Subject Name Solutions

4341102 – Winter 2023

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

Discuss the various communication channels characteristics.

Solution

Channel Characteristic	Description
Bit rate	Maximum number of bits transmitted per second
Baud rate	Number of signal units/symbols transmitted per second
Bandwidth	Range of frequencies required for transmission
Repeater distance	Maximum distance between repeaters to maintain signal quality
Noise immunity	Ability to resist interference from external sources

Mnemonic

"BBRN" - "Better Bandwidth Requires Nice planning"

Question 1(b) [4 marks]

Give the difference between even and odd signal.

Solution

Even Signal	Odd Signal
Mathematical representation: $x(-t) = x(t)$	**Mathematical representation**: $x(-t) = -x(t)$
Symmetry: Mirror symmetry around y-axis	**Symmetry**: Origin symmetry (rotational)
Fourier series: Contains only cosine terms	**Fourier series**: Contains only sine terms
Examples: $\cos(t)$, t^2	**Examples**: $\sin(t)$, t^3

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A["Signal x(t)"] {-{-}{} B\{Test symmetry\}}
    B {-{-}{}|"x({-}t) = x(t)"| C[Even Signal]}
    B {-{-}{}|"x({-}t) = {-}x(t)"| D[Odd Signal]}
    C {-{-}{} E[Mirror symmetry]}
    D {-{-}{} F[Origin symmetry]}
{Highlighting}
{Shaded}
```

Mnemonic

"EVEN signals are Equal when flipped, ODD signals are Opposite when flipped"

Question 1(c) [7 marks]

Define repeater. Explain how repeater works with help of necessary circuit and waveforms.

Solution

Repeater: A device that receives, amplifies, and retransmits a signal to extend the transmission distance without degradation.
Working Principle: Repeaters regenerate digital signals to overcome attenuation and noise accumulation in transmission lines.
Circuit Diagram:

```
            +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+                 +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-
 Input      |             |    Regenerated   |            |    Output
Signal {-{-}{-}{-}|  Receiver   |{-}{-}{-}{-}{-}{-}Signal{-}{-}{-}{-}{-}|  Transmitter|{-}{-}{-}{-}Sign
            |             |                  |            |
            +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+                 +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-
                    |                               |
                    |       +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+          |}
                    +{-{-}{-}{-}{-}{-}|   Clock    |{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
                            | Recovery   |
                            +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
```

Waveform:

```
  Input Signal           Repeater             Output Signal
     \_\_\_\_\_                                       \_\_\_\_\_
    |     |                                    |     |
\_\_\_\_|     |\_\_\_\_     {-{-}     \_\_\_        {-}{-}   \_\_\_\_\_|     |\_\_\_\_\_}
    |     |                                    |     |
    |     |                                    |     |
      Degraded                                   Regenerated
```

- **Signal reception**: Detects incoming weak/distorted signals
- **Amplification**: Strengthens the signal power
- **Regeneration**: Reconstructs original digital waveform
- **Retransmission**: Sends restored signal to next segment

Mnemonic

"RARE" - "Receive, Amplify, Regenerate, Emit"

Question 1(c) OR [7 marks]

Draw block diagram of digital communication system and explain in detail.

Solution

```
flowchart LR
    A[Information Source] {-{-} B[Source Encoder]}
    B {-{-} C[Channel Encoder]}
    C {-{-} D[Digital Modulator]}
    D {-{-} E[Channel]}
    E {-{-} F[Digital Demodulator]}
    F {-{-} G[Channel Decoder]}
    G {-{-} H[Source Decoder]}
    H {-{-} I[Information Sink]}
```

Block	Function
Information Source	Generates message to be transmitted (voice, video, data)
Source Encoder	Converts source data to digital form and removes redundancy
Channel Encoder	Adds controlled redundancy for error detection/correction
Digital Modulator	Converts digital data to signals suitable for transmission
Channel	Physical medium through which signals travel
Digital Demodulator	Extracts digital data from received signals
Channel Decoder	Detects/corrects errors using added redundancy
Source Decoder	Reconstructs original source information

Mnemonic

"Send Clear Data Messages, Carefully Decode Secure Information"

Question 2(a) [3 marks]

Define Unit step function, Unit impulse function, Unit ramp function.

Solution

Function	Definition	Mathematical Form
Unit Step Function	Takes value 0 for negative time and 1 for positive time	$u(t) = \{0, t < 0; 1, t \geq 0\}$
Unit Impulse Function	Infinitely high, zero width pulse with area 1	$(t) = \{\infty, t = 0; 0, t \neq 0\}$
Unit Ramp Function	Increases linearly with time for positive time values	$r(t) = \{0, t < 0; t, t \geq 0\}$

Mnemonic

"SIR" - "Step Instantly, Impulse Rapidly, Ramp Gradually"

Question 2(b) [4 marks]

Define Continues time and discrete time signals and explain with example.

Solution

Signal Type	Definition	Example	Representation
Continuous-time Signal	Defined for all values of time within its duration	Sinusoidal wave $x(t) = \sin(t)$	Smooth, unbroken curve
Discrete-time Signal	Defined only at specific time instants	Digital samples $x[n] = \sin(nTs)$	Sequence of distinct values

Diagram:

```
Continuous{-time:   }
      /{      /      /      /      /  }
     /  {    /      /      /      /   }
{-{-}{-}{-}/    {-}{-}/    {-}{-}/    {-}{-}/    {-}{-}/    {-}{-}{-}{-} t}

Discrete{-time:}
      o       o       o       o       o
     /       /       /       /       /
{-{-}{-}{-}/{-}{-}{-}{-}{-}{-}{-}/{-}{-}{-}{-}{-}{-}{-}/{-}{-}{-}{-}{-}{-}{-}/{-}{-}{-}{-}{-}{-}{-}/{-}
    o       o       o       o       o
```

- **Continuous-time**: Defined for all time t $\in R(infinitevalues)$
- **Discrete-time**: Defined only at specific instants n $\in Z(countablevalues)$

Mnemonic

"CADD" - "Continuous Always, Discrete Dots"

Question 2(c) [7 marks]

Explain the block diagram of ASK modulator and de-modulator with waveform.

Solution

ASK (Amplitude Shift Keying): A digital modulation technique where binary data is represented by varying the amplitude of a carrier wave.
ASK Modulator:

```
flowchart LR
    A[Digital Input] {-{-} B[Product Modulator]}
    C[Carrier Generator] {-{-} B}
    B {-{-} D[Bandpass Filter]}
    D {-{-} E[ASK Output]}
```

ASK Demodulator:

```
flowchart LR
    A[ASK Input] {-{-} B[Envelope Detector]}
    B {-{-} C[Low Pass Filter]}
    C {-{-} D[Comparator]}
    D {-{-} E[Digital Output]}
```

Waveforms:

```
Digital Input:
    \_\_\_     \_\_\_          \_\_\_     \_\_\_
\_\_\_|   |\_\_\_|   |\_\_\_\_\_\_\_|   |\_\_\_|   |\_\_\_
    1   0   1     0     1   0   1

Carrier Wave:
/{/////////////////}

ASK Output:
    /{/    //        //    //}
\_\_\_/    {\_\_/    \_\_\_\_\_\_\_/    \_\_/    \_\_\_}
High  Low  High   Low   High Low  High
```

- **Modulator**: Varies carrier amplitude based on digital input
- **Demodulator**: Extracts envelope and compares to threshold

Mnemonic

"APE" - "Amplify when Positive, Eliminate when zero"

Question 2(a) OR [3 marks]

Explain Singularity function.

Solution

Singularity Function: Mathematical functions that have discontinuities or undefined values at specific points.

Common Singularity Functions	Properties
Unit Step Function u(t)	Jumps from 0 to 1 at t=0
Unit Impulse Function (t)	Infinite at t=0, zero elsewhere, with area=1
Unit Ramp Function r(t)	Derivative of unit step is impulse

Relationships:

- (t) = d/dt[u(t)]
- u(t) = (t)dt
- r(t) = (t)dt

Mnemonic

"SIR" - "Singularities Include Rapid changes"

Question 2(b) OR [4 marks]

Give the difference between bit rate and baud rate.

Solution

Parameter	Bit Rate	Baud Rate
Definition	Number of bits transmitted per second	Number of symbols transmitted per second
Unit	bits per second (bps)	symbols per second (Baud)
Relation	Bit rate = Baud rate $\times Numberofbitspersymbol$	Baud rate = Bit rate $\div Numberofbitspersymbol$
Example	In QPSK, if Baud rate = 1200, Bit rate = 2400 bps	In 16-QAM, if Bit rate = 9600 bps, Baud rate = 2400

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Transmission Rate] {-{-}{} B[Bit Rate]}
    A {-{-}{} C[Baud Rate]}
    B {-{-}{}|"bits/second"| D[Information Transfer Rate]}
    C {-{-}{}|"symbols/second"| E[Modulation Rate]}
    F[Modulation Technique] {-{-}{} G[Bits per Symbol]}
    G {-{-}{} H["Bit Rate = Baud Rate  Bits per Symbol"]}
{Highlighting}
{Shaded}
```

Mnemonic

"BBSR" - "Bits for Binary Speed, Bauds for Symbol Rate"

Question 2(c) OR [7 marks]

Explain the Principle of 8-PSK signal. Also draw constellation diagram and waveforms of its.

Solution

8-PSK (Phase Shift Keying): A digital modulation technique where data is encoded by shifting the phase of a carrier signal to 8 different positions.

Principle:

- Each symbol represents 3 bits ($\log_2 8 = 3$)
- Phase shifts in multiples of $45°(360° \div 8)$
- Maintains constant amplitude

Constellation Diagram:

```
                 000(0^)
                    o
                    |
           001(45^) o         o 111(315^)
                  /             {}
                 /               {}
       010(90^) o                  o 110(270^)
                 {               /}
                  {             /}
          011(135^) o         o 101(225^)
                    |
                    o
                 100(180^)
```

Waveform:

```
Data:   000    001    010    011    100    101    110    111
        \_\_\_    \_\_\_    \_\_\_    \_\_\_    \_\_\_    \_\_\_    \_\_\_    \_\_\_
       |   |  |   |  |   |  |   |  |   |  |   |  |   |  |   |
       |   |  |   |  |   |  |   |  |   |  |   |  |   |  |   |
Phase:  0^    45^    90^   135^   180^   225^   270^   315^
        /{     /     /     /     /     /     /     /}
       /  {   /     /     /     /     /     /     /  }
Signal:/    { /     /     /     /     /     /     /    }
```

- **Bandwidth efficiency**: 3 bits per symbol
- **Constant amplitude**: Better power efficiency
- **Error probability**: Higher than BPSK/QPSK but lower than 16-PSK

Mnemonic

"8 Points Shifted in K-circle" (8-PSK)

Question 3(a) [3 marks]

Explain the block diagram of FSK modulator.

Solution

FSK (Frequency Shift Keying): A digital modulation technique where binary data is represented by varying the frequency of a carrier wave.

```
flowchart LR
    A[Binary Input] {-{-} B\{Switch\}}
```

```
    C[Oscillator f1] {-{-} B}
    D[Oscillator f2] {-{-} B}
    B {-{-} E[Bandpass Filter]}
    E {-{-} F[FSK Output]}
```

Component	Function
Binary Input	Digital data (0s and 1s) to be transmitted
Oscillator 1	Generates carrier at frequency f$_1 forbit$‘1$'$
Oscillator 2	Generates carrier at frequency f$_2 forbit$‘0$'$
Switch	Selects appropriate frequency based on input bit
Bandpass Filter	Smooths transitions between frequencies

Mnemonic

“FISO” - “Frequency Input Selects Oscillator”

Question 3(b) [4 marks]

Draw the ASK and FSK modulation waveform for the sequence of 1010110011.

Solution

```
Binary Input: 1    0    1    0    1    1    0    0    1    1
             \_   \_   \_   \_   \_   \_   \_   \_   \_   \_   \_   \_   \_
             |   |   |   |   |   |   |   |   |   |   |   |   |
             |   |   |   |   |   |   |   |   |   |   |   |   |
            \_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_\_\_|\_

ASK Output:  |||       |||       |||||||||       |||||||||
             |||       |||       |||||||||       |||||||||
            \_|||\_\_\_\_\_|||\_\_\_\_\_|||||||\_\_\_\_\_|||||||\_\_\_\_\_\_\_

FSK Output:  |||       |||       |||       |||       |||
             |||       |||       |||       |||       |||
            \_|||\_{\_|||\_\_|||||||\_\_|||||||\_ }
                 {              }
High freq   (1)  Low(0)  (1)  Low(0)  (1)(1)  Low(0)  Low(0)  (1)(1)
```

Explanation:

- **ASK**: High amplitude for bit ‘1’, low amplitude for bit ‘0’
- **FSK**: Higher frequency f$_1 forbit$‘1$', lowerfrequencyf_2 forbit$‘0$'$

Mnemonic

“ASK changes Amplitude, FSK changes Frequency”

Question 3(c) [7 marks]

Explain PSK signal generation and detection with help of its functional diagram.

Solution

PSK (Phase Shift Keying): A digital modulation technique where data is encoded by changing the phase of a carrier signal.

PSK Modulator:

```
flowchart LR
    A[Binary Input] {-{-} B[Bipolar Converter]}
    B {-{-} C[Product Modulator]}
    D[Carrier Generator] {-{-} C}
```

```
    C {-{-} E[PSK Output]}
```

PSK Demodulator:

```
flowchart LR
    A[PSK Input] {-{-} B[Product Demodulator]}
    C[Carrier Recovery] {-{-} B}
    B {-{-} D[Low Pass Filter]}
    D {-{-} E[Decision Device]}
    E {-{-} F[Binary Output]}
```

Waveforms:

```
Binary Input:  1     0     1     1     0
              \_    \_    \_    \_    \_    \_    \_
              |     |     |     |     |     |     |
              |     |     |     |     |     |     |
             \_|\_\_\_\_|\_\_\_\_|\_\_\_\_|\_\_\_\_|\_\_\_\_|\_\_\_\_|\_\_\_

Bipolar:      +A   {-A    +A   +A   {-}A}
              \_    \_    \_    \_    \_    \_    \_
              |     |     |     |     |     |     |
              |     |     |     |     |     |     |
             \_|\_\_\_\_|\_\_\_\_|\_\_\_\_|\_\_\_\_|\_\_\_\_|\_\_\_\_|\_\_\_

Carrier:      /{///////////////}

PSK Output:   /{/  //  //  //  //}
              phase phase phase phase phase
               0^   180^   0^    0^   180^
```

- **Generation**: Binary 1 $\rightarrow 0° phase, Binary 0 \rightarrow 180° phase$
- **Detection**: Coherent demodulation with carrier recovery
- **Advantages**: Better noise immunity than ASK

Mnemonic

"PSK Phases Shift with Knowledge of carrier"

Question 3(a) OR [3 marks]

Compare Bits PER Symbol for digital modulation techniques-ASK, FSK, PSK, QPSK, 8-PSK and 16-QAM.

Solution

Modulation Technique	Bits per Symbol	States	Bandwidth Efficiency
ASK	1	2	1 bit/Hz
FSK	1	2	0.5 bit/Hz
PSK (BPSK)	1	2	1 bit/Hz
QPSK	2	4	2 bits/Hz
8-PSK	3	8	3 bits/Hz
16-QAM	4	16	4 bits/Hz

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Modulation Techniques]
    A {-{-}{} B[ASK/FSK/BPSK{}br /{}1 bit/symbol]}
    A {-{-}{} C[QPSK{}br /{}2 bits/symbol]}
    A {-{-}{} D[8{-}PSK{}br /{}3 bits/symbol]}
    A {-{-}{} E[16{-}QAM{}br /{}4 bits/symbol]}
{Highlighting}
{Shaded}
```

Mnemonic

"As Frequency/Phase States Quadruple, Bandwidth Efficiency Doubles"

Question 3(b) OR [4 marks]

Draw and explain the constellation diagram of 16-QAM.

Solution

16-QAM (Quadrature Amplitude Modulation): A modulation technique that combines amplitude and phase modulation, where each symbol represents 4 bits.
Constellation Diagram:

```
      Q
      \^{}
      |   o   o   o   o
      |
      |   o   o   o   o
      |
{-{-}{-}{-}{-}{-}|{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-} I}
      |   o   o   o   o
      |
      |   o   o   o   o
      |
```

Explanation:

- **16 distinct states**: Each point represents a unique 4-bit combination
- **Carries 4 bits per symbol**: $\log_2 16 = 4$
- **Modulation parameters**: Both amplitude and phase are varied
- **Symbol mapping**: Gray coding used to minimize bit errors

Mnemonic

"16 Quadrants Arranged in Matrix"

Question 3(c) OR [7 marks]

Explain the Principle of MSK signal. Also draw constellation diagram and waveforms of its.

Solution

MSK (Minimum Shift Keying): A continuous phase FSK modulation with a modulation index of 0.5, ensuring smooth phase transitions.
Principle:

- Special case of CPFSK (Continuous Phase FSK)
- Frequency separation exactly equals half the bit rate
- Maintains continuous phase, avoiding abrupt transitions

- Modulation index h = 0.5

Constellation Diagram:

```
      Q
      \^{}
      |       o
      |     /   {}
      |    /     { }
      |   o       o
{-{-}{-}{-}{-}{-}|{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-} I}
      |   o       o
      |    {     /}
      |     {   /}
      |       o
```

Waveforms:

```
Data:      1      0      1      1      0
           \_      \_      \_      \_      \_      \_
           |      |      |      |      |      |
          \_|\_\_\_\_\_\_|\_\_\_\_\_\_|\_\_\_\_\_\_|\_\_\_\_\_\_|\_\_\_\_\_\_|\_\_\_

MSK:      /        {      /      /        }
         /          {    /      /          }
        /            {  /      /            }
       /              {/      /              }
      /                                        {}
```

Key Features:

- **Constant envelope**: Better power efficiency
- **Spectral efficiency**: Narrower bandwidth than BFSK
- **Continuous phase**: Smoother transitions, reduced spectral spreading
- **OQPSK relation**: Can be viewed as offset QPSK with sinusoidal pulse shaping

Mnemonic

"MSK Makes Smooth K-transitions"

Question 4(a) [3 marks]

Describe the procedure to troubleshoot the FDD multiplexing circuit.

Solution

Step	Troubleshooting Procedure
1. Signal Verification	Check input signals at each frequency band
2. Filter Analysis	Verify bandpass filters for each channel
3. Modulator Testing	Test frequency translation in each channel
4. Power Levels	Measure signal strength at input/output
5. Isolation Check	Test for cross-talk between channels

```
flowchart LR
    A[Start] {-{-} B[Check Input Signals]}
    B {-{-} C\{Signals OK?\}}
    C {-{-}|Yes| D[Test Filters]}
    C {-{-}|No| E[Fix Input Source]}
    D {-{-} F\{Filters OK?\}}
    F {-{-}|Yes| G[Test Modulators]}
    F {-{-}|No| H[Replace/Adjust Filters]}
```

Mnemonic

"SFMPI" - "Signal, Filter, Modulator, Power, Isolation"

Question 4(b) [4 marks]

Compare E1 carrier with T1 carrier.

Solution

Parameter	E1 Carrier	T1 Carrier
Standard	European standard	North American standard
Data Rate	2.048 Mbps	1.544 Mbps
Voice Channels	30 channels	24 channels
Time Slots	32 time slots (TS0, TS1-TS15, TS16, TS17-TS31)	24 time slots + framing bit
Signaling	Channel 16 used for signaling	Robbed bit signaling
Frame Size	256 bits	193 bits
Bit Rate per Channel	64 kbps	64 kbps

Mnemonic

"ET-DR" - "European Thirty, Double Rate"

Question 4(c) [7 marks]

Explain CDMA technique in detail.

Solution

CDMA (Code Division Multiple Access): A multiple access technique where multiple users share the same frequency band simultaneously by using unique spreading codes.

```
flowchart LR
    A[User Data] {-{-} B[Spreading]}
    C[Unique Code] {-{-} B}
    B {-{-} D[Transmission]}
    D {-{-} E[Despreading]}
    F[Same Code] {-{-} E}
    E {-{-} G[User Data Recovery]}
```

Key Feature	Description
Spreading Codes	Unique orthogonal or pseudo-random codes assigned to each user
Process Gain	Ratio of spread bandwidth to original bandwidth
Interference Rejection	Users with different codes appear as noise to each other
Soft Handoff	Mobile can communicate with multiple base stations simultaneously

Power Control	Critical to solve near-far problem
Capacity	Not strictly limited by frequency, but by acceptable noise level

Working Principle:

- Each bit is multiplied by a high-rate spreading code (chips)
- Resulting signal occupies much wider bandwidth
- Receiver uses same code to recover original data
- Other signals appear as random noise, rejected by correlation

Mnemonic

"CUPS" - "Codes Uniquely Provide Separation"

Question 4(a) OR [3 marks]

Write a short not on classification of multiplexing techniques.

Solution

Multiplexing Techniques: Methods to combine multiple signals for transmission over a single medium.

Type	Based On	Examples
Frequency Division Multiplexing (FDM)	Frequency domain	Radio broadcasting, cable TV
Time Division Multiplexing (TDM)	Time domain	Digital telephone systems, GSM
Code Division Multiplexing (CDM)	Code domain	CDMA cellular systems
Wavelength Division Multiplexing (WDM)	Wavelength domain	Fiber optic communications
Space Division Multiplexing (SDM)	Spatial domain	MIMO wireless systems

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Multiplexing Techniques] {-{-}{} B[Frequency Division]}
    A {-{-}{} C[Time Division]}
    A {-{-}{} D[Code Division]}
    A {-{-}{} E[Wavelength Division]}
    A {-{-}{} F[Space Division]}
{Highlighting}
{Shaded}
```

Mnemonic

"FTCWS" - "Five Techniques Create Wide Systems"

Question 4(b) OR [4 marks]

Draw and explain block diagram of Time Division Multiplexing technique (TDM).

Solution

Time Division Multiplexing (TDM): A technique where multiple signals share the same channel by allocating different time slots to each signal.

```
flowchart LR
    A1[Input 1] {-{-} B1[Sampler 1]}
    A2[Input 2] {-{-} B2[Sampler 2]}
    A3[Input 3] {-{-} B3[Sampler 3]}
    A4[Input 4] {-{-} B4[Sampler 4]}
    B1 {-{-} C[Commutator]}
    B2 {-{-} C}
    B3 {-{-} C}
    B4 {-{-} C}
    C {-{-} D[TDM Channel]}
    D {-{-} E[Decommutator]}
    E {-{-} F1[Filter 1] {-}{-} G1[Output 1]}
    E {-{-} F2[Filter 2] {-}{-} G2[Output 2]}
    E {-{-} F3[Filter 3] {-}{-} G3[Output 3]}
    E {-{-} F4[Filter 4] {-}{-} G4[Output 4]}
```

Component	Function
Samplers	Sample each input signal at rate $\geq 2 \times highest frequency$
Commutator	Sequentially selects samples from each input channel
TDM Channel	Carries the combined signal
Decommutator	Distributes received samples to appropriate channels
Filters	Reconstruct original signals from samples

Mnemonic

"SCTDF" - "Sample, Combine, Transmit, Distribute, Filter"

Question 4(c) OR [7 marks]

Explain TDMA technique in detail.

Solution

TDMA (Time Division Multiple Access): A channel access method where multiple users share the same frequency channel by dividing it into different time slots.

```
flowchart TD
    A[TDMA Frame] {-{-} B[Slot 1br /User 1]}
    A {-{-} C[Slot 2br /User 2]}
    A {-{-} D[Slot 3br /User 3]}
    A {-{-} E[Slot 4br /User 4]}
    A {-{-} F[Slot 5br /User 5]}
    A {-{-} G[Slot 6br /User 6]}
```

Key Feature	Description
Frame Structure	Fixed-length frames divided into time slots
Guard Time	Small time gaps between slots to prevent overlap
Synchronization	Requires precise timing coordination
Channel Utilization	Each user gets entire bandwidth for short duration
Power Efficiency	Transmitters operate intermittently, saving power
Capacity	Limited by available time slots in frame

Implementation Details:

- Each user transmits in rapid bursts within assigned slot
- Non-continuous transmission allows handsets to measure signal strengths of nearby cells
- Used in GSM (8 slots per frame), DECT, satellite systems
- Easily adapts to varying data rates by assigning multiple slots

Mnemonic

"TDMA Takes Distinct Moments for Access"

Question 5(a) [3 marks]

Define probability and write it Significance of in communication.

Solution

Probability: A measure of the likelihood of an event occurring, expressed as a number between 0 and 1.

Significance in Communication	Explanation
Reliability Analysis	Calculating error probabilities and system reliability
Noise Performance	Evaluating system performance in presence of random noise
Information Theory	Foundation for Shannon's channel capacity theorem
Signal Detection	Determining optimal detection thresholds

Mnemonic

"PRONIS" - "PRObability Numerically Indicates Signal quality"

Question 5(b) [4 marks]

Explain Huffman code with suitable example.

Solution

Huffman Code: A variable-length prefix coding algorithm that assigns shorter codes to more frequent symbols.
Example: Consider symbols A, B, C, D with probabilities 0.4, 0.3, 0.2, 0.1
Huffman Coding Process:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[A:0.4, B:0.3, C:0.2, D:0.1] {-{-}{} B[A:0.4, B:0.3, CD:0.3]}
    B {-{-}{} C[A:0.4, BCD:0.6]}
    C {-{-}{} D[ABCD:1.0]}
    D {-{-}{} E["A(0) | BCD(1)"]}
    E {-{-}{} F["A(0) | B(10) | CD(11)"]}
    F {-{-}{} G["A(0) | B(10) | C(110) | D(111)"]}
{Highlighting}
{Shaded}
```

Symbol	Probability	Huffman Code
A	0.4	0

B	0.3	10
C	0.2	110
D	0.1	111

Average Code Length $= 0.4 \times 1 + 0.3 \times 2 + 0.2 \times 3 + 0.1 \times 3 = 1.9 bits/symbol$

Mnemonic

"HEMP" - "Huffman Encodes More Probable symbols with shorter codes"

Question 5(c) [7 marks]

Explain concept and key features of Internet of Things (IoT).

Solution

Internet of Things (IoT): A network of physical objects embedded with sensors, software, and connectivity that enables them to collect and exchange data.

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[IoT Ecosystem] {-{-}{} B[Smart Devices]}
    A {-{-}{} C[Connectivity]}
    A {-{-}{} D[Data Analytics]}
    A {-{-}{} E[User Interface]}
    A {-{-}{} F[Security]}
    B {-{-}{} G[Sensors \& Actuators]}
    C {-{-}{} H[Protocols \& Standards]}
    D {-{-}{} I[Cloud Computing]}
    E {-{-}{} J[Apps \& Services]}
    F {-{-}{} K[Authentication \& Encryption]}
{Highlighting}
{Shaded}
```

Key Feature	Description
Connectivity	Devices connected to internet/each other via various protocols (Wi-Fi, Bluetooth, LPWAN, 5G)
Sensing Capability	Ability to detect physical parameters through sensors
Intelligence	Data processing at device (edge) or cloud level
Interoperability	Ability to work across different platforms and systems
Automation	Autonomous functioning without human intervention
Scalability	Ability to handle growth in number of connected devices

Applications:

- Smart homes (thermostats, security systems)
- Healthcare (wearable devices, remote monitoring)
- Industrial automation (predictive maintenance)
- Smart cities (traffic management, waste management)
- Agriculture (precision farming, livestock monitoring)

Mnemonic

"CSIA" - "Connect, Sense, Interpret, Automate"

Question 5(a) OR [3 marks]

Define Channel Capacity in terms of SNR and its importance in communication.

Solution

Channel Capacity: Maximum rate at which information can be transmitted over a communication channel with arbitrarily small error probability.
Shannon's Channel Capacity Formula: C = B $\times log_2(1 + SNR)$
Where:

- C = Channel capacity in bits per second
- B = Bandwidth in Hertz
- SNR = Signal-to-Noise Ratio

Importance in Communication	Explanation
Performance Limit	Sets theoretical maximum data rate for error-free transmission
System Design	Guides selection of modulation, coding schemes
Bandwidth Efficiency	Shows tradeoff between bandwidth and SNR
Link Budget Analysis	Helps determine required transmit power

Mnemonic

"CBLSN" - "Capacity equals Bandwidth times Log of Signal-to-Noise ratio"

Question 5(b) OR [4 marks]

Explain Shanon Fano code with suitable example.

Solution

Shannon-Fano Coding: A technique that assigns variable-length codes to symbols based on their probabilities by recursively dividing the set of symbols into two subsets with approximately equal probabilities.
Example: Consider symbols A, B, C, D with probabilities 0.4, 0.3, 0.2, 0.1
Shannon-Fano Procedure:

1. Sort symbols by probability: A(0.4), B(0.3), C(0.2), D(0.1)
2. Divide into groups with nearly equal probability:
   - Group 1: A(0.4) - assigned '0'
   - Group 2: B(0.3), C(0.2), D(0.1) = 0.6 - assigned '1'
3. Recursively divide Group 2:
   - Group 2.1: B(0.3) - assigned '10'
   - Group 2.2: C(0.2), D(0.1) = 0.3 - assigned '11'
4. Divide Group 2.2:
   - C(0.2) - assigned '110'
   - D(0.1) - assigned '111'

Symbol	Probability	Shannon-Fano Code
A	0.4	0
B	0.3	10
C	0.2	110
D	0.1	111

Average Code Length $= 0.4{\times}1 + 0.3 \times 2 + 0.2 \times 3 + 0.1 \times 3 = 1.9 bits/symbol$

Mnemonic

"SFDS" - "Shannon Fano Divides Symbolsets"

Question 5(c) OR [7 marks]

Draw and explain block diagram of Digital telephone exchange.

Solution

Digital Telephone Exchange: A system that connects telephone calls by converting analog voice signals to digital form and switching them through digital circuits.

```
flowchart LR
    A[Subscribers] {-{-} B["Digital Line Unitsbr /(DLU)"]}
    B {-{-} C["Line/Trunk Groupbr /(LTG)"]}
    C {-{-} D["Switching Networkbr /(SN)"]}
    D {-{-} E["Central Processorbr /(CP)"]}
    E {-{-} D}
    D {-{-} C}
    C {-{-} B}
    B {-{-} A}
    F[Operation \& Maintenance{br /Center] {-}{-} E}
```

Block	Function
Digital Line Units (DLU)	Interface between subscriber lines and exchange, perform A/D conversion, line coding
Line/Trunk Group (LTG)	Manages signaling, multiplexes/demultiplexes subscriber channels
Switching Network (SN)	Core switching fabric, establishes connection paths between channels
Central Processor (CP)	Controls all exchange operations, call processing, routing decisions
Operation & Maintenance Center	Monitors system performance, fault detection, traffic analysis

Key Features:

- **Time Division Switching**: Connects different time slots
- **Space Division Switching**: Connects different physical paths
- **Stored Program Control**: Software-based call processing
- **Common Channel Signaling**: Separate signaling channel (SS7)
- **Non-blocking Architecture**: All calls can be connected simultaneously

Mnemonic

"DLSCO" - "Digital Lines Switch Calls Orderly"