Chair of Communication Networks
TUM School of Computation, Information and Technology
Technical University of Munich

6G-life

Survivability in Multi-Domain Optical Networks

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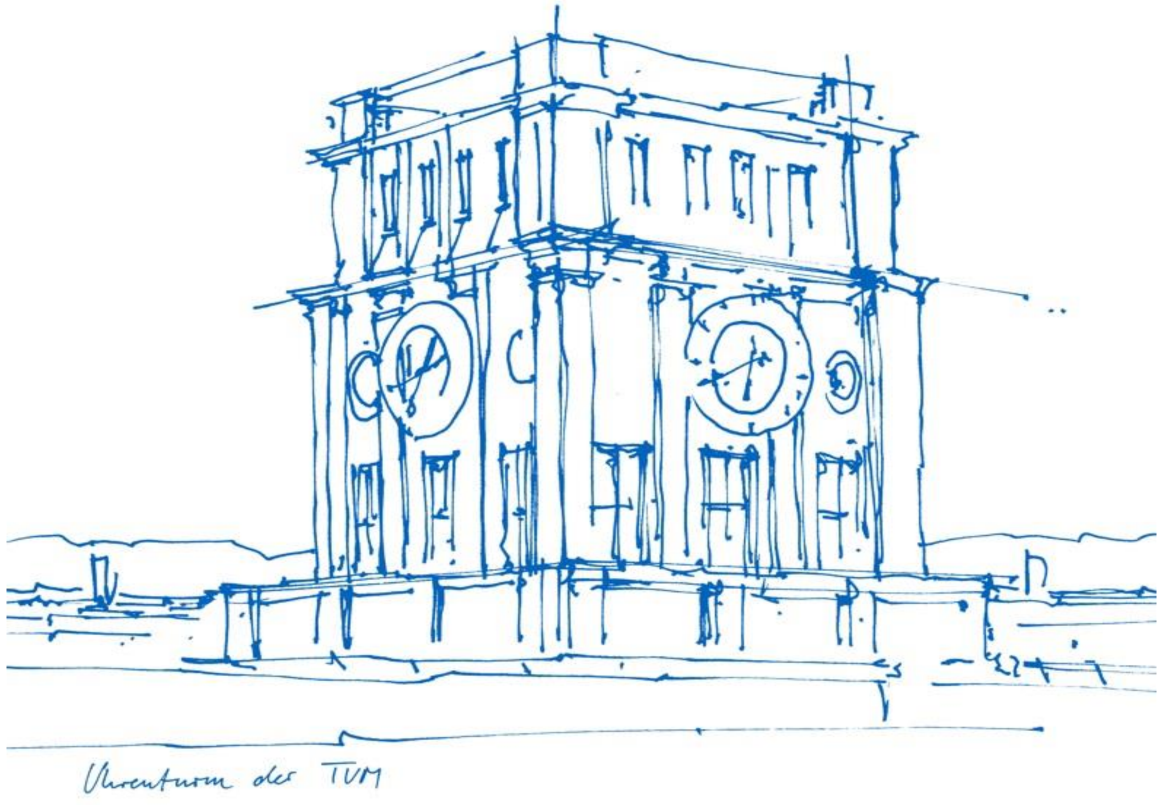
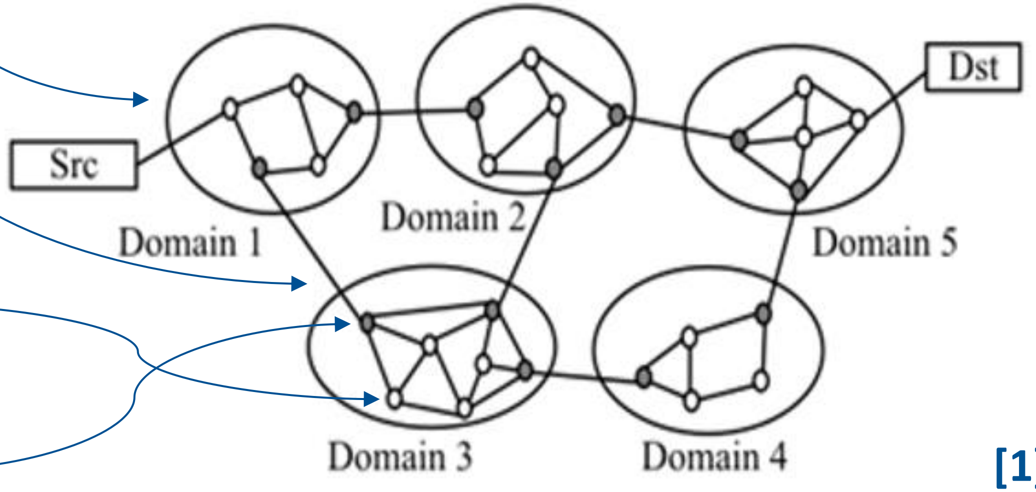


What is a Multi-Domain Network?

A network consisting of several single-domain networks connected by inter-domain links.

- **Domain:** independent network with its own rules and management policies.
- **Internal node:** can only view local network information.
- **Border nodes:** can view both local and global network information.



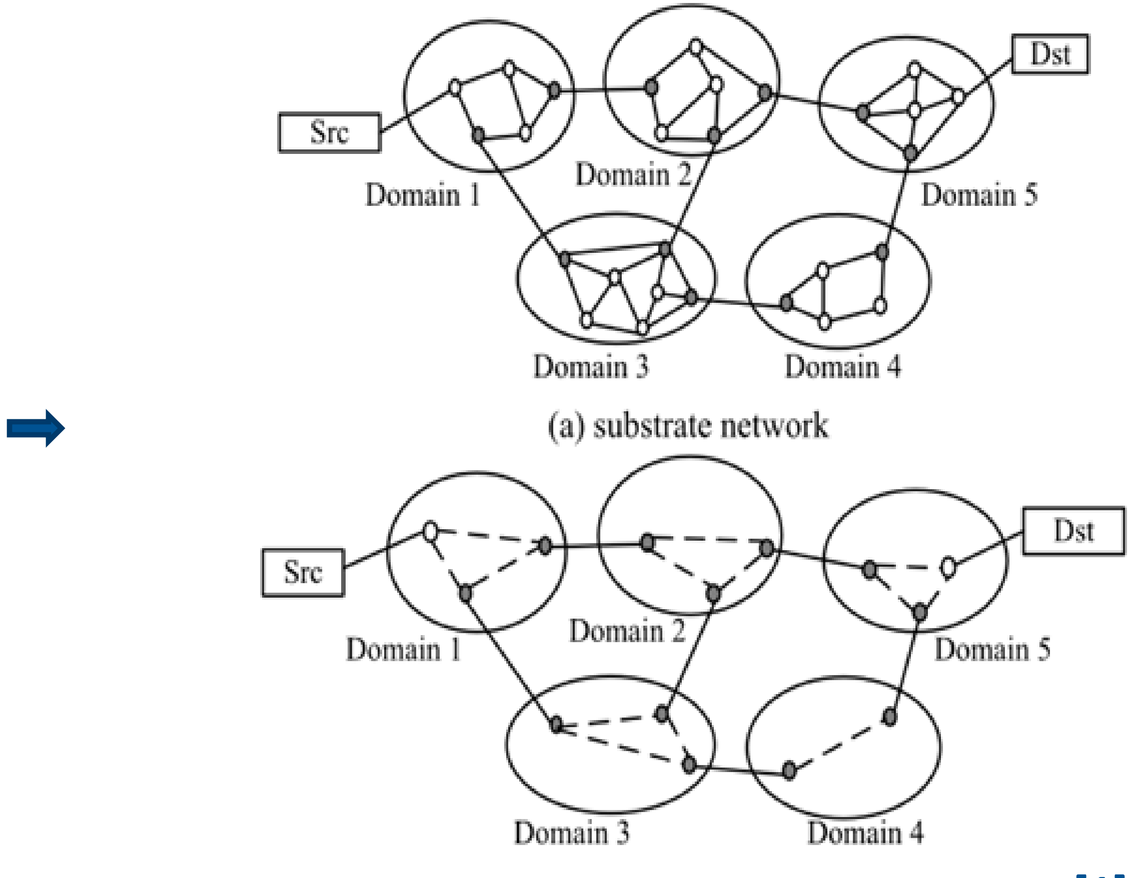
[1]

[1]: Sun, Gang & Li, Yayu & Liao, Dan & Chang, Victor. (2018). Service Function Chain Orchestration Across Multiple Domains: A Full Mesh Aggregation Approach. IEEE Transactions on Network and Service Management. PP. 10.1109/TNSM.2018.2861717.

Problem Description (1)

- **Challenge in multi-domain optical networks:** survivability vs. confidentiality.

- **Topology Aggregation:** abstract domain-specific complete topology into a more concise representation.



(a) substrate network

(b) abstracted network

[1]

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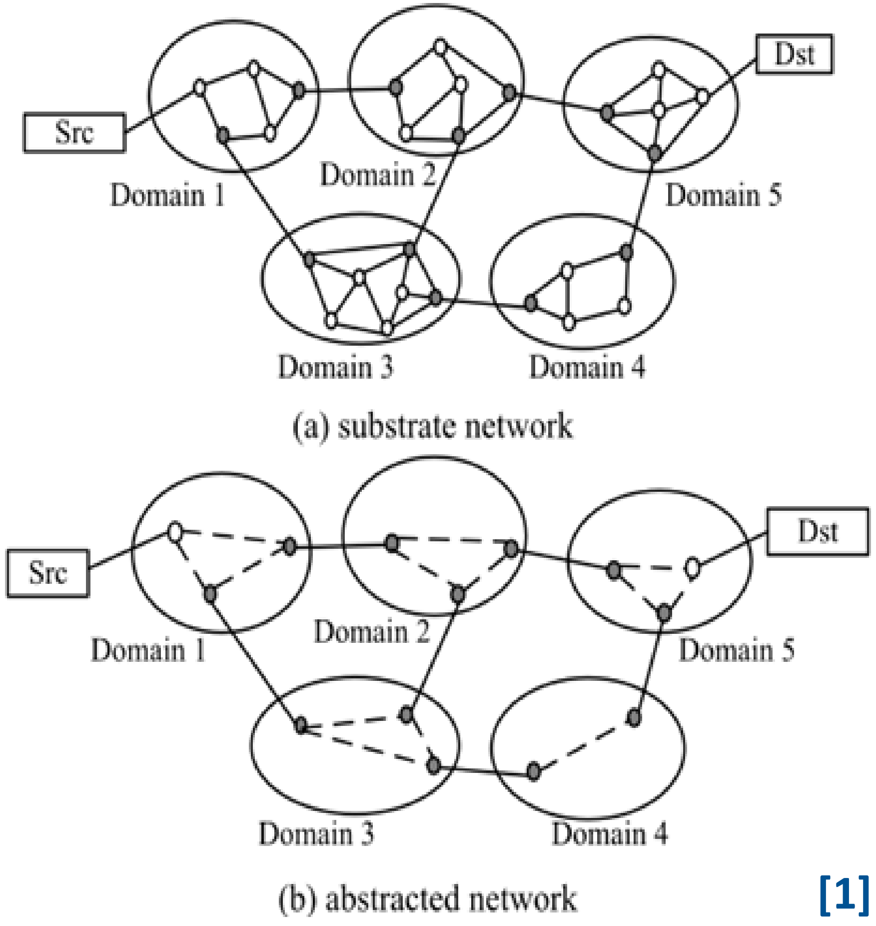
Problem Description (2)

- **Objective:** find **two disjoint paths** on the aggregated multi-domain topology, s.t. the **total cost** of the two paths is **minimized**.

- **Approaches:** Link-Disjoint[2] vs. **Node-Disjoint** Paths
  - Sequential Approach
  - Joint Approach



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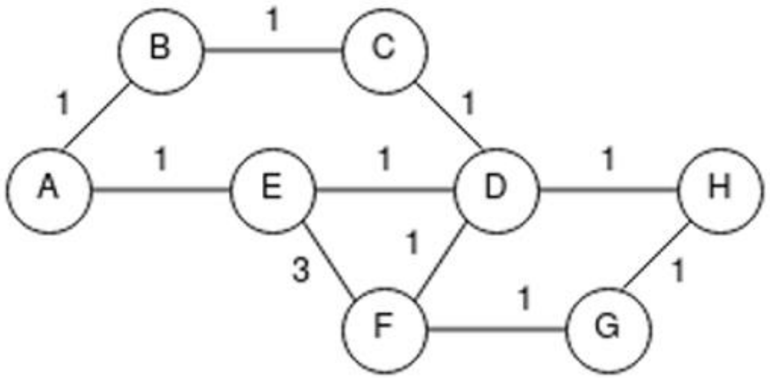
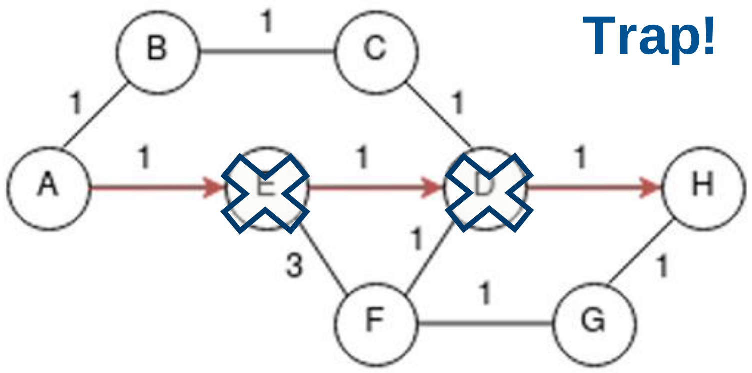
[2]: C. Gao, H. C. Cankaya and J. P. Jue, "Survivable inter-domain routing based on topology aggregation with intra-domain disjointness information in multi-domain optical networks," in *Journal of Optical Communications and Networking*, vol. 6, no. 7, pp. 619-628, July 2014.

Node-disjoint routing – Sequential approach



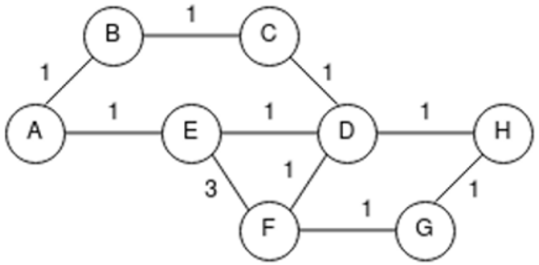
(a)



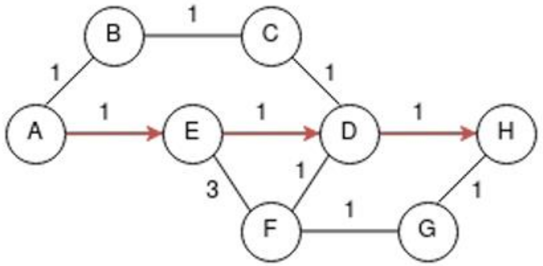
(b)

Trap!

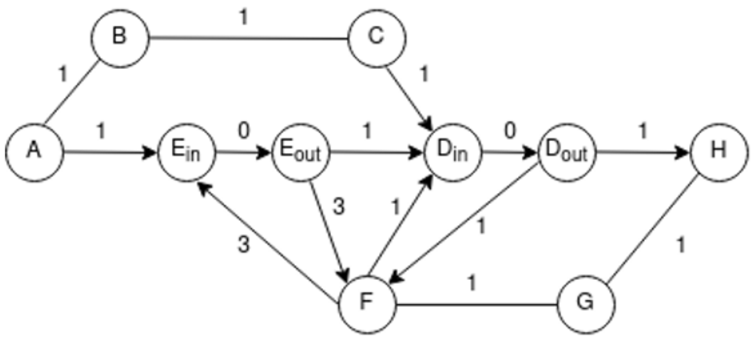
Node-disjoint routing – Joint approach



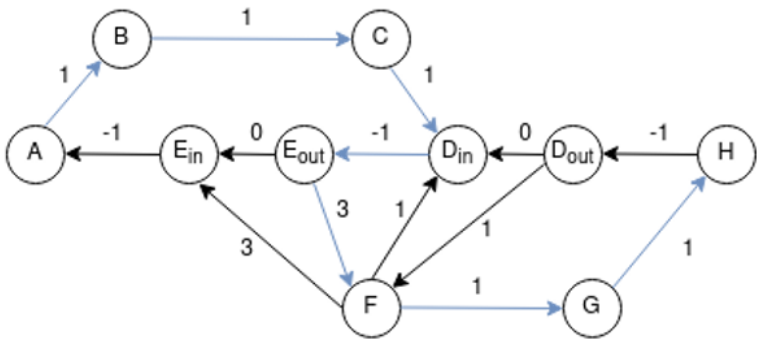
(a)



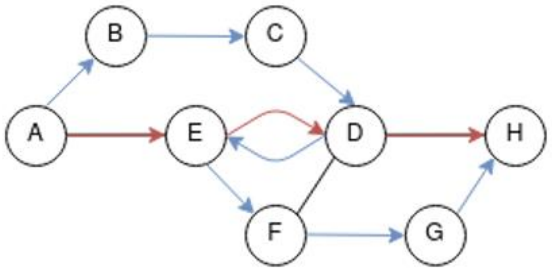
(b)



(c)



(d)



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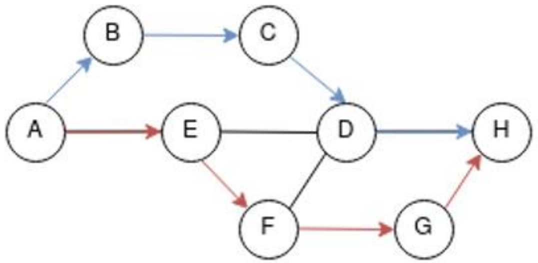
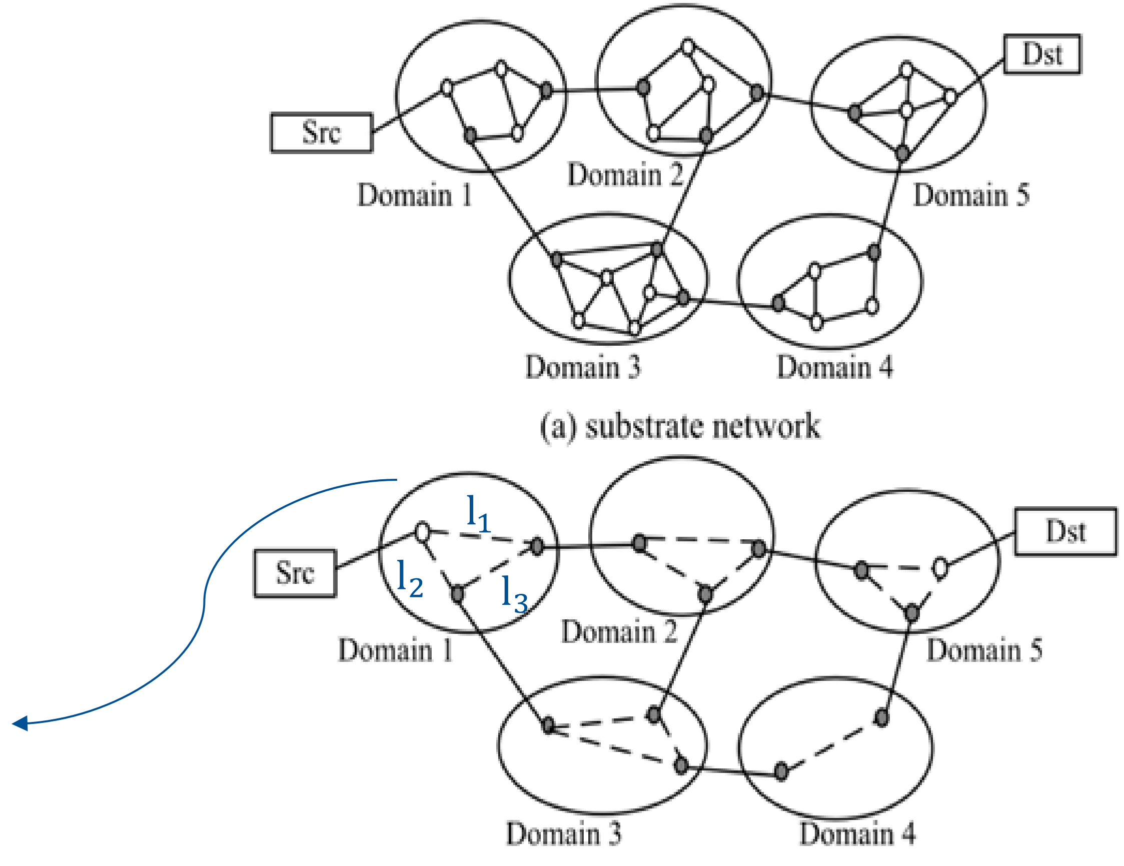


(f)

Intra-domain Disjointness Information

- Each domain provides a **matrix** only with **cost** information for every pair of **aggregated links**.
- The physical mapping of the links into the intra-domain topology is not advertised.
- Each cell of the matrix stores the total cost of the disjoint path pair for each pair of aggregated links.

$l_1 l_1$	$l_1 l_2$	$l_1 l_3$
$l_2 l_1$	$l_2 l_2$	$l_2 l_3$
$l_3 l_1$	$l_3 l_2$	$l_3 l_3$

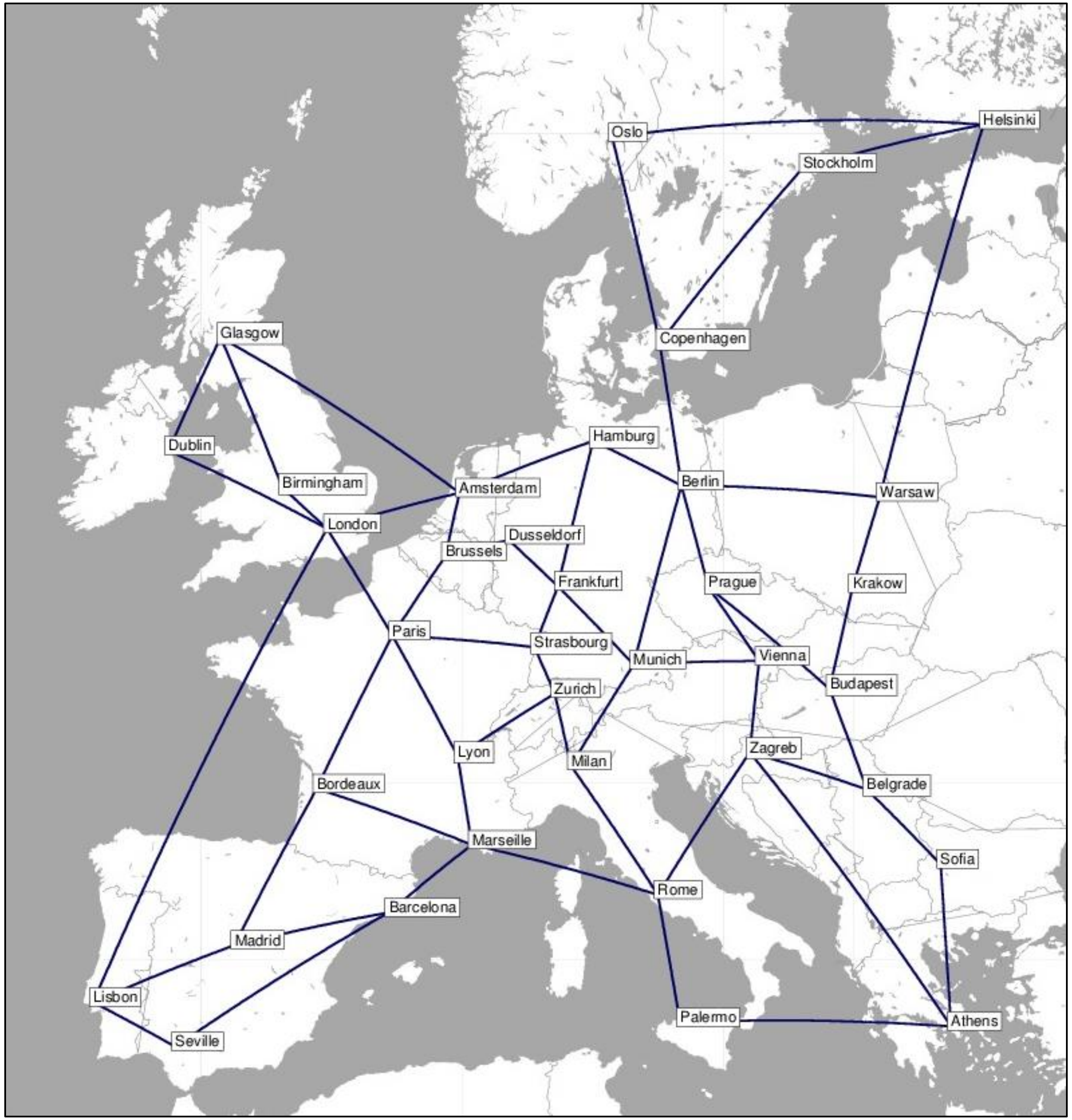


(a) substrate network

(b) abstracted network

Cost266 European Network

- 21 countries/domains.
- 37 nodes in the aggregated topology.
- Blue edges: the edges of the original topology.

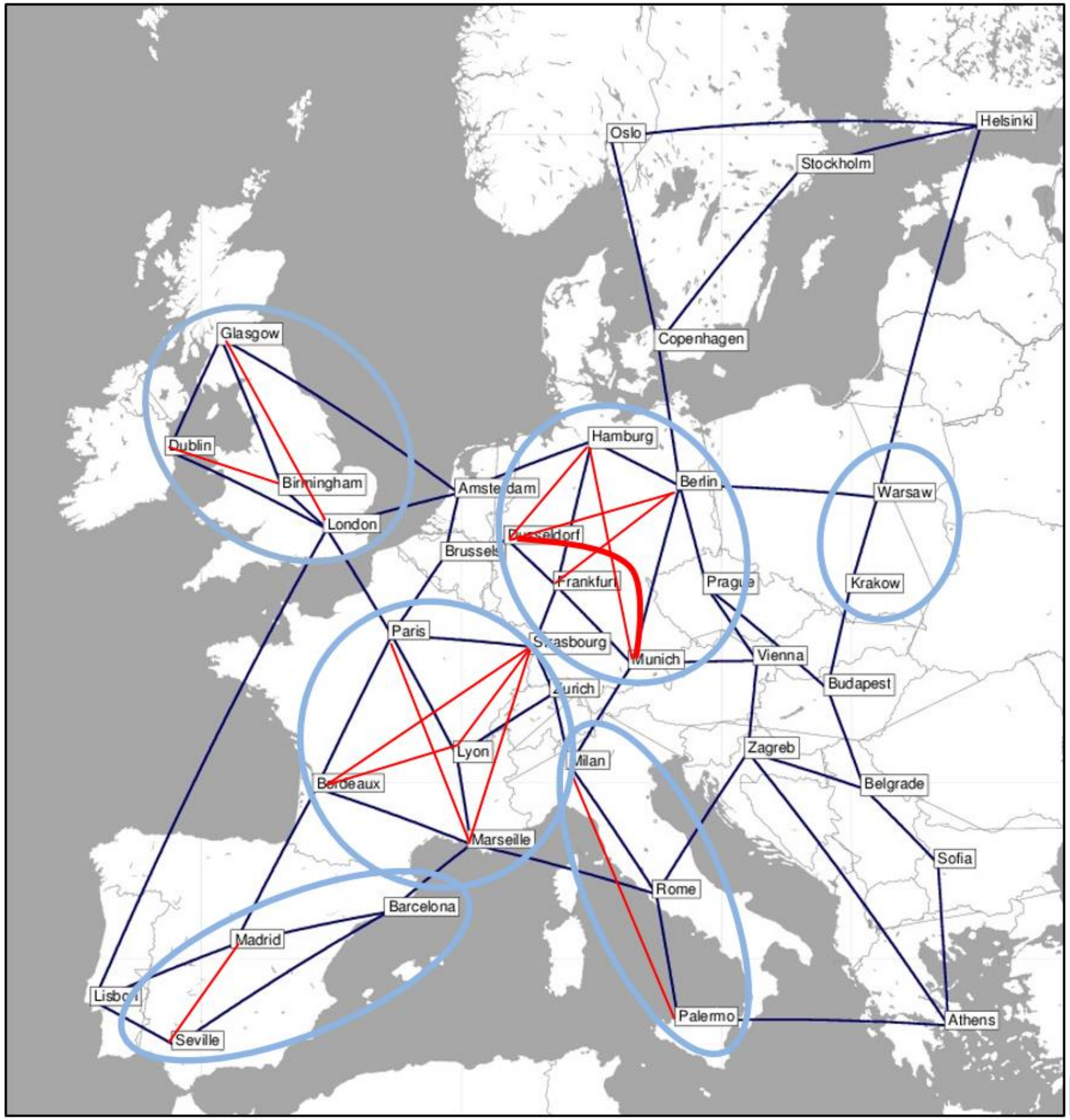


[3]

[3]: http://sndlib.zib.de/home.action

Cost266 European Network

- 21 countries/domains.
- 37 nodes in the aggregated topology.
- Blue edges: the edges of the original topology.
- Red edges: added edges for the full mesh aggregation in the domains.
- 6 domains with more than 1 border node:
  1. Germany
  2. Italy
  3. Spain
  4. UK
  5. France
  6. Poland



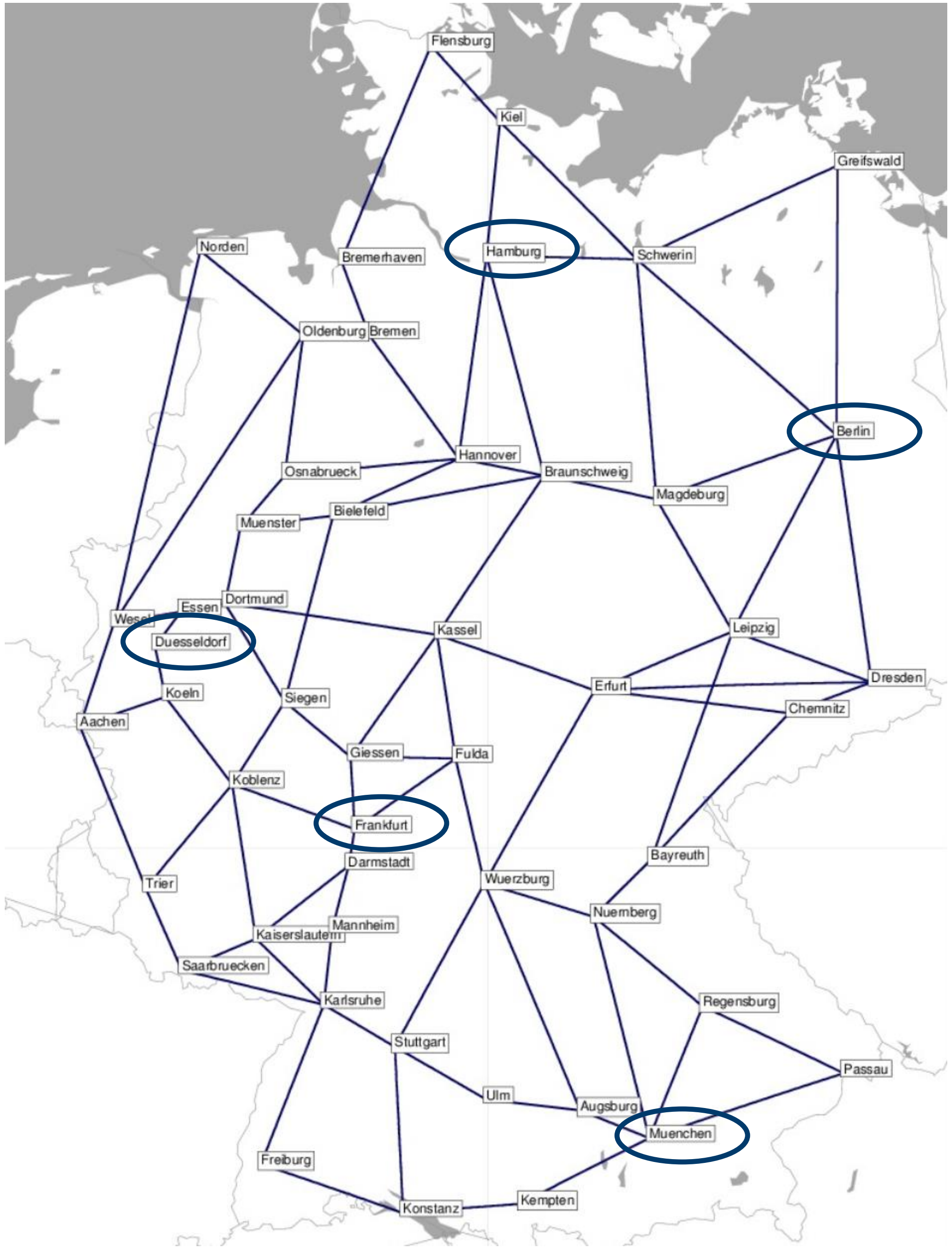
[3]

[3]: http://sndlib.zib.de/home.action

Germany50 Network

Border nodes:

- Munich
- Duesseldorf
- Frankfurt
- Hamburg
- Berlin



[4]

[4]: http://sndlib.zib.de/home.action

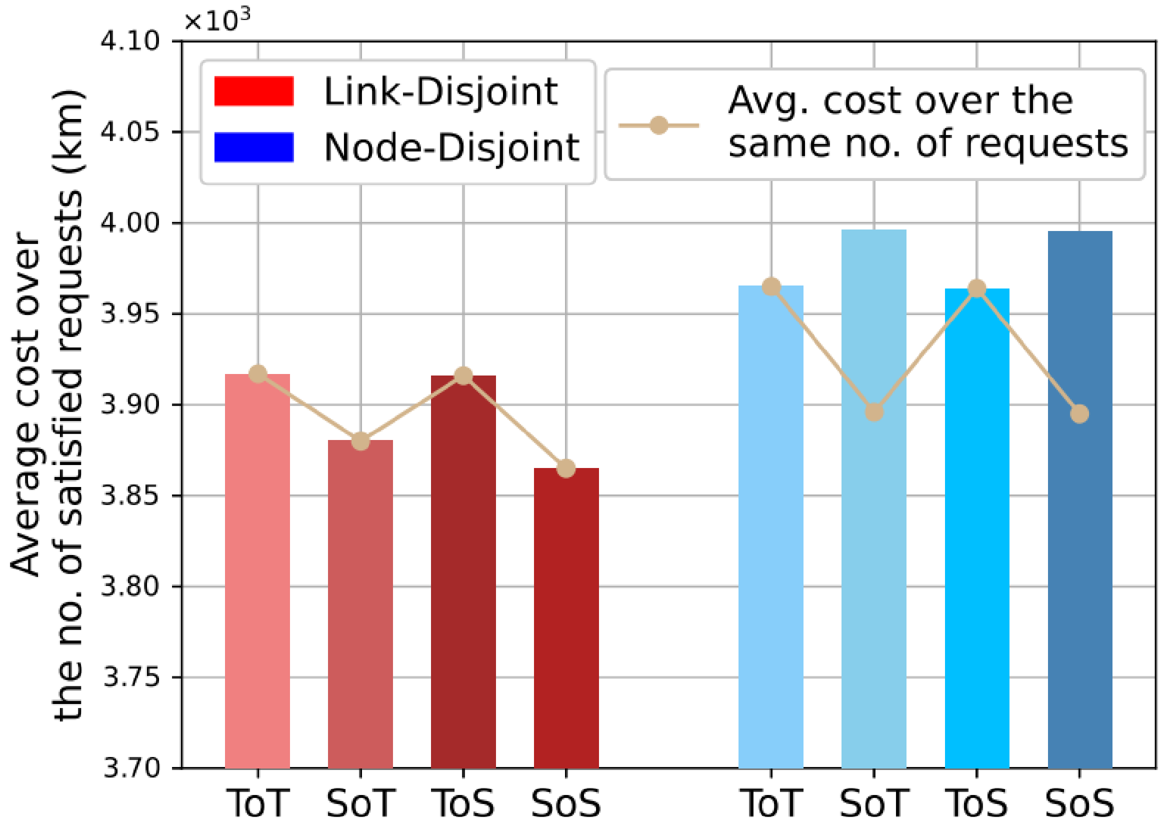
Results – Link lengths as costs

- The costs are the lengths of the links.

- **Link-disjoint** problem:
All requests are satisfied by every method.

- **Node-disjoint** problem:
Almost **8.5%** of the requests not satisfied by the 2 methods that apply the **Sequential approach** over the **inter-domain aggregated topology**.

- **Node- vs. Link-Disjoint:** ~ 5% increase on the average cost.



T: Sequential method
S: Joint method

Inner Capital: Intra-domain routing method
Outer Capital: Inter-domain routing method

Results – Randomized costs

- The costs are completely randomized.

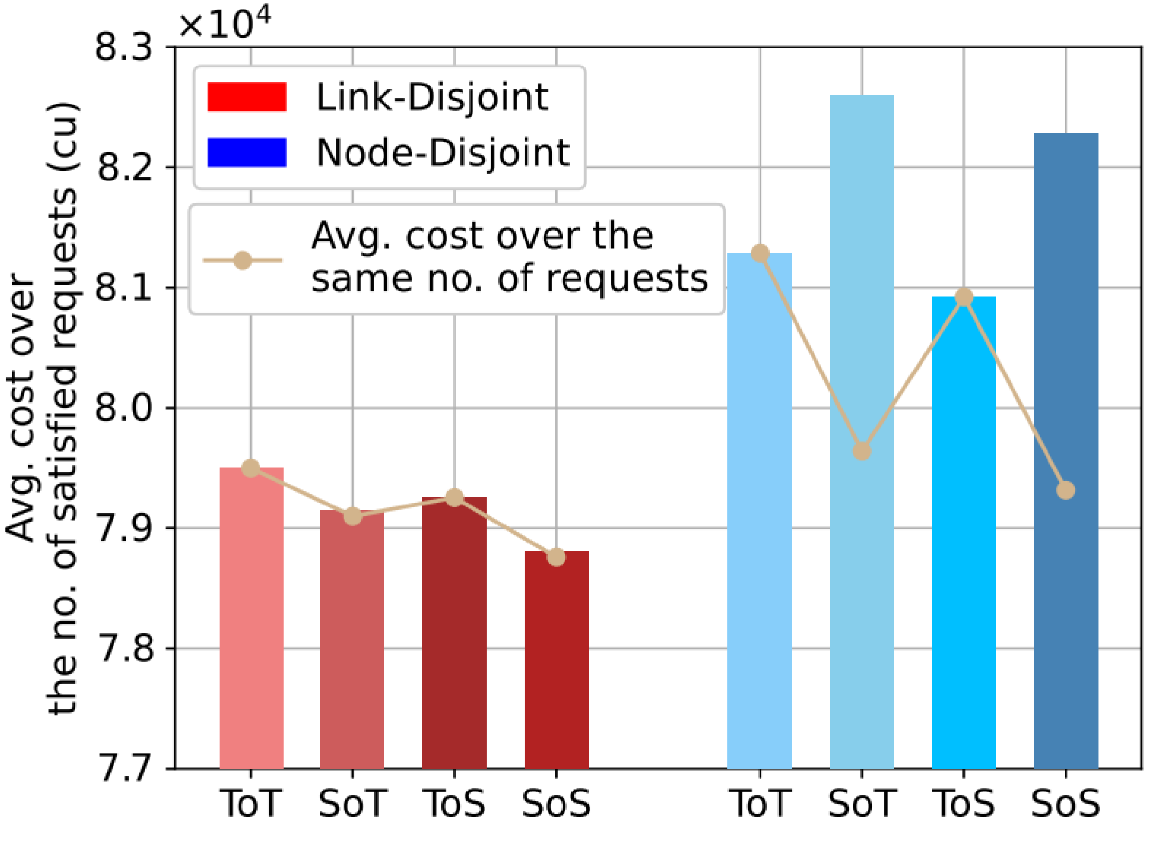
- **Link-disjoint** problem:

Almost **0.5%** of the requests not satisfied by the 2 methods that apply the **Sequential approach** over the **inter-domain aggregated topology**.

- **Node-disjoint** problem:

Almost **10%** of the requests not satisfied by the 2 methods that apply the **Sequential approach** over the **inter-domain aggregated topology**.

- **Node- vs. Link-Disjoint:** ~ 5% increase on the average cost.



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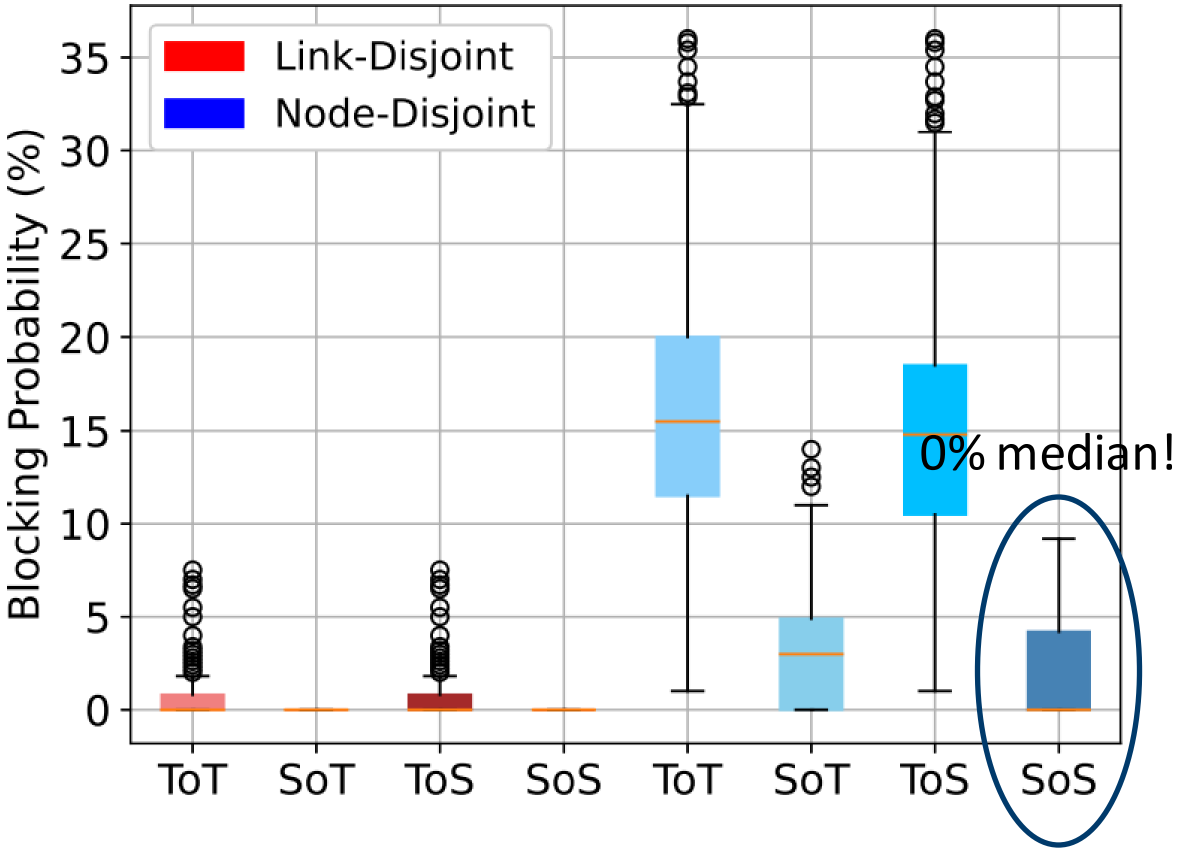
Results – Blocking Probability

- $\boldsymbol{Blocking\ probability} = \frac{\#\ \boldsymbol{unsatisfied\ requests}}{\#\ \boldsymbol{total\ requests}}$

- The costs of the links are randomized in each simulation.

- The results are obtained over **1000** independent simulations.



T: Sequential method
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Inner Capital: Intra-domain routing method
Outer Capital: Inter-domain routing method

Conclusions

- Multi-domain networks:
  1. Domains need to maintain their privacy.
  2. Expose limited information for network services.

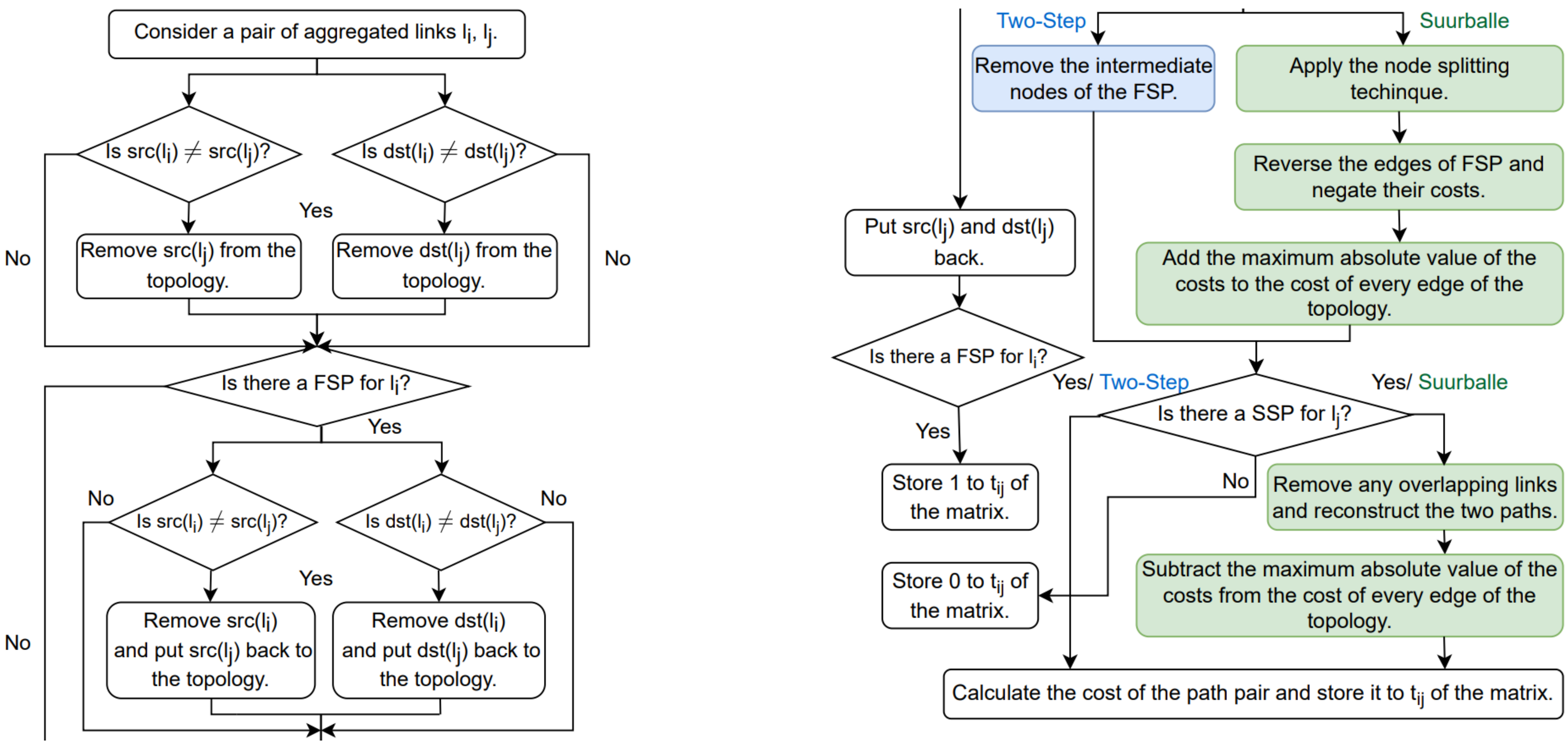
- Survivability
  - Domains provide only cost values for their aggregated links.
  - Link- or Node-Disjoint inter-domain routing between every pair of border nodes.

- Link- vs Node-Disjoint routing:
  1. Node-disjoint case presents higher average cost and blocking probability.
  2. The joint approach can achieve 0% median of blocking probability.
  3. Less than 10% average cost increase from link- to node-disjoint problem.

Thank you!

Questions?

Intra-domain routing algorithm



Inter-domain routing algorithm