ACADEMIC CURRICULA

POST GRADUATE DEGREE PROGRAMMES

Master of Technology

(Choice Based Flexible Credit System)

Regulations 2021

Volume – 24
Syllabi for School of Electrical Engineering Programmes

Professional Core and Elective Courses

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

ACADEMIC CURRICULA

Wireless Communication Technology

Professional Core Courses

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21MAC502T	Course Name	ADVANCED MATHEMATICS FOR COMMUNICATION ENGINEERS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	1	0	4

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mathematics*	**Data Book / Codes / Standards**		*Statistical table*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the concepts of random variables and its applications*
CLR-2:	*learn the concepts of estimation and the various methods of estimation procedure related to random variables.*
CLR-3:	*illustrate the different types of stochastic processes along with examples.*
CLR-4:	*imbibe the statistics and estimating the parameters of random process from detection.*
CLR-5:	*model problems of contention that arise when the set of resources are shared.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*implement the concepts of probability and random variables.*	3	3	
CO-2:	*demonstrate the competency of estimators and method of maximum likelihood estimation in communication networks.*	3	3	
CO-3:	*select and apply suitable random process to model real time problems.*	3	3	
CO-4:	*know the significance of error detection.*	3	3	
CO-5:	*model waiting lines as stochastic process.*	3	3	

Module-1 - Random Variables	***12 Hour***
Definition of a Random Variable - Common Continuous Random Variables - Common Discrete Random Variables - Transformations of One Random Variable -Computation of Expected Values - Two Random Variables.	
Module-2 - Estimation of Random Variables	***12 Hour***
Estimation of Variables - Linear MMSE Estimation - Properties of Estimators of Random Variables - Bayes Estimation - Estimation of Nonrandom Parameters.	
Module-3 - Random Processes	***12 Hour***
Definition of a Random Process - Characterizations of a Random Process - Stationarity of Random Processes - Examples of Random Processes - Gaussian Random Processes - White Random Processes - ARMA Random Processes.	
Module-4 - Detection Theory - Discrete Observation	***12 Hour***
Basic Detection Problem -Maximum A Posteriori Decision Rule - Minimum Probability of Error Classifier - Bayes Decision Rule - General Calculation of Probability of Error.	
Module-5 - Networks of Queues	***12 Hour***
Introduction – Open Queuing Networks – Closed Queuing Networks – Nonexponential Service – Time Distributions and Multiple Jobs Types – Introduction to Non-Product Form Networks.	

Learning Resources	1. *Lonnie C. Ludeman, "Random Processes: Filtering, Estimation and Detection", Wiley India Pvt.Ltd., 2010.* 2. *Probability and Statistics with reliability, queueing and computer science applications, Kishor S.Trivedi, PHI, New Delhi, 2001.* 3. *S. Ross, A First Course in Probability, 8th Ed., Pearson Education India, 2010.*	4. *S.C. Gupta, V.K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand & Sons, 11th Edition, 2015.* 5. *Vijay K. Rohatgi., A.K. Md. Ehsanes Saleh, An Introduction to Probability and Statistics, 2nd Edition, Wiley, 20086.* 6. *K. Sam Shanmugan & A.M. Breipohl, "Random Signals: Detection, Estimation and Data Analysis", Wiley India Pvt. Ltd, 2011.*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*15%*	-	*15%*	-	*15%*	-
Level 2	*Understand*	*25%*	-	*25%*	-	*25%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
Mr. Madhan Shanmugasundaram, Infosys Technologies, madshan@gmail.com	*1. Prof. Y.V.S.S. Sanyasiraju, IIT Madras, sryedida@iitm.ac.in*	*1. Dr. V. Subburayan, SRMIST*
	2. Prof. K.C. Sivakumar, IIT Madras, kcskumar@iitm.ac.in	*2. Dr.R.Varadharajan, SRMIST* *3. Dr.G.Lavanya, SRMIST*

Course Code	21ECC551J	Course Name	DIGITAL MODULATION AND CODING TECHNIQUES	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							2	0	2	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electronics and Communication Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*learn the various pass band modulation techniques*
CLR-2:	*study the source coding and channel coding techniques*
CLR-3:	*acquire the knowledge about fading channels*
CLR-4:	*understand the concepts of different detection techniques*
CLR-5:	*explore the fundamentals of multi carrier systems*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*apply appropriate modulation techniques for wireless communication applications*	3		2
CO-2:	*implement various coding techniques to enhance the performance of wireless communication systems*	2		3
CO-3:	*mathematically model the wireless communication system*		2	3
CO-4:	*identify the suitable detector for wireless communication systems*	2		3
CO-5:	*incorporate multicarrier concepts in next generation wireless systems*	2	2	3

Module-1- Modulation Techniques	***12 Hour***
Coherent and Non coherent binary modulation techniques, Quadrature modulation techniques, Comparison of binary and quaternary modulation techniques, M-ary modulation techniques, Differential modulation, Constellation shaping, power spectra, Bandwidth efficiency, Effect of inter symbol interference, Bit versus symbol error probabilities. ***Practice:*** *Probability of error for coherent modulation, BER performance analysis of M-ary modulation*	
Module-2 - Channel Coding- Part 1	***12 Hour***
Waveform coding and structured sequence, - Mary signaling, waveform coding system example, Linear block codes- Generator and parity check matrix, systematic linear block codes, Syndrome testing, Error correction, Cyclic codes -Algebraic cyclic codes, Binary cyclic code properties, Encoding in systematic form, circuit for dividing polynomials, Hamming codes, BCH codes ***Practice:*** *Linear Code generation, Error detection*	
Module-3 - Channel Coding- Part 2	***12 Hour***
Binary Convolutional codes- Non recursive non-systematic encoding, Recursive systematic encoding, Turbo constructions from convolutional codes, Low density Parity check codes (LDPC)- regular LDPC, irregular LDPC, Bandwidth- efficient coded modulation –Bit interleaved coded modulation, Trellis coded modulation, Algebraic codes ***Practice:*** *Advanced Code generation, Error detection*	
Module-4 - Demodulation and Reception	***12 Hour***
Maximum likelihood sequence detector, Optimum receiver for Continuous Phase Modulation signals, Optimum receivers for binary signals and M-ary orthogonal signals, Probability of error for envelope detection of M-ary orthogonal signals and correlated binary signals, Carrier phase estimation- Phase Locked Loop, Decision directed loops, Symbol timing estimation- Maximum likelihood and Non decision directed	

Practice: *Data detection, Phase estimation error*
Module-5 – Multicarrier Systems ***12 Hour***
Data Transmission using Multiple Carriers, Multicarrier Modulation with Overlapping Sub channels, Mitigation of Subcarrier Fading-Coding with Interleaving over Time and Frequency, Frequency Equalization, Precoding, Adaptive Loading, Discrete Implementation of Multicarrier-The DFT and its Properties, The Cyclic Prefix, Orthogonal Frequency Division Multiplexing (OFDM) ,Matrix Representation of OFDM, Case Study: OFDM in 5G NR
Practice: *Data transmission using multiple carriers, BER performance analysis of OFDM system*

Learning Resources	*1. Heinrich Meyer, Mare Moeneclacy, Stefan. A. Fechtel, "Digital communication receivers ", Vol I & Vol II, John Wiley, New York, 1997.* *2. Bernard Sklar, "Digital Communications - Fundamentals and Applications", Pearson Education (Asia) Pvt. Ltd, 2nd Edition, 2014, ISBN: 1292026065, 9781292026060.* *3. John.G.Proakis, "Digital communication "4th Edition, McGraw-Hill, New York, 2001.* *4. R.G. Gallager, "Principles of Digital Communication", New York, Cambridge University Press, 2008*	*5. Simon Marvin, "Digital communication over fading channel; an unified approach to performance Analysis", John Wiley, New York, 2000.* *6. Andrea Goldsmith, "Wireless communications," Cambridge University Press, 2005* *7. Upamanyu Madhow, "Fundamentals of Digital Communication", Cambridge University press, 2008*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (45%)		Life-Long Learning CLA-2 (15%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	*20%*	-	-	*20%*	*20%*	-
Level 2	*Understand*	*20%*	-	-	*20%*	*20%*	-
Level 3	*Apply*	*30%*	-	-	*30%*	*30%*	-
Level 4	*Analyze*	*30%*	-	-	*30%*	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. Kartik Soundarrajan, Vice President, Quadgen Wireless Solution Pvt. Ltd., Bangalore	*1. Dr. Meenakshi, College of Engineering, Guindy*	*1. Dr. S. Krithiga, SRMIST*
2. Mr. George Jacob, CEO and Founding member, Semicon Design Technologies, Bangalore		*2. Dr. M. Sangeetha, SRMIST*

Course Code	21ECC552J	Course Name	ANTENNA DESIGN TECHNIQUES	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electronics and Communication Engineering*	**Data Book / Codes/Standards**	Nil		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*provide in depth knowledge on radiation mechanism, fundamental antenna properties.*
CLR-2:	*familiarize advanced analytical methods used to analyze and design microstrip and broadband antennas.*
CLR-3:	*discover detailed awareness on measurement techniques for different parameters of antennas and to provide complete knowledge on computational electromagnetic solver methods.*
CLR-4:	*present complete information on wearable antennas and their measurement techniques and to offer in depth study on the design of active integrated antennas and their characterization.*
CLR-5:	*acquire detailed understanding on the methodologies and design considerations of reconfigurable antennas and to grant mathematical formulation and wideband techniques of reflect array antennas*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*explain the concept of radiation mechanism, fundamental properties of antennas*	3		2
CO-2:	*design microstrip and broadband antennas using advanced analytical methods*		2	
CO-3:	*analyze different computational electromagnetic solver methods and measurement techniques*	2		3
CO-4:	*develop wearable and active integrated antennas*		2	3
CO-5:	*explore the methodologies and design considerations of reconfigurable and reflect-array antennas*		2	3

Module-1 - Fundamental Antenna Concepts and Radiation Mechanism	***15 Hour***
Types of antennas, Radiation mechanism from single wire and two wire antenna, Antenna regions, FRISS transmission equation, Fundamental properties-Radiation pattern, radiation power density, radiation intensity and directivity, Antenna efficiency, gain, Beam efficiency, polarization, Maximum efficiency and maximum effective area and problem solving. Introduction to linear wire antennas-Infinitesimal dipole, small dipole, finite length dipole and half wavelength dipole, Power radiation and radiation resistance from half wave dipole, Radiation resistance of half wave dipole, N-element array with uniform and Non uniform amplitude and spacing, Smart antenna benefits and drawbacks. ***Practice:*** *Analyze FRISS transmission equation for distance and power using antenna setup.* ***Practice:*** *Design of Dipole antenna using any EM software.* ***Practice:*** *Design of Monopole antenna using any EM software.*	
Module-2 - Microstrip and Broadband Antennas	***15 Hour***
Microstrip patch antenna radiation concept, Feeding methods, Rectangular microstrip patch antenna and Design considerations, Circular microstrip patch antenna, Microstrip array and feeding networks, Working principle and Design considerations of Horn antenna, Biconical antenna, Helical antenna and Log periodic dipole array antennas, Introduction to Vivaldi antenna.	

Practice: *Design of rectangular Microstrip patch antenna in any EM software.* ***Practice:*** *Determine radiation pattern and gain of Horn antenna using hardware setup.* ***Case Study:*** *Design considerations of long range communication antennas*
Module-3 - Antenna Measurement Techniques ***15 Hour***
Antenna ranges, Description of Anechoic chamber, Construction and Working of Anechoic Chamber, Impedance measurement, Radiation pattern and Gain measurement, Directivity measurement, Efficiency and Polarization measurement, Finite Element Method, Method of Moments, Finite Difference Time Domain method. ***Practice:*** *Construction study of Anechoic Chamber.* ***Practice:*** *Measurements for microstrip patch antenna characteristics using hardware setup – VNA and Anechoic Chamber setup.*
Module-4 - Wearable and Active Integrated Antennas ***15 Hour***
Antennas for wearable devices, Wearable antenna design requirements, Modeling and Characterization of wearable antennas, Domains of operation of wearable antennas, Sources on the human body-Electrical properties, sources and waves on the body, Design of wearable antennas in the vicinity of human body, Phantom configurations, Measurements of wearable antennas using phantom, Fabric material types, Fabric antenna types, Active wearable antenna, Case study on - Wideband wearable printed slot antenna, notch antenna, tunable slot antenna. ***Practice:*** *Design of wearable antenna using any EM software.* ***Practice:*** *On body, Off body and bending scenarios of wearable antenna using any EM software* ***Case Study:*** *Design considerations of Near field communication analysis of antennas*
Module-5 - Reconfigurable and Reflect Array Antennas ***15 Hour***
Reconfigurable planar/printed antenna configurations, Reconfigurable Methodologies and design considerations, Substrate modifications for reconfigurability, Frequency reconfigurability, Pattern reconfigurability, Polarization reconfigurability, Types of reconfigurable antennas, Practical issues of reconfigurable antennas, Evolution of reflect array antennas, Comparison of reflect array and conventional reflector, Mathematical formulation of reflect array antennas, Wideband techniques of reflect arrays – Phase response of reflect arrays, Verification and optimization method. ***Practice:*** *Design a frequency reconfigurable antenna for 2.4/5.8 GHz using any EM software.* ***Practice:*** *Design of pattern and polarization reconfigurable antenna using any EM software.* ***Case Study:*** *Study of modern reflect array antennas*

Learning Resources	1. *Constantine A. Balanis, "Antenna Theory Analysis and Design", 4th Ed., John Wiley & Sons, 2016.* 2. *John D. Kraus, Ronald J. Marhefka, Ahmad S. Khan, "Antennas and Wave Propagation", 4th edition. Tata McGraw Hill, 2010.* 3. *John. D. Kraus and R. J. Marhetka," Antennas for all Applications", 3rd edition. Tata McGraw Hill, 2018.* 4. *W. L. Stutzman, and G. A. Thiele, "Antenna Theory and Design", 2nd Ed., John Wiley & Sons, 2010.* 5. *R. S. Elliot, "Antenna Theory and Design", Revised edition, Wiley-IEEE Press, 2006.*	6. *I.J. Bahl and P. Bhartia, "Microstrip antennas", Artech house, Inc,1980.* 7. *Jim R. James, P.S. Hall, "Hand book of Microstrip Antennas", IEEE Electromagnetic wave series 28, Volume- 2, 1989.* 8. *Liberti, J. C., & Rappaport, T. S., "Smart antennas for wireless communications: IS-95 and third generation CDMA applications", Prentice Hall communications engineering and emerging technologies series, Prentice Hall.1999.* 9. *Frank . B. Gross, "Smart Antennas for Wireless Communications", McGraw-Hill, 2005.* 10. *Clayton R. Paul, "Introduction to Electromagnetic Compatibility", John Wiley & Sons, 2008.*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (45%)		*Life-Long Learning CLA-2 (15%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*5%*			*15%*	*5%*	
Level 2	*Understand*	*10%*			*15%*	*10%*	
Level 3	*Apply*	*10%*			*30%*	*10%*	
Level 4	*Analyze*	*10%*			*30%*	*10%*	
Level 5	*Evaluate*	*10%*			*5%*	*10%*	
Level 6	*Create*	*5%*			*5%*	*5%*	
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Kartik Soundarrajan, Vice President, Quadgen Wireless Solution Pvt. Ltd., Bangalore.*	*1. Dr. M. Meenakshi, College of Engineering Guindy*	*1. Dr. P. Sandeep Kumar , SRMIST*
2. *Mr. George Jacob, CEO and Founding member, Semicon Design Technologies, Bangalore*	*2. Dr. M. Gulam Nabi Alsath,, College of Engineering Guindy*	*2. Dr. M. Sangeetha , SRMIST*

Course Code	21ECC553J	Course Name	ADVANCED WIRELESS COMMUNICATION	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

Pre-requisite Courses	*Nil*	Co- Requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electronics and Communication Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the basics of propagation of EM signals and its mechanisms in Wireless channels*
CLR-2:	*learn the capacity equations of wired and wireless channels*
CLR-3:	*study the various diversity and equalization techniques*
CLR-4:	*explore the fundamentals of Spatially diversified Communication systems*
CLR-5:	*realize the concepts of Multi-user systems*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*analyze the performance of wireless communication system under various fading channel conditions*	3	2	
CO-2:	*evaluate the capacity of wireless communication system*	3		2
CO-3:	*implement the equalization techniques in advanced algorithms for automation of wireless receivers*	2		3
CO-4:	*develop applications involving multi antenna systems*		2	3
CO-5:	*incorporate the Multiuser transceiver concepts*	3	2	

Module-1 - Wireless Propagation Channels Models	***15 Hour***
Introduction - Free space Propagation, Terrestrial Propagation - Physical & Statistical Models, Outdoor and Indoor propagation models, NLOS Multipath Fading Models, Composite Fading, Shadowing Distributions, Channel classification, Time-Selective Channels, Frequency Selective Channels, Coherence Time, Power-Delay Profile, Coherence Bandwidth, Stationary and Nonstationary channels, Link power budget analysis-Free space, Link power budget analysis-Terrestrial ***Practice :*** *Simulation of channel models, Impact on multi path fading, Analysis to evaluate link power budget*	
Module-2 - Capacity of Wireless Channels	***15 Hour***
Introduction, Capacity Analysis, Capacity in AWGN, Capacity of Flat Fading Channels, Channel and System Model, Channel Distribution Information (CDI) Known, Channel Side Information at Transmitter and Receiver, Capacity with Receiver Diversity, Capacity Comparisons, Capacity of frequency selective fading channels, Time-Invariant Channels, Time-Varying Channels. ***Practice** : Compare the performance of AWGN, flat fading and frequency selective fading, Evaluate the capacity of Rayleigh and Rician fading channels.*	
Module-3 - Diversity and Equalization	***15 Hour***
Realization of independent fading paths, Receiver Diversity: Introduction, System model, Selection Combining, Threshold Combining, Maximum-ratio Combining, Equal gain Combining, Transmitter Diversity: Introduction, Channel known at transmitter, Alamouti scheme, Equalization, Directly linear equalizers in communication Receiver, Algorithms for Adaptive Equalization, timing and tracking, Cooperative diversity ***Practice** : Analysis on Receiver diversity,: Types of equalization, Analyze the performance of receiver diversity,*	

Module-4 - MIMO Communications	**15 Hour**
Fundamentals of MIMO, Narrowband MIMO Model, Parallel Decomposition of the MIMO channel, MIMO channel capacity, Static Channels, Fading Channels, MIMO Diversity Gain, Beam forming, Diversity-Multiplexing trade-offs, Space time Modulation and coding, ML Detection and Pairwise Error Probability, Rank and Determinant Criterion, Space-Time, Trellis, Block Codes, Spatial Multiplexing, BLAST Architectures,. Successive interference cancellation (SIC). ***Practice** : Calculate the PDF and CDF of MIMO channel, Calculate the BER of MRC scheme*	
Module-5 - Multi User Systems	**15 Hour**
NOMA, Space-Division Hybrid Techniques Scheduling, Power control, Downlink (Broadcast) Channel Capacity: Channel Model Downlink (Broadcast) Channel Capacity: Capacity in AWGN, Downlink (Broadcast) Channel Capacity: Common Data Downlink (Broadcast) Channel Capacity: Capacity in Fading. Downlink (Broadcast) Channel Capacity: Capacity with Multiple Antennas Uplink (Multiple Access) Channel Capacity: Capacity in AWGN and Fading channels, Uplink (Multiple Access) Channel Capacity: Capacity with Multiple Antennas, Uplink/Downlink Duality, multiuser diversity, MIMO-MU systems. MIMO capacity with water filling and Singular value decomposition Case Study: Multiuser MIMO ***Practice**: Simulate the Alamouti diversity technique in multiuser systems, Analysis of Ergodic channel capacity for MIMO Channel*	

Learning Resources		
	1. *Andrea Goldsmith, Wireless Communications, Cambridge University Press, 2007.* 2. *Rappaport. T.S., "Wireless Communication", Pearson Education, 2003.* 3. *Andreas.F. Molisch, "Wireless Communication" John Wiley, India,2006.* 4. *Arogyaswami Paulraj, et al, "Introduction to Space-Time Wireless Communications", Cambridge University Press, 2003.*	5. *Simon Haykin & Michael Mohar, "Modern Wireless Communications" Pearson Education, 2007.* 6. *Gordon L. Stuber, "Principles of Mobile Communication", Springer International Ltd., 2001*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (45%)		*Life-Long Learning CLA-2 (15%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*5%*			*15%*	*5%*	
Level 2	*Understand*	*10%*			*15%*	*10%*	
Level 3	*Apply*	*10%*			*30%*	*10%*	
Level 4	*Analyze*	*10%*			*30%*	*10%*	
Level 5	*Evaluate*	*10%*			*5%*	*10%*	
Level 6	*Create*	*5%*			*5%*	*5%*	
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr. Kartik Soundarrajan, Vice President, Quadgen Wireless Solution Pvt. Ltd., Bangalore*	1. *Dr. M. Meenakshi, College of Engineering, Guindy*	1. *Dr. C. T. Manimegalai, SRMIST*
2. *Mr. George Jacob, CEO and Founding member, Semicon Design Technologies, Bangalore*	2. *Dr. M. D. Selvaraj, IIITDM, Kancheepuram*	2. *Dr. M. Sangeetha, SRMIST*

Course Code	21ECC554J	Course Name	MACHINE LEARNING FOR WIRELESS COMMUNICATION	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

Pre-requisite Courses	*Nil*	Co- Requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electronics and Communication Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*enable the student to understand the concept of mathematics for machine learning*
CLR-2:	*expose the student to be familiar with a set of well-known concepts and algorithms for machine learning*
CLR-3:	*expose the student to be familiar with a set of well-known concepts and algorithms for neural network*
CLR-4:	*expose the student to be familiar with a set of well-known concepts and algorithms for deep neural network*
CLR-5:	*apply the concepts learnt of neural networks and deep neural networks for wireless and mobile application*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*apply mathematics to machine learning problem-solving*	*3*		*2*
CO-2:	*explore the machine learning algorithms*	*3*		*2*
CO-3:	*analyze neural network architecture*	*3*	*2*	
CO-4:	*develop deep learning models*	*3*	*2*	
CO-5:	*demonstrate the physical layer application using a deep learning model*		*2*	*3*

Module - 1 - Mathematics for Machine Learning	***15 Hour***
Linear Algebra: Arithmetic of metrics, Norms, Eigen Decomposition, Singular Value Decomposition, Principal Component Analysis, Probability& Information Theory, Conditional Probability, Chain Rule, Baye's Rule, Information Theory, Structure Probabilistic models. ***Practice :*** *Principal Component Analysis, Simulation of classifier using Baye's Theorem*	
Module -2 - Machine Learning Algorithms	***15 Hour***
Supervised Learning, classification model Algorithm, Regression-Regression models, Algorithm, Logistic regression, Unsurprised Learning: Clustering, Pattern finding using association rule Reinforcement Learning: Q-learning, Q function and Algorithm, Maximum like look estimate, Modeling and Evaluation, Overfitting, underfitting, Bias Variance trade-off. ***Practice :*** *Use of Linear and logistic regression for wireless communication, Wireless data Clustering*	
Module-3 - Basics of Neural Networks	***15 Hour***
Types of activation functions, Single layer feed-forward network, Multilayer feedforward Network, multi-layer network design, Back propagation algorithm ***Practice :*** *Application of single layer neural network for wireless communication, Application of multilayer neural network for wireless communication*	
Module-4 - Deep Learning Architecture	***15 Hour***
Convolutional operation, Convolutional networks, Concept of autoencoder, autoencoder, autoencoder & its types, architecture of Operation LeNET, Alexnet, ZF-NET,VGG- NET, Google NET, ResNet, Architecture of RNN, LSTM, GRV. ***Practice :*** *Convolutional Neural Network for classification , Auto-encoder for wireless data denoising*	
Module-5 – Deep Learning for Wireless Communication	***15 Hour***

The potential of DL for the Physical layers, Auto encodes for end-to-end Communication, Deep MIMO detectors, Different neural architectures for detection, Machine learning for spectrum access & sharing, and Hands-on experience with Python for developing neural networks. ***Practice :*** *Deep Learning for MIMO DATA decoding, Machine learning for Spectrum detection*

Learning Resources	1. *Jason Brownee, "Basics of linear Algebra for Machine learning", Machine learning Mastery,2018.* 2. *EthemAlpayadin, "Introduction to Machine learning" Cambridge, MA, MIT press, Second Edition, 2010.* 3. *SaikatDutt, Subramanian Chandramouli and Amit kumar Das, "Machine learning", Pearson Education limited, 2019.* 4. *Zsot Nagy, "Artificial Intelligence and Machine learning Fundamentals", Pack Publishing lts. 2018.* 5. *Ian Good fellow, yoshuaBengion and Aaron Courville "Deep learning", Cambridge, MA, MIT Press, 2017* 6. *https://medium.com/analytics-vidhya/cnns-architectures-lenet-alexnet-vgg-googlenet-resnet-and-more- 666091488df5.*	7. *https://towardsdatascience.com/illustrated-10-cnn-architectures-95d78ace614d* 8. *Timothy O shea, JakobHoydis, "An Introduction to Deep learning for Physical layer," IEEE Transactions on Cognitive communication and Networking, Vol.3, no.4, December 2017.DOI:10.1109/TCCN.2017.2758370* 9. *Neev Samuel, TZVI Diskin and Ami Wiesel," Deep MIMO Detection ", IEEE 18th International workshop on signal processing advances in wireless communication, December 2017. DOI: 10.1109/SPAWC.2017.8227772* 10. *NarimanFarsad and Andrea Goldsmith, "Neural Network Detection of Data Sequences in Communication systems", IEEE Transactions on Signal Processing, Vol. 66, No. 21, Nov.,2018.* 11. *Fa-longluo," Machine Learning for future wireless Communications", Machine learning for spectrum access and sharing, Wiley-IEEE press, December 2019.*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (45%)		*Life-Long Learning CLA-2 (15%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	-	*20%*	*20%*	-
Level 2	*Understand*	*20%*	-	-	*20%*	*20%*	-
Level 3	*Apply*	*30%*	-	-	*30%*	*30%*	-
Level 4	*Analyze*	*30%*	-	-	*30%*	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. Kartik Soundarrajan, Vice President, Quadgen Wireless Solution Pvt. Ltd., Bangalore	*1. Dr. Meenakshi, College of Engineering, Guindy*	*1. Dr. P.Vijayakumar , SRMIST*
2. Mr. George Jacob, CEO and Founding member, Semicon Design Technologies, Bangalore		*2. Dr. S. Malarvizhi, SRMIST*

ACADEMIC CURRICULA

Wireless Communication Technology

Professional Elective Courses

Regulations 2021

SRM
INSTITUTE OF SCIENCE & TECHNOLOGY
(Deemed to be University u/s 3 of UGC Act, 1956)

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21ECE551T	Course Name	OPTICAL WIRELESS COMMUNICATION	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electronics and Communication Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*know the principles and evolution of optical wireless communication*
CLR-2:	*design and analyze the optical wireless communication link*
CLR-3:	*get familiar with various optical modulation techniques, system design, and performance measures for OWC*
CLR-4:	*deliberate on the impairments in link and learn AI-based mitigation techniques*
CLR-5:	*explore the performance of the OWC link under various turbulences*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*explain the principles and evolution of Optical Wireless Communication*	3		
CO-2:	*explore the OWC components and channel design*	3	2	
CO-3:	*demonstrate the performance of OWC under various modulation schemes and real-world challenges*	3	2	
CO-4:	*assess the power of AI to Improve the link performance by mitigating the impairments.*	3		3
CO-5:	*design the OWC link as per the application demand.*		2	3

Module-1 - Introduction to Optical Wireless Communication (OWC) System	***9 Hour***
A Brief History of OWC, OWC & Radio Comparison, Link Design and Configuration (Directed LOS), Non-directed LOS, Diffuse, Tracked), Wireless Access Schemes (TDMA, FDMA, CDMA), OWC Application Areas (Last mile access, Optical fiber back-up link, Cellular communication backhaul, Disaster recovery/temporary links), Safety and Regulations, Classification of lasers according to the IEC 60825-1 standard, The eye safety limits, OWC Challenges	
Module-2 - Modeling of The Optical Wireless Communication Link Using Optical Components	***9 Hour***
Light Sources, Light Emitting Diode operating Principle, LED Modulation Bandwidth, Laser operating principle, Basic Semiconductor Laser Structure, The Structure of Common Laser Types, Photodetectors operating Principle, PIN photodetector, APD photodetector, Photo detection Techniques, Direct Detection, Coherent Detection, Photo detection Noise, Indoor Optical Wireless Communication Channel, LOS Propagation Model, Non- LOS Propagation Model, Outdoor Optical Wireless Communication Channel, Atmospheric Channel Loss, Fog and Visibility.	
Module-3 - Modulation Techniques and System Performance	***9 Hour***
Classification of Modulation, Analogue Intensity Modulation & External Modulation, Digital Baseband Modulation Techniques (OOK, PPM, PWM), Analysis of OOK-RZ vs OOK-NRZ, Error performance on Gaussian Channels, Optimum Threshold Level for AWGN enabled OOK for independently and identically distributed (IID), Bit Error Rate Analysis, The Q-Factor, Effect of Ambient/Fluorescent Light on System Performance, Link Performance for Multipath Propagation for OOK, ISI Mitigation Techniques (Filtering & Equalization), Equalization as A Classification Problem	
Module-4 - AI-Assisted Optimization of OWC Link	***9 Hour***
Introduction to Artificial Neural Networks, Neuron, Ann Architectures, Training Network, The ANN-Based Adaptive Equalizer, Comparative Study of Unequalized and ANN Equalized Linear OOK Schemes, Comparative Study of the ANN & FIR-Based Equalizers, Diversity, Types of Diversity Techniques, Diversity Combining Techniques (Selection combining, Maximum ratio combining & Equal gain combining), Alamouti's Transmit Diversity Scheme, Two Transmitter and One Receiver Scheme	

Module-5 – Performance analysis of OWC turbulence link	***9 Hour***
ON-OFF Keying Under Poisson Atmospheric Optical Channel, ON-OFF Keying Under Gaussian Atmospheric Optical Channel, Subcarrier Intensity Modulation, Generation, Detection. Generation of QPSK-modulated single subcarrier signal. Performance in Log Normal Atmospheric Channel. Atmospheric Turbulence assisted Penalty. Atmospheric Turbulence Mitigation Techniques. Case Studies on Atmospheric Turbulence Mitigation Techniques	

Learning Resources	1. *Z. Ghassemlooy, W. Popoola, S. Rajbhandari "Optical Wireless Communications-Systems and channel modelling with MATLAB" CRC press, Taylor & Francis, 2013* 2. *Hemani Kaushal, V.K._Jain, Subrat_Kar , "Free Space Optical Communication", Springer, 2017* 3. *Le Nguyen Binh "Optical Fiber Communication Systems with MATLAB and Simulink Models"CRC Press, Inc., 2nd edition, 2015*	4. *Arun K. Majumdar, "Advanced Free Space Optics (FSO): A Systems Approach" Springer, 2015* 5. *Shlomi Armon, John R. Barry, Geroge K. Karagiannidis, Robert Schober, Murat Uysal "Advanced Optical Wireless Communication Systems" Cambridge university press, 2012*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2- (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*25%*	-	*25%*	-	*25%*	-
Level 2	*Understand*	*25%*	-	*25%*	-	*25%*	-
Level 3	*Apply*	*25%*	-	*25%*	-	*25%*	-
Level 4	*Analyze*	*25%*	-	*25%*	-	*25%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr. Kartik Soundarrajan, Vice President, Quadgen Wireless Solution Pvt. Ltd., Bangalore.*	1. *Dr. M. Meenkashi, College of Engineering, Guindy*	1. *Dr. Vivek Devendra Kachhatiya, SRMIST*
3. *Mr. George Jacob, CEO and Founding member, Semicon Design Technologies, Bangalore*		2. *Dr. Shanthi Prince, SRMIST*

Course Code	21ECE552T	Course Name	WIRELESS AND MOBILE NETWORK SECURITY	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	Nil	Co- Requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department	Electronics and Communication Engineering	Data Book / Codes / Standards	Nil		

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1:	understand the fundamentals of Wireless security
CLR-2:	know the security attacks in Bluetooth and Wi - Fi
CLR-3:	learn the security aspects of Mobile networks
CLR-4:	understand the security of IP based mobile networks
CLR-5:	explain the security threats and mechanisms for Ad hoc and Sensor networks

Course Outcomes (CO):	At the end of this course, learners will be able to:	Programme Outcomes (PO)		
		1	2	3
CO-1:	elaborate different types of wireless networks, their vulnerabilities and various security mechanisms	3	2	
CO-2:	acquire information related to security attacks and mechanisms in Bluetooth and Wi-Fi networks		1	3
CO-3:	distinguish the security mechanisms employed in 2G, 3G and 4G networks			2
CO-4:	analyze the security issues and their solutions adopted in an IP based mobile networks	1		3
CO-5:	investigate the security flaws and countermeasures of Ad hoc and Sensor networks	3	2	

Module-1 - Wireless Security Fundamentals	**9 Hour**
Introduction to types of Wireless networks – Generation of Cellular network - Overview of IEEE wireless networks - WLAN – WPAN – WRAN - Mobile internet networks - Vulnerabilities - Security in the digital age - Fundamental security mechanisms - Basics on Security – security services - Symmetric and asymmetric cryptography, hash functions - Electronic signatures – MAC – PKI - Electronic certificates - Secure communication protocols – SSL and TLS - IPSec protocol suite – Authentication - Access control – Firewalls - Intrusion Detection.	
Module-2 - Security in Bluetooth and Wi – Fi	**9 Hour**
Bluetooth security: Introduction - Organization of Bluetooth nodes in the network - Protocol architecture - SCO and ACL logical transports - Bluetooth security – Modes – Authentication and pairing – Attacks. Wi-Fi Security: Introduction - Attacks on wireless networks - IEEE 802.11 security mechanisms - Wired Equivalent Privacy (WEP) - Security in 802.11i - Security architecture.	
Module-3 - Security in Mobile Networks	**9 Hour**
GSM architecture - Security mechanisms in GSM - Security flaws in GSM radio access and signaling - GPRS architecture - GPRS Security mechanisms - Exploiting GPRS security flaws - Application security - UMTS infrastructure - UMTS security - Security in next generation mobile networks : Introduction - SIP security flaws – VoIP - IP Multimedia subsystem (IMS) architecture - IMS Security flaws – Basics of 4G/5G security.	
Module-4 - Security of IP Based Mobile Networks	**9 Hour**
Introduction, Security issues related to mobility - Vulnerabilities of mobile IP networks - Discovery mechanisms - Authenticity of the mobile location, Data protection - IPV6 mobility mechanisms - Mobile IPV6 Bootstrapping - Network Mobility - Open security issues - Mobility with mobile IPv4 – Security Architecture - Mobility with MOBIKE, HIP and NetLMM (Summary).	

Module-5 - Security in Ad Hoc and Sensor Networks	***9 Hour***
Security in Ad hoc networks – Routing protocols and attacks - Ad hoc network features - Description of attacks - Security mechanisms - Wireless sensor network security - Attacks on various sensor networks – Countermeasures - Prevention mechanisms: authentication and traffic protection – Notations of security protocols - Cost of security protocols in sensors - Security protocols – SNEP, MUTESLA, and TinySec (Summary).	

Learning Resources	1. *Hakima Chaouchi, Maryline Laurent-Maknavicius, "Wireless and Mobile Network Security-Security Basics, Security in On-the-shelf and Emerging Technologies", John Wiley & Sons Inc, 2013.* 2. *Nichols and Lekka, "Wireless Security-Models, Threats and Solutions", Tata McGraw –Hill, New Delhi, 2006.*	3. *Alan Holt , Chi-Yu Huang, "802.11 Wireless Networks-Security and Analysis", Springer, 2010.*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr. Kartik Soundarrajan, Vice President, Quadgen Wireless Solution Pvt. Ltd., Bangalore	*1. Dr. M. Meenakshi, College of Engineering, Guindy*	*1. Dr. B. Ramachandran, SRMIST*
2. Mr. George Jacob, CEO and Founding member, Semicon Design Technologies, Bangalore	*2. Dr. M. D. Selvaraj, IIITDM, Kancheepuram*	*2. Dr. V. Nithya, SRMIST*

Course Code	21ECE553T	Course Name	SIGNAL PROCESSING FOR NEXT-GENERATION COMMUNICATIONS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	Nil	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department	Electronics and Communication Engineering	Data Book / Codes/Standards		Nil	

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1 :	analyze modulation and coding of FTN and SEFDM
CLR-2 :	paraphrase different multiple-access techniques
CLR-3 :	interpret spatial signal processing
CLR-4 :	elucidate about OAM based wireless communication, design, and implementation
CLR-5 :	explicate different next generation system level technologies

Course Outcomes (CO):	At the end of this course, learners will be able to:	Programme Outcomes (PO)		
		1	2	3
CO-1 :	explore new waveforms for next generation wireless system	3		2
CO-2 :	demonstrate different Non-orthogonal Multi-User Superposition and Shared Access techniques	3	2	
CO-3 :	incorporate Spatial Signal Processing for next generation wireless system	3	2	
CO-4 :	plan next-generation Spectrum Transmission Opportunities	3	2	
CO-5 :	compile different System-Level Enabling Technologies	3		2

Module-1 - Faster-than-Nyquist Sampling and Major 5G Waveforms	**9 Hour**
Introduction to Faster-than-Nyquist Signaling, Faster-than-Nyquist Signaling (FTN-concepts), Time FTNR, Receivers and Performance, Frequency FTN, Implementation of Frequency FTN, Need of New Waveforms, Major Multicarrier Modulation Candidates, Waveforms high-level Comparison based on Spectral Efficiency, Tail Issue, Spectrum Confinement Mobility, Latency, Modem Complexity and Compatibility with LTE.	
Module-2 - Non-Orthogonal Multi-User Technique	**9 Hour**
Introduction to NOMA, Basic Principles and Features of Non-orthogonal Multi-user Access, Downlink Non-orthogonal Multi-user Transmission, Uplink Non-orthogonal Multi-user Access (LDS-CDMA/OFDM, SCMA, MUSA, PDMA), Concept of downlink NOMA and uplink NOMA, Benefits and Motivation of downlink NOMA and uplink NOMA, Interface Design for downlink NOMA and uplink NOMA , MIMO Support and Performance Evaluations for downlink NOMA and uplink NOMA. ***Technical Report:*** *On the performance of the NOMA technique in the Gaussian Channel.*	
Module-3 - Spatial Signal Processing For 5G	**9 Hour**
Massive MIMO Theory, Massive MIMO Channels, Massive MIMO Implementation, Testbed Design, Synchronization, Overview of Millimetre-Wave MIMO Transceiver Architectures, Point-to-Point Single-User Systems, Point-to-Multipoint Multiuser Systems. ***Case Study:*** *Channel Models for MIMO*	

Module-4 - Millimeter-wave Communication and Full Duplex for 5G	***9 Hour***
Millimeter Waves for 5G: From Theory to Practice, Building a mmWave PoC System, Desirable Features of a mmWave Prototyping System, Introduction to 5G Millimeter-wave Communication Channel, Millimeter-wave Channel Characteristics, Requirements for a 5G mmWave Channel Model, Millimeter-wave Channel Model for 5G, Signal Processing for mmWave Band 5G RAT, Self-interference: Basic Analyses and Models, SIC Techniques and Algorithms, Hardware Impairments and Implementation Challenges, Looking Toward Full-duplex MIMO Systems. ***Case Study:*** *Description of the Air Interface and PoC System Architecture*	
Module-5 - System-Level Enabling Technologies	***9 Hour***
Signal Processing Challenges in 5G, Uplink System Model, Uplink Channel Estimation at the RRHs, Downlink System Model, Channel Encoding and Precoding at the RRHs, Introduction to Energy-efficient Resource Allocation in 5G, Signal Model for I2D Communication and D2D Communication, Resource Allocation, Fractional Programming, Generalized Concavity, Dinkel Bach's Algorithm, Charnes–Cooper Transform, Sequential Fractional Programming, System Optimization.	

Learning Resources	1. *Fa-Long Luo, Charlie (Jianzhong) Zhang, "Signal Processing For 5g: Algorithms and Implementations", John Wiley & Sons, Ltd, 2016* 2. *Theodore S.Rappaport, Robert W.Heath, Robert C.Danials, James N.Murdock "Millimeter Wave Wireless Communications", Prentice Hall Communications.* 3. *Athanasios G.Kanatos, Konstantina S.Nikita, Panagiotis Mathiopoulos, "New Directions in Wireless Communication Systems from Mobile to 5G", CRC Press.*	4. *Wei Xiang, Kan Zheng, Xuemin (Sherman) Shen, "5G Mobile Communications", Springer, 2017.* 5. *AfifOsseiran, Jose F. Monserrat and Patrick Marsch, "5G Mobile and Wireless Communications Technology", Cambridge University Press, 2016.* 6. *Jonathan rodriguez, "Fundamentals of 5G mobile networks", John Wiley & Sons, Ltd, 2015.*

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*30%*	-	*30%*	-	*30%*	-
Level 2	*Understand*	*30%*	-	*30%*	-	*30%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*10%*	-	*10%*	-	*10%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Kartik Soundarrajan, Vice President, Quadgen Wireless Solution Pvt. Ltd., Bangalore.*	*1. Dr. Meenakshi, College of Engineering, Guindy*	*1. Dr. Uday Kumar Singh, SRMIST*
2. *Dr. Abhijeet Bishnu, Senior Engineer, Microchip Technology Inc UK,*	*2. Dr. Vinay Bankey, NIT Rourkela*	*2. Dr. P. Vijayakumar, SRMIST*

Course Code	21ECE554T	Course Name	5G MOBILE NETWORKS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	Nil	Co- requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department	Electronics and Communication Engineering	Data Book / Codes / Standards		Nil	

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1:	know the evolution of wireless communications and 5G wireless networks
CLR-2:	understand capacity of small cells for mobile networks
CLR-3:	understand operations performed in clouds and cognitive radio for 5G
CLR-4:	explore about Self Organizing Networks (SON)
CLR-5:	understand 5G network ,the VCN and its MAC design

Course Outcomes (CO):	At the end of this course, learners will be able to:	Programme Outcomes (PO)		
		1	2	3
CO-1:	explain the 5G architecture and the QoS	3		
CO-2:	analyze the challenges of small cells in 5G network environment		2	3
CO-3:	explore other spectrum optimization techniques suitable for 5G systems		2	3
CO-4:	analyze the SON evolution in 5G networks	3		
CO-5:	develop an use case in vehicular communication and networking		2	3

Module-1 - 5G Architecture	**9 Hour**
5G Architecture, 5G Internet, Internet of Things and Context Awareness, Networking Reconfiguration and Virtualization Support, Mobility control, Quality of Service, Resource for over - provisioning, Case study discussion.	
Module-2 - Indoor Networks	**9 Hour**
Small Cells for 5G Mobile Networks, WiFi and Femtocells as Candidate Small-Cell Technologies, WiFi and Femto Performance – Indoors vs Outdoors, Capacity Limits and Achievable Gains with Densification, Mobile Data Demand - Approach and Methodology, Demand vs Capacity of mobile data, Small-Cell Challenges	
Module-3 - Spectrum Optimization	**9 Hour**
Mobile Clouds: Technology and Services for Future Communication Platforms, Mobile Cloud Enablers, Cognitive Radio for 5G Wireless Networks, Spectrum Optimization using Cognitive Radio, Key Requirements and Challenges for 5G Cognitive Terminals, The Wireless Spectrum Crunch: White Spaces for 5G, Spectrum Opportunities and Challenges, TV White Space Applications, International Efforts for TV White Space, Role of WS in 5G.	
Module-4 - 5G Broadcast Broadband Architecture	**9 Hour**
Towards a Unified 5G Broadcast-Broadband Architecture, Candidate Network Architectures for a BC-BB, FEFs for LTE Transmission BC-BB Study, 5G Core, Self-Organizing Networks (SON) Evolution for 5G Mobile Networks, SON in UMTS and LTE, Need for SON in 5G, Green Flexible RF for 5G - Radio System	
Module-5 - 5G-Enabled VCN and Effective MAC Designs for VCN	**9 Hour**
Introduction to 5G-Enabled VCN, The Era of Intelligent Vehicles, 5G-Enabled Vehicular Communications and Networking (5G-VCN), Effective MAC Designs in VCN - MAC Designs in VCN, Distributed Congestion Control, Centralized Resource Sharing and Scheduling, Centralized Data Dissemination.	

Learning Resources	*1. Jonathan Rodriguez, Fundamentals of 5G Mobile Networks, 2015 John Wiley & Sons, Ltd.*	*2. Xiang Cheng • Rongqing Zhang Liuqing Yang,5G-Enabled Vehicular Communications and Networking, Springer Nature Switzerland AG 2019.*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr. Kartik Soundarrajan, Vice President, Quadgen Wireless Solution Pvt. Ltd., Bangalore.	*1. Dr. M. Meenakshi, College of Engineering, Guindy*	*1. Dr. M. Sangeetha, SRMIST*
2. Mr. George Jacob, CEO and Founding member, Semicon Design Technologies, Bangalore	*2. Dr. E. S. Gobi, NIT, Tiruchirappalli*	*2. Dr. P. Vijayakumar , SRMIST*

Course Code	21ECE555T	Course Name	SOFTWARE DEFINED NETWORKS FOR WIRELESS COMMUNICATION	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	Nil	Co- requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department	Electronics and Communication Engineering	Data Book / Codes / Standards	Nil		

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1:	know about the evolution of SDN, it's benefits and fundamental architecture
CLR-2:	analyze the functions and components of the SDN architecture.
CLR-3:	discuss the network programmability issues
CLR-4:	deliberate on the SDN applications in various networks
CLR-5:	explore the future directions for SDN in wired and wireless networks

Course Outcomes (CO):	At the end of this course, learners will be able to:	Programme Outcomes (PO)		
		1	2	3
CO-1:	define SDN and delve into the challenges and opportunities associated with adopting SDN compared to traditional approaches to networking	3	2	-
CO-2:	analyse the existing SDN Devices and Controllers and the OpenFlow specifications	3	-	2
CO-3:	apply the network programmability and modern orchestration concepts for SDN	3	-	-
CO-4:	compare the SDN Use cases in Data centres and Real networks	3	2	-
CO-5:	explore the use of SDN for next generation networks	3	-	2

Module-1- Introduction to SDN	**9 Hour**
SDN Origins and Evolution, Data Center Needs, Fundamental Characteristics of SDN, The Control Plane and Data Plane, Moving Information Between Planes, Distributed Control Planes- IP and MPLS forwarding, Creating the IP Underlay, Creating the MPLS Overlay, Centralized Control Planes: Logical Vs Literal Centralization, Introduction to Open Flow Architecture, Open Flow Protocol: Wire Protocol, Packet Replication, Hybrid Approach: Ships in the Night	
Module-2 - SDN Devices and Controllers	**9 Hour**
SDN Operation: Controller to device communication, SDN software and hardware switch anatomy, SDN Controller Anatomy, Core Modules and Interfaces, Idealized SDN Controller/framework, VM ware, Nicira, Mininet, NOX/POX, Trema / Ryu, Big Switch Networks/Floodlight, L3VPN. The OpenFlow Switch/ Open Flow Controller, OpenFlow 1.0 and OpenFlow Basics: Ports and Port Queues, Flow Table, Packet Matching, Packet forwarding, Messaging Between Controller and Switch, Open Flow Limitations	
Module-3 - Network Programmability	**9 Hour**
The Management Interface, The Application-Network Divide, NETCONF overview, SNMP Overview, Publish and Subscribe Interfaces, XMPP, Google Protocol Buffers, Thrift / JSON, Modern Orchestration: OpenStack, Cloud Stack, Puppet, Network Function Virtualization: Service Chaining, Platform virtualization, Network Slicing. Case study: 5G Network Slicing	
Module-4 - SDN Use Cases and Applications	**10 Hour**
Data Center Definition, Data Center Demands, Tunneling Technologies for the Data Center, Path Technologies for the Data Center, SDN Use Cases in the Data Center, Real-World Data Center Implementations, SDN applied to WAN environment, SDN applied to Service Provider and Carrier Networks, SDN applied to Campus Networks, SDN applied to Mobile Networks, SDN applied to Optical Networks, Reactive Applications and Proactive Applications, SDN Applications using Open Daylight Controller: Java APIs, RESTful API, SDN Use Case study: Traffic Engineering for Service Providers	

Module-5 - SDN for Next Generation Networks	***8 Hour***
SDN Open Source: Open Source Licensing Issues, Switch Implementations, Controller Implementations, Intent based Networking, SDN in 5G architectures, Software defined Wide Area Networks (SD-WAN) standardization, Security challenges in SDN	

Learning Resources	1. *Paul Goransson and Chuck Black, "Software Defined Networks: A Comprehensive Approach", Morgan Kaufmann Publications, 2014* 2. *Thomas D. Nadeau & Ken Gray, "SDN - Software Defined Networks", O'Reilly Media, Inc, 2013* 3. *William Stallings, "Foundations of Modern Networking: SDN, NFV,QoE,IoT and Cloud", Addison-Wesley Professional, 1/e, November 2015*	4. *Maede Zolanvari, "SDN for 5G", 2015, https://www.cse.wustl.edu/~jain/cse570-15/ftp/sdnfor5g.pdf* 5. *Standardizations of SDN and Its Practical Implementation https://www.nec.com/en/global/techrep/journal/g13/n02/pdf/130204.pdf.* 6. *Kaue Morcelles, Brendon McHugh, "Understanding software-defined-radios and -networks in 5G architectures", https://www.embedded.com/understanding-software-defined-radios-and-networks-in-5g-architectures/ March 2022*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr. Kartik Soundarrajan, Vice President, Quadgen Wireless Solution Pvt. Ltd., Bangalore.*	1. *Dr. M. Meenakshi, College of Engineering, Guindy*	1. *Dr. M. S. Vasanthi, SRMIST*
2. *J. S. Vidya, Network Support Engineer, Cisco Meraki, Sydney, vidjayap@cisco.com*	2. *Dr. Mydhili ,RV University, Bengaluru.*	2. *Dr. P. Vijayakumar. SRMIST*

Course Code	21ECE556T	Course Name	RADIO FREQUENCY SYSTEM DESIGN	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electronics and Communication Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*design and analyze RF passive components*
CLR-2:	*understand the operation of RF active components and matching techniques*
CLR-3:	*know about the design of RF transistor amplifier*
CLR-4:	*explore about the operation of oscillators in RF design*
CLR-5:	*understand the design of RF circuits for RF transceiver system design*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*demonstrate the performance of RF passive components*	2		2
CO-2:	*apply the concepts of RF active components*	3	2	
CO-3:	*evaluate the characteristics of impedance matching networks*	2		3
CO-4:	*design the RF amplifier.*	3	2	
CO-5:	*analyze the RF oscillators and mixers, RF filters, mixers and oscillators*	3		2

Module – 1 - *RF Filters*	***8 Hour***
Introduction, Basic resonator, Filter parameters, Low pass Filter configuration, Band pass Filter configuration, SAW Filters, Application of RF Filters in UWB systems, Filter implementation Filter implementation Coupled filter, Problems.	
Module-2 - RF Passive and Active Devices	***8 Hour***
Two port Network Models, RF diodes, Bipolar junction transistor, RF field effect transistor, High electron mobility transistors, GaAs MESFET, Diode models – transistor models, Scattering parameter device characterization, Problems.	
Module-3 - Impedance Matching	***10 Hour***
Impedance matching using discrete components, Smith Chart analysis, Micro strip line matching networks, Brief view of simulation matching techniques, Biasing Networks, Case Study	
Module-4 - RF Amplifiers	***10 Hour***
RF Characteristics of amplifiers, Power Amplifier, Low Noise Amplifier, Stability consideration, Constant gain (Concepts) and noise figure, Broadband amplifier, High power amplifier, Multi stage amplifier	
Module-5 - RF Oscillators and Mixers	***9 Hour***
Basic oscillator model Design steps, High frequency oscillator model, Types of oscillators, Basic characteristics of mixer, Frequency domain considerations, Single ended mixer design, Single balanced mixer, Double balanced mixer.	

Learning Resources	1. *Reinhold Ludwig , Gene Bogdanov, "RF circuit design, theory and applications", Pearson Asia Education, 2nd edition, 2011 (Reprint)* 2. *William F Egan, "Practical RF System design", Wiley, 2003*	3. *Rowan Gilmore and Les Besser, "Practical RF Circuit design for Modern Wireless Systems Volume II Active circuits and systems", Artech House, 2003*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Kartik Soundarrajan, Vice President, Quadgen Wireless Solution Pvt. Ltd., Bangalore.*	1. *Dr. M. Meenakshi, College of Engineering, Guindy*	1. *Dr. M. H. Masood, SRMIST*
2. *Rajesh Kunnath, Director, Radio Studio, Chennai*	2. *Dr. B. S. Sreeja, College of Engineering, Guindy*	2. *Dr. M. Sangeetha, SRMIST*

Course Code	21ECE557T	Course Name	INTELLIGENT REFLECTING SURFACE AIDED WIRELESS COMMUNICATION	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electronics and Communication Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the basic principles and working o Intelligent Reflecting Surfaces.*
CLR-2:	*explore the practical design considerations of IRS /RIS*
CLR-3:	*discuss the channel modelling when IRS is implemented in wireless communication*
CLR-4:	*discuss the application of IRS in various wireless networks*
CLR-5:	*explore the application and future perspective of IRS/ RIS*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*explain the principles and working of Intelligent Reflecting Surface*	3		
CO-2:	*apply the design considerations appropriately to target better IRS for the desired application*	3	2	
CO-3:	*analyze the channel modelling for the IRS aided wireless communication*	3	2	
CO-4:	*implement IRS in wireless networks*		2	3
CO-5:	*develop the IRS to improve the performance of in wireless communication and its future perspective*		2	3

Module-1 - Introduction to Intelligent Reflecting Surfaces (IRS)	***10 Hour***
Introduction: Definition and characteristics of IRS - Types of intelligent reflecting surfaces - Material considerations for IRS -IRS deployment scenarios in wireless networks: Concept, Principle, and Composition of IRS - Operation Mode of IRS - Prototypes of Wavefront Manipulation Mode - Prototypes of Information Modulation Mode - Hardware Configuration of IRS.	
Module-2 - Practical Design Considerations for Reconfigurable Intelligent Surfaces (RIS)	***9 Hour***
Intelligent Reflecting Surface Architecture -Tunability of Unit-cell Elements - Configuration Networks - IRS Control Layer - Physical Limitations of IRSs: Bandwidth versus Phase Resolution - Incidence Angle Response - Quantization Effects.	
Module-3 - Channel Modelling in RIS-Empowered Wireless Communications	***8 Hour***
Introduction - A General Perspective on RIS Channel Modelling - Physical Channel Modelling for RIS-Empowered Systems at mmWave Bands and Sub-6 GHz Bands - SimRIS Channel Simulator	
Module-4 - Intelligent Reflecting Surfaces in Wireless Network	***8 Hour***
Intelligent Reflecting Surfaces in Wireless Networks - Non-terrestrial Networks - Non-terrestrial Networks: 3GPP Vision- Non-terrestrial Networks Using Intelligent Reflecting Surfaces - Indoor Connectivity Using Intelligent Reflecting Surfaces - Integration of IRS with Satellite and UAV Networks: Role of IRS in satellite and UAV communications, Challenges and opportunities in integrating IRS with non-terrestrial platforms - Regulatory and Spectrum Considerations for IRS in NTN	
Module-5 – Application and Future Direction of RIS	***10 Hour***
RIS-assisted High-Frequency Communication - RIS-assisted Multi-User Communication - RIS-assisted RF Sensing and Imaging - RIS-assisted-UAV Communication - RIS-assisted Wireless Power Transfer - RIS-assisted Indoor Localization- RIS in Future Technologies, RIS in Optical communication- ***Case study*** *on IRS to improve the performance of wireless networks*	

Learning Resources	*1. Li, Yueheng, "Intelligent Reflecting Surfaces in Wireless Communication Systems", KIT Scientific Publishing, 2024.* *2. Erik G. Larsson, "Intelligent Reflecting Surfaces: On Use Cases and Path Loss Model", Beyond 5G, Commentary, Education, Technical insights, 2020.* *3. M. Richharia, "Satellite Communications Systems: Design Principles," John Wiley & Sons, 2013.* *4. Qurrat-Ul-Ain Nadeem, Ali H. A. F. Mohamed, Imran Shafique Ansari, "Intelligent Reflecting Surfaces for Wireless Communication: Principles, Design, and Applications", John Wiley & Sons, 2021.*	*5. Qingqing Wu , Xinrong Guan , Meng Hua, "Intelligent Reflecting Surface For B5G/6G Wireless Networks", Springer, 2023.* *6.Hongliang Zhang, Boya Di, Lingyang Song and Zhu Han, "Reconfigurable Intelligent Surface-Empowered 6G", Springer Cham, 2021.* *7. M. Di Renzo, Alessio Zappone, Merouane Debbah, Mohamed-Slim Alouini, Chau Yuen, Julien de Rosny, S. A. Tretyakov, "Smart Radio Environments Empowered by Reconfigurable Intelligent Surfaces: How It Works, State of Research, and The Road Ahead," in IEEE Journal on Selected Areas in Communications, vol. 38, no. 11, pp. 2450-2525, Nov. 2020.*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr. Kartik Soundarrajan, Vice President, Quadgen Wireless Solution Pvt. Ltd., Bangalore.	*1. Dr..M. Meenakshi, College of Engineering, Guindy.*	*1. Dr. M. Susila, SRMIST*
2. Mr. R. Pranav Srinivas, Design Validation Engineer, Broadcom, Bangalore.	*2. Dr. Ram Prabhu S, Assistant Professor, Madras Institute of Technology, Anna University, Chennai, Tamilnadu.*	*2. Dr. S. Bashyam , SRMIST*

Course Code	21ECE558T	Course Name	MASSIVE MIMO AND MILLIMETRE WAVE COMMUNICATION	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electronics and Communication Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*explicate about MIMO systems*
CLR-2:	*illustrate the importance of precoding in large MIMO system*
CLR-3:	*paraphrase mmWave characteristics and challenges in propagation*
CLR-4:	*understand Different modulation and transceiver schemes in mmWave communication systems*
CLR-5:	*summarize about wireless MIMO and Millimeter wave systems*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*illustrate MIMO System*	*3*		
CO-2:	*categorize different pre coding techniques in large MIMO systems*		*2*	
CO-3:	*analyze the characteristics, challenges, and propagation of mmWave*		*2*	*3*
CO-4:	*explore different modulation and transceiver schemes in mmWave communication systems*		*2*	*3*
CO-5:	*expose mmWave MIMO Systems*			*3*

Module-1 – MIMO Systems	***9 Hour***
MIMO SYSTEMS - Introduction to MIMO system model - Multiuser MIMO communication - Larger MIMO System; Opportunities & Challenges in large MIMO system; Problems in large dimensions; Channel hardening- Channel hardening in large dimensions; Channel Models - Various distributions - standardized channel models; Channel Models: Effects of spatial correlation - Analysis of spatial correlation; Channel Estimation - Problems in channel estimation; Pilot contamination - Pilot contamination in massive MIMO; Technical challenges - Implementation issues Pilot contamination in massive MIMO; Design of massive MIMO system - Technical challenges	
Module-2 – Precoding in point-to-point MIMO	***9 Hour***
Precoding in point-to-point MIMO ; SVD - SVD precoding Analysis; Precoding in multi-user MIMO; Linear precoding Techniques - Implementation challenges - Design issues; Non-Linear precoding-Methods - Analysis - Challenges in Non-Linear precoding; MISO systems - multi-user MISO systems; Precoding in large multi-user MISO systems - Implementation issues in multi-user MISO systems; Multicell precoding - Multicell precoding Analysis - Problems in Multicell precoding Analysis	
Module-3 – Introduction of Millimeter Waves	***9 Hour***
Introduction of Millimeter waves; Millimeter wave characteristics - Parameters - Potential benefits of millimeter wave system; Challenges & Implementation issues in millimeter wave system - Design methodologies; Radio wave propagation for mmWave - Analysis of Radio wave propagation for mmWave - Technical challenges; Large scale propagation channel effects - Types of Large scale propagation - Analysis of Large scale propagation channel effects - Analysis of small scale propagation and channel effects – Delay spread and Doppler effects	

Module-4 - mmWave communication Systems	**9 Hour**
mmWave communication systems - Modulations for millimeter wave communications - Need of millimeter wave communications; Analysis of OOK - Analysis of PSK - Analysis of FSK - Analysis of QAM; OFDM - OFDM Channel estimation; Link budget analysis for mmWave radio wave ; Transceiver architecture - transceiver without mixer - Receiver without oscillator - Analysis of Receiver without oscillator; Challenges in millimeter wave calibration *Case study: Use cases for mmWave communication*	
Module-5 - Multiple Antennas	**9 Hour**
Multiple Antennas - Multiple Transceivers System analysis - Problems in Multiple Transceivers; Noise coupling - Measuring parameters - Noise coupling in MIMO system; Classification of diversity - Spatial diversity - Temporal diversity - Frequency diversity; Dynamic spatial modulation allocation - frequency modulation allocation - Analysis of frequency modulation allocation; Beam steering - Analysis of Beam steering - Beam forming; mmWave Standardization	

Learning Resources	
1. *Chockalingam and B.SundarRajan," Large MIMO Systems, Cambridge University Press, 2014* 2. *Fundamentals of Massive MIMO- Thomas L Marzetta Bell Labs Nokia* 3. *K.C. Huang, Z. Wang, "Millimeter Wave Communication Systems Wiley-IEEE Press 2011.*	4. *Theodre S. Rappaport , Robert W. Heath, Robert C. Daniel, James N., Murdock, "Millimeter Wave Wireless Communication", Prentice Hall, 2014* 5. *EzioBigileri, Robert Calderbank, Anthony Constantinides, Andrea Goldsmith, ArogyaswamiPaulraj, Vincent Poor" MIMO Wireless Communications", Cambridge University Press, 2006*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Kartik Soundarrajan, Vice President, Quadgen Wireless Solution Pvt. Ltd., Bangalore*	1. *Dr. Meenakshi, College of Engineering, Guindy*	1. *Dr. T. Rama Rao, SRMIST*
2. *Mr. George Jacob, CEO and Founding member, Semicon Design Technologies, Bangalore*		2. *Dr. M. Sangeetha , SRMIST*

Course Code	21ECE651T	Course Name	ADVANCED WIRELESS AND MOBILE NETWORKS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electronics and Communication Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*analyze the Wireless Network for Real Time Communication in Industrial Application*
CLR-2:	*develop the medium access control resource allocation concepts for industrial automation work*
CLR-3:	*implement the wireless powered communication network security and performance evaluation*
CLR-4:	*evaluate the performance of Internet of Nano-Things.*
CLR-5:	*explore routing Protocol for Wireless Body Area Networks (WBAN)*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*explain the Isochronous Wireless Network Integration Aspects for industrials automation.*	*3*	-	-
CO-2:	*explore the Isochronous Medium Access Control (MAC) Resource allocation, admission Control and Scheduling in TDMA-based Wireless*	*3*	-	*2*
CO-3:	*apply WPCNs in Internet of Things, Enhancement methods of Physical Layer Security in Wireless Powered Communication Networks*	*3*	-	*2*
CO-4:	*evaluate the performance of Internet of Nano-Things (IoNT) & WBAN architecture*		*2*	*3*
CO-5:	*analyze the Routing Protocol for WBAN and adaptive W/BAN.*			*3*

Module-1 - Wireless Network for Real Time Communication in Industrial Application	***9 Hour***
Introduction, Application Scenario, Problem Exposition, Solution approach, Industrial Wireless Communication IEEE 802, Wireless Network Topologies, Analysis and Classification of industrial network and topology, Industrial Wireless Channel System Model, Isochronous Wireless Network, Case study: Real Time Communication in Industrial Application	
Module-2 - Medium Access Control, Resource Allocation and Case Study for Industrial Automation network	***9 Hour***
Deterministic Medium Access Control, Coordinated Medium Access Control, Isochronous Medium Access Control, Analysis of the Isochronous MAC, Resource Allocation, Frame Error Admission Control and Scheduling in TDMA-based Wireless network, Dynamic Scheduling of Retransmissions, Case Study: Reconfigurable Manufacturing	
Module-3 - Wireless Powered Communication Network and Security	***9 Hour***
Overview of Wireless Powered Communication Networks (WPCN), Physical Layer Security Challenges in WPCNs, Applications of WPCNs in Internet of Things, Enhancing Physical Layer Security in WPCN, Accumulate-Then-Transmit, Accumulate-and-Jam, System Model and Protocol Design, Analysis, Performance Evaluation	
Module-4 - Internet of Nano-Things (IoNT) and WBAN	***8 Hour***
Internet of Nano-Things (IoNT)- Introduction, IoNT opportunity in the 5G Era, IoNT Architecture in 5G, IoNT Design Factors and Assessment, IoNT Physical Layer and 5G, IoNT Communication Protocols and 5G Case study:IoNT in Healthcare applications, Wireless Body Area Network- Introduction- Rational Routing Protocol for WBAN	
Module-5 – Routing Protocol for WBAN and Adaptive WBAN system	***10 Hour***
System model, Architecture, Rational Routing Protocol for WBAN, Performance, Protocol, Rational Data Delivery Framework, Adaptive WBAN-System Model, Packet-Size Optimization for a Battery less WBASN, A Cognitive Routing Protocol for WBAN, Communication Model, Energy-Aware Routing Protocol for Nanosensor Networks, System Models	

Learning Resources	1. *Henning Trsek, Isochronous Wireless Network for Real-time Communication in Industrial Automation, Springer-Verlag Berlin Heidelberg 2016* 2. *Abbas Jamalipour ,Ying Bi,Wireless Powered Communication Networks From Security Challenges to IoT Applications, Springer Nature Switzerland AG 2019*	*3. Fadi Al-Turjman, Internet of Nano-Things and Wireless Body Area Networks (WBAN), Taylor & Francis Group, 2019.*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr. Kartik Soundarrajan, Vice President, Quadgen Wireless Solution Pvt. Ltd., Bangalore.	*1. Dr. M. Meenakshi, College of Engineering, Guindy*	*1. Dr. R. Dayana, SRMIST*
2. Mr. George Jacob, CEO and Founding member, Semicon Design Technologies, Bangalore		*2. Dr. P. Vijayakumar, SRMIST*

Course Code	21ECE652T	Course Name	OPTICAL NETWORKS FOR BROADBAND SERVICES	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electronics and Communication Engineering*	**Data Book / Codes/Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1 :	*understand the optical network and details of components*
CLR-2 :	*design the SONET and WDM network*
CLR-3 :	*get familiar with network management and deployment considerations*
CLR-4 :	*discover complete information on the Fiber Wireless*
CLR-5 :	*explore the performance of the PON supporting Fi Wi*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1 :	*explain the concept of optical network components*	*3*		
CO-2 :	*analyze the SONET and WDM network*	*2*		*3*
CO-3 :	*apply the various network management functions and deployment considerations*	*2*		*3*
CO-4 :	*construct the access network and fiber wireless*		*3*	*3*
CO-5 :	*implement the PON architecture in Fi Wi convergence*		*3*	*3*

Module-1 - Introduction to Optical Networks and Components	***9 Hour***
Telecommunications Network Architecture, Optical Networks, The Optical Layer, Transparency and All-Optical Networks, Transmission Basics, Components – Couplers, Isolators and Circulators, Multiplexers, Filters, Wavelength Converters, Switches, Optical Amplifiers, Transmitters, Detectors.	
Module-2 - SONET and WDM Networks	***9 Hour***
Optical Transport Network – Hierarchy, Frame Structure, SONET/SDH – Multiplexing, VCAT and LCAS, SONET/SDH Layers, SONET Frame Structure, SONET/SDH Physical Layer, Elements of a SONET/SDH Infrastructure, WDM Network Elements- Optical Line Terminals, Optical Line Amplifiers, Optical Add/Drop Multiplexers, ROADM, Optical Cross connects, Case Study: Traffic grooming in WDM networks	
Module-3 - Network Management and Deployment Considerations	***9 Hour***
Network Management Functions - Management Framework, Information Model, Management Protocols, Configuration Management - Equipment Management, Connection Management, Adaptation Management, Network Survivability- Basic Concepts, Protection in SONET/SDH, Optical Safety - Open Fiber Control Protocol, Deployment Considerations -The Evolving Telecommunications Network, Designing the Transmission Layer	

Module-4– Access Networks and Fiber Wireless	***9 Hour***
Traffic Trend, Technologies of Broadband Access Networks, Fiber-Wireless Convergence and Technology Evolution- Fiber-Based Distributed Antenna Systems (DASs), HetNets, Fiber-Wireless for Backhaul of HetNet, Fiber-Wireless for Fronthaul of HetNet, Convergence of Architectures, Convergence of Links, Convergence of Bands, Analog Radio-over-Fiber - Architectures for Wi-Fi Networks, Digitized Radio-over-Fiber - Architectures for Wi-Fi Networks	
Module-5 – Advanced Architectures for PON Supporting Fi-Wi Convergence	***9 Hour***
Passive Optical Network (PON): Standards and Technology Options, Technology Options- TDM-PON, WDM-PON, OFDM-PON, Hybrid PONs, PON Standards - GPON/EPON, 10G-PON, 10G-Epon, Challenges in PON Design, Distributed Ring-Based WDM-PON Architecture, Architecture Design, Allocation of Network Resources- Dynamic Bandwidth Allocation, Upstream Traffic Flows Rerouting and Sharing	

Learning Resources	1. *R.Ramaswami& K.N. Sivarajan, Optical Networks, A Practical Perspective (3/e), Elsevier,2010* 2. *Vivekanand Mishra, Sunita P. Ugale, "Fiber Optic Communication: Systems and Components", Wiley-India, 1st edition, 2013* 3. *Stamatios V. Kartalopoulos Free Spaceoptical Networks For Ultra-Broadband Services, A John Wiley & Sons, Inc.,Publication, 2011*	4. *John M. Senior, "Optical fiber Communications: Principles and Practice", Pearson Education, 3rd Edition, 2009.* 5. *Murat Uysal, Carlo Capsoni Zabih Ghassemlooy, Anthony Boucouvalas Eszter Udvary Optical Wireless Communications-An Emerging Technology, Springer, 2016* 6. *Massimo Tornatore • Gee-Kung Chang Georgios Ellinas, "Fiber-Wireless Convergence in Next-Generation Communication Networks Systems, Architectures, and Management" Springer 2017*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr. Kartik Soundarrajan, Vice President, Quadgen Wireless Solution Pvt. Ltd., Bangalore.*	*1. Dr. Meenakshi, College of Engineering, Guindy*	*1. Dr. D. Vijayalakshmi, SRMIST*
2. *Mr. George Jacob, CEO and Founding member, Semicon Design Technologies, Bangalore*		*2. Dr. Vivek Kachhatiya, SRMIST*

Course Code	21ECE653T	Course Name	CLOUD MOBILE NETWORKS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electronics and Communication Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:*** *know the concepts cloud, mobile communication and networking*
CLR-1:	*introduce the basic concepts of mobile clouds*
CLR-2:	*understand the functional concepts and network coding for mobile clouds*
CLR-3:	*familiarize social mobile clouds and green aspects of mobile clouds*
CLR-4:	*introduce the basic concepts in the field of computer networks.*
CLR-5:	*acquire knowledge of the network layer protocols*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*explain the basics of mobile cloud and its classification*	*3*		
CO-2:	*classify the services and network coding for mobile clouds*		*2*	*3*
CO-3:	*analyze the various green aspects of mobile clouds*		*2*	*3*
CO-4:	*demonstrate the cloud computing technologies for 5G communication*		*2*	
CO-5:	*explore the services and concepts related to cloud computing*			*3*

Module-1 – Mobile Clouds	***9 Hour***
Introduction, Mobile cloud Definition, Cooperation and Cognition in Mobile Cloud, Mobile cloud Classification, Types of Cooperation, Sharing of resources in mobile clouds Examples of resource sharing.	
Module-2 – Network Coding for Mobile Clouds	***9 Hour***
Introduction to Short Range Technologies, Building clouds, Network coding, Interflow network coding, Interflow network coding for User Cooperation in Mobile clouds, Intra-flow Network coding, Intra-flow Network coding for User Cooperation in Mobile clouds , Mobile cloud Formation and Maintenance.	
Module-3 - Social Mobile Clouds and Green Aspects of Mobile Clouds	***9 Hour***
Social Networks and Mobile clouds, Cooperation in Relaying Networks-Example, Cooperative Download, Cooperative Streaming, Comparison of different Approaches, Energy Gain for the Network operator.	
Module-4 - Mobile cloud for 5G	***9 Hour***
Mobile Cloud Computing in Multi-Cellular HetNets - Multi-Tier Architecture of Cloud RAN for Efficient Data Management in HetNets - Internet of Things in LTE/HetNets - Inband/Outband Vehicular Communication in Small Cell HetNets, Radio Resource Management Schemes for HetNets - Energy-Efficient Schemes for HetNets *Proposed Energy-Efficient RRM Design for HetNets - Energy Efficiency Improvements Using HetNets - Numerical Results*	

Module-5 – Mobile Cloud Services for 5G	***9 Hour***
Virtualization in Cloud Computing Systems and Use of Hypervisors to Create Virtual Machines -Computing as a Service-Server less Computing -Using and Managing Virtual Machines on the Big Clouds -Using and Managing Containers (Container Orchestration)	

Learning Resources	1. *Frank H. P. Fitzek, Marcos D. Katz. Mobile Clouds: Exploiting Distributed Resources in Wireless, Mobile and Social Networks. Wiley Press. 2013.* 2. *Fernando, Niroshinie, Seng W. Loke, and Wenny Rahayu. "Mobile cloud computing: A survey." Future Generation Computer Systems 29, no. 1 (2013)* 3. *Abolfazli, Saeid; Sanaei, Zohreh; Ahmed, Ejaz; Gani, Abdullah; Buyya, Rajkumar. "Cloud-Based Augmentation for Mobile Devices: Motivation, Taxonomies, and Open Challenges". IEEE Communications Surveys & Tutorials, (2013): 1–32.*	4. *M. Bala Krishna, Jaime Lloret Mauri, ―Advances in Mobile Computing and Communications: Perspectives and Emerging Trends in 5G Networks‖, CRC 2016* 5. *Cloud Computing for Science and Engineering, by Ian Foster and Dennis B. Gannon* 6. *Cloud Computing for Machine Learning and Cognitive Applications, by Kai Hwang*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr. Kartik Soundarrajan, Vice President, Quadgen Wireless Solution Pvt. Ltd., Bangalore.	*1.Dr. M. Meenakshi, College of Engineering, Guindy*	*1. Dr. E. Elamaran, SRMIST*
2. Mr. George Jacob, CEO and Founding member, Semicon Design Technologies, Bangalore		*2. Dr. S. Murugaveni, SRMIST*

Course Code	21ECE654T	Course Name	IoT COMMUNICATION TECHNOLOGY	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electronics and Communication Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*classify the components and protocols required to build an IoT System*
CLR-2:	*design IoT system using Communication Protocols*
CLR-3:	*develop IoT Systems using Hardware/Software Applications*
CLR-4:	*analyze the architecture of the IoT System based on LoRa Communication*
CLR-5:	*demonstrate the application of Data Analytics in IoT*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*explain the components and protocols required to build an IoT network.*	3		
CO-2:	*design Communication System using IoT Access Technologies*		2	3
CO-3:	*develop IoT System using Operating System Hardware*		2	3
CO-4:	*analyze the LoRa-based IoT System and cloud computing*			3
CO-5:	*apply computing technology and data analytics in IoT Systems*	3	2	

Module-1 - IoT Fundamentals	***9 Hour***
Fundamentals of IoT, building blocks of IoT, IoT Data and Information Processing, Challenges in Design of IoT Systems, Hardware/Software Applications of IoT, Smart Sensors, Interfacing Electronic Circuits, IoT Communication Protocols, Power/Energy for Sensor Nodes, IoT – Security, and IoT Communication Models and IoT Levels & Deployment	
Module-2 - IoT Access Technologies	***9 Hour***
Communication Mechanism for smart objects – IEEE 802.15.4/g/e, IEEE 802.11/ah and WiFi, IPv6, and Routing, Non-IP smart object technologies Functionality on Raspberry Pi, ESB32, STM32, Setup and Installations of WiFi on Raspberry Pi, Case Study: Design of IoT System using WiFi	
Module-3 - Embedded System for IoT	***9 Hour***
IoT Architecture, Introduction to Single Board Computers, Microcontroller, Function Definitions and Configurations, Setup and Installation, Interfacing Sensors, Programming in Python	
Module-4 - IoT System Design	***9 Hour***
Introduction LoRaWAN architecture, Hardware/Software Applications, LoRa Implementation using Arduino, Need of Cloud Computing, Hardware/Software Applications, LoRa Implementation using Arduino. Case Study: IoT System Design using LoRaWAN	
Module-5 - Data and Analytics for IoT	***9 Hour***
IoT data management – Fog, Edge computing, Data Analytics and its Types, Edge Computing, Edge Analytics, Need of Cloud Computing, Overview & Applications of Cloud Service Offerings – IaaS, PaaS, SaaS	

Learning Resources	1. *A James, A Seth, SC Mukhopadhyay, A James, A Seth, SC Mukhopadhyay IoT System Design: Project Based Approach, 2022* 2. *Hanes David, Salgueiro Gonzalo, Grossetete Patrick, "IoT fundamentals: Networking technologies, protocols and use cases for the Internet of Things", Cisco, Pearson India, 2015.*	3. *Jean-Philippe Vasseur, Adam Dunkels, "Interconnecting Smart Objects with IP, The next Internet", Morgan Kofmann, 2010.* 4. *Arsheep Bahga, Vijay Madlseti, "Internet of Things: A hands-on approach", Elsevier, 2009.* 5. *Adrin McEwan, Hakim Cassimally, "Designing for Internet of Things", John Wiley, 2014.*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr. Kartik Soundarrajan, Vice President, Quadgen Wireless Solution Pvt. Ltd., Bangalore.	*1. Dr. M. Meenakshi, College of Engineering, Guindy*	*1. Dr. T. Deepa, SRMIST*
2. Mr. George Jacob, CEO and Founding member, Semicon Design Technologies, Bangalore	*2. Dr. V. Sathiesh Kumar, MIT Campus*	*2. Dr. M. Sangeetha, SRMIST*

Course Code	21ECE655T	Course Name	COGNITIVE RADIO	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electronics and Communication Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the fundamental concepts of cognitive radio networks.*
CLR-2:	*develop the cognitive radio, as well as techniques for spectrum sensing that cognitive radio takes advantages in order to exploit it.*
CLR-3:	*understand the various optimization techniques for spectrum access*
CLR-4:	*understand technologies to allow an efficient use of radio communications based on spectrum sharing business models/policies.*
CLR-5:	*understand fundamental issues regarding dynamic spectrum access, radio-resource management and trading, research challenges*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*explain the design principles and architecture of cognitive radio*	3		
CO-2:	*develop the ability to design and implement algorithms for cognitive radio spectrum sensing*	3		
CO-3:	*analyze the adaption of cognitive radio environment and cognitive techniques.*		3	2
CO-4:	*organize sensing and dynamic reconfiguration capabilities*	3	2	
CO-5:	*apply the knowledge of advanced features of cognitive radio for real-world applications*		2	3

Module-1 - Introduction to Cognitive Radio	***9 Hour***
Components of cognitive radio, Spectrum sensing, Spectrum analysis and decision, Research Challenges in Cognitive Radio: Network layer and transport layer issues, Potential applications of cognitive radio, Overview of IEEE 802.22 standard architecture	
Module-2 - Spectrum Sensing	***9 Hour***
Spectrum sensing, detection of spectrum holes, Energy detection, feature detection, matched filter, collaborative sensing geo-location database and spectrum sharing business models, Optimum spectrum sensing, Licensed and Unlicensed Spectrum sensing	
Module-3 - Spectrum Sharing and Allocation	***9 Hour***
Optimization Techniques of Dynamic Spectrum Allocation: Linear programming, convex programming, non-linear programming, integer programming, dynamic programming, stochastic programming, Fundamental limits of spectrum sharing, Case Study : Dynamic Frequency Selection	
Module-4 - Spectrum Access	***9 Hour***
Dynamic Spectrum Access and Management: Spectrum broker, centralized dynamic spectrum access, distributed dynamic spectrum access, learning algorithms and protocols, Trade off in spectrum access. Case study: Distributed Power Control, and Adaptive Interference Avoidance	
Module-5 - Implementation and Advancements in Cognitive Radio	***9 Hour***
Implementation of Cognitive radio using SDR and GNU radio - The Role of Cognitive Radio Networks in 5G and beyond technologies, IoT Networking, Massive MIMO and Beamforming, Case Study: Application of Cognitive Radio Networks in Next-Generation Communications.	

Learning Resources	1. *Kwang-Cheng Chen, Ramjee Prasad, "Cognitive radio networks", John Wiley & Sons Ltd., 2009.* 2. *Bruce A. Fette, "Cognitive radio technology", Elsevier, 2nd edition, 2009* 3. *Ekram Hossain, Dusit Niyato, Zhu Han, "Dynamic Spectrum Access and Management in Cognitive Radio Networks", Cambridge University Press, 2010* 4. *Alexander M. Wyglinski, Maziar Nekovee, and Y. Thomas Hou, "Cognitive Radio Communications and Networks - Principles and Practice", Elsevier Inc., 2010* 5. *Babatunde Seun Awoyemi), Bodhaswar TJ Maharaj, "Developments in Cognitive Radio Networks: Future Directions for Beyond 5G", Springer Nature Switzerland AG,2022.*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr. Kartik Soundarrajan, Vice President, Quadgen Wireless Solution Pvt. Ltd., Bangalore.	*1. Dr. M. Meenakshi, College of Engineering, Guindy*	*1. Dr. K. Kalimuthu, SRMIST*
2. Mr. George Jacob, CEO and Founding member, Semicon Design Technologies, Bangalore		*2. Dr. P. Vijayakumar, SRMIST*

Course Code	21ECE656T	Course Name	WIRELESS SENSOR NETWORKS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Electronics and Communication Engineering*	Data Book / Codes / Standards		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*familiarize with the architecture of WSN*
CLR-2:	*provide the knowledge about the medium access mechanisms in WSN*
CLR-3:	*gain knowledge on routing and localization techniques used in WSN*
CLR-4:	*get exposed to 6LoWPAN technology and its protocols.*
CLR-5:	*learn about Underwater WSN (UWSN)*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*illustrate the architecture of WSN.*	*3*	*-*	*2*
CO-2:	*design Mac protocols for WSN.*	*3*	*-*	*2*
CO-3:	*develop Routing protocols for WSN.*	*3*	*2*	*-*
CO-4:	*discuss 6LoWPAN applications*	*3*	*-*	*2*
CO-5:	*explain Underwater Sensor network and its research challenges*	*3*	*-*	*2*

Module -1 - Architecture of WSN	***9 Hour***
Introduction to wireless sensor networks, Comparison with ad hoc network, Node architecture and Network architecture, Design principles, Sensor types, short range radio communication standards - IEEE 802.15.4 Zigbee and Bluetooth. Sensor Node hardware and software, Sensor taxonomy, Characteristics and Design challenges, Applications	
Module-2 - MAC Layer	***9 Hour***
MAC protocols – fundamentals, Performance requirements, Schedule-based and Random-access based protocols - SMAC, BMAC, TRAMA	
Module-3 - Routing and Localization	***9 Hour***
Routing protocols – Requirements, Classification – Flat, Data centric, Hierarchical protocols, Geographical routing, QoS based routing, Challenges in localization, Ranging techniques, Range-based localization, Range-free localization. Case study: Energy efficient routing protocols – Qualitative Analysis	
Module-4 - 6LoWPAN	***9 Hour***
6LoWPAN Architecture - protocol stack, Adaptation Layer, Link layers – Addressing, Routing - Mesh-Under - Route-Over, Header Compression - Stateless header compression – Context based header compression, Fragmentation and Reassembly, Mobility – types, Mobile IPv6, Proxy Home Agent, Proxy MIPv6	
Module-5 - Underwater Wireless Sensor Networks (UWSN)	***9 Hour***
Introduction, Difference between underwater and terrestrial WSN, Components, UWSN Deployment, UWSN architecture – static, hybrid, and mobile, Challenges in UWSN.	

Learning Resources	1. *Holger Karl, Andreas Wiilig, Protocols and Architectures for Wireless Sensor Networks, 2011, 1st Edition, John Wiley & Sons, New Jersey.* 2. *Kazem Sohraby, Daniel Minoli, Taieb Znati, Wireless Sensor Networks-Technology, Protocols, and Applications, 2012, 1st Edition, John Wiley & Sons, New Jersey.* 3. *Ian F. Akyildiz, Mehmet Can Vuran, Wireless Sensor Networks, 2011, 1st Edition, John Wiley & Sons, New Jersey.* 4. *Zach Shelby and Carsten Bormann, "6LoWPAN: The Wireless Embedded Internet" John Wiley and Sons, Ltd, Publication, 2011.*	5. *Heidemann John, Stojanovic Milica and Zorzi Michele (2012), Underwater sensor networks: applications, advances and challenges Phil. Trans. R. Soc. A., 370: 158–175. http://doi.org/10.1098/rsta.2011.0214* 6. *Fattah, S.; Gani, A.; Ahmedy, I.; Idris, M.Y.I.; Targio Hashem, I.A. A Survey on Underwater Wireless Sensor Networks: Requirements, Taxonomy, Recent Advances, and Open Research Challenges. Sensors 2020, 20, 5393. https://doi.org/10.3390/s20185393*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*30%*	-	*30%*	-	*30%*	-
Level 2	*Understand*	*30%*	-	*30%*	-	*30%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*10%*	-	*10%*	-	*10%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. Kartik Soundarrajan, Vice President, Quadgen Wireless Solution Pvt. Ltd., Bangalore.	*1. Dr. M. Meenakshi, College of Engineering, Guindy.*	1. *Dr. V. Nithya, SRMIST*
2. Mr. George Jacob, CEO and Founding member, Semicon Design Technologies, Bangalore		2. *Dr. P. Vijayakumar, SRMIST*

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