Content Connectivity Optimization Problem from an Implementation Aspect

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Outline

- Calculation the number of Network-Connectivity (NC) Cutsets and Content-Connectivity (CC) Cutsets in a logical topology
- Content Connectivity ILPs' complexity in terms of number of variables and constraints: calculation and comparison
- Scenarios where Content Connectivity has advantages over Network Connectivity
- Questions when implementing new approaches for Content Connectivity

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Number of NC Cutsets

- All calculations made on a logical topology $G_L(V_L, E_L)$
- D is set of datacenters in the logical topology.
- Number of nodes and links in the logical topology are $N_L = |V_L|$ and $L_L = |E_L|$.
- A *Cut* divides V_L into two disjoint sets S and $V_L - S$.
- Let number of nodes in S is $k = |S|$, the maximum number of NC cutsets:

$$\frac{N_L!}{k!\,(N_L - k)!}$$

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Number of NC Cutsets

- For each k how may cutsets in NC are valid for a specific logical topology?
  - ✓Cutsets which have direct logical links between S and $V_L - S$
- How may k?
  - ✓ $1 \leq k \leq N_L - 1$
- Total number of valid NC cutsets:
  - ✓ $\sum_{k=1}^{N_L-1} \frac{N_L!}{k!(N_L-k)!}$
  - ✓ Combination with no order and no repetition

Number of CC Cutsets

- Content Connectivity cutset is a subset of the Network Connectivity Cutset

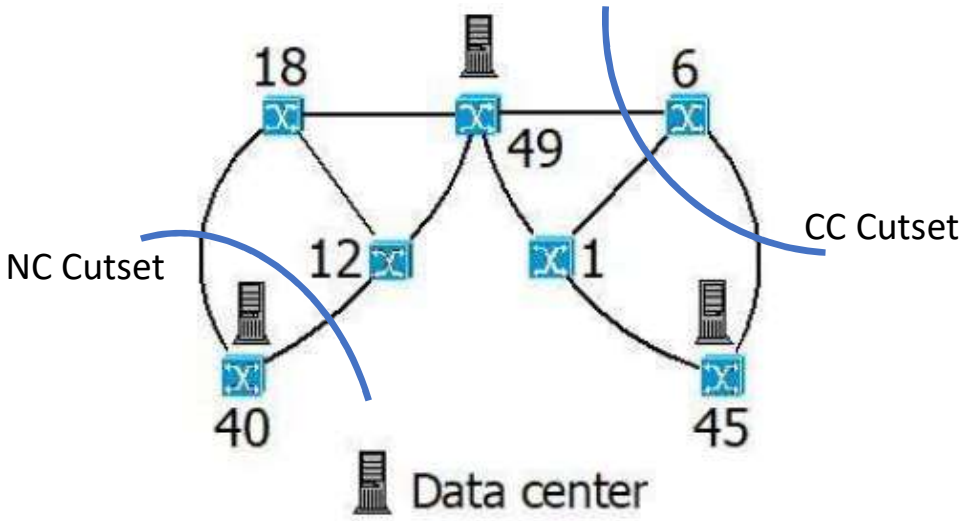
$$CC_{cutset} \subseteq NC_{cutset}$$

which satisfies:

  - ✓ $S \cap D = \emptyset$
  - ✓ Direct logical links between S and $V_L - S$.

✓One example (Figure)

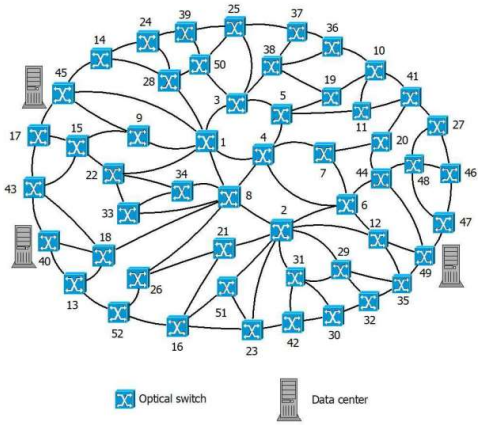
✓Enumeration using a small computer program



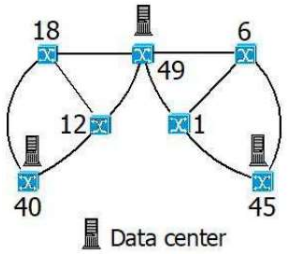
Logical topology

ILP Number of Variables and Constraints

- Depending on the ILP and input data:
  - Logical topology
  - Physical topology
  - Number of datacenters



$N_P = 52$ nodes, $L_P = 196$ links



$N_L = 7$ nodes, $L_L = 20$ links

ILP Number of Variables and Constraints

Objective function:

$$\min \sum_{ij \in E_P,\ st \in E_L} f_{ij}^{st} \tag{2.1}$$

Subject to:

$$\sum_{st \in E_L} f_{ij}^{st} \leq F_{ij} \times W, \forall ij \in E_P \tag{2.2}$$

$$\sum_{j:ji \in E_P} f_{ji}^{st} - \sum_{j:ij \in E_P} f_{ij}^{st} = \begin{cases} -1 \text{ if } i = s \\ 1 \quad \text{if } i = t \\ 0 \text{ otherwise} \end{cases}, \forall i \in V_P, \forall st \in E_L \tag{2.3}$$

$$\sum_{ij \in P_n^k,\ st \in C_{CC}^l} f_{ij}^{st} \leq \left|C_{CC}^l\right| - 1, \forall P_n^k \in P_n, \forall C_{CC}^l \in C_{CC} \tag{2.4}$$

- There are formulas to calculate number of variables and constraints for given input data.
- This ILP has only one variable f_{ij}^{st}.
- Number of variables is $L_P \times L_L = 196 \times 20 = 3920$.

ILP Number of Variables and Constraints

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Subject to:

$$\sum_{st \in E_L} f_{ij}^{st} \leq F_{ij} \times W, \forall ij \in E_P \tag{2.2}$$

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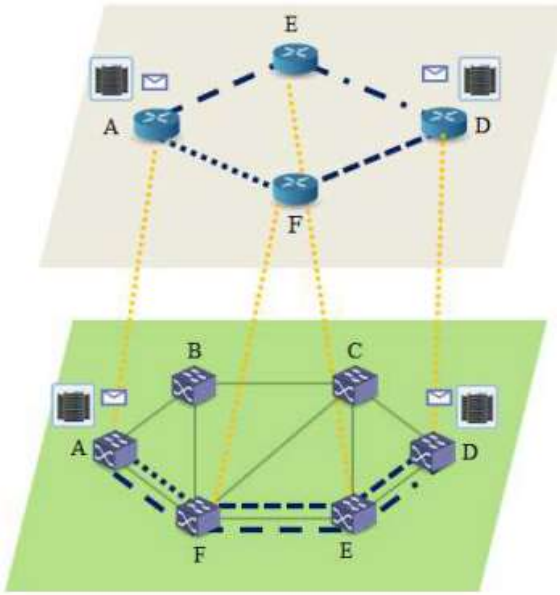
$$\sum_{ij \in P_n^k,\ st \in C_{CC}^l} f_{ij}^{st} \leq \left|C_{CC}^l\right| - 1, \forall P_n^k \in P_n, \forall C_{CC}^l \in C_{CC} \tag{2.4}$$

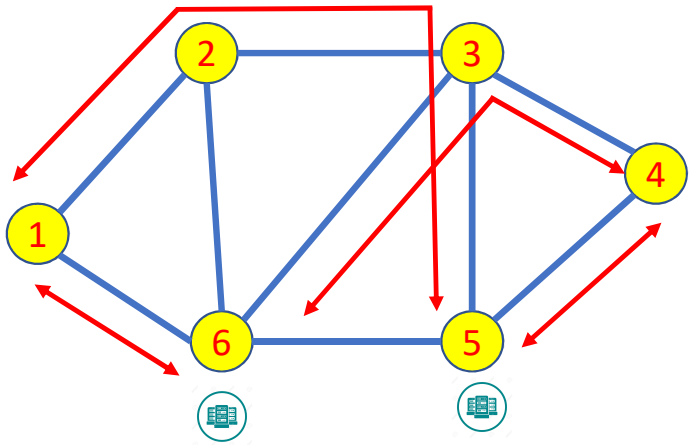
- Equation (2.2) considers for all physical links, hence 196 constraints.
- Equation (2.3) considers for all physical nodes and all logical links, # of constraints:
  $N_P \times L_L = 52 \times 20 = 1{,}040.$
- Equation (2.4), for the logical topology, there are 19110 double-link failure cases (in case of CC-2) and 30 CC cutsets, # of constraints:
  $19110 \times 30 = 573{,}300.$

Scenario CC cost equal to NC cost



CC cost = 12 wavelength channels
NC cost = 14 wavelength channels

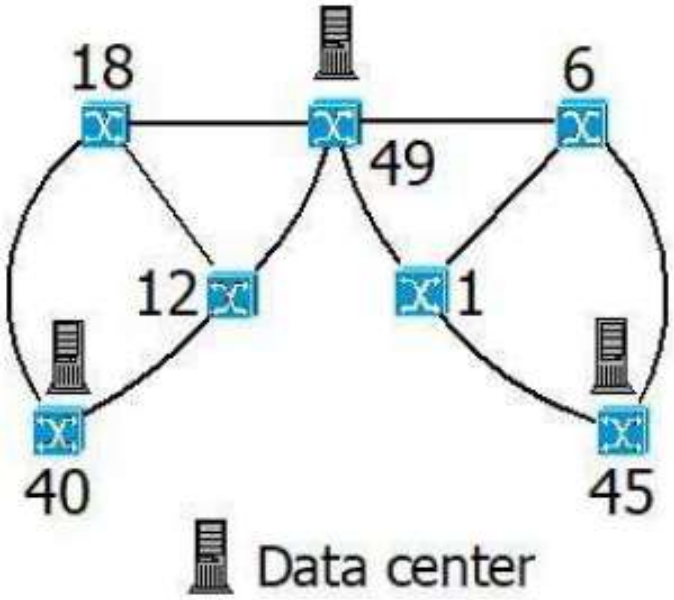
Datacenters moved to nodes 5 and 6



Both NC and CC mappings use 14 wavelength channels.

Discussion

- So far, we worked with content-connected mapping problem.
- All nodes must have access to content.
- Do we need connection/communication between requesting nodes (e.g., node 1 and node 12)?
- This issue arising when we are implementing the dummy node.



Logical topology

Which Physical Topology?

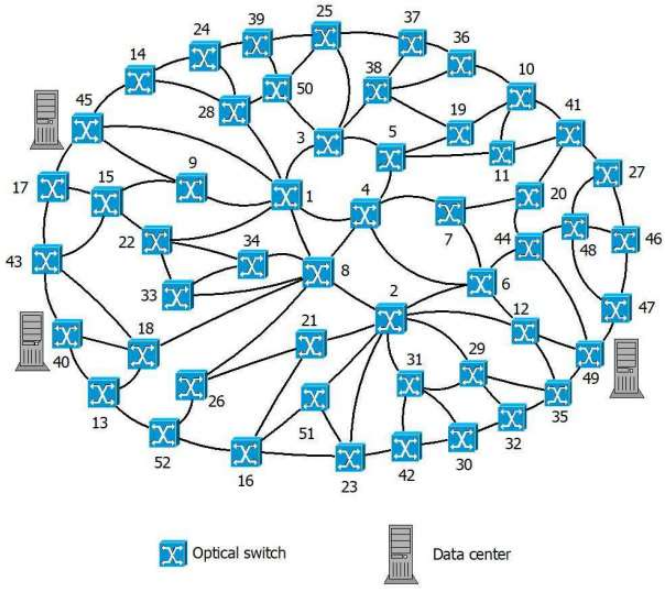


Fig. 1 Modified Italy Telecom 52-node topology

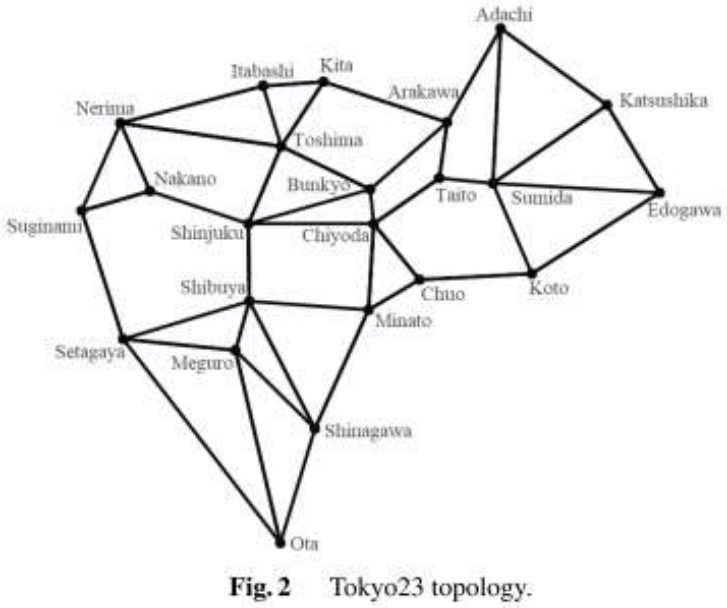


Fig. 2 Tokyo23 topology.

We must consider to include the physical topology in publications.

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