AMRITA CENTRE FOR WIRELESS NETWORKS AND APPLICATIONS

M.TECH – WIRELESS NETWORKS AND APPLICATIONS

This M.Tech programme is intended to generate trained academic and research personnel in the highly demanding, useful and emerging area of wireless communication and networking. The programme includes core subjects from wireless communications, computer science, computer networks, advanced topics in wireless communications, mobile computing, sensor networks, embedded systems, internet-of-things, signal processing, multimedia systems, machine learning, big data analysis, and applications relevant to smart city applications. Building on a very successful joint project called WINSOC with about a dozen international partners, this new M-Tech program was introduced with a view to strengthen the academic and research activities in these highly advanced topics: Wireless Networks and Applications.

Students, when they graduate, will be well trained to enter into a broad spectrum of industries such as computers, communication networks, internet of things, earth sciences, environmental sciences, disaster management, health care, e-governance activities, bio and nano-technologies, VLSI and embedded systems, agriculture and chemical industries and strategic planning.

MTech Program Outcomes: Program outcomes are narrower statements that describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviours that students acquire in their matriculation through the program

PO1: Engineering Knowledge
PO2: Problem Analysis
PO3: Design/Development of Solutions
PO4: Conduct Investigations of complex problems
PO5: Modern tools usage
PO6: Engineer and Society
PO7: Environment and Sustainability
PO8: Ethics
PO9: Individual & Team work
PO10: Communication
PO11: Project management & Finance
PO12: Lifelong learning

PSO-MTech WNA

1. Gain knowledge on Critical review of research papers & develop technical writing skills
2. Modern tools usage: Create, select, adapt and apply appropriate techniques, resources, and modern computing tools to complex computing activities, with an understanding of the limitations.
3. Capability to think Innovatively and creatively in solving real-life challenges

4. Communication efficacy: Communicate effectively with the research community, and with society at large.
5. Develop awareness on social challenges and involve actively in providing affordable, sustainable and environment-friendly solutions for rural communities.
6. Develop skill sets to work in multidisciplinary areas/projects and diverse groups, national and international mission projects.
7. Research development opportunities by collaborating with international experts and get exposure to state of the art technologies for ready absorption in core industries and research institution

CURRICULUM
First Semester

Course Code	Type	Course	L	T	P	Cr
21WN601	FC	Signal Processing for Wireless Communication	2	0	1	3
21MA618	FC	Probability and Statistical Inference	2	0	1	3
21WN602	FC	Advanced Computer Networks	2	0	1	3
21WN611	SC	Principles of Wireless Communication Systems	3	0	1	4
21WN612	SC	Embedded System Design	3	0	1	4
21WN603	FC	Advanced Computer Programming	0	0	1	1
21HU601	HU	Amrita Values Program*	0	0	0	0
21HU602	HU	Career Competency I*	0	0	0	0
21WN681	P	Live-in-Labs-I	0	0	0	0
					Credits	**18**

*Non-credit Course

Second Semester

Course Code	Type	Course	L	T	P	Cr
21WN604		Design and Analysis of Algorithms	2	0	1	3
21WN614		Internet of Things: Architecture and System Design	3	0	1	4
		Elective I	2	0	1	3
		Elective II	2	0	1	3
21WN613		Mobile Communication Networks	2	0	1	3
21RM622		Research Methodology	2	0	0	2
21HU603		Career Competency II	0	0	1	1
21WN682	P	Live-in-Labs-II	0	0	0	0
					Credits	**19**

Third Semester

Course Code	Type	Course	L		P	Cr
	E	Elective III	2	0	1	3
	E	Elective IV	2	0	1	3
21WN798	P	Dissertation-Phase I				10
21WN781	P	Live-in-Labs-III	0	0	0	0
					Credits	**16**

Fourth Semester

Course Code	Type	Course	L		P	Cr
21WN799	P	Dissertation- Phase II				16
21WN782	P	Live-in-Labs-IV	0	0	1	1
					Credits	**17**
					Total Credits	**70**

List of Courses

Foundation Core

Course Code	Type	Course	L		P	Cr
21WN601	FC	Signal Processing for Wireless Communication	2	0	1	3
21MA618	FC	Probability and Statistical Inference	2	0	1	3
21WN602	FC	Advanced Computer Networks	3	0	1	4
21WN603	FC	Advanced Computer Programming	0	0	1	1
21WN604	FC	Design and Analysis of Algorithms	2	0	1	3

Subject Core

Course Code	Type	Course	L		P	Cr
21WN611	SC	Principles of Wireless Communication Systems	3	0	1	4
21WN612	SC	Embedded System Design	3	0	1	4
21WN613	SC	Mobile Communication Networks	2	0	1	3
21RM622	SC	Research Methodology	2	0	0	2
21WN614	SC	Internet of Things: Architecture and System Design	3	0	1	4

Electives

Course Code	Type	Course	L	T	P	Cr
		Elective I				
21WN701	E	Advanced Signal Processing	2	0	1	3
21WN702	E	Distributed Systems	2	0	1	3
21WN703	E	Wireless Local Area Networks	2	0	1	3
21WN704	E	Advanced Embedded Systems	2	0	1	3
21WN705	E	Antenna Design and Applications	2	0	1	3
21WN706	E	Principles of Virtualization and Software Defined Networking	2	0	1	3
		Elective II				
21WN711	E	Machine Learning	2	0	1	3
21WN712	E	Coding and Information Theory	2	0	1	3
21WN713	E	Open Source Networking	2	0	1	3

21WN714	E	Adaptive Signal Processing	2	0	1	3
21WN715	E	Distributed Network Algorithms	2	0	1	3
21WN716	E	Introduction to Platform Technologies and APIs	2	0	1	3
		Elective III				
21WN721	E	Network and Application Security	2	0	1	3
21WN722	E	5G small Cells	2	0	1	3
21WN723	E	Emerging Wireless Communication Technologies	2	0	1	3
21WN724	E	Big Data and Applications	2	0	1	3
21WN725	E	Introduction to Digital Transformation	2	0	1	3
21WN726	E	Edge and Fog Computing	2	0	1	3
21WN727	E	Introduction to Blockchain and Distributed Ledger Technology	2	0	1	3
21WN728	E	Private Cellular Networks	2	0	1	3
21WN729	E	Advanced IoT Protocols	2	0	1	3
		Elective IV				
21MA701	E	Random Processes and Queueing Models	2	0	1	3
21MA702	E	Linear Algebra and its Applications	2	0	1	3
21MA703	E	Detection and Estimation Theory	2	0	1	3
21MA704	E	Computational Optimization	2	0	1	3
21MA705	E	Graph Theory and its Applications in Wireless Networks	2	0	1	3

Project Work

Course Code	Type	Course	L	T	P	Cr
21WN798	P	Dissertation- Phase I				10

21WN799	P	Dissertation- Phase II				16
21WN681	P	Live-in-Labs-I				0
21WN682	P	Live-in-Labs-II				0
21WN781	P	Live-in-Labs-III				0
21WN782	P	Live-in-Labs-IV				1

Specialization

Course Code	Type	Course	L	T	P	Cr
		Specialization I: Wireless Communications				
21WN701	E	Advanced Signal Processing	2	0	1	3
21WN712	E	Coding and Information Theory	2	0	1	3
21WN705	E	Antenna Design and Applications	2	0	1	3
21WN722	E	5G small Cells	2	0	1	3
21WN728	E	Private Cellular Networks	2	0	1	3
21WN723	E	Emerging Wireless Communication Technologies	2	0	1	3
21WN714	E	Adaptive Signal Processing	2	0	1	3
21MA702	E	Linear Algebra and its Applications	2	0	1	3
21MA703	E	Detection and Estimation Theory	2	0	1	3
21MA704	E	Computational Optimization	2	0	1	3
Specialization II: Mobile Networks						
21WN702	E	Distributed Systems	2	0	1	3
21WN712	E	Coding and Information Theory	2	0	1	3
21WN705	E	Antenna Design and Applications	2	0	1	3
21WN715	E	Distributed Network Algorithms	2	0	1	3
21WN721	E	Network and Application Security	2	0	1	3

21WN722	E	5G small Cells	2	0	1	3
21MA701	E	Random Processes and Queueing Models	2	0	1	3
21MA704	E	Computational Optimization	2	0	1	3
21MA705	E	Graph Theory and its Applications in Wireless Networks	2	0	1	3
		Specialization III: Wireless Systems and Application				
21WN702	E	Distributed Systems	2	0	1	3
21WN703	E	Wireless Local Area Networks	2	0	1	3
21WN704	E	Advanced Embedded Systems	2	0	1	3
21WN706	E	Principles of Virtualization and Software Defined Networking	2	0	1	3
21WN711	E	Machine Learning	2	0	1	3
21WN713	E	Open Source Networking	2	0	1	3
21WN715	E	Distributed Network Algorithms	2	0	1	3
21WN729	E	Advanced IoT Protocols	2	0	1	3
21WN727	E	Introduction to Block chain and Distributed Ledger Technology	2	0	1	3
21WN724	E	Big Data and Applications	2	0	1	3
21MA701	E	Random Processes and Queueing Models	2	0	1	3
21MA704	E	Computational Optimization	2	0	1	3
21MA705	E	Graph Theory and its Applications in Wireless Networks	2	0	1	3

21WN601 SIGNAL PROCESSING FOR WIRELESS COMMUNICATION 2-0-1-3

Unit 1

Sampling and Reconstruction: Sampling theorem, Anti-aliasing prefilters, Sampling of sinusoids, Analog reconstruction and aliasing, Spectra of sampled signals, Discrete-Time Fourier transform, Spectrum Replication, Practical Antialiasing prefilters. Basic components of DSP systems: Quantization, Quantization Process, Oversampling and Noise shaping, D/A converters, A/D converters, Analog and Digital Dither.

Unit II

Discrete-Time systems: input/output rules, Linearity and Time invariance, Impulse response, FIR and IIR filters, Causality and Stability. FIR Filtering and Convolution: Block processing methods Sample processing methods, FIR filtering in direct form. Z-Transforms: Region of Convergence, Causality and Stability, Frequency spectrum, Inverse z-Transforms. Transfer functions : Sinusoidal response, Steady-State response, Transient response, Pole/Zero designs, First-Order filters, Parametric resonators and Equalizers, Notch and Comb filters, Deconvolution, Inverse filters, and Stability.

Unit III

Signal processing applications, DFT/FFT algorithms, Design of FIR filters, Using windows, Frequency sampling, Linear phase FIR filters. IIR Filters: Structure for IIR, State Space Analysis, Impulse invariance, Bilinear transformation, Weiner filters.

Lab

Familiarization of Matlab, Discrete Time signals and Manipulations ,z transform, inverse z transform,Sampling and reconstruction of signals, FFT, DFT, DTFT.

TEXT BOOKS/REFERENCES:

1. Sophocles J. Orfanidis, “Introduction to Signal Processing”, US Edition, Prentice Hall, 1995.
2. John G.Proakis and DimitusG.Manolakis, “Digital Signal Processing, Principles, Algorithms and Applications", Third Edition, Prentice Hall of India, 2002.
3. SanjitK.Mitra, "Digital Signal Processing", Third Edition, Tata McGraw Hill, 2001.
4. Richard G. Lyons, "Understanding Digital Signal Processing", Second Edition, Prentice Hall, 2004.
5. Simon Haykin, “Signal and Systems”, John Wiley & Sons, 1999.
6. Smith, Steven W. "The Scientist and Engineer's Guide to Digital Signal Processing." (1997).

Course Outcome Statement (CO)

18WN601.1	Ability to apply current knowledge and applications of mathematics, science, engineering and technology
18WN601.2	Ability to creatively design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
18WN601.3	Ability to identify, formulate, analyze and solve technical and engineering problems
18WN601.4	Ability to use the techniques, skills and modern technical tools necessary for technical or engineering practice

CO – PO Affinity Map

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3
CO1	3	3	3	-	-	-	2	-	3	-	-	-		-	-
CO2	3	3	2	-	-	-	3	-	2	-	-	-	-	-	-
CO3	3	3	3	-	-	-	2	-	2	-	-	-	-	-	-
CO4	3	3	2	-	-	-	2	-	3	-	-	-	-	-	-

3-strong, 2-moderate, 1-weak

21MA618 PROBABILITY AND STATISTICAL INFERENCE 2-0-1-3

Introduction to Probability, Conditional Probability, Bayes' theorem; Random Variables, Analysis of discrete and continuous random variables, Probability Distributions, Distribution Functions, Mean and Variance of random variables, Standard Discrete and Continuous Distributions and their properties; Analysis of Joint Probability Distributions of discrete and continuous random variables, Two or more random variables , Joint, Marginal and Conditional Probability Distributions, independence of random variables, Covariance and correlation, Linear functions of random variables, several functions of random

variables, Convergence of random variables, Law of Large Numbers, Central Limit Theorem.

Point estimation of Parameters and Sampling distributions: General concepts of point estimation, Methods of point estimation, method of moments, method of maximum likelihood, Bayesian estimation of parameters, Interval estimation, Confidence interval for the mean and variance of a normal population, large sample confidence interval for population proportions; Hypothesis Testing, general concepts, tests on mean and variance of one and two normal populations, tests on population proportion, testing for goodness of fit and independence; Introduction to nonparametric statistics, sign test, Wilcoxon signed rank test, Wilcoxon rank sum test.

TEXT BOOKS/REFERENCES:

1. Vijay K Rohatgi and AK Saleh, "An Introduction to Probability and Statistics", Second Edition, John Wiley& Sons, 2011.
2. Douglas C. Montgomery and George C. Runger, "Applied Statistics and Probability for Engineers", Fourth Edition, John Wiley & Sons Inc., 2007.
3. Sheldon M. Ross, "A First Course in Probability", Eighth Edition, Pearson Prentice Hall, 2010.

Course Outcome Statement (CO)

CO1	Evaluate the probabilities and conditional probabilities.
CO2	Learn random variables and their probability distributions and apply selected probability distributions to solve problems
CO3	Learn multiple random variables, evaluate expectations and conditional expectations of random variables, and use linear regression analysis to develop an empirical model of experimental data
CO4	Study Chebychev's inequality and its applications and approximate the distribution of the sum of random variables using CLT
CO5	Construct point estimators using the method of maximum likelihood.
CO6	Design hypothesis tests for a given set of data and select the appropriate thresholds for the tests.

CO – PO Affinity Map

PO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PSO 1	PSO 2	PSO 3
CO													
CO1	3	3	3			2							
CO2	3	3	3			2							

CO3	3	3	3			2							
CO4		3	2	3									
CO5	3	3	3	3	3	2							
CO6	3	3	3	3	3	2							

3-strong, 2-moderate, 1-weak

21WN602 ADVANCED COMPUTER NETWORKS 2-0-1-3

Communication model, Data Communication, Synchronous and asynchronous communication, Network protocols and standards, Network devices, Network servers, OSI model — TCP/IP protocol Suit — Comparison of OSI and TCP/IP. Data transmission: analog and digital transmission, Multiplexing, Physical and logical topologies — Transmission media. Data link layer- Frames and Error detection, Introduction to Wireless Networks — Wireless LAN technology, Standards-Infrared LANs, Spread Spectrum — DSSS, FHSS, Narrow band, Network layer — Internet Addresses, ARP, RARP, IP, Routing algorithm — Interior and Exterior routing. ICMP, Classless and Subnet Address Extensions (CIDR), Internet Multicasting, NAT, VPN — Addressing and Routing, Transport layer services and principles — Principles of congestion control. TCP Client/ Server Model of Interaction and examples. Application layer protocols — World Wide Web: HTTP — File transfer: FTP — Electronic Mail — DNS — SNMP. Introduction to Internet of Things, IoT Protocol Stack. Physical Layer and Datalink Layer: IEEE 802.15.4, Bluetooth/Bluetooth LE Software Defined Network - Comparison between SDN and traditional networks - SDN controller, Switch design, SDN Controller-Switch Protocols, OpenFlow Protocol, OpenFlow for Wireless Mesh Networks, Control Overhead & Handoff algorithms. Network Function Virtualization - NFV Architecture, Use cases, NFV Orchestration, Resource Management, Analytics, Service Chaining, Distributed NFV, and NFV for 5G.
Lab: Implementation of algorithms from the 18WN602Advanced Computer Networks course, Socket Programming using C. Network packet tracing using packet level tracer. Network traffic analysis and hands on experimentation on switches and routers. Socket Introduction-address structures-Value-Result Arguments, Byte Ordering function, Byte manipulation functions. Elementary TCP sockets. Mathematical modeling and research analysis.

TEXT BOOKS/REFERENCES:

1. Andrew S. Tanenbaum, “Computer Networks", Fourth Edition, Pearson Education Asia, 2002.
2. William Stallings, “Data & Computer Communications”, Eighth Edition, Prentice Hall, 2006.
3. Douglas E. Comer, "Internet working with TCP/IP Volume - 1", Fifth Edition, Prentice Hall, 2008.
4. NFV architecture document from ETSI NFV.
5. Computer Networking: A Top-Down Approach 6th edition, J.F. Kurose and K.W. Ross

Course Outcome Statements (CO)

CO1	Understand the concepts of computer networks and its importance in real-world applications.

CO2	Analyze the data traffic using network analyzer
CO3	Designing of computer networks – LAN, WAN
CO4	Understanding subnetting and IP address allocation
CO5	Network socket programming basics

PO / CO	PO1	PO3	PO5	PO6	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3
CO1	3	3	1	3	1	2	-	-			
CO2	3	3	3	3	2	2	1	1			
CO3	3	3	3	3	3	2	1	1			
CO4	3	3	3	3	3	2	1	1			
CO5	3	3	3	3	3	2	1	1			

3-strong, 2-moderate, 1-weak

21WN603 ADVANCED COMPUTER PROGRAMMING 0-0-1-1

Programming in C, Basic Computer Organization and Architecture, Build and Compilation process, Debugging concepts, Data Types and Variables, Input/ Output implementation and usage, Control flow, Modular Programming with functions, Stack Frames and Activation Records, Arrays, Pointers, Strings, Structures, Implementation of Structures, Memory, Stacks, Recursion, Dynamic Memory Allocation, Heap, Program Runtime Analysis, Big-Oh Notation.
Significant labs, e.g., Spell Checker with a real dictionary, complicated data structure such as a Vector/Set, Customer Relationship Management system, custom string Abstract Data Type, Maze, etc.

TEXT BOOKS/REFERENCES:

1. Brian W Kernighan and Dennis M Ritchie, “The C Programming Language”, Second Edition, Prentice Hall, 1988.
2. K. N. King, “C Programming: A Modern Approach”, Second Edition, W. W. Norton & Company, 2008.
3. Yashavant Kanetkar, “Let Us C” 15th Edition.

Course Outcome Statement (CO)

CO1	Develop problem-solving skills. Modularize a complex task and formulate a program structure with defined subtasks
CO2	Mastering fundamental programming constructs that are an indispensable skill in both well established and emerging technologies
CO3	Use low-level language features to directly manipulate memory
CO4	Use high-level language to abstract the algorithms and data structures from hardware-dependent details
CO5	Learning to work with libraries

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3
CO1	3	3	3	3	2	1	-	-	-	-	-	1	-	-	-
CO2	3	3	3	3	3	1	-	-	-	-	-	1	-	-	-
CO3	3	2	2	2	1	1	-	-	-	-	-	1	-	-	-
CO4	3	3	3	2	1	1	-	-	-	-	-	1	-	-	-
CO5	3	2	2	2	2	1	-	-	-	-	-	1	-	-	-

3-strong, 2-moderate, 1-weak

21WN604 DESIGN AND ANALYSIS OF ALGORITHMS 2-0-1-3

Algorithm Analysis: Methodologies for Analyzing Algorithms, Asymptotic Notation, Recurrence Relations. Data Structures: Linear Data Structures (Stacks, Queues, Linked-Lists, Vectors), Trees (Binary Search Trees, AVL trees, Red-Black trees, B-trees), Hash-Tables (Dictionaries, Associative Arrays, Database Indexing, Caches, Sets) and Union-Find Structures. Searching and Sorting(Insertion and Selction Sort, Quick Sort, Merge Sort, Heap Sort, Bucket Sort and Radix Sort), Comparison of sorting algorithms and lower bounds on sorting. Fundamental techniques: The Greedy Method, Divide and Conquer, Dynamic Programming. Graph Algorithms: Elementary Algorithms, ie Breadth-first search, Depth-first search, Topological sort, Strongly connected components. Minimum Spanning Trees, Single-Source Shortest Paths, All-Pairs Shortest Paths, Maximum Flow, Network Flow and Matching, Flows and Cuts. Nondeterministic Polynomial Time Problems: P and NP, NP-Complete, NP-Hard, Important NP-Complete/Hard Problems.

Significant labs: Implementation of algorithms using a structured or object-oriented programming language.

TEXT BOOKS/REFERENCES:

1. Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest and Clifford Stein, "Introduction to Algorithms", Third Edition, MIT Press, 2009.
2. SanjoyDasgupta, Christos Papadimitriou and UmeshVazirani, "Algorithms", McGraw-Hill, 2006.
3. Jon Kleinberg and EvaTardos, "Algorithm Design", Addison Wesley, 2005.
4. RobertSedgewick and Kevin Wayne, "Algorithms", Fourth Edition, Addison Wesley, 2011.
5. Kurt Mehlhorn and Peter Sanders, "Data Structures and Algorithms: The Basic Toolbox", Springer, 2008.

Course Outcome Statement (CO)

CO1	Ability to Understand, Analyze the performance of recursive and non-recursive algorithms and to measure the performance of algorithms.
CO2	Able to apply the knowledge gained to determine the efficiency of algorithms, considering time and space tradeoffs by using asymptotic notations.
CO3	Able to understand the concept of graph traversal and search algorithms.
CO4	Solve problems by applying appropriate algorithm design techniques and analyze the efficiency of various algorithms
CO5	Able to apply divide and conquer strategy for the design of various algorithms
CO6	Able to develop algorithms for well-known problems using greedy methods.
CO7	Able to describe and apply dynamic-programming approach for designing graph and matrix based algorithms
CO8	Synthesize efficient algorithms in common real life situations
CO9	Ability and improve the programming skills by implementing the algorithms in optimal line of codes.
CO10	Ability to analyze and solve common logic and analytical puzzles and provide optimized solutions for the same.

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3

CO1	3	3	3	3	-	-	-	-	3	3	-	2	-	-	-
CO2	3	3	3	3	-	-	-	-	3	3	-	2	-	-	-
CO3	3	1	2	2	2	-	-	-	3	3	-	3	-	-	-
CO4	3	3	3	3	-	-	-	-	3	3	-	2	-	-	-
CO5	3	3	3	3	-	-	-	-	3	3	-	2	-	-	-
CO6	3	3	3	3	-	-	-	-	3	3	-	2	-	-	-
CO7	3	3	3	3	-	-	-	-	3	3	-	2	-	-	-
CO8	3	3	3	3	-	-	-	-	3	3	-	2	-	-	-
CO9	3	3	3	3	-	-	-	-	3	3	-	2	-	-	-
CO10	3	3	3	2	-	1	-	-	3	3	-	3	-	-	-

3-strong, 2-moderate, 1-weak

21WN611 PRINCIPLES OF WIRELESS COMMUNICATION SYSTEMS 3-0-1-4

Overview of Wireless Communications: Wireless communication systems including the RF, IF and based band components. Introduction to underlying building blocks: Modulation, Multiplexing, Noise and Interference. Antennas: Introduction to antennas, Integration of antennas into systems, Characteristic antenna quantities; Types of antennas: Antennas for mobile station, Antennas for base station. Radio Wave Propagation: Types and modes, Free Space Propagation Model; Propagation Mechanisms: Reflection, Diffraction, and Scattering.

Path Loss Models: Outdoor and Indoor Propagation Models, Signal Penetration into Buildings, Ray Tracing and Site Specific Modeling; Physical Modeling for Wireless Channels: Small-Scale Fading and Multipath Propagation, Input /output model of the wireless channel: The wireless channel as a linear timevarying system, Baseband equivalent model, discrete-time baseband model, Additive white noise. Time and frequency coherence: Doppler spread and coherence time, Delay spread and coherence bandwidth, Statistical characterization of channels, Rayleigh and Rician fading;

Capacity of Wireless Channel: AWGN channel capacity, Resources of AWGN channel, Linear time-invariant Gaussian channels, Capacity of fading channels, Frequency Selective Fading. Techniques for enhancing wireless channel capacity: Spatial channel characteristics; Introduction to Wireless MIMO Communications, Multiple Access Techniques: OFDMA, CDMA, SDMA. Wireless Link Improvement: Introduction to types of codes, Equalization techniques, Diversity methods.

Existing design analysis for application scenarios: Visible Light communication systems, communication systems for Healthcare applications, communication systems for nautical applications, communication systems for MM wave applications.

Wireless Communication Laboratory: Conduct hardware and software experiments on Noise analysis and channel modelling, Modulation, Power spectrum analysis and Noise analysis, MIMO systems.

TEXT BOOKS/REFERENCES:

1. David Tse, PramodViswanath, "Fundamentals of Wireless Communications", CambridgeUniversity Press, 2005.
2. Andrea Molisch; "Wireless Communications", Second Edition, John Wiley & Sons, 2011.
3. T. Rappaport; "Wireless Communications - Principles and Practice", Second Edition,PrenticeHall, 2011.
4. Aditya K. Jagannatham, "Principles of Modern Wireless Communication Systems", McGraw-Hill Education, 2015.
5. Jerry R. Hampton, "Introduction to MIMO Communications", Cambridge University Press, 2013
6. Simon Haykin and Michael Moher; "Modern Wireless Communications", Pearson Education, 2005.

Course Outcome Statement (CO)

CO1	Familiarisation of various components in wireless communication system and its design
CO2	Analyze the behaviour of communication system under different scenarios
CO3	System design and implementation of a wireless communication system based on given application
CO4	Techniques to enhance the quality of wireless links: Codes, Equalization and Diversity
CO5	Introduction in to MIMO and Multiple Access Techniques

3-strong, 2-moderate, 1-weak

PO	PO1	PO2	PO3	PO4	PO5	PO6	PO9	PS0	PSO	PSO

CO								1	2	3
CO1	3	2	3	3	3	-	-	-	-	-
CO2	3	3	3	-	2	-	-	-	-	-
CO3	3	3	3	3	2	2	-	-	-	-
CO4	3	3	3	2	3	-	-	-	-	-
CO5	3	3	3	3	2	2	2	-	-	-

21WN612 EMBEDDED SYSTEM DESIGN 3-0-1-4

Microcontroller fundamentals: ARM ASM programming and basic of C; IO Interfacing: LED and Switch; Design and Development Process: Architecture, Microarchitecture, Design, Implementation, Verification and Validation; Development Tools: Block Diagrams, Flow Charts, Call Graphs, Dataflow Graphs, Finite State Machines; The Parallel Interface: GPIO; The Serial Interface: UART, I2C, SPI; PLL programming; Timer: SysTick; Fixed Point; Software: Structs, Stacks and Recursion; Device Driver: Interfacing with an Hitachi HD44780 display; IO Synchronization; Interrupts; DAC: Music Synthesis and Music Playback; ADC: Real world interfacing and Data Acquisition.
Significant labs include prototypes of actual embedded systems, e.g., Traffic Light Controller (FSM), LCD Device Driver (Hitachi HD44780), Digital Piano (DAC, Interrupts), Digital Vernier Caliper (ADC, Interrupts, LCD), Distributed Data Acquisition (Interrupts, ADC, LCD, UART).
Capstone Design Project, A popular video game, e.g., Space Invaders, Connect-4, Pipe Dream, etc.

TEXT BOOKS/REFERENCES:

1. Jonathan WValvano, “Embedded Systems: Introduction to ARM® Cortex™-M Microcontrollers”, Fourth Edition,CreateSpace Independent Publishing Platform, 2013.
2. Joseph Yiu, "The Definitive Guide to ARM® Cortex®-M3 and Cortex®-M4 Processors", Third Edition, Newnes, 2013.
3. Martin, "The Designer's Guide to the Cortex-M Processor Family: A Tutorial Approach", First Edition,Newnes, 2009.
4. Arnold S. Berger, “Embedded System Design”, First Edition, CRC Press, 2001.

Course Outcome Statement (CO)

CO1	Understand the basics of Embedded Systems, Number Systems, and

	Assembly Language
CO2	Design interface circuits to control external devices like over GPIO
CO3	Details of LM3S1968 Internals like PLL, Systick, Interrupts, and software configuration
CO4	Digitization of Analog inputs using ADC, Audible Analog Signal Generation using DAC
CO5	External LCD Device Hardware Interfacing and Software Device Driver implementation Working prototype Embedded product design, build and test

PO / CO	PO 1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3
CO1	3	2	2	2	2	-	-	-	3	3	-	-	-	-	-
CO2	3	3	3	2	2	-	-	-	3	3	-	-	-	-	-
CO3	3	3	3	2	2	-	-	-	3	3	-	-	-	-	-
CO4	3	3	3	3	2	-	-	-	3	3	-	-	-	-	-
CO5	3	3	3	3	2	-	-	-	3	3	-	-	-	-	-
CO6	3	3	3	3	2	-	-	-	3	3	-	-	-	-	-

3-strong, 2-moderate, 1-weak

21WN613 MOBILE COMMUNICATION NETWORKS 2-0-1-3

Foundation - 3G Network architecture- Overall core architecture- Access Stratum and Non-Access Stratum- End to End Security Overview-Radio access network -Physical layer & protocols - Key Network and UE procedures: - Call set-up/release, Mobility management in idle mode and active mode (handover)

Specialist - 4G/LTE/LTE-A, Small Cells-Network evolution from 3G to Evolved Packet Core (EPC) and LTE Small Cells-Architecture changes compared to 3G-Air interface upgrades - LTE-pro, SON &HetNets

Convergence foundations- Unlicensed spectrum- Private Networks-Neutral Hosts-Wi-Fi Technology Evolution-Introductory concepts-LTE in Wi-Fi- Concepts of private networks and insights into Neutral host networks"

2020 Networks - 5G - Introduction to candidate proposals in 5G, Software Defined Networking (SDN)-Performance Management -Introduction to framework of driving testing and log analysis, Network diagnostics using Probes-Key use cases in diagnostics, Life cycle of trouble shooting- Deployment - Introduction to network planning aspects and auto planning in Small Cells-Evolution in network planning.

TEXT BOOKS/REFERENCES:

1. HarriHolma , AnttiToskala, and JussiReunanen, "LTE Small Cell Optimization: 3GPP Evolution to Release 13", 1st Edition
2. Hrishikesh Venkataraman and Ramona Trestian, "5G Radio Access Networks: Centralized RAN, Cloud-RAN and Virtualization of Small Cells".
3. Jonathan Rodriguez, "Fundamentals of 5G Mobile Networks". 1st Edition
4. Alagan Anpalagan, Mehdi Bennis and RathVannitham, "Design and Deployment of Small Cell Networks" 1st Edition

Course Outcome Statement (CO)

CO1	Appreciation of the legacy mobile network technologies providing background to the advances in the Wireless technologies
CO2	Appreciation of convergence in wireless technologies
CO3	Specialist knowledge in 4G networks. Understanding of the key performance improvements compared to 3G and learn about small cells
CO4	Raise the 5G awareness and prepare for focussed R&D at 5G specialist or PhD level
CO5	Ability to work in industrial environment in supporting and service management areas
CO6	Prepare with skill set required in service provider environment and network benchmarking skills

CO – PO Affinity Map

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3

CO1	3	3	2	3	1	2	1	1	3	3	2	3	3	3	3
CO2	3	3	3	3	2	2	1	1	3	3	2	3	3	3	3
CO3	3	3	3	3	2	2	1	1	3	3	2	3	3	3	3
CO4	3	3	2	3	3	2	1	2	3	3	2	3	3	3	3
CO5	3	2	3	3	2	2	1	3	3	3	2	3	3	3	3
CO6	3	3	3	3	2	2	1	3	3	3	2	3	3	3	3

3-strong, 2-moderate, 1-weak

21RM622 RESEARCH METHODOLOGY 2-0-0-2

Overview of Research and its Methodologies: The need for research, Steps in conducting research; Pathway to research: Understanding the structure of a research paper, how to read and write a research paper, Familiarization with Research Tools.

Literature review: Need for literature review, Identify various sources of information for literature review and data collection, Steps to carry out a literature review.

Critical analysis: Critical analysis of top rated research papers including at least one survey paper and one or two good journal paper in the broad areas such as Wireless Communication, Wireless Networks, Wireless Sensor Networks, Internet of Things, Context Aware Systems, Participatory Sensing, Embedded Systems; Understand the research components of the selected paper such as problem definition, assumptions, solution, and solution methodology, Analyze the findings of the paper, Identify the research gaps.

Problem Formulation: Formulate a research problem based on the critical analysis.

Formulation and presentation of research proposals on selected topic.

TEXT BOOKS/REFERENCES:

1. RT Kumar, Research Methodology: A Step-by-Step Guide for Beginners, SAGE pub., 2010.
2. Walliman, Nicholas, and Bousmaha Baiche. 2001. *Your research project: a step-by-step guide for the first-time researcher*.London/ Thousand Oaks, Calif.: Sage Publications
3. C. R. Kothari, Research Methodology: Methods and Techniques, New Age Intl., 1985

Course Outcome Statements (CO)

CO1	Familiarisation of research and steps in conducting research
CO2	Understanding the structure of a research paper, how to read and write a research paper, familiarisation with research tools
CO3	Need for literature review, Identify various sources of information for literature review and data collection, Steps to carry out a literature review
CO4	Critical analysis of top rated research papers including at least one survey paper and one or two good journal paper in the broad areas
CO5	Understand the research components of the selected paper such as problem definition, assumptions, solution, and solution methodology, analyze the findings of the paper, identify the research gaps

CO – PO Affinity Map

PO / CO	PO1	PO2	PO3	PO5	PO6	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3
CO1	3	3	3	3	3	1	1	1	1			
CO2	3	3	3	3	3	2	2	2	2			
CO3	3	3	3	3	3	2	2	2	2			
CO4	3	3	3	3	3	2	2	2	2			
CO5	3	3	3	3	3	2	2	2	2			

3-strong, 2-moderate, 1-weak

21WN614 INTERNET OF THINGS: ARCHITECTURE AND SYSTEM DESIGN 3-0-1-4

Internet of things: Internet of Things definitions and frameworks, Internet of Things application examples, Fundamental IoT mechanisms and key technologies, Evolving IoT standards, Layer 1/2 connectivity: wireless technologies for the IoT; Applications of IoT Scenarios such as Environmental monitoring, Disaster management, Smart city, Smart Building, Healthcare, Structural monitoring. Internet of Aerial (flying) Things

Architectures of IoT: Three Layer and Five Layer Architecture, Cloud and Fog Based architectures, Social IoT.

Overview of IoT Networking: Communication & Networking Requirements in IoT RFID/NFC, IEEE 802.11, GSM/LTE. Standardized LPWA (EC-GSM-IoT, NB-IoT), Non-standard LPWA (LoRaWAN, Sigfox).

Network Layer: IPv6, 6LoWPAN, RPL, IPSec

Transport Layer: TLS1.3, DTLS, TCP, TCP/UDP.

Application Layer: HTTP, XXMPP, DPWS, SOAP, CoAP, MQTT.

Introduction to Security Mechanisms and Technologies for Constrained IoT Devices extending to block chain based security. Cloudification of IoT concepts covering architecture, deployment models, and foundational technology enablers including XML, SoA/ web services, networking protocols, GPS and GIS.
Laboratory Exercises: Programming of microcontrollers and single board computers. .Interfacing Analog and Digital sensors.Interfacing RF modules.UART Communication. Data communication to the cloud. Prototype design of IoT Systems for a specific application: Network protocols, Transport protocols, Application protocols, security protocols.

Course Outcomes (CO)

CO1: Understand the concepts of IoT systems and its importance in real-world applications.

CO2 Programming IoT devices

CO3: Understanding the different IoT based architecture and protocol stack

CO4: Understanding the security Mechanisms and Technologies for Constrained IoT Devices

CO5: Prototype design of IoT systems

CO – PO Affinity Map

PO / CO	PO1	PO2	PO3	PO5	PO6	PO9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	**3**	**3**	**3**	**3**	**3**	**1**	**1**	**1**	**1**			
CO2	**3**	**3**	**3**	**3**	**3**	**2**	**2**	**2**	**2**			
CO3	**3**	**3**	**3**	**3**	**3**	**2**	**2**	**2**	**2**			
CO4	**3**	**3**	**3**	**3**	**3**	**2**	**2**	**2**	**2**			
CO5	**3**	**3**	**3**	**3**	**3**	**2**	**2**	**2**	**2**			

TEXT BOOKS/REFERENCES:

1. Adrian McEwen, Hakim Cassimally, “Designing the Internet of Things”, Wiley, 2014.
2. Dr. OvidiuVermesan , Dr. Peter Friess , “Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems”, River Publishers
3. David Etter, “IOT (Internet of Things) Programming: A Simple and Fast Way of Learning IOT”,
4. Donald Norris, “The Internet of Things: Do-It-Yourself at Home Projects for Arduino, Raspberry Pi and Beagle Bone Black”, Copyright Material, Edition 1, 2015
5. ArsheepBahga, Vijay Madisetti, “internet of Things: A Hands-On Approach”, Universities Press
6. Mark Lutz, “Learning Python: Powerful Object-Oriented Programming: 5th Edition”, O’REILLY, 2013
7. Simon Monk, “Programming Arduino – Getting started with Sketches”, McGraw Hill, 2012.
8. Donald Norris, “The Internet of Things: Do-It-Yourself at Home Projects for Arduino, Raspberry Pi and Beagle Bone Black”, Copyright Material, Edition 1, 2015.

21WN701 ADVANCED SIGNAL PROCESSING 2-0-1-3

Unit 1

Signal Representations in Vector Spaces, Least Square and Minimum Norm Solutions, Inverse and Pseudo Inverse, Symmetry Transformations, Eigenvectors and Eigenvalues.

Unit II

Multi rate Digital Signal Processing, Filter Bank Design and Polyphase Structures. Optimal filtering of Random Signals: Linear Prediction, Least Means Square, Recursive Least squares, Adaptive filtering.

Unit III

Power Spectral Estimation, Periodogram, Non-Parametric Power Spectrum Estimation Methods, Advanced Signal Processing and Image Processing Applications.

TEXT BOOKS/REFERENCES:

1.Proakis JG and Manolakis DG Digital Signal Processing Principles, Algorithmsand Application, PHI.
2.Openheim AV & Schafer RW, Discrete Time Signal Processing PHI
3.Dimitris G. Manolakis, Vinay K. Ingle, Stephen M. Kogon , “Statistical and Adaptive Signal Processing”, Artech House, 2005.
4.Ali H Sayed, “Adaptive Filters”, John Wiley & Sons, 2011.

Course Outcome Statement (CO)

18WN701.1	Ability to apply current knowledge and applications of mathematics, science, engineering and technology
18WN701.2	Ability to creatively design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
18WN701.3	Ability to identify, formulate, analyze and solve technical and engineering problems
18WN701.4	Ability to use the techniques, skills and modern technical tools necessary for technical or engineering practice

CO – PO Affinity Map

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3	3	3	3	3	-			
CO2	3	3	2	2	2	-			
CO3	3	3	3	2	2	-			

CO4	3	3	2	2	2	-			

3-strong, 2-moderate, 1-weak

21WN702 DISTRIBUTED SYSTEMS 2-0-1-3

Introduction: Goals, Types: Distributed Computing Systems, Distributed Information Systems, Distributed Pervasive Systems.

Architecture: Architectural Styles, Middleware Organization, System Architecture - Centralized, Decentralized, Hybrid.

Processes: Threads, Virtualization, Application of virtual machines, Client and Server design, Code Migration.

Communication: Fundamentals, Remote Procedure Call, Message Oriented Communication, Socket interface and messaging with sockets, Multicast Communication

Naming: Flat – Home based solutions, DHTs. Structured – Name Space, Name Resolution, Examples – DNS, NFS. Attribute based; Coordination: Clock synchronization, Lamport'sLogical clocks, Vector clocks, Mutual Exclusion, Global Positioning, Election Algorithms

Consistency and Replication: Introduction, Data Centric, Client Centric models, Replica Management, Consistency Protocols; Fault Tolerance: Introduction, Process Resilience, Reliable Client Server Communication, Reliable group Communication, Distributed Commit, Recovery. Introduction to security.

TEXT BOOKS/REFERENCES:

1. Andrew S. Tanenbaum, Maarten van Steen, "Distributed Systems", Third edition, Version 3.01, Published by Maarten van Steen (2017).
2. George Coulouris, Jean Dollimore and Tim Kindberg, Gordon Blair, "Distributed Systems: Concepts and Design", Fifth Edition, Addison Wesley, 2012.
3. Wan Fokkink, "Distributed Algorithms – An Intuitive Approach", Prentice Hall, 1999.

Course Outcome Statements (CO)

a.

CO1	Understanding about the working of commonly used centralised and decentralized distributed systems such as server client models, torrents, wsn, iot etc.
CO2	Learning the different distributed system architectures and case study of their state of the art examples.

CO3	Analysing trade-offs to be considered while designing a system
CO4	Learning different principals of distributed system design such as Communication mechanisms, Synchronisation and Coordination algorithms, Fault tolerance mechanisms, Replica placement and Consistency management etc

CO-PO AFFINITY MAP

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3
CO1	3	3	3	2	3	2	-	-	-	-	-	1	-	-	-
CO2	3	3	3	3	3	2	-	-	-	-	-	1	-	-	-
CO3	3	3	3	3	1	2	-	-	-	-	-	1	-	-	-
CO4	3	2	3	3	2	2	-	-	-	-	-	1	-	-	-

3-strong, 2-moderate, 1-weak

21WN703 WIRELESS LOCAL AREA NETWORKS 2-0-1-3

Unit 1

Intro to terminology and overview: Networking basics, IEEE Standards, IEEE 802 family, 802.11 LANs, AP, BSS, IBSS, ESS, DS,SSID, BSSID. Overview and 802.11 MAC: Mobility, Security, CSMA/CA, Hidden Node Problem, MAC Access Modes, NAV, Interframe Spacing, Fragmentation, 802.11 MAC frame, Data Frames, Control Frames, Management Frames, RTS/CTS, Structure of Management Frames, Management Frame Components. Management Operations: Management Architecture, Scanning, Authentication, Preauthentication, Association, Power Conservation, Timer Synchronization, Spectrum Management.

Unit 2

Cryptography – Concepts: PRF/PRP, Stream / Block Cyphers, RC4, 3DES, AES, Hashing, Asymmetric key pairs, Certificates. Security - WEP, TKIP, AES-CCMP, Upper Layers: WEP Cryptographic Operations, TKIP Implementation, AES, CCMP, RADIUS, Transport Layer Security (TLS), TLS over EAP, Kerberos. Cisco Light EAP (LEAP), Protected EAP Protocol (PEAP), EAP-SIM.

Unit 3

Hardware Overview, 802.11 a/b/g PHY: Interface card, Access point hardware, chipsets, Physical-Layer, Architecture, The Radio Link, FHSS, DSSS, OFDM, QAM, ERP. 802.11n/ac: MIMO, Beam Forming, Channel Bonding, Block ACK, MU-MIMO, OFDMA. Network & Security Architecture, Network Planning & Analysis: Evaluating logical architectures and topologies, Selecting security protocols, IDP, AP Placement, Network Analyzers. 802.11e (WMM), 802.11s (Mesh), 802.11u, Hotspot 2.0, 802.11ad. Advanced Topics – Long Range Wi-Fi, Li-Fi, Passive Wi-Fi, 802.11ax, 802.11ay

Lab

WLAN Lab based on the above topics will be conducted using Wireless routers, APs, Wi-Fi enabled smart phones, tablets and laptops and Long Range Wi-Fi base stations and CPEs as well as using QualNet simulation platform.

TEXT BOOKS/REFERENCES:

1. Matthew S. Gast, "Wireless Networks: The Definitive Guide", Second Edition, O'Reilly Media, 2006.
2. Matthew S. Gast, “802.11n: A Survival Guide”, Shroff / O'Reilly, 2012.
3. Matthew S. Gast, “802.11ac: A Survival Guide”, Shroff / O'Reilly, 2013.
4. William A. Arbaugh and Jon Edney, “Real 802.11 Security: Wi-Fi Protected Access and 802.11I”, First Edition,Pearson Education, 2011.
5. EldadPerahia and Robert Stacey, "Next Generation Wireless LANs: Throughput, Robustness, and Reliability", Cambridge University Press, 2008.
6. Anurag Kumar, D. Manjunath, Joy Kuri, "Wireless Networking: An Analytical Approach (The Morgan Kaufmann Series in Networking)”, Morgan Kaufmann, First Edition, 2008.

Course Outcome Statement (CO)

18WN703.1	Ability to design, develop, deploy, troubleshoot and optimize a wireless local area network in the home or enterprise environment
18WN703.2	Thorough in-depth knowledge of the 802.11 Wi-Fi standard and its variants
18WN703.3	Ability to configure, monitor and manage COTS Wi-Fi equipment
18WN703.4	Appreciation for the basics of network security as applied to WLAN

18WN703.5	Familiarity with the web-based and mobile apps for Wi-Fi monitoring and management

CO-PO Affinity Map

PO / CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PS01	PSO2	PSO3
CO1	3	3	3	3	3	3	2	2	-	-	-
CO2	3	3	3	3	3	1	-	-	-	-	-
CO3	3	3	3	3	3	3	1	-	-	-	-
CO4	3	3	3	2	2	3	-	-	-	-	-
CO5	3	3	3	3	3	3	2	1	-	-	-

3-strong, 2-moderate, 1-weak

21WN704 ADVANCED EMBEDDED SYSTEMS (2-0-1-3)

Review of Computer Architecture, Logic Design, Electrical and Electronic Circuits, System Design Process, Software Design Principles and Debugging Theory; ARM Cortex-M processor, Programming in Assembly Language and C.
OS Principles: Threads, FIFO, Memory Management; Hardware Software Synchronization, Timing, Interrupts; Timer, PLL, PWM, Period and Frequency Measurement.
Serial Interfacing: RS232, USB, SSI, I2C. Analog Interfacing: Op Amps, Filters, DAC and ADC. Data Acquisition: Discrete Calculus, Noise Analysis, Transducers: Wired and wireless communication systems, System Level Design: Design for Manufacturability, Power, Tolerance, Testability, Performance and Cost, PCB Design.

TEXBOOKS/REFERENCES:

1. Jonathan W. Valvano, "Embedded Systems: Real-Time Interfacing to Arm® Cortex(TM)-M Microcontrollers", Third Edition,CreateSpace Publishing, 2013.
2. Joseph Yiu, "The Definitive Guide to ARM® Cortex®-M3 and Cortex®-M4 Processors", Third Edition, Newnes, 2013.
3. Martin, "The Designer's Guide to the Cortex-M Processor Family: A Tutorial Approach", First Edition,Newnes, 2009.
4. E. A. Lee and S. A. Seshia, “Introduction to Embedded Systems”, Online Book at Berkeley .edu, 2012.

a.

CO1	Principles of Software Design and Debugging Theory
CO2	Programming skills: Assembly Language and C for ARM Cortex-M processor
CO3	Overview of Product development and its various stages
CO4	Designing a product for Manufacturability[DFM] and Testing [DFT]
CO5	Exploration of UART, SPI, I2C protocols
CO6	Introduction to PCB design, System-level Testing for Reliability and Quality

CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PSO1**	**PSO2**	**PSO3**
CO1	**3**	**2**	**2**	**3**		**2**			
CO2	**3**	**3**	**3**	**1**	**2**				
CO3	**3**	**3**	**3**	**3**	**2**				
CO4	**3**	**3**	**3**	**3**	**2**				
CO5	**3**	**3**	**3**	**3**	**3**	**2**			
CO6	**3**	**3**	**3**	**2**	**2**	**3**			
CO7	**3**	**3**	**3**	**1**					
CO8	**3**	**3**	**3**	**2**					
CO9	**3**	**3**		**3**	**3**	**3**			
CO10	**3**	**3**	**3**	**3**	**3**	**3**			

3-strong, 2-moderate, 1-weak

21WN705 ANTENNA DESIGN AND APPLICATIONS 2-0-1-3

Pre-requisite: Antenna Basics and Introduction to wave propagation classification, modes of Propagation, Ground Wave Propagation–Characteristics, Parameters, Wave Tilt, Flat and Spherical Earth Considerations. Sky Wave Propagation.

Overview and types of Antennas: VHF, UHF and Microwave Antennas- Dipole array with Parasitic Elements, Folded Dipoles, Microstrip antennas, Yagi-Uda Antenna, LPDA, metamaterial antennas, Reflector Antennas, Horn antennas.

Antenna Arrays: Two element arrays, Multiplication of patterns, Linear Array with n -isotropic point sources of equal amplitude and spacing (Broadside, End fire Arrays), Scanning Arrays, N element linear array and directivity, Binomial Arrays- Uniform spacing and Non-uniform Amplitude.

Antenna Measurements – Patterns measurement-arrangement for radiation pattern, Distance requirements, Directivity and Gain Measurements. Integration of Antenna to RF Front end system with matching networks,

Mathematical modelling: Computational electromagnetics-Introduction to FDTD, The 1D wave equation, Integral interpretation of FDTD, Dispersion analysis in three dimensions, Boundary condition for open region. FEM, MOM

Antennas and channel modelling in millimetre wave wireless PAN LAN and MAN: Types of antennas in millimetre wave WPAN, WLAN, and WMAN. Traditional and Time reversal channel modelling for ultra-Wide band communications.

Application of Antennas in Upcoming research areas: Long Range Wi-Fi/ Satellite communication/ Biomedical/ High frequency applications.

Lab:

- Design and implementation of antennas Using HFSS:
- Modelling of Designed antennas (MatLab, FDTD)
- Antenna Measurements
- System realization in research perspectives

TEXT BOOKS/REFERENCES:

1. John L. Volakis, “Antenna Engineering Handbook”, Fourth Edition, McGraw-Hill Professional, 2009.
2. Constantine A. Balanis , “Antenna Theory: Analysis and Design”, Third Edition, WileyInterscience, 2005.
3. Rylander, Thomas, PärIngelström, and Anders Bondeson. “Computational electromagnetics”,. Springer Science & Business Media, 2012.

4. Xiao, Shao-Qiu, and Ming-Tuo Zhou, eds. “Millimeter wave technology in wireless PAN, LAN, and MAN”. CRC Press, 2008.

Course Outcome Statement (CO)

CO1	Overview of various types of antennas: Design and implementation.
CO2	Design of antenna arrays and Beamforming techniques
CO3	Antenna measurements and integration of antenna into the RF front end Systems
CO4	Overview of Ground wave, Skywave and Space wave, and Tropospheric wave propagation
CO5	Antennas and channel modelling in millimetre wave wireless PAN LAN and MAN

CO – PO Affinity Map

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3
CO1	3	3	3	3	3	3									
CO2	3	3	3	3	3	3									
CO3	3	3	3	3	3	2									
CO4	3	3	3	2	3										
CO5	3	3	3	3	3	2									

3-strong, 2-moderate, 1-weak

21WN706 PRINCIPLES OF VIRTUALIZATION AND SOFTWARE DEFINED NETWORKING 2-0-1-3

Virtualization-Hypervisors, Virtual machines, Virtual switch- Network Function Virtualization, Concepts and Applications - Virtual LANs - Virtual Service Networks - Virtual Private Networks, NFVI - Existing Network Virtualization Framework - Mininet based examples.

Introduction to Software Defined Networking-SDN Architecture- Control Plane and Data Plane-Network Programming-Control and Data Plane Separation: Concepts, Advantages and Disadvantages - OpenFlow protocol-Data Center Networks: Packet, Optical and Wireless Architectures and Network Topologies.

TEXT BOOKS/ REFERENCES:

1. Foundations of Modern Networking: SDN, NFV, QoE, IoT, and Cloud by William Stallings, Florence Agboma, SofieneJelassi Publisher Pearson, 2015
2. SDN and NFV Simplified: A Visual Guide to Understanding Software Defined Networks and Network Function Virtualization by Jim Doherty
3. Software Defined Networks: A Comprehensive Approach, by Paul Goransson and Chuck Black, Morgan Kaufmann, June 2014, Print Book ISBN: 9780124166752, eBook ISBN : 9780124166844

Course Outcome Statement (CO)

CO1	Preliminary understanding of the skills-set needed and the technology backdrop of the digital transformation
CO2	Understanding the concepts of softwariation (network functions becoming virtual functions) of network fabric from the architecture point of view
CO3	Insights into the main framework of end to end network architecture virtualisation in 5G era
CO4	Understanding the trade-offs in the design of virtualised networks for critical networks
CO5	Develop the capability to map the available open source trends and solutions towards example industry implementations
CO6	Help gain performance evaluation expertise and R&D methodologies, appreciation of tool sets required

CO – PO Affinity Map

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3
CO1	3	3	2	3	3	2	1	1	3	3	1	3			
CO2	3	3	3	3	3	2	1	1	3	3	1	3			
CO3	3	3	3	3	3	2	1	1	3	3	1	3			
CO4	3	3	2	3	3	2	1	1	3	3	1	3			
CO5	3	2	3	3	3	2	1	1	3	3	1	3			
CO6	3	3	3	3	3	2	1	1	3	3	1	3			

3-strong, 2-moderate, 1-weak

21WN711 MACHINE LEARNING 2-0-1-3

Role of learning in intelligent behavior, general structure of a learning system; learning from example; concept learning, Introduction to machine learning and machine learning applications, Supervised learning, Bayesian decision theory, Parametric methods, multivariate methods, dimensionality reduction, Support Vector Machine, clustering, nonparametric methods, decision trees, linear discrimination, Sparse Linear models, multilayer Perceptrons, local models, hidden Markov models, assessing and comparing classification algorithms, combining multiple learners, and reinforcement learning. Machine learning applied to communication systems

Term Project:

TEXT BOOKS/ REFERENCES:

1. Tom. Mitchell, “Machine Learning", McGraw Hill, 1997.
2. E. Alpaydin, “Introduction to Machine Learning", Prentice Hall of India, 2005.
   Nils J. Nilsson, "Introduction to Machine Learning", http://ai.stanford.edu/~nilsson, 1996.
3. Kevin P. Murphey, “Machine Learning, a Probabilistic Perspective”, MIT press, Cambridge, Massachusetts, 2012.
4. Chris Baton et al., “Understanding Big Data”, McGraw Hill, 2012.
5. Christopher Bishop, “Pattern Recognition and Machine Learning”, Springer.
6. Hastie, T., Tibshirani, R, Friedman, J, “Elements of Statistical Learning: Data Mining, Inference, and Prediction.”2nd Edition, 2009.
7. https://www.deepsig.ai/

Course Outcome Statement (CO)

CO1	Formulation of a Machine Learning problem
CO2	Visualization and Preprocessing of data for Data Mining
CO3	Develop a model using Supervised Machine Learning algorithms for classification/prediction
CO4	Evaluate the performance of various Machine Learning algorithms on a dataset
CO5	Analyze dataset using Unsupervised algorithms for dimensionality reduction and clustering
CO6	Usage of Python packages for Machine Learning

3-strong, 2-moderate, 1-weak

21WN712 CODING AND INFORMATION THEORY 2-0-1-3

Coverage of Information Theory, General Architecture of Communication Systems, Mathematical Tools for Information Theory, Source and Channel Models, Entropy, Relative Entropy, and Data Compression, Source Coding, Mutual Information, Channel Capacity, Limit Theories in Source Coding, Limit Theories in Channel Coding: Reliability Function, Introduction to Network Information Theory, Error control coding techniques for wireless mobile channels: Block and Convolutional Codes, Turbo Codes and LDPC Codes with iterative decoding algorithms, iterative receivers and their application for wireless communications;

TEXT BOOKS/REFERENCES:

1. RaymondW Yeung, “Information Theory and Network Coding”, Springer, 2006.
2. Thomas M. Cover and Joy A. Thomas, “Elements of Information Theory”, Second Edition, Wiley-Interscience, 2008.
3. DavidTse and PramodViswanath, “Fundamentals of Wireless Communication”, Cambridge University Press, 2006.
4. Shu Lin, Daniel J. Costello, "Error Control Coding", Second Edition, Prentice Hall, 2004.

Course Outcome Statements (CO)

CO1	Illustrate the various types of source coding algorithms and analyse their performance.
CO2	Detection and estimation of error correction in the communication systems.

CO3	Analyze the entropy, mutual information and channel capacity for different kinds of channel
CO4	Apply coding techniques in application prespective

3-strong, 2-moderate, 1-weak

21WN713 OPEN SOURCE NETWORKING 2-0-1-3

Introduction to the Open Source Tools, - Open Source Air-interfaces, unbundled telecom networks, RAN, EPC - Role of open sourcing in 5G in terms of open interfaces, open HW&SW reference architectures, Open Source software and Open Ecosystem -Introduction to the application of OPNFV, ONAP and Openstack in the ETSI NFV architecture.

Overview of the families of OpenStack - Architecture IaaS principle, OpenStack release timeline, OpenStack Communication -OpenStack APIs, RabbitMQ - OpenStack Basic Services, Keystone and authentication, Glance and image store, Compute Resources and Nova, Nova architecture, Nova scheduling, Network Resources and Neutron, Neutron architecture, Neutron services, Storage Resources, Cinder and Swift, Types of storage, Cinder vs. Swift, Storage and Glance, Ceilometer and Monitoring, Telemetry meter types and Using Ceilometer.

Introduction to major open source initiatives including Facebook TIP, XRAN and ORAN.

TEXT BOOKS/REFERENCES:

The following websites, latest industry white papers and 3GPP, IETF and Open source forums will be used to deliver the course.

1. http://www.xran.org/
2. https://opencord.org/
3. https://telecominfraproject.com/https://www.onap.org/
4. https://www.onap.org/
5. https://www.openstack.org/
6. https://www.opnfv.org/

Course Outcome Statement (CO)

CO1	Preliminary understanding of the skills-set needed and the technology backdrop of the digital transformation

CO2	Develop understanding of information system architectures, software platforms, and Application Programming Interfaces (APIs) as applicable to open source era
CO3	Obtain competence in the area of distributed software engineering tools and processes such as test-driven development, issues tracking, unit testing, code review, distributed version control, and continuous integration
CO4	Exposure to develop web-enabled software using open source tools (such as HTML5, JavaScript and modern web frameworks) and methodologies
CO5	Being able to approach and apply advanced frameworks and tools in a real 5G network project
CO6	Help gain performance evaluation expertise and R&D methodologies, appreciation of tool sets required

CO – PO Affinity Map

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3
CO1	3	3	2	3	1	2	1	1	3	3	1	3			
CO2	3	3	3	3	2	2	1	1	3	3	1	3			
CO3	3	3	3	3	2	2	1	1	3	3	1	3			
CO4	3	3	2	3	3	2	1	1	3	3	1	3			
CO5	3	2	3	3	2	2	1	1	3	3	1	3			
CO6	3	3	3	3	2	2	1	1	3	3	1	3			

3-strong, 2-moderate, 1-weak

21WN714 ADAPTIVE SIGNAL PROCESSING 2-0-1-3

Unit I

Wiener filter, Kalman Filter, Least Mean Square(LMS) and variants, LMS via DFT, DCT, Recursive Least Square(RLS)

Unit II

Fast transversal and Fast Lattice RLS, Convergence and tracking performance of adaptive filters; Applications of ASP, Spectral estimation, System identification, Channel equalization.

TEXT BOOKS/ REFERENCES:

1. Ali H Sayed, "Adaptive Filters", John Wiley & Sons, 2011.
2. Dimitris G. Manolakis, Vinay K. Ingle and Stephen M. Kogon , "Statistical and Adaptive Signal Processing", Artech House, 2005.

Course Outcome Statement (CO)

18WN710.1	Ability to apply current knowledge and applications of mathematics, science, engineering and technology
18WN710.2	Ability to creatively design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
18WN710.3	Ability to identify, formulate, analyze and solve technical and engineering problems
18WN710.4	Ability to use the techniques, skills and modern technical tools necessary for technical or engineering practice

CO – PO Affinity Map

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	-				-	-	-		-	-
CO2	3	3	2	2	2	-				-	-	-	-	-	-
CO3	3	3	3	2	2	-				-	-	-	-	-	-
CO4	3	3	2	2	2	-				-	-	-	-	-	-

3-strong, 2-moderate, 1-weak

21WN715 DISTRIBUTED NETWORK ALGORITHMS 2-0-1-3

Introduction-Synchronous Network Model-Failures-Inputs and Outputs-Executions-Proof Methods-Complexity Measures-Randomization- Algorithms in General Synchronous networks-Leader Election in a General Network-Breadth First Search- Shortest Paths- Minimum Spanning Tree-Maximal Independent Set- Distributed Consensus with Link Failures-The Coordinated Attack Problem-Deterministic Version-Randomized Version- -Distributed Consensus with Process Failures-Algorithms for Stopping Failures-Algorithms for Byzantine Failures-Number of Processes for Byzantine Agreement-Byzantine Agreement in General Graphs-Weak Byzantine Agreement-Number of Rounds with Stopping Failures-Asynchronous System Model-I/O Automata-Operations on Automata-Fairness-Inputs and Outputs for Problems-Properties and Proof Methods-Complexity Measures-Indistinguishable Executions-Randomization-Asynchronous Shared Memory model-Shared Memory Systems-

Environment Model-Indistinguishable States-Shared Variable Types-Complexity Measures-Failures-Randomization- Resource Allocation-Problem-Nonexistence of Symmetric Dining Philosophers Algorithms-Right-Left Dining Philosophers Algorithm-Randomization.Introduction to block chains.

TEXT BOOKS/REFERENCES:

1. HagitAttiya and Jennifer Welch, "Distributing Computing: Fundamentals, Simulations, and Advanced topics", Second Edition, John Wiley and Sons, 2004.
2. Nancy Ann Lynch., "Distributed Algorithms", Morgan Kaufman,Elsevier, 2003.

Course Outcome Statements (CO)

CO1	Identify the advantages and challenges in designing distributed algorithms for different primitives like mutual exclusion, deadlock detection, agreement, etc.
CO2	Differentiate between different types of faults and fault handling techniques in order to implement fault-tolerant systems.
CO3	Analyze different algorithms and techniques for the design and development of distributed systems subject to specific design and performance constraints.

CO – PO Affinity Map

21WN716 INTRODUCTION TO PLATFORM TECHNOLOGIES AND APIS 2-0-1-3

Introduction to Big Data Technology including Hadoop Procedure – Modules- Insights and Data Visualization and examples.

Introduction to the "PLATFORM" concept in research on product development, technological strategy, and industrial economics - Understanding of converged networks in the evolution of the role of platforms including product platform design: building blocks of products, technologies or services - Example platforms based on social networking trends and service provider platforms.

Introduction to the requirements of APIs, using APIs and End-to-End view of API - Insights into simplified API process and Technology behind APIs and Restful APIs - Introduction to OAuth 2 - Introductory concepts of APIs in the Network Transformation with OpenStack APIs for VM principles - APIs in Software-Defined Networking - API Examples including Data center, Wireless networks and API platform.

Introduction to ‘R’ programming language.

TEXT BOOKS/REFERENCES:

1. Steve Wexler, Jeffrey Shaffer and Andy Cotgreave., “The Big Book of Dashboards”, John Wiley & Sons, 2017
2. Matthias Biehl , “API Architecture: The Big Picture for Building APIs”, API University Series - Volume 2, 2015
3. Matthias Biehl , “RESTful API Design: Best Practices in API Design with REST, API-University Series Book 3, 2016
4. Sanjay Patni, “Pro RESTful APIs: Design, Build and Integrate with REST, JSON, XML and JAX-RS”, Apress, Berkeley, CA, 2017
5. Annabelle Gawer , “Platforms, Markets and Innovation”, EdgwardEgar Publishing, 2011.
6. Laure Claire Reillier and Benoit Reillier, “Platform Strategy”, Routledge 2017
7. KleanthisDellios, ConstantinosPatsakis, and DespinaPolemi, “Automobile 2.0: Reformulating the Automotive Platform as an IT System”, IEEE Computer Society, 2016. http://www. computer.org/ITPro

CO1	Preliminary understanding of the skills-set needed and the technology backdrop of the digital transformation and fourth industrial revolution
CO2	Understanding the introductory concepts of 4G, 5G and IoT
CO3	Develop the overview of service management in the pre-5G era
CO4	Extend the knowledge to 5G service management using principle of network orchestration
CO5	Learn about enablers to design network elements and services that leverage the platform paradigm, to plan and operate 5G networks based on NFV and SDN technologies
CO6	Develop use cases for 5G applications for various verticals (utilities, autonomous cars, smart cities, public safety and manufacturing)

CO – PO Affinity Map

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3

CO1	3	2	2	3	3	2	1	1	3	3	1	3			
CO2	3	2	3	3	3	2	1	1	3	3	1	3			
CO3	3	3	3	3	3	2	1	1	3	3	1	3			
CO4	3	3	2	3	3	2	1	1	3	3	1	3			
CO5	3	2	3	3	3	2	1	1	3	3	1	3			
CO6	3	3	3	3	3	2	1	1	3	3	1	3			

3-strong, 2-moderate, 1-weak

21WN721 NETWORK AND APPLICATION SECURITY 2-0-1-3

Introduction, Network Security Model, Types of threats, Linux Security Overview, Malware Primer, Application vulnerabilities, Social Engineering attack techniques and prevention steps, Cryptography Primer - Symmetric keys for data encryption, asymmetric keys for secure key distribution, Diffie-Hellman Key Exchange. Integrity checking with hashes and MACs, User and host identity verification, Detecting and preventing system and network intrusions, Confidentiality with SSL and IPSec tunneling.

Overview of various wireless technologies, protocols, systems and applications and the respective security concerns and challenges - WLAN, WMAN, WPAN, WMN, WS[A]N, MANET, VANET, Smart Home, Smart Grid, Security considerations for various layers of the wireless protocol stack, Cross-layer attack and defense. Enterprise Wireless LAN security, Trust and reputation management, Synchronization & Localization based attacks and mitigation strategies, Smart Grid security, Telecom system and infrastructure attacks, Mobile App and OS security, PAN security, IoT security

TEXT BOOKS/REFERENCES:

1. Charlie Kaufman, Radia Perlman and Mike Speciner, "*Network Security: PRIVATECommunication in a PUBLIC world*", Second Edition, Prentice Hall, 2002.
2. Patrick Tague, "Wireless Network & System Security Group", CMU-SV, http://wnss.sv.cmu.edu/courses/

CO1:	Understanding and appreciation of the nature and kind of threats, vulnerabilities and defences in various wireless networks and technologies

CO2:	Ability to design, analyse and propose threat models for real-world practical systems and applications based on wireless technologies
CO3:	Ability to perform ethical hacking of systems and networks to expose the potential security holes in their design and deployment
CO4:	Familiarity with the cross-layer attack and defence strategies in wireless networks and systems
CO5:	Exposure to the potential security threats in the use of mobile apps and social networks

CO-PO AFFINITY MAP

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PS01	PSO2	PSO3
CO1	3	3	3	3	3	3	1	2	-	-	-
CO2	3	3	3	3	2	3	-	2	-	-	-
CO3	3	3	3	3	3	3	-	3	-	-	-
CO4	3	3	3	3	2	3	1	2	-	-	-
CO5	3	3	3	3	3	3	-	1	-	-	-

21WN722 5G SMALL CELLS 2-0-1-3

Small Cells: Introduction to Small Cells and network densification- Types and applications of small cells - 3GPP releases and developments towards 5G small cells -Private Networks - Neutral host small cells.

Introduction to LTE-Advanced and LTE-Advanced Pro features and evolution to 5G - Network Architecture including NG-RAN architecture - Next Generation Core and Interworking with 4G - 5G Service and performance requirements and supporting technologies covering NFV and SDN in 5G - Network slicing in 5G and Mobile Edge Computing (MEC)- Cloud RAN, Open RAN and 5G NGRAN- Cloud-C-RAN interworking with NFV and SDN- C-RAN interworking with SDN RAN variations

including Open RAN interfaces - Cloud RAN architecture and NG-RAN: CU and DU - Fronthaul and backhaul topics including CPRI overview, CPRI for 5G and Distance requirements – 5G NR

Small Cell Deployment scenarios including RF design considerations - Signal propagation differences, Link budget consideration and Transport network considerations - Cloud and Open RAN Deployment via Centralized BBU and Virtualization in BBU.

TEXT BOOKS/REFERENCES:

1. Jonathan Rodriguez, "Fundamentals of 5G Mobile Networks", Wiley 2015.
2. HolgerClaussen, David López-Pérez, Lester Ho, RouzbehRazavi and StepanKucera,"Small Cell Networks: Deployment, Management, and Optimization", Wiley books 2017.
3. HarriHolma, AnttiToskala and JussiReunanen, " LTE Small Cell Optimization", Wiley 2015
4. Kazi Mohammed, SaidulHuqJonathan and Rodriguez, " Backhauling/Fronthauling for Future Wireless Systems", Wiley 2016

CO1	Understanding of the technologies and interworking architecture of the next generation network including 5G Small Cell
CO2	Knowledge of the technologies to LTE-Advanced and LTE-Advanced Pro, roadmap and evolution towards the next-generation (5G) architecture
CO3	Appreciating the role of supporting key enablers such as Network Function Virtualization, Software Defined Networking, Mobile Edge Computing and Network Slicing in 5G Architecture
CO4	Appreciate the underlying technologies and protocols related to 5G NR
CO5	Insight into the Open RAN, Cloud RAN deployment scenarios based on BBU
CO6	Apply systems thinking to understand and develop architecture frameworks for different use cases in 5G

CO-PO AFFINITY MAPPING

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3

CO1	3	3	2	3	1	2	1	1	3	3	1	3			
CO2	3	2	3	3	2	2	1	1	3	3	1	3			
CO3	3	3	3	3	2	2	1	1	3	3	1	3			
CO4	3	3	2	3	3	2	1	1	3	3	1	3			
CO5	3	2	3	3	2	2	1	1	3	3	1	3			
CO6	3	3	3	3	2	3	1	1	3	3	1	3			

21WN729 ADVANCED IoT PROTOCOLS 2-0-1-3

Syllabus:

Networking: Hierarchical, Non-hierarchical, Clustering, Mutli-hop, Single-hop, Multiple Sinks and Sources. MAC for IoT applications: 802.15.4e MAC protocol, DSME, Adaptive MAC (AMAC), Energy Efficient and Delay Optimised MAC (EEDO-MAC), Routing-Enhanced MAC (R-MAC). Clustering Protocols: Network Stability-Aware Clustering (NSAC) Protocol, LEACH

Routing: Design challenges, AODV, OLSR, Lightweight On-demand Ad hoc Distance Vector Routing - next generation (LOADng), RPL Protocol, Channel-Aware Routing Protocol (CARP), Collection Tree Protocol (CTP), Flat Routing: SPIN, Directed Diffusion; Location based routing: GEAR, GPSR, QoS based routing: TBP, SPEED. Data Aggregation: Types and Challenges, MFS, TAG.

Time synchronization: Types, RBS, LTS, TPSN. PSync: Visible Light-Based Time Synchronization, AirSync: Time Synchronization using Aircraft Signals, LATe: A Lightweight Authenticated Time Synchronization Protocol, CorTiS: Correlation-based Time Synchronization.

Localization and Positioning: Overview, TOA, TDOA, AOA, RSSI, Range based Localization: Triangulation, Trilateration: Iterative and collaborative Multi-lateration, GPS based localization; Range free localization: APS, Event Driven Localization: Light House approach, Multi Sequence Positioning. GROLO Protocol: Range-based Localization via Global Rigidity.

Course Outcomes (CO)

CO1	Understand the different features and characteristics of an IoT network

CO2	Learn about the various MAC protocols used in IoT networks, and how to choose the optimal protocol under different scenarios.
CO3	Learn about the different routing protocols used in IoT networks, and a comparative study of their features
CO4	Understand the need for different node and network management strategies such as Time Synchronization and Localization and learn about some of those recent protocols
CO5	Learn to implement the IoT protocols for any real world application in a chosen IoT platform

CO – PO Affinity Map

PO / CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	2	3	-	2	-	-	-	-	-	-	-			
CO2	3	3	3	2	2	-	-	-	2	-	-	-			
CO3	3	3	3	2	2	-	-	-	2	-	-	-			
CO4	3	3	3	2	2	-	-	-	2	-	-	-			
CO5	3	2	3	-	3	-	-	-	2	-	-	-			

3-strong, 2-moderate, 1-weak

References:

1. Kumar, A., Zhao, M., Wong, K. J., Guan, Y. L., & Chong, P. H. J. (2018). A comprehensive study of iot and wsn mac protocols: Research issues, challenges and opportunities. *IEEE Access*, *6*, 76228-76262. https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8543861

2. Zheng, M., Chen, S., Liang, W., & Song, M. (2019). NSAC: A novel clustering protocol in cognitive radio sensor networks for Internet of Things. *IEEE Internet of Things Journal*, *6*(3), 5864-5865. https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8637771
3. Alahari, H. P., & Yalavarthi, S. B. (2017). A survey on network routing protocols in internet of things (IOT). *International Journal of Computer Applications*, *160*(2), 18-22. http://www.ttcenter.ir/ArticleFiles/ENARTICLE/3938.pdf
4. Sobral, J. V., Rodrigues, J. J., Rabêlo, R. A., Al-Muhtadi, J., & Korotaev, V. (2019). Routing protocols for low power and lossy networks in internet of things applications. *Sensors*, *19*(9), 2144. https://www.mdpi.com/1424-8220/19/9/2144
5. Guo, X., Mohammad, M., Saha, S., Chan, M. C., Gilbert, S., & Leong, D. (2016, April). PSync: Visible light-based time synchronization for Internet of Things (IoT). In *IEEE INFOCOM 2016-The 35th Annual IEEE International Conference on Computer Communications* (pp. 1-9). IEEE. https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7524358
6. Zhu, S., Zheng, X., Liu, L., & Ma, H. (2021). AirSync: Time Synchronization for Large-scale IoT Networks Using Aircraft Signals. *IEEE Transactions on Mobile Computing*. https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9394785
7. Navas, R. E., & Toutain, L. (2018, June). Late: A lightweight authenticated time synchronization protocol for iot. In *2018 Global Internet of Things Summit (GIoTS)* (pp. 1-6). IEEE. https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8534565
8. Zhou, B., & Vuran, M. C. (2019, May). Cortis: Correlation-based time synchronization in Internet of Things. In *ICC 2019-2019 IEEE International Conference on Communications (ICC)* (pp. 1-7). IEEE. https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8761501
9. Dalwadi, N., & Padole, M. (2019). An Insight into Time Synchronization Algorithms in IoT. In *Data, Engineering and Applications* (pp. 285-296). Springer, Singapore. https://link.springer.com/chapter/10.1007/978-981-13-6351-1_23
10. Chen, Z., Xia, F., Huang, T., Bu, F., & Wang, H. (2013). A localization method for the Internet of Things. *The Journal of Supercomputing*, *63*(3), 657-674. https://arxiv.org/ftp/arxiv/papers/1201/1201.0120.pdf
11. Wu, H., Ding, Z., & Cao, J. (2019). GROLO: realistic range-based localization for mobile IoTs through global rigidity. *IEEE Internet of Things Journal*, *6*(3), 5048-5057. https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8625382

Sadowski, S., & Spachos, P. (2018). Rssi-based indoor localization with the internet of things. *IEEE Access*, *6*, 30149-30161. https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8371230

21WN723 EMERGING WIRELESS COMMUNICATION TECHNOLOGIES 2-0-1-3

Pre-requisite: Space-time processing, over view of Beamforming, spatial, temporal, frequency diversity, antenna gain, spatial cancelling of interference. Definition of diversity order; Spatial Channel modelling.

MIMO: Introduction to Wireless Point to point MIMO system Model - Capacity, SISO AWGN model- Performance; SISO Fading Channel Model- Performance; Outage 18 capacity, ergodic capacity; Capacity analysis of - Single user MIMO System with Full CSIT, Partial CSIT and Long term CSIT; Capacity Analysis of MIMO Fading Channel with long term and Short term channel Knowledge; Space-

time Block Coded MIMO System, STTD, Alamouti Coding, Dominant mode Beamforming, ML, V-BLAST, D-BLAST- Performance analysis. Algorithms for MIMO.Spectral efficiency, link budget, coverage gain with MIMO.Limitations and implementation issues.

Millimeter Wave Technology: MAC protocol for millimetre wave wireless LAN and PAN, Millimeter wave for wireless networks, millimetre wave dedicated short range communication (DSRC) standard application and experiment study, millimeter wave wireless MAN cellular configurations

Satellites and Radar Communication: The Space Link, Satellite Link Design, Propagation on Satellite-Earth Paths. Interference between satellite circuits, Energy Dispersal, propagation characteristics of fixed and mobile satellite links.Applications of radar, Prediction of range performance, minimum detectable signal, receiver noise, probability density function, SNR, Integration of radar pulses, radar cross-section of targets, PRF and range ambiguities, transmitter power, system losses.

Cognitive Radio: SDR Architecture – Reconfigurable communication systems, Digital Radio Processing, CR Architecture- Issues related to physical Layer designs in CRs. CRs and Dynamic Spectrum Access. Spectrum Sensing – Detect Primary system, Cognitive OFDMA systems, Energy Detection, Cyclostationary Detection, Covariance Matrix-based Detection, Wavelet Detection, Compressed Sensing, Spectrum Decision , Spectrum Sharing - Intra-network Spectrum Sharing, CR MAC, Routing, CR Control.

TEXT BOOKS/REFERENCES:

1. F. Akyildiz, W. Y. Lee and K. R. Chowdhury, “Cognitive Radio Networks: Theory and Applications”,John Wiley & Sons Ltd, 2009.
2. EzioBiglieri and Robert Calder bank, Anthony Constantinides and Andrea Goldsmith, “MIMO Wireless Communications”, Cambridge University Press, 2007.
3. G Strang, “Introduction to Linear Algebra”, Wellesley – Cambridge Press, 2003.
4. Mustafa E. S¸ Ahin and H¨useyinArslan, “System Design for Cognitive Radio Communications” Proc. Cognitive Radio Oriented Wireless Networks and Commun. (CrownCom), Pages 1-5, 2006
5. Ippolito, Louis J., and Louis J. Ippolito Jr. Satellite communications systems engineering: atmospheric effects, satellite link design and system performance. John Wiley & Sons, 2017.
6. Barton, David K. Radar system analysis and modeling. Vol. 1. Artech House, 2004.

CO1:	Overview of MIMO systems: Performance and capacity analysis of channels, Coverage gain, Beamforming, Spectral efficiency analysis and Block coded MIMO systems.
CO2:	Introduction to Millimeter Wave Technologies for wireless networks, short-range communication system design, and wireless MAN cellular configuration.
CO3:	Familiarisation of Satellites and Radar Communication systems including satellite link design, interference , radar range performance and system analysis
CO4:	Realisation of Cognitive radio architecture and digital radio processing

CO-PO Affinity Map

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PS01	PSO2	PSO3
CO1	3	2	3	3	3	-	-	-	-
CO2	3	3	3	3	2	2	-	-	-
CO3	3	3	3	3	2	2	-	-	-
CO4	3	3	3	2	2	-	-	-	-

21WN724 BIG DATA AND APPLICATIONS 2-0-1-3

Introduction: Large databases and their evolution, Introduction to Data Science - Why Big Data? - Problems solved by Data Science - Data Science Process - Exploratory Data Analytics. Data Preparation: data munging - scraping - sampling - cleaning. Exploring and Analysis of Data - descriptive and inferential statistics, sampling, experimental design, parametric and non-parametric tests of difference, ordinary least squares regression, and general linear models; Data storage and management in order to be able to access data - especially big data - quickly and reliably during subsequent analysis - storage, search and retrieval systems for large scale structured and unstructured information systems.
Data Analytics - Theory and Methods - Supervised learning, Linear/Logistic Regression, Decision tress, Naïve Bayes, Unsupervised learning - K-means clustering - Association rules - Unstructured Data Analytics - Technologies and tools - Text mining - Web mining. Data Communication with Information Visualization - Effective Information Visualization - Visual Encoding - Perception of Visual Cues - Data Scales - Visualizing Time Series Data - Visualizing through stories and interpretable summaries.

TEXT BOOKS/ REFERENCES:

1. Wes McKinney, "Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython", First Edition, O'Reily Media, 2012.
2. Cathy O'Neil and Rachel Schutt, “Doing Data Science Straight Talk from the Frontline", First Edition, O'Reily Media, 2013.
3. Chris Eaton, et al, “Understanding Big Data”, McGraw-Hill, 2012.
4. Henrique C. M. Andrade, BugraGedik and Deepak S. Turaga, "Fundamentals of Stream Processing: Application Design, Systems and Analytics", Cambridge University Press, 2014.

Course Outcomes (CO)

CO1: To provide an overview of big data and its practical applications

CO2: Analyse different modelling techniques for real time data analysis
CO3: To enable students to solve complex real-world problems in for decision support.

21WN725 INTRODUCTION TO DIGITAL TRANSFORMATION 2-0-1-3

Introduction to concepts of Fourth Industrial Revolution and its impacts on the mobile and IT convergence - Overview of the current trends on Search Engines, Multimodal Human Interfaces - Digital Assistants including Home Assistants, Shopping Assistants and Chatbots - Principles of networks, applications and services in the digitalization framework - Overview of network automation trends - digital service design and network operations and performance - Insight into business operations and service operations including the emerging technologies including 5G, DeVOps, Platforms and Blockchain.

TEXT BOOKS/REFERENCES:

1. Klaus Schwab and Nicholas Davis, "Shaping the Fourth Industrial Revolution", World Economic Forum book, 2018.
2. Jason Edelman, Scott S. Lowe and Matt Oswalt, "Network Programmability and Automation: Skills for the Next-Generation Network Engineer", O'Reilly publications, 2016
3. Mark levene, "An introduction to Search engines and Web navigation" Wiley & Sons, 2011
4. KalyanSundhar and Lawrence C. Miller, "5G For Dummies, John Wiley & Sons, Inc.
5. Postor papers for websites and industry forums.

COURSE OUTCOMES

CO1: Preliminary understanding of the skills-set needed and the technology backdrop of the digital transformation and fourth industrial revolution

CO2: Understanding the introductory concepts of 4G, 5G and IoT

CO3: Develop the overview of service management in the pre-5G era

CO4: Extend the knowledge to 5G service management using principle of network orchestration

CO5: Develop use cases for 5G applications for various verticals (utilities, autonomous cars, smart cities, public safety and manufacturing)

CO6: Capability to design an example digital transformation tool box for 5G service providers

CO – PO Affinity Map

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3
CO1	3	2	2	3	3	2	1	1	3	3	1	3			

CO2	3	3	3	3	2	2	1	1	3	3	1	3			
CO3	3	3	3	3	2	2	1	1	3	3	1	3			
CO4	3	3	2	3	3	2	1	1	3	3	1	3			
CO5	3	2	3	3	2	2	1	1	3	3	1	3			
CO6	3	3	3	3	2	2	1	1	3	3	1	3			

21WN726 EDGE AND FOG COMPUTING 2-0-1-3

Edge Computing in Networks: Introduction to Multi-Access Edge computing (MEC) MEC reference architecture with understanding on the role of each element, Characteristics, Technologies, Standardization groups including ETSI MEC framework. Introduction to list of different MEC server locations and list of key use cases and benefits offered by MEC.Overview of the Mobile Edge high level management and MEC services including Digital Enterprise and its connectors including universal CPE (uCPE). Introduction to data dense, high performance, distributed automation architecture in data-world. Fog concepts (cloud-to-sensor) and advantages of Fog computing and 8 pillars of Fog. Data shifting strategies to move compute, storage, communication, control, and decision making closer to IoT sensors and actuator to understand the overall work flow in the Fog era. Industry standards including OpenFog Framework.

TEXT BOOKS/REFERENCES:

1. Dominique Paret, Jean-Paul Huon, “Secure Connected Objects”, Wiley Books 2017
2. Rahmani, A., Liljeberg, P., Preden, J.-S., Jantsch, A. , “Fog Computing in the Internet of Things Intelligence at the Edge”, Springer 2018.
3. Evangelos Markakis, George Mastorakis, Constandinos X. Mavromoustakis and Evangelos Pallis,” Cloud and Fog Computing in 5G Mobile Networks: Emerging advances and applications”, IET book 2017.

COURSE OUTCOMES

CO1	Preliminary understanding of the skill-set needed and the technology backdrop of the digital transformation
CO2	Understanding the concepts of disaggregated network fabric from the architecture point of view
CO3	Insights into the main framework of distributed intelligence in the network architecture
CO4	Understanding the coupling mechanisms for control, data forwarding and management planes

CO5	Exposure to design principles of edge and Fog applications on the top of the above transformation layer
CO6	Help gain performance evaluation expertise and R&D methodologies, appreciation of tool sets required

CO – PO Affinity Map

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3
CO1	3	3	2	3	1	2	1	1	3	3	1	3			
CO2	3	3	3	3	2	2	1	1	3	3	1	3			
CO3	3	3	3	3	2	2	1	1	3	3	1	3			
CO4	3	3	2	3	3	2	1	1	3	3	1	3			
CO5	3	2	3	3	2	2	1	1	3	3	1	3			
CO6	3	3	3	3	2	2	1	1	3	3	1	3			

21MA701 RANDOM PROCESSES AND QUEUEING MODELS 2-0-1-3

Random Processes: Introduction, Classification of random processes, Poisson Process, renewal processes, Markov Process, Markov Chains, Transition Probabilities, classification of states of Markov chains, Chapman-Kolmogorov Equations, steady state probabilities, continuous time Markov chains and birth and death processes and analysis of time series.Introduction to Regeneration process.
Queuing Models: Characteristics of Queuing Systems, Steady state solution of M/M/1 and M/M/C queuing models with Finite and Infinite Capacities, Stationary behavior of M/G/1. Queuing networks, G/G/1.

TEXT BOOKS/REFERENCES:

1. Sheldon M Ross, “Stochastic Processes”, Second Edition, Wiley & Sons Inc, 1996.
2. Gross D. and Harris C. M, John,“Fundamentals of Queuing Theory”, Third Edition, Wiley & Sons Inc, 2004.
3. J. Medhi, “Stochastic Models in Queuing Theory”, Second Edition, Academic Press, Elsevier, 2003.

Course Outcomes (CO)

CO1: Elucidate the power of stochastic/Random processes and their range of applications

CO2: Demonstrate essential stochastic modelling tools including Markov chains and queuing theory

CO3: Demonstrate the ability to formulate continuous-time Markov chain models for relevant practical systems

CO4: Rigorous understanding of the theoretical background of queueing systems.

CO5: Understand and compute quantitative metrics of performance for queueing systems.

CO6: Apply and extend queueing models to analyze real world systems.

21MA702 LINEAR ALGEBRA AND ITS APPLICATIONS 2-0-1-3

Determinants- Row Reduction and Cofactor Expansions, Cramer's rule. Row picture, Column picture, Vector Spaces- Euclidean space, General (real) Vector Spaces, Subspaces, Linear Independence, Dimension, Row, Column and Null spaces.
Inner products: Norms, Orthogonal Bases and Gram-Schmidt Orthogonalization; Matrix Multiplication Problems, Matrix Analysis, Gauss Elimination Technique, LU and LDU Decomposition methods, Diagonalization of a Matrix, Singular value decomposition, Dimensionality Reduction, Principal Component Analysis.
Linear Transformations: Kernel and Range, Inverse Transformations, Matrices of Linear Transformations, Change of Basis, Similarity; Orthogonalizations and Least Squares, Parallel Matrix Computations, Unsymmetric Eigenvalue problem, Symmetric Eigenvalue problem, Iterative methods for linear systems, Lanczos methods.

TEXT BOOKS/ REFERENCES:

1. Golub and Loan, "Matrix Computations", Third Edition, John Hopkins University Press, 1996.
2. Carl. D. Meyer, "Matrix Analysis and Applied Liner Algebra", SIAM, 2001.
3. Gilbert Strang, "Introduction to Linear Algebra", Fourth Edition, Wellesley Cambridge Press, 2009.

Course Outcome Statement (CO)

CO1	Ability to solve problems in science and engineering and can be mathematically formulated by forming a system of linear equations.
CO2	To solve real life problems from massive linear system of equations
CO3	Ability to solve the linear systems computationally.
CO4	Ability to formulate real life applications using eigenvalue problems.
CO5	Learn the mathematical background for search engines, filter design, machine learning etc

CO – PO Affinity Map

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3
CO1	3	2	3	2	3	-	-	-	-	-	-	3	-	-	-

CO2	3	2	3	2	3	-	-	-	-	-	-	3	-	-	-
CO3	3	2	3	2	3	-	-	-	-	-	-	3	-	-	-
CO4	3	3	3	3	2	-	-	-	-	-	-	3	-	-	-
CO5	3	3	3	3	2	-	-	-	-	-	-	3	-	-	-

3-strong, 2-moderate, 1-weak

21MA703 DETECTION AND ESTIMATION THEORY 2-0-1-3

Sufficiency, Exponential families, Methods of estimation: Least Squares, Maximum likelihood, method of moments, Bayes; Algorithms for estimation. Performance: Bayes, minimax, unbiasedness, Cramer-Rao inequality, Rao-Blackwell Theorem; Asymptotic Performance: Consistency, Asymptotic normality, Asymptotic optimality, Hypothesis Testing Neyman-Pearson Lemma, UMP Tests, Monotone likelihood ratio, Generalized likelihood ratio test, confidence bounds.

TEXT BOOKS/ REFERENCES:

1. Bickel and Doksum, “Mathematical Statistics”, Second Edition, Pearson, 2006.
2. Casella and Berger, “Statistical Inference”, Second Edition, Cengage Learning, 2001.

COURSE OUTCOMES

CO1	Understand the basic concepts of signal detection and estimation
CO2	Understand different hypotheses in detection and estimation problems
CO3	Understand the conceptual basics of detection and estimation of signals in white and non-white Gaussian noise
CO4	Understand the detection of random signals and the time varying waveform detection and its estimation

21MA704 COMPUTATIONAL OPTIMIZATION 2-0-1-3

Introduction- mathematical optimization, least-squares and linear programming, convex and nonlinear optimization, Convex sets, Steepest Descent, Newton's Method, Linear optimization,

Quadratic optimization, Generalized inequality constraints, Integer programming, Combinatorial optimization, Dynamic programming, Genetic Algorithms for optimization

Laboratory: Introduction to Optimization in wireless networks, Background, Optimization problems for networks with infrastructure: Mathematical programming models for third generation wireless network design, Optimization based WLAN modeling and design; Optimization problems in Adhoc networks,

Optimization problems in the operation of Wireless Networks, Optimization of Wireless Broadband Systems.

TEXBOOKS/REFERENCES:

1. S. S. Rao, "Optimization Theory and Applications", Second Edition, New Age International (P) Limited, 1995.
2. Kalyanmoy Deb, "Optimization for Engineering Design Algorithms and Examples", Prentice Hall of India, 2004.
3. Jeff Kennington and Eli Olinick, “Wireless Network Design: Optimization Models and Solution Procedures”, Springer, 2011.
4. Edwin K. P., Chong and Stanislaw H. Zak, "An Introduction to Optimization", Second Edition, Wiley-Interscience Series in Discrete Mathematics and Optimization, 2004.
5. M. AsgharBhatti, "Practical Optimization Methods: With Mathematical Applications", Springer Verlag, 2000.

Course Outcomes:

CO1	Introduce the optimization techniques using both linear and non-linear programming.
CO3	Effective learning of computational procedures to solve optimization problems.
CO4	Frame engineering minima maxima problems in the framework of optimization problems.

21MA705 GRAPH THEORY AND ITS APPLICATIONS IN WIRELESS NETWORKS 2-0-1-3

Graph Theory: An Introduction to Graph theory, Definition and examples, Subgraph, Complements and Graph Isomorphism, Vertex Degree: Euler Trials and Circuits, Planar Graphs, Hamilton Paths and Cycles, Probabilistic graph, Social Graphs, Applications in Social Networks, Graph Coloring and Chromatic Polynomials, Digraph, Dijkstra’s Shortest-Path Algorithm , maximal matching- perfect matching – k-factor graphs.
Tree: Properties of Trees, Distances and centers in a tree, Spanning Tree, Minimal and Maximal spanning tree, The Algorithms of Kruskal and Prim, Transport Network: The Max-Flow Min-cut Theorem, Weighted Trees and Prefix Codes Vertex and Horizontal constrained graphs, Interval, Permutations and Intersection graphs with simple properties.
Algorithms and Applications: Shortest and longest path algorithm, Minimal and Maximal spanning tree algorithms, maximal matching algorithms, Coloring algorithms, Graph Partitioning algorithm.
Research Paper Discussion and Presentation on applied graph theory in wireless networks.

TEXT BOOKS/REFERENCES:

1. Frank Harary, “Graph Theory”, Narosa Publishing house, 2001.
2. Douglas B.West, “Graph Theory”, Second Edition, Pearson Education, 2001.

3. Alan Gibbons, “Algorithmic Graph Theory”, Cambridge University Press, 1985.

Course Outcomes:

CO1	To understand the graph terminologies and its notations
CO2	Analyze the real-time problems using different graph theory algorithms
CO3	Evaluate the reliability of the given network using applications of programming techniques

21WN681 LIVE-IN-LABS I 0-0-0-0

AMRITA University has established live-in-labs at 100+ locations, mostly in rural areas spread across the length and breadth of India. Live-in-Labs© is an opportunity for students to live in a village environment so they can study problems first-hand in water, health, education, etc. and work together to devise solutions. Live-In-Labs will provide an experiential learning opportunity where each student can come and spend for 2 weeks to a semester in one of the live in labs basedon the area. They will become part of the interdisciplinary team of students and faculty drawn from across the disciplines from all participating universities. The live-in- labs have varied focus areas such as energy, water, healthcare, education, waste management, ICT for billion, skill building etc.

During this process the students will share village life and observe and understand problems encompassing health and hygiene, energy, water, waste, environment, etc., touching the villagers’ lives, and define projects that seek to address these problems, devise solutions, implement, test and eventually demonstrate innovative solutions. One definitive achievement is that they will receive a deeper understanding of challenges faced by emerging developing countries. This gives the wonderful opportunity since emerging countries have the largest opportunity for new ideas, innovative solutions etc.

Identify the problem, Proposal Writing -Proposal Format, Budget Estimation, Proposal Drafts,Proposal re-evaluation, Final Proposal Draft. Advanced Human Centered Design

21WN682 LIVE-IN-LABS II 0-0-0-0

Sustainable Approach to Product Designing, Project Management, Planning, Implementing Evaluation of Implementation, Plan with Domain Experts, Design Optimization

21WN781 LIVE-IN-LABS III 0-0-0-0

Prototype Development & Evaluation- Model Building, Training on Relevant Simulation Software, Software Simulation of Prototype Iteration (Incorporating HCD)’ Real Time Prototype Development, Prototype Presentation. Prototype Review. Evaluating Implementation Challenges-Space, Budget, Feasibility, External Factors

21WN782 **LIVE-IN-LABS IV** **0-0-1-1**

Field Implementation, Generating Community Awareness, Research Paper Writing-Structure, Writing Skills, Data Compilation, Deliverables

21WN798 **DISSERTATION- Phase I** **10**

Course Outcomes

CO1	Demonstrate a sound technical knowledge of their selected project topic
CO2	Undertake problem identification, formulation and solution
CO3	Design engineering solutions to complex problems utilizing a system approach
CO4	Learning procurement procedures and activity planning and time management
CO5	Implementation of an engineering project with project outcome
CO6	Communication and interaction with engineers and the community at large
CO7	Demonstrate the knowledge, skills and attitudes of a professional engineer
CO8	Developing skill for literature survey, technical presentation and paper writing for presentation/publication in international conferences/journals (Scopus)

CO – PO Affinity Map

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3
CO1	3	2	2	-	3	3	3	-	3	3	-	-	-
CO2	3	3	3	3	2	2	3	-	-	-	-	-	-
CO3	3	3	3	2	2	-	3	-	-	- -	-	-	-
CO4	3	2	2	2	2	-	-	2	-	2	-	-	-
CO5	3	2	2	-	-	3	-	-	-	2	-	-	-
CO6	3	3	-	-	-	-	-	3	2	-	-	-	-

CO7	3	3	-	-	3	-	-	-	3	-	-	-	-
CO8	3	3	-	-	-	-	-	3		-	-	-	-

3-strong, 2-moderate, 1-weak

21WN799 DISSERTATION- Phase II 16

Course Objective

CO1	Demonstrate a sound technical knowledge of their selected project topic
CO2	Undertake problem identification, formulation and solution
CO3	Design engineering solutions to complex problems utilizing a system approach
CO4	Learning procurement procedures and activity planning and time management
CO5	Implementation of an engineering project with project outcome
CO6	Communication and interaction with engineers and the community at large
CO7	Demonstrate the knowledge, skills and attitudes of a professional engineer
CO8	Developing skill for literature survey, technical presentation and paper writing for presentation/publication in international conferences/journals (Scopus)

CO – PO Affinity Map

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3
CO1	3	2	2	-	3	3	3	-	3	3	-	-	-
CO2	3	3	3	3	2	2	3	-	-	-	-	-	-
CO3	3	3	3	2	2	-	3	-	-	- -	-	-	-
CO4	3	2	2	2	2	-	-	2	-	2	-	-	-
CO5	3	2	2	-	-	3	-	-	-	2	-	-	-
CO6	3	3	-	-	-	2	-	3	2	-	-	-	-

CO7	3	3	-	-	3	-	-	-	3	-	-	-	-
CO8	3	3	-	-	-	-	-	3		-	-	-	-

3-strong, 2-moderate, 1-weak

21WN727 Introduction to Blockchain and Distributed Ledger Technology 2-0-1-3

Module 1 (**Theory**): Introduction to Blockchain technologies, types of blockchain networks (Private, Public & Hybrid), State Machine Design, Overview of Bitcoin, Ethereum, Hyperledger, IOTA DLT. Entities in Blockchain, Consensus Mechanism and algorithms, Smart Contracts, Cryptocurrency, Mining and Ledger. Applications of Blockchain in various verticals such as DeFi, Healthcare, Smart Energy, IoT, Supply chain, NFTs. The future of Blockchain.

Module 2 (**Lab/Hands on**): Smart Contracts basics, Setup Ethereum virtual machines (EVM), Introduction to solidity language and Remix IDE. Developing Smart contracts and deploying on EVM. Hands on applications such as eVoting, Healthcare records, etc.

Module 3 (**Application Development/Term Projec**t): Students choose an area and propose blockchain based applications. Applications are further enhanced and possible PoC deployment.

Prerequisites:

1. Any programming language – Python or JavaScript

Textbooks/References:

1. Bitcoin: A Peer-to-Peer Electronic Cash System - Satoshi Nakamoto - https://bitcoin.org/bitcoin.pdf
2. Blockchain for Dummies – Manav Guptha - Wiley - http://gunkelweb.com/coms465/texts/ibm_blockchain.pdf
3. Blockchain for Beginners – Bryan Ford - https://bford.info/log/2016/1102-cybsec-blockchain.pdf
4. https://github.com/BlockchainBooks/blockchainbooks.github.io

Course Outcomes:

CO1. Students learn basic concepts of blockchain technology.

CO2. Students will understand different types of blockchain network and identify where to use these.
CO3. Students will get an opportunity to develop blockchain technology based solutions in various use cases.
CO4. Students will learn to develop smart contracts and deploy them.

Prerequisites:

1. Any programming language – Python or JavaScript or C
2. Basic knowledge on IoT (Good to have but not mandatory)

Textbooks/References:

1. Bitcoin: A Peer-to-Peer Electronic Cash System – Satoshi Nakamoto – https://bitcoin.org/bitcoin.pdf
2. Blockchain for Dummies – Manav Guptha - Wiley - http://gunkelweb.com/coms465/texts/ibm_blockchain.pdf
3. Blockchain for Beginners – Bryan Ford - https://bford.info/log/2016/1102-cybsec-blockchain.pdf
4. Open source references – https://github.com/BlockchainBooks/blockchainbooks.github.io

CO – PO Affinity Map

PO / CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3	PSO 4	PSO 5	PSO 6	PSO 7
CO 1	3	1	3	2	2	2	1	1	2	2	1	2	2	3	3	1	2	3	3
CO 2	3	1	3	2	2	2	1	1	2	2	1	2	3	3	3	1	2	3	3
CO 3	3	2	3	2	3	2	2	1	2	2	2	2	3	3	3	1	2	3	3
CO 4	3	2	3	2	3	2	1	1	2	2	1	2	3	3	3	1	2	3	3

3-strong, 2-moderate, 1-weak

21WN728 Private Cellular Networks 2-0-1-3

- Private Cellular Networks course has been designed to upskill the students pursuing the PG course in the University towards the future networks or the 5G era. This course aims to provide the students an in-depth understanding of Private LTE/5G networks that are compact, edge cloud-based low-cost energy-efficient sustainable dedicated coverage solutions to cover the wide-ranging use cases including public safety, disaster relief, and local community and industrial networks. The course will include the key private network concepts and enablers, advantages, and challenges. Throughout the course, a strong emphasis on the latest trends in the telecom industry, with a particular focus on Industry 4.0,

spectrum usage for private networks, energy-efficient & sustainable network deployment models, and industry verticals will be lectured. The importance of Time-Sensitive Networking and Zero Touch Network Management that includes Machine Learning (ML) or Artificial Intelligence (AI) techniques will be addressed.

- The course follows a mixed mode of delivery including lectures, the study of research papers/industry white papers, assignments, interactive sessions, quizzes, lab exercises, case studies, and exams.

Course Outcomes (CO)

CO1: Appreciation of the legacy mobile network technologies providing background to the advances in the Wireless technologies

CO2: Understanding the difference between public and Non-Public Networks (NPN or Private Networks)

CO3: Raise the awareness in latest technologies such as 5G, Blockchain, Artificial Intelligence (AI)

CO4: Specialist knowledge in the 4G LTE and 5G private networks. Understanding the key requirements for Private Network deployments for different uses case scenarios

CO5: Prepare with skill set required for focussed R&D at industry or PhD level

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PS01	PSO2	PSO3
CO1	3	3	2	1	2	3	2	1	3	3	3
CO2	3	3	3	1	3	3	1	3	3	3	3
CO3	3	3	3	3	3	3	3	3	3	3	3
CO4	3	3	3	3	3	3	2	3	3	3	3
CO5	3	3	3	3	2	3	3	3	3	3	3