Network Recovery by embracing the Uncertainty

D. Z. Tootaghaj†, S. Ciavarella* , H. Khamforoush†, S. Hayes†, N. Bartolini*, T. La Porta†
†The Pennsylvania State University, USA, *Sapienza University, Italy

Objectives and Motivation

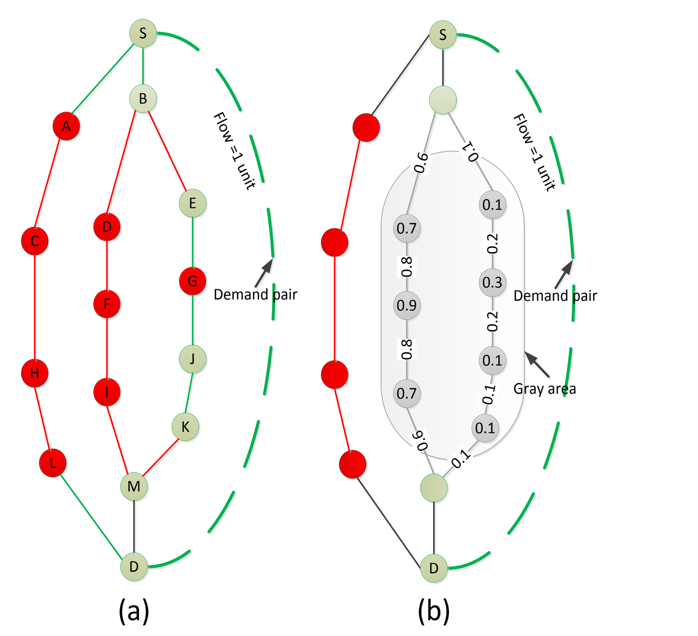


Figure 1: Netwrok failure with full information (a), partial-information (b).

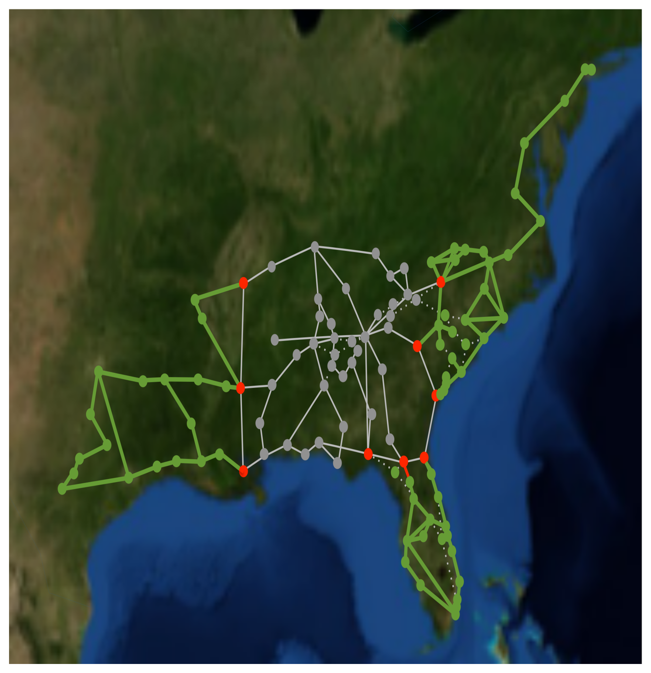


Figure 2: ITC Deltacom from the internet topology zoo [3].

Motivation:

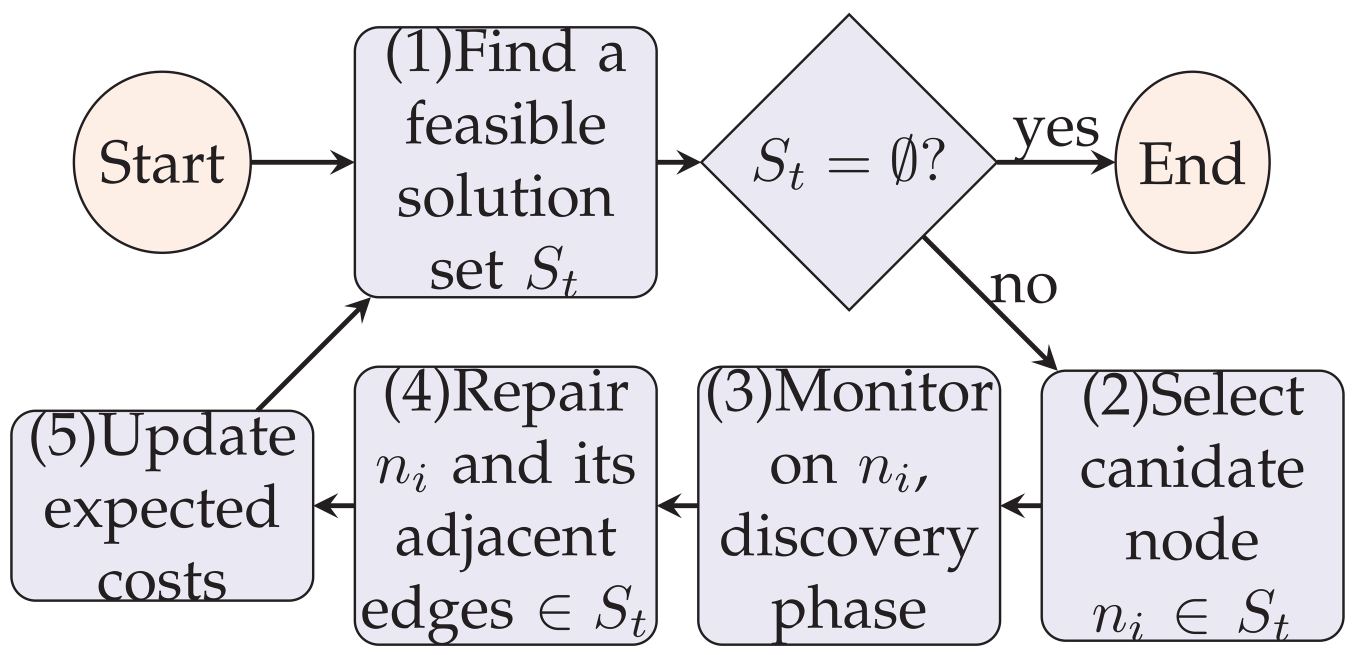
1. Large-scale network failures,
2. Natural disasters:
   - Hurricane Katrina (2005),
   - Hurricane Rita (2005),
3. Malicious attacks,
4. Uncertain failures,

Objectives:

1. Proggressive and timely network recovery,
2. Minimize losses, facilitate rescue mission,
3. Minimize the expected recovery cost (ERC).

Proposed Algorithm

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



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

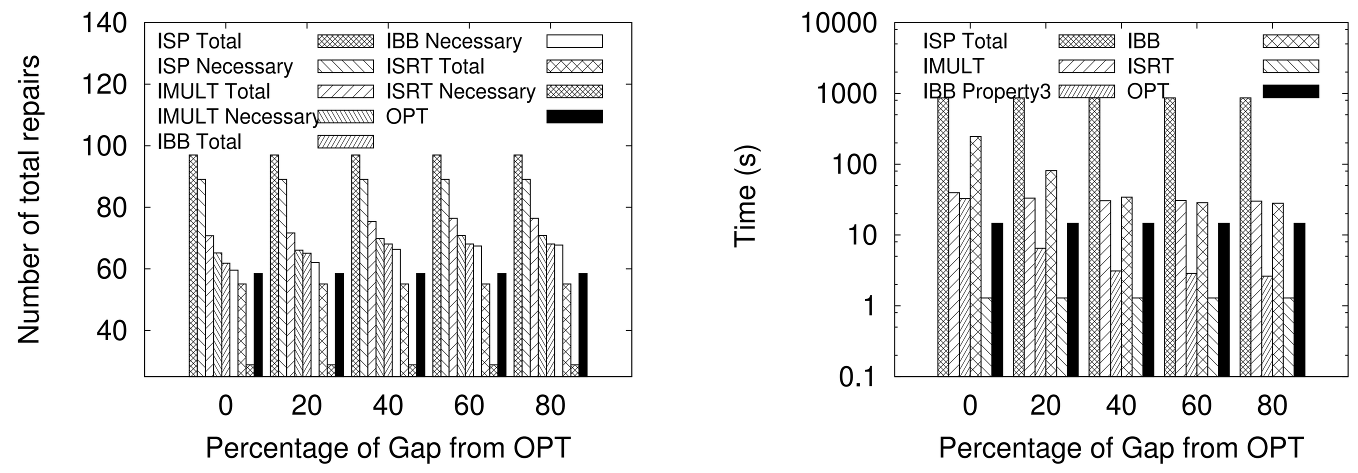
1. An iterative shortest path algorithm (ISRT),
2. An iterative split and prune (ISP),
3. An approximate branch and bound (IBB),
4. An iterative imulticommodity LP relaxation (IMULT).

Selecting the best candidate node (2) is based on one of the following criterias:

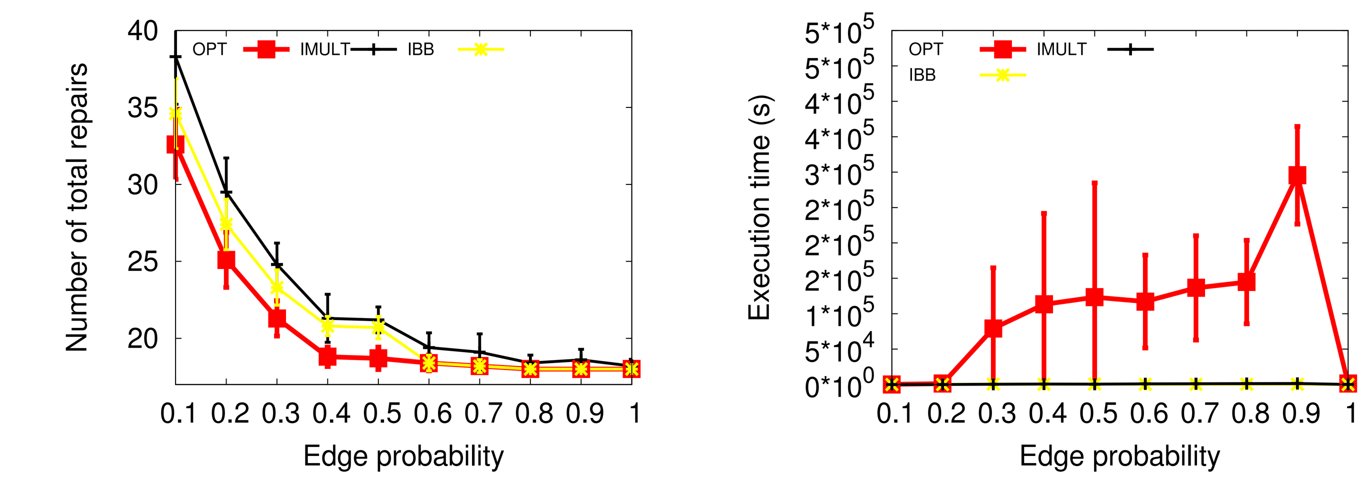
1. Maximum failure probability,
2. Maximum betweeness centrality.
3. Maximum information gain.

Experiments (2)

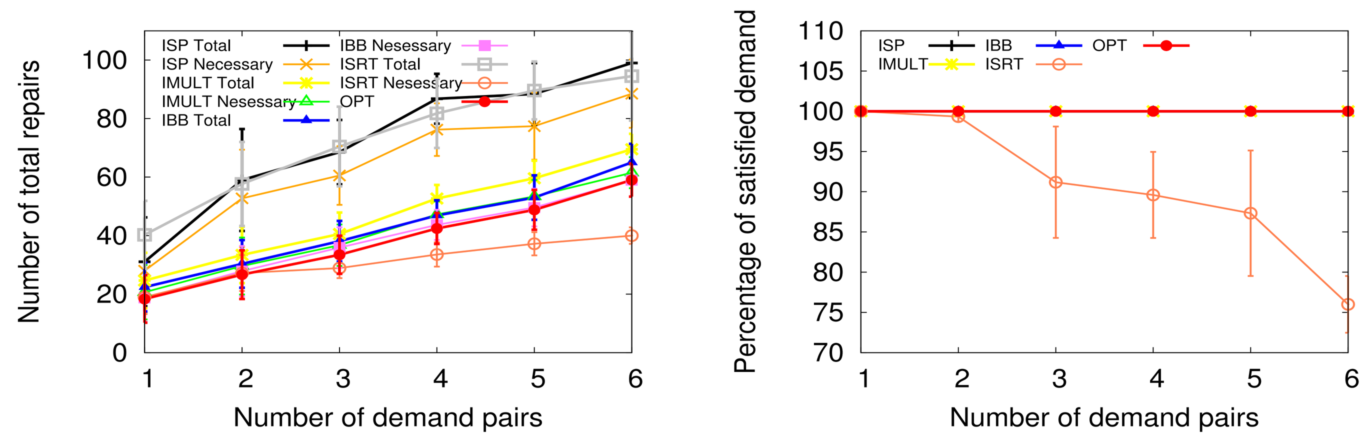
Scenario3: Trade-off execution time and number of repairs (DeltaCom).



Scenario4: Synthetic Erdos-Renyi topology with 100 nodes:



Scenario5: Trade-off between number of repairs and demand loss (Deltacom)



Problem Formulation

Recovery problem can be formulated as follows:

$$\underset{\delta_i,\delta_{i,j}}{\text{minimize}} E_\zeta \left(\sum_{(i,j)\in E_U \cup E_B} k^e_{ij}\zeta^e_{ij}\delta^e_{ij} + \sum_{i\in V_U\cup V_B} k^v_i \zeta^v_i \delta^v_i \right) \quad (1a)$$

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

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

$$\sum\nolimits_{j\in V} f^h_{ij} = \sum\nolimits_{k\in V} f^h_{ki} + b^h_i \qquad \forall (i,h)\in V\times E_H \quad (1d)$$

$$f^h_{ij} \geqslant 0 \qquad \forall (i,j)\in E, h\in E_H \quad (1e)$$

$$\delta^v_i, \delta^e_{i,j} \in \{0,1\} \quad (1f)$$

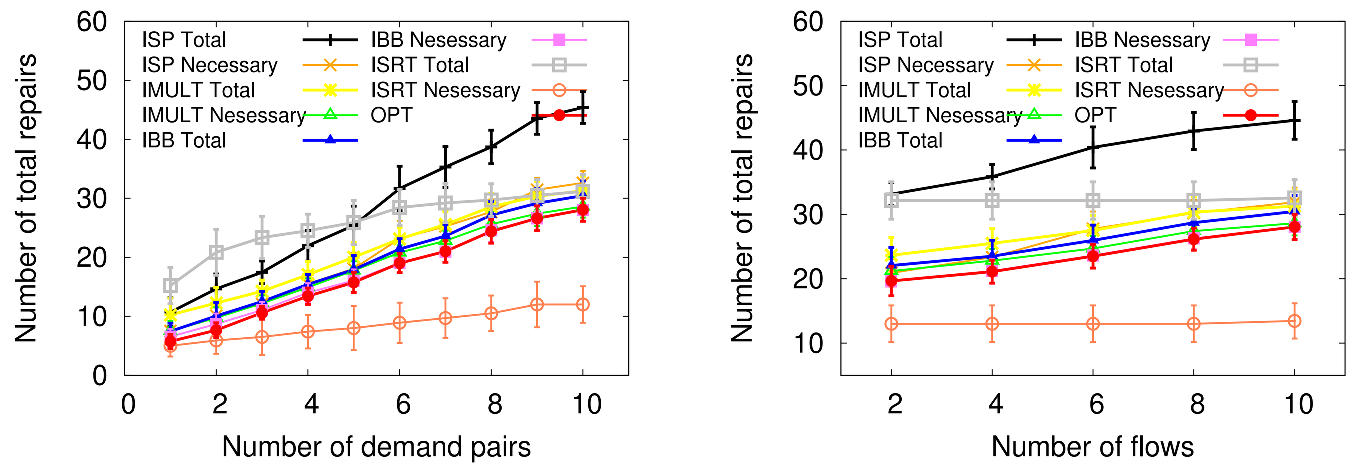
Where the binary variables δ_{ij} and δ_i represent the decision to repair link $(i,j)\in E$ and node $i\in V$.

Experiments (1)

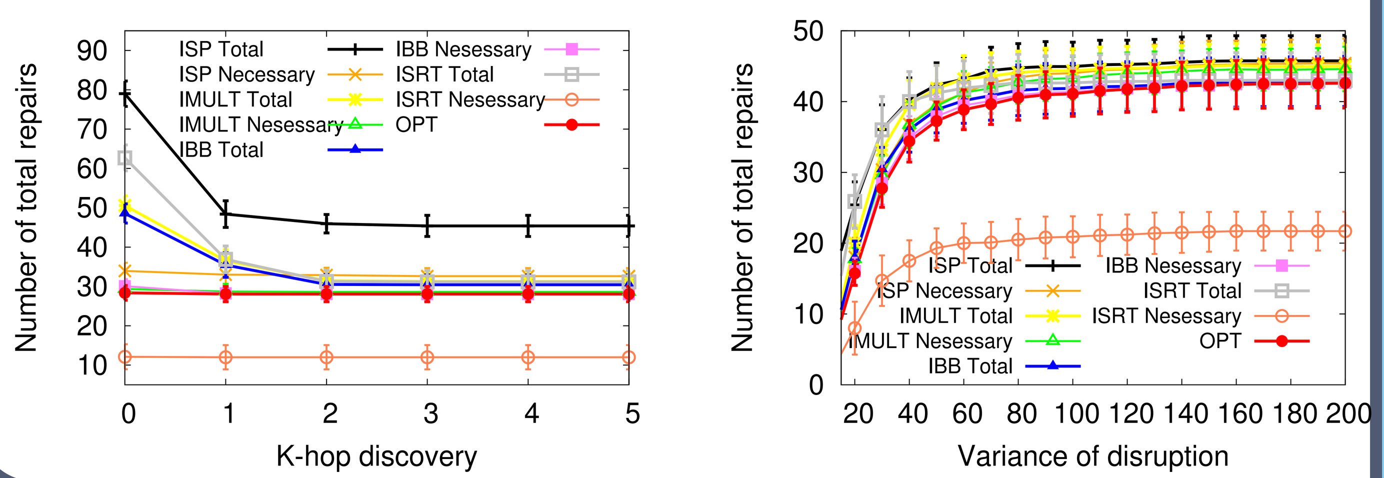
Network Name	# of nodes	# of edges	Average Node degree	Repairs (ISP-partial-info)	Repairs (Progressive ISP)
BellCanada	48	64	2.62	79	45.39
Deltacom	113	161	2.85	112	55.5

Table 1: Network characteristics used in our evaluation.

Scenario1: Increasing demand pairs and flows (BellCanada).



Scenario2: K-hop discovery and increasing disruption (BellCanada).



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:

1. Execution Time,
2. Demand Loss,
3. 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.

References

[1] N. Bartolini, S. Ciavarella, T. F. La Porta, and S. Silvestri. Network recovery after massive failures.
[2] J. Wang, C. Qiao, and H. Yu. On progressive network recovery after a major disruption. In *INFOCOM, 2011 Proceedings IEEE*, 2011.
[3] The internet topology zoo. `http://www.topology-zoo.org/`, accessed in May, 2015.

Future Research

1. Tomography techniques to reveal more information,
2. Uncertain traffic analysis of the network,
3. Dependable networks.