

# Learning the Power of Networks

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# Why We Are the Power Rangers

- Network interest in social media and causation
- Exposure to computational network analysis
- Ecological networks

# New York City



August 14, 2003



# Power Grid Failure

This event contributed to at least 11 deaths and cost an estimated \$6 billion.

## Cause of Failure:

- Natural events
- Human error
- Hardware malfunction

## Affected States and Province:

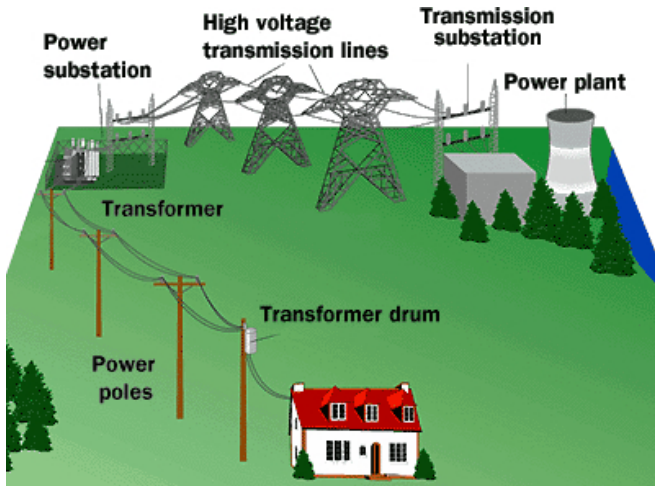
- OH, MI, PA, NY, VT, MA, CT, NJ
- Ontario



<sup>0</sup>"Final Report on the August 14, 2003 Blackout" - U.S.-Canada Power System Outage Task Force

<sup>1</sup>"The anatomy of a power grid blackout" (Pourbeik, P. et al. 2006)

# General Grid Structure



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taken from science.smith.edu

# SciGRID German Transmission Grid

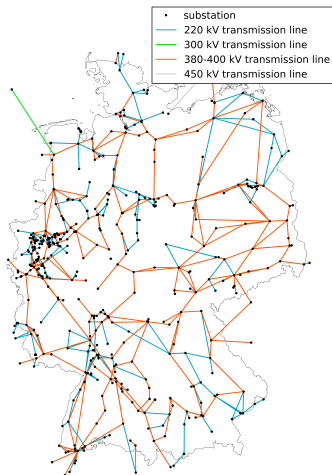


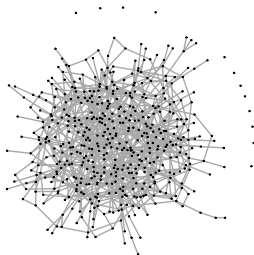
Figure: Data collected July 18, 2016

- Open source
- Extra-high voltage transmission system (220kV+)
- Minimum: two substations and one transmission lines
- *Abstracted transmission network*: transmission lines are *not* actual paths



- Random Graphs (Erdős-Rényi)

- Degree homogeneity
- Low clustering
- Short average paths
- Mathematically constructed



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<sup>1</sup>“On random graphs, 1” (Erdős, P., & Rényi, A., 1959)

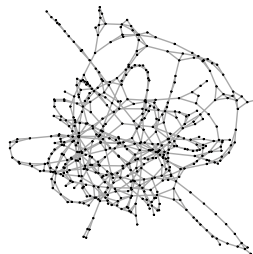
# Types of Networks

- Small-world Graphs (Watts-Strogatz)

- Short average paths
- High clustering
- High modularity

- Small-World Networks

- Social Networks
- Cortical maps



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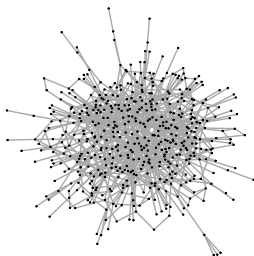
<sup>1</sup>“Collective dynamics of ‘small-world’ networks” (Watts, D. J., & Strogatz, S. H., 1998)

- Scale-free Graphs (Barabási-Albert)

- Degree heterogeneity
- Low clustering
- Fault tolerance

- Scale-free Networks

- Protein-protein interactions
- Semantic maps



<sup>1</sup> "Emergence of scaling in random networks" (Barabási, A. L., & Albert, R., 1999)

# Comparing Measures of Network Models

Network	Germany Grid	Random	Small-world	Scale-free
Nodes	511	511	511	511
Edges	836	836	836	829
Avg Degree	3.27	3.27	3.27	3.25
Max Degree	16	10	6	33
Transitivity	0.11	0.006	0.31	0.01
Avg Path	10.8	5.4	10.2	4.5
Diameter	24	12	24	9
Assortativity	-0.13	-0.07	0.04	-0.03

<sup>1</sup>“The Topological and Electrical Structure of Power Grids” (Hines, P. et al., 2010)

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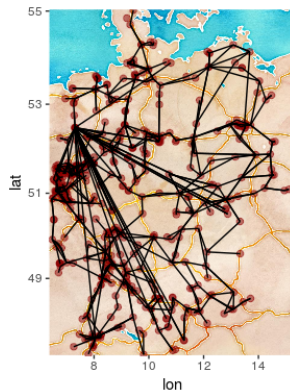
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# Collaborative Abstraction

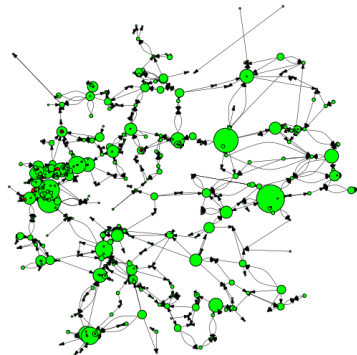
- Modeling as a group
- Identify Goals
  - Generate and compare network models
  - Contrast targeted and random failure





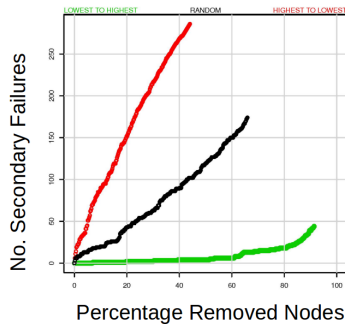
# Final Network

- Maximize generality
- Unweighted, undirected
- Focus on topology



# Results

- Secondary topological failure
  - Sequentially remove nodes
  - Record secondary failures
- R, Igraph, Nexcade
- Degree matters
  - Red - highest to lowest
  - Black - random
  - Green - lowest to highest



# What We Learned

- The nuances of working in an interdisciplinary team
- R and bash scripting (iGraph, Nexcade)
- Network modeling

# Thank You

Industry Advisor

Dr. Mihai Anitescu

# Thank You

## Faculty Advisors

Professor Paul “Find the Data” Maglio

Professor Ashlie “Evaluate” Martini

Professor Michael “It’s About Learning” Spivey

# Questions?

# Open Street Map (OSM)

- Open source
- Local Knowledge
- Community Driven



# Types of Power Grid Data

- Test Cases
- Simulated
- Proprietary
- Natural



# Where We Could Go From Here

- Electrical detail
- Applications in our domains