Network Dynamics With Incomplete Information and Learning

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Networks have Malicious Users!

Wireless sensor networks

Sensors that send useless information drain other sensors' batteries

Organizations/companies

Workers who have a low level of expertise consume other workers' time and effort

Social networks

People who constantly share a lot of random ads annoy their connected friends

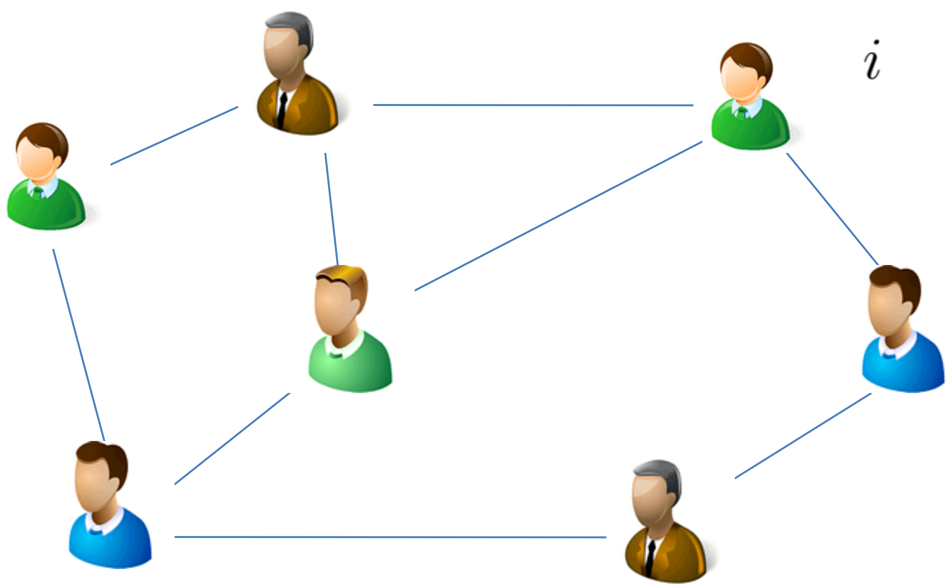
Networks, Agents, Quality

Agents that are of low "quality" should be ostracized from the network…
How can networks best learn about and weed out such agents?

The network evolves over time as agents learn

Network Model

- Infinite horizon continuous time
  - Interactions are on-going and dynamic
- A number of N agents, initially linked according to G^0
  - Physical/geographical/communication connection constraints
  - Can also be planned
- Network evolves G^t
  - Links of each agent changes over time as learning occurs



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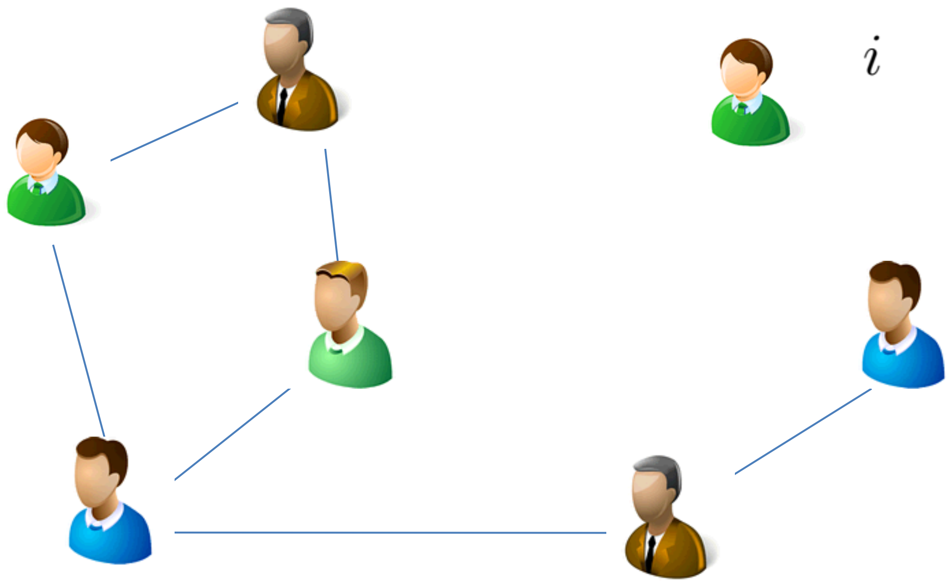
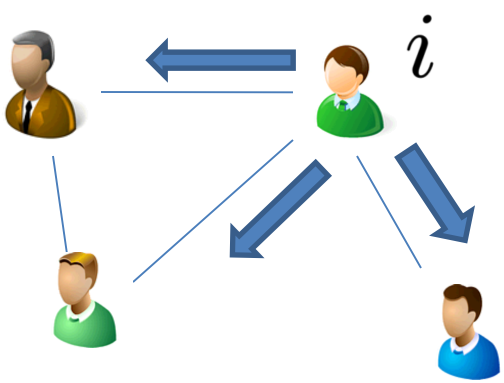


Agent Quality

- Each agent has a quality q_i
  - Unknown a priori to all agents
  - Prior belief is drawn from a normal distribution $\mathcal{N}(\mu_i, \sigma_i^2)$
    - We assume $\mu_i > 0$ for all agents
- An agent sends a (flow) benefit to his neighbors
  - Benefit **reflects the quality** of that agent with **noise**
  - Modeled using Brownian motion diffusion

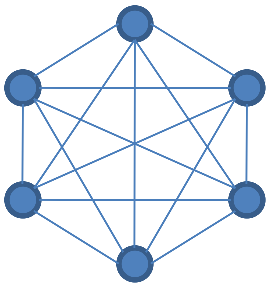


$$dB_i(t) = q_i dt + (k_i^t \tau_i)^{-1/2} dZ(t)$$

Total benefit sent by agent i up to time t

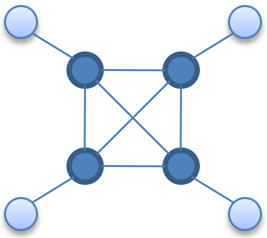
Optimal Initial Networks

- Fully connected network (the world is flat)



Theorem. A fully connected initial network is optimal if the prior mean quality is sufficiently high

- Core-periphery network (the world is not flat)
  - Heterogeneous agents: two levels μ_H μ_L



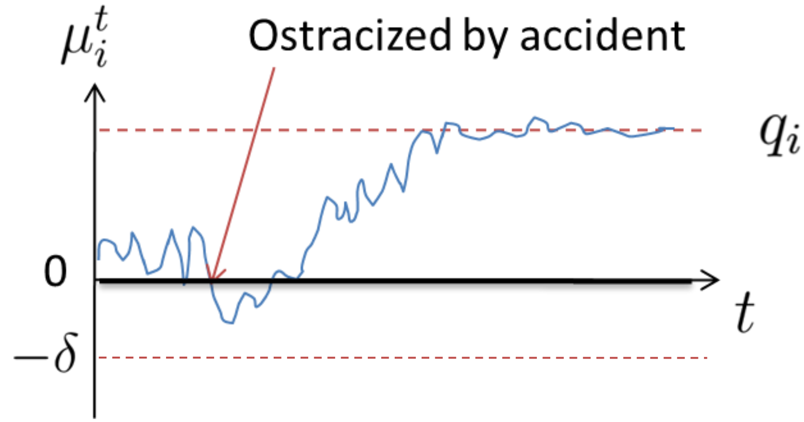
Theorem. Core-periphery is optimal if μ_H is sufficiently higher than μ_L

- Why?
  - Connected at the core → learned more quickly
  - Connected at the periphery → less harm

Dominant

When to cut-off?

Suppose the network designer can choose a threshold δ at which agents cut off links with each other



Theorem. (1) $W(\delta) > W(0)$

(2) There exists $\delta^* < \infty$, such that $\delta^* = \arg\max_\delta W(\delta)$

- Implication
  - Encouraging more experimentation is good for the network
  - Cannot be too tolerant of bad behaviors
  - The exact value depends on the specific networks and we can compute!

Conclusion

- Current Results
  - A first model for analyzing endogenously evolving network formation under incomplete information
    - Rigorous characterization of learning and network co-evolution
    - Understanding emergent behaviors of strategic agents
  - Guidelines for building safer networks
    - Planning for initial connection
    - When to cut-off the links with malicious agents

- Please see the poster for more details and results!