**TELECOMMUNICATIONS**

The interdisciplinary telecom program (ITP) offers to students the skills that allow them to master not only the latest technologies associated with the Internet, but also the business skills and policy knowledge essential to achieving success in the companies driving today's rapidly changing high-tech world. Within ITP, students can develop expertise in the growing fields of cybersecurity, wireless, network engineering and telecommunications policy and strategy. We offer hands-on experience in our world-class labs equipped with state-of-the-art technologies.

ITP also offers graduate certificates, where students gain a foundation of knowledge and skills focusing on a specific technology, as well as best practices and tools immediately applicable to the work environment. Graduate certificates aid the development or enhancement of a specialized expertise. Certificates also provide the flexibility to allow course credit hours to be applied toward a master's degree.

For more information, visit the Interdisciplinary Telecom Program (http://www.colorado.edu/itp) website.

**Course code for this program is TLEN.**

**Master's Degree**

- Telecommunications - Master of Science (MS) (catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/telecommunications/telecommunications-master-science-ms)
- Telecommunications - Professional Master of Science (MST) (catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/telecommunications/telecommunications-professional-master-science-mst)

**Doctoral Degree**

- Telecommunications - Doctor of Philosophy (PhD) (catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/telecommunications/telecommunications-doctor-philosophy-phd)

**Certificates**

- Computer and Network Security - Graduate Certificate (catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/telecommunications/computer-network-security-graduate-certificate)
- Network Architecture - Graduate Certificate (catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/telecommunications/network-architecture-graduate-certificate)
- Telecom Policy and Strategy - Graduate Certificate (catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/telecommunications/telecommunications-policy-graduate-certificate)
- Wireless Networks and Technologies - Graduate Certificate (catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/telecommunications/wireless-networks-technologies-graduate-certificate)

**Courses**

- **TLEN 5000 (3) Fundamentals of CyberSecurity for Leaders and Innovators**
  Designed for students without a computer science background, this course introduces core concepts in cybersecurity including, confidentiality, authentication, risk management, and adversarial thinking. The concepts will be applied to both traditional information technology (IT) systems and cyber physical systems (CPS). At the conclusion of the course, students should have a solid foundation in cybersecurity and hands-on experience.
  **Requisites:** Not open to Computer Science (CSCI) majors.
  **Grading Basis:** Letter Grade

- **TLEN 5010 (3) Network Economics and Finance I**
  Introduces students to the fundamental theoretical framework and tools used by economists to examine decision making under scarcity. Reviews mathematical economics and models. Examines consumer choice and firm supply. These two aspects of the market are brought together to examine how price and output are determined in competitive and imperfectly competitive markets. Introduces financial economics, network effects and public goods.
  **Requisites:** Restricted to students with 87-180 credits (Senior) or graduate students in the College of Engineering or Leeds School of Business only.

**Faculty**

While many faculty teach both undergraduate and graduate students, some instruct students at the undergraduate level only. For more information, contact the faculty member's home department.

- Cook, Charles I (https://experts.colorado.edu/display/fisid_149148) Lecturer
- Dehus, Mark D (https://experts.colorado.edu/display/fisid_146046) Lecturer; MS, University of Colorado Boulder
- McManus, Joseph E (https://experts.colorado.edu/display/fisid_152168) Scholar In Residence; MS, Carnegie Mellon University
- Nettleton, Ray W. (https://experts.colorado.edu/display/fisid_125678) Assoc Professor Adjunct; PhD, Nova University
- Perigo, Levi D. (https://experts.colorado.edu/display/fisid_155562) Scholar In Residence; PhD, Carnegie Mellon University
- Reed, David Palmer (https://experts.colorado.edu/display/fisid_152458) Scholar In Residence; PhD, Carnegie Mellon University
- Santos, Jose Ramon (https://experts.colorado.edu/display/fisid_124623) Senior Instructor; MS, University of Colorado Boulder
- Schwengler, Thomas (https://experts.colorado.edu/display/fisid_143850) Lecturer
TLEN 5050 (3) Leading Oneself
Provides working engineers a background in leadership concepts and methods and enables students to develop practical leadership skills through numerous in-class exercises and experimentation based assignments. Topics include authentic leadership, motivating self and others, cultivating emotional intelligence, personal mastery, creating accountability, conflict resolution, leading change and organizational culture. Required for all Engineering Management degree students. Equivalent - Duplicate Degree Credit Not Granted: EMEN 5050
Requisites: Restricted to Engineering Management graduate students.

TLEN 5100 (3) Next Generation Networks
Provides an in-depth immersion into the foundational theories and technologies of Software-Defined Networking (SDN), Network Functions Virtualization (NFV), and emerging technologies for computer networks. Students will gain direct experience with real-world lab experiments and demonstrations, which will give them an advantage in the job market for this in-demand, constantly changing subject. Requisites: Requires prerequisite TLEN 5330 (minimum grade C). Restricted to TLEN graduate students.
Grading Basis: Letter Grade

TLEN 5106 (3) International Deployment of Broadband Networks
Evaluates the business potential for deploying fixed or mobile broadcast networks in an international context. Guides students to develop financial statements to evaluate the investment potential of the venture. Covers: strategy, market potential, sales channels, costs, regulatory and financial issues all in an international context. Project teams mimic the matrix structure of working teams in business context and present to an investor their recommendations. Requisites: Restricted to students with 87-180 credits (Senior) or graduate students in the College of Engineering or Leeds School of Business only.

TLEN 5130 (3) Telecommunications Business Strategy
Covers concepts, strategies, and practical implementation of market oriented business strategy in the telecom industry grounded with real world examples. Topics include positioning, segmentation/targeting, technology adoption, advertising/outreach, communication strategies, product management, sales process and business intelligence. Requisites: Requires prerequisite course of TLEN 5010 (minimum grade D). Restricted to graduate students only.

TLEN 5150 (1) Managing Effectively in a Changing Telecommunications Environment
Provides students with an opportunity to join international managers and policy makers from around the world in an intensive seminar focused on the challenges of managing in a telecommunications environment in an era of technological change. Guest lecturers provide an effective overview of the cutting-edge issues managers face in telecom and technology companies around the world. Equivalent - Duplicate Degree Credit Not Granted: ATLS 5150

TLEN 5190 (3) Standardization and Standards Wars
Examines current issues and strategy in the standardization of telecommunications and information technologies. Covers topics on the importance of standards, government and private sector perspectives, and impact of information age technologies on standards development. Introduces students to relevance of antitrust and intellectual property law to the topic. Equivalent - Duplicate Degree Credit Not Granted: ATLS 5190

TLEN 5210 (3) Principles of Telecommunications Policy
Learn the key issues and principles that guide the decisions of policy makers with respect to the regulatory treatment of voice, video and data communications. Engage in critical debate, and develop instincts for anticipating the likely regulatory models that may be applied to new technologies. This introductory course covers technical, economic, legal, political and institutional considerations.

TLEN 5230 (3) Spectrum Management and Policy
Studies how spectrum policy is developed and implemented. A general framework is developed for understanding telecommunications law and regulatory objectives. Specifically analyzes international and domestic dimensions of spectrum policy. Considers how economics, administrative processes and innovative technologies affects management of the spectrum. Requisites: Restricted to Telecommunications (TLEN) graduate students only.

TLEN 5240 (3) Telecommunications Law and Policy
Examines laws governing telecommunications industries, including federal and state regulation and international aspects. Includes telephone, cable, satellite, cellular and other wireless systems and the Internet. Equivalent - Duplicate Degree Credit Not Granted: LAWS 7241 Repeatable: Repeatable for up to 6.00 total credit hours. Requisites: Restricted to TLEN or BUSN graduate Students

TLEN 5245 (3) Introduction to Intellectual Property Law
Provides an overview of our nation's intellectual property laws, including patent, copyright, trademark, trade secret and also discusses other assorted matters related to intellectual property, including licensing, competition policy issues and remedies. Equivalent - Duplicate Degree Credit Not Granted: LAWS 6301 Requisites: Restricted to TLEN graduate students.

TLEN 5250 (2-4) Technology Law and Policy Clinic
Features technology law advocacy before administrative, legislative and judicial bodies in the public interest. Instructor consent required. Equivalent - Duplicate Degree Credit Not Granted: LAWS 7809 Requisites: Restricted to TLEN graduate students.
Grading Basis: Letter Grade

TLEN 5260 (3) Seminar: Law and Economics of the Information Age
Examines basic regulatory and legal challenges of our information economy and digital age. Emphasizes the "networked" information industries, the proper role of " unbundling" policies to advance competition and how intellectual property and antitrust rules should be developed. Equivalent - Duplicate Degree Credit Not Granted: LAWS 8341 Requisites: Restricted to TLEN graduate students.

TLEN 5265 (3) Copyright
Examines state and federal laws relating to the protection of works of authorship ranging from traditional works to computer programs. Studies the 1976 Copyright Act as well as relevant earlier acts. Gives attention to state laws, such as interference with contractual relations, the right of publicity, moral right, protection of ideas and misappropriation of trade values, that supplement federal copyright. Equivalent - Duplicate Degree Credit Not Granted: LAWS 7301 Requisites: Restricted to TLEN graduate students.
TLEN 5300 (1-3) Telecommunications Theory and Applications
Examines the mathematical and physical theory of telecommunications. Deals with the fundamental concepts related to a wide range of topics including physical units, numbering systems, trigonometric functions, logarithms, indices, decibels, complex numbers, calculus, elementary probability, and power circuit analysis.
Repeatable: Repeatable for up to 3.00 total credit hours. Allows multiple enrollment in term.

TLEN 5310 (3) Telecommunications Systems
Reviews fundamental technical concepts and terminology in telecommunications. Topics of focus include: decibels, noise analysis, transmission lines, electronic signals, radio spectrum characteristics, link budgets, AM modulation, angle modulation, digital modulation, multiplexing, sampling and digital encoding, detection, and similar physical layer concepts. Systems for analysis include CATV, cellular wireless, WLAN, satellite systems, internet networking and related voice and data networks.
Requisites: Require pre-requisite of TLEN 5310 (minimum grade C-). Restricted to TLEN graduate students or BUSN graduate students.

TLEN 5330 (3) Data Communications 1
Provides a comprehensive technical survey of data and computer communications including Wireless, LAN, MAN, and WAN systems and standards. Covers packet switching, internetworking, addressing, routing, transport layers, TCP/IP internet, wired and wireless LAN technologies, congestion control and flow control schemes.
Requisites: Restricted to ITP (TLEN-MS) students only.

TLEN 5340 (3) VOIP Network Design
Focuses on VoIP network design and optimization. The emphasis is on the convergence of VoIP, PSTN and cell phone networks and signaling. Topics include voice processing as well as IP and SS7 signaling. In addition there will be a review of ISDN, DSL, Sonet, ATM, SIP and MPLS. There will be a case problem for sizing a VoIP network using silence suppression.
Requisites: Requires corequisite of TLEN 5310. Restricted to TLEN or BUSN graduate students.

TLEN 5350 (3) Commercial Spaceflight Operations and Communications
Aimed at a high level fundamental understanding of broadcasting, communication and navigation satellite systems. Topics include orbital mechanics, orbit selection, spacecraft subsystems, spacecraft and earth station configurations, propagation issues, link budgets, modulation and multiplexing techniques, multiple access schemes (FDMA, TDMA, CDMA), error control coding, satellite network architecture, and economic, regulatory and business issues in Geo, Meo, and Leo systems.
Requisites: Requires corequisite of TLEN 5330. Restricted to graduate students in TLEN or BUSN.

TLEN 5370 (3) IP Routing Protocols
Breaks IP routing technologies into two fundamental pieces: an in-depth study of interior and then exterior gateway protocols. Open to Juniors and Seniors with instructor consent.
Requisites: Restricted to graduate students only.

TLEN 5380 (3) Future of Video: Technology, Policy, and Economics
Examines the issues that have been created by the shift from analog to digital technologies, the shift from narrowband/wideband systems to broadband systems, and the shift to converged networks (i.e. networks able to convey voice, data, image and video traffic on a common platform) based upon packet switching and Internet Protocol (IP) suite. Equivalent - Duplicate Degree Credit Not Granted: ATLS 5380
Requisites: Requires prerequisite courses of TLEN 5210 (minimum grade D-). Restricted to graduate students only.

TLEN 5410 (3) Network Management and Operations
Offers students a hands-on experience programatically managing network hardware and essential network services such as DHCP, DNS, ARP, FTP, Telnet, HTTP, SSH, SMTP, TFTP and SNMP through the use of cross-platform scripting. Students with little or no programming experience will learn scripting by replicating functionality provided in common management suites such as HP OpenView, Nagios, Zennos, IBM Netview and others.
Requisites: Requires pre-requisite of TLEN 5330. Restricted to TLEN graduate students.

TLEN 5430 (3) Data Communications 2
Provides a detailed technical study of Internet and Internet-related protocols following a top-down approach through the protocol stack. Bit-level analysis of a large number of Internet and Internet-related protocols, including the study of classic protocol suite principles. Covers real time and near real-time data streaming, IP mobility, IPv6, and an introduction to Internet security.
Requisites: Requires prerequisite course of TLEN 5330 or CSCI 4273 or CSCI 5273 (minimum grade D-). Restricted to TLEN or CSCI or BUSN grad students, or TLEN BS/MS students (C-AMENTLEN; C-CSCTITLEN; C- CSENTLEN; C-ECENTLEN).

TLEN 5438 (3) Internet Lab
Have you ever wondered how the Internet actually works? This course teaches students simple, hands-on understanding of the technical components and challenges of providing Internet Services to everyday users. This is the ideal course for technical or non-technical students who have a passion for the Internet or need to have a more detailed understanding of the Internet within their career.
Grading Basis: Letter Grade

TLEN 5460 (3) Corporate Internet Networking Laboratory
Provides direct experience with Internet technologies and equipment through experiments. Students learn the fundamental operation of data networking and services. Each experiment focuses on some particular aspect of design, management, or maintenance of Enterprise Networks. Procedures make use of actual commercial equipment, applications and services. Student teams and laboratory are defined during the first lecture meeting. Lab sessions require additional 8 hours of work.
Requisites: Requires prerequisite course of TLEN 5330 (all minimum grade D-). Restricted to TLEN Grad students in the Network Engineering (NET) Track.

TLEN 5462 (3) Datacenter Networks
Covers design and configuration principles required to build highly scalable and highly redundant network solutions used by datacenters. Class makes use of commercial grad equipment to build network topologies and services. Students will work in teams to build a virtualized cluster, load balance application traffic between multiple server blades, assure high availability in Ethernet and IP layers, and able to prioritize important services using QoS. Lab sessions require additional 8-12 hours of work per week.
Requisites: Requires prerequisite of TLEN 5460 (minimum grade D-). Restricted to TLEN graduate students.

TLEN 5510 (3) Wireless and Cellular Communications
Presents in detail the technologies and architectures employed in cellular and other modern wireless systems and discusses regulatory and other industry issues. Major topics include radio technology, multiple access techniques, analog and digital cellular telephony, and personal communications systems.
Requisites: Restricted to TLEN or BUSN grad students, and TLEN BS/MS students (C-AMENTLEN; C-CSCTITLEN; C-CSENTLEN; C-ECENTLEN).
TLEN 5520 (3) Wireless Local Area Networks
Examines small-scale wireless networks particularly personal and local area networks. Covers licensed and unlicensed spectrum, indoor and small-scale radio propagation, modulation techniques, network topologies, ad hoc and infrastructure networks, protocol design, TCP/IP-wireless interactions and protocol standards.
Requisites: Requires prerequisite course of TLEN 5310 or TLEN 5330 (minimum grade D-). Restricted to TLEN graduate students only.

TLEN 5530 (3) Applied Network Security
Examines the critical aspects of network security. A technical discussion of threats, vulnerabilities, detection, and prevention is presented. Issues addressed are cryptography, firewalls, network protocols, intrusion detection, security architecture, security policy, forensic investigation, privacy, and the law.
Requisites: Restricted to CSCI juniors and seniors, or TLEN or CSEN graduate students, or TLEN BS/MS students (C-AMENTLEN; C-CSCI-TLEN; C-CSENTLEN; C-ECENTLEN).

TLEN 5540 (3) Network Security Laboratory
Applies what students have learned in computer and network security foundations in a simulated network environment. Topics to be covered include: system hardening, firewalls, intrusion detection, vulnerability assessment, and investigation.
Requisites: Restricted to CSCI juniors and seniors, or TLEN or CSEN graduate students, or TLEN BS/MS students (C-AMENTLEN; C-CSCI-TLEN; C-CSENTLEN; C-ECENTLEN).
Recommended: Prerequisite TLEN 5530 and operating system experience.

TLEN 5550 (3) Computer and Network Security
Studies methods to protect information, and the ability to process and move information, from theft, misuse, tampering, destruction and unauthorized access. Introduces foundational topics of computer and network security, including security models, cryptography and authentication protocols.
Equivalent - Duplicate Degree Credit Not Granted: CSCI 6268
Requisites: Restricted to Engineering Graduate Students and TLEN BS/MS students (C-AMENTLEN; C-CSCI-TLEN; C-CSENTLEN; C-ECENTLEN).
Recommended: Prerequisites CSCI 5273 and significant experience in coding (C or C++) and some experience in networks and familiarity with TCP/IP, UDP and ICMP.

TLEN 5560 (3) Wireless Systems Laboratory
Serves as hands-on exploration of wireless communication systems. Designed to complement TLEN 5510 and TLEN 5520 by taking several subjects to greater depth. Students will work with, and in some cases build, radio frequency test equipment, transmitters, receivers, antennas and wireless communication systems.
Requisites: Requires prerequisite of TLEN 5310 (minimum grade C-). Restricted to TLEN graduate students.
Recommended: Corequisite TLEN 5510 or TLEN 5520.

TLEN 5570 (3) IP Network Design
Implement fundamentals of IP Routing Protocols and apply them directly to design based networking problems. Design scenarios will incorporate physical and logical design, financial analysis, and laboratory configuration.
Requisites: Requires prerequisite course of TLEN 5370. Restricted to TLEN graduate students only.

TLEN 5585 (3) Service Provider Networks
Presents advanced networking design and implementation techniques through experiments with network measurement equipment, switches, router, and management interfaces. Primarily focuses on Service Provider Transport technologies for capacity, scalability and fault tolerance. Students learn the essential network architectures of last mile and long haul network solutions used for public and private network traffic transport; implementation of SLAs, load balancing, first hop redundancy, and MPLS transport and L2/L3 VPN solutions.
Requisites: Requires prerequisite of TLEN 5460 (minimum grade C).
Grading Basis: Letter Grade

TLEN 5600 (1) Telecommunications Seminar
Introduces students to major topics and research at the interface of technology, cybersecurity, and policy by providing a weekly series of lectures with questions and discussion, including guest speakers.
Repeatable: Repeatable for up to 4.00 total credit hours.
Requisites: Restricted to Telecommunications (TLEN) graduate students only.
Grading Basis: Pass/Fail

TLEN 5700 (2) Research Methods
Develop basic concepts and methods for pursuing quantitative and qualitative research. Students will develop a research proposal that will be completed in TLEN 5710 or as a Master’s Thesis. Writing skills test required.
Requisites: Restricted to TLEN or BUSN graduate students

TLEN 5710 (1-3) Capstone
Complete Capstone research project initiated in TLEN 5700.
Repeatable: Repeatable for up to 3.00 total credit hours.
Requisites: Requires prerequisite course of TLEN 5700. Restricted to TLEN or BUSN graduate students only.

TLEN 5830 (1-6) Special Topics
Repeatable: Repeatable for up to 15.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to Telecommunications (TLEN) graduate students only.

TLEN 5840 (3) Voice Over IP Lab: Voice Network Design and Implementation
Provides an in-depth immersion into the foundational theories and technologies of Voice Over IP (VoIP), and direct experience with real-world, hands-on lab experiments and demonstrations. In this class students will learn the fundamentals of voice technologies, services and tools used in industry to design, deploy and troubleshoot VoIP networks.
Requisites: Requires pre-requisite of TLEN 5330. Restricted to TLEN graduate students.
Grading Basis: Letter Grade

TLEN 5841 (3) Secure Web Application Development
Learn to develop and protect secure applications for web and mobile. Students will develop in a production cloud environment mirroring industry trends. Techniques to resist attackers and increase situational awareness will be covered. The class culminates with an end of semester project applying secure coding techniques to build a secure web application from start to finish.
Requisites: Restricted to CSCI juniors and seniors, or TLEN or CSEN graduate students, or TLEN BS/MS students (C-AMENTLEN; C-CSCI-TLEN; C-CSENTLEN; C-ECENTLEN).
Grading Basis: Letter Grade
TLEN 5842 (3) Linux Systems Administration
Introduces Linux system administration and related topics, including
trouble-shooting system and network problems, hardware and software
configuration and installation, basic scripting, and security aspects of
internet hosts. Students build Linux servers from the ground up, using
provided computing resources, and must maintain and secure the servers
themselves.
Requisites: Restricted to CSEN or TLEN graduate students or TLEN BS/
MS students only.
Grading Basis: Letter Grade

TLEN 5920 (1-6) Independent Study
Repeattable: Repeatable for up to 6.00 total credit hours. Allows multiple
enrollment in term.
Requisites: Restricted to TLEN graduate students.

TLEN 6100 (3) Advanced Next Generation Networks
This course provides an advanced, in-depth immersion into the theories
and technologies of Software-Defined Networking (SDN), Network
Functions Virtualization (NFV), and emerging technologies for computer
networks. Students will expand on the experience with real-world
lab experiments and demonstrations learned from the course pre-
require (TLEN 5100-Next Generation Networks), which will give them
an advantage in the job market for this in-demand, constantly changing
subject.
Requisites: Requires prerequisite of TLEN 5100 (minimum grade B-).
Restricted to TLEN graduate students.
Grading Basis: Letter Grade

TLEN 6438 (3) Internet Lab 2
Builds on TLEN 5438 Internet Lab, and teaches students simple, hands-on
understanding of the technical components and challenges of providing
Internet Services to everyday users. This is the ideal course for students
with a basic foundation of technology who have a passion for the Internet
or need to have a more detailed understanding of network security and
wireless networks within their career.
Requisites: Requires prerequisite TLEN 5438 (minimum grade B-).
Grading Basis: Letter Grade

TLEN 6940 (1) Candidate for Degree
Requisites: Restricted to TLEN graduate students.
Grading Basis: Pass/Fail

TLEN 6950 (1-6) Master’s Thesis
Requisites: Restricted to TLEN graduate students.

TLEN 7000 (1-6) Current Topics in Telecommunications
Studies research topics of current interest in telecommunication and
networking.
Repeatable: Repeatable for up to 8.00 total credit hours.
Requisites: Restricted to TLEN graduate students.

TLEN 7001 (3) Interdisciplinary Telecom Analysis
Examines a set of problems, research methodologies and analytical
techniques that are common to the research, problem solving and
analysis of information and communications technology development and
deployment issues. Looks critically at the strengths, limitations and
underlying assumptions of key research and analysis approaches that
relate business, economic and policy objectives to current and future
telecommunications development and deployment efforts.
Requisites: Restricted to TLEN graduate students.
Grading Basis: Letter Grade

TLEN 8990 (1-10) Doctoral Dissertation
Investigates specialized topic or field in the area of telecommunications.
Approved and supervised by faculty members.
Requisites: Restricted to TLEN PhD student