Risk Assessment of Complex Infrastructures

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Presentation Outline

1. Introduction
2. Infrastructure Reliability
3. Network and Cascading Models
4. Infrastructure System Risk
5. Network Performance
6. Conclusions

1. Introduction (1)

- **Attributes of complex systems:**

Interacting

Decentralized

Emergent

Evolving

1. Introduction (1)

- **Attributes of complex systems:**

Interacting

Decentralized

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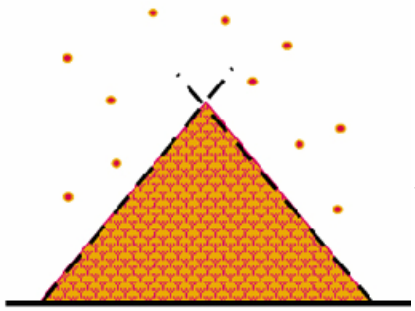
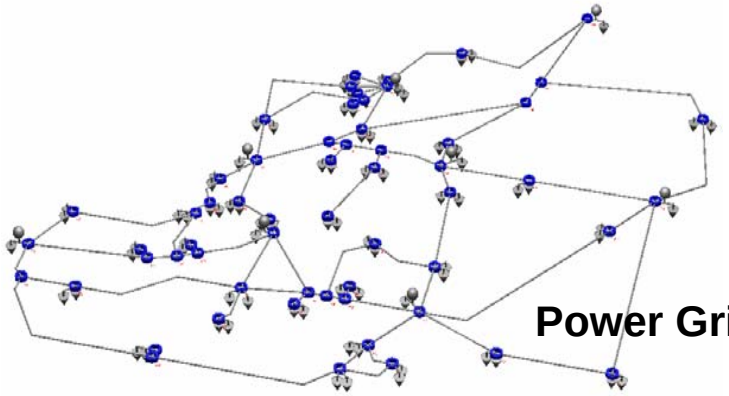
Evolving



Sand Pile

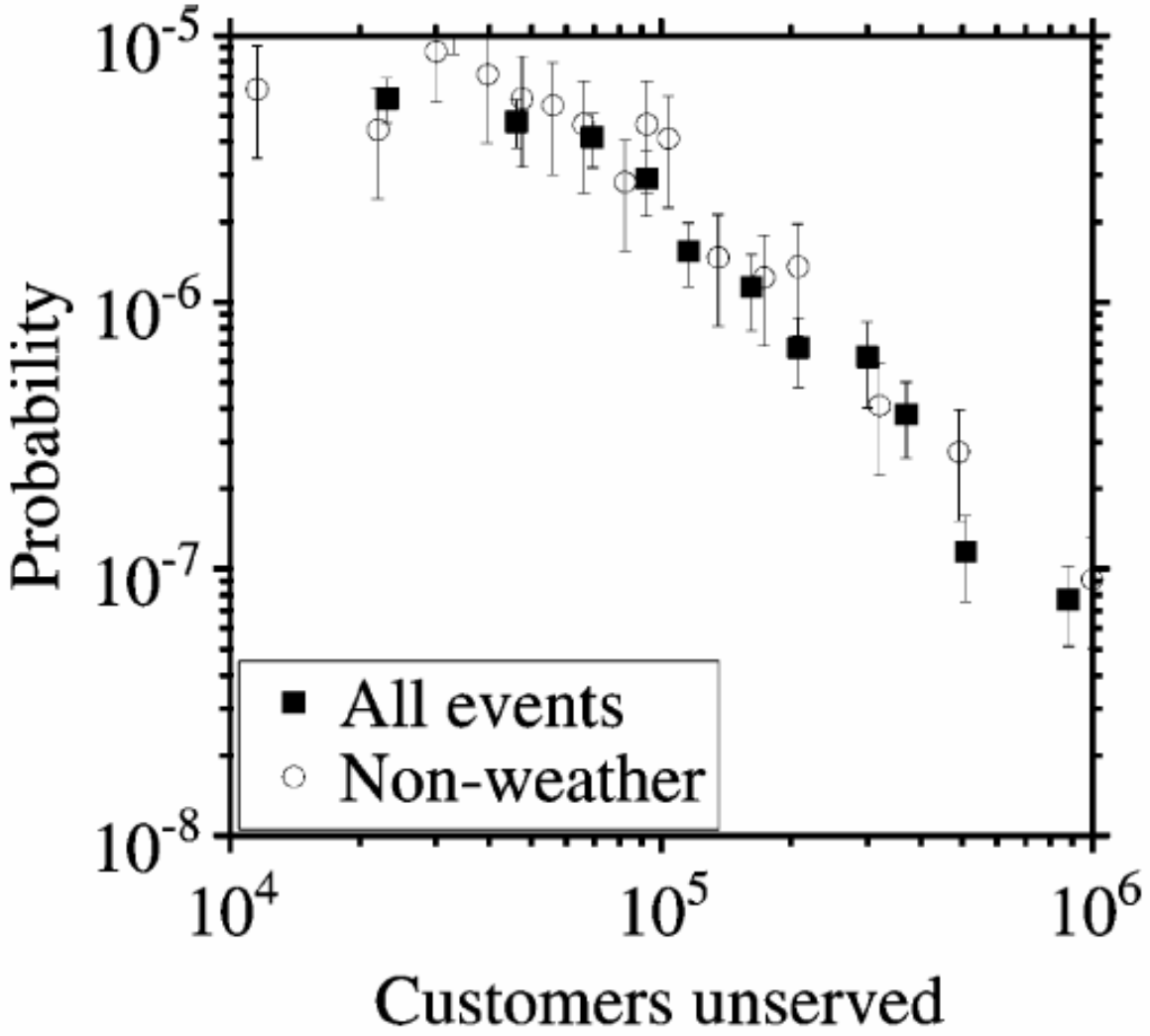
Forest



Power Grid

1. Introduction (2)

- **Properties with power law:**



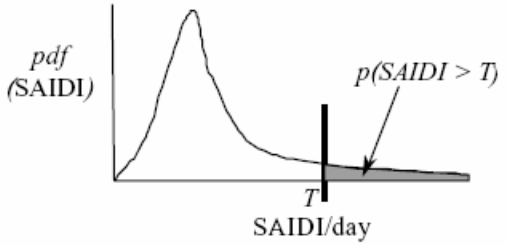
Carreras et al., 2004

2. Infrastructure Reliability

- **Customer-based metrics:**

$$\text{SAIFI} = \frac{\sum \text{Number of customers interrupted}}{\text{Total number of customers served}}$$

$$\text{SAIDI} = \frac{\sum \text{Customer interruption durations}}{\text{Total number of customers served}}$$



  - **Analytical Approach:** Markov state-space model
  - **Numerical Approach:** Monte Carlo simulation

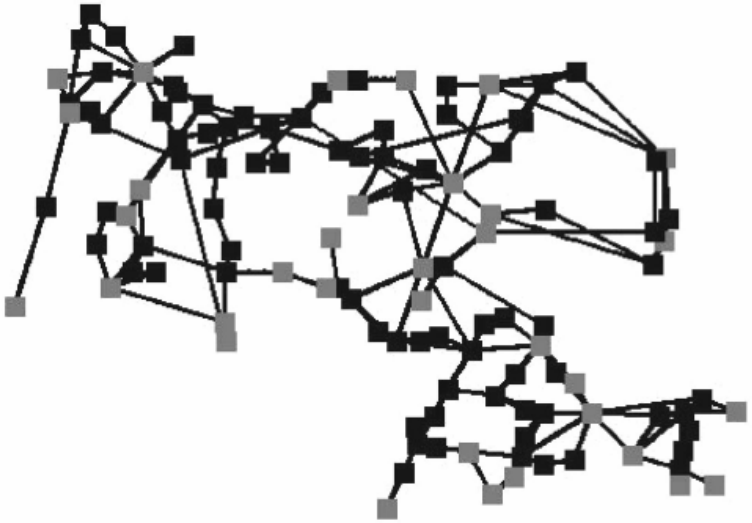
3. Network and Cascading Models (1)

- **Networked systems:**

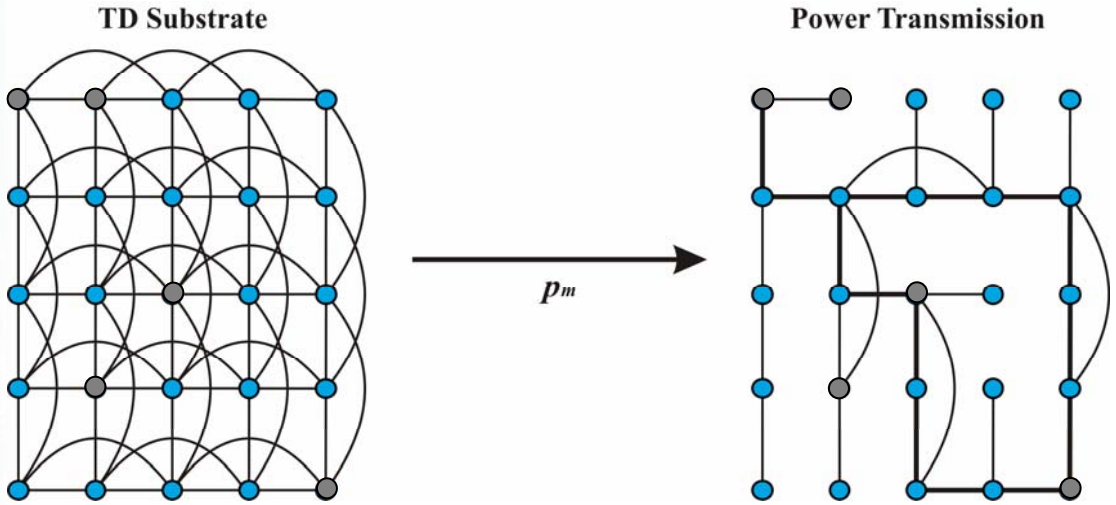
IEEE 118 Node Test System

3. Network and Cascading Models (1)

- **Networked systems:**



IEEE 118 Node Test System



Generic Transmission and Distribution (TD) System

3. Network and Cascading Models (2)

- **Cascading model:**

$$\hat{s} = \mu^t$$

Branching Process

$$C_i = (1+\alpha)L_i$$

L_i - Load

α - Tolerance

C_i - Capacity

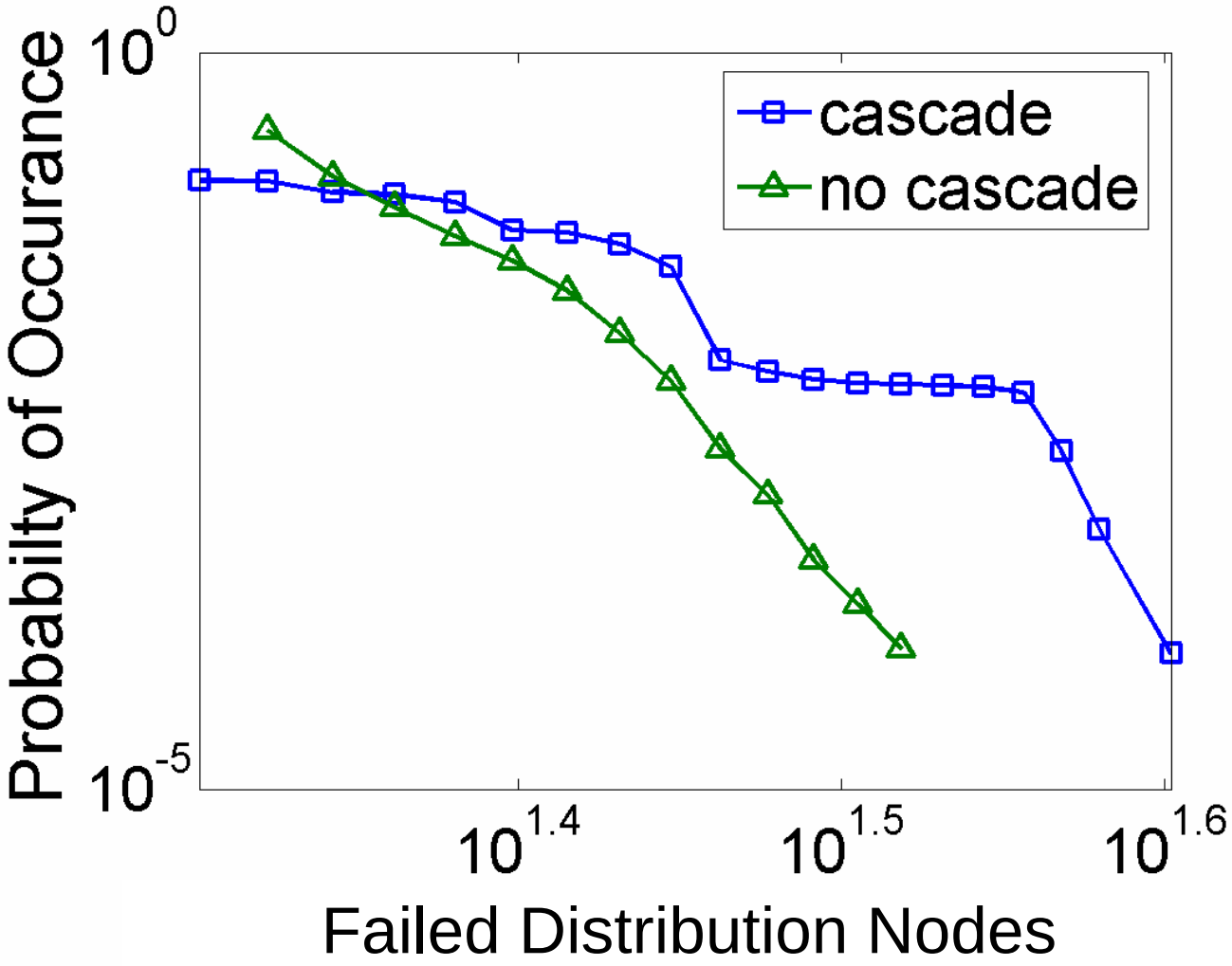
Numerical Simulation

- **Triggering events:**
  - Targeted disruptions: node degree, node load
  - Natural hazards: earthquake and lightning in Western U.S.

- **Performance measure:** $S = \frac{n_D'}{n_D}$

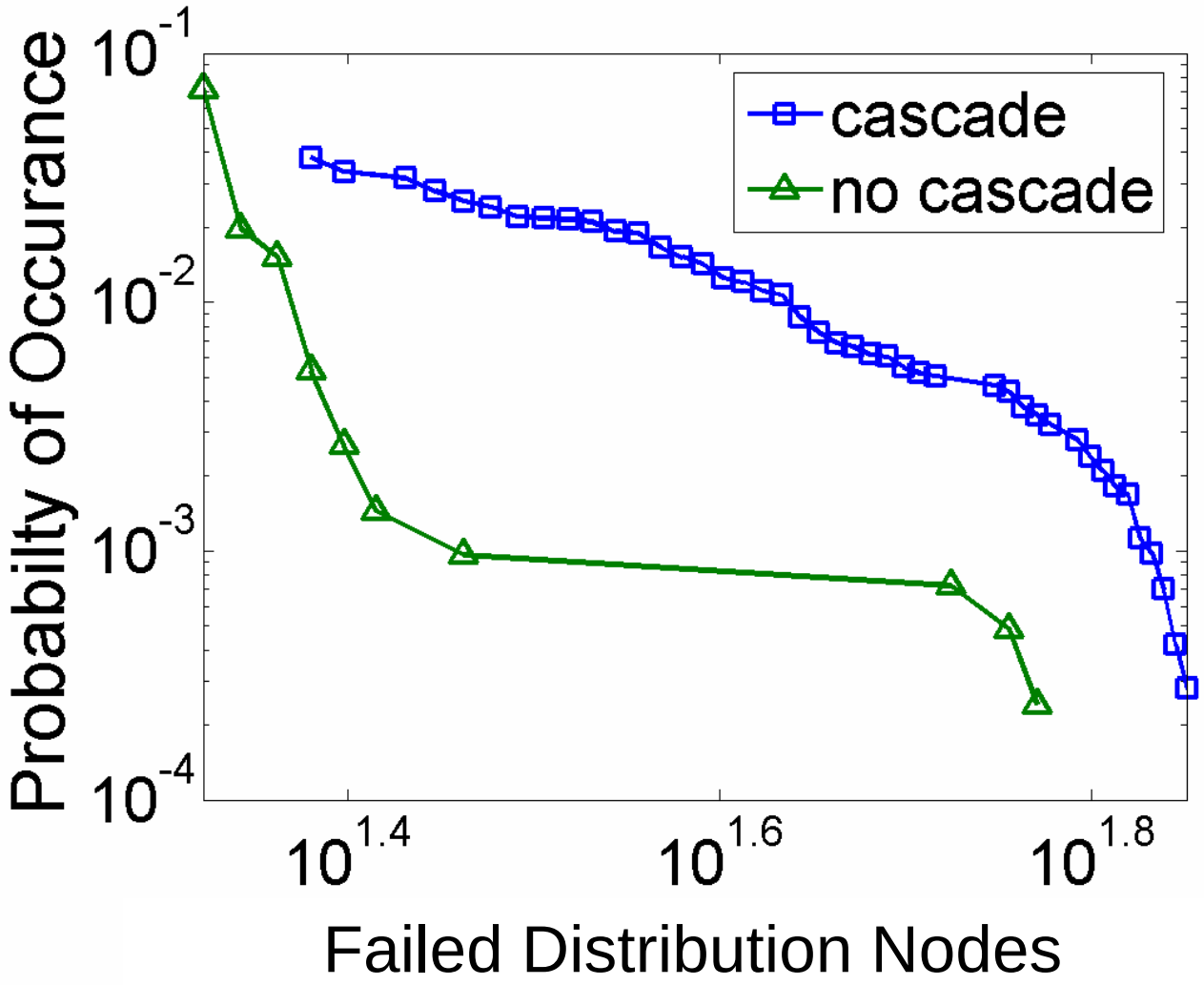
4. Infrastructure Risk (1)

- **Probability of blackout size - LG:**



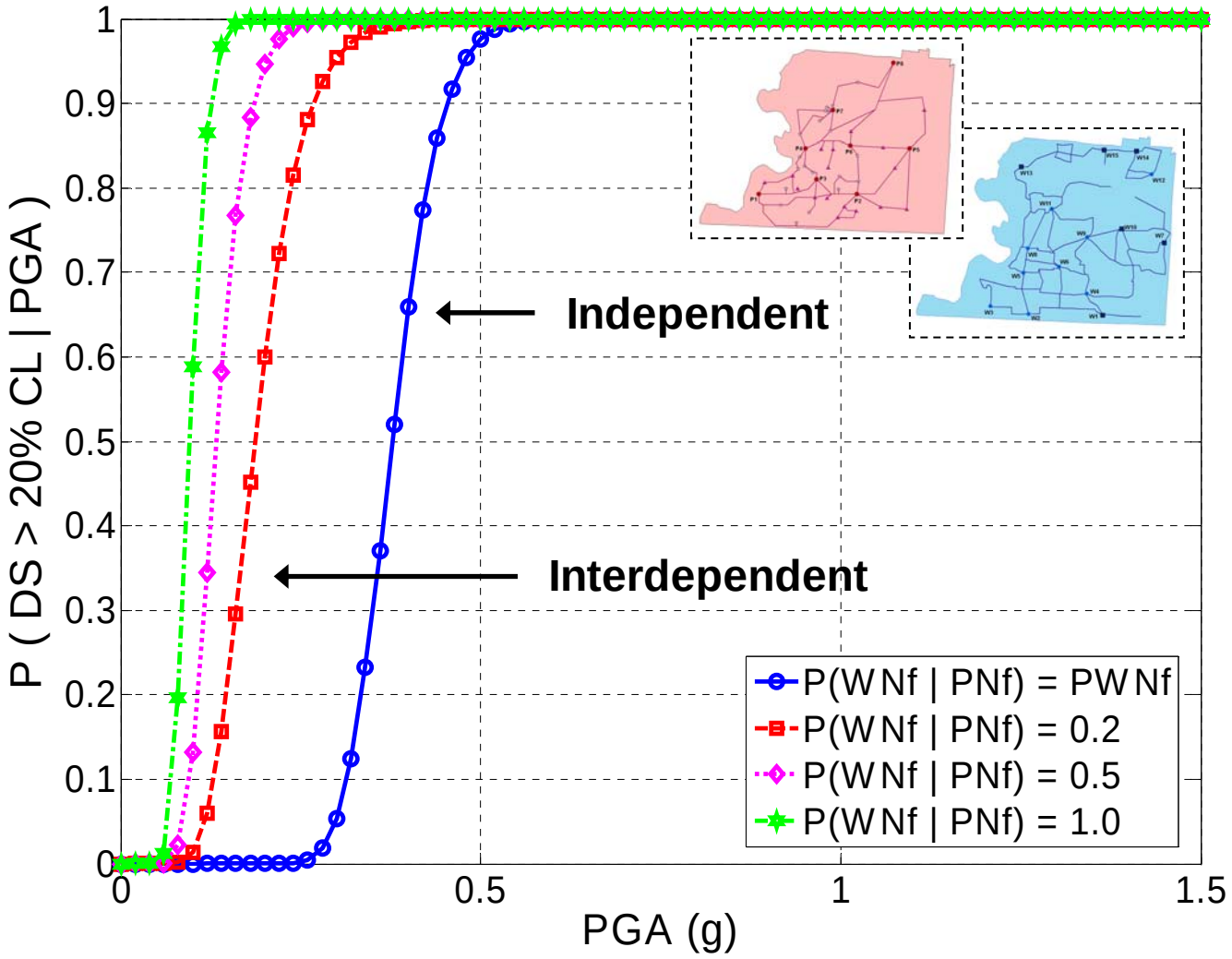
4. Infrastructure Risk (2)

- **Probability of blackout size - EQ:**



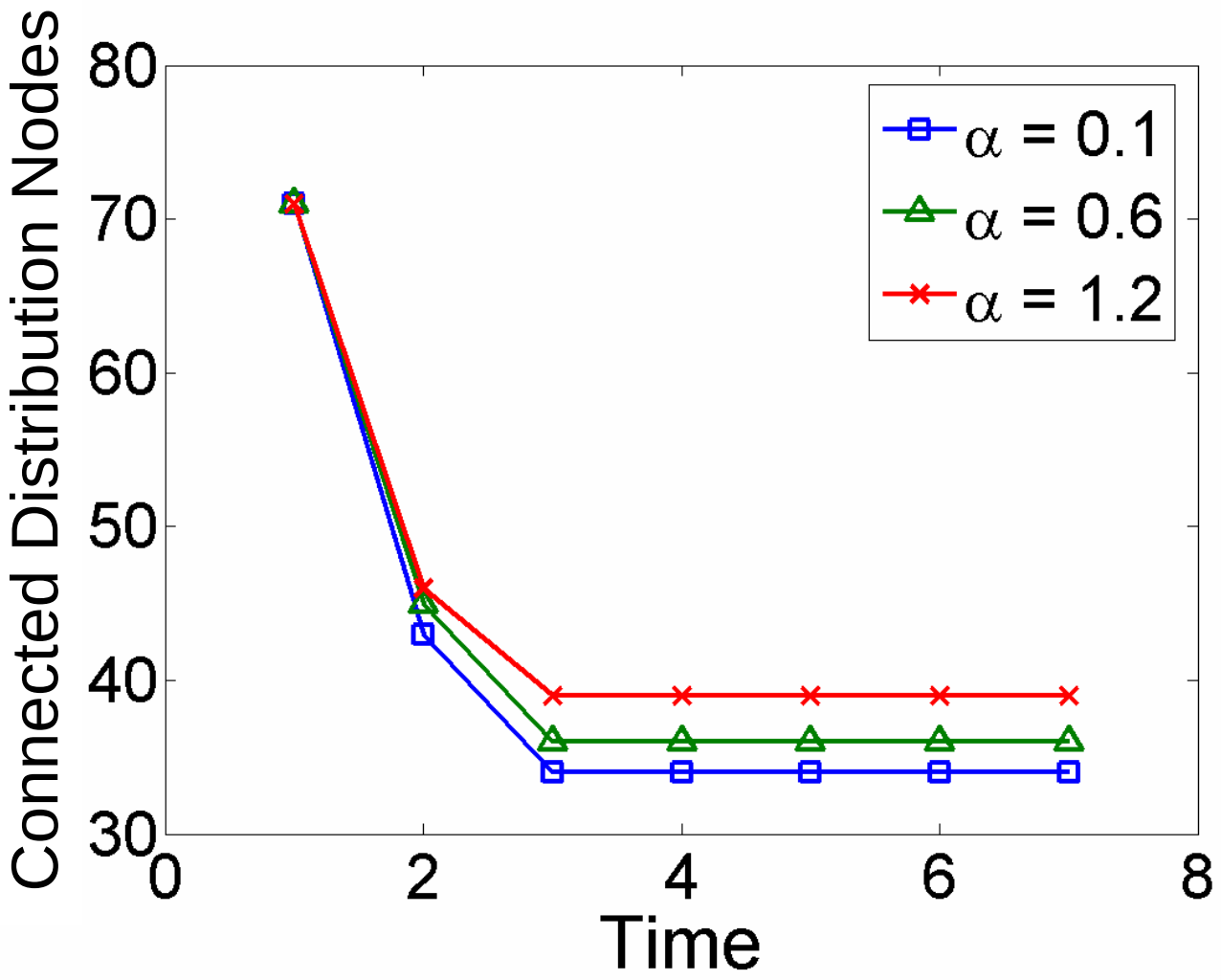
4. Infrastructure Risk (3)

- **Network Interdependencies:**



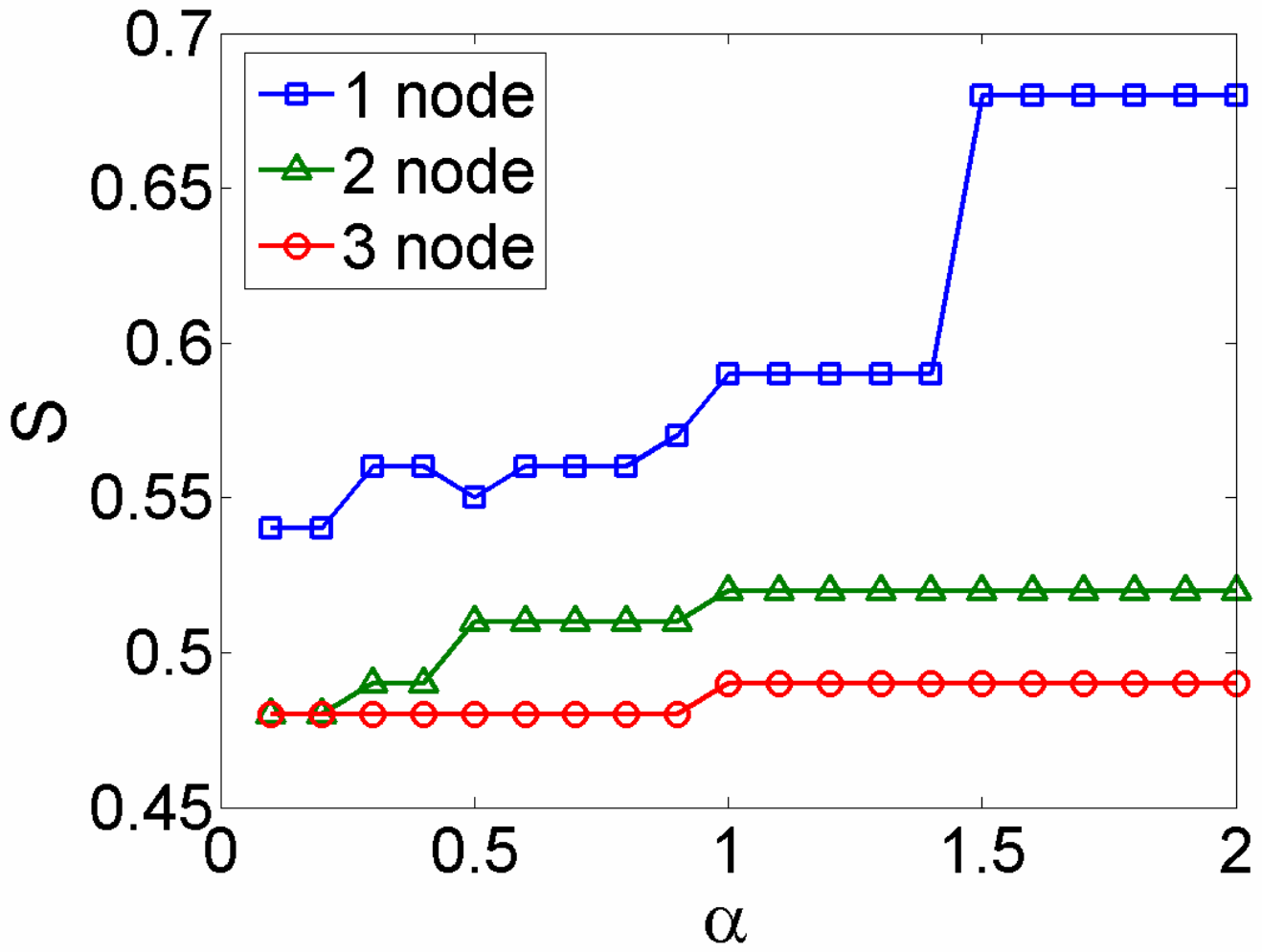
5. Network Performance (1)

- **Evolution of cascading failure:**



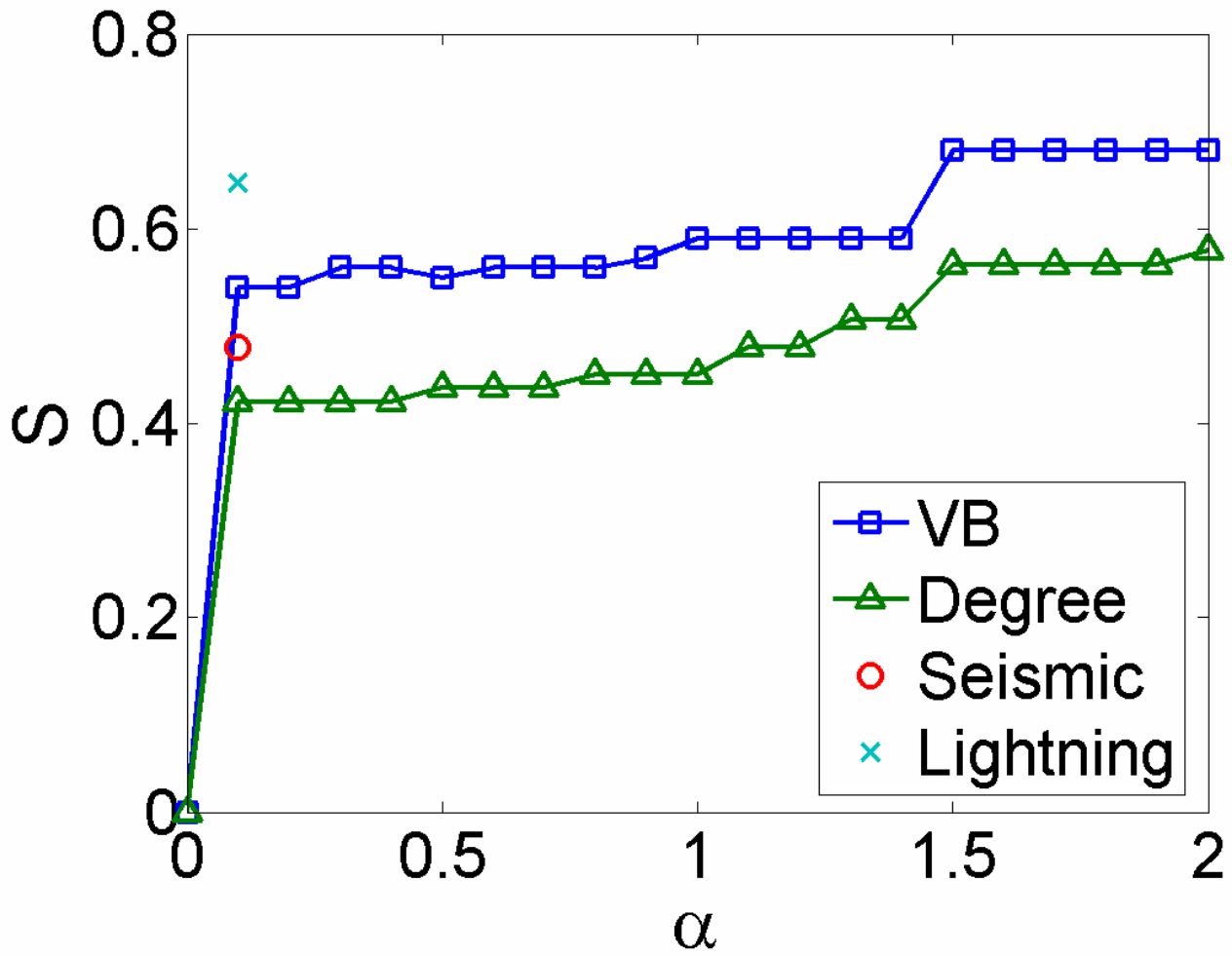
5. Network Performance (2)

- **Size of triggering event:**



5. Network Performance (3)

- **Steady-state response:**



6. Conclusions

- Engineered infrastructures possess the attributes of complex systems
- Tolerance α improves performance but rapidly becomes impractical
- Topological changes are needed for reliability
- Networked systems exhibit increased likelihood of large-scale disruptions

Thank You

Questions and Discussion