Subject Name Solutions

4351104 – Winter 2024

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

Explain umbrella cell.

Solution

Umbrella cell is a large coverage area cell that overlays smaller cells to provide continuous coverage and handle overflow traffic.

Table 1: Umbrella Cell Characteristics

Feature	Description
Coverage	Large geographic area
Purpose	Handle overflow traffic from microcells
Antenna	High-power, elevated position
Users	Fast-moving vehicles, emergency calls

- **Large coverage**: Covers wide geographical area with high-power base station
- **Traffic management**: Handles calls when smaller cells are congested
- **Mobility support**: Serves fast-moving users crossing multiple cell boundaries

Mnemonic

"Umbrella Covers Large Areas"

Question 1(b) [4 marks]

Define cell and cluster.

Solution

Cell and **cluster** are fundamental concepts in cellular communication systems.

Table 2: Cell vs Cluster Comparison

Parameter	Cell	Cluster
Definition	Single coverage area served by one base station	Group of cells using different frequencies
Size	Limited by antenna power and interference	Contains N cells (typically 3, 4, 7, 12)
Frequency	Uses specific frequency set	Uses all available frequencies once
Purpose	Provide coverage to specific area	Enable frequency reuse pattern

- **Cell**: Geographic area served by single base station with specific frequency allocation
- **Cluster**: Group of adjacent cells that collectively use entire frequency spectrum
- **Frequency reuse**: Same frequencies can be reused in different clusters
- **Pattern repetition**: Cluster pattern repeats throughout coverage area

Mnemonic

"Cells Cluster for Complete Coverage"

Question 1(c) [7 marks]

Describe fundamental concept behind cellular communication systems.

Solution

Cellular communication divides service area into small cells to maximize spectrum efficiency and capacity.
Diagram:

```
+{-{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}+}
|   A    |   B    |   C    |
|  f1    |  f2    |  f3    |
+{-{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}+}
|   D    |   E    |   F    |
|  f4    |  f5    |  f6    |
+{-{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}+}
|   G    |   H    |   I    |
|  f7    |  f1    |  f2    |
+{-{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}+}
```

Table 3: Cellular System Benefits

Concept	Advantage
Frequency Reuse	Same frequencies used multiple times
Cell Division	Smaller coverage areas, more capacity
Handoff	Seamless call transfer between cells
Power Control	Reduced interference, longer battery life

- **Small cell concept**: Service area divided into hexagonal cells for efficient coverage
- **Frequency reuse**: Limited spectrum used multiple times with adequate separation
- **Base station control**: Each cell served by low-power base station
- **Capacity improvement**: More users supported compared to single large coverage area
- **Interference management**: Co-channel interference controlled through proper cell planning

Mnemonic

"Small Cells Support Spectrum Sharing Successfully"

Question 1(c OR) [7 marks]

Explain co-channel interference in cellular communication.

Solution

Co-channel interference occurs when cells using same frequencies are too close, causing signal degradation.

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Cell A {- f1] {-}{-}{} B[Interference Zone]}
    C[Cell C {- f1] {-}{-}{} B}
    B {-{-}{} D[Degraded Signal Quality]}
```

```
    E[Distance D] {-{-}{} F[Reduced Interference]}
{Highlighting}
{Shaded}
```

Table 4: Co-channel Interference Parameters

Parameter	Description	Impact
Reuse Distance	Distance between co-channel cells	Higher distance = Less interference
C/I Ratio	Carrier to Interference ratio	Must be $\geq 18 dB for good quality$
Cluster Size	Number of cells in cluster	Larger cluster = More separation

- **Signal overlap**: Same frequency signals from different cells interfere
- **Quality degradation**: Causes call drops and poor voice quality
- **Distance factor**: Interference reduces with square of distance
- **Mitigation methods**: Proper cell planning, power control, antenna design

Mnemonic

"Co-channel Causes Call Quality Concerns"

Question 2(a) [3 marks]

Explain cell splitting.

Solution

Cell splitting divides congested cells into smaller cells to increase system capacity.
Diagram:

```
Original Large Cell          After Cell Splitting
    +{-{-}{-}{-}{-}{-}{-}+                    +{-}{-}{-}+{-}{-}{-}+}
    |       |                    | A | B |
    |   X   |                  +{-{-}{-}+{-}{-}{-}+}
    |       |                    | C | D |
    +{-{-}{-}{-}{-}{-}{-}+                    +{-}{-}{-}+{-}{-}{-}+}
```

- **Capacity increase**: Each new cell handles fewer users with better service quality
- **Power reduction**: New base stations use lower power to cover smaller areas
- **Frequency management**: Original frequencies distributed among new smaller cells

Mnemonic

"Split Cells Serve Subscribers Successfully"

Question 2(b) [4 marks]

Explain channel assignment strategies.

Solution

Channel assignment strategies determine how frequencies are allocated to cells for optimal performance.

Table 5: Channel Assignment Strategies

Strategy	Description	Advantages	Disadvantages
Fixed	Channels permanently assigned to cells	Simple, predictable	Inefficient during low traffic
Dynamic	Channels assigned based on demand	Efficient spectrum use	Complex implementation
Hybrid	Combination of fixed and dynamic	Balanced approach	Moderate complexity

- **Fixed assignment**: Each cell has predetermined set of channels
- **Dynamic assignment**: Channels allocated in real-time based on traffic demand
- **Load balancing**: Distributes traffic evenly across available channels
- **Interference avoidance**: Considers co-channel interference in assignment decisions

Mnemonic

"Dynamic Distribution Delivers Optimal Performance"

Question 2(c) [7 marks]

Calculate voice and control channels per cell for 33MHz bandwidth, 25KHz simplex channels, 7-cell reuse, 1MHz for control.

Solution

Calculation for channel allocation in cellular system.

Given Data:

- Total bandwidth = 33 MHz
- Channel bandwidth = 25 KHz (simplex)
- Full duplex requires = 2 $\times 25KHz = 50KHz$
- Control spectrum = 1 MHz
- Cluster size = 7 cells

Calculations:

Step 1: Total available channels Total channels = 33 MHz $\div 25KHz = 1320 channels$

Step 2: Control channels Control channels = 1 MHz $\div 25KHz = 40 channels$

Step 3: Voice channels Voice channels = 1320 - 40 = 1280 channels

Step 4: Duplex voice channels Duplex voice channels = 1280 $\div 2 = 640 channels$

Step 5: Channels per cell Voice channels per cell = 640 $\div 7 \approx 91 channels Control channels per cell = 40 \div 7 \approx 6 channels$

Final Answer:

- **Voice channels per cell: 91**
- **Control channels per cell: 6**

Mnemonic

"Calculate Carefully for Channel Count"

Question 2(a OR) [3 marks]

Write functions of FCCH and SCH in GSM.

Solution

FCCH and **SCH** are essential control channels in GSM system for synchronization.

Table 6: FCCH and SCH Functions

Channel	Full Form	Function
FCCH	Frequency Correction Channel	Provides frequency reference to mobile
SCH	Synchronization Channel	Provides timing and cell identity

- **FCCH function**: Enables mobile to synchronize with base station frequency
- **SCH function**: Carries BSIC (Base Station Identity Code) and frame number
- **Timing correction**: Both channels help mobile achieve proper timing synchronization

Mnemonic

"FCCH Fixes Frequency, SCH Synchronizes System"

Question 2(b OR) [4 marks]

Write GSM 900 specifications.

Solution

GSM 900 operates in 900 MHz frequency band with specific technical parameters.

Table 7: GSM 900 Specifications

Parameter	Specification
Uplink Frequency	890-915 MHz
Downlink Frequency	935-960 MHz
Duplex Separation	45 MHz
Channel Spacing	200 KHz
Total Channels	124 channels
Access Method	TDMA/FDMA
Modulation	GMSK
Power Classes	2W, 8W, 20W

- **Frequency bands**: Separate uplink and downlink frequencies for full duplex operation
- **TDMA structure**: 8 time slots per carrier frequency

Mnemonic

"GSM 900 Gives Great Global Coverage"

Question 2(c OR) [7 marks]

Draw and explain GSM architecture.

Solution

GSM architecture consists of three main subsystems working together for mobile communication.

```
graph TB
    MS[Mobile Station] {-{-} BSS[Base Station Subsystem]}
    BSS {-{-} NSS[Network Switching Subsystem]}
    BSS {-{-} BTS[Base Transceiver Station]}
    BSS {-{-} BSC[Base Station Controller]}
    NSS {-{-} MSC[Mobile Switching Center]}
    NSS {-{-} HLR[Home Location Register]}
    NSS {-{-} VLR[Visitor Location Register]}
```

```
    NSS {-{-} AuC[Authentication Center]}
    MSC {-{-} PSTN[Public Switched Telephone Network]}
```

Table 8: GSM Architecture Components

Subsystem	Components	Function
Mobile Station	Mobile Equipment + SIM	User interface and identity
BSS	BTS + BSC	Radio interface and control
NSS	MSC, HLR, VLR, AuC	Switching and database management

- **Mobile Station**: Consists of mobile equipment and SIM card for user identification
- **Base Station Subsystem**: Handles radio communication and resource management
- **Network Switching Subsystem**: Manages call switching, routing, and subscriber databases
- **Interfaces**: A-bis (BTS-BSC), A (BSC-MSC) interfaces connect subsystems

Mnemonic

"Mobile Base Network - Complete Communication Chain"

Question 3(a) [3 marks]

Draw block diagram of signal processing in GSM.

Solution

Signal processing in GSM involves multiple stages for voice and data transmission.
Diagram:

```
Speech   Speech   Channel   Interleaving   Burst   RF
Input     Coding    Coding                Formatting  Processing
  ↓        ↓         ↓         ↓           ↓         ↓
13kbps   22.8kbps  Error   Reordering   Time   Modulation
                   Protection             Slot    \& Transmission
```

- **Speech coding**: Converts analog speech to 13 kbps digital data using RPE-LTP
- **Channel coding**: Adds error correction bits increasing rate to 22.8 kbps
- **Interleaving**: Reorders data to combat burst errors from fading

Mnemonic

"Speech Signals Systematically Processed Successfully"

Question 3(b) [4 marks]

Write functions of Common Control Channels in GSM.

Solution

Common Control Channels manage system information and access procedures in GSM.

Table 9: Common Control Channels Functions

Channel	Function
FCCH	Frequency correction and synchronization
SCH	Frame synchronization and cell identification
BCCH	Broadcasts system information and cell parameters

RACH	Random access for call initiation by mobile
AGCH	Assigns dedicated channels to mobiles
PCH	Pages mobiles for incoming calls

- **Broadcast function**: BCCH continuously transmits system information
- **Access management**: RACH allows mobiles to request service
- **Channel assignment**: AGCH allocates resources for active calls
- **Paging service**: PCH notifies mobiles of incoming calls

Mnemonic

"Common Channels Control Communication Completely"

Question 3(c) [7 marks]

Explain GSM identifiers.

Solution

GSM identifiers uniquely identify subscribers, equipment, and network elements.

Table 10: GSM Identifiers

Identifier	Full Form	Purpose	Format
IMSI	International Mobile Subscriber Identity	Unique subscriber ID	15 digits
IMEI	International Mobile Equipment Identity	Unique equipment ID	15 digits
MSISDN	Mobile Station ISDN Number	Phone number	Variable length
TMSI	Temporary Mobile Subscriber Identity	Temporary ID for security	32 bits
LAI	Location Area Identity	Geographic area identification	MCC+MNC+LAC
BSIC	Base Station Identity Code	Cell identification	6 bits

- **IMSI structure**: MCC (3) + MNC (2-3) + MSIN (9-10 digits)
- **Security purpose**: TMSI protects subscriber identity over radio interface
- **Location management**: LAI helps in efficient paging and location updates
- **Network planning**: BSIC prevents confusion between adjacent cells

Mnemonic

"Important Mobile System Identifiers Ensure Security"

Question 3(a OR) [3 marks]

Compare Fast and Slow frequency hopping.

Solution

Frequency hopping techniques differ in hopping rate relative to symbol rate.

Table 11: Fast vs Slow Frequency Hopping

Parameter	Fast Hopping	Slow Hopping
Hopping Rate	> Symbol rate	< Symbol rate

Symbols per Hop	< 1	> 1
Complexity	High	Low
Applications	Military, Bluetooth	GSM, CDMA

- **Fast hopping**: Multiple hops per symbol, better security but more complex
- **Slow hopping**: Multiple symbols per hop, simpler implementation

Mnemonic

"Fast Frequently Flips, Slow Stays Stable"

Question 3(b OR) [4 marks]

Calculate number of users in GSM 900 band without frequency reuse.

Solution

Calculation for maximum users in GSM 900 without frequency reuse.
Given GSM 900 Parameters:

- Uplink: 890-915 MHz (25 MHz)
- Downlink: 935-960 MHz (25 MHz)
- Channel spacing: 200 KHz
- Time slots per channel: 8

Calculations:
Step 1: Available channels Total channels = 25 MHz $\div 200 KHz = 125 channels$
Step 2: Usable channels Guard channels removed $\approx 124 channels$
Step 3: Simultaneous users Users per channel = 8 time slots Total users = 124 $\times 8 = 992 users$

Solution

Mnemonic

"Calculate Channels Times Time-slots"

Question 3(c OR) [7 marks]

Draw and explain general block diagram of mobile handset.

Solution

Mobile handset consists of several functional blocks working together.

```
graph TB
    A[Antenna] {-{-} B[RF Section]}
    B {-{-} C[IF Section]}
    C {-{-} D[Baseband Processor]}
    D {-{-} E[Audio Section]}
    D {-{-} F[Display Unit]}
    D {-{-} G[Keypad]}
    H[Power Management] {-{-} D}
    I[Battery] {-{-} H}
    J[SIM Interface] {-{-} D}
```

Table 12: Mobile Handset Blocks

Block	Function
RF Section	Signal transmission and reception
Baseband	Digital signal processing
Audio	Voice input/output processing
Power Management	Battery and power control
User Interface	Display, keypad, speaker, microphone

- **RF processing**: Handles radio frequency transmission and reception
- **Digital processing**: Baseband performs channel coding, speech processing
- **User interface**: Provides interaction through display, keypad, audio
- **Power control**: Manages battery usage and charging functions

Mnemonic

"Mobile Manages Multiple Modules Simultaneously"

Question 4(a) [3 marks]

Write radiation hazards due to mobile.

Solution

Radiation hazards from mobile phones are a health concern due to RF energy exposure.

Table 13: Mobile Radiation Hazards

Hazard	Effect	Prevention
SAR Exposure	Tissue heating	Use hands-free devices
Brain Effects	Memory, sleep issues	Limit call duration
Cancer Risk	Potential tumor risk	Keep phone away from body

- **SAR (Specific Absorption Rate)**: Measures RF energy absorbed by body tissue
- **Thermal effects**: RF energy can cause localized heating of tissues
- **Non-thermal effects**: Possible impacts on cellular functions and DNA

Mnemonic

"Safety Awareness Reduces Radiation Risk"

Question 4(b) [4 marks]

Explain working of baseband section in mobile handset.

Solution

Baseband section performs digital signal processing functions in mobile handset.

Table 14: Baseband Section Functions

Function	Description
Speech Processing	Encode/decode voice using vocoder
Channel Coding	Add error correction and detection
Modulation	Convert digital data to analog signals
Protocol Processing	Handle signaling and call control

- **Digital signal processor**: Executes speech coding algorithms (GSM: RPE-LTP)
- **Error correction**: Implements convolutional coding for reliable transmission
- **Control functions**: Manages call setup, handoff, and power control
- **Interface**: Connects RF section with user interface components

Mnemonic

"Baseband Brings Better Communication Control"

Question 4(c) [7 marks]

Explain working of DSSS transmitter and receiver.

Solution

DSSS (Direct Sequence Spread Spectrum) spreads signal bandwidth using pseudorandom codes.
Transmitter Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Data Input] {-{-}{} B[PN Code Generator]}
    A {-{-}{} C[XOR Gate]}
    B {-{-}{} C}
    C {-{-}{} D[Modulator]}
    D {-{-}{} E[RF Output]}
{Highlighting}
{Shaded}
```

Receiver Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    F[RF Input] {-{-}{} G[Demodulator]}
    G {-{-}{} H[XOR Gate]}
    I[PN Code Generator] {-{-}{} H}
    H {-{-}{} J[Data Output]}
{Highlighting}
{Shaded}
```

Table 15: DSSS Process

Stage	Transmitter	Receiver
Spreading	Data XOR with PN code	Received signal XOR with PN
Modulation	Spread signal modulated	Demodulate received signal
Processing	Bandwidth increased	Original data recovered

- **Spreading process**: Original data XORed with high-rate pseudorandom sequence
- **Bandwidth expansion**: Signal bandwidth increased by processing gain factor
- **Despreading**: Receiver uses same PN code to recover original data
- **Interference rejection**: Spread spectrum provides resistance to jamming

Mnemonic

"Direct Sequence Spreads Signals Successfully"

Question 4(a OR) [3 marks]

Calculate processing gain for DSSS system with 10 Mcps chip rate and 1 Mbps data rate.

Solution

Processing gain determines spread spectrum system's performance improvement.
Given:

- Chip rate (Rc) = 10 million chips per second = 10 $\times 10^6 cps$
- Data rate (Rd) = 1 Mbps = 1 $\times 10^6 bps$

Calculation: Processing Gain (Gp) = Chip rate $\div DatarateGp = Rc \div Rd = (10 \times 10^6) \div (1 \times 10^6) = 10$
In dB: Gp (dB) = 10 $\log_{10}(10) = 10 \times 1 = 10dB$

Solution

Mnemonic

"Processing Power Provides Protection"

Question 4(b OR) [4 marks]

Explain how data rate is improved in EDGE.

Solution

EDGE (Enhanced Data rates for GSM Evolution) improves data rates through advanced modulation.

Table 16: EDGE Improvements

Parameter	GSM	EDGE	Improvement
Modulation	GMSK	8-PSK	3 bits per symbol vs 1 bit
Data Rate	9.6 kbps	43.2 kbps per slot	~4.5x increase
Coding	Fixed	Adaptive	Link adaptation
Applications	Voice, SMS	Multimedia, Internet	Enhanced services

- **8-PSK modulation**: Transmits 3 bits per symbol instead of 1 bit in GMSK
- **Link adaptation**: Dynamically selects coding scheme based on channel quality
- **Backward compatibility**: Works with existing GSM infrastructure
- **Enhanced applications**: Supports multimedia and higher data rate services

Mnemonic

"EDGE Enhances Exchange Efficiently"

Question 4(c OR) [7 marks]

Explain call processing in CDMA.

Solution

CDMA call processing involves unique procedures for code-based multiple access.

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Mobile Power On] {-{-}{} B[Pilot Channel Search]}
    B {-{-}{} C[Sync Channel Read]}
    C {-{-}{} D[Paging Channel Monitor]}
    D {-{-}{} E[Access Channel Request]}
    E {-{-}{} F[Traffic Channel Assignment]}
    F {-{-}{} G[Active Call State]}
    G {-{-}{} H[Soft Handoff]}
{Highlighting}
{Shaded}
```

Table 17: CDMA Call Processing Stages

Stage	Process	Function
Initialization	Pilot acquisition	Find strongest base station
Idle State	Monitor paging	Listen for incoming calls
Access	Random access	Request service from network
Traffic	Dedicated channel	Active communication
Handoff	Soft handoff	Seamless cell transition

- **Pilot channel**: Provides timing reference and system identification
- **Rake receiver**: Combines multipath signals for improved performance
- **Power control**: Maintains optimal signal levels for all users
- **Soft handoff**: Mobile communicates with multiple base stations simultaneously
- **Code assignment**: Each user assigned unique spreading code

Mnemonic

"CDMA Calls Connect Carefully and Clearly"

Question 5(a) [3 marks]

Compare CDMA and GSM.

Solution

CDMA and **GSM** represent different approaches to cellular communication.

Table 18: CDMA vs GSM Comparison

Parameter	CDMA	GSM
Access Method	Code Division	Time/Frequency Division
Capacity	Higher	Lower
Handoff	Soft handoff	Hard handoff
Security	Better (spreading codes)	Good (encryption)
Global Usage	Limited	Widespread
Power Control	Continuous	Periodic

- **Multiple access**: CDMA uses unique codes, GSM uses time slots
- **Call quality**: CDMA provides soft handoff, GSM has hard handoff

Mnemonic

"Choose CDMA or GSM Carefully"

Question 5(b) [4 marks]

Write advantages of CDMA.

Solution

CDMA advantages make it suitable for high-capacity cellular systems.

Table 19: CDMA Advantages

Advantage	Benefit
High Capacity	More users per spectrum
Soft Handoff	Seamless call transfer
Variable Rate	Adapts to speech patterns
Privacy	Inherent security through spreading
Multipath Resistance	Uses rake receiver
Power Control	Optimizes battery life
Frequency Planning	Same frequency in all cells

- **Spectrum efficiency**: Higher capacity compared to FDMA/TDMA systems
- **Quality advantage**: Soft handoff eliminates call drops during cell transitions
- **Security benefit**: Spread spectrum provides inherent privacy protection
- **Simplified planning**: No frequency reuse planning required

Mnemonic

"CDMA Creates Considerable Communication Capacity"

Question 5(c) [7 marks]

Explain MANET in brief and write its applications.

Solution

MANET (Mobile Ad Hoc Network) is infrastructure-less network of mobile devices.

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Mobile Node A] {-.{-}{} B[Mobile Node B]}
    B {-.{-}{} C[Mobile Node C]}
    C {-.{-}{} D[Mobile Node D]}
    A {-.{-}{} C}
    B {-.{-}{} D}
    A {-.{-}{} D}

    style A fill:\#f9f
    style B fill:\#9ff
    style C fill:\#ff9
    style D fill:\#9f9
{Highlighting}
{Shaded}
```

Table 20: MANET Characteristics vs Applications

Characteristic	Feature	Applications
Self-organizing	No fixed infrastructure	Military communications
Dynamic topology	Nodes move freely	Emergency response
Multi-hop routing	Intermediate node relay	Disaster recovery
Distributed control	No central authority	Sensor networks
Resource constraints	Limited battery, bandwidth	Vehicular networks

Applications:

- **Military operations**: Battlefield communications without infrastructure
- **Emergency services**: Disaster response and rescue operations
- **Sensor networks**: Environmental monitoring and data collection
- **Vehicular networks**: Car-to-car communication for traffic management
- **Personal area networks**: Device-to-device communication
- **Academic research**: Collaborative computing environments

Advantages:

- **Rapid deployment**: No infrastructure setup required
- **Self-healing**: Automatic route reconfiguration when nodes fail
- **Cost effective**: No base station installation costs

Disadvantages:

- **Limited bandwidth**: Shared wireless medium
- **Security challenges**: Vulnerable to attacks
- **Power constraints**: Battery-dependent operation

Mnemonic

"Mobile Ad Hoc Networks Enable Everywhere"

Question 5(a OR) [3 marks]

Write key features of WCDMA.

Solution

WCDMA (Wideband CDMA) is the 3G standard offering enhanced capabilities.

Table 21: WCDMA Key Features

Feature	Specification
Chip Rate	3.84 Mcps
Bandwidth	5 MHz
Data Rates	Up to 2 Mbps
Spreading	Variable spreading factor
Power Control	Fast closed-loop
Handoff	Soft and softer handoff

- **Wideband operation**: 5 MHz bandwidth provides high data rates
- **Variable spreading**: Adapts to different service requirements

Mnemonic

"WCDMA Widens Communication Data Magnificently"

Question 5(b OR) [4 marks]

Enlist advantages of 5G.

Solution

5G advantages represent significant improvements over previous generations.

Table 22: 5G Advantages

Advantage	Benefit
Ultra-high Speed	Up to 20 Gbps peak data rate
Low Latency	<1ms for critical applications
Massive IoT	1 million devices per km^2
Network Slicing	Customized virtual networks
Enhanced Coverage	Better indoor and edge coverage
Energy Efficiency	100x more efficient than 4G
High Reliability	99.999% availability

- **Enhanced mobile broadband**: Supports AR/VR and 4K/8K video streaming
- **Ultra-reliable communications**: Enables autonomous vehicles and remote surgery
- **Massive machine communications**: Supports smart cities and Industry 4.0
- **Flexible network architecture**: Software-defined networking capabilities

Mnemonic

"5G Generates Great Gigabit Growth"

Question 5(c OR) [7 marks]

Explain working of OFDM with block diagram.

Solution

OFDM (Orthogonal Frequency Division Multiplexing) uses multiple subcarriers for high-speed data transmission.

OFDM Transmitter:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Serial Data] {-{-}{} B[Serial to Parallel]}
    B {-{-}{} C[QAM Mapping]}
    C {-{-}{} D[IFFT]}
    D {-{-}{} E[Add Cyclic Prefix]}
    E {-{-}{} F[Parallel to Serial]}
    F {-{-}{} G[RF Transmission]}
{Highlighting}
{Shaded}
```

OFDM Receiver:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    H[RF Reception] {-{-}{} I[Serial to Parallel]}
    I {-{-}{} J[Remove Cyclic Prefix]}
    J {-{-}{} K[FFT]}
```

```
    K {-{-}{} L[QAM Demapping]}
    L {-{-}{} M[Parallel to Serial]}
    M {-{-}{} N[Serial Data]}
{Highlighting}
{Shaded}
```

Table 23: OFDM Process Steps

Stage	Transmitter Function	Receiver Function
Data Conversion	Serial to parallel conversion	Parallel to serial reconstruction
Modulation	QAM mapping on subcarriers	QAM demapping
Transform	IFFT creates time domain signal	FFT recovers frequency domain
Guard Period	Cyclic prefix prevents ISI	Cyclic prefix removal

Key Features:

- **Orthogonal subcarriers**: Multiple parallel low-rate data streams prevent interference
- **FFT/IFFT processing**: Efficient digital implementation using fast transforms
- **Cyclic prefix**: Guard interval prevents inter-symbol interference from multipath
- **Spectral efficiency**: High data rates achieved in limited bandwidth
- **Multipath resistance**: Individual subcarriers experience flat fading

Applications:

- **WiFi (802.11)**: Wireless LAN communications
- **LTE/4G**: Mobile broadband networks
- **Digital TV**: DVB-T terrestrial broadcasting
- **WiMAX**: Broadband wireless access

Advantages:

- **High spectral efficiency**: Optimal bandwidth utilization
- **Robustness**: Resistant to frequency selective fading
- **Flexibility**: Adaptive modulation per subcarrier
- **Implementation**: Digital signal processing simplifies hardware

Table 24: OFDM Parameters

Parameter	Typical Values
Subcarriers	64, 128, 256, 512, 1024
Modulation	BPSK, QPSK, 16-QAM, 64-QAM
Cyclic Prefix	1/4, 1/8, 1/16 of symbol duration
Applications	WiFi, LTE, DVB, WiMAX

Mnemonic

"OFDM Offers Outstanding Data Multiplexing"