OFC 2015

Scheme for Optical Network Recovery Schedule to Restore Virtual Networks after a Disaster

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Outline

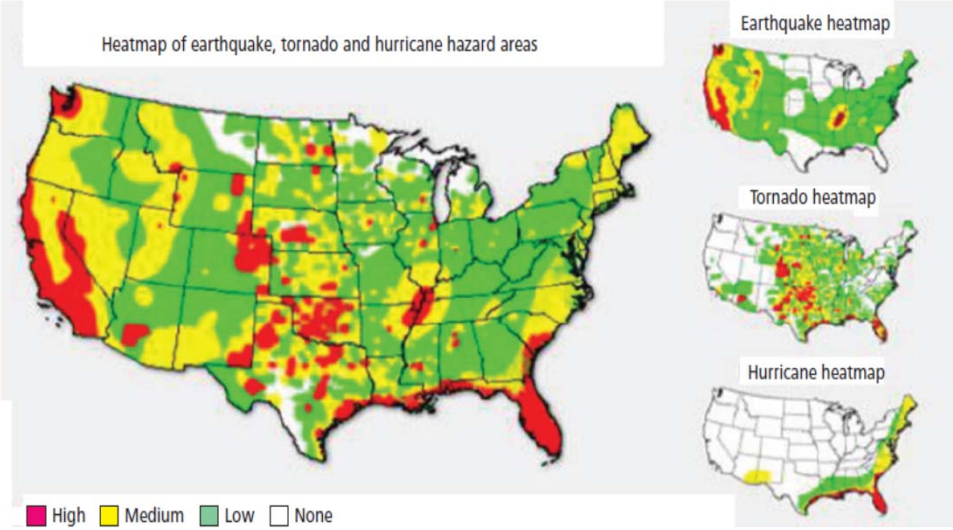
1 **Backgrounds**

2 **Problem and Solution**

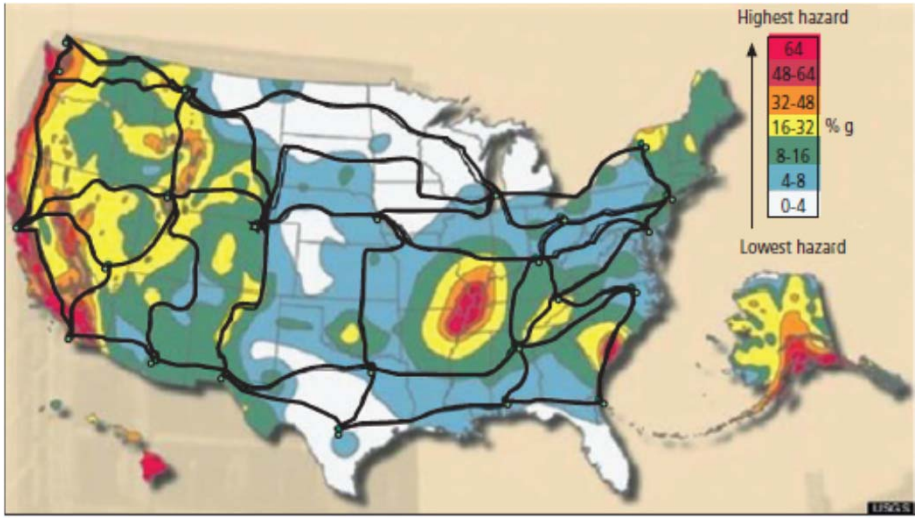
3 **Simulation Results**

4 **Conclusions**

Telecommunication Networks in Disasters



After disaster occurs, what should network operators do?

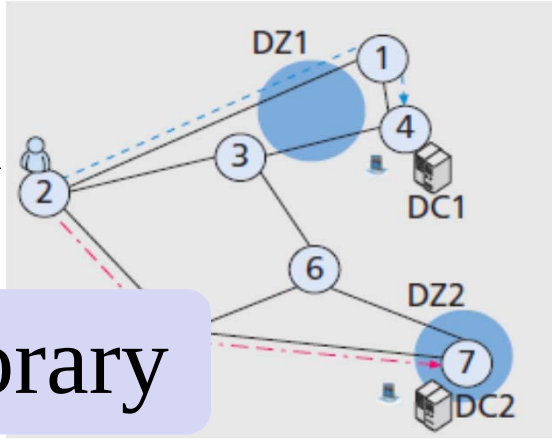


SS. Savas, M.F. Habib, M. Tornatore, F. Dikbiyik, and B. Mukherjee. "Network Adaptability to Disaster Disruptions by Exploiting Degraded-Service Tolerance", IEEE Communications Magazine, 2014

Post-Disaster Technologies

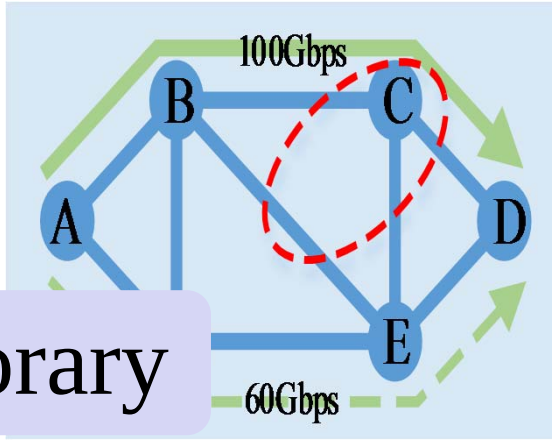
Traffic Engineering

Content-Connectivity



Temporary

Degraded Service

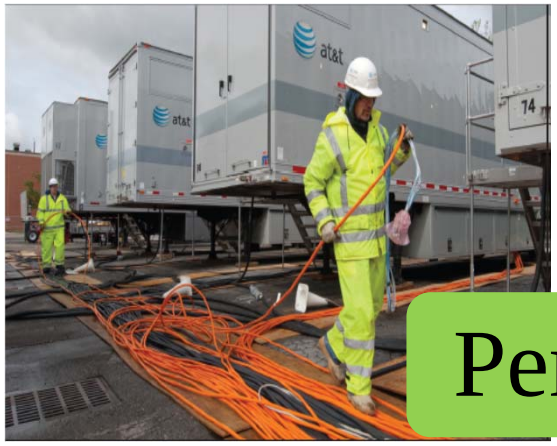


Temporary

Network Engineering

Emergency Communication

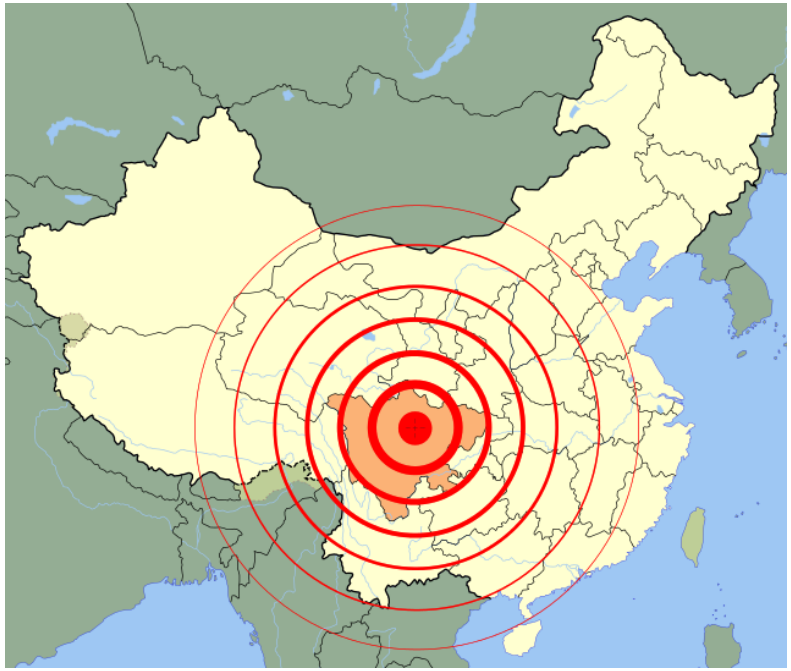
Temporary



Repair Failures

Permanent

Earthquake Recovery in Wenchuan



- Failures in Disaster:

Numerous Failures

4,000 telecommunication offices

- Repair team

Limited teams

Limited Teams

Problem

How to make the recovery schedule for each team?

Y. Ran, “Considerations and Suggestions on Improvement of Communication Network Disaster Countermeasures after the Wenchuan Earthquake”, IEEE Communication Magazine, 2011.

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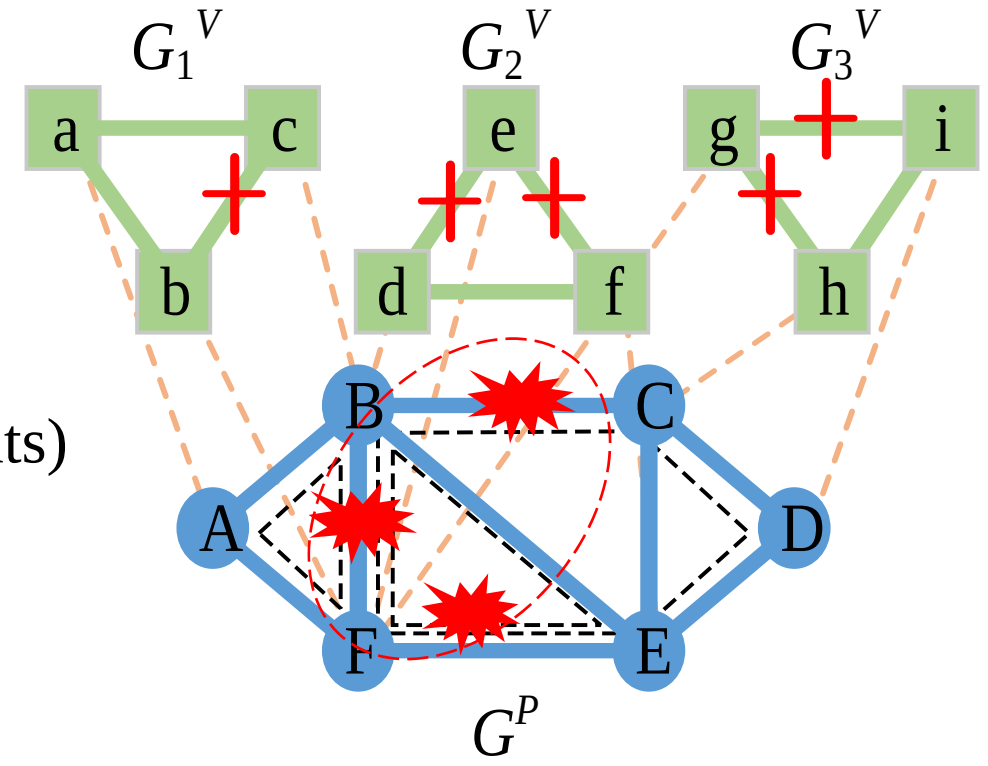
Problem Statement

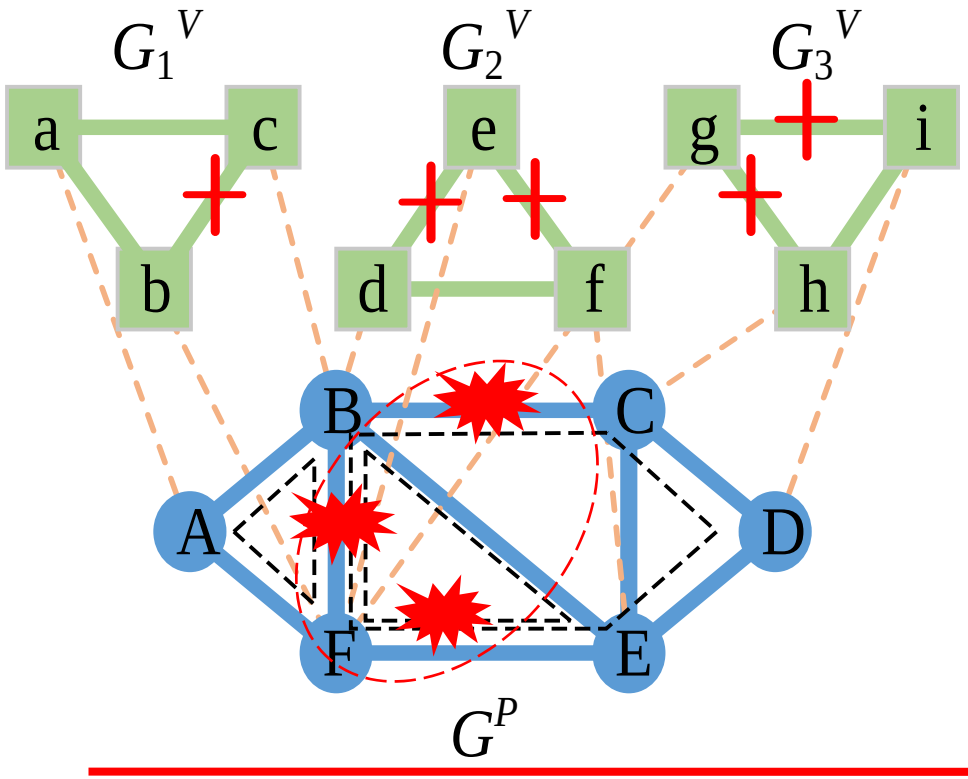
- Input
  - physical networks
  - virtual networks
  - mapping relationship
  - disaster (failed components)
- Output
  - Recovery schedule



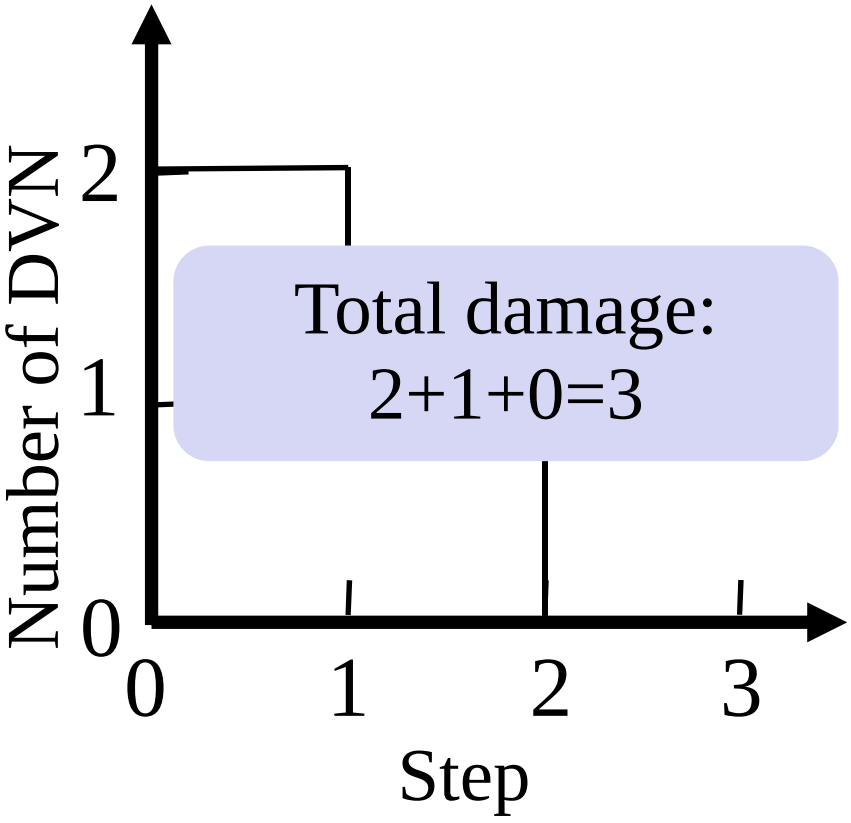
Recovery Process

Metrics

Failed virtual links (FVL)
Un-full virtual networks (UVN)
Disconnected virtual networks (DVN)



Schedule: (B,F), (E,F), (B,C)



ILP Model

- Constraints
  - Statements of Physical Links

$\sum_{k\in\{1,..,K\}} y_{(i,j),k} = 1 \quad \forall (i,j) \in E^D$

$\sum_{(i,j)\in E^D} y_{(i,j),k} = 2 \quad \forall k \in \{1,..,K\}$

$y_{(i,j),k} = y_{(j,i),k} \quad \forall k \in \{1,..,K\}, (i,j) \in E^D$

$c_{(i,j),k=1} = 0 \quad \forall k \in \{1,..,K\}, (i,j) \in E^D$

$c_{(i,j),k} = \sum_{k'\in\{1,..,K\}} y_{(i,j),k'} \quad \forall k \in \{2,..,K\}, (i,j) \in E^D$

  - Damage of UVN

$f_{s,k} = \vee_{(m,n)\in E_s^V} l_{(m,n),s,k} \quad \forall s \in \{1,..,S\}, k \in \{1,..,K\}$

  - Damage of DVN

$\sum'_{(m,n)\in E^D} x_{(p,q),(m,n),s,k} - \sum'_{(n,m)\in E^D} x_{(p,q),(n,m),s,k} =$

$\begin{cases} 1 & if\ n = p \\ -1 & if\ n = q \\ 0 & otherwise \end{cases} \quad \forall p,q,m \in V_s^V, p \neq q, (m,n) \in E_s^V, k \in \{1,..,K\}$

$h_{(p,q),(m,n),s,k} = x_{(p,q),(m,n),s,k} \wedge l_{(m,n,s,k)} \quad \forall p,q \in V_s^V, p \neq q, (m,n) \in E_s^V, k \in \{1,..,K\}$

$r_{s,k} = \vee_{p,q\in E_s^V, p\neq q, (m,n)\in E_s^V} h_{(p,q),(m,n),s,k} \quad \forall s \in \{1,..,S\}, k \in \{1,..,K\}$

  - Damage of FVL

$l_{(m,n),s,k} = \vee_{(i,j)\in E^D} M_{(i,j),(m,n),s} \times \left(1 - c_{(i,j),k}\right) \quad \forall (m,n) \in E_s^V, k \in \{1,..,K\}$

- Objectives
  - Minimum DVN $\min \sum_{k\in\{1,..,K\}} \sum_{s\in\{1,..,S\}} r_{s,k}$
  - Minimum UVN $\min \sum_{k\in\{1,..,K\}} \sum_{s\in\{1,..,S\}} f_{s,k}$
  - Minimum FVL $\min \sum_{k\in\{1,..,K\}} \sum_{s\in\{1,..,S\}} \sum_{(m,n)} l_{(m,n),s,k}$

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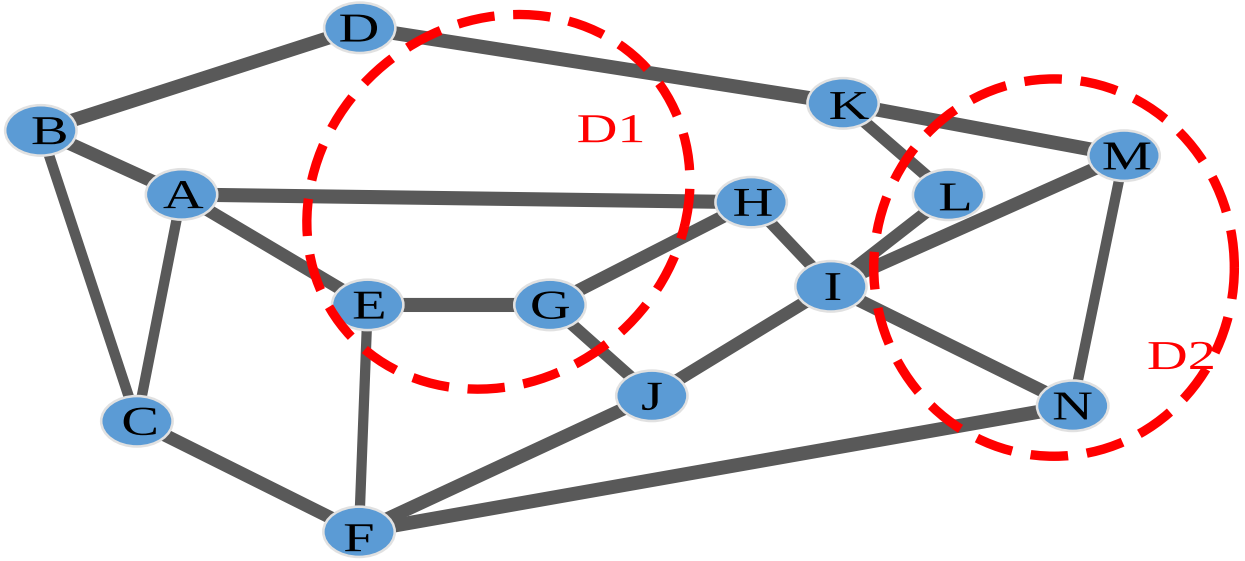
Simulation

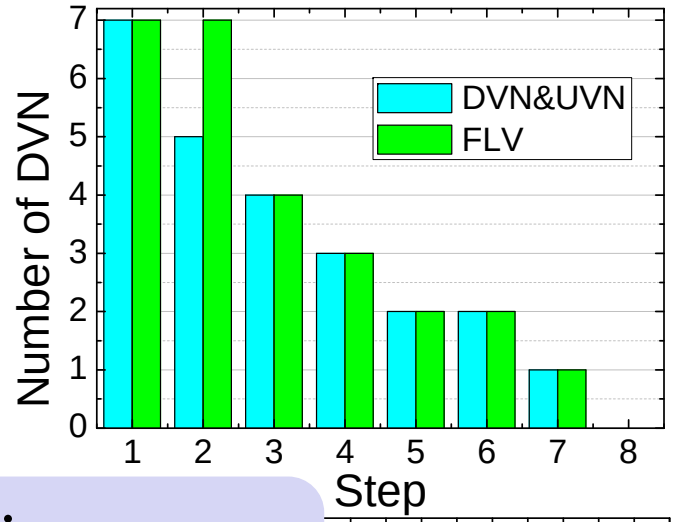


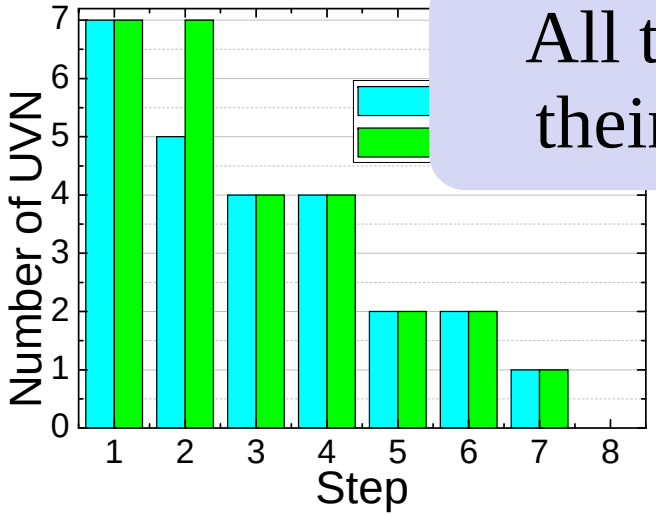
- Modified NSFNet topology
- Two disaster areas with 7 failures each
- Ten virtual networks
  - Four virtual nodes, which are randomly mapped to physical network

Results of OFC

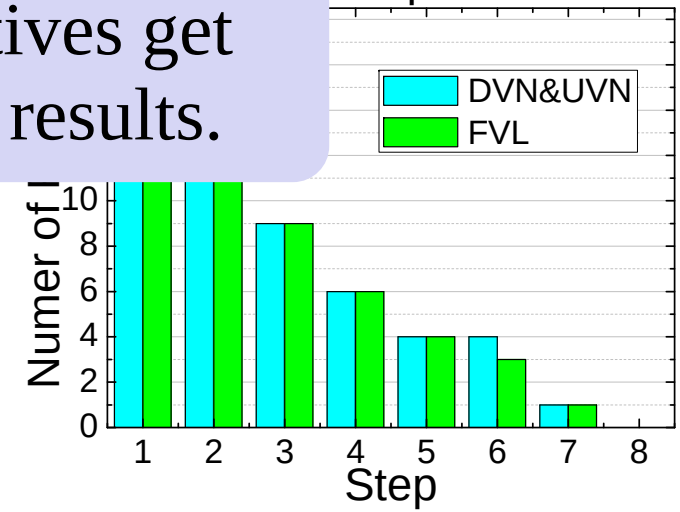
Disaster Area D1

DVN UVN	(A,H)(D,K)(D,E)(E,F)(E,G)(G,H)(G,J)
FLV	(D,K)(A,H)(D,E)(E,F)(G,H)(E,G)(G,J)





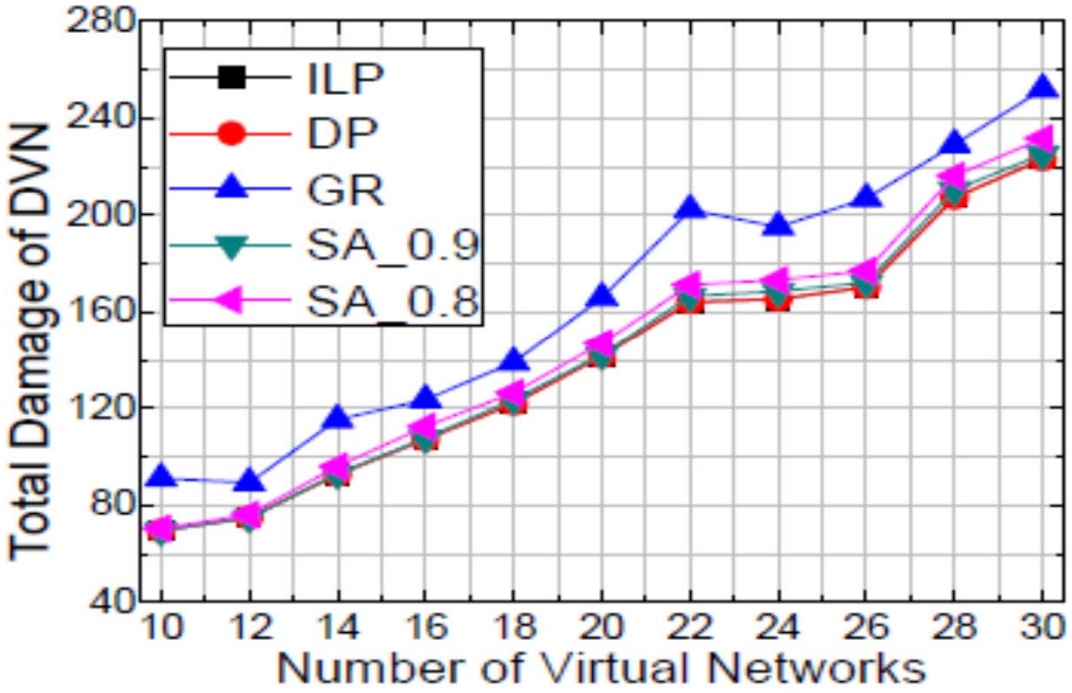
All the objectives get their optimal results.



*Disconnected virtual networks **(DVN)** *Un-full virtual networks **(UVN)** *Failed virtual links **(FVL)**

Results after OFC

- Repair and traveling times are dynamic changed.
- Multiple algorithms (Dynamic Programming, Greedy Algorithm, Simulated Annealing) are proposed.



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Conclusions

- We investigated the recovery schedule of virtual networks after disaster and proposed a mathematic solution for it.
- We proposed and compared different recovery objectives, and showed that each objective can lead to its optimal result.
- **Work after OFC:**
  - Repair time and traveling time to failure locations will be dynamic changed.
  - Heuristic algorithms will be introduced and compared to the problem.


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Thanks!

Q&A