

OSAKA UNIVERSITY

Toward Bio-Inspired Network Robustness

Step 1. Modularity

Copyright © 2007 OSAKA UNIVERSITY. All rights reserved.

Presented by Dr. Suyong Eum
Co-authors : Dr. Shin'ichi Arakawa & Prof. Masayuki Murata

1 Bionetics' 07 Conference – Hungary Budapest 2007

Presentation Outline

1. INTRODUCTION
2. MODULARITY
3. RESULTS
4. CONCLUSIONS

C

ONTENTS

2 Bionetics' 07 Conference – Hungary Budapest 2007

1. INTRODUCTION: Why is Bio system robust ?

The capability of a system to withstand external and internal perturbations
H.Kitano, "*Biological Robustness*" Nature 2004

Adaptation & Evolution

Failure of adaptation

3 Bionetics' 07 Conference – Hungary Budapest 2007

1. INTRODUCTION: Why Modularity ?

- Then, people wanted to know what has been changed in biological system during the evolution process.
- In the paper, we investigated about ROBUSTNESS from network's structure or topology point of view-> **COMPLEX NETWORKS**.
- Degree of a vertex (k):
=> Number of links that a vertex has
- Scale-free property:
=> Probability distribution of degree follows the POWER LAW

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

$\gamma_{in} = 2.1$

- People believed that the scale free property provides the robustness of biological networks. However....

4 Bionetics' 07 Conference – Hungary Budapest 2007

2. MODULARITY

- Split a network into many sub-networks based on their similarities.
- M.E.J. Newman and M. Girvan, PRE 2003.

$$Q_M = \sum_i (e_{ii} - a_i^2)$$

e_{ii} : fraction of links within module i

a_i : expected fraction of links within module i , for a random partition of the nodes

Module 1
Module 2
Module 3
Edge Links

5 Bionetics' 07 Conference – Hungary Budapest 2007

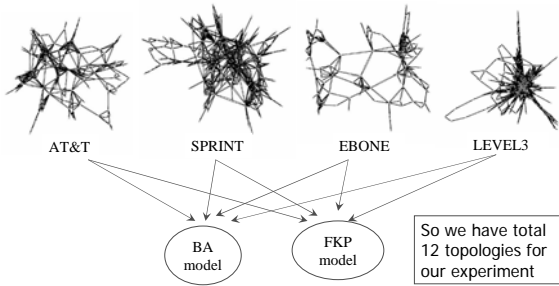
2. MODULARITY: Toy example

(a) (b)

- Both topologies have the same number of nodes and links. The only difference is the way nodes are connected.
- Which topology is more robust ?
- Intentional or Random attack? Failure cascading? Traffic dynamic?

6 Bionetics' 07 Conference – Hungary Budapest 2007

3. EXPERIMENT & RESULTS



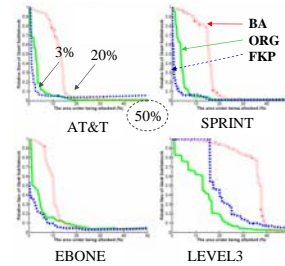
- ❖ All topologies have scale free property.
- ❖ Topologies from **BA** model have **LOW** modularity value
- ❖ Topologies from **FKP** model have **HIGH** modularity value.

7

Bionetics' 07 Conference – Hungary Budapest 2007

3. RESULTS

INTENTIONAL ATTACK



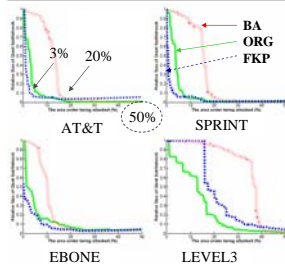
- ❖ X: How many nodes being removed (%), Y: Damage of Network.
- ❖ BA: weak modularity topologies, FKP: strong modularity topologies.

8

Bionetics' 07 Conference – Hungary Budapest 2007

3. RESULTS

INTENTIONAL ATTACK

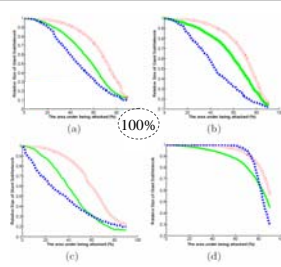


- ❖ BA: weak modularity topologies, FKP: strong modularity topologies.
- ❖ X: How many nodes being removed (%), Y: Damage of Network.

9

Bionetics' 07 Conference – Hungary Budapest 2007

RANDOM ATTACK



4. CONCLUSIONS

- ❖ We have shown the correlation between the robustness of networks and their modularity structure using numerical simulation.
- ❖ From a toy example, we showed that network robustness needs to be understood according to perturbations.
- ❖ Accuracy of topology generation model can be evaluated in terms of how the topology behaves against a certain type of perturbation.
- ❖ Currently, the impact of modularity structure on traffic fluctuation is being investigated.

10

Bionetics' 07 Conference – Hungary Budapest 2007

CONTACT DETAIL

Thanks for your attention

Presenter : Dr. Suyong Eum
E-mail : suyong@ist.osaka-u.ac.jp

Multimedia Network Laboratory Graduated School of
Information and Technology, OSAKA University.

11

Bionetics' 07 Conference – Hungary Budapest 2007