Dynamic Extensions of Network Brokerage Models

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Overview

- MURI framework
- Traditional (static) network models of brokerage
- Katrina dataset
- Dynamic extensions of brokerage
- Comparison of measures: What can dynamic measures add to brokerage analyses?

MURI Tasks and Goals

- Fast network estimation algorithms: is it feasible to compute dynamic network measures on large datasets?
- Scalable temporal methods: as we develop statistical models for network data over time, can we extend traditional network measures to the dynamic environment in a logical way? Will dynamic extensions be feasible for large datasets?
- Network models for heterogeneous data: can dynamic measures more accurately predict actors' states or importance?

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- ONR Goals: using traditional SNA measures but emphasize the observation of networks over time.

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Traditional Measures of Brokerage I

- One actor can act as an intermediary between two others who lack a direct connection (Gould and Fernandez, 1989).
- Brokers were traditionally thought to hold positions of power and influence because they could charge commission for services, restrict information flow, exclude certain actors from activities, etc.
- Identifying actors with significant brokerage roles is a method of identifying important or central actors within the network.

Traditional Measures of Brokerage II



Figure: Simplified Example of Brokerage

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Katrina EMON

- Nodes represent organizations responding to Hurricane Katrina.
- Edges are *undirected* collaboration ties between organization pairs.
- Data collected from achival documents publically available online.
- Time frame: from storm formation through one week after landfall in Louisiana.
- 13 daily snapshots (Aug 23–Sept 5, 2005) of the collaboration network, and an aggregate combined network.
- Aggregate EMON: 1,577 nodes, 857 edges, 997 isolates, 26 non-isolate components, and a mean degree of about 1.

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Aggregate Katrina EMON



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Why Brokerage in Disaster Response?

- In disaster response situations, brokers are important conduits of information and tacit knowledge.
- Brokerage may facilitate coordination of response efforts.
- Brokers become important organizational actors within the collaboration network.
- Research questions:
 - Which organizational subgroups emerge as the primary brokers in the Katrina response?
 - Which individual organizations emerge as the most prominent brokers in the Katrina response?

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Brokerage Analysis of the Katrina EMON I

- Traditional brokerage: easy to count instances of two-path existence in the aggregate and individual snapshots.
- What are we missing in this (static) case?
- Sequential brokerage followed by triadic closure. Brokerage is a dynamics process that unfolds on the changing network.
- Dynamics gives an additional level of analysis and deeper insight into the process of brokerage.

Brokerage Analysis of the Katrina EMON II



Figure: Example of What We Might See in the Aggregate Case

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Brokerage Analysis of the Katrina EMON III



Figure: Simplified Example of Dynamic Brokerage

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3

- 47 ►

Developing a Measure of Dynamic Brokerage I

- There are many possible extensions of traditional brokerage. This is one.
- Consider a news passing metaphor:
 - Every organizations is always up to date on its own information.
 - When organizations debut, i.e. show up for the first time, they know the state of the network at that time. In other words, news is not generated at the time of debut.
 - News may only be passed from source through a direct connection and a two path.
 - Tacit knowledge may only be passed through collaboration. It may not be passed about third parties since this information is specialized.
 - When organizations collaborate they update each other on their current state of tacit knowledge about themselves and their immediate collaborators.

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Developing a Measure of Dynamic Brokerage II



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Developing a Measure of Dynamic Brokerage

- Using this idea we develop a dynamic extension of the traditional network measure for brokerage.
- This idea has been used in some capacity before:
 - Information pathways: Kossinets et al. (2008)
 - Vector clocks: Lamport (1978)
- Actors are assigned "brokerage" scores proportional to the difference in timestamps of old versus new information.

Developing a Measure of Dynamic Brokerage

- Our dynamic brokerage measure captures sequential two-path existence followed by triadic closure.
- Being a broker in the aggragate is a sufficient condition for being a broker in the dynamic case.
- Because of the lack of exact timing information, we end up with some organizations who are identified as brokers in the aggregate but **not** in the dynamic case.
- We now have a method of detecting the conditions for indirect information flow within a large, dynamically evolving network.

Comparison of Brokerage Measures



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Insight from Dynamic Extensions of Brokerage



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Summary

- Dynamic extensions of network brokerage models give additional insight into the process of brokerage.
- While traditional measure capture a significant portion of the phenomena, they miss important parts, namely sequential two-path existence.
- Brokerage is one network measure that can easily be situated in a dynamic context and the dynamics are important to the phenomena under consideration.
- This research illustrates how to extend traditional SNA measures to emphasize the temporal nature of the network itself.

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Future Work and Collaborations

- Consider this dynamic brokerage measure in a network with exact timing information.
- Develop faster algorithms for computing dynamic brokerage scores.
- Do these dynamic metrics aid in prediction taks?

- Gould, Roger V. and Roberto M. Fernandez. 1989. "Structures of Mediation: A Formal Approach to Brokerage in Transaction Networks." *Sociological Methodology* 19.
- Kossinets, Gueorgi, Jon Kleinberg, and Duncan Watts. 2008. "The Structure of Information Pathways in a Social Communication Network."
- Lamport, Leslie. 1978. "Time, clocks, and the ordering of events in a distributed system." *Communications of the ACM* 21:558–565.