Analysis of the Collaboration Structure in Router-level Topologies

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Research Background
• The Internet becomes one of social infrastructures
• Reliability to survive against failures of network

Reliability and Physical connection
• Physical connection of network is essential
• Investigation of relationships between characteristics and structures in networks

Purpose and approach
• Approach
  1. Using knowledge in biology
  • Focus attention on transcriptional regulatory networks (TRNs)
  2. Comparing between router-level topologies and TRNs
  3. Evaluation of a structure relating to reliability
  • Collaboration structure

Networks in living organisms
• The networks with long evolutionary history
  • Many environmental changes
  • Even if some components in the networks are broken, networks did not collapse
    • The organism keeps alive
  high robustness and adaptability
• Focus attention on transcriptional regulatory networks
  • Deeply studied in the field of biology
Transcriptional regulatory networks (TRNs)
- TRNs are in a cell of organisms
  - Components
    - Node: Transcription factors (TF)
    - Link: Transmission of signal
  - Function
    - To regulate proper genes in response to environmental stimuli
- Similarities to router-level topologies
  - Information flow
  - Hierarchical structure

Model of TRNs
- TF: protein
- Gene

Analogy: Downward information flow
- Flow of regulation signal for expression
- Flow of traffic from backbone to access networks

Evaluation of reliability
- Which is more reliable, router-level topologies or TRNs?
- Investigating with a ratio of nodes which can receive signal from top-level nodes when there are failure nodes
- Index for investigating reliability
  - Failure nodes:
  - A ratio of failure nodes
  - Reachable node ratio:
    - A ratio of nodes which can receive signal from top-level nodes

Evaluation of reliability
- Measure of reliability of both networks
  - Calculate the number of nodes which can receive signal from top-level nodes

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Evaluation of reliability
- Measure of reliability of both networks
  - Calculate the number of nodes which can receive signal from top-level nodes
Result of evaluation for reliability

- Most TRNs are more reliable than ISP router-level topologies.

Collaboration structure [3]

- A structure where multiple nodes connect with one node
  - Leading multi paths → Contributing reliability

Hierarchical structure

- Categorizing the topology into three layers
  - top level, middle level and bottom level

Collaboration structure

- A key to identify the collaboration structure
  - Where and how many collaboration structures are?

Definition of collaboration

- Three types of collaboration structure
  - Classify collaboration structure

Degree of collaboration

- Example: Degree of collaboration $D_{collab}$
  - Degree of collaboration reflects amount of collaboration structures in networks

Calculation result of degree of collaboration

- Degree of collaboration of top-level node and middle-level node is low in router-level topologies
- Expectation: Collaboration structure of top level and middle level contributes reliability

Degree of collaboration and reliability

- Confirmation of correlation between collaboration structure and reliability by means of rewiring operation
  - To increase degree of collaboration of top-level and middle-level in router-level topologies

Rewiring Pattern A

- Step. 1 Node X is regulated by three or more nodes included in the same layer.
- Step. 2 Node Y is one of nodes regulating Node X.
- Step. 3 Node Z is regulated by only nodes in one layer.

Rewiring Pattern B

- Step. 1 Node X is regulated by three or more nodes included in the same layer.
- Step. 2 Node Y is one of nodes regulating Node X.
- Step. 3 Node Z is regulated by only nodes in one layer.
Degree of collaboration after rewiring

- Calculating degree of collaboration after rewiring
  - Degree of collaboration of top-level and middle-level increased in router-level topologies

Before rewiring

After rewiring

Change of reliability in router-level topologies

- Reliability of router-level topologies before and after rewiring
- Reliability was improved in all topologies

- AT&T, Ebene, Exodus, Level3, Sprint, Telstra, Tiscali, Verrio

Conclusion and future work

- Conclusion
  - Degree of collaboration of top-level node and middle-level node in router-level topologies is lower than TRNs
  - Collaboration structures of top-level and middle-level contribute reliability

- Future work
  - Investigating why there is difference of improvement of reliability depending on router-level topologies after rewiring