

Location Matters: Using Social Network Analysis to Improve Network and Mechanism Design

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Introduction

Network nodes may experience large disparities in utility according to their location in the network topology. These disparities become more problematic in resource-constrained self-organized networks, such as mobile ad-hoc, peer-to-peer, wireless mesh, or sensor networks, than they have been in traditional infrastructure-based networks.

The impact of node location has so far received relatively little attention, e.g. it is common practice to assume the random-waypoint mobility model in mobile ad-hoc networks, implying that over time node location will be evenly distributed. We are interested in the effect of location on node utility when this assumption is removed.

Applying insights from social network analysis, we introduce centrality metrics and quantify the effect of location and several network topologies. As a concrete application of the general problem, we investigate how incentives for cooperation (such as payment or reputation systems for traffic relay in mobile ad-hoc networks) exacerbate or alleviate node utility disparities due to location. We show that location matters and that without location awareness, such incentive schemes can be unfair.

We propose the use of centrality metrics and discuss their impact on the following networking research areas: mobility models, strategic node behavior (location changes), placement of access points in wireless mesh networks, topology control of overlay networks, location-aware incentives for cooperation, and evaluation of fairness of networking protocols.

What is the center of a network?

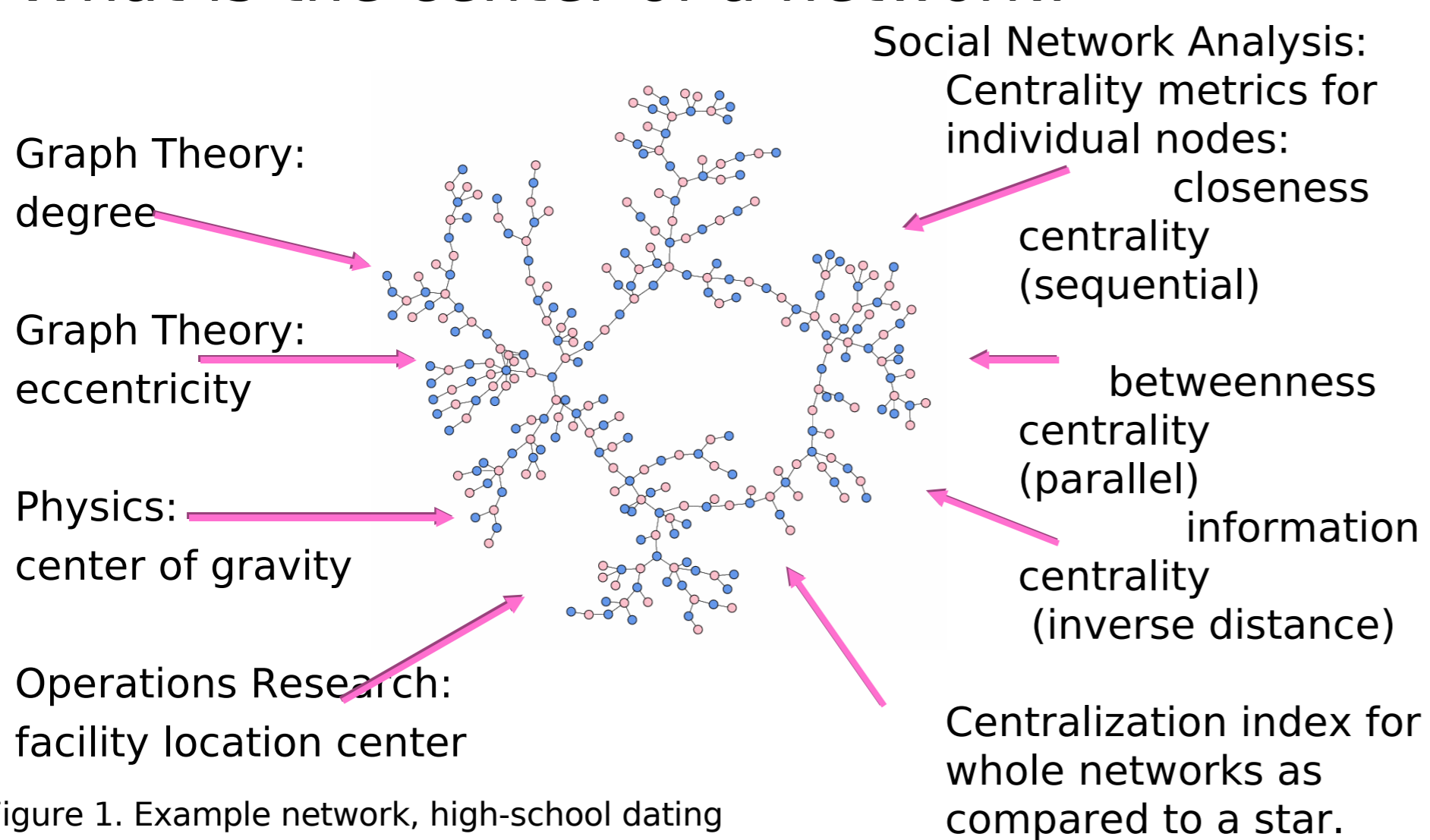


Figure 1. Example network, high-school dating

Methodology:

Measuring Centrality: Social Network Analysis metrics

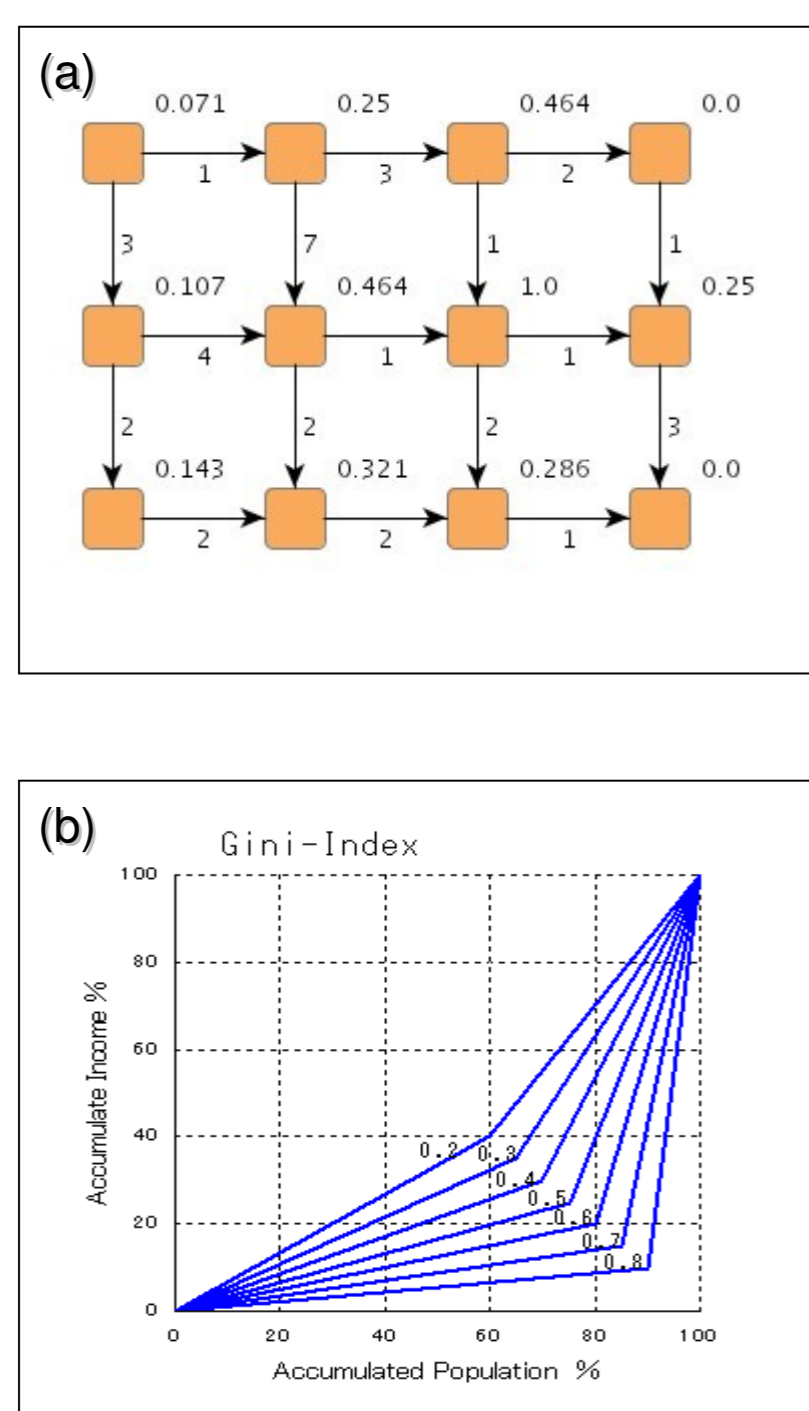


Figure 2. a) Betweenness centrality. b) Gini-Index

Improved Network Design

Measuring Equality: Economics metrics

Example application: incentives for cooperation

- Cooperation in Mobile Ad-hoc Networks.
 - Nodes need to cooperate to communicate.
 - There is immediate cost but not payoff for cooperation.
 - Dominant game-theoretic strategy: DEFECT.

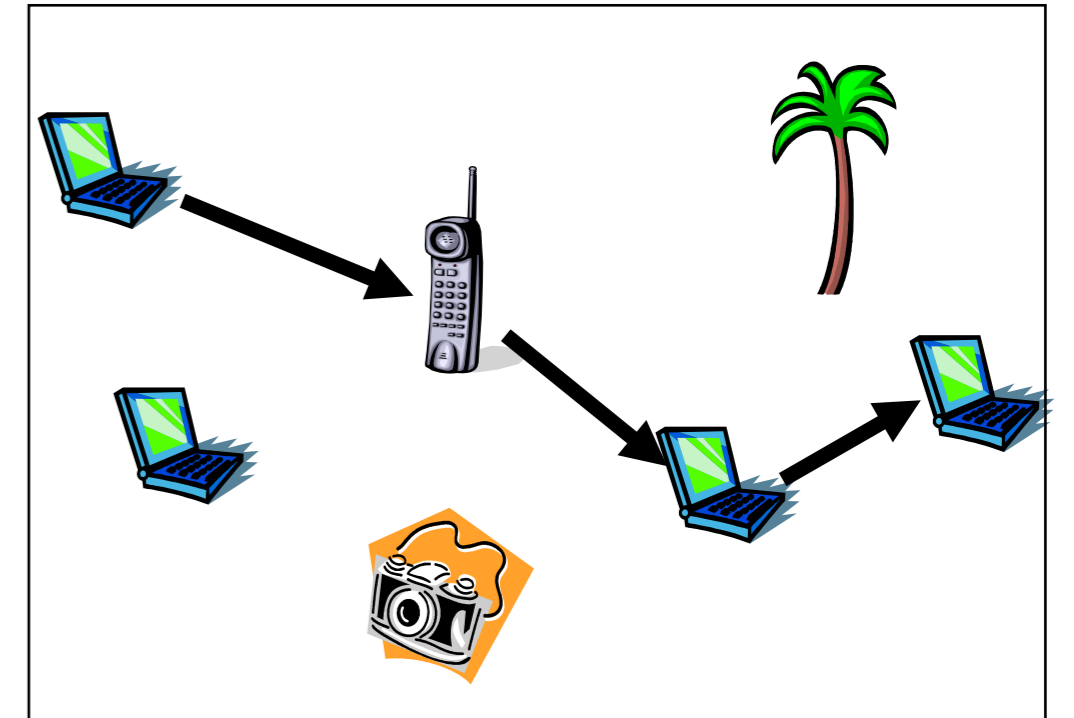
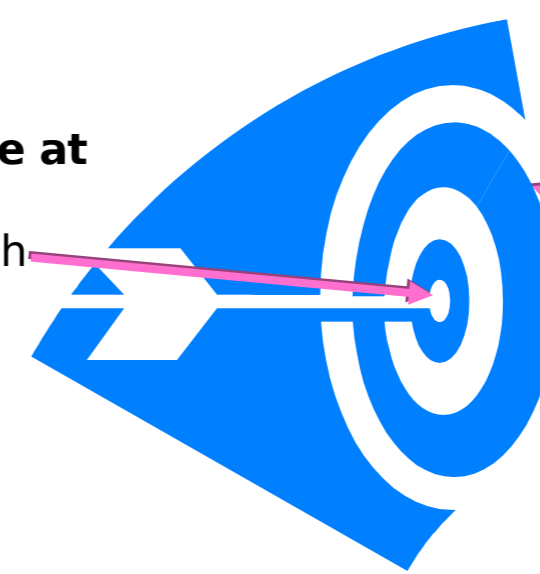


Figure 3. Nodes relay messages for others.

Payment: Good to be at the center:

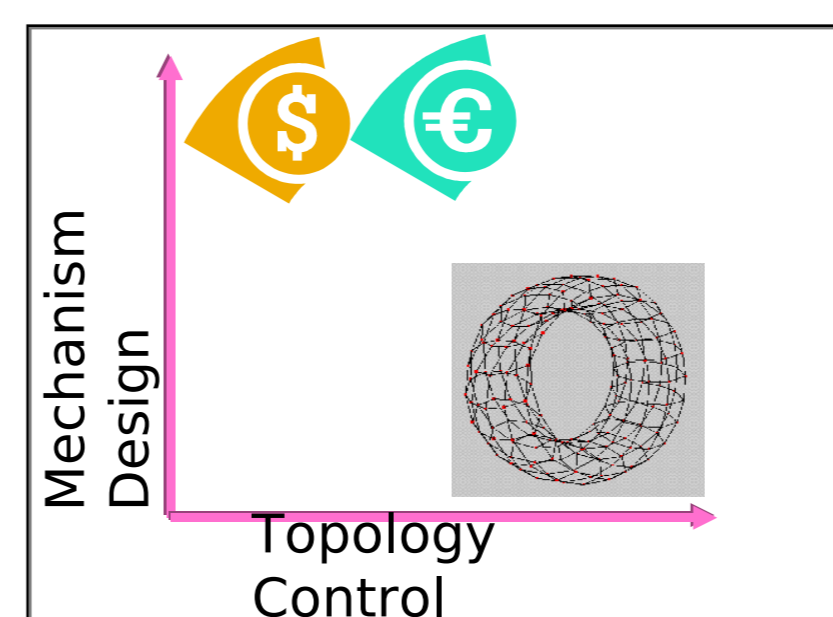
- can generate high income
- edge nodes can starve



Reputation: Good to be at the edge:

- can preserve good reputation with little effort
- center nodes can be excluded despite cooperation effort

Figure 4. Incentive mechanisms such as payment and reputation systems get nodes to cooperate, but nodes are treated differently according to their location in the network topology. Using centrality metrics, this unfairness can be uncovered and addressed.



Measuring centrality helps reducing performance disparities.

Figure 5. Knowing the centrality of individual nodes and the overall centralization index of a topology enables us to decrease inequities on two dimensions: Making incentive mechanisms location aware or enforcing a topology with low centralization and thus create fairness.

Implications for networking research:

- Mobility models: centralization in steady state, traces
- Strategic behavior: movement, churn in P2P
- Placement of access points: for mesh networks.
- Placement of sinks: for sensor networks
- Topology control: overlay networks, anonymity systems.
- Location-aware incentives: pricing, taxation, reputation.
- Fairness evaluation: of networking protocols, using centrality metrics.

Bottom Line: Location Matters, Centrality helps

Literature

- Stanley Wasserman and Katherine Faust, Social Network Analysis – Methods and Applications. Cambridge University Press, 1994.
- Herve J. Moulin, Fair Division and Collective Welfare. MIT Press, 2004.

Collaborators

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For further information

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