Resilience Measurements on Internet Topology Generators

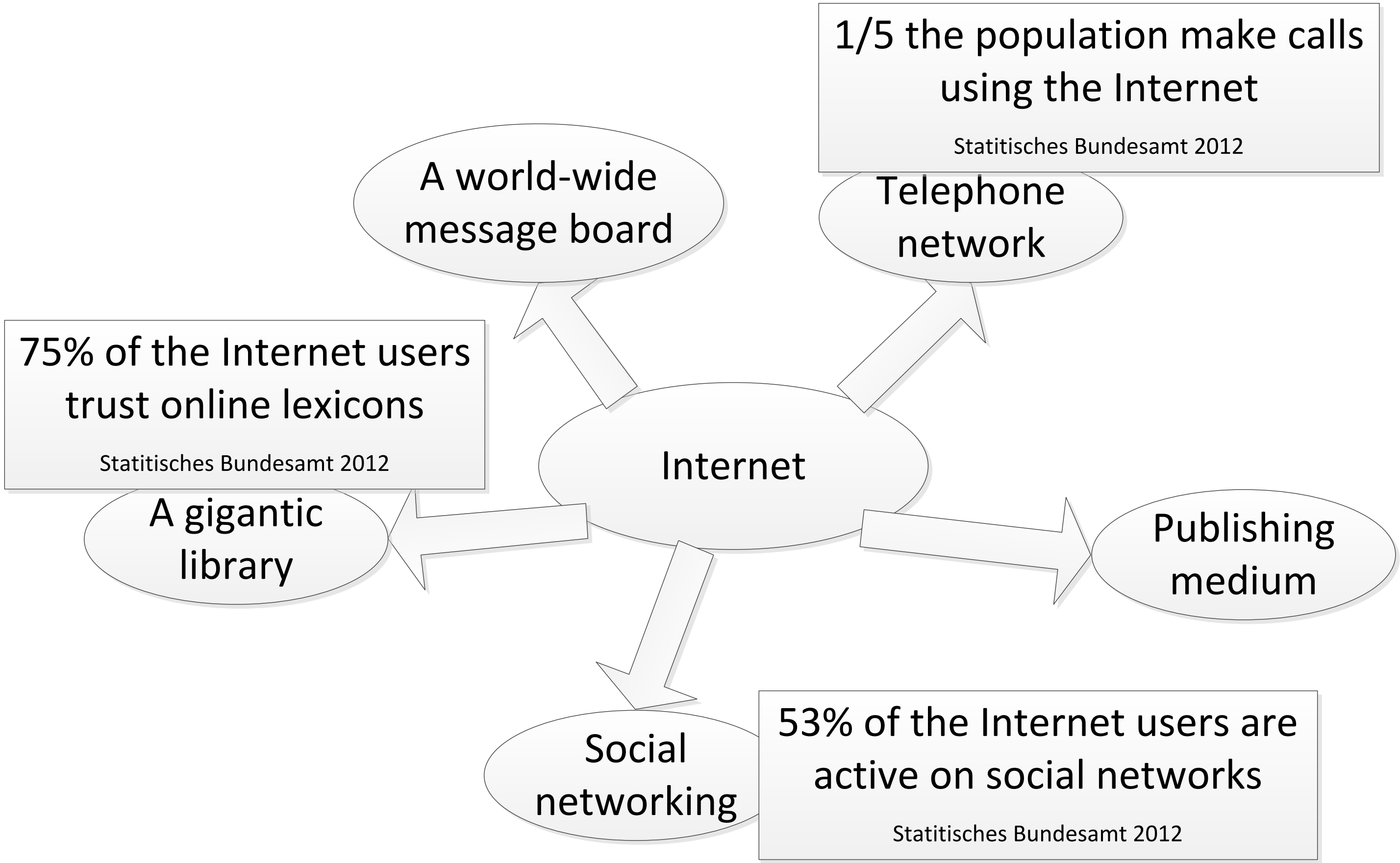
Bachelor-Thesis by Nam Truong Le

September 15th, 2012

Outline

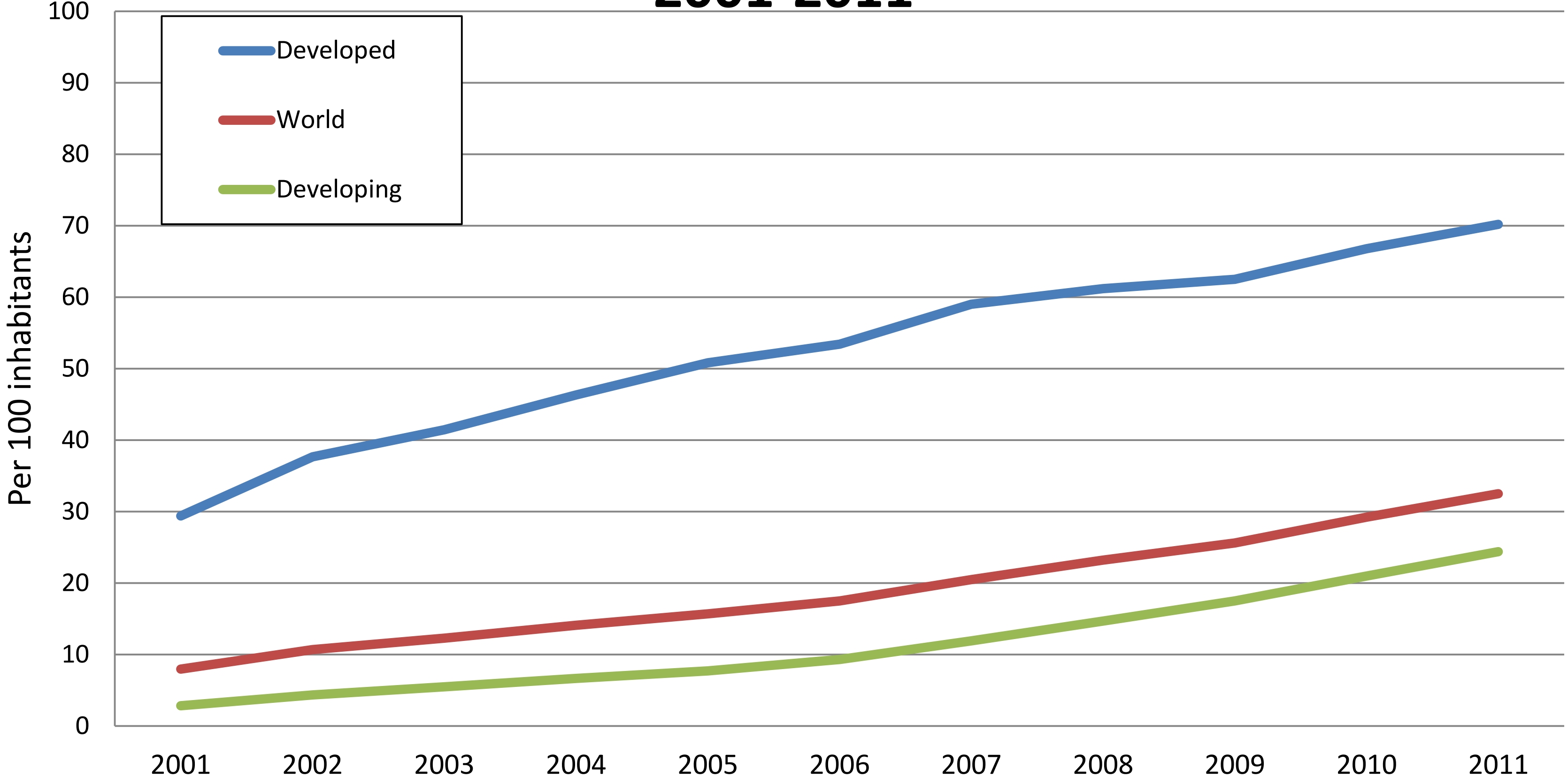
1. Motivation
2. Background
3. Evaluation
4. Results
5. Summary – Conclusion – Outlook

1. Motivation



1. Motivation

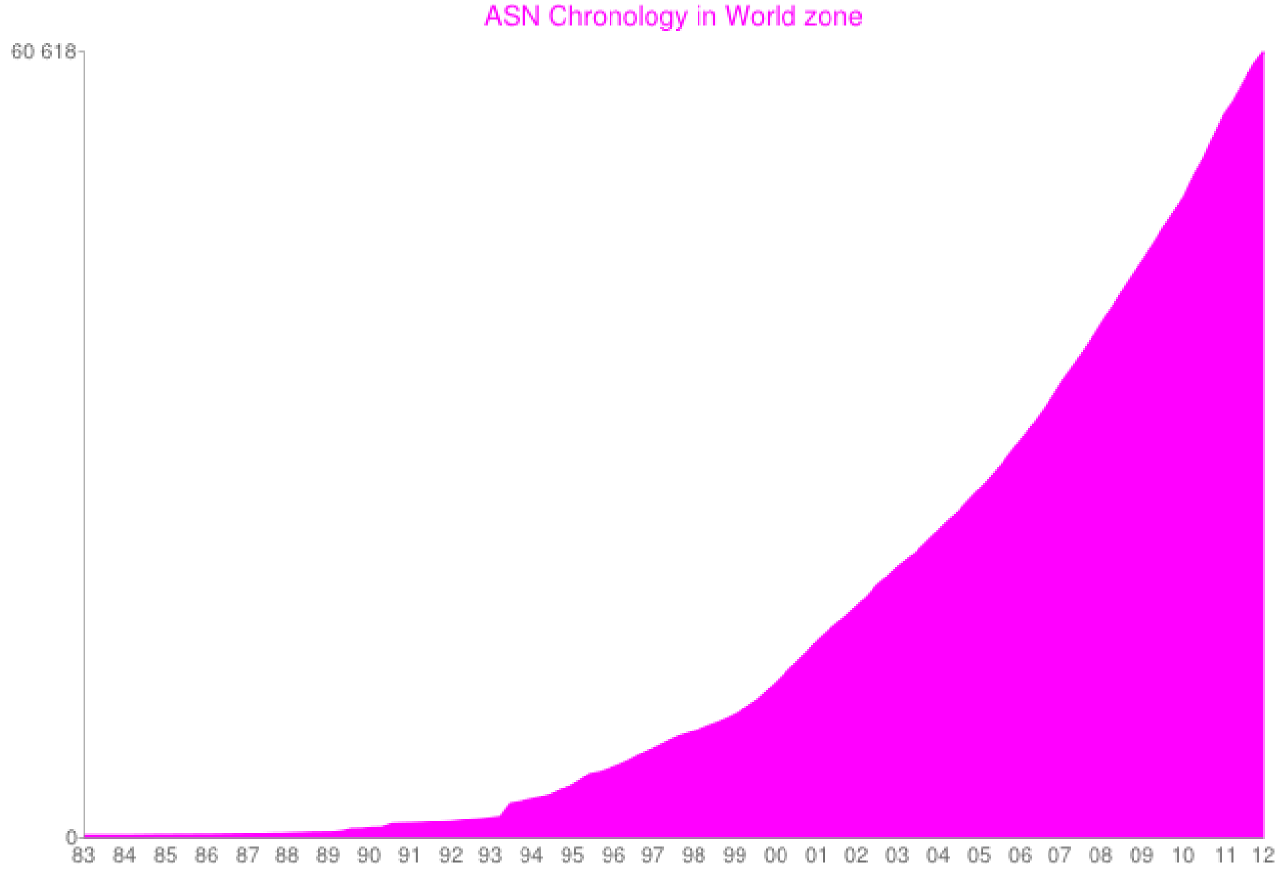
Individuals using the Internet per 100 inhabitants, 2001-2011



The developed/developing country classifications are based on the UN M49, see: http://www.itu.int/ITU-D/ict/definitions/regions/index.html

Source: ITU World Telecommunication /ICT Indicators database

1. Motivation



Data from RIR websites as of: Sun Oct 07 2012
http://www-public.it-sudparis.eu

1. Motivation

- We must increase the resilience of the Internet.
- How do we define the resilience?
- How do we measure it?

2. Background – Resilience Metrics

- Partition Based Metrics
  - The largest component
  - The largest bicomponent
- Path Length Based Metrics
  - The diameter
  - The average shortest path length
  - The effective diameter

2. Background – Resilience Metrics

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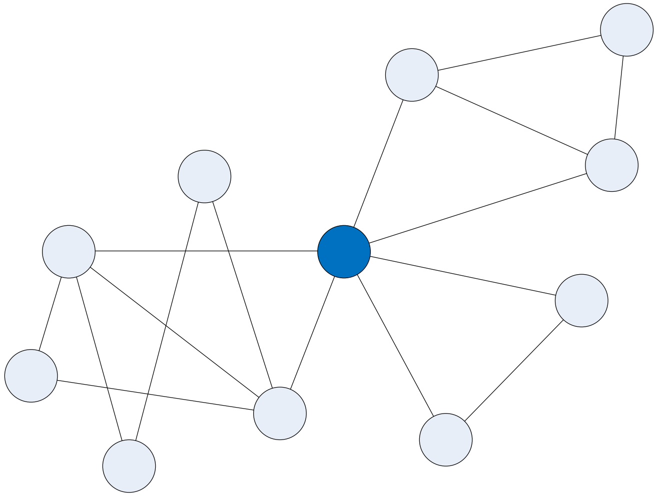

2. Background – Resilience Metrics

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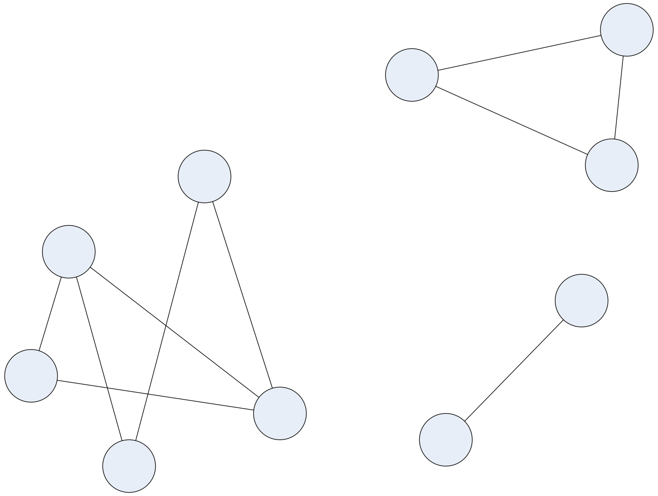

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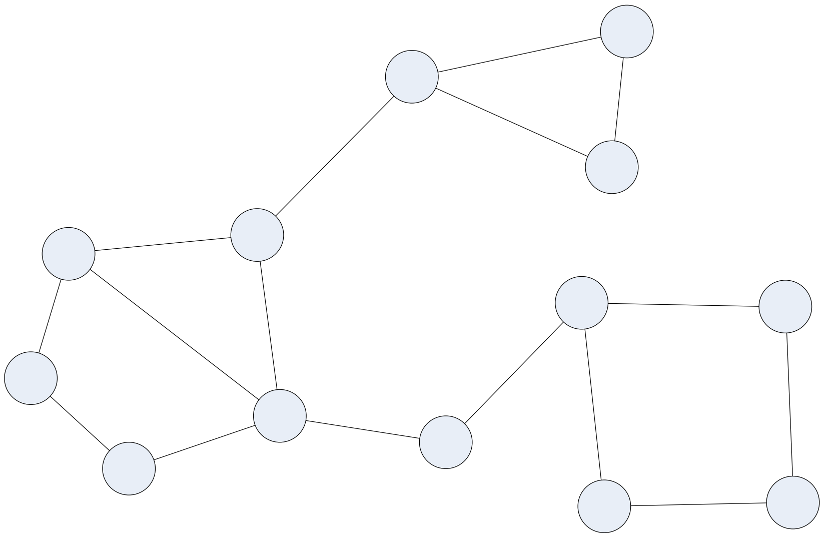

A component is called biconnected if there are at least two independent paths between each two nodes [1]

2. Background – Resilience Metrics

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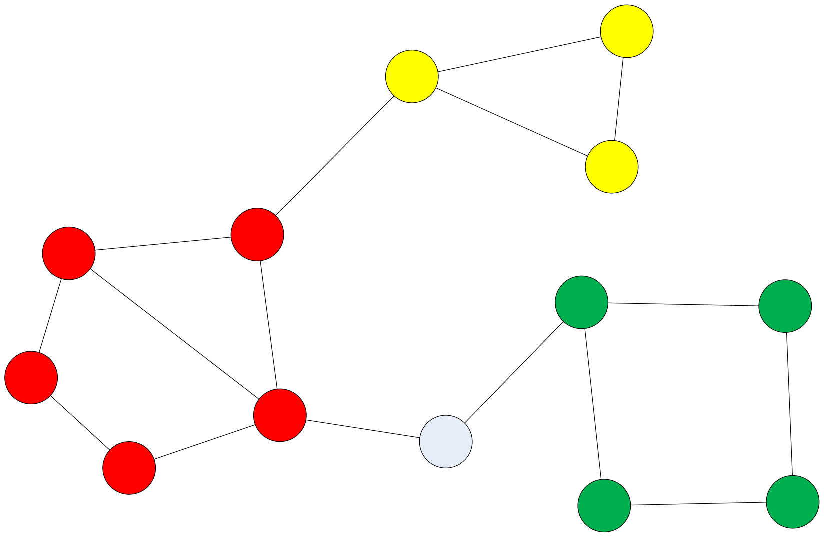

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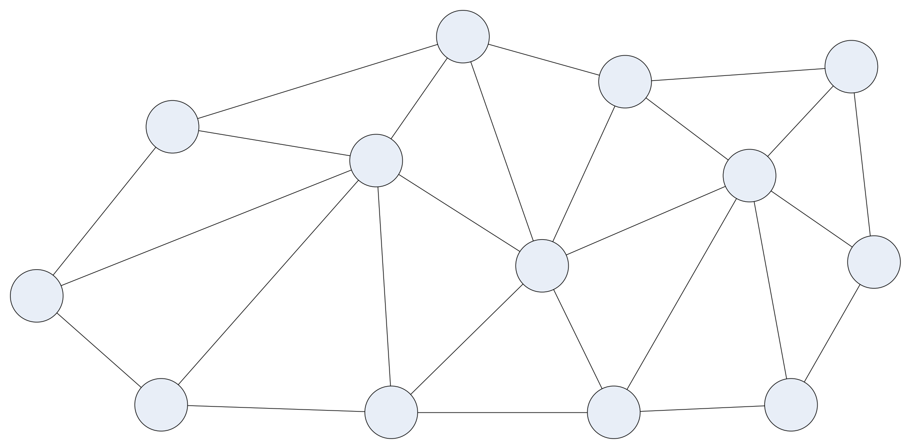


Diameter = 4

ASPL = 2.05

Effective Diameter = 3

2. Background – Internet Topology Models

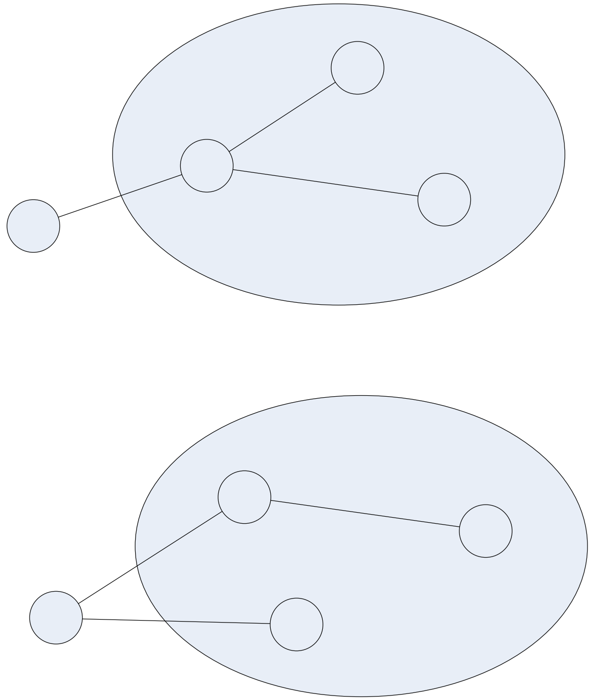
- Barabasi Albert Model
- Interactive Growth Model
- Positive-Feedback Preference Model
- Generalized Linear Preference Model

2. Background – Internet Topology Models

- Barabasi Albert Model
  - The new node is connected with k old nodes.
  - Linear preference: $\Gamma(u) = \frac{d(u)}{\sum_v d(v)}$
- Interactive Growth Model
- Positive-Feedback Preference Model
- Generalized Linear Preference Model

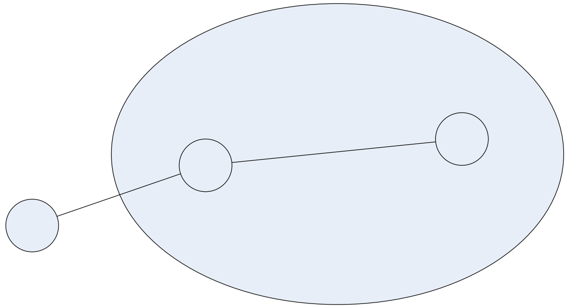
2. Background – Internet Topology Models

- Barabasi Albert Model
- Interactive Growth Model
  - Strategy 1: one host, two peers
  - Strategy 2: two hosts, one peers
  - Linear preference $\Gamma(u) = \frac{d(u)}{\sum_v d(v)}$
- Positive-Feedback Preference Model
- Generalized Linear Preference Model



2. Background – Internet Topology Models

- Barabasi Albert Model
- Interactive Growth Model
- Positive-Feedback Preference Model
  - Take two strategies from Interactive Growth Model
  - One new strategy: one host, one peer
  - Nonlinear preference: $\Gamma(u) = \frac{d(u)^{1+\delta \log_{10} d(u)}}{\sum d(v)^{1+\delta \log_{10} d(v)}}$
- Generalized Linear Preference Model



2. Background – Internet Topology Models

- Barabasi Albert Model
- Interactive Growth Model
- Positive-Feedback Preference Model
- Generalized Linear Preference Model
  - Strategies 1: add m new edges
  - Strategies 2: add one new node and m new edges from this new node to the other nodes
  - Nonlinear preference: $\Gamma(u) = \frac{d(u)-\beta}{\sum(d(v)-\beta)}$

2. Background – Internet Topology Models

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	Scale free	Rich-club connectivity	Characteristic path length	Clustering coefficient
BA	X			
IG	X	X		
PFP	X	X	X	√
GLP	X	√	X	X

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2. Background – Attack Strategies & Failure Scenarios

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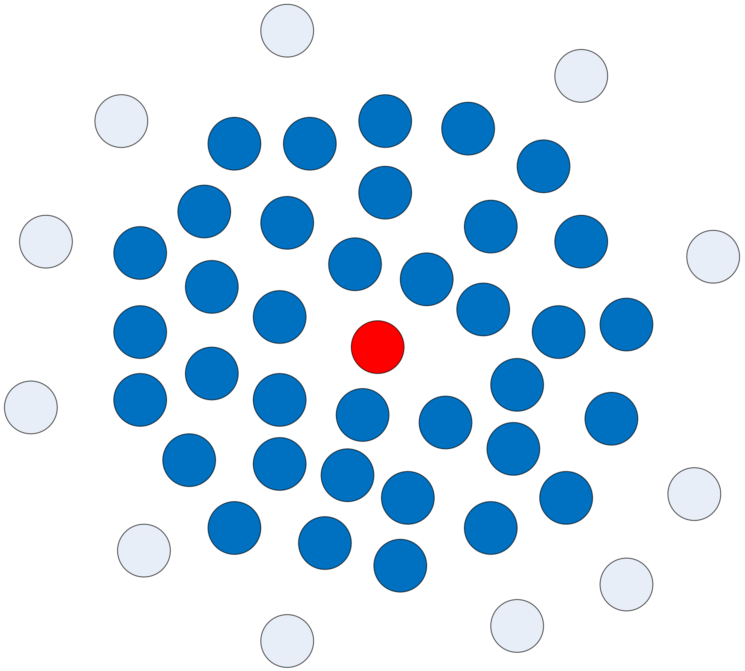
- Random
- Degree
- Closeness Centrality
- Betweenness Centrality
- Eigenvector Centrality
- Effective Eccentricity

2. Background – Attack Strategies & Failure Scenarios

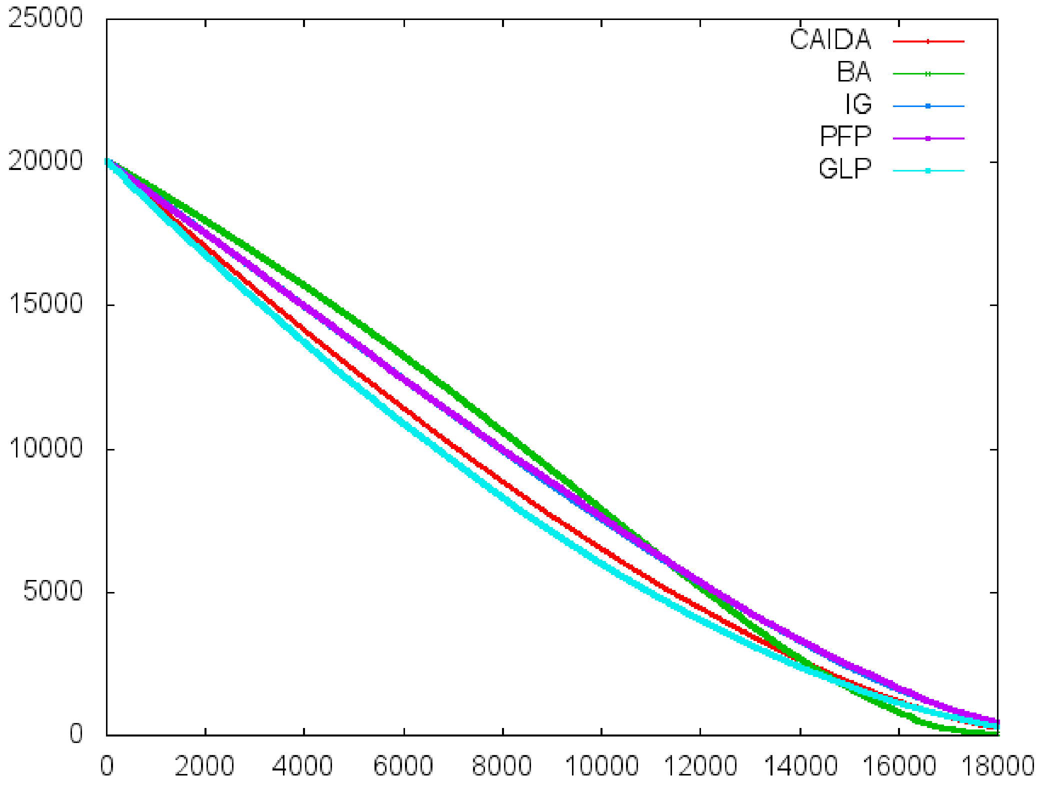
- Random
- Degree
- Closeness Centrality
- Betweenness Centrality
- Eigenvector Centrality
- Effective Eccentricity
  - ➢ Within this distance a node can get 90% number of nodes



3. Evaluation – Setup

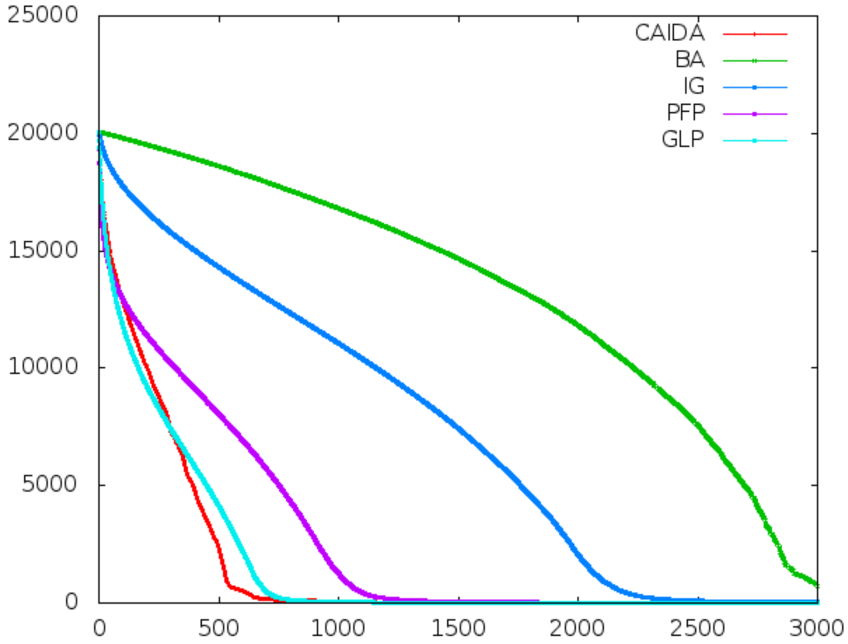
- Measuring topology properties and behaviors against attacks & failures (with respect to various type of metric)
- Internet topology vs. network models

3. Evaluation
Largest component & random removal

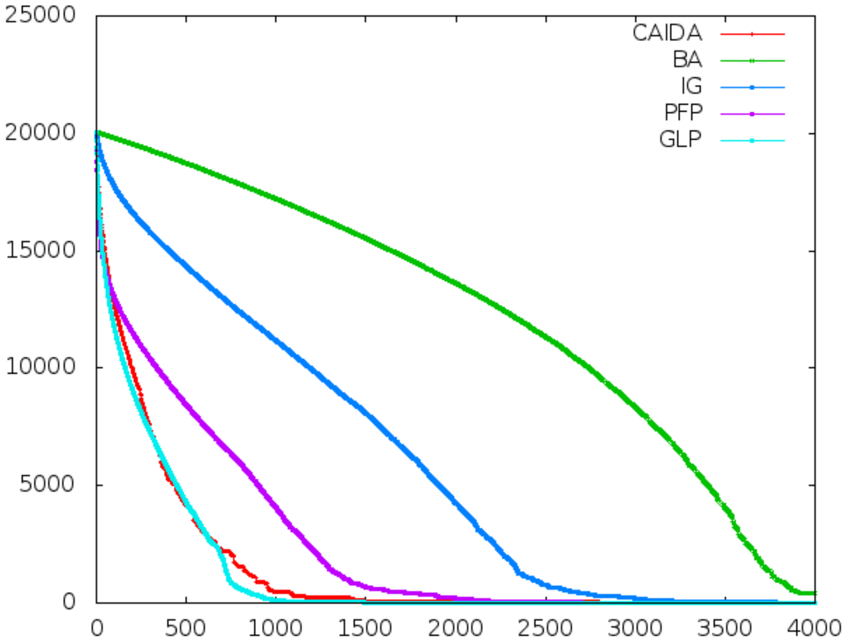


3. Evaluation
Largest component & removal by degree and betweenness

Degree

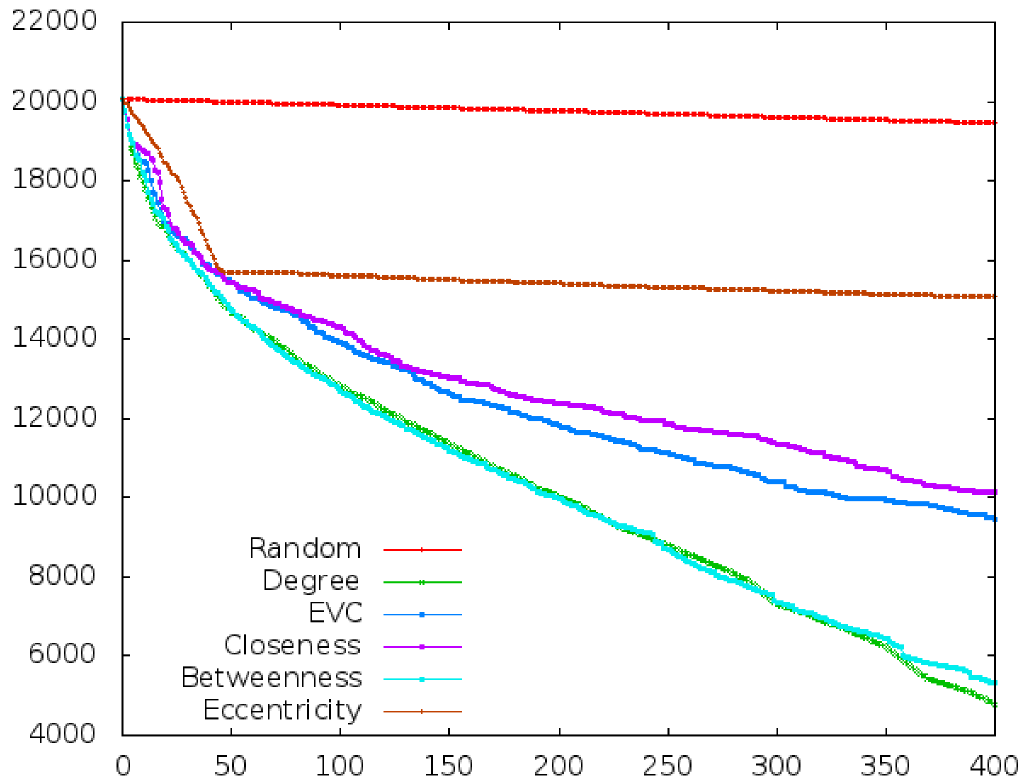


Betweenness



3. Evaluation
Largest component & all types of attack

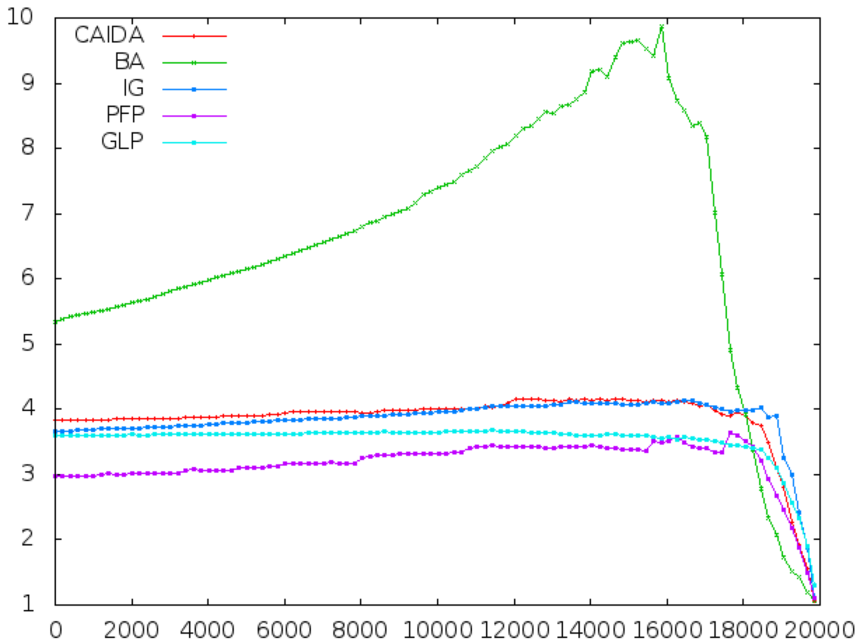
Internet topology

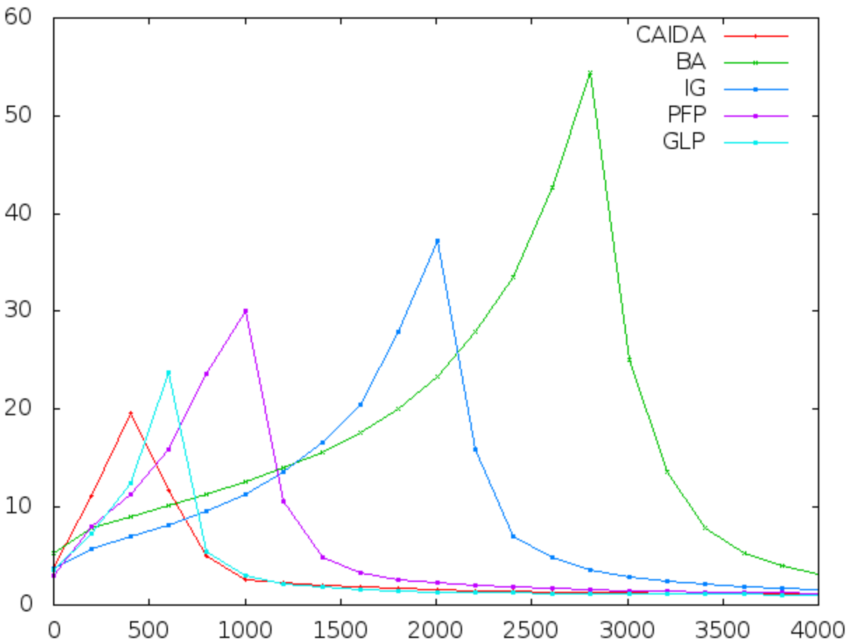


3. Evaluation
ASPL & removal by degree and random

Random

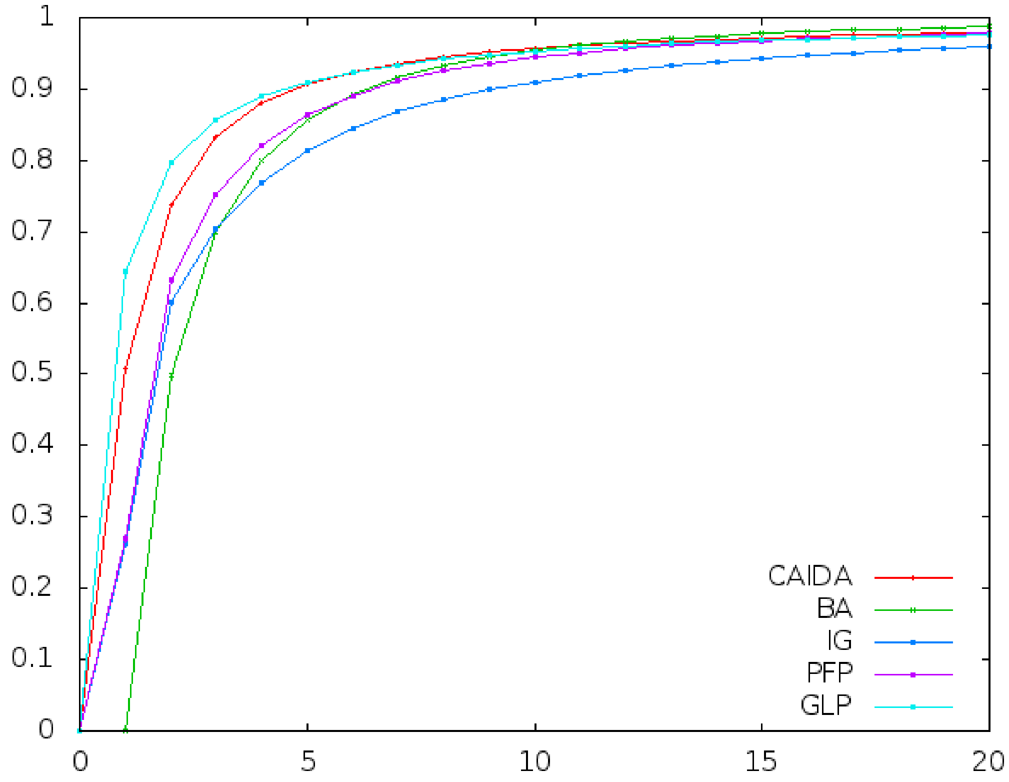
Degree





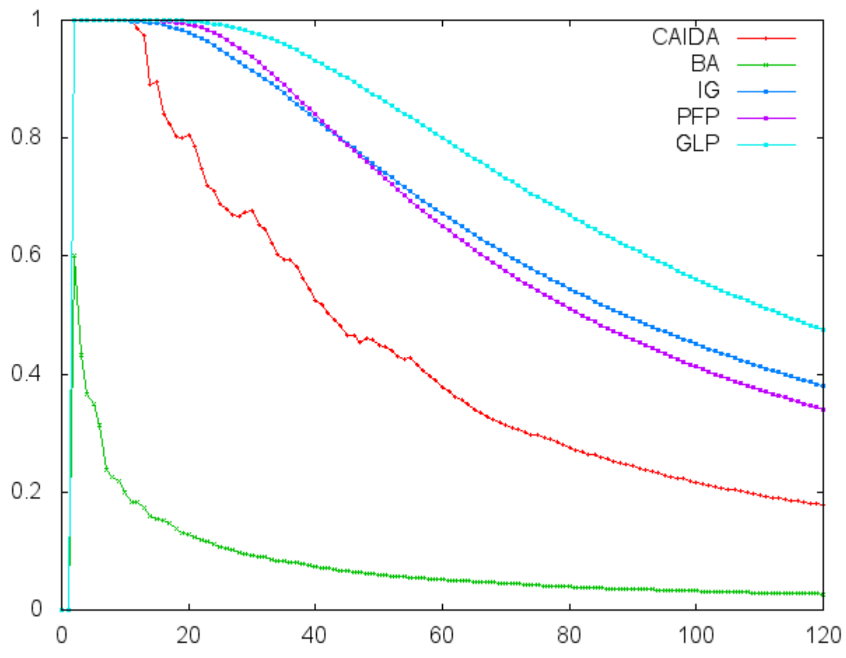
3. Evaluation
ASPL & removal by degree and random

Degree Distribution

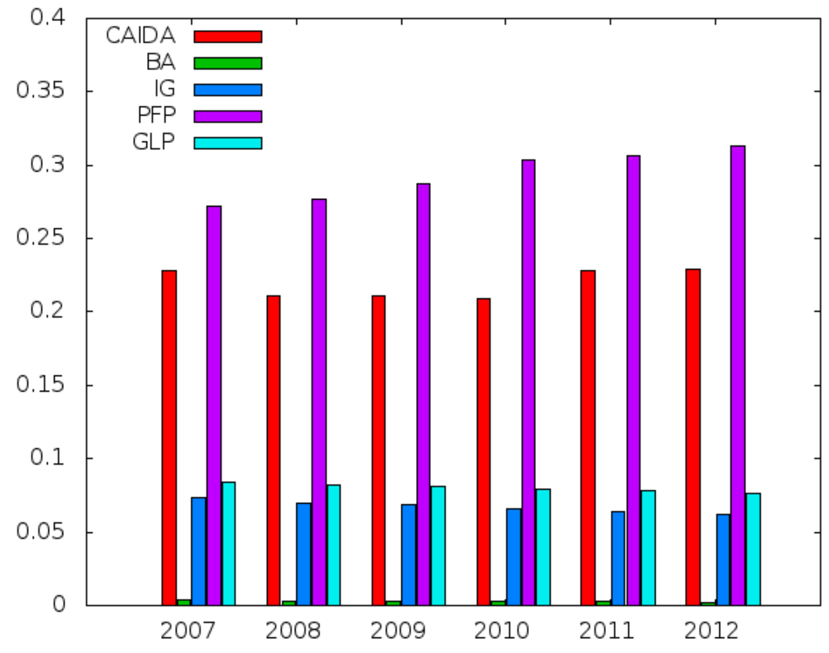


3. Evaluation
Richclub Connectivity & Clustering Coefficient

Richclub Connectivity



Clustering Coefficient



4. Results – Summary

- Internet is resistant against random and sensitive against intentional attacks
- BA is the most resistant
- Attacks by degree and betweenness are very efficient
- PFP and GLP are good in approximation the Internet
- The largest component and the largest bicomponent have the same properties
- The diameter, ASPL and the effective diameter show the same information

5. Outlook

In the Future:

- Recalculate the sorting after each removal
- Use other strategies than random when choosing nodes with the same centrality points

References

- [1] M. E. J. Newman and G. Ghoshal. *Bicomponents and the robustness of network to failure*. Phys. Rev. Lett., Mar 2008.
- [2] C. R. Palmer, G. Siganos, M. Faloutsos, and C. Faloutsos. *The connectivity and fault-tolerance of the internet topology*. In Workshop on Network-Related Data Management (NRDM 2001), 2001.
- [3] R. Cohen, K. Erez, D. ben Avraham, and S. Havlin. *Resilience of the internet to random breakdowns*. Phys. Rev. Lett., Nov 2000.

References

- [4] R. Cohen, K. Erez, D. ben Avraham, and S. Havlin. *Breakdown of the internet under intentional attack*. Phys. Rev. Lett., Apr 2001.