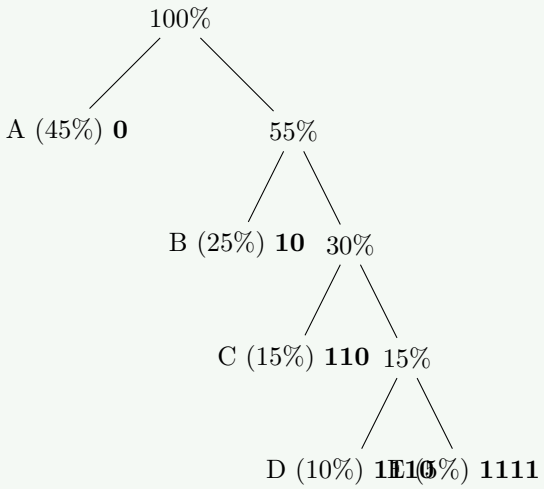


Figure 11. Huffman Tree

Shannon-Fano Code: Shannon-Fano algorithm recursively divides symbols into two groups of similar frequency, then assigns 0 to one group and 1 to the other.
Shannon-Fano Tree:

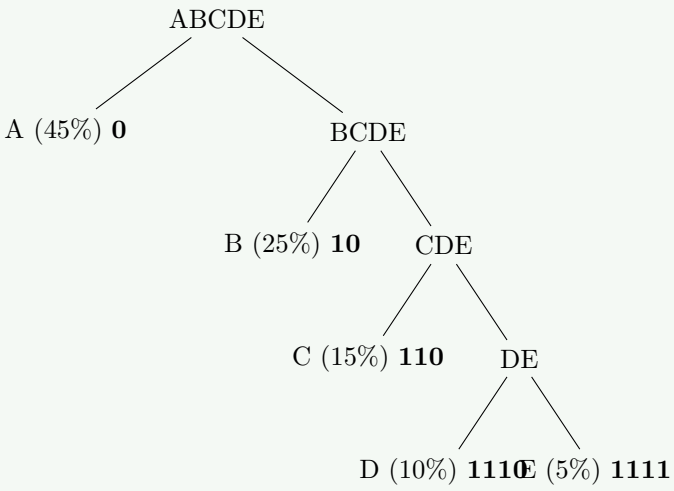


Figure 12. Shannon-Fano Tree

Mnemonic

"FREDS - Frequency Reduces Encoding Digit Size"

Question 3(a OR) [3 marks]

State the features of RS-232.

Solution

Table 13. Features of RS-232

Features of RS-232
Single-ended signaling
Maximum data rate of 20 kbps
Maximum cable length of 15 meters
Point-to-point communication (1 driver, 1 receiver)
Voltage levels: -15V to +15V
25-pin or 9-pin DB connector standard

Mnemonic

"SMPVD - Single Maximum Point-to-point Voltage DB-connector"

Question 3(b OR) [4 marks]

What is channel capacity in terms of SNR? Explain its importance.

Solution

Channel Capacity: The maximum rate at which information can be transmitted over a communication channel with an arbitrarily small probability of error.
Formula: $C = B \times \log_2(1 + SNR)$ Where: C = Channel capacity (bps), B = Bandwidth (Hz), SNR = Signal-to-Noise Ratio.

Table 14. Importance

Importance of Channel Capacity
Sets theoretical limits for data transmission
Guides system design and optimization
Helps evaluate performance of communication systems
Determines required bandwidth for a given data rate
Informs coding techniques to approach capacity

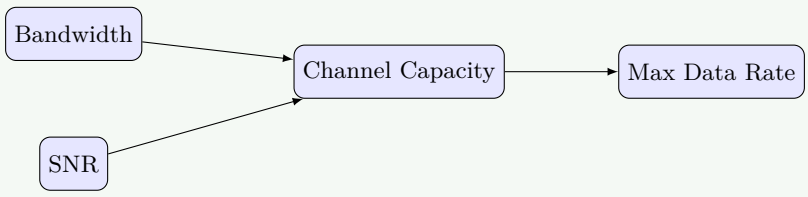


Figure 13. Channel Capacity Factors

Mnemonic

"BSNR - Bandwidth and SNR Need Relationship"

Question 3(c OR) [7 marks]

Explain in detail any one error detection and error correction technique in digital communication.

Solution

Hamming Code Error Detection and Correction: Hamming code is a linear error-correcting code that can detect and correct single-bit errors.

- Data bits are at powers of 2 positions not used by parity.
- Parity bits are at positions 1, 2, 4, 8...

Example: 7-bit Hamming code (4 data, 3 parity)

Table 15. Hamming Code Structure

Position	1	2	3	4	5	6	7
Bit Type	P1	P2	D1	P4	D2	D3	D4

Parity Bit Calculation:

- P1 checks 1, 3, 5, 7.
- P2 checks 2, 3, 6, 7.
- P4 checks 4, 5, 6, 7.

Error Correction: Parity checks indicate error position (binary value of P4 P2 P1 gives position).

Table 16. Error Location

P4	**P2**	**P1**	**Error Position**
0	0	0	No error
0	0	1	Position 1
1	0	1	Position 5
1	1	1	Position 7

Mnemonic

"PECD - Parity Enables Correction of Data"

Question 4(a) [3 marks]

Draw the block diagram of satellite communication and explain in brief.

Solution

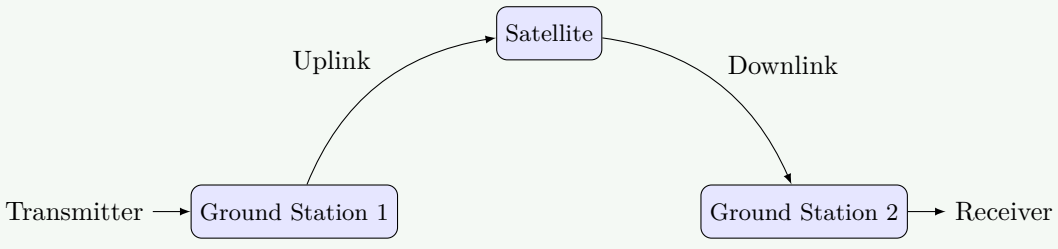


Figure 14. Satellite Communication

Explanation: Satellite communication involves transmitting signals from an Earth station to a satellite (uplink), which amplifies and retransmits them to Earth (downlink).
Key Components:
- **Earth Stations**: Transmit/Receive signals.
- **Transponders**: Satellite repeaters.

Mnemonic

"STAR - Satellite Transmits And Receives"

Question 4(b) [4 marks]

Sketch the Unipolar NRZ, Polar RZ, Polar NRZ and AMI waveform for 10101101 data sequence.

Solution

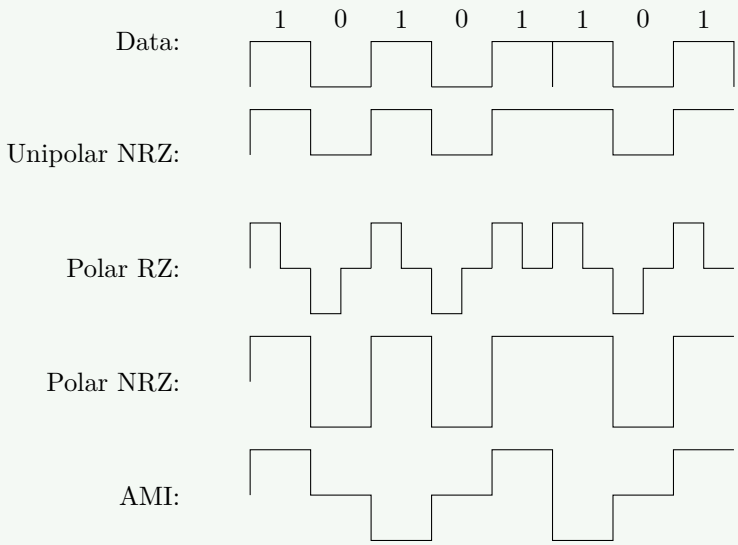


Figure 15. Line Coding Waveforms

Mnemonic

"UPPA - Unipolar Polar Polar AMI"

Question 4(c) [7 marks]

Explain data transmission techniques in details with suitable example for digital communication.

Solution

Data Transmission Techniques:

Table 17. Techniques

Technique	Description	Example
Serial	Data bits sent one after another over single channel	USB, UART
Parallel	Multiple bits sent simultaneously over multiple channels	Printer, SCSI
Synchronous	Continuous stream with timing signals	Ethernet
Asynchronous	Start/stop bits used	RS-232

Serial Transmission (UART Example):

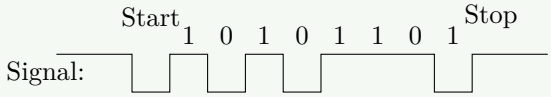


Figure 16. Serial Transmission

Parallel Transmission:

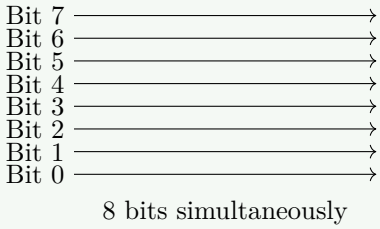


Figure 17. Parallel Transmission

Mnemonic

"SPASH - Serial Parallel Asynchronous Synchronous Half-duplex"

Question 4(a OR) [3 marks]

Interpret the aspects of spread spectrum techniques.

Solution

Table 18. Spread Spectrum Aspects

Aspect	Interpretation
Bandwidth Spreading	Signal spread over wider bandwidth
Security	Difficult to intercept/jam
Noise Immunity	Resistant to narrowband interference
Multiple Access	Allows sharing of frequency
Low Power Density	Signal appears as noise

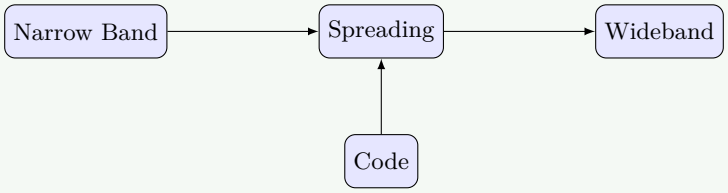


Figure 18. Spread Spectrum Concept

Mnemonic

"BSNML - Bandwidth Security Noise Multiple Low-power"

Question 4(b OR) [4 marks]

Write a short note on probability and discuss its properties for digital communication.

Solution

Probability: Foundation for analyzing error rates and reliability.

Table 19. Properties

Property	Description	Relevance
Range	$0 \leq P(E) \leq 1$	Bounds for error prob
Certainty	$P(S) = 1$	Total prob
Additivity	$P(A \cup B) = P(A) + P(B)$	Total error rate
Conditional	$P(A\|B)$	Channel modeling
Independence	$P(A \cap B) = P(A)P(B)$	Uncorrelated noise

Mnemonic

"RACIC - Range Additivity Certainty Independence Conditional"

Question 4(c OR) [7 marks]

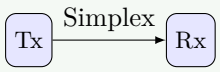
Explain Data transmission mode in details with example.

Solution

Data Transmission Modes:

Table 20. Modes

Mode	Description	Example
Simplex	One-way only	TV, Radio
Half-Duplex	Two-way, one at a time	Walkie-talkie
Full-Duplex	Two-way simultaneous	Telephone



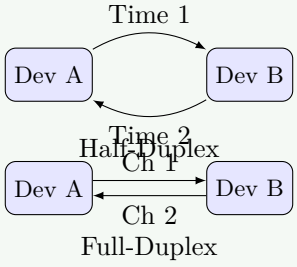


Figure 19. Transmission Modes

Mnemonic

"SHF - Simplex Half Full"

Question 5(a) [3 marks]

Explain Edge Computing in detail.

Solution

Edge Computing: Distributed computing bringing computation closer to data sources.

Table 21. Key Aspects

Aspect	Description
Decentralization	Processing at network edge
Reduced Latency	Faster response
Bandwidth Efficiency	Less data to cloud
Security	Sensitive data remains local

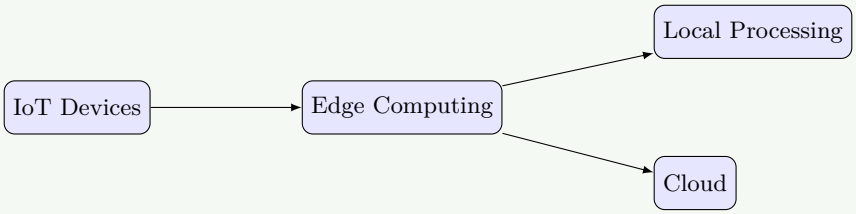


Figure 20. Edge Computing Architecture

Mnemonic

"DRBLES - Decentralized Reduces Bandwidth, Latency, Exposure, Strengthens reliability"

Question 5(b) [4 marks]

Enlist the features of 5G Technology in data communication.

Solution

Table 22. Features of 5G

Features of 5G Technology
High Data Rates (up to 20 Gbps peak)
Ultra-Low Latency (1 ms or less)
Massive Device Connectivity (1M devices per km^2)
Network Slicing (customized virtual networks)
Beamforming (directed signal transmission)
Millimeter Wave Spectrum (24-100 GHz)

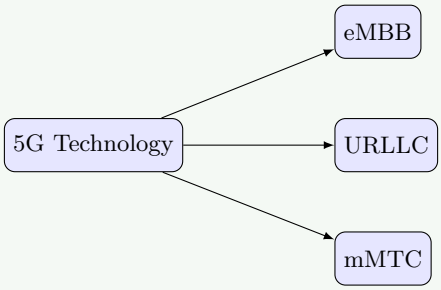


Figure 21. 5G Use Cases

Mnemonic

"HUMBLE-MN - High-speed Ultra-low-latency Massive Beamforming Low-latency Enhanced Millimeter Network"

Question 5(c) [7 marks]

Write a details note on Data communication including its characteristics and components.

Solution

Data Communication: Process of transferring digital information.
Characteristics:

- **Delivery**: Correct destination.
- **Accuracy**: No errors.
- **Timeliness**: On time.
- **Jitter**: Consistent timing.
- **Security**: Protected access.

Components:

Table 23. Components

Component	Description
Message	Information to be communicated
Sender	Device sending data
Receiver	Device receiving data
Medium	Physical path
Protocol	Rules governing communication

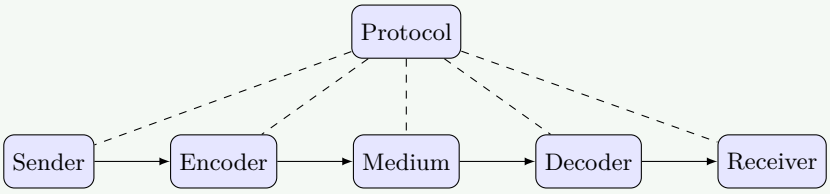


Figure 22. Data Communication Model

Mnemonic

"DATJS-MSRTP - Delivery Accuracy Timeliness Jitter Security - Message Sender Receiver Transmission Protocol"

Question 5(a OR) [3 marks]

Identify and write privacy consideration in Data communication.

Solution

- **Data Encryption**: Protecting data during transmission.
- **Access Control**: Only authorized users.
- **Authentication**: Verifying identity.
- **Data Minimization**: Collecting only necessary data.
- **End-to-End Security**: Protection throughout path.

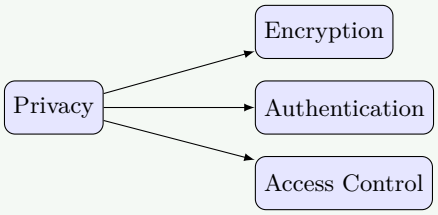


Figure 23. Privacy Considerations

Mnemonic

"DAAESE - Data is Authenticated, Accessed, Encrypted Securely End-to-end"

Question 5(b OR) [4 marks]

What is block chain in communication security? Enlist its features.

Solution

Blockchain: Distributed ledger technology providing secure, tamper-proof records.

Table 24. Features

Feature	Description
Decentralization	No central authority
Immutability	Cannot be altered
Transparency	Visible to participants
Cryptographic Security	Secured using crypto
Consensus	Network agreement

Figure 24. Blockchain Structure

Mnemonic

"DITCSD - Decentralized Immutable Transparent Cryptographic Secure Distributed"

Question 5(c OR) [7 marks]

Write and illustrate different communication ports: USB, HDMI, RCA and Ethernet.

Solution

Communication Ports:

1. **USB (Universal Serial Bus)**: Data/Power, 40 Gbps, Hot-swappable.
2. **HDMI**: Audio/Video, 48 Gbps, HDCP.
3. **RCA**: Analog Audio/Video, Colored (Red/White/Yellow).
4. **Ethernet (RJ-45)**: Network, 10 Gbps, Twisted pair.

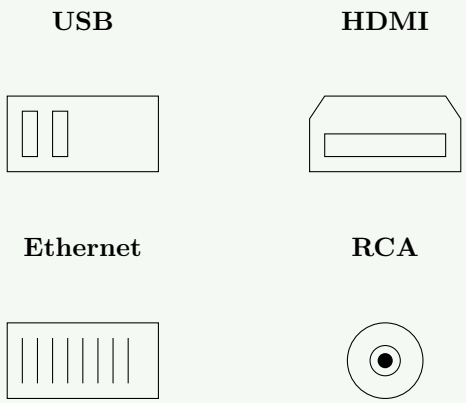


Figure 25. Port Illustrations

Table 25. Comparison

Port	Type	Max Speed	Use
USB	Digital	40 Gbps	Data/Power
HDMI	Digital	48 Gbps	Audio/Video
RCA	Analog	Low	Audio/Video
Ethernet	Digital	10 Gbps	Network

Mnemonic

"UHRE - USB Handles Rapid Ethernet, HDMI Delivers Rich Entertainment"