ज्ञान-विज्ञान विमुक्तये

प्रा. मनिष र. जोशी
सचिव

Prof. Manish R. Joshi
Secretary

सत्यमेव जयते

विश्वविद्यालय अनुदान आयोग
University Grants Commission
(शिक्षा मंत्रालय, भारत सरकार)
(Ministry of Education, Govt. of India)

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Subject: Courses in emerging technologies

Respected Madam/Sir,

As you are aware, in every decade, a new generation of wireless cellular technology is introduced to the world that changes the way the future of communication is perceived. 5G networks are under deployment with rapid pace and now the world has started talks on 6G. To pave the way for 6G services in the country, Hon'ble Prime Minister Narendra Modi unveiled the Bharat 6G vision document on 22nd March, 2023 and launched the 6G research and development testbed. The development of the 6G vision is based on the recommendations of the Technology Innovation Group (TIG) and six task forces formed to explore the major pillars of the 6G Vision and develop a road-map and action plans for 6G in India.

To meet the emerging trends and challenges posed by 6G and leverage the full potential of 5G features, it is imperative that our future researchers and engineers possess the necessary skills and mindset. Achieving the objectives of 6G communications requires a consensus on emerging concepts and enabling technologies. Consequently, it is crucial to update and adapt the undergraduate and graduate education of communications engineering to the demands of the pre-6G era.

Active engagement in research and development of 6G can position India as a front-runner in advanced telecommunications technologies. This not only enhances our global competitiveness but also attracts investments, fostering indigenous innovation and driving technology-led economic growth. A key objective of the Government of India is to secure a 10% share of global patents filed and granted.

To address these needs, the Department of Telecommunications (DoT) had formed a committee with the objective of reviewing the telecom related topics in curriculum of communications engineering. The committee has identified potential research topics for PhD programs, taking into account the requirements of 6G across various areas such as Optical Communications, Satellite Communications, Broadcasting, RF Engineering, Telecom Standardization, IPR, and more. The report of the committee is attached.

The Higher Educational Institutions are requested to examine the report and make suitable upgrades to the M.Tech and Ph.D program.

With kind regards,

Yours sincerely,

(Manish Joshi)

Encl: As Above.

To
The Vice-Chancellors of all Universities
The Principals of all Colleges/Institutes

बहादुरशाह जफ़र मार्ग, नई दिल्ली-110002 | Bahadur Shah Zafar Marg, New Delhi-110002
Ph.: 011-23236288/23239337 | Fax : 011-2323 8858 | E-mail : secy.ugc@nic.in

REPORT OF COMMITTEE TO REVIEW CURRICULUM OF AICTE & TO RECOMMEND COURSES IN EMERGING TECHNOLOGIES

Introduction

A standing committee of following officers was formed with the objective to review the curriculum of AICTE (All India Council for Technical Education) on every six months to recommend AICTE to incorporate add-ons in existing courses and propose new courses on emerging technologies. Committee was allowed to co-opt members from representatives from Industry, Academia and Government to ensure that the engineering and technology curricula remain updated with the necessary skills and knowledge in alignment with technological advancements. Committee in its first meeting co-opted members from academia and industry. The constitution of the committee is as follow -

The Committee

S No	Name	Organization	Designation	Remarks
1	Sh. Ritu Ranjan Mittar	DoT	Advisor & Head, TEC	
2	Sh. Raju Sinha	DoT	Director General, NTIPRIT	
3	Prof. Brejesh Lall	IIT, Delhi	Professor, Electrical Engineering Department	Co-opted Member from academia
4	Sh. Alok Bharti	DoT	DDG (SD)	
5	Sh. Ashok Kumar	DoT	DDG (Wireless Access), NTIPRIT	Co-opted
6	Sh. Bhuvnesh Kumar Yadav	DOT	Director (SD&E)	Co-opted
7	Sh. Alex Vikas	DoT	ADG (SRI) & Mission Coordinator (TSUM)	Co-opted from SRI unit

2. Approach

Bharat 6G Vision

Every decade, a new generation of wireless cellular technology is introduced to the world that changes the way the future of communication is perceived. 5G networks are under deployment with rapid pace and now the world has started talks on 6G.

To pave the way for 6G services in the country, Hon'ble Prime Minister Narendra Modi unveiled the Bharat 6G vision document on 22nd March 2023 and launched the 6G research and development testbed. The development of the 6G vision is based on the recommendations of the Technology Innovation Group (TIG) and six task forces formed to explore the major pillars of the 6G Vision and develop a road-map and action plans for 6G in India. 6G TIG consist of members from various ministries and departments, research and development institutions, academia (Director- IIT Madras/ Kanpur/ Hyderabad/ Delhi and IISc-Bangalore), standardization bodies, and telecom service providers. This vision for 6G technology aligns completely with the national vision of Atamnirbhar Bharat, which is based on principles of affordability, sustainability, and ubiquity.

The Bharat 6G vision document and testbed are expected to create an enabling environment for innovation, capacity building, and faster technology adoption to establish global leadership in the development of telecommunications technology. TIG group have recommended requirement of extensive research in various areas with basic objective to customize 6G implementation plan to need of country and get acceptance & support from the global community to fast forward our commercialization drive and pave the way for further newer technologies. Various recommendations have been given in the vision document for development of eco-system for Research & Development.

To achieve the goals of 6G communications, researchers have reached a preliminary consensus of emerging conceptions and enabling technologies for 6G communications. The major key technologies/ areas identified in 6G Vision report for realization of beyond 5G (B5G) and 6G communication are as follows:

i. Intelligent Reflective Surfaces/ Reconfigurable Intelligent Surfaces (RIS)

ii. Quantum Communication/ Quantum Machine Learning (QML)
iii. Immersive XR
iv. Cell free Massive MIMO
v. mm Wave and Tera-Hertz Communication and sensing
vi. Advanced Artificial Intelligence (AI)/ Machine Learning (ML) (case study-use of AI/ML on the air interface and for network optimization and intelligent network operation)
vii. Advanced Distributed Ledger Technologies (DLT) like blockchain etc.
viii. Wireless Fiber (Wireless Optical Communication)
ix. Tactile Internet and Remote Operations
x. HAPS (High-altitude platform systems)/ HIBS (high altitude platform station as IMT base station)/LEO/MEO/GEO---Satellite-air-ground integrated network (SAGIN)
xi. Multi-sensor man-machine interfaces
xii. Edge cloud computing
xiii. Space-Terrestrial Integration
xiv. Dense optical networks
xv. User-defined virtualized air interfaces
xvi. An orthogonal spectrum sharing scheme for wireless sensor networks
xvii. Semantic Communication

3. Demand to Update Course Content for Engineers

To prepare for the emerging trends and challenges of 6G and to utilize 5G features extensively, future researchers and engineers are expected to be equipped with different competence and mindset. Accordingly, this expectation demands to adjust and update the graduate education of communications engineering in the pre-6G era.

Accordingly, the committee prepared/identified a list of additional topics to be included in UG & MTech level after studying what is being taught in IITs & world top universities covering 5G NR and core, Satellite, Optical wireless communication & communication in Millimeter wave and THz band, reconfigurable intelligent surfaces etc. The list of courses could be considered as valuable additions to the undergraduate engineering program and graduate engineering program (ME/ MTech) regulated by the All India Council for Technical Education (AICTE) is placed respectively at Annexure-I and Annexure-II.

Specialized M. Tech Programs in THz Communication, Optical Communications and Satellite Communications is also proposed for consideration.

The committee also identified probable research topic for PHD after studying reports of various global telecom forums & 6G Vision report. The committee focuses on the needs of various areas, including Telecommunications in 6G, Optical Communications, Satellite Communications, Broadcasting, RF Design, RF chip development, Telecom standardization, IPR & manufacturing, etc. This is done with the aim of fulfilling India's design, research and development, and manufacturing ambitions for India@2030. Detailed report on potential research areas is placed as Annexure-'III'

Research in these areas and related technologies can play a significant role in helping India achieve its ambitions in the following ways:

i. **Technological Leadership:** By actively participating in research and development in 6G, India can position itself as a leader in advanced telecommunications technologies. This can enhance India's global competitiveness, attract investment, and pave the way for indigenous innovation and technology-driven economic growth.
ii. **Skill Development and Talent Retention:** Focusing on research areas in 6G enables the development of specialized skills and expertise among Indian researchers, engineers, and students. This helps retain talent within the country, fosters a culture of innovation, and creates a skilled workforce capable of driving the growth of India's telecommunications industry.
iii. **Empowering Digital Economy:** Research areas in 6G can empower India's digital economy by enabling the development of new services, applications, and business models. By creating an environment conducive to innovation and entrepreneurship, India can stimulate the growth of its digital economy, create job opportunities, and nurture a culture of technology-driven innovation and startups.
iv. **Enhanced Connectivity and Access:** Research in 6G can address the challenge of providing affordable and reliable connectivity to all regions of India. By exploring new communication technologies and deployment strategies, India can improve connectivity in rural and remote areas, empowering citizens with access to information, education, healthcare, and government services, thus fostering inclusive growth and reducing regional disparities.
v. **Localization and Indigenization:** Exploring opportunities for localization and indigenization of communication technologies in India. This could involve research into designing and manufacturing communication equipment, developing indigenous standards, and promoting local innovations and startups in the communication field.

In summary, research in 6G and related technologies can contribute to India's ambitions for India@2030 and India@2047 by accelerating digital transformation, driving technological innovation, promoting sustainability, enabling smart cities and infrastructure, enhancing connectivity and access, strengthening national security, boosting global competitiveness, and empowering the digital economy.

4. Prioritization Strategy and Funding Mechanism for Research and Innovations:

Bharat 6G Mission is already constituted in Department of Telecommunications with various functions including identification of priority areas for 6G research based on India’s competitive advantages and to consider research proposals of various stake holders including universities.

5. Intake in MTech/ PhD Programs - The committee compiled data of MTech and PhDs intake in existing programs and initiatives being run in telecom area in AICTE, IIT Council, IISER and IISC and placed it at Annexure-IV. Data for all colleges have not yet been received but the available data suggest the trend that there is huge demand for MTech & PHD courses in IITs and other top institutes as these institutes are properly equipped with faculties and lab facilities to carry such courses but in other engineering colleges seats are not getting fulfilled and large no of seats remains vacant every year. In order to address the poor response towards MTech programs in various engineering institutions, the following suggestions are proposed for improving the program:

i. Review the necessity of offering MTech courses in colleges where there is low demand and consider reallocating resources accordingly. Increase the number of seats in colleges where there is a high demand for MTech programs to cater to the needs of aspiring students.
ii. Identify and offer a range of specialized courses, preferably 15-20, through the National Programme on Technology Enhanced Learning (NPTEL). Allow students to choose two courses from the available options. Select students based on a thorough evaluation criteria and consider inviting industry professionals to deliver guest lectures. Additionally, NPTEL courses should carry weightage in the job market to enhance the employability prospects of students who complete them.

iii. Identify and engage renowned institutions such as IITs to provide mentorship to 20-25 AICTE recognized institutes in a Hub & Spoke Model. These esteemed institutions will offer guidance and support to the participating institutes in curriculum development, research initiatives, industry collaborations, and practical training. The mentorship provided by IITs will ensure that the MTech programs align with the latest industry trends and standards, thereby enhancing the quality and relevance of the education imparted.

6. Input from Academia, Industry & Govt - Comments/feedback had been called from academia, industry, govt organization & different related unit of DOT on the draft committee report. Comments and suggestion received were discussed in the committee and the final recommendation have been prepared incorporating these comments/feedbacks

7. Recommendations:

i. Update the UG/PG/PhD programs: Various courses/ topics are proposed in Annexure- I & II for consideration. Various courses/ topics may be merged considering the time required and credits linked with the courses. The course structure may vary depending on the institution and specific program requirements. Various elective courses may be combined to offer minor in specialized field of communication. Update the curriculum periodically to stay with current advancements in technology and ensure graduates are well-prepared for the changing demands of the field.

ii. Train the Trainers: Fortify existing train the trainer program and online platforms. Expert lecture series may be organized to provide access to world-class content in communication technologies and related innovation by experts.

iii. The mathematical ability has become the core competency and the key to success in one's graduate studies. This is because the advancement of communications engineering, especially theoretical research, is highly restricted by the limited mathematical advancement, which results in a large number of intractable analytical and optimization problems. Accordingly, both educators and graduate students of communications engineering need to update their research toolbox and have more powerful mathematical tools. The theoretical, computer programming, and practical expertise need to be unified for the graduate education of communications engineering in the pre-6G era.

iv. **To emulate and test communication systems and networks** with complex structures on a massive scale, cloud computing technologies and the basics of using super computers/cloud workstations should be involved in the research and education of communications engineering in the pre-6G era. The corresponding programming languages, e.g., Python, C, and R, for carrying out complex computing tasks should also be explicitly included in the graduate curriculum of communications engineering.

v. **Know widely applied standards and protocols:** It should also be ensured that all developed communications technologies are compliant with the latest telecommunications standards and security regulations. For this reason, widely applied telecommunication standards and protocols released by 3rd Generation Partnership Project (3GPP) and Institute of Electrical and Electronics Engineers (IEEE) would be introduced to graduates for each topic.

vi. **Increase Role of Technical Papers**: Communications engineering is one of the fastest progressing disciplines since the 2000s, it is almost impossible to publish high-quality and comprehensive textbooks to capture its latest achievements in a real-time manner. For some latest research hotspots in communication engineering, e.g., RIS aided communications and space-air-ground integrated network (SAGIN), it is even difficult to find an acknowledged monograph so far, let alone a systematic textbook. As a consequence, graduate students might hardly see the state of the art through textbooks.

Therefore, both educators and graduate students need to get used to the role transition of textbooks. The textbooks of communications engineering in the pre-6G era shall be used for the purpose of teaching methodologies rather than knowledge, while specific knowledge should be gained from reading recently published surveys, tutorials, and technical papers. Overall, canonical textbooks and selected references published recently are of equal importance for pre-6G graduate education, and neither should be treated as gospel.

vii. **Supporting Infrastructure Creation at Institutes**: The infrastructure like test beds, lab equipment, open source simulators etc. are the prime enabler for growth. These may be created in Hub & Spoke model. This will produce the possibility of a free flow of ideas, talent, and knowledge across the full network from small to large, and new to matured institutions.

viii. **Balance curriculum with potential Cyber exposure**: Several fields of emerging technology, such as the use of machine learning, are being implemented at speed, used across a widening range of processes and will affect organization's cyber-risk profile. Artificial intelligence (AI) and machine learning, greater adoption of cloud technology and advances in user identity and access management will have the greatest influence on their cyber risk strategies over the next two years. This suggests that the implementation of new technologies will be undertaken in combination, significantly increasing the complexity of an organization's digital environment and highlighting the need to embed cyber-risk management through all stages of a digital transformation process.
In view of above, Courses on new technologies must be balanced with potential cyber exposure that comes with it to effectively manage risk in the coming years.

ix. **Platform for Networking:** DoT may organize Advanced Research Seminars in Communication Engineering under 6G Mission. This would provide a platform for students to present and discuss their research work, engage in critical analysis of research papers, and participate in scientific discussions. It would foster research-oriented thinking, enhance presentation skills, and encourage collaboration among students and faculty members.

x. **Intake in MTech/ PhD Programs** - It is thus recommended to increase no of seats for MTECH and PHD in IITs, NITs and other top colleges by 25% to 50% in telecom stream/telecom related subject. This will create required no of skilled workforce capable of driving of innovation in the country and will boost the growth of India's telecommunications industry. For other colleges intensive actions are required to be initiated for improvement of lab infrastructure and faculty development so that students may get enrolled in these colleges also.

In addition of above, Research Assistantship (RA) program in emerging technologies may also be developed in academic institution

in support from industry and government. Various test beds across the country may be utilized for this purpose and institutes may offer RA program based on the chosen area of specialization by candidate.

Annexure-I

UNDERGRADUATE ENGINEERING PROGRAM in E&C Stream:

It has been observed that various courses have already been included in the recent revision of the curriculum. However, it is crucial to update these courses regularly to keep up with the dynamics of technological advancements and even extend them to cover future trends. In particular, standards and intellectual properties (IPs) should be covered in each area of telecommunications to ensure that engineering graduates are well-prepared for the market demands. The following subjects related to telecommunication are recommended to be included in Undergraduate Engineering Program me regulated by the All India Council for Technical Education (AICTE).

a) Courses/ Topics related to telecommunication already part of model curriculum:

S.No	Proposed Course/ Telecommunication Area of Interest	Comparable existing course in model curriculum of AICTE for E&C branch
1	5G and Beyond: A course focusing on the fundamentals of 5G technology, including wireless communication principles, network architecture, waveform design, millimeter-wave communication, massive MIMO, beam-forming, network slicing, virtualization and edge computing. It could also cover emerging technologies and trends for future communication systems beyond 5G.	ECEL09: Advanced Mobile Communications (5G)
2	Communication Network Virtualization: With the increasing adoption of virtualization technologies, this course would explore the concepts of network virtualization, software-defined networking (SDN), and network function virtualization (NFV). Students would learn to design, deploy, and manage virtualized communication networks.	ECEL09: Advanced Mobile Communications (5G)
3	Internet of Things (IoT) and Sensor Networks: This course would focus on the principles, protocols, and technologies associated with IoT, including sensor networks, wireless connectivity, communication protocols (e.g., MQTT, CoAP), cloud computing, data analytics, and security. It would also cover applications of IoT in various domains like smart cities, healthcare, agriculture, and industrial automation. It would equip students with the skills to design and deploy IoT systems and utilize sensor networks for various applications.	ECEL17: Internet of Things

4	Artificial Intelligence (AI) and Machine Learning (ML) for Communication Systems: This course would introduce students to AI and ML techniques and their applications in communication systems. It would cover topics such as intelligent signal processing, predictive analytics, pattern recognition, data-driven network optimization, and AI-driven resource allocation in wireless networks.	ECEL20: Machine Learning
5	Cybersecurity in Communication Networks: A course focusing on the principles and techniques of securing communication networks against cyber threats. It could cover topics like secure communication protocols, cryptographic algorithms, network security, intrusion detection, privacy protection, and ethical hacking. It would enable students to design secure communication systems and protect them against cyber-attacks.	ECEL19: Cyber Security
6	Data Science and Analytics for Communication: A course emphasizing data analysis and visualization techniques applicable to communication engineering. It could cover statistical analysis, big data processing, data mining, and predictive modeling, with a focus on applications in communication networks and systems. It would enable students to leverage data-driven approaches in communication engineering.	ECEL17: Data Structures
7	Photonics and Optical Communication: A course covering the principles of photonics and its applications in optical communication systems. It could include topics like fiber optics, optical network architectures, photonic devices, and optical signal processing techniques.	ECEL02: Fiber Optic Communication
8	Satellite Communication Systems: This course would cover the design and analysis of satellite communication systems, including satellite link budgeting, multiple access schemes, satellite network architectures, and satellite constellation design. Students would gain insights into the unique challenges and considerations involved in satellite communication.	ECEL14: Satellite Communication
9	Wireless Sensor Networks: A course focusing on the design, deployment, and management of wireless sensor networks. It could cover topics such as sensor node architecture, energy-efficient protocols, localization algorithms, and applications in environmental monitoring and smart systems.	ECEL12: Wireless Sensor Networks

10	Advanced Antenna Systems: This course would focus on advanced antenna design and analysis techniques, including smart antennas, phased array antennas, MIMO systems, and beamforming. It would provide students with the knowledge and skills to design and optimize advanced antenna systems for next-generation communication networks.	ECEL07: Antennas and Propagation
11	Biomedical Electronics: This course would focus on the interface of electronics and healthcare. It would cover topics such as medical imaging, biomedical signal processing, biosensors, telemedicine, and wearable healthcare devices. It would enable students to contribute to the development of healthcare technologies and devices.	ECEL08: Bio-Medical Electronics

The aforementioned course can be updated to cover the following aspects:

1. Software Defined Radio (SDR) platforms are extensively used for implementing various realizable transceiver systems. It would be valuable to have a core course where students learn to implement simple standards in the baseband using SDRs. At the very least, an introductory course using SDRs for Wireless Communication should be included.
2. Analog RF frontend circuits play a crucial role in modern communication systems. They are responsible for receiving and processing high-frequency signals, ensuring efficient and accurate transmission of information. A dedicated course on analog RF frontend circuits would provide students with a solid foundation in this essential aspect of communication engineering. This course should cover both the design and implementation of Front-End circuits.
3. It would be desirable to have a course where students can design and deploy transmit/receive antennas. The course would provide students with a competitive edge in the job market, empower them with practical skills, and prepare them for the challenges and opportunities in the field of antenna design and deployment.
4. To enhance the device ecosystem in terms of availability and affordability in comparison to network/application solutions, it is essential to incorporate topics related to devices, gateways, and communication modules into the curriculum. Thes additions will specifically focus on addressing the device and sensor aspects, in addition to the existing coverage of network/satellite and applications.
5. The course on ‘Machine Learning’ can be expanded to include aspects of Federated Learning (FL) and Edge Analytics.

By incorporating these updates and additions, the undergraduate engineering program will better equip students with the knowledge and skills needed to thrive in the ever-evolving field of telecommunications.

b) Courses/ Topics related to telecommunication to be introduce:

1. **Emerging Wireless Technologies**: A course exploring the latest trends and advancements in wireless communication technologies, including topics like terahertz communications, Intelligent Reflecting Surfaces, Cell-free massive MIMO, potential waveforms for beyond 5G/6G (for example, Orthogonal Time Frequency Space (OTFS), Non-orthogonal multiple access (NOMA), Filter Bank Multicarrier (FBMC)) visible light communication (VLC), wireless sensor networks, and cognitive radio. It should provide insights into cutting-edge research and future directions in wireless communications.

2. **Quantum Communication, Computing and Cryptography**: As quantum technologies gain prominence, a course on quantum communication and cryptography would be valuable. It could cover quantum key distribution (QKD), quantum cryptography, quantum algorithms, and their potential applications in secure communication and computing. It would also cover topics such as quantum entanglement, quantum teleportation, and the security challenges and advancements in quantum communication. It would prepare students for the future of secure communication systems.

3. **Sustainable and Green Communication**: In line with the growing need for sustainable practices, a course on sustainable communication systems would cover energy-efficient communication protocols, renewable energy integration, green networking, and environmental impact assessment. It would equip students with knowledge to design Eco-friendly communication systems.

4. **Ethical, Legal and Social Implications of Communication Technology**: A course focusing on the ethical, legal, and social considerations associated with the development and deployment of communication technologies. It could cover topics like privacy, data protection, intellectual property, regulatory frameworks, ethical hacking, and the impact of communication technologies on society.

5. **Entrepreneurship and Innovation in Communication Engineering**: This course would focus on nurturing entrepreneurial skills and promoting innovation in the field of communication engineering. It would cover topics such as ideation, intellectual property rights, business models, funding opportunities, market analysis, and technology commercialization.

6. **Project Management in Communication Engineering**: This course would provide students with essential project management skills required to successfully execute communication engineering projects. It would cover project planning, resource

allocation, risk management, team coordination, and effective communication and presentation skills.

These suggested courses aim to align the undergraduate engineering program in Electronics and Communication Engineering with the evolving needs and emerging trends in the industry. It's important to adapt the curriculum periodically to stay current with advancements in technology and ensure graduates are well-prepared for the changing demands of the field.

Annexure-II

M. Tech Program in Electronics & Telecommunication Engineering:

Considering the requirements in the field of Electronics and Communication Engineering and to make students future-ready for research in the communication field, the following courses could be considered as valuable additions to the postgraduate engineering program regulated by the All India Council for Technical Education (AICTE):

1. **Advanced Wireless Communication Systems**: This course would delve into advanced topics in wireless communication systems, including advanced modulation techniques, channel coding, advanced multiple-access schemes, cooperative communication, millimeter wave communication, massive MIMO, beamforming, and cognitive radio. It would focus on the design, analysis, and optimization of next-generation wireless systems and their applications.

2. **Advanced Topics in Communication Networks**: This course would explore advanced concepts in communication network architectures, protocols, and optimization techniques. It could cover topics such as network virtualization, software-defined networking (SDN), network slicing, edge computing, and self-organizing networks. Students would gain expertise in designing and optimizing communication networks for various applications.

3. **5G NR Radio Access Network Signaling**: This course would focus on “5G NR Radio Access Network Signaling” with the following contents: Overview of 5G Air Interface, 5G system architecture, Non-Access Stratum (NAS), Access Stratum (AS), Radio Resource Control (RRC), Next Generation Application Protocol (NGAP), Application protocol (F1AP), Mobility, 5G security, SDAP (Service Data Adaption Protocol), Packet Data Convergence Protocol (PDCP), Radio link control (RLC), Medium Access Control (MAC), New Radio (NR) physical layer, NR physical layer structure, Downlink physical channels and signals (P-SS, S-SS, PBCH, PT-RS, DM-RS, CSI-RS, PDCCH, PDSCH), Uplink physical channels and signals (PT-RS, DM-RS, SRS, PUCCH, PUSCH, PRACH), Overview of 5G-NG ORAN Architecture.

4. **Advanced Topics in 6G Communication Systems**: This course would focus on the future generation of wireless communication systems beyond 5G, including key technologies such as terahertz communication, massive connectivity, intelligent beam-forming, intelligent reflecting surfaces, Cell-free massive MIMO, potential waveforms for beyond 5G/6G (for example, Orthogonal Time Frequency Space (OTFS), Non-orthogonal multiple access (NOMA), Filter Bank Multicarrier (FBMC)), AI-enabled communication, quantum communication technologies. and holographic communication. It would prepare students to conduct advanced research in the development and optimization of 6G communication systems.

5. **Internet of Things (IoT), Edge Computing and Security**: Building upon the undergraduate IoT course, this advanced course would explore IoT architectures, edge computing models, data analytics, security, and privacy in IoT ecosystems. It would emphasize the integration of IoT with cloud computing, AI, and real-time data processing for IoT applications.
   With the increasing deployment of IoT devices, this course would also focus on the security challenges specific to IoT systems, including secure device provisioning, authentication, secure communication protocols, privacy preservation, and vulnerability assessment. Students would gain expertise in securing IoT deployments and mitigating potential security risks.

6. **Advanced Wireless Sensor Networks**: This course would focus on advanced research topics in wireless sensor networks, including energy-efficient protocols, localization algorithms, topology control, data fusion, and security. It would enable students to conduct cutting-edge research in the design and optimization of wireless sensor networks for diverse applications.

7. **Cognitive Radio and Dynamic Spectrum Access:** This course would focus on advanced research topics in cognitive radio systems and dynamic spectrum access techniques. It would cover aspects such as spectrum sensing, spectrum sharing, spectrum auctions, cooperative spectrum sensing, and machine learning-based spectrum management.

8. **Edge Computing and Fog Networking**: With the rise of edge computing and the need for low-latency applications, this course would explore the concepts of edge computing architectures, resource management, task offloading, and service orchestration in fog networks. Students would learn about the integration of edge computing with communication systems to support latency-sensitive and data-intensive applications. It may also delves into the interdisciplinary aspects of 6G and edge/fog networking to tackle the complex challenges of future wireless communication systems.

9. A**dvanced Antenna Systems**: This course would focus on advanced antenna design and analysis techniques, including smart antennas, phased array antennas, MIMO systems, and beamforming. It would provide students with the knowledge and skills to design and optimize advanced antenna systems for next-generation communication networks.

10. **Advanced Topics in RF and Microwave Engineering**: This course would explore advanced concepts in RF and microwave engineering, including RF circuit design, microwave passive and active components, microwave measurements, and electromagnetic compatibility. It would prepare students for research in areas such as high-frequency communication systems, radar systems, and RF integrated circuits.

11. **Artificial Intelligence (AI) and Machine Learning (ML) for Communication Systems**: This course would provide advanced knowledge in applying AI and ML

techniques specifically to communication systems. Topics would include reinforcement learning for resource allocation, network optimization using ML algorithms, intelligent network management, and AI-driven signal processing. It may also delves into the interdisciplinary aspects of 6G and AI/ ML to tackle the complex challenges of future wireless communication systems.

12. **Quantum Information and Communication**: With the rise of quantum technologies, this course would focus on quantum information theory, quantum computing, quantum communication protocols, and quantum cryptography. Students would gain insights into the theoretical foundations and practical aspects of quantum communication systems and would enable students to conduct research in the emerging field of quantum communication and its applications.

13. **Advanced Digital Signal Processing**: This course would cover advanced topics in digital signal processing (DSP), such as adaptive filtering, array signal processing, compressive sensing, and image and video processing techniques. It would focus on developing advanced algorithms and methodologies for signal analysis and processing in communication systems.

14. **RF Measurements and Signal Analysis in Wireless Systems**: It may cover comprehensive understanding of the principles and techniques involved in accurately measuring and analyzing RF signals. Through a combination of theoretical knowledge and practical hands-on experience, students learn about the importance of precise measurements in wireless systems and gain proficiency in using network analyzers for RF testing. The course covers topics such as power, frequency, and modulation measurements, as well as signal analysis techniques including spectrum analysis and time-domain analysis. Practical lab sessions give students the opportunity to work with network analyzers, perform RF measurements on various devices and components, and analyze the collected data. By the end of the course, students are equipped with the skills to interpret measurement results, apply signal analysis techniques, and effectively communicate their findings in professional reports.

15. **Cybersecurity and Privacy in Communication Networks**: This course would provide an in-depth understanding of cybersecurity challenges in communication networks, including network threats, intrusion detection and prevention, advanced cryptographic algorithms, secure protocols, privacy-enhancing technologies, and secure network design principles. Students would gain expertise in designing and implementing secure communication networks.

16. **Advanced Topics in Photonics and Optical Communication:** This course would focus on advanced concepts in photonics, optical communication systems, and fiber-optic networks. It would cover topics such as wavelength division multiplexing (WDM), optical switching, optical network design, and emerging trends in optical communication technologies.
17. **Satellite Communication Systems**: This course would cover the design and analysis of satellite communication systems, including satellite link budgeting,

multiple access schemes, satellite network architectures, and satellite constellation design. Students would gain insights into the unique challenges and considerations involved in satellite communication.

18. **VLSI Design for Communication Systems**: This course would focus on the design and implementation of VLSI circuits and systems for communication applications. It would cover topics such as digital circuit design, ASIC and FPGA implementation, system-on-chip (SoC) design, and low-power VLSI design techniques, asynchronous design, fault modeling and testing, and design for testability (DFT). It may also delves into the interdisciplinary aspects of 6G and VLSI to tackle the complex challenges of future wireless communication systems.

19. **Network Function Virtualization (NFV) and Software**-Defined Networking (SDN): Building upon the undergraduate virtualization course, this advanced course would explore the concepts and applications of NFV and SDN in communication networks. It would cover topics such as virtual network functions (VNFs), network slicing, network orchestration, and software-defined radio (SDR).

20. **Advanced Topics in Biomedical Signal Processing and Imaging**: This course would focus on advanced techniques in biomedical signal processing and medical imaging, including EEG analysis, ECG analysis, medical image processing, and machine learning in healthcare. It would enable students to apply signal processing techniques to analyze and interpret biomedical data for medical diagnosis and monitoring.

21. **Innovation and Entrepreneurship in Communication Engineering**: This course would focus on fostering an entrepreneurial mindset and providing students with the skills and knowledge to develop innovative solutions in the field of communication engineering. It would cover topics such as technology commercialization, intellectual property rights, startup management, and innovation ecosystems.

22. **Advanced Research Methodologies and Project Management** in Communication Engineering: This course would provide advanced training in research methodologies, statistical analysis, data interpretation, scientific writing, literature review, experimental design, and project management specific to the communication engineering domain. It would prepare students for conducting independent research projects and dissertations, as well as equip them with skills for effective project planning and execution.

These courses aim to deepen the knowledge & expertise of postgraduate students to make them empower to delve into advanced research topics, contribute to the cutting-edge developments in the communication field, and prepare them to address the emerging challenges and opportunities. The courses should be designed to emphasize hands-on research experience, encourage interdisciplinary collaboration, and promote innovation in the communication engineering domain. It is important to adapt the curriculum regularly to align with industry advancements, emerging technologies, and research directions.

Specialized M. Tech Programs

Postgraduate Engineering Program Specializing in Millimeter wave/ Terahertz (THz) Communications & Sensing

Proposed course structure for a postgraduate engineering program specializing in mm & THz Communication and Sensing:

Semester 1:

i. Advanced Electro-magnetic for mm & THz Communication
ii. Fundamentals of Communication Systems
iii. Digital Communication Systems
iv. Signals and Systems
v. Signal processing for RF based sensing
vi. Antenna Design and Beam-forming Techniques for mm & THz Systems
vii. Channel Modeling and Propagation in mm & THz Communication
viii. Semiconductor Devices and Circuits (Elective)
ix. mm & THz Transceiver Architecture and Circuit Design (Elective)
x. Digital Signal Processing for mm & THz Communication Systems (Elective)

Semester 2:

i. Modulation Techniques and Coding for mm & THz Communication
ii. Networking and Protocol Design for mm & THz Networks (Elective)
iii. mm & THz Wireless Back-haul and Access Networks (Elective)
iv. mm & THz Imaging and Sensing Techniques
v. Research Methodologies and Experimental Techniques in mm & THz Communication

Semester 3:

1. Advanced Topics in THz Communication Systems
2. mm & THz Integrated Circuit Design and Technology
3. Security and Privacy in mm & THz Communication
4. mm & THz Communication for IoT and Wireless Sensor Networks
5. mm & THz Wireless VR/AR
6. mm & THz Spectroscopy (Elective)
7. Thesis/Research Project in mm & THz Communication- Part1 (conducted under faculty guidance

Semester 4:

1. Thesis/Research Project in mm & THz Communication- Part2 (conducted under faculty guidance)

Note: The course structure may vary depending on the institution and specific program requirements. The above course structure provides a comprehensive foundation in mm & THz communication, covering essential theoretical knowledge, practical skills, and

research-oriented topics. It includes courses in electromagnetic theory, communication systems, semiconductor devices, signal processing, and networking, along with specialized courses focused on mm & THz communication. The elective courses provide flexibility for students to tailor their studies to their specific research interests and career goals.

The research project spans two semesters, allowing students to delve deeper into a specific research area within THz communication under the guidance of a faculty advisor. The elective courses provide flexibility for students to tailor their studies to their specific research interests and career goals.

In addition to the above courses, the program should also include laboratory sessions, research papers review, research seminars, and opportunities for students to engage in hands-on projects and industry collaborations. Practical experience with mm & THz measurement equipment, simulation tools, and software for system design should be incorporated.

It is important to note that the course structure should be regularly reviewed and updated to align with the latest developments and trends in mm & THz communication technology, considering the rapidly evolving nature of this field.

Postgraduate Engineering Program Specializing in Optical Communication

A sample course structure for a postgraduate engineering program in Optical Communication, focusing on the utilization of optical communication technology in 6G wireless networks. This structure spans four semesters and emphasizes the integration of optical communication with 6G technology.

Semester 1:

1. Optical Fiber Communications
    - Introduction to optical fiber communication systems
    - Fiber optic waveguides and fibers
    - Optical transmitters and receivers
    - Fiber optic system design and performance analysis
2. Optical Network Design and Management
    - Overview of optical networks
    - Network architectures and topologies
    - Routing and wavelength assignment
    - Network management and control
3. Advanced Photonics
    - Principles of photonics
    - Photonic materials and devices
    - Lasers and optical amplifiers
    - Nonlinear optics
4. Electromagnetic Theory for Optical Communication
    - Maxwell's equations and wave propagation
    - Electromagnetic waveguides and resonators
    - Scattering and diffraction of light
    - Numerical methods for electromagnetic analysis

Semester 2:

1. Optical System Design and Simulation
    - Optical system design principles
    - System-level modeling and simulation
    - Optical components and subsystems
    - Performance evaluation and optimization
2. Optical Signal Processing
    - Principles of optical signal processing

- Linear and nonlinear optical processes
- Optical modulation formats
- Optical filters and equalization techniques

3. Fiber Optic Sensors and Applications
    - Introduction to fiber optic sensors
    - Principles and types of fiber optic sensors
    - Sensor applications in various fields
    - Sensor system design and integration
4. Digital Signal Processing for Optical Communication
    - Fundamentals of digital signal processing
    - Digital modulation and demodulation techniques
    - Error correction coding
    - Signal detection and equalization

Semester 3:

1. Optical Amplifiers and Networks
    - Optical amplifier principles and types
    - Amplifier noise and performance analysis
    - Optical network architectures
    - Wavelength division multiplexing (WDM) systems
2. Optical Switching and Routing
    - Overview of optical switches and routers
    - Switching techniques: wavelength, space, and time
    - Optical cross-connects and interconnects
    - Optical packet and burst switching
3. Fiber Optic Communication Systems
    - System-level analysis and design
    - Performance evaluation and impairment mitigation
    - Long-haul and metro optical networks
    - Access networks and passive optical networks (PONs)
4. Optical Wireless Communication for 6G
    - Introduction to 6G wireless communication
    - Integration of optical and wireless communication
    - Optical wireless networks for 6G
    - Optical wireless communication technologies
5. Research Methodology and Project Management
    - Research process and methodologies
    - Literature review and research planning

- Experimental design and data analysis

Project management principles and techniques

Semester 4:

1. Emerging Trends in Optical Communication
    - Current advancements in optical communication
    - Photonic integration and silicon photonics
    - Free-space optical communication
    - Quantum communication and cryptography
2. Optical Communication Lab
    - Hands-on experiments with optical components
    - Optical fiber characterization and measurements
    - Optical system simulations and analysis
    - Project work related to optical communication
3. 6G Wireless Communication and Optical Integration Lab
    - Experimental setups for 6G wireless communication
    - Optical and wireless integration experiments
    - Performance evaluation and optimization
    - Project work related to optical communication in 6G
4. Thesis or Project Work
    - Independent research under the guidance of a faculty advisor
    - Development of a thesis or project proposal
    - Execution of research work
    - Thesis writing and presentation

This course structure provides a comprehensive understanding of optical communication while highlighting its integration with 6G wireless networks. It includes dedicated courses and laboratory work focusing on the use of optical communication technology in 6G wireless systems, preparing students for advanced research and development in this emerging field. Please note that the specific courses and their order may be customized based on the specific focus areas, available resources and expertise of the faculty.

Postgraduate Engineering Program Specializing in Satellite Communication

A sample course structure for a postgraduate engineering program in Satellite Communication, with a specific focus on the utilization of satellite communication technology in 6G wireless networks. This structure spans four semesters and integrates the study of satellite communication with the emerging field of 6G technology.

Semester 1:

1. Satellite Communication Systems
    - Introduction to satellite communication principles and systems
    - Satellite orbits and constellations
    - Link budget analysis for satellite communication
    - Satellite system design and performance evaluation
    - Regulatory and licensing aspects of satellite communication
2. Digital Communication Systems
    - Fundamentals of digital communication theory
    - Modulation and demodulation techniques for satellite communication
    - Multiple access techniques for satellite networks
    - Error control coding and decoding
3. Antenna Systems for Satellite Communication
    - Antenna fundamentals and characteristics
    - Types of antennas for satellite communication
    - Antenna radiation patterns and performance analysis
    - Antenna array systems for satellite applications
4. Satellite Network Design and Protocols
    - Satellite network architectures and protocols
    - Routing and congestion control in satellite networks
    - Quality of Service (QoS) considerations for satellite communication
    - Satellite network management and optimization

Semester 2:

1. Satellite Link Design and Analysis
    - Satellite link budget calculations and analysis
    - Satellite transponders and transceivers
    - Noise and interference analysis in satellite links
    - Power control and rain fade mitigation techniques
2. Satellite Earth Station Engineering

- Earth station design and components
- Earth station antennas and RF subsystems
- Earth station synchronization and clocking
- Earth station performance evaluation and optimization

3. Satellite Payload Design and Optimization
    - Satellite payload design principles and components
    - Satellite payload architectures and configurations
    - Satellite payload power management and optimization
    - Payload testing, validation, and performance analysis
4. Advanced Topics in Satellite Communication
    - Advanced satellite communication techniques and technologies
    - Satellite constellations and formation flying
    - Inter-satellite links and crosslinking
    - Satellite communication for Internet of Things (IoT) applications

Semester 3:

1. Satellite Navigation and Positioning Systems
    - Global Navigation Satellite Systems (GNSS) principles
    - Satellite-based positioning techniques (GPS, Galileo, etc.)
    - Differential GPS and augmentation systems
    - Indoor positioning and location-based services
2. Satellite Remote Sensing
    - Principles of satellite remote sensing
    - Satellite imaging systems and sensors
    - Remote sensing data acquisition and processing
    - Applications of satellite remote sensing in various domains
3. 6G Wireless Communication Technologies
    - Introduction to 6G wireless communication systems
    - Key features and requirements of 6G networks
    - Integration of satellite communication in 6G networks
    - Satellite-based services and applications in 6G
4. Satellite Communication Lab
    - Hands-on experiments with satellite communication equipment
    - Satellite link budget calculations and simulations
    - Satellite communication system performance analysis
    - Project work related to satellite communication technology

Semester 4:

1. Emerging Trends in Satellite Communication
    - Current advancements in satellite communication technology
    - High-throughput satellites and next-generation systems
    - Small satellite and CubeSat technology
    - Future directions and challenges in satellite communication
2. 6G Wireless Communication and Satellite Integration Lab
    - Experimental setups for 6G wireless communication
    - Satellite communication and 6G integration experiments
    - Performance evaluation and optimization
    - Project work related to satellite communication in 6G
3. Thesis or Project Work
    - Independent research under the guidance of a faculty advisor
    - Development of a thesis or project proposal
    - Execution of research work
    - Thesis writing and presentation

This course structure provides a comprehensive understanding of satellite communication while emphasizing its integration with 6G wireless networks. It covers various aspects of satellite systems, networks, and applications, as well as specific topics related to 6G satellite communication.

Annexure-III

Potential Research Areas

Research topics related to 5G

1. 5G Network Optimization: Investigating methods to enhance the performance and efficiency of 5G networks, including optimizing network architecture, resource allocation, and quality of service (QoS) management.

2. Millimeter Wave Communication: Exploring techniques to overcome challenges associated with millimeter wave frequencies, such as propagation loss and limited coverage, to enable reliable and high-speed communication in 5G networks.

3. Edge Computing in 5G: Investigating the integration of edge computing capabilities into 5G networks to enable low-latency and high-bandwidth applications, as well as optimizing resource allocation and workload management at the network edge.

4. Massive Multiple-Input Multiple-Output (MIMO): Studying advanced antenna technologies and signal processing techniques for massive MIMO systems in 5G networks to improve spectral efficiency, coverage, and overall network capacity.

5. Network Slicing: Exploring the concept of network slicing in 5G, which allows the creation of virtual network instances tailored to specific use cases, and investigating methods for efficient slice management, resource allocation, and isolation.

6. Security and Privacy in 5G: Investigating novel security and privacy mechanisms to protect against emerging threats in 5G networks, including authentication protocols, secure key exchange, privacy-preserving data aggregation, and secure network slicing.

7. Energy Efficiency in 5G: Researching energy-efficient strategies and protocols for 5G networks, including energy-aware resource allocation, power management, sleep mode optimization, and renewable energy integration to reduce the environmental impact of wireless communications.

Research topics related to 6G

The research areas currently emerging in 6G that can be considered for further exploration are as follows:

1. Terahertz (THz) Communications: Investigate the feasibility of utilizing the THz frequency band for high-speed wireless communication, including channel modeling, modulation schemes, antenna design, signal processing techniques and THz transceiver technologies to enable high-speed and ultra-low latency communication in the THz frequency range.
2. Intelligent Reflecting Surfaces (IRS): Explore the utilization of intelligent reflecting surfaces in 6G networks. Research could include the development of efficient algorithms for optimizing the placement and configuration of IRS elements to enhance coverage, capacity, and energy efficiency in wireless communication systems.
3. Massive MIMO and Holographic Beam-forming: Explore advanced techniques for massive multiple-input multiple-output (MIMO) systems and intelligent beam-forming to allow increased spatial reuse and enhance the spectral and energy efficiency of 6G networks. This could involve optimizing antenna arrays, signal processing algorithms, hybrid precoding architectures, and resource allocation strategies.
4. Tactile Internet: Exploring the concept of the Tactile Internet, which aims to provide ultra-low latency and high-reliability communication for haptic feedback and real-time control applications, and investigating the network architectures and protocols required to support such services.
5. Artificial Intelligence (AI) and Machine Learning (ML) in 6G: Investigate the integration of AI and ML techniques to optimize various aspects of 6G networks, such as intelligent resource allocation, network management, traffic prediction, interference mitigation, self-organizing networks, network security, and AI-assisted spectrum sharing.
6. Ultra-Reliable and Low-Latency Communications (URLLC): Investigate techniques to achieve ultra-reliable and low-latency communication in 6G networks, addressing the requirements of mission-critical applications. Research could focus on latency reduction mechanisms, reliability-enhancing protocols, and error correction coding techniques to support real-time applications such as autonomous vehicles, remote surgery, and industrial automation.
7. Internet of Things (IoT) and 6G: Study the integration of IoT devices and services within the 6G ecosystem, including the development of low-power and low-latency communication protocols, energy-efficient networking solutions, IoT data analytics

for handling the massive volume of IoT-generated data and scalable architectures to support massive IoT deployments.

8. Quantum Communications and Security: Explore the application of quantum principles to enhance communication security and enable ultra-secure information transfer in 6G networks. This could involve researching quantum key distribution (QKD), quantum-resistant cryptography, and quantum-based network protocols.
9. Human-Machine Interaction and Wearable Technologies: Exploring the integration of 6G networks with wearable devices, augmented reality (AR), virtual reality (VR), and haptic feedback systems. Research can focus on designing efficient wireless interfaces, immersive user experiences, context-aware applications, and intelligent interaction between humans and machines.
10. Edge Computing and Mobile Edge Computing (MEC): Investigate the potential of edge computing and MEC to enable low-latency and high-bandwidth services in 6G networks. This includes optimizing resource allocation, task offloading strategies, and developing efficient algorithms for computation and data management at the network edge.
11. Green Communications and Energy Efficiency: Focus on designing energy-efficient network architectures, protocols, and algorithms for 6G systems to reduce their environmental impact. This could involve optimizing power consumption, intelligent sleep mode strategies, renewable energy integration, and developing sustainable communication technologies.
12. Network Slicing and Virtualization: Explore network slicing techniques and network function virtualization (NFV) to enable dynamic resource allocation and efficient management of heterogeneous services in 6G networks. This includes investigating service orchestration, network slicing optimization, and scalability issues.
13. Trust, Security, and Privacy in 6G: Investigate privacy-preserving techniques and robust security mechanisms for safeguarding user data and ensuring secure communications in 6G networks. This could involve researching encryption algorithms, authentication protocols, privacy-enhancing technologies, secure data storage and transmission, threat detection/prevention mechanisms, and blockchain-based security solutions.
14. Sustainable Spectrum Management: Explore sustainable spectrum management approaches for 6G networks. Research could include dynamic spectrum sharing, cognitive radio technologies, spectrum sensing algorithms, and policy frameworks that promote efficient spectrum utilization, alleviate spectrum scarcity, and ensure fair access to wireless resources.

15. Cross-Disciplinary Collaborations: Promote interdisciplinary research collaborations by incorporating domains like computer science, data analytics, social sciences, and human-computer interaction to address the diverse challenges and requirements of 6G telecommunications.
16. Social and Ethical Implications of 6G: Investigating the broader societal impact of 6G technology and its ethical implications. Research can explore the implications of 6G on privacy, data governance, digital divide, social inclusion, and the role of telecommunication in shaping future societies.
17. Semantic Communication: Research in semantic communication in the context of 6G focuses on exploring and developing innovative techniques and methodologies to enable intelligent, context-aware, and meaningful communication between devices and systems. This field aims to go beyond traditional communication paradigms by incorporating semantic understanding, natural language processing, machine learning, and advanced data analytics. By leveraging these technologies, researchers seek to enhance the efficiency, reliability, and user experience of 6G networks, enabling seamless interaction and collaboration among diverse devices, services, and applications. Semantic communication research in 6G also addresses challenges such as dynamic network conditions, massive data processing, security, privacy, and the integration of emerging technologies like artificial intelligence and Internet of Things. Ultimately, this research area aims to pave the way for a new era of intelligent and context-aware communication systems, revolutionizing the way we interact with and benefit from future 6G networks.

These research areas provide a glimpse into the evolving landscape of 6G telecommunications and present exciting opportunities for further exploration and advancements in wireless communication, networking protocols, system architectures, and enabling technologies for future generations of telecommunications.

Optical and Satellite Communications

Below is a list of possible new and emerging areas for research and potential upgrades to PhD programs in the context of telecommunications, with a specific focus on Optical Communications and Satellite Communications, taking into account the requirements of 6G:

Optical Communications:

1. High-Capacity Optical Networks: Investigate advanced modulation formats, coding schemes, and multiplexing techniques to achieve higher data rates and capacity in optical communication systems. Research could focus on developing new photonic components, optical amplifiers, and signal processing algorithms for efficient transmission and reception of high-capacity optical signals.
2. Space Division Multiplexing (SDM): Explore the potential of SDM in optical communication networks to further increase capacity and spectral efficiency. Research could include novel optical fiber designs, spatial multiplexing techniques, and signal processing algorithms to enable the simultaneous transmission of multiple independent data streams.
3. Free-Space Optical Communications (FSOC): Investigate the use of optical wireless communication links for high-speed data transmission, especially in scenarios where traditional wired or wireless solutions face limitations. Research could focus on beamforming techniques, beam steering and tracking algorithms, atmospheric turbulence mitigation techniques and channel modeling, and adaptive modulation schemes to enhance the performance and reliability of FSOC systems. Research could also focus on hybrid FSO-RF (Radio Frequency) communication solutions for high-speed and long-range wireless links.
4. Visible Light Communications (VLC): Explore the potential of VLC, also known as Li-Fi, as an alternative or complementary technology to RF-based communication systems. Research could include developing advanced modulation techniques, receiver designs, multiple access schemes, and integration of VLC with existing RF networks for seamless connectivity in 6G.
5. Integrated Fiber-Wireless Networks: Explore the integration of optical and wireless communication systems to develop hybrid networks that leverage the advantages of both technologies. Research could focus on seamless connectivity, hybrid modulation schemes, optical-wireless convergence, and resource management in integrated fiber-wireless networks for 6G applications.
6. Quantum Communications in Optical Networks: Explore the integration of quantum communication protocols and technologies within optical networks. Research could include quantum key distribution (QKD) over optical fibers or free-space links,

quantum repeaters for long-distance quantum communication, quantum memory devices, quantum error correction codes, and quantum signal processing techniques for secure and efficient data transmission.

7. Nonlinear Optical Signal Processing: Investigate novel nonlinear optical signal processing techniques for advanced modulation formats, signal regeneration, and wavelength conversion in optical communication systems. Research could include the development of all-optical devices, such as optical parametric amplifiers and nonlinear optical switches, to address the challenges of 6G networks.
8. Optical Network Virtualization: Study the virtualization of optical networks to provide flexible and scalable infrastructure for 6G and future telecommunications systems. Research could focus on software-defined networking (SDN) and network function virtualization (NFV) techniques applied to optical networks, dynamic resource allocation, network slicing, and efficient orchestration of virtualized resources.

Satellite Communications:

1. Satellite Constellations and Inter-Satellite Links: Investigate the design, deployment, and optimization of satellite constellations for 6G applications. Research could include inter-satellite link architectures, routing protocols, resource management schemes, and satellite constellation planning algorithms to provide global coverage and high-capacity connectivity.
2. Terabit/Satellite Systems: Explore the development of high-capacity satellite systems capable of delivering multi-Terabit-per-second data rates. Research could focus on advanced satellite payloads, advanced modulation and coding techniques, multi-beam and multi-user satellite architectures, and interference management strategies for efficient spectrum utilization.
3. Hybrid Terrestrial-Satellite Networks: Investigate the integration of satellite communication systems with terrestrial networks to provide seamless connectivity in 6G scenarios. Research could include hybrid network architectures, handover mechanisms, efficient routing algorithms, and interference mitigation techniques for reliable and ubiquitous connectivity.
4. Space-based Optical Communications: Explore the potential of space-based optical communication systems, such as optical inter-satellite links (OISL) and Earth-to-space optical links, for high-speed and long-distance data transmission in 6G networks. Research could involve the design and optimization of optical terminals, adaptive optics systems, and protocols for space-based optical communication.
5. New Frequency Bands and Spectrum Sharing: Explore the utilization of new frequency bands, such as V-band and W-band, for satellite communications in 6G. Research could focus on spectrum sharing techniques, interference management,

and regulatory frameworks to maximize the utilization of available spectrum resources.

These areas of research can provide a foundation for PhD programs that aim to address the needs of telecommunications in 6G, Optical Communications, and Satellite Communications. As technology advances and new challenges emerge, it is essential to stay up-to-date with the latest developments in these fields to identify further research opportunities.

6G and Broadcasting

Below is a list of possible new and emerging areas for research and potential up-gradations to PhD programs that align with the needs of telecommunications in 6G and broadcasting:

1. Network Slicing and Quality of Experience (QoE): Investigate efficient network slicing techniques for 6G networks to provide tailored services and optimal QoE for broadcasting applications. Research could focus on resource allocation, dynamic slicing, QoE optimization algorithms, and network architecture design for broadcast content delivery.

2. Next-Generation Broadcasting Technologies: Explore advancements in broadcasting technologies to support immersive and interactive experiences in 6G networks. Research could include Ultra High Definition (UHD) video streaming, virtual and augmented reality (VR/AR) content delivery, multi-view video coding, and low-latency broadcasting systems.

3. Immersive Audio and Spatial Sound: Investigate advanced audio technologies for immersive and spatial sound experiences in broadcasting. Research could include audio object-based coding, 3D audio rendering, personalized audio delivery, and optimization of audio quality for various broadcast scenarios, such as virtual reality (VR) and augmented reality (AR) applications.

4. Next-Generation Content Delivery Networks (CDNs) for Broadcasting: Study CDN architectures and optimization techniques for efficient content delivery in broadcasting applications. Research could focus on adaptive streaming algorithms, content caching and prefetching, network traffic management, and CDN deployment strategies for 6G networks.

5. Edge Computing for Broadcast Services: Investigate the integration of edge computing capabilities in broadcasting systems for low-latency and high-bandwidth content delivery. Research could include edge server placement, content caching at the edge, edge-based video processing, and dynamic offloading strategies for broadcasting in 6G networks.

6. Hybrid Broadcasting and Broadband Convergence: Explore the convergence of broadcasting and broadband communication technologies in 6G networks. Research could focus on hybrid broadcast-broadband delivery models, efficient spectrum allocation, seamless switching between broadcast and uni-cast modes, and integration of over-the-top (OTT) services in broadcasting systems.

7. Personalized and Targeted Broadcasting: Investigate personalized and targeted content delivery techniques in broadcasting to enhance user engagement and satisfaction. Research could include user profiling, content recommendation algorithms, advanced metadata management, and interactive broadcasting systems for 6G networks.

8. Security and Privacy in Broadcasting: Study security and privacy challenges in broadcasting systems, including content protection, piracy prevention, and user data privacy. Research could focus on watermarking techniques, digital rights management (DRM), content encryption, and secure content delivery mechanisms in 6G broadcasting networks.
9. Content Analytics and Recommender Systems: Study advanced analytics techniques and recommender systems for content discovery, personalization, and targeted advertising in broadcasting. Research could include content understanding, user behavior modeling, sentiment analysis, and AI-based recommendation algorithms to enhance the viewer's engagement and satisfaction.

These research areas can contribute to the advancement of telecommunications in 6G and broadcasting, fostering the development of new technologies, enhancing the quality of broadcasting services, and providing immersive and personalized content experiences to viewers.

6G and RF Engineering

Below is a list of possible new and emerging areas for research and potential up-gradations to PhD programs that align with the needs of telecommunications in 6G and and RF Engineering:

1. mm Wave and Terahertz RF Design: Investigate the design and optimization challenges and opportunities associated with millimeter-wave (mm Wave) and terahertz frequency ranges for wireless communication in 6G networks. Research could focus on developing low-noise amplifiers, power amplifiers, mixers, transceiver architectures, frequency synthesizers, on-chip antenna integration, and other key RF components tailored for these high-frequency bands.
2. Integrated RF Systems: Explore the design and optimization of integrated RF systems for compact and energy-efficient wireless devices in 6G networks. Research could focus on RF front-end integration, RF transceiver architectures, co-design of antennas and circuits, power management techniques, and system-level optimization for improved performance and power efficiency.
3. RF Energy Harvesting: Investigate techniques for harvesting and utilizing ambient RF energy for powering wireless devices and sensor networks. Research could include efficient rectenna designs, energy management circuits, power extraction algorithms, and integration of RF energy harvesting with other energy harvesting techniques for self-powered wireless communication systems.
4. Reconfigurable RF Systems: Study reconfigurable RF systems that can adapt to different operating conditions and requirements in 6G networks. Research could focus on developing reconfigurable filters, antennas, amplifiers, and other RF components that can dynamically adjust their characteristics to optimize performance and adapt to changing communication scenarios.
5. Nonlinear RF Circuit Design: Explore nonlinear RF circuit design techniques for improved efficiency and linearity in 6G communications. Research could include nonlinear distortion mitigation techniques, linearization methods, and nonlinear modeling and analysis of RF circuits to achieve better overall system performance.
6. Cognitive Radio and Spectrum Sharing: Study cognitive radio techniques for dynamic spectrum access and efficient spectrum sharing in 6G networks. Research could focus on spectrum sensing, interference management, adaptive modulation and coding, spectrum database design, and machine learning-based cognitive radio systems to enable spectrum-efficient and dynamic RF communication.
7. RF Circuit Optimization for Low Power: Explore techniques for designing RF circuits with low power consumption in 6G networks. Research could include low-noise amplifier (LNA) design, power amplifier efficiency improvement, voltage-

controlled oscillator (VCO) design, RF filter optimization, and low-power RF circuit architectures to address the power constraints of energy-efficient wireless devices.

8. Antenna Design for 6G Applications: Investigate antenna designs optimized for the requirements of 6G applications, such as massive MIMO, beamforming, and intelligent reflecting surfaces. Research could focus on innovative antenna structures, compact and multi-band antennas, adaptive antenna arrays, and antenna systems for improved coverage, capacity, and spectral efficiency.
9. RF Circuitry for IoT, sensor networks and Wearable Devices: Study RF circuit design for Internet of Things (IoT) devices and wearable technologies in the context of 6G networks. Research could include low-power RF transceivers, miniaturized antennas, energy-efficient communication protocols, and integration of RF circuitry with IoT platforms for seamless connectivity and efficient data transmission.
10. RF Transceiver Integration and Miniaturization: Explore integration and miniaturization techniques for RF transceivers in 6G devices. Research could include system-on-chip (SoC) designs, multi-functional RF front-ends, on-chip passive component integration, and advanced packaging technologies-such as flip-chip, 3D integration, and system-in-package (SiP) approaches- to reduce size, power consumption, and cost while improving performance.

These research areas can contribute to the advancement of telecommunications in 6G networks and RF Engineering, enabling the development of innovative wireless communication systems, development of innovative RF chip architectures, energy-efficient RF circuits, and optimized RF architectures for next-generation wireless technologies.

6G and telecom standardization

Below is a list of possible new and emerging areas for research and potential up-gradations to PhD programs that align with the needs of telecommunications in 6G and telecom standardization:

1. 6G Standardization Frameworks: Investigate the development of standardization frameworks for 6G networks, considering the unique requirements and challenges of next-generation telecommunications. Research could focus on identifying key technical aspects, defining performance metrics, establishing interoperability guidelines, and addressing regulatory considerations for 6G standardization.

2. Network Slicing Standardization: Study the standardization of network slicing technologies for 6G networks. Research could include defining network slicing architectures, interfaces, and protocols, as well as addressing challenges related to orchestration, management, security, and scalability of network slices in a multi-operator and multi-domain environment.

3. Security and Privacy Standardization: Explore the standardization of security and privacy frameworks for 6G networks. Research could focus on developing secure and privacy-preserving communication protocols, authentication mechanisms, encryption algorithms, and security architectures to protect sensitive data and ensure secure communication in the 6G era.

4. Spectrum Management and Regulation: Study the standardization and regulatory aspects of spectrum management for 6G networks. Research could include the development of standardized procedures for spectrum allocation, sharing mechanisms, dynamic spectrum access, and coordination frameworks to enable efficient and fair spectrum utilization in the context of 6G communication.

5. AI and Machine Learning Standardization: Investigate the standardization of AI and machine learning techniques for 6G networks. Research could include defining common interfaces, protocols, and formats for AI-enabled network management, intelligent resource allocation, network optimization, and AI-driven decision-making processes in 6G telecommunication systems.

6. Quality of Service (QoS) and Quality of Experience (QoE) Standardization: Investigate the standardization of QoS and QoE metrics, measurement methodologies, and performance evaluation techniques for 6G networks. Research could focus on defining standardized metrics for network performance, latency, reliability, throughput, and user-centric QoE parameters to ensure a high-quality communication experience in 6G systems.

7. Energy Efficiency Standardization: Explore the standardization of energy efficiency methodologies and metrics for 6G networks. Research could include defining energy efficiency metrics, energy-aware protocols, power management

mechanisms, and energy-efficient network architectures to optimize energy consumption and promote sustainable practices in 6G telecommunication systems.

8. Interoperability and Roaming Standardization: Investigate the standardization of interoperability and roaming mechanisms for 6G networks, enabling seamless communication across different networks and service providers. Research could focus on defining protocols, interfaces, and procedures.
9. Cross-Layer Standardization: Investigate the standardization of cross-layer communication protocols and interfaces in 6G networks. Research could include the development of standardized interfaces between different layers of the protocol stack, coordination mechanisms, and cross-layer optimization techniques to enable efficient and seamless communication across multiple network layers.

These research areas can contribute to the advancement of telecommunications in 6G networks and telecom standardization, fostering the development of standardized frameworks, protocols, and mechanisms for efficient, secure, and interoperable communication in future telecommunication systems.

6G and Intellectual Property Rights (IPR)

Below is a list of possible new and emerging areas for research and potential up-gradations to PhD programs that align with the needs of telecommunications in 6G, telecom standardization, and Intellectual Property Rights (IPR):

1. Standard Essential Patents (SEPs) in 6G: Investigate the impact of SEPs on 6G technology development and deployment. Research could include analyzing the challenges and opportunities associated with SEPs, exploring licensing models, assessing FRAND (Fair, Reasonable, and Non-Discriminatory) obligations, and studying the role of IPR policies in fostering innovation and collaboration in 6G standardization.
2. IPR Policies and Strategies for 6G: Study the development and implementation of IPR policies and strategies for 6G networks. Research could include the analysis of licensing models, patent valuation methodologies, IPR clearinghouses, collaborative innovation frameworks, and IPR management practices to ensure a balanced approach to intellectual property in the context of 6G telecommunications.
3. Patent Analytics and Technology Mapping: Explore patent analytics and technology mapping techniques to identify emerging technologies, trends, and potential IPR conflicts in the field of 6G telecommunications. Research could involve the use of data mining, machine learning, and natural language processing techniques to analyze patent databases and identify key technological advancements and IPR landscapes in 6G.
4. IPR Protection and Enforcement: Investigate the challenges and solutions related to IPR protection and enforcement in the development of 6G technologies. Research could include analyzing legal frameworks, studying mechanisms for resolving IPR disputes, exploring technological solutions for IPR protection, and evaluating the effectiveness of IPR enforcement strategies in fostering innovation and competition in 6G.
5. Standardization Policy and IPR Considerations: Study the relationship between standardization policy and IPR considerations in the context of 6G networks. Research could focus on understanding the interaction between standardization organizations and IPR holders, examining policy frameworks for IPR disclosure and licensing commitments, and analyzing the impact of IPR policies on technological development and market competition in 6G.
6. Technology Transfer and Commercialization: Investigate the strategies and mechanisms for technology transfer and commercialization of 6G innovations while considering IPR aspects. Research could include studying technology transfer frameworks, analyzing licensing models and agreements, exploring collaboration

mechanisms between academia and industry, and evaluating the role of IPR in facilitating technology transfer and commercialization in the 6G ecosystem.

7. IPR Considerations for Emerging Technologies in 6G: Explore the IPR implications and considerations specific to emerging technologies in 6G networks. Research could include analyzing IPR issues related to artificial intelligence (AI), machine learning, blockchain, Internet of Things (IoT), and other disruptive technologies in the context of 6G, and examining strategies for managing IPR in these domains.
8. IPR and International Collaboration: Investigate the role of IPR in international collaboration and partnerships for 6G technology development. Research could focus on analyzing the impact of divergent IPR policies across different countries, exploring mechanisms for cross-border IPR collaboration, and studying the implications of IPR regulations on international cooperation in 6G standardization and innovation.
9. Open Innovation and IPR Collaboration: Study the role of open innovation and collaborative IPR frameworks in the development of 6G networks. Research could focus on exploring open-source initiatives, patent commons, technology sharing platforms, and collaborative licensing models to foster innovation, knowledge exchange, and IPR collaborations in the 6G ecosystem.

These research areas can contribute to the understanding and management of IPR considerations in the context of 6G telecommunications and telecom standardization, fostering the development of effective IPR policies, strategies, and frameworks to support innovation, collaboration, and technology transfer in the 6G ecosystem.

ANNEXURE IV

A. **Details of institutes having M.E/ M. Tech Programs related to Telecommunications field and their current intake & corresponding enrollment**.

(I) List of IITs and IIITs

Sl. No.	Name of State	Name of Institute	Program Name	Approved Intake	No of Students Enrolled
1	Maharashtra	IIT Bombay	M.Tech In Communication Engineering	130	112
			M.Tech in Power Electronics & Power System		
			M.Tech In Electronics System		
			M.tech in Integrated Circuit & System		
			M.Tech In Solid State Device		
			M.Tech In Control & Computing		
		IIIT Nagpur	M.Tech in Information Communication Technology	50	40
2	Tamil Nadu	Indian Institute of Technology Madras	M. Tech. in Electrical Engineering	20	19
			Web-enabled M. Tech. in Electrical Engineering(Communications and Signal Processing) (For industry professionals)	40	192 (across all years)
		IIIT Tiruchirappalli	M.Tech in VLSI systems, and CSE	24	Nil
		IIIT Design and Manufacturing, Kanchipuram	1. Electronics and Communication Engineering with Specialization in Communication Systems	20	4
			2. Electronics and Communication Engineering with specialization in Microelectronics and VLSI Systems.	20	11
3	Rajasthan	IIT Jodhpur	M.Tech in Intelligent Communication Systems	21	
			M.Tech. in Sensors and Internet of Things in the Telecom domain.	21	
4	MP	IIT Indore	M.Tech in Communication, &	15	06 in

Sl. No.	Name of State	Name of Institute	Program Name	Approved Intake	No of Students Enrolled
			Signal Processing		2022-23 & 12 in 2021-22
5	Karnataka	IIT Dharwad	M. Tech in electrical engineering with specialization in communication, signal processing and machine learning is starting from August 2023	30	
		IIIT Bangalore	Integrated MTech (iMTech) in Electronics and Communication Engineering (ECE)	60	69
			MTech in Electronics and Communication Engineering (ECE)	30	27
		IISC Bangalore	**M.tech in Electronics and Communication Engineering** , study in the Area of Communications and Networking; Information and Coding Theory; Wireless Communication, AI/ML for Communications, Cyber Physical Systems, High Frequency Circuits & Systems, Signal & Information Sciences	27	
			M.Tech in Electronic Systems Engineering, study in the area of Communication Networks; Embedded Systems; Power Conversion; VLSI Design; Electronics Systems Packaging; Electro Magnetic Compatibility; Analog Circuits; Mechatronics; Product Engineering. Signal Processing and Information Theory; VLSI Systems Architecture.	32	
			M.tech in Quantum Technology (QT), study in the area of Quantum Computation and Simulations, Quantum Communications and Cryptography, Quantum Sensing and Metrology,	8	

Sl. No.	Name of State	Name of Institute	Program Name	Approved Intake	No of Students Enrolled
			Quantum Materials and Devic		
			M.Tech in Signal Processing (SP)	13	
7	J&K	IIT Jammu	MTech in Electronics and Communication Engineering (ECE)	30	27
8	HP	IIT Mandi	M Tech- Communications & Signal Processing	35	
9	CG	IIIT Raipur	M.Tech. in ECE (Specialization in Communication and Signal Processing)	20	Nil
10	Assam	IIT Guwahati	MTech in Electronics and Electrical Engineering with Specialization in Communication Engineering	20	
			MTech in Electronics and Electrical Engineering with Specialization in Microelectronics, Photonics & RF Engineering	10	
			MTech in Electronics and Electrical Engineering with Specialization in Signal Processing and Machine Learning	21	
			MTech in Electronics and Electrical Engineering with Specialization in VLSI and Nanoelectronics #	20	
			MTech in Electronics and Electrical Engineering with Specialization in Systems, Control and Automation	11	
11	DELHI	Indraprastha Institute of Information Technology Delhi (IIIT-Delhi)	M.Tech Specialization in VLSI & Embedded Systems Courses for Specialisation	42	30
			M.Tech. in ECE with specialization in ML	22	12
			M.Tech. (ECE) with specialization in Cyber-Physical Systems	21	15
12	West Bangal	IIT Kharagpur	M.Tech. in RF and Microwave Engineering	34	

Sl. No.	Name of State	Name of Institute	Program Name	Approved Intake	No of Students Enrolled
			M.Tech. in Communications and Signal	34	
			M.Tech. in Vision and Intelligent Systems	34	
			M.Tech. in Microelectronics and VLSI Design	38	
			M.Tech. in Wireless Communications and Network	24	
			M.Tech. in Signal Processing And Machine Learning	20	

(ii) List of NITs

Sl. No.	Name of State	Name of Institute	Program Name	Approved Intake	No of Students Enrolled
1	Tamil Nadu	National Institute of Technology, Tiruchirappalli	M. Tech (Communication System)	35	33
			M. Tech (VLSI System)	35	31
2	Puducherry	NIT Puducherry	M. Tech. in VLSI Design-(VN)	10	
			M. Tech. in Power Electronics-(PE)	10	
3	J&K	National Institute of Technology, Srinagar	M. Tech in Communication and Signal Processing	25	18
4	HP	NIT Hamirpur	M Tech in Electronics & Communication Engineering (Communications System and Networks)-(US)	19	
			M. Tech in Electronics & Communication Engineering (VLSI Design)-(UT)	19	
5	Jharkhand	NIT Jamshedpur	M. Tech programme in Communication Engineering	20	02
6	MP	NIT Bhopal	Digital Communications	22	08
7	Chhattisgarh	NIT Raipur	M. Tech in VLSI & Embedded Systems-(VS)	24	
8	Meghalaya	NIT Meghalaya	M. Tech in VLSI & Embedded Systems-(VS)	25	
9	Tripura	NIT Agartala	M. Tech programme in Communication Engineering.	15	
10	Manipur	NIT Manipur	M.TECH IN COMMUNICATION AND SIGNAL PROCESSING	10	
11	Sikkim	NIT Sikkim	M. Tech programme in Communication & Signal Processing-(SL)	7	
12	Assam	National Institute of Technology, Silchar	M. Tech programme in RF and Terahertz Communications-(R3)	13	
			M. Tech programme in Communication & Signal Processing-(SL)	25	

Sl. No.	Name of State	Name of Institute	Program Name	Approved Intake	No of Students Enrolled
13	Nagaland	NIT Nagaland	M. Tech in Communication Engineering	16	
			M. Tech in VLSI Systems-(VI)	17	
14	Mizoram	NIT, Mizoram	M. Tech Programme of Microelectronics and VLSI System Design	10	
15	Punjab	Dr. B R Ambedkar National Institute of Technology, Jalandhar-(	M .Tech Programme in Signal Processing and Machine Learning-(SB)	20	
16	Rajasthan	Malaviya National Institute of Technology Jaipur-(202999)	M. Tech Programme Electronics and Communication Engineering-(EF)	21	
			M. Tech Programme Wireless & Optical Communication-(WO)	15	
17	UP	Motilal Nehru National Institute of Technology Allahabad-	M. Tech Programme in Communication Systems-(CY)	25	
			M. Tech Programme in Signal Processing-(SP)	25	
18	Kerala	National Institute of Technology Calicut-	M. Tech Programme in Signal Processing-(SP	16	
			M. Tech Programme in Telecommunication-(TK)	16	
19	Delhi	National Institute of Technology Delhi-(207999)	M. Tech Programme in Electronics and Communication Engineering-(EF)	13	9
			M. Tech Programme in Electronics and Communication Engineering with specialisation in VLSI-(VX)	19	13
20	West Bengal	National Institute of Technology Durgapur	M. Tech Programme in Next Generation Communication and Networks-(N1)	20	
21	Karnataka	National Institute of Technology, Surathkal	M. Tech programme in Communication Engineering and Networks-(CX)	33	
			M. Tech programme in Signal Processing and Machine Learning-(SB)	29	
22	Bihar	National Institute of Technology Patna	M. Tech programme in Communication Systems	23	

Sl. No.	Name of State	Name of Institute	Program Name	Approved Intake	No of Students Enrolled
23	Haryana	National Institute of Technology, Kurukshetra	M. Tech programme in Communication Systems-(CY)	30	
24	Odisha	National Institute of Technology, Rourkela	M. Tech programme in Communication & Networks-(CW)	25	
			M. Tech programme in Electronics and Instrumentation Engineering-(EI)	25	
			M. Tech programme in Microwave and Radar Engineering-(M1)	15	
			M. Tech programme in Signal & Image Processing-(SI)	25	
			M. Tech programme in Electronic Systems & Communication-(EC)	25	
25	Telangana	National Institute of Technology, Warangal	M. Tech programme in Advanced Communication Systems-(AS)	30	
26	Gujrat	Sardar Vallabhbhai National Institute of Technology, Surat-(229999)	M. Tech programme in Communication System-(NX)	30	
27	Maharashtra	Visvesvaraya National Institute of Technology, Nagpur-(230999)	M. Tech programme in Communication System-(NX)	23	
28	Uttarakhand	National Institute of Technology Uttarakhand	M. Tech programme in Microelectronics & VLSI Design-(MG)	19	
			M. Tech programme in Power Electronics & Drives-(PD)	19	
29	Goa	National Institute of Technology Goa	M. Tech programme in VLSI-(VL)	23	
			M. Tech programme in Power Electronics & Power Systems-(PZ)	23	
30	Arunachal Pradesh	National Institute of Technology	VLSI Design & Embedded Systems-(VE)	22	

(iii)List of Other Technical Institute (Engineering college or Technical university)

Sl. No.	Name of State	Name of Institute	Program Name	Approved Intake	No of Students Enrolled
1	Delhi	Netaji Subhas University of Technology Main Campus and East Campus Delhi	M Tech (Mobile Communication, & Network Technology .	30	
			M. Tech in Signal Processing	15	
			M. Tech in Embedded Systems& VLSI	30	
			M. Tech in Communication Network	30	
			M. Tech in Digital Communications	15	
		Delhi Technological University	M.Tech Programme in Microwave & Optical Communication Engineering	37	
			M.Tech Programme in Signal Processing & Digital Design (SPD)	38	
			M.Tech in VLSI Design &Embedded Systems(VLS)	38	
		Indira Gandhi Delhi Technical University For Women	M.Tech in VLSI Design	32	
			M.Tech in Cyber Security	32	
2	Jharkhand	BIT Mesra	M. Tech. program in Electronics and Communication Engineering, which is telecom related.	30	14
			The M. Tech. program in Electronics and Communication Engineering of the department offers four specializations: 1.Wireless Communication 2. Microwave engineering 3. Instrumentation 4. VLSI design and Embedded system		
3	Bihar	Govt. Engg.college Vaishali	M.Tech Course in 5G Under approval (AICTE)	18	

Sl. No.	Name of State	Name of Institute	Program Name	Approved Intake	No of Students Enrolled
4	HP	JAYPEE University, Solan	M Tech (ECE) (specialization in IOT), M Tech (Communications);	24	
		Shoolini University	M Tech (ECE)- includes courses on Advanced Wireless & Mobile Communication, Optical Networks, Advanced Digital Communication,	18	
5	Meghalaya	NEHU Shillong,	M.Tech Courses in telecom sector .	18	11
6	Mizoram	Mizoram University	M.Tech in Electronics and communication engineering with different subjects related to communication	15	
7	Andhra Pradesh	KLEF Deemed University	M.Tech courses in "1. Modern Satellite Communication Systems 2. 5G NR - Next Generation Wireless Technologies 3. Machine Learning for Wireless Communications 4. Modern Satellite Communication Systems 5. High Performance Communication Networking 6. Optical Wireless Communications 7. Foundations of Advanced Wireless Communication 8. Wireless Communication and Data Networks 9. Estimation & Detection Theory"	6	2
8	Telangana	CBIT-Hyderabad	M.E. in "Communication Engineering"	18	5
		University College of Engineering, Osmania University - Hyderabad	M.tech Courses in 1. Software defined radio 2. Optical Communication and Networks 3. Coding theory techniques 4. Wireless and mobile communications.		
9	Puducherry	Puducherry Technological University	M.Tech (Electronics and Communication Engineering	24	1
			M.Tech (Wireless	18	nil

Sl. No.	Name of State	Name of Institute	Program Name	Approved Intake	No of Students Enrolled
			Communication		
10	Tamil Nadu	Institute of Technology, Chennai	M.Tech [Embedded Systems]	18	14
		Madras Institute of Technology(MIT) under Anna University	M.E communication & Networking	18	1
			M.E VLSI Design & Embedded system	18	6
			M.E. Wireless technology	18	2
		Vellore Institute of Technology, Vellore	M.Tech [Embedded Systems]	60	46
			M.Tech [IOT and Sensor Systems]	18	11
			M.Tech [Communication Engineering]	18	07
		Annamalai University	M.E. (Communication Systems)	18	10
		College of Engineering Guindy, Anna University, Chennai	M.E. (Communication Systems)	24	15
11	Rajasthan	LNM Institute of Information Technology Jaipur	Master of Technology with specialization in Wireless Communication and Network Engineering. The curriculum includes number of courses related to telecom, listed as follows: a. Advanced Wireless Communication b. Communication Signal Processing and Algorithms c. Wireless and Mobile Networks d. 5G Wireless Technology	23	30
12	Rajasthan	MBM UNIVERSITY, JODHPUR	Digital, 4G/5G, Optical Fibre Communication, OFDM, Signal and Image Processing	20	
			Cyber Physical Systems and Internet of Things, Cloud Computing, Wireless & Mobile Computing, Network Security	18	

Sl. No.	Name of State	Name of Institute	Program Name	Approved Intake	No of Students Enrolled
13	Karnataka	MIT Manipal	M. Tech in Wireless and Mobile Communications (WMC) offered by the Electronics and Communication Engineering in the field of wireless and mobile communications, 5G, 6G and beyond, antenna design for wireless communication with a foundation of Communication Engg	30	
		BMSCE Bangalore	M.Tech programme, Mobile communication and 5G technology, Internet of Things, Cyber security etc	18	for AY 2020 is 14, 2021 is 17 and for AY 2022 is 11
		KLEMSSCET Belagavi	M.Tech programme in The program focuses on the industry trends in Embedded systems, Communication (Telecom), and Signal Processing.	24	
		Dayananda sagar University Bangalore	M.Tech programme in These Courses have incorporated few telecom subject such as Iot, Mobile & web Applications, Iot and Network security.	18	
		BNMIT Bangalore	M.Tech programme VLSI & Embedded systems. This course has many courses related to Telecom	18	
		MSRIT Bangalore	[M.Tech] programme in Digital Electronics & Communication under ECE Department, Digital communication It covers all network related Courses like Computer Networks, Web socket Network Programming, Mobile communication and 5G technology, Internet of Things, Cyber security etc	18	
14	J&K	Govt. College of Engineering & Technology, Jammu	M.Tech courses in three disciplines Electronics and Communication Engineering.	18	12
15	Odisha	DRIEMS Cuttack	M.Tech in Electronics & Telecommunications	9	5

Sl. No.	Name of State	Name of Institute	Program Name	Approved Intake	No of Students Enrolled
			Engineering		
		BHADRAK INSTITUTE OF ENGINEERING & TECHNOLOGY, BARAPADA, BHADRAK	M.Tech in Electronics & Telecommunications Engineering	12	0
		KALINGA INSTITUE OF INDUSTRIAL TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	25	25
		TRIDENT ACADEMY OF TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	9	0
		VIGNAN INSTITUTE OF TECHNOLOGY AND MANAGEMENT	M.Tech in Electronics & Telecommunications Engineering	9	2
		KONARK INSTITUTE OF SCIENCE AND TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	9	1
		MAHAVIR INSTITUTE OF ENGINEERING AND TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	13	0
		BARRISTER RANJIT MOHANTY INTERNATIONAL INSTITUTE OF TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	14	4
16	Chhattisgarh	SHRI SHANKARACHARYA TECHNICAL CAMPUS	M.Tech in Electronics & Telecommunications Engineering	6	0
17	Kerala	SAINTGITS COLLEGE OF ENGINEERING	M.Tech in Electronics & Telecommunications Engineering	12	0
		MAR BASELIOS COLLEGE OF ENGINEERING AND TECHNOLOGY		18	0
18	Maharashtra	MCT'S RAJIV GANDHI INSTITUTE OF TECHNOLOGY, MUMBAI	M.Tech in Electronics & Telecommunications Engineering	18	0
		SHRI TULJABHAVANI COLLEGE OF ENGINEERING	M.Tech in Electronics & Telecommunications Engineering	9	
		BHARATI	M.Tech in Electronics &	6	1

Sl. No.	Name of State	Name of Institute	Program Name	Approved Intake	No of Students Enrolled
		VIDYAPEETH'S COLLEGE OF ENGINEERING KOLHAPUR	Telecommunications Engineering		
		PILLAI HOC COLLEGE OF ENGINEERING AND TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	12	0
		H.V.P.MANDAL'S COLLEGE OF ENGINEERING & TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	18	3
		SIPNA COLLEGE OF ENGINEERING & TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	18	3
		DR.RAJENDRA GODE INSTITUTE OF TECHNOLOGY AND RESEARCH,AMRAVATI	M.Tech in Electronics & Telecommunications Engineering	12	1
		VEERMATA JIJABAI TECHNOLOGICAL INSTITUTE	M.Tech in Electronics & Telecommunications Engineering	25	24
		DEOGIRI INSTITUTE OF ENGINEERING AND MANAGEMENT STUDIES	M.Tech in Electronics & Telecommunications Engineering	18	7
		COLLEGE OF ENGINEERING	M.Tech in Electronics & Telecommunications Engineering	18	11
		SF'S SANDIP INSTITUTE OF TECHNOLOGY AND RESEARCH CENTRE	M.Tech in Electronics & Telecommunications Engineering	18	0
		PADMABHOOSHAN VASANTRAODADA PATIL INSTITUTE OF TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	12	6
		MAHARSHI KARVE STREE SHIKSHAN SAMSTHA'S CUMMINS COLLEGE OF ENGINEERING FOR WOMEN	M.Tech in Electronics & Telecommunications Engineering	18	2
		SAINTGITS COLLEGE OF ENGINEERING	M.Tech in Electronics & Telecommunications	12	0

Sl. No.	Name of State	Name of Institute	Program Name	Approved Intake	No of Students Enrolled
			Engineering		
		D. Y. PATIL COLLEGE OF ENGINEERING & TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	18	
		RAMRAO ADIK INSTITUTE OF TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	18	6
		J.T. MAHAJAN COLLEGE OF ENGINEERING	M.Tech in Electronics & Telecommunications Engineering	18	0
		PROF. RAM MEGHE INSTITUTE OF TECHNOLOGY AND RESEARCH	M.Tech in Electronics & Telecommunications Engineering	18	0
		CSMSS CHH. SHAHU COLLEGE OF ENGINEERING	M.Tech in Electronics & Telecommunications Engineering	12	7
		VIDYALANKAR INSTITUTE OF TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	12	1
		DR BABASAHEB AMBEDKAR TECHNOLOGICAL UNIVERSITY LONERE	M.Tech in Electronics & Telecommunications Engineering	16	4
		ADITYA ENGINEERING COLLEGE	M.Tech in Electronics & Telecommunications Engineering	18	9
		SHRI BALASAHEB MANE SHIKSHAN PRASARAK MANDAL'S ASHOKRAO MANE GROUP OF INSTITUTIONS	M.Tech in Electronics & Telecommunications Engineering	24	5
		GANGAMAI COLLEGE OF ENGINEERING	M.Tech in Electronics & Telecommunications Engineering	18	6
		P R POTE(PATIL) EDUCATION & WELFARE TRUST'S, GROUP OF INSTITUTIONS, COLLEGE OF ENGINEERING & MANAGEMENT	M.Tech in Electronics & Telecommunications Engineering	12	2

Sl. No.	Name of State	Name of Institute	Program Name	Approved Intake	No of Students Enrolled
		M.G.M'S COLLEGE OF ENGINEERING ,NANDED	M.Tech in Electronics & Telecommunications Engineering	9	
		VISHWAKARMA INSTITUTE OF TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	6	0
		SVERI'S COLLEGE OF ENGINEERING, PANDHARPUR	M.Tech in Electronics & Telecommunications Engineering	18	3
		THAKUR COLLEGE OF ENGINEERING & TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	18	0
		DR. D. Y. PATIL INSTITUTE OF TECHNOLOGY.	M.Tech in Electronics & Telecommunications Engineering	6	
		VIVEKANAND EDUCATION SOCIETY'S INSTITUTE OF TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	6	0
		SHREEYASH PRATISHTHAN'S, SHREEYASH COLLEGE OF ENGINEERING & TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	18	3
		KOTI VIDYA CHARITABLE TRUST'S ALAMURI RATNAMALA INSTITUTE OF ENGINEERING AND TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	18	2
		SHRI VILE PARLE KELAVANI MANDAL'S DWARKADAS J. SANGHVI COLLEGE OF ENGINEERING	M.Tech in Electronics & Telecommunications Engineering	9	1
		AJEENKYA DY PATIL SCHOOL OF ENGINEERING	M.Tech in Electronics & Telecommunications Engineering	24	8
		SHREE L.R. TIWARI COLLEGE OF ENGINEERING	M.Tech in Electronics & Telecommunications Engineering	12	4
		ST. FRANCIS INSTITUTE OF	M.Tech in Electronics & Telecommunications	18	1

Sl. No.	Name of State	Name of Institute	Program Name	Approved Intake	No of Students Enrolled
		TECHNOLOGY (ENGG. COLLEGE)	Engineering		
		SWVSM'S TATYASAHEB KORE INSTITUTE OF ENGINEERING AND TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	24	5
		MAR BASELIOS COLLEGE OF ENGINEERING AND TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	18	0
		BHARATIYA VIDYA BHAVANS SARDAR PATEL INSTITUTE OF TECHNOLOGY	M.Tech in Electronics & Telecommunications Engineering	18	0
		DATTA MEGHE COLLEGE OF ENGINEERING	M.Tech in Electronics & Telecommunications Engineering	18	0
		GOVERNMENT COLLEGE OF ENGINEERING ,JALGAON(M.S.)	M.Tech in Electronics & Telecommunications Engineering	18	0
		TERNA PUBLIC CHARITABLE TRUST'S TERNA ENGINEERING COLLEGE	M.Tech in Electronics & Telecommunications Engineering	18	0
	Maharashtra	M.S. Bidve Engineering College, Latur	M.Tech in Electronics and Communication Engineering	18	1
		Lokmanya Tilak Jankalyan Shikshan Sanstha, Priyadarshani College of Engineering, Nagpur	M.Tech in Electronics and Communication Engineering	8	0
		Vidarbha Bahu-Uddeshiya Shikshan Sanstha's Tulshiramji Gaikwad Patil College of Engineering & Technology, Nagpur	M.Tech in Electronics and Communication Engineering	24	9
		Anjuman College of Engineering & Technology, Nagpur	M.Tech in Electronics and Communication Engineering	18	4
		Priyadarshini Bhagwati College of Engineering,	M.Tech in Electronics and Communication Engineering	22	3

Sl. No.	Name of State	Name of Institute	Program Name	Approved Intake	No of Students Enrolled
		Harpur Nagar, Umred Road,Nagpur			
		Krushi Jivan Vikas Pratishthan, Ballarpur Institute of Technology, Mouza Bamni	M.Tech in Electronics and Communication Engineering	18	1
		K.D.M. Education Society, Vidharbha Institute of Technology,Umred Road ,Nagpur	M.Tech in Electronics and Communication Engineering	24	4
		Nagaon Education Society's Gangamai College of Engineering, Nagaon, Tal Dist Dhule	M.Tech in Electronics and Communication Engineering	18	0
		Kolhapur Institute of Technology's College of Engineering(Autonomous), Kolhapur	M.Tech in Electronics and Communication Engineering	6	1
		VNIT Nagpur	M.Tech in Electronics and Communication Engineering	23	0

2. **Details of institutes having PhD Programs related to Telecommunications field and their current intake & corresponding enrollment. You are also requested to make available list of research topics of ongoing researches in telecom domain in academic institutions**.

i. List if IIT and IIITs

Sl. No.	State	Name of Institute	Program Name	Approved Intake
1	Maharashtra	IIT Bombay	PhD program in communication, which allows a student to specialize in all aspects of telecom, including 5G.	
2	Tamil Nadu	Indian Institute of Technology Madras	Ph. D. in Electrical Engineering Areas: Wireless Communications Information Theory and Coding Communication Networks Optimization Queuing Theory Network Theory and Queuing Theory DSP Algorithms and Applications Speech processing Image Processing and Computer Vision	15
			M. S. (by research) in Electrical Engineering Areas: Wireless Communications Information Theory and Coding Communication Networks Optimization Queuing Theory Network Theory and Queuing Theory DSP Algorithms and Applications Speech processing Image Processing and Computer Vision	12
3	Tamil Nadu	IIIT Design and Manufacturing, Kancheepuram	• Bioelectronics and Biosensors • Biomedical Image/signal Processing • Photonics • Microelectronics and VLSI • Communication Networks • RF & Microwave • Wireless Communication/Networks • 5G/6G technologies • Wireless Sensor Networks/IoT	40

Sl. No.	State	Name of Institute	Program Name	Approved Intake
			• Power Electronics and Drives • Power Systems • Renewable Energy systems • Electric Vehicle Technologies • Smartgrid • Quantum Devices, circuits, and computing	
		Indian Institute of Information Technology Tiruchirappalli	Institute offers the PhD program in various branches including ECE. In ECE domain, we offer, wireless and fibre optic communication as an integral part of various research areas undertaken by the faculty/scholars.	Depending on the availability of the seats with the concerned supervisors
4	MP	IIT Indore	PHD in Telecommunication Engineering	20 student are pursuing the program in current Year
5	Karnataka	IIT Dharwad	PHD programme in 9 faculty members working broadly in the area of 5G and beyond communication. In particular, faculty are working on Intelligent reflection surfaces, signaling design for synchonizaiton (adhering to standards), IoT standards, channel estimation, join communication and sensing, RAN architecture, FoG networks, content network or caching, AI/ML/FL for Networks and many more.	25 PHD and 25 MS student enrolled
		Indian Institute of Information Technology Dharwad	PHD in the area of Next Gen IoT, 6G and Edge Intelligence as a research area under ECE Dept.	
6	Telangana	IIIT -Hyderabad	PhD in 'Electronics & Communication Engineering'	
7	Chhattisgarh	IIIT Raipur	M.S. (Research) Ph.D.	3 (Graduated) 8 (Pursuing)
8	Assam	IIT Guwahati	PHD in Electronics and Electrical Engineering	51
			Centre for Intelligent Cyber Physical Systems	10

ii. List of NITs

Sl. No.	State	Name of Institute	Program Name	Approved Intake
1	CG	NIT Raipur	Ph.D. in IT-5G Technology	1 (Graduated) 1 (Pursuing)
2	Meghalaya	NIT Meghalaya	PhD Electronics and Communication Engineering(Machine Learning for Communications and Signal Processing	
3	Tripura	NIT Agartala	Ph.D. in the field of advanced communication, microwave circuits, smart antenna, image processing, semiconductor devices , advanced control system, Bio medical	
4	Nagaland	NIT Nagaland	Ph.D. degree in the Electronics and Communication Engineering area.	
5	HP	NIT Hamirpur	Ph.D in Telecom/ Wireless Communications/ 5G	10
6	Tamil Nadu	National Institute of Technology, Trichy, Tamil Nadu	PhD/ Research Topic Wireless Communication 2. RF and Microwave 3. Wireless communication 4. Orthogonal time and frequency space 5. Deep learning classification techniques 6. Fiber optic communication 7. RF and Microwave 8. Metamaterial inspired MIMO Antenna 9. Metamaterial based MIMO Antenna for 5G Applications. 10. Microwave and Millimeter-wave Balanced Antipodal Vivaldi Antennas for Imaging and Ultra wideband Localization Applications 11. Neural Information pro-	28 per Academic year)

Sl. No.	State	Name of Institute	Program Name	Approved Intake
			cessing 12. Array Signal Processing 13. Antenna and microwave 14. Wireless Networks 15. R.F. and Microwave 16. 5G millimeter wave wireless systems 17. Optical Communication 18. Optical Communication and Optical networks 19. Reconfigurable Intelli-gent Surface For Beyond 5G 20. Vehicular Communica-tion 21. R.F. and Microwave 22. Machine Learning for Wireless communication	
7	Jharkhand	NIT Jamshedpur	PHD Programme Advanced Communication Engg., Wireless Communication, Microwave Antenna, IoTs, A1, and on devices applicable for 5G technology	54 research scholars working in E&C Department out of 32 scholars are working on various emerging technologies in the area of Communicati on Engineering
8	MP	NIT Bhopal	PHD in Communication, & Signal Processing	14
9	J&K	National Institute of Technology, Srinagar	Ph D programs in following fields of Telecommunications: □ Optical Fibre Communication System, □ RF Communication System, □ Microwave Communication areas □ Millimeter and Terahertz Technology □ Wireless Communications □ Computer Networking □ Antenna Systems The	

Sl. No.	State	Name of Institute	Program Name	Approved Intake
			Department as produced around **20 Ph D Scholars since 2015** in the field of wireless telecommunication. A good number of papers have been also published and presented in reputed journals and international/national conferences	

(iii)List of List of Other Technical Institute (Engineering college or Technical university)

Sl. No.	State	State Name of Institute	Program Name	Approved Intake
1	Jharkhand	BITS Mesra	The ECE department of BIT Mesra offers PhD programs in the following areas of research related to the field of telecom technology. 1·Wireless Communication & 2. Satellite Communications ·3. Visible light communication 4. RF and Microwave Engg. 5.EMI & EMC 6. Signal & Image Processing 7. Signal Processing and Automations 8. Cyber Security 9.VLSI Design 10 Embedded IoT 11.Sensors and Actuators 12. fibre Optic Communication	
2	Telangana	University College of Engineering, Osmania University - Hyderabad	1. Wireless Communications, 2. Sensor Networks 3. 5G and LTE 4. 5G network Security 5. 5G technologies, Architecture and Protocols 6. Software Defined Networks (SDN)	

Sl. No.	State	State Name of Institute	Program Name	Approved Intake
3	Andhra Pradesh	KLEF Deemed University	Modern Digital Communication, Detection and Estimation Of Signals, Adaptive Signal Processing, Digital Video Processing, wireless communications.	
4	Mizoram	Mizoram University	PhD in MEMS, communication, Signal and image processing, microwave and Antenna	
5	HP	JAYPEE University, Solan	Ph D. in Antennas & 5G wireless Communications	12
		Shoolini University	Ph.D include Advanced 9.Optical fibre communications	4
6	Tamil Nadu	Vels Institute of Science, Technology and Advanced Studies(VISTAS)	Ph.D., (Electronics & Communication Engg.)	62 Enrolled 60 student
		Vellore Institute of Technology, Chennai	Ph.D. program in 1 Wireless Communication 2 VLSI Circuits & Nano Devices 3 Signal & Image Processing 4 Optics Photonics 5 Microwave, Millimetre wave and Terahertz 6 Flexible Electronics 7 Embedded Systems 8 Data Engineering	126
		Annamalai University	Ph.D. (Electronics and Communication Engineering 1. Wireless Communication and Networks 2. Microwave and Antenna Design 3. Signal, Image and Audio/Video Processing 4. Micro/Nano Electronics, MEMS and VLSI Design	

Sl. No.	State	State Name of Institute	Program Name	Approved Intake
			5. Medical Image Processing 6. Speech Technology	
		SRMIST Kattankulathur, Chengalpattu District,	Ph.D. Program related to Telecom Field	Intake 272 Enrolled student 188
7	Rajasthan	MBM UNIVERSITY, JODHPUR	PHD in 5G/6G, TerraHertz, MMWave, Antenna & Wave Communication, Radars, E-Healthcare, Smart Diagnosis	9
			PHD in Wireless Sensor Networks, Internet of Things, Network Optimization & Security, Cloud Computing, AI & NLP, Comp. Vision, Quantum Cryptography	10
8	Karnataka	MIT Manipal	MIMO Wireless Communications, Spatial Modulation for 5G, Modulation and Detection strategy desgin for 5G and beyond and many more topics have been offered.	
		BMSCE Bangalore	Ph.D Programme is available and many students are working on Mobile communication, IoT and 5G Networking problems	
		Amrita School of Engineering	PhD graduated in 5G related area and joined company to work. 6 are doing PhD in 5G-6G area. School is seeking 50 full time scholars to work in 5G-6G Communication. University is ready to fund. We have testbed where use cases can be validated. Some support to enhance hardware in the	50 Scholars 3 PHD in 5G 6 PHD in 5G-6G Area

Sl. No.	State	State Name of Institute	Program Name	Approved Intake
			lab is requested.	
		Indian Institute of Information Technology Dharwad	PHD in the area of Next Gen IoT, 6G and Edge Intelligence as a research area under ECE Dept.	
9	J&K	Islamic University of Science & Technology Awantipora	research in the area of 5G technology (MIMO Design, millimetre Wave generation), for which Three scholars have been awarded Ph.D degrees till date.	

अखिल भारतीय तकनीकी शिक्षा परिषद्
(भारत सरकार का एक सांविधिक निकाय)
(मानव संसाधन विकास मंत्रालय, भारत सरकार)
नेल्सन मंडेला मार्ग, वसंत कुंज, नई दिल्ली-110070

ALL INDIA COUNCIL FOR TECHNICAL EDUCATION
(A Statutory Body of the Govt. of India)
(Ministry of Human Resource Development, Govt. of India)
Nelson Mandela Marg, Vasant Kunj, New Delhi-110070

Phone : 011-26131577 - 78, 80
011-29581000
Website : www.aicte-india.org

Dr. Mamta Rani Agarwal
Advisor-I (P&AP)

F. No. F.AD (P&AP)/Misc/2023 **Dated**: 30.05.2023

To,

Sh. Bhuvnesh Kumar Yadav
Director (Skill Development & Entrepreneurship), DoT
Jawaharlal Nehru Marg, New Delhi- 110002

Subject- Compilation of data on M.E/M.Tech and Ph.D. Programs related to Telecom filed- Reg.

Sir,

Please refer to your email dated 08 May 2023 requesting for data on M.E/M.Tech programs. Accordingly, AICTE has successfully compiled the requested data for the Task force on Telecommunications Needs. Please find attached the following information to support the task force's objectives: -

1. Number of AICTE approved institutes offering M.E./M.Tech and Ph.D. programs in the field of Telecommunications, along with their current intake and corresponding enrollment.

2. Number of AICTE approved institutes that have included or applied for the recently approved courses on mobile communication in accordance with the AICTE model curriculum.

The Council will extend its full support to the task force in its mission to suggest modifications and amendments in existing curricula, as well as proposed ways and means to make students industry-ready; especially for research and development (R&D) roles.

This is issued with the approval of competent authority.

Yours sincerely,

30 May, 23

Dr. Mamta Rani Agarwal

Annexure No. I

Sl.no.	Institute Name	State	Program Name	Approved Intake	Total Enrollment
1	ORIEMS	Odisha	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	9	5
2	MCT'S RAJIV GANDHI INSTITUTE OF TECHNOLOGY, MUMBAI	Maharashtra	ELECTRONICS AND TELECOMMUNICATION ENGINEERING (RADIO AND SYSTEM)	18	0
3	BHADRAK INSTITUTE OF ENGINEERING & TECHNOLOGY, BARAPADA, BHADRAK	Odisha	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	12	0
4	KALINGA INSTITUE OF INDUSTRIAL TECHNOLOGY	Odisha	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	25	25
5	SHRI TULJABHAVANI COLLEGE OF ENGINEERING	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	9	
6	BHARATI VIDYAPEETH'S COLLEGE OF ENGINEERING KOLHAPUR	Maharashtra	ELECTRONICS AND TELECOMMUNICATION ENGINEERING	6	1
7	PILLAI HOC COLLEGE OF ENGINEERING AND TECHNOLOGY	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	12	0
8	SHRI SHANKARACHARYA TECHNICAL CAMPUS	Chhattisgarh	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	6	0
9	H.V.P.MANDAL'S COLLEGE OF ENGINEERING & TECHNOLOGY	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	18	3
10	SIPNA COLLEGE OF ENGINEERING & TECHNOLOGY	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	18	
11	DR.RAJENDRA GODE INSTITUTE OF TECHNOLOGY AND RESEARCH,AMRAVATI	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	12	1
12	VEERMATA JIJABAI TECHNOLOGICAL INSTITUTE	Maharashtra	ELECTRONICS AND TELECOMMUNICATION ENGINEERING	25	24
13	DEOGIRI INSTITUTE OF ENGINEERING AND MANAGEMENT STUDIES	Maharashtra	ELECTRONICS AND TELECOMMUNICATION ENGINEERING	18	
14	COLLEGE OF ENGINEERING	Maharashtra	ELECTRONICS AND TELECOMMUNICATION ENGINEERING	18	11
15	TRIDENT ACADEMY OF TECHNOLOGY	Odisha	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	9	0
16	SF'S SANDIP INSTITUTE OF TECHNOLOGY AND RESEARCH CENTRE	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	18	
17	PADMABHOOSHAN VASANTRAODADA PATIL INSTITUTE OF TECHNOLOGY	Maharashtra	ELECTRONICS AND TELECOMMUNICATION ENGINEERING	12	6
18	MAHARSHI KARVE STREE SHIKSHAN SAMSTHA'S CUMMINS COLLEGE OF ENGINEERING FOR WOMEN	Maharashtra	Electronics and Telecommunication Engineering with specialization in Artificial Intelligence	18	2
19	SAINTGITS COLLEGE OF ENGINEERING	Kerala	TELECOMMUNICATION ENGINEERING	12	0
20	D. Y. PATIL COLLEGE OF ENGINEERING & TECHNOLOGY	Maharashtra	ELECTRONICS AND TELECOMMUNICATION ENGINEERING	18	
21	RAMRAO ADIK INSTITUTE OF TECHNOLOGY	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	18	6
22	J.T. MAHAJAN COLLEGE OF ENGINEERING	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	18	0
23	PROF. RAM MEGHE INSTITUTE OF TECHNOLOGY AND RESEARCH	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	18	0
24	CSMSS CHH. SHAHU COLLEGE OF ENGINEERING	Maharashtra	ELECTRONICS AND TELECOMMUNICATION ENGINEERING	12	7
25	VIDYALANKAR INSTITUTE OF TECHNOLOGY	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	12	1
26	DR BABASAHEB AMBEDKAR TECHNOLOGICAL UNIVERSITY LONERE	Maharashtra	ELECTRONICS AND TELECOMMUNICATION ENGINEERING	16	4
27	ADITYA ENGINEERING COLLEGE	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	18	9
28	VIGNAN INSTITUTE OF TECHNOLOGY AND MANAGEMENT	Odisha	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	9	2
29	SHRI BALASAHEB MANE SHIKSHAN PRASARAK MANDAL'S ASHOKRAO MANE GROUP OF INSTITUTIONS	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	24	5
30	GANGAMAI COLLEGE OF ENGINEERING	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	18	6
31	P R POTE(PATIL) EDUCATION & WELFARE TRUST'S, GROUP OF INSTITUTIONS, COLLEGE OF ENGINEERING & MANAGEMENT	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	12	2
32	M.G.M'S COLLEGE OF ENGINEERING ,NANDED	Maharashtra	ELECTRONICS AND TELECOMMUNICATION ENGINEERING	9	
33	VISHWAKARMA INSTITUTE OF TECHNOLOGY	Maharashtra	ELECTRONICS AND TELECOMMUNICATION ENGINEERING	6	0
34	SVERI'S COLLEGE OF ENGINEERING, PANDHARPUR	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	18	3
35	THAKUR COLLEGE OF ENGINEERING & TECHNOLOGY	Maharashtra	ELECTRONICS AND TELECOMMUNICATION ENGINEERING	18	0
36	DR. D. Y. PATIL INSTITUTE OF TECHNOLOGY	Maharashtra	ELECTRONICS AND TELECOMMUNICATION ENGINEERING	6	
37	VIVEKANAND EDUCATION SOCIETY'S INSTITUTE OF TECHNOLOGY	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	6	0
38	SHREEYASH PRATISHTHAN'S, SHREEYASH COLLEGE OF ENGINEERING & TECHNOLOGY	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	18	3
39	KOTI VIDYA CHARITABLE TRUST'S ALAMURI RATNAMALA INSTITUTE OF ENGINEERING AND TECHNOLOGY	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	18	2
40	SHRI VILE PARLE KELAVANI MANDAL'S DWARKADAS J. SANGHVI COLLEGE OF ENGINEERING	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	9	1

41	KONARK INSTITUTE OF SCIENCE AND TECHNOLOGY	Odisha	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	9	1
42	AJEENKYA DY PATIL SCHOOL OF ENGINEERING	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	24	8
43	SHREE L.R. TIWARI COLLEGE OF ENGINEERING	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	12	4
44	ST. FRANCIS INSTITUTE OF TECHNOLOGY (ENGG. COLLEGE)	Maharashtra	ELECTRONICS AND TELECOMMUNICATION ENGINEERING	18	1
45	SWVSM'S TATYASAHEB KORE INSTITUTE OF ENGINEERING AND TECHNOLOGY	Maharashtra	ELECTRONICS AND TELECOMMUNICATION ENGINEERING	24	5
46	MAR BASELIOS COLLEGE OF ENGINEERING AND TECHNOLOGY	Kerala	TELECOMMUNICATION ENGINEERING	18	0
47	BHARATIYA VIDYA BHAVANS SARDAR PATEL INSTITUTE OF TECHNOLOGY	Maharashtra	ELECTRONICS AND TELECOMMUNICATION ENGINEERING	18	0
48	MAHAVIR INSTITUTE OF ENGINEERING AND TECHNOLOGY	Odisha	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	13	
49	DATTA MEGHE COLLEGE OF ENGINEERING	Maharashtra	ELECTRONICS AND TELECOMMUNICATION ENGINEERING	18	0
50	GOVERNMENT COLLEGE OF ENGINEERING ,JALGAON(M.S.)	Maharashtra	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	18	0
51	BARRISTER RANJIT MOHANTY INTERNATIONAL INSTITUTE OF TECHNOLOGY	Odisha	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING	14	4
52	TERNA PUBLIC CHARITABLE TRUST'S TERNA ENGINEERING COLLEGE	Maharashtra	ELECTRONICS AND TELECOMMUNICATION ENGINEERING	18	0

Annexure-II

Sl.no.	Institute Name	State	Program	Total Approved Intake
1	G.NARAYANAMMA INSTITUTE OF TECHNOLOGY & SCIENCE, FOR WOMEN	Telangana	ENGINEERING AND TECHNOLOGY	12
2	GUJARAT TECHNOLOGICAL UNIVERSITY - GRADUATE SCHOOL OF ENGINEERING AND TECHNOLOGY	Gujarat	ENGINEERING AND TECHNOLOGY	18
3	UNIVERSITY INSTITUTE OF SCIENCE AND TECHNOLOGY	Madhya Pradesh	ENGINEERING AND TECHNOLOGY	24
4	SREE DATTHA GROUP OF INSTITUTIONS	Telangana	ENGINEERING AND TECHNOLOGY	9
5	MANIPAL INSTITUTE OF TECHNOLOGY	Karnataka	ENGINEERING AND TECHNOLOGY	30
6	JIS COLLEGE OF ENGINEERING	West Bengal	ENGINEERING AND TECHNOLOGY	18
7	NETAJI SUBHAS UNIVERSITY OF TECHNOLOGY	Delhi	ENGINEERING AND TECHNOLOGY	30
8	SONA COLLEGE OF TECHNOLOGY	Tamil Nadu	ENGINEERING AND TECHNOLOGY	18
9	BHARAT INSTITUTE OF ENGINEERING AND TECHNOLOGY	Telangana	ENGINEERING AND TECHNOLOGY	18

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