Osaka University

A Study on the Effect of Physical Topology on the Robustness of Fractal Virtual Networks

フラクタル性を有する仮想ネットワーク収容に適した物理トポロジー構成の評価

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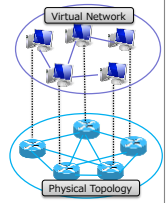
Background

- **Information networks**
  - Trend of the next generation networks, i.e. SDN
  - Trend of constructing virtual networks
- **Fractal virtual network[3]**
  - Robust brain networks
    - One of properties – Fractal property
  - Virtual network inspired by fractality in brain
    - Keeping reachability against node failures
    - Relaxing the traffic concentration
- **Bottleneck of information networks**
  - The capacity of physical topology to support diverse and new virtual networks

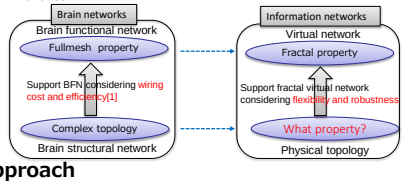


The property of physical topology which can support fractal virtual network should be investigated.

[3] Yoshinobu Shijo, "A Conguration Method of Virtual Networks with Hierarchical Robustness Inspired by the Fractality of Brain Functional Networks," Master's thesis, Graduate School of Information Science and Technology, Osaka University, February 2016.

Purpose and Approach

- **Purpose**
  - To investigate what property of physical topology can support the robustness of fractal virtual networks
    - Flexibility: having low distance cost in normal state
    - Robustness: having low distance costs and holding connectivity under failures

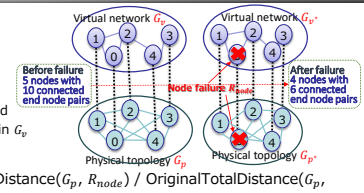


- **Approach**
  - Compare many types of physical topologies based on their performances of supporting fractal virtual networks

[1] E. Bullmore and O. Sporns, "The economy of brain *network organization*," *Nature Reviews Neuroscience*, vol. 13, pp. 336–349, May 2012.

Evaluation Measure

- **Cost**
  - TotalDistance(G_p)
    - Hop distance in G_p between all the connected end node pairs in G_v
- **Relative cost**
  - AfterFailureTotalDistance(G_p, R_{node}) / OriginalTotalDistance(G_p, R_{node})
    - Changing on cost between before and after R_{node} failures
    - AfterFailureTotalDistance(G_p, R_{node})
      - TotalDistance(G_{p*})
      - G_{p*} : Physical topology obtained when R_{node} failed in G_p
    - OriginalTotalDistance(G_p, R_{node})
      - Hop distance in G_p between all the connected end node pair in G_{v*} which is virtual network provided when R_{node} fails in G_p
      - G_{v*} : Virtual topology obtained when R_{node} failed in G_p



Evaluation Environment

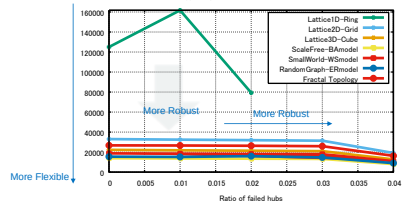
- **Conditions**
  - Physical topology supports fractal virtual networks
- **Generation method of fractal virtual networks[2]**
- **Nodes matching from virtual networks to physical topology**
  - At random
- **Failure type**
  - Node failures which lead to hub failures in virtual networks

Topology Models		Total Nodes	Total Links
Lattice Graph	1D-Ring	100	100
	2D-Grid		180
	3D-Cube		235
Random Graph	ER model		
Small-world	WS model		
Scale-free	BA model		

[2] C. Song, S. Haclin, and H. A. Makse, "Origins of fractality in the growth of complex networks," Nature physics, vol. 2, pp. 275–281, Apr. 2006.

Evaluation Results on Cost

- **Scale-free physical topology where the degree distribution follows a power law is optimal in this evaluation.**
  - BA model has low cost in normal state.
  - The cost of BA model is lowest when failure rate is from 0 to 0.04.
  - BA model can keep virtual network connected till 0.04 failure rate.

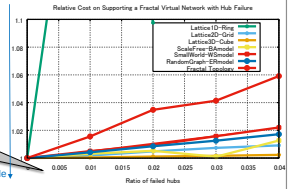


Evaluation Results on Relative Cost

An optimal physical topology not only has low cost but also has less changing on cost between before and after node failures.

Evaluated by relative cost

- **Scale-free physical topology where the degree distribution follows a power law is stable on low cost after failures.**



Though Lattice2D-Grid(sky-blue curve) and Lattice3D-Cube(orange curve) are more stable than Bamodel(yellow curve), their costs after node failures are higher than BAmodel.

More stable

Conclusion and Further Works

- **Conclusion**
  - Mathematical formulation of optimization problem of physical topology with capacity and connectivity requirements provides measures on performance evaluation.
  - Scale-free physical topology where the degree distribution follows a power law is optimal to support fractal virtual network flexibly and robustly.
- **Further Works**
  - Considering more generating methods of physical topology candidates on mixing multiple topological properties
  - Evaluation on the effect of physical topology candidates with multiple topological properties on the robustness of fractal virtual networks on more realistic scale of nodes and links
  - Proposing a design method of physical topology