Program Collaborative Graduate Certificate in Cyber Security

Admission Requirements:
1. B.S. or equivalent degree with a GPA of 2.75 or more from an educational institution of recognized standing.
2. At least 12 semester hours or equivalent of coursework in Computer Science, Computer Engineering, Electrical Engineering, Software Engineering, Information Technology, or Information Systems. An acceptable alternative to the coursework background is one or more years of directly related professional experience.

Curriculum:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>CSCI 577 - Foundations of Digital Enterprise (online)</td>
<td>Ken Nygard</td>
<td>3</td>
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<tr>
<td>CSCI 568 - Applied Cryptography (online)</td>
<td>Paul Loree</td>
<td>3</td>
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<tr>
<td>EE 590 - Emerging Threats and Defenses</td>
<td>Prakash Ranganathan</td>
<td>3</td>
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<td>As early as Summer 2017 or Fall 2018 - NDUS Institution</td>
<td>Elective*</td>
<td>3</td>
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*Electives choices likely will include: Data Security; Cyber-Physical Security Systems Algorithms for Threat Modeling and Defenses; Cryptographic Methods; Next Generation E-commerce, and secure software coding.

Three-credit Project Course in Cyber Security with a faculty member mentoring a special project (UND, NDSU, MiSU):
CSCI 544. Soft Computing: Computational Intelligence I. 3 Credits.
A study of the computational intelligence with the Soft Computing paradigm. The topics include the theory and computational methods of Fuzzy Logic and system, Neural Network, Evolutionary Algorithm and other topics, whose paradigms and hybrid techniques are widely applied to data science and mining, pattern classification and clustering, information retrieval, control engineering, decision making, and optimization problem, etc. S, even years.

CSCI 545. Discrete Dynamical Systems Modeling and Simulation. 3 Credits.
A study of various modeling methods applicable to large scale distributed and parallel systems. Topics include cellular automata, grid models, and chaos theory. Prerequisite: CSCI 445.

CSCI 546. Advanced Computer Graphics. 3 Credits.
An introduction to advanced topics in computer graphics. Included are light and color theory, image processing and compression, spatial-frequency transformations, raytracing, sampling theory, and topics of current interest. Prerequisites: CSCI 466 and MATH 265. S, even years.

CSCI 547. Scientific Visualization. 3 Credits.
A study of visualization techniques useful in the analysis of engineering and scientific data. Topics include the study of physical models; methods of computational science; two -and three-dimensional data types; visual representation schemes for scalar, vector, and tensor data; isosurface and volume visualization methods. The course will also cover image processing and pattern recognition, with topics, including Fourier transforms, fractal geometry, and neural networks. Prerequisite: CSCI 466. F, even years.

CSCI 551. Security for Cloud Computing. 3 Credits.
Cloud computing scheme aims to provide users with a shared computing infrastructure. The privacy and security concerns in cloud computing are different from the security concerns present in a dedicated data center. This course focuses on these security concerns and countermeasures for a cloud environment. This course provides an overview of cloud computing and virtualization, the critical technology underpinning cloud computing, and the major threats to the operations of cloud computing. Topics may include access control, identity management, denial of service, account and service hijacking, secure APIs, malware, forensics, regulatory compliance, trustworthy computing, and secure computing. Prerequisites: CSCI 370, CSCI 451; and one of the following: CSCI 327, CSCI 427 or CSCI 555. S, odd years.

CSCI 552. Cyber Physical Systems Security. 3 Credits.
This course provides an introduction to security issues relating to various cyber-physical systems including industrial control systems and those considered critical infrastructure systems. Topics include: Industrial cyber security history and threats, hacking industrial control systems, securing industrial control systems, advanced cyber-physical systems security concepts, and privacy in cyber-physical systems. F, even years.

CSCI 554. Applications in AI/Computational Intelligence. 3 Credits.
A continuous study of the computational paradigms of Soft Computing in the field of Computational Intelligence. The topics include the applications of the various soft computing techniques in Computational Intelligence as well as more evolutionary algorithms in Swarm Intelligence. Prerequisite: CSCI 544. F, even years.

CSCI 555. Computer Networks. 3 Credits.
A study of new and developing network architectures and communication protocols. Broadband technologies will be considered including BISDN, ATM networks, and other high-speed networks. Prerequisite: CSCI 327.

CSCI 562. Formal Specification Methods. 3 Credits.
A foundational course that introduces several formal specification techniques for construction and analysis of software artifacts. Included are rigorous program development, abstract specifications of modules, and modeling of concurrent and distributed software. Prerequisites: CSCI 435 and CSCI 463.

CSCI 565. Advanced Software Engineering. 3 Credits.
A study of current topics related to the design and implementation of large software systems. Course content may vary with instructor and student interest. Potential topics include: software testing and validation, programming environments, program metrics and complexity, design methodologies, software reliability and fault tolerance. Prerequisite: CSCI 463.

CSCI 575. Analysis of Algorithms. 3 Credits.
The time and space complexity of classical computer algorithms is analyzed. NP hard and NP complete problems are characterized and illustrated. Prerequisite: CSCI 435.

CSCI 582. Software Architecture. 3 Credits.
Software architecture is a fairly young sub-discipline within software engineering; it is aimed at shifting the designer's focus from algorithmic control structure to interactive interrelations among components. This course, among other things, will expose students to the concepts of design, design of design, principles and state-of-the-art methods and techniques in software architectures, which include the discussion of architectural patterns (or styles), domain specific architectural design, formal architectural description languages (ADLs), software connectors (simple and composite), architectural analysis, and middleware and component-based software development. Prerequisites: CSCI 463 and CSCI 435.

CSCI 588. Data Structure, Algorithms, and Software Design in C++. 3 Credits.
This course is intended for the Scientific Computing Ph.D students. The course attempts to introduce C++ via laboratory sessions. More specifically, this course tries to incorporate Data Structures and Algorithms in C++ as well as Software Design in C++. During these sessions the students are introduced to C++ concepts using a series of examples. Having examined the examples given in the session and having understood the concepts covered, the student should be able to complete open-ended problems. This course assumes no prior knowledge of C++.

CSCI 591. Directed Studies. 1-3 Credits.
An investigation of some specific area by an individual or small group of students working closely with a member of the graduate faculty. 1-3 credits in each graduate degree program. Prerequisites: Graduate standing and consent of instructor. Repeatable to 9 credits. F,S,SS.

CSCI 599. Research. 1-6 Credits.
This course is intended for Ph.D students to obtain credit for their research efforts. Repeatable to 21 credits. Repeatable to 21 credits. S/U grading.

CSCI 996. Continuing Enrollment. 1-12 Credits.

CSCI 997. Independent Study. 2 Credits.
Independent Study.

CSCI 998. Thesis. 1-9 Credits.
Thesis. Repeatable to 9 credits.

CSCI 999. Dissertation. 1-12 Credits.
Dissertation. Repeatable to 12 credits. F,S,SS.

Undergraduate Courses for Graduate Credit

CSCI 427. Cloud Computing. 3 Credits.
This is the undergraduate-level course on cloud computing models, techniques, and architectures. Cloud computing is an infrastructure model which enables information, software, and other shared resources to be provisioned over the network as services in an on-demand manner. This course introduces the current practices in cloud computing. Topics may include distributed computing models and technologies, Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), Software-as-a-Service (SaaS), virtualization, performance and systems issues, capacity planning, disaster recovery, Cloud OS, federated clouds, challenges in implementing clouds, data centers, hypervisor CPU and memory management, and cloud hosted applications. S, even years.

CSCI 435. Formal Languages and Automata. 3 Credits.
A study of automata, grammars, and Turing machines as specifications for formal languages. Computation is defined in terms of deciding properties of formal languages, and the fundamental results of computability and decidability are derived. Prerequisites: CSCI 242 with a grade of C or better and minimum second semester junior standing. F.

CSCI 445. Mathematical Modeling and Simulation. 3 Credits.
A study of various mathematical applications for digital computers, including the modeling, simulation and interpretation of the solution of complex systems. Prerequisites: CSCI 161 or CSCI 170, and MATH 166 and a statistics course. F, even years.

CSCI 446. Computer Graphics I. 3 Credits.
Introduction to computer graphics. Topics include raster scan graphics, 2D and 3D representations, affine transformations, light and color, texture mapping, image processing, ray-tracing, and computer animation. Team-based weekly homework develops a 4 minute computer animation. Prerequisites: CSCI 242, CSCI 363, and MATH 166. F, odd years.
CSCI 448. Computer Graphics II. 3 Credits.
A continuation of CSCI 446. Topics covered include: 3D graphics, game engines, and AI engines. Prerequisite: CSCI 446. S, even years.

CSCI 451. Operating Systems I. 3 Credits.
Introduction to operating system theory and fundamentals. Topics include: CPU scheduling, memory management, file systems, interprocess communication, and security. Weekly homework assignments focus on process synchronization using fork, exe, threads, mutexes, pipes, semaphores, and shared memory. Prerequisites: CSCI 242 and CSCI 370; both with a grade of C or better. F.

CSCI 452. Operating Systems II. 3 Credits.
A study of the implementation of operating systems and parts of operating systems, and development of system software. Prerequisites: CSCI 451. On demand.

CSCI 455. Database Management Systems. 3 Credits.
Database concepts, database design (ER, UML), database programming languages (SQL), NoSQL Database, Database Concurrency and recovery techniques, and Database security. Prerequisite: CSCI 242 with a grade of C or better. S, even years.

CSCI 457. Electronic Commerce Systems. 3 Credits.
A study of the system architecture, content design and implementation, and data analysis, management, and processing of electronic commerce. Topics include Internet basics, business issues, data management and processing, static and dynamic web programming, e-commerce content design and construction, and databases and host languages with embedded SQL. Prerequisite: CSCI 260 with course topic of Dot Net. S, odd years.

CSCI 463. Software Engineering. 3 Credits.
This course teaches software engineering principles and techniques used in the specification, design, implementation, verification and maintenance of large-scale software systems. Major software development methodologies are reviewed. As development team members, students participate in a group project involving the production or revision of a complex software product. Prerequisites: CSCI 242 and CSCI 363. S.

CSCI 465. Principles of Translation. 3 Credits.
Techniques for automatic translation of high-level languages to executable code. Prerequisites: CSCI 365 and CSCI 370. F, odd years.

CSCI 491. Seminars in Computer Science. 1 Credit.
A course for advanced students. Repeatable to 3 credits. Prerequisite: Consent of instructor. Repeatable to 3 credits. S/U grading. F.S.

EE Courses

EE 505. Control Systems II. 3 Credits.
Advanced topics in control systems including nonlinear systems, robust control, optimal control, and pole placement techniques; selective topics from the state of the art. Prerequisite: EE 405.

EE 506. Digital Control Systems. 3 Credits.
Digital systems representation, analysis and simulation; Z-transform; digital controllers design and realization; microprocessor based controllers. Prerequisite: EE 405.

EE 508. Intelligent Decision Systems. 3 Credits.
Systems and networks will be designed to work in an uncertain environment. Systems will be optimized using Neural Networks and Fuzzy Logic concepts. Prerequisite: EE 314 or consent of instructor.

EE 509. Signal Integrity. 3 Credits.
Fundamental concepts of signal integrity are presented. Topics include propagation of digital signals, electrical noise, and system timing. Prerequisite: EE 409 or consent of instructor.

EE 511. Power Electronics. 3 Credits.
Principles of power electronics switching control circuits. Including AC/DC, DC/DC, DC/AC converters, their harmonics and filtering techniques, and their application in switching power supplies, electric drives, renewable energy systems, etc. Prerequisite: EE 321 or consent of instructor. On demand.

EE 512. Wireless Communications. 3 Credits.
Key concepts, underlying principles, and practical applications of ever-growing wireless and cellular communication technologies. Prerequisite: EE 411 or consent of instructor.

EE 521. Digital Signal Processing. 3 Credits.
Modern methods of digital signal processing will be studied. Techniques that will be used include the recursive and nonrecursive discrete-time filters and the Fourier Transform. Prerequisite: EE 314.

EE 522. Renewable Energy Systems. 3 Credits.
This course will provide engineering students with an understanding of the principles of renewable energy conversion systems. Emphasis is on wind, photo-voltaic, hydrogen fuel, and fuel cell energy conversion and storage systems, along with their associated design and control issues.

EE 523. Power Systems II. 3 Credits.
Electric power systems analysis and control. Power flow; system response and stability; voltage and frequency control; computer methods in system analysis. Prerequisite: EE 423.

EE 524. Application Specific Integrated Circuit (ASIC) Design. 3 Credits.
To gain an historic perspective of ASIC Design. To familiarize students with the existing IC technology and their attributes. To recognize basic fabrication process, layout, circuit extraction and performance analysis. To understand CAD tools, hardware, systems engineering, and operational issues. Prerequisite: EE 421 or consent of instructor.

EE 525. Electromagnetic Fields. 3 Credits.
Static electric and magnetic fields, field mapping, and applications to transmission lines, wave-guides, and antennas. Prerequisite: EE 316.

EE 526. Engineering Systems Reliability. 3 Credits.
This course teaches the basics of reliability engineering concepts and techniques applicable to all engineering disciplines including electrical, mechanical, chemical, geological, aeronautical, and civil. To benefit the most from this course, some basic knowledge of probability and statistics would be helpful but is not necessary as the required background and tools are presented and discussed in the class. Prerequisite: Consent of the instructor. On demand.

EE 532. Antenna Theory. 3 Credits.
Physical principles underlying antenna behavior and design as applied to antennas. Prerequisite: EE 316 or consent of instructor.

EE 534. Advanced Wireless Communications Engineering. 3 Credits.
A combination of theory and practice underlying principles and practical applications of Wireless Communications. Prerequisite: Consent of Instructor. On demand.

EE 536. Optical Fiber Communications. 3 Credits.
Propagation in optical fibers, optical receivers, amplifiers, detectors, sources, transmission links, noise consideration, optical fiber communications systems, applications and future developments. Prerequisite: EE 434 or consent of instructor.

EE 537. Graduate Cooperative Education. 1-2 Credits.
The is course is a practical research experience under supervision of an employer that is closely associated with the student's academic area. A written report which includes a literature survey and research findings and an oral presentation are required. Prerequisite: Approval of the Electrical Engineering Graduate Committee or Electrical Engineering Department Graduate Director, completion of the program of study. Repeatable to 3 credits. S/U grading. F,S,SS.

EE 539. Electromagnetic Compatibility. 3 Credits.
Introduction to design considerations and techniques used to ensure electromagnetic compatibility. Prerequisite: EE 409 or consent of instructor.

EE 540. Computer Networks Communications. 3 Credits.
Computer Communications is an undergraduate/graduate course that introduces fundamental concepts in the design and implementation of computer communication networks and their protocols. Prerequisite: Consent of the instructor. On demand.

EE 542. Network Architectures. 3 Credits.
Several network architectures are used today for transporting data and providing a good network service and performance. This course explains the fundamental network architecture concepts and their communications protocols. Prerequisite: Consent of the instructor. On demand.

EE 544. Advanced Microwave Engineering. 3 Credits.
Analysis of passive microwave components including power dividers, resonators, filters, ferromagnetic and MEMs components. On demand. Prerequisites: EE 409 and EE 434, or consent of instructor. On demand.
EE 545. Introduction to Biomedical Engineering. 3 Credits.
This course introduces biomedical engineering and several systems of the human physiology. Signals of biological origin obtained from these systems, biosensors, transducers and bioelectrodes used to acquire such signals, along with medical quality amplifiers for measuring bipotentials, are discussed. Prerequisite: EE 314, EE 421 or consent of instructor.

EE 546. Biomedical Signal Processing. 3 Credits.
This course presents the several fundamental of digital signal processing methods applied to biomedical signals. Topics include data acquisition and related issues, filtering, feature extraction, classification, and decision making. The course is based on a series of labs and experiments of applying different methods to real biomedical signals. Lectures cover signal processing topics relevant to the lab exercises. Prerequisite: Consent of the instructor. On demand.

EE 547. Deep Learning Applications in Biomedical Engineering. 3 Credits.
Applications of different machine learning techniques to biomedical image and signal processing are evaluated. Prerequisite: EE 314 or the consent of the instructor. On demand.

EE 550. Biomedical Instrumentation. 3 Credits.
Introduction to circuits and systems that allow electrical technology to interface with biological systems. Prerequisite: EE 314, EE 316 and EE 421, or consent of instructor.

EE 551. Cryptography Techniques and their VLSI Implementations. 3 Credits.
Modern cryptography algorithms are necessary for protecting data storage and communication streams from disclosure and manipulation of information by hackers. This course exposes students to the standard cryptography algorithms and their implementation in VLSI chips, Field Programmable Array devices, using VHDL language. Prerequisite: Consent of the instructor. On demand.

EE 552. Advanced Embedded Systems Design. 3 Credits.
This course provides students with cutting-edge techniques in the design and implementation of advanced embedded systems that involve analog/digital conversion, interrupts, timers, CCP modules, and parallel/serial communications. Prerequisite: EE 452 or consent of instructor.

EE 560. Engineering Computation. 3 Credits.
Development and application of optimization techniques in practical problems encountered in electrical engineering, Downhill and probabilistic optimization techniques, Modeling of complex systems by partial differential equations and their numerical solution by finite difference and finite element methods. Prerequisite: Consent of instructor. On demand.

EE 562. Advanced Linear Programming Modeling. 3 Credits.
This course will focus on the solution of large-scale linear optimization problems and systems of linear inequalities. Theoretical topics to be addressed include some fundamental results from convex analysis applied to linear programs, and basic ideas from complexity theory especially the importance of polynomial-time algorithms. Algorithmic topics include extensions to the simplex method, the primal-dual simplex method, interior point algorithms, and decomposition and column-and row-generation methods and Mixed integer programming and network flow topics. Prerequisite: EE 304 or consent of the instructor. On demand.

EE 570. Seminar. 1 Credit.
The purpose of the course is to practice communication skills in writing papers and preparing presentations. Open to qualified advanced undergraduate students and graduates. Repeatable to 3 credits. On demand.

EE 590. Advanced Electrical Engineering Problems. 1-6 Credits.
Credit hours for new graduate courses and special topics in Electrical Engineering. Prerequisites: Open by permission to graduate students and qualified seniors. Repeatable. On demand.

EE 591. Electrical Engineering Research. 1-6 Credits.
Students perform a project under the supervision of a member of the staff. A written report is required. Repeatable for credit. Prerequisites: Admission to one of Electrical Engineering graduate programs and consent of instructor. Repeatable to 9 credits. On demand.

EE 595. Design Project. 3-6 Credits.
A three to six credit course of engineering design experience involving individual effort and a formal written report. Repeatable to 6 credits. Prerequisites: Restricted to Master of Engineering student candidates and subject to approval by the student’s advisor. Repeatable to 6 credits.

EE 599. Doctoral Research in Electrical Engineering. 1-15 Credits.
Doctoral Reserach. Repeatable. F,S,SS.

EE 601. Foundations of Cyber Security. 3 Credits.
This course provides a solid foundation for further study in cyber security. The course incorporates numerous topics that are fundamental to the field beginning with a high-level overview of cyber security and continuing into the topics of calculus and computer programming. These topics are presented utilizing real-world cyber security applications. Prerequisite: Students enrolled/admitted in the MS in Cyber Security program. F,S,SS.

EE 611. Emerging Threats and Defenses. 3 Credits.
Cyber-attacks are a serious economic and security threat. To combat both immediate and future dangers, businesses and governments are investing in cyber security. Understanding trends in cyber-security and how machine-learning techniques defenses can respond to threats is a critical component of protecting networks, infrastructure and users. This course explores the growing challenges of securing sensitive data, networks to defend against malicious acts. Prerequisite: Consent of the instructor. On demand.

EE 612. Spread Spectrum Communications for Cyber Security. 3 Credits.
This course brings students up-to-date in key concept, underlying principles and practical applications of Spread Spectrum Technology. A course that presents timely information that student can immediately put to use in tackling real world cyber threats. Prerequisite: Consent of the instructor. On demand.

EE 613. Advanced Cyber Security Principles. 3 Credits.
This course is a comprehensive study of the principles and practices of computer system security including operating system security, network security, software security and web security. Topics include common attacking techniques such as virus, trojan, worms and memory exploits; the formalisms of information security such as the access control and information flow theory; the common security policies such as BLP and Biba model; the basic cryptography, RSA, cryptographic hash function, and password system; the real system implementations, with case study of UNIX, SE-Linux, and Windows; network intrusion detection; software security theory; web security; legal and ethical issues in computer security. Prerequisite: Consent of the instructor. On demand.

EE 614. Applied Cryptography. 3 Credits.
Modern cryptography algorithms are necessary for protection of data storage and communication streams from disclosure and manipulation of information to distrusted or malicious parties. This course explains the inner workings of cryptographic primitives and how to implement them. Assignments will be both theoretical and application based. Experience with C/ C++ programming is required. Prerequisite: Consent of the instructor. On demand.

EE 615. Cyber Forecasting. 3 Credits.
There are literally millions of enterprises and organizations that already conduct business on the World Wide Web and millions more that will in the future. Many are not sure on how much to spend to defend themselves against Internet Security attacks and many are afraid to conduct business on the Web because of the lack of security in their infrastructure and information systems. Prerequisite: Consent of the instructor. On demand.

EE 616. Cyber-Physical Energy Systems Security. 3 Credits.
This course discusses the basics of integrated power and communication infrastructures in cyber-physical electrical energy and power systems. In order to understand planning, design and operation of such systems, this course includes both cyber and physical topics related to modern power systems, such as technologies for storing and generating electric power (including renewable energy), layering, networking, packets routing, coding, cellular networks, WLAN, and sensors. Approaches for an integrated operation, management and control of such systems, as well as the application of signal processing techniques in electric power grids are also explored in this course. Implication of such integrated power and communications cyber-physical systems in terms of sustainability, security, resiliency, and reliability will also be reviewed. Prerequisites: EE 313 and EE 423 or consent of the instructor. On demand.

EE 617. Data Operations and Security. 3 Credits.
This course explains the key concepts used in database systems and demonstrates the features of a Database management software. The course will discuss the different types of commercial database systems and will explain the concepts used to design a database. Also this course will teach how to implement a database using the relational DBMS. The course also illustrates the usage of database management systems. The course will also discuss data base attacks, ACID properties. Prerequisite: Consent of the instructor. On demand.
EE 623. Introduction to Smart Grid I. 3 Credits.
This course is an in-depth study of the ways in which information and communication technologies (ICT) are being deployed to modernize the electric energy infrastructure, i.e. ‘Smart Grid.’ In this course we will define Smart Grid as the use of ICT (in combination with power electronics and policy) to make electricity cleaner, less costly, and more reliable. Prerequisite: EE 313 or graduate student standing. On demand.

EE 624. Introduction to Smart Grid II. 3 Credits.
This is the next sequence of smartgrid course is an in-depth study of the ways in which information and communication technologies (ICT) are being deployed to modernize the electric energy infrastructure, i.e. ‘Smart Grid.’ In this course we will define Smart Grid as the use of ICT (in combination with power electronics and policy) to make electricity cleaner, less costly, and more reliable. Prerequisite: EE 623. On demand.

EE 640. Communication Protocols: OSI model and TCP/IP Protocol Stack. 3 Credits.
Communication between computers and networks uses protocols. This course introduces students to the OSI model and TCP/IP protocol stack. Functions of each layer in the network are explained and their security analyzed. Prerequisite: Consent of the instructor. On demand.

EE 740. Intrusion Detection Algorithms. 3 Credits.
With the increasing number of cyber-attacks, intrusion detection systems become crucial tools for detecting anomalies and enhancing computers and networks security. This course exposes students to the existing intrusion detection techniques and algorithms, including signature-based and anomaly-based approaches. Prerequisite: Consent of the instructor. On demand.

EE 750. Internet of Things and Security. 3 Credits.
Internet of Things (IoT) is an emerging field where computing devices are interconnected through the existing internet infrastructure. The IoT has changed the world with new innovative products such as autonomous vehicles, smart home, and smart wearables devices. This course explains the concept of IoT, its applications, networks and communication architectures, and security threats. Prerequisite: Consent of the instructor. On demand.

EE 751. Wireless Sensor Networks. 3 Credits.
This class provides a hands-on introduction to wireless sensor networking. We will start with a discussion of the WSN+ubiquitous computing vision and applications, and also discuss emergent/swarm behavior in distributed and networked systems. We will provide a tutorial on programming wireless sensor network applications in Tinyos. Finally, we will quickly cover protocols for MAC layer, Localization, Routing, Querying, and Tracking. Prerequisite: Consent of the instructor. On demand.

EE 752. Introduction to Autonomous Systems. 3 Credits.
Advanced topics in autonomous and intelligent mobile robots, with emphasis on planning algorithms and cooperative control. Robot kinematics, path and motion planning, formation strategies, cooperative rules and behaviors. The application of cooperative control spans from natural phenomena of groupings such as fish schools, bird flocks, deer herds, to engineering systems such as mobile sensing networks, vehicle platoon. Prerequisite: Consent of the instructor. On demand.

EE 994. Capstone. 3 Credits.
This course is intended for students enrolled in a graduate program, who need to complete a semester long project. The class will emphasize applied learning to demonstrate real world problem solving skills. F,S,SS.

EE 996. Continuing Enrollment. 1-12 Credits.
Repeatable. S/U grading.

EE 997. Independent Study. 3 Credits.
This course is independent study for MS Non-Thesis Students. Prerequisite: Consent of Advisor.

EE 998. Thesis. 1-6 Credits.
Repeatable to 9 credits.

EE 999. Dissertation in Electrical Engineering. 1-18 Credits.
Dissertation for Ph.D. EE students. Repeatable to 18 credits. F,S,SS.

Undergraduate Courses for Graduate Credit

EE 411. Communications Engineering. 3 Credits.
Mathematical definition of random and deterministic signals and a study of various modulation systems. Prerequisite: EE 314. On demand.