

Investigating Resiliency of U.S. Airlines Network

Final Project Presentation

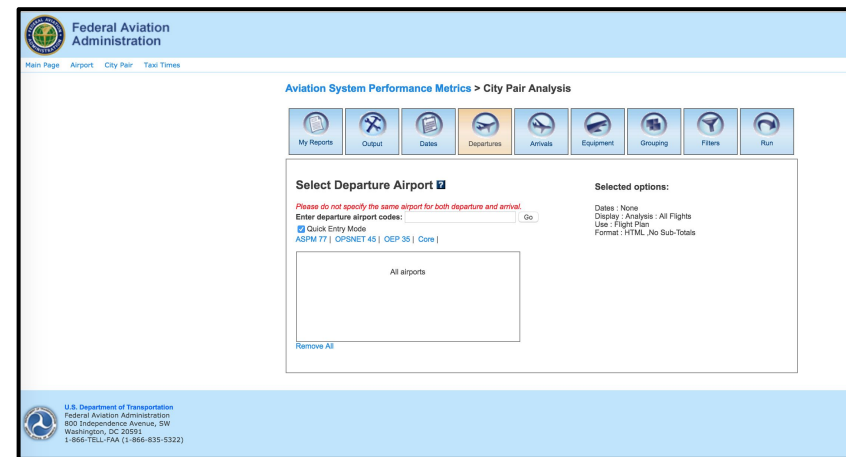
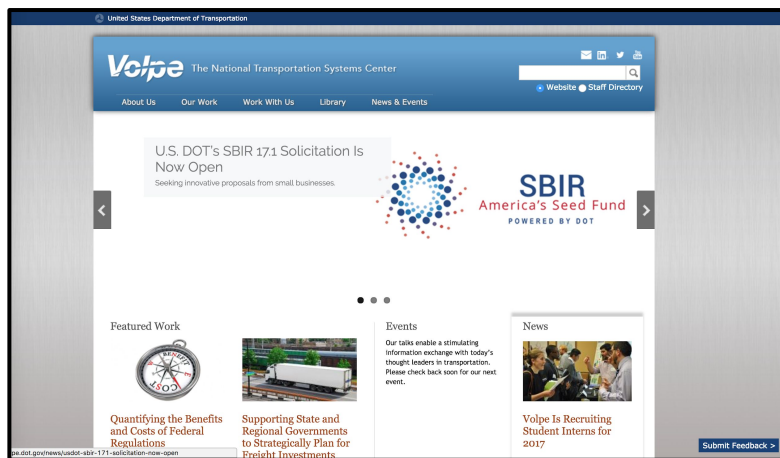
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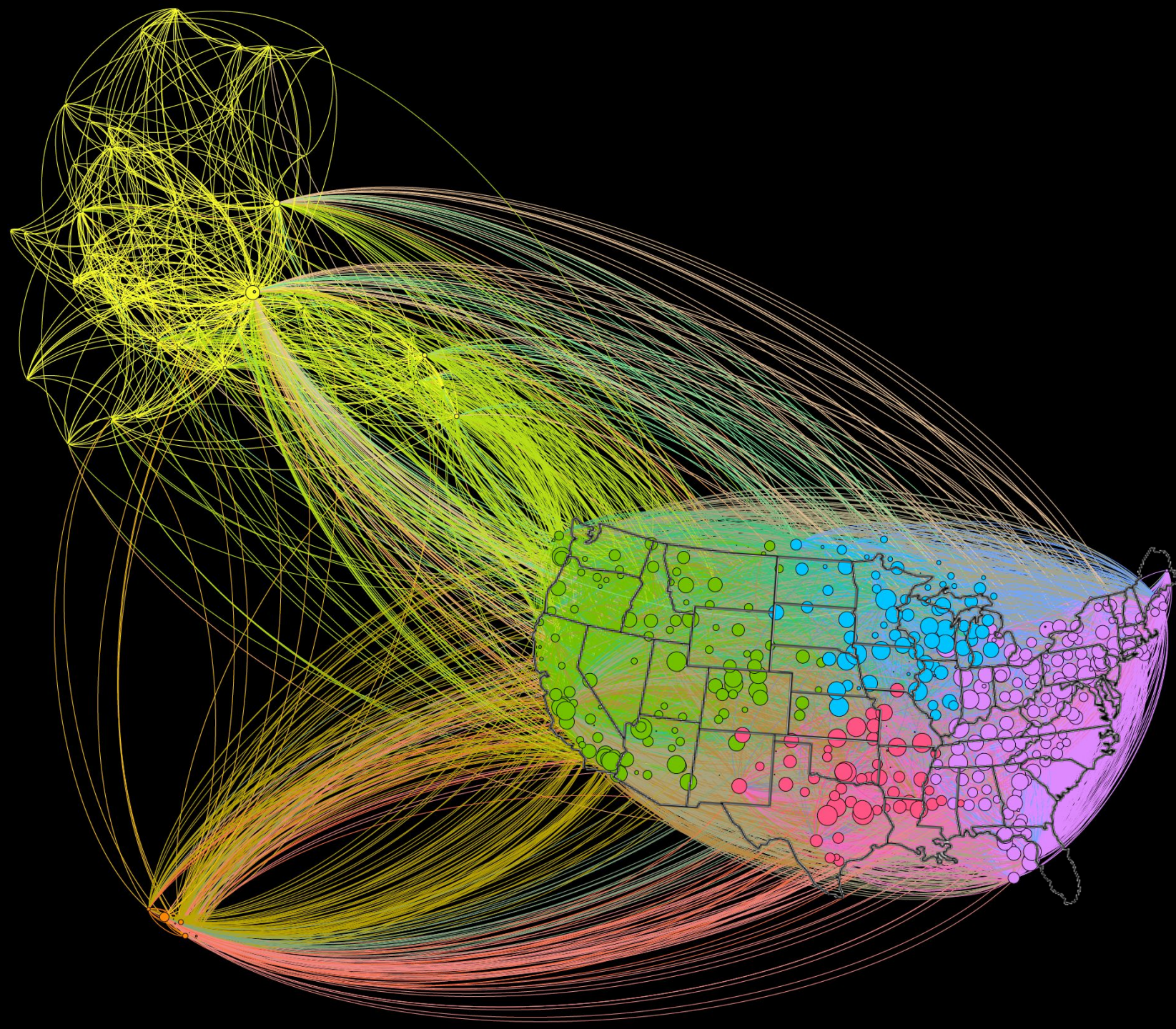
Data Source

- Domestic flights in the U.S. for 2014
- Undirected
- Two airports connected if at least one flight between them
- Weight = Number of flights
- Data collected by Volpe National Transportation System Center
- Obtained from FAA Aviation Statistics and Performance Metrics



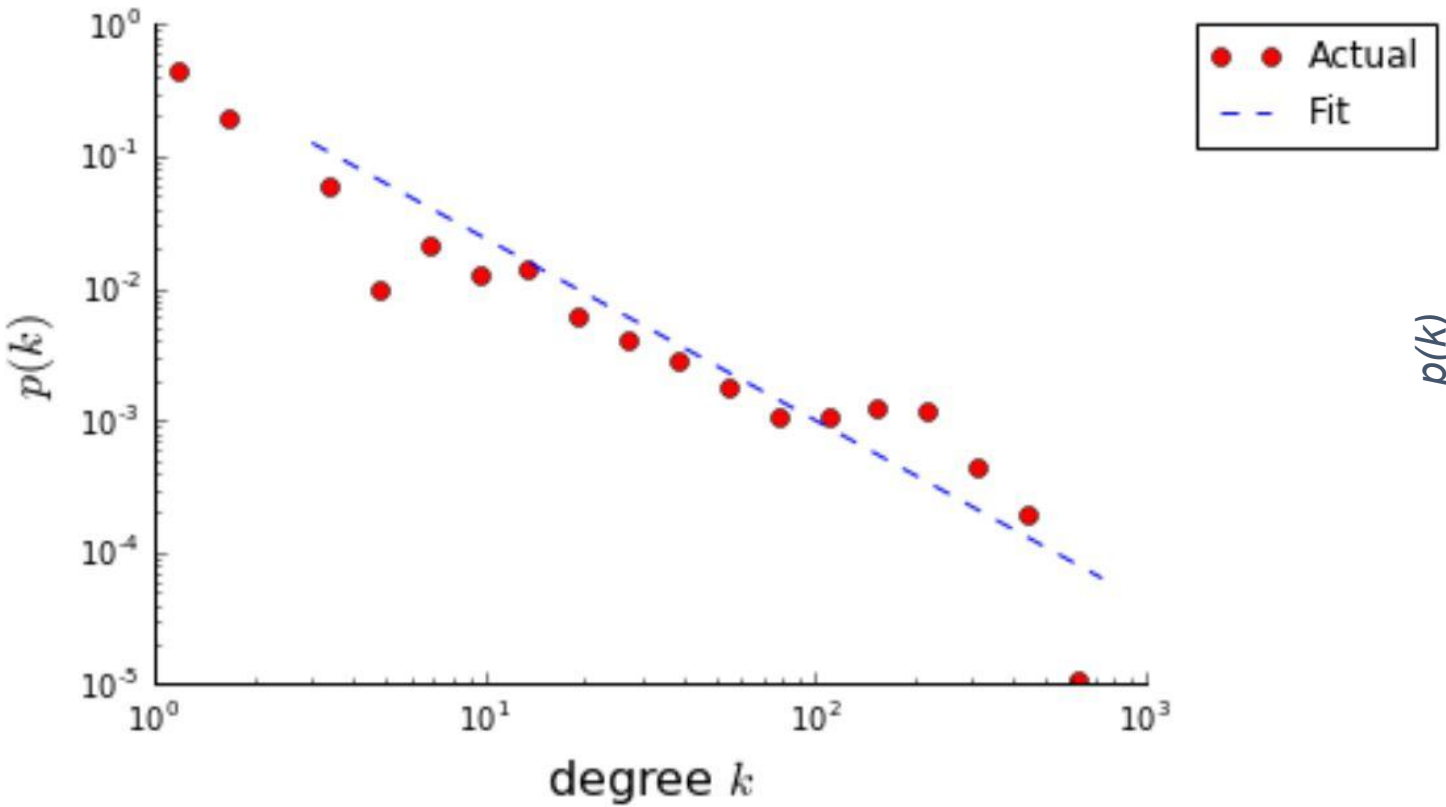
Comparing Networks

Network	N	L	<K>	<I>	<C>	Diameter
Actual	1,263	47,350	75	2.28	0.67	5
Degree Preserved						
GNM				1.95	0.06	3
Refined Nodes	461	35,796	155.30	1.77	0.74	4

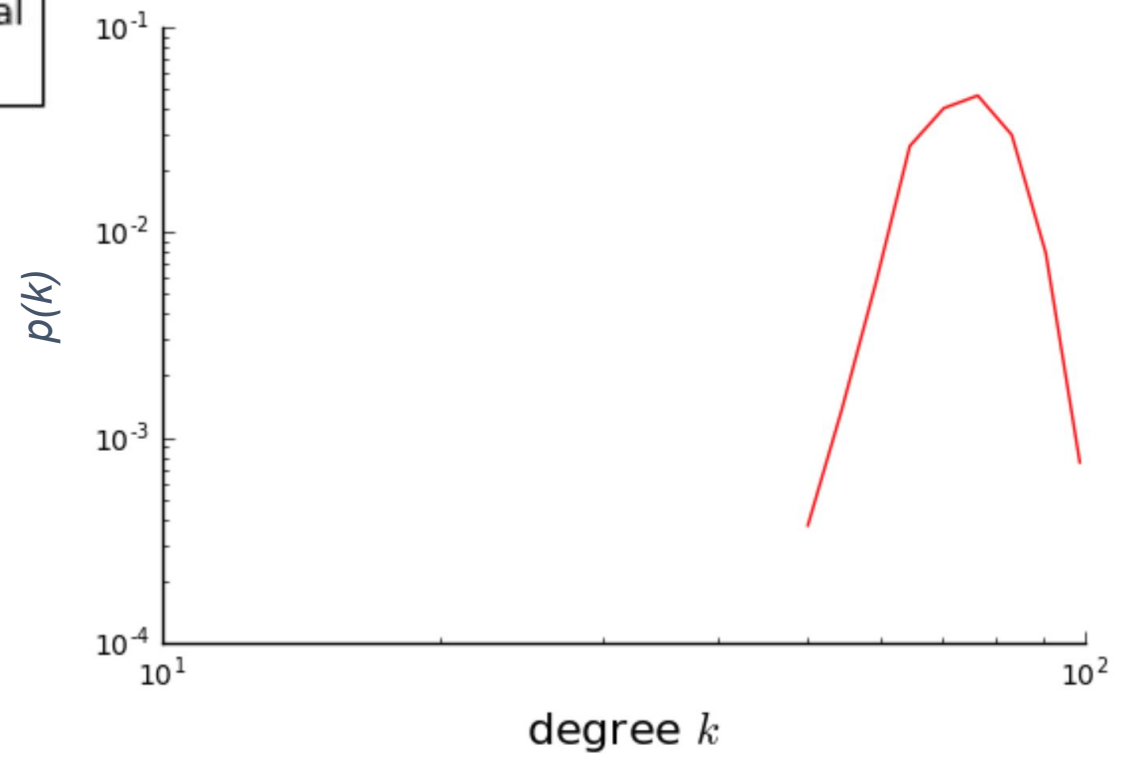


Degree Distribution Graphs

Degree distribution

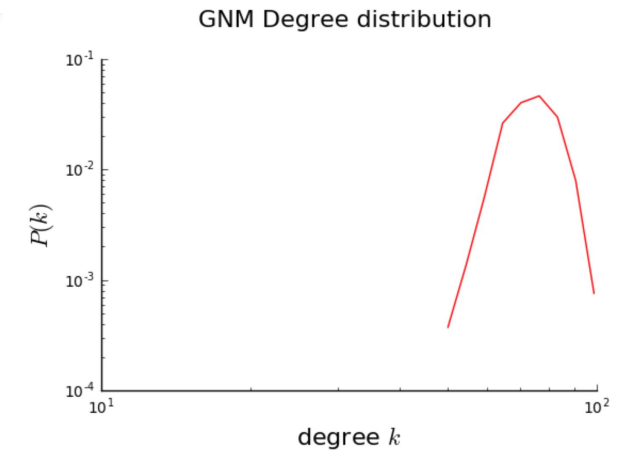
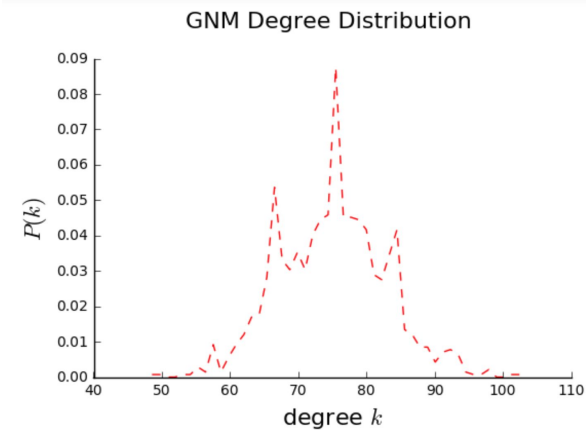
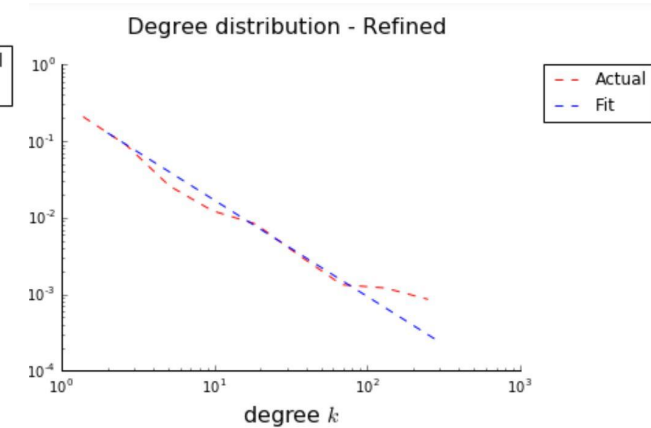
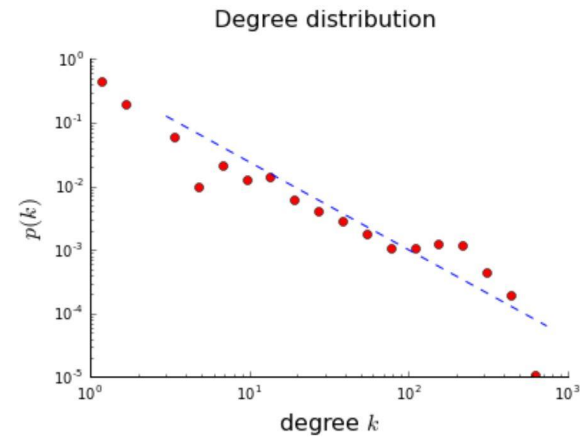


GNM Degree distribution

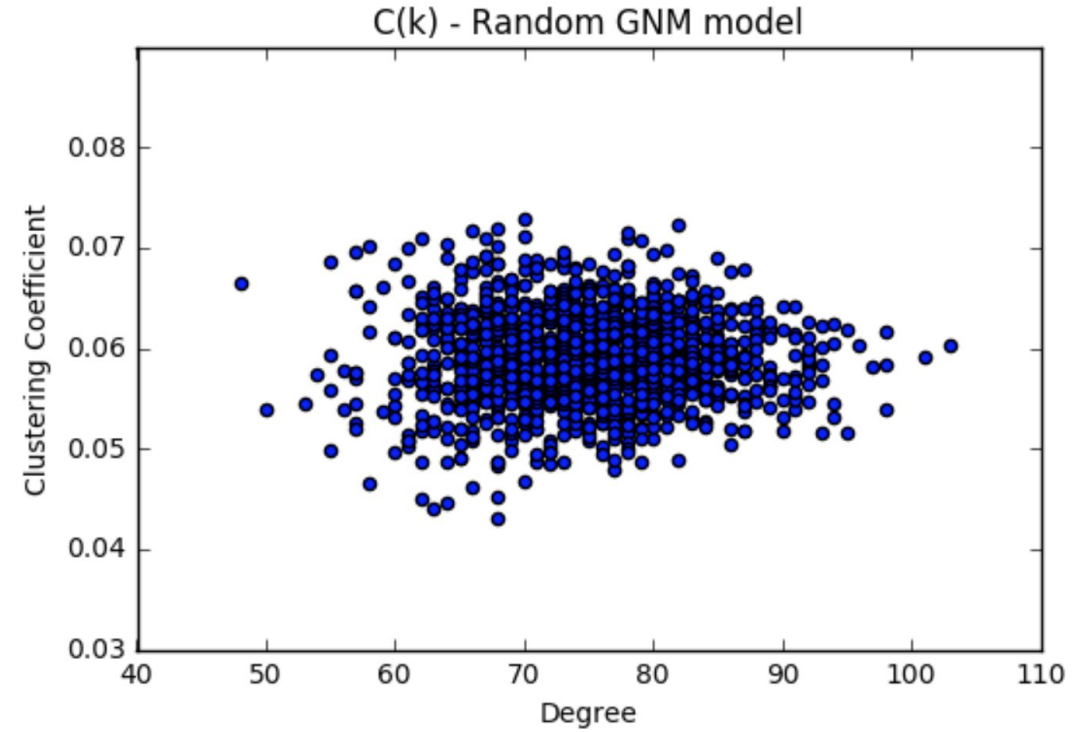
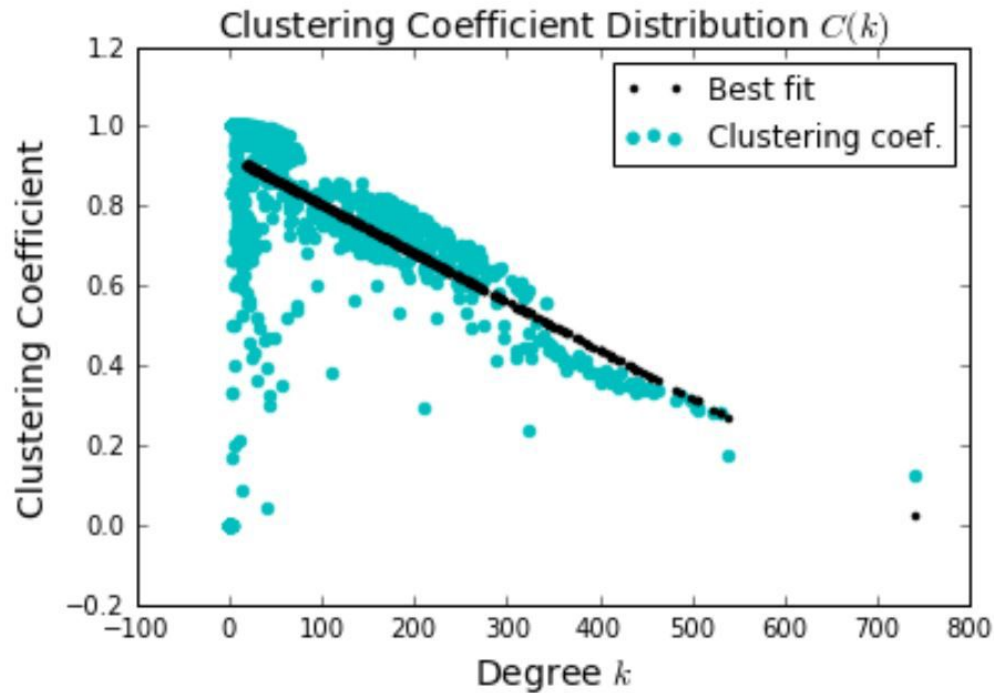


Degree Distribution

- Overrepresentation of low and high degree nodes
 - Require truncated $P(k)$
- Distribution as expected
- Average degree same, distribution different in GNM vs. Actual
- Many local/regional airports, few hubs



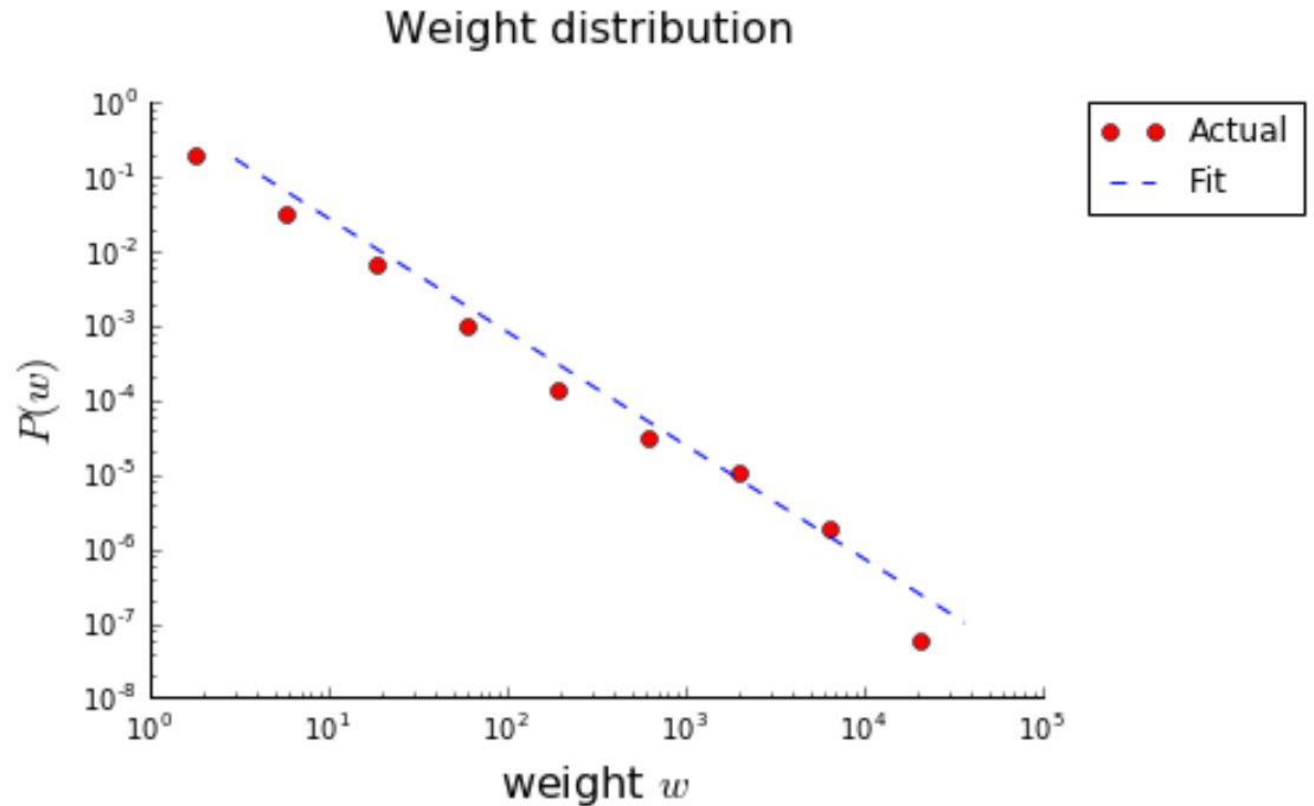
Clustering



- Average clustering: Actual = 0.67, GNM = 0.06
- Actual: Expected $C \sim k^{-1}$ ✓
- GNM: $\langle k \rangle / N = 0.06$ ✓
- High degree nodes have small C because they connect to different communities
- Small degree nodes have high C because they reside in dense communities

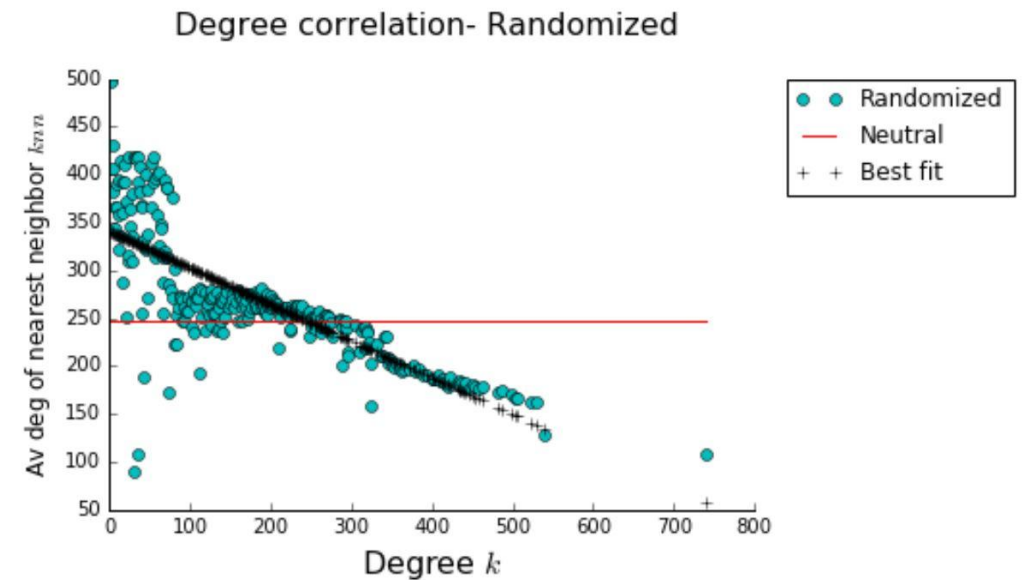
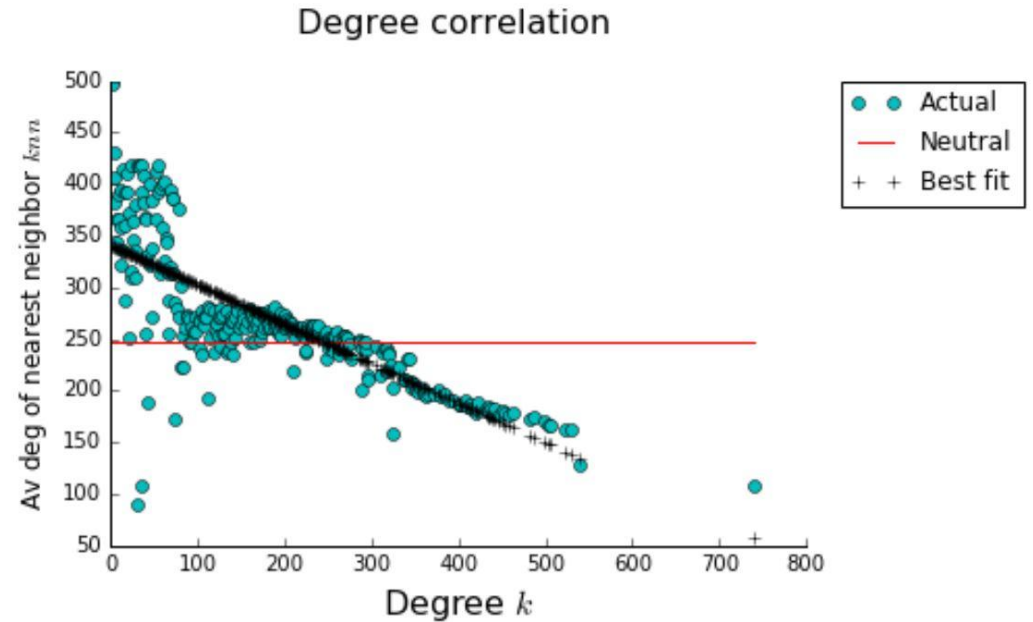
Weight Distribution

- Probability distribution of weights
- Power law behavior Few links with high weight
- Most nodes have low weights, therefore few flights
- Data includes commercial and charter flights

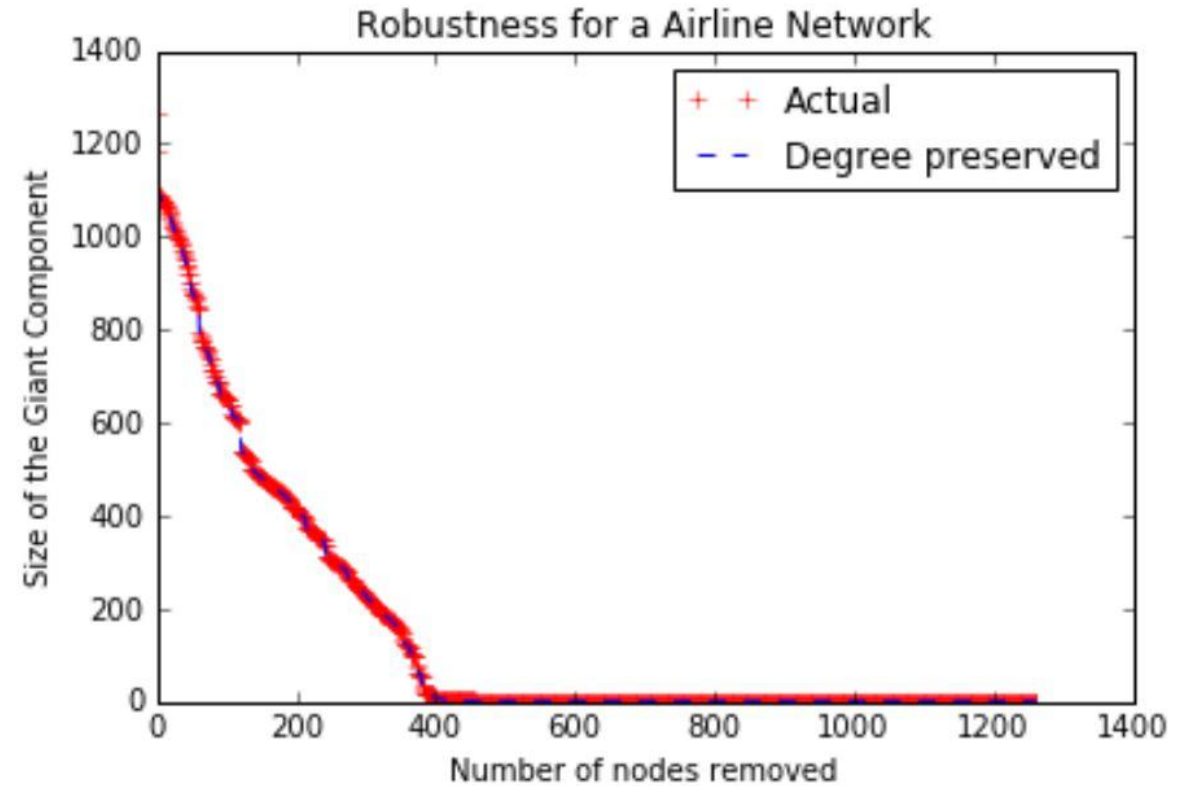
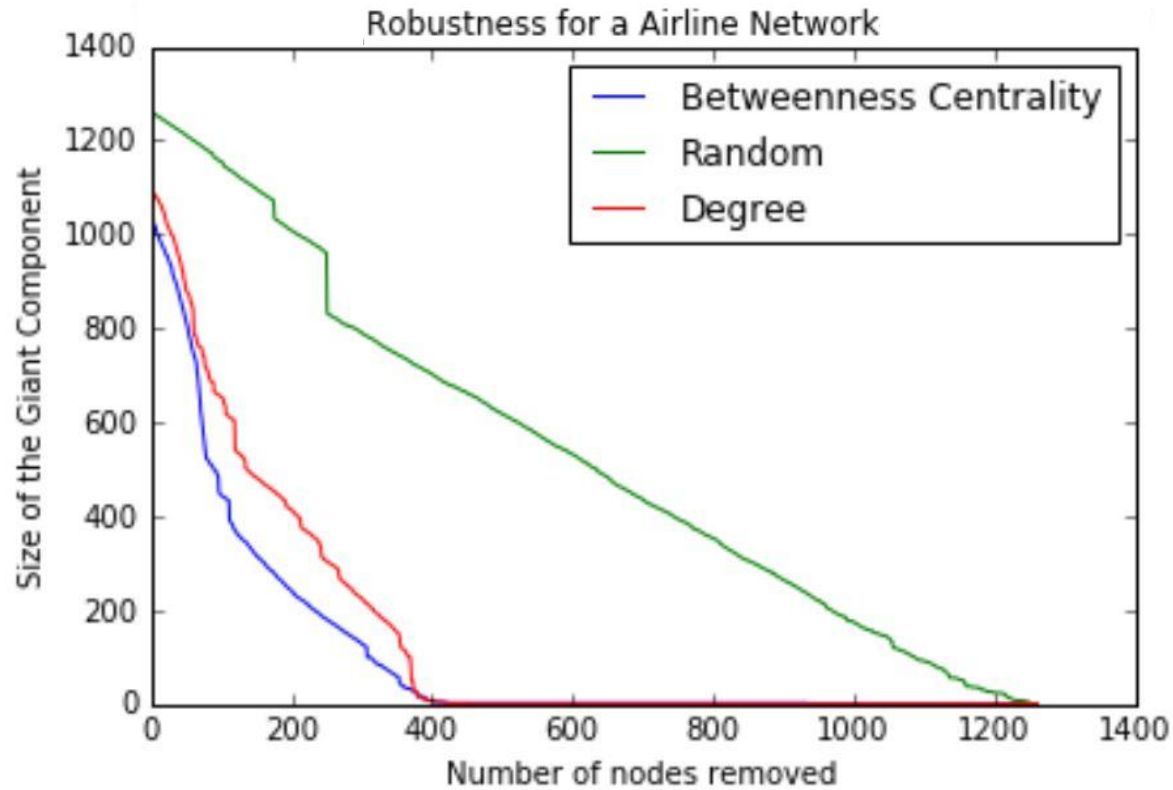


Degree Correlation

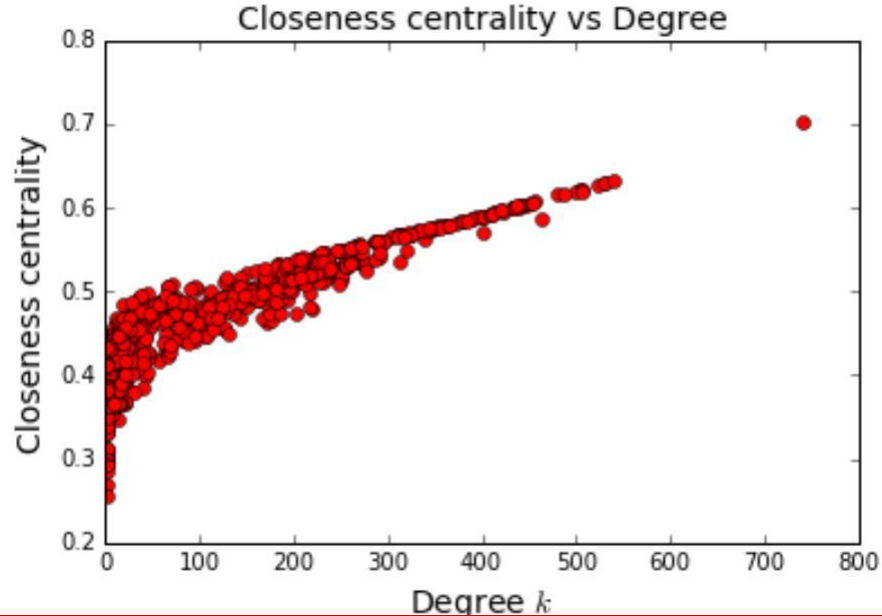
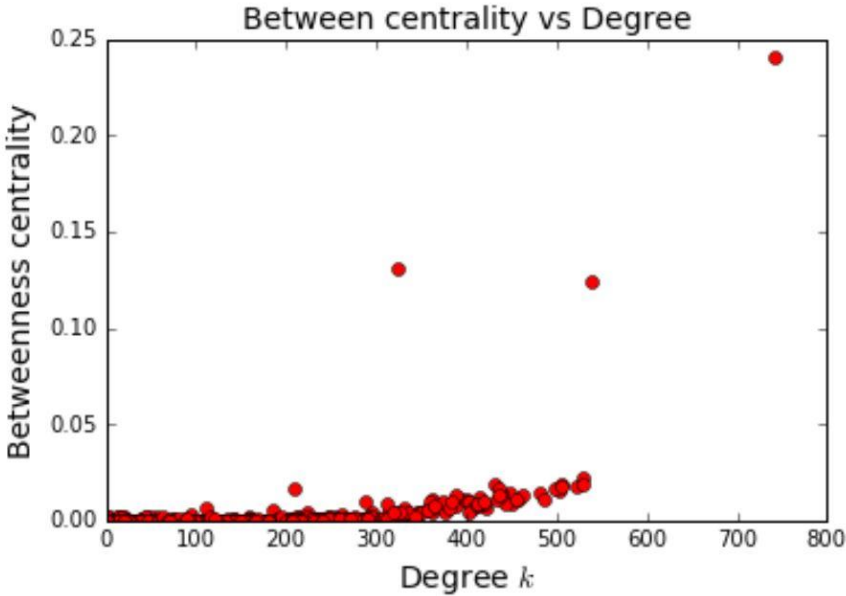
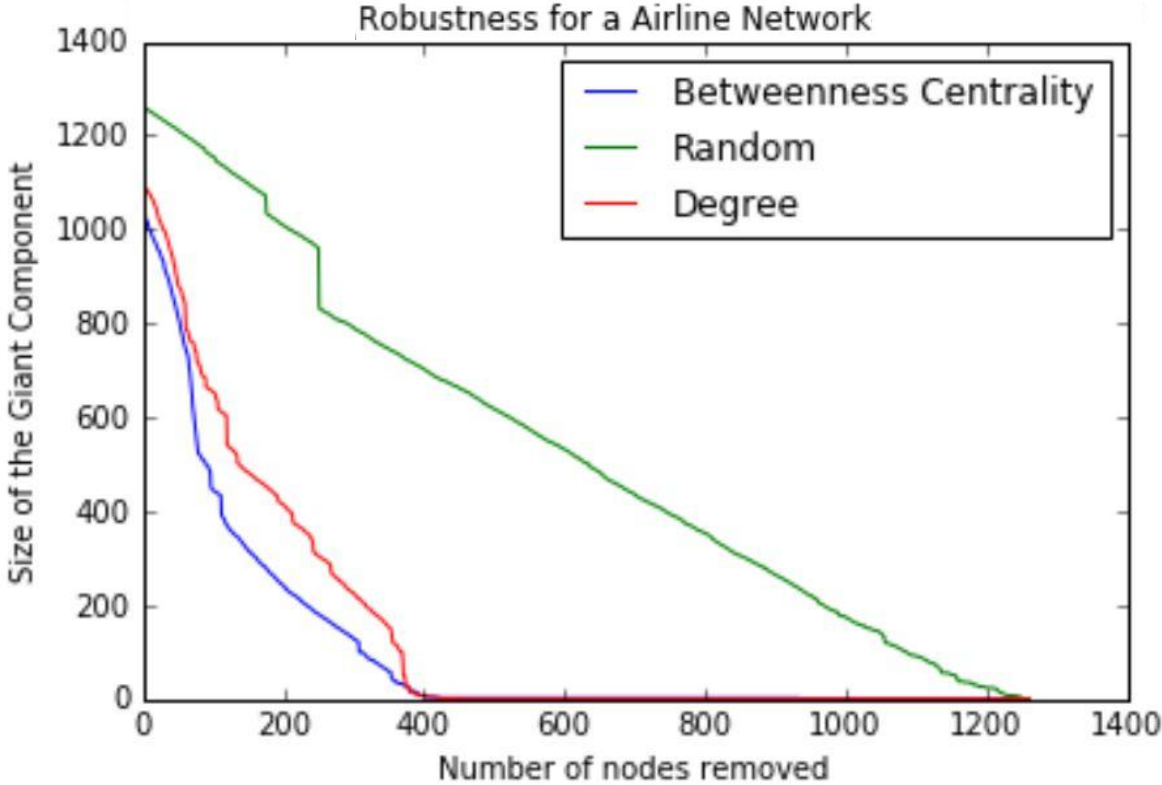
- Network is disassortative
 - Structural
- Degree correlation coefficient (r) = -0.36
- $k_s(N) = (\langle k \rangle N)^{1/2} = 307.7$
- Neutral network $k_{nn} = \frac{\langle k^2 \rangle}{\langle k \rangle} = 247.4$
- Small airports generally connect to hubs



Robustness Analysis



Robustness Analysis



Robustness Analysis

- Random: $f_c = 0.99$
- Attack: $f_c = 0.32$
 - Degree and betweenness centrality
- Expected: Targeted attack looks the same for actual network and degree-preserving randomization network ✓
- GNM shows attacks and random failures have similar behavior
- GNM not as vulnerable to targeted attacks
- Betweenness centrality target and degree target look very similar

Conclusions

- Degree distribution is heavy tailed, not perfect powerlaw
 - Airports build hubs to reduce stops between airports
 - Hierarchical qualities: regional clustering
- Network is disassortative: regional and local airports connect to hubs
 - Structure of network accounts for disassortativity, can do further analysis
 - Communities developed based on geographic regions
- Hubs make network susceptible to attack, robust to random failure
 - Sabotage/Terror vs. Natural/Accidental