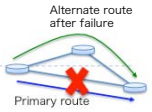
A new method of proactive recovery mechanism for large-scale network failures

Takuro Horie[1], Go Hasegawa[1], Satoshi Kamei[2] and Masayuki Murata[1]
[1]Osaka University, Japan
[2]NTT Service Integration Laboratories, NTT, Japan

Research background (1)



- Recovery from network failures
  - Reactive recovery
    - Calculates network configurations (e.g. routing tables) after detecting failures
    - Generally, distributes new configurations in a hop-by-hop manner
    - All failures can be recovered, but it takes long time to converge routing configurations throughout the network
  - Proactive recovery
    - Calculate network configurations for assumed failures beforehand and share them all network nodes
    - When detecting failure, select one configuration corresponding to the failure
    - Quick recovering when the failure was assumed in pre-calculated configurations
    - Can not recover failure when it was not assumed

Research backgrounds (2)

- Most of existing recovery methods assume single failure model
  - Assumes only one failure occurs at one time
- Trade-off relationships between redundancy and recovery performance
  - To improve the recovery performance, add higher-level redundancy to network equipments
- Large-scale network failures
  - Earthquakes, terrorist attacks, large-scale power outages and software bugs, …
    - Difficulty: probability of such failures is very low, but cost for preparing them is quite large
  - Quick recovery of network reachability is important

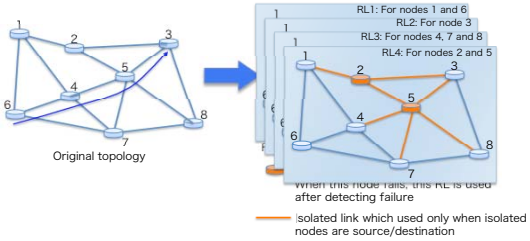
Objectives

- Proactive recovery method for large-scale network failures
  - Calculates a set configurations (network topology and corresponding routing table) for possible failures beforehand
  - Select one configuration after detecting the failure
  - Simple calculation, but high performance
    - Reachability and path length after recovery
  - Based on Resilien Routing Layers (RRL) [15]
    - Extended for simultaneous multiple failures

[15] A. Hansen, A. Kvalbein, T. Cicic, and S. Gjessing, "Resilient routing layers for network disaster planning," *Lecture notes in computer science*, vol. 3421, pp. 1097–1105, Apr. 2005.

Resilient Routing Layers (RRL) [15]

- Proactive recovery mechanism
- Calculates multiple network topologies (Routing Layers: RLs) for possible node failures



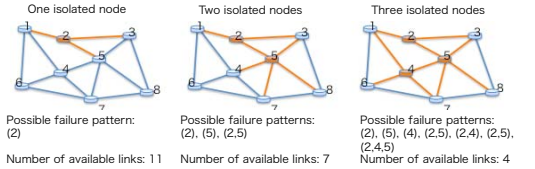
 [15] A. Hansen, A. Kvalbein, T. Cicic, and S. Gjessing, "Resilient routing layers for network disaster planning," *Lecture notes in computer science*, vol. 3421, pp. 1097–1105, Apr. 2005.

Characteristics of RRL

- Simple calculation algorithm
  - Select a candidate node and isolate it and its adjacent links, while keeping network connectedness
- When all nodes are isolated in a certain RL, 100% recovery can be achieved for any single node failure
- For multiple node failure, when all failing nodes are isolated in a certain RL, 100% reachability can be achieved for all node pair
  - If not, some node pairs can not be reachable

RRL for recovering from large-scale failure (1)

- As more nodes are isolated in a RL, the RL can accommodate more failure patterns
  - But the RL would have less available links, causing the increase of path length



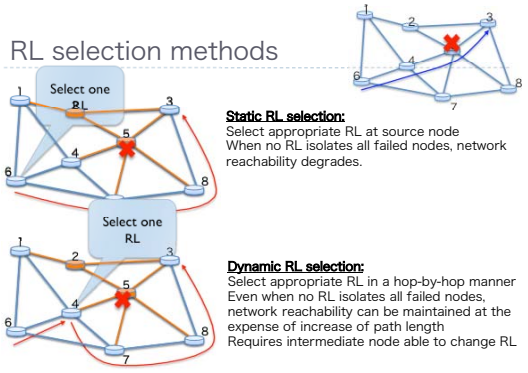
RRL for recovering from large-scale failure (2)

- To construct effective set of Routing Layers (RLs), we should determine:
  - The number of RLs which are prepared
    - Affected by protocol implementation and router memory size
  - The number of isolated nodes in each RL
  - How to choose isolated nodes in each RL
    - Both affected by assumed failure patterns
- To apply proposed methods, we should consider:
  - RL selection mechanism in routing decision

Algorithms to select isolating nodes in Routing Layers

- HUB-based algorithm
  - Isolates high-degree nodes and its adjacent nodes
- Attribute-based algorithm
  - Isolates nodes having the same attributes in one RL
    - Attribute: node location, vender name, OS version, topological information, …
- Degree-based algorithm
  - Isolate nodes in the order of node's degree
- Random-based algorithm
  - Isolate nodes in random order

RL selection methods



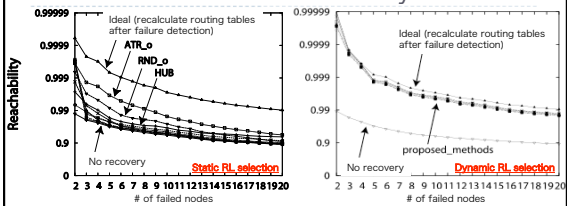
Static RL selection:
Select appropriate RL at source node
When no RL isolates all failed nodes, network reachability degrades.

Dynamic RL selection:
Select appropriate RL in a hop-by-hop manner
Even when no RL isolates all failed nodes, network reachability can be maintained at the expense of increase of path length
Requires intermediate node able to change RL

Settings for numerical evaluations

- Network topology
  - AS-level topology in Japan's Internet environment
    - 259 nodes and 1162 links
- Parameters for proposed method
  - Number of RLs: 250-300
- Failure patterns
  - F_RND: randomly selected nodes
  - F_ADJ: nodes which are connected each other
  - F_ATR: nodes with same attribute
  - F_LNK: link failure between randomly selected nodes
- Performance metric
  - Reachability, which is the ratio of node pairs which have valid route after failure recovery
  - Average path length of reachable node pairs

Evaluation results: reachability



- Effective for small number of failed nodes, but not so close to ideal case
  - Performance degrades as number of failed nodes increases
- Proposed methods are close to ideal case
  - Network reachability increases from 87% to 98% even when 20 nodes go down.
  - High reachability is maintained regardless of the number of failed nodes

Evaluation results: average path length

RLSet	Static RL selection				Dynamic RL selection			
	F_RND	F_ADJ	F_ATR	F_LNK	F_RND	F_ADJ	F_ATR	F_LNK
ATR	2.79	2.80	2.83	2.86	2.89	2.92	2.88	2.98
RND	2.99	2.99	2.99	2.98	3.10	2.96	2.96	2.95
No recovery	2.84	2.82	2.84	2.85	2.84	2.83	2.84	2.85
IDEAL	2.70	2.78	2.70	2.70	2.70	2.79	2.70	2.70

- Path length after failure recovery is not so increased, even with dynamic RL selection

Summary

- Proactive recovery mechanism from large-scale network failures
  - Simple calculation
    - Extension of RRL
  - Strong performance
    - Network reachability after failure recovery
    - Limited increase of path length, even with dynamic configuration selection
- Future work
  - Consideration of update interval for network growth
  - Application to routing on overlay networks