Analysis of Internet Topologies: A Historical View

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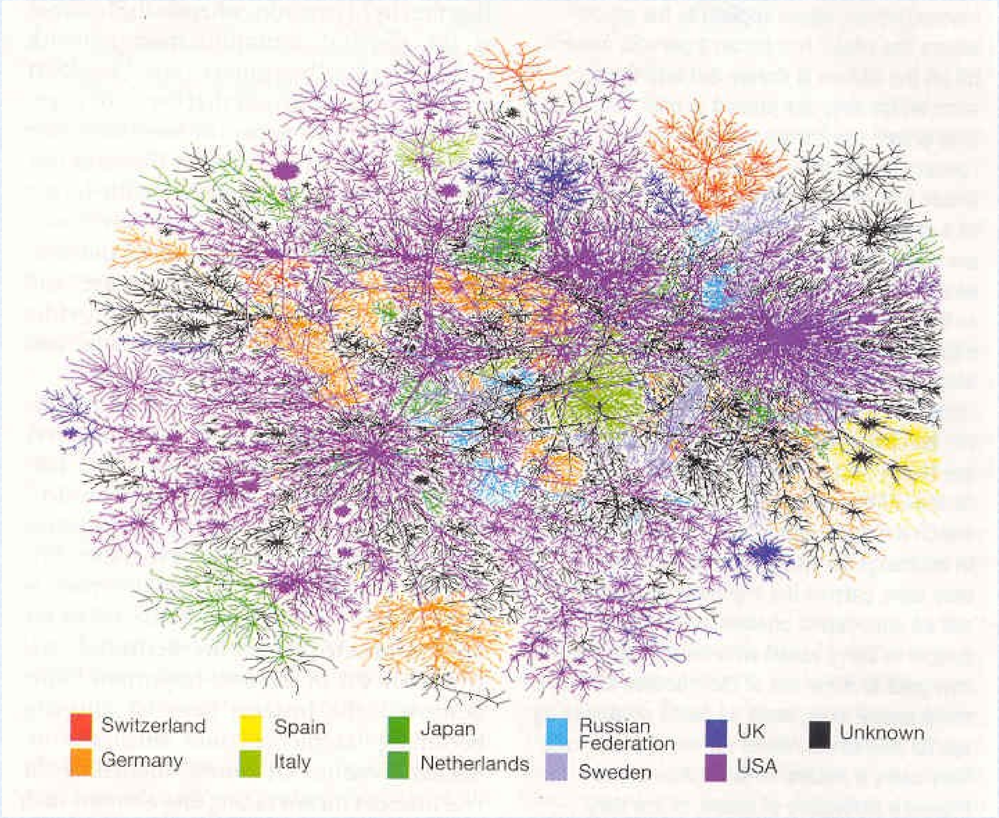
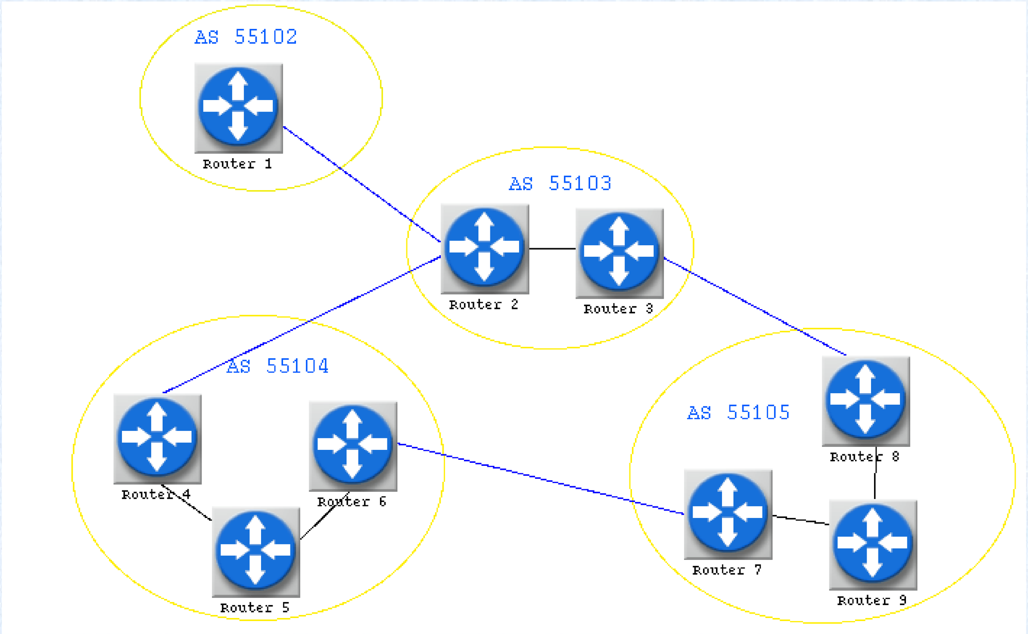
Introduction:

- Analyzing the Internet topology and finding properties of associated graphs rely on mining data and capturing information about Autonomous Systems (ASes).
- We examine datasets from the Route Views project at the University of Oregon.
- These datasets are collected from Border Gateway Protocols (BGP) routing tables from multiple geographically distributed BGP Cisco routers and Zebra servers.



Internet is a complex network.

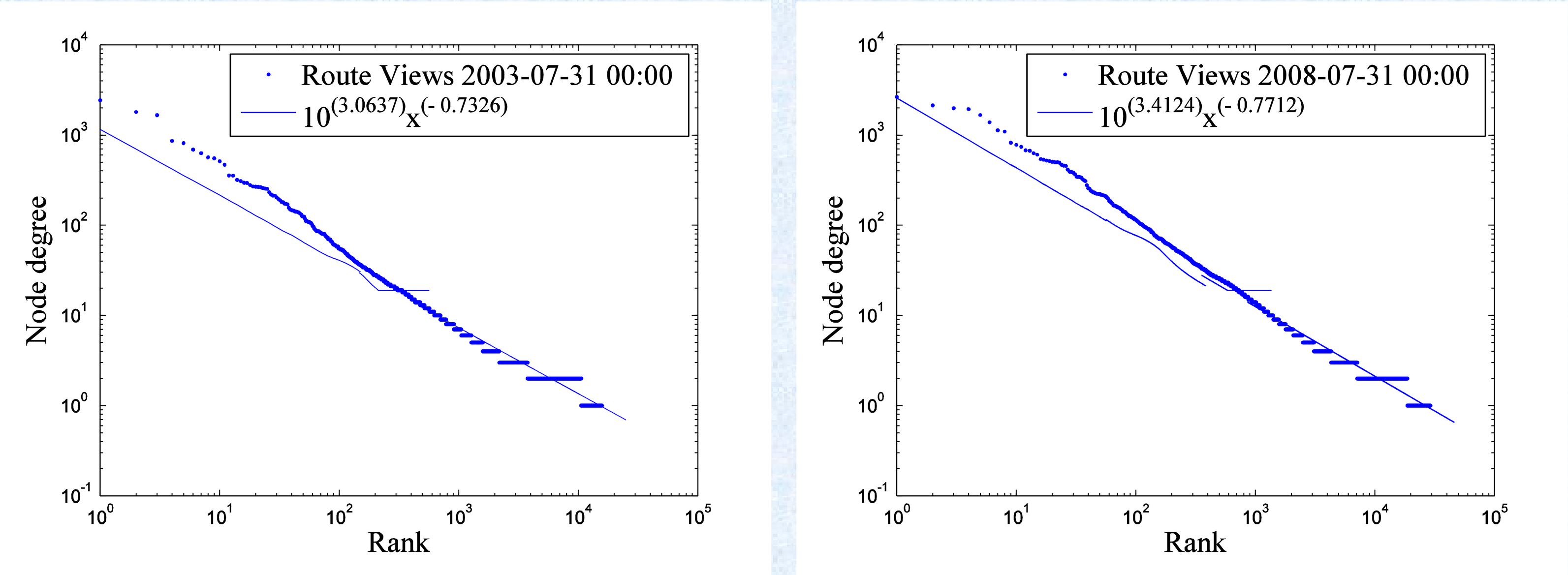
- Calculated and plotted on a log-log scale are: node degree vs. rank, frequency of node degree vs. node degree, and eigenvalues vs. index.
- A high correlation coefficient between the regression line and the plotted data indicates the existence of a power-law.
- The power-law exponents are calculated from the linear regression lines $10^{(a)}x^{(b)}$, with segment a and slope b when plotted on a log-log scale.
- We calculate the second smallest and the largest eigenvalues and associated eigenvectors of normalized Laplacian matrix for each Route Views dataset.



Autonomous Systems are connected via BGP routers.

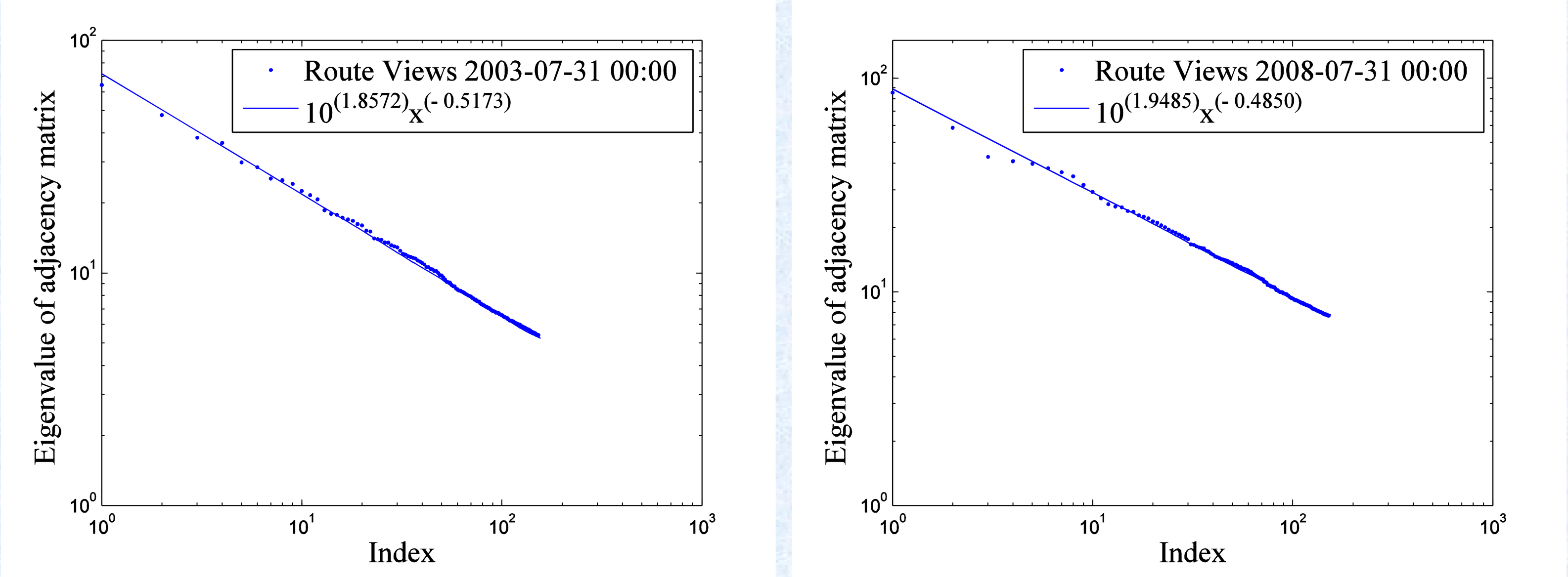
Observations:

- The power-law implies $d_v \propto r_v^R$, where v is the node number and R is the node degree power-law exponent.



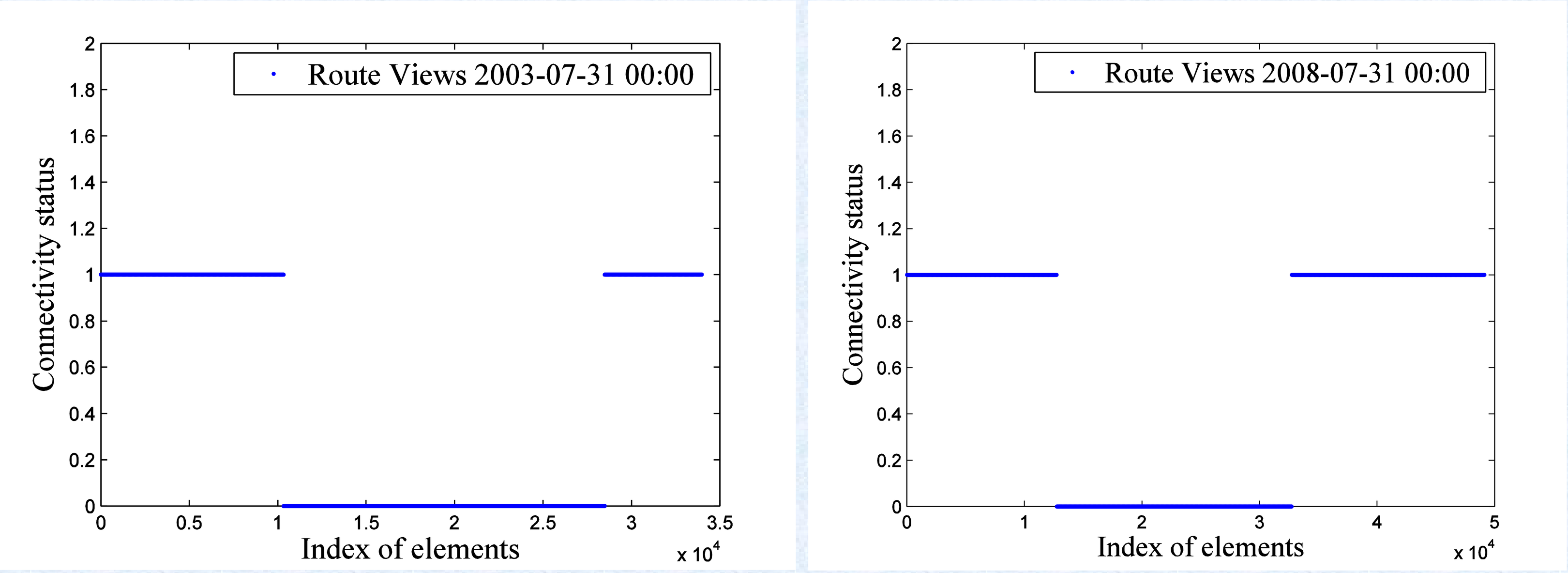
Node degree vs. rank. The correlation coefficients are 0.9661 for 2003 (left) and 0.9686 for 2008 (right) datasets.

- The power-law for the adjacency matrix implies $\lambda_i \propto i^{\varepsilon}$, where ε is the eigenvalue power-law exponent.



Eigenvalue of adjacency matrix vs. index. The correlation coefficients are 0.9990 for 2003 (left) and 0.9882 for 2008 (right) datasets.

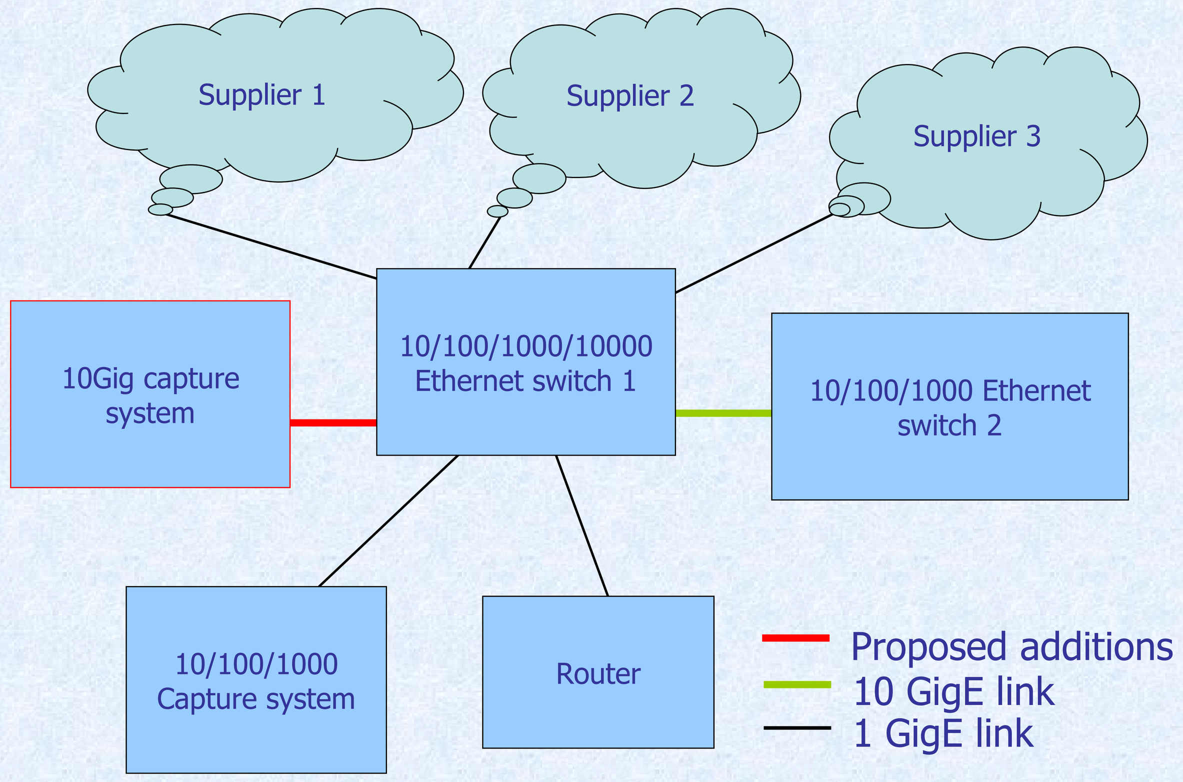
- The connectivity status is equal to 1 if the AS is connected to another AS or zero if the AS is isolated or is absent from the routing table.



Spectral views of the AS connectivity based on the largest eigenvalue. Route Views 2003 (left) and 2008 (right) datasets.

Collecting traffic from BC.NET:

- Collected data are used to characterize, model, and analyze network traffic and identify self-similarity.
- BGP routing tables provide insight into the behavior of the Internet routing protocols.
- Measurements from a deployed network help understand dynamical behavior of the network viewed as a complex system.



BC.NET client diagram.

Conclusions:

- The analysis captured historical trends in the development of the Internet topology over the past five years.
- We confirmed the presence of power-laws in graphs capturing the AS-level Internet topology.
- Various power-law exponents have remained similar in spite of the Internet growth, increasing number of users, and the deployment of new network elements.
- The power-laws do not capture every property of a graph and are only one measure used to characterize the Internet.
- Spectral analysis based on the normalized Laplacian matrix indicated visible changes in the clustering of AS nodes and the AS connectivity.

References:

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