Department of Information Technology
Indian Institute of Engineering Science and Technology, Shibpur
Proposed Course Structure for Two-Year M. Tech (Information Technology) Program
(From 2019 Onward)

First Semester

Serial Number	Subject Code	Paper	Credit
1	IT 5101	Paper I: Algorithms	3
2	IT 5102	Paper II: Advanced Computer Architecture	3
3	IT 5103	Paper III: Advanced Communication Systems	3
4	IT 512X	Paper IV: Electives (Dept.)	3
5	IT 516X	Paper V: Electives (Open)	3
	Theory Subtotal		15
6	IT 5171	Lab I: Algorithms Laboratory	2
7	IT 5172	Lab II: Advanced Computer Architecture-Laboratory	2
8	IT 5173	Lab III: Advanced Communication SystemsLaboratory	2
	Practical Subtotal		6
	Total Credit		21

First Semester Electives

Paper –IV: Elective (Departmental)	Paper –V: Elective (Open)
1. Soft Computing Techniques (IT 5121) 2. Embedded Systems and IoT (IT 5122) 3. Pervasive Computing (IT 5123) 4. Discrete and Computational Geometry (IT 5124) 5. Information and Coding Theory (IT 5125) 6. Design of Operating Systems (IT 5126) 7. Mathematics for Computation (IT 5127)	1. Complex Systems and Cellular Automata (IT 5161) 2. Wireless Networks (IT 5162) 3. Cryptographic Techniques (IT 5163) 4. Medical Image Processing (IT 5164) 5. Multi-core Architecture and Parallel Programming (IT 5165) 6. Introduction to Embedded Systems (IT 5166)

Second Semester

Serial Number	Subject Code	Paper	Credit

1	IT 5201	Paper VI: Advanced Database Management System	3
2	IT 5202	Paper VII: Network and Information Security	3
3	IT 5203	Paper VIII: Internet and Distributed Computing	3
4	IT 522X	Paper IX: Electives (Dept.)	3
5	IT 526X	Paper X: Elective (Open)	3
	Theory Subtotal		15
6	IT 5291	M. Tech Project Part I (Term Paper)	4
7	IT 5292	Term Paper Seminar and Viva-voce	2
	Practical Subtotal		6
	Total Credit		21

Second Semester Electives

Paper –IX: Elective (Departmental)	**Paper –X: Elective (Open)**
1. Multimedia Coding and Compression (IT 5221) 2. Mobile Computing (IT 522) 3. Approximation Algorithms (IT 5223) 4. Real Time Systems (IT 5224) 5. Machine Learning (IT 5225) 6. Cloud and Services Computing (IT 5226)	1. CAD Algorithms for VLSI (IT 5261) 2. Computational Topology (IT 5262) 3. IoT Systems (IT 5263) 4. DSP Algorithms (IT 5264) 5. Embedded System Security (IT 5265) 6. Cognitive Radio and Networks (IT 5266)

Third Semester

Sl. No	**Subject Code**	**Subject**	**Credit**
1	IT6191	M. Tech Thesis Part - II (Progress Report)	12
2	IT6192	Progress Report Seminar & Viva-voce	6
	Total Credit		**18**

Fourth Semester

Sl. No	**Subject Code**	**Subject**	**Credit**
1	IT6291	M. Tech Final thesis	22

2	IT6292	Thesis Seminar & Viva-voce	8
	Total Credit		**30**

FIRST SEMESTER

Paper I: IT 5101 Algorithms

Pre-requisites: Discrete Mathematics, Programming and Data Structure

SI No.	Module Name and Topics	No. of Classes
1.	Models of Computation; Algorithms and Complexity; Best case, worst case and average case; asymptotic notations	6
2.	Elementary Algorithms: Sorting and searching; search trees; balanced trees; hashing	6
3.	Lower bound theory	2
4.	Optimization problems; Dynamic programming and Greedy method; theoretical foundations of greedy method	6
5.	Graph algorithms: BFS and DFS, Minimum Spanning Trees, Shortest Paths, Max Flow	6
6.	Randomized algorithms: identity testing, primality and min cut, Number theoretic algorithms	6
7.	Limit of computation, complexity classes: P, NP and NP completeness	6
	TOTAL	**38**

Books:

1. Aho, Hopcroft and Ullman: The Design and Analysis of Computer Algorithms (Pearson)
2. Cormen, Leiserson, Rivest and Stein: Introduction to Algorithms, 3rd Edition (The MIT Press)

Paper II: IT 5102 Advanced Computer Architecture

Pre-requisites: Computer Architecture and Organization

Course Objectives:

- To provide an exposure to current and emerging trends in Computer Architectures, focusing on performance and the hardware/software interface.
- To provide the fundamental aspects of computer architecture design and analysis.
- To teach some computer instruction set and know how to design a control unit, arithmetic unit, data path, memory to implement a computer with that instruction set.
- To understand concepts of parallel processing and design choices of implementing parallel execution within a single processor (Processor design, pipeline, VLIW, and superscalar) and multiprocessor systems.

Syllabus:

Sl. No.	Module Name and Topics	No. of Classes
1.	Overview of von Neumann architecture: CISC and RISC processors, Instruction set architecture; Architecture, Measuring and reporting performance, Data Path Design.	8

2.	Pipelining: Basic concepts of pipelining, data hazards, control hazards, and structural hazards; Techniques for overcoming or reducing the effects of various hazards	6
3.	Hierarchical Memory Technology: Inclusion, Coherence and locality properties; Cache memory organizations, Techniques for reducing cache misses; Virtual memory organization, mapping and management techniques, memory replacement policies	8
4.	Instruction-level parallelism: Concepts of instruction-level parallelism (ILP), Techniques for increasing ILP; Superscalar, super-pipelined and VLIW processor architectures; Vector and symbolic processors; Case studies of contemporary microprocessors	8
5.	Multiprocessor Architecture: Taxonomy of parallel architectures; Centralized shared-memory architecture, synchronization, memory consistency, interconnection networks; Distributed shared-memory architecture, Cluster computers. Multi-core architectures	8
	TOTAL	**38**

Text Books:

1. Computer Architecture: A quantitative approach – John L. Hennessy, David A. Patterson – Morgan Kaufmann
2. Computer organization and Architecture: Designing for performance William Stallings – Pearson
3. Advanced Computer Architecture: Parallelism,Scalability and programmability Kai Hwang, NareshJotwani – Mc Graw Hill,2008.

Reference Books:

1. Computer Organization and design: The Hardware/Software Interface, David A. Patterson, John L. Hennessy -Morgan Kaufmann, Year: 2004.

Paper III: IT 5103 Advanced Communication Systems

Pre-requisites: Students are expected to have knowledge on probability and statistics, random processes, and communication engineering.

Syllabus:

Sl. No.	**Module Name and Topics**	**No. of Classes**
1.	Baseband, narrowband and wideband signals and noise representation and characteristics of communication channels.	4
2.	Baseband binary signal transmission over band limited channels, Transmission coding and PSD, ISI and its control	4
3.	Synchronization techniques: Carrier, bit and frame synchronization, optimum receive filtering, match filtering.	4
4.	M-ary signals orthogonal representation, Gram-Schmidt procedure, signal space concept, Bandwidth efficient	4
5.	Digital carrier modulation techniques: Binary and M-ary shift keying techniques, QPSK, MPSK, MSK, GMSK, coherent and non-coherent detection, PSD and bit error rate calculation	8

6.	Spread Spectrum: Concept of spectrum spreading, process gain, properties and generation of code patterns, DSSS, FHSS, THSS techniques and their comparison	8
7.	Principle of detection and estimation: Binary and M-ary hypothesis testing. Bayes' likelihood ratio test, waveform estimation, linear estimation problems, Wiener filtering, Kalman filtering	6
	TOTAL	**38**

Books:

1. Digital communications by Simon Haykin-Wiley.
2. Modern Communications and Spread Spectrum by G. R. Cooper and C. D. McGllem-McGraw-Hill Int.
3. Digital Communication Techniques Signal Design and Detection by Marvin K. Simon, Sami M. Hinedi, William C. Lindsey, PHI
4. Digital Communication by J. R. Barry, E. A. Lee and D. G. Messerschmitt, Springer International.

Paper IV: IT 512X Elective (Departmental)

Paper IV: IT 5121 Elective (Departmental)
Soft Computing Techniques

Prerequisites: Following subjects are assumed to be taken by the students:
Discrete mathematics, Calculus: Integration and Differentiation, Concepts of Algorithm and Programming.

Syllabus:

Sl. No.	**Module Name and Topics**	No. of Classes
1	**Introduction:** Limitations of Artificial Intelligence; Definition of Soft Computing; Difference between Hard and Soft Computing; Domain soft computing techniques; Introduction to Fuzzy Systems, Artificial Neural Network, Genetic Algorithm, Rough Set Theory; Hybrid Systems	2
2	**Fuzzy Logic System:** --Fuzzy Set Theory --Fuzzy Relation --Fuzzy Logic and Approximate Reasoning --Fuzzy logic system design, --Applications	12
3	**Artificial Neural Network (ANN):** --Basic electrical model of artificial neuron. --NN Architectures: Single Layer feed forward, Multiple layer feed forward and Recurrent network. --Learning Processes: Error correction, memory based, competitive learning, Hebbian learning and Boltzman learning. --Learning Single layer perceptron and *Backpropagation Learning* --Hopfield NN and Associative Memory --SOM Models and related algorithms. --Applications	10

4	**Genetic Algorithm:** Difference between Traditional Algorithms and GA, Encoding, Fitness Function, Reproduction, Cross Over, Mutation, Applications.	4
5	**Rough Set Theory:** Indiscernibility Relations Reducts Rough Approximation Applications.	4
6	**Meta-heuristics** PSO, Ant Colony Optimization, Honey Bee etc.	4
TOTAL		**38**

Text Books:

1. Neural networks A comprehensive foundation, Simon Haykin, Pearson Education 2nd Edition 2004
2. Neural Fuzzy Systems- A Neuro-Fuzzy Synergism to Intelligent System, C.T. Lin and George Lee, Prentice Hall
3. Genetic Algorithms in Search, Optimization and Machine Learning, David E. Goldberg.

Reference Books:

1. Artificial neural networks by B.Vegnanarayana Prentice Halll of India P Ltd 2005
2. Neural networks in Computer intelligence, Li Min Fu TMH 2003
3. Neural networks, James A Freeman David M S Kapura Pearson Education 4. An Introduction to Genetic Algorithms, Melanie Mitchell, MIT Press.
4. Uncertain Rule-Based Fuzzy Logic Systems: Introduction and New Directions, Jerry M. Mendel.
5. Fuzzy Logic with Engineering Applications, Timothy. J. Ross
6. Fuzzy Sets and Fuzzy Logic – Theory and Applications, G. J. Klir and Bo Yuan, Prentice Hall India

Paper IV: IT 5122 Elective (Departmental)
Embedded Systems and IoT

Prerequisites: Digital Logic and Circuit Design, Knowledge of microprocessors, microcontrollers.
Course Objective: Primary objective of this course is to introduce the concepts of necessity, characteristics, design, and detailed working principles of an embedded system dominating each electronic and computing sector in industry.
Program outcome:

1. Students will get a first-hand introduction towards the basic design as well as working principle of embedded systems.
2. Details regarding different components used as building blocks in an embedded system should be introduced to the reader.
3. Both electronic/electrical aspects as well as programming aspects to be introduced to get the entire working flavour of the system.
4. Different case studies taken from different application sectors to be introduced to prepare the students ready for the real-life applications of such systems.

Syllabus:

Sl. No.	**Module Name and Topics**	**No. of Classes**

1	**Introduction to Embedded System** Definition of Embedded System & its classification, characteristics of embedded systems, design parameters/Metrics of embedded systems. Components of embedded systems with review of Microprocessor & Microcontrollers, introduction to embedded processor, Digital signal processor, Application specific system processor, Multiprocessor systems using General Purpose Processor.	8
2	**System Processor** Standard Single purpose processors: Peripherals, Introduction, Timers, Counters and watchdog Timers, UART, Pulse Width Modulators, Clocking unit, Real Time Clock Reset Circuitry. Processor and memory organization, processor and memory selection, Memory Types, Memory map and addresses.	6
3	**I/O Interfacing** I/O devices: ADC/DAC, Optical Devices such as LED/LCD Display devices, Keyboard controller, Timer & counting devices, serial communication using I2C, SPI,CAN, RS232, & USB. Device drivers & interrupt service Mechanism: ISR concepts and ISR handling mechanisms	6
4	**Programming Concepts, Embedded System Programming C & C++** Assemble language high level lang. C program Elements, Micros & Function, Data types, Data Structures, Modifiers, Statement, loops & Pointers, queues & Stacks, List & order list, Embedded System Programming in C++ & Java. C Program Compilers & Cross Compilers. In Circuit emulator. Software engineering practices in the embedded software development process.	6
5	**Real Time Operating Systems** Real Time & embedded system OS: off the shelf operating Systems, Embedded OS, Real Time OS, hand held OS.	2
6	**Overview & Applications of Embedded System** Case Study of coding for Vending machine system using MUCOSRTOS, Case study coding for send application layer byte streams on A TCP/IP Network Using RTOS Vx works, Case study of an Embedded System for an adapting Cruise control System in a car, Case Study in embedded system for Smart Card, Case Study of Digital camera.	6
7	**Internet of Things** IoT evolution, Basics of IoT, Embedded systems design standards and metrics for IoT, IoT in home automation, healthcare, agriculture, and industrial applications, Different IoT platforms (hardware), Emerging directions in IoT.	4
	TOTAL	**38**

Text Books:

1. Embedded System Design A Unified Hardware/Software Introduction (3e) - by Frank Vahid / Tony Givargis - Wiley India
2. Embedded systems architecture, programming and design (2e) - by Raj Kamal – TMH

Reference Books:

1. Introduction to Embedded Systems (2e) – by Shibu K V, McGraw Hill Education (India)
2. Computer Organization and Embedded Systems (6e) – by Carl Hamacher et al, McGraw Hill International

3. Embedded Systems – Concepts, Design and Programming - by Dave and Dave, Pearson
4. Embedded/Real Time Systems: Concepts, Design and Programming – by Prasad, Dreamtech Press
5. Embedded Microcontrollers and Processor Design – by Osborn, Pearson
6. Embedded Systems Architecture – by Noergaard, ELSEVIER
7. Embedded System Design for students – by Verma, SPD
8. Designing Embedded Hardware – by Catsoulis, SPD, O'Reilly

Paper IV: IT 5123 Elective (Departmental)
Pervasive Computing

Prerequisites: The student may have basic concepts on computer networks and operating system.
Course outcome: After completion of this course the student will learn about the basics of modern smart computing, sensing system, context aware and intelligent system, HCI, and pervasive communication

Syllabus:

Sl. No.	Module Name and Topics	No. of Classes
1.	Introduction to pervasive computing Introduction to ubiquitous computing, modelling the property, system environment, architecture design	3
2.	Application and requirements Introduction, discussion on pervasive computing research projects, application in every day life and in industry.	6
3	Smart devices for pervasive computing Introduction to smart devices; mobile smart device users, resources and programming; operating system for pervasive computing	6
5.	Human computer interaction User interface and its interaction, human centered design, hidden UI via smart, wearable and implanted device, user model acquisition and representation	3
6	Tagging sensing and controlling Tagging the physical world, sensor and its network, embedded and real time system,	6
7	Context aware system Modelling of context aware system, mobility awareness, spatial awareness, temporal awareness	3
8.	Intelligent systems Basic concept, architecture, design, and systems operation	3
9.	Pervasive communication Introduction, data network, wireless network, ubiquitous network, future network and issues	8
	TOTAL	**38**

Books:
1. Ubiquitous Computing: Smart Devices, Environments and Interactions, By Stefan Poslad, J Wiley.
2. Fundamentals of Mobile And Pervasive Computing, By Adelstein, Tata McGraw-Hill Education

3. Pervasive Computing and Networking edited by Mohammad S. Obaidat, Mieso Denko, Isaac Woungang, J Wiley
4. Pervasive Computing, by Jochen Burkhardt, Dr. Horst Henn, Stefan Hepper, Klaus Rindtorff, Thomas Schack, Pearson Education India
5. Pervasive Computing: Concepts, Technologies and Applications, By Minyi Guo, Jingyu Zhou, Feilong Tang, Yao Shen, CRC

Paper IV: IT 5124 Elective (Departmental)
Discrete and Computational Geometry

Prerequisite(s): Concepts of Computer Graphics, Data Structures and Algorithms
Course Objectives - (a) Introduce rigorous algorithmic analysis for problems in Computational Geometry. (b) Discuss applications of Computational Geometry to graphical rendering. (c) Introduce the notions of Voronoi diagrams and Delaunay Triangulations.
Course Outcome - (a) Analyze randomized algorithms for small domain problems. (b) Use line-point duality to develop efficient algorithms. (c) Apply geometric techniques to real-world problems in graphics.

Syllabus:

Sl. No.	Module Name and Topics	No. of Classes
1.	Computational Geometry: Introduction, degeneracy and robustness, Application domains	3
2.	Orthogonal range searching (in brief): kd-tree, range tree, Lower Bounds on Algebraic tree model and Geometric data structures (DCEL)	5
3.	The Maximal Points Problem (closest pair and farthest pair), Geometric searching, Slab method, Range searching	3
4.	Point Location and Triangulation, triangulating monotone polygon	4
5.	Convex Hull, Different Paradigms, Voronoi Diagram and Delaunay Triangulation, and Quickhull	5
6.	Line segment intersection, Linear programming, Intersection of convex polygons, planes	5
7.	Clustering Point Sets using Quadtrees and Applications	2
8.	Medial Axis, Straight Skeleton, Minkowski Sums	3
9.	Shortest Paths and Geodesics	3
10	Intersection geometry and empty space recognition	2
11.	Some applications and case studies	3
	TOTAL	**38**

Books:
1. Computational Geometry Algorithms and Applications, Authors: de Berg, M., Cheong, O., van Kreveld, M., Overmars, M.
2. Computational Geometry, An Introduction, Authors: Preparata, Franco P., Shamos, Michael.
3. Discrete and Computational Geometry, Satyan L. Devadoss& Joseph O'Rourke.
4. Matoušek, Jiří. Lectures on discrete geometry. Vol. 108. New York: Springer, 2002.

Paper IV: IT 5125 Elective (Departmental)
Information and Coding Theory

Pre-requisites: Students are expected to have knowledge on Probability, Statistics, random process, and Communication Engineering.

Syllabus:

Sl. No.	Module Name and Topics	No. of Classes
1.	Sources-memoryless and Markov; Information; Entropy for discrete ensembles; Shannon's noiseless coding theorem; source coding; Mutual Information; channel capacity; BSC and other channel	6
2.	Shannon's noisy coding theorem and converse for discrete channels; Continuous channels	4
3.	Channel Coding, linear block codes; cycle codes, Golay codes and cyclic Redundancy Check (CRC) codes; BCH and Reed-Soloman codes, LDPC codes; Convolution codes; majority logic decoding; Viterbi decoding algorithm	14
4.	Space-time coding for SISO and MISO systems	4
5.	Information theory and coding for physical layer security: Wire-tap channel, Slowly fading wiretap channel, Relay channel and in presence of un-trusted relay	10
	TOTAL	**38**

Books:
1. Information Theory, Coding and Cryptography by Ranjan Bose, TMH
2. Elements of Information Theory, 2nd Edition **Thomas M. Cover**, **Joy A. Thomas**, Wiley
3.An Introduction to information theory by REZA, FAZLOLLAH M.
4.Error Control Coding from theory to practice by Peter Sweeney John Wiley

Paper IV: IT 5126 Elective (Departmental)
Design of Operating Systems

Prerequisites: None

Course Objectives: This course aims towards providing a detailed understanding of structure, purpose and functions of modern operating systems, including hardware and software concepts related to design of OS, process control, concurrency control, processor/disk scheduling, memory management, storage management.
The course will include case studies on Linux and Windows operating systems.

Course Outcome: Upon successful completion of this course a student will gain the followings:

1. Detailed understanding of structure, purpose and functioning of modern operating systems
2. Problem solving capabilities related to process management, scheduling, synchronization,concurrency control, deadlock handling
3. Understand memory management, use of virtual memory in modern operating systems, and the structure of the most common file-systems
4. Understanding of Linux and Windows operating systems

Syllabus:

Sl. No.	Module Name and Topics	No. of Classes
1.	**Introduction to Operating Systems:** Review of operating systems evolution, operating systems structure, user perspective, introduction to kernel, system calls, system programs, interrupts, context switching	3
2.	**Hardware and Software Concepts:** Hardware components, caching, direct memory access (DMA), hardware support for operating systems, bootstrapping, buffering, software overview, firmware	3
3.	**Process/Thread Concepts**: Concept of process, Process synchronization, Process Management and Scheduling, Co-operating processes, Inter-process communication (IPC), Remote procedure call (RPC), Hardware requirements: protection, privileged mode, Threads and their management, Communication in client-server systems	2
4.	**Concurrency Control:** The critical section problem, Synchronization hardware, Semaphores, Classical problems of synchronization, Tools and constructs for concurrency, Detection prevention and avoidance of deadlocks, Recovery from deadlocks, Dynamic resource allocation	4
5.	**Processor Scheduling:** Scheduling criteria, Pre-emptive Non-pre-emptive scheduling, Priorities, Aging, Scheduling algorithms, Multiple processor scheduling, Algorithm evaluation	3
6.	**Memory Management:** Physical and Virtual Memory, Paging, Segmentation, Locality, Demand Paging, Process creation, Page replacement, Frame allocation, Thrashing	5
7.	**Disk Performance Optimization:** Evolution of secondary storage, disk scheduling criteria, disk scheduling algorithms, rotational optimization, caching and buffering, RAID	3
8.	**File Management:** File Systems, File Organization, File Allocation, Free Space Management, Swap Space Management, File Access Control	3
9.	**I/O Management:** I/O Hardware, Application I/O Interface, Kernel I/O Subsystem, Transforming I/O Requests to Hardware Operations	2
10.	**Case Studies:** **Design of UNIX operating system:** Architecture of Unix OS, kernel, structure of buffer cache, buffer pool, file system, process control, I/O system	5
11.	**Design of Windows operating systems:** Design Principles, Architecture, System Components, Environmental Subsystems, File system, Programmer Interface	5
	TOTAL	**38**

Essential Reading:

1. Abraham Silberschatz, Peter B. Galvin, Greg Gagne, Operating System Concepts, Wiley.
2. Harvey M. Deitel, Paul J. Deitel and David R. Choffnes. Operating systems. Delhi.: Pearson Education: Dorling Kindersley.
3. Maurice J. Bach, The design of the UNIX operating system. Englewood Cliffs, NJ: Prentice-Hall.
4. Arpaci-Dusseau, Remzi H., and Andrea C. Arpaci-Dusseau. Operating systems: Three easy pieces. Vol. 1. Arpaci-Dusseau Books, 2015.

References:

1. William Stallings, Operating Systems, Internals and Design Principles, Pearson Education.
2. Andrew S. Tanenbaum, Herbert Bos, Modern Operating Systems, Prentice Hall
3. Randal E. Bryant and David Richard O'Hallaron. Computer systems: a programmer's perspective, Prentice Hall

Paper IV: IT 5127 Elective (Departmental)
Mathematics for Computation

Prerequisites: Basics of Discrete Mathematics, Programming and Data Structure.

Sl. No.	Module Name and Topics	No. of Classes
1.	Review of Group Theory, Rings and Fields	6
2.	Queuing Theory: Introduction, Analysis of a single queue, Queuing Network, Operational Loss	6
3.	Vector Calculus: Surface and Volume Integral, Stoke's Theorem, Green's Theorem, Divergence Theorem	8
4.	Probability and Statistics Basics of Covariance and Correlation, Conditional probability and Bayes Theorem, Probability distribution functions for univariate and multivariate variables, Maximum Likelihood estimation, Maximum a posteriori estimation, Random Process, Stochastic Process and Modelling	10
5.	Linear Algebra:Matrix Decomposition, Matrix Diagonalization and its Applications, Vector Space, Tensor algebra and tensor analysis	8
	TOTAL	**38**

Books:

1. Lehman, Eric, Tom Leighton, and Albert R. Meyer. Mathematics for computer science. Technical report, 2006. Lecture notes, 2010.
2. Kleinrock, Leonard. "Queueing Systems: Volume 1: Theory, 1975." A Wiley-Interscience Publication (1975).
3. Kleinrock, Leonard. Queueing systems, volume 2: Computer applications. Vol. 66. New York: wiley, 1976.
4. Gilbert and Nicholson: Modern algebra with applications. Second Edition.
5. S Barry Cooper: Computability Theory
6. Angelo Margaris: First order mathematical logic.

Paper V: IT 516X Elective (Open)

Paper V: IT 5161 Elective (Open)
Complex Systems and Cellular Automata

Prerequisite: Discrete Mathematics

Syllabus:

Sl. No.	Module Name and Topics	No. of Classes
1.	Function Composition, Parallel Map, Computable Functions, Finite Automata, Turing Machine	4
2	Introduction to cellular automata, basic definitions, symbolic dynamics, Hedlund's theorem; Game of Life: an example of a cellular automaton	2
2.	Injectivity and Surjectivity of cellular automata, Garden-of-Eden theorem, balance property	4
3.	Reversible cellular automata, de Bruijn graphs and testing reversibility and surjectivity of one-dimensional CA, Amoroso and Patt's algorithm, Reachability tree	8
4.	Models of Computation, Computation in Nature, Cellular Automata as Natural Models of Computation, Computational universality in cellular automata	4
5.	Introduction to dynamical systems, cellular automata as discrete dynamical systems, limit sets and attractors, Undecidability	4
6.	Chaos, sensitivity and mixing properties, expansivity, Lyapunov Exponent, Modelling of physical systems, Understanding biological self-reproduction using cellular automata	4
7.	Uniformity in cellular automata, introduction of non-uniformity, hybrid, asynchronous and network cellular automata	4
8.	Cellular automata as technology	4
	TOTAL	**38**

References:

1. Joel L. Schife. *Cellular Automata: A Discrete View of the World.* Wiley-Interscience
2. TommasoToffoli, Norman Margolus. *Cellular Automata Machines: A New Environment for Modeling.* MIT Press

Paper V: IT 5162 Elective (Open)
Wireless Networks

Prerequisite: Students should have knowledge in communication technologies and computer networking.
Course objective: This course covers advanced topics in wireless networking and mobile computing, including supporting wireless technologies, various types of wireless networks, mobile protocols, and emerging wireless and mobile technologies.

Syllabus:

Sl. No.	Module Name and Topics	No. of Classes
1	Introduction: Wireless medium, channel modelling	2
2	Wireless physical layer alternatives for networks: Carrier modulation, broadband communication and spread spectrum	2

3	Concept of antennas for radio transmission, path loss	2
4	Spectrum access: Cellular system, TDMA, FDMA, CDMA, (C/I) ratio	4
5	Wireless network operation: Mobility management, radio resource and power management	2
6	Advanced air-interface concepts: Radio frequency analysis, OFDM, SISO MIMO concept,LTE andLTE advanced	4
7	Data network: GPRS and higher data rate, short messaging service	4
8	Wireless LAN: Standards – Architecture – Services – physical layer and MAC sublayer management, IEEE 802.11a, b, g	4
9	Wireless HIPERLAN	2
10	Mobile Ad hoc Networks- WiFi and WiMAX - Wireless Local Loop	4
11	Wireless PAN: Bluetooth technology	4
12	Modern wireless technologies: SDR, WRAN, LoRa, Introduction to 5G	4
	TOTAL	**38**

Books:

1. William Stallings, "Wireless Communications and Networks", Pearson Education, 2002.
2. Jochen Schiller, "Mobile Communications", Second Edition, Pearson Education, 2003.
3. Cory Beard and William Stallings, "Wireless Communication Networks and Systems", 1st edition
4. KavehPahlavan, PrasanthKrishnamoorthy, "Principles of Wireless Networks", First Edition, Pearson Education, 2003.
5. C.K.Toh, "AdHoc Mobile Wireless Networks", First Edition, Pearson Education, 2002.

Paper V: IT 5163 Elective (Open)
Cryptographic Techniques

Prerequisite(s): Number Theory, Discrete Mathematics

Course Objectives: This course aims towards teaching the basics of computer/data security goals and techniques. This will help the students to develop a mathematical basis of cryptography and cryptanalysis.

Course Outcome: On successful completion of the course, the students will gain in-depth knowledge on the followings:

1. Basic knowledge of classical cryptosystems and the major goals of security
2. Private and public key cryptosystems with mathematical foundation
3. Key domain analysis of traditional and modern cryptosystems
4. Message authentication, digital signature, cryptographic hash functions, public key infrastructure
5. Entity authentication and key distribution infrastructures

Syllabus:

Sl. No.	Module Name and Topics	No. of Classes
1.	**Basics of Security and Cryptography:** Three major goals of security, major security attacks, security services related to three goals of security, security mechanisms, cryptography and steganography. Cryptanalysis attacks, classes of cryptanalysis attacks	3
2.	**Mathematical Background:** Introduction to Number theory, Modular arithmetic, Prime number generation, Primality Testing, Euclidean Algorithm, Chinese Remainder Theorem, Fermat's Little Theorem and Euler's Theorem, Index of Coincidence	3
3.	**Cryptographic Techniques:** Introduction to Substitution Ciphers, Transposition Ciphers, Encryption and Decryption, Symmetric and Asymmetric Key Cryptography, Key Range and Key Size, Key Domain Analysis	3
4.	**Traditional Private Key Cryptography:** Symmetric Encryption. Definitions. Chosen-Plaintext Attack. Chosen-Ciphertext Attack, Known-Plaintext Attack. Known-Ciphertext Attack, Pattern Analysis Attacks, Statistical Attacks. Block ciphers and Stream ciphers	3
5.	**Modern Private Key Cryptosystems:** Data Encryption Standard (DES), Advanced Encryption Standard (AES), Triple DES, Variations on DES - RC4, RC5, Modes of operation of block ciphers, Key stream generation in Stream ciphers	6
6.	**Public Key Cryptosystems:** RSA, ElGamal, Elliptic curve cryptosystems, Public Key Infrastructure (PKI), Digital Signatures, Digital Certificates, Key Management and Key Distribution techniques	6
7.	**Message Authentication and Integrity Verification:** Message Authentication Codes, Modification Detection Codes, Hash Functions, Cryptographic Hash Functions, Merkle-Damgard Scheme, Preimage Resistance, Second Preimage Resistance, Collision Resistance, Random Oracle Model. Digital Signatures, RSA Digital Signature	8
8.	**Entity Authentication:** Differentiate between message authentication and entity authentication, Data origin vs. entity authentication, Verification categories, Password based authentication, Challenge-response based authentication, Zero-knowledge authentication, biometric authentication	3
9.	**Key Management:** Key Distribution Center (KDC), Symmetric key agreement protocol, Kerberos as a KDC, Certification Authorities for Public Keys, Role of Public Key Infrastructure	3
	TOTAL	**38**

Essential Reading:

1. Behrouz A. Forouzan and D. Mukhopadhyay - Cryptography & Network Security, McGraw Hill.
2. Douglas R. Stinson, Cryptography: Theory and Practice, Chapman and Hall.

3. William Stallings, Cryptography and Network Security: Principles and Practice, Prentice Hall.
4. Schneier, Bruce. Applied cryptography: protocols, algorithms, and source code in C. john wiley & sons, 2007.
5. Katz, Jonathan, and Yehuda Lindell. Introduction to modern cryptography. CRC press, 2014.

Paper V: IT 5164 Elective (Open)
Medical Image Processing

Pre-requisites: Image processing/signal processing

Syllabus:

Sl. No.	Module Name and Topics	No. of Classes
1.	**Introduction to Different Medical Imaging Methods** Introduction to Imaging Methods in Medicine and Diagnosis. Introduction to basic physical and technological aspects of medical imaging. Different medical imaging modalities-Magnetic resonance imaging (MRI), x-ray imaging, CT, USG and microscopic imaging-principles of operation, relative merits and demerits	4
2.	**Compressed Sensingand MR image Reconstruction** Introduction to Compressed sensing-theory and algorithms, signal sparsity, incoherence, different reconstruction algorithms, MR image reconstruction using CS/pMRI-theory, merits and demerits of different methods, MR Image Segmentation	6
3.	**Medical Image Enhancement** Pre-processing for medical images, de-noising techniques, filtering techniques for medical image enhancement	4
4.	**Segmentation medical images** Segmentation of Medical Images, information theoretic approaches, graph cut methods, SVM methods	6
5.	**Feature Extraction, selection and Classifier Design** Features in Biomedical Images, Feature extraction, Review of Selected Features, Feature matching. Classifier design introduction to machine learning	4
6.	**3D Image Analysis** Feature extraction and analysis of 3D MR images	2
7.	**CAD for Medical images** **Case studies:** **Diabetic Retinopathy** Diabetic retinopathy, vascular net/vessel detection, Lesion detection on retinal images, stage detection of PDR based on classifier design **Epilepsy on MR images** Computer-aided Diagnosis of Epilepsy based on MR Images. Image Registration, Template Matching, Feature Extraction, Classification of Epileptic lesions **CAD for Skin Biopsy Images** Computer-aided Diagnosis of Skin Biopsy Images. Image Segmentation and Skin layer detection, Nuclei Detection, Diagnosis based on various image features **X-Ray image analysis: Fracture Detection**	12
	TOTAL	**38**

Books:

1. Gonzalez R. C. y Woods, R. E. "Digital Image Processing" Prentice Hall 3rd Ed. (2007)
2. Davies, E.R. "Computer and Machine Vision: Theory, Algorithms, Practicalities" Academic Press 4th Ed. (2012),
3. Bushberg, J. T., Seibert, J. A., Leidholt, E. M. and Boone, J. M. "The essential physics of medical imaging" Wolters Kluwer and Lippincott Williams & Wilkins 3rd Ed. (2012)
4. Frackowiack et al "Human Brain Function" Academic Press 2nd Ed. (2004), 1144 pgs.

Paper V: IT 5165 Elective (Open)
Multicore Architecture and Parallel Programming

Prerequisites: First course on Digital Logic and Circuit Design, Knowledge of microprocessors, microcontrollers, first course on programming.
Course Objective: Primary objective of this course is to provide a comprehensive introduction towards the gradual transition from single core based computing to multi-core era, design and architecture details of multi-core based systems, programming and examples with case studies.
Program Outcome: After attending this course students will be able to

1. Get the idea of benefits achieved due to transition from single core to multi-core based computing systems.
2. Get to know detailed architecture of different multi-core based systems in use.
3. Get to know and experience with different types of programming models used to optimize the performance of multi-core systems.
4. Acquire the art of parallel processor programming with MPI and OpenMP programming models – state of the art programming model used by industry for parallel programming on multi-core systems.
5. Compare programming for serial processors and programming for parallel processors.

Syllabus:

Sl. No.	Module Name and Topics	No. of Classes
1	**Multi-core Processors** Single core to Multi-core architectures – SIMD and MIMD systems – Interconnection networks - Symmetric and Distributed Shared Memory Architectures – Cache coherence - Performance Issues – Parallel program design.	8
2	**Parallel Program Challenges** Performance – Scalability – Synchronization and data sharing – Data races – Synchronization primitives (mutexes, locks, semaphores, barriers) – deadlocks and livelocks – communication between threads (condition variables, signals, message queues and pipes).	10
3	**Shared Memory Programming with OpenMP** OpenMP Execution Model – Memory Model – OpenMP Directives – Work-sharing Constructs - Library functions – Handling Data and Functional Parallelism – Handling Loops - Performance Considerations.	8
4	**Distributed Memory Programming with MPI** MPI program execution – MPI constructs – libraries – MPI send and receive – Point-to-point and Collective communication – MPI derived datatypes – Performance evaluation.	8
5	**Parallel Program Development** Case studies - n-Body solvers – Tree Search – OpenMP and MPI implementations and comparison.	4
	TOTAL	**38**

Text Books:

1. An Introduction to Parallel Programming – by Peter S. Pacheco, Morgan-Kauffman/ELSEVIER
2. Multicore Application Programming for Windows, Linux and Oracle Solaris – by Darryl Gove, Pearson

Reference Books:

1. Parallel Programming in C with MPI and OpenMP – by Michael J Quinn, TMH
2. Multi-core Programming – by Shameem Akhter and Jason Roberts, Intel Press

Paper V: IT 5166 Elective (Open)
Introduction to Embedded Systems

Prerequisites: A first course on Digital Logic and Circuit Design, Basic knowledge of microprocessors, microcontrollers (essential), Basic programming concepts (desirable)
Course Objective: Primary objective of this course is to introduce the concepts of necessity, characteristics, design, and detailed working principles of an embedded system dominating each electrical/electronic and computing application sector in industry.
Program outcome:

1. Students will get a first-hand introduction towards the basic design as well as working principle of embedded systems.
2. Details regarding different components used as building blocks in an embedded system should be introduced to the reader.
3. Both electronic/electrical aspects as well as programming aspects to be introduced to get the entire working flavour of the system.
4. Different simple case studies taken from different application sectors to be introduced to prepare the students ready for the real-life applications of such systems.

Syllabus:

Sl. No.	Module Name and Topics	No. of Classes
1	**Introduction to Embedded System** Definition of Embedded System & its classification, characteristics of embedded systems, design parameters/Metrics of embedded systems. Components of embedded systems with review of Microprocessor & Microcontrollers, introduction to embedded processor, Digital signal processor, Application specific system processor, Multiprocessor systems using General Purpose Processor.	8
2	**System Processor** Standard Single purpose processors: Peripherals, Introduction, Timers, Counters and watchdog Timers, UART, Pulse Width Modulators, Clocking unit, Real Time Clock Reset Circuitry. Processor and memory organization, processor and memory selection, Memory Types, Memory map and addresses.	8
3	**I/O Interfacing** I/O devices: ADC/DAC, Optical Devices such as LED/LCD Display devices, Keyboard controller, Timer & counting devices, serial communication using I2C, SPI,CAN, RS232, & USB. Device drivers & interrupt service Mechanism: ISR concepts and ISR handling mechanisms	8

4	**Programming Concepts, Embedded System Programming C & C++** Assemble language high level lang. C program Elements, Micros & Function, Data types, Data Structures, Modifiers, Statement, loops & Pointers, queues & Stacks, List & order list, Embedded System Programming in C++. C Program Compilers & Cross Compilers. In Circuit emulator.	6
5	**Overview & Applications of Embedded System** Simple case studies from different application sectors of electrical/electronic/computing etc [e.g. Vending machine system, adapting Cruise control System in a car, Smart Card, Digital camera etc].	8
	TOTAL	**38**

Text Books:

1. Embedded System Design A Unified Hardware/Software Introduction (3e) - by Frank Vahid / Tony Givargis - Wiley India
2. Embedded systems architecture, programming and design (2e) - by Raj Kamal – TMH

Reference Books:

1. Introduction to Embedded Systems (2e) – by Shibu K V, McGraw Hill Education (India)
2. Computer Organization and Embedded Systems (6e) – by Carl Hamacher et al, McGraw Hill International
3. Embedded Systems – Concepts, Design and Programming - by Dave and Dave, Pearson
4. Embedded/Real Time Systems: Concepts, Design and Programming – by Prasad, Dreamtech Press
5. Embedded Microcontrollers and Processor Design – by Osborn, Pearson
6. Embedded Systems Architecture – by Noergaard, ELSEVIER
7. Embedded System Design for students – by Verma, SPD
8. Designing Embedded Hardware – by Catsoulis, SPD, O'Reilly

Lab I: IT 5171 Algorithms Laboratory

1. Study of time requirements of searching and sorting algorithms.

2. Implementation of graph algorithms; Study of data structures' roles in developing efficient algorithms (in connection with graph algorithms)

3. Role of randomness in computing

4.. Implementation of some of the number theoretic algorithms

Lab II: IT 5172 Advanced Computer Architecture Laboratory

1. Software Simulation and verification in hardware platform different transmission coding signaling- ON OFF, Polar, Biploar techniques and spectrum analysis
2. Baseband data decoding using integrate and dump receiver
3. Software simulation and verification in hardware digital carrier modulation-BASK, BPSK, BFSK
4. Generation and verification of MLS (maximum length sequence) properties.
5. DS-SS modulation and demodulation in baseband transmission
6. CDMA code generation and DS-CDMA decoding in baseband transmission

7. Software simulation on binary and M-ary hypothesis, likelihood ratio test

Lab III: IT 5173 Advanced Communication Systems Laboratory

SECOND SEMESTER

Paper VI: IT 5201 Advanced Database Management Systems

Pre-requisites: Programming andData structure, Discrete Mathematics

Course Outcome: The following are the major outcome of this course:
I. To design, construct and maintain a database and various database objects using procedural language constructs.
II. To provide detailed knowledge of Transaction, concurrency and recovery, security strategies of DBMS.
III. Describe the design of Distributed Databases and the basic concept of Data warehousing and Data mining.
IV. To provide future research techniques for implementing single site DBMS.

Syllabus:

Sl. No.	Module Name and Topics	No. of Classes
1	**Introduction:** Database, Database Management Systems, Structures of Relational Databases, Integrity Constraints.	2
2	**Relational Database Design**: Functional Dependency, Normal Forms, BCNF, 4NF, 5NF, Inclusion Dependency and Template Dependency.	4
3	**Storage Strategies:** File organization, Indexing, Hashing Techniques, B tree and B+ tree, multiple key access.	5
4	**Query Processing and Optimization:** Evaluation of Relational Algebra Expressions, Join strategies, Query Optimization Algorithms.	4
5	**Transaction processing**: Transaction concept, Serializability, Testing for serializability, Lock Based Protocols, Deadlock, Timestamp Based Protocols, Validation Based Protocols, Multiple Granularity. Recovery Techniques, Remote Backup Systems.	4
6	**Database Security:** Levels of database security, discretionary access control, mandatory access control, Introduction to statistical database security.	2
7	**Distributed Databases**: DDBMS architectures, Data Fragmentation, Replication and Allocation Techniques, Distributed query processing, Distributed transactions and concurrency management, deadlock management.	7
8	**Object Oriented Database**: **O**bject, object identity, object reference, architecture ofObject-oriented and Object Relational database.	2
9	**Data Warehousing and Data Mining**: Introduction to Data warehouse and OLAP, Data Warehouse architecture, Introduction to Data mining, Classification of data mining techniques.	4
10	**Emerging Database Models**: Multimedia database, web database, Mobile database, GIS, Gnome databases.	4

	TOTAL	38

References:

1. Abraham Silberschatz, Henry F. Korth and S. Sudarshan, "Database System Concepts", Mc Graw Hill, 6th ed, 2013.
2. Ramez Elmasri and Shamkant B. Navathe, "Fundamentals of Database Systems", Pearson, 7th ed, 2016.
3. C. J Date, "An Introduction to Database System", Pearson, 8th ed, 2003.
4. G. Pelagatti and S. Cerri, "Distributed Databases:Principles and Systems", Mc Graw Hill, 2008

Paper VII: IT 5202 Network and Information Security

Prerequisite(s): Number Theory, Discrete Mathematics, Computer Networking

Course Objectives: This course aims towards presenting an overview of security requirements and challenges in network communication. This course will include the concepts of internetworking and various goals of security at different layers of the ISO/OSI model. It focusses on addressing those network security challenges using cryptographic techniques and protocols. This also includes state-of-the-art applications and practices that are implemented to provide email and web security.

Course Outcome: On successful completion of the course, the students will be able to

1. Identify network security threats at different layers of the ISO/OSI model and propose solutions to overcome those.
2. Achieve secure network communications
3. Verify the integrity of information exchanges in computer networks
4. Develop email and file transfer security systems
5. Develop SSL or Firewall based solutions against security threats

Syllabus:

Sl. No.	Module Name and Topics	No. of Classes
1.	**Networking and Internetworking Concepts** The ISO Open Systems Interconnection (OSI) model of communication, Technology underlying the TCP/IP Internet protocol suite and the architecture of an internet	3
2.	**Classical Cryptography and Overview:** Model of secure network communication, Security goals and services, Overview of attacks, Security Architecture for Open System Interconnection (OSI), cryptanalysis	2
3.	**Cryptographic Techniques:** Introduction to SubstitutionTechniques, Transposition Techniques, Encryption and decryption, Symmetric and Asymmetric Key Cryptography, Key Range and Key Size	2
4.	**Private Key Cryptography:** Symmetric Encryption. Definitions. Chosen-Plaintext Attack. Chosen-Ciphertext Attack, Data Encryption Standard (DES), Advanced Encryption Standard (AES), Triple DES, Variations on DES - RC4	8
5.	**Public Key Cryptography:** RSA, ElGamal, DSA, Elliptic curve cryptosystems, Public Key Cryptography standard (PKCS), PKI, Digital Certificates, and Key management techniques	6

6.	**Message Integrity and Message Authentication:** Message integrity, Random Oracle Model, Message authentication, Cryptographic Hash Functions, Digital Signature, Blind Signature	4
7.	**Security Protocols at Various Layers:** E-mail System, Pretty good privacy (PGP), Secure/Multipurpose Internet Mail extension. Security services at transport layer, SSL/TLS architecture, four protocols, SSL Message format. Security at the network layer, IP Security (IPSec), Modes of IPSec, Security Protocols, Security Association, Security Policy, Internet Key Exchange (IKE)	8
8.	**System Security:** Buffer overflow and malicious software, malicious programs, intrusion detection system. Firewalls: Definition, Construction, Working principles	2
9.	**Media Security:** Data hiding, Steganography &Steganalysis, Digital watermarking, Visual Cryptography	3
	TOTAL	**38**

Essential Reading:

1. Behrouz A. Forouzan and D. Mukhopadhyay - Cryptography & Network Security, McGraw Hill.
2. William Stallings, Cryptography and Network Security: Principles and Practice, Prentice Hall.
3. Douglas E. Comer and David L. Stevens. Internetworking with TCP/IP: Volume II: Design, Implementation, and Internals. Prentice Hall.

References:

1. Douglas R. Stinson, Cryptography: Theory and Practice, Chapman and Hall.

Paper VIII: IT 5203 Internet and Distributed Computing

Prerequisites: Computer Networks

Syllabus:

Sl. No.	**Module Name and Topics**	**No. of Classes**
1.	Review of TCP/IP Protocol Stack: IPv4, IPv6, TCP, UDP, ARP, ICMP, SMTP etc.	4
2.	Introduction to Distributed Systems, Internet as a Distributed System, Transparency and Openness in Internet, RFCs	4
3.	Model of Distributed Computation; Synchronous, Asynchronous Networks, and Anonymous Networks; Introduction to Design and Analysis of Concurrent Algorithms, Message Complexity	6
4.	World Wide Web as a Distributed Document Based System, Client-Server Architecture in Web, Document Model: Markup languages,	3
5.	Election algorithms, Impossibility results, Lower bound for synchronous networks	5
6.	Logical clock; Synchronization; Mutual exclusion algorithms	4

7.	Distributed Consensus and Fault tolerance, Fault tolerance in Internet	4
8.	Internet bot, Web crawler and Search engines	4
9.	IoT evolution, Basics of IoT, Applications of IoT in home automation, healthcare, agriculture, and industrial applications, Emerging directions in IoT.	4
	TOTAL	**38**

Books:

1. Ajoy D. Kshemkalyani and MukeshSinghal. Distributed Computing: Principles, Algorithms, and Systems. Cambridge University Press
2. Andrew S. Tannenbaum and Maarten van Steen. Distributed Systems: Principles and Paradigms. Prentice Hall, 2nd Edition
3. Bruce Croft, Donal Metzler and Trevor Strohman. Search Engines: Information Retrieval in Practice. Pearson Education

Paper IX: IT 522X Elective (Departmental)

Paper IX: IT 5221 Elective (Departmental)
Multimedia Coding and Compression

Pre-requisites: Basic knowledge of multimedia systems and information and coding theory

Syllabus:

Sl. No.	Module Name and Topics	No. of Classes
1.	**Introduction to image and video Compression**, Video signal representation, Lossless Coding Techniques, Entropy Coding, Huffman and Arithmetic Coding, Predictive Coding.	2
2.	**Transform Coding** Transforms, block-wise transform coding, orthogonal and orthonormal transform, Transform coding gain, Bit allocation for transform coefficients, DCT & DFT, Threshold coding, Typical coding artifacts, Fast implementation of the DCT, Haar Transform, KarhunenLoève Transform (KLT),Walsh-Hadamard Transform (WHT)	6
3	**Wavelet Coding** Embedded Zero Tree Wavelet (EZW), Set-Partitioning in Hierarchical Trees (SPIHT), Embedded Block Coding with Optimized Truncation (EBCOT), Wavelet Difference Reduction (WDR), Space – Frequency Quantization (SFQ), Stack- Run (SR), Geometric Wavelet (GW), Filters and Filterbanks	6
5.	**Video Coding Standards** H.261/H.263, MPEG2/MPEG4, H.264	4
6	**Error-resilient coding techniques** Error propagation in video coding, Spatial error resilience coding, Temporal error resilience coding	4
7	**Image Compression** JPEG, JPEG 2000, Embedded Block Coding with Optimized Truncation (EBCOT) in JPEG 2000. JPEG XT	4

8.	**Audio Compression** PCM, ADPCM in Speech Coding, Linear Predictive Coding, MP3, MPEG	4
9.	**Video Compression, Motion Estimation** Motion Estimation Techniques, Temporal correlation and motion compensation, Differential methods, Blockmatching, Sub-pixel accuracy, Fast algorithm, Rate-constraint Motion Estimation Standard Video Compression Techniques MPEG, MPEG2/MPEG4, H.261/H.263, H.264	8
	TOTAL	**38**

Text Books:

1. Sun, Huifang, and Yun Q. Shi. Image and video compression for multimedia engineering: Fundamentals, algorithms, and standards. CRC press, 2008.
2. Gibson, J. D., Berger, T., Lookabaugh, T., Baker, R., & Lindbergh, D. (1998). Digital compression for multimedia: principles and standards.
3. Steinmetz, R., &Nahrstedt, K. (2002). Multimedia fundamentals, volume 1: media coding and content processing. Pearson Education.

Reference Books:

1. Steinmetz, Ralf, and KlaraNahrstedt. Multimedia: Computing, Communications and Applications: Media Coding and Content Processing. Prentice Hall PTR, 2002.
2. Nelson, Mark, and Jean-Loup Gailly. The data compression book. New York: M & t Books,
3. Richardson, Iain E. H. 264 and MPEG-4 video compression: video coding for next-generation multimedia. John Wiley & Sons, 2004.

Paper IX: IT 5222 Elective (Departmental)
Mobile Computing

Pre requisites: The students opting this subject must have prior knowledge in Networking, Operating System and basic communication.

Syllabus:

Sl. No.	Module Name and Topics	No. of Classes
1.	Introduction to mobile computing	2
2.	Wireless and Cellular network, channel allocation, multiple access	2
3.	1G, 2G, systems, GSM standards, architecture	2
4.	Location management,Handoffs, Authentication	2
5.	2G CDMA, 3G CDMA, 4G standards and advances	4
6.	IEEE 802.11 WLAN	4
7.	Bluetooth, HiperLAN architecture, comparison of wireless technologies	4
8.	Mobility adaptation, process migration, mobile IP	4
9.	Mobile Ad-hoc networking. MAC protocols, Routing	4
10.	Energy efficient computing, Impact of mobility on algorithms	4

11.	Mobile Computing Architecture	2
12	Mobile Computing through Telephony	2
13	Security Issues in Mobile Computing	2
	Total	**38**

Books:

1. Fundamentals of Mobile Computing by Pattnaik Mall, PHI.
2. Mobile Computing, by TalukderAsoke K. Hasan Ahmed and Roopa Yavagal, Mcgraw Hill.
3. Mobile Computing Third Edition, by RAJ KAMAL, Oxford University Press.
4. Mobile Communications, by Jochen Schiller, Second Edition, Pearson Education, 2003.

Paper IX: IT 5223 Elective (Departmental)
Approximation Algorithms

Prerequisites: Design and Analysis of Algorithms

Syllabus:

Sl. No.	**Module Name and Topics**	**No. of Classes**
1	Introduction: a. Preliminaries and Basic Definitions b. Absolute Performance Guarantees c. Relative Performance Guarantees	4
2	**Combinatorial Algorithms:** Approximation Schemes: a. Approximation Scheme for Scheduling b. Approximation Scheme for Knapsack c. Fully Polynomial Approximation Schemes d. Pseudo-Polynomial Algorithms e. Strong N P-completeness and FPAS	4
3	Vertex Cover and Set Cover a. Approximating Vertex Cover b. Approximating Weighted Vertex Cover i) A Randomized Approximation Algorithm ii) The Nemhauser Trotter Algorithm iii) Clarkson's Algorithm b. Improved Vertex Cover Approximations i) The Nemhauser-Trotter Algorithm Revisited ii) A Local Ratio Theorem iii) An Algorithm for Graphs Without Small Odd Cycles iv) The Overall Algorithm c. Approximating Set over	6
4	Knapsack a) A pseudo-polynomial time algorithm for knapsack b)An FPTAS for knapsack c) Strong NP-hardness and the existence of FPTAS's	4
5	Bin Packing a) Asymptotic Approximation Scheme i) Restricted Bin Packing ii) Eliminating Small Items iii) Linear Grouping iv) APAS for Bin Packing b) Asymtotic Fully Polynomial Scheme i) Fractional Bin Packing and Rounding ii) AFPAS for Bin Packing iii) Near-Absolute Approximation	5
6.	**LP-Based Algorithms** Introduction to LP-Duality a. The LP-duality theorem b. Min–max relations and LP-duality c. Two fundamental algorithm design techniques	4
6	Set Cover via Dual Fitting a) Dual-fitting-based analysis for the greedy set cover algorithm b) Generalizations of set cover	4

7	Maximum Satisfiability a) Dealing with large clauses b) Derandomizing via the method of conditional expectation c) Dealing with small clauses via LP-rounding d) A 3/4 factor algorithm	4
8	Facility Location a) An intuitive understanding of the dual b) Relaxing primal complementary slackness conditions c) Primal–dual schema based algorithm d) Analysis	3
	TOTAL	**38**

Books:

1. Vazirani, Vijay V. Approximation algorithms. Springer Science & Business Media, 2013.
2. Motwani, Rajeev. "Lecture notes on approximation algorithms: Volume I." Dept. Comput. Sci., Stanford Univ., Stanford, CA, Tech. Rep. CS-TR-92-1435 (1992).

Paper IX: IT 5224 Elective (Departmental)
Real Time Systems

Prerequisites: Introductory course on Embedded Systems, First course on Operating Systems.

Syllabus:

Sl. No.	**Module Name and Topics**	**No. of Classes**
1	**Introduction to Real Time Systems** Introduction to Real time Embedded System, need for a real-time system, different kinds, Embedded system Design cycle, Types of Real Time systems, Real Time Applications and features, Issues in real time computing, aspects of real-time systems, Performance measures of Real Time System, real-time requirement specifications, modelling/verifying design tools (real time UML, state charts, etc.,).	4
2	**Hardware for Real Time Systems** Selection criteria for Real time system - Hardware and Software perspective, need for partitioning, criteria for partitioning, System Considerations, Basic development environment-host vs target concept, CPU features – Architecture, on-chip peripherals, Real time implementation considerations, pipeline, bus architecture, Fast Interrupt Response Manager, Introduction to Interrupts, Interrupt vector table, interrupt programming, Pipeline and Parallelism concepts.	6
3	**On-chip peripherals and Communication protocols** Role of peripherals for Real time systems, On-Chip peripherals & hardware accelerators, Peripherals [Direct Memory Access, Timers, Analog to Digital Conversion (ADC), DAC, Comparator, Pulse Width Modulation (PWM)], Need of real time Communication, Communication Requirements, Timeliness, Dependability, Design Issues, Overview of Real time communication, Real time Communication Peripherals – I2C, SPI & UART.	6

4	**Embedded Software and RTOS** Software Architecture of real time System, Introduction to RTOS, role of RTOS, Real time kernel, qualities of good RTOS, Functionalities of RTOS – Task Management, I/O management, Memory management, Inter Task Communication, Task, Task states, Task control block, attributes of TCB, Context switching, Interrupts handling, Multi-processing and multitasking.	6
5	**Scheduling, Synchronization and Inter task communication in RTS** Basic Concepts for Real-Time Task Scheduling, Scheduling: definitions, Overview of Scheduling policies, Task Synchronization – Need of synchronization, shared data problems and its ways of handling, Role of Semaphore, types of semaphores, Inter task communication – Need of communication, Message Mailbox and Message Queues, RTOS problems - Priority inversion phenomenon, Deadlock phenomenon and steps to handle them.	8
6	**RTOS Programming I: MicroC/OS-II and VxWorks** Basic functions and types of RTOSES, RTOS mCOS – II, RTOS VxWorks	4
6	**RTOS Programming II: Windows CE, and RT Linux** Windows CE, RTLinux.	4
	TOTAL	**38**

Text Books:

1. Real-Time Systems by Jane W. S. Liu Prentice Hall; 1 edition ISBN: 978-0130996510
2. Krishna .C.M "Real Time Systems" Mc-Graw Hill Publication.
3. Hamid A. Toliyat and Steven G. Campbell, "DSP based Electromechanical Motion Control" CRC Press, 2003, ISBN 9780849319181.
4. Embedded systems architecture, programming and design (2e) - by Raj Kamal – TMH.

Reference Books:

1. Jean J Labrosse, "Embedded System Design blocks", CMP books, Second Edition, ISBN 0-87930-604-1.
2. Embedded Systems Architecture – by Noergaard, ELSEVIER

Paper IX: IT 5225 Elective (Departmental)
Machine Learning

Prerequisite:

- Linear algebra: Simple linear algebra.
- Basic Programming concepts.
- Calculus: Some differential calculus.

Syllabus:

Sl. No.	Module Name and Topics	No. of Classes
1	**Introduction and Review** Preliminaries, Boolean Functions, Linear Algebra, Matrix Calculus, Probability and Statistics.	6
2	**Neural Networks** Single and multi-layer perceptron learning algorithms	4

3	**Supervised Learning** Linear Regression (Gradient Descent, Normal Equations), Weighted Linear Regression (LWR), Logistic Regression, Perceptron, Newton's Method, KL-divergence, (cross-)Entropy, Natural Gradient, Exponential Family and Generalized Linear Models, Generative Models (Gaussian Discriminant Analysis, Naive Bayes) , Kernel Method (SVM, Gaussian Processes), Tree Ensembles (Decision trees, Random Forests, Boosting and Gradient Boosting).	8
4	**Learning Theory** Regularization, Bias-Variance Decomposition and Trade-off, Concentration Inequalities, Generalization and Uniform Convergence, VC-dimension.	8
5	**Unsupervised Learning** K-means, Gaussian Mixture Model (GMM), Expectation Maximization (EM), Variational Auto-encoder (VAE), Factor Analysis, Principal Components Analysis (PCA), Independent Components Analysis (ICA).	8
6	**Reinforcement Learning (RL)** Markov Decision Processes (MDP), Bellmans Equations, Value Iteration and Policy Iteration, Value Function Approximation, Q-Learning	4
TOTAL		**38**

Text books

1. Christopher M. Bishop. Pattern Recognition and Machine Learning (Springer)
2. David Barber, Bayesian Reasoning and Machine Learning (Cambridge University Press).
3. Tom Mitchell. Machine Learning (McGraw Hill)
4. Richard O. Duda, Peter E. Hart, David G. Stork. Pattern Classification (John Wiley & Sons)

Reference texts

- Trevor Hastie, Robert Tibshirani, Jerome Friedman, The Elements of Statistical Learning, Springer, 2009 (freely available online)
- Hal Daumé III, A Course in Machine Learning, 2015 (in preparation; most chapters freely available online)
- Kevin Murphy, Machine Learning: A Probabilistic Perspective, MIT Press, 2012
- Christopher Bishop, Pattern Recognition and Machine Learning, Springer, 2007.
- Shai Shalev-Shwartz and Shai Ben-David. Understanding Machine Learning: From Theory to Algorithms, Cambridge University Press, 2014.

Paper IX: IT 5226 Elective (Departmental)
Cloud and Services Computing

Prerequisites: The students required to know about the basic computer network, data structure, database managements, operating systems

Sl. No.	Module Name and Topics	No. of Classes
1	**Introduction to cloud computing** Introduction, characteristics of cloud computing, cloud model, cloud service, cloud applications	6

2	**Cloud concepts and technologies** Virtualisation, load balancing, scalability, deployment, replication, monitoring, software defined network, service level agreement, billing	6
3	**Cloud services and platforms** Compute services, storage services, database services, application services, content delivery services, analytics services, deployment and management services,	7
4	**Hadoop and MapReduce** Hadoop MapReduce job execution, Hadoop schedular, Hadoop cluster setup	6
5	**Cloud application design** Introduction, reference architecture, design methodology, data storage approaches	7
6	**Cloud application development and case studies**	6
TOTAL		**38**

Books:

1. Cloud Computing: A Hands-On Approach By Arshdeep Bahga, Vijay Madisetti,
2. Fox, Armando, et al. "Above the clouds: A berkeley view of cloud computing." Dept. Electrical Eng. And Comput. Sciences, University of California, Berkeley, Rep. UCB/EECS 28.13 (2009): 2009.
3. Cloud Computing: Concepts, Technology & Architecture, Book by Richardo Puttini, Thomas Erl, and Zaigham Mahmood, Prentice Hall.

Paper X: IT 526X Elective (Open)

Paper X: IT 5261 Elective (Open)
CAD Algorithms for VLSI

Prerequisites: Introductory course on Embedded Systems.
Course Objective: Primary objective of this course is to introduce the concepts of Computer Aided Design Algorithms used during the VLSI Design Process.
Program outcome: After attending this course, students will be able to get the idea of

1. Overall idea of VLSI Design cycle and role of CAD.
2. Different techniques and algorithms used during synthesis, layout design, test and verification process during VLSI design cycle.
3. Acquaintance with the state-of-the-art design automation tools used during CAD based VLSI design and hands-on experience.

Syllabus:

Sl. No.	Module Name and Topics	No. of Classes
1	**Introduction:** VLSI design flow, challenges.	2
2	**Verilog/VHDL**: Introduction and use in synthesis, modeling combinational and sequential logic, writing test benches.	6

3	**Logic synthesis**: two-level and multilevel gate-level optimization tools, state assignment of finite state machines.	4
4	**Basic concepts of high-level synthesis**: partitioning, scheduling, allocation and binding, Technology mapping.	4
5	**Physical design automation**: Review of MOS/CMOS fabrication technology, VLSI design styles: full-custom, standard-cell, gate-array and FPGA.	4
6	**Physical design automation algorithms:** Floor-planning, placement, routing, compaction, design rule check, power and delay estimation, clock and power routing, etc. Special considerations for analog and mixed-signal design.	8
7	**Testability issues**: Fault modelling and simulation, test generation, design for testability, built-in self-test. Testing SoCs.	6
8	**Basic concepts of verification**: Design verification techniques based on simulation, analytical and formal approaches. Functional verification. Timing verification, Formal verification, Basics of equivalence checking and model checking. Hardware emulation.	4
	TOTAL	**38**

Text Books:

1. M.D.Ciletti, "Modeling, Synthesis and Rapid Prototyping with the Verilog HDL", Prentice-Hall.
2. M.G.Arnold, "Verilog Digital – Computer Design", Prentice-Hall.
3. VLSI Physical Design Automation Theory and Practice – by Sait, Youssef, World Scientific.
4. Algorithms for VLSI Physical Design Automation by Naveed Shervani, Springer International Edition, 3rd Edition, 2005.
5. G. De Micheli. Synthesis and optimization of digital circuits, 1st edition, 1994
6. Gary D. Hachtel and Fabio Somenzi, Logic Synthesis and Verification Algorithms. Springer.

Reference Books:

1. Digital Integrated Circuits- A Design Perspective by J M Rabaey, Prentice Hall, 3rd Edition, 2012.
2. S. Palnitkar, Verilog HDL: A Guide to Digital Design and Synthesis, Prentice Hall, 2nd edition, 2003.
3. Douglas L. Perry, VHDL: Programming by Example 4th Edition, TMH.
4. D. D. Gajski, N. D. Dutt, A.C.-H. Wu and S.Y.-L. Lin, High-Level Synthesis: Introduction to Chip and System Design, Springer, 1st edition, 1992.
5. Rudiger E bendt, Görschwin Fey, Rolf Drechsler. Advanced BDD Optimization.

Paper X: IT 5262 Elective (Open)
Computational Topology

Prerequisites: Basics of set theory, Basic idea about algorithms

Sl. No.	Module Name and Topics	No. of Classes
1.	Introduction to point set topology: Open and Closed Sets, Neighborhoods, Definition of Topology, Basis for Topology, Continuous maps, Connectedness, Path-connectedness Compactness, Separation, Quotient Topology	4
2.	Graph: Connected components, Curves and Knots, Planar graphs	4

3.	Surfaces: Two-dimensional Manifolds, Searching a Triangulation, Self-intersections, Surface Simplification	4
4.	Complexes: Simplicial Complexes, Convex Set Systems, Delaunay Complexes, Alpha Complexes	4
5.	Homology: Homology groups, Matrix reduction, Relative homology, Exact Sequences	4
6.	Duality: Cohomology, Poincaŕe Duality, Intersection Theory, Alexander Duality	4
7.	Persistence: Persistent homology, Efficient Implementation, Stability, Extended persistence, Spectral Sequence	4
8.	Morse Function: Generic smooth functions, Transversality condition, Piecewise linear functions, Reeb graphs	4
9.	Applications: Image Segmentation, Elevation, Gene Expression, Local Homology for Plant Root Architecture	3
	TOTAL	**38**

Books:

1. P. S. Alexandroff. *Elementary Concepts in Topology.* translated by A. E. Farley, Dover, New York, 1961.
2. H. Edelsbrunner. *Geometry and Topology for Mesh Generation.* Cambridge Univ. Press, England, 2001.
3. P. J. Giblin. *Graphs, Surfaces and Homology.* 2nd edition, Chapman and Hall, London, 1977.
4. Y. Matsumoto. *An Introduction to Morse Theory.* Amer. Math. Soc., Providence, Rhode Island, 2002.
5. J. W. Milnor. *Topology from the Differential Viewpoint.* Princeton Univ. Press, New Jersey, 1965.
6. J. R. Munkres. *Topology. A First Course.* Prentice-Hall, Englewood Cliffs, New Jersey, 1975.
7. J. R. Munkres. *Elements of Algebraic Topology.* Perseus, Cambridge, Massachusetts, 1984.

Paper X: IT 5263 Elective (Open)
IoT Systems

Prerequisite: The student may have concepts of embedded systems, wireless and computer network, operating system.

Course outcome: After completion of the course, students will gather knowledge on:

- IoT architecture and smartness of IoT
- IoT open source web infrastructure
- IoT network and transport layer protocols
- IoT Data analytics
- Introductory overview on embedded computing and IoT systems
- IoT security

Syllabus:

Sl. No.	**Module Name and Topics**	**No. of Classes**
1.	Introduction to internet of things, emergence of IoT, smartness in IoT, Improving quality of life	2

2.	Basic of Internet technologies, IoT architecture, resource management, data management, communication protocols	5
3.	IoT standards, open source vs close source, open source web infrastructure, openIoT architecture, cloud convergence	5
4.	Intelligent cloud collaboration framework, device-cloud collaboration, introduction to fog computing	4
5.	IP as the IoT network layer, optimization of IP, IP for smart objects	4
6.	Application protocols for IoT, IoT transport layer, IoT application layer	4
7.	Data and analytics for IoT: streaming process, scalability, robustness, framework for distributed data analysis	6
8.	Introduction of embedded computing: embedded device programming language, virtualization on embedded boards, cloud assisted cyber-physical systems	4
9.	IoT security and privacy, network and transport layer challenges, security framework: light weight cryptography	4
	TOTAL	**38**

Books:

1. Designing the Internet of Things By Adrian McEwen, Hakim Cassimally, J Wiley
2. Precision - Principles, Practices and Solutions for the Internet of Things, Book by Timothy C K Chou, McGraw-Hill
3. Getting Started with the Internet of Things, Cuno Pfister, O Reilly media
4. IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things, David Hanes, Gonzalo Salgueiro, Patrick Grossetete, Robert Barton, Jerome Henry, Cisco Press

Paper X: IT 5264 Elective (Open)
DSP Algorithms

Prerequisite: Concept on signals and systems, digital electronics, computer architecture

Course outcome: Students who successfully complete the course will be able to:

1. Determine the frequency response and the z-transform of discrete-time systems.
2. Determine the discrete Fourier transform of discrete-time signals
3. Design Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) filters
4. Design adaptive filters

Syllabus:

Sl. No.	**Module Name and Topics**	**No. of Classes**
1.	Introduction to digital signal processing-its benefits and applications, Sampling and quantization -analog to digital conversion (ADC), Digital to analog conversion (DAC)	2
2	Mathematical operations on discrete-time signals, linear time invariant systems, causality, stability, difference equations, frequency response, discrete Fourier series, , Implementation of discrete-time systems	4

3	Z–transform - definition, properties of Z-transform, system function, digital filter implementation from the system function, region of convergence in the Z plane, determining filter coefficients from the singularity locations, geometric evolution of Z transform in the Z plane, relationship between Fourier transform and Z transform, inverse Z transform.	4
4	Digital filter structures: system describing equations, filter categories, direct form I and II structures, cascade and parallel communication of second order systems	4
5	FIR filter design techniques: Fourier Transform Design, Windowing method, combining DFT and window method for designing FIR filter, frequency sampling method for designing FIR filter, Optimal Design method	6
6	IIR filter design techniques: Approximation theory, Impulse invariant and bilinear transformations, Frequency transformations	6
7	Transform technique: Fourier transform, its properties, inverse Fourier transform, discrete Fourier transform, properties of DFT, circular convolution, computations for evaluating the DFT, decimation in time and decimation in frequency FFT algorithms, discrete Hilbert transform	6
8	Finite word length effect	2
9	Introduction to adaptive filter-LMS FIR, Weiner filter theory; multi-rate filter design-Up-sampling, down-sampling, sub-band decomposition, Applications	4
	TOTAL	**38**

Books:

1. Digital Signal Processing, Principles, Algorithms and Applications- Proakis, Manolakis and Sharma, Pearson Education.
2. Digital Signal Processing by Alan V. Openheim and Ronald W. Schafer, Prentice-Hall.
3. Digital Signal Processing Fundamentals and Applications- Li Tan and Jean Jiang.
4. Digital Signal Processing- A computer-Based Approach- Sanjit K. Maitra, TMH.
5. Digital Signal Processing with Field Programmable Gate Arrays, U.Meyer-Baese, Springer Third Edition.

Paper X: IT 5265 Elective (Open)
Embedded System Security

Prerequisites: Introductory course on Embedded Systems.
Course Objective: Primary objective of this course is to introduce the concepts of necessity of security, different attacks, countermeasures in embedded systems, secured ES design aspects both in hardware as well as software levels.
Program outcome: After attending this course, students will be able to get the idea of

4. Overall idea of necessity of security in designing an embedded system.
5. Different types of attacks and countermeasure techniques during designing an ES.
6. During the design flow, both in hardware as well as software levels, different practices and techniques used to develop a secure ES.

Syllabus:

Sl. No.	**Module Name and Topics**	**No. of Classes**

1	**Introduction** Embedded systems and need for security, Embedded security trends, Security policies, Security threats.	4
2	**System Software Considerations** Role of OS, Multiple independent levels of security, Microkernel versus Monolith, Core embedded OS security requirements, Access control and capabilities, Hypervisors and system virtualization, I/O virtualization, Remote management, Assuring integrity of the TCB.	6
3	**Secure Embedded Software Development** Introduction to PHASE – Principles of High-Assurance Software Engineering, Minimal Implementation, Component architecture, Least privilege, Secure development process, Independent expert validation, Case study – High Assurance Web Server, Model Driven Design, Using MDD in safety and security-critical systems.	6
4	**Embedded Cryptography** Introduction, One-time pad, Cryptographic modes, Block ciphers, Authenticated encryption, Public key cryptography, Key agreement, Public key authentication, Elliptic curve cryptography, Cryptographic hashes, Message authentication codes, Random number generation, Key management for embedded systems, Cryptographic certifications – FIPS, NSA.	6
5	**Data Protection Protocols for Embedded Systems** Introduction, Data-in-motion protocols – Ethernet security protocols, IPsec, SSL/TLS, Embedded VPN Clients, DTLS, SSH, Data-at-rest protocols – selection of symmetric encryption algorithms, storage encryption key management, Advanced threats.	6
6	**Hardware Security for Embedded Systems** Introduction, Different types of physical attacks on ES – Invasive, Semi-invasive, Non-invasive, Countermeasures, Different hardware security design approaches, Different Hardware Trust Anchors (HTA) – SHE, HSM, TPM, case studies.	6
7	**Emerging Applications** Embedded network transactions, Automotive security, Secure Android, Next generation Software Defined Radio.	4
	TOTAL	**38**

Text Books:

1. Embedded Systems Security – Practical Methods for Safe and Secure Software and Systems Development - by Kleidermacher and Kleidermacher – Newnes, ELSEVIER
2. Security in Embedded Devices – by Cathy Gebotys, Springer US

Reference Books:

1. Trusted Computing for Embedded Systems – Bernard Candaele et al, Springer International
2. Embedded Systems Architecture – by Noergaard, ELSEVIER
3. Designing Embedded Hardware – by Catsoulis, SPD, O'Reilly.

Paper X: IT 5266 Elective (Open)
Cognitive Radio and Networks

Pre-requisites: The students are expected to have basic knowledge on Wireless Communications/Wireless Networks, Communication Engineering

Course Outcome: Cognitive networks represent a relatively novel paradigm in which it is supposed that users device sense and understand the electromagnetic environment to become aware of the available transmission opportunities even in frequency intervals nominally assigned to other specific service. When available, cognitive devices may exploit these opportunities provided they vacate the channel as soon as a legitimate user starts transmission. Besides providing potential very high gains in terms of spectrum efficiency, cognitive radios and networks pose several challenges that will be described in the lectures.

Syllabus:

Sl. No.	Module Name and Topics	No. of Classes
1.	**Next generation/5G wireless networks**: Introduction to cognitive radio networks, spectrum scarcity problem, network architectures, Cognitive cycle and functional components	2
2.	**Spectrum sensing (SS) in CRN:** Different SS techniques,- energy detection, Matched filter detection, , feature detection, Cyclo-stationary feature detection, likelihood ration test (LRT), GLRT techniques **Cooperative SS**: Energy Efficient CSS, security threats in CSS, PUEA and SSDF arracks	8
3.	**Joint SS and Data Transmission**: Link layer design and common control channel, resource allocation-power allocation and channel assignment, optimized system design	8
4.	**Multi-hop CRN**: Routing protocols, both centralized, and distributed geographic forwarding and probabilistic approaches-outage analysis	4
5.	**Network Protocol Design for CR:** Transport layer protocol design, both TCP- and equation-based Standards and applications	4
6.	**Security in CRN data transmission**: Eavesdropping and secrecy outage in CRN, Jamming for eavesdropping protection, jammer selection, ergodic capacity analysis	4
7.	**Energy Harvesting in CRN**-Wireless energy transfer and scavenging, SWIPT concept, linear and non-liner modeling of EH, Circuit design and interfacing RF energy harvesting boards	2
8.	**Application Specific System Design in CRN**- Wireless Medical Telemetry Services (WMTS), cognitive radio vehicular networks (CR-VANET), CR for emergency communication, CR-IoT	6
	TOTAL	**38**

Books:

1) Principles of Cognitive Radio, EzioBiglieri, Andrea J. Goldsmith, Larry J. Greenstein, H. Vincent Poor, Narayan B. Mandayam, Cambridge University Press, 2013 - Computers - 299 pages.
2) Handbook of Cognitive Radio, Editors: Zhang, Wei (Ed.) Springer
3) Cognitive Wireless Communication Networks, Editors: Hossain, Ekram, Bhargava, Vijay K. (Eds.) Springer

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