Network Topology

Julian Shun

On Power-Law Relationships of the Internet Topology (Faloutsos 1999)

- Observes that Internet graphs can be described by "power laws" ($P[X > x] = k^a x^{-a} L(x)$)
- Introduces power-law exponents to characterize Internet graphs
- Comments
  - Limited data
    - Especially linear fit to measure hop-plot exponents (Fig. 7 and 8)
  - How well have power laws held up since 1999?
  - Explanatory power of power-law exponents?
  - Other metrics?

Data

- Power Laws and the AS-Level Internet Topology (Siganos, Faloutsos, 2003)
  - Use much more data, obtained from Route Views
  - Shows that power laws continue to hold for AS topology over 5 year interval
  - Variation of power-law exponents less than 10%

5-year intervals of exponents

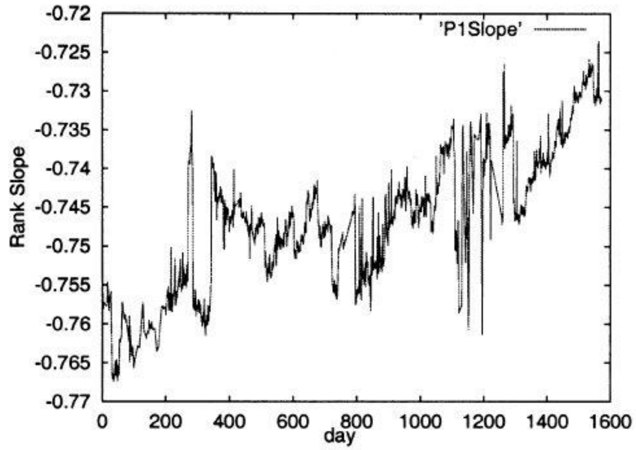


Fig. 8. Evolution of the slope of the rank exponent.

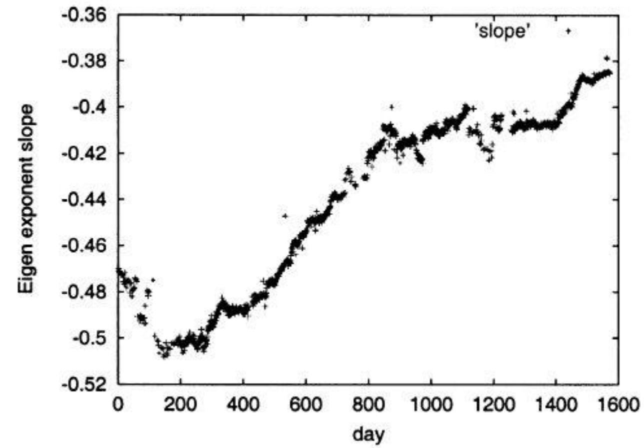


Fig. 10. Evolution of the slope of the eigen exponent.

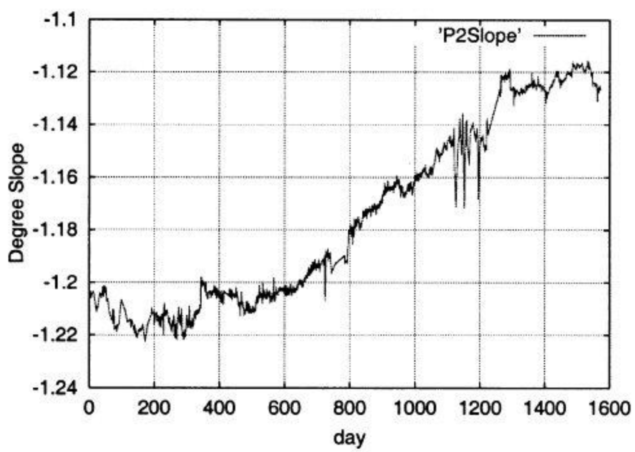


Fig. 9. Evolution of the slope of the degree exponent.

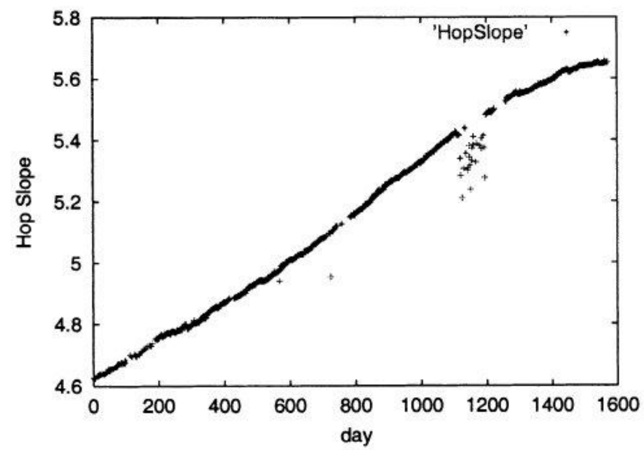


Fig. 11. Evolution of the slope of the hop-plot exponent.

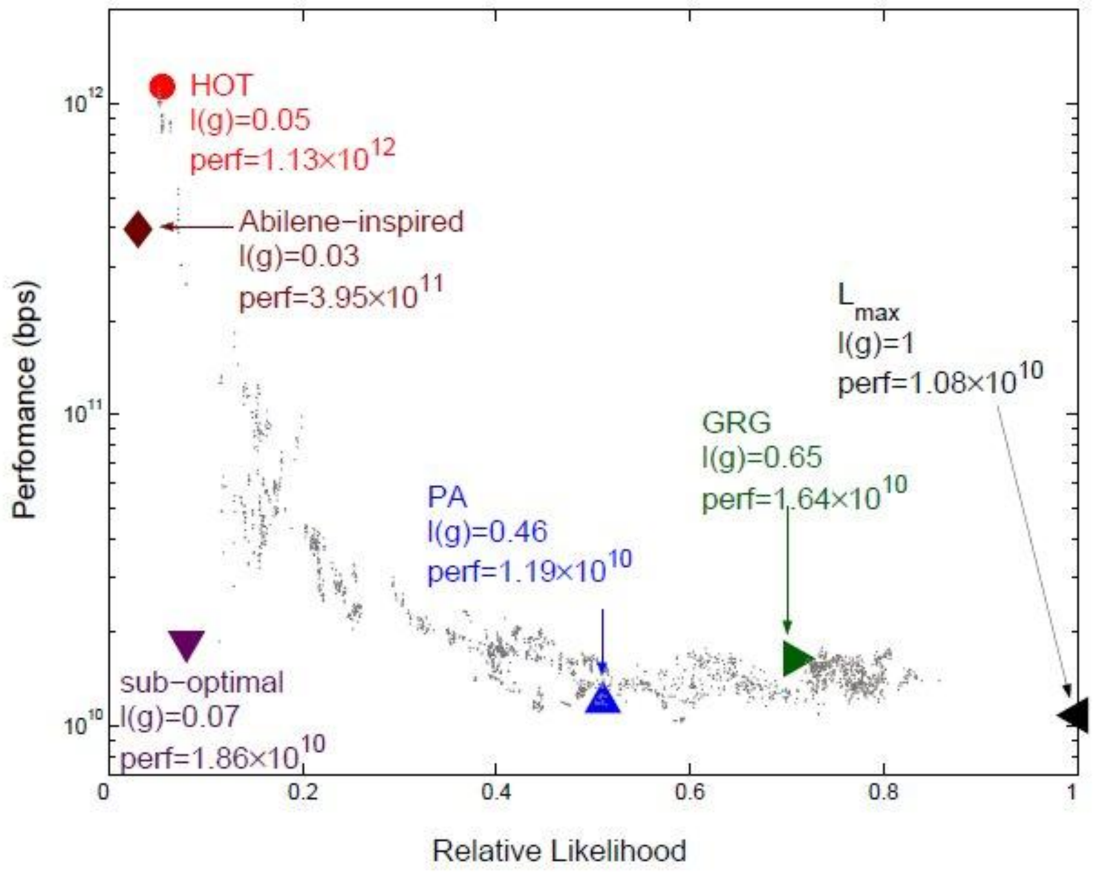
Data

- Measuring ISP Topologies with Rocketfuel (Spring, Mahajan and Wetherall, 2002)
  – Obtains much more router-level data, and show that the topologies mostly obey a power law
- Faloutsos' 1999 paper won "Test of Time" award at SIGCOMM 2010

A First-Principles Approach to Understanding the Internet's Router-level Topology (Li et.al. 2004)

- Argues that previous metrics do not accurately model real Internet graphs
- Introduces metrics based on first principles, such as throughput, router utilization, end user bandwidth distribution, likelihood metric
- Comments
  - Does not use real Internet data in evaluation
  - Does not incorporate robustness into model
  - Applicable to AS-level topology?
  - Other metrics?

Data



HOT
l(g)=0.05
perf=1.13×10^12
Abilene−inspired
l(g)=0.03
perf=3.95×10^11
L max
l(g)=1
perf=1.08×10^10
GRG
l(g)=0.65
perf=1.64×10^10
PA
l(g)=0.46
perf=1.19×10^10
sub−optimal
l(g)=0.07
perf=1.86×10^10
Perfomance (bps)
Relative Likelihood
10^12
10^11
10^10
0
0.2
0.4
0.6
0.8
1

Applicability to AS-level topology

- Too many factors, such as political and economical ones, to consider
- AS graph, Web graph, P2P networks left for future work

Other metrics

- *Distance distribution d(x)* – the number of pairs of nodes distance x, divided by the total number of pairs (Shenker et.al. 2002)
- *Betweenness* – weighted sum of # of shortest paths passing through a node or link (related to *router utilization*) (HOT paper and Shenker et.al. 2002)
- *Clustering C(k)* – how close neighbors of the average k-degree node are to forming a clique (Bu and Towsley 2002)
- *dK-distribution* – describes the correlation of degrees of d connected nodes (Vahdat et. Al. 2006)

Why is this important?

- Gain more insight into structure of Internet
- Create graph generators that produce “Internet-like” graphs for testing
- Open question: How can we model the time evolution of Internet graphs?