Multi-layer Traffic Engineering

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ICTON
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• Multilayer network
• Network models
• Routing policies
• Simulation results
Physical Network
Logical Network

Physical Network

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• Layers differentiated
• Find route in a single layer
• Layers differentiated
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- Layers differentiated
- Find route in a single layer

**Diagram:**

- IP/Lightpath layer
- Optical layer

**Note:**

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Both layers considered together \( \rightarrow \) GMPLS
Finding route on this combined graph model
We investigate this model
Both layers considered together ➔ GMPLS
Finding route on this combined graph model
We investigate this model
Routing:

1. Routing on a direct lightpath, if exist

2. Routing in the optical layer?

3. Routing in the IP/lightpath layer?

2. Routing in the IP/lightpath layer?

3. Routing in the optical layer?

In which layer to route new connection requests?
• Always set up new lightpath (direct lightpath or combination of new and existing lightpaths)

• Advantages:
  – Paths reserve minimal resources

• Disadvantages:
  – Frequent reconfiguration of the optical devices
  – Wavelength fragmentation: free wavelengths decrease
• Uses only existing lightpaths as long as possible
• Advantages
  – Rare reconfiguration of optical devices
• Disadvantages
  – Loop can often occur in the physical network
  – Long paths in the physical network
• Loop free path on physical network is NP-Complete
• Avoid creating very long paths
• Avoid creating loops as long as possible
• Multiply the weight of IP/lightpath layer path with the length of the optical layer
• Peer-model with Dijkstra’s Shortest Weighted Path algorithm
• 500 simulation rounds on KL-network
• Long-lived calls (filling up the network)
• 3 wavelengths
• Calculating link weights on the peer graph
• Multiplying the link weights of the IP/lightpath layer by \( \frac{1}{1-\alpha} \)
• Multiplying the link weights of the optical layer by \( \frac{1}{\alpha} \)
• Where \( \alpha \) is \([0..1] \)
• If lower layer preferred (a:< 0.5)
  – Short paths until free wavelengths used up, then routing on existing lightpaths
  † Wavelength fragmentation
• If upper layer preferred (0.5 < a≤)
  – Relatively long path at the beginning
  – As the number of lightpaths increase, the length of paths decreases
• If lower layer preferred
  \(a:< 0.5\)
  – No loops until new lightpath can be established, then increases highly

• If upper layer preferred
  \(0.5 < a\)
  – Loops increase at the beginning

• Min-phys-hop
  – No loops, because its high extra costs
We have investigated routing GMPLS peer model

- IP/lightpath layer preferred
  - Too long paths
  - Large number of loops

- Optical layer preferred
  - Short paths, until all wavelengths used up, then the length of the paths increases
  - Wavelength fragmentation

- Min-phys-hop
  - Trade-off between these policies
  - Avoids routing loops, short paths, fewer blocked calls
• One (small) wavelength
  – High blocking, because new lightpath causes extra high changes in the logical network
  – Better to route in the lower layer

• Some wavelength with small capacity
  – Better to route in the upper layer

• Min-phys-hop
  – Fewer blocked calls