



University Senate TRANSMITTAL FORM

Senate Document #:	17-18-04
PCC ID #:	16053
Title:	Establish a Post-Baccalaureate Certificate in Computing Systems
Presenter:	Dylan Roby, Chair, Senate Programs, Curricula, and Courses Committee
Date of SEC Review:	August 29, 2017
Date of Senate Review:	September 6, 2017
Voting (highlight one):	<ol style="list-style-type: none"> 1. On resolutions or recommendations one by one, or 2. In a single vote 3. To endorse entire report
Statement of Issue:	<p>The A. James Clark School of Engineering and Department of Electrical and Computer Engineering propose to establish a 12-credit Post-Baccalaureate Certificate in Computing Systems. This certificate program will be for students who are enrolled in the Master of Science in Telecommunications program. Computing systems have become ubiquitous and relied upon every day for work, communication, and entertainment. Smart phones, tablets, and wireless access points all contain small embedded computing systems that run software and firmware. Consequently, our society needs professionals who both understand communication technologies and protocols and have the skills to implement and test those technologies in various embedded computing devices.</p> <p>Course requirements for the certificate program include four courses from the following list: ENTS689A Special Topics: Algorithms and Data Structures, and the ENTS669X Special Topics in Computing series. These courses can also be used to fulfill the elective requirements for the Master of Science program.</p> <p>This proposal was approved by the Graduate School Programs, Curricula, and Courses committee on March 17, 2017, and was approved by the Senate Programs, Curricula, and Courses committee on May 5, 2017.</p>

Relevant Policy # & URL:	N/A
Recommendation:	The Senate Committee on Programs, Curricula, and Courses recommends that the Senate approve this new certificate program.
Committee Work:	The committee first considered this proposal at its meeting on April 7, 2017. The committee recommended changes to the proposal. The revised proposal was presented to the committee on May 5, 2017. Zoltan Safar, director of the Master of Science in Telecommunications program, presented the proposal. The revised proposal was unanimously approved by the committee.
Alternatives:	The Senate could decline to approve this new certificate program.
Risks:	If the Senate declines to approve this certificate program, students in the Master of Science in Telecommunications program will lose an opportunity to have their focus in computing systems formally recognized.
Financial Implications:	There are no significant financial implications with this proposal.
Further Approvals Required:	If the Senate approves this proposal, it would still require further approval by the President, the Chancellor, and the Maryland Higher Education Commission.

**THE UNIVERSITY OF MARYLAND, COLLEGE PARK
PROGRAM/CURRICULUM/UNIT PROPOSAL .**

• Please email the rest of the proposal as an MSWord attachment to pcc-submissions@umd.edu.

PCC LOG NO.	16053
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• Please submit the signed form to the Office of the Associate Provost for Academic Planning and Programs, 1119 Main Administration Building, Campus.

College/School: A. James Clark School of Engineering

Please also add College/School Unit Code-First 8 digits:

Unit Codes can be found at: https://hypprod.umd.edu/Html_Reports/units.htm

Department/Program: Department of Electrical and Computer Engineering/Master's in Telecommunications program

Please also add Department/Program Unit Code-Last 7 digits:

Type of Action (choose one):

- | | |
|---|--|
| <input type="checkbox"/> Curriculum change (including informal specializations) | <input checked="" type="checkbox"/> <i>New academic degree/award program</i> |
| <input type="checkbox"/> <i>Renaming of program or formal Area of Concentration</i> | <input type="checkbox"/> New Professional Studies award iteration |
| <input type="checkbox"/> <i>Addition/deletion of formal Area of Concentration</i> | <input type="checkbox"/> New Minor |
| <input type="checkbox"/> <i>Suspend/delete program</i> | <input type="checkbox"/> Other |

Italics indicate that the proposed program action must be presented to the full University Senate for consideration.

Summary of Proposed Action: The Master's in Telecommunications program is proposing a new Graduate Certificate Program in Computing Systems.

APPROVAL SIGNATURES - Please print name, sign, and date. Use additional lines for multi-unit programs.

1. Department Committee Chair Dr. Zoltan Safar Zoltan Safar 02.16.17.
2. Department Chair Dr. Rama Chellappa Rama Chellappa
3. College/School PCC Chair Jenna Bucci Jenna E. Bucci 3/7/17
4. Dean/Dr. Peter Kofinas Peter Kofinas 3/6/17
5. Dean of the Graduate School (if required) Jeffy Franke, Jeffy Franke 4/12/2017
6. Chair, Senate PCC Andrew Harris Andrew Harris 5/5/17
7. University Senate Chair (if required) _____
8. Senior Vice President and Provost _____

Proposal to Establish a Graduate Certificate in Computing Systems

I. OVERVIEW

A. Overview and Rationale

Established in 1992, the Master of Science in Telecommunications (ENTS) program provides a unique cross-disciplinary industry-oriented graduate education in telecommunications. It is run jointly by the Department of Electrical and Computer Engineering in the A. James Clark School of Engineering and the Robert H. Smith School of Business. Combining rigorous technical education with invaluable business insight and entrepreneurial skills, the ENTS program offers students a unique perspective on the telecommunications industry and profession. The ENTS program caters to both full-time students and working professionals. Most ENTS courses are offered once a week and are scheduled in the afternoon or evening to suit working professionals, while some courses additionally offer daytime sections. All ENTS courses are “traditional” (residential) courses; the program does not offer off-campus locations or online options. ENTS students are responsible for a differential tuition rate and the program is considered a self-support unit within the University of Maryland. Currently, approximately 240 students are enrolled and approximately 110-120 MS degrees are awarded each year.

To be considered for admission, applicants to the ENTS program must have earned a bachelor’s degree, typically in a technical field (engineering, computer science, etc.) and have an undergraduate GPA of 3.0. Applicants must also submit a personal statement and three letters of recommendation. To earn the MS in Telecommunications degree, students must successfully complete 30 credits of course work (10 three-credit courses) with a GPA of 3.0 or more and a scholarly paper. A typical ENTS student takes 6-8 core courses (up to 2 of the 8 core courses may be waived if justified) and 2-4 elective courses.

The ENTS program is taught by full-time and part-time instructors employed by the Electrical and Computer Engineering Department and the Robert H. Smith School of Business. They all hold PhDs in their respective fields (engineering/computer science or business), and they all have worked in the industry for several years and have considerable industrial experience.

In the past decades, computing devices have penetrated almost every system we interact with, from handheld devices helping us find the optimal driving route to smart buildings and bridges. Smart phones, tablets, wireless access points have all become ubiquitous, providing us with the means to get connected to the internet, obtain and process information leading to better decision making. All of these devices contain small embedded computing systems that run software and firmware. Thus, our society needs professionals who both understand communication technologies and protocols and have the skills to implement and test those technologies in various embedded computing devices. In the upcoming Internet of Things (IoT) era, we will have more and more of such tiny connected computing devices around us. This certificate aims to help produce professionals who will have the expertise to design, create, test

and configure such devices. We need to create expertise which combines knowledge in telecommunication technology as well as embedded computing skills thereby leading to well-rounded professionals.

We propose the creation of a Graduate Certificate Program in Computing Systems embedded in the ENTS program. The Certificate Program will be offered to current ENTS students, and its aim is to provide official recognition for acquiring focused knowledge in a particular subfield of telecommunications. Over the past years, many of our students opted to take additional electives (i.e. electives in addition to meeting the minimum degree requirements) to improve their skill sets and their marketability to employers after graduation. This trend is beneficial to both students and the program as it results in better prepared and more marketable graduates with stronger, focused technical background, thus improving the quality of our graduates. This enhances their transcripts, resumes, and chances of finding employment or promotion in their current employment, further improving the reputation of the ENTS program and its alumni base. We would like to encourage, organize and recognize such efforts by offering the Graduate Certificate in Computing Systems, a well-defined, focused area within telecommunications. The certificate will be comprised of existing ENTS elective courses, which include special topics and advanced topics courses in computing. Within the telecommunications industry, certificates are widely accepted proof of expertise in a given technical subfield such as routing, computer security, etc. A Graduate Certificate is an appropriate recognition for the additional coursework, time and effort the student needs to invest to obtain the knowledge/expertise. The Graduate Certificate in Computing Systems will be one of the several proposed certificates designed to strengthen the ENTS program.

Currently we are witnessing the convergence of computing and communications. More and more computing systems and devices need to also function as a communicating device, and the trend is becoming stronger and stronger. Example applications where communication and computing have already become closely intertwined are: cloud computing, smart phones, smart televisions, and set top boxes. Examples of applications that will soon become ubiquitous are: Internet of Things (IoT) devices, smart homes, smart watches, smart cars, smart grid, software defined networking and network function virtualization. In fact, it is hard to find any computing systems that can function without communicating with other systems and/or humans.

The aim of the Graduate Certificate in Computing is to extend the knowledge and skills of our students in the direction of computing, including algorithms and data structures, embedded and high-performance computing and machine learning. The core components of the ENTS program provide a strong foundation in traditional telecommunications, such as wireless communications and computer networking, but they do not provide a similarly solid background in computing. Based on the above described trends in the industry, we feel that such a certificate program would fill an important need by providing additional specialized knowledge and skills that are not present in the core ENTS curriculum. This additional knowledge would produce ENTS graduates who are not only knowledgeable in the traditional areas of telecommunications, but

are also well versed in the very closely related field of computing. The knowledge gained from this Certificate Program would complement the knowledge gained from the core ENTS curriculum and increase the competitive advantage of our students compared to graduates of other telecommunications programs that do not offer specialized courses and certificates in computing systems. While completing the certificate program, students will also acquire/develop additional practical problem-solving, programming and analytical skills. Typical industry positions our students take after graduation that would benefit from this Certificate include: software engineer or software quality engineer (for a software service like Oracle or a business analytics company like Microstrategy), system engineer, or cloud engineer.

The Master's in Telecommunications program is unique to the University System of Maryland, and thus adding certificate programs for current ENTS students would not replicate or detract from any existing programs. Since the ENTS program specializes in Telecommunications, we offer a wide range of special-topics and advanced-topics courses in computing that no other units offer. The ENTS electives will serve as the basis for the proposed Graduate Certificate Program.

The University of Colorado Boulder offers the "Interdisciplinary Telecom Program" (ITP). UCB has marketed ITP as "a highly-integrated and comprehensive program combining technology, policy, and business with hands-on experience." As a peer program to the ENTS, ITP offers a Master of Science in Telecom. MS students have the option to pursue "tracks" in network engineering, wireless engineering, network security and telecom policy. These tracks enable students to tailor the technical content of their degree to prepare themselves for careers in industry. Embedded with the tracks is the opportunity for students, who complete the requirements, to earn the corresponding 12-credit Graduate Certificate. Students may be awarded the certificate while completing the MS degree. ITP also offers the Graduate Certificates to non-degree seeking students. The Graduate Certificates include: Computer and Network Security; Network Architecture; Telecom Policy and Strategy; and Wireless Networks and Technologies.

The Graduate Certificate in Computing Systems allows ENTS students to have the option of enhancing their MS degree with specific technical knowledge and also enable them to remain competitive in the marketplace with graduates from similar degree programs at peer institutions.

Additional information:

<http://www.colorado.edu/itp/>

<http://www.colorado.edu/itp/masters-degree>

<http://www.colorado.edu/itp/prospective-students/graduate-certificates>

B. Student Audience

The Certificate in Computing Systems will only be available to current ENTS students. For a typical ENTS student, this will mean taking 1-2 extra electives in addition to the courses taken to satisfy the MS degree requirements.

Based on the results of a survey we have recently conducted among current ENTS students, there is a significant interest in obtaining Graduate Certificates. Out of 58 responses, 46.6% found a Graduate Certificate very valuable to their portfolios, and 36.2% found it somewhat valuable. Demonstrating their interest, 58.6% responded that they would most definitely obtain a Graduate Certificate if offered, and 32.8% responded that they would most likely obtain one. Finally, 22.4% of the responding students showed interest in obtaining a Graduate Certificate in Computing/Embedded Systems.

We also reached out to 39 ENTS alumni to poll their opinions on the value a Graduate Certificate program. Out of 24 responses, 54.2% found it very valuable, and 37.5% found it somewhat valuable to their portfolios. We also asked if they would encourage current ENTS students to obtain a Graduate Certificate if it was offered, and 45.8% responded “yes, most definitely”, and 41.7% responded “yes, most likely”. Out of the responding alumni, 62.5% responded that they found a Graduate Certificate in the area of Computing/Embedded Systems valuable.

C. Eligibility

Enrollment in this program will be limited to ENTS students, so the admission requirements are the same as the ENTS program’s.

II. CURRICULUM

A. Title

The proposed title is: Graduate Certificate in Computing Systems.

B. Structure and Course Requirements

The ENTS program has grouped its electives into course series according to specialization areas within telecommunications. The course series relevant to computing is Special Topics in Computing. These courses series will be included in the certificate program in order to maintain dynamic and up-to-date program offerings. New courses are offered almost every year to effectively respond to the dynamic changes in the telecommunications industry and to produce graduates who are well versed in the latest technology and telecommunications industry trends. At the end of this section, we will provide an example set of courses satisfying the certificate requirements based on our Spring 2016, Summer 2016 and Fall 2016 offerings.

The Graduate Certificate in Computing Systems is a 12-credit program, by coursework only. The courses taken to earn the Graduate Certificate may also be counted toward meeting the MS degree requirements, and the MS degree and the Graduate Certificate may be earned and

awarded in the same semester. Each student must complete four 3-credit courses from the following list.

- ENTS 689A Special Topics: Algorithms and Data Structures
- 669X Series: Special Topics in Computing

Course Descriptions:

ENTS 689A Special Topics: Algorithms and Data Structures

This course provides both a broad coverage of basic algorithms and data structures and an in-depth discussion on selected important topics. We will learn exact algorithms, heuristics, and counter-example development skills in solving problems in sorting, graph, string, and job scheduling problems. Moderate to heavy programming (in C under UNIX) is expected. Through this study and practice, students will develop and improve their programming and problem solving techniques.

ENTS 669A Special Topics in Computing: Embedded Systems

Prerequisites: Equivalent to undergraduate course on Computer Architecture, equivalent to undergraduate course on Digital Logic Design, equivalent to undergraduate course on programming (preferably C). The first decade of the 21st century was marked by the emergence of smart devices that are used in everyday life. Smart phones, smart cars, smart TVs, smart thermostats, smart vacuum cleaners, just to name a few. These developments are powered in large part by the embedded systems. This course will provide students with the essential knowledge base that will enable them to tackle complex problems encountered in embedded systems design. In addition to the overview of associated hardware components and software methodologies and tools used in the development of modern embedded systems, and theory behind them, the course will include a carefully selected collection of hands-on lab exercises that would help students get a sense of how the presented theoretical concepts connect with the real-world embedded systems applications.

ENTS 669B Special Topics in Computing: Distributed Systems in a Virtual Environment

This course will provide hands-on experience with the administration and configuration of Ubuntu Linux running as a virtual machine under VMware vSphere. Students will learn how to interact with Ubuntu Linux as well as learning fundamentals that can be applied to any Linux distribution. Students will also interact with VMware vSphere and will be provided with an introduction to the vSphere environment. Linux topics will include system architecture and components, kernel, task scheduling, memory management, device drivers, partitioning, file systems, boot processes, command line, customizing the environment, shell scripting, networking, and securing the system. vSphere topics will include hypervisors, virtual machines, virtual hardware, virtual networking, copying, backing up, and migrating. During the lab sessions, students will create virtual machines, manage virtual machines, install Ubuntu Linux on a virtual machine, work with the Linux command

line, customize his/her Linux environment, perform various system administration tasks, write shell scripts, and configure firewalls and other network services.

ENTS 669D Special Topics in Computing Systems: Introduction to Machine Learning

A broad introduction to machine learning and statistical pattern recognition. Topics include: Supervised learning (Bayesian learning and classifier, parametric/non-parametric learning, discriminant functions, support vector machines, neural networks, deep learning networks); Unsupervised learning (clustering, dimensionality reduction, auto-encoders). The course will also discuss recent applications of machine learning, such as computer vision, data mining, autonomous navigation, and speech recognition.

An example course sequence:

1. **ENTS 689A Special Topics: Algorithms and Data Structures** (3 credits)
2. **ENTS 669A Special Topics in Computing: Embedded Systems** (3 credits)
3. **ENTS 669D Special Topics in Computing Systems: Introduction to Machine Learning** (3 credits)
4. **ENTS 669B Special Topics in Computing: Distributed Systems in a Virtual Environment** (3 credits)

III. STUDENT LEARNING OUTCOMES AND ASSESSMENT MEASURES

Since this graduate certificate program will be embedded in the standard ENTS curriculum, the learning outcomes will also be similar to those of the ENTS program. The items relevant to the Graduate Certificate Program are as follows:

1. Academic outcome goals:
 - Students acquire specialized knowledge and skills in the technical area of computing systems. Students acquire/develop practical problem-solving, programming and analytical skills necessary to succeed in industry.
2. Academic outcome assessment measures:
 - Percentage of students mastering the foundations of computing systems: computer architecture, embedded systems, software development for embedded devices, real-time operating systems, and FPGA system design.
 - Percentage of students who work on course-related projects requiring programming
3. Percentage of students acquiring hands-on lab experience using state-of-the art system design and verification tools for embedded software development, FPGA modeling and development and debugging tools.
4. Non-academic outcome goals:
 - Diversity: The ENTS program promotes diversity and strives to admit and educate a diverse student population.

- Degree completion and student retention: The ENTS program will make every effort to help its students from admission to degree completion and minimize the number of students who leave the program without a degree.
 - Quality of learning experience: The ENTS program will actively improve the student experience and increase its perceived value.
5. Non-academic outcome assessment measures:
- Diversity: Percentage of female students; percentage of female faculty /instructors; percentage of minority faculty /instructors
 - Degree completion and student retention: Percentage of students who obtain the graduate certificate within two years after entering the program
 - Quality of learning experience: Graduate student to faculty ratio in the classroom; number of students receiving education in state-of-the art facilities/labs or using state-of-the-art tools; number of offered elective courses in computing systems.

IV. PROGRAM ADMINISTRATION

Administrative oversight and program management will be provided by ENTS staff. This includes student services, academic advising, marketing and outreach, program evaluation and assessment, and degree requirement verification.

A. Program Faculty

The courses for this certificate program are all ENTS courses, so they will be taught by ENTS instructors.

B. Program Offerings

The program will be wholly residential. There will be no off-campus locations nor distance/online education components.

IV. FINANCE (Budget Resources)

The ENTS program is a self-support unit and the Graduate Certificate in Computing Systems program will be administered through its resources.

V. ADDITIONAL RESOURCES

A. Library

No additional resources are needed. See library assessment (Appendix A.)

B. Facilities

No new facilities are required.

C. Outside Academic Units

This program will not rely upon courses provided through other academic units.

D. Personnel

No new personnel are required. The new program will involve a small increase in administrative work for some staff. Existing staff members have experience in handling ENTS student records.



February 13, 2017

VPAC - PCC Committees
University of Maryland
College Park, MD 20742

To whom it may concern:

The R. H. Smith School of Business hereby expresses its support for the new initiatives of the MS in Telecommunications Program to establish graduate certificate programs in (a) Networking Software Development, (b) Wireless Communications and (c) Computing. It is understood that the Electrical and Computer Engineering Department will be responsible for managing all aspects of the above certificate programs as they are based on technical/engineering discipline rather than business discipline.

Sincerely,



Michael Faulkender
Associate Dean, Masters Programs
R. H. Smith School of Business
University of Maryland

DATE: February 7, 2017

TO: Leah Grosse
Program Coordinator, Masters in Telecommunication Program

FROM: On behalf of the University of Maryland Libraries:
Elizabeth Soergel, Engineering Librarian
Maggie Saponaro, Head of Collection Development
Daniel Mack, Associate Dean, Collection Strategies & Services

RE: Library Collection Assessment

We are providing this assessment in response to a proposal by the Department of Electrical and Computer Engineering's Masters in Telecommunications program in the A. James Clark School of Engineering to create a Graduate Certificate in Computing Systems. The Masters in Telecommunications program asked that we at the University of Maryland Libraries assess our collection resources to determine how well the Libraries support the curriculum of this proposed program.

Serial Publications and Research Databases

The University of Maryland Libraries currently subscribe to a large number of scholarly journals—almost all in online format—that focus on telecommunications, including computing systems. Most articles in journals that we do not own electronically are available through either the Libraries' Scan and Deliver program or via Interlibrary Loan. The Libraries' "Database Finder" offers online access to databases that provide indexing and access to popular and scholarly journal articles, and other information sources. Many of these databases cover subject areas that would be relevant to this proposed graduate certificate. These databases can be accessed remotely by authenticating using UMD login credentials.

Most of the relevant research is available through the following databases to which the Libraries subscribe:

- IEEEExplore
- ACM Digital Library
- Web of Science

In addition, the general, multidisciplinary database Academic Search Complete provides information for nearly every area of academic study, including computing systems. Academic

Search Complete includes an enormous collection of the most valuable peer-reviewed full text journals, as well as additional journals, magazines, newspapers and books.

As noted previously, in those instances in which either the Libraries do not subscribe to the journal or the journal articles are available only in print format, the Libraries can supply copies through the Libraries' Scan and Deliver program or via Interlibrary Loan.

Monographs

The Libraries regularly acquire scholarly monographs in telecommunications and allied subject disciplines, such as computing systems. The UMD Libraries' acquisition policies and budgets are expected to ensure scholarly books about computing systems continue to be added to the collection. As the University of Maryland already has a robust tradition of acquiring materials related to telecommunications, current collection development practices in the Libraries should adequately support the new graduate certificate in computing systems. Monographs not already part of the collection can usually be added upon request.

Monographs are typically purchased in electronic format, but the Libraries have a large collection of print materials related to telecommunications and computing systems. Students will be able to take advantage of the print book collection by checking out these items or requesting specific chapters be sent to them through the Libraries' Scan and Deliver program. Faculty can also request, within fair use copyright guidelines, that sections of print books be made available digitally through course reserves.

Scan and Deliver and Interlibrary Loan

The Scan and Deliver program (<http://www.lib.umd.edu/access/scan-deliver>) mentioned above allows students to request chapters of books or journal articles that the University Libraries own in print. Digital copies of these resources are sent directly to the student. For materials not owned by the University Libraries, students can request either digital or physical delivery of bibliographic materials that otherwise would not be available to the UMD community via Interlibrary Loan (<http://www.lib.umd.edu/access/ill-classic>). As a member of the Big Ten Academic Alliance, UMD students have access to physical materials from other institutions in the Big Ten. These items can be requested through the UBorrow service (<http://www.lib.umd.edu/access/uborrow>) and users typically receive the items within one week. Scan and Deliver and Interlibrary Loan are available free of charge.

Conclusion

The University of Maryland Libraries' serials holdings and research databases have an established record for providing bibliographic support for researchers and professionals in subject disciplines that are relevant to telecommunications and computing systems. These materials are supplemented by relevant monograph collections. In addition, the Libraries' Scan

and Deliver and Interlibrary Loan services make materials that otherwise would not be available online or through the UM Libraries. The Libraries also offer students a wide range of services to ensure their success. Additionally, the libraries are already supporting the Master of Science in Telecommunications, so no additional library resources should be necessary for the proposed graduate certificate, which compliments the Masters program. As a result, our assessment is that the University of Maryland Libraries are able to meet the curricular and research needs of the proposed Graduate Certificate in Computing Systems.