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# Traveling Repairman Problem (TRP) in All-Optical Networks (AON)

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# Outlines

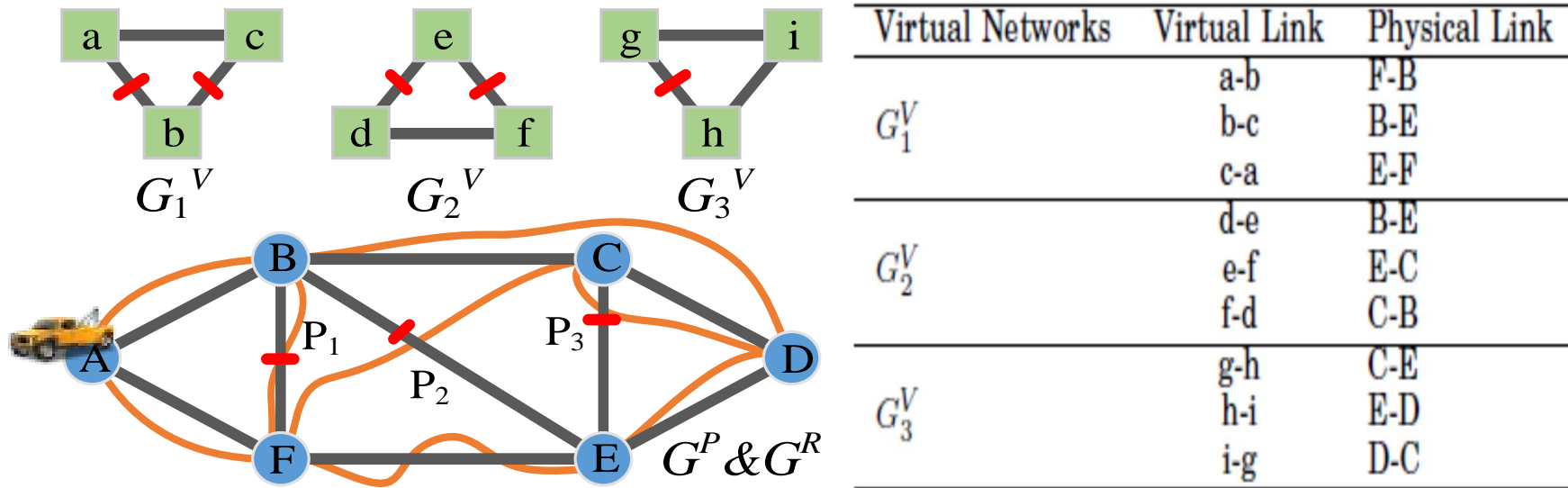
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- **TRP in Optical Networks**
- TRP in All-Optical Networks
- Future Work of TRP



# Scenarios



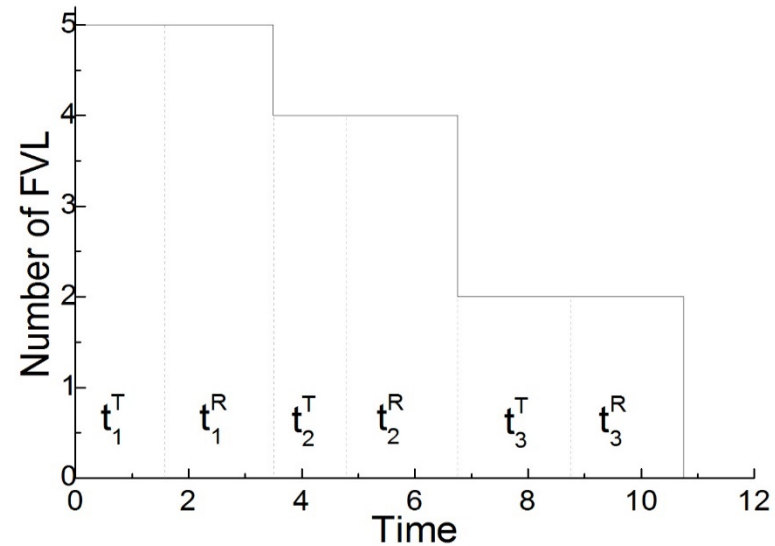
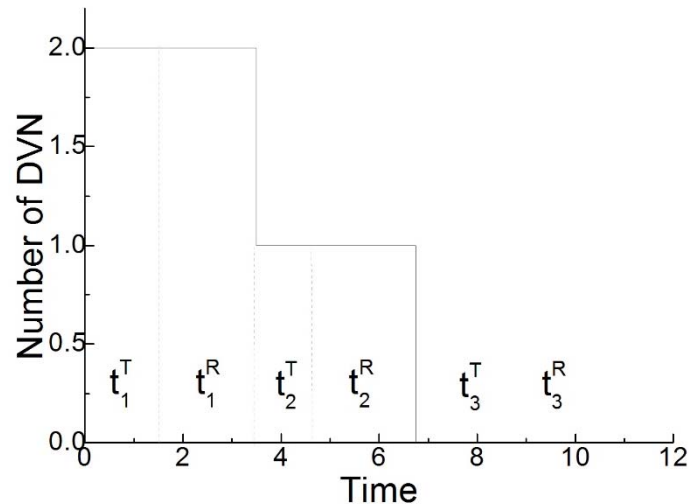
Pre-conditions:

- The repairman knows the exact position of each failure in physical network and road network.
- The repairman knows the repair time of each failure.



## The damage of DVN and FVL

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- Damage of DVN: the product of the number of DVN and its lasting time.
- Damage of FVL is similar with DVN.



# Problem Statement

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## Given:

- $G^R$ : a road network.
- $G^P$ : a physical network.
- $G^V$ : a set of  $S$  virtual networks.
- $\Pi^{PV}$ : a basic mapping relationship of  $G^P$  and  $G^V$ .
- $P$ : the accurate positions of failure.

## Output:

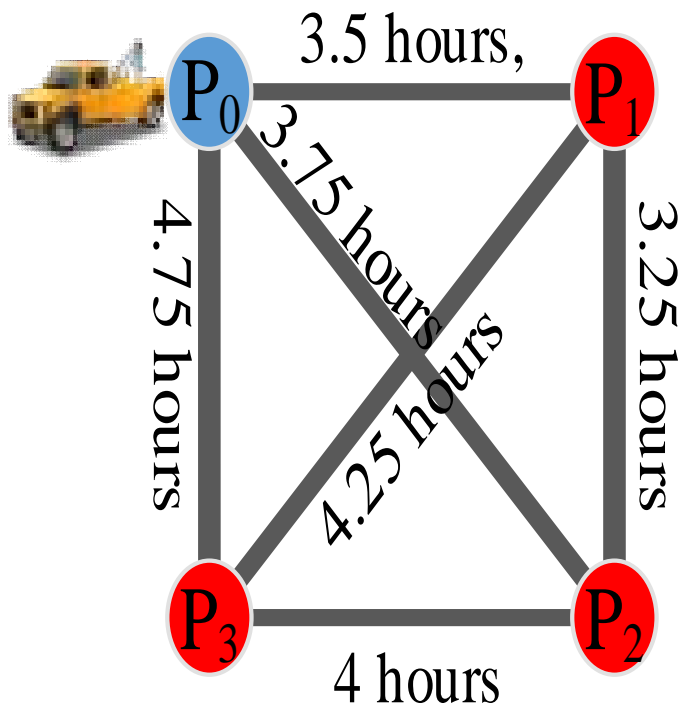
- The repairing path for the repairman.

## Objective:

- 1) Minimizing the damage of DVN;
  - 2) Based on Objective 1, minimizing the damage of FVL.
  - 3) Based on Objective 1 and 2, minimizing the damage of repaired time.
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# Auxiliary Graph



## Given:

- $G^A$ : the auxiliary graph, and the weight of each two nodes is the summary of traveling time and repair time.
- $G^V$ : a set of  $S$  virtual networks.
- $\Pi^{AV}$ : mapping relationship of  $G^A$  and  $G^V$ .
- $P_0$ : the start node of the repairman.

## Output:

A path in  $G^A$ , which obey the following rules:

- The path begins with repairman's location  $P_0$ .
- The path travels all the auxiliary nodes in  $G^A$ .

## Objective:

- Minimizing the total damage  $C$  of virtual networks in the whole recovery process.

# Algorithms

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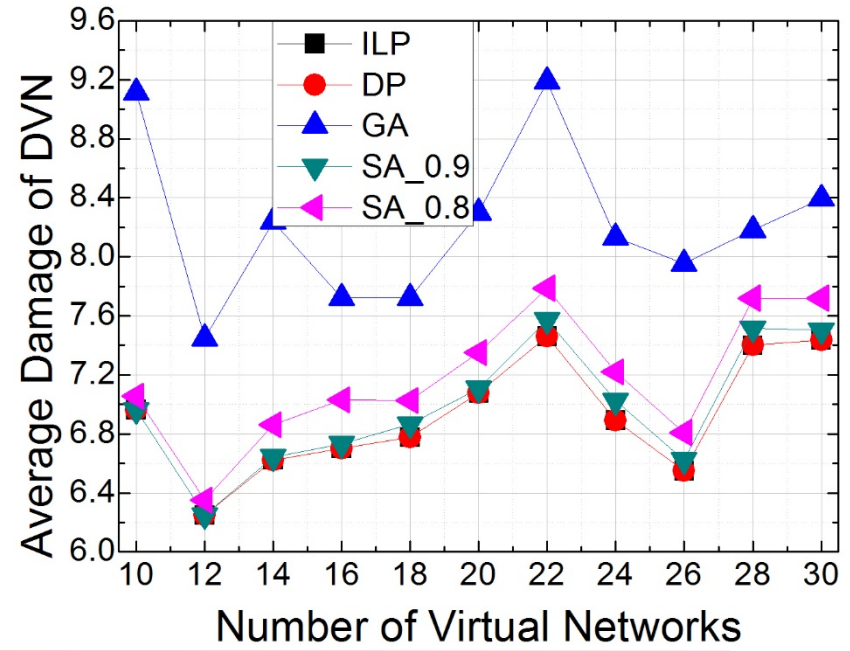
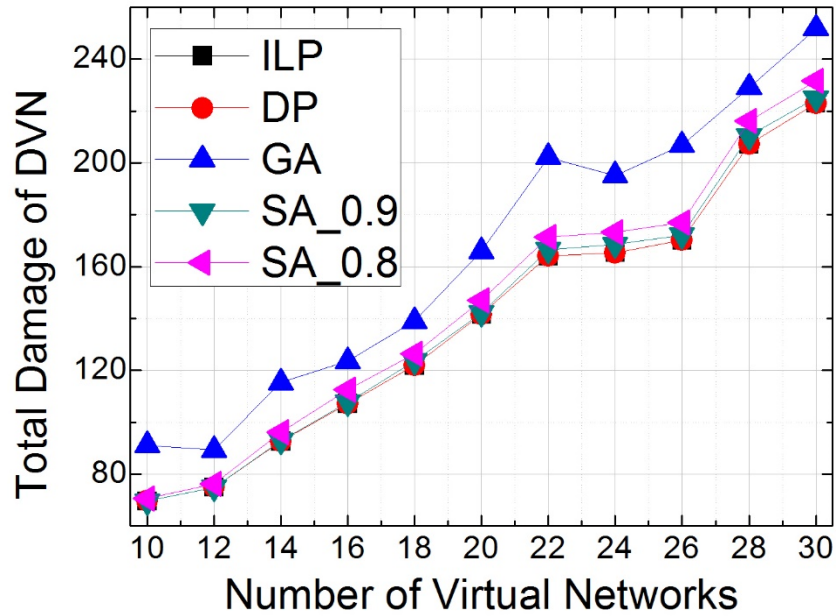
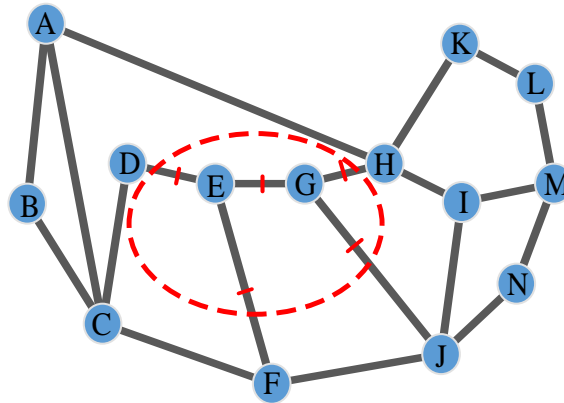


- ILP
- Greedy Algorithm (GA)
- Dynamic Programming (DP)
- Simulated Annealing (SA)





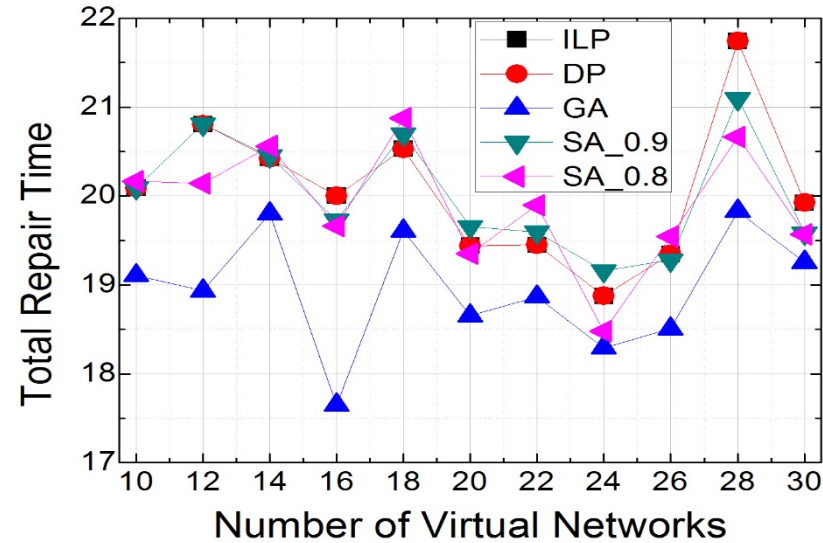
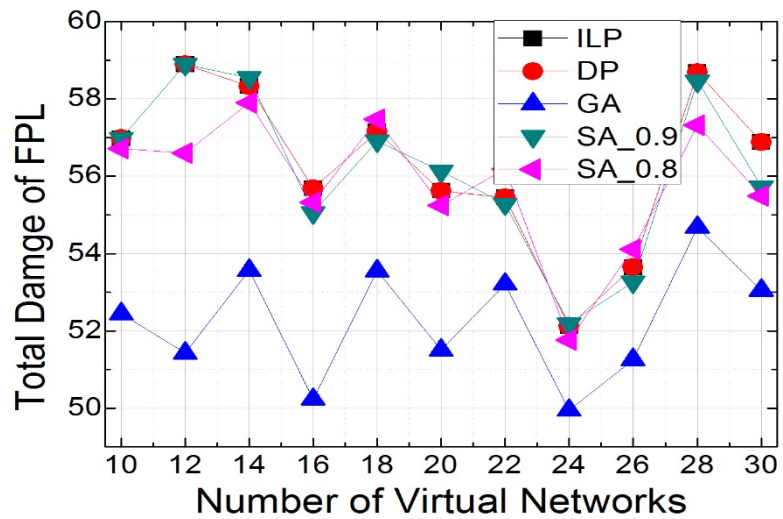
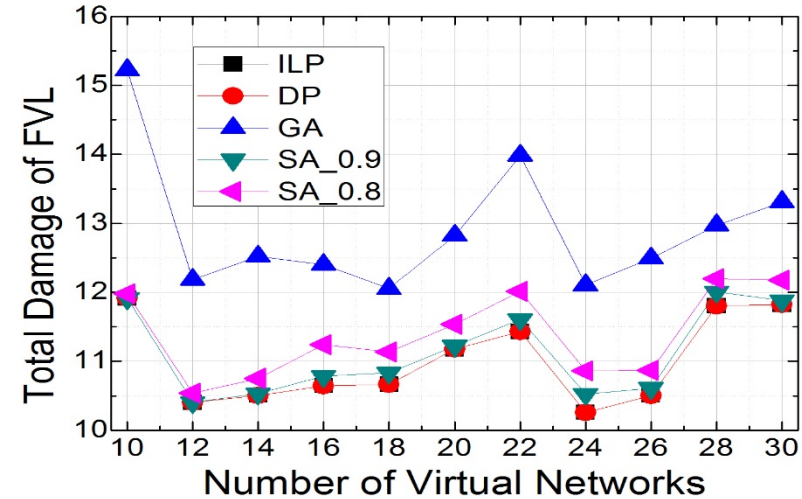
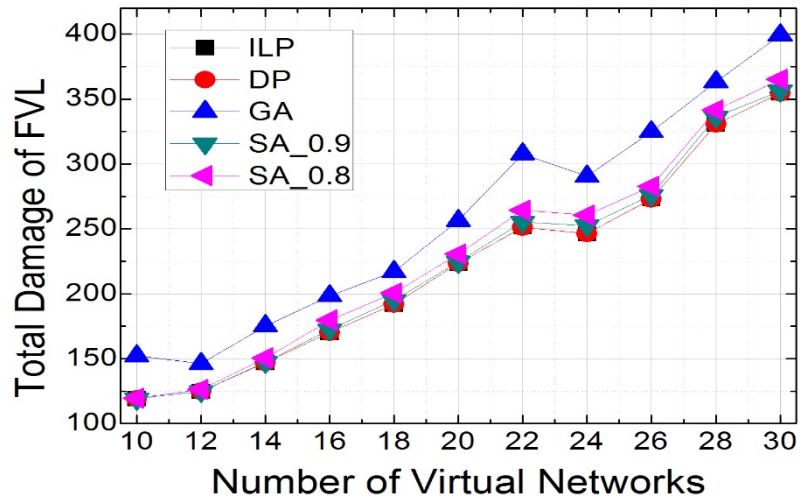
# Simulation Results - 1







# Simulation Results - 2



# Outlines

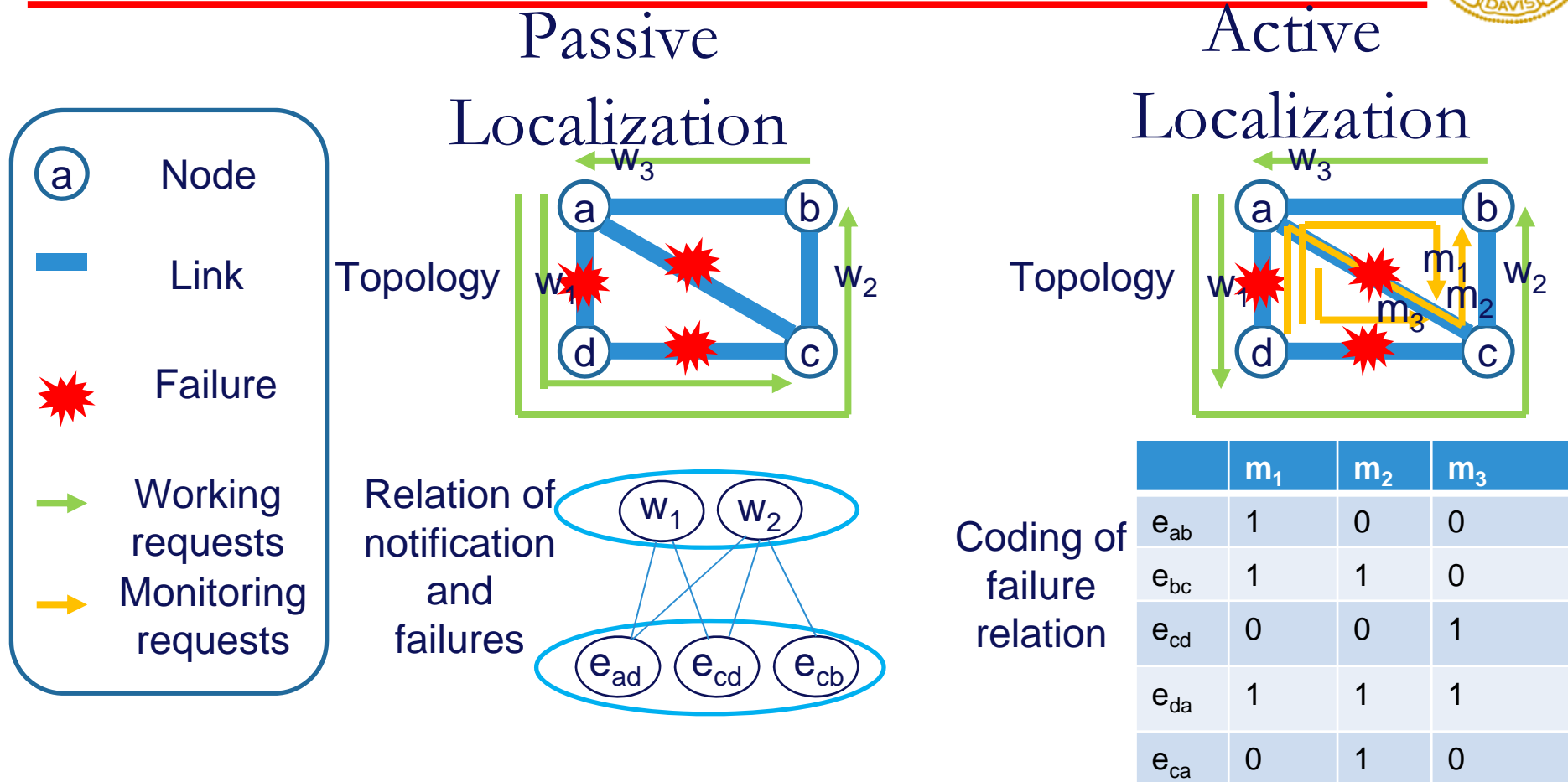
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# Failure Localization in AON (background)



- ◆ Advantages and disadvantages:
- Passive Localization: it can deal with dual-link failure, but it is inaccurate.
- Active Localization: it can accurately locate single-link failure, but cannot deal with multi-link failure.

# Publications of Localization Schemes

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Research Group (Bin Wu, Pin-Han Ho, Kwan L. Yeung, Janos Tapolcai) in the University of Waterloo and the University of Hong Kong has done a lot of work about active localization schemes.

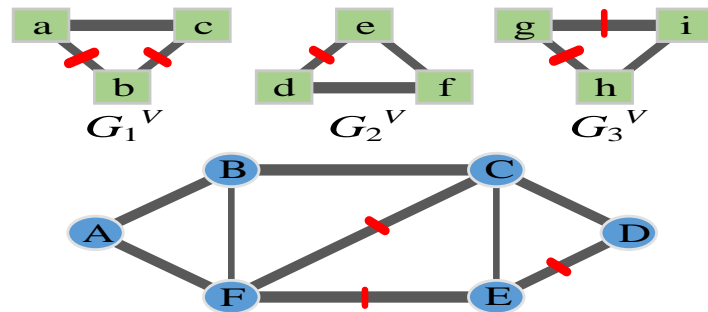
- IEEE Communications Surveys & Tutorials:2011
- IEEE/ACM Transactions on Networking: 2011\*2
- JLT: 2009\*2, 2011
- JOCN: 2012
- INFOCOM:2009, 2010
- Globecom: 2011

Research Group in BUPT has done some work about passive localization schemes.

- Optics Express: 2013
  - OFC: 2012
  - ECOC: 2012
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# Scenarios of TRP in All-Optical Networks



FVL: (a-b), (b-c), (e-d), (g-h), (g-i)  
 Suspected FPL: (B-F), (C-F), (D-E), (E-F)  
 Actual FPL: (C-F), (D-E), (E-F)

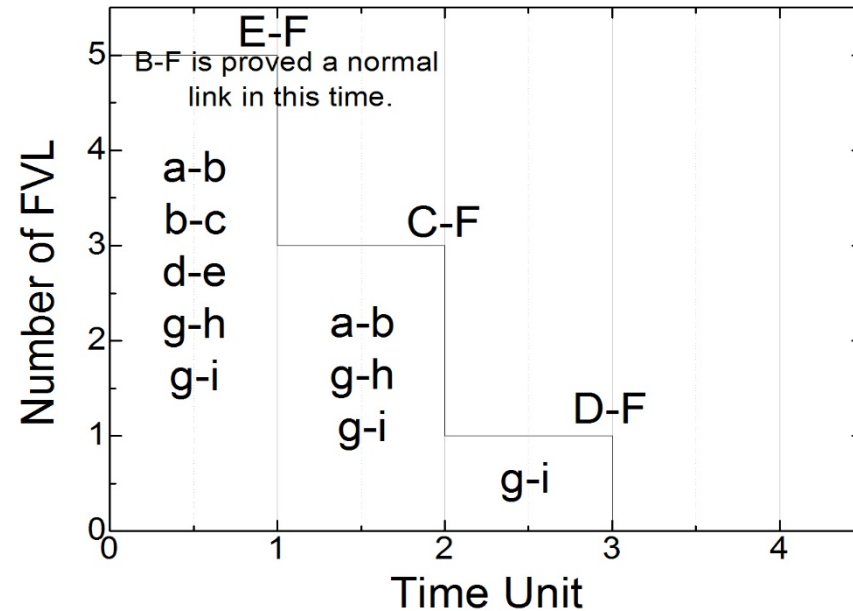
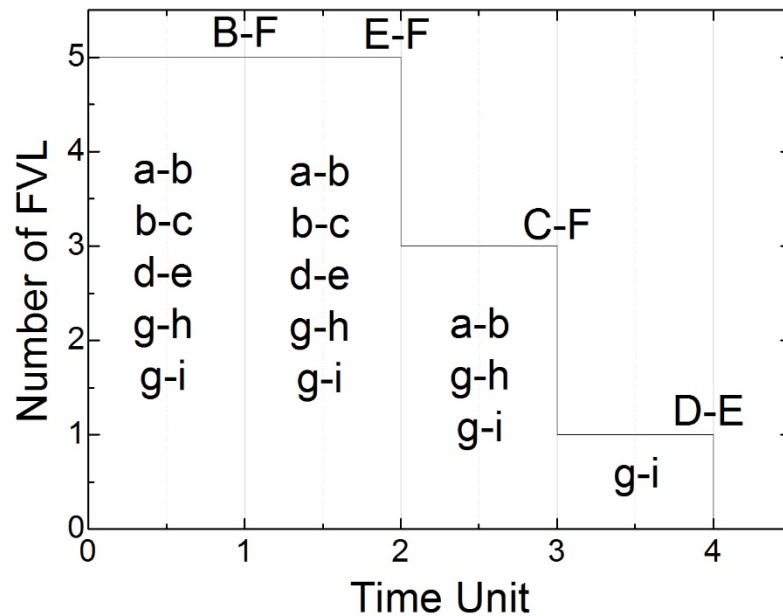
Virtual Networks	Virtual Link	Physical Link
$G_1^V$	a-b	C-F-B
	b-c	B-F-E
	c-a	C-E
$G_2^V$	d-e	E-F-B
	e-f	B-C
	f-d	C-E
$G_3^V$	g-h	E-F-C
	h-i	C-D
	i-g	D-E

## Pre-Conditions:

- The repairman does not know which physical links are out of work, but he knows the statements of virtual links and virtual networks.
- One time unit, the repairman can arrive one failure location, find the failure and repair it.



# Damage of FVL and DVN



- The damage of DVN and FVL for the TRP in AON is similar with the first problem.
- However, the steps of the TRP in AON is variable.





# Problem Statement

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## Input:

- $G^P$ : an all-optical network.
- $G^V$ : a set of  $S$  VNs.
- $G^{DVN}$ : the set of disconnected VNs (DVN).
- $\Pi^{VP}$ : a basic mapping relationship of  $G^P$  and  $G^V$ .
- $E^{FVL}$ : the set of failed virtual links (FVL).
- $E^{NVL}$ : the set of normal virtual links (NVL).

## Output:

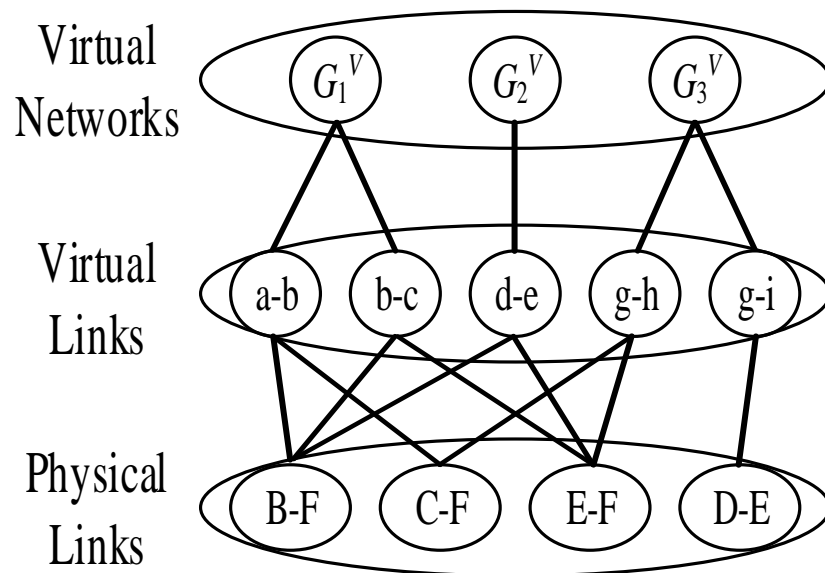
- The repairing process of all the failed virtual links.

## Objective:

- 1) Minimizing the damage of DVN;
  - 2) Based on Objective 1, minimizing the damage of FVL.
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# Mapping Relationship and Fuzzy Expectation



- Fuzzy Membership (it has been published in *Optics Express*):

$$\mu_{IJ} = \sum |E_{IJ}^{FVL}| / |E^{SF}| \quad \forall e_{IJ}^P \in E_i^{SF}$$

- Fuzzy expectation of FVL:

$$B_{(IJ),k}^{FVL} = \mu_{(IJ),k} \times \sum_{(ij) \in E^{FVL}} F_{(ij),k}^{FVL} \quad \forall e_{IJ}^P \in E^{SF}$$

- Fuzzy expectation of DVN:

$$B_{(IJ),k}^{DVN} = \mu_{(IJ),k} \times \sum_{G_i^V \in G^{DVN}} F_{i,k}^{DVN} \quad \forall e_{IJ}^P \in E^{SF}$$

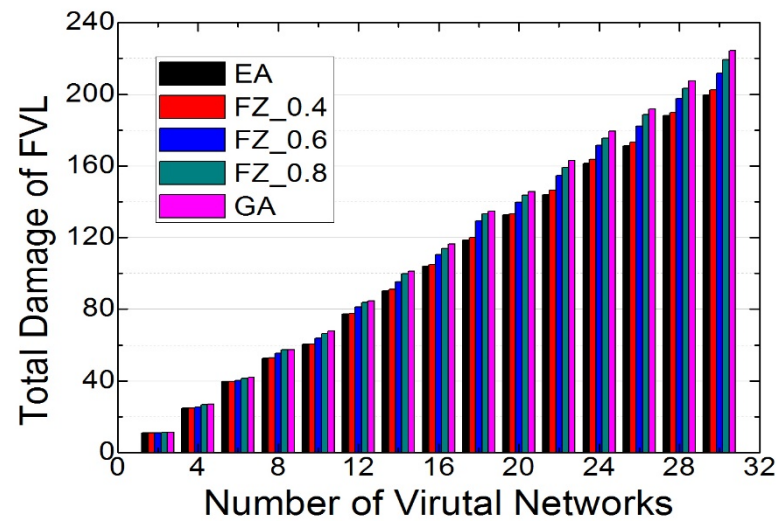
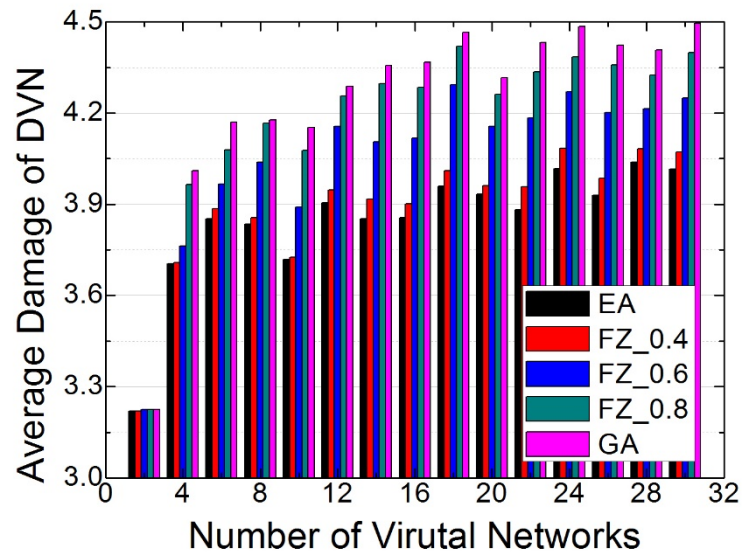
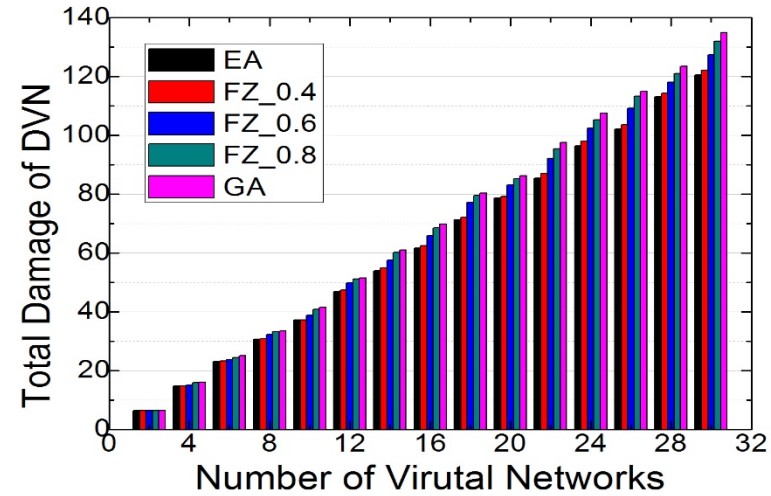
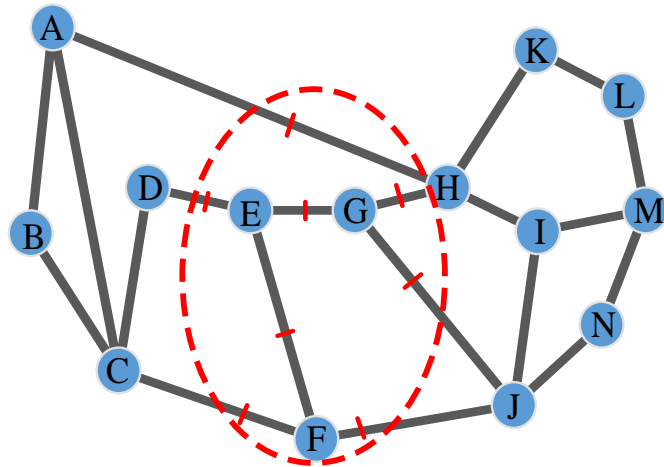
# Algorithms

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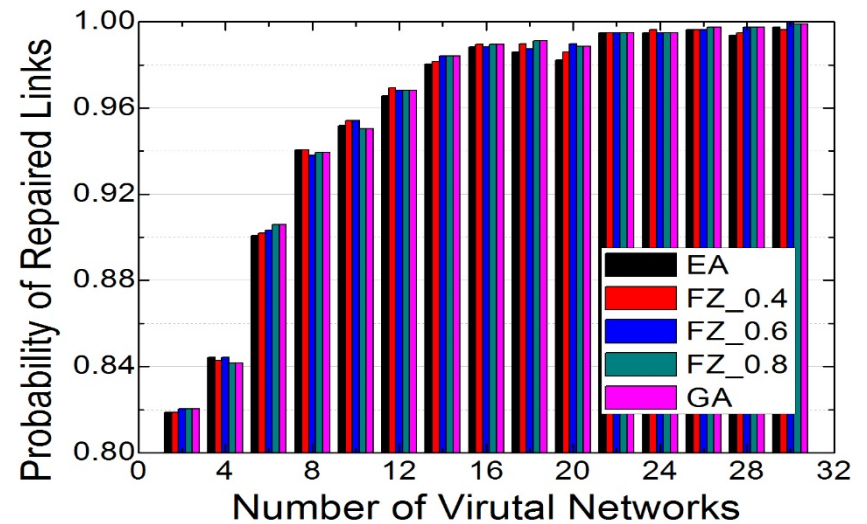
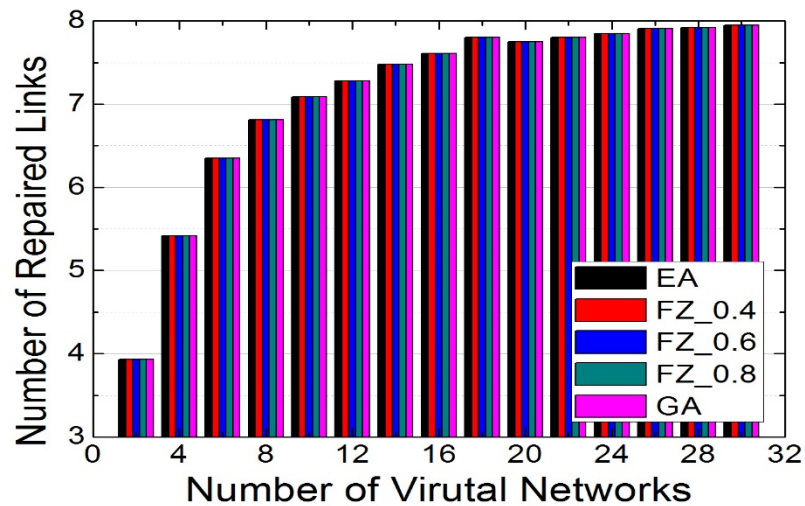
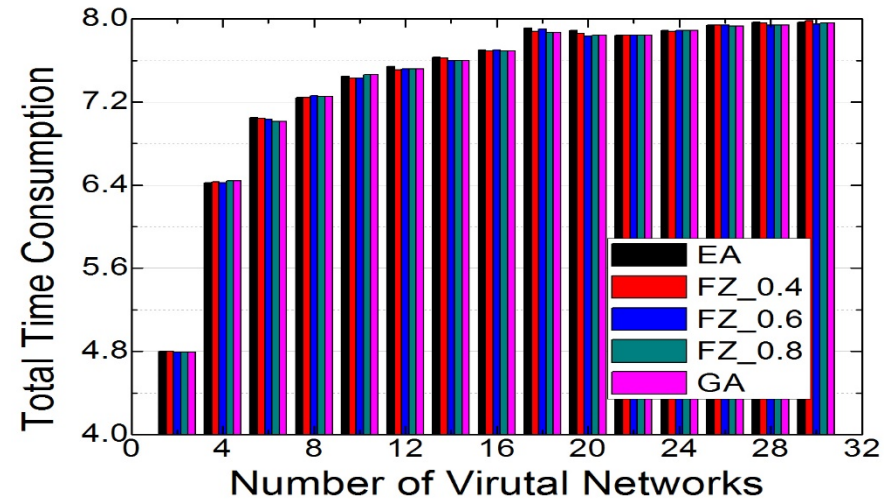
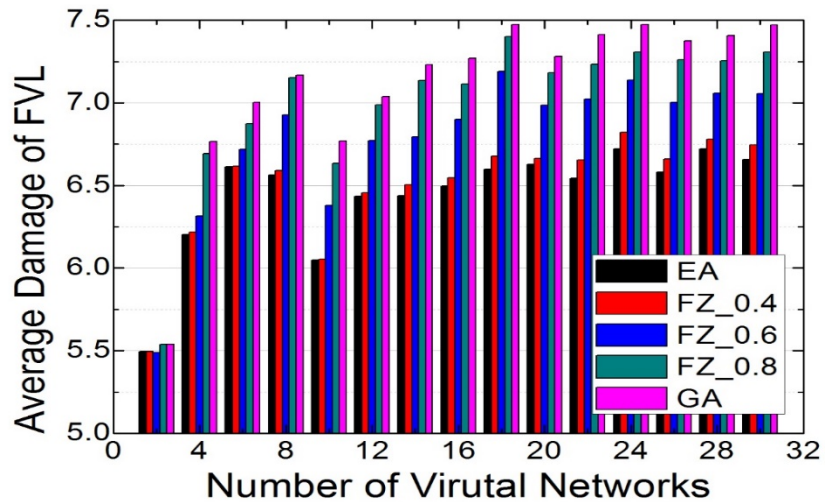


- Greedy Algorithm (GA)
- Enumeration Algorithm (EA)
- Fuzzy Thresh (FZ)

# Simulation Results - 1



# Simulation Results - 2



# Outlines

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## Future Works of TRP

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1. Improve the two proposed problems.
2. New **problems** for TRP:
  - Game Theory (Roy)
  - Remapping (Sedef)
  - Multi-Domain (Carlos)
  - Energy
3. The **algorithms** for the problems.



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Thank you!