Network Recovery from Massive Failures under Uncertain Knowledge of Damages

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Motivation:

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

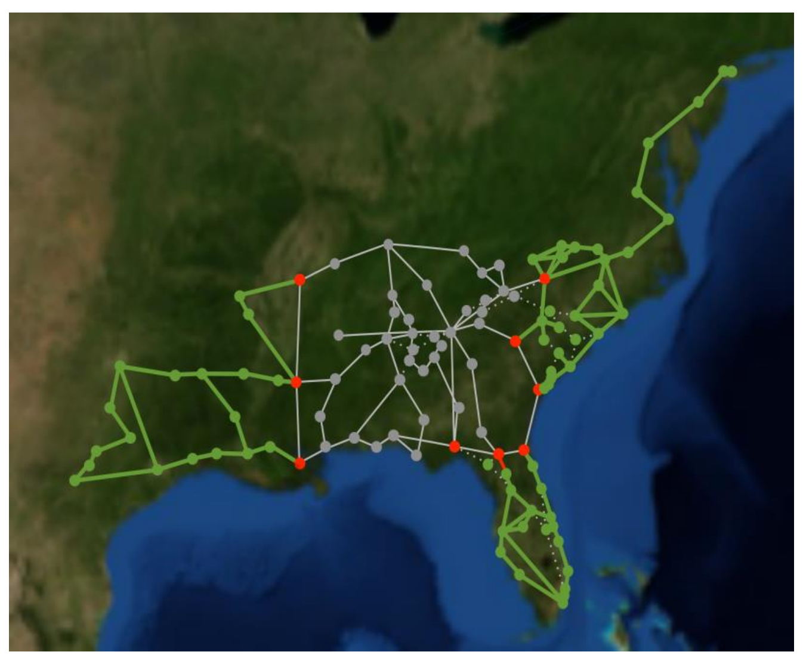


Figure 1. ITC Deltacom from the internet topology zoo [3]

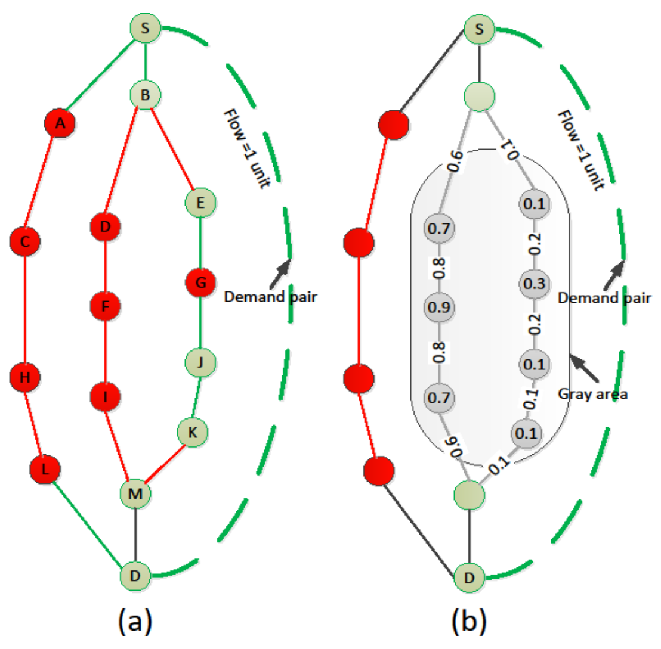


Figure 2. Network failure with full information (a), partial-information (b).

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:

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

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

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

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

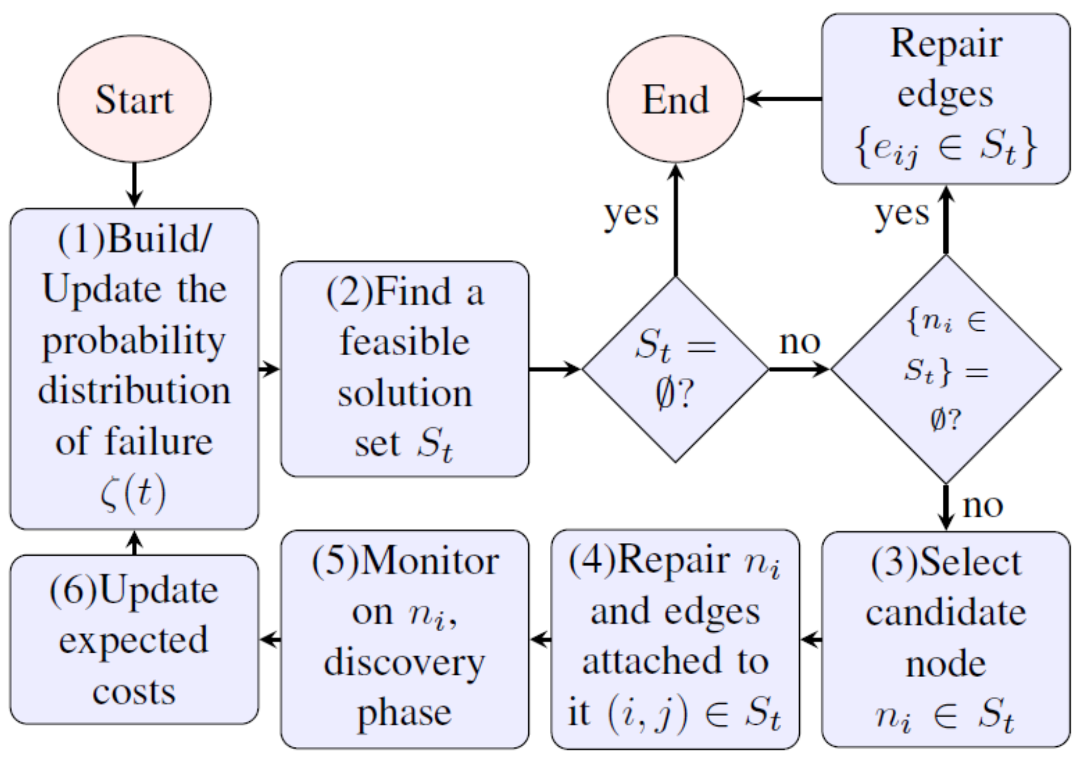
$$f_{ij}^h(n) \geqslant 0 \qquad \forall (i,j) \in E, h \in E_H \qquad (1d)$$

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

Where the binary variables δ_{ij} and δ_i represent the decision to repair link $(i,j) \in E$ and node $i \in V$.

Approach

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



Selecting the candidate node (3) is based on betweeness centrality.

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

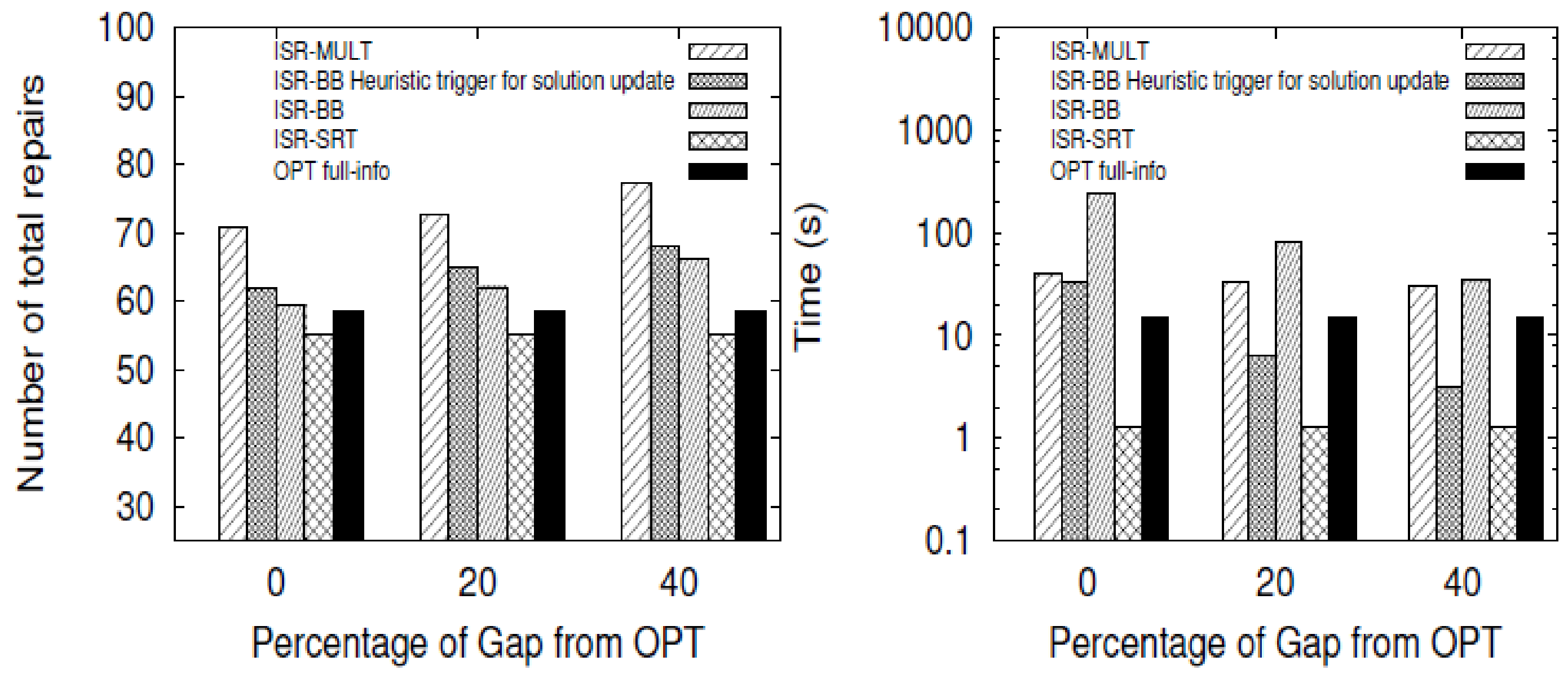
Finding a feasible solution set (1) is based on one of the following algorithms:

1. Iterative Shortest Path (ISR-SRT),
2. An Approximate Iterative Branch and Bound (ISR-BB),
3. An iterative multicommodity (ISR-MULT),
4. Progressive Iterative Split and Prune (P-ISP)

Experiments (2)

Network Name	OPT full-info	ISP full-info	ISP uncertain-info	Progressive ISP
BellCanada	28	34.23	79	45.39
Deltacom	36.94	43.26	112	55.5
KDL	55.2	63.2	165.65	83.55

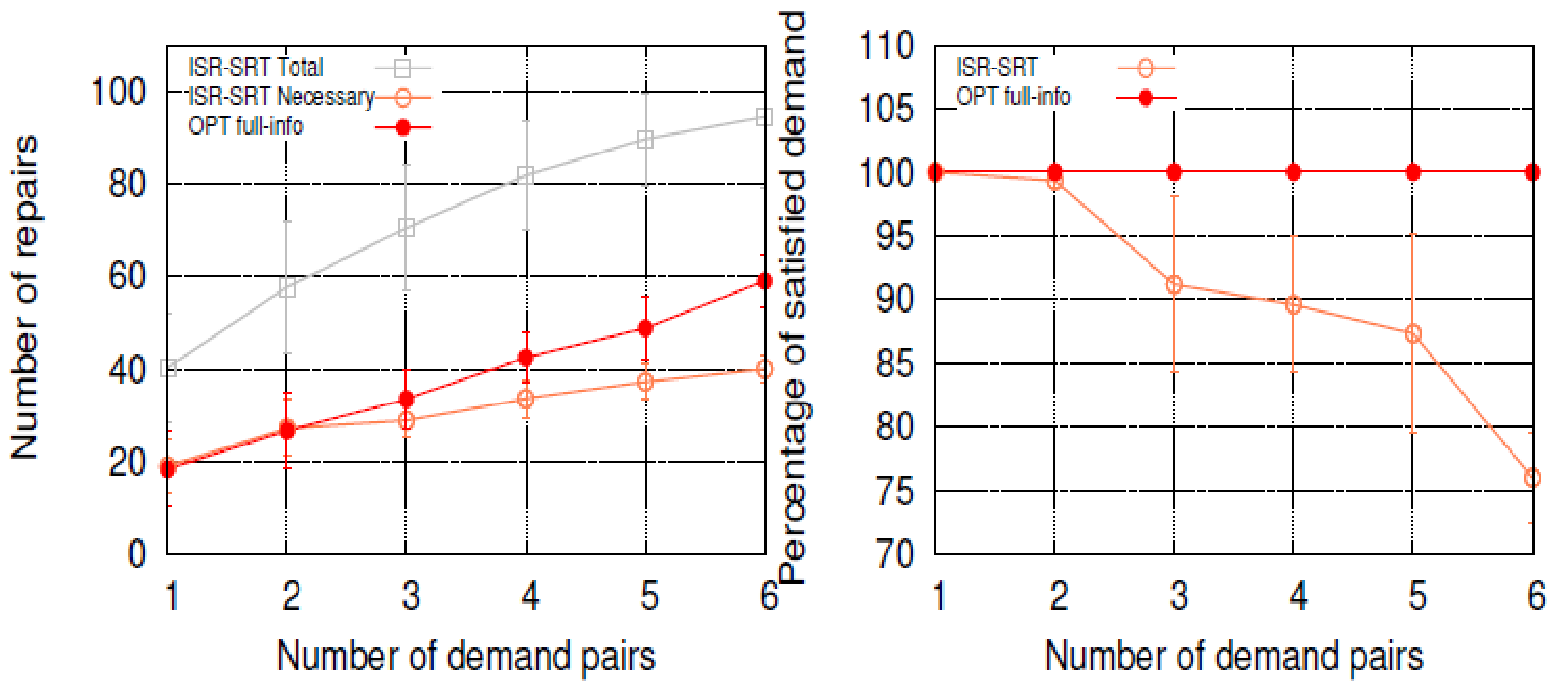
Trade-off execution time and number of repairs (DeltaCom).



(a) repairs. (b) time.

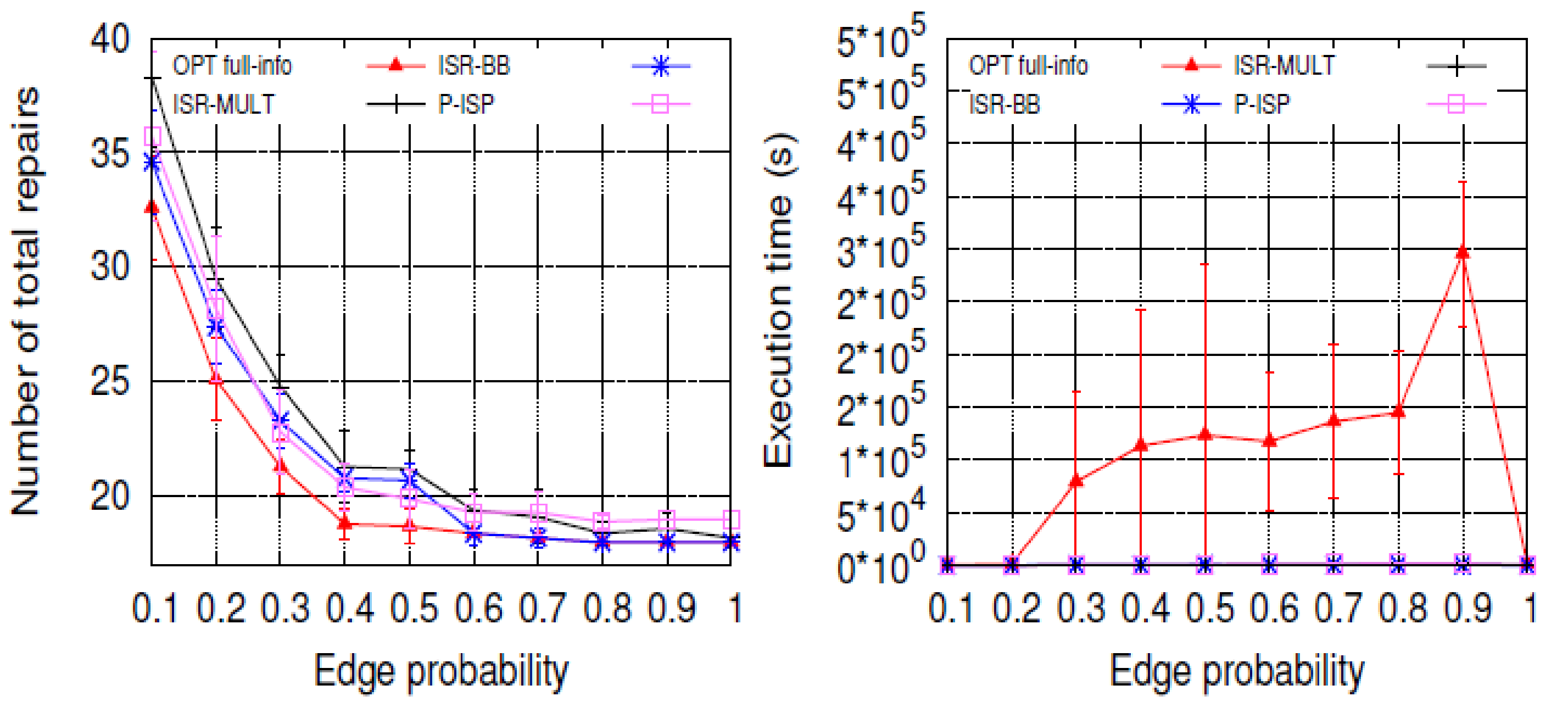
Experiments (1)

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



(a) repairs. (b) demand loss.

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



(a) repairs. (b) time.

Conclusion

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).

Our iterative recovery algorithm reduces the total number of repairs' gap with full-knowledge and partial knowledge from 79 repairs to 45.39 repairs in Bellcanada topology which is the smallest topology in our experiments.

Related Publications

[1] N. Bartolini et al. Network recovery after massive failures. In Dependable Systems and Networks (DSN), 2016.

[2] D. Z. Tootaghaj et al. Network Recovery from Massive Failures under Uncertain Knowledge of Damages. In Proceedings of the IFIP Networking Conference (IFIP NETWORKING 2017).

[3] The internet topology zoo. http://www.topology-zoo.org/, accessed in May, 2015.