Impact of Slice-ability on Dynamic Restoration in GMPLS-based Flexible Optical Networks

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Introduction

• Elastic Optical Networks (EONs)
  – De-fragmentation techniques cannot be applied upon failure

• Slice-ability
  – Sliceable Bandwidth Variable Transponders (SBVTs)
  – Sub-carriers can be merged in a single super-channel or sliced and assigned to different spectrum slots and paths

• Slice-ability has implementation costs
  – Data plane
  – Control plane

• Is slice-ability useful during restoration?
  – Slicing can potentially increase the recovered traffic
  – Slicing introduces spectrum overhead that can potentially decrease the recovered traffic
Slice-ability spectrum overhead

- The number of spectrum slices totally occupied by the sliced sub-carriers is higher than the number of spectrum slices originally occupied by the whole super-channel
Slice-ability during restoration

- Before failure 3 LSPs
  - Red, 200 Gbps, 5 slices
  - Yellow, 400 Gbps, 8 slices
  - Blue, 200 Gbps, 5 slices

- Failure on link A-C
  - Yellow LSPs disrupted

- Restoration
  - Two recovery paths
  - 8 contiguous slices are not available in any path
  - Slice-ability is applied dividing the 400 Gbps LSP in two super-channels at 200 Gbps
  - 5 contiguous slices are available on both recovery paths
GMPLS/PCE restoration

- Restoration is performed relying on a centralized Path Computation Element (PCE)
- Procedure
  - Failure
  - Detecting node sends RSVP-TE Notify to the source of disrupted LSPs
  - Upon reception of RSVP-TE Notify the source node:
    - TearDown message to the destination
    - PCReq to PCE for computation of the backup path
  - PCE computes a backup path and replies with PCRep
  - Source node triggers RSVP-TE to establish the backup path
RSA schemes using slice-ability

• RSA is performed at the PCE
• Provisioning
  – LSPs requests are routed as a whole without using slice-ability
  – The least congested path is selected among paths within one hop from the shortest path using locally stored TED
• Restoration
  – PCE applies Sliceable RSA schemes:
    ▪ **NO SPLIT**: slice-ability is not considered
    ▪ **MAX SPLIT**: all the sub-carriers composing disrupted LSPs are routed independently applying slice-ability
    ▪ **ADAPTIVE SPLIT**: if possible disrupted LSPs are recovered as a whole, otherwise slice-ability is applied
Simulation scenario

- **OPNET Modeler**
  - RSVP-TE
  - OSPF-TE
  - PCEP

- **Pan European network**
  - 27 nodes
  - 55 bidirectional links
  - 256 slices per link (3.2 THz)

- **Traffic**
  - Uniform traffic matrix
  - Bandwidth request:
    - 400 Gbps (8 slices)
    - 100 Gbps (3 slices)
  - Poisson traffic
    - Fixed mean holding time 1 hour

- **Restoration**
  - 100 Gbps: recovered as a whole
  - 400 Gbps: as a whole, two 200, each 200 in two 100
Results (1)

- Restoration blocking probability vs traffic load
  - Ratio between recovered and disrupted bandwidth

- MAX SPLIT
  - At low loads, it degrades the blocking due to spectrum overhead
  - At high loads with highly fragmented spectrum, recovering LSPs as a whole is very unlikely, MAX split provides slight benefit

- ADAPTIVE SPLIT
  - Independently on the network, load it significantly decreases the restoration blocking probability
  - Blocking is decreased of 75% at 600 Erlang
• Slice-ability introduces the possibility to partially recover LSPs
• Percentage of recovered/not recovered LSPs with NO split scheme
• Percentage of recovered/partially recovered/not recovered LSPs with ADAPTIVE split
• The figures show that most of the disrupted LSPs are totally recovered with the ADAPTIVE split
Conclusion

• Slice-ability during dynamic restoration in GMPLS/PCE based EONs has been evaluated

• Simulation results
  – Applying slice-ability to all the disrupted LSPs (i.e., MAX SPLIT scheme) degrades the restoration blocking probability due to the introduced spectrum overhead
  – Applying slice-ability only when the LSP cannot be recovered as a whole (i.e., ADAPTIVE scheme) reduces the restoration blocking probability

• Slice-ability benefits overcome the resource overbuild

• Future work
  – Evaluation of delays possibly introduced in the recovery process by the application of slice-ability