Reliable Slicing

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Group Meeting
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Outline

- Slicing scenarios
- Slicing protection
- Problem definition
- Reliable slicing ILP
- Proposed Heuristic
- Preliminary results
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.
Virtual service chains for mobile network slicing

Slicing Overview

- Slicing
  - Logical Isolation
    - Dedicated Network
      - Common RF
    - Common DU
    - Common CU/Dedicated Transport
    - Common CU
    - Common Core Network
  - Virtualization
    - Service Chains
    - Virtual Networks
    - VWP
    - WP
  - Optical network
  - Hard
    - Ligthpath
    - TDM
  - Hardest (fiber)
Slice Isolation (1)

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

Traffic cannot be groomed over lambdas serving other slices.

Slice Isolation (L3)

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

Traffic cannot flow over fibers serving other slices.
Slice Isolation (L4)

- Common Central Unit
- Without dedicated physical transport network
Slice Isolation (L5)

- Common Core Network
- No logical elements per slice
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

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- Virtualization
  - Service Chains
  - Virtual Networks
  - VWP
  - WP
- Optical network

- Hard
- Hardest (fiber)
- Lightpath
- TDM
Slice Protection Overview

- Layer
  - PAL
  - PAC

- Strategy

- Resource Provisioning
  - Dedicated
  - Sharing

- Physical resources
  - Link
  - Node
  - Subpath
  - End-to-End
Protection strategy

• Link protection
Protection strategy

• Link protection
Protection strategy

- Link protection
Slice Protection Overview

- **Layer**
  - PAL
  - PAC

- **Strategy**
  - Resource Provisioning
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    - End-to-End

- **Physical resources**

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Slice protection
Protection at Lightpath

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

**Protection at Lightpath**

• Each lightpath has its own protection
  • $l^w_i$ and $l^p_i$ form the p-lightpath $l_i$
  • Slice 1 uses p-lightpaths $l_1$ and $l_2$
  • Slice 2 uses p-lightpaths $l_1$ and $l_4$

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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

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)

Logical Isolation
- Dedicated Network
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  - Common Core Network
- Virtual Networks
- Service chains
- VWP
- WP

Slicing
- Hard
- Hardest (fiber)
- Litepath
- TDM

Virtualization
- Dedicated Transport
- Common CU
- Common Core Network

Optical network

Layer
- PAL
- PAC

Slice protection

Strategy
- Resource Provisioning
  - Dedicated
  - Sharing
  - Link
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  - Subpath
  - End-to-End

Physical resources
Reliable slicing with PAL (ILP)

• Objective function:

\[
\text{minimize } \sum_{i,j} \sum_{m,n} (z_{mn}^i + \xi_{mn}^i)
\]

• Such that:

\[
\sum_{j \in N_P \setminus i} p_{ij}^{bc} - \sum_{j \in N_P \setminus i} p_{ji}^{bc} = \begin{cases} 
  l_{bc}^e & \text{if } i = b \\
  -l_{bc}^s & \text{if } i = e \\
  0 & \text{otherwise}
\end{cases}
\]

\[
\forall i, b, c \in N_P, s \in N_S
\]

\[
l_{bc}^e = \sum_{u,v \in N_V} (b_{uv}^e \times b_{vu}^{auv}) \quad \forall b, e \in N_P, s \in N_S
\]

\[
\sum_{b,c \in N_P} p_{ij}^{bc} \leq C \times x_{ij}^{s} \quad \forall i, j \in N_P, s \in N_S
\]

\[
\sum_{b,c \in N_P \setminus s \in N_S} (p_{ij}^{bc} \times x_{ij}^{s}) \leq C \times x_{ij} \quad \forall i, j \in N_P,
\]

\[
\sum_{n \in N_P \setminus n \neq m} z_{mn}^i - \sum_{n \in N_P \setminus n \neq m} z_{nm}^i = \begin{cases} x_{ij} & \text{if } m = i \\
  -x_{ij} & \text{if } m = j \\
  0 & \text{otherwise}
\end{cases}
\]

\[
\forall m, i, j \in N_P
\]

Wavelength utilization of working and backup paths

Routing constraints
Reliable slicing with PAL (ILP)

Such that:

\[ h_{bc}^{uv} = y_{ab}^u \times y_{vc}^v \quad \forall b, c \in N_P, u, v \in N_V, s \in N_S \]

\[ \sum_{n \in N_P} y_{an}^u = 1 \quad \forall u \in N_V, s \in N_S \]

\[ \sum_{n \in N_V, s \in N_S} y_{an}^u \times K_u^s \leq C_n \quad \forall u \in N_V, n \in N_P, s \in N_S \]

\[ y_{nn}^a \leq M_{nn}^a \quad \forall n \in N_P, u \in N_V, s \in N_S \]

Placement constraints

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
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 endpoints
     - If a placement is not found
       - Place the functions on the nodes with lowest betweenness
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