

## Master of Science in Wireless and Network Engineering

### 1. Program description

The Institute for the Wireless Internet of Things and the Department of Electrical and Computer Engineering propose a new **Master of Science in Wireless and Network Engineering**. This program is aimed at preparing highly qualified researchers and a specialized workforce that will lead the future of our hyperconnected society. The program will provide students with the necessary knowledge and skills to understand, design and implement present and future wireless and wired communication networks, through a combination of coursework, master thesis research and/or industry experience.

The Master of Science in Wireless and Network Engineering is structured as follows: a total of 32 credits are required, which students can obtain by following one of two tracks, namely, *course-only* and *thesis-course*. All students are required to complete 8 *semester hours* (SH) in *core courses* (two courses of 4 SH each), and either 24 or 16 SH in *elective courses* for course-only and thesis-course options, respectively. Thesis-course students will complete their requirements by taking thesis credits (8 SH). The courses are primarily from the ECE graduate curriculum, with courses from the CS graduate curricula identified as breadth courses to complement the ECE offerings. The program largely depends on existing courses; therefore, it could start being offered as early as Fall 2022 in Boston, and then being expanded to regional campuses after appropriate approval. New courses are being designed to bring the proposed program up to date with current and trending technology and national and international regulations.

### 2. Program contributions to the university's mission

The proposed program is well aligned with the department, college, institute, and university objectives:

- At the **department level**, the program builds on the strengths of both electrical engineering (communications, signal processing and control) and computer engineering (computer networking and security) and offers an integrated path for students who want to cover the entire protocol stack, from communications and signal processing to networking and application. Traditionally, this has not been the case as students with an interest in communication networks have been asked to choose between the Communications, Control and Signal Processing (CCSP) or the Computer Networks and Security (CNWS), creating a historical artificial division between classical communication theory and modern computer networks and internetworking.
- At the **college level**, the program builds on the existing strengths and international leadership of our faculty in research initiatives that continue to shape the future of our hyperconnected society. Wireless and Network engineering are foundational for any aspect of society.
- At the **institute level**, the Institute for the Wireless Internet of Things (WIoT) is at the forefront of next generation wireless and wired communication networks, with emphasis on 6G wireless systems, the use of machine learning for network orchestration and management, and, overall, large scale experimental research. All these will be key components of the proposed program.
- At the **university level**, the program contributes to the mission of providing an innovative, experientially driven education to students who can make a positive impact on society. Students graduating from this program will be equipped with theoretical and experimental tools to address critical societal needs, such as the development of technologies to bridge the digital divide in our nation and in the world.

### 3. Program market analysis

#### a. Projected Demand

Since their inception, computer networks and the Internet have changed the way we live, from how we learn and work to how we shop, entertain, and interact with one another. In 2018, there were 3.9 billion Internet users (51% of the global population), a number expected to grow to 5.3 billion (66% of global population) by 2023.\* Interestingly, by the same time, the number of devices connected to the Internet will be more than three times the global population. Moreover, over 70% of the global population will have mobile wireless connectivity, 10% of which through 5G devices. **Such wired and wireless networks will not design, deploy, and operate themselves (at least anytime soon), but will require a highly qualified workforce** covering all the wireless and network engineering aspects ranging from hardware design and electromagnetic characterization to communication techniques and networking protocols for present and future network generations (from 5G to 6G and beyond).

To develop such a highly qualified workforce is the goal of this program. From the expected growth in networked systems, the skills that the proposed program will provide to students are and will continue to be in high demand not only by industry, but also by any entity (federal agencies, national research labs, K-12 and higher education institutions, etc.) devoted to remaining meaningful in our future society. In fact, 5G and 6G wireless systems alone will affect 100% of the national economy, creating some 4.6 million jobs by 2034.\*\*

\* Cisco Annual Internet Report (2018–2023) White Paper

<https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html>

\*\* M. Mandel and E. Long, “The third wave: How 5G will drive job growth over the next fifteen years,” *PPI Radically Pragmatic*, September 17, 2020. <https://www.progressivepolicy.org/publication/the-third-wave-how-5g-will-drive-job-growth-over-the-next-fifteen-years/>

#### b. Relation with Existing Programs at Northeastern University

The proposed program partially overlaps with the existing Computer Networks and Security (CNWS) concentration and, to a lesser extent, with the Communications, Control and Signal Processing (CCSP) concentration, both in the Master of Science in Electrical and Computer Engineering. As mentioned above (Sec. 2), the proposed program aims at bridging the historical yet unnecessary divide between communications (traditionally EE) and networking (traditionally CE). In agreement with the Graduate Affairs Committee and the Chair of ECE, the plan is to let the CNWS concentration phase out.

The other potentially related program in the Master of Science in Telecommunication Networks offered directly by the College of Engineering under the MGEN programs. The focus of that program is more on preparing *practitioners* of current computer networks, without leveraging the research capabilities available to the Department of ECE or the Institute for the Wireless Internet of Things.

#### c. Relation with Industry and Opportunities for Coop

WIoT has strong relationships with several companies in the wireless, defense, computing, and manufacturing areas, which are sponsoring WIoT’s research or partnering in various ways with WIoT faculty and researchers. These companies, which include AT&T, Raytheon, Verizon, MITRE, Interdigital, Mavenir, Dell, NVIDIA, Qualcomm, Draper, Facebook, Red Hat, Mathworks, JMA Wireless, VIAVI, Keysight, National Instruments, US Ignite, Intelligent Automation, Andro Computational Solutions, Airanaculus, will be targeted as coop partners for the new program.

#### d. Competition from Other Programs

With the continuously growing demand for wireless and network engineers, it is not surprising that other

top institutions are revamping their offerings in the same. Nevertheless, **none of the existing programs** in other institutions (summarized in Table 1) currently offer or **can match the unique experiential components that, through the Institute for the WIoT, this program offers**. These include, among others, access to Colosseum, the world’s largest wireless RF emulation platform, and X-Mili and TeraNova, i.e., the largest millimeter-wave and terahertz networking platforms in the nation. Our testbeds leverage the exclusive Innovation Zone designation of both Boston and Burlington’s campuses by the US Federal Communications Commission (FCC). (There are only a handful of such Innovation Zones in the country.) Last, but not least, through direct participation from members of the Institute for the Wireless Internet of Things, Northeastern University is one of the handful academic institutions to be part of the International Telecommunication Union (ITU), the United Nations specialized agency for information and communication technologies. Our premier position in both national (FCC) and international (ITU) telecommunication landscapes will make our proposed educational programs even more unique and compelling for anybody interested in pursuing a graduate degree in wireless and networked systems.

University Name	Location	Program and Link
Southern Methodist University	Dallas, TX	<a href="#">MS in Network Engineering</a>
Boston University	Boston, MA	<a href="#">MS in Computer Networks</a>
Rochester Institute of Technology	Rochester, NY	<a href="#">MS in Communication Networks</a>
UC Boulder	Boulder, CO	<a href="#">Prof. Master's in Network Engineering</a>
Vanderbilt University	Nashville, TN	<a href="#">MS in Cyber-Physical Systems</a>
U Mass Lowell	Lowell, MA	<a href="#">MS in Microwave &amp; Wireless Eng</a>
University of Southern California	Los Angeles, CA	<a href="#">MS in Electrical Engineering - Wireless Networks</a>
Tufts University	Medford, MA	<a href="#">Certificate in Microwave &amp; Wireless Engineering</a>
Illinois Tech	Chicago, IL	<a href="#">M. Eng. Wireless Comm &amp; Computer Networks</a>
Lehigh University	Bethlehem, PA	<a href="#">MS in Wireless Comm &amp; Network Eng</a>
University of Houston	Houston, TX	<a href="#">MS in Engineering Tech - Network Comm</a>
University of Southern Florida	Tampa, FL/Online	<a href="#">Grad Certificate in Wireless Engineering</a>
Columbia University	New York, NY/ Online	<a href="#">MS in Comp Sci - Network Systems</a>
UCLA	ONLINE	<a href="#">MS in Engineering - Comp Networking</a>
UC Irvine	Irvine, CA	<a href="#">MS, Networked Systems</a>
University of New Haven	New Haven, CT	<a href="#">MS, Cybersecurity &amp; Networks</a>
University of Advancing Technology	Tempe, AZ	<a href="https://www.uat.edu/network-engineering-degree">https://www.uat.edu/network-engineering-degree</a>
University of New Hampshire	Online	<a href="#">Grad Certificate in Wireless Comm Systems</a>
Capitol Technology University	Laurel, MD	<a href="#">AAS in Wireless Engineering Tech</a>
UCSD	La Jolla, CA	<a href="#">MAS - Wireless Embedded Systems</a>

#### 4. Program requirements

##### *a. Admission criteria and process*

The Master of Science in Wireless and Network Engineering will apply the high standards and admission criteria of all the ECE Graduate Programs. In general, successful applicants to the program will have a background in electrical and/or computer engineering, in computer science, or other related disciplines. **Strong candidates in other STEM disciplines**, including both engineering and sciences (e.g., physics, math) with prior exposure to calculus, linear algebra, probability theory and programming will also be considered.

The admission criteria for the program are:

- Undergraduate degree with a minimum GPA of 3.00.
- Statement of purpose including description of relevant work experience.

- TOEFL: 100 (for international applicants with a bachelor's degree from a non-native English speaking country).
- Two (2) letters of recommendation from professional and/or academic references.

We explicitly **remove the GRE requirement** from this list, as it does generally not reflect the actual skills needed by a wireless and network engineer. This is in line with other graduate programs in top engineering institutions in the nation.

The applicants to the program will be reviewed by an admission committee created within the WIoT and chaired by the MS program director.

#### b. Degree requirements

The program requires 32 credits in total. To meet this requirement, students are required to take a varying number of *semester hours* (SH) in core and elective courses as well as in experiential components (either industry experience or research experience), according to their program track. In particular, the program defines three tracks:

- **Course-only track:**
  - o 8 credits in the form of 2 core courses
  - o 24 credits in the form of 6 elective courses
- **Thesis-course track:**
  - o 8 credits in the form of 2 core courses
  - o 16 credits in the form of 4 elective courses
  - o 8 credits in the form of a MS thesis

For Course Courses, students need to select 2 out of 3 among:

- EECE 7374 Fundamentals of Computer Networks
- EECE 5576 Wireless Communication Systems
- EECE 7364 Mobile and Wireless Networking

The elective courses are given in Appendix 1.

### **5. Program assessment (based on the NECHE E-series)**

#### a. Student Learning Outcomes

Students who complete the Master of Science in Wireless and Network Engineering will be able to:

- **Outcome 1:** Understand the state-of-the-art wireless and wired communication network architectures, including their building blocks, functionalities, and integration.
- **Outcome 2:** Design, implement and orchestrate wired and wireless communication networks, utilizing theoretical, numerical, and experimental tools.
- **Outcome 3:** Anticipate and adapt to new distributed application requirements, networking architectures and communication techniques.

#### b. Assessment

##### *Collection and Interpretation of Evidence*

In addition to the students' GPA and, when applicable, the MS thesis grade, the ability of the program to provide students with the targeted learning outcomes will be assessed through as follows:

- **Direct assessment:** this will include an anonymized assessment of student coursework to be sampled at random from the depth courses. Selected work will be cumulative and synthetic to each course, such as final projects. The program faculty will develop quality rubric to assess the outcomes of each course and the level of achievement by current students. Coursework will be sampled annually.
- **Indirect assessment:** this will include standard institutional metrics including but not limited application statistics, enrollment data, completion and persistence rates, TRACE evaluations, and

student surveys (current and graduate). The program will also conduct student interviews (group and individual) to understand student perceptions of program and course operation.

**The collected information will be interpreted by the MS Program Director together with the WIoT Education and Workforce Development (EWD) Committee.** The assessment will be utilized to continually improve the admissions rubric, identify curricular gaps, employment/coop trends, as well as program strengths and weaknesses. The Assessment, Evaluation, Feedback & Intervention System (AEFIS) platform, which is already well-integrated with Canvas and other assessment information requirement tools at Northeastern, will be adopted from the beginning to facilitate the program assessment.

The timeline for assessment will be as follows:

- **Current student survey:** every summer
- **MS thesis grade:** every semester
- **Graduate surveys:** annually after graduation of first cohort
- **TRACE evaluation:** every semester
- **Program data** (which includes admission rubric review, persistence and completion rate, and grade distribution review): every summer

**6. Program accreditation or adherence to licensing standards (if applicable)**

Not applicable currently.

**7. Resources**

The Master of Science in Wireless and Network Engineering program will be based upon existing resources in the Department of Electrical and Computer Engineering, the Institute for the Wireless Internet of Things, and the College of Engineering.

**8. Budget (for Provost Office review only)**

- a. Provide detailed information on the start-up budget needed (prior to any revenue) including marketing expenses.
- b. Using the form below, provide projected enrollment and estimated revenue and expenses for the first five years of the program.

Year	Application Fees	Total Projected Full-Time Headcount	Total Projected Part-Time Headcount	Total Student Credit Hrs Taught	Projected Tuition Revenue @ current rates	Total Expenses (current & new funds) exclude Tuition remission	Total Projected Tuition Remission Expenses	Projected Revenue Less Projected Expenses
One								
Two								
Three								
Four								
Five								

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c. Will any new funds for this program, including tuition remission be required? If so, how much?

Year	Total New Tuition Remission Required (including ongoing new funds from prior year)	Total Other New Funds Required (including ongoing new funds from prior year)	Total New Funds Required -tuition remission and other (including ongoing new funds from prior year)
One			
Two			
Three			
Four			
Five			

d. Include any additional information for consideration.

## Appendix 1: Elective Courses

EECE 5155 Wireless Sensor Networks and the Internet of Things  
EECE 5360 Combinatorial Optimization  
EECE 5610 Digital Control Systems  
EECE 5612 Statistical Inference: An Introduction for Engineers and Data Analysts  
EECE 5640 High-Performance Computing  
EECE 5641 Introduction to Software Security  
EECE 5643 Simulation and Performance Evaluation  
EECE 5644 Introduction to Machine Learning and Pattern Recognition  
EECE 5645 Parallel Processing for Data Analytics  
EECE 5666 Digital Signal Processing  
EECE 5693 Electromagnetic Devices for RF and Wireless Communications  
EECE 5697 Acoustics and Sensing  
EECE 5698. ST GNSS Signal Processing  
EECE 5698. ST Network Programming  
EECE 5699 Computer Hardware and System Security  
EECE 7200 Linear Systems Analysis  
EECE 7202 Electromagnetic Theory 1  
EECE 7204 Applied Probability and Stochastic Processes  
EECE 7205 Fundamentals of Computer Engineering  
EECE 7242 Integrated Circuits for Mixed Signals and Data Communication  
EECE 7245 Microwave Circuit Design for Wireless Communication  
EECE 7247 Radio Frequency Integrated Circuit Design  
EECE 7275 Antennas and Radiation  
EECE 7352 Computer Architecture  
EECE 7336 Digital Communications  
EECE 7345 Big Data and Sparsity in Control, Machine Learning, and Optimization  
EECE 7337 Information Theory  
EECE 7393 Analysis and Design of Data Networks  
EECE 7398 ST Wireless Network Systems and Applications  
EECE 7398 ST An Experimental Approach to Wireless Communications  
EECE 7398 ST Terahertz Communications  
EECE 7400 Special problems in Electrical and Computer Engineering  
EECE 7990 Master's Thesis 4 SH (course-only students cannot take this course)

CS 5520 Mobile Application Development  
CS 5610 Web Development  
CS 6620 Fundamentals of Cloud Computing  
CS 6650 Building Scalable Distributed Systems  
CY 6740 Network Security  
CS 7610 Foundations of Distributed Systems