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A Novel Optimization Algorithm for Resilient T-SDN Control-Plane Design in Optical Transport Networks

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Agenda

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- Definition of Network Scenario
- Formulation of Optimization Algorithm
  - Algorithm Description
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Motivation / Problem Statement

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- With the uncoupled approach of network control using SDN, numerous studies propose optimization strategies to solve the *Controller Placement Problem (CPP)* in IP networks [1].
- However, the control plane design extends beyond the CPP problem and includes the interconnections between the data plane devices and the controllers.
- The *control traffic* is also often overlooked even for IP networks.
  - →Mainly due to the lack of approaches for control plane traffic modelling.
  - →*The study in [2] is one of the few rare studies that solves the CPP problem to minimize control traffic for OpenDaylight-based cluster of controllers.*

Proposition:-

i. Model the control traffic for optical networks [3] –that is derived from the characterization of the signalling procedures for lightpath setup and termination in a fully-disaggregated testbed with OpenROADM devices.

ii. Propose an algorithm that applies this traffic model for the design of the control plane in optical systems controlled by a monolithic controller.

Definition of Network Scenario

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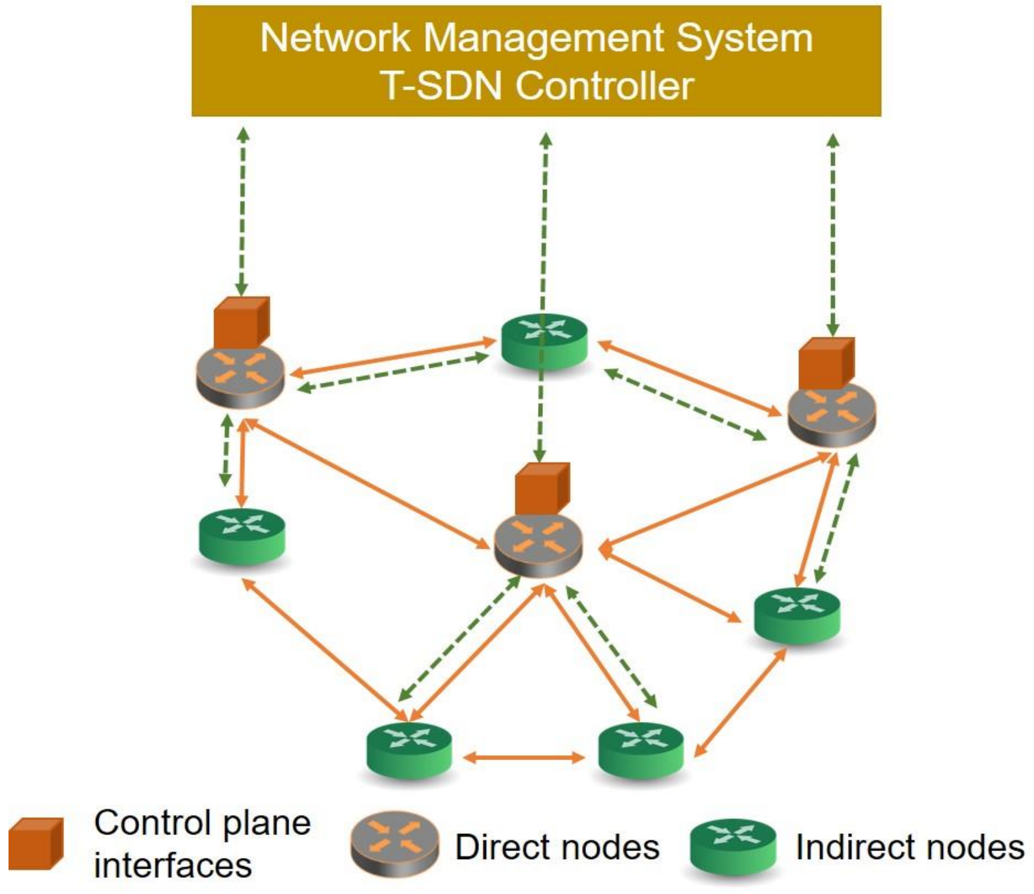
- Given a network that consists of nodes - e.g. ROADMs, fibre links, and a centralized controller, the nodes are connected via control plane interfaces to the controller.
- Control plane interfaces are installed only on a set of nodes, denoted as ***direct nodes***.
- Remaining nodes utilize the fibre links, hence denoted as ***indirect nodes***.
- Further consideration of ***in-fibre*** and ***out-of-band*** control network.
- *Challenges:-*
  1. Determining the number and placement of control plane interfaces - the definition of the *direct nodes.*
  2. Optimization of the routing of the control traffic between *indirect* and *direct nodes.*



Example optical transport network architecture with T-SDN controller

Formulation of optimization algorithm

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- *Objective*: Minimize the cost of the control plane network.
- *Considerations*: Reliability constraints against single node and/or link failures.

Cost of the control plane network C_{CP}

- Overall cost of the interfaces required to connect the controller to the direct nodes of the network- C_C
- Capacity costs of the fibre links incurred to carry control traffic between the indirect and direct nodes C_L

Algorithm Description

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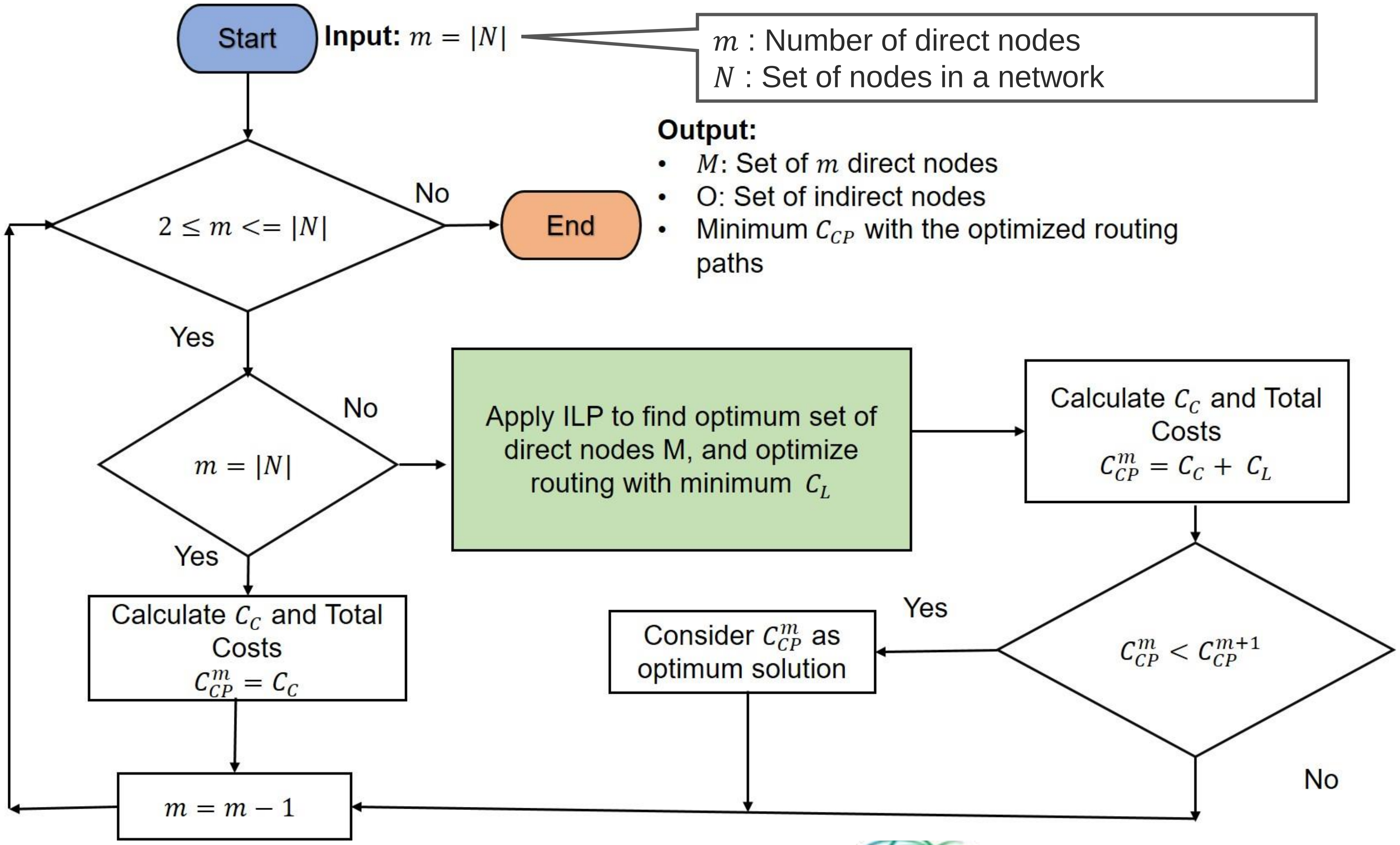

Optimization of the Control Plane Traffic Routing

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minimize $$C_L = \sum_{e \in E} \xi_e \sum_{n \in N} \frac{h(n)}{\eta_n} \sum_{p \in P(n)} \delta_e^p \mu_p^n$$

subject to

C1: $$\sum_{p \in P(n)} \mu_p^n = \eta_n (1 - x_n) \quad , \quad \forall\, n \in N$$

C2: $$\sum_{p \in P(n \to \tilde{n})} \mu_p^n \le x_{\tilde{n}} \quad , \quad \forall\, n, \tilde{n} \in N; \; n \ne \tilde{n}$$

C3: $$\sum_{p \in P(n)} \delta_e^p \mu_p^n \le 1 - x_n \quad , \quad \forall\, n \in N; \; e \in E$$

C4: $$\sum_{n \in N} x_n \le m$$

TABLE I
DEFINITION OF PARAMETERS AND SETS

Notation	Definition
$n \in N$	Node n where N is the set of nodes
$e \in E$	Fibre link e, where E is the set of fibre links
$p \in P(n)$	Path p from the set of all feasible paths between node n and all direct nodes, $\forall n \in N$
$h(n)$	Bandwidth of the control traffic flow between node n and the controller
ξ_e	Unit capacity cost of link $e \in E$
m	Number of direct nodes, where $2 \le m \le \lvert N \rvert$
δ_e^p	Binary: 1 if path $p \in P(n)$ contains link e, 0 otherwise
η_n	Positive integer: Diversity factor that defines the number of paths over which the flow $h(n)$ is split

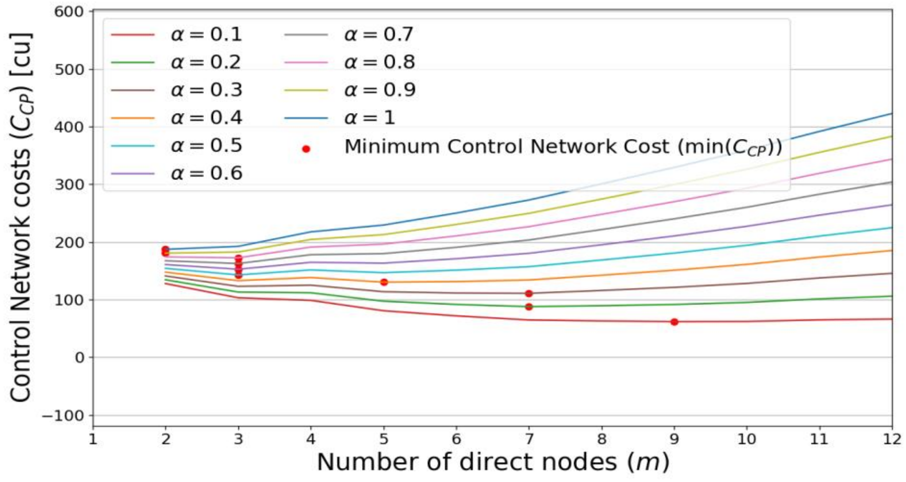
TABLE II
DEFINITION OF DECISION VARIABLES

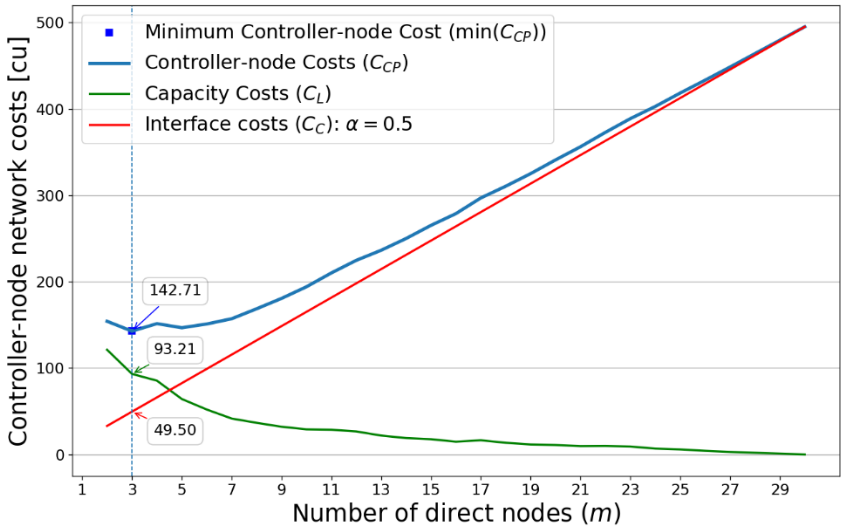
Notation	Definition
μ_p^n	Binary: 1 if path $p \in P(n)$ is selected, 0 otherwise
x_n	Binary: 1 if node $n \in N$ is a direct node, 0 otherwise

Results and analysis w.r.t CORONET-30 network

Considerations:

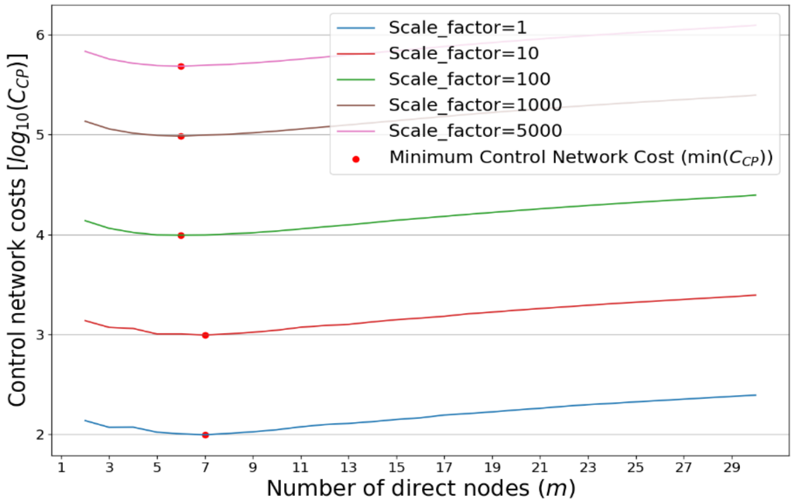
- Use of traffic model in [3] for calculating $h(n)$.
  - Arrival rate of approx. 0.17 optical connections per second at each node, and an average holding time of 600 seconds.
- Unit capacity cost of each fibre link: $\delta_e = 1$ cost units (cu).
- $C_C = \alpha \cdot \sum_{n \epsilon N} h(n) \cdot m \cdot k$ cu
  - $0 < \alpha < 1$ represents the capability of the control interface to sustain the control traffic load from all nodes.
  - k is the unit capacity cost, and is defined as $k = 1$ cu
- DIVERSITY_FACTOR: $\eta_n = 2$.



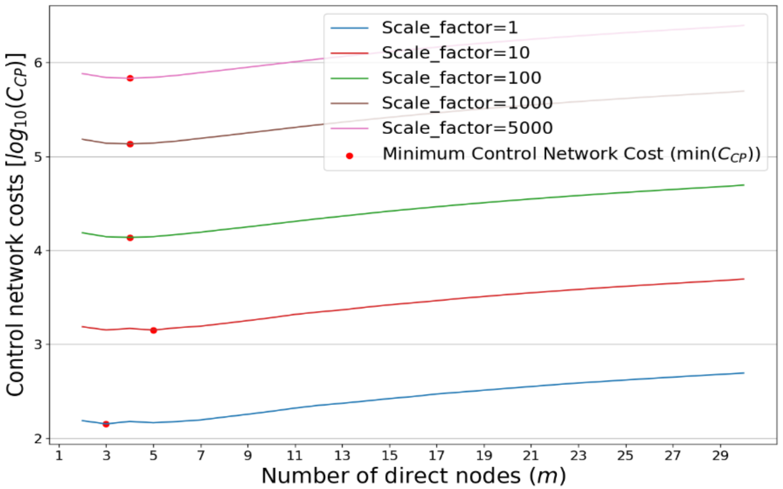


Scalability of the Cost of the Control Network

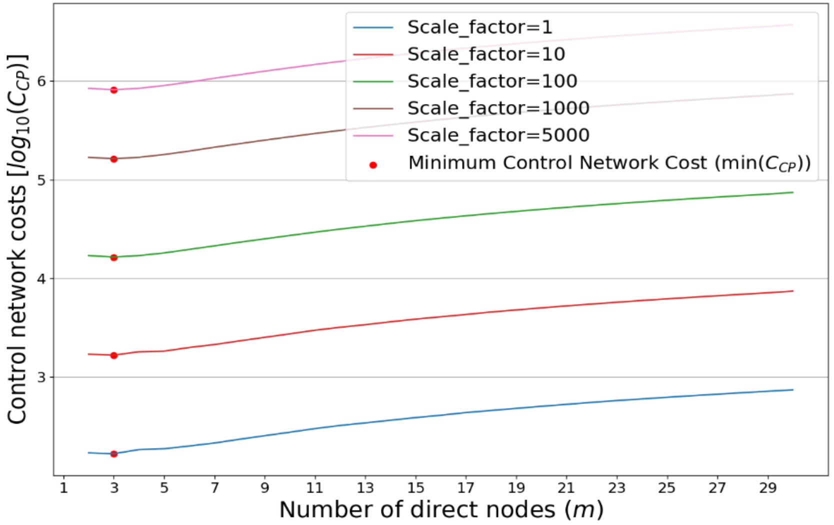
$\alpha = 0.25$



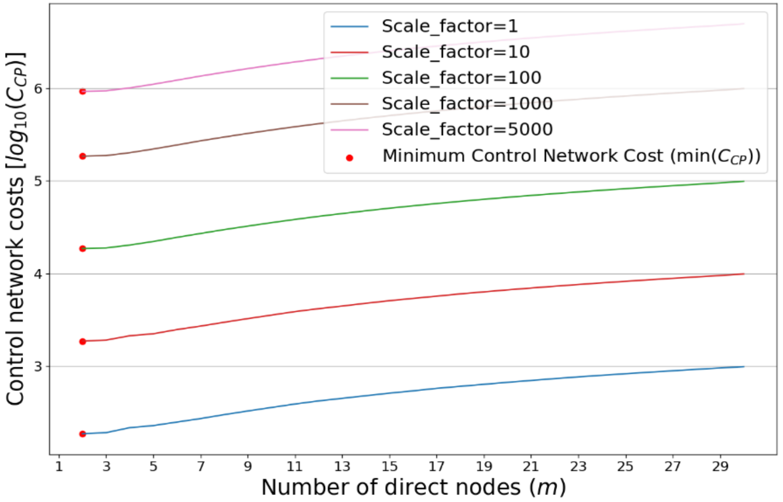
$\alpha = 0.50$



$\alpha = 0.75$



$\alpha = 1$



Conclusion

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- This paper presents a novel optimization algorithm to determine an optimal control plane network design in the context of optical transport networks.
- The objective of this algorithm is to optimise the cost of the control network considering two types of costs- namely, link capacity costs (C_L) and interface costs (C_C).
- The algorithm solves the definition of the number and placement of control plane interfaces as well as the routing of control traffic.
- The study revealed the impact of C_L and C_C on the cost of the control network.
- The impact of factors such as the control traffic load and the capacity of the interfaces on the optimum solutions have been further evaluated.
- Extension of this algorithm to evaluate design of the control plane implementing distributed SDN control can be part of our future work.

References

[1] A. Kumari and A. Sairam, “Controller placement problem in software-defined networking: A survey,” Networks, vol. 78, pp. 195–223, 2021.

[2] M. Karatisoglou, K. Choumas, and T. Korakis, “Controller placement for minimum control traffic in opendaylight clustering,” in 2019 IEEE 2nd 5G World Forum (5GWF), pp. 353–358, 2019.

[3] S. Sultana, R. R. Reyes, and T. Bauschert, “Control-plane traffic modelling for connection management in t-sdn optical networks using transport pce and openroadm,” in Photonic Networks; 23th ITG-Symposium, pp. 1–9, 2022.

Thank You

Q & A

Placement and Routing