Competition and cooperation: Topology formation

Ramesh Johari

Joint work with E. Arcaute (Stanford), E. Dallal (McGill), S. Mannor (McGill)
Competition and cooperation

• Fundamental question: When can local competition yield global cooperation?

• Distributed coordination: Design the system so individually “selfish” behavior leads to a collectively “good” outcome.
Topology formation

If MANETs try to build a network topology (for routing, distributed computation or control, etc.), they suffer from a lack of global information.

What local link formation dynamic leads to a good global topology?
Topology formation

• Most game theoretic models applied to engineering use static analysis, as many dynamic models are often intractable.
• But dynamics of decision making are critical in MANETs!
• Reasonable analytical approach: Myopic best response dynamics
  Each node chooses its best course of action, but only in the current stage (i.e., ignoring past history or predicted future evolution)
The model

• N nodes
• Traffic matrix: uniform all-to-all
• Cost of link maintenance: $M$ for each endpoint
• Traffic transit/termination cost: $c_i$ per unit through node $i$
• Cost per unreachable destination: $\lambda$ (assumed large)
Node payoff

- Given a graph $G = (V, E)$, let $P(i, j; G)$ denote contracted payment from $i$ to $j$
- Traffic routed along shortest paths
- Payoff to node $i =$ payments received – payments made
  - $M \ £$ adjacent links
  - $\lambda \ £$ unreachable nodes
  - $c_i \ £$ traffic through $i$
Contracting function

- P is called the *contracting function*
- It is a *design variable*

Our design choice:
Assume P (i, j ; G) is antisymmetric, and “monotone” in routing cost of j

Example:
Local cost sharing
  (incremental cost of a link is shared by endpoints)
Myopic best response dynamics

• Suppose at each step, nodes can choose to break one link, and/or form another
  \textit{(Payments on all other links remain the same before and after)}

• Nodes act to maximize \textit{single stage payoff}

\textit{Theorem:} Dynamics converge to a “pairwise stable” tree with minimum routing cost nodes in interior

\textit{Moral:} Antisymmetry and monotonicity guide dynamics to a \textit{good equilibrium}
Roadmap

1. Study local information exchange needed to converge to good global topology (*current*)
2. Simulate performance under non-homogeneous assumptions
3. Add robustness (i.e., redundancy) to payoff model
4. Study tradeoff between *complexity* of local exchange and *robustness* of global dynamics