

# CSCI7000-016: Optimization and Control of Networks

## Introduction

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# Basic information

- ❑ Website: <http://spot.colorado.edu/~lich1539/ocn.html>
- ❑ Time: TUE 3:30pm-6:00pm
- ❑ Office hours
  - ❑ 1:30pm-3:15pm on Tuesdays; ECOT335
  - ❑ By appointment (email is most convenient)
- ❑ Grading (tentative)
  - ❑ Homework – 10%
    - About 2 homework sets; collaboration strongly encouraged, but write your own solutions
  - ❑ Topic review report – 50%
  - ❑ Project – 40%

# Topic review

- ❑ Seminar style course: read/discuss foundational and recent papers on network optimization and control
- ❑ Instructor and student presentation
- ❑ Topic review
  - ❑ read all the papers
  - ❑ Two brief essays on how to read
    - [http://spot.colorado.edu/~lich1539/ned/HowToRead\\_Keshav.pdf](http://spot.colorado.edu/~lich1539/ned/HowToRead_Keshav.pdf)
    - [http://spot.colorado.edu/~lich1539/ned/HowToRead\\_C.pdf](http://spot.colorado.edu/~lich1539/ned/HowToRead_C.pdf)
  - ❑ Write a review for each topic
    - at least one page (standard ACM or IEEE double-column and single-space format)
    - due before the class for the topic

# Topic review

- ❑ What is this topic about?
  - ❑ The problem addressed and what motivates it
  - ❑ The challenges in addressing the problem
  - ❑ The approach/technique used
  - ❑ The main results
- ❑ Strengths and weaknesses?
- ❑ Is the main technique clear to you?
- ❑ Is evaluation convincing?
- ❑ Improve the papers?
  - ❑ Improve its technique?
  - ❑ A different approach or perspective to address the problem?
- ❑ Apply similar approach/technique to other problems?

# Project

- ❑ Project proposal due in week 6 (Feb 15-19)
  - ❑ Use your current research topic that is relevant
  - ❑ Work on a new one
- ❑ Biweekly meetings with me, starting in week 7
- ❑ Project presentation on April 26
  - ❑ 30 minutes
- ❑ Project report due in the last week
  - ❑ 6 pages (standard ACM or IEEE double-column single-space format)

# Prerequisite

- ❑ Some knowledge in networks (communications, power, social, and finance, etc)
  - ❑ Preferred but not required; will review as needed
  - ❑ Strongly recommend to read Walrand & Parehk, *Communication Networks: A Concise Introduction* (as a leisure reading)
- ❑ Basic convex optimization theory and game theory
  - ❑ Preferred but not required
  - ❑ Will review as needed

# Reference papers & texts

- ❑ About 20 journal/conference papers
- ❑ Walrand & Parehk, Communication Networks: A Concise Introduction
- ❑ Boyd & Vandenburghe, *Convex Optimization*
- ❑ Fudenberg & Tirole, *Game Theory*
- ❑ Bertsekas, *Network Optimization: Continuous and Discrete Models*
- ❑ Godsil & Royle, *Algebraic Graph Theory*
- ❑ Mas-Colell, Whinston & Green, Microeconomic Theory

# Policies and legal requirements

- ❑ Accommodations for disability
- ❑ Religious observance
- ❑ Classroom behavior
- ❑ Discrimination and harassment
- ❑ Honor code

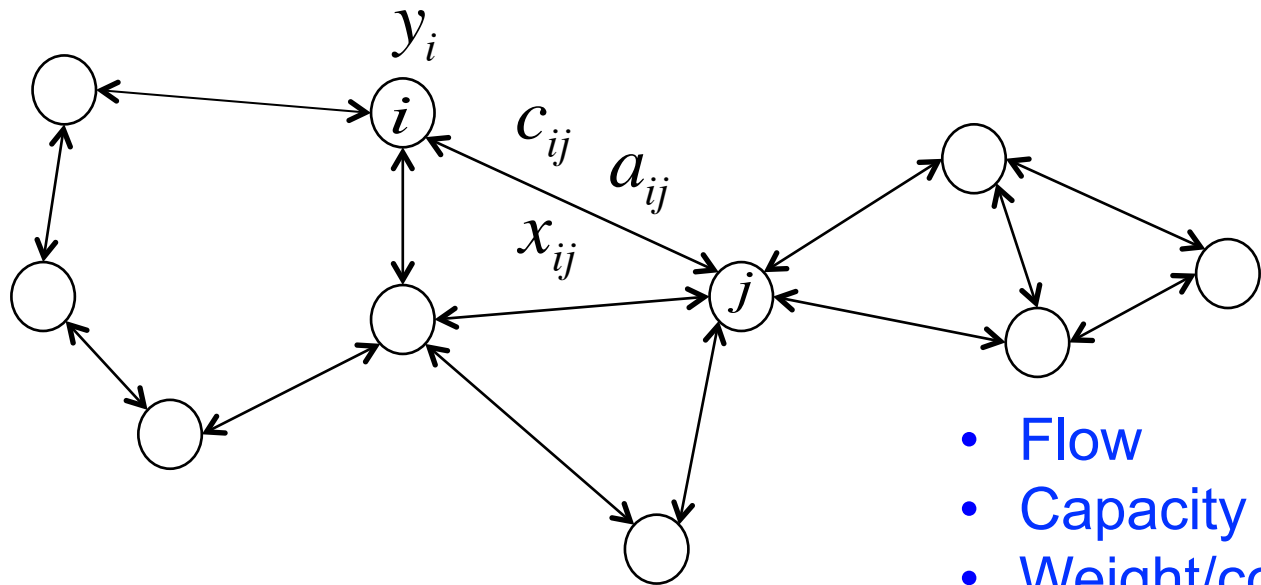


# What this course is about

# Networks

- ❑ Communication/computer networks
  - ❑ The internet, cellular networks, ...
- ❑ Power/electricity networks
- ❑ Transportation networks
  - ❑ Highway systems, rivers, ...
- ❑ Cyber-physical networks
  - ❑ Networks of unmanned vehicles or robots ...
- ❑ Social networks
  - ❑ Facebook, citation networks, financial networks, ...
- ❑ Bio/eco networks
  - ❑ Gene networks, food chains (predator-prey nets), ...

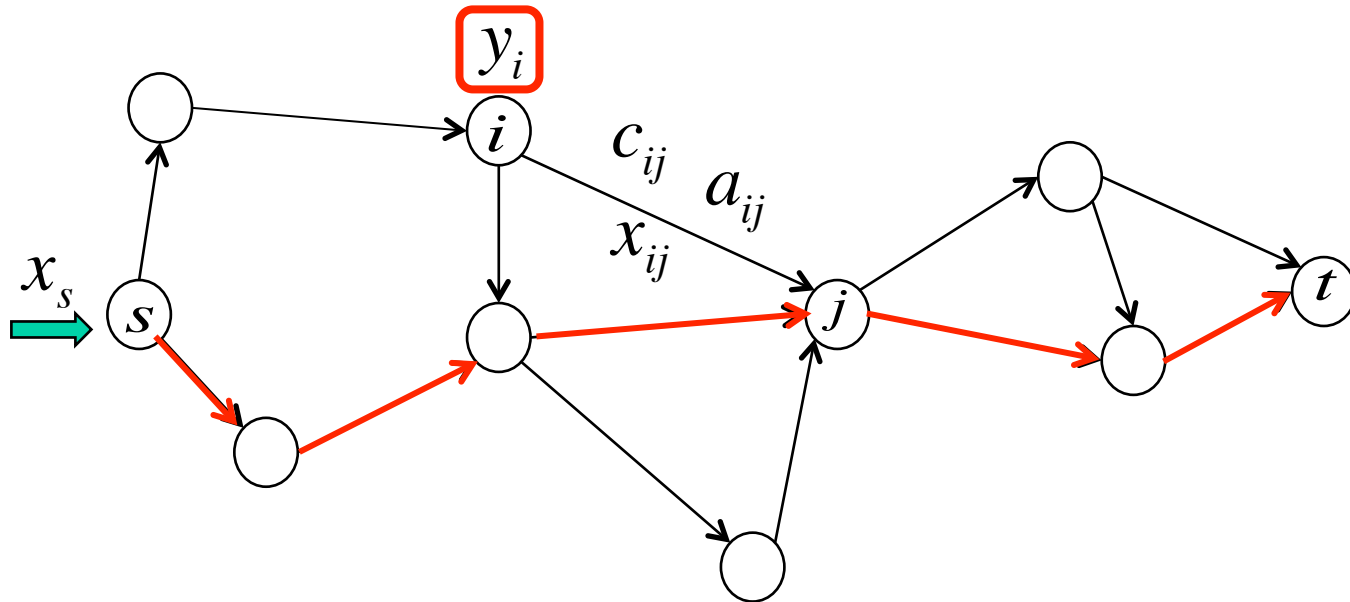
# Represent a network



- Flow
- Capacity
- Weight/cost
- State

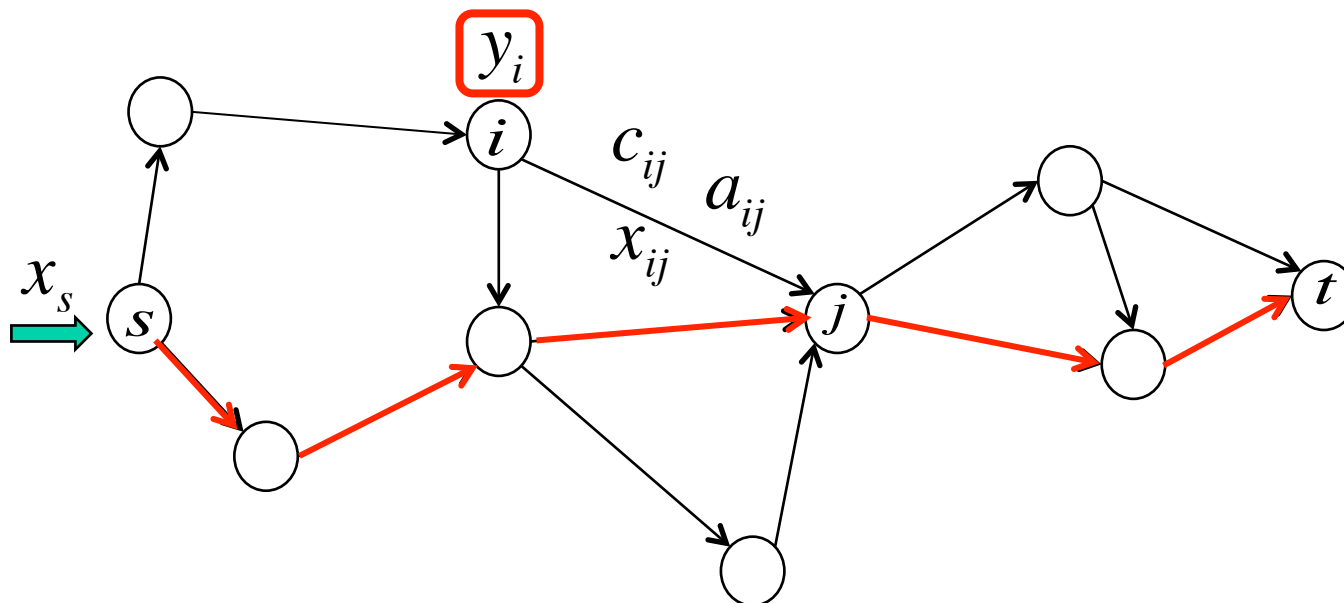
A Graph  $G = (N, L)$

# What we care about networks



- Maximum flow
- Min-cost flow  $\min \sum_{(i,j)} a_{ij} x_{ij}$
- Routing
- Congestion control
- Dynamics over net
- Many, many more ...

# What we care about networks



- Fundamental limits on what is achievable
- Algorithms/protocols and control/management that achieve these limits
  - Incomplete information, distributed/local decisions, uncertainty
- Dynamics and behaviors of the network

# Analytical foundations

- ❑ Analysis of networks and protocols to understand network-wide behaviors or properties
  - ❑ Efficiency, fairness, responsiveness, and robustness, etc
  - ❑ Models and theories to characterize structural properties
- ❑ Design of networks and protocols to achieve the desired behaviors
  - ❑ Efficiency, fairness, responsiveness, and robustness, etc
  - ❑ Models, theories, tools, and algorithms
  - ❑ Unified framework and language
    - To reason about computational, informational, and incentive constraints
    - To guide systematic design: how to layer various mechanisms and their interaction

# The objectives of this course

- ❑ To introduce analytical foundations for analyzing networks and protocols and designing new ones
  - ❑ Open issues
- ❑ By going through different network systems and design problems, to help you
  - ❑ Master the analytical tools without having to read existing, extensive references
  - ❑ Model the problems of your own
- ❑ Develop skills for critically reading research papers
- ❑ Develop skills for identifying and formulating research questions

# Tentative course outline

- ❑ WK 1: Game theory
- ❑ WK 2: Review on convex optimization (if needed)
- ❑ WK 3: Minimum cost flow
- ❑ WK 4: Duality model of TCP/AOM
- ❑ WK 5: Path algebra and routing
- ❑ WK 6: Random access game and MAC
- ❑ WK 7: S-modular game and power control
- ❑ WK 8: Architectural principles of the Internet
- ❑ WK 9: CDS perspective to network protocols and architecture



# Tentative course outline

- ❑ WK 10: Computation, information, and incentive constraints in complex networks
- ❑ WK 12: Financial networks
- ❑ WK 13: Optimal power flow
- ❑ WK 14: Duality model of coupled oscillators
- ❑ WK 15: Cyber-physical systems
- ❑ WK 16: Presentation

# Questions?