Modeling, Monitoring and Scheduling Techniques for Network Recovery from Massive Failures

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Motivation:

- Large-scale network failures,
- Natural Disasters:
  - Hurricane Katrina (2005),
  - Hurricane Rita (2005),
- Malicious attacks,
- Uncertain failures,

Figure 1. ITC Deltacom from the internet topology zoo [3]

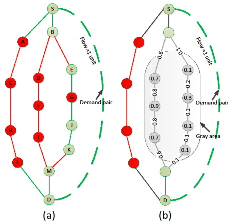


Figure 2. Network failure with full information (a), partial-information (b).

Objectives:

- Progressive and timely network recovery,
- Minimize losses, facilitate rescue mission,
- Minimize the expected recovery cost (ERC).

Problem Formulation:

Recovery Problem can be formulated as follows:

$$\underset{\delta_i^v,\delta_{i,j}^e}{\text{minimize}} E_\zeta \sum_{(i,j)\in E_U\cup E_B} k_{ij}^e(\zeta_{ij}^e(n))\zeta_{ij}^e(n)\delta_{ij}^e + \sum_{i\in V_U\cup V_B} k_i^v(\zeta_i^v(n))\zeta_i^v(n)\delta_i^v$$

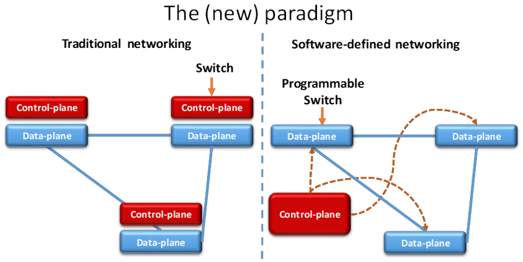
$$\text{subject to} \quad c_{ij}.\delta_{ij}^v \geqslant \sum_{h=1}^{|E_H|} f_{ij}^h(n) + f_{ji}^h(n) \qquad \forall (i,j)\in E \qquad (1a)$$

$$\delta_i^v.\eta_{max} \geqslant \sum\nolimits_{(i,j)\in E_B} \delta_{ij}^e \qquad \forall i\in V \qquad (1b)$$

$$\sum\nolimits_{j\in V} f_{ij}^h(n) = \sum\nolimits_{k\in V} f_{ki}^h(n) + b_i^h(n) \qquad \forall (i,h)\in V\times E_H \qquad (1c)$$

$$f_{ij}^h(n) \geqslant 0 \qquad \forall (i,j)\in E, h\in E_H \qquad (1d)$$

$$\delta_i^v, \delta_{i,j}^e \in \{0,1\} \qquad (1e)$$



Reconfigure network quickly in face of risk, attack or disruption:

Straggler switch, Avoiding congestion, Preserving Consistency

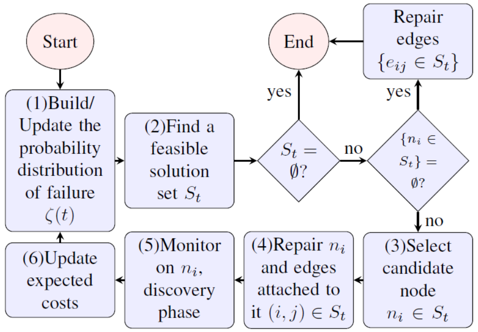
Approach

We use an iterative approach to place monitors and gain more information at each recovery step.

$$N_i^* = argmax_{n_i\in S_t} \frac{\sum_{p\in P_{n_i}^*} f(p)}{\sum_{p\in P^*} f(p)}$$

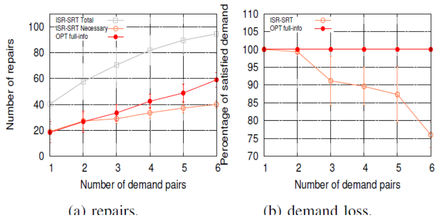
We consider for the first time a progressive network recovery algorithm under uncertainty. Our extensive simulation shows that our algorithm outperforms the state-of-the-art recovery algorithm while we can configure our choice of trade-off between:

- Execution time, Demand loss, Number of repairs (cost).

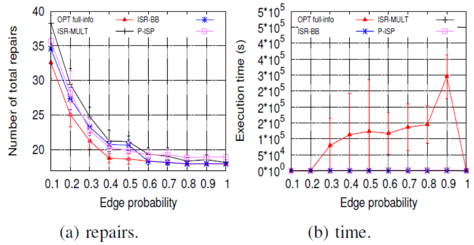


Experiments

Trade-off between number of repairs and demand loss (DeltaCom).



Execution time: Synthetic Erdos-Renyi topology with 100 nodes.



Publication

[1] D. Z. Tootaghaj, et. Al., “Homa: An Efficient Topology and Route Management Approach in SD-WAN Overlays”. In INFOCOM 2020.

[2] D. Z. Tootaghaj, et. Al., “Parsimonious Tomography: Optimizing Cost-Identifiability Trade-off for Probing-based Network Monitoring”. in SIGMETRICS Performance Evaluation Review, 2017.

[3] D. Z. Tootaghaj, et. Al., “Mitigation and Recovery from Cascading Failures in Interdependent Networks under Uncertainty”. In IEEE Transactions on Control of Network Systems, 2018.

[4] D. Z. Tootaghaj, et. Al., “On Progressive Network Recovery from Massive Failures under Uncertainty”, to appear in IEEE IEEE Transactions on Network and Service Management, 2018.