M-TECH – WIRELESS NETWORKS AND APPLICATIONS

Amrita Centre for 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, signal processing, multimedia systems 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, 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
16WN601	FC	Basics of Digital Signal Processing	2	0	1	3
16MA622	FC	Probability and Statistical Inference	2	0	1	3
16WN602	FC	Advanced Computer Networks	3	0	1	4
16WN621	SC	Fundamentals of Wireless Communications	3	0	1	4
16WN622	SC	Embedded System Design	3	0	1	4
16WN603	FC	Advanced Computer Programming	0	0	1	1
16HU601	HU	Cultural Education*	0	0	0	0
16WN794	P	Live-in-Labs-I	0	0	0	0
					Credits	**19**

*Non-credit Course

Second Semester

Course Code	Type	Course	L	T	P	Cr
16WN604	FC	Design and Analysis of Algorithms	3	0	1	4
16WN623	SC	Wireless Sensor Networks	3	0	1	4
	E	Elective I	3	0	0	3
	E	Elective II	2	0	1	3
16WN624	SC	Mobile Communication Networks	2	0	1	3
16WN625	SC	Research Learning and Problem Formulation	0	0	1	1
16EN600	HU	Technical Writing*	0	0	0	0

16WN795	P	Live-in-Labs-II	0	0	0	0
					Credits	**18**

*Non-credit Course

Third Semester

Course Code	Type	Course	L	T	P	Cr
16WN605	FC	Object Oriented Programming	0	0	1	1
	E	Elective III	2	0	1	3
	E	Elective IV	2	0	1	3
16WN798	P	Dissertation				6
16WN796	P	Live-in-Labs-III	0	0	0	0
					Credits	**13**

Fourth Semester

Course Code	Type	Course	L	T	P	Cr
16WN799	P	Dissertation				16
16WN797	P	Live-in-Labs-IV	0	0	1	1
					Credits	**17**

Total Credits 67

List of Courses

Foundation Core

Course Code	Type	Course	L	T	P	Cr
16WN601	FC	Basics of Digital Signal Processing	2	0	1	3
16MA622	FC	Probability and Statistical Inference	2	0	1	3
16WN602	FC	Advanced Computer Networks	3	0	1	4
16WN603	FC	Advanced Computer Programming	0	0	1	1
16WN604	FC	Design and Analysis of Algorithms	3	0	1	4
16WN605	FC	Object Oriented Programming	0	0	1	1

Subject Core

Course Code	Type	Course	L	T	P	Cr
16WN621	SC	Fundamentals of Wireless Communications	3	0	1	4
16WN622	SC	Embedded System Design	3	0	1	4
16WN623	SC	Wireless Sensor Networks	3	0	1	4
16WN624	SC	Mobile Communication Networks	2	0	1	3
16WN625	SC	Research Learning and Problem Formulation	0	0	1	1

Electives

Course Code	Type	Course	L	T	P	Cr
		Elective I				
16WN701	E	Advanced Signal Processing	3	0	0	3
16WN702	E	Distributed Systems	3	0	0	3
16WN703	E	Wireless Local Area Networks	2	0	1	3
16WN704	E	Advanced Embedded Systems	2	0	1	3
16WN705	E	Mobile Computing and Networking	2	0	1	3
		Elective II				
16WN706	E	Smart Sensor Technology	2	0	1	3
16WN707	E	Machine Learning	2	0	1	3
16WN708	E	Coding and Information Theory	3	0	0	3
16WN709	E	Wireless Multimedia Networks	2	0	1	3
16WN710	E	Antenna Engineering: Theory & Design	2	0	1	3
16WN711	E	Distributed Network Algorithms	2	0	1	3
		Elective III				
16WN712	E	Security in Wireless Networks	2	0	1	3
16WN713	E	4G Mobile Broadband and Small Cell Networks	2	0	1	3
16WN714	E	Advanced Wireless Communication Technologies	2	0	1	3
16WN715	E	Big Data and Applications	3	0	0	3
16WN716	E	Adaptive Signal Processing	2	0	1	3
16WN717	E	Cloud Computing and Internet of Things	2	0	1	3
		Elective IV				
16MA704	E	Random Processes and Queuing Models	3	0	0	3
16MA705	E	Linear Algebra and its Applications	2	0	1	3
16WN718	E	Detection and Estimation Theory	2	0	1	3
16MA706	E	Computational Optimization	2	0	1	3
16MA707	E	Graph Theory and its Applications in Wireless Networks	2	0	1	3

Project Work

Course Code	Type	Course	L	T	P	Cr
16WN798	P	Dissertation				6
16WN799	P	Dissertation				16
16WN794	P	Live-in-Labs-I				0
16WN795	P	Live-in-Labs-II				0
16WN796	P	Live-in-Labs-III				0
16WN797	P	Live-in-Labs-IV				1

Specialization

Course Code	Type	Course	L	T	P	Cr
Specialization I: Wireless Communications						
16WN701	E	Advanced Signal Processing	3	0	0	3
16WN708	E	Coding and Information Theory	3	0	0	3
16WN710	E	Antenna Engineering: Theory & Design	2	0	1	3
16WN713	E	4G Mobile Broadband and Small Cell Networks	2	0	1	3
16WN714	E	Advanced Wireless Communication Technologies	2	0	1	3
16WN716	E	Adaptive Signal Processing	2	0	1	3
16MA705	E	Linear Algebra and its Applications	2	0	1	3
16WN718	E	Detection and Estimation Theory	2	0	1	3
16MA706	E	Computational Optimization	2	0	1	3
Specialization II: Mobile Networks						
16WN702	E	Distributed Systems	3	0	0	3
16WN708	E	Coding and Information Theory	3	0	0	3
16WN710	E	Antenna Engineering: Theory & Design	2	0	1	3
16WN711	E	Distributed Network Algorithms	2	0	1	3
16WN712	E	Security in Wireless Networks	2	0	1	3
16WN713	E	4G Mobile Broadband and Small Cell Networks	2	0	1	3
16WN717	E	Cloud Computing and Internet of Things	2	0	1	3
16MA704	E	Random Processes and Queuing Models	3	0	0	3
16MA706	E	Computational Optimization	2	0	1	3
16MA707	E	Graph Theory and its Applications in Wireless Networks	2	0	1	3
Specialization III: Wireless Systems and Application						
16WN702	E	Distributed Systems	3	0	0	3
16WN703	E	Wireless Local Area Networks	2	0	1	3
16WN704	E	Advanced Embedded Systems	2	0	1	3
16WN705	E	Mobile Computing and Networking	2	0	1	3
16WN706	E	Smart Sensor Technology	2	0	1	3
16WN707	E	Machine Learning	2	0	1	3
16WN709	E	Wireless Multimedia Networks	2	0	1	3
16WN711	E	Distributed Network Algorithms	2	0	1	3
16WN712	E	Security in Wireless Networks	2	0	1	3
16WN715	E	Big Data and Applications	3	0	0	3
16MA704	E	Random Processes and Queuing Models	3	0	0	3
16MA706	E	Computational Optimization	2	0	1	3
16MA707	E	Graph Theory and its Applications in Wireless Networks	2	0	1	3

16WN601 BASICS OF DIGITAL SIGNAL PROCESSING 2-0-1-3

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— 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 — 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:Implementation using MATLAB.

TEXT BOOKS/REFERENCES:

1. Sophocles J. Orfanidis, "Introduction to Signal Processing", US Edition, Prentice Hall, 1995.
2. John G.Proakis and Dimitus G.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 and Sons, 1999.

16MA622 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; Point estimation of Parameters and Sampling distributions: Central limit theorem, 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.

16WN602 ADVANCED COMPUTER NETWORKS 3-0-1-4

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, NFV for 5G.
Lab: Implementation of algorithms from the WN604 Advanced 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.

16WN603 ADVANCED COMPUTER PROGRAMMING 0-0-1-1

Programming in C, Basic Computer Organization and Architecture, Build and Compilation process, Debugging con…llllll////cepts, 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.

16WN604 DESIGN AND ANALYSIS OF ALGORITHMS 3-0-1-4

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, i.e., 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.

16WN605 OBJECT ORIENTED PROGRAMMING 0-0-1-1

Java Atomic Data Types and Operators, Reference types, Date and time types, Enumerations, Selection statements (If else, switch), Iterations(while, for), Working with Arrays, Objects and Classes, Access modifiers and methods, Constructors, Inheritance and Polymorphism, Interfaces, Anonymous interfaces, Java Generics, Generic Collections (Lists, Sets, Maps), Exceptions, Java IO library (java.nio), Functional programming with Java 8 lambdas, Java 8 Streams, Multithreading in Java, Design patterns in Java (Singleton, Factory, Builder), UML Diagrams (Object, Activity, DataFlow), Agile methodologies, Test driven development, Unit testing in Java with JUnit and Netbeans

TEXT BOOKS/REFERENCES:

1. Naughton P and Schildt H, “Java 2 Complete Reference”, Fifth Edition, Tata McGraw-Hill, 2002.
2. Bloch J., “Effective Java”, Second Edition, Prentice Hall, 2008.
3. Eckel B, “Thinking in Java”, Fourth Edition, Prentice Hall, 2006.

16WN621 FUNDAMENTALS OF WIRELESS COMMUNICATIONS 3-0-1-4

Overview of Wireless Communications: Introduction to Wireless Communication Systems; Evolution of Modern Wireless Communication Systems; Overview of Modern Wireless Communication Systems.
Transmission Fundamentals: Signals, Types and Properties of Signals, Frequency bands and its properties, Noise and Interference.
Modulation: AM Techniques, DM Techniques: An Overview, Linear and constant envelope Modulation Techniques and its combination, Spread Spectrum Modulation Techniques: DSSS and FHSS.
Antennas: Introduction to Antennas, Integration of antennas into systems, characteristic antenna quantities, Types of antennas: Antennas for mobile station, Antennas for base station.
Introduction to Radio Wave Propagation, Types of propagation modes; Free Space Propagation Model, Propagation Mechanisms: Reflection, Diffraction, 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 time-varying system, Baseband equivalent model, A discrete-time baseband model, Additive white noise, Time and frequency coherence: Doppler spread and coherence time, Delay spread and coherence bandwidth,Statistical channel models: Modeling philosophy, Rayleigh and Rician fading; Capacity of Wireless Channel: AWGN channel capacity, Resources of AWGN channel, Linear time-invariant Gaussian channels, Capacity of fading channels, Multiplexing: FDM, OFDM, TDM.
Cellular Networks: Basic Concepts, Multiple Access Techniques: FDMA, TDMA, CDMA, OFDMA and SDMA; Wireless Link Improvement: Introduction to types of codes, Equalization Techniques, Diversity methods.
Research Paper Discussion and Presentation.
Wireless Communication Laboratory: Conduct experiments using Labview, C and Matlab.

TEXT BOOKS/REFERENCES:

1. David Tse, PramodViswanath, "Fundamentals of Wireless Communications", Cambridge University Press, 2005.
2. T. Rappaport; "Wireless Communications - Principles and Practice", Second Edition,Prentice Hall, 2011.
3. Andrea Molisch; "Wireless Communications", Second Edition, John Wiley & Sons, 2011.
4. Simon Haykin and Michael Moher; "Modern Wireless Communications", Pearson Education, 2005.

16WN622 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; 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.

16WN623 WIRELESS SENSOR NETWORKS 3-0-1-4

Overview of WSN: Introduction, Applications, Unique Constraints and challenges. Platforms for WSN: Sensor Node Hardwares (Introduction): Mica2, MicaZ, TelosB, Cricket, i-Mote2, TMote, BTnode, Wasp mote, Comparisons of these based on the specifications. Sensor Node Softwares (Introduction): TinyOS, MANTIS, Contiki and RetOS, Programming Tools: C, nesC. Tiny DB.
General Architecture of a WSN: Von Neumann, Harvard Architecture, Super Harvard Architectures, Sensing Unit: ADC, Sampling, Quantization, Sensor Characteristics, Transducers, Impedance Matching. Processing Unit: Microcontrollers, DSP, ASIC, FPGA, General Constraints and Pros and Cons. Communication Unit: SPI, I2C. Power Management Unit.
Networking in WSN: Hierarchical, Nonhierarchical, Clustering, Mutli hop, Single hop, Multiple Sinks and Sources. Coverage and Connectivity. Self-Organization, Self-configuration. MAC Protocols- Introduction, Low Duty cycle Protocols: SMAC, Contention Based Protocols: CSMA, PAMAS, Scheduling based Protocols: Leach, SMACS, TRAMA.
Optimization in WSN: Power, Delay, QOS, Data Aggregation; Time synchronization: Types, RBS, LTS, HRTS; Routing: Proactive routing: DSDV, Optimized Link State Routing, DSR and Reactive routing: Flooding, Gossiping, Hierarchical Routing, Location based routing – Unicast, Multicast; Localization and Positioning: Overview, TOA, TDOA, AOA, RSSI, Range based Localization: Triangulation, TrilaterationIterative and collaborative Multilateration, GPS based localization; Range free localization: APS, Event Driven Localization: Light House approach, Multi Sequence Positioning; Wireless Sensor Network for Specific Application.
Research Paper Discussion and Presentation.
Laboratory**:**includes the OSs /platforms/Simulators detailed below.

- TinyOS Libraries: http://www.tinyos.net/scoop/special/working_groups
- Omnet++: http://www.omnetpp.org/pmwiki/index.php?n=Main.NesCT
- Comparison of OS: MANTIS - http://rosejn.net/publications/mantis-monet.pdf
- NS2, NS3
- Qualnet

Creating hierarchical network, Implementation of Data aggregation, clustering and Time synchronization Algorithms, Indoor and outdoor testing of algorithms to study the effects on range, delay and data loss at different power levels, Integration of Sensor networks with Wireless LAN.

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 Practise”, 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.

16WN624 MOBILE COMMUNICATION NETWORKS 2-0-1-3

Overview of the legacy second generation (2G) and third generation 3G networks including key developments in spectrum aspects. Review of the stake holders including Service Providers (SPs), product manufactures and regulatory bodies and interplay and context for MCN. Architecture of 4G networks from 3GPP and introduction to the physical layer and resource management. Key elements underpinning the network architecture including access stratum and non-access stratum, end to end security principles, network and UE procedures. Network design framework for call set-up/release, mobility management in idle mode and active mode (handover) and the dependency on the user experience. Introduction to network operations, management and support (BSS/OSS) including relevant use cases in diagnostics, life cycle of trouble shooting. Role of network planning and performance management and deployment of the networks for Quality of Support (QoS) and Quality of Experience (QoE). Network evolution towards Evolved Packet Core (EPC), Mobile Edge Computing (MEC)focus on architecture changes plus impactassessment. Overview of air interface upgrades, scalable air interface, Self Organising Networks (SON) and Heterogeneous Networks (HetNets). Wifi technology evolution to upcoming concepts pertaining to LTE in WiFi and introduction to candidate proposals in 5G [5].

TEXT BOOKS/REFERENCES:

1. Moray Rumney., “Design and Measurement Challenges, Second Edition”, John Wiley & Sons , 2008
2. Pierre Lescuyer and Thierry Lucidarme, “Evolved Packet System (EPS); The LTE and SAE evolution of 3G UMTS”, John Wiley & Sons , 2008
3. Ajay R Mishra, “Advanced Cellular Network Planning and Optimisation2G/2.5G/3G. . .EVOLUTION TO 4G”, John Wiley & Sons , 2007
4. Ralf Kreher, KarstenGaenger, “LTE Signaling: Troubleshooting and Optimization”, John Wiley & Sons , second edition 2016
5. Information from IEEE papers and various standardization bodies including IETF, ETSI, 3GPP, WiFi alliance and 5GPPP.

16WN625 RESEARCHLEARNING AND PROBLEM FORMULATION 0-0-1-1

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, Context Aware Systems, Participatory Sensing, Embedded Systems etc. Formulation and presentation of research proposals on selected topics.

16WN701 ADVANCED SIGNAL PROCESSING 3-0-0-3

Discrete-Time Bases and Filter Banks, Continuous-Time Bases and Wavelets, Over complete Expansions and Continuous Transforms, Sparse representation, Linear and non-linear approximation in various bases, Non-linear signal estimation, Multidimensional filter banks and wavelets, Multifractal analysis using Wavelets, Multiscale geometric representation

andprocessing, Compressed sensing, Multidimensional Transforms, Synthetic-aperture radar (SAR) Technology.

TEXT BOOKS/REFERENCES:

1. MartinVetterli, Jelena Kovacevic and Vivek K Goyal, "The World of Fourier and Wavelets: Theory, Algorithms and Application", manuscript. http://FourierAndWavelets.org
2. Gilbert Strang and Truong Nguyen, "Wavelets and Filter Banks", Wellesley-Cambridge Press, 1996.
3. James S. Walker, "A Primer on Wavelets and Their Scientific Applications", Chapman & Hall, 1999.
4. Yonina C. Eldar and Gitta Kutyniok, "Compressed Sensing: Theory and Applications", Cambridge University Press, 2012.
5. Jean-Luc Starck, FionnMurtagh and Jalal M. Fadili, "Sparse Image and Signal Processing: Wavelets, Curvelets, Morphological Diversity", Cambridge University Press, 2010.

16WN702 DISTRIBUTED SYSTEMS 3-0-0-3

Introduction: Goals, Types: Distributed Computing Systems, Distributed Information Systems, Distributed Pervasive Systems. Architecture: Centralized, Decentralized, Hybrid, Architecture Vs Middleware, Self-Management. Processes: Threads, Virtualization, Clients, Servers, Code Migration.

Communication: Fundamentals, Remote Procedure Call, Message Oriented Communication, Stream Oriented Communication, Multicast Communication, Naming: Flat, Structured, Attribute based; Synchronization: Clock, Logical, 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.

Security: Secure Channels, Access Control, Security Management, Distributed Object based systems, Distributed File Systems, Distributed Web based Systems.

TEXT BOOKS/REFERENCES:

1. Andrew Tanenbaum, Maarten van Steen, "Distributed Systems, Principles and Paradigms." Prentice-Hall, 2007.
2. George Coulouris, Jean Dollimore and Tim Kindberg, "Distributed Systems: Concepts and Design", Second Edition, Addison Wesley, 1994.
3. Barry Wilkinson and Michael Allen, "Parallel Programming Techniques and Applications Using Networked Workstations and Parallel Computers", Prentice Hall, 1999.

16WN703 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.

16WN704 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.

16WN705 MOBILE COMPUTING AND NETWORKING 2-0-1-3

Short range networks: Introduction, Fundamentals of short range wireless; Bluetooth – Introduction to Bluetooth, Bluetooth Technology, Bluetooth Topology, Bluetooth Networking, Connection Establishment, Bluetooth 3.0, RFID Technology, NFC - Evolution of NFC, NFC as a New Technology, NFC Essentials, Smart NFC Devices, General Architecture of NFC Enabled Mobile Phones, NFC Operating Modes, Wireless Communication as a Communication Media for NFC Technology; M2M - Machine to Machine Architecture and Protocols; Performance Analysis.
Mobile OS: Android, iOS; Software Systems; Smartphone architecture and Software development.

TEXT BOOKS/ REFERENCES:

1. Nick Hunn, "Essentials of Short-Range Wireless", Cambridge University Press, 2010.
2. Nathan J.Muller, "Bluetooth Demystified", First Edition, Tata McGraw-Hill Education, 2001.
3. Vedat Coskun, Kerem Ok and Busra Ozdenizci, "Near Field Communication (NFC): From Theory to Practice", John Wiley & Sons, 2011.
4. Greg Milette, Adam Stroud, "Professional Android Sensor Programming", Wrox Publishers, First Edition, 2012.
5. VedatCoskun, Kerem Ok and BusraOzdenizci, "Professional NFC Application Development for Android", John Wiley & Sons, 2013.

16WN706 SMART SENSOR TECHNOLOGY 2-0-1-3

General concepts and terminology of measurement systems, transducer classification - Variable resistance transducers, Inductive transducers, capacitive transducers, general input-output configuration, static and dynamic characteristics of a measurement system, Statistical analysis of measurement data. Standards and Calibration.
Smart materials and systems: Piezoelectric materials, Shape-memory materials, Electro-Rheological (ER) fluids, Magneto-Rheological (MR) fluids.
MEMS: Introduction, emergence, devices and application, scaling issues, materials for MEMS, Thin film deposition, lithography and etching.Bulk micro machining, surface micro machining and LIGA process.MEMS devices, Engineering Mechanics for Micro System Design, Design of Micro Pressure Sensor.
Introductionto Nanotechnology, Nano sensors, Molecular Nanotechnology, CNT Types, synthesis and applications.
Introduction to Sensor networks: Advances in WSN-MEMS-Micro sensor, RF-MEMS-Micro radios.

TEXT BOOKS/ REFERENCES:

1. John P. Bentley, "Principles of Measurement Systems", Third Edition, Pearson Education, 2000.
2. Mukesh V Gandhi and Brian S Thompson, "Smart Materials and Structures", Kluwer Academic Publishers, 1992.
3. Tai Ran Hsu, "MEMS & Microsystem Design and Manufacture", Tata McGraw Hill, New Delhi 2002.
4. Michael Wilson, Kamali Kannangara, Geoff Smith, Michelk Simon, "Nanotechnology: Basic Science and Emerging Technologies", 2002.

5. C.S.Ragavendra, Krishna M.Sivalingam and Taieb F.Znati, “Wireless Sensor Networks”, Springer, ISBN: 1402078838, 2006.
6. Doebelin E.O, “Measurement Systems: Application and Design”, Fourth Edition, McGraw Hill, New York, 2003.
7. Marc Madou, “Fundamentals of Micro Fabrication”, CRC Press, 1999.
8. Peter D. Senturia, “Microsystem Design”, Kluwer Academic Publishers, Boston, 2001.

16WN707 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.

16WN708 CODING AND INFORMATION THEORY 3-0-0-3

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; Coding for Cooperative Communication, Network Coding, Coding for Multiuser Communication, Information Theory with Feedback,Information Theory for wireless, fading channels, etc.
Discussion on Selected Journal Papers.

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.

16WN709 WIRELESS MULTIMEDIA NETWORKS 2-0-1-3

Introduction: Analog and Digital Audio and Video, Audio compression, Video compression, Discrete Cosine Transform and Motion Estimation, Joint Photography Experts Group (JPEG) compression, Motion Picture Experts Group (MPEG) Compression, MPEG-1, MPEG-2, and MPEG-4 standards, Audio and Video synchronization, Multimedia conferencing Paradigms and systems, Video call control and management, Video Editing in compressed domain, Multimedia Security, Multimedia File Servers, Video on Demand, Multimedia Networking and Communication-Synchronization-Quality of Service-Requirements and Constraints - Performance Evaluation, Deterministic, Best Effort, and Statistical Performance Guarantees, Media Caching in the Internet, Cable Networks, Multimedia Wireless Networks, Buffering, Streaming, Scalability, Multimedia Applications, Multimedia on Gigabit networks, Multimedia on mobile devices and networks.
Research paper reading - IEEE Transactions and journal papers by Mihaela van der Schaar.
Mathematical Modeling and Analysis.

TEXT BOOKS/REFERENCES:

1. Sugata Mika and Gaurav Bhatnagar, "Introduction to Multimedia Systems", Elsevier Direct, 2004.
2. Ze-Nian Li, and Mark S. Drew, “Fundamentals of Multimedia”, Pearson Prentice Hall, 2003.
3. Z. S. Bolzkovic, D. A. Milanovic and K. Rammohanarao, “Multimedia Communication Systems” , First edition, Prentice Hall, 2002.
4. Yao Wang, Joern Ostermann and Ya-Qin Zhang, “Video Processing and Communications”, Prentice Hall, 2002.
5. Anurag Kumar and D. Manjunath, Joy Kuri, "Communication Networking: An Analytical Approach (The Morgan Kaufmann Series in Networking)”, First Edition, Morgan Kaufmann Publishers In, 2004.

16WN710 ANTENNA ENGINEERING: THEORY AND DESIGN 2-0-1-3

Introduction, Antenna Basics, Antenna Arrays: Two element arrays, Multiplication of patterns, Linear Array with n -isotropic point sources of equal amplitude and spacing (Broadside, End fire Arrays), EFA with Increased Directivity, Scanning Arrays, N element linear array and directivity, Binomial Arrays- Uniform spacing and Non-uniform Amplitude.
VHF, UHF and Microwave Antennas**:** Dipole array with Parasitic Elements, Folded Dipoles & their characteristics, Yagi-Uda Antenna, Reflector Antennas : Flat Sheet and Corner Reflectors, Paraboloidal Reflectors –Beam formation, Types of parabolic reflectors, F/D Ratio, Spill Over, Back Lobes, Aperture Blocking, Feed systems, Off-set Feeds, Cassegrain Feeds, Horn Antennas – Types, Optimum Horns, Design Characteristics of Pyramidal Horns; Lens Antennas – principle, types of lens antenna, non metallic dielectric lens antenna, primary feed and its uses, E –plane metal plate lens antenna, Antenna Measurements – Patterns measurement-arrangement for radiation pattern, Distance requirements, Directivity and Gain Measurements, Introduction to microstrip antennas.
Wave Propagation: Introduction, classification, modes of Propagation, Ground Wave Propagation–Characteristics, Parameters, Wave Tilt, Flat and Spherical Earth Considerations. Sky Wave Propagation – Formation of Ionospheric Layers and their Characteristics, Mechanism of Reflection and Refraction, Critical Frequency, Virtual Height, MUF– Calculations, LUHF, Skip Distance, Optimum working Frequency, Ionospheric Abnormalities, Ionospheric Absorption, multi-hop propagation, Space Wave Propagation – LOS, Tropospheric Wave Propagation – Radius of Curvature of path, Effective Earth’s Radius, Effect of Earth’s Curvature, Field Strength Calculations, Duct Propagation(M-curves).

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, Wiley-Interscience, 2005.
3. Simon Saunders and Alejandro Aragón-Zavala, "Antennas and Propagation for Wireless Communication Systems", Second Edition, Wiley, 2007.
4. John D. Kraus and Ronald J. Marhefka, "Antennas for All Applications", Third Edition, Tata McGraw Hill, 2007.
5. K. D. Prasad and SatyaPrakashan, "Antennas and Wave Propagation", Tech India Publications, 2001.
6. C. A. Balanis, "Antenna Theory", Second Edition, John Wiley & Sons, 2001.

16WN711 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.

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.

16WN712 SECURITY IN WIRELESS NETWORKS 2-0-1-3

Aspects of Wireless Networking and Security - Confidentiality, Integrity, Availability, Eavesdropping, Masquerading, Denial of Service, Cryptography – Concepts - PRF/PRP, Stream / Block Cyphers, RC4, 3DES, AES, Hashing, Asymmetric key pairs, Certificates, 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, Cross-layer attack and defense, Tunneling - SSL and IPSec, Enterprise Wireless LAN Security - 802.1X, EAP, TLS, Kerberos, PEAP, TTLS, LEAP, EAP-SIM, Physical layer security considerations -Jamming, Spread Spectrum, Proposed mitigations, Link & Upper layer security considerations - MAC misbehavior, Routing and Forwarding misbehavior, Transport layer misbehavior, Proposed mitigations, Cross-layer attacks and defenses, Trust and Reputation Management - Attacks and Defense strategies, Synchronization & Localization based attacks and mitigation strategies, Privacy, & Anonymity, Smart Grid Security, Introduction to Telecom

systems-2G/3G/4G, Telecom system and infrastructure attacks, Mobile app and OS security, PAN Security, IoT, NFC.
Lab: Wireless Security Lab based on the above topics will be conducted using Network Analyzers and QualNet simulation platform.

TEXT BOOKS/REFERENCES:

1. William A. Arbaugh Jon Edney, "Real 802.11 Security: Wi-Fi Protected Access and 802.11i", Pearson Education, 2011.
2. Nicholos Lekkas, "Wireless Security", McGraw-Hill, 2000.
3. KavehPahlavan and Prashant Krishnamurthy, "Principles of Wireless Networks", Prentice Hall, 2006.
4. Patrick Tague, "Wireless Network & System Security Group", CMU-SV, http://wnss.sv.cmu.edu/courses/

16WN713 4G MOBILE BROADBAND AND SMALL CELL NETWORKS 2-0-1-3

LTE: Architecture, Frame structure, Bandwidth Concepts, Cell search and reference signals, Scheduling- Proportional fair Scheduling, Link Adaptation; Uplink Controlling, Downlink Controlling, Inter-cell Interference control; LTE performance verification.
Heterogeneous Networks: Seamless Service Provisions, Power Management, Concurrent Aggregation in Wireless Networks: CoBA, Network Information Flow, XOR.
4G: Evolution to 4G; Fundamentals- 4G Networks and Composite Radio Environment, Protocol Boosters, Hybrid 4G Wireless Network Protocols, Green Wireless Networks;
Small cell networks: Macro, Micro, Pico, Femto cell design and Applications, Fundamentals of access control in femto cells, Multiple Antenna Techniques in small cell networks, Mobility and Interference Management in small cell networks, Throughput improvement using small cells, Channel Modeling for 4G, Mobility Management; Security.

TEXT BOOKS/REFERENCES:

1. Savo G Glisic, "4G Advanced Wireless Networks", John Wiley and Sons, 2006.
2. Farooq Khan, "LTE for 4G Mobile Broadband", Cambridge University Press, 2009.
3. Tony Q. S. Quek, Guillaume de la Roche, Ismail Guvenc and MariosKountouris, "Small Cell Networks", First Edition, Cambridge University Press, 2013.
4. Moray Rumney, "LTE and the Evolution to 4G Wireless: Design and Measurement Challenges", Agilent Technologies, 2009.
5. AymanElNashar, Mohamed El-saidny and Mahmoud Sherif, "Design, Deployment and Performance of 4G-LTE Networks: A Practical Approach", First Edition, Wiley, 2014.

16WN714 ADVANCED WIRELESS COMMUNICATION TECHNOLOGIES 2-0-1-3

Pre-requisite: Introduction to vectors, Norm, Energy, Power of vectors. Properties of matrices, Transposes, Dot products, Solving Linear Equations, Rank of the matrixes, Orthogonality, Determinant, Eigen values, eigen vectors, SVD.
Space-time processing: Beamforming, spatial, temporal, frequency diversity, antenna gain, spatial canceling of interference. Definition of diversity order; Spatial Channel modeling.
MIMO: Introduction to Wireless MIMO Communications- Types of MIMO systems- SISO, SIMO, MISO, MIMO, MIMO interference systems. Point to point MIMO system Model - Capacity, SISO AWGN model- Performance; SISO Fading Channel Model- Performance; Outage

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.
Cognitive Radio: SDR Architecture – Reconfigurable communication systems, Digital Radio Processing- Evolution to CR. 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. I. 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. David Tse and Pramod Viswanath, "Fundamentals of Wireless Communication", Cambridge University Press, 2007.

16WN715 BIG DATA AND APPLICATIONS 3-0-0-3

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.

16WN716 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.

16WN717 CLOUD COMPUTING AND INTERNET OF THINGS 2-0-1-3

Cloud Computing: Infrastructure as a Service (IaaS) providers - Google Compute Engine, Amazon AWS, Microsoft Azure; Cloud Database providers - Google Cloud SQL, Microsoft Cloud SQL Database; Cloud Storage providers: Google Drive API, Google Cloud Storage, Azure Blob Storage Platform as a Service (PaaS) providers for Web Rapid Application Development (RAD) - Google App Engine; Distributed Storage providers:Google Cloud Datastore, Azure tables; Distributed Computing providers and frameworks: Google Cloud Dataflow, Apache Spark.
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 in Environmental monitoring and Smart grid, Cloud solutions providers for IoT - Google Weave.
Laboratory:Deploying an application using an IaaS provider, Deploying an application using a PaaS provider, Writing applications using SQL vs NoSQL cloud storage solutions, Writing an application for Distributed Computing environments (Google Dataflow).

TEXT BOOKS/REFERENCES:

1. Thomas Erl, "Cloud Computing: Concepts, Technology & Architecture", Prentice Hall, May 2013.
2. Michael J. Kavis, "Architecting the Cloud: Design Decisions for Cloud Computing Service Models (SaaS, PaaS, &IaaS)", Wiley CIO Series, January 2014.
3. George Reese, "Cloud Application Architectures: Building Applications and Infrastructure in the Cloud", O'Reilly, 2009.
4. Daniel Minoli, "Building the Internet of Things with IPv6 and MIPv6: The Evolving World of M2M Communications", Wiley, 2013.
5. Olivier Hersent, David Boswarthick and Omar Elloumi, "The Internet of Things: Key Applications and Protocols", Wiley, 2012.

16MA704 RANDOM PROCESS AND QUEUEING MODELS 3-0-0-3

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.

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.

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.

16MA705 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.
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.

16WN718 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.

16MA706 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.

16MA707GRAPH 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.

16WN797 LIVE-IN-LABS 0-0-1-1

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.