Protection in Cloud: from Network Connectivity to Content Connectivity

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Workshop

Design and Provisioning Strategies for Optical Networks @ KTH

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Content, Content Everywhere

- Social media
- Multimedia streaming
- Online search
- Online gaming
- eScience data
- Bank/financial transactions
- …
- 90% of the total Internet traffic
  is generated due to content dissemination

Is Content Protected in the Cloud?

November 6, 2012

IEEE is experiencing significant power disruptions to our U.S. facilities in New Jersey and New York. As a result, you may experience disruptions in service from IEEE.

- The **Sidekick data outage of 2009** resulted in an estimated 800,000 smartphone users in the United States losing personal data

- **Amazon's cloud crash in April, 2011** took down a plethora of sites (e.g., Reddit, Foursquare, Quora, etc.) for days and permanently destroyed many customers' data

- **Hotmail data loss in Dec. 2010** temporarily wiped emails for thousands of users

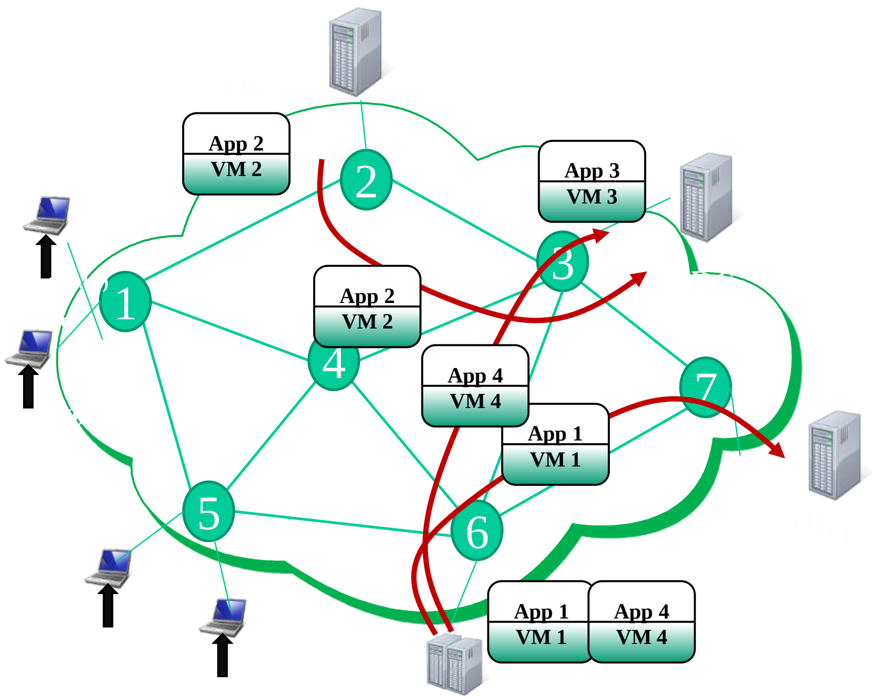
Is Content Protected in the Cloud?

- **In June 2012, a lightning storm hit the Amazon Virginia data center**, taking Netflix as well as Pinterest, Instagram and other sites off line for hours
- Two **Sprint fiber optic cuts disrupted Alaska Airline's operation** in Oct. 2012
- Recent survey shows **"data loss" at no. 2** of top cloud threat list
- Survey shows that in 2011, **19% of the businesses that experienced data loss are from the cloud**
- ….

"Fault-Tolerant Virtual Network Mapping to Provide Content Connectivity in Optical Networks," M. F. Habib et al.

Optical Networks & Cloud Services

- Nowadays ***Cloud Services*** are changing the basic connectivity paradigm in optical networks: *from user-to-user to user-to-content*



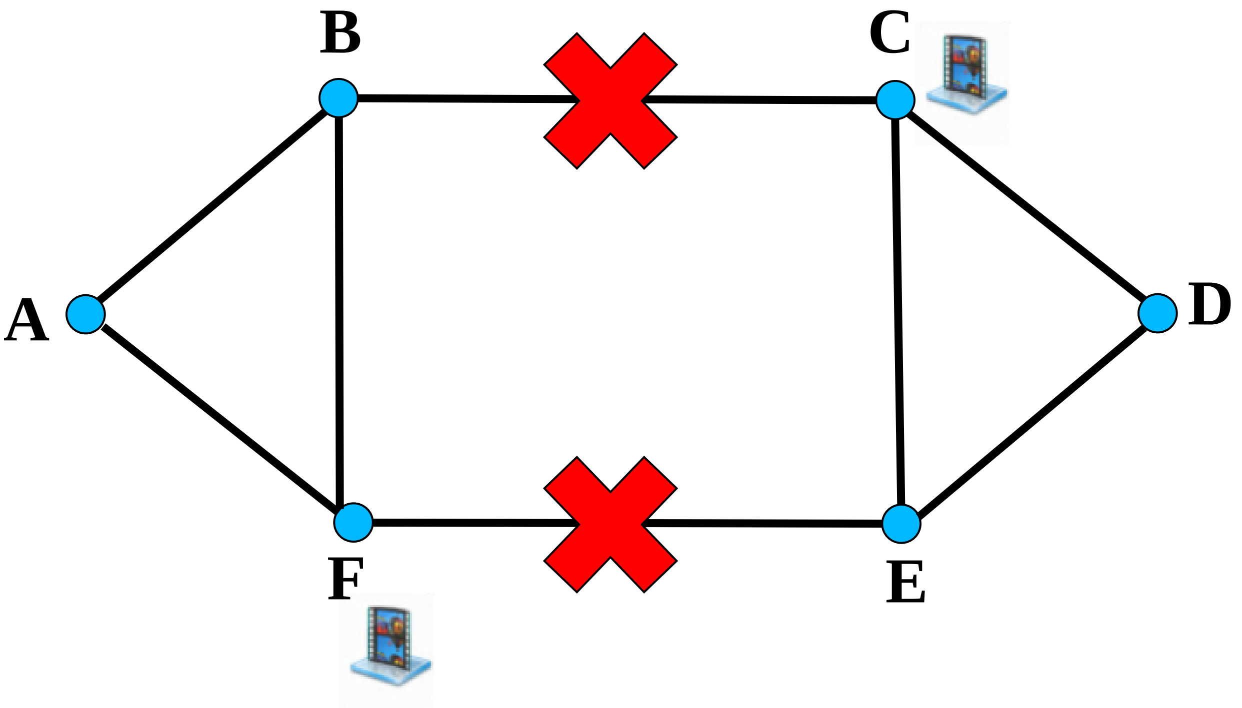
End-to-End → End-to-Content

- Traditional Concept: <u>Network Connectivity</u>
  - Reachability of every network node from all other nodes

- New Concept: <u>Content Connectivity</u>
  - Reachability of every content from any point of a network

"Fault-Tolerant Virtual Network Mapping to Provide Content Connectivity in Optical Networks," M. F. Habib et al.

Content Connectivity

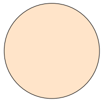


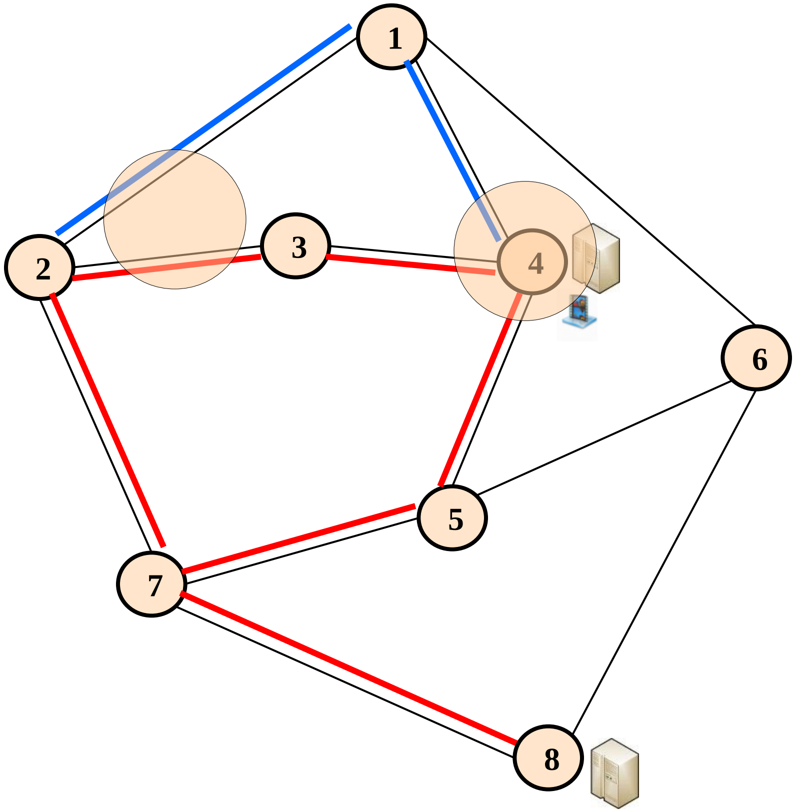
Design of Disaster-Resilient Datacenter Networks

F. Habib, M. Tornatore, M. De Leenheer, F. Dykbyik, B. Mukherjee, in IEEE/OSA Journal of Lightwave Technology, Vol. 30, No. 16, pp. 2563-2573 , Aug. 2012

Protection in Cloud

 Datacenter

 Disaster zone



- Issues
  - Path failure
  - Datacenter failure
  - Content/service failure

Mathematical Optimization

Objective

$$\min \left(\sum_{i,j} \pi_{i,j} + \sum_{i,j} \sum_{s,c} P_{(i,j)}^{(s,c)} \right)$$

Flow-Conservation Constraints

$$\sum_{j:(i,j)\in E} P_{(i,j)}^{(s,c)} - \sum_{j:(j,i)\in E} P_{(j,i)}^{(s,c)} = \begin{cases} 1 & \text{if } i = s \\ -A_i^{(s,c)} & \text{if } i \in V' \quad \forall (s,c) \in T, \forall i \in V \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

$$\sum_{j:(i,j)\in E} B_{(i,j)}^{(s,c)} - \sum_{j:(j,i)\in E} B_{(j,i)}^{(s,c)} = \begin{cases} 1 & \text{if } i = s \\ -\bar{A}_i^{(s,c)} & \text{if } i \in V' \quad \forall (s,c) \in T, \forall i \in V \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

$$\sum_{d\in V'} A_d^{(s,c)} = 1 \quad \forall (s,c) \in T \quad (3)$$

$$\sum_{d\in V'} \bar{A}_d^{(s,c)} = 1 \quad \forall (s,c) \in T \quad (4)$$

Datacenter Assignment and Content Placement

$$R^{(c,d)} \geq A_d^{(s,c)} + \bar{A}_d^{(s,c)} \quad \forall c \in C, \forall d \in V', \forall (s,c) \in T \quad (5)$$

$$\sum_{d\in V'} R^{c,d} \leq K \quad \forall c \in C \quad (6)$$

Capacity Constraints

$$\sum_{(s,c)} P_{(i,j)}^{(s,c)} + \pi_{(i,j)} \leq W \quad \forall (i,j) \in E \quad (7)$$

Disaster-Zone-Disjoint Path Constraints

$$\frac{\sum_{(i,j)\in x} P_{(i,j)}^{(s,c)}}{M} \leq \alpha_x^{(s,c)} \leq \sum_{(i,j)\in x} P_{(i,j)}^{(s,c)} \quad \forall (s,c) \in T, \forall x \in D \quad (8)$$

$$\frac{\sum_{(i,j)\in x} B_{(i,j)}^{(s,c)}}{M} \leq \beta_x^{(s,c)} \leq \sum_{(i,j)\in x} B_{(i,j)}^{(s,c)} \quad \forall (s,c) \in T, \forall x \in D \quad (9)$$

$$\alpha_x^{(s,c)} + \beta_x^{(s,c)} \leq 1 \quad \forall (s,c) \in T, \forall x \in D \quad (10)$$

Shared Protection Constraints

$$\pi_{(i,j)} \geq \sum_{(s,c)} B_{(i,j),x}^{(s,c)} \quad \forall x \in D, \forall (i,j) \in E \quad (11)$$

$$B_{(i,j),x}^{(s,c)} \leq \alpha_x^{(s,c)} \quad \forall (s,c) \in T, \forall x \in D, \forall (i,j) \in E \quad (12)$$

$$B_{(i,j),x}^{(s,c)} \leq B_{(i,j)}^{(s,c)} \quad \forall_{(s,c)\in T}, \forall x \in D, \forall (i,j) \in E \quad (13)$$

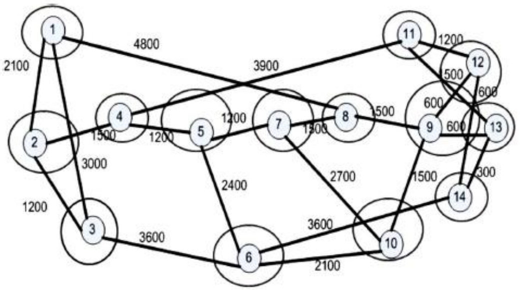
$$B_{(i,j),x}^{(s,c)} \geq \alpha_x^{(s,c)} + B_{(i,j)}^{(s,c)} - 1 \quad \forall (s,c) \in T, \forall x \in D, \forall (i,j) \in E \quad (14)$$

Summary of Results

- Resource consumption for disaster protection exploiting anycasting -
  - 5-10% less than dedicated single link failure protection
  - 10-20% more than shared single link failure protection

- A small number of datacenters and content replicas can ensure disaster survivability

T. L. Weems, “How far is far enough,” *Disaster Recovery J.*, vol. 16, no. 2, Spring 2003



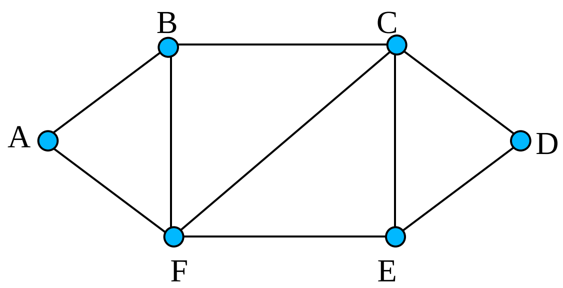
Fault-Tolerant Virtual Network Mapping to Provide Content Connectivity in Optical Networks

OFC/NFOEC 2013

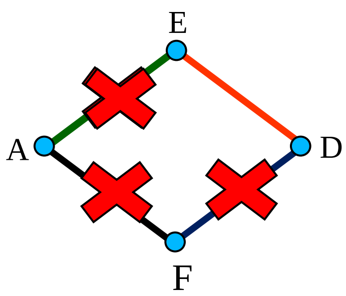
Session: OTh3E - Virtualization in Networks

March 21, 2013

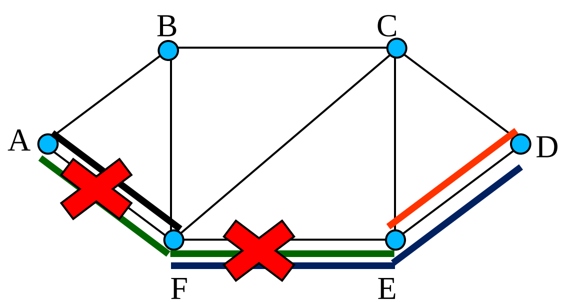
Traditional Virtual Network Mapping
(Ensuring Network Connectivity)



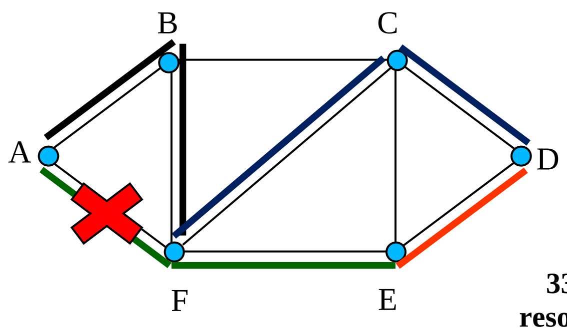
Physical Topology



Logical Topology



Non-Survivable Mapping



33% more resource usage

Survivable Mapping

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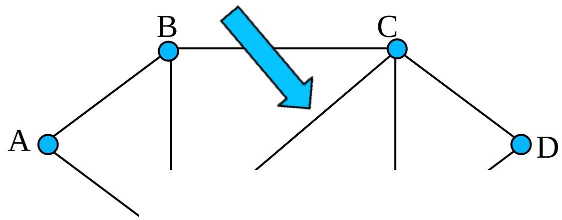
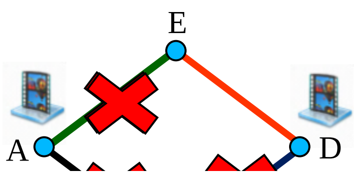
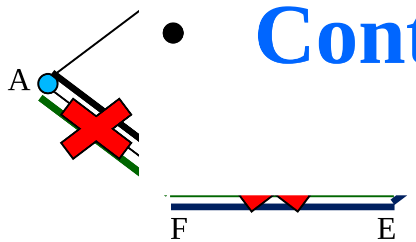
New Virtual Network Mapping
(Ensuring Content Connectivity)





Factors:
- Virtual network mapping
- Content placement



Content-Connected
Survivable Mapping

Network-Connected
Survivable Mapping

No survivable mapping for network connectivity

re
resource usage

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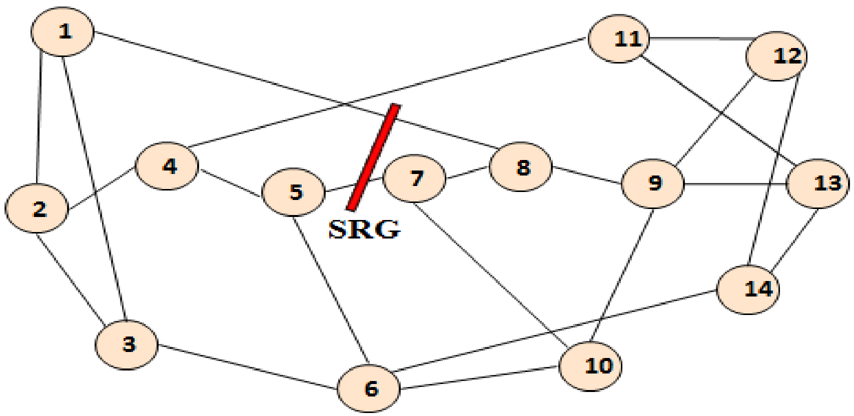
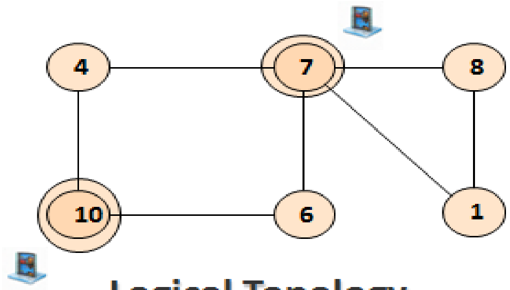
Overall Optimization Problem

- Input
  - Physical topology
  - Logical topology
  - Storage locations
- Output
  - Routing
  - Content placement
- Objective
  - Ensure content connectivity
  - Minimize network resource usage
- Constraints
  - Storage constraint
  - Flow constraint

Resource Savings

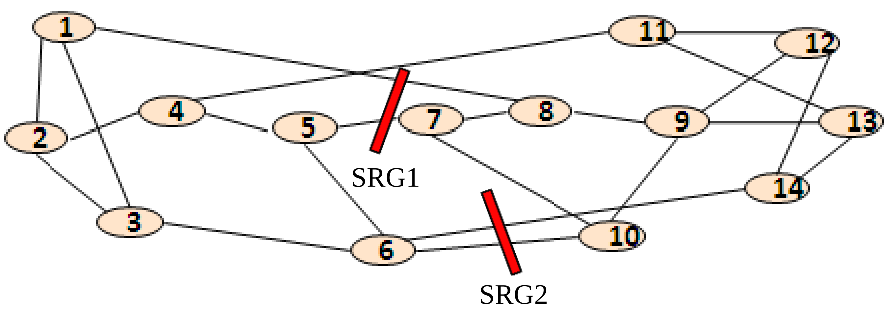


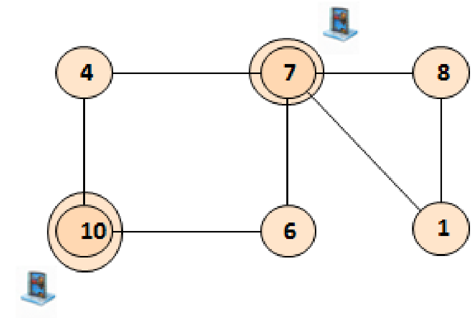
Physical Topology



Logical Topology

Impact of Multiple Failures





	Single link failure	Single link failure and SRG 1	Single link failure and SRGs 1 and 2
Content Connectivity			
Network Connectivity			

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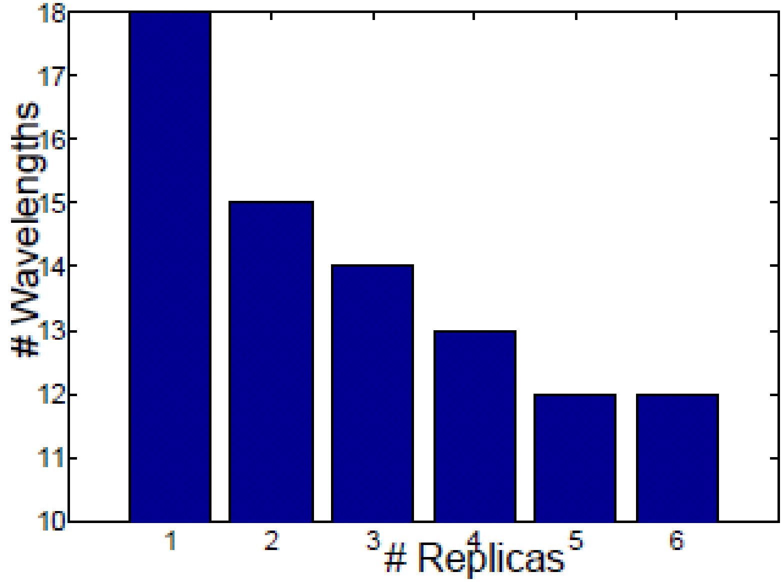
Effects of Replicas and Storage Locations



	# Storage Locations			
# Wavelengths	1	2	3	4
	18	15	15	15

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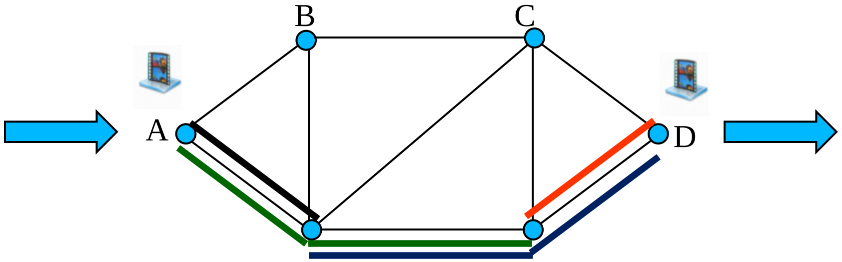
Conclusion

- As network is becoming progressively content-centric, ensuring ***content connectivity*** is becoming increasingly important
- Maintaining network connectivity may not always be possible after failures. Content connectivity can help us to provide/continue services in such scenarios
- Ensuring content connectivity requires less network resources than network connectivity



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Thanks