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ENGINEERS WITH
SOCIAL RESPONSIBILITY

NAAC Accredited
Recipient of Centre of Excellence Award by the Government of Gujarat
Recipient of '5 Star' in GSIRF Ranking by Government of Gujarat

A Joint Program by DA-IICT and CR Rao AIMSCS
for
Master of Technology (MTech) Program
in
Electronics and Communication (EC)
with Specialization in
Wireless Communication and Embedded Systems

PREAMBLE

The exponential growth of data traffic passing through communication and networking infrastructure across the world is accelerating the development of new technologies and embedded design approaches. The spread of connectivity spurred by Internet of Things (IoT) and the proliferation of mobile devices are helping to address embedded communication systems requirements for hardware, software, and security.

5G technology will have profound impact in business and on consumers across the world. It promises a revolutionary experience with much faster data, shorter network response time (lower latency), instant access anywhere and everywhere, and the capacity for billion devices. Unlike 3G and 4G, 5G promises to expand far beyond our mobile devices and into the applications that touch all facets of our lives.

5G wireless represents the next major generation of mobile telecommunication standard beyond 4G. Forming the next true generation of wireless systems (5G) will require embedded engineering teams to adapt to new integrated design workflows and collaborative with a variety of ecosystem players. From enabling the Industrial Internet of Things to ensuring the safety of autonomous vehicle, 5G will change our lives in ways are hard to even imagine.

DA-IICT GANDHINAGAR

5G is a catalyst that will bring forward things like AI and ML, Smart Cities and Smart Cards and telematics and Internet of Things. It is the catalyst that has been missing in a lot of these adjacent technologies. 5G is more a disruptive catalyst than a technology in and of itself.

5G continues to develop ahead of limited commercialization and more scaled deployments and better device support in coming years, the Internet of Things (IoT) is quickly connecting objects of all sorts in an effort to capture, analyze and take action on data. In fact support for massive IoT is a core 5G use case as is ultra-reliable low latency communications, which includes IoT applications like industrial, robotics and autonomous drones.

So, what does this all mean for the embedded design community?

As 5G and IoT co-evolve, the race in on to produce even smaller, more powerful chips and modems, modules and other embedded systems needed to build the next generation devices. This program will provide excellent opportunities for future developers looking to learn the design for the IoT, as well as seasoned professionals in need of quick refreshers in wireless techniques, technologies and embedded system.

The need for and pursuit of 5G

54% of IoT solutions will require Gbit/Sec data traffic speed.
53% of engineers' management cite 802.11 and or LTE technology as critical to future success.
53% believe 5G will help customers lower operating/services cost.

Current trends in 5G Technology

5G features new technologies such as Massive MIMO and mm wave. Both technologies use multiple antennas and beam forming which is a huge departure from current and previous wireless architecture. 5G also includes new wireless control mechanisms that split the control and data to facilitate the concept of network slicing, which scales the level of service to an individual user device.

In addition, the standard proposed for 5G are for more complex than 3G and 4G standards. 5G will transform our networks, so that industry must transform the way these systems are designed, developed and tested. For algorithm design, simply modeling systems without any real-world validation has not been enough for an idea to

advance from concept to production. For test traditional component will not be able to account for the overall impact to the system.

The challenge and opportunity of the Internet of Things

The Internet of Things (IoT) is the ecosystem of physical objects devices, vehicles, building and all kinds of other objects that embedded electronics software, sensors and network connectivity. As a by-product, these objects collect and exchange vast quantities of information generating a wealth of actionable insights mode available through big data and analytics.

The network platform supports a diversity of potential use cases called logical network slices, which will enable optimized network experiences to be made available to specific services taking the idea of virtualization as applied to the data center in the development of cloud services and applying to the radio network. Thus slices of this radio network can be associated with specific services taking the idea of virtualization as applied to the data centre in the development of Cloud Services and applying to radio network. Thus slices of the radio network can be associated with specific services and can be logically applied to vertical segments.

The 5G network slices will allow the same infrastructure to address things such as IoT data collection, mission critical real-time inter-vehicle control interaction and medical information or emergency and government services. This transmission also sets the stage to leverage traditional enterprise features and application such as skill based routing to the IoT capabilities back into more personal, more intelligent responses. To do this, the network service architecture needs to be secure, scalable and elastic (carrier-grade) to match these expectations.

Today's IoT is often thought of as simple element of home automation or fitness monitors that are hi-fi based. The computation services or experiments associated with these applications are typically implemented over the Top (OTT) of broad band connection on a 'best efforts' basis. For early adoptions and un-stressed networks this is a satisfactory solution.
The mobile cloud based IoT of 2020 will be embedded in the critical infrastructure of smart automotive smart health care, smart power distribution and smart cities. The integration of service platform with connectivity solution will be a key area of focus for the mobile network provider.

The role of the network provider evolves

In the 5G network, voice, video and messaging are embedded in a vehicle, incorporated into a smart home infrastructure or offered through a wearable.

Generally, the network provider will continue to host the services, but in specific enterprise use cases, there is no reason why the services cannot be hosted in the enterprise cloud.

Today, 4G LTE prioritizes carrier voice traffic (QoS implementation). With network slices and increased granularity of policy control, the 5G networks will be able to offer a wide variety of QoS to different network consumers.

We face a future where next generation 5G networks enabling IoT will become central to everything that we do. The network provider will just one of the providers of communication services in this world in many cases will use the slicing technologies of 5G to allow the network as a service (Naas) to be directly monetized.

How does one address this massive 5G technological transformation which is redefining the (embedded) communication space?

DA-IICT and C R Rao AIMCS proposed jointly a 2 year MTech program in Electronics and Communication (EC) with specialization in Wireless Communication and Embedded systems to create quality intellectual human resources having sound knowledge in wireless communication and embedded systems so that this skill set can enable them to handle next generation 5G research and innovation challenges.

GENESIS AND OBJECTIVES

This program is developed with following objectives:

(i) to educate and train the PG students who can contribute to advanced wireless communication systems (including 5G systems), cognitive and collaborative communication, satellite communication, embedded systems, IoT and sensor networks, etc., and

(ii) to initiate/develop research projects on wireless communication systems in collaboration with the industry (Qualcomm, Broadcomm, etc.), R&D organizations (such as ISRO, DRDO, etc.) and academia (IITs and IISc, NIT, etc.).

The students will undertake a graduate level study and research program on the principles of wireless communication systems and the hardware and firmware implementation paradigms in the context of embedded systems. The students will study the conversion of the information to be transmitted into a stream of bits, and then into symbols that can be transmitted over wireless channels.

This wireless transmission of information, for different type of information generating source (audio, video, image, data, etc.) and for different types of information conveying medium or channel (satellites, microwave, cellular wireless links, etc.), will be extensively studied and researched by the students.

A high-level summary of the topics that the students will engage with are advanced modulation and demodulation techniques, Forward Error Correction (FEC) techniques, multi-antenna (SIMO, MISO and MIMO) and multi-carrier (FDMA, OFDMA, SC-FDMA) systems, models of space-time-angle channels, multiuser detection (MUD) and adaptive interference cancellation, iterative message-passing and belief propagation techniques, phased array beam forming and opportunistic scheduling methods over wireless channels, etc.

In today's world, a mastery over the principles and theory of wireless communication systems is best complemented by an expertise in the digital implementation techniques, such as Field Programmable Gate Arrays (FPGAs), Very Large Scale Integrated (VLSI) circuits, and Digital Signal Processing (DSP) methods. Both a practicing engineering in the industry and a research scholar in the academia face the task of a realistic and tangible implementation of the wireless communication systems on practical hardware.

As an example, all the major companies in the industry (such as Qualcomm, Broadcom, Intel, Texas Instruments, Analog Devices, National Semiconductor, Keysight/Agilent, Apple, Microsoft, IBM, etc.) have not only a group of systems engineers who not only research and develop advanced designs of wireless communication systems but also provide a detailed prototype implementation on the hardware and software of their proposed designs.

Accordingly, the students enrolled in this PG program will study both the hardware and the software aspects of the embedded systems, i.e., the systems (in the form of FPGAs, ASICs and DSPs and combinations thereof) on which the mathematical and algorithmic designs of the wireless communication systems are realized/practiced.

In summary, this MTech program will combine elegant mathematics and practical applications. Students will study how the application of mathematics to a branch of

engineering has lead to a key enabler of today's technology - the wireless method of communication. As a part of their PG research, the students will explore ways of furthering the current state of the art in the wireless communications.

Program Outcomes (POs)

As stated by NBA, POs represent the knowledge, skills and attitudes the students should have acquired at the end of the program.

PO1: **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2: **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3: **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6: **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11: **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12: **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Programme Specific Outcomes (PSOs)

PSO1: To apply the theoretical concepts of communication, signal processing and embedded systems in analysis, design and development of computing systems and interdisciplinary applications.

PSO2: To work as a socially responsible professional by applying communication and signal processing in real-world problems.

Programme Educational Objectives (PEOs)

PEO1: To prepare students with a strong foundation of core principles in specialized areas of Wireless Communication and Embedded Systems, who will be able to solve and analyze real-world problems.

PEO2: To prepare students for their contributions in research and development by pursuing higher studies in the field of engineering, science, business, or administration.

PEO3: To prepare students with the necessary theoretical background and technical skills to work professionally as communication engineer, hardware engineer, system analyst, research scientist, entrepreneur, and teaching professionals.

PEO4: To prepare students who will be socially responsible citizen with ethical and leadership qualities and effective interpersonal skills.

SALIENT ASPECTS

Following are several key aspects of the MTech program that will be jointly offered by CR Rao AIMSCS and DA-IICT.

Intake

The total number of seats offered will be 23 (18 plus 5 sponsored candidates).

Course Fees

The fees to be paid for the course shall be as per the existing structure at DA-IICT. Details are available at
https://www.daiict.ac.in/admissions/post-graduate/m-tech-ict-admissions/#fees-structure

Eligibility and Admission Process

B.E. (first class) or equivalent in Electronics and Communication (EC) or equivalent with consistent good academic records, and having a valid GATE score in EC will be eligible to apply for this program. Admission process will be conducted jointly by CR Rao AIMSCS and DA-IICT.

Final selection will be based on the valid GATE score in EC and personal interview of the select candidates.

Important Dates

Online application website opens	15 April 2019
Last date for submission of online applications	17 May 2019
Announcement of list of candidates called for Interview	31 May 2019
Interview for candidates called for the same	17 June 2019
Announcement of first merit list for admissions	19 June 2019
Commencement of academic session	TBD

Financial Assistantship

Stipend of Rs.12,400/- (Rupees Twelve thousand four hundred only) as per UGC norms will be provided to all the regular admitted candidates. The scholarship for the first and second semesters will be paid by DA-IICT and third and fourth semesters by AIMSCS for those students who report in CR Rao AIMSCS.

Graduation Process

Students will be required to complete the first two semesters at DA-IICT campus at Gandhinagar where they will take the core and elective courses. Besides the coursework, the graduation requirement includes a thesis, developed over the third and the fourth semester. The students, based on their research interest, will select whether to conduct their thesis at DA-IICT or CR Rao AIMSCS. The degree will be awarded by DA-IICT.

Outcome of the Program

The course is planned to be a comprehensive study of current and requirements of next generation wireless and the mobile industries. The syllabus will include core subjects from Wireless Communications, Electronics and communication engineering, Computer Networks, and will cover advanced topics in mobile computing, sensor networks, embedded systems, and signal processing.

During the proposed two-year program, the students will obtain a balance of theory, lab practice and projects. The proposed program will generate academic and research personnel well-trained in the highly demanding and emerging fields of wireless communication networks and embedded systems.

COURSE LIST WITH CREDITS

	Semester-wise Courses and Credits	*L*	*T*	*P*	*C*
	Semester I				
1	Linear Algebra, Random Variables and Processes	3	0	0	3
2	Advanced Digital Communication	3	0	2	4
3	RF and Antenna Engineering	3	0	0	3
4	Digital Design using HDL and FPGA	3	0	2	4
5	Advanced Digital Signal Processing	3	0	2	4
	Total Credits	*15*	*0*	*6*	*18*
	Semester II				
1	Wireless Communication	3	0	2	4
2	Real Time Operating Systems for Embedded Systems	3	0	2	4
3	Cyber Physical Systems	3	0	2	4
4	Detection and Estimation Theory	3	0	0	3

5	Elective I	3	0	0	3
	Total Credits	*15*	*0*	*6*	*18*
	Semester III				
1	Elective II	3	0	2	4
2	Communication Skills and Technical Writing	1	0	0	1
3	M. Tech. Research Seminar	0	0	4	2
4	M. Tech. Thesis Preliminary Research	0	0	12	6
	Total Credits	*4*	*0*	*18*	*13*
	Semester IV				
1	M. Tech. Thesis Research	0	0	24	12
		0	*0*	*24*	*12*

	Summary of Credit Requirements				
	MTech Degree Credits	34	0	54	61
	Credits for the Core Courses	27	0	12	33
	Credits for the Elective Courses	6	0	2	7
	Research Credits (including Research Seminar)	1	0	40	21
	Tentative Menu for the Elective I				
1	Embedded Systems for Smart Sensing	3	0	0	3
2	Advanced Computer Architecture	3	0	0	3
3	Information Theory and Coding	3	0	0	3
	Tentative Menu for the Elective II				
1	Next Generation Advanced Wireless Systems	3	0	2	4
2	Advanced VLSI and FPGA Design	3	0	2	4
3	Network and Physical Layer Security	3	0	2	4
4	* Side Channel Analysis	3	0	2	4
5	* Pattern Recognition and AI	3	0	2	4
6	* Cognitive and Software Defined Radio	3	0	2	4

* These courses may be offered at CR Rao AIMSCS

COURSE SYLLABUS

Linear Algebra, Random Variables and Processes

Topic 1: Basics of Vectors, Matrices, and Linear Systems of Equations

Additions, Multiplications – Scalar-Matrix, Matrix-Matrix, Inner and Outer Products, Transpose/Conjugate Transpose, Hermitian, Symmetric, Unitary, Orthogonal, Triangular, Diagonal and other special matrices, Vector and Matrix Norms, Determinant and Inverse

Topic 2: Solution of Linear Systems of Equations

Sensitivity and Conditioning, Solution of Triangular Systems, LU, Cholesky and QR Factorization, Iterative Methods – Steepest Descent, Richardson

Topic 3: Vector Spaces

Vector Spaces, Subspaces, Linear Dependence and Independence, Rank, Basis and Dimension

Topic 4: Eigenvalues and Singular Value Decomposition

Eigenvalues and Eigenvectors, Characteristic Polynomial, Diagonalization, Quadratic forms and Positive Definiteness, SVD, Solution of Linear Least Squares Problems, Computational aspects.

Topic 5: Random Variables

Overview of Probability, Conditional Probability and Random Variables, Discrete and Continuous Random Variables, Functions of One Random Variable, Expectation, Mean, Variance and Moments, Characteristic Function

Topic 6: Multiple Random Variables

Joint Random Variables and Joint Distribution Functions – Discrete and Continuous, Conditional Distributions, Covariance and Correlation Coefficient, LLN and Central Limit Theorem

Topic 7: Random Processes

Random Processes, their Characterization and Classification, Power Spectrum

Topic 8: Markov Chains and Applications

Discrete Markov Chains, Continuous Markov Chains, Mean First Passage Time, Poison Processes, Queuing Theory, Birth-Death Processes

Topic 9: Noise and Communication

Random Walk, Brownian Motion and Thermal Noise, Shot Noise, White Gaussian Noise, Modulation, Bandlimited Processes and Sampling Theory, Response of Linear Systems to Random Processes, K-L Expansion, Wiener-Khinchin Theorem.

References:

1. I.C.F. Ipsen, Numerical Matrix Analysis Linear Systems and Least Squares, SIAM, Philadelphia, 2009.
2. S. Lipschutz and M. L. Lipson, Linear Algebra (Schaum's outlines), 4th Ed., McGraw Hill, New York, 2009.
3. A. Jeffrey, Matrix Operations for Engineers and Scientists An Essential Guide in Linear Algebra, Springer, Heidelberg, 2010.
4. H. P. Hsu, Theory and Problems of Probability, Random Variables, and Random Processes (Schaum's outlines), McGraw Hill, New York, 1997.
5. A. Papoulis, Probability, Random Variables, and Stochastic Processes, 3rd Ed., McGraw Hill, New York, 1991

Advanced Digital Communication

Topic 1: Information Theoretic Limits and Power versus Bandwidth Tradeoff

Entropy and Mutual Information, Channel Capacity, power and bandwidth efficiencies, and trade-off between them

Topic 2: Digital Modulation Schemes

Base band and bandpass communication, vector space representation of signals, linear and nonlinear modulation techniques, M-ary modulation techniques (PSK, QAM), orthogonal modulation techniques, spectral characteristics of digital modulation

Topic 3: Design of Receivers and Demodulators

Maximum A Posteriori Decision Theory, Optimum Receivers, Probability of Error Analysis, Correlation demodulator, matched filter, maximum likelihood sequence detector, differential and noncoherent detectors; characterization of fading multipath channels, RAKE demodulator, multiuser detection techniques.

Topic 4: Digital Communication Transceiver Signal Processing

Transmitter side signal processing (pulse shaping and zero ISI Nyquist criteria, Direct Digital Synthesis), signal processing at the receiver (symbol timing, carrier

frequency and phase offset estimation), interference mitigation techniques (Intersymbol Interference and Channel Equalization)

Topic 5: Wireless Communication Channels and Advanced Architectures

Flat and frequency selective channel fading, SIMO and MISO diversity for fade mitigation, MIMO architectures, OFDM and SC-FDMA, spread-spectrum techniques and Non-Orthogonal Multiple Access (NOMA)

Topic 6: Channel Coding Schemes

Linear block codes, convolution codes, trellis-coded modulation, Turbo coding, Soft-Output Viterbi Algorithm (SOVA), LDPC Codes, Message Passing Algorithms

References:

1. John G. Proakis and Masoud Salehi, Digital Communications, Fifth Edition, McGraw-Hill, 2014
2. Bernard Sklar., 'Digital Communications', second edition, Pearson Education,2001.
3. Heinrich Meyer, Mare Moeneclacy, Stefan Fechtel," Digital communication receivers ", Vol I & Vol II, John Wiley, New York, 1997.
4. Tse, David, and Pramod Viswanath. Fundamentals of Wireless Communication. Cambridge, UK: Cambridge University Press, 2005.
5. Wilson, Stephen G. Digital Modulation and Coding. Upper Saddle River, NJ: Prentice Hall, 1996.
6. D. J C MacKay, Information Theory, Inference, and Learning Algorithms, Cambridge University Press, 2003

RF and Antenna Engineering

Topic 1: Introduction

RF Spectrum, High frequency (Radio Frequency and Microwaves) in Perspective and Applications, RF versus DC or Low AC signals, High Frequency Behaviour of Passive Components.

Topic 2: RF Networks

Concept of Distributed Elements and Transmission Line, Transmission Line Calculations using the Smith Chart, Phase and Attenuation Constants, Propagation Constant and Characteristic Impedance, Lossless, Low-Loss and

Distortion-less Lines, Travelling and Standing Waves, Reflection Coefficient and Standing Wave Ratio, Input Impedance, Impedance and Admittance Transformations, Impedance Matching – Quarter and Half-Wave Lines, Equivalent Reactive Elements, Load Impedance Measurement, Analysis of Open-circuited and Short-circuited Lines, Power Flow in a Transmission Line, Maximum Power Transfer Condition, Design of Matching Networks and Stub Matching. Single and Multi-port Networks, Symmetric and Reciprocal Networks, Scattering Parameters and Scattering Matrix.

Topic 3: Noise and Distortion in RF Systems

Noise Figure, Equivalent Noise Temperature, Harmonic and Inter-modulation Distortion, Gains/Losses, Signal-to-Noise Ratio, Tracking noise and signal level through a complete system. Receiver Sensitivity, Spurious-free and Blocking (Linear) Dynamic ranges.

Topic 4: RF System Design Considerations

Amplifier Design using S-Parameters, Stability, RF Oscillators, Injection-locked Oscillators, Oscillator Phase Noise, Receiver Design.

Topic 5: EM Radiation and Antennas

EM fundamentals, Solution of Maxwell's equations for Radiation Problems, Retarded Potential., Hertzian Dipole, Monopoles and Electrically Small Dipoles. Antennas Parameters - Directivity, Gain, Efficiency, Effective Area, Antenna Noise Temperature, Radiation Mechanism, Near- and Far-Field Antenna Radiation Patterns, Half Power Beamwidth and First Null Beamwidth, Polarization, Field Zones, Friis' Equation.

Topic 6: Practical Antennas and Antenna Arrays

Microstrip Antennas, Quarter-wave Patch Antennas, Shorted Microstrip antennas, Yagi-Uda Antenna, Horn Antennas, Parabolic Reflectors, Antenna Arrays - Pattern Multiplication, Array Directivity, Linear Array of N Elements, Phased Arrays, Planar Arrays. Analysis of Uniformly Spaced Arrays with Uniform and Non-uniform Excitation Amplitudes, Extension to Planar Arrays, Synthesis of Antenna Arrays using Schelkunoff Polynomial Method, Fourier Transform Method, and Woodward-Lawson method. Integrated Active Antennas and Smart Antennas.

References:

1. R. Ludwig and Pavel Bretchke, RF Circuit Design: Theory and Applications, Pearson Education Asia Publishers, ISBN-81-7808-333-7, 2001.
2. Peter Vimuller, RF Design Guide: Systems, Circuits, and Equations, Artech House, January 2003, ISBN: 0890067546.
3. John D. Kraus and Ronald J. Marhefka and Ahmad S.Khan, "Antennas and Wave Propagation", TMH, New Delhi, 4th Edition, (special Indian Edition), 2010.
4. C.A. Balanis, "Antenna Theory - Analysis and Design", John Wiley & Sons, 2nd Edition, 2001.

Digital Design using HDL and FPGA

Topic 1: Introduction to Digital Design, Concept of Hierarchical and Structured Design

Digital meaning and essence, Basics of digital VLSI design, role of CAD tools in VLSI design process, Hierarchical and design methodologies in VLSI systems, CAD algorithms for device, circuit, gate and system levels of abstraction, Physical design process in VLSI design, Testing.

Topic 2: Introduction to HDL, Synthesis and FPGA

Introduction to hardware description language, Basic language elements of Verilog, Behavioral modeling, Data flow modeling, Structural modeling, Switch level modeling, Constructs and conventions in Verilog, Data types, Number system, Operators.

Modeling and synthesis issues in Verilog, Familiarization with analog and mixed signal designing in Verilog.

Concept of CPLD, FPGA, Familiarization with Xilinx Spartan-3E FPGA development board, design constraints using FPGA, implementing designs using FPGA.

Topic 3: Combinational Systems Realization Using HDL and FPGA

Verilog description of gates, User-defined primitives, Instantiation, Design of arithmetic functions – adder, subtractor, multiplier, divider, Implementation of multiplexer, demultiplexer, encoder and decoder, code converters, Design of complex systems, Parameterized module, Realization of test benches, Timing and delay models.

Topic 4: Description and Design of Sequential Circuits

Defining procedural blocks, Procedural flow control, Blocking and non-blocking assignments, Realization of latches, flip-flops, register, counter, Implementation of synchronous and asynchronous designs.

Topic 5: Data Subsystems

Storage modules, Memory, Stack, Queue, Functional modules, Data paths, Control subsystems.

Topic 6: FSM and I/O Subsystem

Finite state machine, Mealy and Moore designs, System Task and functions, Operations related to I/O subsystems, Compiler directives, VeSPA (Very Small Processor Architecture) processor—developing behavioral and structural modeling using HDL and FPGA, Design of practical systems.

References:

1. Samir Palnitkar, Verilog HDL: A Guide to Digital Design and Synthesis, Prentice Hall.
2. Stephen Brown and Zvonko Vrsaniec, Fundamentals of Digital Logic with Verilog Design, McGraw Hill.
3. Zainalabedin Navabi, Verilog Digital System Design, McGraw Hill.
4. Vivek Sagdeo, The Complete Verilog Book, Kluwer Academic Pub.
5. Peter R. Wilson, Design Recipes for FPGAs, Elsevier.

Advanced Digital Signal Processing

Topic 1: Discrete-Time Filters

DTFT, DFT, Design of FIR and IIR Filters

Topic 2: Multirate Signal Processing

Sampling Rate Change Operations: Upsampling and Downsampling; Fractional Sampling; Interpolation

Topic 3: Compressive Sensing

Sub-Nyquist Sampling, Reconstruction of sparse signals- Orthogonal Matching Pursuit, Orthogonal Least Square, Subspace Pursuit, Basis Pursuit, Generalized Orthogonal Matching Pursuit

Topic 4: Wavelet Transform and Filter Banks
Haar Wavelets, Daubechies Wavelets, Orthogonal and Biorthogonal Wavelets, Gabor Transform

Topic 5: Graph Signal Processing
Representation of Signals over Graphs, Graph Fourier Transform, Graph Filters

References:

1. L. R. Rabiner and B. Gold, "Theory and Application of Digital Signal Processing", Prentice-Hall, 1975
2. A. V. Oppenheim and R. W. Schafer, " Discrete-Time Signal Processing", Pearson Education, 2007
3. J. G. Proakis and D. G. Manolakis, "Digital Signal Processing: Principles, Algorithms, and Applications", Pearson Education, 2007.
4. P. P. Vaidyanathan, "Multirate Systems and Filter Banks", Pearson Education, Low Price Edition.
5. Stephane Mallat, "A Wavelet Tour of Signal Processing", Academic Press, 1999
6. Yonina C. Eldar and Gitta Kutyniok,, "Compressed Sensing: Theory and Applications", Cambridge University Press, 2012

Wireless Communication

Topic 1: Cellular Concepts – System Design Fundamentals
Cellular concept-channel reuse- handoff strategies-dynamic resource allocation-interference and
system capacity-improving capacity and coverage of cellular systems. Second and third generation network standards: GSM standardization-architecture and function partitioning-GSM radio aspects-security aspects-protocol model-call flow sequences-evolution to 2.5G mobile radio networks. IS-95 service and radio aspects, key features of IS-95 CDMA systems ECWDMA-UMTS physical layer-UMTS network architecture-CDMA 2000 physical layer.

Topic 2: Radio Wave Propagation
Free space propagation model- basic propagation mechanisms –reflection- ground reflection model diffraction-scattering-practical link budget design-outdoor and indoor propagation models. Small scale fading and multipath: Small scale multipath propagation-Impulse response model of multipath channel –small scale multipath measurements-parameters of mobile multipath channels –types of small-scale fading.

Topic 3: Capacity of Wireless Channels

Capacity of Flat Fading Channel- Channel Distribution Information known – Channel Side Information at Receiver – Channel Side Information at Transmitter and Receiver – Capacity with Receiver diversity – Capacity comparisons – Capacity of Frequency Selective Fading channels. Performance of digital modulation over wireless channels: Error probability of BPSK, FSK, MSK, GMSK, QPSK, M-ary PSK, M-ary QAM and M-ary FSK on AWGN channels- Fading– Outage Probability, Average Probability of Error, Combined Outage.

Topic 4: Diversity

Realization of Independent Fading Paths – Receiver Diversity – Selection Combining – Threshold Combining – Maximal-Ratio Combining – Equal - Gain Combining – Transmitter Diversity – Channel known at Transmitter – Channel unknown at Transmitter – The Alamouti Scheme-basic concepts of RAKE receivers.

Topic 5: Multiple Access Techniques

Frequency division multiple access-time division multiple access-spread spectrum multiple access space division multiple access- packet radio. MIMO and multicarrier modulation: Narrowband MIMO model-parallel decomposition of MIMO channel-MIMO channel capacity-MIMO diversity gain –data transmission using multiple carrier multicarrier modulation with overlapping sub channels-mitigation of subcarrier fading-basic conceptsof OFDM.

References:

1. T.S. Rappaport, "Wireless Communications," Pearson Education, 2003
2. Andrea Goldsmith, "Wireless Communications," Cambridge University Press

Detection and Estimation Theory

Topic 1: Foundations

Probability: conditional probability, PDFs, Continuous random variable, Functions of random variables, Characteristic Functions, Expectation and Moments, Central Limit Theorem.

Random processes: Ensemble Correlation Functions, Time averages, Power Spectral Density, Gaussian Process, Sampling and Random Sequences, Poisson Process

Linear Vector Spaces, Hilbert Spaces

Constrained and unconstrained optimization

Topic 2: Detection Theory

Hypothesis testing: The Neyman-Pearson Criterion, Bayes Criterion, Minimum Error Probability Criterion, Minimax Criterion, Sequential Hypothesis Testing.

Detection in the Presence of Unknowns: Random Parameters, Non-random parameters

Detection of Signals in Gaussian Noise: White Gaussian, Colored Gaussian, Spectral detection

Detection in the Presence of Uncertainties: Unknown signal and Noise parameters

Non-Gaussian Detection Theory: Robust Hypothesis Testing, Non-Parametric Model Evaluation, Partially Known Signals and Noise, Partially Known Signal Waveform, Partially Known Noise Amplitude Distribution, Non-Gaussian Observations

Topic 3: Estimation Theory

Terminology in Estimation Theory

Minimum variance unbiased estimation: Unbiased estimators, Minimum variance criterion, Existence and search of the minimum variance unbiased estimator, Extension to a vector parameter.

Cramer-Rao Lower Bound: Signals in white Gaussian noise, parameter transformation, vector parameter, general Gaussian case, and WSS Gaussian random process.

Practical Estimation of Signal Parameter: Best Linear Unbiased Estimators, Maximum Likelihood Estimators, Least Squares estimation.

Parameter Estimation via Bayesian: Bayesian linear model, nuisance parameter, Bayesian Estimation for Deterministic Parameters, Risk Functions, MMSE and MAP Estimator, Sequential Linear MMSE estimators, Wiener Filtering.

Kalman Fitering

References:

1. Steven M. Kay - Fundamentals of Statistical Signal Processing, Volume II_ Detection Theory-Prentice Hall (1998)
2. Steven M. Kay - Fundamentals of Statistical Signal Processing, Volume I_ Estimation Theory-Prentice Hall (1993)
3. H. Vincent Poor - An introduction to signal detection and estimation-Springer-Verlag (1988)
4. H.L. Van Trees, K.L.Bell, and Z. Tian - Detection Estimation and Modulation Theory, Part I: Detection, Estimation, and Filtering Theory, 2nd Edition- Wiley, 2013.
5. R. N. McDonough, and A. D. Whalen, "Detection of Signals in Noise," 2nd Edition, Academic Press

Information and Coding Theory

Topic 1: Basics of Information Theory

Introduction to Information theory - Information –- Measure of Information – Average information content (Entropy) of symbols in long independent sequences - Average information content (Entropy) of symbols in long dependent sequences – Joint and conditional entropies – Mutual information - Markov statistical model for information sources – Entropy and information rate of Markov sources – Information measure for continuous random variables.

Topic 2: Source Encoding

Shannon's first fundamental theorem – Noiseless coding – Source with finite memory – Shannon's second fundamental theorem on coding for memory less noisy channels – Channel capacity theorem - Shannon's Encoding algorithm – Huffman Coding Algorithm.

Topic 3: Channels and Channel Capacity

Communication channels, discrete communication channel - Rate of information transmission over a discrete channel - capacity of a discrete memory less channel – Shannon – Hartley theorem and its implications. Types of channels and their capacities – Binary channel - BSC, BEC - cascaded channels-symmetric channel –unsymmetric channel - channel capacity for MIMO system.

Topic 4: Error Correcting Codes

Types of errors – Linear block codes – Error detection and error correction – Single error correcting Hamming codes – Binary cyclic codes – Encoder, Syndrome calculation, error detection and correction - BCH Codes – Burst Error Correcting codes – Burst and random error correcting codes - Galois fields, vector spaces and matrices – Convolution codes and Trellis codes – Viterbi decoding of convolutional codes – Turbo codes – Encoding and Decoding- Trellis coded modulation – Majority logic decoding – Two dimensional codes – ARQ.

References:

1. T. Cover and J. Thomas, "Elements of Information Theory," Wiley, 2006.

2. J.Das,SK.Mullick and PK Chatterjee, "Principles of Digital Communication," Wiley Eastern Limited, 2008.
3. Ranjan Bose, "Information Theory Coding and Cryptography", Tata McGraw Hill Education Private Ltd, New Delhi, 2010.

ANNEXURE – II

PARTICIPATING INSTITUTIONS

Dhirubhai Ambani Institute of Information and Communication Technology (DA-IICT), Gandhinagar https://www.daiict.ac.in/

Dhirubhai Ambani Institute of Information and Communication Technology (DA-IICT), Gandhinagar, seeks to invoke the wider vision of the late Dhirubhai Ambani and weave both knowledge and innovation as part of an evolving style.

We realize that the idea of information does not exhaust the possibilities of knowledge. We understand that knowledge that is relevant has to be understood as communication, information and meaning. We believe that DA-IICT cannot be a first world institute to solve first world problems, but a world class institute to solve third world problems. We honour relevance by constantly reworking the idea of citizenship, leadership, innovation and responsibility. While global in vision, we seek to constantly repay the local hospitality of Gujarat as a site of world class institutions. DA-IICT was visualized as a research driven institute embodying the vision of India as a knowledge society. It was an intellectual experiment combining the twin segments of information and communication into a unified system called ICT.

This fundamental innovation combining the computer sciences and computer engineering was embedded in a large matrix of inter-disciplinary subjects including Film, Animation, Design, Science Studies and Management along with the traditional Humanities and Social Sciences. This vision, we are proud to say goes beyond the traditional idea of Liberal Arts wedded to an engineering institute. It visualizes the student as a professional and as a citizen dealing with knowledge systems at large but with a core competence in ICT. The integrated ICT program is offered in lieu of individual programs in Computer Science.

CR Rao Advanced Institute of Mathematics, Statistics and Computer Science (AIMSCS), Hyderabad http://www.crraoaimscs.org/

About the Institute: CR Rao Advanced Institute of Mathematics, Statistics and Computer Science (AIMSCS) was established in honor of Prof CR Rao, FRS in 2005. It is located on the campus of the University of Hyderabad in an area of about five acres. The institute is autonomous body registered society under AP Societies Registration Act. (Regd.No. 547/2005) and recognized as SIRO by Department of Scientific and

Industrial Research (DSIR) and also research centre recognition by University of Hyderabad and jointly conducting two-year M.Tech program in Information Security with Cyber Security specialization started from 2018-10 academic year approved by AICTE. It will be headed by a Director of International fame and reputation. It has a two-tier administrative set up comprising of: (i) The Governing Council (ii) CR Rao AIMSCS Society. It is partially self-financing, autonomous institute with vested powers that normally exist in similar institutes of excellence / advanced study in the country.

Activities: The institute envisages coming together of best of minds in the fields of Mathematics, Statistics, and Computer Science, Wireless communications and allied areas such as Cyber Security, Artificial Intelligence (AI) and Machine Learning and working in an enabling environment. It is expected to be a model in cooperation with emphasis on Synergy of efforts in problem solving. The Institute having outstanding faculty and research staff drawn in equal pro-portions from the fields of Mathematics, Statistics, Computer Science and Electronics and Communications. The institute has also undertaken several Crypto and Information security projects from various Govt Departments, Ministries and Ministry of Defences. Institute credit 180+research papers, prepared many technical reports and developed software tools. At present 8 faculties, 30 research scholars and 5 adjunct faculties, and also about 25 scientists, GoI are working in theory and practical applications in Cryptology, Wireless less communication and Information security fields and NLP and Machine Learning applications.
The Institute organizing workshops, conferences, lecture series and symposia to bring the various developments in these disciplines to attention of mathematicians, scientists, scholars, industry personnel/ entrepreneurs and the general public. To create awareness of statistics and to encourage those with an aptitude for numbers and numerical reasoning. On the advice of Prof. CR Rao, the institute is organizing Statistics Olympiad on lines similar to Mathematics Olympiad every year.

Centre of Excellences: AIMSCS is engaged in cutting edge research in interdisciplinary fields, and provides a forum for national and international experts from different fields to meet and address problems of mutual interest. Institute established the following:

1. Centre of Excellence in Mathematical Sciences
2. Centre of Excellence in Machine Learning and Artificial Intelligence
3. Centre of excellence in Cryptography and Cryptanalysis
4. Centre of excellence in Wireless Communication
5. Centre of excellence in Cyber Security

AIMSCS Library: It has rich collection of Books in the subject areas of Statistics, Mathematics, Computer Science, AI, ECE, Data Science and Cryptography etc. The library has large collection bound volume journals, non-print materials such as

CDs/DVDs and online access to e-journals. Total Number of Books in Library are 1520 and has access to 1000+ national and international online journals through UoH NKN.

Facilities: The institute established state of art Wireless Lab for GSM network interception/analysis, Network Security Lab for protocol analysis and 100 TeraFlop High Performance computing facility for carry out large scale computations, password breaking and practical/real time cryptanalysis of ciphers. Also established, Side channel Lab with instruments and accessories to carry out the side channel cryptanalysis of ciphers.

Centre of Excellence in Wireless Communication

The mission of this centre is to conduct advanced research in current wireless technologies like 2G, 3G, 4G-LTE, Bluetooth, Satellite Communication, Wi-Fi and next generation wireless technologies like 5G, IoT, millimeter wave, near field communications, etc. It aims at developing solutions for addressing the near and far-term technological challenges related to wireless communications and its security aspects. To achieve the mission, the institute collaborates with various industries, R&D institutions and Govt. organizations. Future wireless networks will allow people on the move to communicate with anyone, anywhere, at any time, using a range of multimedia services. The Institute has conducted several national and international conferences, training programs and workshops in Wireless Communication domain.

The wireless transmission of data has emerged as one of the most important technologies currently in use, with its importance expected to increase in the future. The industries developing these technologies are looking for students with competence in the wireless field. Not only is this technology achieving broader application, but efforts to improve performance are ongoing and critical as higher and higher data rates under more adverse operating conditions are desired. The need is increasing for students to be prepared in this field in order to be competitive in the marketplace. Furthermore, enrolled ECE students will be engaged in projects which include wireless communication subsystems. This course is intended to help ensure our students' competency in the emerging wireless communications field for now and into the future. Laboratories and projects are a fundamental component of this course. The Wireless Communication Laboratory is engaged in research and education in the broad area of wireless communications and networking, as to provide ubiquitous access to wired and wireless resources for mobile and wireless multimedia users.

MTech in Electronics and Communication is a 2-year postgraduate course divided into 4 semesters. It also offers a specialization in Wireless Communication where the program

involves cutting edge research and teaching in several frontier areas of next generation wireless communication technologies like 5G, MIMO, Cognitive radio, SDR, compressive sensing etc. Students take intensive courses during the first year. In the second year they carry out research activities under the supervision of a professor in the areas - 5G, IoT, Information theory and Coding, Speech processing, Machine Learning. To facilitate the research, the Institute has state of art facilities of Wireless Communications System (WCS) Laboratory and Side Channel Analysis Laboratory.

Wireless Communication System (WCS) Laboratory

The Wireless Communication System (WCS) Laboratory covers design and verification of the concepts of current and next generation wireless technologies that operates in MHz-THz range. The main focus of the laboratory is to get introduced to these technologies through hands-on experimentation in system design and analysis. Research into various domains of wireless communication technologies can be conducted in this lab: Machine-to-Machine (M2M) communications, cellular networks, cognitive radio, 2G, 3G, 4G-LTE, and next generation wireless communications like 5G and IoT.

The WCS lab provides the state-of-art facilities for research and development in wireless communication field. It helps to develop the technical solutions to various wireless communication related projects. Topics of particular interest are:

- Software Defined Radio (SDR) /USRP experimental implementation
- Next generation Wireless Communication Technologies –IoT and 5G.
- Cognitive radio.
- Machine Learning algorithms for Wireless technologies.
- Wi-Fi Security Analysis
- Advanced coding and modulation techniques
- 2G and 4G – Test-bed and Security analysis.
- IoT Security and its Application in various fields.
- Multiple Input Multiple Output (MIMO) systems.
- Satellite Communication.
- Bluetooth and its applications to IoT.

Facilities:

- USRP X310 (KINTEX7-410T FPGA, 2 CHANNELS, 10 GIGE AND PCIE BUS)
- BladeRF x40
- OpenBTS and Wireshark
- Digital Oscilloscope : MSO and DPO
- RTL-SDR DONGLES (RTL2832U)

- Power amplifier and related ancillaries
- IoT – BLE mote, UBI mote, Wi-Fi mote
- Alfa 150Mbps Wireless USB Adaptor
- Ettus USRP X310
- BladeRf x40

Side Channel Analysis (SCA) Laboratory

Side Channel Analysis (SCA) covers the basics of cryptography, cryptanalysis, hardware Implementation of cryptographic algorithms and finding vulnerabilities by applying various side channel attacks. The Side Channel Analysis (SCA) laboratory consists of various FPGA Boards required to perform differential power analysis and differential fault analysis.

SAKURA-G **Xilinx BASYS 3** **Xilinx Kintex-7 Board**

The SAKURA-G FPGA board is designed for research and development on hardware security, such as Side-Channel Attacks (SCA), Fault Injection Attacks (FIA), Physical Unclonable Functions (PUF), and dynamic reconfiguration. Two Spartan™-6 FPGAs are integrated on the board and serve as the controller and main security circuits, respectively.

The various types of research experiments have been carried out in this lab.

- Differential Power attack on cryptographic algorithms.
- Differential Faulty attack on stream as well as block ciphers.

Facilities:

- SAKURA –G
- Kintex – 7
- BASYS – 3
- Xilinx Vivado licence software package
- Digital Oscilloscope : MSO and DPO
- Power amplifier and related ancillaries

Executive Registrar
DA-IICT, Gandhinagar

DA-IICT GANDHINAGAR