Lecture 1:
Intro to Game Theory

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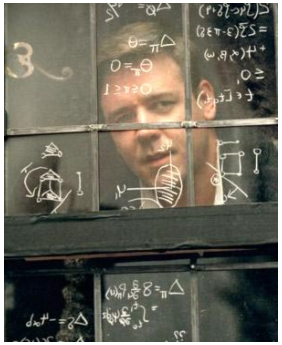
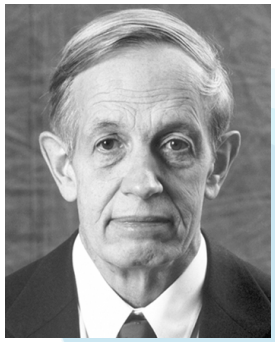
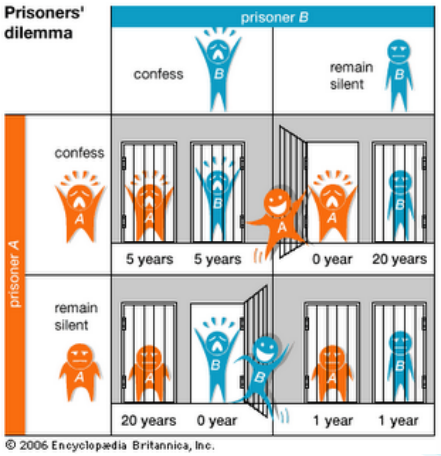
"A Beautiful Mind" (2001)





Sneak Peek: Prisoner's Dilemma



What is Game Theory?

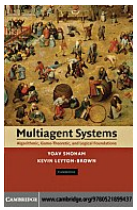
- (Distributed) Optimization Theory
  - Optimize a single objective over a design variable x,

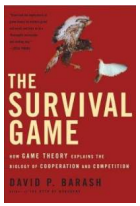
$$\begin{aligned} \text{minimize} \quad & \textstyle\sum_i u_i(x) \\ \text{subject to} \quad & x \in X \subset \mathbb{R}^n. \end{aligned}$$

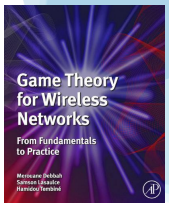
- Game theory
  - Study of multi-person decision problems
  - Competition and cooperation among agents
  - Role of threats/punishments in long-term relations
  - Models of adversarial behavior

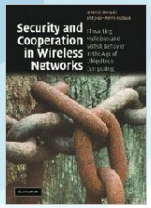
Applications of Game Theory

- Theory developed mainly by mathematicians and economists
  - contributions from biologists
- Widely applied in many disciplines
  - from economics to philosophy, including computer science (Systems, Theory and AI)
  - goal is often to understand some phenomena









Limitations of Game Theory

- No unified solution to general conflict resolution
- Real-world conflicts are complex
  - models can at best capture important aspects
- Players are (usually) considered rational
  - determine what is best for them given that others are doing the same
- No unique prescription
  - not clear what players should do

- **But it can provide intuitions, suggestions and partial prescriptions**
  - **best mathematical tool we currently have**

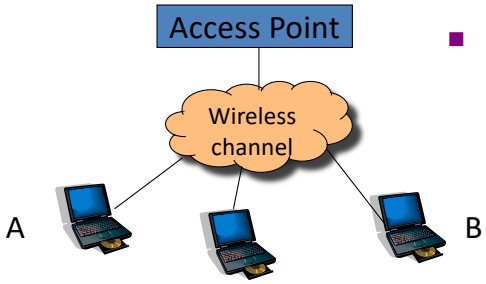
What is a Game?

- A Game consists of
  - at least two players
  - a set of strategies for each player
  - a preference relation over possible outcomes
- Player is general entity
  - individual, company, nation, protocol, animal, etc
- Strategies
  - actions which a player chooses to follow
- Outcome
  - determined by mutual choice of strategies
- Preference relation
  - modeled as utility (payoff) over set of outcomes

Classification of Games

- Many, many types of games
  - Two major categories
- Non-Cooperative Games
  - individualized play, no bindings among players
  - What strategies do I have to take when other strategic (rational) people interact with me?
- Cooperative Games
  - play as a group, possible bindings
  - What advantages are given to me if I cooperate with others in the group?
  - Whom do I have to make a coalition with in order to maximize the gain given to me?

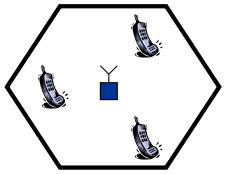
Example 1: WiFi MAC Access



- Nodes are required to follow Medium Access Control (MAC) rules

Misbehaving nodes may violate MAC rules
: access probability, different backoff times

Example 2: Uplink Power Control



Network with a single point of interest

- Uplink transmission
- My power will make significant impact on the throughputs of other mobiles at the BS
- Strategic situation
- How can we model and analyze this system?

Example 3: Security

- An intruder who sends a malicious packet to a node in the network
- A defender who uses packet sampling on links in an attempt to detect this intrusion

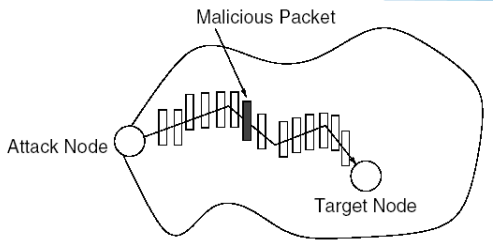
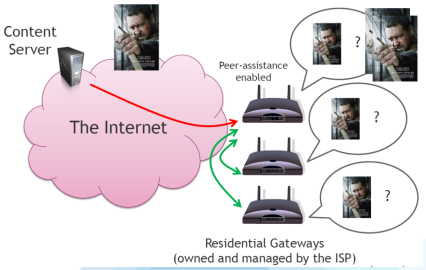


Fig. 1. Network Intrusion Game

Example 4: Peer-Assisted Service

- Client-Server
  - Limited by server side's capability: access bandwidth and computing power
- P2P
  - Exponential capacity growth and significant reduction of delivery cost
  - Too much copyright violation
- Peer-assisted Services
  - Peers legally assist CP by commitment
  - Examples deployed: Nano data center and IPTV



Question:
1. How to incentivize peers?
2. What kind of viable revenue sharing principle among CP and peers?

Two Views of Game Theory

- As an analysis tool
  - Model of a strategic situation and study what situation we will end up with having
  - Example: Analysis of Coke market (Coca Cola and Pepsi)

- As a control tool
  - Development of a control mechanism that leads to a “good” conclusion
  - Inverse game theory or often called mechanism design
  - Example: Auction