Department of Electronics and Communication Engineering Curriculum 2021

M. Tech Communication Systems

Information and communication technology (ICT) has become one of the essential infrastructures for modern society and transforming the lifestyle integrated with digital devices. ICT will facilitate integrated decision making in power, transportation, sensor, healthcare, industrial automation and others. M.Tech in Communication Systems programme addresses the fundamental premise for potpourri of computational paradigms for communication networks, energy efficient architecture and protocols aiming to deliver ubiquitous, secure and resilient next generation networks. This program also provides insights into the design aspects of wireless communication systems using computational optimization. The program by and large meets core industry requirements and facilitates required background for higher education.

Programme Educational Objectives (PEOs)

PEO1	To create manpower in the state of the art communication technology using the mathematical foundations and concepts to meet the demands of industry, teaching and research.
PEO2	To provide a platform for innovation and research contribution in diverse areas of advanced wireless communication, networks and computational engineering
PEO3	To exhibit professional competence and leadership qualities with a harmonious blend of ethics leading to an integrated personality development

Programme Outcomes (POs)

PO1	An ability to independently carry out research /investigation and development work to solve practical problems.
PO2	An ability to write and present a substantial technical report/document.
PO3	An ability to demonstrate a degree of mastery over the area as per the specialization of the program
PO4	An ability to use modern tools for engineering design problems, analyze the performance and optimize the systems-level approaches.
PO5	An ability to engage in independent and life-long learning in the context of technological change and industrial demands.

Department of Electronics and Communication Engineering Curriculum 2021

M. Tech Communication Systems

Semester – I

Type	Code	Course Name	Teaching Schemes			Credits
			L	T	P	
FC	21CM601	Embedded Computing and Programming	3	0	0	3
FC	21CM602	Machine Learning & Algorithm Design	3	0	0	3
SC	21CM611	Hardware design using FPGA	3	0	0	3
SC	21CM612	Wireless Communication	3	0	0	3
SC	21CM613	RF System Design	3	0	0	3
SC	21CM681	Machine Learning & Embedded Computing Lab	0	0	4	2
SC	21CM682	Communication Systems Lab	0	0	4	2
HU	21HU601	Amrita Value Program				P/F
HU	21HU602	Career Competency- I				P/F
		Total	15	0	8	19

Semester – II

Type	Code	Course Name	Teaching Schemes			Credits
			L	T	P	
SC	21CM614	Wireless Networks and Protocols	3	0	0	3
SC	21CM615	Network on Chip & Cloud Computing	3	0	0	3
E		Elective I	3	0	0	3
E		Elective II	3	0	0	3
E		Elective III	3	0	0	3

SC	21CM683	NoC Cloud Computing Lab	0	0	4	2
SC	21CM684	Wireless Networks and Protocols lab	0	0	4	2
SC	21RM604	Research Methodology	2	0	0	2
HU	21HU603	Career Competency – II	0	0	2	1
		Total	17	0	10	22

Semester – III

Type	Code	Course Name	Teaching Schemes			Credits
			L	T	P	
E		Open Elective*	3	0	0	3
SC	21LIV603*	Open Lab / Live-in Lab	0	0	4	2
P	21CM798	Dissertation - Phase I	0	0	20	10
		Total	3	0	24	15

*Open Elective can be either regular courses on campus or online portal based
* 21LIV603-Code for Live-in-Lab

Semester – IV

Type	Code	Course Name	Teaching Schemes			Credits
			L	T	P	
P	21CM799	Dissertation - Phase II	0	0	28	14
		Total	0	0	28	14

Total Credits: 70

Program Specific Elective Courses

Domain Name: Secure Communications and Networking

Sl. No	Code	Course Name	Teaching Schemes			Credits
			L	T	P	

1	21CM701	Security for Wireless Communications	3	0	0	3
2	21CM702	Wireless Security	3	0	0	3
3	21CM703	Vehicular Communications and Networks	3	0	0	3
4	21CM704	Wireless Sensor Networks	3	0	0	3
5	21CM705	Multisensor data fusion	3	0	0	3
6	21CM706	Massive MIMO	3	0	0	3

Domain Name: Internet of Things

Sl.No	Code	Course Name	Teaching Schemes			Credits
			L	T	P	
1	21CM711	Internet of Things	3	0	0	3
2	21CM712	Software Defined Radio	3	0	0	3
3	21CM713	Cyber Physical Systems	3	0	0	3

Domain Name: Machine Intelligence

Sl.No	Code	Course Name	Teaching Schemes			Credits
			L	T	P	
1	21CM721	Big Data Analytics	3	0	0	3
2	21CM722	Game theory	3	0	0	3
3	21CM723	Convex Optimization	3	0	0	3
4	21CM724	Natural Language Processing	3	0	0	3
5	21CM725	Deep Learning	3	0	0	3

Domain Name: Futuristic Communications

Department of Electronics and Communication Engineering Curriculum 2021

M. Tech Communication Systems

Sl.No	Code	Course Name	Teaching Schemes			Credits
			L	T	P	
1	21CM731	Millimeter Wave Communication Systems	3	0	0	3
2	21CM732	Cooperative and Relay Communication	3	0	0	3
3	21CM733	Automotive RADAR systems	3	0	0	3
4	21CM734	Error control coding	3	0	0	3
5	21CM735	Optical Wireless Communication	3	0	0	3
6	21CM736	Quantum Communications	3	0	0	3
7	21CM737	Wireless Communications for Unmanned aerial vehicles	3	0	0	3
8	21CM738	Estimation and Detection Theory	3	0	0	3

Embedded Computing and Programming

21CM601 **3-0-0-3**

Learning Objectives (LO)

LO1 To introduce design concepts of embedded systems.

LO2 To provide insights on embedded C programming for configuring microcontroller and peripherals

LO3 To enable development of embedded system models.

Course Outcomes (CO)

CO1 Able to identify the features of STM32F microcontroller.

CO2 Able to apply embedded C programming skills for configuring STM32F peripherals.

CO3 Able to analyze external peripheral interfacing with a microcontroller.

CO4 Able to design and develop embedded systems using STM32F microcontroller.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	-	-	-
CO 2	-	-	3	-	2
CO 3	-	-	3	-	2

CO4	-	-	3	3	2

Skills acquired:

Provide detailed insight on configuration and programming of various peripherals in STM32 Microcontroller.

Course Contents

Unit.1: (15 hours)

STM32F Processor: Introduction to Embedded Systems - Introduction to ARM - Advanced RISC Features - Core Data path - Register Organization - System Architecture - Memory Organization - Low Power Modes - Power Control Registers – Backup Registers - Programming STM32F

Unit.2: (15 hours)

STM32F Peripherals: Introduction to Embedded C Programming – General Purpose Input Output - UART - ADC - DAC - Timers - Interrupts and Exceptions - PWM - SPI

Unit.3: (15 hours)

External Peripheral Interfacing: LCD - Keypad - Motor - Servo Motor - EEPROM - Seven Segment Interfacing - Sensor Interfacing

References

1. Muhammad Ali Mazidi, *STM32 Arm Programming for Embedded Systems*, 2019.
2. Donald Norris, *Programming with STM32: Getting Started with the Nucleo Board and C/C++*, McGraw-Hill Education, 2018
3. *STM32F446xx advanced Arm®-based 32-bit MCUs, Reference Manual*, 2020

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

*CA – Can be Quizzes, Assignment, Projects, and Report

Machine Learning and Algorithm Design

21CM602 **3-0-0-3**

Learning Objectives (LO)

LO1 To introduce the concepts and provide a mathematical foundation for developing machine learning models.

LO2 To provide insights on the evaluation of machine learning models for various applications.

LO3 To impart knowledge on algorithm design and its applications.

Course Outcomes (CO)

CO1 Ability to understand concepts of machine learning and algorithm design.

CO2 Ability to apply machine learning and algorithm design concepts for analysis of problems

CO3 Ability to analyze and process datasets using machine learning techniques for extracting useful information.

CO4 Ability to design and implement machine learning models for the given task

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	2	-	-
CO 2	-	-	2	3	2
CO 3	-	-	2	3	2
CO4	-	-	2	3	3

Skills Acquired: The design and programming ability in machine learning model development for a wide range of industrial applications.

Course Contents

Unit.1: (15 hours)

Mathematical concepts review - Central tendency - Dispersion of data - Descriptive data summaries - k-nearest neighbor classifier - Bayes classifiers - Classifier performance measures

Unit.2: (15 hours)

Decision tree - Ensemble methods - Ordinary Least Squares - Artificial neurons - Perceptron - Multi Layer Perceptron and backpropagation -Hyperparameter tuning - Cluster analysis - Partitioning methods - Hierarchical methods -Density-based methods - Cluster evaluation

Unit.3: (15 hours)

Graphs - Definitions and applications - Graph Connectivity - Graph Traversal - Testing Bipartiteness - Breadth-First Search - Directed graphs - Directed Acyclic Graphs Topological ordering - Interval scheduling - Optimal caching - Shortest paths - Minimum Spanning Tree - Clustering - Huffman Codes - Data Compression - Partitioning Problems - Graph Coloring

References

1. Jiawei Han, Micheline Kamber, Jian Pei, *Data Mining: Concepts and Techniques*, Third Edition, Morgan Kaufmann Publishers (Elsevier), 2011.

2. Aurélien Géron, *Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems,* Second Edition, O'Reilly Media, 2019.
3. Earl Gose, Richard Johnsonbaugh, Steve Jost, *Pattern Recognition and Image Analysis*, Pearson Education India, 2015
4. Jon Kleinberg, Éva Tardos, *Algorithm Design*, Pearson, 2006

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Hardware Design Using FPGA

21CM611 **3-0-0-3**

Learning Objectives (LO)

LO1 To introduce HDL design flow targeted at FPGA platforms
LO2 To impart background in RTL abstraction and writing synthesizable Verilog models for combinational and sequential building blocks
LO3 To provide understanding of state machines and their modeling styles in Verilog
LO4 To provide exposure to RTL architecturing of simple digital systems for FPGA implementation

Course Outcomes (CO)

CO1 Able to understand FPGA design flow
CO2 Able to write FPGA synthesizable models for combinational and sequential subsystems in Verilog
CO3 Able to develop and model state machines for a problem specification
CO4 Able to architecture simple systems at the RTL abstraction, model them in Verilog and implement them in an FPGA environment

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	2	2	-
CO 2	-	-	2	3	-
CO 3	-	-	3	3	-
CO 4	-	-	3	3	2

Skills Acquired: Ability to Design, Model and Synthesize a Digital System for a given specification and implement it on an FPGA platform.

Course Contents

Unit.1: (15 hours)

Evolution of FPGAs – Architecture of FPGA fabrics – FPGA Design Flow – RTL Abstraction in HDL based FPGA flow – HDL Modeling styles (Structural, Dataflow and Behavioral) – Verilog Modeling of Combinational Subsystems – Effect of Modeling on Synthesis

Unit.2: (15 hours)

Modeling of sequential building blocks: Flip-flops, Counters, Registers and Shift Registers – State Machines – Different Modeling styles of state machines

Unit.3: (15 hours)

Subsystem Design – FIFOs and Memories – Buffers – DSP Blocks – Wordlength – High Level Synthesis and Block Based Design for FPGAs –DSP Slices and Block Transceivers – Case Studies References

1. Stephen Brown and Zvonko Vranesic, *Fundamentals of Digital Logic with Verilog Design*, Third Edition, McGraw Hill, 2014
2. Wayne Wolf, "*FPGA based System Design*", First Edition, Prentice Hall, 2004
3. Michael D. Ciletti,*Advanced Digital Design with Verilog HDL*, Second Edition, Pearson Higher Education, 2011.
4. Morris Mano and Michael D. Ciletti, *Digital Design: With an Introduction to the Verilog HDL,* Fifth Edition, Pearson Higher Education, 2013. Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Wireless Communications

21CM612 **3-0-0-3**

Learning Objectives (LO)

LO1 To provide a comprehensive introduction to the power and spectrally efficient wireless communication systems.

LO2 To impart knowledge on resource allocation in multiuser environment.

LO3 To provide insights into the various diversity and multiplexing techniques for the design of broadband and reliable wireless communication systems

Course Outcomes (CO)

CO1 Ability to understand the physical medium characteristics of the wireless systems.

CO2 Ability to analyse the resource utilization in the multiuser environment.

CO3 Ability to apply the signal processing techniques in communication systems.
CO4 Ability to evaluate communication systems conforming to industry standards.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	2	-
CO 2	-	-	3	3	-
CO 3	-	-	3	2	2
CO4	-	-	3	3	3

Skills Acquired: Design and analyze the signal processing aspects of wireless communication systems.

Course Contents
Unit 1: (15 hours)
Review of mathematical concepts on signals, systems and channel models - Digital Modulation Schemes - Large Scale Channel Models - Small Scale Channel Models - Channel Estimation - Equalization - Diversity and multiplexing - Time diversity - Frequency diversity and Space diversity – Multiple Access Techniques.

Unit 2: (15 hours)
Multiple-Input Multiple-Output Wireless Communications - Introduction to MIMO - MIMO Channel Capacity - SVD and Eigen modes of the MIMO Channel - MIMO Channel Capacity - Alamouti and Space-Time Code – Performance Comparison of Transmit diversity and Receive diversity - OSTBC - Nonlinear MIMO Receiver: VBLAST- MIMO Spatial Multiplexing - MIMO Diversity - MIMO Beam Forming.

Unit 3: (15 hours)
Multi Carrier Communication – OFDM - Multicarrier Modulation and cyclic prefix - PAPR, Frequency offset estimation - SCFDMA- MIMO OFDM - Performance in respect of BER - Capacity of MIMO-OFDM - Machine Learning for Wireless Communications.

References
1. Andrea Goldsmith, Wireless Communications, Cambridge University Press, 2006 2. David Tse and Pramod Vishwanath, Fundamentals of Wireless Communication, Cambridge University Press, July 2005.
3. Aditya K. Jagannatham, Principles of Modern Wireless Communication Systems, McGraw-Hill Education, 2016.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50

Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Radio Frequency System Design

21CM613 **3-0-0-3**

Learning Objectives (LO)
LO1 To introduce radio frequency communication systems and design aspects
LO2 To provide insights into the design and analysis of passive and active systems
LO3 To impart knowledge on the performance of devices and systems using EM tools

Course Outcomes (CO)

CO1 Ability to understand the basic concepts and working principles of radio frequency systems and devices
CO2 Ability to apply the principles of electromagnetic concepts to RF circuits
CO3 Ability to analyze the RF circuits and systems for optimizing the performance
CO4 Ability to evaluate the characteristics and performance of the RF circuits and systems.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	-
CO 2	-	-	3	-	2
CO 3	-	-	3	3	2
CO4	-	-	3	3	2

Skills Acquired: Design and analyze characteristics and performance of RF circuits and systems

Course Contents
Unit.1: (15 hours)
Review of scattering parameters and systems level approach – Non linearity RF circuits – Harmonic distortion – Gain compression – Cross modulation – Intermodulation – Cascaded nonlinear stages – Noise spectrum – Noise in RF circuits – Noise in cascaded systems – Sensitivity – Dynamic range – Planar transmission lines – Microstrip – Stripline – Coplanar – Substrate integrated waveguide – Transmission line based planar devices –
Planar antennas and excitations - Electromagnetic simulation and analysis

Unit.2: (15 hours)
RF Transistor amplifier design – Amplifier power relations – Transducer power gain – Stability considerations – stability circles – conditional and unconditional stability – Low noise amplifier – Power amplifier - Impedance matching using microstrip line networks – Single and double stub matching networks – Amplifier matching – Basic characteristics of oscillators and Mixers – Receiver and transmitter architectures

Unit.3: (15 hours)
Phased array antenna – Beamforming concepts – Analog and digital beamforming concepts – Beamforming Integrated circuits – Functional description of beamformers – Applications of beamforming in 5G networks - Electromagnetic simulation of antenna arrays and evaluation of beamforming characteristics.

References
1. Reinhold Ludwig and Gene Bogdanov, RF Circuit Design – Theory and Applications, Second Edition, Pearson, 2013
2. Behzad Razavi, RF Microelectronics, Second Edition, Pearson, 2013
3. David M Pozar, Microwave Engineering, Fourth Edition, John Wiley and Sons, 2012
4. Robert Mailloux, Phased Array Antenna – Handbook, Artech House, 2005

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Machine Learning and Embedded Programming Lab

21CM681 **0-0-4-2**

Learning Objectives (LO)
LO1 To provide design concepts on implementation of Embedded Systems
LO2 To provide insight on communication protocols used in embedded domain
LO3 To demonstrate peripheral configuration of a microcontroller platform
LO4 To provide insights into design and implementation of machine learning algorithms

Course Outcomes (CO)
CO1 Ability to interface external peripherals with a programmable platform
CO2 Ability to implement and analyze serial communication protocol
CO3 Ability to design and implement embedded system or machine learning based solutions for a specific application
CO4 Ability to analyze and optimize the performance of the given embedded system/machine learning based system.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5

CO 1	2	-	2	3	2
CO 2	2	-	2	3	2
CO 3	3	3	3	3	3
CO 4	3	3	2	3	3

Skills Acquired:

The programming ability in embedded system design and machine learning model development for a wide range of applications.

Course Contents:

Ex. No.	Experiment details
1	General purpose input output configuration and programming
2	LCD and keypad interfacing
3	Universal asynchronous receiver and transmitter (UART) configuration and programming
4	Analog to digital conversion (ADC) peripheral configuration and programming
5	Timer configuration and programming
6	PWM generation and motor speed control
7	Design and implementation of a Bayes classifier for two-class and multi-class classification
8	Design and implementation of an MLP based Artificial Neural Network Model for classification or regression
9	Design and implementation of a deep learning classifier model using transfer learning
10	Design and implementation of a simple DAG Network for deep learning
11	Design and implementation of clustering algorithms
12	Determining the Bipartiteness of a graph using search algorithms

Recommended Tools:

STM32CubeMX, Keil µVision, MATLAB, Python

References

1. Muhammad Ali Mazidi, *STM32 Arm Programming for Embedded Systems*, 2019
2. Donald Norris, *Programming with STM32: Getting Started with the Nucleo Board and C/C++*, McGraw-Hill Education, 2018
3. *STM32F446xx advanced Arm®-based 32-bit MCUs, Reference Manual,* 2020
4. Aurélien Géron, *Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems*, 2nd Edition, O'Reilly Media, 2019

Evaluation Pattern:

Assessment	Internal	External

*Continuous Assessment (CA)	70	NA
End Semester	NA	30
Total	70	30

*CA – Based on Lab experiments and Term work with report

Communication Systems Lab

21CM682 **0-0-4-2**

Learning Objectives (LO)
LO1 To address implementation concerns and architectures in signal processing algorithms for digital transceivers
LO2 To design and develop RF circuits and systems for given specifications LO3 To provide HDL design flow targeted at FPGA platforms.

Course Outcomes (CO)
CO1 Ability to apply the concepts and principles of wireless, radio frequency and FPGA systems for practical realization.
CO2 Ability to analyze the practical aspects of implementing FPGA based communication systems and RF passive devices.
CO3 Ability to design, simulate and evaluate the FPGA implementation, RF and baseband communication systems using standard tools.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	3	3	3	3
CO 2	3	3	2	3	3
CO 3	3	3	3	3	3

Skills Acquired:
- Design and analysis of RF and baseband communication systems.
- FPGA based simple Block Design and Implementation.

Course Contents

Ex. No.	Experiment details
1	Design and performance analysis of spatial diversity.
2	Computation of Probability of error for digital modulation schemes.
3	Pilot based channel estimation for OFDM systems.
4	Performance analysis of channel equalizer.
5	Electromagnetic simulation of planar line based devices and performance evaluation
6	Electromagnetic simulation and characteristics of planar antennas and arrays
7	Modeling and simulation of beamforming networks and performance evaluation
8	Design and performance evaluation of beamforming systems
9	FPGA: Modeling and Implementation of a combinational block
10	FPGA: Modeling and Implementation of a sequential block

11 FPGA: Modeling and Implementation of an FSM
12 FPGA: Simple Block Design and Implementation

Recommended Tools

Python, Synopsys, Xilinx, ADS, HFSS, GNU, USRP

References

1. Robert Mailloux, Phased Array Antenna – Handbook, Artech House, 2005.
2. Constantine A Balanis, Antenna Theory – Analysis and Design, Second Edition, Wiley India, 2010
3. Arogyaswami Paulraj, Rohit Nabar, and Dhananjay Gore. 2008 - Introduction to Space-Time Wireless Communications, First edition, Cambridge University Press, USA.
4. Aditya K. Jagannatham, Principles of Modern Wireless Communication Systems, McGraw- Hill Education, 2016.
5. Vivado Design Suite User Guide, Design Flows Overview UG892 (v2020.1), July 8, 2020, Xilinx

Evaluation Pattern:

Assessment	Internal	External
*Continuous Assessment (CA)	70	NA
End Semester	NA	30
Total	70	30

*CA – Based on Lab experiments and Term work with report

Wireless Networks and Protocols

21CM614 **3-0-0-3**

Learning Objectives (LO)

LO1 To introduce mobile and wireless systems concepts.

LO2 To impart knowledge of computation methods and algorithms for routing and different network topologies.

LO3 To provide insights into the wireless protocols currently used in practice at various networking layers.

Course Outcomes (CO)

CO1 Ability to understand the basic theories, principles, technologies, standards and system architecture of wireless networks.

CO2 Ability to analyze wireless network scenarios and their performances CO3 Ability to design algorithms for routing and different network topologies.

CO4 Ability to evaluate and compare wireless access technologies

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	2
CO 2	-	-	3	-	2
CO 3	-	-	3	2	2
CO 4	-	-	3	2	2

Skills Acquired: Design of wireless networks architecture and protocol stacks.

Course Contents

Unit.1: (15 hours)

Layering and Standards - Fundamental principles of network layering - TCP/IP reference model - Physical and Medium Access Control Layers - Review of wireless channel characteristics and PHY layer techniques to combat channel impairments - Centralized access methods (TDMA, FDMA, CDMA, OFDMA)

Unit.2: (15 hours)

Distributed random access methods (ALOHA, CSMA/CA) - Graph-based algorithms for routing and topology control in wireless networks - Network and Transport Layer protocols - Wireless Local Area Networks - IEEE 802.11 WLANs - MAC and PHY layer variants

Unit.3: (15 hours)

Wireless Personal Area Networks - Bluetooth (IEEE 802.15.1) - ZigBee (IEEE 802.15.4) - Wireless Body Area Networks - IEEE 802.15.6 WBANs - Wireless Wide Area Networks - Cellular networks (2G, 3G, 4G, 5G) - LTE, LTE-A - Introduction to Internet of Things (IoT) architectures and protocols

References

1. Eldad Perahia, and Robert Stacey, *Next generation wireless LANs*, Cambridge university press, 2013.
2. Sauter, Martin, *From GSM to LTE-advanced Pro and 5G: An introduction to mobile networks and mobile broadband*, John Wiley & Sons, 2017.
3. Xiao, Yang, and Yi Pan, eds., *Emerging wireless LANs, wireless PANs, and wireless MANs: IEEE 802.11, IEEE 802.15, 802.16 wireless standard family*, Vol. 57. John Wiley & Sons, 2009.
4. O. Jorge. *Guide to wireless communications*. Cengage Learning, 2016
5. Steve Rackley, *Wireless Networking Technology- From Principles to Successful Implementation*, Elsevier, 2007

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA

*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Network on Chip and Cloud Computing

21CM615 **3-0-0-3**

Learning Objectives (LO)

LO1 To provide the basic concepts of NoC design by studying the topologies, router design and MPSoC styles.
LO2 To impart insights on routing architectures and routing algorithms on a NoC.
LO3 To facilitate understanding of the functions of reconfigurable NoC.
LO4 To provide knowledge on the basic concepts of Cloud Computing and its future trends.

Course Outcomes (CO)

CO1 Ability to understand NoC, Cloud computing and their architectures.
CO2 Ability to apply routing algorithms and flow control mechanisms in NoC.
CO3 Ability to analyze NoC architectures and reconfiguration techniques.
CO4 Ability to evaluate NoC based reconfigurable accelerators in cloud computing.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO1	-	-	3	2	-
CO2	-	-	3	2	2
CO3	-	-	3	3	2
CO4	-	-	3	3	-

Skills Acquired: Design aspects of NoC topologies, routing algorithm and reconfigurable NoCs.

Course Contents:

Unit 1: (15 hours)

Introduction - On-chip vs. Off-Chip Networks - On-Chip Network Building Blocks. Interface with system architecture - Shared Memory Networks in Chip Multiprocessors - Synthesized NoCs in MPSoCs. Topology - Direct Topologies - Indirect Topologies - Irregular Topologies. Routing algorithms - types - Oblivious Routing - Adaptive Routing - Source Routing - Node Table-Based Routing - Routing on Irregular Topologies

Unit 2: (15 hours)

Flow Control - Message-Based Flow Control - Packet-Based Flow Control - Flit-Based Flow Control - Flow Control Implementation in MPSoCs. Router Microarchitecture - Pipeline -

Buffer Organization - Allocators and Arbiters. Architecture Design of Networkon-Chip - Wormhole Router Architecture Design - Traffic Modelling - Localized Traffic. Reconfigurable Network-on-Chip Design.

Unit 3: (15 hours)
Introduction to Cloud Computing –Evolution of Cloud Computing –Underlying Principles of Parallel and Distributed Computing – Cloud Characteristics – Elasticity in Cloud – Ondemand Provisioning - Layered Cloud Architecture Design – NIST Cloud Computing Reference Architecture – Public, Private and Hybrid Clouds – laaS – PaaS – SaaS – Architectural Design Challenges – Cloud Storage.
Cluster Based Application Mapping Strategy for 2D NoC - Reconfigurable Accelerators for Cloud Computing – NoC based virtualized accelerators for cloud computing.
References

1. Santanu Kundu, Santanu Chattopadhyay, *Network-on-Chip: The Next Generation of System-on-Chip Integration*, CRC Press, 2018.
2. N. Enright Jerger and L-S. Peh, *On-Chip Networks*, Synthesis Lectures on Computer Architecture, Morgan & Claypool, 2009.
3. Konstantinos Tatas, Kostas Siozios, DimitriosSoudris, Axel Jantsch, *Designing 2D and 3D Network on Chip Architecture*, Springer, 2013.
4. A Jantsch and H. Tenhunen, *Networks on Chip*, Kluwer Academic Publishers, 2003.
5. Selvi, S., Vecchiola, C., Buyya, R. Mastering Cloud Computing: Foundations and Applications Programming. Netherlands: Elsevier Science, 2013

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

NoC and Cloud Computing Lab

21CM683 **0-0-4-2**

Learning Objectives (LO)
LO1 To address implementation concerns routing algorithms in NoC
LO2 To address implementation concerns flow control algorithms in NoC
LO3 To make the students understand concepts of virtualization and to use cloud as Infrastructure, Platform, Software services

Course Outcomes (CO)
CO1 Ability to understand NoC simulators and Cloud computing tools
CO2 Ability to analyze and evaluate routing algorithms in NoC CO3
Ability to analyze architecture of KVM.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	2	-	3	2	2
CO 2	3	3	3	2	2
CO3	3	3	3	3	2

Skills Acquired:

- Design and Simulation of routing algorithm.
- Implementation of sample cloud services.

Lab Course Contents

Ex.No.	Experiment details	CO Mapping
1	Study of 3D Network-on-chip (NoC) simulation tool –Access Noxim	CO1
2	Simulation of Flow control	CO2
3	Performance analysis of Routing algorithm	CO2
4	Performance analysis of Forwarding algorithm	CO2
5	Simulation Arbitration Comparison	CO2
6	Study of NS3	CO1
7	Study of BookSim	CO1
8	Packet traffic analysis using Booksim	CO2
9	Study of cloud architecture and cloud computing model.	CO1
10	Installation and Configuration of virtualization using KVM	CO1, CO3
11	Implementation of sample cloud services.	CO3

Recommended Tools

Python, Noxim, BookSim, Kernel-based Virtual Machine (KVM)

References

1. Cinkler, Tibor & Coudert, David & Flammini, Michele & Monaco, Graphs and Algorithms in Communication Networks: Studies in Broadband, Optical, Wireless, and Ad Hoc Networks, Springer; 2010th edition.
2. V. Catania, A. Mineo, S. Monteleone, M. Palesi and D. Patti, "Noxim: An open, extensible and cycle-accurate network on chip simulator," 2015 IEEE 26th International Conference on Application-specific Systems, Architectures and Processors (ASAP), 2015.
3. Gautam Shroff , Enterprise Cloud Computing Cambridge,2010
4. Aditya Patawar, Getting Started with OwnCloud , Packt Publishing Ltd, 2013

Evaluation Pattern:

Assessment	Internal	External
*Continuous Assessment (CA)	70	NA

End Semester	NA	30
Total	70	30

*CA – Based on Lab experiments and Term work with report

Wireless Networks and Protocols Lab

21CM684 **0-0-4-2**

Learning Objectives (LO)

LO1 To learn the wireless networks simulation tools used in research and industry

LO2 To gain experience in evaluating mobile computing applications, computation methods and algorithms through experiments and simulations

LO3 To develop knowledge and experience in mobile interface and applications design, and development techniques and methodologies set in the context of a research project addressing a real-world application

LO4 To evaluate the performance of network protocols and algorithms by computer simulations

Course Outcomes (CO)

CO1 Understand wireless network simulation paradigms

CO2 Applying simulation methods and practices for studying wireless networks

CO3 Analyzing protocol stacks and cross layer design

CO4 Evaluating network performance in terms of throughput and latency

CO5 Designing optimized network flow for selected applications

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	2	2	2	2	3
CO 2	2	3	2	2	-
CO 3	3	3	2	2	2
CO4	3	3	-	3	2
CO5	3	3	-	3	2

Skills Acquired: Network modeling tools, hardware platforms & protocol stack design

Course Contents

Ex.No.	Experiment details
1	Understanding Simulation tools for wireless Network design and analysis
2	Study on PHY layer of Wireless Networks
3	Study on MAC layer design
4	Study on Mesh networks
5	Design and analysis of a 802.11
6	Analysis on Multiple access schemes
7	Study on scheduling in wireless networks
8	Implementation of Zigbee networks
9	Simulation studies on Mobile Ahdoc Networks (MANETs)

10 Study and Analysis of V2X and V2V models (VANETs)

Recommended Tools
Python Package, Matlab, NS2 or NS 3, OMNet ++, Gnuradio, ZigBee

References
6. Steve Rackley, *Wireless Networking Technology- From Principles to Successful Implementation*, Elsevier, 2007.
7. Xiao, Yang, and Yi Pan, eds., *Emerging wireless LANs, wireless PANs, and wireless MANs: IEEE 802.11, IEEE 802.15, 802.16 wireless standard family*, Vol. 57. John Wiley & Sons, 2009.
8. O. Jorge. *Guide to wireless communications*. Cengage Learning, 2016
9. Eldad Perahia, and Robert Stacey, *Next generation wireless LANs*, Cambridge university press, 2013.
10. Sauter, Martin, *From GSM to LTE-advanced Pro and 5G: An introduction to mobile networks and mobile broadband*, John Wiley & Sons, 2017.

Evaluation Pattern:

Assessment	Internal	External
*Continuous Assessment (CA)	70	NA
End Semester	NA	30
Total	70	30

*CA – Based on Lab experiments and Term work with report

Research methodology

21RM604 **2-0-0-2**

Learning Objectives (LO)

LO1 To enable defining and formulating research approaches towards obtaining solutions to practical problems.

LO2 To facilitate development of scientific oral and written communication skills. LO3 To comprehend the concepts behind adhering to scientific ethics and values.

Course Outcomes (CO)

CO1 Ability to understand some basic concepts of research and its methodologies.

CO2 Ability to define and apply appropriate parameters and research problems.

CO3 Ability to develop skills to draft a research paper.

CO4 Ability to analyse and comprehend the ethical practices in conducting research and dissemination of results in different forms.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	2	2	3	-	2
CO 2	2	2	2	-	2

CO 3	3	2	3	-	3
CO4	3	2	2	3	3

Skills Acquired: Design, analyse and conduct research and comprehend the results

Course Contents Unit
1:
Meaning of Research - Types of Research - Research Process - Problem definition – Objectives of Research - Research Questions - Research design - Approaches to Research - Quantitative vs. Qualitative Approach - Understanding Theory - Building and Validating Theoretical Models - Exploratory vs. Confirmatory Research - Experimental vs. Theoretical Research – Importance of reasoning in research.

Unit 2:
Problem Formulation - Understanding Modeling & Simulation - Conducting Literature Review – Referencing - Information Sources - Information Retrieval - Role of libraries in Information Retrieval - Tools for identifying literatures - Indexing and abstracting services - Citation indexes.

Unit 3:
Experimental Research: Cause effect relationship - Development of Hypothesis – Measurement Systems Analysis - Error Propagation - Validity of experiments - Statistical Design of Experiments - Field Experiments - Data/Variable Types & Classification - Data collection - Numerical and Graphical Data Analysis: Sampling, Observation, Surveys, Inferential Statistics, and Interpretation of Results.

Unit 4:
Preparation of Dissertation and Research Papers - Tables and illustrations - Guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript - References, Citation and listing system of documents.

Unit 5:
Intellectual property rights (IPR) - patents - copyrights - Trademarks - Industrial design geographical indication - Ethics of Research - Scientific Misconduct - Forms of Scientific Misconduct - Plagiarism - Unscientific practices in thesis work, Ethics in science.

References

1. Bordens, K. S. and Abbott, B. B., “Research Design and Methods – A Process Approach”,
8thEdition, McGraw-Hill, 2011
2. C. R. Kothari, “Research Methodology – Methods and Techniques”, 2nd Edition, New Age
International Publishers
3. Davis, M., Davis K., and Dunagan M., “Scientific Papers and Presentations”, 3rd Edition, Elsevier Inc.
4. Michael P. Marder,“ Research Methods for Science”, Cambridge University Press, 2011

5. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008
6. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age". Aspen Law & Business; 6th Edition July 2012
7. Tony Greenfield and Sue Greener., *Research Methods for Postgraduates*, 3rd Edition, John Wiley & Sons, Ltd. 2016.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

21xxxxx/21LIV603* **Open lab / Live-in lab** **0-0-4-2**

Learning Objectives (LO)
LO1 To enable the students to acquire independent research aptitude.
LO2 To provide a platform to utilize the existing facilities / tools to address socially relevant problems.
LO3 To facilitate the design and development of a proof of concept system.

Course Outcomes (CO)
CO1 Ability to understand the research needs to address practical problems.
CO2 Ability to define and apply relevant concepts to the research problem.
CO3 Ability to develop a proof of concept system.
CO4 Ability to evaluate and analyse the results for further improvement.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	2	-	3	-	3
CO 2	2	-	3	-	3
CO 3	2	3	3	3	-
CO4	2	3	3	3	-

Skills Acquired:
- Ability to understand the research needs.
- Develop a meaningful proof of concept system.

Course Contents:

Design and development of a proof of concept system for the chosen problem.

Evaluation Pattern:

Assessment	Internal	External
*Continuous Assessment (CA)	70	NA
End Semester	NA	30
Total	70	30

*CA – Based on lab experiment and Term work with report

DISSERTATION - PHASE I

21CM798 **0 0 20 10**

Learning Objectives (LO)

LO1 To impart knowledge of computational and electronic concepts in communication systems.

LO2 To provide a platform for innovations in communication systems.

LO3 To facilitate the identification of the state-of-the-art research challenges in communication systems.

Course Outcomes (CO)

CO1 Ability to define a research problem.

CO2 Ability to apply mathematical concepts to the research problem.

CO3 Ability to design and conduct independent research in the domain of interest. CO4 Ability to evaluate and analyze the outcomes of the research.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	3	3	-	-
CO 2	3	3	3	3	3
CO 3	3	3	3	3	3
CO4	3	3	3	-	3

Skills Acquired:
- Design and perform independent research.
- Evaluate and analyze the outcomes of the research.

Course Contents:

Problems and concepts may be defined based on extensive literature survey by standard research articles - Significance of proposed problem and the state-of the art to be explored -

Industry relevant tools may be used for demonstrating the results with physical meaning and create necessary research components - Publications in reputed journals and conferences may be considered for authenticating the results.

Evaluation Pattern:

Assessment	Internal	External
*Continuous Assessment (CA)	70	NA
End Semester	NA	30
Total	70	30

*CA – Can be Periodical Reviews, Demonstrations and Reports

DISSERTATION - PHASE II

21CM799 **0 0 28 14**

Learning Objectives (LO)

LO1 To impart knowledge of computational and electronic concepts in communication systems.

LO2 To provide a platform for innovations in communication systems.

LO3 To facilitate the identification of the state-of-the-art research challenges in communication systems.

Course Outcomes (CO)

CO1 Ability to define a research problem.

CO2 Ability to apply mathematical concepts to the research problem.

CO3 Ability to design and conduct independent research in the domain of interest. CO4 Ability to evaluate and analyze the outcomes of the research.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	3	3	-	-
CO 2	3	3	3	3	3
CO 3	3	3	3	3	3
CO4	3	3	3	-	3

Skills Acquired:
- o Design and perform independent research.
- o Evaluate and analyze the outcomes of the research.

Course Contents:

Problems and concepts may be defined based on extensive literature survey by standard research articles - Significance of proposed problem and the state-of the art to be explored -
Industry relevant tools may be used for demonstrating the results with physical meaning and create necessary research components - Publications in reputed journals and conferences may be considered for authenticating the results.

Evaluation Pattern:

Assessment	Internal	External
*Continuous Assessment (CA)	70	NA
End Semester	NA	30
Total	70	30

*CA – Can be Periodical Reviews, Demonstrations and Reports

Electives

Security for Wireless Communication

21CM701 **3-0-0-3**

Learning Objectives (LO)

LO1 To introduce the key concepts and analytical models of physical layer security in single-user communication systems
LO2 To impart the concept of designing physical layer security enhancements
LO3 To provide the concepts to evaluate multi user and heterogeneous communication systems

Course Outcomes (CO)

CO1 Ability to analyze the performance of secrecy schemes and impact of attacks
CO2 Ability to apply the tools from game theory and graph theory to analyze and design wireless networks with physical layer security considerations
CO3 Able to analyze issues and solutions in providing physical layer security in practical wireless systems
CO4 Able to design and implement secure communication systems

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	3
CO 2	-	-	3	3	3
CO 3	-	-	3	-	2

CO 4	-	-	3	3	2

Skills Acquired: Design and analysis of secure communication algorithms

Course Contents

Unit.1: (15 hours)

Fundamentals of Physical layer security – Information theoretic secrecy metrics – channel models - Secret Communication - Coding for Security - Asymptotic Analysis - Key Generation from wireless channels

Unit.2: (15 hours)

Key agreement techniques - Secrecy With Feedback - Achieving Secrecy through Discussion and Jamming. MIMO Signal Processing Algorithms for Enhanced Physical Layer Security - Secrecy Performance Metrics -Physical Layer Security in OFDMA Networks –Power Allocation Law for Secrecy - Multiple Eavesdroppers

Unit.3: (15 hours)

Resource Allocation for Physical Layer Security in OFDMA Networks- Application of Cooperative Transmissions to Secrecy Communications - Stochastic Geometry Approaches to Secrecy in Large Wireless Networks.

References

1. Xiangyun Zhou, Lingyang Song and Yan Zhang, *Physical Layer Security in WirelessCommunications*, CRC Press, 2013.
2. Lidong Chen and Guang Gong, *Communication System Security*, Chapman and Hall/CRC, 2012
3. Matthieu Bloch and João Barros, *Physcial Layer Security*, Cambridge University Press, 2011.
4. Le, Khoa N, *Physcial Layer Security*, Springer, 2021.
5. Wang**,** Li, *Physical Layer Security in Wireless Cooperative Networks*, Springer, 2018.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Department of Electronics and Communication Engineering
Curriculum 2021
M. Tech Communication Systems

Wireless Security

21CM702 **3-0-0-3**

Learning Objectives (LO)

LO1 To provide a comprehensive introduction to Cryptography and wireless security LO2 To facilitate the importance of security in different layers of network stack.

LO3 To provide insights into the wireless security models of Wireless LAN

Course Outcomes (CO)

CO1 Ability to understand Cryptography and key distributions.

CO2 Ability to analyze security in different layers of wireless network stack

CO3 Ability to evaluate issues and solutions to provide security in practical wireless systems

CO4 Ability to design secure wireless network.

CO-PO Mapping

CO/PO		PO 1	PO 2	PO 3	PO 4	PO 5
CO 1		-	-	2	-	-
CO 2		-	-	2	-	-
CO 3		-	-	3	2	2
CO4		-	-	3	2	2

Skill Acquired: Design and analyze the protocols for secured wireless networks.

Course Contents

Unit 1

Overview of Cryptography: Introduction - Information security and cryptography - Wireless Networks- Trends -Security threats and challenges in wireless networks - Trust Assumptions and Adversary models: Trust- Trust in Ubiquitous computing - Physical Layer Security: Jamming – Wiretapping - Physical Layer defenses - MAC Layer Security: Operating principles of IEEE 802.11 - Detecting selfish behavior in hotspots - Selfish behavior in pure ad hoc networks - MAC layer defenses - Network Layer Security: Securing ad hoc network routing protocols - Secure routing in sensor networks - Network layer defenses. Privacy in Wireless Networks

Unit 2

Wireless LAN transmission media: WAP security architecture – BLUETOOTH - wireless access to internet - Cryptographic Security - Classical crypt analysis - digital cryptography - DES modern Cipher Breaking - non-Keyed Message Digest - Public key Cryptography - Diffie - Hellman and Elliptic curve cryptography - Comparison of Public key Crypto systems - Wireless Transport Layer Security (WTLS): Wireless Transport Layer Security and WAP

Unit 3

Wireless security models - Cisco implementation with LEAP - WLAN Authentication and Key management with Radius - Wireless Access with IP Security - Secure Wireless Public Access, Secure Wireless Point to Point Connectivity.

References

1. Randall K. Nichols, Panos C. Lekkas *Wireless Security: Models, Threats, and Solutions* 1st Edition, McGraw-Hill, 2000.
2. Jon Edney and William A. Arbaugh, Real 802.11 Security: *Wi-Fi Protected Access and 802.11i*, Addison-Wesley Professional, 1st Edition, 2003.
3. W. Stallings, *Wireless Communications and Networks*, 2nd Edition, Pearson Education Ltd, 2009.
4. Wolfgang Osterhage, *Wireless Network Security*, CRC Press, Second edition ,2018.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

21CM703 Vehicular Communications and Networks 3-0-0-3

Learning Objectives (LO)

LO1 To understand various communication protocols used in automotive applications

LO2 To analyse the CAN-FD and LIN based communication protocols with suitable hardware

LO3 To design and develop a prototype of an automotive embedded system, which uses any of the communication protocol.

Course Outcomes (CO)

CO1 Understand vehicular networking architectures CAN-FD, CAN security

CO2 Understand the architecture of LIN and MOST communication protocol CO3 Evaluating vehicular networking architectures using simulation tools

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	2	-	2
CO 2	-	-	2	-	2
CO 3	-	-	2	3	2

Skills Acquired: Design and analysis of vehicular communication networks models for vehicular applications.

Course Contents

Unit.1: (15 Hours)

In-Vehicle Communication Networks- Historical Perspective and Review-CANFD Protocol-Overview of CANFD bus architecture – Physical Layer – Topology – frame architecture – CAN vs CANFD - Bit stuffing and CRC – Delay compensation – Error Handling. Instrument Cluster Simulator (ICSim) for SocketCAN- Car loop Simulator, Virtual CAN Network- CAN Developer Studio- Virtual ECU tools - Introduction to CAN bus security and simulations.

Unit.2: (15 Hours)

LIN Protocol- Overview – Frame Format – Bus Timing – Topology – Error detection – Sleep/Wake-up modes – Advanced Frames.

Unit.3: (15 Hours)

MOST Protocol-Overview - Physical Layer – Network and Fault Management – Diagnostics – Interface Controller – Applications – Overview of Automotive Ethernet protocols.

References

1. Richard Zurawski, "Industrial Communication Technology Handbook", 2nd Edition, CRC Press, 2014.
2. Gilbert Held, "Inter- and Intra-Vehicle Communications", Auerbach Publications, 2007.
3. Dominique Paret, Roderick Riesco, "Multiplexed Networks for Embedded Systems: CAN, LIN, FlexRay, Safe-by-Wire", John Wiley and Sons, 2007.
4. Andreas Grzemba, "MOST- The Automotive Multimedia Handbook", Franzis Verlag GmbH, 2011.
5. Olaf Pfeiffer, Implementing Scalable CAN Security with CANcrypt Authentication and encryption for the Controller Area Network (CANcrypt), Embedded Systems Academy GMBH, 2017.
6. Wilfried Voss, Controller Area Network Prototyping with Arduino, Copperhill Technologies Corporation, 2014.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

WIRELESS SENSOR NETWORKS

21CM704 **3-0-0-3**

Learning Objectives (LO)

LO1 To facilitate understanding of the theoretical aspects of wireless sensor networks.
LO2 To educate the ideas and illustrations from distributed signal processing, communications and cross-layer optimization to design Wireless sensor network.
LO3 To enable the students to design a wireless sensor network for specific application.
LO4 To educate the students to analyze the attributes required for transmission in large wireless senor networks.

Course Outcomes (CO)

CO1 Ability to understand and conceptualize WSNs from different angles.
CO2 Ability to design large-scale sensor networks with constraints and perform parametric analysis.
CO3 Ability to design the network for specific applications in WSN’s
CO4 Ability to evaluate a wireless sensor networks by performing distributed signal processing, applying communication algorithms and novel cross-layer design paradigms.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	-
CO 2	-	-	3	3	2
CO 3	-	-	3	3	3
CO 4	-	-	3	-	3

Skills Acquired: Acquiring the skills for designing a wireless sensor network.

Course Contents

Unit.1: (15 hours)

Introduction – WSN- challenges of WSN-Architectures- single node architecture-network architecture-Enabling technologies for WSN- Network Topology-Fundamental Properties and Limits: Information-theoretic Bounds on Sensor Network Performance - Network Information Processing in Wireless Sensor Networks - Sensing Capacity of Sensor Networks - Law of Sensor Network Lifetime and Its Applications.

Unit.2: (15 hours)

Signal Processing for Sensor Networks: Detection in Sensor Networks - Distributed Estimation Under Bandwidth and Energy Constraints - Distributed Learning in Wireless Sensor Networks - Graphical Models and Fusion in Sensor Networks - Communications, Networking and Cross-Layered Designs: Randomized.

Unit.3: (15 hours)

Cooperative Transmission in Large-Scale Sensor Networks.

Application Dependent Shortest Path Routing in Ad-Hoc Sensor Networks - Data-Centric and Cooperative MAC Protocols for Sensor Networks -Game Theoretic Activation and Transmission Scheduling in Unattended Ground Sensor Networks: Applications of wireless sensor networks -localization- hazardous area monitoring-habitat monitoring

References:

1. Ananthram Swami, Qing Zhao, Yao-Win Hong, & Lang Tong, "Wireless Sensor Networks: Signal Processing and Communications" Wiley Inc, 2007.
2. Holger Karl, &Andreas Willig "Protocols and Architectures for Wireless Sensor Networks", Wiley Inc, 2005.
3. Azzedine Boukerche, "Handbook of Algorithms for Wireless Networking and Mobile Computing", Chapman & Hall/CRC, 2006
4. Nirupama Bulusu and Sanjay Jha, "Wireless Sensor Networks: A systems perspective", Artech House, August 2005.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Multi Sensor Data Fusion

21CM705 **3-0-0-3**

Learning Objectives (LO)

LO1 To introduce of the mathematical foundations of data fusion methods.

LO2 To provide appropriate data fusion methods to problems in signal processing applications.

LO3 To characterise various intelligent fusion algorithms based on soft computing techniques

LO4 To provide insights for the design of data fusion models for signal processing applications

Course Outcomes (CO)

CO1 Ability to understand the benefits and shortcomings of various data fusion algorithms.

CO2 Ability to apply appropriate data fusion techniques to problems in signal processing applications.

CO3 Ability to analyse the intelligent fusion algorithms based on soft computing techniques

CO4 Ability to create fusion models for signal processing applications

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	-
CO 2	-	-	3	-	-
CO 3	-	-	3	3	3
CO4	-	-	3	3	-

Skills Acquired: Design and Analysis of various data fusion models for signal processing applications.

Course Contents

Unit.1: (15 hours)

Introduction to data fusion process: data fusion models- configurations and architectures. Probabilistic Data Fusion: Maximum Likelihood- Bayesian- and Maximum Entropy methods. Recursive Bayesian methods for estimation and data fusion: Kalman filter theory-Kalman filter as a natural data-level fuser.

Unit.2: (15 hours)

Data fusion by nonlinear Kalman filtering; Information filtering; H-infinity filtering-Multiple hypothesis filtering: Data fusion with missing measurements- Possibility theory and Dempster-Shafer Method- ANN and Fuzzy Logic based Decision Fusion.

Unit.3: (15 hours)

Decision Theory based Fusion: Bayesian decision theory- decision making with multiple information sources- Fuzzy approach- decision making based on voting- Performance Evaluation of Data Fusion systems: Monte Carlo methods. JDL Process: Review of algorithms used for Object Refinement, Situation Refinement, Threat Refinement and Process Refinement.

References

1. Jitendra R Raol, *Data Fusion Mathematics: Theory and Practice*, CRC Press, 2016.
2. David L. Hall, *Mathematical Techniques in Multisensor Data Fusion*, Artech House, Boston, 1992.
3. R. Brooks and S.S. Iyengar, *Multisensor Fusion: Fundamentals and Applications with Software*, Prentice Hall
Inc., New Jersey, 1998.
4. James V. Candy, *Signal Processing: The Model Based Approach*, McGraw –Hill Book Company, 1987.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA

Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Massive MIMO

21CM706 **3-0-0-3**

Learning Objectives (LO)

LO1 To introduce the basic Massive MIMO concept, results and properties.

LO2 To provide an introduction to the theoretical tools that are suitable for analyzing the Massive MIMO performance.

LO3 To impart advanced Massive MIMO techniques and algorithms

Course Outcomes (CO)

CO1 Ability to understand and analyze Massive MIMO systems with baseband signal processing aspects.

CO2 Ability to apply the modeling and simulation concepts to massive MIMO system

CO3 Ability to analyze complex wireless communication systems

CO4 Ability to design massive MIMO communication system

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	3
CO 2	-	-	3	3	3
CO 3	-	-	3	-	2
CO 4	-	-	3	-	2

Skills Acquired: Designing wireless networks for next generation systems and backhaul architectures.

Course Contents

Unit.1: (15 hours)

Introduction – multi antenna channels – Large MIMO systems – opportunities – challenges – MIMO encoding – spatial multiplexing – space time coding – spatial modulation

Unit.2: (15 hours)

MIMO detection – Linear detection – LR aided detection – sphere decoding – detection based on local search – probabilistic data association – message passing on graphical models – factor graphs

Unit.3: (15 hours)

Markov chain Monte Carlo – Channel estimation – iterative channel estimation - MIMO Precoding – multi cell prrecoding – multiuser precoding - Channel Models – Analytical channel model – standard channel model – antenna arrays– Large MIMO Testbeds

References

1. A. Chockalingam & B. Sundar Rajan, *Large MIMO Systems*, Cambridge University Press, 2014.
2. T.L.Marzetta, E.G.Larsson, Hong Yang, H.Q.Ngo, *Foundations of Massive MIMO*, Cambridge University Press, 2017.
3. Emil Björnson, Jakob Hoydis and Luca Sanguinetti (2017), *Massive MIMO Networks: Spectral, Energy, and Hardware Efficiency*, Foundations and Trends in Signal Processing, 2017.
4. Shahid Mumtaz, Jonathan Rodriguez, *MmWave Massive MIMO: A Paradigm for 5G*, Elsevier Science, 2016.
5. Hien Quoc Ngo, *Massive MIMO: Fundamentals and System Designs*, Linköping University Press, 2015.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Internet of Things

21CM711 **3-0-0-3**

Learning Objectives (LO):

LO1 To introduce the emerging technologies, standards and applications of Internet of Things.

LO2 To impart insights on the challenges and design considerations of Internet of Things.

LO3 To enable identification of different access technologies and protocols to build an IoT network.

Course Outcomes (CO):

CO1 Ability to understand IoT architectures, communication technologies and protocols.

CO2 Ability to analyze routing protocols for low power IoT applications.

CO3 Ability to evaluate and compare access technologies for IoT applications.

CO4 Ability to design and develop IoT applications using off-the-shelf wireless technology.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	-
CO 2	-	-	3	3	-
CO 3	-	-	3	-	-
CO4	-	-	3	3	2

Skill Acquired: Design and Analysis of IoT prototype for a specific application.

Course Contents:
Unit 1: (15 Hours)
Introduction - M2M to IoT - IoT Network Architecture - Constrained devices and networks – Sensors - Actuators and smart objects - Sensor networks and protocols - Communication criteria for choosing between access technologies - Building small IoT Projects with Arduino.

Unit 2: (15 Hours)

IoT Access Technologies - IEEE 1901.2a - IEEE 802.15.4/e/g - IEEE 802.11ah -LoRa WAN - NB-IoT and other LTE variations - IoT Network Layer - Adoption vs. adaptation of IP for IoT - IP versions – 6LoWPAN (IPv6 over Low power WPAN) - Mesh addressing - Mesh-under Vs. mesh-over routing - 6TiSCH, RPL (Routing Protocol for Low-Power and Lossy Networks).

Unit 3: (15 Hours)
IoT Transport and Application Layers - CoAP (Constrained Application Protocol) - MQTT (Message Queuing Telemetry Transport) -Cognitive RPL (CORPL) - Content Centric Networking - IoT Applications and Use Cases - Hardware prototyping of IoT use cases.

References:
1. Hanes, David, Gonzalo Salgueiro, Patrick Grossetete, Robert Barton, and Jerome Henry, IoT fundamentals: Networking technologies, protocols, and use cases for the internet of things, Cisco Press, 2017.
2. Houda Labiod, Hossam Afifi, and Costantino De Santis, Wi-Fi, Bluetooth, Zigbee and WiMAX, Springer, 2007.
3. Javed, Adeel, Building Arduino projects for the Internet of Things: experiments with realworld applications, Apress, 2016.
4. Waher, Peter, Pradeeka Seneviratne, Brian Russell, and Drew Van Duren, IoT: Building Arduino-Based Projects, Packt Publishing Ltd., 2016.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA

End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Software Defined Radio

21CM712 **3-0-0-3**

Learning Objectives (LO):

LO1 To introduce the design concepts of communication systems on reprogrammable and reconfigurable hardware platform.

LO2 To provide insights into multirate signal processing in digital transceiver.

LO3 To impart knowledge on different architectures and tools in software defined radio.

Course Outcomes (CO):

CO1 Ability to understand basic theories, principles, technologies in Software Defined Radio.

CO2 Ability to apply multirate signal processing concepts in digital transceiver.

CO3 Ability to analyze efficient architectures for multirate systems.

CO4 Ability to design and evaluate performance of digital transceiver.

CO-PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	-
CO 2	-	-	3	2	-
CO 3	-	-	3	3	-
CO 4	-	-	3	3	3

Skills Acquired: Design and analyze digital transceiver.

Course Contents

Unit.1: (15 hours)

Introduction to software-defined radio - Digital filtering - Signal recovery - Baseband and Bandpass Sampling - Hardware and Software Architecture for SDR - Universal Software Radio Peripheral - RTL-SDR

Unit.2: (15 hours)

Multirate signal processing - Sample Rate conversion principles - Efficient Structures for Decimation and Interpolation Filters – Polyphase filters – Digital Filters Banks– Arbitrary sampling rate conversion – CIC Filter - Quadrature Mirror Filters (QMF) - Wavelet filters.

Unit.3: (15 hours)

Application in communication systems – Conventional Digital down converters (DDC) - Aliasing DDC- carrier acquisition and tracking – timing recovery – channel equalization – Baseband PAM transceiver - QAM transceiver.

References
1. Jeffrey H Reed, *Software Radio: A Modern Approach to Radio Engineering*, Prentice Hall PTR, 2002.
2. Johnson, C.R. and W.A. Sethares, *Telecommunication Breakdown: Concepts of Communication Transmitted via Software-Defined Radio*, Pearson Prentice Hall, 2004.
3. Tony J. Rouphael, *RF and Digital Signal Processing for Software-Defined Radio: A Multi-Standard Multi-Mode Approach*, Elsevier Inc., 2009.
4. Walter Tuttlebee, *Software Defined Radio: Origins, Drivers and International Perspectives*, John Wiley and Sons Ltd, 2002.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Cyber Physical Systems

21CM713 **3-0-0-3**

Learning Objectives (LO)

LO1 To provide the knowledge and skills in various hardware and software design aspects of Cyber Physical Systems

LO2 To introduce real world problems, design and validation of solutions

LO3 To impart an exposition of the challenges in implementing a cyber-physical system from a computational perspective

Course Outcomes (CO)

CO1 Ability to understand the various platform aspects of cyber physical systems

CO2 Ability to apply various modeling formalisms for CPS

CO3 Ability to analyze CPS security and safety aspects

CO4 Ability to design and implement a simple CPS platform

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5

CO 1	-	-	3	-	3
CO 2	-	-	3	-	3
CO 3	-	-	3	2	2
CO 4	-	-	3	3	2

Skills Acquired: Design and implementation of CPS platforms, customization and automation.

Course Contents

Unit.1: (15 hours)

Cyber-Physical Systems Overview - Cyber-Physical Systems (CPS) in the real world - Basic principles of design and validation of CPS - CPS Network - CPS Software stack – RTOS - Scheduling Real Time control tasks.

Unit.2: (15 hours)

Principles of Automated Control Design - Dynamical Systems and Stability - Controller Design Techniques - Stability Analysis- CPS implementation issues - CPS Performance Analysis - effect of scheduling, bus latency, sense and actuation faults on control performance, network congestion - Building real-time networks for CPS

Unit.3: (15 hours)

Intelligent CPS - Safe Reinforcement Learning - Robot motion control - Autonomous Vehicle control - Gaussian Process Learning - Smart Grid Demand Response - Building Automation. Secure Deployment of CPS - Secure Task mapping and Partitioning

References

11. Rajeev Alur, *Principles of Cyber-Physical Systems*, MIT Press, 2015.
12. E. A. Lee, Sanjit Seshia, *Introduction to Embedded Systems – A Cyber–Physical Systems Approach*, MIT Press, 2013.
13. Gaddadevara Matt Siddesh, Ganesh Chandra Deka, Krishnarajanagar GopalaIyengar Srinivasa, Lalit Mohan Patnaik, *Cyber-Physical Systems: A Computational Perspective*, CRC Press, 2015.
14. B Vinoth Kumar, J.Uma Maheswari, Xiao-Zhi Gao, *Smart Cyber Physical Systems: Advances, Challenges and Opportunities*, CRC Press, 2020
15. Danda B. Rawat, Sabina Jeschke, Christian Brecher , *Cyber-Physical Systems: Foundations, Principles and Applications*, Elsevier Science, 2016.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA

*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Big Data Analytics

21CM721 **3-0-0-3**

Learning Objectives (LO)
LO1 To facilitate understanding of the techniques to handle large datasets using MapReduce.
LO2 To impart knowledge on how to analyze and interpret streaming data.
LO3 To impart insights into applications of machine learning techniques to Big Data.

Course Outcomes (CO)
CO1 Ability to understand the concepts of Big-Data analytics
CO2 Ability to apply Big-Data concepts for analysis of static and streaming data
CO3 Ability to analyze the given large scale data processing problem using Apache Spark.
CO4 Ability to design algorithms for machine learning based solutions to big-data problems.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	3	2
CO 2	-	-	3	3	2
CO 3	-	-	2	3	2
CO4	-	-	2	3	2

Skills Acquired: Extract information from large datasets using big data analytics concepts.

Course Contents
Unit.1: (15 hours)
Introduction to data mining- Statistical limits on data mining- Importance of words in documents- Hash functions- Indexes-Secondary storage- Base of natural logarithms-Power laws-MapReduce and the new software stack- Distributed file systems- MapReduce-Algorithms using MapReduce- extensions to MapReduce- Communication-Cost model-Complexity theory for MapReduce.

Unit.2: (15 hours)
Spark core concepts and architecture- Spark unified stack- Apache Spark applications -Resilient Distributed Datasets- Introduction to RDDs- RDD operations- Working with key/value pair RDD-Spark SQL-DataFrames-Datasets-SQL-Aggregations- Joins-Functions-Stream processing concepts-Spark streaming overview-Spark structured

streaming-Event time-Arbitrary stateful processing- Handling duplicate data- Fault tolerance- Streaming query metrics and monitoring.

Unit.3: (15 hours)
Machine learning with Spark- Machine learning types- Machine learning process-Machine learning pipelines-Transformers-Estimators-Pipeline-Model tuning-Machine learning applications-classification-regression-recommendation.

References
1. Jure Leskovec, Anand Rajaraman and Jeffrey David Ullman, “Mining of Massive Datasets”, 3rd Edition, Cambridge University Press, 2020
2. Hien Luu, “Beginning Apache Spark 2: With Resilient Distributed Datasets, Spark SQL, Structured Streaming and Spark Machine Learning library”, APress, 2018
3. Bill Chambers and Matei Zaharia, “Spark: The Definitive Guide- Big Data Processing Made Simple”, Oreilly, 2018.
4. By Rajdeep Dua, Manpreet Singh Ghotra and Nick Pentreath, "Machine Learning with Spark", 2nd Edition, Packt Publishing, 2017.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Game Theory

21CM722 **3-0-0-3**

Learning Objectives (LO)
LO1 To provide an introduction to the study of game theory and its applications.
LO2 To introduce to the fundamental tools of game theory.
LO3 To provide an understanding of equilibrium concepts.

Course Outcomes (CO)
CO1 Able to understand mathematical concepts of game theory
CO2 Able to apply game theory concepts for analysis of equilibria.
CO3 Able to employ game theory for evaluation of strategic games.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	2	3
CO 2	-	-	2	3	2

CO 3	-	-	2	3	2

Skills Acquired: The ability to apply game theory for a wide range of real-life applications.
Course Contents:
Unit 1: (15 hours)
Introduction to Game Theory-The theory of rational choice-Games with Perfect Information- Nash Equilibrium- Theory, Strategic games -Examples of Nash equilibriumBest response functions- Dominated actions- Equilibrium in a single population.

Unit 2: (15 hours)
Mixed Strategy Equilibrium - Strategic games in which players may randomize - Mixed strategy Nash equilibrium - Dominated actions - Pure equilibria when randomization is allowed - The formation of players' beliefs.

Unit 3: (15 hours)
Extensive games with perfect information - Strategies and outcomes - Subgame perfect equilibrium - backward induction - Coalitional Games- the Core - Games with Imperfect Information - Bayesian Games.

References
1. Martin Osbome, "An Introduction to Game Theory", Oxford University Press, 2003.
2. Allen B. MacKenzie, Luiz A. DaSilva, "Game Theory for Wireless Engineers", Morgan & Claypool, 2006.
3. Joel Watson, "Strategy- An Introduction to Game Theory", Third Edition, W. W. Norton & Company, 2013.
4. Paul R. Thie and G. E. Keough, "An Introduction to Linear Programming and Game Theory", Third Edition, John Wiley & Sons, 2008.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Convex Optimization

21CM723 **3-0-0-3**

Learning Objectives (LO)
LO1 To introduce mathematical optimization problems which arise in a variety of applications

LO2 To provide knowledge of various applications in areas such as, estimation and signal processing, communications and networks.
LO3 To impart computational optimization techniques for scientific problems.

Course Outcomes (CO)

CO1 Ability to understand convex optimization problems
CO2 Ability to apply sophisticated algorithms based on convex Optimization for applications
in communication and signal processing
CO3 Ability to analyze computationally efficient techniques for convex optimization problems
CO4 Ability to evaluate computational aspects of convex optimization techniques

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	3
CO 2	-	-	3	-	3
CO 3	-	-	3	3	2
CO 4	-	-	3	3	2

Skills Acquired: Competency in Computational optimization and advanced problem solving.

Course Contents

Unit.1: (15 hours)
Introduction - linear algebra fundamentals - Solving linear equations with factored matrices - Block elimination and Schur complements - Convex sets - Convex functions - examples

Unit.2: (15 hours)
Classes of Convex Problems - Linear optimization problems - Quadratic optimization problems - Geometric programming - Vector optimization -Reformulating a Problem in Convex Form

Unit.3: (15 hours)
Lagrange Duality Theory and KKT Optimality Conditions - Interior-point methods- Primal and Dual Decompositions-Applications

References

1. Stephen Boyd and Lieven Vandenberghe, *Convex Optimization*, Cambridge University Press, 2004.
2. Daniel Palomar, *Convex Optimization in Signal Processing and Communications*, Cambridge University Press, 2009.
3. Dimitri P Bertsekas, *Convex Optimization Theory*, Athena Scientific, 2009.
4. Steven G. Krantz, *Convex Analysis*, CRC Press, 2014.

5. Ralph Tyrell Rockafellar, *Convex Analysis*, Princeton University Press, 2015.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Natural Language Processing

21CM724 **3-0-0-3**

Learning Objectives (LO)

LO1 To provide foundational understanding in natural language processing methods and strategies.
LO2 To help apply the ideas and illustrations to evaluate the strengths and weaknesses of various NLP technologies.
LO3 To use NLP technologies to explore and gain a broad understanding of text data
LO4 To use NLP methods to perform topic modelling

Course Outcomes (CO)

CO1 Ability to understand approaches to syntax, and semantics processing in NLP.
CO2 Ability to apply NLP techniques.
CO3 Ability to design a text processing system.
CO4 Ability to evaluate mathematical models and methods used in NLP applications.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	-
CO 2	-	-	3	3	2
CO 3	-	-	3	3	-
CO 4	-	-	3	-	3

Skills Acquired: Designing aspects of a natural language processing system.

Course Contents:
Unit 1: (15 hours)
Introduction - human languages - models, ambiguity, processing paradigms - phases in natural language processing, applications - text representation in computers - encoding schemes - linguistics resources - introduction to corpus - elements in balanced corpus - TreeBank, WordNet, etc. - resource management using NLTK

Unit 2: (15 hours)
Regular expressions - finite state automata - word recognition – lexicon - morphology, - Ngrams – smoothing – entropy – HMM – SVM - part of speech tagging - stochastic POS tagging - transformation based tagging, handling of unknown words - named entities, multi word expressions - a survey on natural language grammars - context free grammar - spoken language – syntax - parsing - meaning representation.

Unit 3: (15 hours)
Word sense disambiguation - dictionary based approaches - discourse - reference resolution - algorithm for pronoun resolution - text coherence - discourse structure - applications of NLP - spell-checking - summarization - information retrieval - vector space model - machine translation, an overview – introduction to deep learning - applications of deep learning in NLP – word2vec – sentiment modeling and analysis – grouping words by their semantic similarities.

References:
1. Daniel Jurafsky and James H Martin. Speech and Language Processing, 2e, Pearson Education, 2009
2. Manning and Schutze, "Statistical Natural Language Processing", MIT Press; 1st edition June 18, 1999
3. Steven Bird, Ewan Klein, and Edward Loper, Natural Language Processing with Python, OReilly, Aug. 2018.
4. R Arumugam, and R. Shanmugamani, Hands-on Natural Language Processing with Python, Packt Publishing Limited, July 2018.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Department of Electronics and Communication Engineering Curriculum 2021

M. Tech Communication Systems

Deep Learning

21CM725 **3-0-0-3**

Learning Objectives (LO)

LO1 To introduce the idea of artificial neural networks and their architecture

LO2 To introduce algorithms used for training artificial neural networks.

LO3 To enable design of artificial neural networks for classification and sequence analysis.

LO4 To enable design and deployment of deep learning models for machine learning problems

Course Outcomes (CO)

CO1 Ability to understand the mathematics behind functioning of artificial neural networks

CO2 Ability to apply deep learning concepts to classification problems.

CO3 Ability to analyze the given dataset for designing a neural network based solution.

CO4 Ability to design and implement of deep learning models for signal/image processing applications.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	3
CO 2	-	-	3	2	2
CO 3	-	-	3	3	2
CO4	-	-	3	3	3

Skills Acquired: Design and implementation of deep learning models for real-world applications.

Course Contents

Unit 1: (15 hours)

The Neuron-Expressing Linear Perceptrons as Neurons- Feed-Forward Neural Networks- Linear neurons and their limitations- Sigmoid- tanh- ReLU neurons- Softmax output Layers- Training feed-forward neural networks - gradient descent - delta rule and learning rates - Gradient descent with sigmoidal neurons - Backpropagation algorithm - Stochastic and minibatch gradient descent - Test sets - Validation sets and Overfitting - Preventing overfitting in deep neural networks - Local Minima in the error surfaces of deep networks- Model identifiability- Spurious local minima in deep networks- Flat regions in the error surface – Momentum based optimization- Learning rate adaptation.

Unit 2: (15 hours)

Convolutional Neural Networks (CNN) architecture - Accelerating training with batch normalization- Visualizing learning in convolutional networks - Embedding and representation learning - Autoencoder architecture - Denoising - Sparsity in autoencoders.

Unit 3: (15 hours)

Models for sequence analysis - Recurrent Neural Networks- Vanishing gradients- Long Short-Term Memory (LSTM) Units-Augmenting Recurrent networks with Attention.
Deep Generative Networks - Generative Adversarial Networks - Deep Reinforcement Learning - Markov Decision Processes (MDP) - Explore versus Exploit - Policy versus Value learning - Q-Learning and Deep Q-Networks.

References

1. Nikhil Buduma, Fundamentals of Deep Learning: Designing Next-Generation Machine Intelligence Algorithms, O’Reilly, 2017.
2. Shaoshan Liu, Liyun Li, Jie Tang, Shuang Wu and Jean-Luc Gaudiot. Creating Autonomous Vehicle Systems, Morgan & Claypool Publishers,2018.
3. Ian Goodfellow, Yoshua Bengio and Aaron Courville, Deep Learning , MIT Press, 2016.
4. Aurélien Géron, Hands-On Machine Learning with Scikit- Learn and TensorFlow, O’Reilly, 2017.
5. Nikhil Ketkar, Deep Learning with Python: A Hands-on Introduction, Apress, 2017.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Millimeter Wave Communication Systems

21CM731 **3-0-0-3**

Learning Objectives (LO)

LO1 To facilitate understanding of channel behavior in millimeter wave communication systems
LO2 To provide insights of transceiver architecture in mm wave communication range
LO3 To impart knowledge on beam steering and beam forming techniques in multi antenna array

Course Outcomes (CO)

CO1 Ability to understand channel models for millimeter wave systems
CO2 Ability to apply single carrier, multicarrier modulation and MIMO techniques for millimeter wave communication systems based on channel models.
CO3 Ability to analyze the diversity and beamforming techniques in millimeter wave systems.

CO4 Ability to evaluate the performance of multiantenna millimeter wave system

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	-
CO 2	-	-	3	2	-
CO 3	-	-	3	3	-
CO 4	-	-	3	3	3

Skills Acquired: Design and evaluate the performance of millimeter wave systems

Course Contents:

Unit.1: (15 hours)

Millimeter Wave (MMW) characteristics - 60GHz MMW Case Study and Technical Challenges - Channel performance at 60 GHz - ITU Indoor Path Loss Model - Log Distance Path Loss Model - Link Budget.

Unit.2: (15 hours)

Modulation Schemes for MMW communications- PSK - OFDM. MMW Transceiver architecture- MMW Antennas- Path Loss and Antenna Directivity - Antenna Beam width - Beam steering Antenna- Need for MIMO – Channel Capacity of SISO and MIMO Systems

Unit.3: (15 hours)

Spatial Diversity of Antenna Arrays - Noise Coupling in a MIMO System - Potential Benefits of Advanced Diversity for MMW- Dynamic Spatial, Frequency and Modulation Allocation - Advanced Beam steering and Beam forming.

References

1. Kao- Cheng Huang and Zhoacheng Wang, *Millimeter Wave Communication Systems*, Wiley IEEE Press, 2011.
2. Theodore S.Rappaport, Robert W. Heath Jr. Robert C. Daniels and James N. Murdock, *Millimeter Wave Wireless Communication*, Prentice Hall, 2014.
3.John S. Seybold, *Introduction to RF Propagation*, John Wiley and Sons, 2005.
4. Chia-Chin Chong, Kiyoshi Hamaguchi, Peter F. M. Smulders an d Su-Khion g, *Millimeter- Wave* Wireless *Communication Systems*: *Theory and Applications*, Hindawi .2007.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50

Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Cooperative and Relay Communication

21CM732 **3-0-0-3**

Learning Objectives (LO)

LO1 To facilitate understanding of cooperative and relay communication in wireless networks

LO2 To provide insights of principles in cooperative and relay system

LO3 To impart knowledge on design of distributed communication in wireless system

Course Outcomes (CO)

CO1 Ability to understand cooperative and relay communication in wireless networks

CO2 Ability to apply different relay techniques suitable for modern wireless systems

CO3 Ability to analyze relay and multihop communication in wireless networks

CO4 Ability to evaluate performance of relay based systems over conventional wireless systems.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	-
CO 2	-	-	3	2	-
CO 3	-	-	3	3	-
CO 4	-	-	3	3	3

Skills Acquired: Design and analyze relay and multihop communication in wireless networks.

Course Contents

Unit 1: (15 hours)

Overview of cooperative and relay communication - Brief history of cooperative and relay Channels - Standardization of cooperative communication and relay technology - Review of wireless communications and MIMO techniques

Unit 2: (15 hours)

Two user cooperative transmission schemes - Decode and forward - Amplify and forward Coded cooperation - Compress and forward relaying schemes - Channel estimation in single relay schemes

Unit 3: (15 hours)

Cooperative transmission schemes with multiple relays - Orthogonal cooperation - Transmit beamforming - Selective relaying - Distributed space-time coding- Channel estimation in multirelay systems - Multihop cooperative transmissions.

References

1. Y.-W. Peter Hong, Wan-Jen Huang, C.-C. Jay Kuo, *Cooperative Communications and Networking: Technologies and System Design*, Springer, 2010
2. Murat Oysal, *Cooperative Communications for Improved Wireless Network Transmission: Framework for Virtual Antenna Array Applications*, IGI Global, 2010.
3. Mischa Dohler, Yonghui Li, *Cooperative Communications: Hardware, Channel & Phy, Wiley, 2010.*
4. Yan Zhang, Hsiao-Hwa Chen, Mohsen Guizani, *Cooperative Wireless Communications*, CRC, 2009.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Automotive Radar Systems

21CM733 **3-0-0-3**

Learning Objectives (LO)
LO1 To introduce radar principles and associated systems design aspects.
LO2 To provide understanding of radar performance and analysis.
LO3 To characterize the performance of radar antenna and sub systems.
LO4 To impart the principles of automotive radars and its characteristics.

Course Outcomes (CO)

CO1 Ability to understand the basic concepts and working principles of radar systems.
CO2 Ability to apply the principles of electromagnetic concepts to radar signal propagation and systems.
CO3 Ability to analyze the antenna systems for optimizing the performance and design aspects of automotive radar applications.
CO4 Ability to evaluate the characteristics and performance of the automotive radar systems.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5

CO 1	-	-	3	-	3
CO 2	-	-	3	2	3
CO 3	-	-	3	3	2
CO4	-	-	3	3	2

Skills Acquired: Design and analysis of Automotive Radar Systems.

Course Contents
Unit.1: (15 hours)
Introduction to radar systems – frequency spectrum – Functions of radar – waveform, power and energy – range measurement – Doppler effect and target motion – automotive radar principles – automotive radar specifications – Radar equation – Radar cross section – radar cross section on various surfaces – basic types of radar systems

Unit.2: (15 hours)
Radar antenna systems – planar antenna systems – antenna design and analysis – array antenna design – phased array antenna – beamforming antenna array principles – system level approach for scanning beam antenna arras – system level approaches for beamforming antennas and applications – descriptions of automotive radar antenna systems

Unit.3: (15 hours)
Millimeter wave wave propagation principles – ADAS – concepts of autonomous driving – materials for radar system design – various type of automotive radar components and its applications – specifications of radar components – examples.

References

1. Peyton Z Peebles, Jr Radar principles, John Wiley & Sons, 2015
2. C A Balanis, Antenna Theory Analysis and Design, Second Edition 2010
3. David M Pozar, Microwave Engineering, Fourth Edition, John Wiley and Sons, 2012
4. Robert Mailloux, Phased Array Antenna – Handbook, Artech House, 2005

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Error Control Coding

Department of Electronics and Communication Engineering
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21CM734 **3-0-0-3**

Learning Objectives (LO)

LO1 To provide understanding of the properties, encoding and decoding techniques of error control codes.

LO2 To introduce the state-of-the-art error control codes.

LO3 To impart knowledge on the performance metrics of the error control codes.

Course Outcomes (CO)

CO1 Ability to understand concepts of Galois field.

CO2 Ability to apply the concept of channel coding theorem and be able to select codes based on the properties of codes and perform encoding of the data to be transmitted.

CO3 Ability to analyse the performance of codes using the decoding algorithms.

CO4 Ability to evaluate the improvement in error control performance using strong codes.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	-
CO 2	-	-	3	2	-
CO 3	-	-	3	3	-
CO 4	-	-	3	3	3

Skills Acquired: Design and analysis of error control coding in communication systems.

Course Contents

Unit.1: (15 hours)

Computations using Galois field arithmetic -Review of linear block codes-BCH codes- Code construction– Decoding of BCH codes - Interleaved codes - Product codes

Unit.2: (15 hours)

Encoding and decoding of Reed Solomon codes - Trellises for linear block codes - Optimum decoding of Convolutional codes: Soft output Viterbi algorithm (SOVA), BCJR algorithm - single level and multilevel concatenated codes.

Unit.3: (15 hours)

Turbo codes- Design and properties of Turbo codes, Iterative decoding of Turbo codes - LDPC codes- Construction of LDPC codes-Bit flipping- Sum product and Min sum decoding algorithms- Polar codes -Properties- Encoding and Decoding of polar codes.

References

1. Shu Lin and Daniel J.Costello, Error Control Coding – Fundamentals and Applications, Second Edition, Prentice-Hall, 2004.
2. Tom Richardson and Rudiger Urbanke, Modern Coding Theory, Cambridge University Press, 2008.

3. Richard E. Blahut, Algebraic Codes for Data Transmission, Cambridge University Press, 2003.
4. Richard B. Wells, Applied Coding and Information Theory for Engineer, Pearson Education, LPE, First Indian Reprint, 2004.
5. W.C. Huffman and V. Pless, Fundamentals of Error-Correcting Code, Cambridge, 2003
6. Sanvicente**,** Emilio, Understanding Error Control Coding Springer International Publishing, 2019

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Optical Wireless Communication

21CM735 **3-0-0-3**

Learning Objectives (LO)

LO1	To introduce the concepts of optical wireless channel models.
LO2	To impart knowledge on the modulation techniques used in optical wireless systems.
LO3	To provide insights on concepts of indoor and outdoor optical wireless communication.

Course Outcomes (CO)

CO1	Ability to understand the optical wireless channel models
CO2	Ability to apply the concepts of communication theory for optical wireless systems
CO3	Ability to analyze the performance of optical wireless communication systems
CO4	Ability to design optical communication systems conforming to industry standards

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	-
CO 2	-	-	3	-	3
CO 3	-	-	3	-	2

CO 4	-	-	3	2	2

Skills Acquired: Design and analyze optical wireless communication systems.

Course Contents

Unit.1: (15 hours)

Introduction to optical wireless communication systems - OWC/Radio comparison - Optical sources - Optical detectors - Photo-detection noises - Indoor optical wireless channel model - Outdoor optical wireless channel.

Unit.2: (15 hours)

Analogue Intensity Modulation – Digital Baseband modulation techniques - Pulse Position Modulation – Subcarrier Intensity Modulation – OFDM for Optical wireless communication - Optical Polarization Shift Keying.

Unit.3: (15 hours)

Effect of ambient light sources on Indoor optical wireless channel - Link Performance for Multipath Propagation - Mitigation Techniques - FSO Link Performance under the Effect of Atmospheric Turbulence - Outdoor OWC Links with Diversity Techniques - Aperture Averaging - Visible Light Communications.

References

1. Z. Ghassemlooy, W. Popoola, S. Rajbhandari, *Optical Wireless Communications*, Second Edition, Cambridge University Press, 2017.
2. George Karagiannidis, John Barry, Murat Uysal, Robert Schober, Shlomi Arnon, *Advanced Optical Wireless Communication Systems*, Cambridge University Press, 2012.
3. Anthony Boucouvalas, Carlo Capsoni, Eszter Udvary, Murat Uysal, Zabih Ghassemlooy, *Optical Wireless Communications An Emerging Technology*, Springer International Publishing, 2016.
4. Zabih Ghassemlooy, Luis Nero Alves, Stanislav Zvanovec, Mohammad-Ali Khalighi, *Visible Light Communications Theory and Applications,* First Edition, CRC Press, 2019.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Department of Electronics and Communication Engineering
Curriculum 2021
M. Tech Communication Systems

Quantum Communications

21CM736 **3-0-0-3**

Learning Objectives (LO)
LO1 To introduce the concepts and provide a mathematical foundation for Quantum theory.
LO2 To impart knowledge on the concepts of Quantum communication systems. LO3 To provide insights on concepts of Quantum information.

Course Outcomes (CO)

CO1 Ability to understand the concepts of quantum theory
CO2 Ability to apply the concepts of quantum theory for communication
CO3 Ability to analyze the Shannon channel capacity limits for quantum communication systems
CO4 Ability to design quantum communication systems conforming to industry standards

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	-
CO 2	-	-	3	-	2
CO 3	-	-	3	-	2
CO 4	-	-	3	2	2

Skills Acquired: Design and analyze quantum communication systems.

Course Contents:
Unit.1: (15 hours)
Concepts of Quantum Mechanics - Quantum Information - Vector and Hilbert Spaces - Elements of Quantum Mechanics - The Environment of Quantum Mechanics - Statistical Description of a Closed Quantum System - Dynamical Evolution of a Quantum System - Quantum Measurements.

Unit.2: (15 hours)
Classical and Quantum Communications Systems – Analysis of a Quantum Communications System - Quantum Decision Theory – Formulation of Optimal Quantum Decision - Holevo’s Theorem - Kennedy’s Theorem - Square Root Measurements - Performance Evaluation with the SRM Decision - Quantum Binary Communications Systems - Quantum Communications Systems with Thermal Noise - Implementation of QTLC Systems

Unit.3: (15 hours)
Introduction to Quantum Information - Overview of Entanglement - Quantum Entropy - Quantum Data Compression - Quantum Channels and Open Systems - Accessible Information and Holevo Bound - Transmission Through a Noisy Quantum Channel - Introduction to Quantum Cryptography - Quantum Key Distribution (QKD).

References:

1. Gianfranco Cariolaro, *Quantum Communications*, Springer International Publishing, 2015.
2. Mark M. Wilde, *Quantum Information Theory*, Second Edition, Cambridge University Press, 2017.
3. Nielsen, Michael A., and Isaac L. Chuang. *Quantum Computation and Quantum Information. Cambridge*, Cambridge University Press, 2000.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Wireless Communications for Unmanned Aerial Vehicles

21CM737 **3-0-0-3**

Learning Objectives (LO)

LO1 To introduce wireless communications and networking with unmanned aerial vehicles

LO2 To provide insights on aerial channel models and waveform design

LO3 To impart knowledge on system models of static and mobile unmanned aerial vehicles base station

Course Outcomes (CO)

CO1 Ability to understand concepts of wireless communications and networking with unmanned aerial vehicles.

CO2 Ability to apply channel models for air-to-air and air-to-ground communications

CO3 Ability to analyze the downlink performance of static and mobile unmanned aerial vehicles.

CO4 Ability to design wireless communication framework considering ground station scenarios.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	-
CO 2	-	-	2	-	-
CO 3	-	-	3	2	-
CO 4	-	-	3	2	3

Skills Acquired: Design and analysis of communication framework using unmanned aerial vehicles.

Course Contents:
Unit.1: (15 hours)
Evolution of unmanned aerial vehicle technology – UAV types and regulations – Wireless communications and networking with UAVs –Use cases - UAV assisted ground wireless networks for information dissemination – Cellular connected UAV user equipments

Unit.2: (15 hours)
Aerial wireless channel characteristics – Large scale and small scale propagation channel effects- Waveform design

Unit.3: (15 hours)
UAV network modeling – Downlink performance analysis for UAV base station – System model – Network with a static UAV – Mobile UAV base station scenario

References
1. Walid Saad, Mehdi Bennis et. al. *Wireless Communication and Networking for Unmanned Aerial Vehicles*, Cambridge University Press, 2020.
2. A.R. Jha, *Theory, Design and Applications of Unmanned Aerial Vehicles*, CRC press, 2017.
3. Yong Zeng, Rui Zhang, and Teng Joon Lim, *Wireless Communications with Unmanned Aerial Vehicles: Opportunities and Challenges*, IEEE Communications Magazine, 2016.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report

Estimation and Detection Theory

21CM738 **3-0-0-3**

Learning Objectives (LO):
LO1 To introduce the fundamental principles of decision making under uncertainty..
LO2 To make the students appreciate how practical problems are formulated and solved using the classical and Bayesian approaches.
LO3 To boost the mindset of application-oriented learning of random process theory through programming assignments.

Course Outcomes (CO):

CO1 Ability to understand the fundamental principles behind frequently applied estimation and detection techniques in communication systems.
CO2 Ability to apply appropriate estimation and detection techniques for problems arising in communication systems.
CO3 Ability to analyze detection techniques for discrete and continuous time signals
CO4 Ability to evaluate the performance of commonly used estimation and detection techniques for real applications

CO-PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	-
CO 2	-	-	3	2	2
CO 3	-	-	3	2	-
CO 4	-	-	3	3	3

Skills Acquired: Apply and evaluate commonly used estimation and detection techniques for real applications.

Course Contents

Unit.1: (15 hours)

Review of probability and random processes - Applications of statistical estimation and detection techniques in communication systems - Classical estimation - Bias and variance – Cramer Rao lower bound - Sufficient statistic – MVUE – Fischer Neyman factorization theorem- Rao Blackwell theorem.

Unit.2: (15 hours)

Maximum likelihood estimation - Linear models – BLUE - Least squares - Consistency, efficiency and asymptotics - Bayesian estimation - MMSE and MAP estimation - Kalman and Weiner filtering-Detection theory - Bayesian and Neyman-Pearson detection.

Unit.3: (15 hours)

Minimax Detection - Composite hypothesis testing- GLRT - Sequential detection - Performance analysis by Monte Carlo method - Signal detection in continuous time - Karhunen Loève (KL) theorem - Detection of random signals in Gaussian noise.

References

1. H. V. Poor, *An Introduction to Signal Detection and Estimation*, 2nd Ed., SpringerVerlag, 1994.
2. S.M. Kay, *Fundamentals of Statistical Signal Processing*, Volume I and II, Prentice Hall Inc., 1998.

3. H. L. Van Trees, *Detection, Estimation and Modulation Theory, Part 1*, 2nd Ed., John Wiley, 2013.
4. M. D. Srinath, P. K. Rajasekaran and R. Vishwanathan, *An Introduction to Statistical Signal Processing with Applications*, Prentice-Hall, 1996.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA – Can be Quizzes, Assignment, and Term work with report