Savitribai Phule Pune University

Faculty of Science and Technology

Syllabus for

M.E (Electronics and Communication)
(Wireless Communication Technology)

(Course 2020)

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
(With effect from Academic Year 2020-21)

Semester-I

Course Code	Course Name	Teaching Scheme (Hours/Week)		Examination and Marking Scheme					Credit		
		Theory	Practical	In-Sem	End-Sem	TW	OR	Total	TW	OR	Theory
504601	Advanced Digital Communications	03	-	50	50	-	-	100	-	--	03
504602	Cellular Wireless Communications	03	-	50	50		-	100	-	-	03
504603	Probability and Stochastic Processes	03	-	50	50	-	-	100	-	-	03
504604	Research Methodology	03	-	50	50	-	-	100	-	-	03
504605	Elective – I	04	-	50	50	-		100	-	-	04
504606	Lab Practice-I	-	08	-	-	50	50	100	02	02	-
504607	Non- Credit Course-I										-
Total		**16**	**08**	**250**	**250**	**50**	**50**	**600**	**02**	**02**	**16**
								Total Credits		**20**	

Abbreviations:

In-Sem: In semester — End-sem: End semester — TH : Theory

TW : Term Work — PR : Practical

Elective – I / MOOCs

1. **Mathematics for Wireless Communications**
2. **Key Technologies for 5G Wireless Communications**
3. **Internet of Things**
4. **Modelling and Simulation of Communication Systems**

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
(With effect from Academic Year 2020-21))

Semester-II

Course Code	Course Name	Teaching Scheme (Hours/Week)		Examination and Marking Scheme					Credit		
		Theory	Practical	In-Sem	End-Sem	TW	OR	Total	TW	OR	Theory
504608	Signal Processing Wireless Communication	03	-	50	50	-	-	100	-	--	03
504609	Information Theory and Coding	03	-	50	50		-	100	-	-	03
504610	Antennas for Modern Wireless Communications	03	-	50	50	-	-	100	-	-	03
504611	Elective - II	04	-	50	50	-	-	100	-	-	04
504612	Mini Project / Seminar-I	-	03	-	-	50	50	100	01	02	-
504613	Lab practice-II	-	08	-	-	50	50	100	02	02	-
504614	Non- Credit Course-II										-
Total		**13**	**11**	**200**	**200**	**100**	**100**	**600**	**03**	**04**	**13**
								Total Credits	**20**		

Abbreviations: In-Sem: In semester End-sem: End semester TH : Theory
TW : Term Work PR : Practical OR : Oral

Elective – II / MOOCs

1. **Machine Learning for Wireless Communications**
2. **Optical Wireless Communication**
3. **Modern Satellite Communications**
4. **Radar Communications**

Savitribai Phule Pune University, Pune
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(With effect from Academic Year 2020-21)

Semester-III

Course Code	Course Name	Teaching Scheme (Hours/Week)		Examination and Marking Scheme					Credit		
		Theory	Practical	In-Sem	End-Sem	TW	OR	Total	TW	OR	Theory
604601	Advanced Wireless Networks	03	-	50	50	-	-	100	-	-	03
604602	SDR and Cognitive Radio	03	-	50	50	-	-	100	-	-	03
604603	Elective - III	04	-	50	50	-	-	100	-	-	04
604604	Industry Internship-I / In-house Research Project-I / Seminar-II	-	03	-	-	50	50	100	01	02	-
604605	Dissertation Stage - I	-	08	-	-	50	50	100	04	04	-
604606	Non- Credit Course-III										-
Total		**10**	**11**	**150**	**150**	**100**	**100**	**500**	**05**	**06**	**10**
								Total Credits	**16**	**04**	**21**

Abbreviations: In-Sem: In semester End-sem: End semester TH : Theory
TW : Term Work PR : Practical OR: Oral

Elective – III

1. **Wireless Adhoc Networks**
2. **Telecommunications Network Management**
3. **Wireless Network Security**
4. **MIMO Wireless Communications**
5. **Open Elective**

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
(With effect from Academic Year 2020-21)

Semester-IV

Course Code	Course Name	Teaching Scheme (Hours/Week)	Examination Scheme and Marks			Credit	
		PR	TW	OR	Total	TW	OR
604607	Industry Internship-II/ In-house Research Project-II / Seminar-III	03	50	50	100	01	02
604608	Dissertation Stage - II	18	150	50	200	08	10
Total		**21**	**200**	**100**	**300**	**09**	**12**
					Total Credits	**21**	

Abbreviations: TW : Term Work PR : Practical OR : Oral

SEMESTER - I

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
504601: Advanced Digital Communications

Teaching Scheme	Credits	Examination Scheme
TH: 03 Hrs. / Week	**03**	**In-Semester: 50 Marks** **End Semester: 50 Marks**

Prerequisite: Signals and Systems, Probability Theory, Linear Algebra

Course Objectives

Objective of this course is to provide students with

1. The knowledge and understanding of advanced digital telecommunications systems
2. Provide a strong foundation of fundamental digital communication system
3. Detailed analysis of end to end digital communication system
4. Performance evaluation of various modulation schemes, optimum receivers, synchronization techniques.

Course Outcomes

CO1: Model digital communication signals and systems using appropriate mathematical techniques
CO2: Represent and analyze various digital modulation schemes mathematically, and geometrically.
CO3: Carry Out the comparative analysis in terms of specified parameters
CO4: Carry out detailed analysis of Optimum receiver for AWGN Channel
CO5: Choose an appropriate modulation schemes and Optimum Receivers according to design criteria
CO6: Provide sound evaluation of practical digital communication systems in terms of their performance and complexity.

Course Contents

Module I	**Introduction to Digital Communication Systems**	**8Hrs**
Introduction to digital communication system, block diagram of modern digital communication system, characterization of communication signals, source coding, signal space representation		
Module II	**Modulation Schemes**	**10 Hrs**
Representation and spectral characteristics of digitally modulated signals Memory less Modulation, PAM, Phase modulation, QAM, Linear modulation with memory, CFSK, CPM and MSK		
Module III	**Optimum Receivers**	**10 Hrs**
Correlation demodulator, matched filter demodulator, optimum detector, MAP detector, Maximum likelihood sequence detector, performance of detectors under AWGN		
Module IV	**Synchronization, Equalization and Estimation Techniques**	**8Hrs**
Signal parameter estimation, likelihood function, carrier recovery, carrier phase estimation, ML phase estimation, symbol timing estimation, various types of equalizers. Case Study of 5G systems		

Text Book

1. John G Proakis, Masoud Salehi, , "Digital Communications", McGraw-Hill, Indian 5th Edition, 2018

Reference Book

1. Bernard Sklar, "Digital Communications: Fundamentals & Applications", Prentice Hall

Relevant MOOCs Course

1. Modern digital communication techniques, By Prof. SuvraSekhar Das | IIT Kharagpur https://onlinecourses.nptel.ac.in/noc21_ee11/preview

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
504602: Cellular Wireless Communications

Teaching Scheme	Credits	Examination Scheme
TH: 03 Hrs. / Week	**03**	**In Semester:50 Marks** **End Semester: 50 Marks**

Prerequisite: Cellular Technology, Digital Communication

Course Objectives: To provide good understanding of cellular communication, wireless channel issues and understanding of future cellular technology.

Course Outcomes:

CO1: Demonstrate their understanding on functioning of wireless communication system and evolution of different wireless communication systems and standards.

CO2: Compare different technologies used for wireless communication systems.

CO3: Demonstrate an ability explain recent techniques for Wireless Communication systems.

Course Contents

Module I	**Introduction to cellular systems and traffic engineering**	**8 Hrs**
Overview of Cellular Systems and evolution 2G/3G/4G/5G, Cellular Concepts – Frequency reuse, Co channel and Adjacent channel Interference, C/I, Handoff, Blocking, Erlang Capacity.		
Module II	**Fundamentals of wireless communication**	**10 Hrs**
Wireless Channel, Wireless propagation, Link budget, Free-space path loss, Noise figure of receiver, Multipath fading, Shadowing, Fading margin, Shadowing margin, Wireless Channel Capacity, OFDM and LTE, Large Scale Propagation effects and Channel Models		
Module III	**Fundamentals of 5G architecture**	**10 Hrs**
Difference between 4G and 5G,, 5G Architecture, Planning of 5G Network, Quality of Service, Radio Network, Requirements, Security, SIM in 5G Era, Specifications, Standardization, Terminal States,		
Module IV	**Future Generations**	**8 Hrs**
Future Generations(where is the 6G?), Health Considerations, Identifiers, Interfaces, ,Key Derivation, Location Based Services, Massive Internet of Things, Measurements, Network Functions Virtualization, Network Slicing, Open Source, , User Equipment, Vehicle-to-Vehicle communications (V2V),Virtual Reality (VR/AR/XR).		

Text Books

1. Theodore S. Rappaport, “Wireless Communications: Principles and Practice”, Pearson, 2nd Edition.

Reference Books

1. Aditya K Jagannatham, “Principles of Modern Wireless Communications”, McGraw Hill, 2017

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
504603: Probability and Stochastic Process

Teaching Scheme	Credits	Examination Scheme
TH: 03Hrs. / Week	**03**	**In-Semester: 50 Marks** **End Semester: 50 Marks**

Prerequisite: Set Theory, Counting principles, Calculus

Course Objectives

Objective of this course is to provide students with

1. The knowledge and understanding of advanced digital telecommunications systems
2. Provide a strong foundation of fundamental digital communication system
3. Detailed analysis of end to end digital communication system
4. Performance evaluation of various modulation schemes, optimum receivers, synchronization techniques.

Course Outcomes

CO1: Model digital communication signals and systems using appropriate mathematical techniques
CO2: Represent and analyze various digital modulation schemes mathematically, and geometrically.
CO3: Carry Out the comparative analysis in terms of specified parameters
CO4: Carry out detailed analysis of Optimum receiver for AWGN Channel
CO5: Choose an appropriate modulation schemes and Optimum Receivers according to design criteria
CO6: Provide sound evaluation of practical digital communication systems in terms of their performance and complexity.

Course Contents

Module I	**Basics of Probability Theory**	**8Hrs**

Introduction to deterministic and probability model with suitable example, Random experiment and its sample space: discrete and continuous sample space, Events, Axiomatic definition of probability, Discrete uniform law.

Conditional probability, Multiplication rule of probability, Total probability rule, Bayes' theorem for probability, Notion of independency.

Module II	**Random Variable**	**10Hrs**

Definition of random variable, Discrete, continuous and mixed random variable.

Probability mass function (PMF), probability density function (PDF), cumulative distribution function (CDF). Standard discrete distributions: Uniform, Bernoulli, Binomial, Geometric and Poisson. Standard continuous distribution: Uniform, exponential, Gaussian, Rayleigh random variable.

Function of one random variable: expectations, conditional expected value, and transformations of a random variable.

Multiple random variables: introduction, vector random variable, joint PMF, PDF and CDF, marginal, conditional PMF and PDF, independency, sum of two or more random variables.

Function of multiple random variables: expectations, correlation, covariance, transformations.

Jointly Gaussian random variables, properties, linear transformation of Gaussian random variable, central limit theorem.

Module III	**Random Process**	**10 Hrs**
Introduction, Classification, Joint CDF and PDF, Statistical averages: mean variance, mean square value, autocorrelation, autocovariance, cross-correlation, and cross-covariance. Stationarity: strict sense stationary (SSS) and weak sense stationary (WSS) process. Concept of jointly WSS process, Properties of autocorrelation and cross-correlation function. Time-averages and Ergodicity. Gaussian random process and its properties.		
Module IV	**Linear System Response to Random Input**	**8Hrs**
Spectral characteristics of a random process: power spectral density (PSD), cross-power spectral density and their properties, white and colored noise. Random signal response of a linear system: mean, mean square value and autocorrelation function of system response, cross correlation function.		
Text Books		
1. Peyton Z. Peebles, "Probability, Random Variables, and Random Signal Principles", McGraw Hill, 2nd Edition. 2. Bertsekas, Dimitri, and John Tsitsiklis,"Introduction to Probability", Athena Scientific, 2nd Edition,2008.		
Reference Books		
1. Athanasios Papoulis, S. Unnikrishna Pillai, "Probability, Random Variables, and Stochastic Process", McGraw Hill, 4th Edition, 2002. 2. Alberto Leon-Gracia, "Probability, Statistics, and Random Processes for Electrical Engineering", Pearson, 3rd Edition, 2008.		
Relevant MOOCs Course		
1. **MIT OCW course on:** "Introduction to Probability by Prof.John Tsitsiklis" https://ocw.mit.edu/resources/res-6-012-introduction-to-probability-spring-2018/ 2. **NPTEL course on:** "Probability and Random Variables/ Processes for Wireless Communications by Prof.Aditya K. Jagannatham" https://nptel.ac.in/courses/117/104/117104117/		

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
504604: Research Methodology

Teaching Scheme	Credits	Examination Scheme
TH: 03 Hrs. / Week	03	In- Semester: 50 Marks End Semester : 50 Marks

Prerequisite: --

Course Objectives:

Objective of this course is to provide students with:

1. The knowledge of research and its methodologies
2. Systematic approach for literature survey and technical writing
3. Strong foundation of research design and applied statistics
4. Understanding the concepts of plagiarism and IPR

Course Outcomes:

Upon the completion of this course, students will be able to:

CO1: Formulate a well-defined research problem, aim and objectives

CO2: Design appropriate experiments for systematic research and critically analyse the data using applied statistical tools.

CO3: Develop enhanced skillset for effective technical /scientific writing, quality manuscript and research proposal.

Course Contents

Module I	**Introduction to Research, Literature Survey and Problem Definition**	**10Hrs**

Introduction to research, Types of research, Phases of research, Features of a good research study, Importance of literature survey, Resources for literature survey, Reading scientific paper, white paper and patent, Recording and summarizing the findings and observations, Identifying the gaps, Formulating a problem statement, Defining the scope and objectives of the defined research problem.

Module II	**Research Design and Applied Statistics**	**10 Hrs**

Introduction to research design, Approaches of research design, Types of research designs, Principles of experimental design, Design of experiments, sampling concepts.

Regression analysis, Parameter estimation, Multivariate statistics, Principal component analysis, State vector machines, uncertainty analysis, concepts of mathematical modeling and performance prediction.

Module III	**Presenting and Publishing the Research Findings**	**8Hrs**

Types of publications, Journal ranking, Journal metrics, Citation index, various documentation tools, referencing tools and presentation tools, Scientific writing - writing quality research manuscript / paper, report and thesis, Developing a research proposal, related case studies.

Module IV	**Research Ethics (Plagiarism and Intellectual Property Rights -IPR)**	**8 Hrs**

Introduction to plagiarism, Types of plagiarism, Software used to identify plagiarism, Plagiarism polices, Techniques to avoid plagiarism.

Introduction to IPR and its significance, Various forms of IPR, Patent filing process in India, Role of IPR in technology transfer, Recent developments, Case studies related to Plagiarism and IPR.

Text Books:

1. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction", Juta & Co.Ltd., 2nd Edition.
2. Ranjit Kumar, "Research Methodology: A Step-by-Step Guide for Beginners", Sage Publications, 3rd Edition.

Reference Books:

1. Stuart Melville and Wayne Goddard, "Research Methodology: An introduction for Science & Engineering students", Juta & Co. Ltd

Relevant MOOCs Course:

1. Introduction to research, by professors in IIT Mumbai and IIT Madras https://onlinecourses-archive.nptel.ac.in/noc18_ge12/course
2. Research Writing, By Prof. A. Malik | IIT Kharagpur https://onlinecourses-archive.nptel.ac.in/noc18_mg13/course
3. Research Methodology, By Prof. G.S.Bajpai | National Law University, Delhihttps://onlinecourses.swayam2.ac.in/cec21_ge16/ preview?
4. MCO-03: Research Methodology and Statistical Analysis (Commerce Category) By Dr. Subodh Kesharwani | Indira Gandhi National Open University, https://onlinecourses.swayam2.ac.in/nou21_cm03/preview?

Other Resources/Links:

1. Understanding Research Methods (Coursera)
2. Being a researcher in Information Science and Technology (Coursera)

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
504605 (A): Mathematics for Wireless Communication (Elective I)

Teaching Scheme	Credits	Examination Scheme
TH: 04 Hrs. / Week	**04**	**In Semester: 50 Marks** **End Semester: 50 Marks**

Prerequisite: Functions, Calculus, Counting Principles.

Course Objectives

Objective of this course is to provide students with

1. The knowledge and understanding of advanced digital telecommunications systems
2. Provide a strong foundation of fundamental digital communication system
3. Detailed analysis of end to end digital communication system
4. Know about the applications of convex optimization in signal processing, wireless communications, and networking research

Course Outcomes

CO1: Model digital communication signals and systems using appropriate mathematical techniques
CO2: Represent and analyze various digital modulation schemes mathematically, and geometrically.
CO3: Carry Out the comparative analysis in terms of specified parameters
CO4: Carry out detailed analysis of Optimum receiver for AWGN Channel
CO5: Choose an appropriate modulation schemes and Optimum Receivers according to design criteria
CO6: Provide sound evaluation of practical digital communication systems in terms of their performance and complexity.

Course Contents

Module I	**Linear Algebra-I**	**8Hrs**

Vectors: geometrical representation, angle and dot product**.**
n-Space: dot product, norm, angle, properties of dot product and norm, orthogonality, Normalization.
Generalized Vector Space: vector space, inner product, norm, span, subspace, linear dependence, bases, expansion, dimension, Gram-Schmidt Orthogonalization, best approximation and orthogonal series expansion.
System of Linear equations: homogenous and nonhomogeneous equations, consistent and inconsistent solutions, solution using Gauss elimination, matrix notation, Gauss-Jordan reduction method.

Module II	**Linear Algebra-II**	**10Hrs**

Matrix Algebra: matrix addition, scalar multiplication, matrix multiplication, transpose, rank and its application in linear dependence, existence and uniqueness for Ax=c, square matrix,determinants and its properties.
Solution of Linear System: inverse matrix method, Cramer's rule and LU factorization. Eigenvalue Problem Ax=λx: solution procedure and applications, Cayley-Hamilton theorem, symmetric matrix andeigenvalue problem, diagonalization**.**

Module III	**Convex Optimization**	**12Hrs**

Introduction: mathematical optimization, role of convex optimization. Convex sets: affine and convex sets, examples, operations that preserve convexity, generalized inequalities. Convex functions: properties and examples, operations that preserve convexity, conjugate function, quasi-convex functions. Convex optimization problems: linear optimization problems, quadratic optimization problems, vector optimization. Duality: Lagrange dual function and problems, geometric and saddle-point interpretation, optimality conditions, perturbation and sensitivity analysis.

Module IV	**Field Theory**	**6Hrs**

Group: subgroup, cyclic group and order of an element, cosets, Lagrange theorem, isomorphism, homomorphism, field, finite field, binary field arithmetic, Galois field (GF(2^m)): basic properties and computation using GF(2^m).

Text Books

1. Michael D. Greenberg, "Advanced Engineering Mathematics", Pearson, 2nd Edition, 2002.
2. Stephen Boyd and LievenVandenberghe, "Convex Optimization", Cambridge University Press.
3. Shu Lin, Daniel J. Costello, "Error Control Coding", Pearson, 2nd Edition, 2011.

Reference Books

1. Strang, Gilbert, "Introduction to Linear Algebra", Wellesley-Cambridge Press, Fourth Edition, 2009.
2. D. P. Palomar, Y. C. Eldar, "Convex Optimization in Signal Processing and Communications", Cambridge Press, 2010.
3. Dimitri P. Bertsekas, "Convex Analysis and Optimization", Athena-Scientific, 2003.

Relevant MOOCs Course

1. **MIT OCW course on:**"Linear Algebra by Prof.Gilbert Strang" https://ocw.mit.edu/courses/mathematics/18-06-linear-algebra-spring-2010/video-lectures/
2. **NPTEL course on:**
   a. Lecture Notes on "Algebra-II by Prof.Jugal K. Verma" https://nptel.ac.in/courses/111/101/111101001/#
   b. "Galois Theory by Prof.DilipPatil" https://nptel.ac.in/courses/111/101/111101117/#

Other Resources/Links

1. Stephen Boyd and LievenVandenberghe, "Convex Optimization", Cambridge University Press [Online: https://web.stanford.edu/~boyd/cvxbook/]

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
504605 (B): Key Technologies for 5G Wireless Communications (Elective – I)

Teaching Scheme	Credits	Examination Scheme
TH: 04 Hrs. / Week	**04**	**In Semester: 50 Marks** **End Semester: 50 Marks**

Prerequisite: Signals and Systems, Probability Theory, Linear Algebra

Course Objectives

Objective of this course is to provide students with

1. Overview and Requirements for 5G
2. Advanced Techniques and Trends in 5G
3. The key technologies for 5G
4. Provide a detailed trends of technologies for 5G
5. State of the art technologies and current status of 5G

Course Outcomes

CO1: Update the latest trends in wireless communications.
CO2: Identify the features and requirements of 5G.
CO3: Present a detailed report on various key technologies for 5G.

Course Contents

Module I	**Overview of 5G Technologies**	**8Hrs**
Evolution of 1G to 5G, Requirements of 5G, 5G Architecture, Functionalities		
Module II	**Non Orthogonal Multiple Access**	**10 Hrs**
OFDMA, Limitations of OFDMA, NOMA, concept of NOMA, features, mathematical foundation for NOMA, Transmission and Receiver architecture, case study.		
Module III	**Massive MIMO**	**10 Hrs**
Concept of massive MIMO, MIMO architecture, challenges, implementation issues, research trends and applications to 5G		
Module IV	**mmWave and Visible Light Communications**	**8Hrs**
Back ground and concept of mmWave Communications, Frequency bands, propagation characteristics, channel models, applications and challenges in 5G		

Text Books

1. L. Dai, B. Wang, Z. Ding, Z. Wang, S. Chen and L. Hanzo, "A Survey of Non-Orthogonal Multiple Access for 5G," in *IEEE Communications Surveys & Tutorials*, vol. 20, no. 3, pp. 2294-2323, thirdquarter 2018, doi: 10.1109/COMST.2018.2835558.
2. Robin Chataut, Robert Akl, “Massive MIMO Systems for 5G and beyond Networks—Overview, Recent Trends, Challenges, and Future Research Direction” Sensors, May 2020, doi:10.3390/s20102753
3. A. N. Uwaechia and N. M. Mahyuddin, "A Comprehensive Survey on Millimeter Wave Communications for Fifth-Generation Wireless Networks: Feasibility and Challenges," in *IEEE Access*, vol. 8, pp. 62367-62414, 2020, doi: 10.1109/ACCESS.2020.2984204.

Reference Books

1. Vincent W.S Wong, Key Technologies for 5G Wireless Systems, Cambridge University Press, April 2017

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
504605 (C): Internet of Things (Elective – I)

Teaching Scheme	Credits	Examination Scheme
TH: 04 Hrs. / Week	**04**	**In - Semester: 50 Marks** **End Semester: 50 Marks**

Prerequisite: Computer Networks, Embedded Systems

Course Objectives

Objective of this course is to provide students with

1. The knowledge and understanding of Internet of Things
2. Provide a strong foundation of fundamentals of Internet of Things and need of IoT Security
3. Get acquainted with various communication protocols of Internet of Things
4. Detailed understanding of present scope of Internet of Things with case studies

Course Outcomes

CO1: Model Internet of Things using various protocols of standard communication layers.
CO2: Represent and analyze various communication models, carry out the comparative analysis in terms of specified parameters.
CO3: Choose an appropriate communication model for given design criteria
CO4: Understand essentials of IoT Security
CO5: Provide most optimum model of connectivity solution to various things in different application areas.

Course Contents

Module I	**Introduction to Internet of and Things (IoT)**	**10 Hrs**

Introduction: Enabling Technologies of IoT, Physical Design of IoT, Logical Design of IoT, IoT communication Models, IoT Communication API's
Cloud Services: IAAS, PAAS, SAAS, IoT Specific Cloud Services
RFID: Introduction to RFID and its Applications in IoT.

Module II	**Key Protocols-1**	**10 Hrs**

PHY/MAC Layer: Wireless HART, ZWave, Bluetooth Low Energy, Zigbee Smart Energy
Network Layer: IPv4, IPv6, 6LoWPAN, ICMP, RPL,COAP
Transport Layer: (TCP, UDP, DCCP, SCTP)-(TLS, DTLS)
Session Layer: HTTP, CoAP, XMPP, AMQP, MQTT

Module III	**IoT Security**	**10 Hrs**

Vulnerabilities Security Requirements and Threat Analysis, Misuse Cases, IoT Security Tomography, and Layered Attacker Model, Identity Management and Establishment, Access Control, and Secure Message Communication, Security Models, IoT Security Protocols.

Module IV	**IoT development Tools and Case Studies**	**10 Hrs**

Software and Hardware Platforms: Contiki OS, Cooja Simulator, Raspberry Pi Platform for ioT

IoT Case Studies: Smart Cities, Agriculture, Health and Lifestyle, Industry, Home Automation, Telecom/5G.

Text Books

1. Vijay Madisetti and Arshdeep Bahga, "Internet of Things (A Hands-on Approach)", University Press 1st Edition, 2014
2. Jeeva Jose, "Internet of Things", Khanna Book Publishing, 2018
3. Raj Kamal, Internet of Things: Architecture and Design Principle", McGraw Hill Education (India) 2017

Reference Books

1. Lu Yan, Yan Zhang, Laurence T. Yang, Huansheng Ning, "The Internet of Things: From RFID to the Next-Generation Pervasive Networked"
2. Adrian McEwen, Hakim Cassimally, "Designing the Internet of Things"
3. HakimaChouchi, "The Internet of Things Connecting Objects to the Web", Wiley Publications.
4. Asoke K Talukder and Roopa R Yavagal, "Mobile Computing," Tata McGraw Hill, 2010.
5. Tanenbaum, Andrew S, "Computer Networks", Pearson Education, 4th Edition.
6. William Stallings, "Data and Computer Communications", Pearson Education, 6th Edition.

Relevant MOOCs Course

NPTEL-

Introduction to internet of things - Course (nptel.ac.in)

Coursera

An Introduction to Programming the Internet of Things (IOT) | Coursera

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
504605 (D): Modeling & Simulation of Communication Systems (Elective – I)

Teaching Scheme:	Credits	Examination Scheme:
TH: 04 Hrs./ Week	04	In-Semester: 50 Marks End Semester: 50 Marks

Prerequisite: Signals and Systems, digital communications systems, software tools MATLAB/ LabVIEW

Course Objectives

Objective of this course is to provide students with

1. The knowledge and understanding of Modeling & Simulation of Communication Systems
2. To study the modeling methodologies of a telecommunication system.
3. To analyze the techniques involved in performance estimation of telecommunication systems.
4. To apply random process concepts in telecommunication system simulation.
5. To simulate the QAM in digital radio link environment

Course Outcomes

CO1: To Analyze the role of important elements of simulation and modelling paradigm.
CO2: To compare and analyze different modeling methodologies of a telecommunication system.
CO3: Generate random numbers of arbitrary PDF for modelling communication data and channels.
CO4: Analyze and design Monte Carlo simulation algorithms.
CO5: Apply suitable modelling and simulation techniques in generating channel models to simulate the QAM in specified digital radio link environment.

Course Contents

Module I	**Simulation Methodology**	**8Hrs**
Introduction, Concepts of methodology, Performance Estimation, Simulation sampling frequency, Low pass equivalent simulation models for bandpass signals, Multicarrier signals, Non-linear and time-varying systems, Post processing – Basic graphical techniques and estimations.		
Module II	**Random Signal Generation & Processing, Monte Carlo Simulation**	**12Hrs**
Uniform random number generation, mapping uniform random variables to an arbitrary pdf, Correlated and Uncorrelated Gaussian random number generation, PN sequence generation, Random signal processing, testing of random number generators, Fundamental concepts, Application to communication systems, Monte Carlo integration, Semi-analytic techniques.		
Module III	**Modeling of Communication Systems: Transmitter and Receiver Subsystems**	**10 Hrs**
Information Sources, Formatting/Source Coding, Digital Waveforms, Line Coding, Channel Coding, Radiofrequency modulation, Demodulation and Detection, Calibration of Simulations.		
Module IV	**Estimation of parameters and Performance Measures from Simulation, Case Studies**	**12 Hrs**
Estimating the Average Level of a Waveform, Estimation of Signal-to-Noise Ratio, Estimating Performance Measures for Digital Systems, Case Study: 64-QAM Modulation Scheme in a Fading Environment.		

Text Books

1. M.C. Jeruchim, P.Balaban and K. Sam Shanmugam, Simulation of Communication Systems: Modeling, Methodology and Techniques, Plenum Press, New York, 2001.

2. William.H.Tranter, K. Sam Shanmugam, Theodore. S. Rappaport, Kurt L. Kosbar, Principles of Communication Systems Simulation, Pearson Education (Singapore) Pvt. Ltd, 2013.

Reference Books

1. Averill. M. Law and W. David Kelton, Simulation Modeling and Analysis, McGraw Hill Inc., 2000.
2. Geoffrey Gorden, System Simulation, Prentice Hall of India, 2nd Edition, 1992.
3. Jerry Banks and John S. Carson, Discrete Event System Simulation, Prentice Hall of India, 1984
4. Frevert, R., Haase, J., Jancke, R., Knochel, U., Schwarz, P., Kakerow, R., Darianian, M. Modeling and Simulation for RF System Design, Springer US, 2005

Relevant Coursera/ MOOCs Course

https://www.coursera.org/lecture/modeling-simulation-natural-processes/modeling-and-simulation-F7vas

Other Resources/Links

- www.cse.wustl.edu/~jain/cse567-08/ftp/k_27trg.pdf
- https://www.iitk.ac.in/new/ee669a

Savitribai Phule Pune University, Pune M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course 504607: Lab Practice-I		
Teaching Scheme:	**Credits**	**Examination Scheme:**
PR: 08 Hrs./ Week	**04**	**TW: 50 Marks** **OR: 50 Marks**
Laboratory experiments based on the courses being taught. Minimum ten experiments, case studies to be carried out including hardware and simulation based experiments.		

SEMESTER - II

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
504608: Signal Processing for Wireless Communication

Teaching Scheme	Credits	Examination Scheme:
TH: 03 Hrs. / Week	**03**	**In -Semester: 50 Marks** **End Semester: 50 Marks**

Prerequisite: Signals and Systems, Signal processing, Probability Theory

Course Objectives

Objective of this course is to provide students with

1. The knowledge and understanding of signal processing for wireless communication.
2. Basics of stochastic signal processing.
3. Knowledge of Power spectrum estimation and adaptive flters.
4. Detailed understanding of the concept of Hypothesis testing.
5. Apply the hypothesis testing concepts to detection of signals.
6. Provide a strong foundation of detection and estimation theory.

Course Outcomes

CO1: Discuss and design adaptive filters.
CO2: Compare and contrast the various power estimation techniques in the estimation of PSD.
CO3: Discuss and analyze the properties of stochastic signals.
CO4: Apply hypothesis testing to signal detection problems.
CO5: Detection of signals in white gaussian noise.
CO6: Given a parameter estimation tasks select the suitable estimator.

Course Contents

Module I	**Power Spectrum Estimation and Adaptive Filters**	**8Hrs**

Spectrum Estimation and Modelling: Definition, Problem of PSE, Non parametric and parametric spectral estimation, AR model, MA model and ARMA model, least mean square estimation.

Adaptive Filters: Introduction to steepest descent adaptive filters, LMS algorithm, application to noise cancellation, RLS algorithm.

Module II	**Stochastic Signal processing, Hypothesis Testing**	**10 Hrs**

Definition of detection and estimation, review of deterministic and random signal concepts, Transformation of random variables using Gaussian density, Rayleigh density, Cauchy density, Uniform density, Chi squared density, Hypothesis testing, Bayes detection, Max detection, ML detection, Neyman Pearson criterion, Multiple hypothesis testing, composite hypothesis testing, Receiver operating characteristic and performance

Module III	**Detection of Signals in Gaussian white Noise and colored Gaussian noise**	**10 Hrs**

Sign detector and its performance analysis, binary detection problem, matched filters, M-ary communication system, detection of signals with random parameters, Whitening filter, Discrete time detection of known signals in colored gaussian noise, Discrete time colored noise detector, Whitening via spectral factorization.

Module IV	**Estimation Theory**	**8Hrs**
Introduction, Basic estimation schemes, MAP estimation estimation, Bayes estimator, Properties of estimator, Waveform estimation		
Text Books		
1. M.D.Srinath, P.K.Rajasekaran and R.Vishwanathan, “Introduction to statistical signal processing with application”, Pearson Edition. 2. Ralph D Hippensteil, “Detection Theory applications and Digital Signal Processing” , CRC Press. 3. John G. Proakis, “Digital Signal Processing: Principles, Algorithms, And Applications”, Pearson Education.		
Reference Books		
1. E Ifeachor and W.Jervis, “Digital Signal Processing a practical approach”,Prentice Hall.		

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
504609: Information Theory & Coding

Teaching Scheme	Credits	Examination Scheme:
TH: 03 Hrs. / Week	**03**	**In -Semester: 50 Marks** **End Semester: 50 Marks**

Prerequisite: Digital communications systems, Probability theory and software tools like MATLAB/ LabVIEW are desirable, but not necessary

Course Objectives

1. Explain various fixed length and variable length source coding algorithms,
2. Understand the concept of a communication channel, Mutual information, and the channel capacity.
3. Give emphasis on coding and decoding of Error control coding techniques like Linear bock code, Cyclic codes, Convolution codes which can correct mainly random errors.
4. Study modern error coding like Turbo codes and LDPC codes

Course Outcomes

CO1: Identify the need of source coding, Define, Calculate Entropy, Mutual information for various types of sources and channels.
CO2: Apply the various source coding algorithms to Generate codeword, Calculate average code word length, efficiency, and redundancy.
CO3: Formulate generator matrix for linear block code and Compute all code words. Determine the error detection and correction capacity for linear block code.
CO4: Design BCH codes for varying error correction capacity and compare the performance with RS codes. Sketch tree diagram, Trellis diagram and state diagram and Apply the concept of Viterbi Decoding.
CO5: To apply LDPC codes to 5G wireless networks for given specification.

Course Contents

Module I	**Information Theory & Source Coding**	**8 Hrs.**

Introduction: Entropy, Relative Entropy, Mutual Information; InformationInequalities; Block to variable length coding: Prefix-free code, Bounds onoptimal codelength; Huffman coding. Variable to block length coding, theasymptotic equipartition property, UniversalSource Coding: Lempel-Ziv Algorithm-LZ77, Lempel-Ziv Welch Algorithm(LZW). Coding for sources with memory, Channel capacity of discrete memoryless channels. Noisy channel coding theorem; Gaussian Channel; ParallelGaussian Channel. Rate Distortion Theory; Blahut-Arimoto Algorithm forcomputation of channel capacity and rate-distortion function.

Module II	**Linear Block Codes and Cyclic codes**	**12Hrs**

Introduction to error control coding, Introduction to linear block codes &Cyclic Codes, Properties of linear block codes & Cyclic Codes: Syndrome,error detection. Decoding of linear block codes& Cyclic Codes, Distanceproperties of linear block codes & Cyclic Codes. Some simple linear block
codes: Repetition codes, Single parity check codes, Hamming codes, ReedMuller codes, Burst error-correcting code. Bounds on size of codes: Hamming bound, Singleton bound, Low density parity check codes, Decoding of low density parity check codes: Belief propagation algorithm on BEC , BSC and AWGN channels.

Module III	**BCH, RS Convolutional and Turbo Code**	**12Hrs**
Encoding and decoding using BCH code and RS codes, Introduction to convolutional codes: Encoding, state diagram, trellis diagram, Classification, realization, distance properties. Decoding of convolutional codes: Viterbi algorithm, BCJR algorithm. Performance bounds forconvolutional codes. Turbo codes: Turbo decoding, Distance properties ofturbo codes, Convergence of turbo codes, Applications of linear codes		
Module IV	**Information Theory and coding applications and case study**	**10 Hrs**
Channel coding techniques for 5G wireless networks, LDPC and Polar codes Codes, Advantages, and drawbacks of LDPC codes and Polar codes. Quasi Cyclic LDPC code.Case study: LDPC (low density parity check) Codes in many of the standards including mMTC (massive machine type communication) and D2D (device to device communication)		
Text Books		
1. Shulin and Daniel j, Cistellojr., "Error control Coding", Pearson, 2nd Edition,2010 2. Ranjan Bose, "Information Theory coding and Cryptography", McGraw-Hill, 2nd Edition.		
Reference Books		
1. Todd Moon, "Error Correction Coding: Mathematical Methods and Algorithms", Wiley Publication 2. BernadSklar, "Digital Communication Fundamentals & applications", Pearson Education. Second Edition		
Relevant NPTEL/ MOOCs Course		
1. NPTEL course on Coding Theory by Dr. Andrew Thangaraj, Department of Electrical Engineering IIT Madras		
Other Resources/Links		
1. C. E. SHANNON," A Mathematical Theory of Communication" The Bell System Technical Journal, Vol. 27, pp. 379–423, 623–656, July, October 1948. 2. Arora, K., Singh, J. & Randhawa, Y.S. A survey on channel coding techniques for 5G wireless networks. Telecommunication System 73, 637–663 (2020). 3. Bae, J., Abotabl, A., Lin, H., Song, K., & Lee, J. (2019). An overview of channel coding for 5G NR cellular communications. *APSIPA Transactions on Signal and Information Processing, 8*, E17. doi:10.1017/ATSIP.2019.10		

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
504610: Antennas for Modern Wireless Communications

Teaching Scheme	Credits	Examination Scheme:
TH: 03 Hrs. / Week	**03**	**In -Semester: 50 Marks** **End Semester: 50 Marks**

Prerequisite: Electromagnetics, Antenna Fundamentals, Signal Processing

Course Objectives

Objective of this course is to provide students with

1. An overview antennas for the modern wireless communications
2. Latest trends, and multiple antenna techniques
3. The foundation of Smart antennas, MIMO techniques
4. Fundamentals of beamforming techniques

Course Outcomes

CO1: Identify a suitable antenna for the given standards with specifications.
CO2: Apply the signal processing techniques to antenna arrays.
CO3: Apply beamforming principles to multiple antennas and Optimize SNR, BER.
CO4: Analyze and apply space time coding techniques to MIMO.
CO5: Apply estimation and detection techniques using multiple antennas.

Course Contents

Module I	**Antenna Arrays**	**8Hrs**
Antenna parameters, array principles, linear, planar arrays, phased arrays		
Module II	**Adaptive and Smart Antennas**	**10 Hrs**
Fundamental principle of Adaptive and Smart Antennas, adaptive antenna algorithms, analog and digital beamforming, transmit and receive beam forming		
Module III	**Multiple Input Multiple Output Antennas**	**10 Hrs**
Introduction to MIMO systems, SISO, SIMO, MISO, MIMO structures and capacity, MIMO channel models, introduction to space time codes, diversity techniques, detection and estimation for MIMO		
Module IV	**Direction of Arrival Estimation**	**8Hrs**
Fundamental principle of direction of arrival estimation, mathematical analysis, classification of DOA estimation algorithms, subspace methods, MVDR, MUSIC and its variants, comparative study		

Text Books

1. Rakhesh Singh Kshetrimayum, “Fundamentals of MIMO Wireless Communications”,Cambridge University Press, 2017
2. Theodore S Rappaport, “Smart Antennas: Adaptive Arrays, Algorithms, & Wireless Position Location”, IEEE, 1998

Reference Books

1. Mietzneretal, Multiple Antenna Techniques for Wireless Communications, A Comprehensive Survey, IEEE Communications Surveys & Tutorials, Vol. 11, No. 2, Second Quarter 2009

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
504611 (A): Machine Learning for Wireless Communications (Elective – II)

Teaching Scheme	Credits	Examination Scheme
TH: 04 Hrs. / Week	**04**	**In -Semester: 50 Marks** **End Semester: 50 Marks**

Prerequisite: --

Course Objectives:

Objective of this course is to provide students with:

1. A strong foundation of fundamentals of Machine learning.
2. The knowledge and understanding of ML based various applications to wireless networks
3. Detailed analysis of MIMO systems in wireless communication designed using ML algorithms.

Course Outcomes:

CO1: Understand the principles of machine learning and apply the fundamental principles for regression and classification.

CO2: Apply machine learning principles in the design of some physical layer techniques in wireless communications.

CO3: Design massive MIMO system by applying the principles of machine learning and deep learning.

Course Contents

Module I	**Introduction of ML for WC**	**11Hrs**

Fundamentals of ML in WC, ML architectures, Supervised, un-supervised, reinforcement and hybrid learning networks and approaches, various aspects and fundamentals of ML and DL and its applications to wireless networks, Various aspects of communication systems, wireless system design, where machine learning can be applicable in various OSI layers of a communication system, how real time schedulers can benefit from advanced machine learning techniques

Module II	**Supervised Learning and its applications in wireless systems**	**12Hrs**

Overview of supervised learning algorithms, Support vector machines (SVM), Sparse Bayesian learning (SBL), SVM for beamforming and data detection in millimeter wave systems, SBL for channel estimation in massive MIMO, Applications in modulation classification, adaptive modulation and coding mechanisms for wireless systems.

Module III	**Un-supervised Learning and its applications in wireless systems**	**12Hrs**

Overview of unsupervised learning algorithms, K-means clustering, Gaussian mixture models (GMM), Clustering for massive MIMO system using K means and GMM, Use of principal component analysis in massive MIMO system design, auto encoders in wireless communication transceiver design.
Overview of reinforcement learning, Reinforcement learning-based channel sharing in wireless vehicular networks

Module IV	**Deep Learning and its applications in wireless systems**	**10 Hrs**

Deep learning for the physical layer, Deep architectures for Modulation Recognition, Channel State Information Prediction for 5G Wireless Communications and Deep Learning Based MIMO Communication. Deep Learning Techniques in Wireless Signal Recognition. Study of recent papers in the WC domain that explored deep learning approaches.

Reference Books:

1. Fa-Long Luo, " Machine Learning for Future Wireless Communications", Wiley-IEEE Press, Feb 2020 (ISBN: 9781119562252)
2. Ruisi He, Zhiguo Ding, "Applications of Machine Learning in Wireless Communications", Institution of Engineering & Technology, 2019 (ISBN : 1785-616579, 9781785616570)

Other Resources/Links:

Some of the research papers and case studies may be included like:

1. "Deep Learning in Mobile and Wireless Networking: A Survey" (Jan -2019 , Zhang et al., IEEE Communications Survey and Tutorial,(https://arxiv.org/pdf/1803.04311.pdf)
2. "Wireless Networks Design in the Era of Deep Learning: Model-Based, AI-Based, or Both?",(June – 2019), AlessioZappone, Senior Member, IEEE, (https://arxiv.org/pdf/1902.02647.pdf)
3. "6G White Paper on Machine Learning in Wireless Communication Networks" (April 2020) , Samad Ali et al., https://arxiv.org/pdf/2004.13875.pdf)
4. "Machine Learning for 5G/B5G Mobile and Wireless Communications: Potential, Limitations, and Future Directions," (2019), Morocho et al., (doi: 10.1109/ACCESS.2019.2942390)

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
504611 (B): Optical Wireless Communication (Elective -II)

Teaching Scheme	Credits	Examination Scheme
TH: 04 Hrs. / Week	**04**	**In -Semester: 50 Marks** **End Semester: 50 Marks**

Prerequisite: Knowledge of Semiconductor Devices, Data Communication, Fiber Optic Communication

Course Objectives

1. To understand the characteristics of Indoor and Outdoor IR systems, performance of Wireless IR link under Atmospheric turbulence.
2. To understand the transmitter design considerations and receiver design considerations for optical wireless communication.
3. To understand different modulation schemes and different multiple access techniques for sharing IR medium.
4. To understand the standards of IrDA technology, features and the different layers of the IrDA protocols for optical wireless networking.

Course Outcomes

CO1: To explain the characteristics of Indoor and Outdoor IR systems, transmission impairments of Wireless IR communication.
CO2: To design the transmitter based on LED/Laser diode for optical wireless communication.
CO3: To design the receiver based on semiconductor photodiodes for optical wireless communication.
CO4: To choose a right modulation scheme for indoor & outdoor applications and the different multiple access techniques.
CO5: To apply IrDA protocols to create simple, cost-effective and low power transceivers that enable wireless IR communication in a number of devices.

Course Contents

Module I		**8 Hrs**
Basic concept of Optical wireless communication, Optical Wireless channels, Light sources, Modulators, Detectors, Atmospheric transmission limitations, Effect of Rain, Fog, and Mist, Scintillation, Optical Path Length and Fermat's Principle, The Etendue or Lagrange Invariant, Edge Ray Principle.		
Module II		**8Hrs**
Gaussian Beam, Telescope, beam expander, Optical filter and anti- reflection coating, Optical Concentrators, Wireless IR Receiver Requirements, DTIRC Characteristics. Comparison of Concentrators. Practical Issues. Different Shapes of DTIRCs, Tracking system, Laser beam steering device.		
Module III		**8Hrs**
Optical Wireless Transmitter Design, Transmitter Design Considerations, Optical Source Characteristics. Types of Optical Modulation. Driver Circuit Design Concepts. Current Steering Output Circuit, Back Termination Circuit, Predriver, Data Retiming, Automatic Power Control, Transmitters Linearization Techniques.		
Module IV		**8 Hrs**
Optical wireless receiver design, Receiver Design Considerations, Photodetection in Reversebiased Diodes. Choosing the Photodetector, Receiver Noise Consideration, Bit Error Rate and Sensitivity, Bandwidth, Signal Amplification Techniques, Receiver Main Amplifier (RMA). Transceiver Circuit Implementation Technologies.		

Module V		**8 Hrs**
Modulation and Multiple Access Techniques, IrDA PROTOCOLS. Wireless Protocol Standards. The Infrared Data Association, The Physical Layer Protocol, Framer/Driver, IrLAP, IrLMP, Information Access Service and Protocol, Tiny Transport Protocol, Session and Application Layer Protocols, WIRELESS IR NETWORKING, The Ad Hoc Network, Quality of Service (QoS), MIMO Wireless optical channel, Pixelated Wireless optical channel. Introduction to **OFDM based visible light communication**		
Text Books		
1. Sadiku, Matthew N. O., "Optical and Wireless Communications", CRC Press. 2. Ramirez-Iniguez, Roberto Idrus, Sevia M, "Optical Wireless Communications: IR for Wireless Connectivity", Auerbach Publications.		
Reference Books		
1. Chi Lee, "Microwave Photonics", CRC Press, 2006. 2. Steve Hranilovic, "Wireless Optical Communication Systems", Springer.		
Relevant MOOCs /NPTEL Course		
https://nptel.ac.in/courses/117/104/117104127/		

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
504611 (C): Modern Satellite Communication (Elective -II)

Teaching Scheme	Credits	Examination Scheme
TH: 04 Hrs. / Week	**04**	**In -Semester: 50 Marks** **End Semester: 50 Marks**

Prerequisite: Knowledge of Semiconductor Devices, Data Communication, Fiber Optic Communication

Course Objectives

1. To exemplify in depth knowledgeof Satellite communication system.
2. To have a detailed understanding of the critical RF parameters in satellite transceiver and their effects on performance.
3. To have a detailed understanding of the fundamental theory and concepts of the Global Positioning and inertial navigation System.

Course Outcomes

CO1: Design the orbital and functional metrics of satellite communication systems.
CO2: Design the link budget for satellite services and analyze various parameters of transmitted and received signals through satellite.
CO3: Analyze user position using GPS pseudo-range data and error sources for GPS position calculations.
CO4: Analyze strap down inertial navigation systems including coordinate frames, attitude representation, and mechanization in various coordinate frame.
CO5: Develop a location based service using external data sources and services, web mapping and aspects of mobile technology.
CO6: Analyze the estimation techniques for integration of remote sensing sensors in an optimal navigation system

Course Contents

Module I		**06 Hrs**
Introduction to Satellite Communication Overview of satellite communications Types of satellites Kepler's three laws of planetary motion, Orbital elements, Look angle determination, Orbital pert		
Module II		**06 Hrs**
Launch and Satellite Systems Launch vehicles, Launching techniques, Orbital effects in satellite communication systems performance, Satellite subsystems, Satellite constellations		
Module III		**08 Hrs**
Global Navigation Satellite System Global Navigation Satellite Systems, Basic concepts of GPS, Space segment, Controlsegment, user segment, GPS constellation, GPS measurement characteristics, Selective availability, Anti spoofing(AS). Applications of satellite and GPS for 3D position, Velocity, determination as function of time, Regional navigation systems		
Module IV		**06 Hrs**
Inertial Navigation Introduction to Inertial Navigation, Inertial sensors, Navigation coordinates, System implementations, System, Level error models, introduction to Differential GPS, LADGPS, WADGPS, WAAS, GEO Uplink Subsystem (GUS), Clock steering algorithms, GEO orbit determination		

Module V		**08 Hrs**
Distress and safety, Cospas, Sarsat, Inmarsat distress system, Location-based service, Problems. Overview of sensors, Optical sensors: cameras, Non-Optical sensor, Image processing, Image interpretation, System characteristics.Introduction to remote sensing systems, Commercial imaging, Digital globe, GeoEye, Meteorology, Meteosat, Land observation, Landsat, Remote sensing data		
Module VI		**06 Hrs**
Introduction, Satellite radio systems, XM satellite radio inc., Sirius satellite radio, World space, Direct multimedia broadcast, MBCO and TU multimedia, European initiatives, Direct To Home (DTH) television, Implementation issues, DTH Services, representative DTH Systems, Military multimedia broadcasts, US Global Broadcast Service (GBS), Business TV(BTV), GRAMSAT, Specialized services, Email, Video conferencing, Internet		

Text Books

1. Mohinder S. Grewal, Lawrence R. Weill, Angus P. Andrews, "Global Positioning Systems, Inertial Navigation, and Integration",John Wiley & Sons, 1st Edition, 2011.
2. T. Pratt, C.W. Boastian, Jeremy Allnutt, "Satellite Communication", John Wiley & Sons, 2nd Edition, 2013.

Reference Books

1. Madhavendra Richaria,, "Mobile Satellite Communications: Principles and Trends",John Wiley &Sons, 2nd Edition , 2014.
2. D. Roddy, "Satellite Communications", McGraw Hill, 4th Edition, 2011.
3. W.L. Pritchard, H.G Suyderhoud, "Satellite Communication Systems Engineering",Pearson Education, 2nd Edition, 2011.
4. Tri T. Ha, "Digital Satellite Communications, 2011", McGraw Hill, 2nd Edition.

Relevant MOOCs/NPTEL Course

Modern Satellite Communication By Prof. Prof. KalyankumarBandyopadhyay | IIT Kharagpur https://onlinecourses.nptel.ac.in/noc21_ee11/preview

Other Resources/Links

https://nptel.ac.in/content/syllabus_pdf/117105131.pdf
https://www.satcom.co.uk

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
504611 (D): Radar Communications (Elective -II)

Teaching Scheme	Credits	Examination Scheme
TH: 04 Hrs. / Week	**04**	**In -Semester: 50 Marks** **End Semester: 50 Marks**

Prerequisite: Signals processing, Microwave engineering, Antenna system

Course Objectives

1. To provide good understanding of radar system, radar signal processing, target tracking and image formation with design aspects

Course Outcomes

CO1: Understand radar systems.
CO2: Analyze radar signal processing.
CO3: Appreciate the wide range of applications of radar system.
CO4: Able to design and develop the low power radar system.

Course Contents

Module I	**Fundamentals of Radar**	**8Hrs**
Radar Range Equation, Radar cross section estimation methods, RCS of simple and complex target Radar parameters: PRF, unambiguous range, velocity, frequency agility, pulse width, resolution, bearing angle, blind speed etc.		
Module II	**Types of Radar**	**10 Hrs**
Pulse radar, CW radar, MTI, tracking and search radar, weather radar, Navigational radar, MST radar, Synthetic Aperture radar, Phased array radar, Display types		
Module III	**Detection of radar signal**	**10 Hrs**
Radar signal processing, radar imaging, interferometry, polarimetry, beamforming techniques for radar		
Module IV	**Low power Radar design and case studies**	**8Hrs**

Text Books

1. Merrill Skolnik, "Radar Handbook", 3rd Edition
2. Jiaguo Lu, "Design Technology of Synthetic Aperture Radar", Wiley-IEEE Press.
3. Kung Yao, "Signal Processing Algorithms for Communication and Radar Systems", Cambridge University Press.
4. William L. Melvin, "Principles of Modern Radar: Radar Applications".

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
504612: Mini Project / Seminar - I

Teaching Scheme	Credits	Examination Scheme
PR: 03 Hrs./Week	**03**	**TW: 50 Marks** **OR: 50 Marks**

Prerequisite: Basics and Fundamental knowledge of the Engineering Graduate Subjects

Course Objectives:

Objective of this course is to provide students with

1. The knowledge and understanding of the subjects
2. To refer library resources- Journals/Magazines/Transactions
3. To have hands on practice

Course Outcomes:

CO1: To practice the concept learned.
CO2: To build a project and its implementation.
CO3: To Contribute to the technical domain.

Course Contents

Module I	**Literature Survey in current technologies**	**8Hrs**
Student must refer to good publications (IEEE Transactions, ACM & Indexed Journal		
Module II	**Scope Identification**	**6Hrs**
Findings, Observation, Motivation, Problem Definition		
Module III	**Resources and Platforms**	**8Hrs**
Student to identify and learn the resources required to carry out the work		
Module IV	**Implementation, Experimentation and Validation**	**8Hrs**
Lab work under guidance of teacher		
Module V	**Report writing and presentation**	**8Hrs**
Student to write and prepare report as per prescribed format		
Module VI	**Publication**	**6Hrs**
To present and publish results in reputed conferences/ journals, approved by college/University/UGC		
Evaluation by mentor, Feedback by Student		

Text Books

1. Journals/ Transactions/ Magazines from Library
2. Books related to Technical Writing

Reference Books

1. As specified by Teacher/ Mentor/ Guide/PG Committee of the Centre

Savitribai Phule Pune University, Pune M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course 504614: Lab Practice-II		
Teaching Scheme:	**Credits**	**Examination Scheme:**
PR: 08 Hrs./ Week	**04**	**TW: 50 Marks** **OR: 50 Marks**
Laboratory experiments based on the courses being taught. Minimum ten experiments, case studies to be carried out including hardware and simulation based experiments.		

SEMESTER - III

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
604601: Advanced Wireless Network

Teaching Scheme	Credits	Examination Scheme
TH: 03 Hrs. / Week	**03**	**In -Semester: 50 Marks** **End Semester: 50 Marks**

Prerequisite: Digital communication, Computer networks

Course Objectives

Objective of this course is to provide students with

1. The knowledge and understanding of advanced wireless networking fundamentals
2. Provide a strong foundation of fundamental wireless networking system
3. Detailed analysis of end-to-end wireless networking system and its frame formats
4. Build an understanding of thevarious protocol stacks and standards of different wireless networks
5. Performance evaluation of Wireless networks technologies.

Course Outcomes

CO1: Understand and familiarize various wireless data networking technologies, analyze IEEE 802.11-physical layer-MAC layer standards, its Security Mechanisms and Comparing their performances.

CO2: Describe and analyze various WPAN and WMAN wireless networks, its specifications, protocol stack understanding, and its Security Mechanisms.

CO3: Represent and analyze various advanced wireless technologies like LoRa, SigFox, NFC, LMDS, MMDS in the terms of network architecture, Frame structure, specifications, advantages, disadvantages and their technical comparison in detail.

CO4: Explain and analyzevarious advanced wireless technologies likeZigbee, Z-wave, Ultra-Wideband (UWB)in the terms of network architecture, Frame structure, specifications, advantages, disadvantages and their technical Comparison in detail

Course Contents

Module I	**Introduction to wireless data networks and 802.11 WLAN**	**8Hrs**

Data Networks and Internetworking, Introduction to Wireless Data Networks, MAC layer, Physical layer of IEEE 802.11, The 802.11 Standards (WLAN or WI-FI), Potential Security Issues with Wireless LAN Systems, Overview of 802.11b Security Mechanisms.

Module II	**WPAN and WMAN networks**	**10 Hrs**

Overview of the 802.15 WPAN,Bluetooth Network, Bluetooth technical specifications, High-Level View, The General Requirements of 802.15, How WPANs differ from WLANs, Power Levels and Coverage, Control of the Medium. Lifespan of the Network, 802.15 Security,the 802.16 Wireless MAN Standards, Metropolitan Area Mesh Networks, Implementing Wireless MANs.

Module III	Wireless Technologies-I	**10 Hrs**

LoRa network architecture, LoRa Frame structure, LoRa protocol stack, SigFox specifications, SigFox network architecture, SigFox Frame structure, SigFox protocol stack. NFC features, NFC working, NFC network modes, NFC Frame structure, NFC protocol stack, NFC versus RFID, NFC security. LMDS architecture, LMDS advantages and disadvantages, MMDS architecture, MMDS advantages and disadvantages, Comparison between LMDS and MMDS.

Module IV	Wireless Technologies-II	**8Hrs**
Zigbee network overview, Forming the Zigbee Network, Joining the Zigbee Network, zigbee protocol stack, Zigbee Physical and MAC Layer. Z-wave specifications, z-wave frequency bands, z-wave network, z-wave frame structure, z-wave protocol stack.Ultra Wideband (UWB)wireless working, UWB transmitter, UWB receiver, Modulation Schemes, typical specifications.		
Text Books		
1. Vern Dubendorf, "Wireless Data technologies reference Handbook", Wiley Publication. 2. Behrouz A. Foruzan, "Data communication and Networking", Tata McGraw-Hill,5th Edition.		
Reference Books		
1. Steve Rackley, "Wireless Networking Technology: From Principles to Successful Implementation", Elsevier publisher. 2. https://www.rfwireless-world.com/Tutorials		
Relevant MOOCs Course		
Lecture Series on Wireless Communications by Dr.Ranjan Bose, Department of Electrical Engineering, IIT Delhi.		

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
604602: Software Defined Radio and Cognitive Radio

Teaching Scheme	Credits	Examination Scheme
TH: 03 Hrs. / Week	**03**	**In -Semester: 50 Marks** **End Semester: 50 Marks**

Prerequisite: Digital communications systems, Communication Networks, software tools MATLAB/ LabVIEW are desirable, but not necessary

Course Objectives

Objective of this course is to provide students with

1. The knowledge and understanding of SDR Architectures
2. To study the Challenges, and issues regarding the implementation of SDR.
3. To analyzethe techniques involved in Cognitive Radio Communications and networks
4. To applySpectrum Sensing techniques to Detect Primary System.
5. To review Cognitive radio in recent applications

Course Outcomes

CO1: To Analyze and compare different SDR Architectures.
CO2: To investigates Challenges, and issues regarding the implementation of SDR.
CO3: To analyze the techniques involved in Cognitive Radio Communications and networks for a specific network scenario.
CO4: To compare various Spectrum Sensing techniques and to apply it to Detect Primary System.
CO5: To design and simulate Cognitive radio system for given specification and application.

Course Contents

Module I	**Software Defined Radio**	**8Hrs**

Software Defined Radio Architecture, Digital Signal Processor and SDR Baseband Architecture, Reconfigurable Wireless Communication Systems, Reconfigurable OFDM Implementation, Digital Radio Processing, Digital Radio Processing (DRP) Based System Architecture, Challenges, and issues regarding the implementation of SDR, Processing, programmability (flexibility) vs power consumption. Application of SDR in advanced communication systems, Low-Cost Cognitive Radio Platform, Convergence between military and commercial systems,case study of universal software radio peripheral (USRP)

Module II	**Cognitive Radio Communications and networks**	**12Hrs**

Cognitive Radios and Dynamic Spectrum Access, the Capability of Cognitive Radios, Spectrum Sharing Models of DSA, Opportunistic Spectrum Access: Basic Components , Networking the Cognitive Radios, Analytical Approach and Algorithms for Dynamic Spectrum Access , Dynamic Spectrum Access in Open Spectrum , Opportunistic Spectrum Access , Opportunistic Power Control, Fundamental Limits of Cognitive Radios. Network Coding for Cognitive Radio Relay Networks , System Model , Network Capacity Analysis on Fundamental CRRN Topologies , Cognitive Radio Networks Architecture, Network Architecture , IP Mobility Management in CRN , Terminal Architecture of CRN , Cognitive Radio Device Architecture , Radio Access Network Selection , QoS Provisional Diversity Radio Access Networks , cooperative/Collaborative Diversity and Efficient Protocols , Statistical QoS Guarantees over Wireless Asymmetry, Collaborative Relay Networks , Scaling Laws of Ad-hoc and Cognitive Radio Networks , Network and Channel Models.

Module III	**Spectrum Sensing and awareness**	**10 Hrs**
Spectrum Sensing to Detect Specific Primary System, Conventional Spectrum Sensing, Power efficiency and energy/battery awareness, Device capability awareness, RF Awareness Interference/noise temperature awareness, channel (medium, radio channel) awareness. Location Awareness, Power Control, Power-Scaling Power Control, Cooperative Spectrum Sensing, Spectrum Sensing for Cognitive OFDMA Systems, Cognitive Cycle , Discrimination of States of the Primary System , Spectrum Sensing Procedure , Spectrum Sensing for Cognitive Multi-Radio Networks, Multiple System Sensing , Radio Resource Sensing.		
Module IV	**Cognitive radio in recent applications and case study**	**12 Hrs**
Medium access control for CR, Applications of cognitive radio, Cognitive features in the standards (like 802.16m, LTE advanced, 802.11n, adaptive frequency hopping in Bluetooth), Femto-cells and relation to cognitive radio, UWB and Cognitive radio (underlay and overlay) systems. Security issues in CRN. CR based Internet of Things (IoT). Case study: IEEE 802.22 WRAN standard		
Text Books		
1.PeymanSetoodeh and Simon Haykin, Fundamentals of Cognitive Radio, First Edition, by John Wiley & Sons, Inc, 2017 2.Kwang-Cheng Chen and Ramjee Prasad Cognitive Radio Networks, John Wiley & Sons Ltd.,2009		
Reference Books		
1. HüseyinArslan, Cognitive Radio, Software Defined Radio, and Adaptive Wireless Systems Published by Springer 2007.		
Relevant Coursera/ MOOCs Course		
Basic of SDR and Practical applications by Dr. MeenakshiRawat, IIT Roorki. https://nptel.ac.in/courses/108/107/108107107/		
Other Resources/Links • Akyildiz, I. F., Lee, W.Y., Vuran, M.C., Mohanty, S., "NeXt Generation/Dynamic Spectrum Access/Cognitive Radio Wireless Networks: A Survey," Computer Networks (Elsevier) Journal, September 2006. • Akyildiz, I.F., Lee W. Y., and Chowdhury, K., "CRAHNs: Cognitive Radio Ad Hoc Networks," Ad Hoc Networks (Elsevier) Journal, vol. 7, no. 5, pp. 810-836, July 2009. • HaythemBanySalameh and Marwan Krunz, "Channel access protocols for multi-hop opportunistic networks: Challenges and recent developments," IEEE Network, Vol. 23, Issue 4, pp. 14-19, July-August 2009 • Rezwanul Mahmood M., Matin M.A. (2020) Current Research Trends on Cognitive Radio Based Internet of Things (IoT). In: Matin M. (eds) Towards Cognitive IoT Networks. Internet of Things (Technology, Communications and Computing). Springer, Cham, March 2020.		

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
604603(A): Wireless Adhoc Network (Elective – III)

Teaching Scheme	Credits	Examination Scheme
TH: 04 Hrs. / Week	**04**	**In -Semester: 50 Marks** **End Semester: 50 Marks**

Prerequisite: Digital communication, Computer networks, wireless communication

Course Objectives

Objective of this course is to provide students with

1. The knowledge and understanding of Ad Hoc Wireless Networks, Wireless Sensor Networks, Hybrid wireless Networks and related MAC, Network and Transport layer Protocols
2. To know the constraints of the wireless physical layer that affect the design and performance of ad hoc and sensor networks, protocols, and applications.
3. To understand MAC, Routing protocols that have been proposed for ad hoc and sensor networks.
4. To understand the energy issues in sensor networks and how they can be addressed using scheduling, media access control, and special hardware.
5. To develop efficient protocols for sensor and mobile networks. Also, apply Fundamental principles characteristics and develop information dissemination protocols for sensor and ad hoc networks.
6. Build an understanding of the Hybrid wireless Networks and carry out the Performance evaluation related to Power Control Schemes.

Course Outcomes

CO1: Identify and disseminate the various unique issues in ad-hoc/sensor networks, describe current technology trends for the implementation, deployment of wireless ad-hoc/sensor networks and discuss the challenges in designing MAC protocols for ad-hoc networks.

CO2: Understand various the challenges in designing routing protocols, transport protocols and their classifications for wireless Ad-hoc networks and accordingly, apply different routing technologies for designing a routing protocol.

CO3: Comprehend, describe and analyzevarious sensor network platforms, tools, applications, MAC Protocols, Quality of a Sensor Network and related evolving standards.

CO4: Exemplify and evaluate various Next-Generation Hybrid Wireless Architectures and related optimized routing mechanisms and efficient power control schemes

Course Contents

Module I	**Ad Hoc Wireless Networks and MAC Protocols**	**8Hrs**
Introduction. Issues in Ad Hoc Wireless Networks. Ad Hoc Wireless Internet. Introduction, Issues in Designing a MAC Protocol for Ad Hoc Wireless Networks. Design Goals of a MAC Protocol for Ad Hoc Wireless Networks. Classifications of MAC Protocols. Contention-Based Protocols.		
Module II	**Routing Protocols and Transport Layer Protocols**	**10 Hrs**
Introduction to Routing algorithm, Issues in Designing a Routing Protocol for Ad Hoc Wireless Networks. Classifications of Routing Protocols. Introduction. Issues in Designing a Transport Layer Protocol for Ad Hoc Wireless Networks. Design Goals of a Transport Layer Protocol for Ad Hoc Wireless Networks. Classification of Transport Layer Solutions. TCP Over Ad Hoc Wireless Networks. Other Transport Layer Protocols for Ad Hoc Wireless Networks.		
Module III	**Wireless Sensor Networks**	**10 Hrs**

Introduction. Sensor Network Architecture. Data Dissemination. Data Gathering. MAC Protocols for Sensor Networks. Location Discovery. Quality of a Sensor Network. Evolving Standards. Other Issues.		
Module IV	**Hybrid wireless Networks**	**8Hrs**
Introduction. Next-Generation Hybrid Wireless Architectures. Routing in Hybrid Wireless Networks. Pricing in Multi-Hop Wireless Networks. Power Control Schemes in Hybrid Wireless Networks. Load Balancing in Hybrid Wireless Networks.		
Text Books		
1. Siva Ram Murthy, C. and Manoj,B. S., "Adhoc Wireless Networks Architectures and Protocols", Prentice Hall, 2nd Edition, 2004. 2. Perkins, Charles E., "Ad hoc Networking", Addison Wesley, 3rd Edition, 2003.		
Reference Books		
1. Toh, C. K., "Ad hoc Mobile Wireless Networks Protocols and Systems", Prentice Hall, 3rd Edition 2001. 2. Pahlavan, Kaveh., Krishnamoorthy, Prashant., "Principles of Wireless Networks: A united approach" ,Pearson Education, 2nd Edition, 2002. 3. Wang X. and Poor H.V., "Wireless Communication Systems", Pearson Education, 3rd Edition,2004. 4. Schiller Jochen., "Mobile Communications", Person Education , 2nd Edition, 2003. 5. Carlos De Morais Cordeiro and Dharam P Agrawal, "Adhoc and Sensor Networks-Theory & Applications", Cambridge Univ Press India Ltd, 2nd Edition.		
Relevant MOOCs Course		
Lecture Series on Wireless Ad Hoc Networks and sensor networks by Prof. SudipMisra, Department of Computer Science and Engineering, IIT Kharagpur.		

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
604603 (B): Telecommunications Network Management (Elective -III)

Teaching Scheme	Credits	Examination Scheme
TH: 04 Hrs. / Week	**04**	**In -Semester: 50 Marks** **End Semester: 50 Marks**

Prerequisite: Basics and Fundamental of the Signals- Systems and Networking subjects

Course Objectives:

Objective of this course is to provide students with

1. The principles of Telecommunication Network Management.
2. To gain knowledge on telecomm network management protocols.

Course Outcomes:

CO1: Understanding of Telecom Network Management.
CO2: To implement in network, the better management practices.

Course Contents

Module I	**Introduction**	**8Hrs**
Overview of Data Communication and Network Management – Goals, Organization and Functions; Network Management – Architecture and Organization; Network Management Perspectives; Current Status and Future of Network Management. Network Topology, Network Node Components, Transmission Technology.		
Module II	**SNMP And Network Management**	**8Hrs**
Network Management Standards, Network Management Models, Organizational Model, Information Model, Communication Model. SNMPv1 –History of SNMP, Internet Organization and Standards, SNMP Model, Organizational Model, System Overview, Information Model. SNMP Communication Model, Functional Model.SNMPv2 and SNMv3.		
Module III	**Telecommunications Management Network**	**8Hrs**
TMN Conceptual Model, TMN Standards, TMN Architecture, TMN Management Service Architecture, TMN Integrated View, TMN Implementation.		
Module IV	**Network Management Applications**	**8 Hrs**
Configuration Management, Fault Management, Performance Management, Security Management, Service Level Management, Accounting Management, Report Management, Policy- Based Management		
Module V	**Web Based Management**	**6Hrs**
Setting-UP LAN Access, SNMP configuration, Switched Port Analyzer, Web Browser / Web Server Communication.		
Module VI	**IP Network Management**	**6Hrs**
IP Network Management – Configuration, Management Information Base, Simple Network Management Protocol, IP-Based Service Implementation- Network Management Issues, OSS Architecture.		
Evaluation by mentor, Feedback by Student		

Text Books

1. Mani Subramanian “Network Management – Principles and Practice”, Addison- Wesley, 2000.
2. Salah Aiidarons, Thomas Plevayk, "Telecommunications Network Technologies and Implementations", Eastern Economy Edition IEEE press, New Delhi, 1998.

Reference Books

1. Lakshmi. G, Raman, "Fundamentals of Telecommunication Network Management", Eastern Economy Edition IEEE Press, New Delhi
2. J. Richard Burke, “Network Management: Concepts and Practice, A Hands-on Approach “, Pearson Education, 2008.

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
604603 (C): Wireless Networks Security (Elective- III)

Teaching Scheme	Credits	Examination Scheme
TH: 04 Hrs. / Week	**04**	**In -Semester: 50 Marks** **End Semester: 50 Marks**

Prerequisite: Digital communication, Computer networks, wireless communication

Course Objectives: Objective of this course is to provide students with

1. The knowledge and understanding of wireless networks insecurities, and related wireless security terminologies.
2. Provide a strong foundation of fundamental wireless Security Principles, Wireless Tools and Gadgets requirements.
3. Detailed analysis of end-to-end wireless network security and wireless client's security fundamentals, especially the factors that exacerbate Wireless Client Vulnerabilities
4. Build an understanding of thevarious attacks on protocol stacks and along with hardware and software entities of different wireless networks
5. Performance evaluation of different defense mechanisms of Wireless networks securities and effectiveness of them.

Course Outcomes

CO1: Recognize and disseminate the various security principles required for making strong Wireless Security foundations with related standards, equipment, encryption techniques and tools for implementations.
CO2: Understand and implement various attacks on wireless networks passively and actively with standard WEP and WPA mechanisms and Comparing their performances.
CO3: Describe and analyze various Wireless Client Vulnerabilities, its deep understanding, and sniffing insecure Communications with tools and related technical procedures.
CO4: Represent and evaluate various Defense for Securing Wireless Networks like WPA2-Enterprise with certificates Architecture, its correct deployment, selection of secured network operating system and its error free configuration for rugged wireless security implementations.

Course Contents

Module I	**Wireless Security Foundations**	**8Hrs**
Introduction to the Wireless Security,Security Principles, Wireless Networking Basics:802.11a/b/g/n, Access Points, Autonomous vs. Controller Based, SSID, BSSID, MAC Address, Beacons and Broadcasts, Associating and Authenticating, Encryption,Wireless Tools and Gadgets.		
Module II	**Theory of Attacks on Wireless Networks**	**10 Hrs**
Setting the Stage, Authentication, Encryption, How WEP Works, How WPA Works, Attacking Wireless Networks, Wireless Reconnaissance, Actively Attacking Wireless Networks, Cracking WEP Encryption, Cracking a WPA Passphrase.		
Module III	**Attacking Wireless Clients**	**10 Hrs**
Wireless World, Wireless Client Vulnerabilities, Factors That Exacerbate Wireless Client Vulnerabilities, Wireless Reconnaissance, Sniffing Insecure Communications, Default Operations, Man-in-the-Middle Attacks.		
Module IV	**Real-World Wireless Security Defenses**	**8Hrs**

Theory of Defense for Securing Wireless Networks, Setting the Stage, Phases of Wireless Deployment, Secure Design Principles for Wireless Networks, Useless Defenses, Good Wireless Defenses, Understanding the WPA2-Enterprise with Certificates Architecture, Deploying Secure Wireless Networks, Handling Wireless Guest Access, Handling Rogue Access Points and the Future of Wireless Security, The Wireless Engineer's Operating System of Choice.

Text Books

1. Tyler Wrightson, "Wireless Network Security A Beginner's Guide", US: McGraw-Hill Osborne Media, 1st Edition 2012.2017
2. Wolfgang Osterhage , "Wireless Network Security", Kindle Edition, 2nd Edition, 2018.

Reference Books

1. Yang Xiao, Xuemin Shen, Ding-Zhu Du, "Wireless Network Security" , Springer Science & Business Media.
2. Aaron E. Earle, "Wireless Security Handbook", Taylor & Francis Group, LLC, Auerbach Publications, 2006.

Relevant MOOCs Course

Lecture Series on Cryptography and Network Security by Prof. D. Mukhopadhyay, Department of Computer Science and Engineering, IIT Kharagpur.

Savitribai Phule Pune University, Pune
M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course
604603 (D): MIMO Wireless Communications (Elective -III)

Teaching Scheme	Credits	Examination Scheme
TH: 04 Hrs. / Week	**04**	**In -Semester: 50 Marks** **End Semester: 50 Marks**

Prerequisite: Wireless Communication Principles, Antenna Fundamentals, Signal Processing

Course Objectives

Objective of this course is to provide students with

1. Understanding the importance of MIMO for next generation networks.
2. Identify the role of different diversity formats and spatial multiplexing in combating the effect of fading and maximizing transmission capacity.
3. An introduction to advanced MIMO concepts like multi-user MIMO, massive MIMO and SM-MIMO for next generation communication

Course Outcomes

1. Characterize and model the MIMO wireless channel
2. Design and implement diversity coding techniques to overcome the effect of fading
3. Assemble different forms of diversity to improve the error performance
4. Design low-complexity, linear and non-linear receivers
5. Evaluate the performance of concatenated codes for MIMO communication

Course Contents

Module I	**Introduction to MIMO Systems**	**8Hrs**

Introduction, Multi antenna systems, Array gain, Diversity gain, Data pipes, Spatial multiplexing, Wireless channel, MIMO channel characteristics, MIMO system model, MIMO system capacity, Water pouring principle

Module II	**Diversity Techniques**	**8Hrs**

Diversity, Types, Selection diversity, Scanning diversity, Maximum ratio combining, Equal gain combining, Calculation of SNR

Module III	**Space-Time Block and Trellis Codes**	**12Hrs**

Transmit diversity with two antennas: The Alamouti scheme –Orthogonal. and Quasi-orthogonal space-time block codes –Linear dispersion codes –Generic space-time trellis codes –Basic space-time code design principles –Representation of space-time trellis codes for PSK constellation –Performance analysis for space-time trellis codes –Comparison of space-time block and trellis codes

Module IV	**Introduction to Massive MIMO**	**8Hrs**

Potential of massive MIMO systems, massive MIMO concept, uplink transmission with linear detection, down link with linear precoding, spectral efficiency, power allocation, limitations of massive MIMO

Text Books

3. Aditya K. Jagannatham, Principles of Modern Wireless Communications Systems, 2015, 1stEdition, McGraw-Hill Education, India
4. Marzetta, T.L. Massive MIMO: An Introduction.Bell Labs Tech. J.2015,20, 11–22
5. Erik G. Larsson etal, Massive MIMO for Next GenerationWireless Systems, IEEE Communications Magazine • February 2014

Reference Books

1. A. B. Gershman, N. D. Sidiropoulus, Space-time Processing for MIMO Communications, 2011, 1stEdition, Wiley, NJ, USA
2. M. Janakiraman, “Space-time codes and MIMO systems”, Artech House, 2004.3.
3. H. Jafarkhani, “Space-time coding: Theory & Practice”, Cambridge University Press, 2005.

Relevant MOOCs Course

Fundamentals of MIMO Wireless Communication, By Prof. SuvraSekhar Das | IIT Kharagpur
https://nptel.ac.in/courses/117/105/117105132/

Other Resources/Links

Savitribai Phule Pune University, Pune M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course 604604: Industry Internship-I / In-house Research Project-I / Seminar - II		
Teaching Scheme:	**Credits**	**Examination Scheme:**
TH: 03 Hrs. / Week	**03**	**TW: 50 Marks** **OR : 50 Marks**

Students shall be permitted to choose Industry internship, In House Research Project or Employability Entrepreneurship as per the following Guidelines.

Industry Internship/Entrepreneurship: Institution shall facilitate or student may chose an industry internship in the appropriate field of Wireless Communication Technologies. Student shall directly report to industry for the duration of the course weekly on prescribed days as per the mutual convenience of the institute and industry without missing the course work at the institution. Student is required to prepare a detailed proposal on the nature of the work/project undertaken at the industry, name of the expert, and letter of intent from the industry, get it approved from the institute. Student is required to submit the weekly report to the institute. Student shall present a find report on the work carried out at industry in prescribed format to the institute. Appropriate evaluation scheme shall be evolved by the institute and marks shall be awarded appropriately as per the performance of the student.

In-House Research Project: Student shall be permitted to work under an ongoing funded research project under the faculty who is the Principal Investigator for funded project or student may choose any other topic of interest in the field of Wireless Communication. Student is required to submit the proposal with clear problem definition, scope of the work and a weekly progress on the work. Student is required to report to the institute/lab as per the regular schedule. Progress will be closely monitored by the institute. Student shall present a find report on the work carried out at industry in prescribed format to the institute. Appropriate evaluation scheme shall be evolved by the institute and marks shall be awarded appropriately as per the performance of the student.

Savitribai Phule Pune University, Pune M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course 604605: Dissertation Stage - I		
Teaching Scheme:	**Credits**	**Examination Scheme:**
TH: 08 Hrs. / Week	**08**	**TW: 50 Marks** **OR : 50 Marks**
Dissertation Stage – I : 604605		
As per the dissertation guidelines common to all the streams of E&TTC		

SEMESTER – IV

Savitribai Phule Pune University, Pune M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course 604607: Industry Internship-II / In House Research Project – II Seminar – III		
Teaching Scheme	**Credits**	**Examination Scheme**
PR: 03 Hrs/week	**03**	**TW: 50 Marks** **OR : 50 Marks**
Students shall be permitted to continue the work carried out in seminar – II or may chose the different industry/project following the similar guidelines		

Savitribai Phule Pune University, Pune M.E. (Electronics Communication- Wireless Communication Technology) 2020 Course 604608: Dissertation Stage – II		
Teaching Scheme	**Credits**	**Examination Scheme**
PR: 03 Hrs/week	**18**	**TW: 150 Marks** **OR : 50 Marks**
As per the dissertation guidelines common to all the streams of E&TC		