C S 5483 – Network Science
Fall 2020

Instructor	Dr. Sridhar Radhakrishnan (sridhar@ou.edu)
Office Hours	Saturday's After Class
Course Timings	9:00 AM to 12:00 PM (Saturday)
Course Location	VIDC – Synchronous Online and Asynchronous Online Topic: CS 5483 - Network Science **Join Zoom Meeting** https://oklahoma.zoom.us/j/93747656458?pwd=dlRpNnFZQkl3dmoranhCMndpdC9xQT09 Meeting ID: 937 4765 6458 Passcode: F6Y&5Sn0
Course Prerequisite	CS/DSA 4413 or permission of the instructor
Course Objectives	Topics to be covered include fundamental algorithms for network analysis, investigating properties of networks, learning community detection methods, understanding network inference methods, understanding dynamics of networks, percolation, resilience, spreading phenomenon, social influence, and cascades. A variety of application contexts will be used, including physical, informational, biological, cognitive, and social systems.
Useful Course Material	1. *Networks:* Book by *Mark Newman*, 2nd Edition, Oxford University Press, 2020, ISBN-13: 978-0123850591, ISBN-10: 0123850592 2. *Social Media Mining*: *An Introduction*, Cambridge University Press New York, NY, USA ©2014 ISBN:1107018854 9781107018853 3. Material that will be placed on canvas.
Course Requirements	Students will be required to take several quizzes that will embedded within the videos. In addition, there will a set of homework assignments some of which will involve programming exercises with Python and Network X library. There will be an individual final project and a presentation. Failure to complete the final project and the presentation will result in an automatic F as the overall course grade.

Course Grading

The course letter grade will be assigned based on the overall percentage: 90-100 (A), 80-89 (B), 70-79 (C), 60-69 (D), and < 60 (F). The allocation of percentages is given below:

	Grade Distribution
Video Embedded Quizzes	15%
Python Programming Assignments	25%
Homework Assignments	15%
Final Project – Proposal (5%), Progress Reports (5%), Demonstration (10%)	20%
Presentation	10%
Participation on all project presentations	5%

Final Project and Milestones

There are several ways in which this course project can be completed:

(1) Development of software to perform network analysis or modeling on very large networks.

(2) Reproduce some results of a paper based on different data or different methods.

All projects must involve some sort of visualization. Here are the due dates. The evaluation percentages are also provided below.

October 17: project proposal
November 7: progress report-1
November 21: progress report-2
November 28: project demonstrations
December 5: project presentations
December 12: project presentations

Lecture Notes and Attendance

It is advised that students listen all lectures.

Tentative Lecture Schedule

Date	Topics
August 29, 2020	Module 0: About this course Module 1: Introduction to Network Science, Programming with Python and Network X
September 5, 2020	Module 2: Technological, Information, Social, and Biological Networks
September 12, 2020	Module 2 (contd.): Technological, Information, Social, and Biological Networks Module 3: Fundamentals of Network Theory: Mathematics of Networks
September 19, 2020	Module 3 (contd.): Fundamentals of Network Theory: Mathematics of Networks Module 4: Fundamentals of Network Theory: Measures and Metrics
September 26, 2020	Module 4 (contd.): Fundamentals of Network Theory: Measures and Metrics Module 5: Fundamentals of Network Theory: Graph Algorithms
October 3, 2020	Module 5 (contd.): Fundamentals of Network Theory: Graph Algorithms Module 6: Fundamentals of Network Theory: Network Statistics and Measurement Error
October 10, 2020	Module 7: Fundamentals of Network Theory: The Structure of Real-World Networks
October 17, 2020	Module 8: Network Models: Random Graphs
October 24, 2020	Module 9: Network Models: The Configuration Model
October 31, 2020	Module 10: Network Models: Models of Network Formation
November 7, 2020	Module 11: Applications: Community Structure
November 14, 2020	Module 11 (contd.): Applications: Community Structure Module 12: Applications: Percolation and Network Resilience
November 21, 2020	Module 13: Applications: Epidemics on Networks
November 28, 2020	**Thanksgiving Break**
December 5, 2020	Module 14: Advanced Topics
December 12, 2020	Final Project Demonstration and Presentations

Module 0: About this course

0.1 Introducing your Professor
- a. Professor
- b. Contact Information

0.2 Course Contents
- a. About network science
- b. Textbooks used
- c. Topics to be covered

0.3 Course tools
- a. Python – GitHub, Jupyter, NetworkX, and visualization tools

0.4 Grading Policies

0.5 How to learn online

Module 1: Introduction to Network Science, Programming with Python and Network X

1.1 Networks Definition and Examples
- d. What are networks? Nodes (vertices) and links (edges), directed, undirected
- e. Examples of various networks along with their sizes

1.2 Networks Classification and the Information it Conveys
- a. Classification of the types of networks: technology, information, social, and biological
- b. What can we learn from networks?

1.3 Properties of networks
- a. Degree, in-degree, out-degree, hubs, distance, radius, diameter, small-world effect (degrees of separation), clusters, communities

1.4 Python
- a. Python notebook, NetworkX, Simple visualization

Module 2: Technological, Information, Social, and Biological Networks

2.1 Technological Networks
- a. The Internet – How is it organized? How can we get its structure using TRACEROUTE? What are routing tables? How can be it used to understand the structure of the Internet?
- b. The Telephone Network: Circuit-Switched Network and Packet-Switched Networks
- c. Power Grids: How are they modeled? What are smart Grids?
- d. Transportation Networks: Modeling – Road network and train network
- e. Delivery and Distribution Networks
- f. Interdependent Networks

2.2 Information Networks
- a. The world wide web: A directed network
- b. Using a crawler to get WWW's structure: wget, Nutch, GRUB, and Sphinx
- c. Citation Networks, Peer-to-Peer Networks, Recommender Networks, and Keyword indexes
- d. Drug-drug interaction network

2.3 Social Networks
- c. Empirical study of social networks
- d. Constructing social networks: interviews and questionnaire, ego-centric networks, direct observation, archival data
- e. Affiliation networks
- f. Small-World Experiment
- g. Snowball sampling, contact tracing, and random walks

2.4 Biological Networks
- a. Metabolic networks, protein-protein interaction network, genetic regulatory networks

b. Networks in the Brain – Networks of neurons, networks of functional connectivity in the brain
c. Ecological networks: Food webs, Host-parasite networks, Mutualistic networks

2.5 Python
a. Downloading various types of networks and visualizing with python and graphViz

Module 3: Fundamentals of Network Theory: Mathematics of Networks

3.1 Networks and their representations:
a. Edge list, Adjacency Matrix, Adjacency List, Weighted Networks, Sparse vs Dense Graph

3.2 Varieties of graphs
a. Directed and Acyclic
b. Bipartite, Hypergraphs
c. Trees
d. Planar
e. Multilayer and Dynamic

3.3. Properties of Graphs: degree, density, sparsity, walks, paths, shortest paths, diameter
a. Degree, average degree, and moments
b. Density and Sparsity
c. Paths: walks, shortest paths, and diameter
d. Components: connected components, strongly connected components

3.3 Independent Paths, connectivity, cut sets, max flow, min cut
a. Vertex and edge disjoint paths
b. Connectivity: bi-connectivity and k-connectivity
c. Cut sets and relationship to connectivity, max flow and min cut on weighted networks

3.4 Graph Laplacian
a. Definition and properties
b. Graph Partitioning definition
c. Network Visualization
d. Random walks
e. Resistor networks

3.5 Python
a. Take a graph and show how the various properties, paths, cuts, connectivity, and graph Laplacian can be calculated

Module 4: Fundamentals of Network Theory: Measures and Metrics

4.1 Centrality
a. Degree Centrality
b. Eigenvector Centrality
c. Katz Centrality
d. Page Rank
e. Hubs and Authorities
f. Closeness Centrality
g. Betweenness Centrality

4.2 Groups of Nodes
a. Cliques
b. Components and K-Components

4.3 Transitivity
a. Clustering Coefficient
b. Reciprocity

4.4 Signed Edges and Structural Balance

4.5 Similarity
   a. Structural Equivalence
   b. Regular Equivalence
4.6 Homophily and Assortative Mixing
   a. Assortative Mixing by unordered characteristics
   b. Assortative Mixing by ordered characteristics
4.7 Python
   a. Take a graph's adjacency matrix and calculate various centrality measures
   b. Write a python code to determine a k-clique in a graph

Module 5: Fundamentals of Network Theory: Graph Algorithms

5.1 Running time and computational complexity
5.2 Representation of Networks: Edge List, Adjacency Matrix, Adjacency List
5.3 Depth First Search Algorithm: Finding Connected Components
5.4 Breadth First Search: Counting Triangles and Finding Diameter of a network
5.5 Single Source Shortest path algorithm – Dijkstra's
5.6 All-Pair Shortest path algorithm – Floyd's algorithm: Betweenness Centrality
5.7 Max-Flow and Min-Cut
5.8 K-disjoint paths algorithm
5.9 Finding maximal cliques in a graph
5.10 Python
   a. Using the NetworkX library and sample random graphs, determine compute the number of connected components in a graph.

Module 6: Fundamentals of Network Theory: Network Statistics and Measurement Error

6.1 Types and Sources of Errors
6.2 Estimating Errors: Statistical, Maximal Likelihood, Expectation Maximization Algorithm
6.3 Correcting Errors: Link Prediction, Node Disambiguation
6.4 Python
   a. Implement a link prediction algorithm using Phyton and NetworkX

Module 7: Fundamentals of Network Theory: The Structure of Real-World Networks

7.1 Connected and Strongly Connected Components of a Network
7.2 Small-World Effect
7.3 Degree Distributions
7.4 Power laws and scale-free networks, Detecting and Visualizing power-laws
7.5 Distribution of Centrality measures
7.6 Clustering Coefficients
7.7 Assortative Mixing
7.8 Python
   a. Take a set of real-world graphs and show its degree distributions

Module 8: Network Models: Random Graphs

8.1 Random Graphs
8.2 Mean Number of Edges and Mean Degree
8.3 Degree Distribution
8.4 Clustering Coefficient
8.5 Giant Component
8.6 Small Components
8.7 Path Lengths
8.8 Issues with Random Graphs
8.9 Python

a. Write a program to generate various type of random graphs

Module 9: Network Models: The Configuration Model

9.1 The configuration model: Edge probability and Expected degree
9.2 Excess Degree distribution
9.3 Clustering Coefficient
9.4 Tree-Like Networks
9.5 Number of second neighbors of a node
9.6 Giant, Small Components, and Diameter
9.7 Python
   a. Take a large graph, run connected components algorithm, show the giant component by removing edges at random.

Module 10: Network Models: Models of Network Formation

10.1 Preferential Attachment – Price Model
10.2 Barabasi and Albert Model
10.3 Node-copying Model
10.4 Python
   a. Implement the preferential attachment model.

Module 11: Applications: Community Structure

11.1 Dividing Networks into groups
11.2 Modularity Maximization: Louvain Algorithm
11.3 Kernighan-Lin Algorithm
11.4 Spectral Paritioning
11.5 Other Community Detection Algorithms: Betweeness, Hierarchical Clustering,
11.6 Measuring Performance of Community Detection Algorithms
11.7 Python
   a. Implement and execute the Louvain algorithm on a chosen network

Module 12: Applications: Percolation and Network Resilience

12.1 Percolation
12.2 Uniform Removal of Nodes
12.3 Percolation in Real-World Networks
12.4 Algorithm for Percolation
12.5 Python
   a. Implement and execute the percolation algorithm discussed

Module 13: Applications: Epidemics on Networks

13.1 Models of Spread of Infection
13.2 SI Model
13.3 SIR Model
13.4 SIS Model
13.5 SIRS Model
13.6 Outbreak Sizes and Percolation
13.7 Python
   a. Implement and execute SI and SIR model on a random network

Module 14: Advanced Topics

14.1 Time-Evolving Network Structures and Algorithms
14.2 Interdependent Networks, Resilience, and Restoration
14.3 Dynamics of Brain Networks
14.4 Financial Markets Meets Network Science

Student Evaluations:

The College of Engineering utilizes student ratings as one of the bases for evaluating the teaching effectiveness of each of its faculty members. The results of these forms are important data used in the process of awarding tenure, making promotions, and giving salary increases. In addition, the faculty uses these forms to improve their own teaching effectiveness. The original request for the use of these forms came from students, and it is students who eventually benefit most from their use. Please take this task seriously and respond as honestly and precisely as possible, both to the machine-scored items and to the open-ended questions.

University Policies:

In this section, include the mandatory University policies.

University Mandatory Masking Policy
"Each OU campus has implemented and will enforce a policy mandating that masks be worn by employees, students, patients, and visitors (1) when they are inside University facilities and vehicles and (2) when they are outdoors on campus and social distancing of at least six feet is not possible. 1 Each campus policy has been reviewed and approved by OU's Chief COVID Officer 2 and is effective until further notice." (https://www.ou.edu/coronavirus/masking-policy)

Canvas Learning Management System https://canvas.ou.edu
Log in with your OUNetID (usually the first 4 letters of your last name followed by a 4-digit number). All assignments, deadlines, grades, announcements, and course documents will be posted to the CS 5483 Canvas page. It is your responsibility to regularly check for updates. (You can configure Canvas to email you notifications.)

Academic Integrity
Cheating is strictly prohibited at the University of Oklahoma, because it devalues the degree you are working hard to get. As a member of the OU community, it is your responsibility to protect your educational investment by knowing and following the rules. A student must complete his/her tests, projects and assignments on his/her own. A student's signature on any tests, projects and assignments indicates that the student neither gave nor received unauthorized aid. Academic misconduct is defined as any act which improperly affects the evaluation of a students academic performance or achievement. It specifically includes cheating, plagiarism, fabrication, fraud, destruction of property, and bribery or intimidation, as well as assisting others or attempting to engage in such acts. It is the responsibility of each student to be familiar with the definitions, policies and procedures concerning academic misconduct. For more information, please review the Student's Guide to Academic Integrity at http://integrity.ou.edu/students_guide.html.

Incomplete Grades: A letter grade of I (incomplete) is intended for the rare circumstance when a student, who has been successful in class, has an unexpected event occur shortly before the end of the semester. I generally will not consider giving an incomplete grade unless three conditions are met:
1. It is close to the end of the semester.
2. You have a grade of C or better in the class.
3. The reason you are unable to complete the class is compelling.

Religious Observance
It is the policy of the University to excuse the absences of students that result from religious observances and to reschedule examinations and additional required classwork that may fall on religious holidays, without penalty.

Reasonable Accommodation Policy
Students requiring academic accommodation should contact the Disability Resource Center for assistance at (405) 325-3852 or TDD: (405) 325-4173. For more information please see the Disability Resource Center website http://www.ou.edu/drc/home.html. Any student in this course who has a disability that may prevent him or her from fully demonstrating his or her abilities should contact me personally as soon as possible so we can discuss accommodations necessary to ensure full participation and facilitate your educational opportunities.

Title IX Resources and Reporting Requirement
For any concerns regarding gender-based discrimination, sexual harassment, sexual assault, dating/domestic violence, or stalking, the University offers a variety of resources. To learn more or to report an incident, please contact the Sexual Misconduct Office at 405/325-2215 (8 to 5, M-F) or smo@ou.edu. Incidents can also be reported confidentially to OU Advocates at 405/615-0013 (phones are answered 24 hours a day, 7 days a week). Also, please be advised that a professor/GA/TA is required to report instances of sexual harassment, sexual assault, or discrimination to the Sexual Misconduct Office. Inquiries regarding non-discrimination policies may be directed to: Bobby J. Mason, University Equal Opportunity Officer and Title IX Coordinator at 405/325-3546 or bjm@ou.edu. For more information, visit http://www.ou.edu/eoo.html.

Adjustments for Pregnancy/Childbirth Related Issues
Should you need modifications or adjustments to your course requirements because of documented pregnancy-related or childbirth-related issues, please contact your professor or the Disability Resource Center at 405/325-3852 as soon as possible. Also,
see http://www.ou.edu/eoo/faqs/pregnancy-faqs.html for answers to commonly asked questions.

Final Exam Preparation Period
Pre-finals week will be defined as the seven calendar days before the first day of finals.

Emergency Protocol
During an emergency, there are official university procedures that will maximize your safety.
Severe Weather: If you receive an OU Alert to seek refuge or hear a tornado siren that signals severe weather *1. LOOK* for severe weather refuge location maps located inside most OU buildings near the entrances *2. SEEK* refuge inside a building. Do not leave one building to seek shelter in another building that you deem safer. If outside, get into the nearest building. *3. GO* to the building's severe weather refuge location. If you do not know where that is, go to the lowest level possible and seek refuge in an innermost room. Avoid outside doors and windows. *4.* GET IN, GET DOWN, COVER UP. 5. *WAIT* for official notice to resume normal activities.
Link to Severe Weather Refuge Areas , Severe Weather Preparedness - Video

Armed Subject/Campus Intruder: If you receive an OU Alert to shelter-in-place due to an active shooter or armed intruder situation or you hear what you perceive to be gunshots:
1. GET OUT: If you believe you can get out of the area WITHOUT encountering the armed individual, move quickly towards the nearest building exit, move away from the building, and call 911. *2. HIDE OUT*: If you cannot flee, move to an area that can be locked or barricaded, turn off lights, silence devices, spread out, and formulate a plan of attack if the shooter enters the room. *3. TAKE OUT*: As a last resort fight to defend yourself.
For more information, visit http://www.ou.edu/emergencypreparedness.html
Shots Fired on Campus Procedure - Video

Fire Alarm/General Emergency: If you receive an OU Alert that there is danger inside or near the building, or the fire alarm inside the building activates: *1. LEAVE* the building. Do not use the elevators. *2. KNOW* at least two building exits *3. ASSIST* those that may need help *4. PROCEED* to the emergency assembly area *5 ONCE safely outside, NOTIFY first responders of anyone that may still be*

inside building due to mobility issues. 6. .WAIT for official notice before attempting to re-enter the building.
OU Fire Safety on Campus

**Every part of this syllabus is subject to adjustment as the semester progresses. If you are dissatisfied with the course policies, grading, and assignments, please contact the instructor. Reasonable requests for modifications may be accommodated at the instructor's discretion.*