Content Connectivity Against Multilink Failures in Optical Metro Networks: Result Comparison

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Outline

- Result comparison of new approach with previous works [1], [2], [3]
- Qualifying Exam (Q.E.) agenda

[1] M. F. Habib, M. Tornatore, and B. Mukherjee, "Fault-tolerant virtual network mapping to provide content connectivity in optical networks," *Proc. IEEE/OSA Opt. Fiber Commun. Conf. (OFC13)*, Mar. 2013.
[2] A. Hmaity, F. Musumeci, and M. Tornatore, "Survivable virtual network mapping to provide content connectivity against double-link failures," *Proc. 12th Conf. Design of Reliable Comm. Networks (DRCN)*, Mar. 2016.
[3] E. Modiano and A. Narula-Tam, "Survivable lightpath routing: a new approach to the design of wdm-based networks," *IEEE Journal on Selected Areas in Communications*, vol. 20, no. 4, pp. 800–809, May 2002.

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Content Connectivity Against Multilink Failures

- CC-n Existence:

Theorem 1. *Given $G_P(V_P, E_P)$, $G_L(V_L, E_L)$, and $D \subset V_L$, to find the mapping of G_L over G_P that guarantees CC-n, the following conditions must be satisfied:*

- *each logical node $s \in V_L - D$ has a nodal degree $\delta(s) \geq n+1$, and*
- *each physical node $i \in V_P : i = s$ has a nodal degree $\delta(i) \geq n+1$.*

- CC-n Enforcement:

Theorem 2. *Given $G_P(V_P, E_P)$, $G_L(V_L, E_L)$, $D \subset V_L$, let $\mathcal{P}_n = \{\{P_n^k\} : |\{P_n^k\}| = n, \{P_n^k\} \subset E_P\}$ be the set of all possible combinations of n distinct physical links, and $C_{CC} = \{C_{CC}^l(S_l, V_L - S_l) : S_l \cap D = \varnothing\}$ be the set of logical topology content-connected cutsets where the removal of all logical links in each cutset C_{CC}^l disconnects $G_L(V_L, E_L)$ and divides V_L into two disjoint sets with one set without DCs, the mapping of G_L over G_P is CC-n if and only if*

$$\sum_{\substack{ij \in P_n^k \\ st \in C_{CC}^l}} f_{ij}^{st} \leq |C_{CC}^l| - 1, \ \forall P_n^k \in \mathcal{P}_n, \ \forall C_{CC}^l \in C_{CC}.$$

- Mathematical Formulation

Inputs and variables

- $G_P(V_P, E_P)$, $G_L(V_L, E_L)$, n, D, $\mathcal{P}_n$, C_{CC}, and f_{ij}^{st} have been introduced in Section II.
- W is the number of wavelengths per physical link.
- F_{ij} is the number of fibers on the physical link ij.

Objective function

$$\min \sum_{ij \in E_P, \ st \in E_L} f_{ij}^{st} \quad (1)$$

Subject to:

$$\sum_{st \in E_L} f_{ij}^{st} \leq F_{ij} \times W, \quad \forall ij \in E_P \quad (2)$$

$$\sum_{j: ji \in E_P} f_{ji}^{st} - \sum_{j: ij \in E_P} f_{ij}^{st} = \begin{cases} -1 & \text{if } i = s \\ 1 & \text{if } i = t \\ 0 & \text{otherwise} \end{cases}, \quad \forall i \in V_P, \forall st \in E_L \quad (3)$$

$$\sum_{\substack{ij \in P_n^k \\ st \in C_{CC}^l}} f_{ij}^{st} \leq |C_{CC}^l| - 1, \ \forall P_n^k \in \mathcal{P}_n, \ \forall C_{CC}^l \in C_{CC} \quad (4)$$

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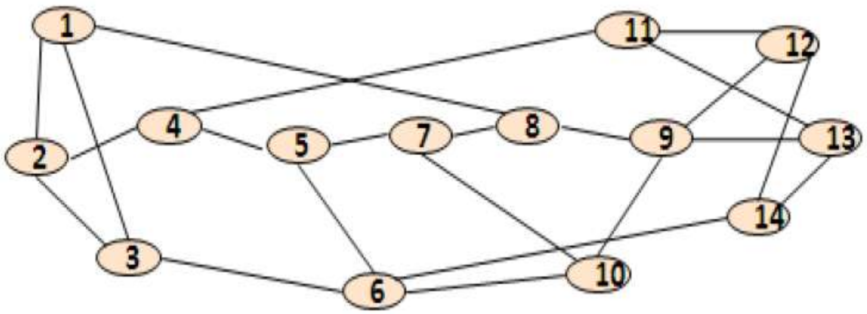
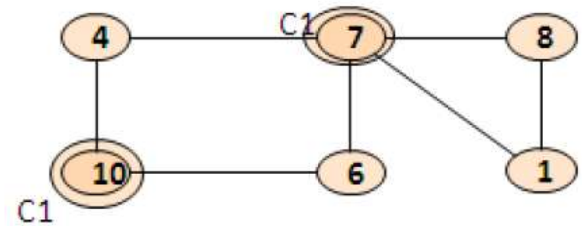
Result Comparison with Previous Works [1]



(a) Physical Topology



DCs at Node 7 and 10

(b) Logical Topology

Protection	Previous work [1]	This work
NC-1	15	15
CC-1	17	17

- In [1], single-link failures are considered.
- In [1], Shared Risk Groups (SRG, deterministic model) are considered.

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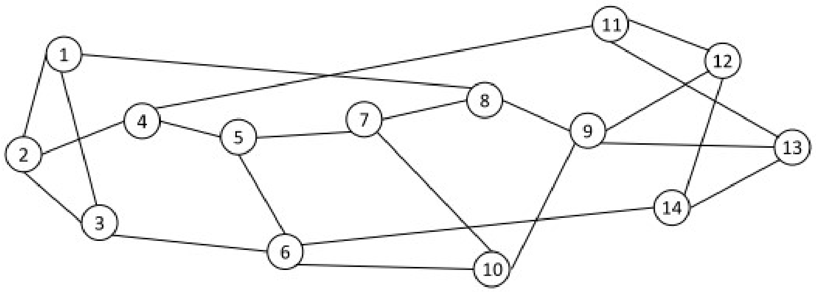
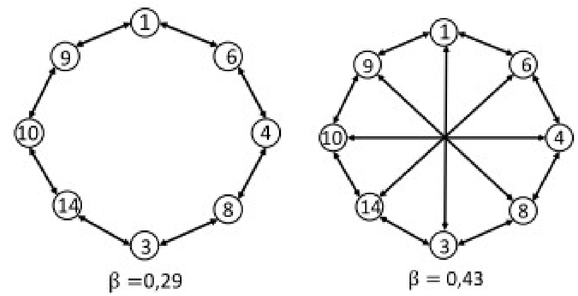
[1] M. F. Habib, M. Tornatore, and B. Mukherjee, "Fault-tolerant virtual network mapping to provide content connectivity in optical networks," *Proc. IEEE/OSA Opt. Fiber Commun. Conf. (OFC13)*, Mar. 2013.

Result Comparison with Previous Works [2]



Physical Topology



Logical Topologies

Protection	Beta = 0.29		Beta = 0.43	
	[2]	This work	[2]	This work
NC-1	28	NA	48	46
CC-1	42	42	42	46
NC-2	NA	NA	70	NA
CC-2	NA	NA	46	NA
NC-1 + CC-2	NA	NA	46	NA

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[2] A. Hmaity, F. Musumeci, and M. Tornatore, "Survivable virtual network mapping to provide content connectivity against double-link failures," *Proc. 12th Conf. Design of Reliable Comm. Networks (DRCN)*, Mar. 2016.

Novelty and Extendable Considerations

- Scalability: In addition to number of constraints and variables, a formal method to analyze complexity is required.
- Better network preparation for disasters by generalizing the CC problem to an arbitrary number of link failures
- Considerations:
  - ✓Do we need to consider all possible failure combinations?
  - ✓Risk probability, SRGs should be included to highlight scenarios NC is not possible.

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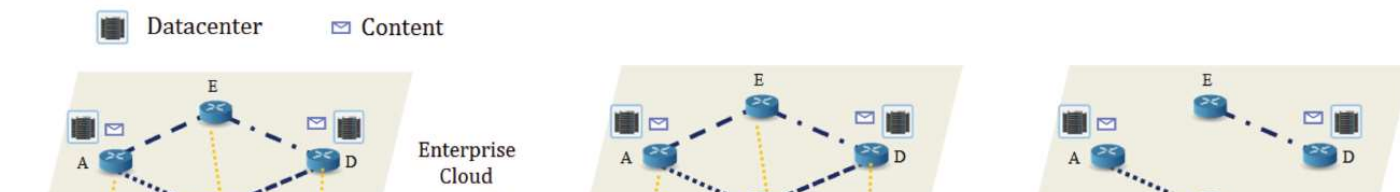
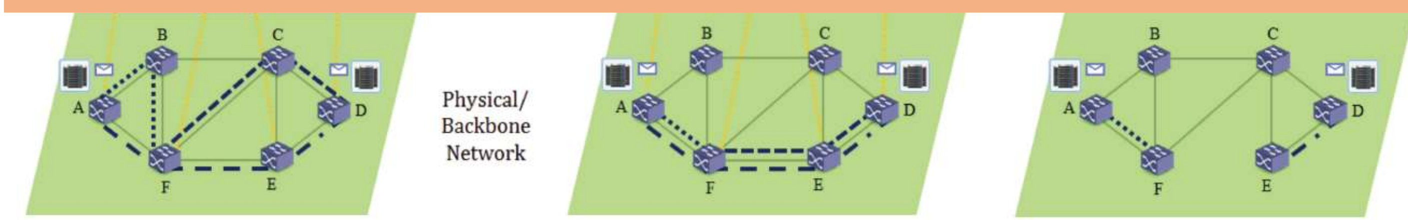
Dummy Node Solution for the CC Problem

Content Connectivity - **ensure reachability of content from any point of a network (end-to-content) even in case of a disaster partitioning the network**



- ***But we need lot of overhead traffic for replica and synchronization of content!***
- ***-> Task 4***



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Optical Multicast for Effective Content Sync

"Content connectivity" can be realized only if relevant data is replicated in several edge DCs

- *Constant and intensive synchronization and backup procedures among edge DCs via optical multicasting (Verification on OPCI network testbed)*

- ***Selection of multicast tree leaves for disaster resiliency*** - How do we determine which nodes receive the synchronization data of the multicast tree?
- ***Slicing and multicasting*** - How to slice network resources for multicast transmissions?
- ***Verification of optical multicasting with SDN control in Sendai testbed*** - SDN controllers need to monitor transmitted data and to construct multicasting slices considering the locations of edge DCs.

OPCI network testbed @Sendai NICT branch

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Qualifying Exam Agenda

Title: Disaster-Resiliency Strategies for Next-Generation Metro Optical Networks

Sections:

- Cover (title, committee)
- Acknowledgements
- Abstract
- Table of content
- List of figures
- List of tables

Sections:

- Chapter 1: Introduction
  - ✓ Why metro optical network resiliency
  - ✓ Components and how to provide the resiliency
- Chapter 2: Content Connectivity in Optical Metro Networks
- Chapter 3: Future Work
  - ✓ Short-termed: extend ANTS: delay (propagation and processing) as BW, latency, and resiliency are three important attributes of future networks, shared protection
  - ✓ Long-termed: load balance, risk probability, degraded, grooming, diverse capacity and traffic

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