Reliable Slicing

Andrea Marotta

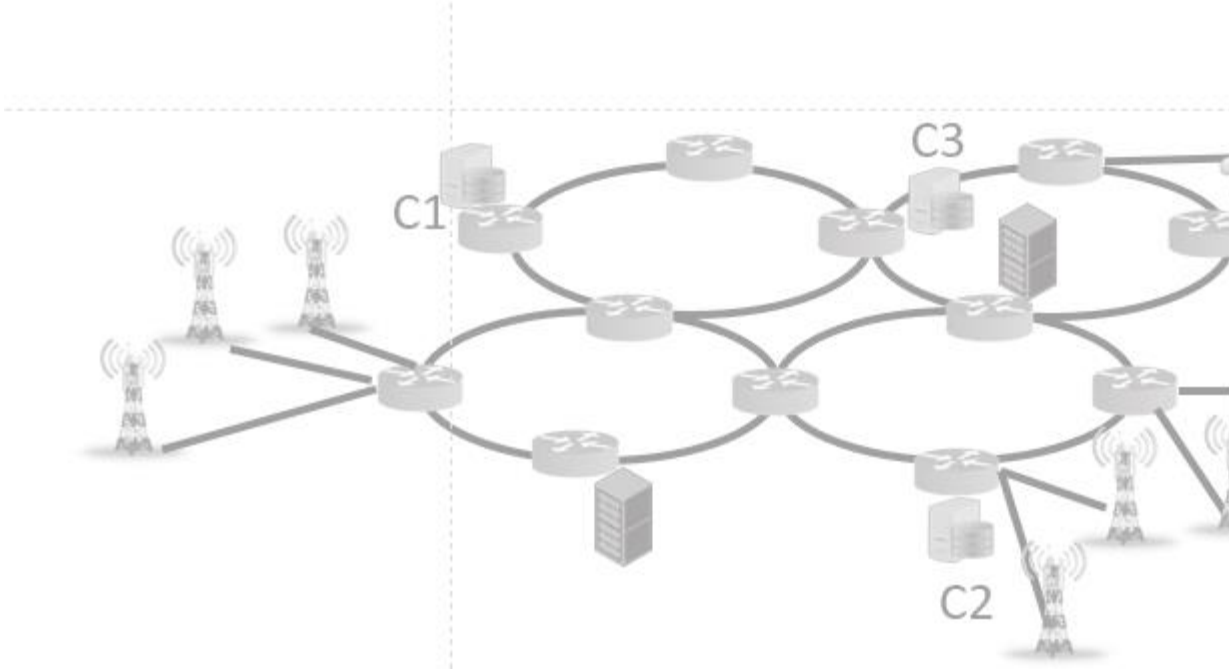
Group Meeting

Wednesday, July 3, 2019

UCDAVIS
UNIVERSITY OF CALIFORNIA

Outline

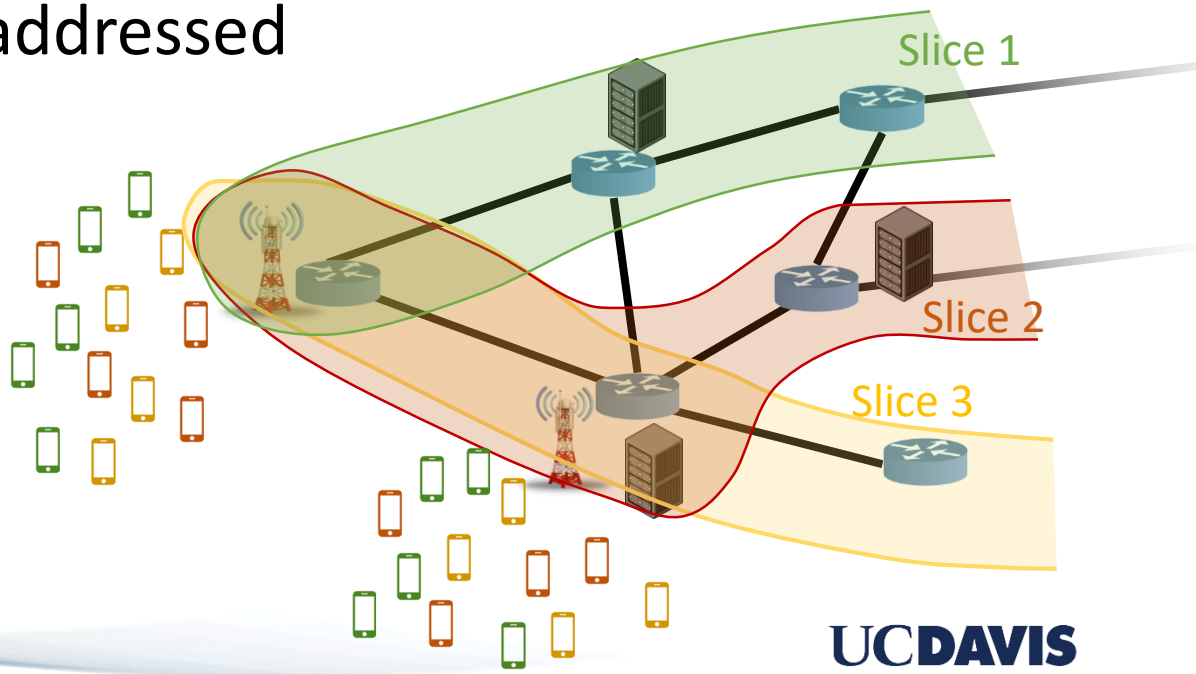
- Slicing scenarios
- Slicing protection
- Problem definition
- Reliable slicing ILP
- Proposed Heuristic
- Preliminary results



UCDAVIS

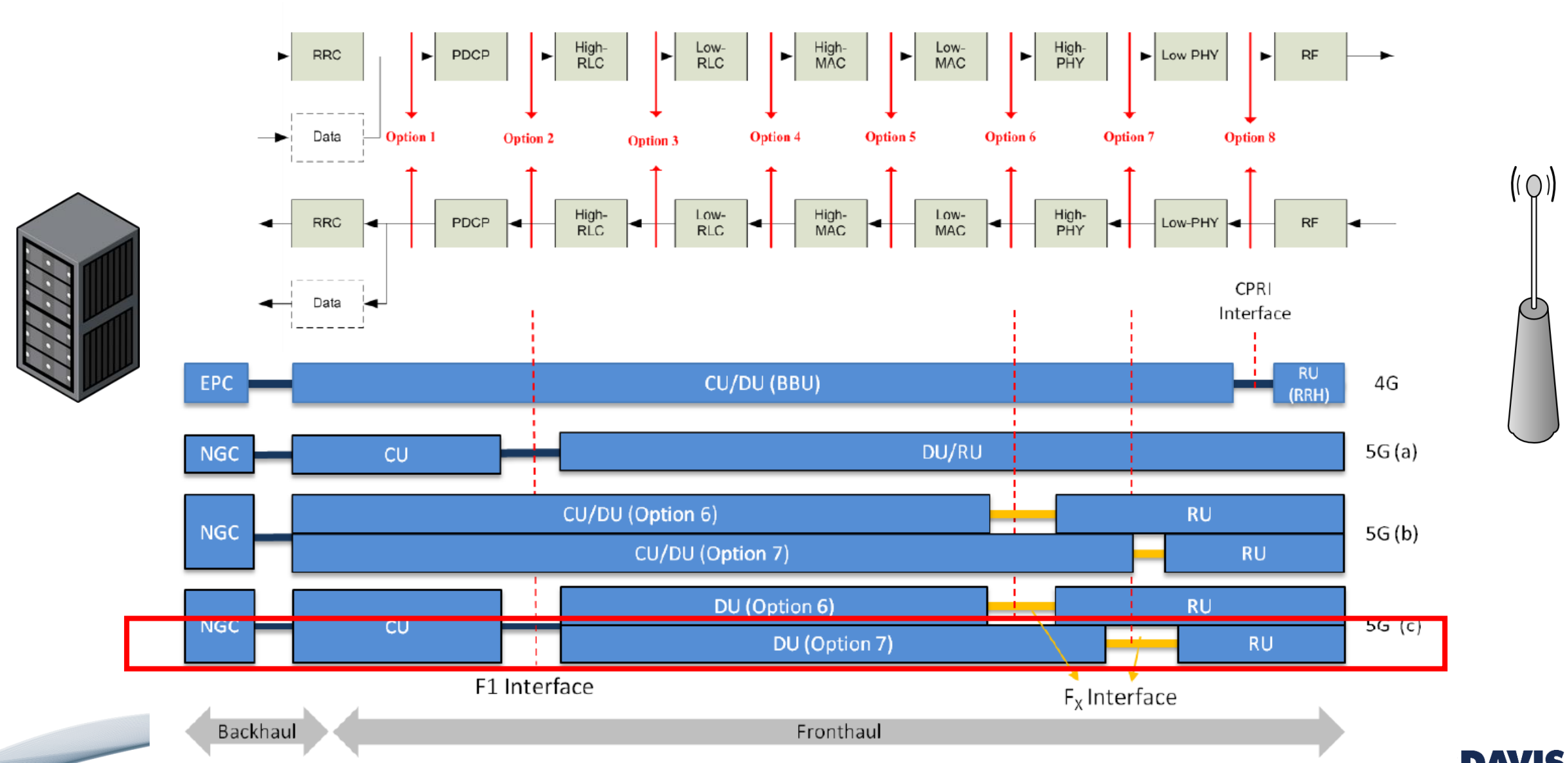
Introduction

- Network slicing allows a network operator to provide *dedicated* virtual networks with functionality and performance specific to the service or customer over a common network infrastructure
- The utilization of mobile networks as supporting infrastructure for high reliability services is increasing
- Reliability in slicing context needs to be addressed



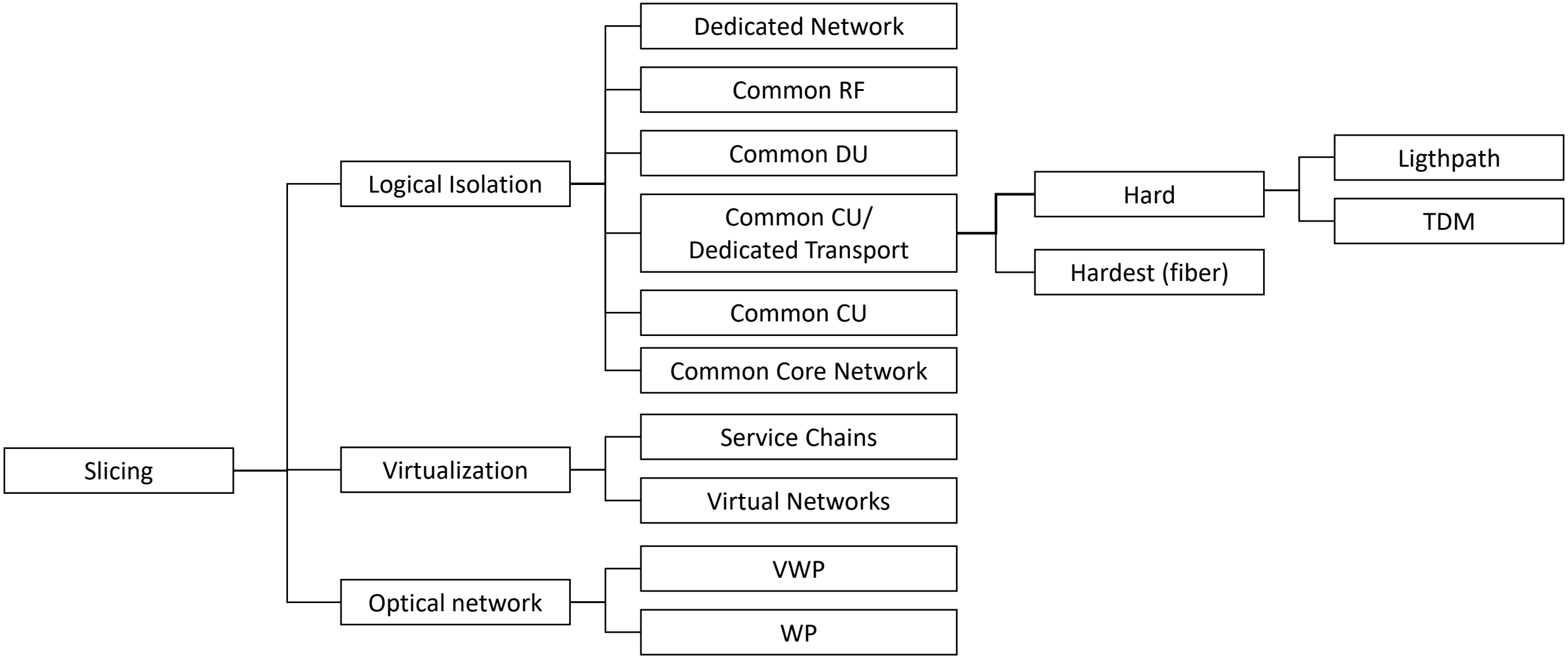
UCDAVIS

Virtual service chains for mobile network slicing



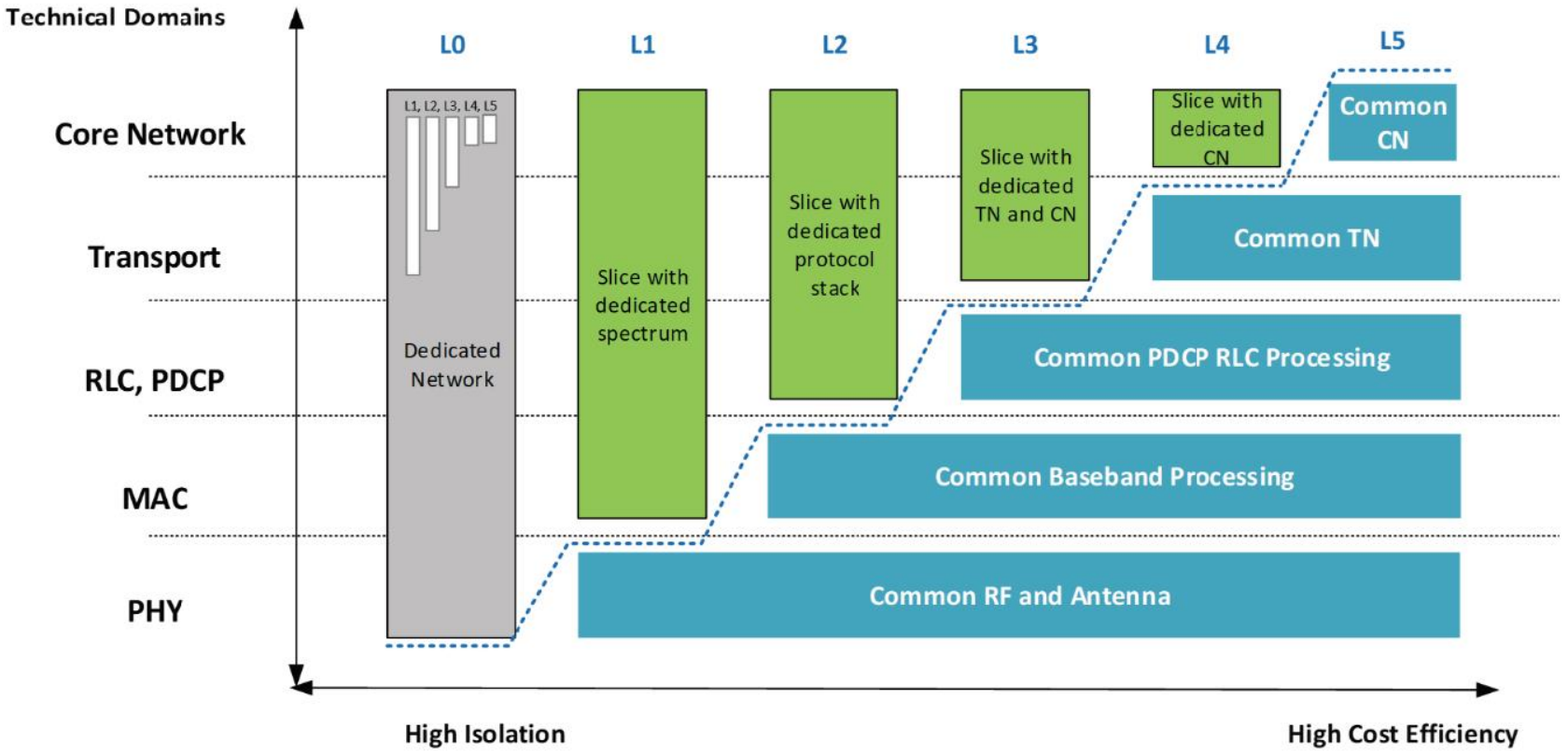
ITU-T, "Transport network support of IMT-2020/5G", Technical Report, Feb. 2018

Slicing Overview



Slice Isolation (1)

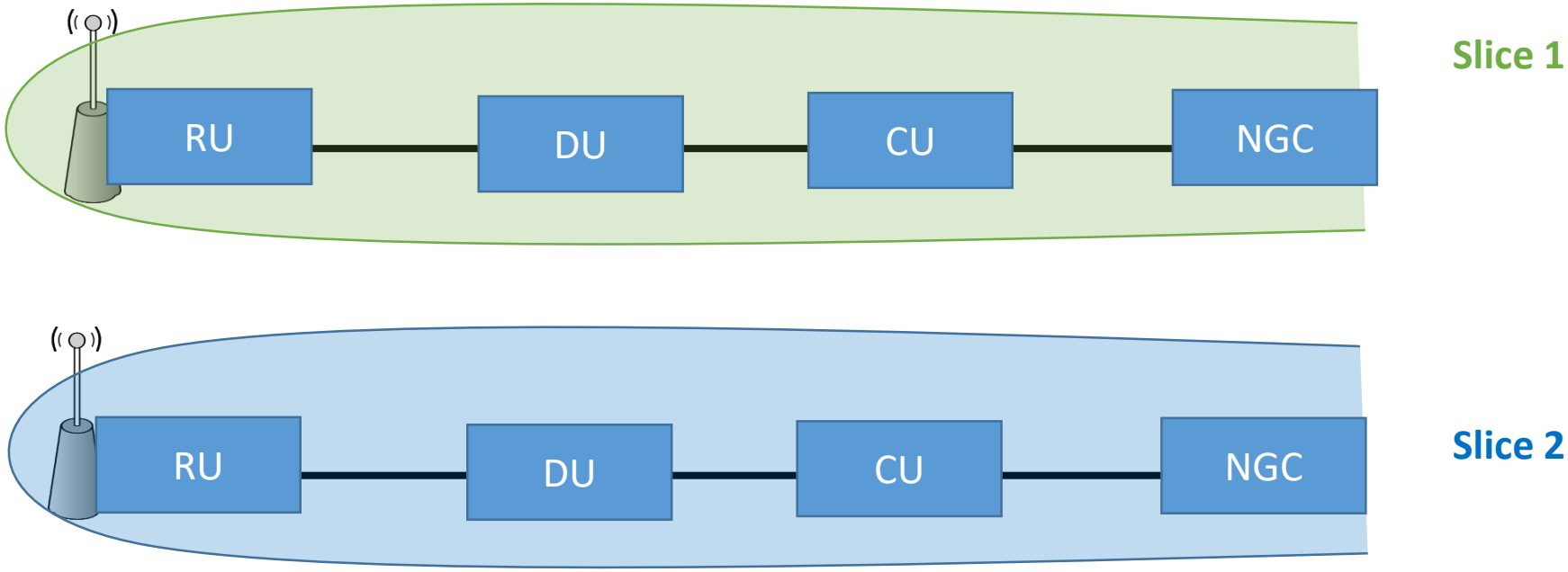
- Slice Isolation determines the possibility to share logical functions among different slices



GSMA, "Network Slicing: Use Case Requirements," Technical Report, Apr. 2018

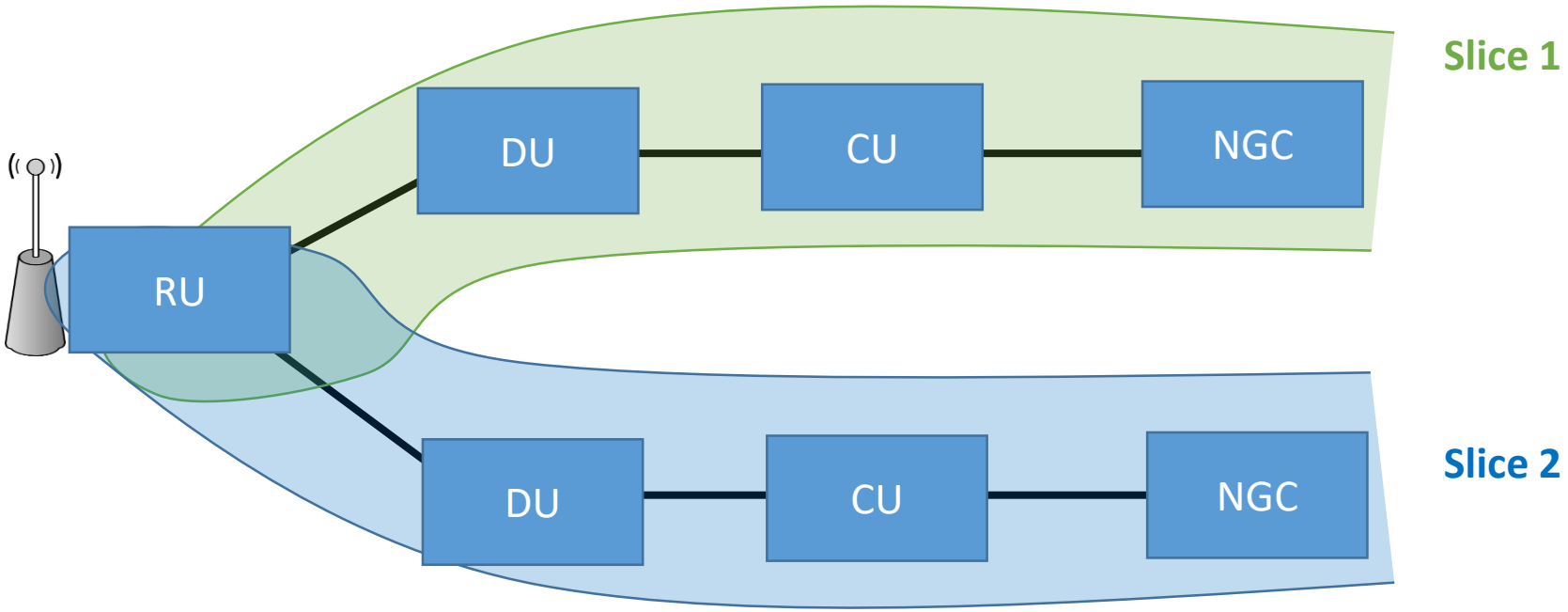
Slice Isolation (L0)

- Dedicated network
- Each slice has its own elements
- High cost



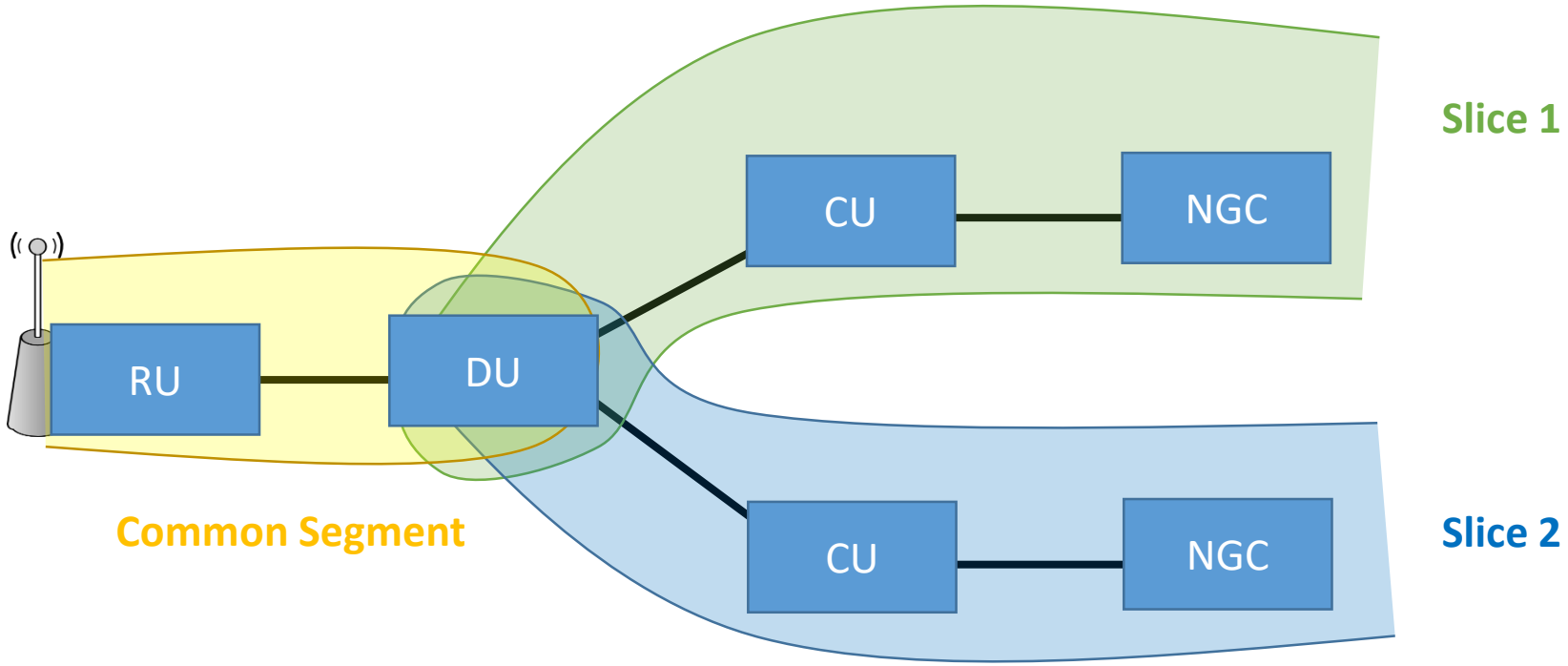
Slice Isolation (L1)

- Common Radio Unit



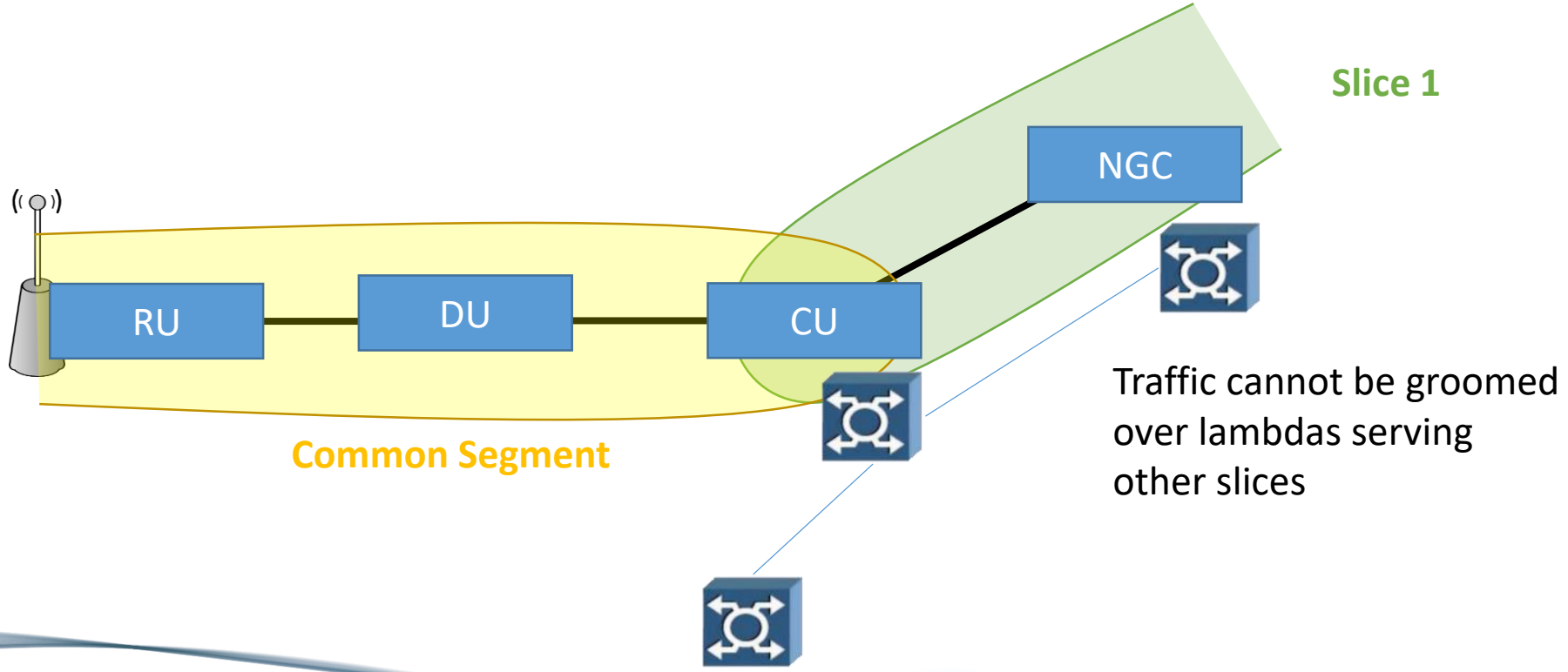
Slice Isolation (L2)

- Common Distributed Unit
- Slicing is implemented at the radio scheduler



Slice Isolation (L3)

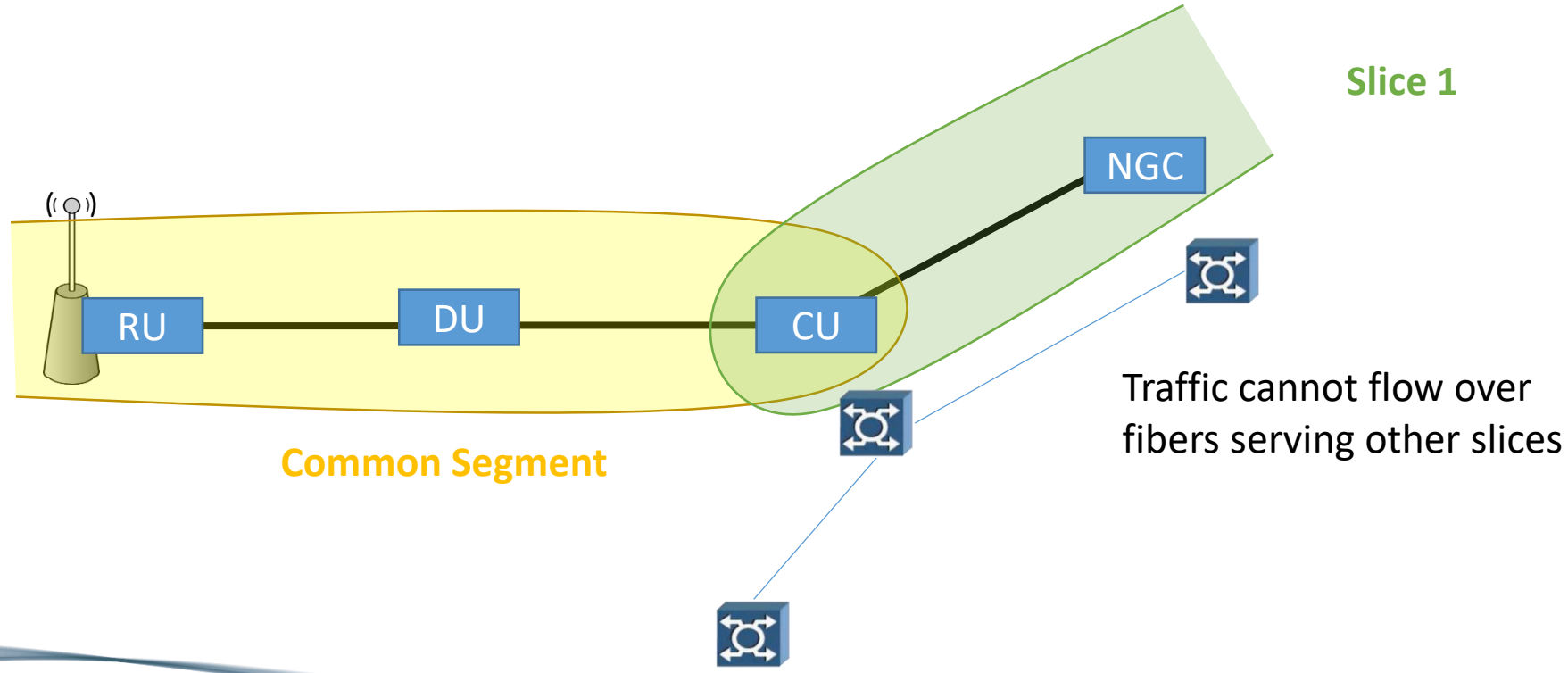
- Common Central Unit
- Dedicated physical transport network
  - Hard slicing (dedicated wavelengths, TDM resources)
  - Hardest (dedicated fibers, routing resources)



ITU-T, “Transport network support of IMT-2020/5G,” Technical Report, Feb. 2018

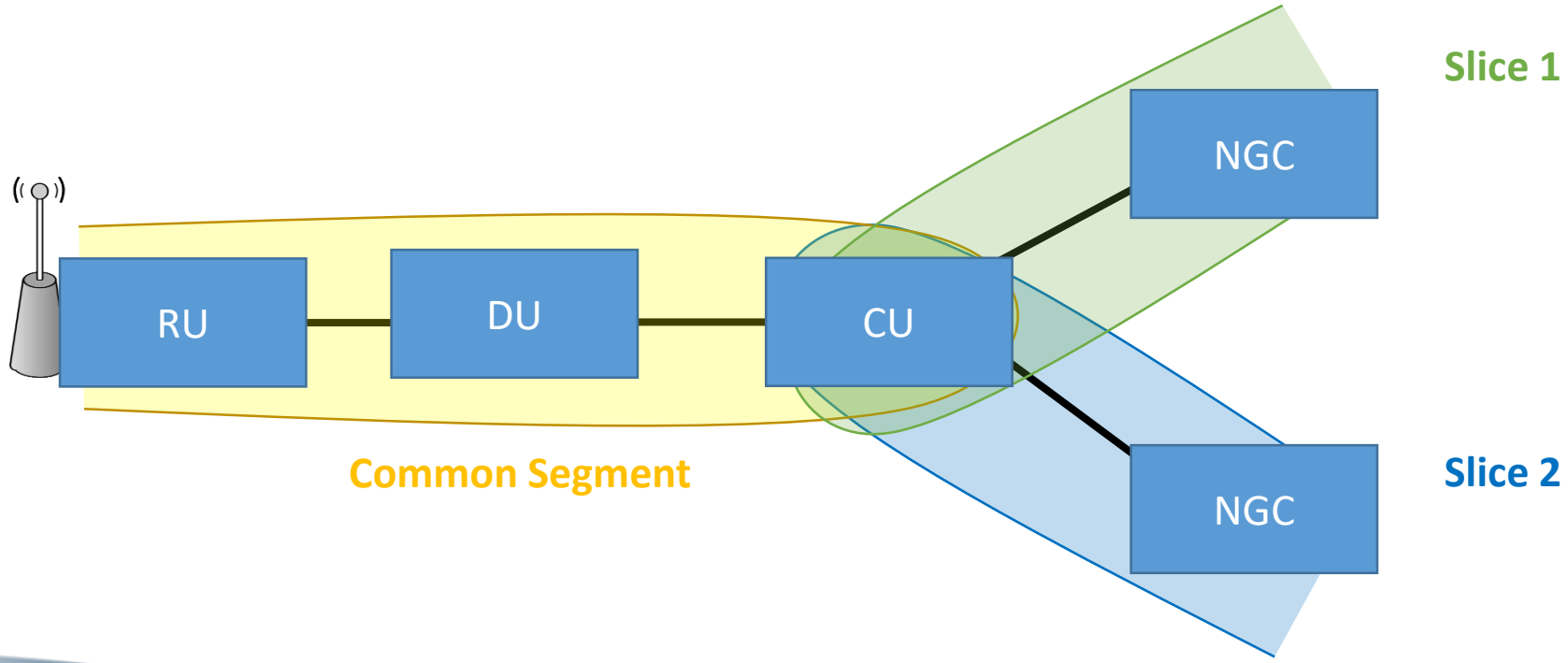
Slice Isolation (L3)

- Common Central Unit
- Dedicated physical transport network
  - Hard slicing (dedicated wavelengths, TDM resources)
  - Hardest (dedicated fibers, routing resources)



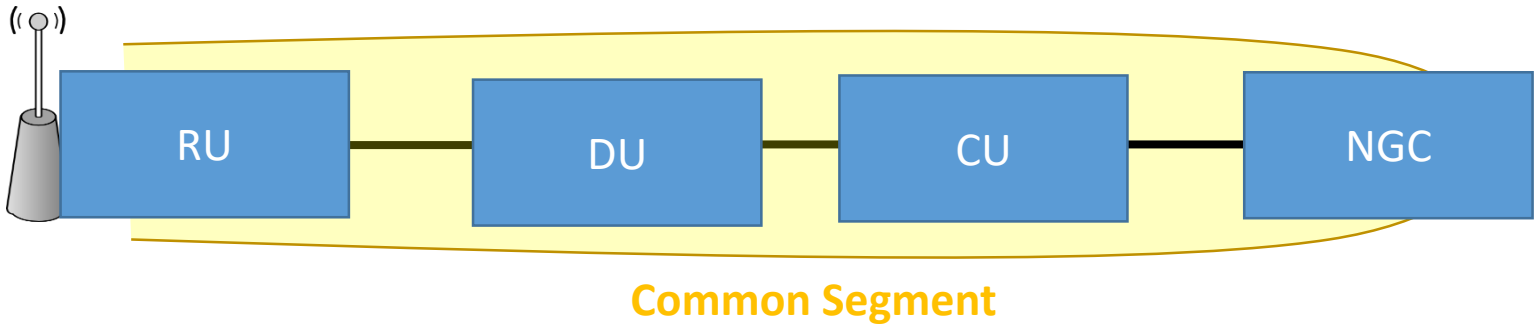
Slice Isolation (L4)

- Common Central Unit
- Without dedicated physical transport network

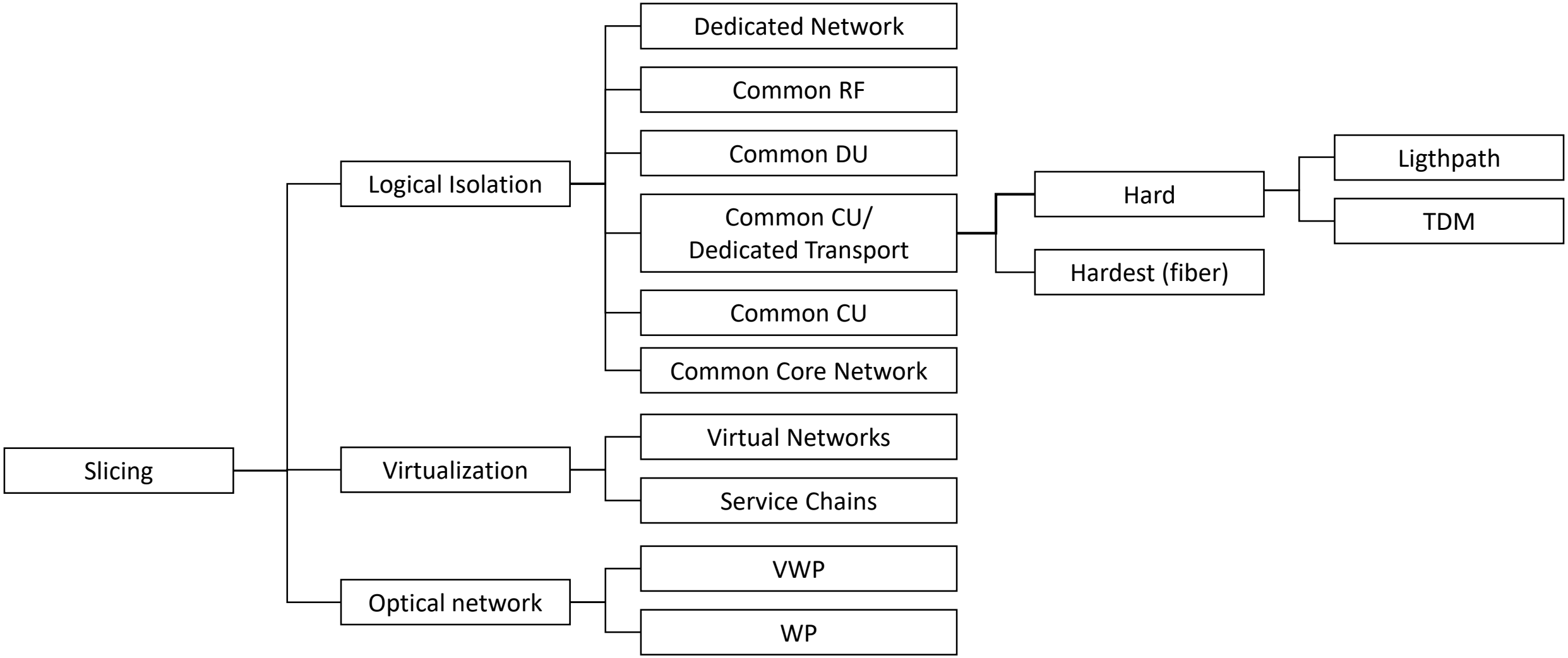


Slice Isolation (L5)

- Common Core Network
- No logical elements per slice

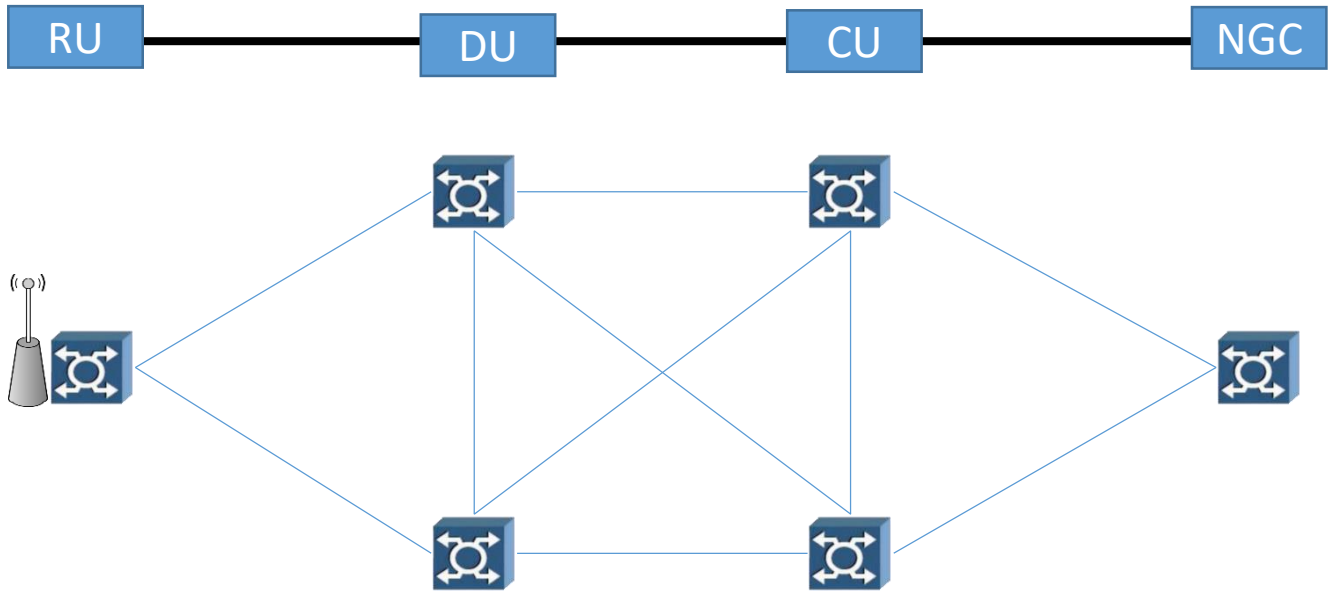


Slicing Overview



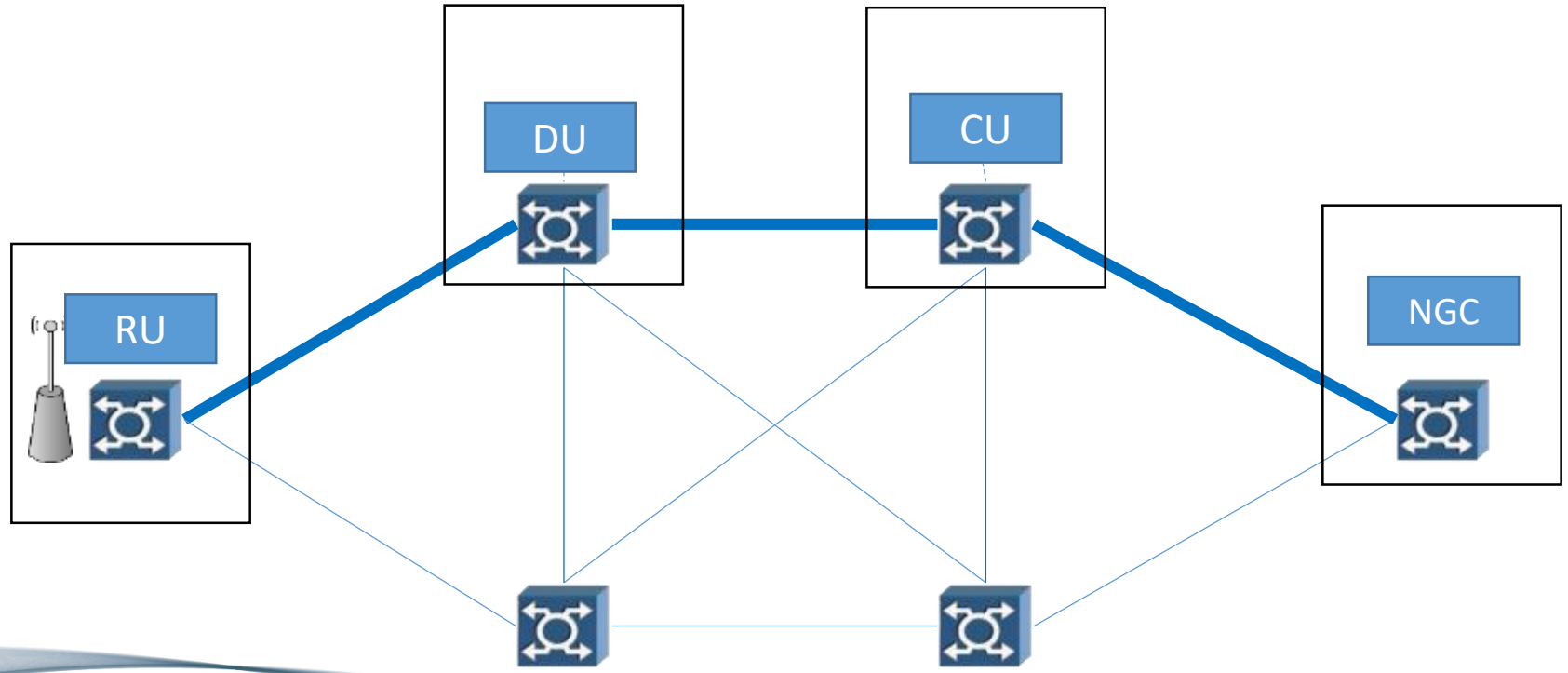
Virtual Networks vs. Service Chains (1)

- Slice:
  - Set of virtual nodes and virtual links with capacity requirements
  - Associated to reliability requirements
  - Dedicated transport



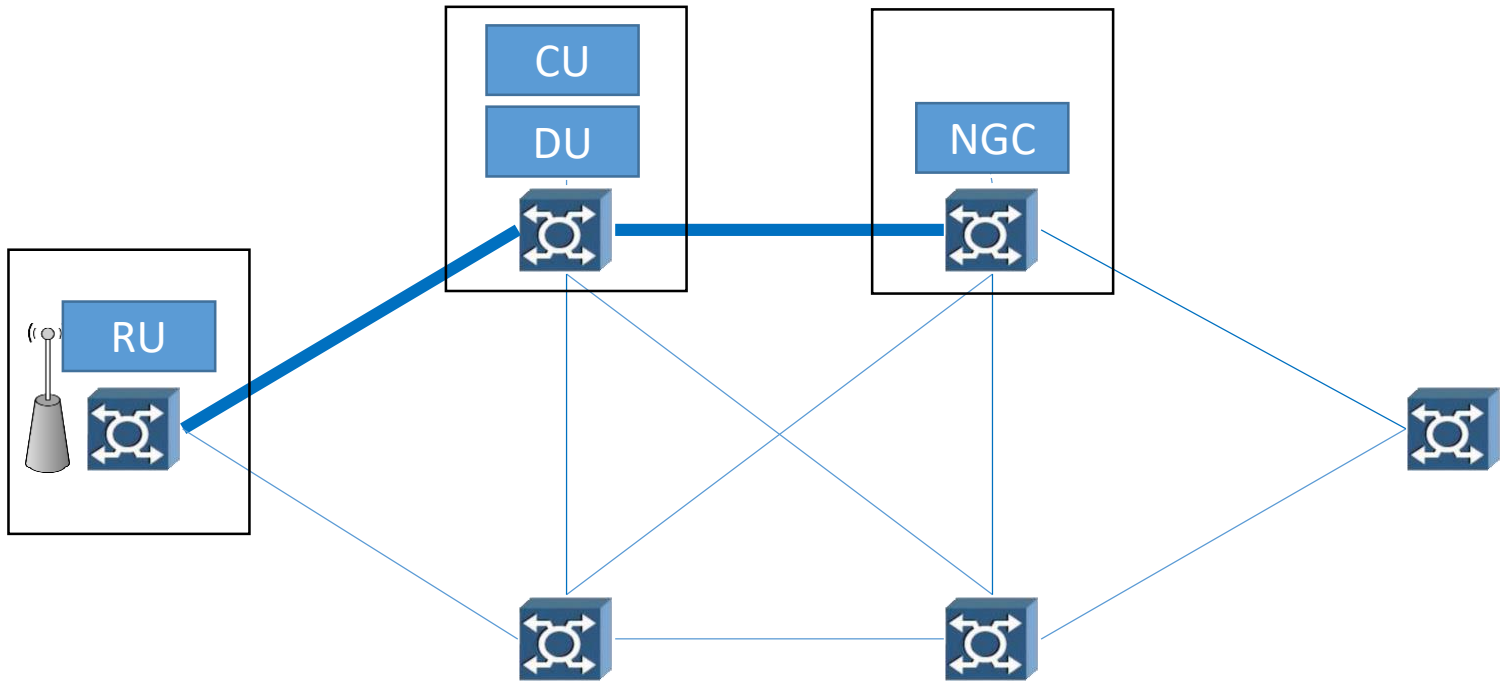
Virtual Networks vs. Service Chains (1)

- Virtual network embedding
  - Each virtual node is mapped on a separate substrate node
  - Each virtual link is mapped to one or multiple physical links

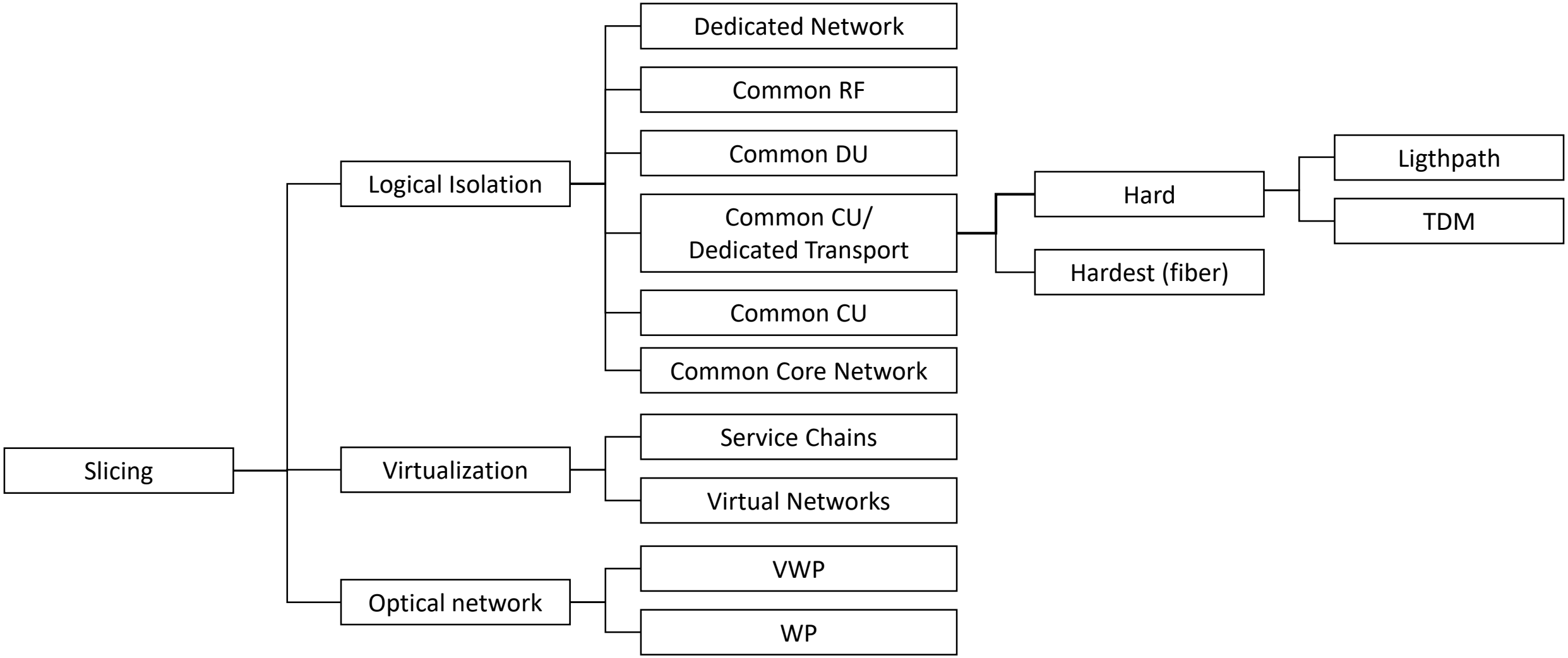


Virtual Networks vs. Service Chains (1)

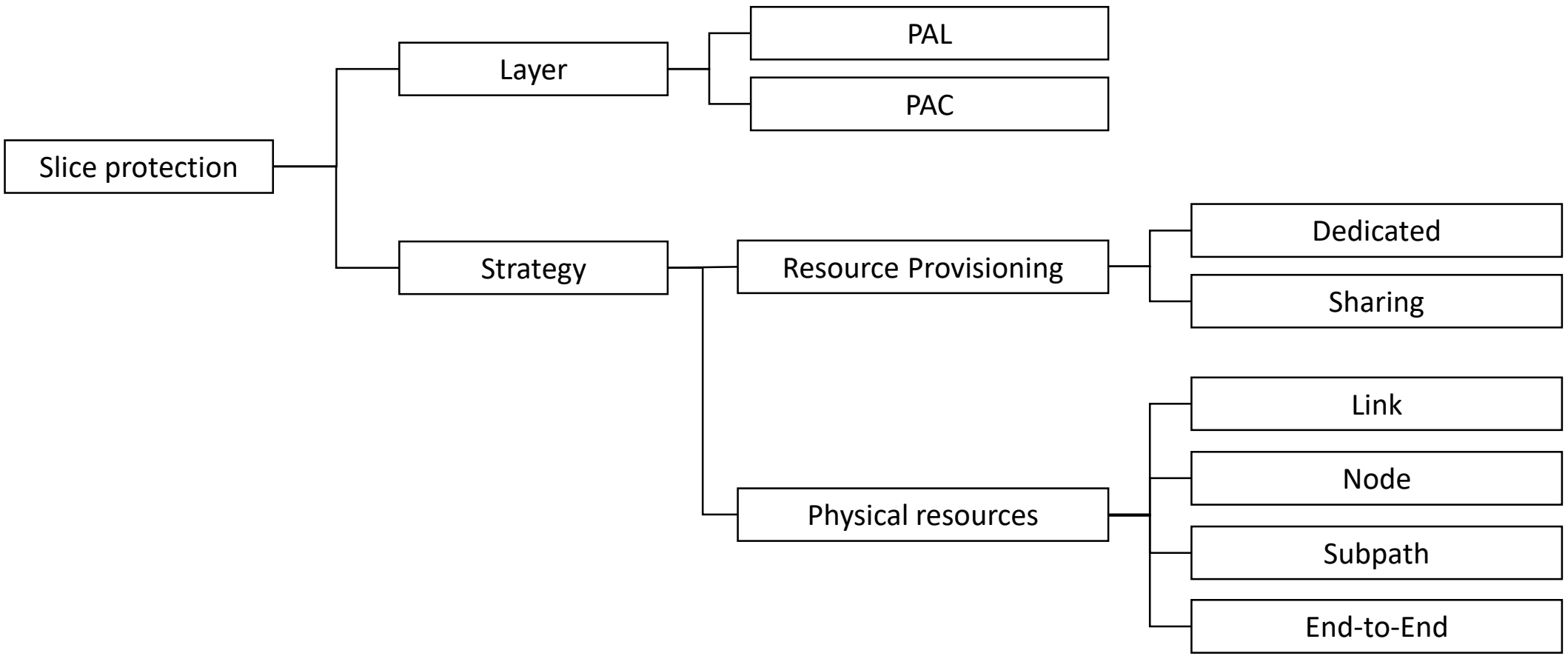
- Service chains
  - Functions are provisioned to compose the service chain
  - Several functions can be mapped on the same node



Slicing Overview

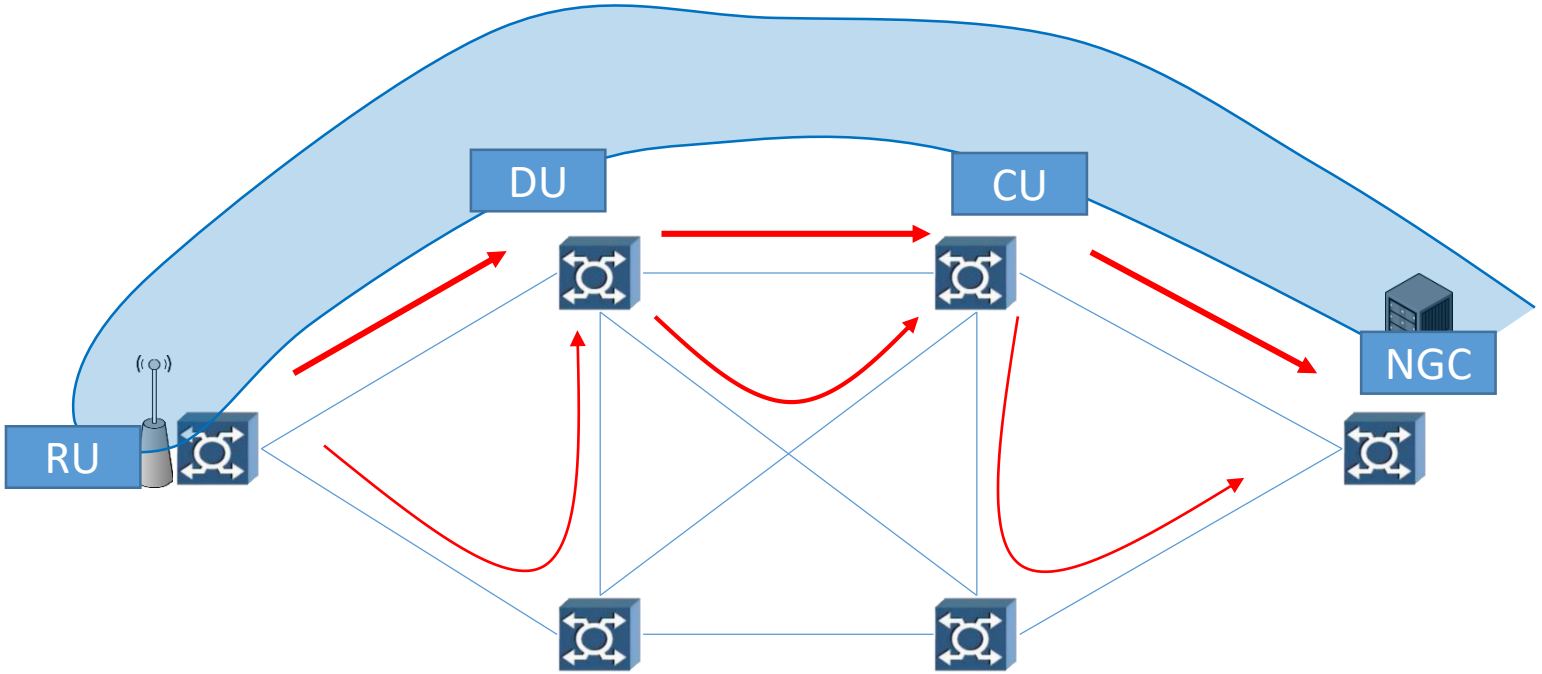


Slice Protection Overview



Protection strategy

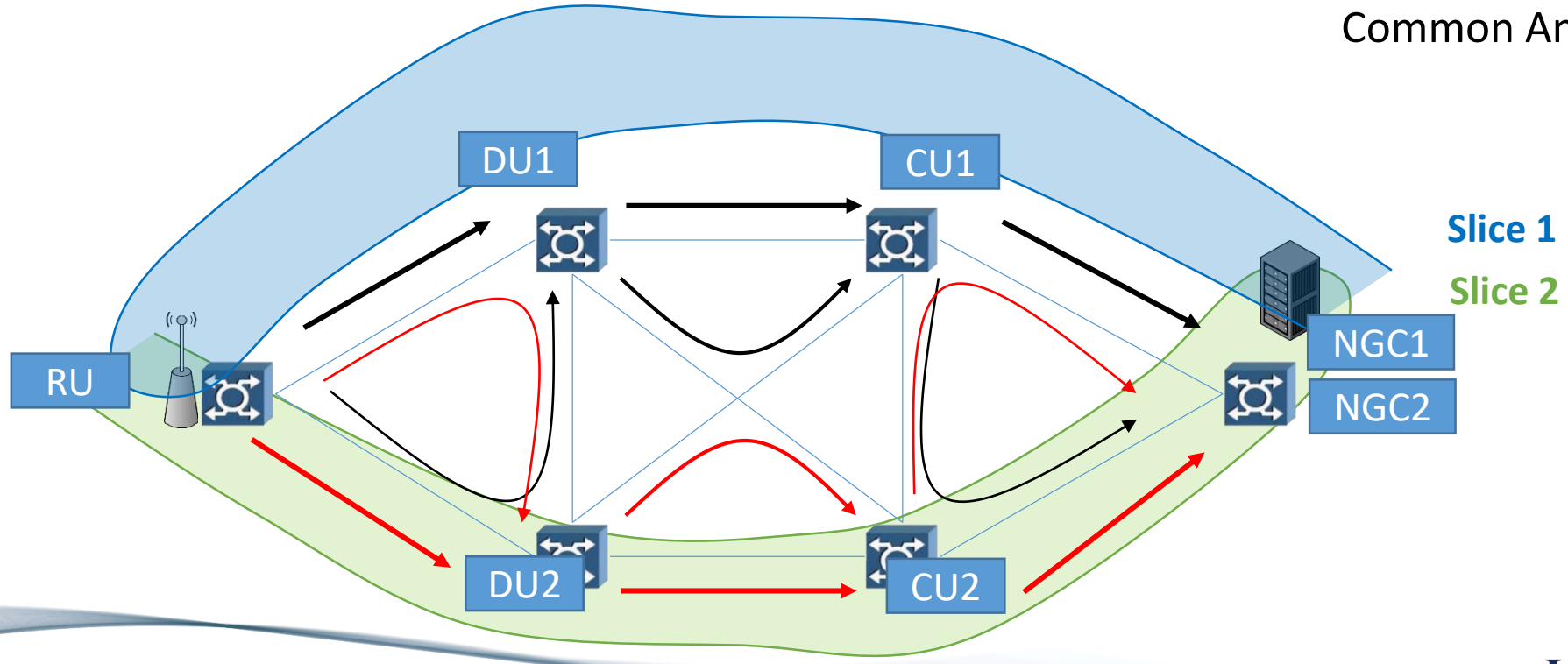
- Link protection



Slice 1

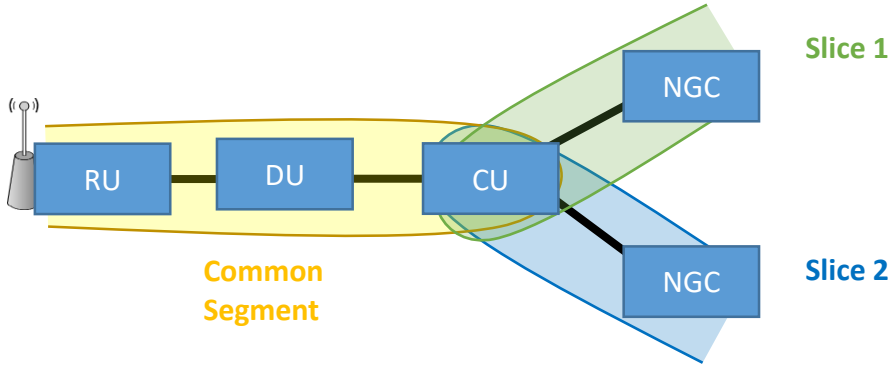
Protection strategy

- Link protection



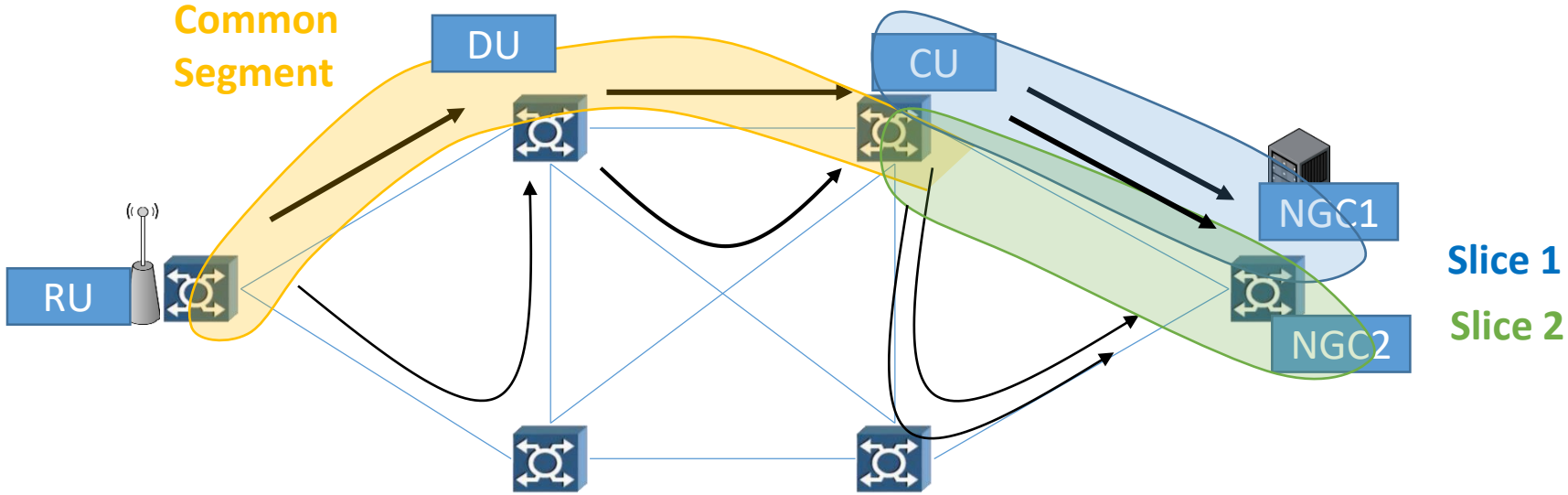
Protection strategy

- Link protection

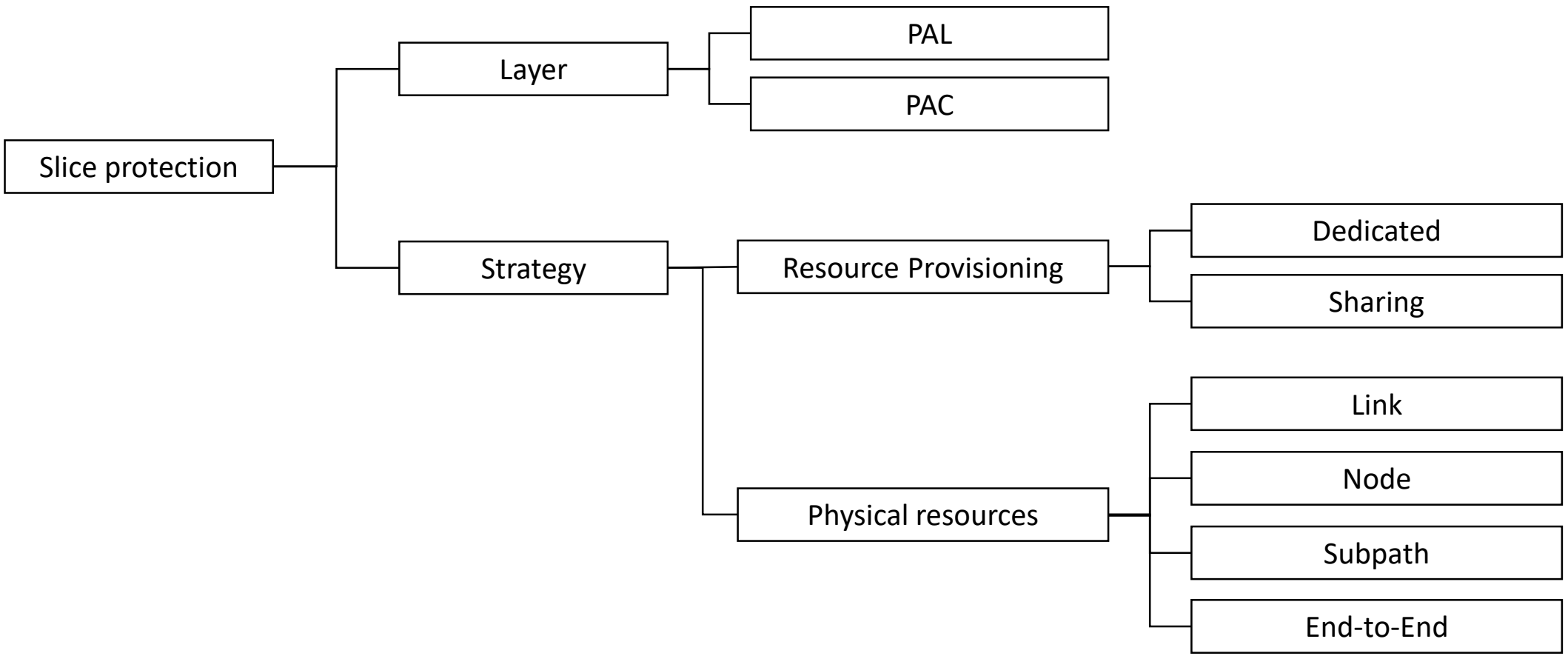


Isolation 4

Common CU

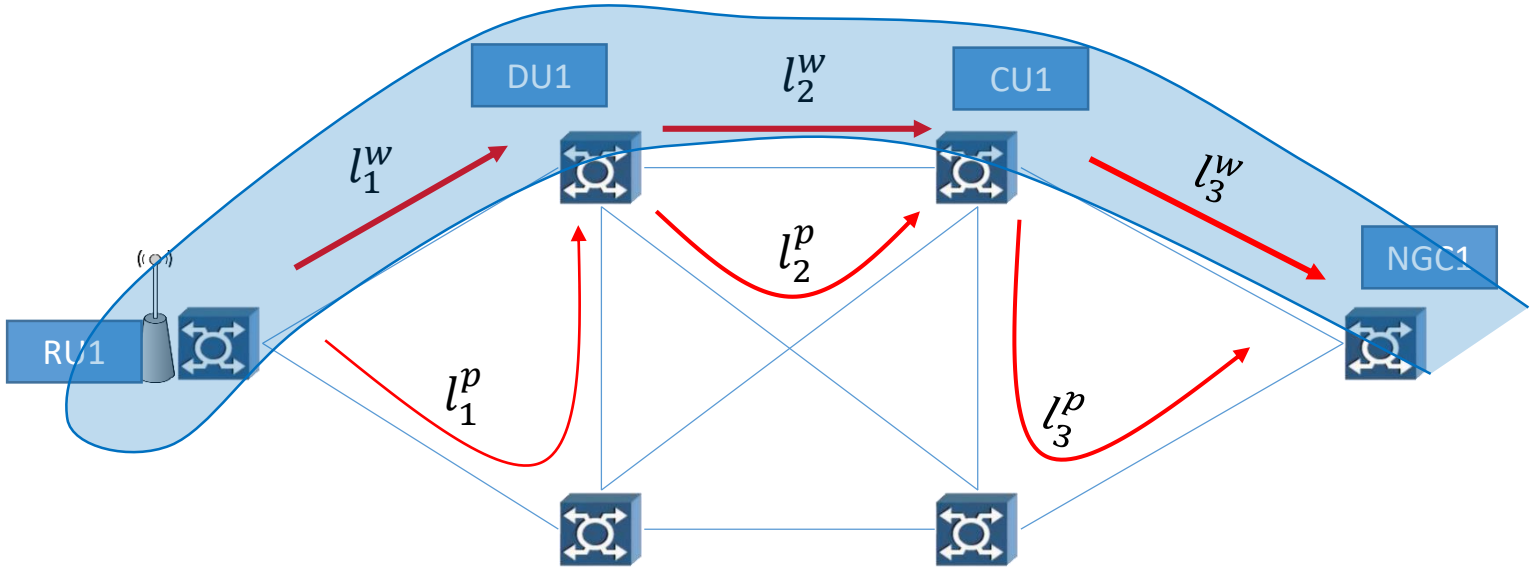


Slice Protection Overview



Protection at Lightpath

- Each lightpath has its own protection
  - l_i^w and l_i^p form the p-lightpath l_i

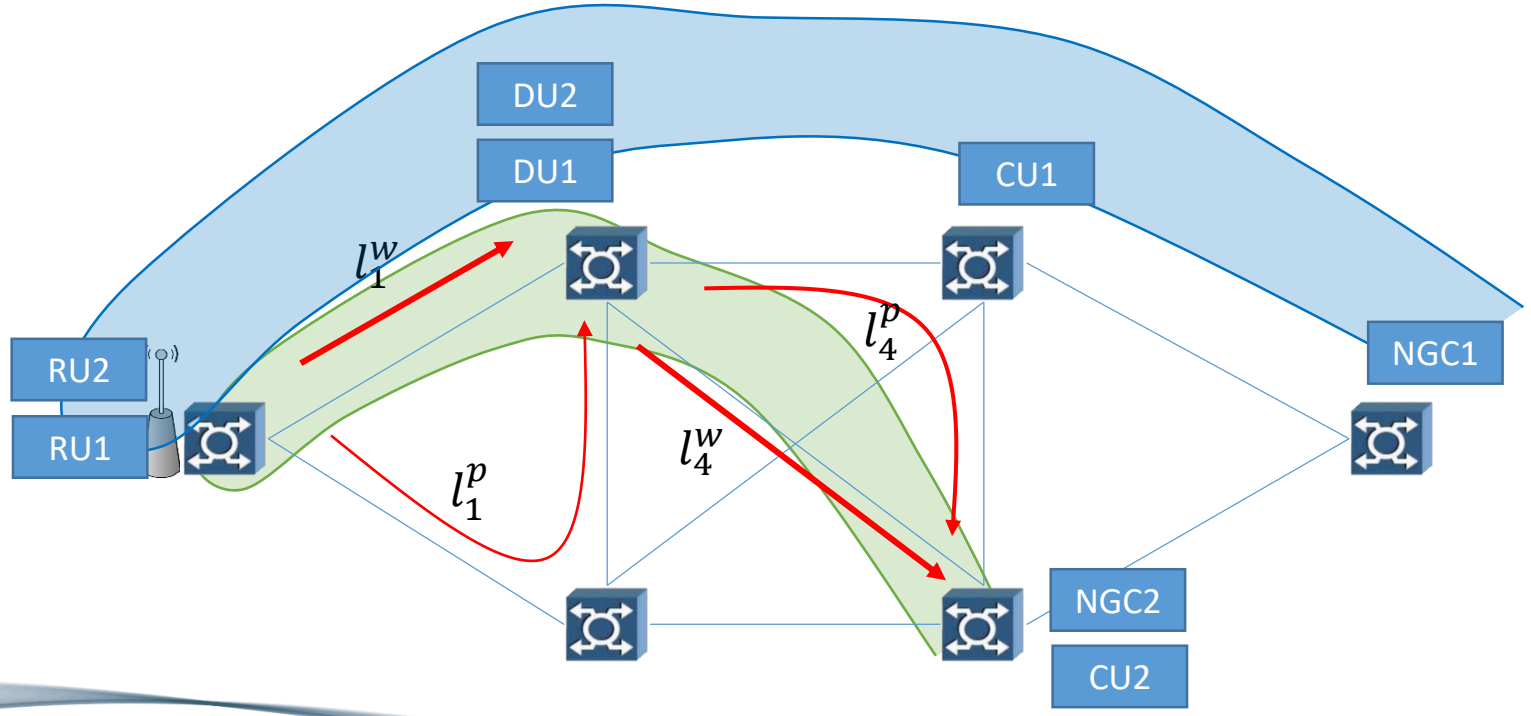


C. Ou, K. Zhu, J. Zhang, H. Zhu, B. Mukherjee, H. Zang, and L. Sahasrabuddhe,"Traffic grooming for survivable WDM networks—dedicated protection," J. Opt. Netw., vol. 3,no. 1, pp. 50–74, Jan. 2004.

UCDAVIS

Protection at Lightpath

- Each lightpath has its own protection
  - l_i^w and l_i^p form the p-lightpath l_i
  - Slice 1 uses p-lightpaths l_1 and l_2
  - Slice 2 uses p-lightpaths l_1 and l_4



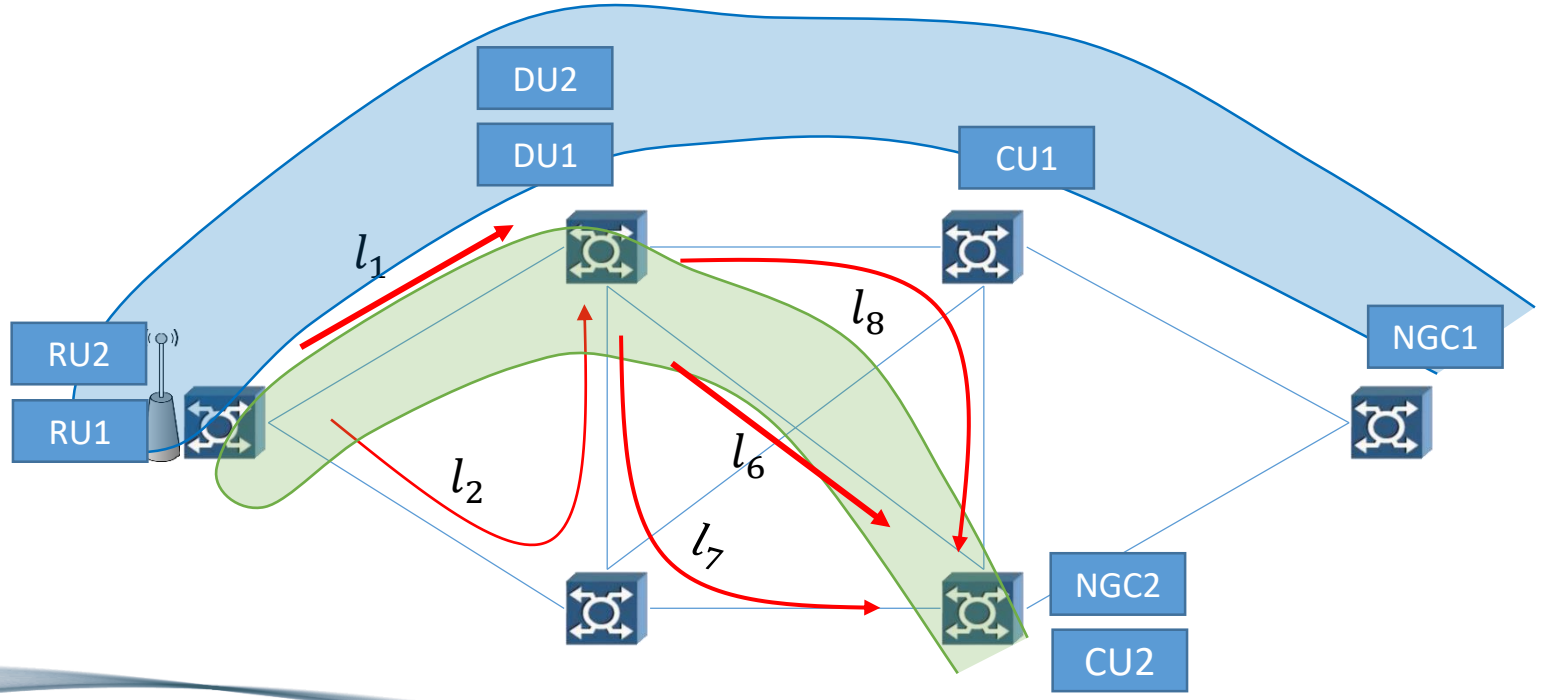
Slice 1

Slice 2

C. Ou, K. Zhu, J. Zhang, H. Zhu, B. Mukherjee, H. Zang, and L. Sahasrabuddhe,"Traffic grooming for survivable WDM networks—dedicated protection,"J. Opt. Netw., vol. 3,no. 1, pp. 50–74, Jan. 2004.

Protection at Connection

- Each lightpath is a separated entity
- Working and backup connections can be routed independently
  - Slice 2 uses lightpaths l_1, l_6 as working
    - Can use (l_2, l_7) or (l_2, l_8) as protection



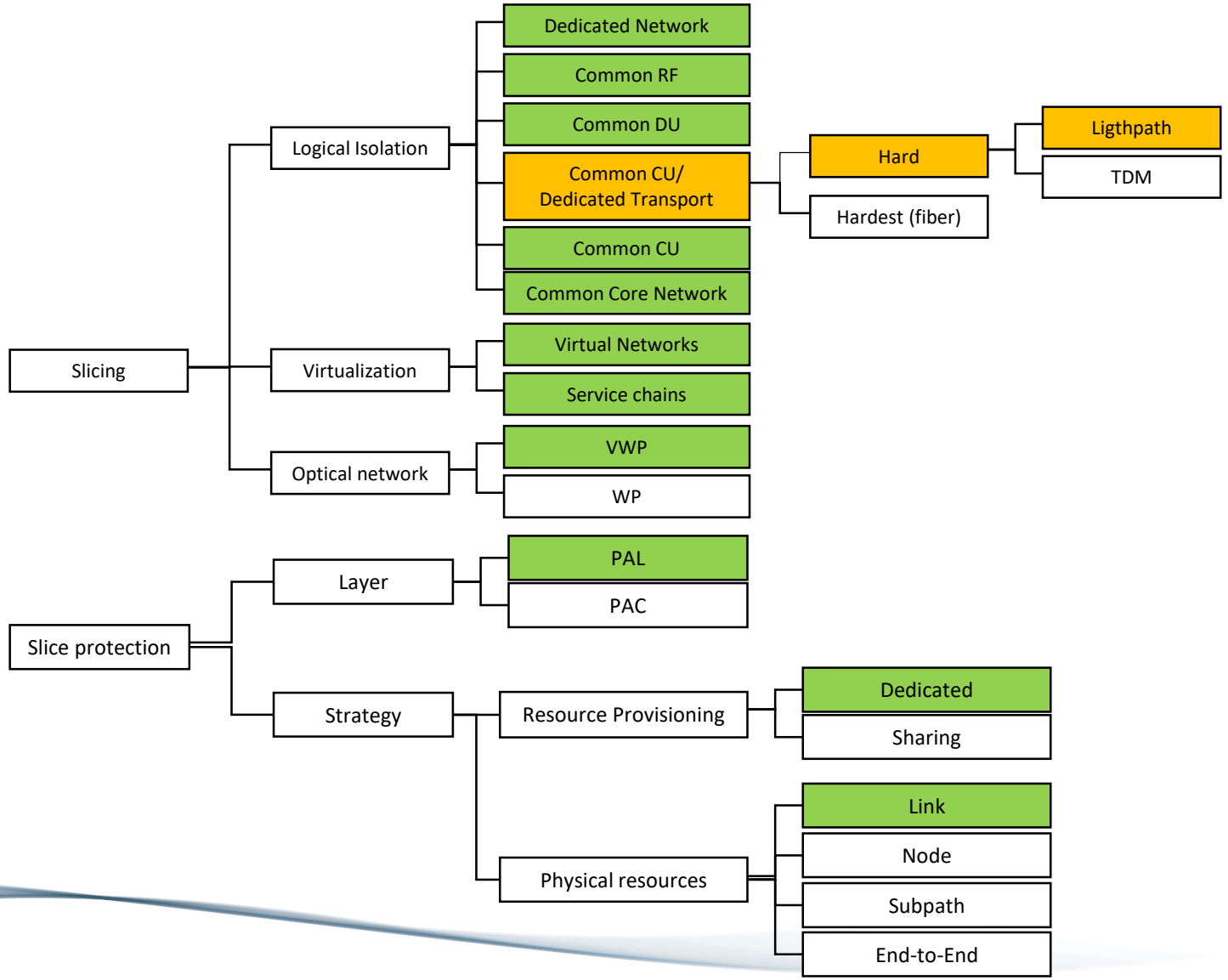
Slice 1

C. Ou, K. Zhu, J. Zhang, H. Zhu, B. Mukherjee, H. Zang, and L. Sahasrabuddhe,"Traffic grooming for survivable WDM networks—dedicated protection,"J. Opt. Netw., vol. 3,no. 1, pp. 50–74, Jan. 2004.

Problem definition

- We investigate the problem of realizing reliable path provisioning for network slices through Protection At Lightpath taking into account:
  - Slice isolation
  - Dedicated resources
  - Virtualization techniques
- We want to minimize
  - Wavelength channels utilization

Reliable slicing with PAL (ILP)



Reliable slicing with PAL (ILP)

- Objective function:

$$\text{minimize} \sum_{i,j} \sum_{m,n} (z_{mn}^{ij} + \zeta_{mn}^{ij})$$

Wavelength utilization of working and backup paths

- Such that:

$$\sum_{\substack{j \in N_P \\ j \neq i}} p_{ij}^{sbe} - \sum_{\substack{j \in N_P \\ j \neq i}} p_{ji}^{sbe} = \begin{cases} l_{be}^{s} & \text{if } i = b \\ -l_{be}^{s} & \text{if } i = e \\ 0 & \text{otherwise} \end{cases} \quad \forall i, b, e \in N_P, s \in N_S$$

$$l_{be}^{s} = \sum_{u,v \in N_V} (b_{uv}^{s} \times h_{be}^{suv}) \quad \forall b, e \in N_P, s \in N_S$$

$$\sum_{b,e \in N_P} p_{ij}^{sbe} \leq C \times x_{ij}^{s} \quad \forall i, j \in N_P, s \in N_S$$

$$\sum_{\substack{b,e \in N_P \\ s \in N_S}} (p_{ij}^{sbe} \times x_{ij}^{s}) \leq C \times x_{ij} \quad \forall i, j \in N_P,$$

$$\sum_{\substack{n \in N_P \\ n \neq m}} z_{mn}^{ij} - \sum_{\substack{n \in N_P \\ n \neq m}} z_{nm}^{ij} = \begin{cases} x_{ij} & \text{if } m = i \\ -x_{ij} & \text{if } m = j \\ 0 & \text{otherwise} \end{cases} \quad \forall m, i, j \in N_P$$

Routing constraints

Reliable slicing with PAL (ILP)

- Such that:

$$h_{be}^{suv} = y_{ub}^{s} \times y_{ve}^{s} \quad \forall b, e \in N_P, u, v \in N_V, s \in N_S$$

$$\sum_{n \in N_P} y_{un}^{s} = 1 \quad \forall u \in N_V, s \in N_S$$

$$\sum_{\substack{u \in N_V \\ s \in N_S}} y_{un}^{s} \times K_u^s \leq C_n \quad \forall u \in N_V, n \in N_P, s \in N_S$$

$$y_{un}^{s} \leq M_{un}^{s} \quad \forall n \in N_P, u \in N_V, s \in N_S$$

Placement constraints

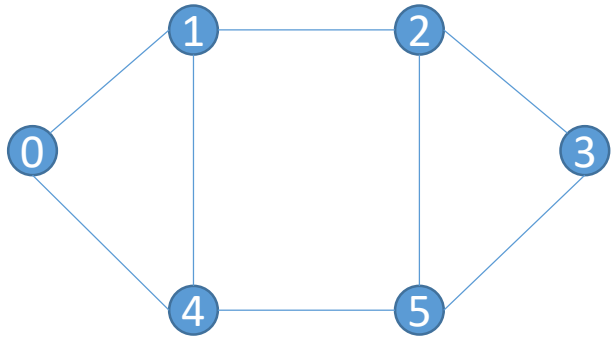
$$\sum_{\substack{n \in N_P \\ n \neq m}} \zeta_{mn}^{ij} - \sum_{\substack{n \in N_P \\ n \neq m}} \zeta_{nm}^{ij} = \begin{cases} x_{ij} & \text{if } m = i \\ -x_{ij} & \text{if } m = j \\ 0 & \text{otherwise} \end{cases} \quad \forall m, i, j \in N_P$$

$$\hat{z}_{mn}^{ij} + \hat{z}_{nm}^{ij} + \hat{\zeta}_{mn}^{ij} + \hat{\zeta}_{nm}^{ij} \leq 1 \quad \forall i, j, m, n \in N_P$$

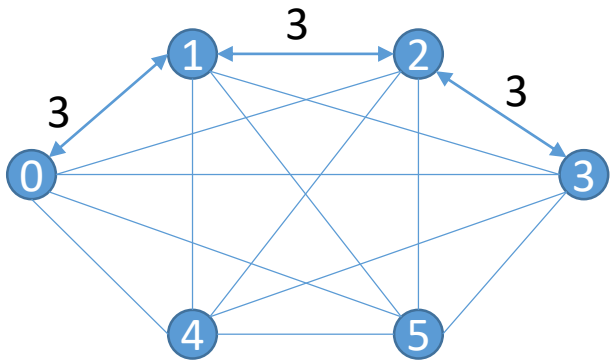
$$\sum_{i,j \in N_P} (z_{mn}^{ij} + \zeta_{nm}^{ij}) \leq W \times F_{mn} \quad \forall m, n \in N_P$$

Protection constraints

Reliable slicing with PAL (Heuristic)

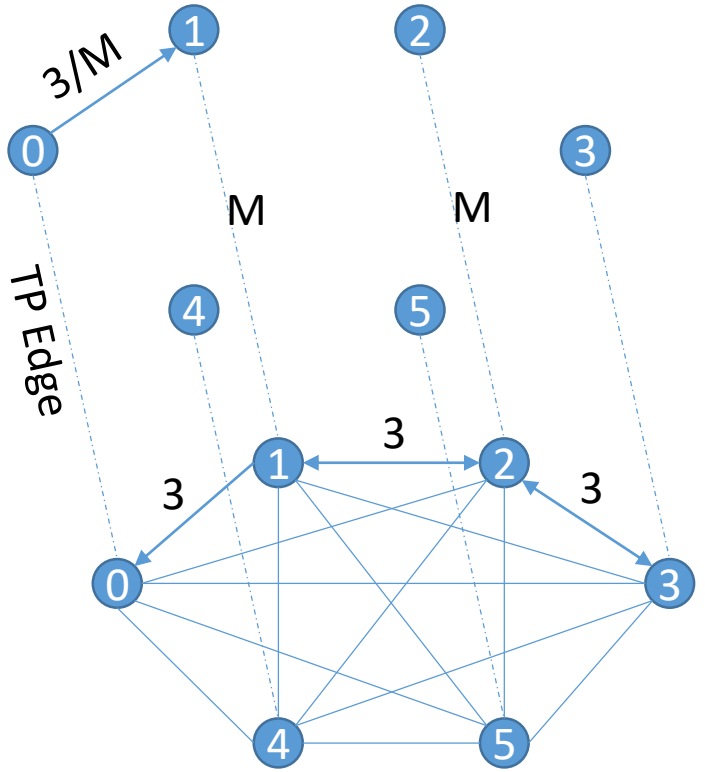


Physical connectivity graph

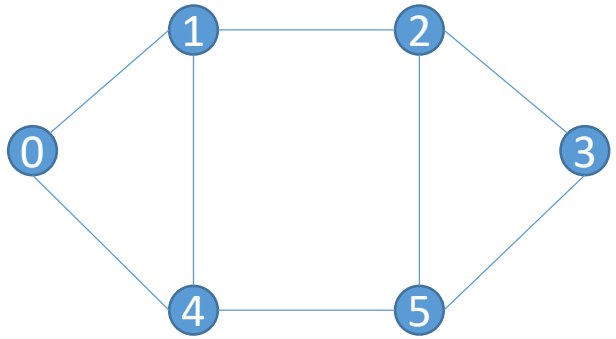


P-lightpath connectivity graph

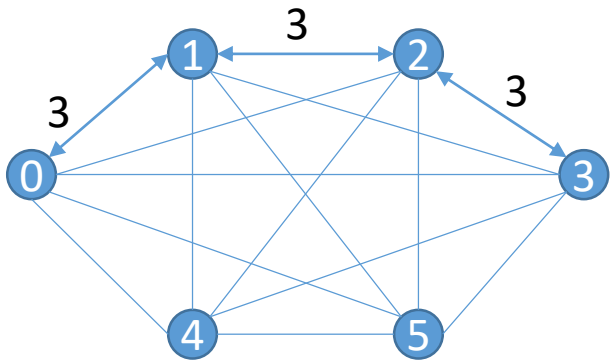
P-lightpath grooming graph



Reliable slicing with PAL (Heuristic)

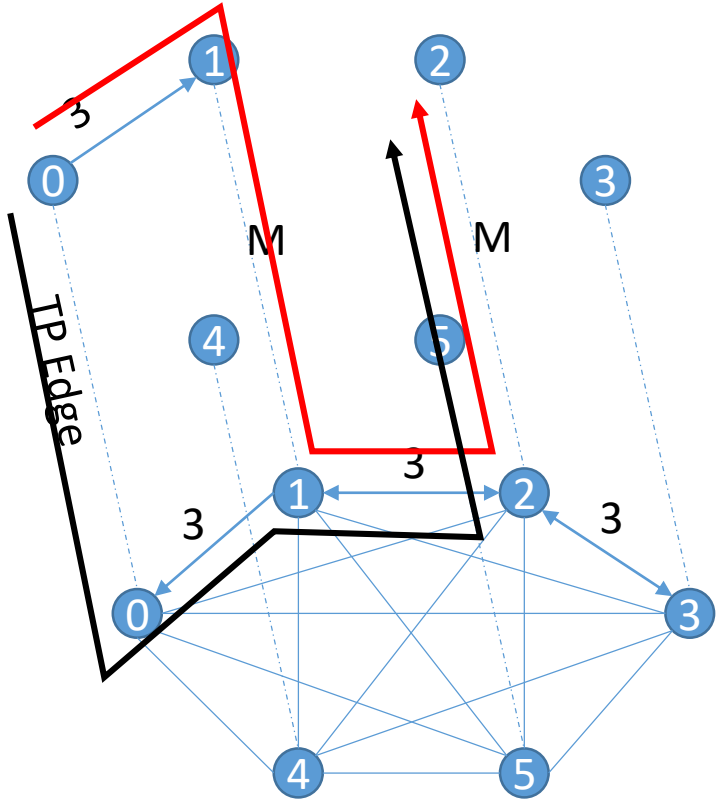


Physical connectivity graph

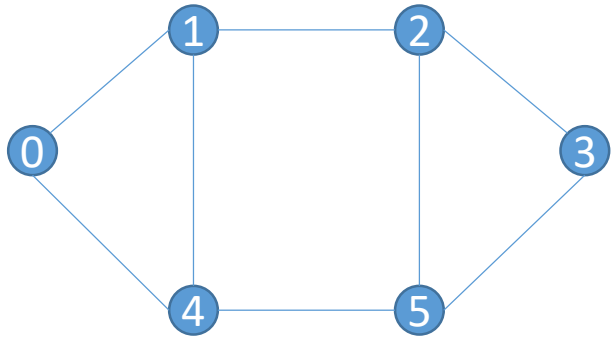


P-lightpath connectivity graph

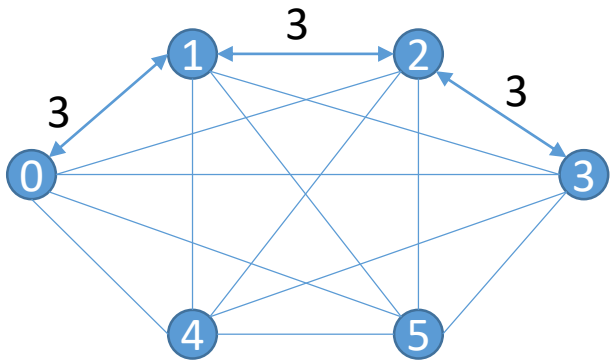
P-lightpath grooming graph



Reliable slicing with PAL (Heuristic)

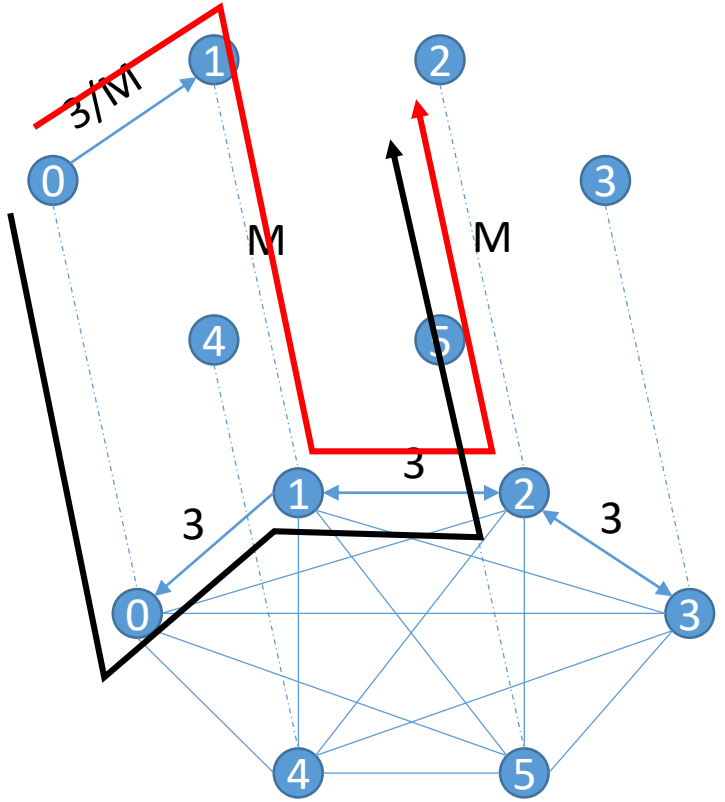


Physical connectivity graph



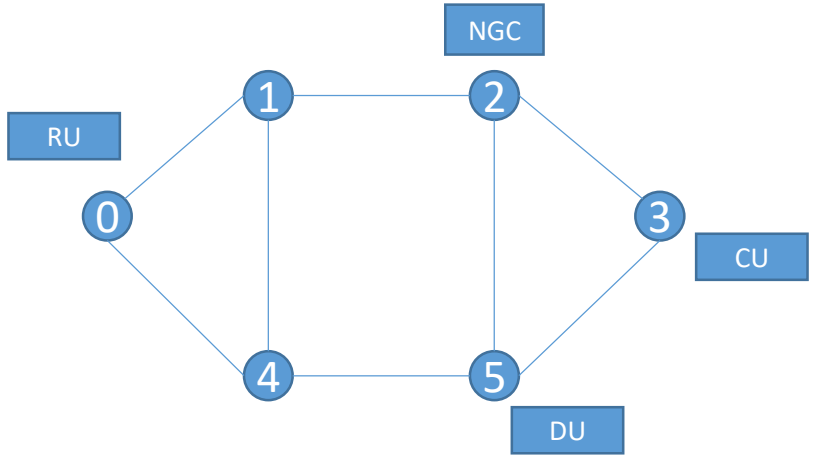
P-lightpath connectivity graph

P-lightpath grooming graph

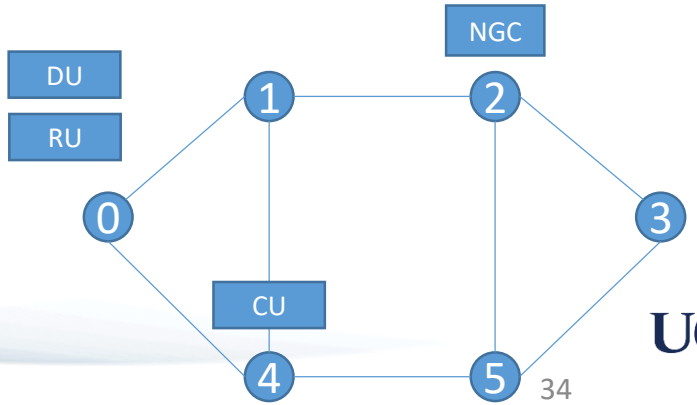


Reliable slicing with PAL (Heuristic)

1. Node Mapping
   - Virtual Network mapping
     - Calculate k shortest paths between the endpoints
     - Look for a path
       - With sufficient length
       - Able to host all the functions of the slice

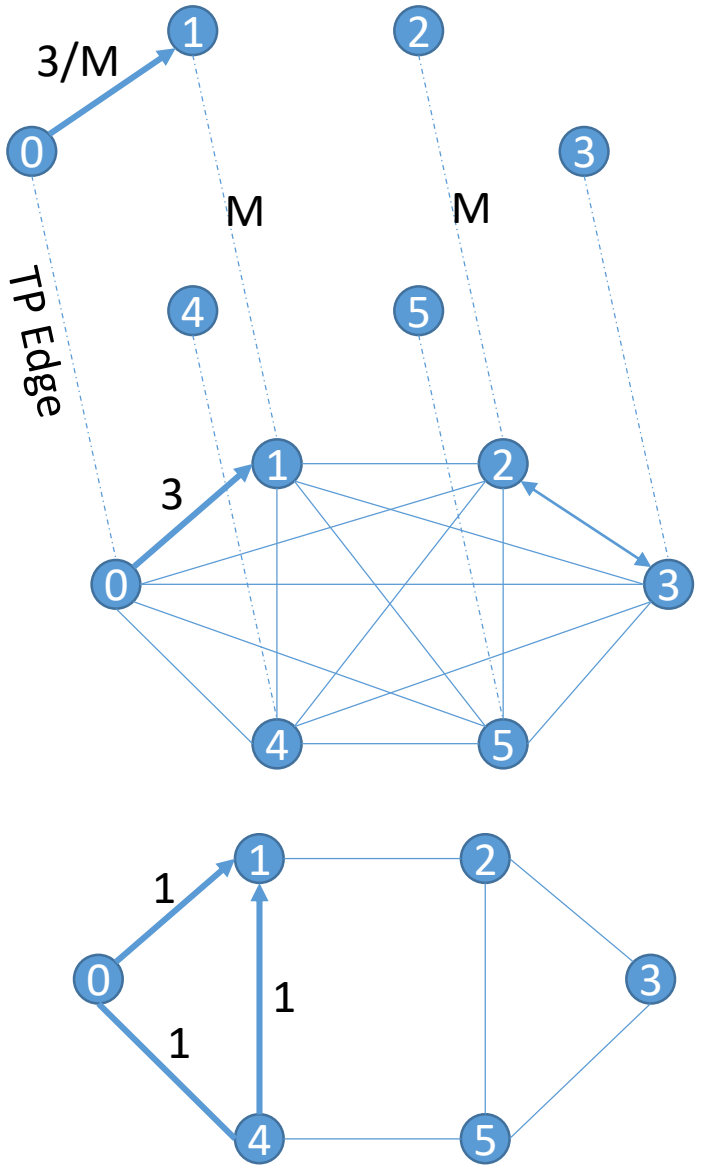


   - Service Function Chaining mapping
     - Try to place the functions of the slice on the shortest path between the endopoints
     - If a placement is not found
       - Place the functions on the nodes with lowest *betweennes*



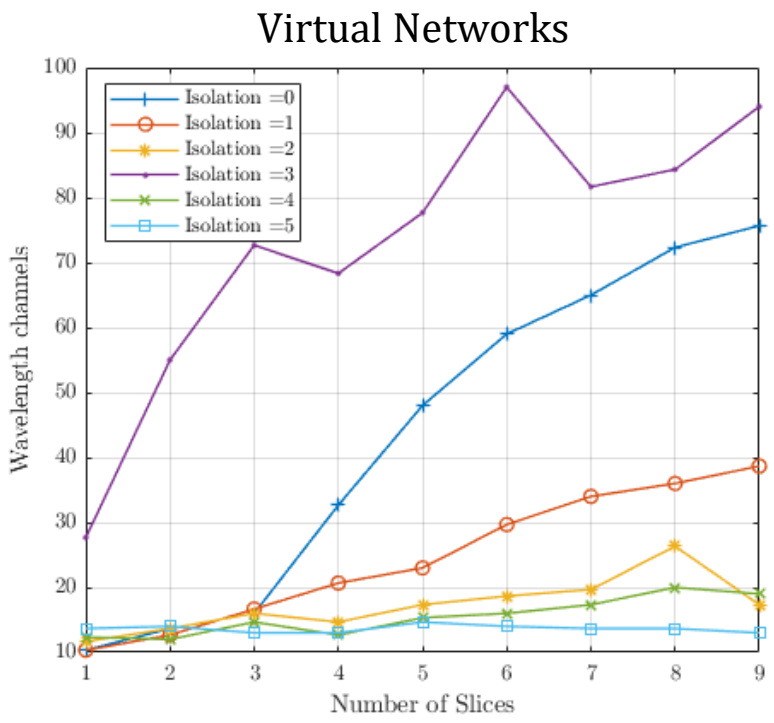
Reliable slicing with PAL (Heuristic)

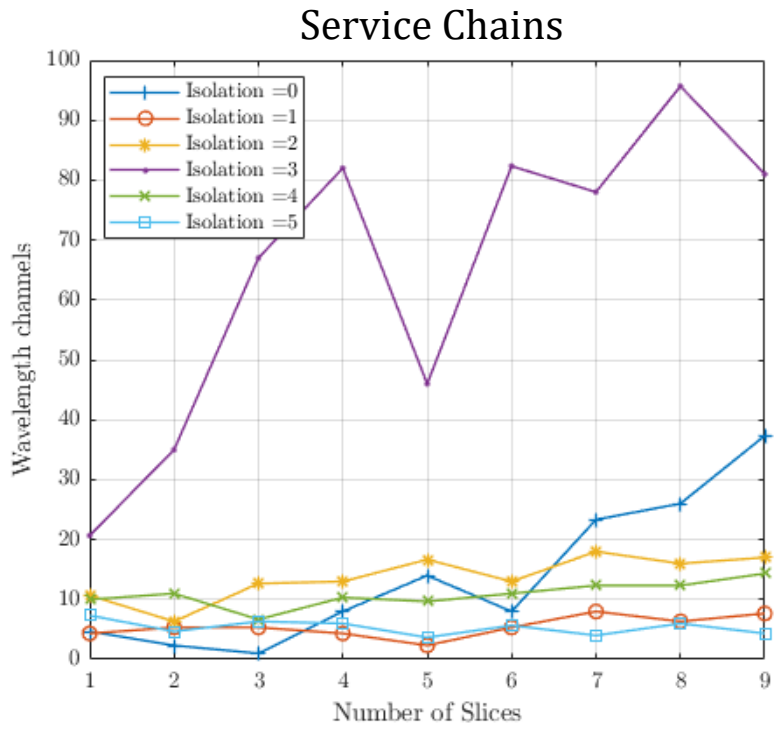
1. Link Mapping
    1. Construct plightpath connectivity graph
    2. Construct the plightpath grooming graph
    3. For each traffic request
        - Find a shortest path between the endpoints
        - Check if available resources in the corresponding links are sufficient
        - Update plightpath grooming path (add or remove links)



Preliminary results

- Protection in higher isolation requires lower optical resources provisioning
- Service Function Chaining reduces wavelength channel utilization with respect to Virtual Network deployment
- Dedicated Transport (Isolation 3) requires a much higher amount of resources





Expected results

- We want to study optical resource utilization for reliable slicing analyzing the impact of:
  - Slice Isolation
  - SFC vs VN
  - Size of the slices
  - Aggregation of slices
  - Network Connectivity

Thank you