Applications of Game Theory in Ad Hoc Networks

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Aim of the Thesis

- Survey prior game theoretic research
  - Focus on ad hoc networks
  - Generally in telecommunications
- Model the interaction between a node and the rest of the network as a game

Ad Hoc Networks

- Wireless networks without fixed infrastructure
- Terminals act as routers forming multihop connections
- Terminals are often battery powered
- Cooperation is crucial for the operation
  - Selfish and malicious nodes
  - Protocols that enforce cooperation are needed
    - Reputation based
    - Pricing based

Game Theory

- Analyzes multiperson decision making situations
- Each decision maker tries to maximize his own utility (selfishness)
- Examines equilibrium points
- Own benefit vs. common good

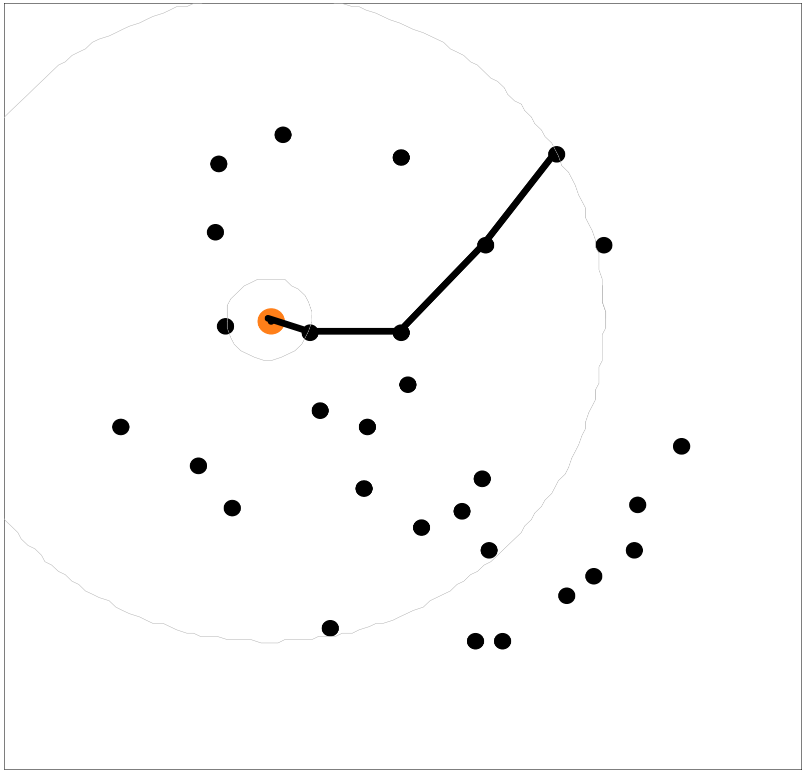
Applications of Game Theory in Telecommunications

- Ad hoc networks
  - So far only a few articles on the subject
  - Game theoretic formulations, but little interesting results
- Internet
  - First references to game theory in the 1980s
  - Routing, flow control, traffic pricing
  - In fixed networks the capacities of the links are interdependent

    => Not applicable to ad hoc networks

Energy Consumption Game

- How much forwarding effort the network can require from a node?
- Transmission power $p \sim r^{\alpha}$
- Direct connection p_d
- Routed connection p_r
- Forwarding effort e



Game with an Honest Node

- Game procedure
  1. The network offers to forward the node's traffic in exchange for forwarding effort e
  2. The node either accepts or rejects the offer

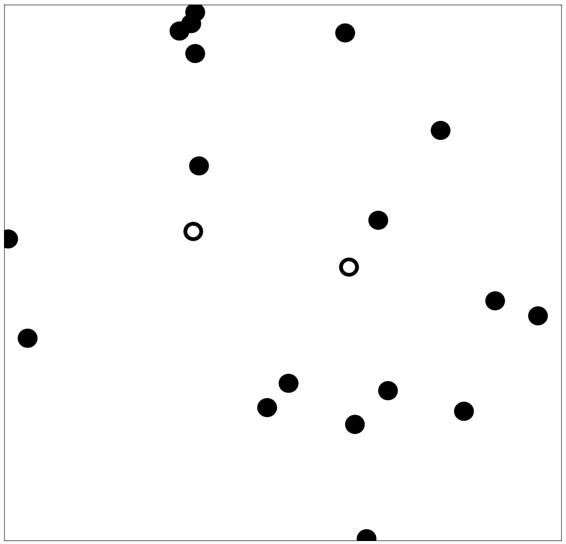
- The node cooperates if $e <= p_d - p_r$

Game with a Cheating Node

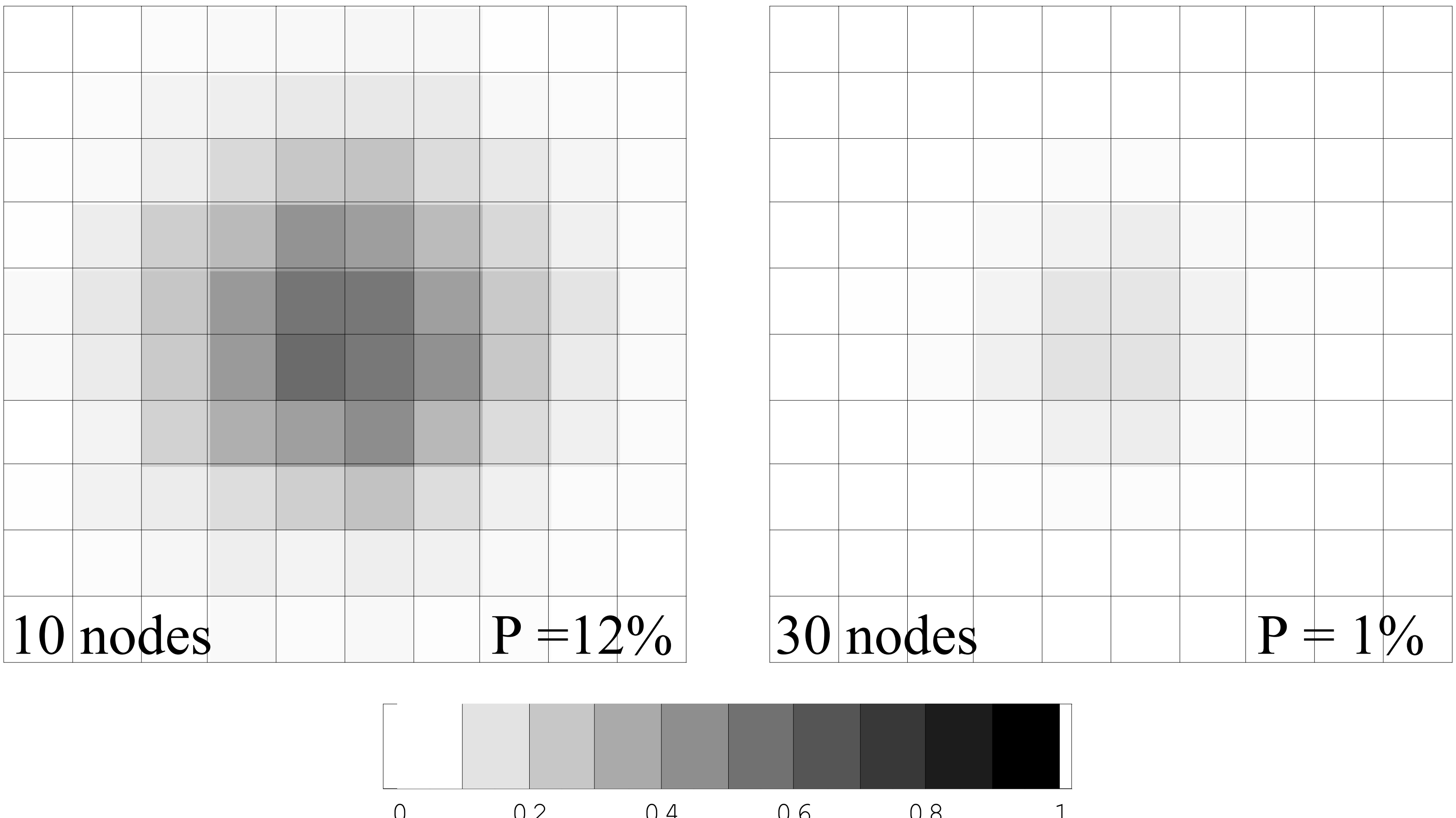
- Game procedure
  1. The network offers to forward the node's traffic
  2. The node either cooperates or freerides
- Transmission time exponentially distributed with mean $1/\mu$
- Freeriding is detected in an exponentially distributed time with mean $1/d$
- If caught cheating, the node needs to finish the transmission directly to the receiver
- The node cooperates if $e \le (p_d - p_r) / (1 + \mu/d)$

Simulation

- Assumptions
  - Nodes in a unit square
  - Uniform traffic pattern
  - Nodes either transmit directly or cooperate
- Simulation procedure
  1. Generate a random network
  2. Determine the needed forwarding effort
  3. Identify nodes that lose energy when joining



The probabilities that independent operation saves energy



Simulation Results

- Considering energy consumption, it is not always beneficial to join the network
- Minimum energy routing is better than minimum hop routing
- The risk of losing energy is only a problem in networks with few nodes
- The higher the parameter α in $p \sim r^{\alpha}$, the more beneficial it is to join

Summary

- This study presented
  - Survey of prior game theoretic research
  - Energy consumption games
  - Simulations of energy consumption

- Questions?