Control-Based Mobile Ad Hoc Networks

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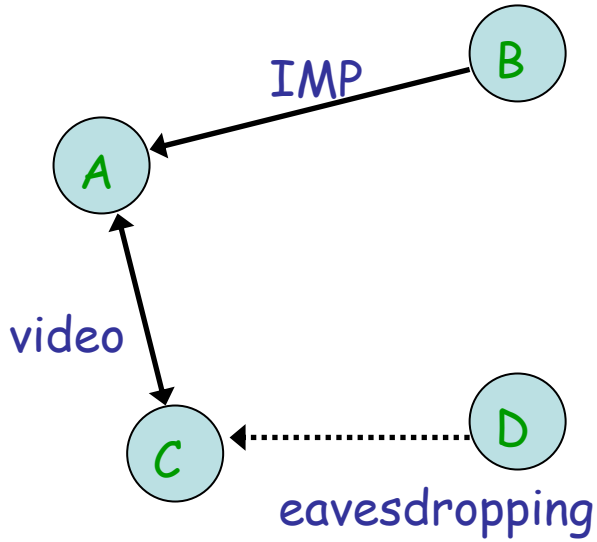
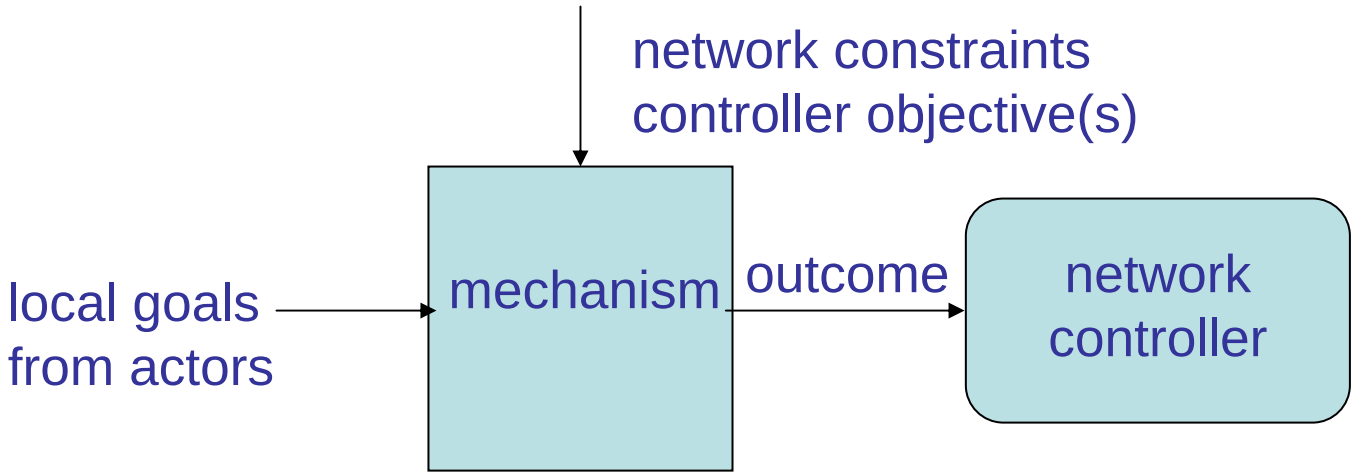
Problem: Scarce Wireless Resources

- The Setting:
  - mobile ad hoc networking in tactical military environments
- The Problem:
  - resource allocation (e.g, bandwidth)
- How is it Solved Now?
  - static priorities, constraints with traditional offline optimization of network structure
  - solutions tend to be brittle, unpredictable
- Why is it Economic?



Abstract Problem

- Control-Based Mobile Ad Hoc Network Problem:
  - dynamic resource allocation problem in distributed systems, given shifting priorities, an uncertain environment, and multiple actors
  - premise: local actors have the best information about local priorities, e.g. importance of particular messages, information…. but controller has global view of the relative importance of different actors and of different kinds of situations
  - sounds very like mechanism design (MD):



- Except: distributed decision making; sequential decision problem; uncertainty/incomplete knowledge.

Challenges in Applying MD to MANETs and Expertise (I)

- Distributed decision making:
  - the “rules” of the resource allocation mechanism must be implemented via a distributed algorithm, implemented in the network layer
  - **Expertise**: distributed optimization and implementation of mechanisms (Parkes); game-theory on networks (Kearns, Singh); QoS, policies and route optimization in networks (Rexford).
- Sequential decision problem:
  - the population of actors is changing over time
  - the system has state, e.g. bandwidth must be allocated for some contiguous period of time
  - **Expertise**: online mechanisms (Parkes, Singh); Markov Decision Processes/ Adaptive control (Kearns, Singh);

Challenges in Applying MD to MANETs and Expertise (II)

- Uncertainty/ Incomplete Knowledge:
  - the global priorities will be always changing
  - the local goals and priorities will be always changing, may be incomplete knowledge
  - the environment will be always changing, e.g. due to adversaries, equipment failure and availability, etc.
  - **Expertise**: reinforcement learning (Kearns, Singh); adapting rules of a mechanism (Parkes, Singh); preference elicitation (Parkes).

Broader Challenges, Opportunities

- Virtual Currency Policy
  - computational mechanism design is silent about allocation of money, which is usually out of scope. Yet, currency in MANETs is likely to be virtual and must be assigned and redistributed
  - **Issues**: how does currency allocation relate to priorities? how is money that is spent redistributed? can autonomous currency policies better support heterogeneity across units?
- Utility as a "default interface" for modular design
  - typical o/s and network protocols are designed on a proportional-share principle with each process/traffic-flow satisfied on a best-effort basis
  - can lead to "tragedy of commons" and unsatisfactory performance for all, when better to block some processes/flows completely
  - **Idea:** economics suggests utility as a "default interface" within modular systems, with module architects specifying a performance profile (e.g. utility vs. resource bundles, perhaps environment dependent) for each component.

Brief Biographies

- Michael Kearns
  - Professor, University of Pennsylvania.
  - **Interests**: machine learning, probabilistic inference, finance, game theory.
- David Parkes
  - Associate Professor, Harvard University
  - **Interests**: mechanism design, electronic markets, distributed optimization, multi-agent systems, preference elicitation.
- Jennifer Rexford
  - Professor, Princeton University.
  - **Interests**: Internet routing, network measurement and management, optimization and policy in networks.
- Satinder Singh
  - Associate Professor, University of Michigan.
  - **Interests**: reinforcement learning, computational game theory, mechanism design, adaptive control.