CDS270: Optimization, Game and Layering in Communication Networks (Overview)

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Basic information

- 6 units (2-0-4)
- No homework or exam, but some suggested reading
  - about 15 journal/conference papers
- Pass/fail; if prefer letter grade, may submit a write-up of no shorter than 6 pages
  - A project report
  - A survey on a particular topic
  - A detailed review of a particular reference

Prerequisites

- Basic convex optimization theory
  - Lagrange Duality and KKT optimality condition
  - Gradient, and primal-dual algorithms
  - Dr. Fazel will give a guest lecture…
- Basic knowledge in communication networks
  - Layered architecture and the main functionality of each layer
  - Will give necessary review, when come to specific topics

What this course is about

- Network equilibrium: stable operating point
- Dynamics: distributed convergent algorithms to the equilibria
- Network design and control: design a system in which individual agents interact in a way that achieves an equilibrium with some desired system-wide properties
  - e.g., in routing we would like to find a path for each S-D pair such that the aggregate delay is minimum
- Need a modeling framework that involves seeking an equilibrium

Optimization framework

- Associate an objective function to each agent
  - User utility function or link cost function
- Optimizes some global objective function
  - Aggregate user utility
  - Aggregate cost
- Permeates all engineering disciplines
- Its prevalence is due to two reasons
  - Many performance metrics are 'natural' objectives to be optimized
    - e.g., to minimize aggregate delay in routing
    - e.g., maximum flow problem

- Many network equilibrium models can be reverse-engineered as optimality conditions for some appropriately defined optimization problems
  - e.g., network equilibrium for congestion control as KKT optimality condition for NUM problem

- The underlying mathematical structure is convexity and strong duality
  - These iterative (e.g. gradient-based) algorithms applied to the primal or/and the dual are implementable in the networks, which describe or specify the network dynamics achieving the equilibrium

- Optimization framework has its limitations
  - May be difficult nonlinear, nonconvex optimization with integer constraints
  - Informational constraint may prevent the system from achieving a global optimal
    - e.g, extensive message passing might be impractical in wireless network
  - Some design problems intrinsically do not fit in an optimization paradigm, because of the information structure or incentive issue
    - e.g., network equilibrium involving several classes of users with different cost/price functions
    - e.g., the stable path problem in interdomain routing

Game theoretic framework

- Game theoretic models are inherently distributed, as agents are independent decision makers
  - directly model/specify the behaviors of individual agents
  - System-wide properties are 'emergent' behaviors
- Provides a series of equilibrium solutions that differ in assumptions about agent rationality and information, and thus are suitable for different situations
  - e.g., interdomain routing can be seen as seeking a dominant strategy equilibrium
- Provides a basis for designing systems to achieve given desired goals (mechanism design)
  - e.g, to maximize aggregate utility

The objective of this course

- To introduce those analytical tools in optimization and game theory for analyzing current network systems/protocols and designing new ones
  - The underlying mathematical structures (e.g, the properties of objective functions, the information structure involved) that guarantee the existence and distributed convergence of the desired equilibria.
  - Open issues.
- By going through different network systems and design problems, to help you
  - Get a rough idea of the state of the art
  - Master the analytical tools without having to read existing, extensive references
  - Model the problems of your own

Draft course outline

- Week 2: Network equilibria and convergent algorithms
- Week 3: Lagrange duality and optimality conditions (guest lecture by Dr. Fazel)
- Week 4: Network architecture / Duality model of TCP congestion control
- Week 5: Layering as optimization decomposition
- Week 6: Potential game, selfish routing and the price of anarchy
- Week 7: Inerdomain routing and path algebra
- Week 8: Random access game and contention control
- Week 9: S-modular game and power control
- Week 10-11: Distributed mechanism design

Questions?