Experiences applying game theory to system design

Ratul Mahajan
Maya Rodrig
David Wetherall
John Zahorjan

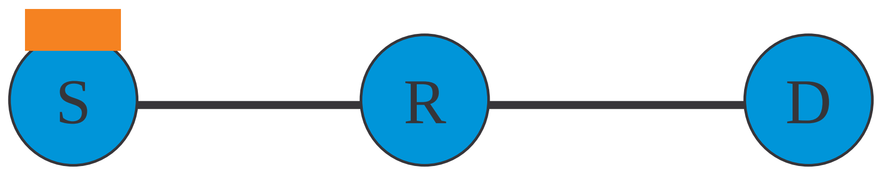
University of Washington

Introduction

- Game theory appears to be a natural tool for studying systems composed of autonomous entities
- We found a straightforward application of GT difficult for two systems problems
  - multi-hop wireless networks and inter-ISP routing
- This talk describes our experiences
  - hope to push towards more amenable formulations

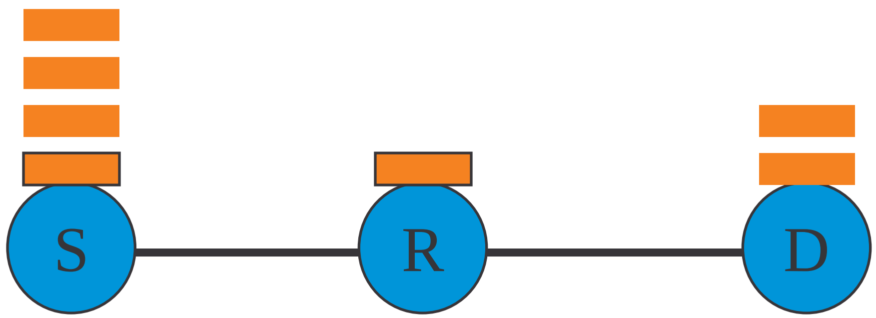
Case study 1: Packet forwarding in multi-hop wireless networks

- A multi-hop wireless network can survive only if nodes forward packets for others
  - but forwarding requires resources; incentive to "cheat"



- Goal: encourage packet forwarding
- Practical requirements: effective support for heterogeneity, light-weight, weak identities and uncertainty

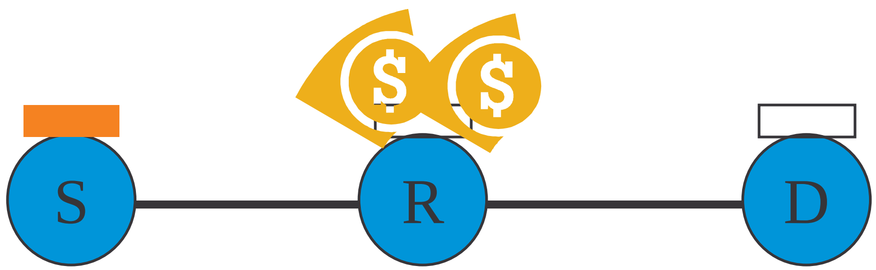
Heterogeneity in wireless networks



- Amount of traffic generated
- Timing of traffic generation
- Position in the topology

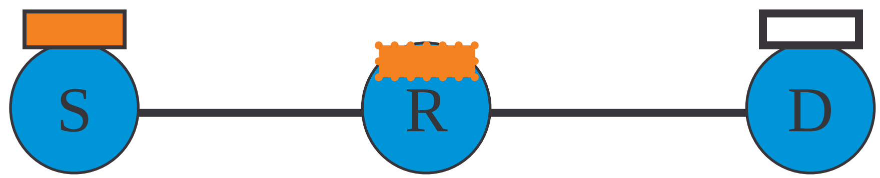
Traffic should flow as if all nodes were fully cooperative

Mechanisms to induce cooperation conflict with heterogeneity



- **Barter:** I'll forward for you if you forward for me
  - temporal differences may lead to large delays
- **Virtual currency:** get paid for forwarding, pay to send
  - some nodes can get satiated; not all nodes can make money

Our solution: *Catch*

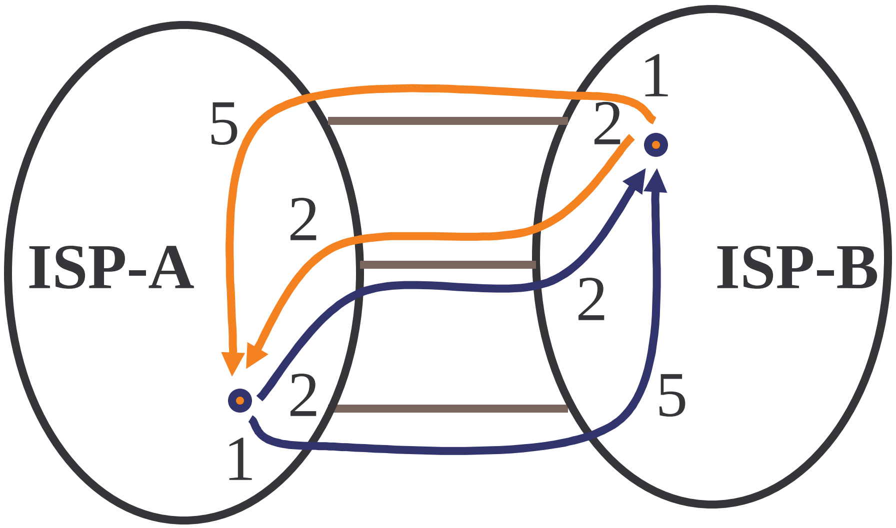


- Preserve cooperation in a mostly cooperative setting
  1. Overhear packets (*watchdog*) to test data forwarding
  2. Anonymous messages to test connectivity
  3. Notify all neighbors of the cheater to isolate it

- Does *Catch* provably preserve cooperation?
  - we tried using evolutionary games and ESS
  - hard to characterize cooperation and all possible rational cheating strategies

Case study 2: inter-ISP routing

- Peering point selection is locally optimal (early exit)



	Early exit	Opt. exit
Early exit	6, 6	7,3
Opt. exit	3,7	4,4

- Goal: design mechanisms to compute better paths
- Requirements: limited information disclosure, flexibility, efficiency and strategy-proofness

Mechanism design issues in inter-ISP routing

- Direct mechanisms ignore competitive concerns
  - information revealed as part of the game can be misused
- Mechanism design with flexible objectives
- Incentive compatibility vs. efficiency
  - Myerson-Satterthwaite impossibility for bilateral trading

Our solution: flexible bargaining

1. ISPs map the routing options for flows to opaque utilities (MEDs) and disclose this utility list
2. One ISP proposes routing options based on both lists of utilities; the other ISP accepts or rejects the proposal
3. Overall, both ISPs gain

- Not strictly strategy-proof
  - is there an incentive to cheat?

Concluding remarks

- Need new GT formulations to address practical concerns
  - heterogeneity, implementation cost, efficiency, uncertainty, weak identities, side channels, flexibility, competitive concerns
- Model the backdrop of cooperation (irrational?)
  - relax perfect selfishness