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 networks. 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 such as landslide detection, environmental monitoring, etc. 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 this 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.

CURRICULUM
First Semester

Course Code	Type	Course	L	T	P	Cr
18WN601	FC	Signal Processing for Wireless Communication	2	0	1	3
18MA614	FC	Probability and Statistical Inference	2	0	1	3
18WN602	FC	Advanced Computer Networks	2	0	1	3
18WN621	SC	Principles of Wireless Communication Systems	3	0	1	4
18WN622	SC	Embedded System Design	3	0	1	4
18WN603	FC	Advanced Computer Programming	0	0	1	1
18HU601	HU	Amrita Values Program*	0	0	0	0
18HU602	HU	Career Competency I*	0	0	0	0
18WN794	P	Live-in-Labs-I	0	0	0	0
					Credits	**18**

*Non-credit Course

Second Semester

Course Code	Type	Course	L	T	P	Cr
18WN604	FC	Design and Analysis of Algorithms	2	0	1	3
18WN623	SC	Design of Wireless Sensor Networks	2	0	1	3
	E	Elective I	2	0	1	3
	E	Elective II	2	0	1	3
18WN624	SC	Mobile Communication Networks	2	0	1	3
18RM602	SC	Research Methodology	0	0	2	2
18WN625	SC	Introduction to IoT Programming	0	0	1	1
18HU603	HU	Career Competency II	0	0	1	1
18WN795	P	Live-in-Labs-II	0	0	0	0
					Credits	**19**

Third Semester

Course Code	Type	Course	L	T	P	Cr
18WN626	SC	Internet of Things: Architecture and System Design	2	0	1	3
	E	Elective III	2	0	1	3
	E	Elective IV	2	0	1	3
18WN798	P	Dissertation				6
18WN796	P	Live-in-Labs-III	0	0	0	0
					Credits	**15**

Fourth Semester

Course Code	Type	Course	L	T	P	Cr
18WN799	P	Dissertation				14
18WN797	P	Live-in-Labs-IV	0	0	1	1
					Credits	**15**

Total Credits 67

List of Courses

Foundation Core

Course Code	Type	Course	L	T	P	Cr
18WN601	FC	Signal Processing for Wireless Communication	2	0	1	3
18MA614	FC	Probability and Statistical Inference	2	0	1	3
18WN602	FC	Advanced Computer Networks	3	0	1	4
18WN603	FC	Advanced Computer Programming	0	0	1	1
18WN604	FC	Design and Analysis of Algorithms	2	0	1	3

Subject Core

Course Code	Type	Course	L	T	P	Cr
18WN621	SC	Principles of Wireless Communication Systems	3	0	1	4
18WN622	SC	Embedded System Design	3	0	1	4
18WN623	SC	Design of Wireless Sensor Networks	2	0	1	3
18WN624	SC	Mobile Communication Networks	2	0	1	3
18RM602	SC	Research Methodology	0	0	2	2
18WN625	SC	Introduction to IoT Programming	0	0	1	1
18WN626	SC	Internet of Things: Architecture and System Design	2	0	1	3

Electives

Course Code	Type	Course	L	T	P	Cr
		Elective I				
18WN701	E	Advanced Signal Processing	2	0	1	3
18WN702	E	Distributed Systems	2	0	1	3
18WN703	E	Wireless Local Area Networks	2	0	1	3
18WN704	E	Advanced Embedded Systems	2	0	1	3

18WN705	E	Antenna Design and Applications	2	0	1	3
18WN706	E	Principles of Virtualization and Software Defined Networking	2	0	1	3
		Elective II				
18WN707	E	Machine Learning	2	0	1	3
18WN708	E	Coding and Information Theory	2	0	1	3
18WN709	E	Open Source Networking	2	0	1	3
18WN710	E	Adaptive Signal Processing	2	0	1	3
18WN711	E	Distributed Network Algorithms	2	0	1	3
18WN712	E	Introduction to Platform Technologies and APIs	2	0	1	3
		Elective III				
18WN713	E	Network and Application Security	2	0	1	3
18WN714	E	5G small Cells	2	0	1	3
18WN715	E	Emerging Wireless Communication Technologies	2	0	1	3
18WN716	E	Big Data and Applications	2	0	1	3
18WN717	E	Introduction to Digital Transformation	2	0	1	3
18WN718	E	Edge and Fog Computing	2	0	1	3
		Elective IV				
18MA704	E	Random Processes and Queueing Models	2	0	1	3
18MA705	E	Linear Algebra and its Applications	2	0	1	3
18WN719	E	Detection and Estimation Theory	2	0	1	3
18MA706	E	Computational Optimization	2	0	1	3
18MA707	E	Graph Theory and its Applications in Wireless Networks	2	0	1	3

Project Work

Course Code	Type	Course	L	T	P	Cr
18WN798	P	Dissertation				6
18WN799	P	Dissertation				14
18WN794	P	Live-in-Labs-I				0
18WN795	P	Live-in-Labs-II				0
18WN796	P	Live-in-Labs-III				0
18WN797	P	Live-in-Labs-IV				1

Specialization

Course Code	Type	Course	L	T	P	Cr
Specialization I: Wireless Communications						
18WN701	E	Advanced Signal Processing	2	0	1	3
18WN708	E	Coding and Information Theory	2	0	1	3
18WN705	E	Antenna Design and Applications	2	0	1	3
18WN714	E	5G small Cells	2	0	1	3
18WN715	E	Emerging Wireless Communication Technologies	2	0	1	3

18WN710	E	Adaptive Signal Processing	2	0	1	3
18MA705	E	Linear Algebra and its Applications	2	0	1	3
18WN719	E	Detection and Estimation Theory	2	0	1	3
18MA706	E	Computational Optimization	2	0	1	3
Specialization II: Mobile Networks						
18WN702	E	Distributed Systems	2	0	1	3
18WN708	E	Coding and Information Theory	2	0	1	3
18WN705	E	Antenna Design and Applications	2	0	1	3
18WN711	E	Distributed Network Algorithms	2	0	1	3
18WN713	E	Network and Application Security	2	0	1	3
18WN714	E	5G small Cells	2	0	1	3
18MA704	E	Random Processes and Queueing Models	2	0	1	3
18MA706	E	Computational Optimization	2	0	1	3
18MA707	E	Graph Theory and its Applications in Wireless Networks	2	0	1	3
Specialization III: Wireless Systems and Application						
18WN702	E	Distributed Systems	2	0	1	3
18WN703	E	Wireless Local Area Networks	2	0	1	3
18WN704	E	Advanced Embedded Systems	2	0	1	3
18WN706	E	Principles of Virtualization and Software Defined Networking	2	0	1	3
18WN707	E	Machine Learning	2	0	1	3
18WN709	E	Open Source Networking	2	0	1	3
18WN711	E	Distributed Network Algorithms	2	0	1	3
18WN716	E	Big Data and Applications	2	0	1	3
18MA704	E	Random Processes and Queueing Models	2	0	1	3
18MA706	E	Computational Optimization	2	0	1	3
18MA707	E	Graph Theory and its Applications in Wireless Networks	2	0	1	3

18WN601 SIGNAL PROCESSING FOR WIRELESS COMMUNICATION 2-0-1-3

Basics of Signals and Systems: Sampling, Reconstruction, Quantization, Discrete-Time Systems.
Signal Representation in Vector spaces: Basis, Linear independence, Norm, Inner products, Parseval's theorem, Fourier, Discrete, Cosine, Splines, Wavelets. Singular Value Decomposition, Weighted Least Squares, Linear Estimation, Power Spectral Analysis.
Digital Filters and Transfer Functions: DFT/FFT Algorithms, FIR Filter Design, Adaptive Filtering.
Advance Signal Processing Applications: Bandpass Sampling, Filtering and Applications, Speech Processing, Digital Audio Effects, Image Processing.
Lab: Implementation using MATLAB/SystemVue.

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).

18MA614 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.

18WN602 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. 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

18WN603 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.

18WN604 DESIGN AND ANALYSIS OF ALGORITHMS 2-0-1-3

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

TEXT BOOKS/REFERENCES:

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

18WN621PRINCIPLES OF WIRELESS COMMUNICATION SYSTEMS 3-0-1-4

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

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

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

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

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

TEXT BOOKS/REFERENCES:

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

18WN622 EMBEDDED SYSTEM DESIGN 3-0-1-4

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

TEXT BOOKS/REFERENCES:

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

18WN623DESIGN OF WIRELESS SENSOR NETWORKS 2-0-1-3

Overview of WSN: Introduction, Applications, Unique Constraints and challenges. Wireless sensor node architecture. Coverage and Connectivity: Efficient set –k cover techniques, integrated coverage

and connectivity. MAC Protocols- Low Duty cycle Protocols: SMAC, STEAM, Contention Based Protocols: CSMA, PAMAS, Scheduling based Protocols: Leach, SMACS, TRAMA.

Networking in WSN: Hierarchical, Non-hierarchical, Clustering, Mutli-hop, Single-hop, Multiple Sinks and Sources. Topology Control and Management: Power control and energy conservation, topology control using transmission power adjustment – Min-MAX algorithm, tree topology control, k-hop connected dominating set, topology control by adaptive node activity.Optimization in WSN: Power, Delay, Bandwidth.

Routing: Design challenges in WSN, Flat Routing: SPIN, Directed Diffusion, Hierarchical routing: LEACH, PEGASIS, TTDD, Location based routing: GEAR, GPSR, QoS based routing: TBP, SPEED. Data Aggregation: Types and Challenges, MFS, TAG.

Time synchronization: Types, RBS, LTS, TPSN. Localization and Positioning: Overview, TOA, TDOA, AOA, RSSI, Range based Localization: Triangulation, Trilateration: Iterative and collaborative Multilateration, GPS based localization; Range free localization: APS, Event Driven Localization: Light House approach, Multi Sequence Positioning.

Security in WSN: Overview, Types and Challenges. Design of Wireless Sensor Network for emerging scenarios. Design analysis of transition from WSN to IoT.

TEXT BOOKS/REFERENCES:

1. Holger Karl and Andreas Willing, “Protocols and Architectures for Wireless Sensor Networks”, John Wiley and Sons, 2005.
2. WaltenegusDargie and Christian Poellabauer, “Fundamentals of Wireless Sensor Networks:Theory and Practice”, First Edition, John Wiley and Sons, 2010.
3. Feng Zhao and Leonidas J. Guibas, “Wireless Sensor Networks”, Morgan Kaufmann, 2004.
4. Anna Hac, “Wireless Sensor Networks Designs”, John Wiley and Sons, 2004.

18WN624 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

18RM602 RESEARCH METHODOLOGY 0-0-2-2

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.

18WN625 INTRODUCTION TO IoT PROGRAMMING 0-0-1-1

Introduction to Internet of Things (IoT), IoT Devices such as Raspberry Pi, Arduino, Waspmote.IoT Devices vs. Computers, Trends in the Adoption of IoT, Societal Benefits of IoT, and Overview of Risks, Privacy, and Security.Interfacing Analog and Digital sensors.Interfacing RF modules.UART Communication.

Introduction to Python programming. Python Programming Environment, Python Expressions, Strings, Functions, Function Arguments, Lists, List Methods, Control Flow. Basic Object Oriented Programming concepts.

TEXT BOOKS/REFERENCES:

1. ArsheepBahga, Vijay Madisetti, “internet of Things: A Hands-On Approach”, Universities Press
2. Mark Lutz, “Learning Python: Powerful Object-Oriented Programming: 5th Edition”, O’REILLY, 2013
3. Simon Monk, “Programming Arduino – Getting started with Sketches”, McGraw Hill, 2012.
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

18WN626INTERNET OF THINGS: ARCHITECTURE AND SYSTEM DESIGN2-0-1-3

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 IoTScenarios 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. IoT Protocol Stack. Physical Layer and Datalink Layer: IEEE 802.15.4, Bluetooth/Bluetooth LE, RFID/NFC, IEEE 802.11, GSM/LTE. Standardized LPWA (EC-GSM-IoT, NB-IoT), Non-standard LPWA (LoRaWAN, Sigfox).

Network Layer: IPv6, 6LoWPAN, RPL, IPSec

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

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

Introduction to Security Mechanisms and Technologies for Constrained IoT Devices extending to block chain based security.Cloudification of IoT concepts covering architecture, deployment models, and foundational technology enablers including XML, SoA/ web services, networking protocols, GPS and GIS.
Laboratory Exercises:Prototype design of IoT Systems for a specific application: Network protocols, Transport protocols, Application protocols, security protocols.

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

18WN701 ADVANCED SIGNAL PROCESSING2-0-1-3

Signal Representations in Vector Spaces, Least Square and Minimum Norm Solutions, Inverse and Pseudo Inverse, Symmetry Transformations, Eigenvectors and Eigenvalues. 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. Power Spectral Estimation, Periodogram, Non-Parametric Power Spectrum Estimation Methods, Advanced Signal Processing and Image Processing Applications.

TEXT BOOKS/REFERENCES:

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

18WN702 DISTRIBUTED SYSTEMS 2-0-1-3

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

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

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

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

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

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

TEXT BOOKS/REFERENCES:

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

18WN703 WIRELESS LOCAL AREA NETWORKS 2-0-1-3

Introduction to WLAN terminology and overview of WLAN : Wireless Challenges, IEEE Standards, IEEE 802 family, 802.11 LANs, AP, BSS, IBSS, ESS, DS,SSID, BSSID, Mobility, Security, 802.11 MAC: CSMA/CA, Hidden & Exposed Node Problems, MAC Access Modes, NAV, Interframe Spacing, Fragmentation, MAC Frames - 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, Hardware Overview: Network Interface card, Access point hardware,
chipsets, 802.11 a/b/g PHY - Physical-Layer, Architecture, The Radio Link, FHSS, DSSS, OFDM, QAM, ERP; 802.11n : MIMO, Beam Forming, Channel Bonding, Block ACK, 802.11e QoS / WMM, 802.11s Mesh network, 802.11ac, 802.11ad, Performance Analysis, Mathematical Modeling and Analysis.
Cryptography – Concepts : PRF/PRP, Stream / Block Cyphers, RC4, 3DES, AES, Hashing, Asymmetric key pairs, Certificates, WLAN Security : WEP, TKIP, AES-CCMP, RADIUS, TLS, TLS over EAP, Kerberos, LEAP, PEAP, EAP-SIM, Network & Security Architecture, Network Planning & Analysis.
Advanced Topics: Long Range Wi-Fi, Li-Fi, Passive Wi-Fi, 802.11ah (HaLow), 802.11af (White-Fi),802.11ax, 802.11ay
Lab: WLAN Lab based on the above topics will be conducted using Wireless routers, APs, Wi-Fi enabled smart phones, tablets and laptops and Long Range Wi-Fi base stations and CPEs as well as using QualNet simulation platform.

TEXT BOOKS/REFERENCES:

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

18WN704 ADVANCED EMBEDDED SYSTEMS 2-0-1-3

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

TEXBOOKS/REFERENCES:

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

18WN705 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,Microstripantennas, Yagi-Uda Antenna, LPDA, metamaterial antennas, Reflector Antennas, Horn antennas.

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

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

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

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

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

Lab:

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

TEXT BOOKS/REFERENCES:

1. John L. Volakis, “Antenna Engineering Handbook”, Fourth Edition, McGraw-Hill Professional, 2009.
2. Constantine A. Balanis , “Antenna Theory: Analysis and Design”, Third Edition, WileyInterscience, 2005.
3. Rylander, Thomas, PärIngelström, and Anders Bondeson. “Computational electromagnetics”,. Springer Science & Business Media, 2012.
4. Xiao, Shao-Qiu, and Ming-Tuo Zhou, eds. “Millimeter wave technology in wireless PAN, LAN, and MAN”. CRC Press, 2008.

18WN706PRINCIPLES 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

18WN707 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.

TEXT BOOKS/ REFERENCES:

1. Tom. Mitchell, “Machine Learning", McGraw Hill, 1997.
2. E. Alpaydin, “Introduction to Machine Learning", Prentice Hall of India, 2005.
   Nils J. Nilsson, "Introduction to Machine Learning", http://ai.stanford.edu/~nilsson, 1996.
3. Kevin P. Murphey, “Machine Learning, a Probabilistic Perspective”, MIT press, Cambridge, Massachusetts, 2012.
4. Chris Baton et al., “Understanding Big Data”, McGraw Hill, 2012.
5. Christopher Bishop, “Pattern Recognition and Machine Learning”, Springer.

6. Hastie, T., Tibshirani, R, Friedman, J, “Elements of Statistical Learning: Data Mining, Inference, and Prediction.”2nd Edition, 2009.

18WN708 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, iterativereceivers 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.

18WN709 OPEN SOURCE NETWORKING 2-0-1-3

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

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

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

TEXT BOOKS/REFERENCES:

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

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

6. https://www.opnfv.org/

18WN710 ADAPTIVE SIGNAL PROCESSING 2-0-1-3

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

18WN711 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.

18WN712INTRODUCTION TO PLATFORM TECHNOLOGIES AND APIS 2-0-1-3

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

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

Introduction to the requirements of APIs, using APIs and End-to-End view of API - Insights into simplified API process and Technology behind APIs and Restful APIs - Introduction to OAuth 2 -

Introductory concepts of APIs in the Network Transformation with OpenStack APIs for VM principles - APIs in Software-Defined Networking - API Examples including Data center, Wireless networks and API platform.

Introduction to 'R' programming language.

TEXT BOOKS/REFERENCES:

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

18WN713 NETWORK AND APPLICATION SECURITY 2-0-1-3

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

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

TEXT BOOKS/REFERENCES:

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

18WN714 5G SMALL CELLS 2-0-1-3

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

Introduction to LTE-Advanced and LTE-Advanced Pro features and evolution to 5G - Network Architecture including NG-RAN architecture - Next Generation Core and Interworking with 4G - 5G Service and performance requirements and supporting technologies covering NFV and SDN in 5G - Network slicing in 5G and Mobile Edge Computing (MEC)- Cloud RAN, Open RAN and 5G NGRAN- Cloud-C-RAN interworking with NFV and SDN- C-RAN interworking with SDN RAN variations including Open RAN interfaces - Cloud RAN architecture and NG-RAN: CU and DU - Fronthaul and backhaul topics including CPRI overview, CPRI for 5G and Distance requirements – 5G NR

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

TEXT BOOKS/REFERENCES:

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

18WN715EMERGING WIRELESS COMMUNICATION TECHNOLOGIES 2-0-1-3

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

MIMO: Introduction to Wireless Point to point MIMO system Model - Capacity, SISO AWGN model- Performance; SISO Fading Channel Model- Performance; Outage 18 capacity, ergodic capacity; Capacity analysis of - Single user MIMO System with Full CSIT, Partial CSIT and Long term CSIT; Capacity Analysis of MIMO Fading Channel with long term and Short term channel Knowledge; Space-time Block Coded MIMO System, STTD, Alamouti Coding, Dominant mode Beamforming, ML, V-BLAST, D-BLAST- Performance analysis. Algorithms for MIMO.Spectral efficiency, link budget, coverage gain with MIMO.Limitations and implementation issues.

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

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

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

TEXT BOOKS/REFERENCES:

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

18WN716 BIG DATA AND APPLICATIONS 2-0-1-3

Introduction: Large databases and their evolution, Introduction to Data Science - Why Big Data? - Problems solved by Data Science - Data Science Process - Exploratory Data Analytics. Data Preparation: data munging - scraping - sampling - cleaning. Exploring and Analysis of Data - descriptive and inferential statistics, sampling, experimental design, parametric and non-parametric tests of difference, ordinary least squares regression, and general linear models; Data storage and management in order to be able to access data - especially big data - quickly and reliably during subsequent analysis - storage, search and retrieval systems for large scale structured and unstructured information systems.

Data Analytics - Theory and Methods - Supervised learning, Linear/Logistic Regression, Decision tress, Naïve Bayes, Unsupervised learning - K-means clustering - Association rules - Unstructured Data Analytics - Technologies and tools - Text mining - Web mining. Data Communication with Information Visualization - Effective Information Visualization - Visual Encoding - Perception of Visual Cues - Data Scales - Visualizing Time Series Data - Visualizing through stories and interpretable summaries.

TEXT BOOKS/ REFERENCES:

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

18WN717INTRODUCTION 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.

18WN718EDGE AND FOG COMPUTING2-0-1-3

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.

18MA704 RANDOM PROCESSES AND QUEUEING MODELS 2-0-1-3

Random Processes: Introduction, Classification of random processes, Poisson Process, renewal processes, Markov Process, Markov Chains, Transition Probabilities, classification of states of Markov

chains, Chapman-Kolmogorov Equations, steady state probabilities, continuous time Markov chains and birth and death processes and analysis of time series.Introduction to Regeneration process.
Queuing Models: Characteristics of Queuing Systems, Steady state solution of M/M/1 and M/M/C queuing models with Finite and Infinite Capacities, Stationary behavior of M/G/1. Queuing networks, G/G/1.

TEXT BOOKS/REFERENCES:

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

18MA705 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.

18WN719 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.

18MA706 COMPUTATIONAL OPTIMIZATION 2-0-1-3

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

Quadratic optimization, Generalized inequality constraints, Integer programming, Combinatorial optimization, Dynamic programming, Genetic Algorithms for optimization
Laboratory: Introduction to Optimization in wireless networks, Background, Optimization problems for networks with infrastructure: Mathematical programming models for third generation wireless network design, Optimization based WLAN modeling and design; Optimization problems in Adhoc networks, Optimization problems in the operation of Wireless Networks, Optimization of Wireless Broadband Systems.

TEXBOOKS/REFERENCES:

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

18MA707GRAPH 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.

18WN794 LIVE-IN-LABS I 0-0-0-0

AMRITA University has established live-in-labs at 100+ locations, mostly in rural areas spread across the length and breadth of India. Live-in-Labs© is an opportunity for students to live in a village environment so they can study problems first-hand in water, health, education, etc. and work together to devise solutions. Live-In-Labs will provide an experiential learning opportunity where each student can come and spend for 2 weeks to a semester in one of the live in labs basedon the area. They will

become part of the interdisciplinary team of students and faculty drawn from across the disciplines from all participating universities. The live-in- labs have varied focus areas such as energy, water, healthcare, education, waste management, ICT for billion, skill building etc.

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

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

18WN795 **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

18WN796 **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

18WN797 **LIVE-IN-LABS IV** **0-0-1-1**

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