Post-Disaster Technologies in Network Virtualization

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Group Meeting

August, 28, 2015

Outlines

1. **Review of Post-Disaster Technologies**
2. **(Open Problem 1) Multiple Traveling Repairmen Problem with Reprovisioning**
3. **(Open Problem 2) Virtual Network Degradation**

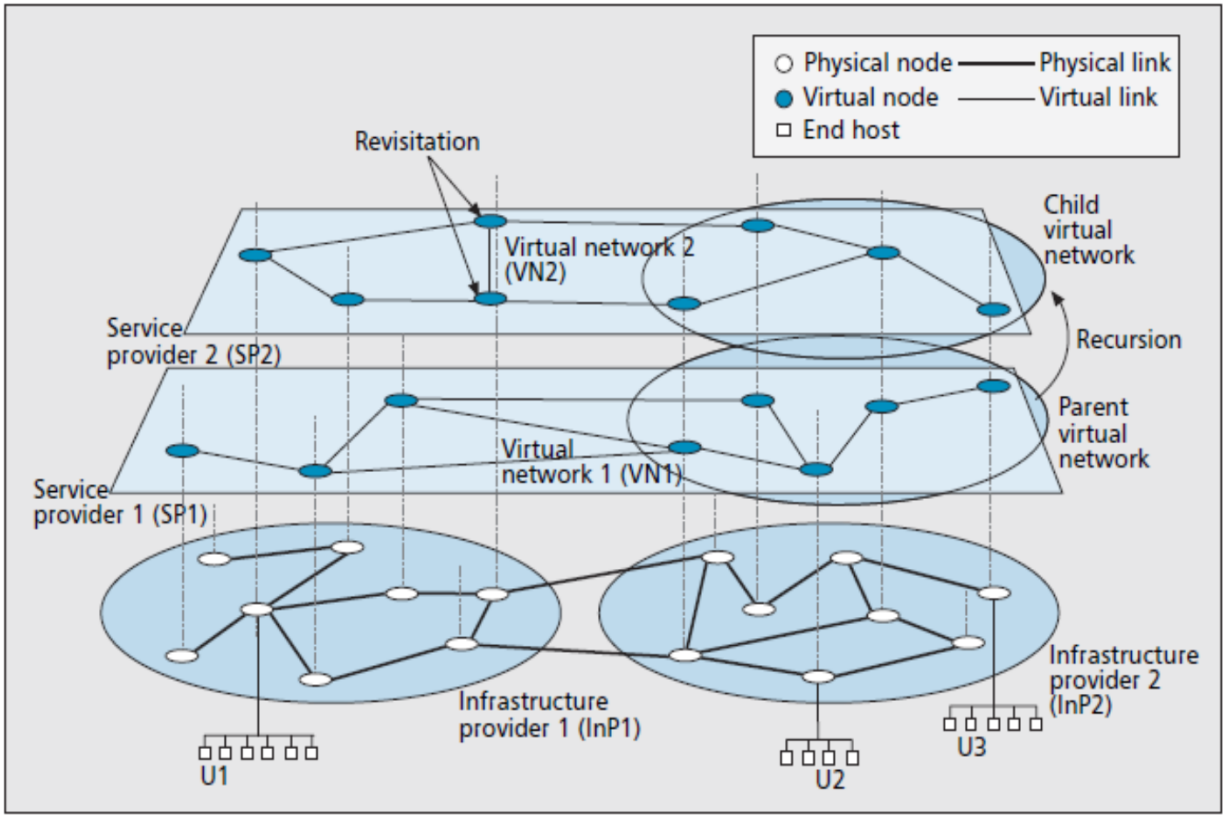
References

1. N. M. Mosharaf Kabir Chowdhurry, and Raouf Boutaba, “Network Virtualization: State of the Art and Research Challenges”, Communication Magazine, 2009.
2. http://www.bloomberg.com/news/articles/2013-10-20/at-t-agrees-to-4-85-billion-tower-deal-with-crown-castle
3. http://finance.sina.com.cn/focus/dxgg_ttgs/
4. Kenichi Mase, “How to Deliver Your Message from/to a Disaster Area,” Communication Magazine, 2011.
5. S. S. Savas, et al., “Network Adaptability to Disaster Disruptions by Exploiting Degraded-Service Tolerance,” Communication Magazine, 2014.
6. N. H. Bao, et al., “Global Versus Essential Post-Disaster Re-Provisioning in Telecom Mesh Networks,” JOCN, 2015.
7. A. Basta, I. B. Barla, M. Hoffmann, G. Carles, and D. A. Schupke, “Failure Coverage in Optimal Virtual Networks,” OFC, 2013.
8. C. C. Meixner, et al. “Cloud-Network Disaster Recovery Against Cascading Failures,” Globecom 2015
9. Kenichi Mase, “How to Deliver Your Message from/to a Disaster Area,” Communication Magazine, 2011.
10. Mahsa Pourvali, Kaile Liang, Feng Gu, Hao Bai, Khaled Shaban, Samee Khan, Nasir Ghani, “Progressive Recovery For Network Virtualization After Large-Scale Disasters,” ICNC 2016 (reviewed)

Background

- In recently years, the concept of network virtualization has attracted significant attention in both industry and academia [1].
- Network virtualization is defined by decoupling the roles of the traditional Internet service providers (ISPs) into two independent entities: infrastructure providers (InPs), who manage the physical infrastructure, and service providers (SPs), who create virtual networks (VNs) by aggregating resources from multiple InPs and offer end-to-end services [1].
- In the USA, Crown Castle and American Tower Corporation are the largest infrastructure providers for telecommunication. AT&T sold 9,700 wireless towers to Crown Castle in 2013, which means AT&T focus on providing service to end users [2].
- In China, China Tower Corporation was established in 2014. And China Mobile, China Union, China Telecom separate their towers and basic infrastructures to China Tower [3].

Business Model



■ **Figure 1.** *Network virtualization environment.*

Infrastructure provider (InP): InPs deploy and actually manage the underlying physical network resources. They offer their resources through programmable interfaces to different SPs.

Service provider (SP): SPs lease resources from multiple InPs to create and deploy VNs by programming allocated network resources to offer end-to-end services to end users. An SP can also provide network services to other SPs.

End user: End users in the network virtualization are similar to those of the existing Internet.

Survivability of Network Virtualization

Virtual Node

Capacity of computing, storing, transportation, et.al. It may be out of work after the disaster.

Virtual Link

Transportation capacity. It may be disconnected after the disaster.

Virtual Network

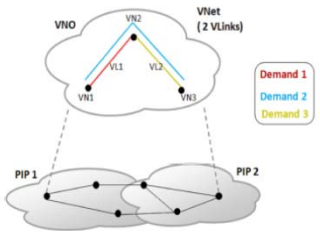
It is composed of virtual links and nodes. And it may be disconnected after the disaster.

End to end connection	Virtual networks
Affect to a connection path.	1. Affect to virtual links/nodes. 2. Affect to virtual networks.
Node cannot be replaced	Virtual node can be replaced. Such as virtual node migration.

Post-Disaster Technologies

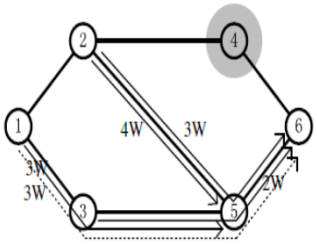
Protection [7]

ms, preconfigured before disaster
Temporary
Traffic Engenerring



Reprovisioning [5,6,8]

minutes~hours, after disaster
Temporary
Traffic Engineering



Emergence Communication [9]

hours~days, after disaster
Temporary
Network Engineering

Change the physical topology.

Repair [10]

hours~weeks, after disaster
Permanent
Network Engineering

Outlines

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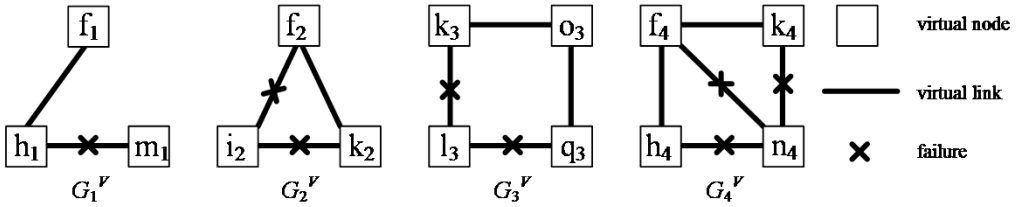
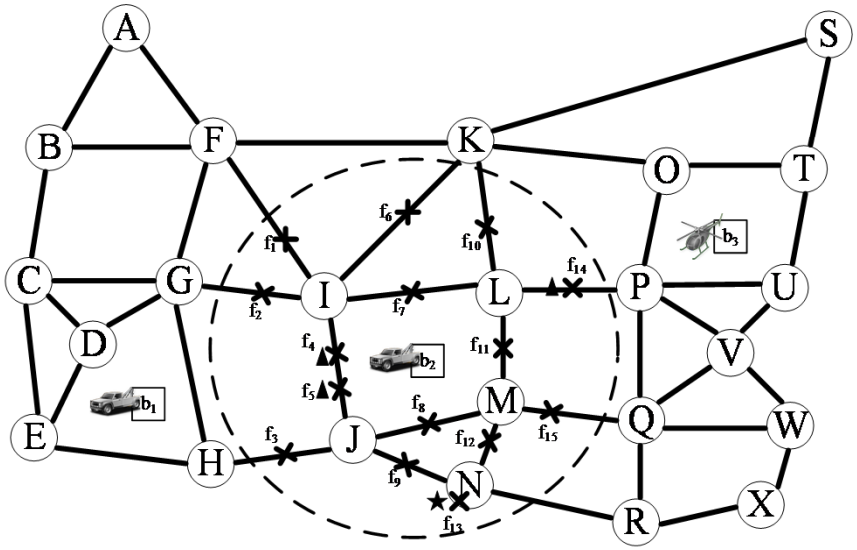
3. (Open Problem 2) Virtual Network Degradation

Problem Statement



VN	Virtual Link	Physical Link	Failure Location
G_1^V	$f_1 - h_1$	$F - G - H$	
	$h_1 - m_1$	$H - J - M$	f_3, f_8
G_2^V	$f_2 - i_2$	$F - I$	f_{10}, f_{11}
	$i_2 - k_2$	$I - L - K$	f_{15}
	$p_2 - k_2$	$P - K$	
G_3^V	$k_3 - m_3$	$K - L - M$	f_{10}, f_{11}
	$m_3 - q_3$	$M - Q$	f_{15}
	$q_3 - o_3$	$Q - P - O$	
	$o_3 - k_3$	$O - K$	
G_4^V	$f_4 - h_4$	$F - G - H$	
	$h_4 - n_4$	$H - J - N$	f_3, f_9, f_{13}
	$n_4 - k_4$	$N - M - L - K$	$f_{13}, f_{12}, f_{11}, f_{10}$
	$k_4 - f_4$	$K - F$	
	$f_4 - n_4$	$F - I - J - N$	$f_1, f_4, f_5, f_9, f_{13}$



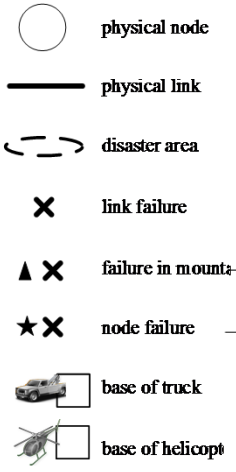


TABLE II: Travel and repair time of trucks (Hours).

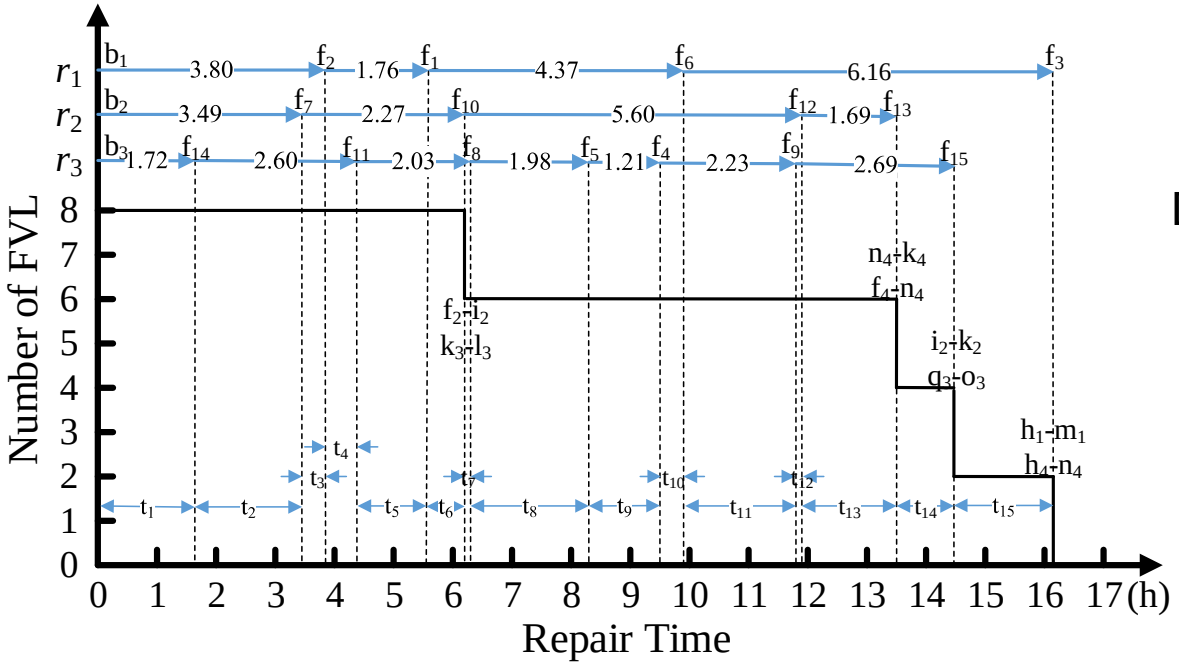
	f_1	f_2	f_3	f_6	f_7	f_8	f_9	f_{10}	f_{11}	f_{12}	f_{13}	f_{15}
b_1	4.85	3.80	4.61	7.18	6.44	6.73	7.05	7.74	7.63	7.28	7.36	8.69
b_2	5.50	4.92	4.78	5.26	3.49	3.68	4.58	5.11	4.40	4.52	4.61	4.46
f_1	-	1.76	6.37	4.37	4.06	7.16	7.23	5.07	7.10	8.18	8.42	8.46
f_2	1.76	-	5.81	5.38	4.75	6.66	6.49	5.44	7.70	8.09	8.02	8.29
f_3	6.37	5.81	-	6.16	5.12	4.90	4.67	6.67	5.26	4.91	4.88	5.27
f_6	4.37	5.38	6.16	-	2.77	5.96	6.23	2.52	4.79	5.98	6.34	6.35
f_7	4.06	4.75	5.12	2.77	-	3.54	3.90	2.72	3.24	4.26	4.50	5.69
f_8	7.16	6.66	4.90	5.96	3.54	-	1.57	5.66	2.57	1.59	2.26	3.74
f_9	7.23	6.49	4.67	6.23	3.90	1.57	-	6.46	4.02	1.83	1.62	4.22
f_{10}	5.07	5.44	6.67	2.52	2.72	5.66	6.46	-	3.40	5.60	6.21	6.02
f_{11}	7.10	7.70	5.26	4.79	3.24	2.57	4.02	3.40	-	3.49	4.14	3.28
f_{12}	8.18	8.09	4.91	5.98	4.26	1.59	1.83	5.60	3.49	-	1.69	2.45
f_{13}	8.42	8.02	4.88	6.34	4.50	2.26	1.62	6.21	4.14	1.69	-	3.81
f_{15}	8.46	8.29	5.27	6.35	5.69	3.74	4.22	6.02	3.28	2.45	3.81	-

TABLE III: Travel and repair time of helicopter (Hours).

	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	f_{10}	f_{11}	f_{12}	f_{14}	f_{15}
b_3	4.21	4.37	4.22	3.69	3.63	3.32	3.98	3.69	4.02	2.28	3.01	3.04	1.72	3.02
f_1	-	1.70	3.55	2.78	2.81	2.75	2.62	3.87	3.89	3.03	3.84	4.27	4.08	4.39
f_2	1.70	-	3.33	1.67	1.65	3.15	2.90	3.61	3.60	3.18	4.08	4.24	4.16	4.31
f_3	3.55	3.33	-	1.72	1.68	3.46	3.05	2.96	2.87	3.67	3.10	2.96	3.80	3.11
f_4	2.78	1.67	1.72	-	1.21	2.87	2.05	2.01	2.33	3.01	3.03	2.87	3.28	2.98
f_5	2.81	1.65	1.68	1.21	-	2.91	2.10	1.98	2.29	3.03	3.04	2.85	3.25	2.95
f_6	2.75	3.15	3.46	2.87	2.91	-	2.11	3.39	3.49	2.01	2.92	3.39	2.99	3.54
f_7	2.62	2.90	3.05	2.05	2.10	2.11	-	2.42	2.56	2.09	2.30	2.71	2.91	3.28
f_8	3.87	3.61	2.96	2.01	1.98	3.39	2.42	-	1.67	3.27	2.03	1.64	3.10	2.49
f_9	3.89	3.60	2.87	2.33	2.29	3.49	2.56	1.67	-	3.58	2.61	1.73	3.41	2.69
f_{10}	3.03	3.18	3.67	3.01	3.03	2.01	2.09	3.27	3.58	-	2.36	3.24	2.15	3.41
f_{11}	3.84	4.08	3.10	3.03	3.04	2.92	2.30	2.03	2.61	2.36	-	2.40	2.60	2.31
f_{12}	4.27	4.24	2.96	2.87	2.85	3.39	2.71	1.64	1.73	3.24	2.40	-	3.14	1.98
f_{14}	4.08	4.16	3.80	3.28	3.25	2.99	2.91	3.10	3.41	2.15	2.60	3.14	-	2.62
f_{15}	4.39	4.31	3.11	2.98	2.95	3.54	3.28	2.49	2.69	3.41	2.31	1.98	2.62	-

Recovery without Reprovisioning

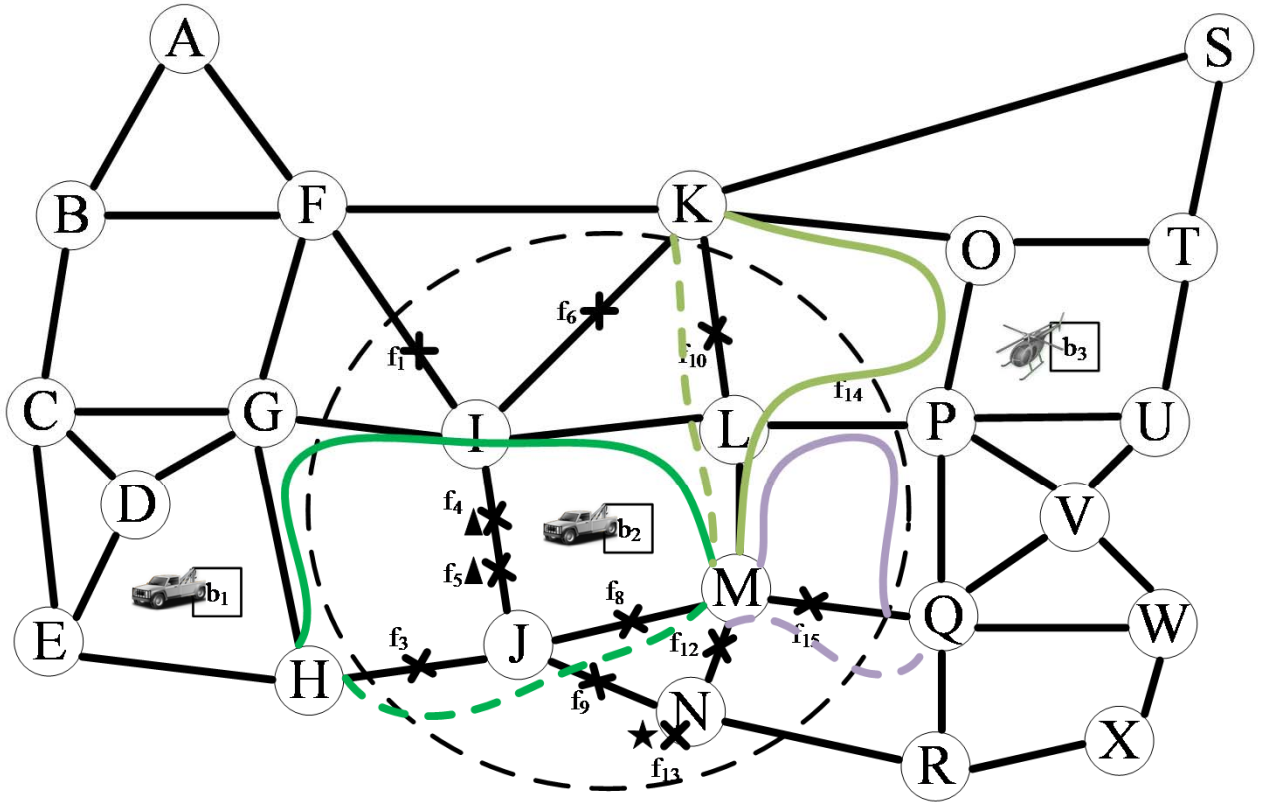
Failure:	▲f_{14}	f_7	f_2	f_{11}	f_1	f_{10}	f_8	▲f_5	▲f_4	f_6	f_9	f_{12}	★f_{13}	f_{15}	f_3
Repairmen:	r_3	r_2	r_1	r_3	r_1	r_2	r_3	r_3	r_3	r_1	r_3	r_2	r_2	r_3	r_1
Time:	1.72	1.77	0.31	0.52	1.24	0.65	0.14	1.98	1.21	0.39	1.84	0.04	1.69	0.96	1.63



D^{FVL}=5.76*8+7.29*6
+7.17*4+1.63*2
=122.13

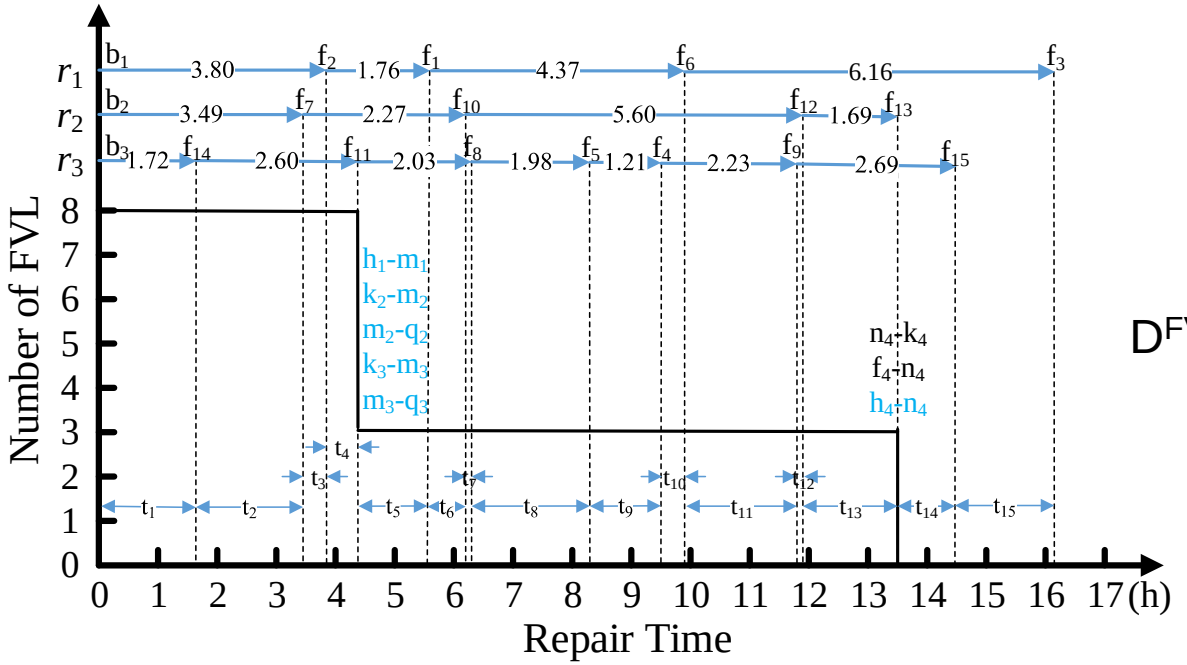
Recovery with Reprovisioning

Failure:	▲f_{14}	f_7	f_2	f_{11}	f_1	f_{10}	f_8	▲f_5	▲f_4	f_6	f_9	f_{12}	★f_{13}	f_{15}	f_3
Repairmen	r_3	r_2	r_1	r_3	r_1	r_2	r_3	r_3	r_3	r_1	r_3	r_2	r_2	r_3	r_1
Time:	1.72	1.77	0.31	0.52	1.24	0.65	0.14	1.98	1.21	0.39	1.84	0.04	1.69	0.96	1.63



Recovery with Reprovisioning

Failure:	▲f_{14}	f_7	f_2	f_{11}	f_1	f_{10}	f_8	▲f_5	▲f_4	f_6	f_9	f_{12}	★f_{13}	f_{15}	f_3
Repairmen:	r_3	r_2	r_1	r_3	r_1	r_2	r_3	r_3	r_3	r_1	r_3	r_2	r_2	r_3	r_1
Time:	1.72	1.77	0.31	0.52	1.24	0.65	0.14	1.98	1.21	0.39	1.84	0.04	1.69	0.96	1.63



D^{FVL}=4.32*8+8.73*3
=60.75

Two Problems of MTRPR

- How to find a repair schedule?
- How to figure out the damage of a schedule?

How to figure out the damage of a schedule.

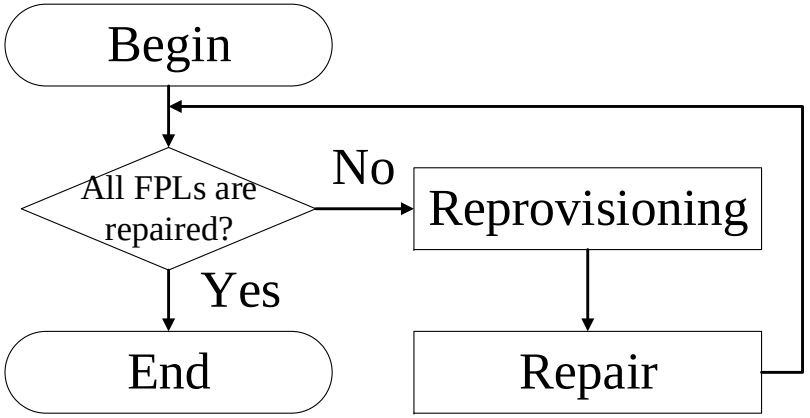
Given:

A repair schedule.

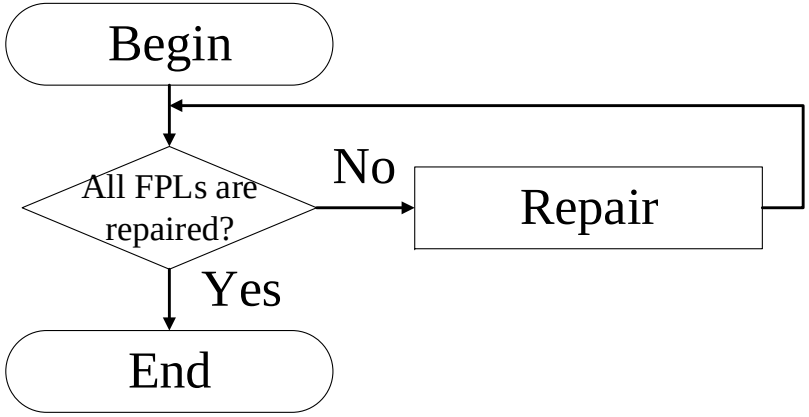
Output:

Damage caused by the FVL and DVN in the schedule.

Recovery with Reprovisioning



Recovery without Reprovisioning

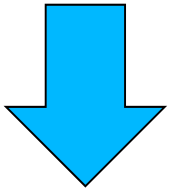


How to find a repair schedule.

Genetic Algorithm

Repair Schedule

Failure:	▲f_{14}	f_7	f_2	f_{11}	f_1	f_{10}	f_8	▲f_5	▲f_4	f_6	f_9	f_{12}	★f_{13}	f_{15}	f_3
Repairmen:	r_3	r_2	r_1	r_3	r_1	r_2	r_3	r_3	r_3	r_1	r_3	r_2	r_2	r_3	r_1
Time:	1.72	1.77	0.31	0.52	1.24	0.65	0.14	1.98	1.21	0.39	1.84	0.04	1.69	0.96	1.63

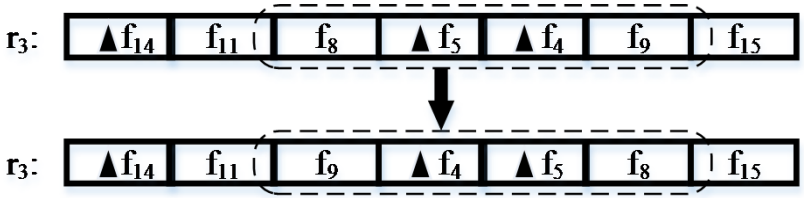


r_1:	f_2	f_1	f_6	f_3			
r_2:	f_7	f_{10}	f_{12}	★f_{13}			
r_3:	▲f_{14}	f_{11}	f_8	▲f_5	▲f_4	f_9	f_{15}

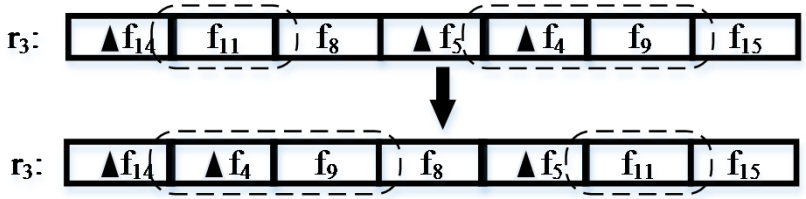
Multiple Chromosomes

Genetic Operators

Internal-route operator

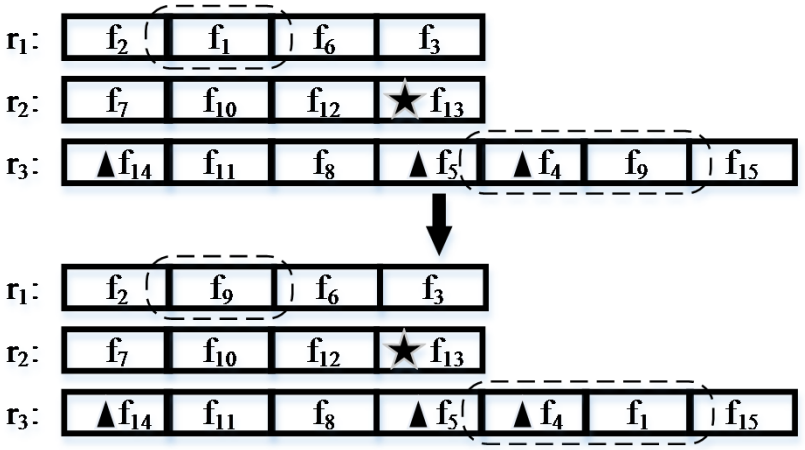


Internal-route inversion



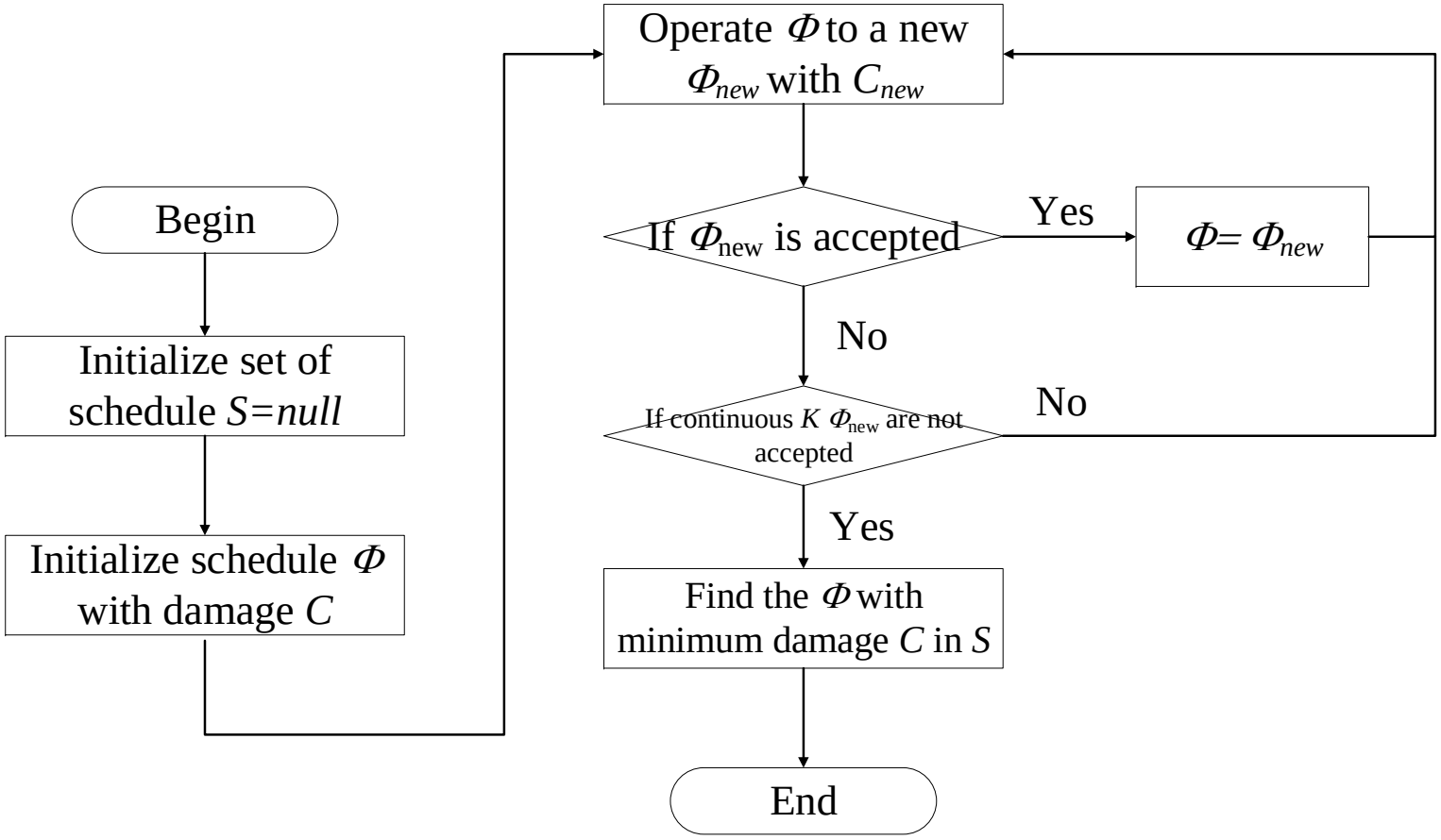
Internal-route transposition

External-route operator



External-route transposition

Process of GA



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2. (Open Problem 1) Multiple Traveling Repairmen Problem with Reprovisioning
3. (Open Problem 2) Virtual Network Degradation

Virtual Network Degradation (VND)

- After a disaster occurs,
  - which virtual network should be degraded?
  - what we can do to degrade the virtual networks?
  - which is different with the degradation in end to end connection?
- May be the answer:
  - In the schedule, network operators can select minimum the number of degraded virtual networks as the objective.
  - (1) Degrade the capacity of virtual links.

    (2) Delete several virtual links of a degraded virtual network.
  - Network operators should consider the connectivity of virtual networks.

Thanks!

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Charles U Martel

Massimo Tornatore

Everyone!

谢谢！