

## 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
<b>Credits</b>						<b>18</b>

\*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
<b>Credits</b>						<b>19</b>

### Third Semester

Course Code	Type	Course	L	T	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
<b>Credits</b>						<b>16</b>

### Fourth Semester

Course Code	Type	Course	L	P	C r
21WN799	P	Dissertation- Phase II			16
21WN782	P	Live-in-Labs-IV	0	0	1
<b>Credits</b>					<b>17</b>

**Total  
Credits      70**

### List of Courses

#### Foundation Core

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

### Subject Core

Course Code	Type	Course	L	P	C r	
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	C r
<b>Elective I</b>						
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
<b>Elective II</b>						
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
<b>Elective III</b>						
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
<b>Elective IV</b>						
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	C r
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
<b>Specialization I: Wireless Communications</b>						
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
<b>Specialization II: Mobile Networks</b>						
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
<b>Specialization III: Wireless Systems and Application</b>						
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



**Unit I**

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)**

<b>18WN601.1</b>	Ability to apply current knowledge and applications of mathematics, science, engineering and technology
<b>18WN601.2</b>	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
<b>18WN601.3</b>	Ability to identify, formulate, analyze and solve technical and engineering problems
<b>18WN601.4</b>	Ability to use the techniques, skills and modern technical tools necessary for technical or engineering practice

### CO – PO Affinity Map

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

<b>CO1</b>	Evaluate the probabilities and conditional probabilities.
<b>CO2</b>	Learn random variables and their probability distributions and apply selected probability distributions to solve problems
<b>CO3</b>	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
<b>CO4</b>	Study Chebychev’s inequality and its applications and approximate the distribution of the sum of random variables using CLT
<b>CO5</b>	Construct point estimators using the method of maximum likelihood.
<b>CO6</b>	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	PO10	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)**

<b>CO1</b>	Understand the concepts of computer networks and its importance in real-world applications.
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<b>CO2</b>	Analyze the data traffic using network analyzer
<b>CO3</b>	Designing of computer networks – LAN, WAN
<b>CO4</b>	Understanding subnetting and IP address allocation
<b>CO5</b>	Network socket programming basics

<b>PO</b>	<b>PO1</b>	<b>PO3</b>	<b>PO5</b>	<b>PO6</b>	<b>PO9</b>	<b>PO10</b>	<b>PO11</b>	<b>PO12</b>	<b>PS01</b>	<b>PS02</b>	<b>PS03</b>
<b>CO</b>											
<b>CO1</b>	3	3	1	3	1	2	-	-			
<b>CO2</b>	3	3	3	3	2	2	1	1			
<b>CO3</b>	3	3	3	3	3	2	1	1			
<b>CO4</b>	3	3	3	3	3	2	1	1			
<b>CO5</b>	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)**

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

PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PS02	PS03
<b>CO1</b>	3	3	3	3	2	1	-	-	-	-	-	1	-	-	-
<b>CO2</b>	3	3	3	3	3	1	-	-	-	-	-	1	-	-	-
<b>CO3</b>	3	2	2	2	1	1	-	-	-	-	-	1	-	-	-
<b>CO4</b>	3	3	3	2	1	1	-	-	-	-	-	1	-	-	-
<b>CO5</b>	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 Selection 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.



<b>C01</b>	3	3	3	3	-	-	-	-	3	3	-	2	-	-	-
<b>C02</b>	3	3	3	3	-	-	-	-	3	3	-	2	-	-	-
<b>C03</b>	3	1	2	2	2	-	-	-	3	3	-	3	-	-	-
<b>C04</b>	3	3	3	3	-	-	-	-	3	3	-	2	-	-	-
<b>C05</b>	3	3	3	3	-	-	-	-	3	3	-	2	-	-	-
<b>C06</b>	3	3	3	3	-	-	-	-	3	3	-	2	-	-	-
<b>C07</b>	3	3	3	3	-	-	-	-	3	3	-	2	-	-	-
<b>C08</b>	3	3	3	3	-	-	-	-	3	3	-	2	-	-	-
<b>C09</b>	3	3	3	3	-	-	-	-	3	3	-	2	-	-	-
<b>C010</b>	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, Pramod Viswanath, “Fundamentals of Wireless Communications”, Cambridge University Press, 2005.
2. Andrea Molisch; “Wireless Communications”, Second Edition, John Wiley & Sons, 2011.
3. T. Rappaport; “Wireless Communications - Principles and Practice”, Second Edition, Prentice Hall, 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)**

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

- Jonathan WValvano, "Embedded Systems: Introduction to ARM® Cortex™-M Microcontrollers", Fourth Edition, CreateSpace Independent Publishing Platform, 2013.
- Joseph Yiu, "The Definitive Guide to ARM® Cortex®-M3 and Cortex®-M4 Processors", Third Edition, Newnes, 2013.
- Martin, "The Designer's Guide to the Cortex-M Processor Family: A Tutorial Approach", First Edition, Newnes, 2009.
- 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
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	Assembly Language
<b>CO2</b>	Design interface circuits to control external devices like over GPIO
<b>CO3</b>	Details of LM3S1968 Internals like PLL, SysTick, Interrupts, and software configuration
<b>CO4</b>	Digitization of Analog inputs using ADC, Audible Analog Signal Generation using DAC
<b>CO5</b>	External LCD Device Hardware Interfacing and Software Device Driver implementation Working prototype Embedded product design, build and test

PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PS02	PS03
<b>CO1</b>	3	2	2	2	2	-	-	-	3	3	-	-	-	-	-
<b>CO2</b>	3	3	3	2	2	-	-	-	3	3	-	-	-	-	-
<b>CO3</b>	3	3	3	2	2	-	-	-	3	3	-	-	-	-	-
<b>CO4</b>	3	3	3	3	2	-	-	-	3	3	-	-	-	-	-
<b>CO5</b>	3	3	3	3	2	-	-	-	3	3	-	-	-	-	-
<b>CO6</b>	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)**

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

**CO – PO Affinity Map**

<b>PO</b>															
<b>CO</b>	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>	<b>PO7</b>	<b>PO8</b>	<b>PO9</b>	<b>PO10</b>	<b>PO11</b>	<b>PO12</b>	<b>PS01</b>	<b>PS02</b>	<b>PS03</b>

<b>CO1</b>	3	3	2	3	1	2	1	1	3	3	2	3	3	3	3
<b>CO2</b>	3	3	3	3	2	2	1	1	3	3	2	3	3	3	3
<b>CO3</b>	3	3	3	3	2	2	1	1	3	3	2	3	3	3	3
<b>CO4</b>	3	3	2	3	3	2	1	2	3	3	2	3	3	3	3
<b>CO5</b>	3	2	3	3	2	2	1	3	3	3	2	3	3	3	3
<b>CO6</b>	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)**

<b>CO1</b>	Familiarisation of research and steps in conducting research
<b>CO2</b>	Understanding the structure of a research paper, how to read and write a research paper, familiarisation with research tools
<b>CO3</b>	Need for literature review, Identify various sources of information for literature review and data collection, Steps to carry out a literature review
<b>CO4</b>	Critical analysis of top rated research papers including at least one survey paper and one or two good journal paper in the broad areas
<b>CO5</b>	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	PO1	PO2	PO3	PO5	PO6	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
<b>CO</b>												
<b>CO1</b>	3	3	3	3	3	1	1	1	1			
<b>CO2</b>	3	3	3	3	3	2	2	2	2			
<b>CO3</b>	3	3	3	3	3	2	2	2	2			
<b>CO4</b>	3	3	3	3	3	2	2	2	2			
<b>CO5</b>	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, XMPP, 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	PS O1	PS O2	PS O3
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 Madiseti, “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, Algorithms and 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)**



<b>18WN701.1</b>	Ability to apply current knowledge and applications of mathematics, science, engineering and technology
<b>18WN701.2</b>	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
<b>18WN701.3</b>	Ability to identify, formulate, analyze and solve technical and engineering problems
<b>18WN701.4</b>	Ability to use the techniques, skills and modern technical tools necessary for technical or engineering practice

### CO – PO Affinity Map

PO	PO1	PO 2	PO 3	PO 4	PO5	PO6	PO7	PO8	PO9
CO									
CO1	3	3	3	3	3	-			
CO2	3	3	2	2	2	-			
CO3	3	3	3	2	2	-			

CO4	3	3	2	2	2	-			
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**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’s Logical 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.**

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

<b>CO3</b>	Analysing trade-offs to be considered while designing a system
<b>CO4</b>	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	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PS02	PS03
CO															
<b>CO1</b>	3	3	3	2	3	2	-	-	-	-	-	1	-	-	-
<b>CO2</b>	3	3	3	3	3	2	-	-	-	-	-	1	-	-	-
<b>CO3</b>	3	3	3	3	1	2	-	-	-	-	-	1	-	-	-
<b>CO4</b>	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 802.11P", First Edition, Pearson Education, 2011.
5. Eldad Perahia 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)

<b>18WN703.1</b>	Ability to design, develop, deploy, troubleshoot and optimize a wireless local area network in the home or enterprise environment
<b>18WN703.2</b>	Thorough in-depth knowledge of the 802.11 Wi-Fi standard and its variants
<b>18WN703.3</b>	Ability to configure, monitor and manage COTS Wi-Fi equipment
<b>18WN703.4</b>	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**

<u>PO</u>	<u>PO 1</u>	<u>PO 2</u>	<u>PO 3</u>	<u>PO 4</u>	<u>PO 5</u>	<u>PO 6</u>	<u>PO 7</u>	<u>PO 8</u>	<u>PS0 1</u>	<u>PS O2</u>	<u>PS O3</u>
<u>CO</u>											
<u>CO1</u>	3	3	3	3	3	3	2	2	-	-	-
<u>CO2</u>	3	3	3	3	3	1	-	-	-	-	-
<u>CO3</u>	3	3	3	3	3	3	1	-	-	-	-
<u>CO4</u>	3	3	3	2	2	3	-	-	-	-	-
<u>CO5</u>	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:**

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

**a.**

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

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





**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)**

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

**CO – PO Affinity Map**

PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PS02	PS03
CO															
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." 2<sup>nd</sup> Edition, 2009.
7. <https://www.deepsig.ai/>

### Course Outcome Statement (CO)

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

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

<b>CO3</b>	Analyze the entropy, mutual information and channel capacity for different kinds of channel
<b>CO4</b>	Apply coding techniques in application perspective

**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, XTRAN 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://telecominfrastructure.com/><https://www.onap.org/>
4. <https://www.onap.org/>
5. <https://www.openstack.org/>
6. <https://www.opnfv.org/>

**Course Outcome Statement (CO)**

<b>CO1</b>	Preliminary understanding of the skills-set needed and the technology backdrop of the digital transformation
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<b>CO2</b>	Develop understanding of information system architectures, software platforms, and Application Programming Interfaces (APIs) as applicable to open source era
<b>CO3</b>	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
<b>CO4</b>	Exposure to develop web-enabled software using open source tools (such as HTML5, JavaScript and modern web frameworks) and methodologies
<b>CO5</b>	Being able to approach and apply advanced frameworks and tools in a real 5G network project
<b>CO6</b>	Help gain performance evaluation expertise and R&D methodologies, appreciation of tool sets required

### CO – PO Affinity Map

PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PS02	PS03
CO															
<b>CO1</b>	3	3	2	3	1	2	1	1	3	3	1	3			
<b>CO2</b>	3	3	3	3	2	2	1	1	3	3	1	3			
<b>CO3</b>	3	3	3	3	2	2	1	1	3	3	1	3			
<b>CO4</b>	3	3	2	3	3	2	1	1	3	3	1	3			
<b>CO5</b>	3	2	3	3	2	2	1	1	3	3	1	3			
<b>CO6</b>	3	3	3	3	2	2	1	1	3	3	1	3			

**3-strong, 2-moderate, 1-weak**

**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)**

<b>18WN710.1</b>	Ability to apply current knowledge and applications of mathematics, science, engineering and technology
<b>18WN710.2</b>	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
<b>18WN710.3</b>	Ability to identify, formulate, analyze and solve technical and engineering problems
<b>18WN710.4</b>	Ability to use the techniques, skills and modern technical tools necessary for technical or engineering practice

### CO – PO Affinity Map

PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PS02	PS03
CO															
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)**

<b>CO1</b>	Identify the advantages and challenges in designing distributed algorithms for different primitives like mutual exclusion, deadlock detection, agreement, etc.
<b>CO2</b>	Differentiate between different types of faults and fault handling techniques in order to implement fault-tolerant systems.
<b>CO3</b>	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.





<b>C01</b>	3	2	2	3	3	2	1	1	3	3	1	3			
<b>C02</b>	3	2	3	3	3	2	1	1	3	3	1	3			
<b>C03</b>	3	3	3	3	3	2	1	1	3	3	1	3			
<b>C04</b>	3	3	2	3	3	2	1	1	3	3	1	3			
<b>C05</b>	3	2	3	3	3	2	1	1	3	3	1	3			
<b>C06</b>	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: PRIVATE Communication 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/>

<b>C01:</b>	Understanding and appreciation of the nature and kind of threats, vulnerabilities and defences in various wireless networks and technologies
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<b>CO2:</b>	Ability to design, analyse and propose threat models for real-world practical systems and applications based on wireless technologies
<b>CO3:</b>	Ability to perform ethical hacking of systems and networks to expose the potential security holes in their design and deployment
<b>CO4:</b>	Familiarity with the cross-layer attack and defence strategies in wireless networks and systems
<b>CO5:</b>	Exposure to the potential security threats in the use of mobile apps and social networks

#### CO-PO AFFINITY MAP

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



<b>CO1</b>	3	3	2	3	1	2	1	1	3	3	1	3			
<b>CO2</b>	3	2	3	3	2	2	1	1	3	3	1	3			
<b>CO3</b>	3	3	3	3	2	2	1	1	3	3	1	3			
<b>CO4</b>	3	3	2	3	3	2	1	1	3	3	1	3			
<b>CO5</b>	3	2	3	3	2	2	1	1	3	3	1	3			
<b>CO6</b>	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)**

<b>CO1</b>	Understand the different features and characteristics of an IoT network
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<b>CO2</b>	Learn about the various MAC protocols used in IoT networks, and how to choose the optimal protocol under different scenarios.
<b>CO3</b>	Learn about the different routing protocols used in IoT networks, and a comparative study of their features
<b>CO4</b>	Understand the need for different node and network management strategies such as Time Synchronization and Localization and learn about some of those recent protocols
<b>CO5</b>	Learn to implement the IoT protocols for any real world application in a chosen IoT platform

### CO – PO Affinity Map

PO	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
<b>CO</b>															
<b>CO1</b>	3	2	3	-	2	-	-	-	-	-	-	-			
<b>CO2</b>	3	3	3	2	2	-	-	-	2	-	-	-			
<b>CO3</b>	3	3	3	2	2	-	-	-	2	-	-	-			
<b>CO4</b>	3	3	3	2	2	-	-	-	2	-	-	-			
<b>CO5</b>	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](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 Calderbank, 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 HuseyinArslan, “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.

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



## CO-PO Affinity Map

PO	PO1	PO2	PO3	PO4	PO5	PO6	PS01	PSO2	PSO3
CO									
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 tree, 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'Reilly Media, 2012.
2. Cathy O'Neil and Rachel Schutt, "Doing Data Science Straight Talk from the Frontline", First Edition, O'Reilly 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	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3
CO															
CO1	3	2	2	3	3	2	1	1	3	3	1	3			

<b>C02</b>	3	3	3	3	2	2	1	1	3	3	1	3			
<b>C03</b>	3	3	3	3	2	2	1	1	3	3	1	3			
<b>C04</b>	3	3	2	3	3	2	1	1	3	3	1	3			
<b>C05</b>	3	2	3	3	2	2	1	1	3	3	1	3			
<b>C06</b>	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**

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

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

**CO – PO Affinity Map**

<b>PO</b>	<b>PO1</b>	<b>PO2</b>	<b>PO3</b>	<b>PO4</b>	<b>PO5</b>	<b>PO6</b>	<b>PO7</b>	<b>PO8</b>	<b>PO9</b>	<b>PO10</b>	<b>PO11</b>	<b>PO12</b>	<b>PS01</b>	<b>PS02</b>	<b>PS03</b>
<b>CO1</b>	3	3	2	3	1	2	1	1	3	3	1	3			
<b>CO2</b>	3	3	3	3	2	2	1	1	3	3	1	3			
<b>CO3</b>	3	3	3	3	2	2	1	1	3	3	1	3			
<b>CO4</b>	3	3	2	3	3	2	1	1	3	3	1	3			
<b>CO5</b>	3	2	3	3	2	2	1	1	3	3	1	3			
<b>CO6</b>	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.

Queueing Models: Characteristics of Queueing Systems, Steady state solution of M/M/1 and M/M/C queueing models with Finite and Infinite Capacities, Stationary behavior of M/G/1. Queueing 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 Queueing Theory”, Third Edition, Wiley & Sons Inc, 2004.
3. J. Medhi, “Stochastic Models in Queueing 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 queueing 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	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS01	PS02	PS03
CO															
CO1	3	2	3	2	3	-	-	-	-	-	-	3	-	-	-

<b>C02</b>	3	2	3	2	3	-	-	-	-	-	-	3	-	-	-
<b>C03</b>	3	2	3	2	3	-	-	-	-	-	-	3	-	-	-
<b>C04</b>	3	3	3	3	2	-	-	-	-	-	-	3	-	-	-
<b>C05</b>	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**

<b>CO1</b>	Understand the basic concepts of signal detection and estimation
<b>CO2</b>	Understand different hypotheses in detection and estimation problems
<b>CO3</b>	Understand the conceptual basics of detection and estimation of signals in white and non-white Gaussian noise
<b>CO4</b>	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.

**TEXTBOOKS/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:**

<b>CO1</b>	Introduce the optimization techniques using both linear and non-linear programming.
<b>CO3</b>	Effective learning of computational procedures to solve optimization problems.
<b>CO4</b>	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:**

<b>CO1</b>	To understand the graph terminologies and its notations
<b>CO2</b>	Analyze the real-time problems using different graph theory algorithms
<b>CO3</b>	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 based on 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	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	PO1	PO2	PO3	PO4	PO5	PO6	PO9	PO10	PO11	PO12	PS01	PSO2	PSO3
CO													
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 Project**): 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](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.
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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](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	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	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PS01	PS02	PS03
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