Graduate Certificate in 5G Technologies
North Carolina State University

This request has been reviewed and approved by the appropriate campus committees and authorities.

Endorsed By: Paul D. Franzon  
DGP ECE  
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919.513.0501  
11/12/18
Head, Department/Director of Graduate Program  
(Printed Name and Signature)  
Date

Recommended By:  
Kanjana Than  
11/16/18
Chair, College Graduate Studies Committee  
(Printed Name and Signature)  
Date

Endorsed By:  
Douglas Reeves  
11/11/2018
College Dean  
(Printed Name and Signature)  
Date

Recommended By:  
Conditional - see attached  
Thomas K. Rees  
1/15/19
Vice Provost, DELTA (if DE degree)  
(Printed Name and Signature)  
Date

Approved By:  
Pete J. Harries  
9/25/19
Dean of the Graduate School  
(Printed Name and Signature)  
Date

Recommended By:  
Duane Larick  
10/10/19
Dean's Council  
(Printed Name and Signature)  
Date

Approved By:  
Warwick Arden  
10/10/19
Executive Vice Chancellor and Provost  
(Printed Name and Signature)  
Date

Approved By:  
W. Randy Woodson  
11/13/19
Chancellor  
(Printed Name and Signature)  
Date

(revised August 2015)
MEMORANDUM

TO: Melissa Nosbisch, Coordinator, Administrative Board of The Graduate School

FROM: Thomas Miller, Senior Vice Provost for Academic Outreach and Entrepreneurship, Vice Provost, DELTA

DATE: 15th January, 2019

SUBJECT: Conditional recommendation to approve Graduate Certificate in 5G Technologies

The proposal for a Graduate Certificate in 5G Technologies, which would be available online and on campus, is conditionally recommended for approval by the Vice Provost, DELTA. The certificate would require 12 credit hours of classes, including one required course, ECE 592, LTE and 5G Communications, and three additional courses from among alternative tracks, with a least two courses to be taken from the same track. Each of the elective tracks could be completed with courses available for the existing online master’s degree in computer engineering. However, the required course, ECE 592, LTE and 5G Communications, has not yet been offered online. It is recommended that the certificate be approved for online delivery only after the required course in LTE and 5G Communications is available online.
Certificate Title: **Graduate Certificate in 5G Technologies**

- New: X  
- Revision: □

Classification of Instructional Programs (CIP) Discipline # (6 digits): **14.1001**  
*Please ensure that you select the appropriate CIP code for your certificate program. Please consult this website for more information about CIP codes: [https://nces.ed.gov/ipeds/cipcode/default.aspx?v=55](https://nces.ed.gov/ipeds/cipcode/default.aspx?v=55)*

Certificate Type:  
- On-Campus: □  
- Distance: □  
- On-Campus & Distance: X

Proposed Effective Date: **Fall 2019**

Director of the Certificate Program: **Paul Franzon**  
Program Coordinator (if different from Director): **N/A**  
Graduate Services Coordinator: **Fenlie Jones**  
College: **College of Engineering**  
Department/Program: **Electrical and Computer Engineering**

Catalog Description:

The Graduate Certificate in 5G Technologies provides students with advanced academic credentials in the algorithmic, chip, circuit, system and antenna technologies that will underpin 5G Wireless systems.

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Attachments:

- Proposal Document
- Statement of other departments likely to be affected and summary of consultation with those departments
- Program-level assessment
- Campus Routing Form
- Signature Page
Graduate Certificate in 5G Technologies

Program Justification
The Electrical and Computer Engineering (ECE) department proposes to offer a Graduate Certificate Program (GCP) in 5G Technologies (5GT). “5G” refers to the wireless data communications system that will replace the 4G LTE systems that your phone uses now. However, 5G is not an update on 4G. It is a radically new system, using many different architectures, algorithms, circuits, chips and antenna than the previous system. It is also a major business opportunity creating the need for several new generations of small cell base stations and smart phones. 5G will enable faster streaming to your mobile device than you probably enjoy to your home today.

Right now industry is working out how to build these systems. Thus, there is a high demand for engineers who know what 5G means, how it is different than 4G and how the technological need is different from 4G. We’ve been strongly encouraged by our Strategic Advisory Board to offer this certificate as a way to educate these engineers and stake our claim of early leadership in this area.

This program is primarily intended for individuals who wish to contribute to designing the chips, software and hardware that will be needed for the 5G rollout. It will be available to both residential students and distance education students through Engineering Online (EOL).

Program Objectives
1. In this certificate program, students will learn advanced concepts, methods and tools underlying 5G technologies and apply them to designing 5G hardware/software systems.

Program of Study
The 5GT GCP requires a total of 12 credit hours consisting of four graduate-level Electrical and Computer Engineering courses taken for a letter grade. Courses labeled “EOL” will be offered both as live classes and also through EOL. Those without “EOL” are only offered to on campus students. (Note some of these are planned EOL offerings, not current.).

I. All students must complete the following course:
   • ECE 592 LTE and 5G Communications (EOL)

II. Students must then choose three 5G-related courses, taking at least two courses from a single track:
   • Circuits Track
     a. ECE 511 Analog Electronics (EOL)
     b. ECE 712 Integrated Circuit Design for Wireless Communications (EOL)
     c. ECE 792 Design of Millimeter-Wave Circuits and Systems (EOL)
• Microwave Systems and Applied EM Track
  a. ECE 524 Radio System Design
  b. ECE 549 RF Design for Wireless (EOL)
  c. ECE 592 Antennas and Arrays (EOL)

• Communications Track
  a. ECE 575 - Wireless Networks
  b. ECE 766 - Signal Processing for Communications and Networking
  c. ECE 570 - Computer Networking (EOL)

Note, due to the timely nature of this technology not all of these courses are regular numbered courses yet but are special topics. We request University permission to go ahead with the Certificate with Special topic courses included so we don’t have to wait the long times it takes to turn these into regularly numbered courses. We are planning to convert the special topics courses to become regular numbered courses.

**Admission Requirements**
Students must meet ONE of the following requirements for admission into the 5G Graduate Certificate Program:

- Have a BS degree in Electrical or Computer Engineering from a regionally accredited four-year college or university, and have an overall GPA of at least 3.0 on a 4-point scale.
- Have a BS degree in the sciences or engineering from a regionally accredited four-year college or university with an overall GPA of at least 3.0 on a 4-point scale.
- Be a degree-seeking student in good standing in an NC State University graduate program in the sciences or engineering.
- Premium tuition is charged on this certificate, students who are currently pursuing other degrees and/or certificates will not be admitted to this certificate until they complete those other programs. Once they are enrolled in this certificate, credit hours will be subject to the Electrical and Computer Engineering MS tuition premium, until the certificate is received.

**Application and Completion Process**
An application for acceptance into the GCP is required for all new students. Students must complete the Graduate School application, found at [https://grad.ncsu.edu/apply/](https://grad.ncsu.edu/apply/).


New applications will be reviewed at the department/program level.

Registration procedures, registration dates and course availability for each semester can be found on the NCSU Registration and Records webpage at [http://www.ncsu.edu/registrar/](http://www.ncsu.edu/registrar/).

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1 Premium tuition is charged based on a student’s program of study, not individual courses the student takes, and this policy is outside the department’s control. For instance, ECE Masters students pay the ECE premium even if in a given semester they take one, two, or three courses outside the ECE department. Similarly, once a student is admitted to the ADV GCP and the certificate is added to their program of study, they will be charged the premium. We plan to include this information on the certificate website so that students make an informed decision.
Additional information regarding the 5G GCP can be found on the Electrical and Computer Engineering (http://www.ece.ncsu.edu) website. Questions regarding the 5G GCP can be directed to the certificate coordinator. Information regarding Engineering Online can be found at http://engineeringonline.ncsu.edu.

Admission to Other Graduate Programs
Academic success in the 5G GCP might have a strong bearing on admission to a graduate degree program. However, completion of a graduate certificate program in no way guarantees entry into a graduate degree program, which must be done through a separate application process.

Academic Performance Requirements
- The 5G GCP requires a total of 12 credit hours.
- To receive a Graduate Certificate, a student must maintain a minimum 3.00 grade point average (GPA) on Graduate Certificate coursework taken at NCSU. All grades on courses taken towards the GCP in courses numbered 500 and above are included in the GPA. Any courses taken at the 400 level and below are not eligible for certificate credit.
- All courses taken for certificate credit must be completed with a grade of "B-" or better.
- All courses at the 500- or 700-level taken for certificate credit must be letter-graded. Credit-only courses cannot be used for certificate credit.
- Transfer credit from other institutions is not allowed for the GCP. All coursework must be registered through NC State University.
- Up to three (3) credit hours of NDS coursework, if not already used in another graduate program, may be transferred into the GCP. All transfer credit must carry a grade of B or better.
- Graduate Certificate courses taken by students who are enrolling after completion of a degree program may be double-counted towards that degree (1) to the extent that the courses unique to the degree remain at 18 hours for a Masters degree or 30 hours for a PhD degree and (2) subject to the course requirements of that degree.
- All GCP requirements must be completed within four (4) calendar years, beginning with the date the student commences courses applicable to the GCP. In addition, students must maintain continuous enrollment every semester until all coursework is completed. A one-semester leave of absence may be granted if the student is unable to enroll in a course due to extenuating circumstances. The leave of absence must be approved in writing by the ECE DGP before the start of the semester.

Program Administration
The 5G GCP will be administered by the Director of Graduate Programs in the Department of Electrical and Computer Engineering, in cooperation with the NCSU Engineering Online program for distance-education students.
All certificate courses are existing courses in Electrical and Computer Engineering. The implementation and presentation of the certificate is not expected to require effort outside the normal academic activities of the course instructors. No additional staff or resources are required to support the administration of this program.

**Enrollment Projection**

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<tr>
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<th>Yr 3</th>
<th>Yr 4</th>
<th>Yr 5</th>
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These projections are based on (1) discussions with industry members of the Electrical and Computer Engineering Strategic Advisory Board and (2) repeated unsolicited requests and questions received by our program, and take into account the different pace of on-campus vs. online students.

**Tuition and Fees**

The department will seek approval for a tuition structure that is identical to that of the Electrical and Computer Engineering Master’s program, i.e., that includes the tuition premium. Tuition premium is charged based on the student’s program.

**Faculty Participants**

All faculty who teach courses listed in the Certificate will participate in the 5G GCP.

**Departments likely to be affected**

ECE 570 is often taught by CSC. Students in this certificate will need to be able to be enrolled in those sections. The DGP of CSC was consulted and agreed to permit that.

**Outcomes Assessment Plan**

**Objectives**

1. The certificate program will provide a graduate level working knowledge of current Computer Engineering concepts and methods.
2. The certificate program will provide an educational experience that satisfies the expectations of its graduates.

**Outcomes**

1. By the time they complete this certificate program, graduates should be able to:
   - Identify and describe the major principles, methods, and tools of one field of 5G systems Engineering
   - Apply the methods and tools learned during the certificate studies to tackle computational problems and tasks
   - Use relevant software packages and tools in their own professional activities
2. At the time they complete this certificate program, graduates are expected to:
   - Be satisfied with the usefulness of the certificate program in enabling them to achieve their professional goals
   - Be sufficiently satisfied with the certificate program to recommend it to others with the same professional goals
   - Be satisfied with the appropriateness of the courses in providing the knowledge or training they anticipate needing for their professional goals
   - Be satisfied with the frequency and timeliness of courses offered for the certificate
   - Be satisfied with the quality of teaching in certificate courses
   - Be satisfied with the overall educational experience of the certificate program

Objective 1. Students will learn advanced concepts, methods and tools of 5G Engineering and apply them to a variety of computational problems tasks.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Evidence to be Collected</th>
<th>Source of Evidence</th>
<th>Frequency of Collection</th>
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</thead>
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<td>Identify and describe the major principles, methods, and tools of in</td>
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<td>engineering for 5G</td>
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<tr>
<td>Apply the concepts and methods learned during the certificate studies</td>
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<td>to tackle design problems and tasks</td>
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<tr>
<td>Use relevant software packages and tools in their own professional</td>
<td>Projects in corresponding courses</td>
<td>Students</td>
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<td>activities</td>
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Objective 2. The certificate program will provide an educational experience that satisfies the expectations of its graduates

<table>
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<td>Annually</td>
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<td>enabling them to achieve their professional goals</td>
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<tr>
<td>Objective</td>
<td>Method</td>
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<td>To be sufficiently satisfied with the certificate program to recommend it to others with the same professional goals</td>
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<td>To be satisfied with the appropriateness of the courses in providing the knowledge or training they anticipate needing for their professional goals</td>
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<td>Annually</td>
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<td>To be satisfied with the frequency and timeliness of courses offered for the certificate</td>
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<td>Annually</td>
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<td>To be satisfied with the quality of teaching in certificate courses</td>
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<td>Annually</td>
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