

**Chapter 1 : Introduction to Wireless Communication Systems** **1-1 to 1-38**

**Syllabus :** Evolution of mobile communications, Mobile Radio System around the world, Types of Wireless communication System, Comparison of Common wireless system, Trend in Cellular radio and personal communication. Second generation Cellular Networks, Third Generation (3G) Wireless Networks, Wireless Local Loop(WLL), Wireless Local Area network (WLAN), Bluetooth and Personal Area Networks.

1.1	Introduction .....	1-2
1.1.1	Wireless Communication .....	1-2
1.1.2	Need of Wireless Communication .....	1-2
1.2	Evolution of Mobile Communications .....	1-3
1.3	Mobile Radiotelephony in the U.S. ....	1-4
1.3.1	Cellular Radiotelephony .....	1-4
1.3.2	AMPS .....	1-4
1.3.3	Spectrum Allocated to the U.S. Cellular Radio Service .....	1-5
1.3.4	Digital Cellular Telephony .....	1-5
1.3.5	CDMA Based Systems .....	1-5
1.4	Mobile Radio Systems Around the World .....	1-6
1.4.1	AMPS .....	1-6
1.4.2	Narrowband-AMPS (N-AMPS) .....	1-7
1.4.3	CDMA IS-95 .....	1-8
1.4.4	GSM (Global System for Mobile Communications) .....	1-8
1.4.5	UMTS (Universal Mobile Telecommunication Service) .....	1-8
1.4.6	CDMA 2000 .....	1-9
1.5	Examples of Wireless Communication Systems .....	1-9
1.5.1	Important Definitions .....	1-9
1.5.2	Paging Systems .....	1-11
1.5.3	Cordless Telephone Systems .....	1-12
1.5.4	Cellular Telephone System .....	1-13
1.5.5	Comparison of Wireless Systems .....	1-15
1.6	Trends in Cellular Radio and Personal Communications .....	1-16
1.6.1	Advantages of Wireless Communication Systems .....	1-17
1.6.2	Disadvantages of Wireless Communication Systems .....	1-17
1.6.3	Applications of Wireless Communication Systems .....	1-17

1.7	Wireless Generations .....	1-18
1.7.1	First Generation Cellular Networks .....	1-18
1.8	Growth of Cellular Communication .....	1-19
1.9	Second Generation Cellular Networks .....	1-20
1.9.1	Types of 2G Standards .....	1-20
1.9.2	Technical Specifications .....	1-21
1.9.3	Features of 2G Systems .....	1-22
1.9.4	Evolution to 2.5G Mobile Radio Networks .....	1-23
1.9.5	Evolution for 2.5-G TDMA Standards .....	1-24
1.9.5.1	HSCSD for 2.5-G GSM .....	1-24
1.9.5.2	GPRS for 2.5- G GSM and IS-136 .....	1-25
1.9.5.3	EDGE for 2.5-G GSM and IS-136 .....	1-26
1.9.6	IS-95 B for 2.5-G CDMA .....	1-27
1.9.7	Comparison of HSCSD, GPRS and EDGE .....	1-27
1.10	Third Generation (3-G) Wireless Networks .....	1-28
1.10.1	Features of Third Generation .....	1-28
1.10.2	Services Provided by 3G Systems .....	1-28
1.10.3	Advantages of 3-G Networks .....	1-29
1.10.4	3G W-CDMA (UMTS) .....	1-29
1.10.5	Comparison of GSM and W-CDMA .....	1-31
1.10.6	Comparison of Various Mobile System Generations .....	1-31
1.11	Fixed Wireless Networks .....	1-32
1.11.1	Wireless Local Loop (WLL) .....	1-32
1.11.2	Wireless Local Area Network (WLAN) .....	1-33
1.12	Bluetooth and Personal Area Networks.....	1-36

**• Review Questions..... 1-37****Chapter 2 : The Cellular Concept** **2-1 to 2-42**

**Syllabus : The Cellular Concept : System Design**

**Fundamentals :** Cellular system, Hexagonal geometry cell and concept of frequency reuse, Channel Assignment Strategies, Distance to frequency reuse ratio, Channel and co-channel interference reduction factor, S/I ratio consideration and calculation for Minimum Co-channel and adjacent interference, Handoff Strategies, Umbrella Cell Concept, Trunking and Grade of Service, Improving Coverage and Capacity in Cellular System-Cell splitting, Cell sectorization, Repeaters, Micro cell zone concept, Channel antenna system design considerations.



2.1	Cellular Concept.....	2-2	2.9	Trunking and Grade of Service .....	2-31
2.1.1	Advantages of Cellular Concept .....	2-2	2.9.1	Trunking .....	2-31
2.2	The Basic Cellular System .....	2-2	2.9.2	Trunking and Queueing Theory .....	2-32
2.2.1	Structure of Cellular Phone System .....	2-3	2.9.3	Grade of Service (GOS).....	2-32
2.2.2	Advantages of Cellular Concept .....	2-4	2.9.4	Definitions Related to Trunking Theory .....	2-32
2.3	Hexagonal Cell Geometry .....	2-5	2.9.5	Capacity of a trunked system .....	2-33
2.4	Frequency Reuse .....	2-6	2.9.6	Types of Trunked systems .....	2-33
2.4.1	Advantages of Frequency Reuse .....	2-6	2.9.7	Blocked calls Cleared (BCC) System .....	2-33
2.4.2	Frequency Reuse Schemes .....	2-6	2.9.8	Blocked calls Delayed (BCD) System .....	2-34
2.4.3	Analysis of Frequency Reuse Concept .....	2-7	2.10	Improving Coverage and Capacity in Cellular Systems.....	2-34
2.4.4	Capacity of Cellular System (C) .....	2-7	2.10.1	Cell Splitting .....	2-34
2.4.5	Frequency Reuse Distance .....	2-7	2.10.2	Cell Sectoring .....	2-36
2.4.6	Selection of Cluster Size .....	2-9	2.10.3	Repeaters for Range Extension .....	2-38
2.5	Channel Assignment Strategies .....	2-15	2.10.4	A Microcell Zone Concept .....	2-39
2.5.1	Fixed Channel Assignment (FCA) .....	2-15	2.10.5	Comparison between Cell Sectoring and Cell Splitting .....	2-40
2.5.2	Dynamic Channel Assignment (DCA) .....	2-16	2.10.6	Types of Cells .....	2-40
2.5.3	Hybrid Channel Assignment .....	2-16	2.11	Channel Antenna System Design Considerations .....	2-40
2.5.4	Difference Between FCA and DCA .....	2-17	2.11.1	Antenna Requirements.....	2-41
2.6	Cellular System Operation and Planning .....	2-17	•	<b>Review Questions.....</b>	<b>2-42</b>
2.6.1	System Architecture .....	2-17			
2.6.2	Location Updating and Call Setup .....	2-18			
2.7	Hand Off .....	2-19			
2.7.1	Handoff Strategies .....	2-20			
2.7.2	Dwell Time .....	2-21			
2.7.3	Different Types of Hand Offs .....	2-21			
2.7.4	Cell Dragging .....	2-23			
2.7.5	Comparison of Hard and Soft Handoffs .....	2-23			
2.7.6	Comparison of Delayed and Queued Handoffs .....	2-23			
2.7.7	Umbrella Cell Approach .....	2-23			
2.7.8	Prioritizing Handoffs .....	2-24			
2.8	Interference and System Capacity .....	2-25			
2.8.1	Co-channel Interference and System Capacity .....	2-25			
2.8.2	The S/I Ratio of a Mobile System .....	2-27			
2.8.3	Channel Planning for Wireless Systems .....	2-30			
2.8.4	Adjacent Channel Interference .....	2-30			
2.8.5	Power Control for Reducing Interference .....	2-31			

**Chapter 3 : Mobile Radio Propagation      3-1 to 3-68**

**Syllabus :** Mobile Radio Propagation Model, Small Scale Fading and diversity : Large scale path loss : Free Space Propagation loss equation, Path-loss of NLOS and LOS systems, Reflection, Ray ground reflection model, Diffraction, Scattering, Link budget design, Maximum Distance Coverage formula, Empirical formula for path loss, Indoor and outdoor propagation models, Small scale multipath propagation, Impulse model for multipath channel, Delay spread, Feher's delay spread, Upper bound Small scale, Multipath Measurement parameters of multipath channels, Types of small scale Fading, Rayleigh and Rician distribution, Statistical models for multipath fading channels and diversity techniques in brief.

3.1	Introduction.....	3-3
3.1.1	Radio Wave Propagation .....	3-3
3.1.2	Multipath Propagation .....	3-4
3.1.3	Multipath Fading .....	3-4
3.2	Propagation Models .....	3-4



3.3	Free Space Propagation Model .....	3-5	3.15.1	Effects of Small Scale Fading .....	3-36
3.3.1	Friis Free Space Equation .....	3-6	3.15.2	Factors Affecting Small-Scale Fading ..	3-37
3.3.2	EIRP .....	3-6	3.15.3	Coherence Bandwidth .....	3-37
3.3.3	Path Loss .....	3-6	3.15.4	Doppler Shift .....	3-37
3.3.4	Validity of Friis Model .....	3-7	3.16	Impulse Response Model of a Multipath	
3.3.5	Fraunhofer Region .....	3-7		Channel .....	3-40
3.3.6	Received Power in Terms of Reference Distance .....	3-7	3.17	Delay Spread .....	3-41
3.4	Basic Propagation Mechanisms .....	3-10	3.17.1	Power Delay Profile.....	3-43
3.5	Reflection .....	3-11	3.18	Feher's Delay Spread - Upper Bound .....	3-44
3.5.1	Reflection from Dielectrics .....	3-11	3.19	Small-Scale Multipath Measurements .....	3-45
3.5.2	Plots of Reflection Coefficients .....	3-13	3.19.1	Direct RF Pulse System .....	3-45
3.5.3	Brewster Angle .....	3-14	3.19.2	Spread Spectrum Sliding Correlator Channel Sounding .....	3-46
3.5.4	Reflection from Perfect Conductors ...	3-15	3.19.3	Frequency Domain Channel Sounding .....	3-48
3.6	Ground Reflection (Two Ray) Model .....	3-15	3.20	Parameters of Multipath Channels .....	3-49
3.6.1	Advantages of Two Ray Model .....	3-17	3.20.1	Time Dispersion Parameters .....	3-50
3.6.2	Disadvantage of Two Ray Model .....	3-17	3.20.2	Coherence Bandwidth ( $B_c$ ) .....	3-51
3.7	Diffraction .....	3-18	3.20.3	Doppler Spread and Coherence Time .....	3-52
3.7.1	Huygen's Principle .....	3-18	3.21	Types of Small Scale Fading .....	3-53
3.7.2	Fresnel Zone Geometry .....	3-18	3.21.1	Small-Scale Fading Effects Due to Multipath Time Delay Spread .....	3-53
3.7.3	Knife-edge Diffraction Model .....	3-20	3.21.1.1	Flat Fading .....	3-53
3.7.4	Multiple Knife-Edge Diffraction .....	3-21	3.21.1.2	Frequency Selective Fading .....	3-55
3.8	Scattering .....	3-23	3.21.2	Fading Effects Due to Doppler Spread .....	3-56
3.9	Link Budget Design .....	3-23	3.22	Rayleigh and Rician Distributions .....	3-57
3.9.1	Log-Distance Path Loss Model .....	3-24	3.22.1	Rayleigh Distribution .....	3-57
3.9.2	Log-normal Shadowing .....	3-25	3.22.2	Rician Fading Distribution .....	3-59
3.10	Maximum Distance Coverage Formula .....	3-25	3.22.3	Difference between Rayleigh and Ricean Distribution .....	3-60
3.11	Empirical Formula for Path Loss .....	3-26	3.23	Statistical Models for Multipath Fading Channels .....	3-60
3.12	Outdoor Propagation Models .....	3-27	3.23.1	Clarke's Model for Flat Fading .....	3-60
3.12.1	Okumura Propagation Model .....	3-27	3.23.2	Simulation of Clarke and Gans Fading Model .....	3-61
3.12.2	Hata Model .....	3-29	3.23.3	Level crossing and Fading Statistics ...	3-61
3.12.3	Longley-Rice Propagation Model .....	3-30	3.23.4	Two-Ray Rayleigh Fading Model .....	3-62
3.12.4	Durkin's Propagation Model .....	3-30	3.23.5	Saleh and Valenzuela Indoor Statistical Model .....	3-62
3.13	Indoor Propagation Models .....	3-31	3.24	Diversity Reception .....	3-63
3.13.1	Partition Losses (Same Floor of a Building) .....	3-32	3.25	Diversity Techniques .....	3-63
3.13.2	Partition Losses between Floors .....	3-32			
3.13.3	Log-distance Path Loss Model .....	3-33			
3.13.4	Ericsson Multiple Breakpoint Model ..	3-34			
3.13.5	Attenuation Factor Model .....	3-34			
3.14	Signal Penetration into Buildings .....	3-35			
3.15	Small Scale Multipath Propagation .....	3-36			



3.26 Types of Diversity Techniques ..... 3-65	4.5.6 Disadvantages ..... 4-12
3.26.1 Space Diversity ..... 3-65	4.5.7 CDMA Applications ..... 4-12
3.26.1.1 Classification of Space Diversity Reception Methods ..... 3-66	4.6 Spread-Spectrum Multiple Access (SSMA) ..... 4-12
3.26.1.2 Advantages of Space Diversity ..... 3-66	4.6.1 Model of Spread Spectrum Modulation System ..... 4-14
3.26.1.3 Disadvantages Space Diversity ..... 3-66	4.7 Direct Sequence Spread Spectrum (DSSS) Multiple Access ..... 4-15
3.26.2 Polarization Diversity ..... 3-66	4.7.1 Advantages of DS-SS System ..... 4-15
3.26.3 Frequency Diversity ..... 3-66	4.7.2 Disadvantages of DS-SS System ..... 4-16
3.26.4 Time Diversity ..... 3-67	4.7.3 Applications of DS-SS System ..... 4-16
• Review Questions ..... 3-67	4.8 Frequency Hop Spread Spectrum (FH-SS) Multiple Access ..... 4-16
<b>Chapter 4 : Multiple Access Techniques 4-1 to 4-30</b>	4.8.1 Operation of FHSS ..... 4-16
<b>Syllabus :</b> Introduction, Comparisons of multiple Access Strategies TDMA,CDMA, FDMA, OFDM, CSMA Protocols, NOMA.	4.8.2 Types of Frequency Hopping ..... 4-17
4.1 Multiple Access ..... 4-2	4.8.3 Advantages of FH-SS System ..... 4-18
4.1.1 Frequency Division Duplexing (FDD) ... 4-2	4.8.4 Disadvantages of FH-SS System ..... 4-18
4.1.2 Time Division Duplexing (TDD) ..... 4-2	4.8.5 Applications of FHSS ..... 4-18
4.2 Multiple Access Techniques ..... 4-3	4.8.6 Comparison of DS-SS and FHSS ..... 4-18
4.2.1 Types of Multiple Access Based on the Bandwidth Availability ..... 4-3	4.9 Orthogonal Frequency Division Multiplexing (OFDM) ..... 4-18
4.3 Frequency Division Multiple Access (FDMA) ..... 4-4	4.9.1 Orthogonality ..... 4-18
4.3.1 Features of FDMA ..... 4-4	4.9.2 Assigning the Subcarriers ..... 4-19
4.3.2 Nonlinear Effects in FDMA ..... 4-5	4.9.3 Generation of OFDM Signals ..... 4-20
4.3.3 Number of FDMA Channels ..... 4-5	4.9.4 OFDM-PAPR (OFDM-Peak-to-peak Average Power Ratio) ..... 4-20
4.3.4 Merits of FDMA ..... 4-6	4.9.5 Comparison of FDM and OFDM ..... 4-20
4.3.5 Demerits of FDMA ..... 4-6	4.10 OFDMA (Orthogonal Frequency Division Multiple Access) ..... 4-21
4.4 Time Division Multiple Access (TDMA) ..... 4-6	4.10.1 Features of OFDMA ..... 4-22
4.4.1 Number of Channels in TDMA System ..... 4-7	4.10.2 Disadvantage of OFDMA ..... 4-22
4.4.2 Efficiency of TDMA System ..... 4-7	4.10.3 Applications of OFDMA ..... 4-22
4.4.3 TDMA Features ..... 4-8	4.11 CSMA Protocols ..... 4-22
4.4.4 Advantages of TDMA ..... 4-8	4.11.1 Types of CSMA ..... 4-22
4.4.5 Advantages of TDMA over FDMA ..... 4-8	4.11.2 Flow diagram of CSMA-CA ..... 4-22
4.4.6 Disadvantages of TDMA ..... 4-8	4.11.3 RTS/CTS Handshake ..... 4-23
4.4.7 Problems with FDMA and TDMA ..... 4-8	4.11.4 Types of CSMA / CA ..... 4-24
4.5 Code Division Multiple Access (CDMA) ..... 4-9	4.12 Comparison of Multiple Access Strategies ..... 4-25
4.5.1 Spread Spectrum and CDMA ..... 4-10	4.13 NOMA ..... 4-26
4.5.2 Basic Structure of CDMA System ..... 4-10	4.13.1 Classification of NOMA ..... 4-28
4.5.3 Salient Features of CDMA Systems .... 4-11	4.13.2 Resource Management in NOMA Networks ..... 4-28
4.5.4 Multiple Access Techniques in Cellular Systems ..... 4-12	4.13.3 Implementation Challenges of NOMA ..... 4-28
4.5.5 Advantages of CDMA ..... 4-12	



4.13.4 Performance Enhancement.....	4-28	5.6.4 Subscriber Identity Module (SIM) .....	5-15
4.13.5 Advantages of NOMA.....	4-28	5.6.5 Mobile System ISDN (MSISDN) .....	5-15
4.13.6 Drawbacks of NOMA.....	4-29	5.6.6 LAI (Location Area Identity) .....	5-16
4.13.7 Comparison of OMA and NOMA.....	4-29	5.6.7 IMEI (International MS Equipment Identity) / IMEI (International Mobile Equipment Identity) .....	5-16
• Review Questions .....	4-29	5.6.8 MS Roaming Number (MSRN) .....	5-17
<b>Chapter 5 : Wireless Systems-GSM</b>	<b>5-1 to 5-40</b>	5.6.9 TMSI [Temporary Mobile Subscriber Identity] .....	5-17
<b>Syllabus :</b> GSM system architecture, Radio interface, Protocols, Localization and calling, Handover, Authentication and security in GSM, GSM speech coding.		<b>5.7</b> GSM Channels .....	<b>5-17</b>
5.1 Global System for Mobile (GSM).....	5-2	5.8 GSM Logical Channel .....	5-17
5.2 GSM System Architecture .....	5-2	5.8.1 GSM Traffic Channels (TCHs) .....	5-18
5.2.1 Detail Architecture of GSM .....	5-3	5.8.2 GSM Control Channels (CCH) .....	5-19
5.2.2 Various Subsystems in GSM .....	5-4	<b>5.9</b> Frame Structure of GSM System .....	<b>5-20</b>
5.2.3 MS (Mobile Station) .....	5-4	<b>5.10</b> GSM Burst Structures .....	<b>5-22</b>
5.2.4 BSS (Base Station Subsystem) .....	5-5	5.10.1 Normal Burst / Frame Structure of GSM System .....	5-22
5.2.5 NSS (Network Switching Subsystem) ...	5-6	5.10.2 Frequency Correction Burst .....	5-23
5.2.6 OMSS Operation and Maintenance Subsystem.....	5-7	5.10.3 Synchronization Burst .....	5-23
5.2.7 Characteristics / Features of GSM Standard .....	5-8	5.10.4 Access Burst .....	5-23
5.3 GSM Radio Interface.....	5-9	5.10.5 Dummy Burst .....	5-24
5.3.1 GSM air Interface Specifications .....	5-10	<b>5.11</b> Signal Processing in GSM .....	<b>5-24</b>
5.4 GSM Signalling Protocol Architecture .....	5-11	5.11.1 An Example of Call Routing .....	5-26
5.4.1 GSM Interfaces .....	5-12	<b>5.12</b> PLMN Interfaces .....	<b>5-27</b>
5.4.2 Mobile Station-Base Transceiver Station Signaling Protocols .....	5-12	<b>5.13</b> Calling in GSM .....	<b>5-28</b>
5.4.3 Abis Interface / Base Transceiver Station (BTS)-Base Station Controller (BSC) Signaling Protocols .....	5-13	5.13.1 Location Updating .....	5-28
5.4.4 A Interface / Base Station Controller (BSC) – Mobile Switching Centre (MSC) Signaling Protocols .....	5-14	5.13.2 Mobile Terminated Call.....	5-28
5.5 Signalling System - 7 (SS7) .....	5-14	5.13.3 Mobile Originated Call .....	5-29
5.5.1 Primary Characteristics of SS7 .....	5-14	<b>5.14</b> GSM Handoff or Handover .....	<b>5-30</b>
5.5.2 Functions of SS7 .....	5-14	5.14.1 Handover in GSM .....	5-30
5.5.3 Features of SS7 .....	5-14	5.14.2 Types of Handovers in GSM .....	5-30
5.6 Identifiers and Addresses used in GSM .....	5-14	<b>5.15</b> Security in GSM .....	<b>5-31</b>
5.6.1 IMSI (International Mobile Subscriber Identity) .....	5-15	5.15.1 Access Control and Authentication ....	5-32
5.6.2 MSIN (Mobile Subscriber Identification Number) .....	5-15	5.15.2 Confidentiality .....	5-32
5.6.3 MSRN (Mobile Station Roaming Number) .....	5-15	5.15.3 Anonymity .....	5-32
		5.15.4 Authentication in GSM .....	5-32
		5.15.5 Authentication Algorithm A-3 .....	5-33
		5.15.6 Data Encryption Process using A-5 and A-8 Algorithm .....	5-33
		<b>5.16</b> GSM Services .....	<b>5-34</b>
		5.16.1 Teleservices .....	5-35
		5.16.2 Data Services / Bearer Services .....	5-35
		5.16.3 Bearer Services .....	5-36



5.16.4	Supplementary Services .....	5-36
5.17	Applications of GSM .....	5-37
5.17.1	Other applications of GSM .....	5-38
5.18	Advantages of GSM.....	5-38
5.19	Disadvantages of GSM .....	5-39
•	<b>Review Questions .....</b>	<b>5-39</b>

**Chapter 6 : Wireless Systems-IS-95                  6-1 to 6-38**

**Syllabus :** Concept of spread spectrum, Architecture of IS-95 CDMA system, Air interface, CDMA forward channels, CDMA reverse channels, Soft handoff, CDMA features, Power control in CDMA, Performance of CDMA System, RAKE Receiver, CDMA 2000 cellular technology, GPRS system architecture.

6.1	Introduction to 2G Cellular Systems .....	6-2
6.1.1	Evolution from 2G to 3G Cellular Networks .....	6-2
6.2	Interim Standard CDMA IS-95 .....	6-2
6.2.1	Types of Channels in IS-95 System .....	6-3
6.3	Frequency and Channel Specifications of CDMA IS-95 .....	6-3
6.3.1	Frequency Specifications of IS-95 .....	6-4
6.3.2	Features of CDMA IS-95 .....	6-4
6.3.3	Forward Link .....	6-4
6.3.4	Reverse Link .....	6-5
6.3.5	Interferences in CDMA IS-95 System ....	6-5
6.4	CDMA IS-95 System Architecture .....	6-6
6.5	CDMA Air Interface .....	6-7
6.5.1	Classification of CDMA IS-95 Channels .....	6-10
6.5.2	IS-95 Air interface Standards .....	6-11
6.6	IS - 95 CDMA Channel Structure .....	6-11
6.6.1	The IS-95 CDMA Forward Channels ...	6-11
6.6.2	The IS-95 CDMA Reverse Channels ....	6-13
6.6.3	Comparison of Forward and Reverse IS-95 CDMA Channels .....	6-16
6.7	Forward and Reverse Channel Modulation Process .....	6-16
6.7.1	Forward Channel Modulation Process .....	6-16
6.7.2	Reverse Channel Modulation Process .....	6-16
6.8	IS-95 CDMA Call Processing .....	6-17
6.9	IS-95 CDMA Packet and Frame Format .....	6-17

6.9.1	IS-95 Forward Channels	
	Frame Format .....	6-18
6.9.2	Frame Formats of Reverse Channel ....	6-19
6.10	Handoffs in IS-95 CDMA .....	6-20
6.10.1	Soft handoff .....	6-20
6.10.2	Hard handoff .....	6-21
6.10.3	Inter-sector or Softer handoff .....	6-21
6.10.4	Soft-softer handoff.....	6-21
6.11	Near-Far Problem .....	6-21
6.12	Mobility and Radio Resource Management ....	6-22
6.12.1	Mobility Management .....	6-22
6.12.2	Concept of Resource Management ....	6-22
6.13	Security and Authentication in IS-95 CDMA ....	6-24
6.14	Output Power Control in CDMA .....	6-24
6.14.1	Performance of the CDMA System ....	6-25
6.15	Comparison of GSM and IS-95 .....	6-25
6.16	Advantages of CDMA IS-95 .....	6-26
6.17	Disadvantages of CDMA IS-95 .....	6-26
6.18	Rake Receiver .....	6-27
6.18.1	Advantages of RAKE Receiver .....	6-29
6.19	Evolution from GSM to 3G Networks .....	6-29
6.20	GPRS - General Packet Radio Service .....	6-29
6.20.1	Features of GPRS .....	6-30
6.20.2	GPRS Architecture .....	6-30
6.20.3	GPRS Radio Interface .....	6-32
6.20.4	Advantages of GPRS .....	6-33
6.20.5	Disadvantages of GPRS .....	6-33
6.20.6	Applications of GPRS .....	6-33
6.20.7	Comparison of GSM and GPRS .....	6-33
6.21	Need of 3G Technology .....	6-34
6.21.1	Advantages of 3G Wireless Networks .....	6-34
6.21.2	Disadvantages of 3G Wireless Networks .....	6-34
6.21.3	Applications of 3G Networks .....	6-34
6.21.4	Various 3G Standards .....	6-35
6.22	CDMA 2000 Technology .....	6-35
6.22.1	Advanced Versions of CDMA 2000 ....	6-35
6.22.2	Specifications of CDMA 2000 .....	6-36
6.22.3	Forward and Reverse Channels .....	6-36
6.22.4	Handoff and Power Control .....	6-36
6.22.5	Features of CDMA 2000 .....	6-37



6.22.6 Advantages of CDMA 2000 .....	6-37	7.10.3 Spread Spectrum Technology .....	7-13
6.22.7 Disadvantages of CDMA 2000 .....	6-37	7.11 IEEE 802.11 Standard for WLAN .....	7-14
6.22.8 Comparison of IS-95 and CDMA 2000 .....	6-37	7.11.1 Classification of WLANs .....	7-14
• <b>Review Questions</b> .....	<b>6-38</b>	7.11.2 The IEEE 802.11 Protocol Stack .....	7-14
<b>Chapter 7 : Recent Trends</b>	<b>7-1 to 7-54</b>	7.11.3 802.11 Network Architecture .....	7-15
<b>Syllabus :</b> Introduction to Wi-Fi, WiMAX, ZigBee Networks, MIMO, Software Defined Radio, UWB Radio, Wireless Adhoc Network and Mobile Portability, Security issues and challenges in 5-G and above Wireless networks.		7.11.4 Types of Stations .....	7-16
7.1 Introduction to WLAN/Wi-Fi.....	7-2	7.12 The Physical Layer .....	7-16
7.1.1 IEEE Standards .....	7-2	7.12.5 Various PHY Specifications .....	7-17
7.1.2 Wi-Fi .....	7-2	7.13 MAC Sublayer .....	7-17
7.1.3 ISM Band .....	7-2	7.13.1 RTS and CTS Messages .....	7-18
7.2 Architectural Comparison of Wired and Wireless LANs .....	7-3	7.13.2 The Retry Counters .....	7-18
7.3 WLAN Equipment .....	7-4	7.13.3 Distributed Co-ordination Function (DCF) .....	7-18
7.3.1 LAN Adapter .....	7-4	7.13.4 Hidden Station Problem .....	7-20
7.3.2 Access Point (AP) .....	7-4	7.14 Point Co-ordinate Function (PDF) .....	7-20
7.3.3 Outdoor LAN Bridges .....	7-5	7.14.1 Fragmentation .....	7-21
7.4 WLAN Topologies .....	7-6	7.14.2 Exposed Station Problem .....	7-21
7.4.1 Peer-to-peer (ad hoc) Topology .....	7-6	7.15 Framing in WLAN .....	7-22
7.4.2 AP Based Topology .....	7-6	7.15.1 Advantages of WLANs .....	7-23
7.5 Characteristics of WLANs .....	7-6	7.15.2 Disadvantages of WLAN .....	7-23
7.5.1 Attenuation .....	7-6	7.15.3 Applications of Wireless LAN .....	7-23
7.5.2 Interference .....	7-7	7.16 Wireless MAN (WMAN) .....	7-24
7.5.3 Multipath Propagation .....	7-7	7.16.1 Wi-MAX .....	7-24
7.5.4 Error .....	7-7	7.16.2 Wi-Bro (Wireless Broadband) .....	7-25
7.6 Design Goals for WLANs .....	7-7	7.16.3 Need of Wireless MAN (WMAN) .....	7-25
7.6.1 Factors Considered to Deploy WLAN .....	7-8	7.17 IEEE 802.16 (Wi-MAX) .....	7-25
7.7 Technical Issues in WLANs .....	7-9	7.17.1 Wi-Max Standards .....	7-25
7.8 Medium Access Control .....	7-9	7.17.2 Structure of WMAN .....	7-25
7.9 MAC Protocol Issues .....	7-10	7.17.3 IEEE Project 802.16 (Wi-Max) .....	7-26
7.9.1 Hidden Terminal Problem .....	7-10	7.17.4 New Standards .....	7-26
7.9.2 Exposed Station Problem .....	7-11	7.17.5 Spectrum Allocation .....	7-27
7.9.3 Reliability .....	7-12	7.17.6 Specifications of IEEE 802.16 .....	7-27
7.9.4 Collision Avoidance .....	7-12	7.18 Wi-Max Services .....	7-27
7.10 WLAN Technologies .....	7-12	7.18.1 Fixed Wi-Max Services .....	7-27
7.10.1 IR (Infrared) Technology .....	7-12	7.18.2 Mobile Wi-Max Services .....	7-27
7.10.2 UHF Narrowband Technology .....	7-13	7.18.3 Internet Access .....	7-28
		7.18.4 Mobile Phones based on Wi-Max .....	7-28
		7.18.5 Spectral Efficiency .....	7-28
		7.18.6 Advantages of IEEE 802.16 (Wi-MAX) .....	7-28
		7.18.7 Disadvantages of Wi-MAX .....	7-29
		7.18.8 Uses / Applications of Wi-Max .....	7-29



7.18.9 Comparison of IEEE 802.11 and IEEE 802.16 .....	7-29	7.25.5 UWB Disadvantages .....	7-41
7.19 Wireless PAN (WPAN) .....	7-30	7.25.6 UWB Applications .....	7-42
7.19.1 Need of Wireless PAN .....	7-30	7.25.7 Comparison between WPAN Systems .....	7-42
7.20 ZigBee (IEEE 802.15.4) .....	7-30	7.26 Wireless Ad hoc Network .....	7-43
7.20.1 Features of ZigBee .....	7-31	7.26.1 Need of adhoc Wireless Networks .....	7-43
7.20.2 Radio Specifications .....	7-31	7.26.2 Features of Wireless Ad hoc Network .....	7-43
7.21 ZigBee Topologies .....	7-31	7.26.3 Quantitative Features .....	7-43
7.21.1 Star Topology .....	7-32	7.26.4 Qualitative Features .....	7-44
7.21.2 Mesh (Peer to Peer) Topology .....	7-32	7.26.5 Advantages of Wireless Ad hoc Network .....	7-45
7.21.3 Cluster Tree Topology .....	7-32	7.26.6 Applications of Wireless Ad hoc Network .....	7-45
7.21.4 Applications of ZigBee .....	7-33	7.26.7 Difference between Ad-hoc and Cellular Networks .....	7-45
7.21.5 Comparison of Bluetooth and ZigBee .....	7-33	7.27 5-G and Above Wireless Networks .....	7-46
7.22 Multi-antenna Technologies .....	7-34	7.27.1 Why 5-G? .....	7-46
7.22.1 Single Input Single Output (SISO) .....	7-34	7.27.2 Features of 5-G .....	7-46
7.22.2 Single Input Multiple Output (SIMO) .....	7-34	7.27.3 Features of Fifth Generation .....	7-47
7.22.3 Multiple Input Single Output (MISO) .....	7-34	7.27.4 Expectations in 5-G Network .....	7-47
7.22.4 Multiple Input Multiple Output (MIMO) .....	7-35	7.27.5 Technologies of 5G .....	7-47
7.23 MIMO Systems .....	7-35	7.27.6 Advantages of 5-G Technology .....	7-47
7.23.1 Types of MIMO .....	7-35	7.27.7 Applications of 5-G .....	7-47
7.23.2 A 2 x 2 MIMO .....	7-36	7.27.8 Challenges for 5G Networks .....	7-48
7.23.3 Advantages of MIMO .....	7-36	7.28 Security Issues in Wireless Networks .....	7-48
7.23.4 Disadvantages of MIMO .....	7-36	7.28.1 Security Issues of Wireless Networks .....	7-49
7.23.5 Applications of MIMO .....	7-36	7.28.2 Attacks .....	7-49
7.24 Software Defined Radio (SDR) .....	7-36	7.28.3 Attacks on Confidentiality .....	7-49
7.24.1 Features/ Advantages of SDR .....	7-37	7.28.4 Attacks on Integrity .....	7-49
7.24.2 Problems in SDR Communications .....	7-38	7.28.5 Attacks on Availability .....	7-50
7.24.3 Applications of SDR .....	7-39	7.29 Security Issues in 5G and Above Technologies .....	7-50
7.25 UWB Radio .....	7-39	7.30 University Questions and Answers .....	7-52
7.25.1 UWB Radio Specifications .....	7-40	• <b>Review Questions.....</b>	<b>7-51</b>
7.25.2 UWB Features .....	7-41		
7.25.3 Antenna Systems in UWB .....	7-41		
7.25.4 UWB Advantages .....	7-41		

