New Course EFD Template

TO: The Engineering Faculty

FROM: The Faculty of the Lyles School of Civil Engineering

RE: New graduate course – CE 56601: Network Models For Connected And Autonomous Vehicles

The Faculty of the Lyles School of Civil Engineering has approved the following new graduate course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

FROM:

CE 59700 Network Models For Connected And Autonomous Vehicles, 3 credits

Fall 2023 (2); Spring 2022 (4), Fall 2021 (6)

No Prerequisites

TO:

CE 56601: Network Models For Connected And Autonomous Vehicles

Spring or Fall

Three total credits

No Prerequisites

Course Description: This course provides an introduction to mathematical foundations of the analysis of transportation networks. The course will be divided into two main sections. Section 1 will introduce the basic foundations of network routing problems including user equilibrium (selfish routing) and system optimal games on networks. Various optimization-based formulations, algorithms and extensions will be discussed. A particular emphasis will be on devising efficient algorithms and computation on city networks. Students will be expected to know how to design efficient algorithms for network analysis and implement them on various datasets. The second half of the course will tailor the network models learned in the first half to understanding the impacts of connected and autonomous vehicles (CAVs). This will be done by taking specific example problems such as autonomous intersection control, parking design, network design for CAVs, etc. Recent research papers will form the basis for developing these models. Extensive use of intuitive arguments, counterintuitive phenomenon (paradoxes) and network structures will be

utilized to illustrate many situations graphically. In addition, computing the solutions efficiently using various network algorithms will be discussed. The course is research based and students in addition to learning the concepts will extend the concepts to a research project to be finished within the semester.

RATIONALE:

The rapid evolution of transportation networks, especially with the advent of connected and autonomous vehicles (CAVs), requires specialized knowledge in network routing problems, optimization algorithms, and game theory. This course addresses this gap by providing students with the mathematical foundations needed to analyze complex transportation networks. It offers an in-depth look into selfish routing and system optimization, and extends these foundational principles to tackle real-world challenges related to CAVs. As urban environments grow more complex and demand for efficient transportation systems increases, a course like this becomes indispensable for professionals aiming to contribute meaningfully to the field of transportation network analysis and planning.

Head/Director of the Lyles School of Civil Engineering

Link to Curriculog entry: https://purdue.curriculog.com/proposal:25619/form

Course Information
- **Course number and title: CE 56601: Network Models for Connected and Autonomous Vehicles**
- **Meeting day(s) and time(s)**: If you have any questions, you can post your questions on the discussion board at Piazza. Either the TA or I will attempt to answer your questions as soon as possible. Please note that we may not be able to answer your questions over the weekends.
- **Prerequisites:** Undergraduate calculus, knowledge of probability, statistics, and linear algebra at the undergraduate level. Basic programming skills in languages such as MATLAB or C++.

Instructor(s) Contact Information
Provide information on the ways students can reach your Brightspace, Purdue email, phone, text, office location, and dedicated student contact/consultation hours. If additional individuals are key contact persons (TAs, co-instructors, course coordinators, etc.), include information for them as well.
- **Name of the instructor:** Professor Satish Ukkusuri
- **Office Location:** HAMP G167D
- **Office Phone Number:** (765) 494-2296
- **Purdue Email Address:** sukkusur@purdue.edu
- **Student Consultation hours, times, and location**: Emails or Piazza questions are read 8 a.m. to 5 p.m. daily and will be responded to within 24 hours. Be flexible with these times before deadlines and exams.

Course Description
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Learning Resources, Technology & Texts
- **Informed Learning resources such as**
  - **Required texts**
    - Sheffi, Y. *Urban Transportation Networks: Equilibrium Analysis with Mathematical programming methods*. Prentice-Hall Inc., Englewood Cliffs, NJ, 1985. [Out of print]. Required handout from this text will be distributed in class. You can download a free copy of the book here: http://web.mit.edu/sheffi/www/urbanTransportation.html

- ○ **Additional readings**
    - ■ Ahuja, R.K., Magnanti, T.L. and Orlin, J.B. Network Flows: Theory, Algorithms and Applications. Prentice-Hall Inc., 1993.
    - ■ Cascetta, E. *Transportation systems engineering: theory and methods*. Dordrecht ; Boston, MA : Kluwer Academic, 2001.
    - ■ Bell, M.G.H., and Iida, Y. Transportation Network Analysis. John Wiley & Sons, 1997. ISBN 0471 96493 X
- ○ **Databases**
    - ■ Transportation Research Part B: Methodological
    - ■ Transportation Research Part C: Emerging Technologies
    - ■ IEEE Transactions on Intelligent Transportation Systems
- ● **Software/web resources**
    - ○ Programming: Python, MATLAB, and so on.
- ● **Hardware requirements**
    - ○ Webcam for exam proctoring
- ● **Tutoring support**
- ● **Brightspace learning management system**

Learning Outcomes

A student completing this course is expected to be able to:

1. Analyze transportation systems using game theory and optimization by drawing on analogies between the interactions of supply and demand in economic markets.
    a. Define selfish routing (user equilibrium) and system optimal problems
    b. Develop solution algorithms for large scale networks
2. Apply specialized network structures to solve selfish routing games efficiently.
3. Rigorously formulate and apply various extensions of the selfish routing game – traffic assignment with elasticity, stochastic user equilibrium, network design and OD estimation.
4. Understand the basic concepts of Connected and Autonomous vehicles (CAVs).
5. Apply the static network models to CAV planning and operations problems.
6. Use software to analyze various large-scale transportation networks and understand issues from real world practitioners.

Assignments

- Problem sets will be given, and the analysis of these assignments will be the basis for some class discussion.
- Problem sets are due at the beginning of class on designated days; late problem sets will not be accepted.
- For the problem sets, you may (are encouraged to) discuss with other students but the final written solution should be your own work. The exam will be open textbook and open class notes.
- The project report must be scholarly and, if possible, should have some original input from the student. The project report should be prepared according to Transportation Research Part B format. Students will need to code any algorithm of their choice related to the course and test it on a network under different OD flows.
- **The project report should be submitted in Brightspace.**

Assignments	Points
Homework	25
Exam	50
Project report	25
	Total: 100

Grading Scale

A+ = 97-100%	C+ = 77-80%
A = 93-96%	C = 73-76%
A- = 90-92%	C- = 70-72%
B+ = 87-90%	D+ = 67-70%
B = 83-86%	D = 63-66%
B- = 80-82%	D- = 60-62%
	F = 59% and below

Attendance Policy

This course follows Purdue's academic regulations regarding attendance, which states that students are expected to be present for every meeting of the classes in which they are enrolled. Attendance will be taken at the beginning of each class and lateness will be noted. When conflicts or absences can be anticipated, such as for many University-sponsored activities and religious observations, the student should inform the instructor of the situation as far in advance as possible. For unanticipated or emergency absences when advance notification to the instructor is not possible, the student should contact the instructor as soon as possible by email or phone. When the student is unable to make direct contact with the instructor and is unable to leave word with the instructor's department because of circumstances beyond the student's control, and in cases falling under excused absence regulations, the student or the student's representative should contact or go to the Office of the Dean of Students website to complete appropriate forms for instructor notification. Under academic regulations, excused absences may be granted for cases of grief/bereavement, military service, jury duty, and parenting leave. For details, see the Academic Regulations & Student Conduct section of the University Catalog website. Guidance on class attendance related to COVID-19 are outlined in the Protect Purdue Pledge for Fall 2021 on the Protect Purdue website.

Academic Guidance in the Event a Student is Quarantined/Isolated

If you must miss class at any point in time during the semester, please reach out to me via email so that we can communicate about how you can maintain your academic progress. If you find yourself too sick to progress in the course, notify your adviser and notify me via email or Brightspace. We will make arrangements based on your particular situation. Please note that, according to Details for Students on Normal Operations for Fall 2021 announced on the Protect Purdue website, "individuals who test positive for COVID-19 are not guaranteed remote access to all course activities, materials, and assignments."

Classroom Guidance Regarding Protect Purdue

Any student who has substantial reason to believe that another person is threatening the safety of others by not complying with Protect Purdue protocols is encouraged to report the behavior to and discuss the next steps with their instructor. Students also have the option of reporting the behavior to the Office of the Student Rights and Responsibilities. See also Purdue University Bill of Student Rights and the Violent Behavior Policy under University Resources in Brightspace.

Academic Integrity

Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing integrity@purdue.edu or by calling 765-494-

8778. While information may be submitted anonymously, the more information is submitted the greater the opportunity for the university to investigate the concern. More details are available on our course Brightspace table of contents, under University Policies.

Nondiscrimination Statement

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. A hyperlink to Purdue's full Nondiscrimination Policy Statement is included in our course Brightspace under University Policies.

Accessibility

Purdue University is committed to making learning experiences accessible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247.

Mental Health/Wellness Statement

If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try WellTrack. Sign in and find information and tools at your fingertips, available to you at any time.

If you need support and information about options and resources, please contact or see the Office of the Dean of Students. Call 765-494-1747. Hours of operation are M-F, 8 am- 5 pm.

If you find yourself struggling to find a healthy balance between academics, social life, stress, etc. sign up for free one-on-one virtual or in-person sessions with a Purdue Wellness Coach at RecWell. Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is completely free and can be done on BoilerConnect. If you have any questions, please contact Purdue Wellness at evans240@purdue.edu.

If you're struggling and need mental health services: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office on the second floor of the Purdue University Student Health Center (PUSH) during business hours.

Basic Needs Security

Any student who faces challenges securing their food or housing and believes this may affect their performance in the course is urged to contact the Dean of Students for support. There is no appointment needed and Student Support Services is available to serve students 8 a.m.-5 p.m. Monday through Friday. Considering the significant disruptions caused by the current global crisis as it related to COVID-19, students may submit requests for emergency assistance from the Critical Needs Fund

Emergency Preparation

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructors or TAs via email or phone. You are expected to read your @purdue.edu email on a frequent basis.