**Objectives and Motivation**

![Image of network failure](image1)

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

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

![Image of network topology](image2)

**Problem Formulation**

Recovery problem can be formulated as follows:

\[
\begin{align}
\text{minimize } & E_\epsilon \left( \sum_{(i,j) \in E_B} k_{ij}^e c_{ij}^e \delta_{ij}^e + \sum_{i \in V_B} k_{ii}^e c_{ii}^e \delta_i^e \right) \\
\text{subject to } & c_{ij} \delta_{ij} \geq \sum_{h=1}^{k_{ij}} f_{ij}^h, \quad \forall (i,j) \in E \\
& \delta_i \eta_{\max} \geq \sum_{(i,j) \in E_B} \delta_{ij}, \quad \forall i \in V \\
& \sum_{j \in V} f_{ij}^h = \sum_{h \in V} f_{ki}^h + b_i^h, \quad \forall (i,h) \in E \times E_B \\
& f_{ij}^h \geq 0, \quad \forall (i,j), (h,h) \in E \times E_B \\
& \delta_i^e, \delta_{ij}^e \in \{0, 1\}
\end{align}
\]

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

**Proposed Algorithm**

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

1. Find a feasible solution set \(S_t\)
2. Select candidate node \(n_t\) and its adjacent edges \(E_t\)
3. Monitor on \(n_t\) discovery phase
4. Repair \(n_t\) and its adjacent edges \(E_t\)
5. Update expected costs

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

**Experiments (1)**

Table 1: Network characteristics used in our evaluation.

<table>
<thead>
<tr>
<th>Network Name</th>
<th># of nodes</th>
<th># of edges</th>
<th>Average Node</th>
<th>Repairs (ISP-partial)</th>
<th>Repairs (Progressive ISP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BellCanada</td>
<td>48</td>
<td>64</td>
<td>2.62</td>
<td>59</td>
<td>45.39</td>
</tr>
<tr>
<td>Deltacom</td>
<td>113</td>
<td>161</td>
<td>2.80</td>
<td>122</td>
<td>55.5</td>
</tr>
</tbody>
</table>

**Experiments (2)**

Scenario 3: Trade-off execution time and number of repairs (DeltaCom).

Scenario 4: Synthetic Erdos-Renyi topology with 100 nodes.

Scenario 5: Trade-off between number of repairs and demand loss (DeltaCom).

**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**


**Future Research**

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