A Series of Unfortunate Events in Complex Networks

Robustness Metrics for Cascading Failures

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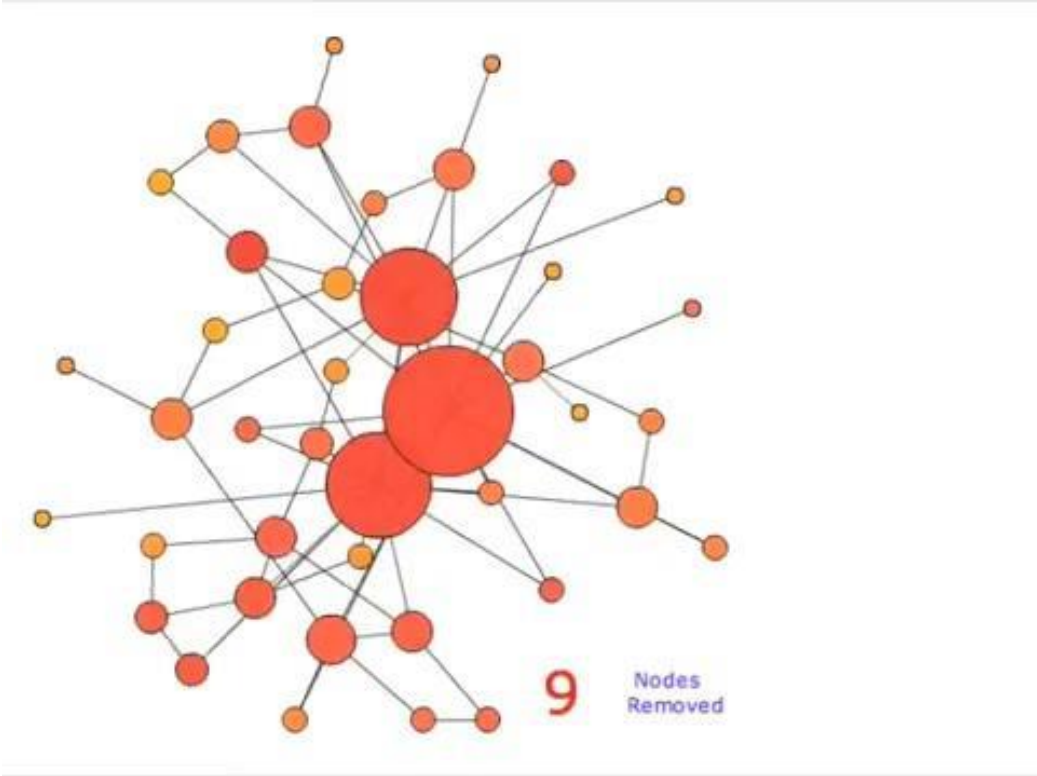
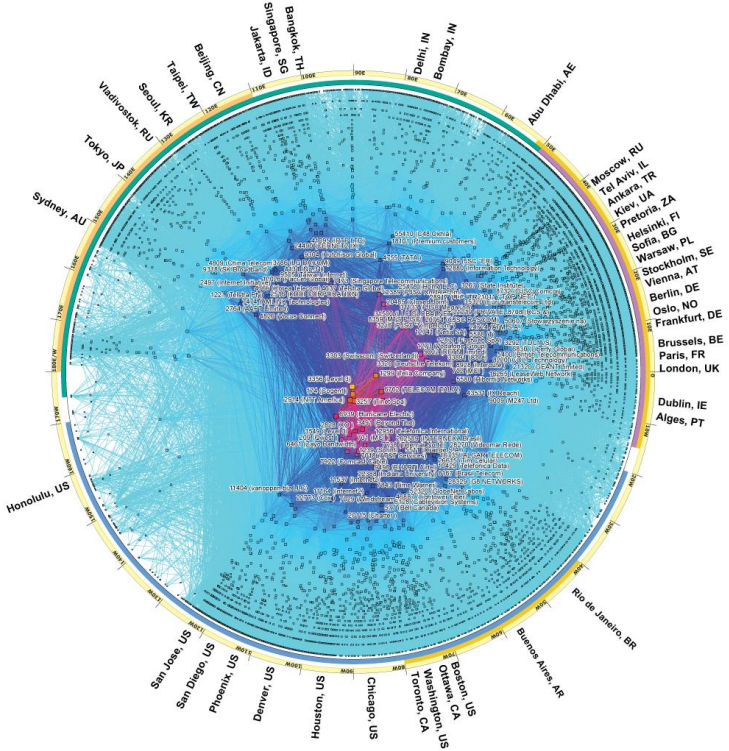
Removing nodes one by one

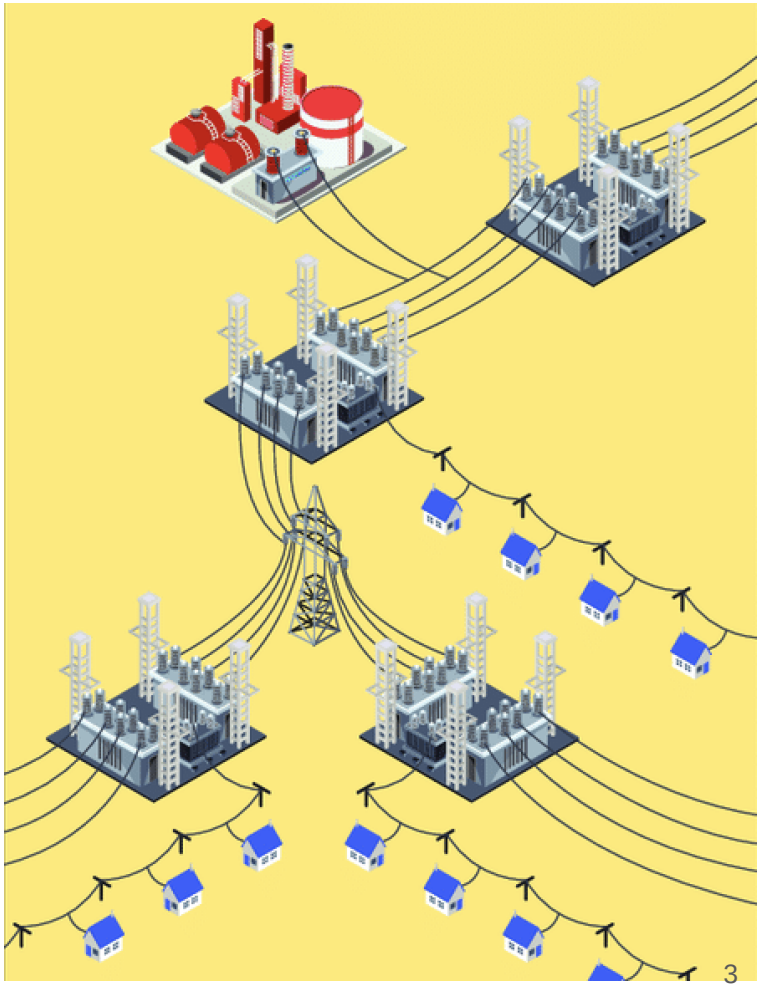
Real-world networks are robust to random failures

For targeted attacks, removing a minimal amount of nodes cripples the network.



Networks as transportation systems





The Motter-Lai Model

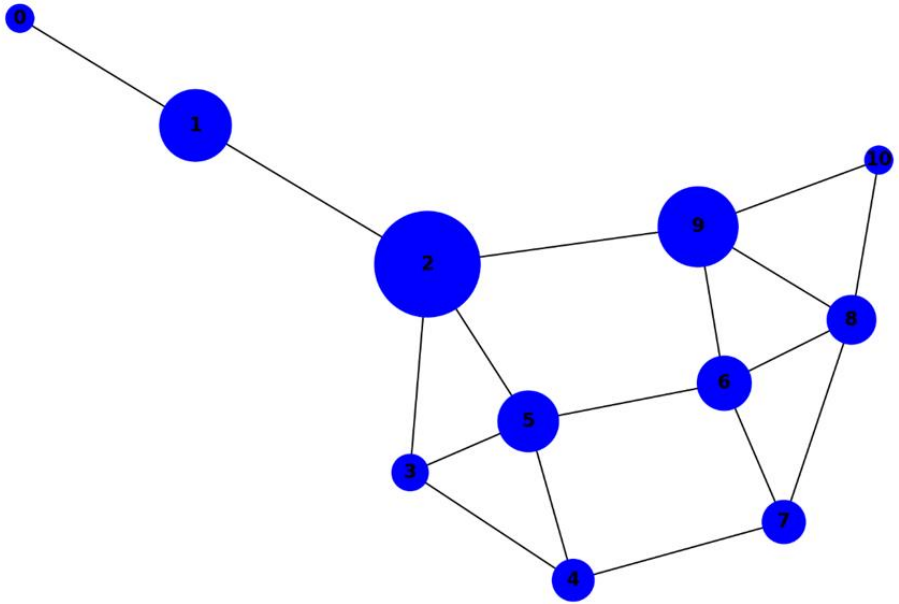
$$C_i = (1+\alpha)L_i^0 \ , \qquad i = 1, 2, ..., N$$

$$L_i^t > C_i \qquad \Longrightarrow$$

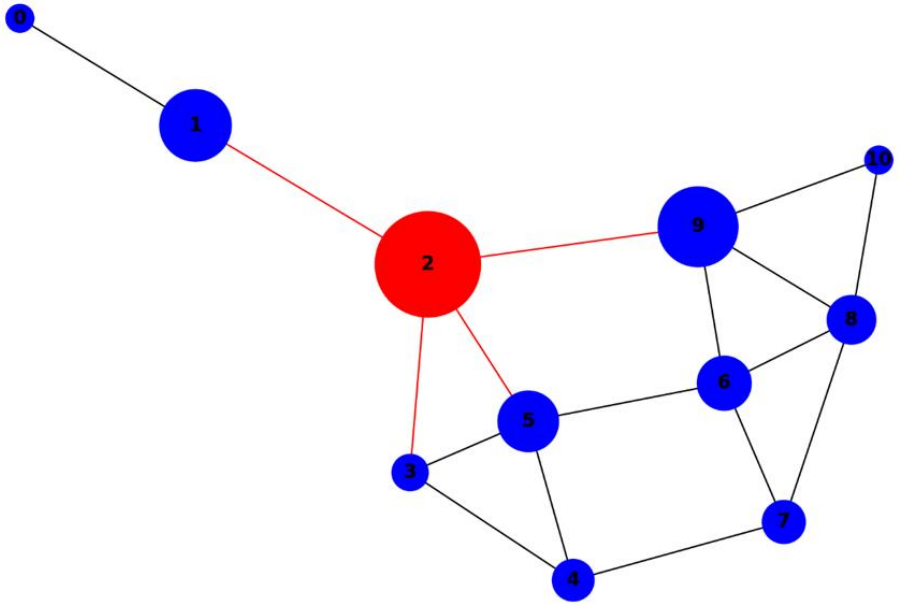
How to choose the initial node to attack?

- Random
- Degree
- Betweenness Centrality (Load)
- Clustering Coefficient

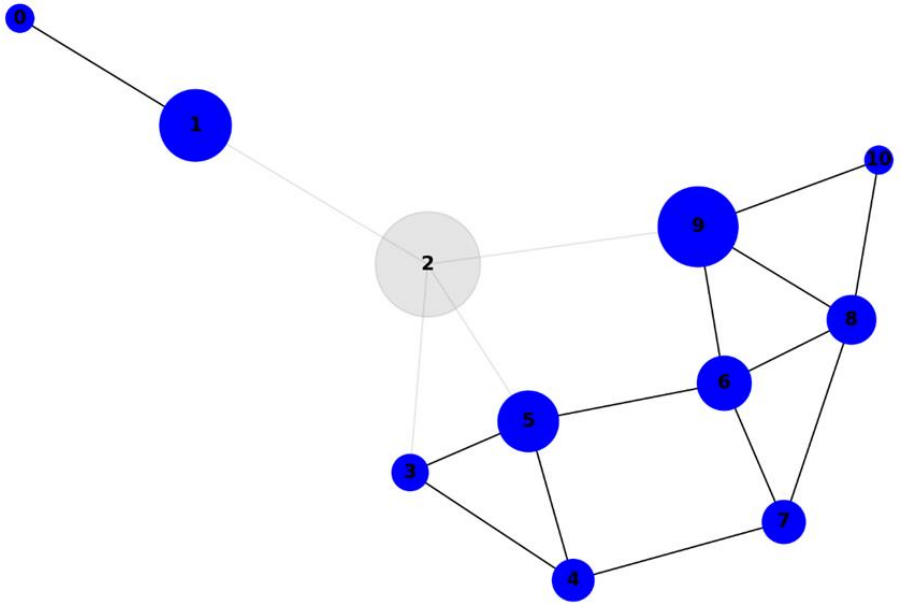
Algorithm



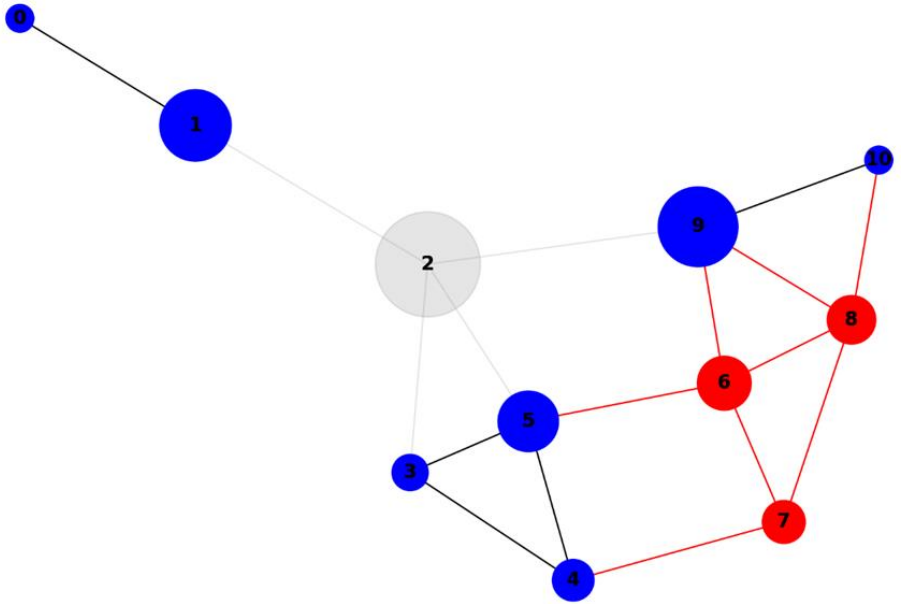
Algorithm



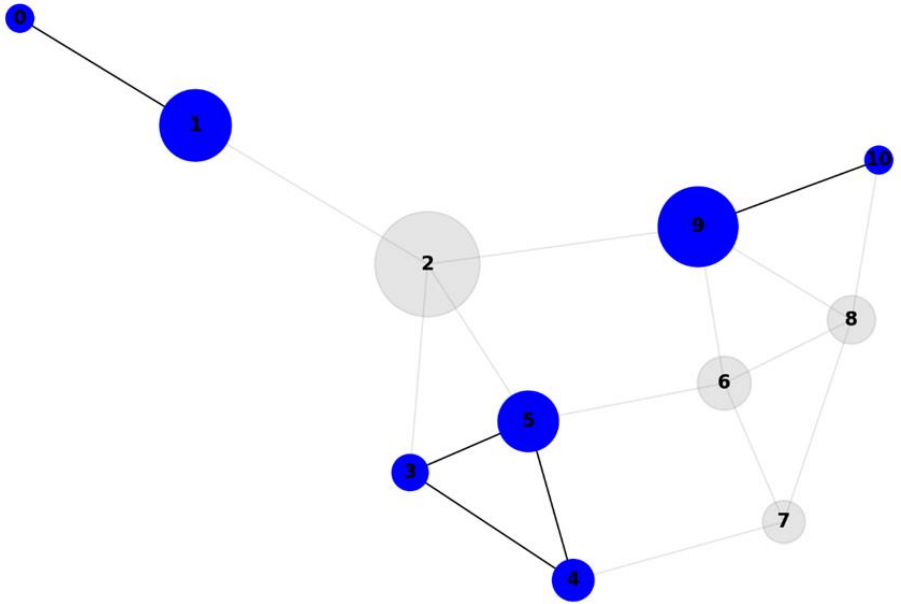
Algorithm



Algorithm



Algorithm



The Giant Component Metric

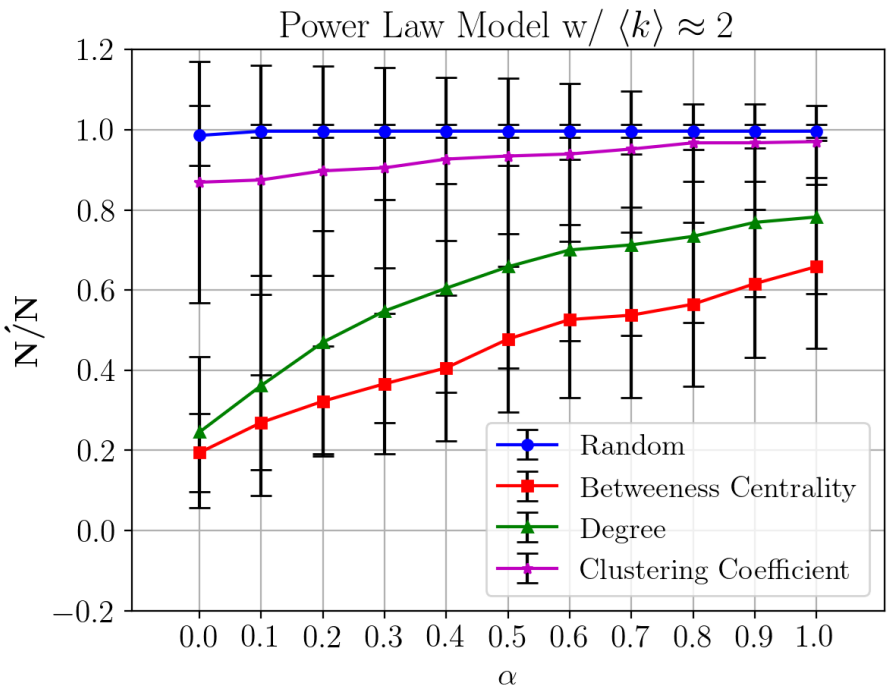
How to evaluate the robustness of a network?

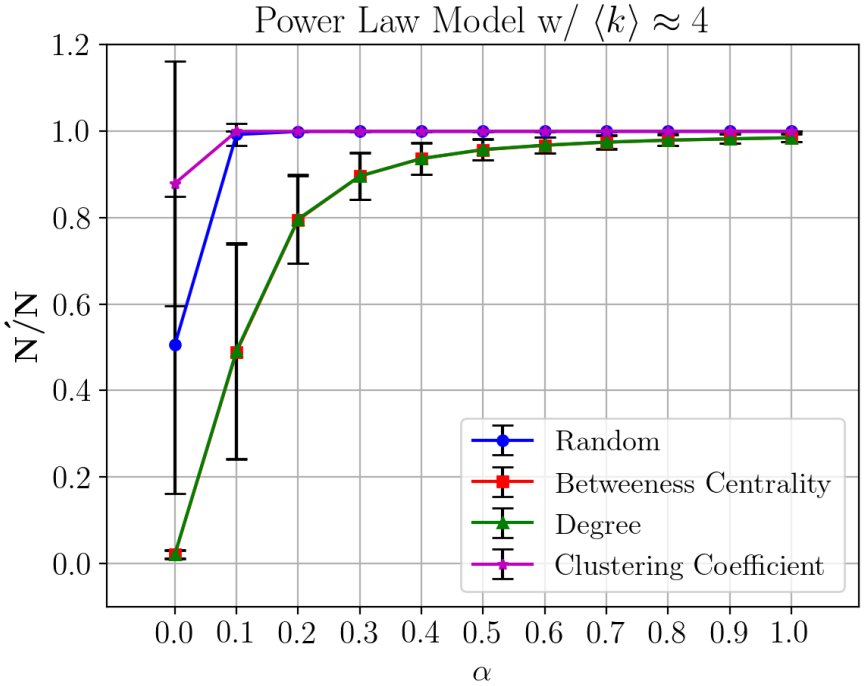
$$G = \frac{N'}{N}$$

What models to use for testing?

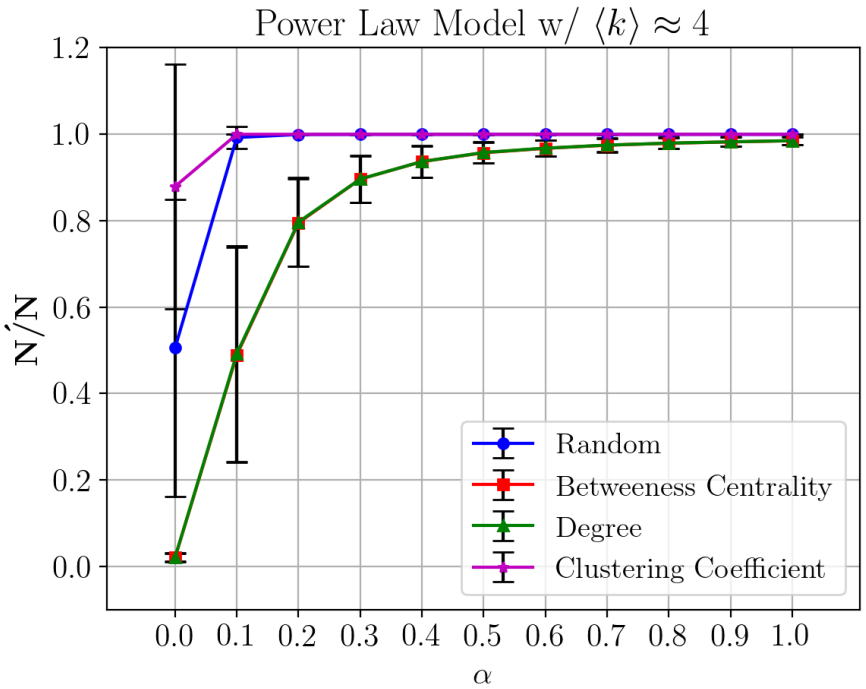
$$P(k) \sim k^{-\gamma}$$

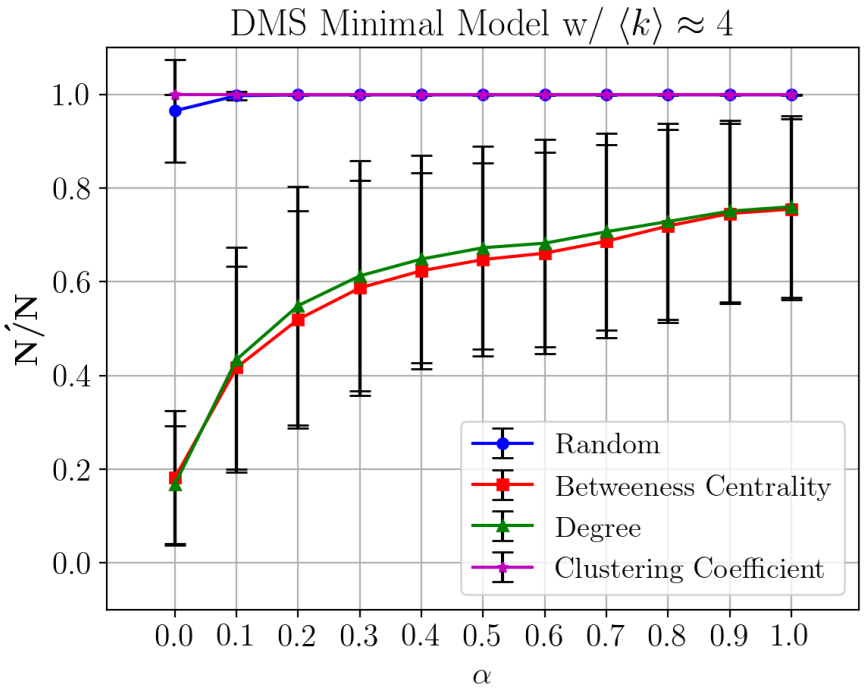
Power Law Avg. Degree 2 VS 4 (N = 5000)





Power Law VS DMS (Avg. Degree 4, N = 5000)





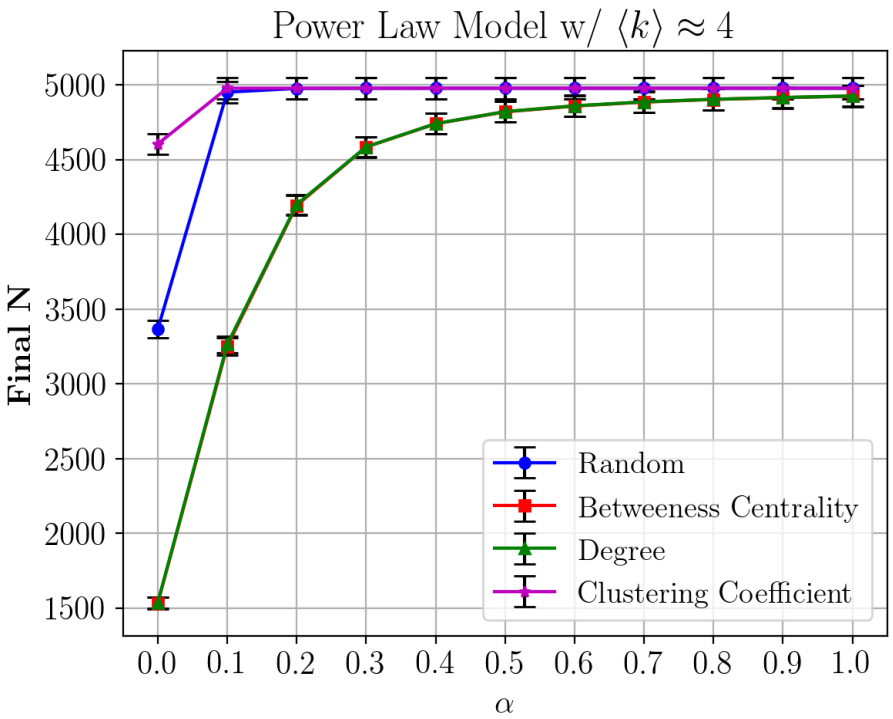
Power Law VS DMS (Avg. Degree 4)

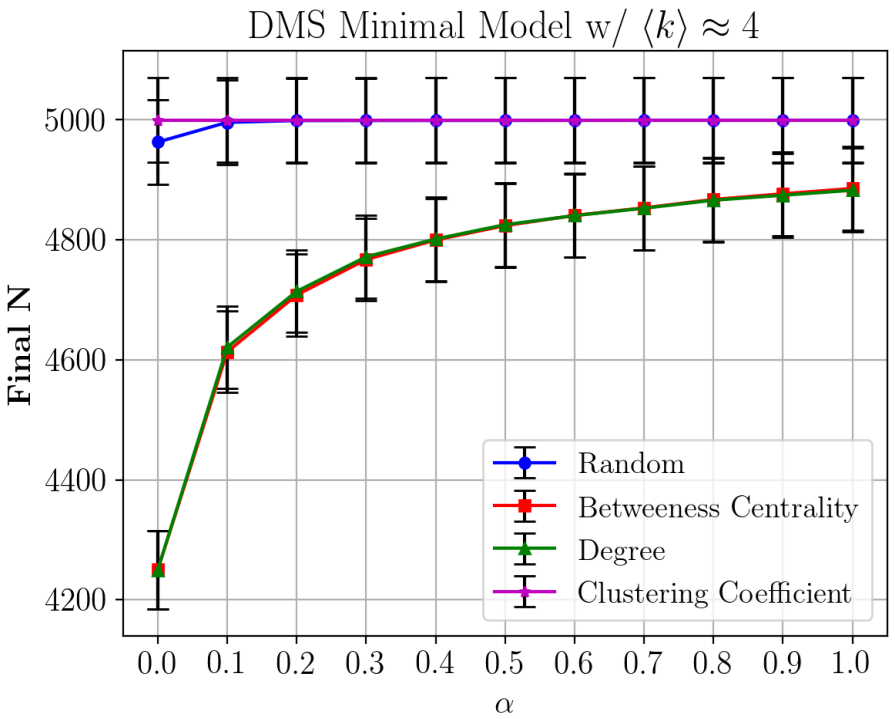
The DMS Model seems less robust to targeted attacks...

What about if we use a different metric?

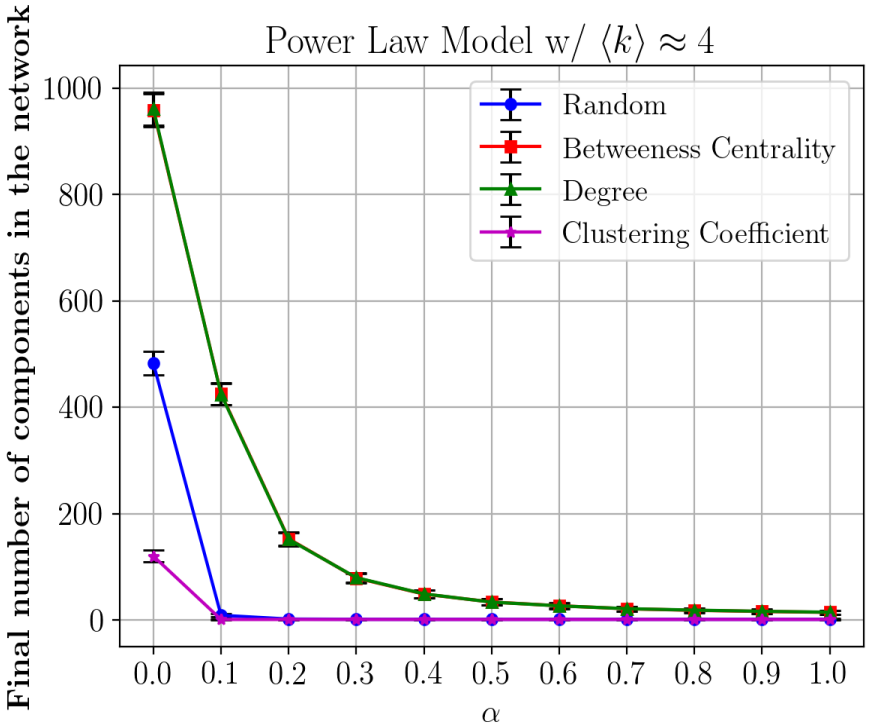
Will the results be the same?

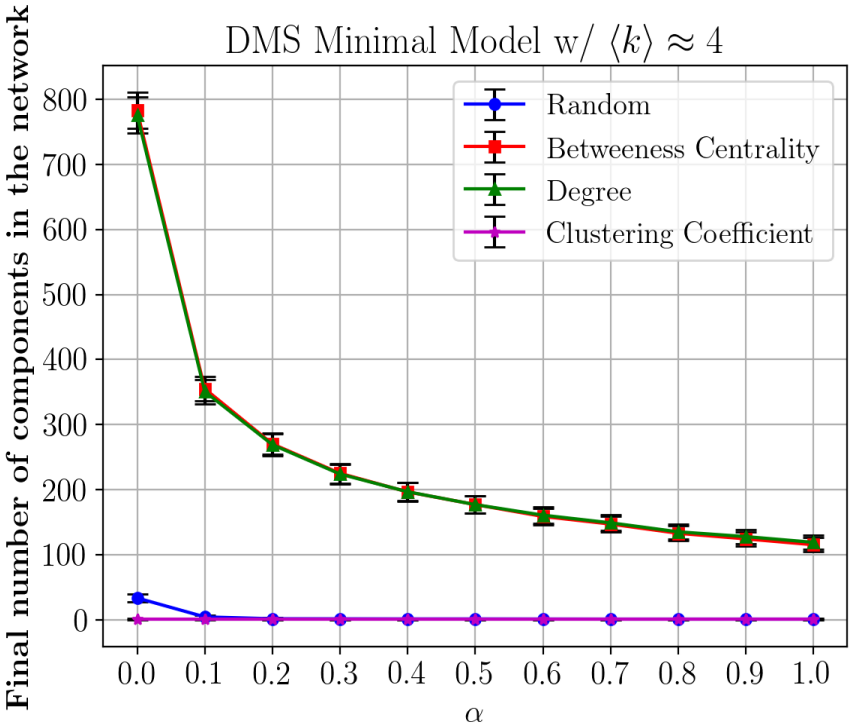
Power Law VS DMS (Avg. Degree 4)



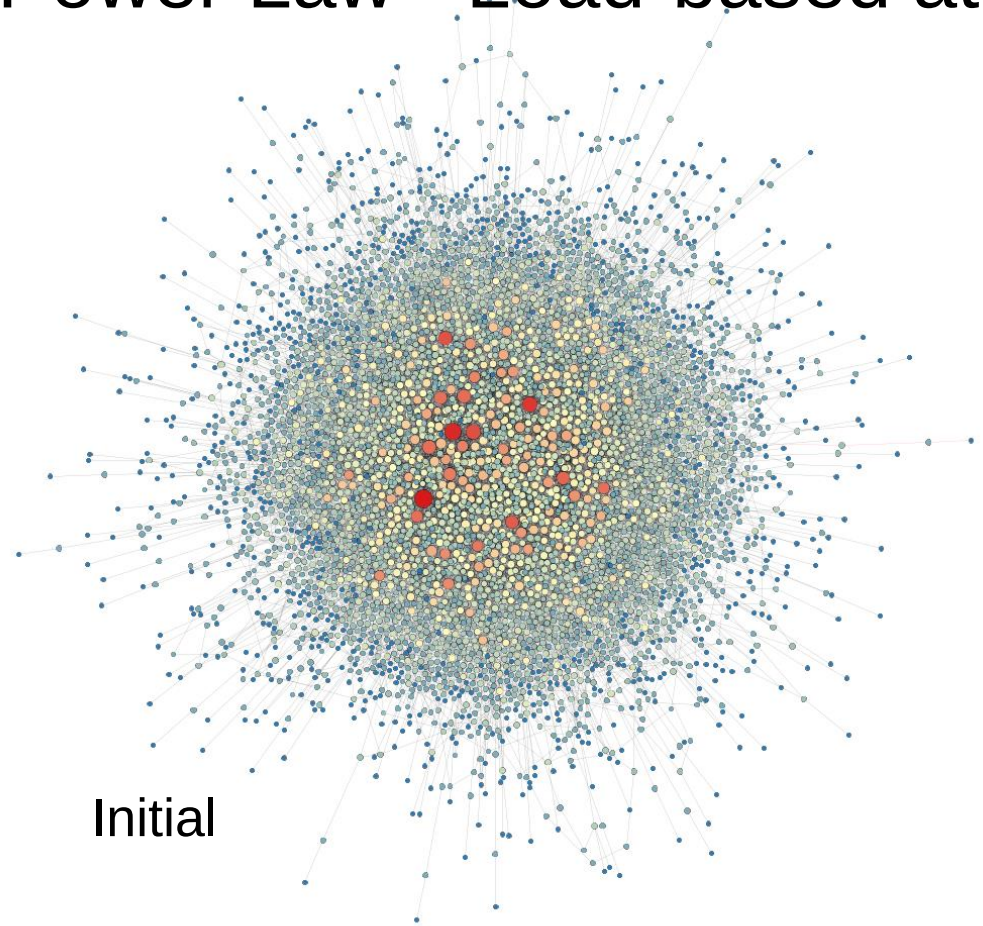


Power Law VS DMS (Avg. Degree 4)

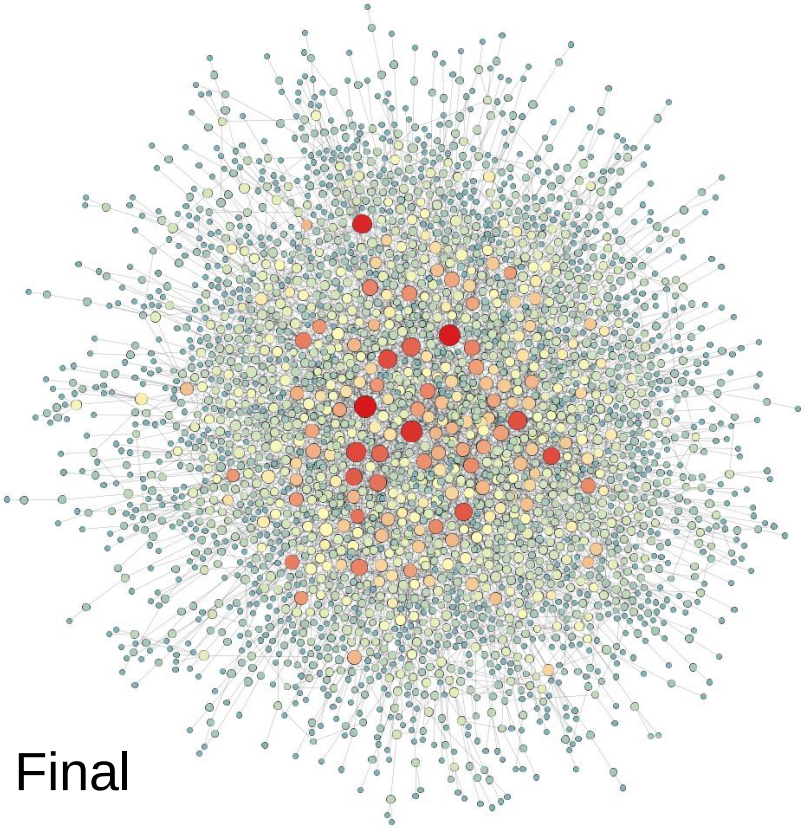




Power Law - Load-based attack - α = 0.2 - N = 5000



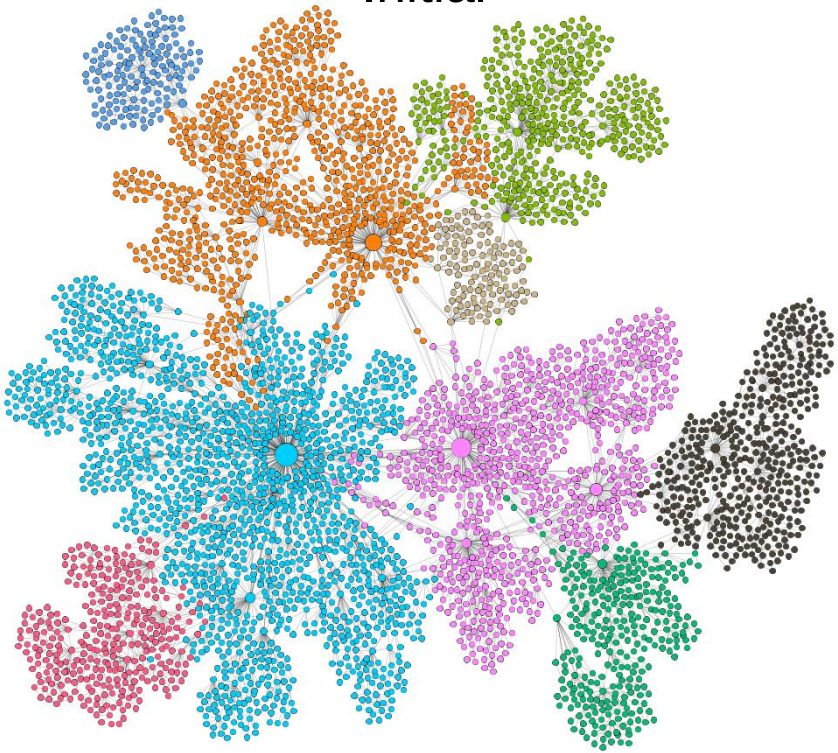
Initial



Final

DMS - Load-based attack - α = 0.2 - N = 5000

Initial



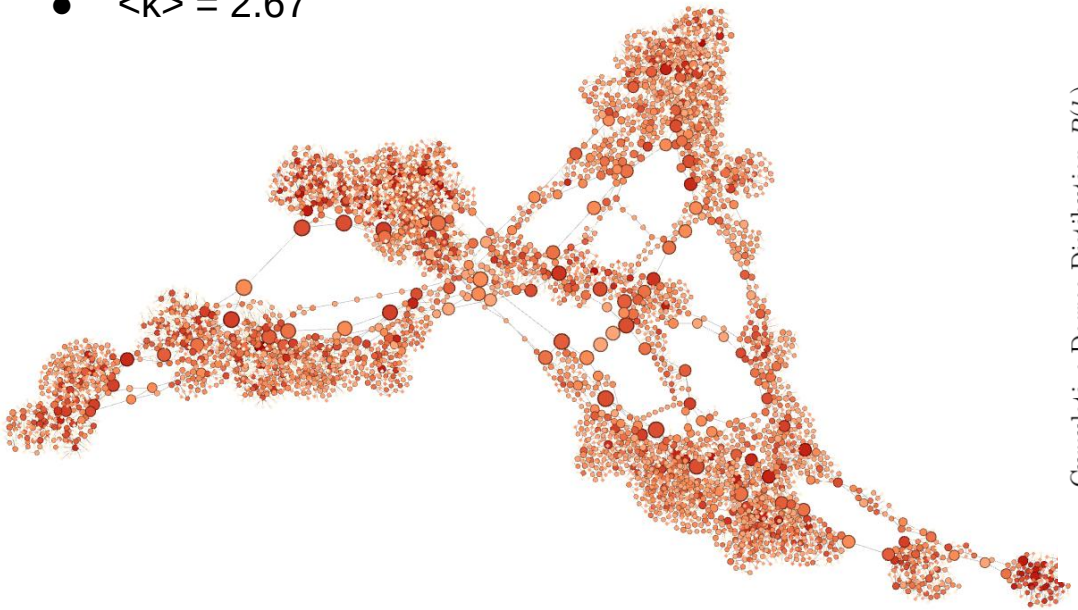
Final

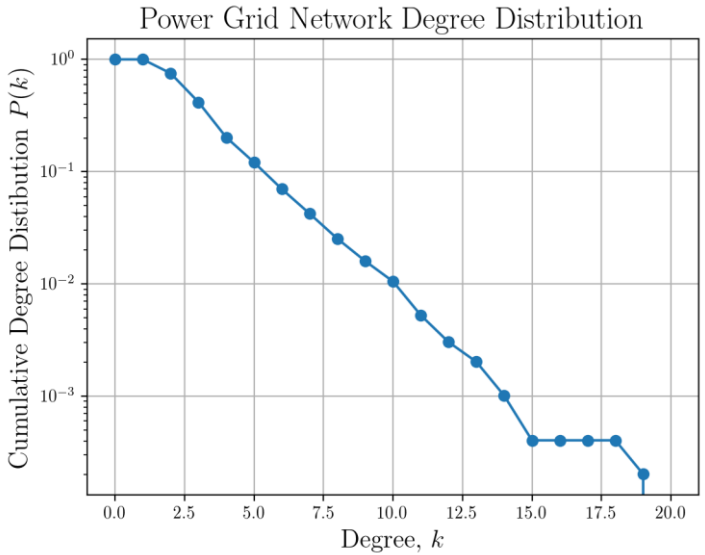
Power Law and DMS comparison for α = 0.2

Final values	**Power Law**	**DMS**
# of Nodes	3193	4483
# of Nodes w/ k > 0	2995 (94%)	4125 (92%)
# of Nodes in biggest comp.	2751 (86%)	1095 (24%)
# of Components	83	175
Average Degree	2.695	3.411

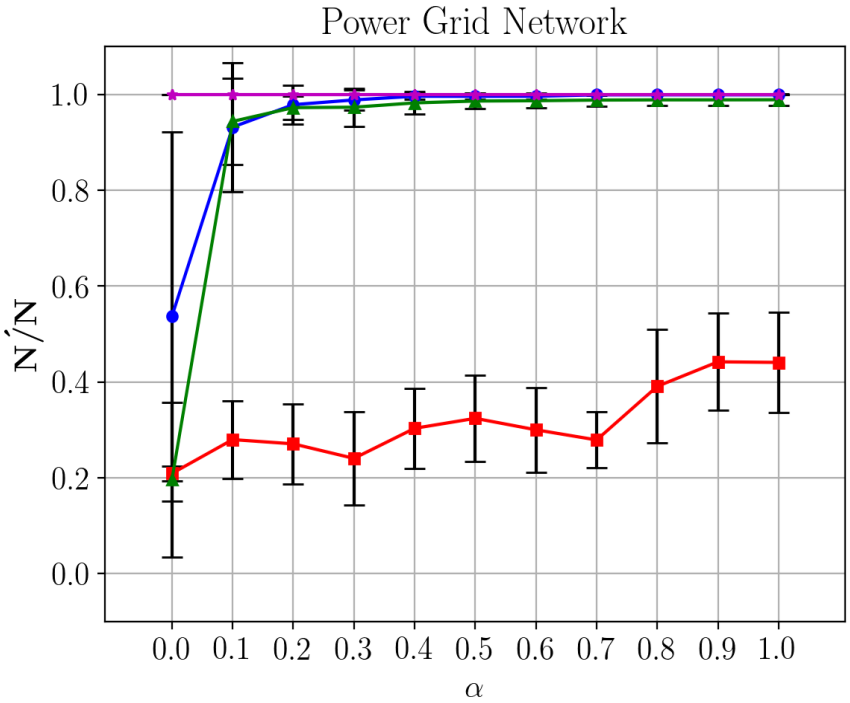
Power Grid

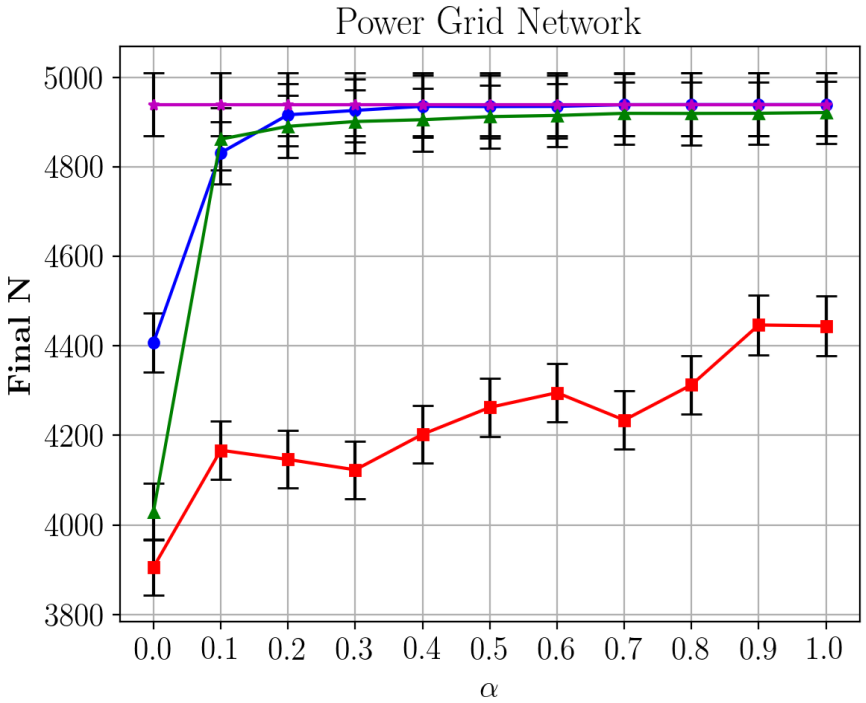
- N = 4941
- <k> = 2.67



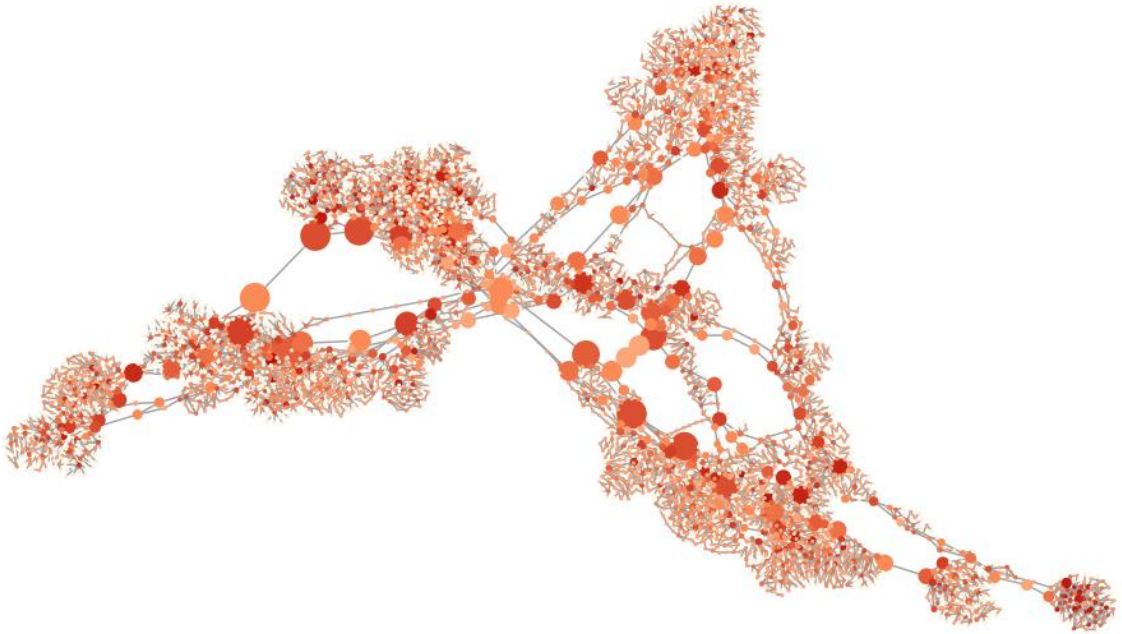


Power Grid


Power Grid Network
N´/N
1.0
0.8
0.6
0.4
0.2
0.0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
α


Power Grid Network
Final N
5000
4800
4600
4400
4200
4000
3800
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
α

Power Grid - Load-based attack - α = 0.2



Conclusion

How to attack a network?

- Degree
- Betweenness Centrality

Higher degree ⇒ More robustness

- Robustness ⟺ Number of nodes ⇒ Choose a DMS Model
- Robustness ⟺ Size of the giant component ⇒ Choose a Power Law Model

Thank you!