

## C S 5970 Network Science

Fall 2015

**Instructor:** Dr. K. Thulasiraman

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Course Time: 12 Noon - 1:15 PM

Office Hours: Monday : 9:00 - 10:30 AM

Wednesday 9: - 10:30 AM

**Pre-requisite:** CS 4413 Algorithm Analysis or Equivalent; Non-CS students are encouraged to discuss with the instructor the specific pre-requisites.

In the last sixty to seventy years, graphs and networks have played a great role in fuelling advances in engineering and computer science and vice versa. These areas of applications of graph theory may be broadly classified as network engineering. Recently, a new area called network science has emerged. Ted Lewis in his 2009 book defines network science as “the study of the theoretical foundations of network structure /dynamic behavior and the applications to many subfields”. Its roots can be traced to graph theory and, in particular, the pioneering works by Erdos-Renyi on random graphs. It is “the convergence of several subfields: graph theory, social network analysis, epidemic modeling, market competition modeling, synchronization of physical and biological systems”.

In this course, a broad range of fundamental concepts and algorithms used in network science applications will be discussed. Special topics dealing with recent advances in spectral graph theory and applications of network science principles to telecommunication networks, cascading failure process in power grids etc. will be discussed. A project to be selected by each student will provide further opportunities to learn and explore specific research topics that suit the student’s needs and interests.

### **Syllabus:**

1. Chapter 6 : Introductory Concepts in Mathematics of Networks
2. Chapter 7: Measures and Metrics for Network Evaluation
3. Chapter 8: Large Scale Structure of Networks
4. Chapter 10: Fundamental Network Algorithms
5. Chapter 11; Matrix, Partitioning and Other Algorithms for Network Evaluation
6. Chapter 12: Random Graphs
7. Chapter 14 : Models of Network Formation
8. Chapter 19: Dynamical Systems on Networks

9. Special Topics: A few of the following topics in the following emerging areas of Network Science. Reference papers dealing with these topics will be provided.

- Spectral Graph Theory ( emphasizing Laplacian Matrices , their eigenvalues and relationships to network criticality metrics)
- Topological Characterization of Network Criticality Metrics
- Telecommunication Networks: Kirchhoff Index, Node/edge criticality and Relationship to Network Robustness.
- Control - Theoretic Concepts and Applications
- Cascading Failure Process in Communication Networks and Power Grids.

**Grading Scheme:**

**Two Tests: 60%**

**Project: 40% ( Report and presentation)**

**Text:**

- M.E.J. Newman, *Networks: An Introduction*, Oxford University Press, 2011.

**Reference:**

- Ted G. Lewis, *Network Science: Theory and Practice*, Wiley, 2008.

**Other Selected References:**

- Jason J. Molitierno , *Applications of Combinatorial Matrix Theory to Laplacian Matrices of Graphs*, Discrete Mathematics and Applications Series, CRC Press, 2012..
- Piet van Mieghem, *Graph Spectra for Complex Networks*, Cambridge University Press, 2011.
- Fernando Vega-Redondo, *Complex Social Networks*, Cambridge University Press, w2007.
- David Easley and Jon Kleinberg, *Networks, Crowds and Markets: Reasoning about a Highly Connected World*, Cambridge University Press, 2010.
- Stefan Bornholdt and Heinz Schuster (Editors), *Handbook of Graphs and Networks: From the Genome to the Internet*, Wiley-VCH, 2003.
- M. N. S. Swamy and K. Thulasiraman, *Graphs, Networks and Algorithms*, Wiley-Inter-science, 1981.
- Ali Tizghadam, *Autonomic Core Network Management System*, Ph. D. Thesis , Department of Electrical and Computer Engineering, University of Toronto, Canada, 2009.
- Yang-Yu Liu , Jean-Jacques Slotine and Albert-Laszlo Barabasi, " Controllability of Complex Networks", Nature, Vol.473, May 2011.
- Yang-Yu Liu , Jean-Jacques Slotine and Albert-Laszlo Barabasi, " Control Centrality and Hierarchical Structure in Complex Networks", Physics ?
- Anna Lombardi and Michael Horquist, " Copntrollabili Analysis of Networks", Physical Review, E 75, 056110, 2007.

