TO: The Faculty of the College of Engineering

FROM: School of Electrical and Computer Engineering of the College of Engineering

RE: New Graduate Course, ECE 60872 Fault Tolerant Computer System Design

The faculty of the School of Electrical and Computer Engineering has approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

ECE 60872 Fault Tolerant Computer System Design

Sem. 1, Lecture 3, Cr. 3.
Prerequisite by Topic: Any one high level programming language experience; A basic background in probability

Description: The course provides an introduction to the hardware and software methodologies for specifying, modeling and designing fault-tolerant systems supported by case studies of real systems. The material presents a broad spectrum of hardware and software error detection and recovery techniques that can be used to build reliable networked systems. The lectures discuss how the hardware and software techniques interplay, what techniques can be provided in COTS hardware, what can be embedded into operating system and network communication layers, and what can be provided via a distributed software layer and in the application itself.

The course focuses on hands-on learning through the design and development of systems in the course project, which carries 50% of the weightage for the course grade.

We will be using a modeling software called UltraSAN to model a realistic system and then learn how the model can be solved to evaluate various dependability properties of the system.

Reason: This course introduces students to the critical skill of building reliable and secure software and hardware-based systems. The course provides the relevant theoretical background and then practical systems building skills. It also discusses techniques to evaluate if a system is meeting the requirements. Finally, it pulls together the techniques learned into two practical deployed and popular systems which exemplify good reliability and security practices.

- This course replaces ECE 57200.
- The course covers several advanced topics in reliability needing mathematical and modeling background beyond that covered in most undergraduate curricula. Also, the emphasis on a semester-long project on a cutting-edge research problem makes this course more suitable to our graduate curriculum. The course project accounts for 50% of the grade. I had earlier taught a course 572 on the same topic and I revised the course including the practical modeling exercise and other graduate-level material to create the current 695 course.
- About 50% of the course material is from text and reference books, 35% from research literature, and 15% from synthesis of material from multiple sources including official reports, news stories, and investigative reports.
- The students demonstrate their mastery of the topics by doing (among other activities) a course project in teams of 2-3 students. Each team does a different and novel project, with the objective of developing publishable material.
- The course includes two lectures by practitioners from the industry about their applications of reliability and security principles.

Michael R. Melloch, Associate Head
School of Electrical and Computer Engineering

Approved for the faculty of the Schools
of Engineering by the Engineering
Curriculum Committee
ECC Minutes #36 Date 11-15-16
Chairman ECC

Office of the Registrar
FORM 40G REV. 4/13

PURDUE UNIVERSITY
REQUEST FOR ADDITION, EXPIRATION,
OR REVISION OF A GRADUATE COURSE
(50000-60000 LEVEL)

DEPARTMENT: Electrical and Computer Engineering — EFFECTIVE SESSION: Spring 2016

INSTRUCTIONS: Please check the items below which describe the purpose of this request.

- [x] 1. New course with supporting documents (complete proposal form)
- [ ] 2. Add existing course offered at another campus
- [ ] 3. Expiration of a course
- [ ] 4. Change in course number
- [ ] 5. Change in course title
- [ ] 6. Change in course credit/type
- [ ] 7. Change in course attributes
- [ ] 8. Change in instructional hours
- [ ] 9. Change in course description
- [ ] 10. Change in course requisites
- [ ] 11. Change in semesters offered
- [ ] 12. Transfer from one department to another

PROPOSED:		EXISTING:	
Subject Abbreviation	ECE	Subject Abbreviation	
Course Number	60872	Course Number	
Long Title	Fault Tolerant Computer System Design		
Short Title	Fault Tolerant Comp Sys Design		

Abbreviated title will be entered by the Office of the Registrar if omitted. (30 CHARACTERS ONLY)

TERMS OFFERED
Check All That Apply:
[x] Fall [ ] Spring [ ] Summer

CAMPUS(ES) INVOLVED
- [ ] Calumet
- [ ] Cont Ed
- [ ] Ft. Wayne
- [ ] Indianapolis
- [ ] N. Central
- [ ] Tech Statewide
- [x] W. Lafayette

CREDIT TYPE
1. Fixed Credit: Cr. Hrs. 3
2. Variable Credit Range:
   Minimum Cr. Hrs
   (Check One) To [ ] Or [ ]
   Maximum Cr. Hrs
3. Equivalent Credit: Yes [ ] No [x]
4. Thesis Credit: Yes [ ] No [x]

COURSE ATTRIBUTES: Check All That Apply
1. Pass/Not Pass Only [ ]
2. Satisfactory/Unsatisfactory Only [ ]
3. Repeatable [ ]
   Maximum Repeatable Credit: [ ]
4. Credit by Examination [ ]
5. Fees [ ] Coop [ ] Lab [ ] Rate Request
   Include comment to explain fee
6. Registration Approval Type
   Department [ ] Instructor [ ]
7. Variable Title [ ]
8. Honors [ ]
9. Full Time Privilege [ ]
10. Off Campus Experience [ ]

Schedule Type	Minutes Per Mtg	Meetings Per Week	Weeks Offered	% of Credit Allocated
Lecture	3	50	16	100
Recitation				
Presentation				
Laboratory				
Lab Prep				
Studio				
Distance				
Clinic				
Experiential				
Research				
Ind. Study				
Pract/Observ				

Cross-Listed Courses

COURSE DESCRIPTION (INCLUDE REQUISITES/RESTRICTIONS):
The course provides an introduction to the hardware and software methodologies for specifying, modeling and designing fault-tolerant systems supported by case studies of real systems. The material presents a broad spectrum of hardware and software error detection and recovery techniques that can be used to build reliable networked systems. The lectures discuss how the hardware and software techniques interplay,

*COURSE LEARNING OUTCOMES:
a. 1. An ability to formulate design principles for dependable systems [b, c, d]
2. An ability to analyze mathematically a system for its dependability properties [a, c]
3. An ability to understand and apply hardware dependability techniques [a, c]

	Date		Date		Date
Calumet Department Head		Calumet School Dean		Calumet Director of Graduate Studies	
Fort Wayne Department Head		Fort Wayne School Dean		Fort Wayne Director of Graduate Studies	
Indianapolis Department Head		Indianapolis School Dean		IUPUI Associate Dean for Graduate Education	
North Central Department Head		North Central School Dean		North Central Director of Graduate Studies	
West Lafayette Department Head	10/28/15	West Lafayette College/School Dean	12/2/15	Date Approved by Graduate Council	
Graduate Area Committee Convener		Graduate Dean		Graduate Council Secretary	
				West Lafayette Registrar	

OFFICE OF THE REGISTRAR

Supporting Document to the Form 40G for a New Graduate Course

To: Purdue University Graduate Council

From: Faculty Member: Saurabh Bagchi

Department: Electrical and Computer Engineering

Campus: West Lafayette

Date:

Subject: Proposal for New Graduate Course

Contact for information if questions arise:
Name: Matt Golden
Phone: 494-3374
Email: goldenm@purdue.edu
Address: EE Building, Room 135

Course Subject Abbreviation and Number: ECE 60872

Course Title: Fault Tolerant Computer Systems

Course Description:

The course provides an introduction to the hardware and software methodologies for specifying, modeling and designing fault-tolerant systems supported by case studies of real systems. The material presents a broad spectrum of hardware and software error detection and recovery techniques that can be used to build reliable networked systems. The lectures discuss how the hardware and software techniques interplay, what techniques can be provided in COTS hardware, what can be embedded into operating system and network communication layers, and what can be provided via a distributed software layer and in the application itself.

The course focuses on hands-on learning through the design and development of systems in the course project, which carries 50% of the weightage for the course grade.

We will be using a modeling software called UltraSAN to model a realistic system and then learn how the model can be solved to evaluate various dependability properties of the system.

Semesters Offered:

For the benefit of graduate student plan of study development, how frequently will this prototype be offered? Which semesters?
Fall

A. Justification for the Course:

Provide a complete and detailed explanation of the need for the course (e. g., in the preparation of students, in providing new knowledge/training in one or more topics, in meeting degree requirements, etc.), how the course contributes to existing majors and/or concentrations, and how the course relates to other graduate courses offered by the department, other departments, or interdisciplinary programs.

Justify the level of the proposed graduate course (500- or 600-level) including statements on, but not limited to: (1) the target audience, including the anticipated number of undergraduate and graduate students who will enroll in the course; and (2) the rigor of the course.

- This course introduces students to the critical skill of building reliable and secure software and hardware-based systems. The course provides the relevant theoretical background and then practical systems building skills. It also discusses techniques to evaluate if a system is meeting the requirements. Finally, it pulls together the techniques learned into two practical deployed and popular systems which exemplify good reliability and security practices.

- This course replaces ECE 57200.
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- About 50% of the course material is from text and reference books, 35% from research literature, and 15% from synthesis of material from multiple sources including official reports, news stories, and investigative reports.
- The students demonstrate their mastery of the topics by doing (among other activities) a course project in teams of 2-3 students. Each team does a different and novel project, with the objective of developing publishable material.
- The course includes two lectures by practitioners from the industry about their applications of reliability and security principles.

Use the following criteria:
Graduate Council policy requires that courses at the 50000 level in the Purdue system should be taught at the graduate level and meet four criteria: a) the use of primary literature in conjunction with advanced secondary sources (i.e., advanced textbooks); b) assessments that demonstrate synthesis of concepts and ideas by students; c) demonstrations that topics are current, and; d) components that emphasize research approaches/methods or discovery efforts in the course content area (reading the research, critiquing articles, proposing research, performing research). Such courses should be taught so that undergraduate students are expected to rise to the level of graduate work and be assessed in the same manner as the graduate students.

- Anticipated enrollment
  - Undergraduate 0
  - Graduate 15-25

B. Learning Outcomes and Method of Evaluation or Assessment:

ECE Graduate Learning Outcomes:

a. Knowledge and Scholarship (thesis/non-thesis)
b. Communication (thesis/non-thesis)
c. Critical Thinking (thesis/non-thesis)
d. Ethical and Responsible Research (thesis) or Professional and Ethical Responsibility (non-thesis)

- List Learning Objectives for this course and map each Learning Objective to one or more of the ECE Learning Outcomes (a-d, listed above):

1. An ability to formulate design principles for dependable systems [b, c, d]
2. An ability to analyze mathematically a system for its dependability properties [a, c]
3. An ability to understand and apply hardware dependability techniques [a, c]
4. An ability to understand and apply software dependability techniques [a, c]
5. An ability to understand and apply networking dependability techniques [a, c]
6. An ability to design, develop, and present an innovative project on dependable systems [b, c, d]

- Methods of Instruction
  - Lecture: 50%
  - Group discussion: 35%

- Presentation by industry leaders: 15%

- Will/can this course be offered via Distance Learning?
  - No.

- Grading Criteria

  Grading criteria (select from checklist); include a statement describing the criteria that will be used to assess students and how the final grade will be determined. Add and delete rows as needed.

  - Exams: One mid-term and one final exam, both open book, open notes, and open computers
  - Project: One semester-long course project on an innovative topic from among those suggested by the instructor or proposed by the students. This will be done in teams of 2-3 students.
  - Homework: 3 homeworks, including one programming homework.

► Describe the criteria that will be used to assess students and how the final grade will be determined:

Course project: 50%
Mid-term: 15%
Final: 20%
Homeworks: 15%

C. Prerequisite(s):

List prerequisites and/or experiences/background required. If no prerequisites are indicated, provide an explanation for their absence. Add bullets as needed.

- Graduate Standing
- Prerequisite by Topic: Any one high level programming language experience; A basic background in probability

D. Course Instructor(s):

Provide the name, rank, and department/program affiliation of the instructor(s). Is the instructor currently a member of the Graduate Faculty? (If the answer is no,

indicate when it is expected that a request will be submitted.) Add rows as needed.

Name	Rank	Dept.	Graduate Faculty or expected date
Saurabh Bagchi	Professor	ECEN	Yes

E. Course Outline:

Provide an outline of topics to be covered and indicate the relative amount of time or emphasis devoted to each topic. If laboratory of field experiences are used to supplement a lecture course, explain the value of the experience(s) to enhance the quality of the course and student learning. For special topics courses, include a sample outline of a course that would be offered under the proposed course. **(This information must be listed and may be copied from syllabus).**

Topics	# Lecture Hours
Introduction: Motivation, System view of high availability design, Terminology	2
Stochastic analysis of reliability • Discrete distributions • Continuous distributions	6
Hardware redundancy: Basic approaches, Static & Dynamic, Voting, Coding for detection and recovery • *Application*: SEC-DED codes	3
Error detection techniques: Watchdog processors, Heartbeats, Consistency and capability checking, Data audits, Assertions, Control-flow checking • *Application*: Dynamic Host Configuration Protocol (DHCP)	3
Software fault tolerance: Process pairs, Robust data structures, N version programming, Recovery blocks, Replica consistency & reintegration, Multithreaded programs • *Application*: Quantitative evaluation of NVP and RB	5
Secure coding practices: Principles and practice • *Application*: Coding examples	2
Network fault tolerance: Reliable communication protocols,	6

Agreement protocols, Byzantine fault tolerance • *Application*: Bitcoin	
Modeling • *Application*: UltraSAN, Sharpe	4
Checkpointing & Recovery • *Application*: Microcheckpointing	4
Experimental Evaluation: Simulation and Fault-injection based	2
Practical Systems for Fault Tolerance: Putting it all together • *Application*: Amazon Web Service • *Application*: Hadoop	2
Industry presentations	2
Discussion of projects	2
Tests	1
Total	**44**

F. Reading List (including course text):

A primary reading list or bibliography should be limited to material the students will be required to read in order to successfully complete the course. It should not be a compilation of general reference material.

A secondary reading list or bibliography should include material students may use as background information.

- Primary Reading List
  - "Fault-Tolerant Systems" by Israel Kohen and C. Mani Krishna, Morgan Kaufmann, 2007.
- Secondary Reading List
  - "Fault Tolerance in Distributed Systems" by Pankaj Jalote, Prentice Hall, 1994.
  - "Probability and Statistics with Reliability, Queuing and Computer Science Applications" KishorTrivedi, John Wiley & Sons, 2nd edition, 2001.

G. Library Resources

Describe any library resources that are currently available or the resources needed to support this proposed course.

- Digital libraries from IEEE, ACM, and Usenix for research literature

H. Course Syllabus

(While not a necessary component of this supporting document, an example of a course syllabus is available, for information, by clicking on the link below, which goes to the *Graduate School's Policies and Procedures Manual for Administering Graduate Student Program.*
See Appendix K.
http://www.purdue.edu/gradschool/faculty/documents/Graduate_School_Policies_and_Procedures_Manual.pdf