SIDDAGANGA INSTITUTE OF TECHNOLOGY

DEPARTMENT OF ELECTRONICS & TELECOMMUNICATION

ENGINEERING

SCHEME & SYLLABUS

OF

VII & VIII SEMESTER

B.E.

Electronics & Telecommunication Engg.

2025 - 26

Vision of the Dept.:

To become center of excellence in Electronics & Telecommunication Engineering and empower graduates to take up global challenges in emerging areas to harness technological competence while harmoniously blending with spiritual pursuits.

Mission of the Dept.

1. To provide best learning experience for students through excellent curriculum, industry collaboration and innovative teaching learning processes.

2. To create good academic ambience for faculty and students by establishing high-quality R & D labs leading to quality research in Electronics & Telecommunication Engineering and allied disciplines.

3. To prepare graduates with technological competence, necessary professional skills and ethics.

Program Educational Objectives (PEOs)

The graduates of Electronics & Telecommunication Engineering are able to:

- Build successful careers in industry, R&D Labs by applying mathematical, scientific and state-of-the-art Engineering knowledge with multidisciplinary approaches to solve real world problems in the fields of Telecommunication Engineering and allied disciplines.

- Pursue higher education by lifelong learning in the areas of Electronics & Telecommunication Engineering and allied disciplines.

- Display professional and ethical attitude, spiritual values with effective communication skills and leadership qualities.

Program Outcomes (POs):

1: Engineering Knowledge, 2: Problem analysis, 3: design/development of solutions, 4: conduct investigations of complex problems, 5: Engineering tool usage, 6: The engineer and The world, 7: Ethics, 8: Individual and Collaborative team work, 9: communication, 10: project management and finance, 11: Life-Long learning

PROGRAM SPECIFIC OUTCOMES (PSOs):

- Apply and analyze the concepts of circuits and systems for real time challenges in the areas of electronic circuits, signal processing, VLSI/Embedded and IoT Systems.

- Identify, design and develop solutions for complex engineering problems related to, wired, wireless, or Optical communication systems, Security using analytical techniques, AI, state of the art simulation tools and hardware.

SIDDAGANGA INSTITUTE OF TECHNOLOGY, TUMAKURU

(An autonomous institution affiliated to VTU, Belagavi, Approved by AICTE, New Delhi, Accredited by NAAC with 'A++' grade & ISO 9001:2015 Certified)

B.E. in Electronics and Telecommunication Engineering

SCHEME OF TEACHING AND EXAMINATION

VII Semester (Swappable VII and VIII Semester)

Sl. No.	Course and Course Code		Course Title	Teaching / Paper setting Dept.	Teaching hrs.				Examination				Credits
					Lecture	Tutorial	Practical/ Drawing	Self-Study Component	Duration in hrs.	CIE Marks	SEE Marks	Total Marks	
					L	T	P	S					
1.	IPCC	S7ETI01	Wireless Communication	ETE	42	0	28	50	3	50	50	100	4
2.	IPCC	S7ETI02	Satellite and Radar Systems	ETE	42	0	28	50	3	50	50	100	4
3.	PCC	S7ET01	Telecom Networks And Business Support Systems	ETE	52	0	0	68	3	50	50	100	4
4.	PEC	SETExx	Professional Elective Course-III	ETE	42	0	0	50	3	50	50	100	3
5.	OEC	SOExx	Open Elective Course-II	-	42	0	0	48	3	50	50	100	3
6.	PROJ	S7ETP2	Major Project Phase II	ETE	0	0	168	12	3	100	100	200	6
			Total							**350**	**350**	**700**	**24**
		AAP	AICTE Activity Points (Applicable for both Regular and Lateral Entry students)	40 hours community service to be documented and produced for the examination									

Note: **IPCC**: Integrated Professional Core Course, **PCC**: Professional Core Course; **PEC**: Professional Elective Course;

OEC: Open Elective Course; **PROJ:** Project Phase –II;

L: Lecture, **T**: Tutorial, **P**: Practical **S= SDA**: Skill Development Activity, **CIE**: Continuous Internal Evaluation, **SEE**: Semester End Evaluation.

Professional Elective Course (PEC) (Offered by the Department)

SETE15	Optical Fiber Communication	SETE21	5G Technologies
SETE16	Speech Processing	SETE22	Natural Language Processing
SETE17	Adhoc Wireless Networks	SETE23	Communication Protocol Engineering
SETE18	RF Analog Impairments Modeling	SETE24	Cyber Security
SETE19	Millimeter Wave Communication	SETE25	Computer Vision
SETE20	Cloud Technologies		

Note: VII and VIII semesters of IV years of the program

1) Institutions can swap the VII and VIII Semester Schemes of Teaching and Examinations to accommodate research internships/ industry internships after the VI semester.

2) Credits earned for the courses of VII and VIII Semester Scheme of Teaching and Examinations shall be counted against the corresponding semesters whether the VII or VIII semesters is completed during the beginning of the IV year or the later part of IV years of the program.

Professional Core Course (IPCC): Refers to Professional Core Course Theory Integrated with practical of the same course. Credit for IPCC can be 04 and its Teaching–Learning hours (L : T : P) can be considered as (3 : 0 : 2) or (2 : 2 : 2). The theory part of the IPCC shall be evaluated both by CIE and SEE. The practical part shall be evaluated by only CIE (no SEE). However, questions from the practical part of IPCC shall be included in the SEE question paper. For more details, the regulation governing the Degree of Bachelor of Engineering (B.E.) 2022-23 may please be referred.

Professional Elective Courses (PEC): A professional elective (PEC) course is intended to enhance the depth and breadth of educational experience in the Engineering and Technology curriculum. Multidisciplinary courses that are added supplement the latest trend and advanced technology in the selected stream of Engineering. Each group will provide an option to select one course. **The minimum number of students' strengths for offering a professional elective is 10. However, this conditional shall not be applicable to cases where the admission to the program is less than 10.**

Open Elective Courses:
Students belonging to a particular stream of Engineering and Technology are not entitled to the open electives offered by their parent Department. However, they can opt for an elective offered by other Departments, provided they satisfy the prerequisite condition if any. Registration to open electives shall be documented under the guidance of the Program Coordinator/ Advisor/Mentor. The minimum numbers of students' strength for offering Open Elective Course is 10. However, this condition shall not be applicable to class where the admission to the program is less than 10.

Project Work: The objective of the Project work is

i)   **To encourage independent learning and the innovative attitude of the students.**

ii)   **To develop interactive attitude, communication skills, organization, time management, and presentation skills.**

iii)   **To impart flexibility and adaptability.**

iv)   **To inspire team working.**

v)   **To expand intellectual capacity, credibility, judgment and intuition.**

vi)   **To adhere to punctuality, setting and meeting deadlines.**

vii)   **To install responsibilities to oneself and others.**

viii)   **To train students to present the topic of project work in a seminar without any fear, face the audience confidently, enhance communication skills, involve in group discussion to present and exchange ideas.**

CIE procedure for Project Work:

1)   **Single discipline: The CIE marks shall be awarded by a committee consisting of the Head of the concerned Department and two senior faculty members of the Department, one of whom shall be the Guide.**

The CIE marks awarded for the project work, shall be based on the evaluation of the project work Report, project presentation skill, and question and answer session in the ratio 50:25:25. The marks awarded for the project report shall be the same for all the batch mates.

2)   **Interdisciplinary: Continuous Internal Evaluation shall be group-wise at the college level with the participation of all guides of the college. Participation of external guide/s, if any, is desirable. The CIE marks awarded for the project work, shall be based on the evaluation of project work Report, project presentation skill, and question and answer session in the ratio 50:25:25. The marks awarded for the project report shall be the same for all the batch mates.**

SEE procedure for Project Work: SEE for project work will be conducted by the two examiners appointed by the University. The SEE marks awarded for the project work shall be based on the evaluation of project work Report, project presentation skill, and question and answer session in the ratio 50:25:25.

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B.E. in Electronics and Telecommunication Engineering
SCHEME OF TEACHING AND EXAMINATION NEP 1 Scheme

VIII Semester (Swappable VII and VIII Semester)

Sl. No.	Course and Course Code		Course Title	Teaching / Paper setting Dept.	Teaching hrs./week				Examination				Credits
					Lecture	Tutorial	Practical/ Drawing	Self-Study Component	Duration in hrs.	CIE Marks	SEE Marks	Total Marks	
					L	T	P	S					
1.	PEC	S8ETPE0x	Professional Elective (Online Courses)		42	0	0	48	3	50	50	100	3
2.	OEC	S8ETOE0x	Open Elective (Online Courses)		42	0	0	48	3	50	50	100	3
3.	INT	S8ETINT	Internship (Industry/Research) (14-20 weeks)		0	0	280	20	3	100	100	200	10
			Total		**84**	**0**	**280**	**66**	**9**	**200**	**200**	**400**	**16**
		AAP	AICTE Activity Points (Applicable for both Regular and Lateral Entry students)	40 hours community service to be documented and produced for the examination									

Note: **PEC**: Professional Elective Course**; OEC:** Open Elective Course (Online); **INT:** Industry Internship / Research Internship / Rural Internship
L: Lecture, **T**: Tutorial, **P**: Practical **S= SDA**: Skill Development Activity, **CIE**: Continuous Internal Evaluation, **SEE**: Semester End Evaluation.

Professional Elective (Online Courses – suggested by BoS, NPTEL)

S8ETPE01	5G Wireless Standard Design	S8ETPE13	Introduction to Photonics
S8ETPE02	Artificial Intelligence: Concepts and Techniques	S8ETPE14	Introduction to Semiconductor Devices
S8ETPE03	Biomedical Ultrasound: Fundamentals of Imaging and Micromachined Transducers	S8ETPE15	Introduction to Wireless and Cellular Communications
S8ETPE04	Cloud Computing	S8ETPE16	Mathematical Aspects of Biomedical Electronic System Design
S8ETPE05	Cyber Security and Privacy	S8ETPE17	Microelectronics: Devices to Circuits
S8ETPE06	Deep Learning - IIT Ropar	S8ETPE18	Microsensors and Nanosensors
S8ETPE07	Deep Learning for Computer Vision	S8ETPE19	Neural Networks for Signal Processing - I
S8ETPE08	Fiber Optic Communication Technology	S8ETPE20	Passive Microwave Circuits, Devices, and Measurements
S8ETPE09	Foundations of Virtual Reality	S8ETPE21	Phase-Locked Loops
S8ETPE10	Fundamentals of Nano and Quantum Photonics	S8ETPE22	RFIC Design
S8ETPE11	Introduction to Biomedical Imaging Systems	S8ETPE23	Signal Processing for mm Wave Communication for 5G and Beyond
S8ETPE12	Introduction to Machine Learning	S8ETPE24	Simulation of Communication Systems using Matlab

Open Elective (Online Courses – suggested by BoS, NPTEL)			
S8ETOE01	Big Data Computing	S8ETOE09	Privacy and Security in Online Social Media
S8ETOE02	Data Base Management System	S8ETOE10	Programming with Generative AI
S8ETOE03	Electronic Systems Design: Hands-on Circuits and PCB Design with CAD Software	S8ETOE11	Remote Sensing: Principles and Applications
S8ETOE04	Ethical Hacking	S8ETOE12	Social Network Analysis
S8ETOE05	Foundations of Accounting & Finance	S8ETOE13	Social Networks
S8ETOE06	Operating System Fundamentals	S8ETOE14	Software Testing
S8ETOE07	Practical Cyber Security for Cyber Security Practitioners	S8ETOE15	Space Environment and its Effects on Orbital Space crafts
S8ETOE08	Principles of Economics		

Note: VII and VIII semesters of IV years of the program

1) Institutions can swap the VII and VIII Semester Schemes of Teaching and Examinations to accommodate research internships/ industry internships after the VI semester.

2) Credits earned for the courses of VII and VIII Semester Scheme of Teaching and Examinations shall be counted against the corresponding semesters whether the VII or VIII semesters is completed during the beginning of the IV year or the later part of IV years of the program.

Elucidation:

At the beginning of IV years of the program i.e., after VI semester, VII semester classwork and VIII semester Research Internship /Industrial Internship / Rural Internship shall be permitted to be operated simultaneously by the University so that students have ample opportunity for an internship. In other words, a good percentage of the class shall attend VII semester classwork and a similar percentage of others shall attend to Research Internship or Industrial Internship or Rural Internship.

Research/Industrial /Rural Internship shall be carried out at an Industry, NGO, MSME, Innovation center, Incubation center, Start-up, center of Excellence (CoE), Study Centre established in the parent institute and /or at reputed research organizations/institutes.

The mandatory Research internship /Industry internship / Rural Internship is for 14 to 20 Weeks. The internship shall be considered as a head of passing and shall be considered forthe award of a Degree. Those, who do not take up/complete the internship shall be declared to fail and shall have to complete it during the subsequent University examination after satisfying the internship requirements.

Research internship: A research internship is intended to offer the flavor of current research going on in the research field. It helps students get familiarized with the field and imparts the skill required for carrying out research.

Industry internship: Is an extended period of work experience undertaken by students to supplement their Degree for professional development. It also helps them learn to overcome unexpected obstacles and successfully navigate organizations, perspectives, and cultures. Dealing with contingencies helps students recognize, appreciate, and adapt to organizational realities by tempering their knowledge with practical constraints.

Rural Internship: Rural development internship is an initiative of Unnat Bharat Abhiyan Cell, RGIT in association with AICTE to involve students of all departments studying in different academic years for exploring various opportunities in techno-social fields, to connect and work with Rural India for their upliftment.

The faculty coordinator or mentor has to monitor the student's internship progress and interact with them to guide for the successful completion of the internship. The students are permitted to carry out the internship anywhere in India or abroad. University shall not bear any expenses incurred in respect of the internship.

With the consent of the internal guide and Principal of the Institution, students shall be allowed to carry out the internship at their hometown (within or outside the state or abroad),provided favorable facilities are available for the internship and the student remains regularly in contact with the internal guide. University shall not bear any cost involved in carryingout the internship by students. However, students can receive any financial assistance extended by the organization.

Professional Elective /Open Elective Course: These are ONLINE courses suggested by the respective Board of Studies. Details of these courses shall be made available for studentson the VTU web portal.

WIRELESS COMMUNICATION

Contact Hours/ Week:	: 3 (L)+2(P)	Credits:	4
Total Lecture Hours:	: 42(L) + 28(P)	CIE Marks:	50
Sub. Code:	S7ETI01	SEE Marks:	50

Course objectives:	
This course will enable students to:	
1.	Analyze the concepts of wireless communication.
2.	Realize knowledge of basic wireless communication parameters and their design.
3.	Apply the wireless communication concepts to design wireless communication systems.
4.	Realize the knowledge of latest developments in the field of wireless communication.
UNIT I	
Introduction to Wireless Communication Systems: Examples of Wireless Communication Systems, Introduction to 2G, 3G, 4G and 5G Standards. Wireless Networks, WLL, WLANs, Bluetooth and PANs. The Cellular Concept – System Design Fundamentals: Introduction, Frequency Reuse, Channel Assignment Strategies, Handoff Strategies, Interference and System Capacity. Trunking and Grade of Service, Improving Coverage & Capacity in Cellular Systems	
	10 Hours
UNIT II	
Mobile Radio Propagation: Large Scale Path Loss Introduction to Mobile Radio Wave Propagation, Free Space Propagation Model, Relating Power to Electric Field, The Three Basic Propagation Mechanisms, Reflection, Ground Reflection (Two-Ray) Model, Diffraction, Scattering, Practical Link Budget Design Using Path Loss Models, Outdoor Propagation Models. **Mobile Radio Propagation: Small-Scale Fading and Multipath:** Small- Scale Multipath Propagation, Impulse Response Model of a Multipath Channel, Small-Scale Multipath Measurements, Parameters of Mobile Multipath Channels, and Types of Small-Scale Fading	
	8 Hours
UNIT III	
Principles of Wireless Communications: The wireless communication environment, Modelling of wireless channel, System model for narrowband signals, Rayleigh fading wireless channel, BER performance of wireless systems for various modulations, Intuition for BER in a fading channel, Channel estimation in wireless systems	
	8 Hours
UNIT IV	
Equalization: introduction, Fundamentals of Equalization, Linear and Non Linear Equalizers. **Diversity in Wireless Communications:** Diversity Techniques, Multiple receive antenna system model, Symbol detection in multiple antenna systems, BER in multi-antenna wireless systems, Diversity Order	
	8 Hours

UNIT V
Orthogonal Frequency Division Multiplexing (OFDM): **Introduction to OFDM**, Subcarrier concept, OFDM signal generation, IFFT/FFT operations in OFDM, Addition of cyclic prefix, End-to-End system model for OFDM. **Multiple-Input Multiple-Output (MIMO):** Introduction to MIMO, MIMO system model, MIMO Zero Forcing (ZF) Receiver, MIMO MMSE Receiver Introduction to 5G architecture and applications. Introduction to 6G.
8 Hours

TEXT BOOKS		
1	Theodore S. Rappaport	Wireless Communications - Principles and Practice, updated 2nd edition, Pearson Education, 2010.
2	Aditya K Jagannatham	Principles of Modern Wireless Communication Systems, 1st edition Mc. Graw-Hill Education (India), 2015
REFERENCE BOOKS		
1	Dr. Kamilo Feher	Wireless digital Communications, PHI, 1st edition, 1995.
2	William C.Y. Lee	Wireless and Cellular Telecommunication, 3rd edition, McGraw Hill, professional, 2005

Lab Experiments	
1.	Modeling of wireless communication systems using Matlab for Freespace propagation and Two ray channel model
2.	Modeling of wireless communication systems using Matlab for Okumura and Hata model
3.	Modeling and simulation of Multipath fading channel
4.	Design, analyze and test Wireless standards and evaluate the performance measurements such as BER, throughput, capacity for 4G using Matlab
5.	Design, analyze and test Wireless standards and evaluate the performance measurements such as BER, throughput, capacity for 5G using Matlab
6.	Modulation: Spread Spectrum – DSSS Modulation & Demodulation
7.	Wireless Channel equalization: Zero-Forcing Equalizer (ZFE), MMSE Equalizer (MMSEE), Adaptive Equalizer (ADE), Decision Feedback Equalizer (DFE)
8.	Modeling and simulation of TDMA and FDMA for wireless communication
9.	Modeling and simulation of CDMA for wireless communication
10.	Modeling and simulation of OFDM system with 2X2, 4X4 MIMO channel

Course Outcomes:	
Upon completion of this course the student will be able to:	
CO1	Analyze the wireless standards and cellular concepts.
CO2	Evaluate the power received/ path loss for outdoor propagation models.
CO3	Analyze the Rayleigh fading channel and its performance.
CO4	Analyze the performance of various diversity techniques and equalizers.
CO5	Analyze the performance of OFDM techniques and MIMO system.

Course Articulation Matrix
**Mapping of Course Outcomes (COs) to Program Outcomes (POs) &
Program Specific Outcomes (PSOs)**

CO's		PO's												PSO's	
		1	2	3	4	5	6	7	8	9	10	11	12	1	2
	1	2	3	1				1								2
	2		2	1		1	1	1								2
	3	2	2			1		1								2
	4		2	1		1						1	1			2
	5	1	2			1						1	1			2

Note: 1- Weak correlation 2-Medium correlation 3-Strong correlation

SATELLITE AND RADAR SYSTEMS

Contact Hours/ Week	: 3(L)+2(P)	Credits :	4
Total Lecture Hours	: 42(L)+28(P)	CIE Marks :	50
Sub. Code	: S7ETI02	SEE Marks :	50

Course objectives:	
Introduce this course will enable students to:	
1.	Calculate Orbital mechanics of the satellites.
2.	Introduce Satellite link components in a broadband communication system.
3.	Design the satellite subsystems.
4.	Study satellites constellation for applications such as meteorological data collection, search, navigation and rescue, GPS, etc. and understand the basics of radars and applications

UNIT I
OVER VIEW OF SATELLITE SYSTEMS: Introduction, frequency allocation, INTELSAT. **ORBITS:** Introduction, Kepler laws, definitions, orbital elements, apogee and perigee heights, orbit perturbations, inclined orbits, calendars, universal time, sidereal time, orbital plane, local mean time and sun synchronous orbits, Geostationary orbit: Introduction, antenna, look angles, polar mount antenna, limits of visibility, earth eclipse of satellite, sun transit outage, launching orbits. **Text-1: Chap 1.1-3; 2.1-2.10; 3.1-3.8.**
Tutorial/lab components : Types of satellites, Orbital elements calculations, Look angle determinations.
10 Hours

UNIT II
PROPAGATION IMPAIRMENTS AND SPACE LINK: Introduction, atmospheric losses, ionospheric effects, rain attenuation, other impairments. **SPACE LINK:** Introduction, EIRP, transmission losses, link power budget, system noise, CNR, uplink, down link, effects of rain, combined CNR. Intermodulation, Inter-satellite Links. **Text-1: Chapter 4.1-4.5; Chapter 12.1-12.12.**
Tutorial/lab components : Losses Estimation, Rain loss predictions, CNR calculations for satellite links.
8 Hours

UNIT III
SUBSYSTEMS: SPACE SEGMENT- Introduction, power supply units, attitude control, station keeping, thermal control, TT&C, transponders, antenna subsystem.

EARTH SEGEMENT- Introduction, receive only home TV system, outdoor unit, indoor unit, MATV, CATV, Tx – Rx earth station. **Text-1: Chap 7.1- 7.8; 8.1-8-5.**

Tutorial/lab components : Design of solar panels for the given requirements, Case study on cubesat.

8 Hours

UNIT VI

An Introduction to Radar: Basic Radar, The Simple Form of the Radar Equation, Radar Block Diagram, Radar Frequencies, Applications of Radar, The Radar Equation: Introduction, Detection of Signals in Noise, Receiver Noise and the Signal to Noise Ratio, Probabilities of Detection and False Alarm, Radar Cross section of Simple Targets, Transmitter Power, Pulse Repetition Frequency. System losses.

8 Hours

UNIT V

MTI and Pulse Doppler Radar: Introduction to Doppler and MTI Radar, Delay Line Cancellers, Digital MTI Processing, Pulse Doppler Radar, Tracking Radar: Tracking with Radar, Mono-pulse Tracking, Conical Scan and Sequential Lobing, Tracking in Range. Space-Based Remote Sensing Radars and Meteorological Radar.

8 Hours

Tutorial/ Lab Components:	
1.	Types of satellites and their requierements
2.	Orbital elements calculassions
3.	Look angle determination for a given satellite
4.	Losses Estimation, Rain loss predictions,
5.	CNR calculations for satellite links.
6.	Design of solar panels for the given requirements,
7.	Multiple Access used in the satellite links
8.	Case study on cubesat.
9.	Evaluate Radar range equation, Signal-to-Noise Ratio (SNR)
10.	Detection Probability vs. False Alarm Probability.
11.	Calculate Pulse Repetition Frequency (PRF) and Unambiguous Range.
12.	Track targets using Kalman filter.
13.	Analyze delay line canceller.
14.	Analyze MTI radar processing.

Text Books:		
1	Dennis Roddy	Satellite Communications, 4th Edition, McGraw- Hill, 2019.
2	Merrill I. Skolnik	Handbook of Radar Systems, McGraw Hill; 3rd edition, 2008.

Reference Books:		
1	Satellite Communications	Timothy Pratt, Charles Bostian and Jeremy Allnutt, 2nd Edition, John Wiley Pvt. Ltd & Sons, 2008.
2	Pinliang Dong	LiDAR Remote Sensing and Applications, CRC Press, 2017.

Course Outcomes:
Upon completion of this course the student will be able to:

CO1	Apply Kepler laws of planetary motion to develop different orbital mechanics for a satellite.
CO2	Identify and analyze components of Losses for development links between earth station and satellite.
CO3	Perform computations related to antenna gain, look angles and identify the subsystems for a given communication satellite.
CO4	Explain the fundamental concepts of radar systems, identify key parameters such as SNR, PRF, and system losses and develop radar range equation
CO5	Analyze Moving Target Indication (MTI), Pulse Doppler radar principles, and radar tracking techniques such as mono-pulse tracking, conical scan, and sequential lobing.

Course Articulation Matrix
Mapping of Course Outcomes (COs) to Program Outcomes (POs) &
Program Specific Outcomes (PSOs)

CO's		PO's											PSO's	
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
	1	3	3	3					1	1		1	1	2
	2	3	3	3					1	1		2	2	2
	3	3	3	3		2			1	1		2	2	3
	4	3	2			2								2
	5	2	2			2								2

Note: 1- Weak correlation 2-Medium correlation 3-Strong correlation

TELECOM NETWORKS AND BUSINESS SUPPORT SYSTEMS

Contact Hours/ Week	: 4 (L)	Credits :	4
Total Lecture Hours	: 52	CIE Marks :	50
Sub. Code	:S7ET01	SEE Marks :	50

Course objectives:
This course will enable students to:

1.	Provide foundations of Telecommunication and usages of transmission medium for establishing communication.
2.	Introduce the international telecom industry standard at college level.
3.	Expose the practical aspects that a student should be equipped with to work successfully in a telecom industry.
4.	Introduce the concepts of eTOM, OSS and BSS in telecom industry.
5.	Provide the insight into the latest standards used in Telecom networks.

UNIT I
Telecommunication Technology Fundamentals, Transmission medium & Establishing Communication Channels: Transmission lines, Types of network connections, The Electromagnetic spectrum and bandwidth, Analog and Digital Transmission and Multiplexing, Twisted pair, coaxial cable, Microwave, Satellite and Fiber optics, Establishing Connections, The PSTN versus the Internet.
12 Hours

UNIT II
Wireless Communications: Wireline, Wireless, Telecom Evolution (GSM-6G), Cloud, Containers. Spectrum reuse- space division, Multiple access techniques, spread spectrum techniques, compression techniques, duplexing techniques, Wireless WANs-analog & digital cellular network architechture,CDPD,GSM,GPRS,EDGE,3G technology evolution, Wireless MANs-Wireless local loop applications and options, Wireless LANs & Wireless PANs-Bluetooth, Home RF
10 Hours

UNIT III
Operational Support System: OSS basics, Introduction to products and services, OSS components, CRM systems – types and functionalities, Introduction to OSS processes.
Order/Service Fulfilment: *Order Management:* Introduction, types of orders, Order capture functionality – Lead time, address verification, number reservation, engineer visit, booking engineer appointment.
Service Provisioning: Order data verification, Order feasibility check, Customer eligibility check, Service provider eligibility check, Order

decomposition, Order orchestration, Manage logical inventory, Network reservation, Service activation, Hardware activation.
Prepaid, Postpaid, MVNO (Mobile Virtual Network Operator), Network Function Virtualization

	10 Hours

UNIT VI
Inventory Management: Number inventory, product inventory, customer data inventory, physical inventory, logical/network inventory, Service inventory. **Service Assurance:** Proactive service assurance, Reactive service assurance, Customer and network Fault & Trouble Ticket Management, Network Performance Management Introduction to BSS: BSS components, High level processes of BSS, BSS intersection with *eTOM*, CRM (Customer Relationship Management) functionalities, CRM functional areas, CRM sales management, CRM Marketing management.

	10 Hours

UNIT V
Mediation, Roaming and Interconnect: Introduction, Event, UDR, CDR, CDR attributes, real time mediation, Functionalities of a mediation system, CDR processing, mediation for various scenarios – home subscribers, in-roaming, out-roaming, international roaming (within and outside own service provider network), national roaming (within and outside own service provider network), Interconnect CDRs. Introduction to roaming and interconnect, In-Network subscribers, Out-of-network subscribers, Tap-In files, Tap-out files, Point of interconnect. **Rating:** Product and service modelling, Service tariff – types of charges, Basic functionalities of a rating engine, duplicate events, rejected events, real time rating, batch rating, re-rating events, partial rating, threshold and actions, rating time discounts. **Billing:** Bill Generation Flow, Convergent Billing

	10 Hours

Text Books:		
1	Lillian Goleniewski	Telecommunications Essentials, Pearson, Edition, Year, ISBN 0-201-76032-0
2	Rahul Wargad	OSS/BSS for converged Telecommunication networks: A Practical Approach, EPCS, Pune, First Edn. 2013.
3	Jithesh Sathyan	Fundamentals of EMS, NMS, and OSS/BSS.

	Reference Books and E-resources:	
1	Roger L Freeman	Fundamentals of Telecommunications, 2nd Edition, John Wiley & Sons, 2005
2	Thiagarajan Vishvanathan	Telecommunications Switching systems & networks – PHI-2010
3	Harry Newton with Steve Schoen	Newton's Telecom Dictionary: 27th Updated and Expanded Edition
4	Shailendra Jain, Mark Hayward, Sharad Kumar	Broadband Infrastructure: The Ultimate Guide to Building and Delivering OSS/BSS
5	https://www.transform.org	Telemanagement Forum Business process Framework (eTOM): G921

	Course Outcomes:
	Upon completion of this course the student will be able to:
CO1	Identify the types of telecommunication networks and list out the parameters for establishing the connections.
CO2	Identify the functions under operations support systems and analyze the functionality of customer relationship management, service fulfillment and service provisioning in Telecom Industry.
CO3	Outline the types and importance of inventory management and illustrate the process of service assurance.
CO4	Analyze the process of mediation, roaming and interconnect in various scenarios and list the parameters affecting service tariff charges in telecom industry.
CO5	Evaluate the wireless networks and standards used in telecommunication Industry.

Course Articulation Matrix
Mapping of Course Outcomes (COs) to Program Outcomes (POs) & Program Specific Outcomes (PSOs)

CO's		PO's											PSO's	
		1	2	3	4	5	6	7	8	9	10	11	1	2
	1	3	3	3		1				1		1		2
	2	3	3			1				1		1		3
	3	3	3			1				1		1		3
	4	3	3			1				1		1		2
	5	3	3	3		1				1		2		2

Note: 1- Weak correlation 2-Medium correlation 3-Strong correlation

OPTICAL FIBER COMMUNICATION

Contact Hours/ Week:	3(L)	Credits:	3
Total Lecture Hours:	42	CIE Marks:	50
Sub. Code:	SETE15	SEE Marks:	50

Course objectives:	
This course will enable students to:	
1.	Understand the fundamentals of optical communication system.
2.	Analyze the propagation of light through optical fiber, the losses that occur in the optical fiber, and system design
3.	Analyze and evaluate the performance of optical fiber communication systems, focusing on key metrics such as bit error rate (BER), signal-to-noise ratio (SNR), and power budget.
4.	Understand the various components and devices used in optical fiber communication systems, such as light sources optical amplifiers, photodetectors, and modulators

UNIT I
Introduction: The evolution of fiber optic systems, elements of an optical fiber transmission link, advantages of optical fiber communication, applications.
Optical Laws: Ray theory transmission, total internal reflection acceptance angle, numerical aperture and skew rays.
Electromagnetic Analysis: Electromagnetic mode theory and propagation, single mode and multimode fibers, TE and TM modes, b-V curves.
Optical fibers: Types of fiber based on structure, Fiber material, fiber cables and fiber fabrication.
10 Hours

UNIT II
Transmission Characteristic of Optical Fiber
Attenuation: Absorption, scattering losses, bending losses.
Dispersion: Pulse broadening, Modal dispersion, bit rate-length product, waveguide dispersion, material dispersion and polarization Mode dispersion.
Optimization of Fiber: Dispersion shifted and dispersion flattened fibers, fractional power in the core, single mode fiber cut-off wavelength and mode field diameter.
8 Hours

UNIT III
Optical Sources and Power launching and Coupling
Optical Sources: sources for optical fiber communication, light emitting diode, internal and external quantum efficiencies, LED characteristics, LASER diode and Threshold condition.
Power launching and coupling: Source to fiber power launching, Lensing schemes, LED coupling to single mode fibers, fiber splicing.
8 Hours

UNIT IV
Optical detectors and Receiver Operation
Optical Detectors: Working principle and characteristics of detectors PIN and APD, noise analysis in detectors.
Receiver Operation: Receiver structure, bit error rate of optical receivers, and receiver performance.
Power Budgeting of fiber link: link power budget, rise time budget, transmission distance for single mode links
8 Hours

UNIT V
Optical Fiber Components and Optical Network
Optical fiber components: Directional coupler, power splitter, WDM coupler, polarization controllers, fiber Bragg gratings, Mach Zehnder Interferometer, erbium doped fiber amplifier.
Optical Networks: SONET and SDH standards, architecture of optical transport networks (OTNs), network topologies, Operational principle of WDM, WDM network elements and Architectures.
8 Hours

TEXT BOOKS		
1	Gerd Keiser	Optical Fiber Communication, 5th Edition, McGraw Hill Education, 2017.

REFERENCE BOOKS		
1	G P Agarwal	"Fiber Optic Communication System", 4th Edition, John Wiley and sons, 2010
2	J. M. Senior	"Optical Fiber Communication, Principles and Practice", 3rd Edition, Prentice Hall of India, 1994.
3	G P Agarwal	"Fiber Optic Communication System", 4th Edition, John Wiley and sons, 2010

Course Outcomes:

Upon completion of this course the student will be able to:

CO1	Design and analyze different types of optical fibers.
CO2	Analyze the mechanisms of signal transmission in optical fibers, such as attenuation and dispersion losses.
CO3	Design and analyze different types of optical sources (lasers, LEDs) used in fiber optic systems, and explain their characteristics.
CO4	Design and analyze various types of optical detectors used in fiber optic systems, and apply the design considerations for optical receivers.
CO5	Analyze different optical components and optical networks used in optical communication system.

Course Articulation Matrix
Mapping of Course Outcomes (COs) to Program Outcomes (POs) &
Program Specific Outcomes (PSOs)

CO's	PO's											PSO's	
	1	2	3	4	5	6	7	8	9	10	11	1	2
1	2	2			1								1
2	2	2	2		1								1
3	2	2	2		1								2
4	3	3	3		1								2
5	3	3	3		1								2

Note: 1- Weak correlation 2-Medium correlation 3-Strong correlation

SPEECH PROCESSING

Contact Hours/ Week:	3(L)	Credits:	3
Total Lecture Hours:	42	CIE Marks:	50
Sub. Code:	SETE16	SEE Marks:	50

Course objectives:	
This course will enable students to:	
1.	Understand the characteristics of speech signal
2.	Apply signal processing concepts to speech signal,
3.	Get an insight into an application on speech/speaker recognition and speech enhancement.

UNIT I
Digital Models for the Speech Signal: Introduction, The process of speech production, The acoustic theory of speech production, Lossless tube models, Digital models for the speech signals
10 Hours

UNIT II
Time-Domain Models for Speech Processing: Introduction, Time-dependent processing of speech, Short-time energy and average magnitude, Short-time average zero-crossing rate, Speech vs. silence discrimination using energy and zero-crossings, Pitch period estimation using a parallel processing approach, The short-time autocorrelation function, The short-time average magnitude difference function, Pitch period estimation using the autocorrelation function. **Short-Time Fourier Analysis:** Fourier transform interpretation, Linear filtering interpretation, Sampling rates of STFT in time and frequency, Filter bank summation method of short-time synthesis, Overlap addition method of short-time synthesis
8 Hours

UNIT III
Homomorphic Speech Processing: Homomorphic systems for convolution, The complex spectrum of speech, Pitch detection, Formant estimation, vocoders
8 Hours

UNIT IV
Linear Prediction Analysis of Speech: Basic principles of linear predictive analysis, Computation of the gain for the model, Solution of the LPC equations, Comparisons between the methods of solution of the LPC analysis equations, Frequency domain interpretations of linear predictive analysis, Synthesis of speech from linear predictive parameters, Applications of LPC parameters: pitch detection and formant analysis using LPC parameters
8 Hours

UNIT V
Applications of Speech Processing,   **Automatic Speech Recognition:** Speech recognition systems (Isolated word recognition, connected word recognition and large vocabulary word recognition)   **Speech Recognition:** Introduction, Spectral features for speaker recognition, Speaker recognition algorithm.   **Speech Enhancement**: Background, Nature of interfering sounds, Speech enhancement techniques, Spectral subtraction
8 Hours

TEXT BOOKS		
1	Lawrence R. Rabiner and Ronald W. Schafer	Digital Processing of Speech Signals, 2nd Edition,Indian Reprint, Pearson Education India, 1st Edition , 2003

Reference Books:		
1	Thomas F. Quatieri	Discrete-Time Speech Signal Processing: Principles And Practice, Pearson Education India, 1st Edition , 2012
2	Lawrence R. Rabiner, Biing-Hwang Juang, B. Yegnanarayana	Fundamentals of Speech Recognition, Pearson Education India, 1st Edition , 2008.

Course Outcomes:

Upon completion of this course the student will be able to:

CO1	Analyze the mechanism of speech production & its representation digitally
CO2	Classify the phonemes depending upon the manner and place of articulation
CO3	Make use of short-term analysis for speech signals
CO4	Extract the information of the speech signals in terms of cepstral features Analyze the speech signals using linear predictive coding.
CO5	Apply speech processing concepts in various applications of speech

Course Articulation Matrix

Mapping of Course Outcomes (COs) to Program Outcomes (POs) & Program Specific Outcomes (PSOs)

CO's		PO's											PSO's	
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
	1	1	1	2		2			1		1		1	
	2	3	2			2			1		1		1	
	3	2	2	1		2			1		1		2	
	4	1	2			2			1		1		2	
	5	3	2	1		2			1		1		2	

Note: 1- Weak correlation 2-Medium correlation 3-Strong correlation

AD HOC WIRELESS NETWORKS

Contact Hours/ Week:	3(L)	Credits:	3
Total Lecture Hours:	42	CIE Marks:	50
Sub. Code:	SETE17	SEE Marks:	50

Course objectives:	
This course will enable students to:	
1.	Provide students the fundamental concepts, issues.
2.	Design in developing the architecture and protocols in MAC layer, Network layer, Transport layer for ADHOC wireless networks.
3.	Introduction to security implementation issues in ADHOC wireless networks.

UNIT I
AD HOC NETWORKS: Introduction, Application of Ad-Hoc wireless networks, Issues in Ad hoc wireless networks, Ad hoc wireless internet
10 Hours

UNIT II
MAC PROTOCOLS FOR AD HOC WIRELESS NETWORKS:
Introduction, Issues in designing a MAC protocol for Ad hoc wireless Networks, Design goals of a MAC protocol for Ad hoc wireless Networks, Classification of MAC protocols. MACAW protocol, Busy Tone Multiple Access Protocols, Media Access with Reduced Handshake, Five-Phase Reservation Protocol, Distributed Priority Scheduling and Medium Access in Ad Hoc Networks.
8 Hours

UNIT III
ROUTING PROTOCOLS FOR AD HOC WIRELESS NETWORKS-1:
Introduction, Issues in designing a routing protocol for Ad hoc wireless Networks, Classification of routing protocols, DSDV protocol, Cluster-Head Gateway Switch Protocol, DSR protocol, AODV protocol, TORA protocol, Location-Aided protocol.
8 Hours

UNIT IV
ROUTING PROTOCOLS FOR AD HOC WIRELESS NETWORKS-2:
Hybrid routing protocol, ZRP protocol, routing protocols with efficient flooding, OLSR protocol, Fisheye State Protocol, Multicast Routing in Ad-Hoc Wireless networks: Multicast Ad-Hoc on demand Distance vector routing protocol, Core assisted mesh protocol.
8 Hours

UNIT V
TRANSPORT LAYER PROTOCOLS FOR AD HOC WIRELESS NETWORKS AND OTHER MODELS OF AD HOC NETWORKS: Introduction, Issues in designing a transport layer protocol for Ad hoc wireless Networks, TCP-F protocol, TCP Bus, ATCP. **UAV Networks:** Introduction, FANETs, Handover types. Wireless Sensor Network: Introduction, WSN coverage-OGDC Algorithm, Topology management in WSN, MAC protocols for WSN, Routing protocol for WSN.
8 Hours

TEXT BOOKS

1	C. Siva Ram Murthy, B.S.Manoj	Ad hoc wireless Networks, Pearson Education, 2ndEdition, reprint 2005

REFERENCE BOOKS

1	Ozan K.Tonguz, Gianguigi Ferrari	Ad hoc wireless Networks, Wiley, 2007
2	Xiuzhen Cheng, Xiao Hung, Ding- Zhu Du	Ad hoc wireless Networking Kluwer academic publishers. 2004.

Course Outcomes:

Upon completion of this course the student will be able to:

CO1	Outline the fundamental concepts and issues in Ad Hoc Wireless Networks.
CO2	Analyze the MAC protocols of Ad Hoc Wireless Networks.
CO3	Classify and analyze various Routing protocols of Ad Hoc Wireless Network.
CO4	Identify and Analyze optimized Routing protocols of Ad Hoc Wireless Networks
CO5	Analyze various transport layer protocols of Ad Hoc Wireless Networks and outline the concepts of UAV and WSN technologies.

Course Articulation Matrix
Mapping of Course Outcomes (COs) to Program Outcomes (POs) & Program Specific Outcomes (PSOs)

CO's		PO's											PSO's	
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
	1	2	2				1						1	
	2	2	2					2						2
	3	2	2	2			1						1	2
	4	2	1							2			1	2
	5	2						2					1	2

Note: 1- Weak correlation 2-Medium correlation 3-Strong correlation

RF ANALOG IMPAIRMENTS MODELING

Contact Hours/ Week:	3(L)	Credits:	3
Total Lecture Hours:	42	CIE Marks:	50
Sub. Code:	SETE18	SEE Marks:	50

Course objectives:	
This course will enable students to:	
1.	Understand the architecture and components of Communication System-on- Chip (SoC) with OFDM modulation.
2.	Analyze various RF analog front-end impairments affecting wireless communication systems.
3.	Learn digital techniques to model and compensate for RF analog impairments in modern transceivers.
4.	Gain knowledge of digital signal processing techniques for wireless standards like WiFi and WiMAX.
5.	Explore the fundamentals and performance considerations of Visible Light Communication (VLC) systems.

UNIT I
Introduction to Communication System-on-Chip, RF Analog Front-End, OFDM Modulation, and Performance Metrics:
Communication System-on-Chip, RF AFE Overview, Superheterodyne Transceiver, Homodyne Transceiver, Low-IF Transceiver, OFDM Modulation, OFDM as a Multicarrier Modulation, Fourier Transform and Orthogonal Subcarriers, Channel Estimation and Equalization in Frequency Domain, OFDMA for Multiple Access SNR, EVM, and E_b/N_0 Definitions and Relationship.
10 Hours

UNIT II
RF Analog Impairments Description and Modeling:
Thermal Noise, Oscillator Phase Noise, Sampling Jitter, Carrier Frequency Offset, Sampling Frequency Offset, I and Q Mismatch, DAC/ADC Quantization Noise and Clipping, IP2 and IP3: Second- and Third-Order Nonlinearities, Power Amplifier Distortion
8 Hours

UNIT III
Digital Compensation of RF Analog Impairments
WLAN and Mobile WiMAX PHY Overview, WiFi OFDM and Mobile WiMAX Signals, PAPR, Transmitter Impairments Simulation, Receiver Impairments Simulation, Adaptive Modulation Illustration
8 Hours

UNIT IV
Digital Compensation of RF Analog Impairments
CFO Estimation and Correction, SFO Estimation and Correction, IQ Mismatch Estimation and Correction, Power Amplifier Linearization
8 Hours

UNIT V
Visible light wireless communications (VLC); Transmitter, Channel, Receiver, performance, MIMO-VLC.
8 Hours

TEXT BOOKS

1	Lydi Smaini	RF Analog Impairments Modeling for Communication Systems Simulation: Application to OFDM-based Transceivers, John-Wiley & Sons, 2012.
2	Tony J. Rouphael	Wireless Receiver Architectures and Design: Antenna, RF, Synthesizers, Mixed Signal and Digital Signal Processing, Academic Press, 2014.

REFERENCE BOOKS

1	Abbas Mohammadi and Fadhel M. Ghannouchi	RF Transceiver Design for MIMO Wireless Communications, Springer-Verlag, 2012.
2	Jerry R. Hampton	Introduction to MIMO Communications", Cambrid University Press, 2014.

Course Outcomes:

Upon completion of this course the student will be able to:

CO1	Analyze the structure of Communication SoCs and compute performance metrics such as SNR and EVM for OFDM-based systems.
CO2	Identify and mathematically model various RF analog impairments like phase noise, jitter, and non-linearities.
CO3	Evaluate the impact of RF analog impairments like phase noise, jitter, and nonlinearities on communication system performance.
CO4	Apply digital compensation techniques such as CFO/SFO correction, IQ mismatch correction, and amplifier linearization.
CO5	Evaluate the components, transmission channel, and performance parameters of VLC systems, including MIMO-based VLC.

Course Articulation Matrix
Mapping of Course Outcomes (COs) to Program Outcomes (POs) &
Program Specific Outcomes (PSOs)

		POs												PSOs	
		1	2	3	4	5	6	7	8	9	10	11	12	1	2
COs	CO1	2	2												2
	CO2	2	2												2
	CO3	2	2												2
	CO4	2	2												2
	CO5	2	2												2

Note: 1- Weak correlation 2-Medium correlation 3-Strong correlation

MILLIMETER WAVE COMMUNICATIONS

Contact Hours/ Week:	3(L)	Credits:	3
Total Lecture Hours:	42	CIE Marks:	50
Sub. Code:	SETE19	SEE Marks:	50

Course objectives:	
This course will enable students to:	
1.	Understand the requirement of Millimeter wave and models
2.	Understand the fundamentals of Millimeter wave devices and circuits.
3.	Understand the modulation techniques of Millimeter wave Communications system
4.	Understand the MIMO Communications system
5.	Know the antenna design at Millimeter wave frequencies.

UNIT I
Introduction To Millimeter Wave Millimeter: wave characteristics-millimeter wave wireless, implementation challenges, Radio wave propagation for mm wave: Large scale propagation channel effects, small scale channel effects, Outdoor and Indoor channel models, Emerging applications of millimetre wave communications
10 Hours

UNIT II
MM Wave Devices And Circuits: Millimeter wave generation and amplification: Peniotrons, Ubitrons, Gyrotrons and Free electron lasers. HEMT, models for mm wave Transistors, transistor configurations, Analog mm wave components: Amplifiers, Mixers, VCO, PLL. Metrics for analog mm wave devices, Consumption factor theory, Trends and architectures for mm wave wireless, ADC"s and DAC"s
8 Hours

UNIT III
MM Wave Communication Systems: Modulations for millimeter wave communications: OOK, PSK, FSK, QAM, OFDM, Millimeter wave link budget, Transceiver architecture, Transceiver without mixer, Receiver without Oscillator, Millimeter wave calibration, production and manufacture, Millimeter wave design considerations.
8 Hours

UNIT IV
MM Wave MIMO Systems: Massive MIMO Communications, Spatial diversity of Antenna Arrays, Multiple Antennas, Multiple Transceivers, Noise coupling in MIMO system, Potential benefits for mm wave systems, Spatial, Temporal and Frequency diversity, Dynamic spatial, frequency and modulation allocation.
8 Hours

UNIT V
Antennas For MM Wave Systems: Antenna beam width, polarization, advanced beam steering and beam forming, mm wave design consideration, On-chip and In package mm wave antennas, Techniques to improve gain of on-chip antennas, Implementation for mm wave in adaptive antenna arrays, Device to Device communications over 5G systems, Design techniques of 5G mobile.
7 Hours

TEXT BOOKS		
1	K.C. Huang, Z. Wang,	"Millimeter Wave Communication Systems", Wiley-IEEE Press, March 2011.
2	Robert W. Heath, Robert C. Daniel, James N. Theodore S. Rappaport, Murdock,	"Millimeter Wave Wireless Communication", Prentice Hall, 2014.

REFERENCE BOOKS		
1	Xiang, W; Zheng, K; Shen, X.S;	5G Mobile Communications: Springer, 2016

Course Outcomes:	
Upon completion of this course the student will be able to:	
CO1	Know the requirement of Millimeter wave and working models
CO2	Identify the Millimeter wave devices and circuits.
CO3	Identify the different modulation techniques of Millimeter wave Communications system
CO4	Work in MIMO Millimeter wave Communications system
CO5	Design and parameters involved in antenna for Millimeter wave frequencies application.

Course Articulation Matrix
Mapping of Course Outcomes (COs) to Program Outcomes (POs) &
Program Specific Outcomes (PSOs)

CO's		PO's												PSO's	
		1	2	3	4	5	6	7	8	9	10	11	12	1	2
	1	2														2
	2	2														2
	3	2														2
	4	2				1										2
	5	2				1										2

Note: 1- Weak correlation 2-Medium correlation 3-Strong correlation

CLOUD TECHNOLOGIES

Contact Hours/ Week:	3(L)	Credits:	3
Total Lecture Hours:	42	CIE Marks:	50
Sub. Code:	SETE20	SEE Marks:	50

Course objectives:	
This course will enable students to:	
1.	Introduce the rationale behind the cloud computing revolution and the business drivers
2.	Understand various models, types and challenges of cloud computing
3.	Understand the design of cloud native applications, the necessary tools and the design tradeoffs.
4.	Realize the importance of Cloud Virtualization, Abstraction`s, Enabling Technologies and cloud security

UNIT I
Distributed System Models and Enabling Technologies: Scalable Computing Over the Internet, Technologies for Network Based Systems, System Models for Distributed and Cloud Computing, Software Environments for Distributed Systems and Clouds, Performance, Security and Energy Efficiency. **Textbook 1: Chapter 1: 1.1 to 1.5**
10 Hours

UNIT II
Virtual Machines and Virtualization of Clusters and Data Centers: Implementation Levels of Virtualization, Virtualization Structure/Tools and Mechanisms, Virtualization of CPU/Memory and I/O devices, Virtual Clusters and Resource Management, Virtualization for Data Center Automation. **Textbook 1: Chapter 3: 3.1 to 3.5**
8 Hours

UNIT III
Cloud Platform Architecture over Virtualized Datacenters: Cloud Computing and Service Models, Data Center Design and Interconnection Networks, Architectural Design of Compute and Storage Clouds, Public Cloud Platforms: GAE, AWS and Azure, Inter-Cloud Resource Management. **Textbook 1: Chapter 4: 4.1 to 4.5**
8 Hours

UNIT IV
Cloud Security: Risks, Top concern for cloud users, Privacy Impact Assessment, Trust, OS security, VM Security, Risks Posed by Shared Images and Management OS, XOAR, A trusted VM monitor.   **Cloud Security and Trust Management:** Cloud Security Defense Strategies, Distributed Intrusion/Anomaly Detection, Data and Software Protection Techniques, Reputation-Guided Protection of Data Centers. **Textbook 2: Chapter 9: 9.1 to 9.11 Textbook 1: Chapter 4: 4.6**
8 Hours

UNIT V
Cloud Programming and Software Environments: Features of Cloud and Grid Platforms, Parallel and Distributed Computing Paradigms, Programming Support for Google App Engine, Programming on Amazon AWS and Microsoft, Emerging Cloud Software Environments. **Textbook 1: Chapter 6: 6.1 to 6.5**
8 Hours

TEXT BOOKS		
1	Distributed and Cloud Computing	Kai Hwang, Geoffrey C Fox, and Jack J Dongarra, Morgan Kaufmann, Elsevier 2012
2	Cloud Computing Theory and Practice,	Dan C. Marinescu, Morgan Kaufmann, 2nd Edition, Elsevier 2018

REFERENCE BOOKS		
1	Mastering Cloud Computing	Rajkumar Buyya, Christian Vecchiola, and Thamrai Selvi, McGrawHill Education, 1st Edition, 2017.
2	Cloud Computing: A Practical Approach	Toby Velte, Anthony Velte, McGraw-Hill Education, 2017.

Course Outcomes:	
Upon completion of this course the student will be able to:	
CO1	Describe various cloud computing platforms and service providers.
CO2	Illustrate the significance of various types of virtualization.
CO3	Identify the architecture, delivery models and industrial platforms for cloud computing based applications.
CO4	Analyze the role of security aspects in cloud computing.
CO5	Demonstrate cloud applications in various fields using suitable cloud platforms.

Course Articulation Matrix
Mapping of Course Outcomes (COs) to Program Outcomes (POs) & Program Specific Outcomes (PSOs)

<table>
<tr><td rowspan="2"></td><td rowspan="2"></td><td colspan="12">PO's</td><td colspan="2">PSO's</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>1</td><td>2</td></tr>
<tr><td rowspan="5">CO's</td><td>1</td><td>2</td><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td>2</td><td>2</td><td></td><td></td><td></td><td>2</td></tr>
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Note: 1- Weak correlation 2-Medium correlation 3-Strong correlation

5G TECHNOLOGIES

Contact Hours/ Week:	: 3 (L)	Credits:	3
Total Lecture Hours:	: 42	CIE Marks:	50
Sub. Code:	: SETE21	SEE Marks:	50

Course objectives:	
This course will enable students to:	
1.	Trace the Evolution of Wireless Technologies
2.	Comprehend 5G Requirements and Radio Resource Management
3.	Analyze the 5G Network Architecture
4.	Explore 5G Radio Access Technologies
5.	Understand Interference and Mobility Management in 5G
6.	Engage in Practical Instructional Activities

UNIT I: Overview of 5G Wireless Communications
Evaluation of mobile technologies 1G to 4G; D2D: From 4G to 5G; An overview of 5G requirements, Regulations for 5G, Radio Resource Management and its techniques for 5G; Propagation Channels: Channel modeling requirements, propagation scenarios (Relaying and Cooperative Communication and challenges in the 5G modeling, Channel Models for mmWave MIMO Systems.
10 Hours

UNIT II: 5G Architecture
Introduction, NFV and SDN, Basics about RAN architecture, High-level requirements for the 5G architecture, Functional architecture and 5G flexibility, Functional split criteria, Functional split alternatives, Functional optimization for specific applications; Integration of LTE and new air interface to fulfill 5G Requirements, Enhanced Multi-RAT coordination features, Physical architecture and 5G deployment.
8 Hours

UNIT III: 5G Radio-Access Technologies
Access design principles for multi-user communications, Orthogonal multiple-access systems, Spread spectrum multiple access systems, Capacity limits of multiple-access methods, SCMA, IDMA, Radio access for dense deployments, OFDM numerology for small-cell deployments, Radio access for V2X communication, Radio access for massive MIMO.
8 Hours

UNIT IV: Interference And Mobility Management
Network deployment types, UDN, Moving networks, Heterogeneous networks, Interference management in 5G and UDN moving relay nodes, Interference cancelation; Mobility management in 5G and heterogeneous networks, User equipment controlled versus networkcontrolled handover.
8 Hours
UNIT V: : Instructional Activity
Simulation of 5G Communications Link Analysis with Ray Tracing/ Wireless Connectivity in the 5G Era for WLAN/ Factors affecting deployment of 5G on Indian Scenario using open source software too
8 Hours

TEXT BOOKS		
1	Afif Osseiran, Jose F.Monserrat, Patrick Marsch,	"5G Mobile and Wireless Communications Technology", Cambridge University Press 2nd Edition 2011.
2	Erik Dahlman, Stefan Parkvall, Johan Sko¨ld	"5G NR: The Next Generation Wireless Access Technology" Elsevier First Edition 2016.
3	Jonathan Rodriguez	"Fundamentals of 5G Mobile Networks", Wiley, 1st Edition,2010

Course Outcomes:	
Upon completion of this course the student will be able to:	
CO1	Describe the evolution of mobile communication systems from 1G to 4G and identify the key enhancements introduced in 5G. (Level: Remembering, Understanding)
CO2	Analyze the technical requirements, regulatory aspects, and radio resource management techniques for efficient 5G deployment. (Level: Analyzing, Evaluating)
CO3	Explain the architectural components of 5G including NFV, SDN, and RAN, and evaluate the design flexibility enabled by functional splits. (Level: Understanding, Evaluating)
CO4	Compare various 5G radio access technologies and assess their suitability for dense and high-mobility scenarios such as V2X and massive MIMO. (Level: Analyzing, Evaluating)
CO5	Apply interference and mobility management strategies in heterogeneous and ultra-dense 5G network deployments.(Level: Applying, Analyzing)

Course Articulation Matrix
Mapping of Course Outcomes (COs) to Program Outcomes (POs) &
Program Specific Outcomes (PSOs)

		PO's												PSO's	
		1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO's	1	2	2	1									1		
	2	2	2	1		1									
	3	2	2	1		1									
	4	2	2	2		1				1			1		
	5	2	2	1		1				1			1		

Note: 1- Weak correlation 2-Medium correlation 3-Strong correlation

NATURAL LANGUAGE PROCESSING

Contact Hours/ Week:	3(L)	Credits:	3
Total Lecture Hours:	42	CIE Marks:	50
Course Code:	SETE22	SEE Marks:	50

Course objectives:

This course will enable students to:

1.	Understand the NLP techniques like parsing, POS-tagging and Word sense disambiguation.
2.	Explore language modeling techniques such as N-grams.
3.	Explore the applications of NLP such as Machine translation, Information retrieval etc.
4.	Understand the basic architecture of the NLG system and the role of NLP in a search engine.
5.	Demonstrate the use of modern NLP techniques for processing of text like extracting the data. Text to Feature representation etc

UNIT I
Introduction: What is NLP? Language and Knowledge, The challenges of NLP, NLP Applications.   **Word level Analysis:** Introduction, Regular Expressions, Finite-state Automata, Morphological Parsing.   **Extracting the Data:** Text data collection using APIs, Reading PDF file in Python, Reading word document, Reading JSON object, Reading HTML page and HTML parsing, Regular expressions, String handling, Web scraping.   **Exploring and Processing Text Data:** Lowercasing, Punctuation removal, Stop words removal, Text standardization, Spelling correction, Tokenization, Stemming, Lemmatization, Exploratory data analysis, End-to-end processing pipeline.   **(Text Book-1: 1.1,1.3,1.4,1.7,3.1-3.4), (Text Book-2: 1,2)**
8 Hours

UNIT II
Language Modeling: Introduction, Statistical Language Model- N-gram model, Add-one smoothing, Good-Turing smoothing.   **Part-of-Speech Tagging**: Rule-based Tagger, Stochastic Tagger, Hybrid Tagger.   **Syntactic Analysis**: CFG, Parsing- Top-down parsing, Bottom-up parsing, Probabilistic Parsing- Estimating Rule probabilities.   **(Text Book-1: 2.1,2.3,3.7,4.2,4.4.1-4.4.2,4.5.1)**
8 Hours

UNIT III
Information Retrieval-1: Introduction, Design features of Information Retrieval Systems, Information Retrieval models, Classical Information Retrieval models, Alternative models of IR, Evaluation of the IR system. **Information Retrieval-2:** Cross-Lingual Information Retrieval **Converting Text to Features:** One Hot encoding, Count vectorizer, Co-occurrence matrix, Hash vectorizer, Word embedding, Implementing fastText. **Information retrieval using word embeddings.** (Text Book-1: 9.1-9.4,9.6.1-9.6.2,9.7,10.6), (Text Book-2: 3,6.1)
8 Hours

UNIT IV
Ambiguity, Word sense Disambiguation: Knowledge based approaches, Supervised Learning of WSD. **Machine Translation:** Introduction, Problems in Machine Translation, Machine translation approaches, Direct Machine translation, Rule-based machine translation, Corpus based MT. **(Text Book-1: 5.4,5.5.2,8.1-8.7)**
8 Hours

UNIT V
Natural Language Generation: Introduction, Architectures of NLG systems, Generation tasks and representations (Except "Approach based on functional unification grammar"). **Other Applications of NLP:** Introduction, Information Extraction, Automatic Text Summarization, Question-Answering System. **Lexical Resources:** WordNet. **Disambiguating word sense using Wordnet**, **NLP in a Search Engine.** **(Text Book-1: 7.1-7.3, 11.1-11.4, 12.2), (Text Book-2: 4.8,5.6)**
8 Hours

TEXT BOOKS		
1	Tanveer Siddiqui, U S Tiwary	Natural Language Processing and Information Retrieval Oxford University Press2nd Edition, 2010.
2	Akshay Kulkarni, Adarsha Shivananda.	Natural Language Processing Recipes Unlocking Text Data with Machine Learning and Deep Learning using Python Apress 2019

	REFERENCE BOOKS	
1	Daniel Jurafsky and James H Martin	Speech and Language Processing: An introduction to Natural Language Processing, Computational Linguistics and Speech Recognition, Prentice Hall,, Low Price Edition, 2000.
2	Christopher D. Manning	Foundations of Statistical Natural Language Processing MIT Press, 1999.
3	Steven, Ewan Klein, and Edward Loper	Natural language processing with Python , O'Reilly Media, 1st Edition, 2009.

Course Outcomes:	
Upon completion of this course the student will be able to:	
CO1	Illustrate the basics of NLP and design finite state automata and context free grammars for word level and syntax level analysis respectively.
CO2	Describe and Apply N-grams Language model to predict the next word in the text sequence.
CO3	Outline Natural Language Generation techniques and various lexical resources.
CO4	Identify various applications of NLP like Machine Translation, information Retrieval, etc.
CO5	Describe the use of various NLP techniques like POS tagging, WSD, Word embeddings etc. for text processing and develop python code for the same.

Course Articulation Matrix
Mapping of Course Outcomes (COs) to Program Outcomes (POs) & Program Specific Outcomes (PSOs)

		POs											PSOs	
		1	2	3	4	5	6	7	8	9	10	11	1	2
COs	CO1	2		2		2								2
	CO2	2		2										2
	CO3	2		2										2
	CO4	1		1										2
	CO5	2		2		2								2

Note: 1- Weak correlation 2-Medium correlation 3-Strong correlation

COMMUNICATION PROTOCOL ENGINEERING

Contact Hours/ Week:	: 3 (L)	Credits:	3
Total Lecture Hours:	: 42	CIE Marks:	50
Sub. Code:	:SETE23	SEE Marks:	50

Course objectives:	
This course will enable students to:	
1.	Understand the principles for the design and development of communication protocols
2.	Analyze the protocol specifications
3.	Realize the specifications of protocol using SDL
4.	Verify and validate the protocols
5.	Understand the conformance testing of the protocol

UNIT I
INTRODUCTION:
Communication Model, Software, Subsystems, Communication Protocols: Definition, Representation of Protocol, Communication Protocol Development Methods: Informal Method, Formal Methods, Protocol Engineering Process: Need for Protocol Engineering, Phases.   Chapter 1:1.2-1.6
8 Hours

UNIT II
PROTOCOL SPECIFICATION : Components of Protocol to be specified, Communication Service Specification: Service Specification, Specification of Behavior Aspects of a Protocol, Protocol Entity Specification: Sender Entity Specifications, Receiver Entity Specifications, Channel Specifications, Interface specifications, Interactions, Internet Protocol Specifications: Examples - Alternating Bit Window Protocol, HDLC Protocol, RSVP, TCP Protocol. Chapter 3:3.1- 3.5 , 3.7
8 Hours

UNIT III
PROTOCOL SPECIFICATION LANGUAGES: SDL: Salient Features, Description of a Communication System by SDL, Examples of SDL Based Protocol Specifications.
PROTOCOL VERIFICATION/VALIDATION: Protocol Verification: Safety Properties, Liveness Properties, Verification of a Protocol Using Finite State Machines. Chapter 4:
8 Hours

UNIT IV
Verification of ABP, Verification of TCP, Protocol Validation, Protocol Design Errors: State Deadlocks, Unspecified Receptions, Non-executable Interactions, State Ambiguities.   **Protocol Validation Approaches**: Algorithms for Automated Protocol Validation, Perturbation Technique: Reachability Analysis, Fair Reachability Graphs, Process Algebra Based Validation, SDL Based Protocol Verification: Verification of the ABP, SDL Based Protocol Validation: Validation of ABP. Chapter 5: 5.1-5.7
8 Hours

UNIT V
COMMUNICATION PROTOCOL CONFORMANCE TESTING   Communication Protocol Conformance Test Principle, Test Execution, Conformance Testing Methodology and Framework, Conformance Test Architectures: Local Conformance Test Architecture, Distributed Conformance Testing Architecture, Coordinated Method, Remote Method, Test Case Derivation, Test Sequence Generation Methods: T-method, U-method, D-method, and W-method. Chapter 6, 7:
8 Hours

TEXT BOOKS		
1	Pallapa Venkatram, Sunil Kumar S Manvi, and B. Sathish Babu	Communication Protocol Engineering, PHI, 2014

REFERENCE BOOKS		
1	Mohammed G Gouda	Elements of Protocol Design, Mohammed G Gouda, Wiley First Edition, 2008.
2	Dinesh Goyal, S. Balamurugan, Sheng-Lung Peng, O. P. Verma	Design and Analysis of Security Protocol for Communication, Wiley-Scrivener, 1st Edition, 2020

Course Outcomes:

Upon completion of this course the student will be able to:

CO1	Apply the concepts of communication systems, software protocols and formal specification of protocol and identify its components.
CO2	Apply the concepts for Communicating Finite State Machines and outline the formal specifications of protocols (Knowledge, Application).
CO3	Describe the syntax and semantics of SDL protocol specification language (Comprehension), design and develop the SDL based specifications of protocol.
CO4	Classify the protocol design errors and validate the protocols with various approaches.
CO5	Discuss the various techniques of conformance testing of a protocol.

Course Articulation Matrix

Mapping of Course Outcomes (COs) to Program Outcomes (POs) &
Program Specific Outcomes (PSOs)

		POs											PSOs	
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
COs	**CO1**	2		2		2								2
	CO2	2		2										2
	CO3	2		2										2
	CO4	1		1										2
	CO5	2		2		2								2

Note: 1- Weak correlation 2-Medium correlation 3-Strong correlation

CYBER SECURITY

Contact Hours/ Week:	3(L)	Credits:	3
Total Lecture Hours:	42	CIE Marks:	50
Sub. Code:	SETE24	SEE Marks:	50

Course objectives:	
This course will enable students to:	
1.	Illustrate the understanding of Cyber Security Fundamentals.
2.	Analyses the attacker motivation and the techniques used by them to break the security of the application
3.	Study the vulnerabilities in applications and networks. Analyses the possible attacks that can be built by the hacker.
4.	Evaluation of Malicious code and analysis of attacks against Privileged User Accounts.
5.	Analysis of Defense Techniques for Cyber Security.

UNIT I
Cyber Security Fundamentals: Network and Security Concepts, Information Assurance Fundamentals, Basic Cryptography, Symmetric Encryption, Public Key Encryption, The Domain Name System (DNS), Firewalls, The Six Cybersecurity Domains, Case studies.
10 Hours

UNIT II
Attacker Techniques and Motivations: How Hackers Cover Their Tracks (Anti-forensics), How and Why Attackers Use Proxies, Tunneling Techniques, Fraud Techniques, Phishing, Smishing, Vishing and Mobile Malicious Code, Rogue Anti-Virus, Click Fraud, Threat Infrastructure, Botnets, Fast-Flux, Advanced Fast-Flux
8 Hours

UNIT III
Exploitation: Techniques to Gain a Foothold, Shellcode, Integer Overflow, Vulnerabilities, Stack Based Buffer Overflows, Format-String Vulnerabilities, SQL Injection, Malicious PDF Files, Race Conditions, Web Exploit Tools, DoS Conditions, Brute-Force and Dictionary Attacks, Misdirection, Reconnaissance and Disruption Methods, Cross-Site Scripting (XSS), Social Engineering, WarXing, DNS Amplification Attacks.
8 Hours

UNIT IV
Malicious Code: Self-Replicating Malicious Code, Worms, Viruses, Evading Detection and Elevating Privileges, Obfuscation, Virtual Machine Obfuscation, Persistent Software Techniques, Rootkits, Spyware, Attacks against Privileged User Accounts and Escalation of Privileges, Token Kidnapping, Virtual Machine Detection, Stealing Information and Exploitation, Form Grabbing, Man-in-the-Middle Attacks, DLL Injection, Browser Helper Objects.
8 Hours

UNIT V
Defense and Analysis Techniques: Memory Forensics, Why Memory Forensics Is Important, Capabilities of Memory Forensics, Memory Analysis Frameworks, Dumping Physical Memory, Installing and Using Volatility, Finding Hidden Processes, Volatility Analyst Pack, Honeypots, Malicious Code Naming, Automated Malicious Code Analysis Systems, Passive Analysis, Active Analysis, Physical or Virtual Machines, Intrusion Detection Systems, Cyber Security Essentials.
8 Hours

TEXT BOOKS		
1	Cyber Security Essentials	James Graham, Richard Howard, Ryan Olson, CRC Press, 2011

REFERENCE BOOKS		
1	Cyber security: The Essential Body of Knowledge.	Dan Shoemaker and Wm. Arthur Conklin, Cengage Learning, 2011
2	Cyber security Operations Handbook	John W. Rittinghouse, PhD, CISM, and William M. Hancock, PhD, CISSP, CISM, Digital Press, 2003

Course Outcomes:	
Upon completion of this course the student will be able to:	
CO1	Apply the cryptographic concepts underlying Cyber Security.
CO2	Analyze the techniques used by hackers to create frauds.
CO3	Analyze the vulnerabilities in a network or in an application that will help hackers to build the attack.
CO4	Analyze various types of malicious codes and security tools.
CO5	Demonstrate Memory Forensics as a defense technique for Cyber Security.

Course Articulation Matrix
Mapping of Course Outcomes (COs) to Program Outcomes (POs) &
Program Specific Outcomes (PSOs)

		PO's												PSO's	
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**
CO's	**1**	2		2						2	2				2
	2	2	2			2				2	2				2
	3	2	2							2	2				2
	4	2	2							2	2				2
	5	2	2			2				2	2				2

Note: 1- Weak correlation 2-Medium correlation 3-Strong correlation

COMPUTER VISION

Contact Hours/ Week:	3	Credits:	3
Total Lecture Hours:	42	CIE Marks:	50
Course Code:	SETE25	SEE Marks:	50

Computer vision enables computers to "see" and interpret images and videos, much like humans do. It involves development of algorithms and training computers to identify, classify, and understand objects and scenes within visual data. This field has broad applications across various industries, including manufacturing, healthcare, security, and autonomous vehicles etc.

Course objectives:	
This course will enable students to:	
1.	Represent the image videos digitally and estimate the memory requirement for transmission
2.	Provide insight to image filtering, segmentation fundamentals, descriptors for transmission
3.	Introduce camera models, calibration, virtual view and 3D vision.
4.	Provide basics of machine learning concepts that help in computer vision applications.

UNIT I
Digital Image Fundamentals: Fundamental Steps in Digital Image Processing, Components of an Image Processing System, Image Sampling and Quantization, Some Basic Relationships between Pixels, Distance metrics, connected component analysis.
10 Hours

UNIT II
Linear Filters and Segmentation: Fundamentals of Spatial Filtering, Smoothing Spatial Filters, Sharpening Spatial Filters, Filters as Templates, **Segmentation:** Fundamentals, Point, Line and Edge Detection, Hough transform, Thresholding
8 Hours

UNIT III
Image Descriptors and Features: Boundary descriptors, Region feature descriptors, Principal Component as Feature descriptor, Object Boundary and Shape Representations, Histogram of Oriented Gradients, Scale Invariant Feature transform
8 Hours

UNIT IV
Geometric Camera Models and Multiview Geometry: Pinhole Cameras, Two Views, Stereopsis: Reconstruction, Depth from Stereo, Elements of Analytical Euclidean Geometry, Camera Parameters and the Perspective Projection, Affine Cameras and Affine Projection Equations, Geometric Camera Calibration: Least-Squares Parameter Estimation, 3D Vision, Virtual View Synthesis
8 Hours
UNIT V
Machine Learning for Computer Vision: Linear Regression, Basic Concepts of Decision Functions, Elementary Statistical Decision Theory, Dimension Reduction, Linear Discriminant Analysis, Clustering, Applications of Computer Vision: Artificial Neural Network for Pattern Classification, Convolutional Neural Networks, Applications
8 Hours

TEXT BOOKS		
1	Rafael C. Gonzalez and Richard E. Woods	"Digital Image Processing", Pearson Education, 2018.
2	David A Forsyth Jean Ponce	"Computer Vision – A Modern Approach", PHI Learning, 2009.
3	Richard Hartley, Andrew Zisserman	"Multiple View Geometry in Computer Vision," Cambridge University Press, 2004

REFERENCE BOOK		
1	E. R. Davies	"Computer and Machine Vision Theory, Algorithms and Practicalities," Elsevier (Academic Press), 2013

Course Outcomes:	
Upon completion of this course the student will be able to:	
CO1	Apply fundamental image processing operations required for computer vision.
CO2	Choose suitable technique to enhance an image and apply suitable technique to extract region of interest for further analysis.
CO3	Analyze various descriptors for feature extraction.
CO4	Apply geometric concepts and multiview geometry of camera for 3D vision applications.
CO5	Identify Machine Learning and Neural Network concepts and develop Computer Vision applications

Course Articulation Matrix
Mapping of Course Outcomes (COs) to Program Outcomes (POs) &
Program Specific Outcomes (PSOs)

		POs											PSOs	
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
COs	**CO1**	2	2			1						1	2	2
	CO2	3	3			1						1		3
	CO3	3	3			1						1	2	3
	CO4	2	2	1		1			1	1		1		2
	CO5	2	2	1	1	1			2	1		1		2

Note: 1- Weak correlation 2-Medium correlation 3-Strong correlation