Study on Network Survivability for IP/MPLS over WDM

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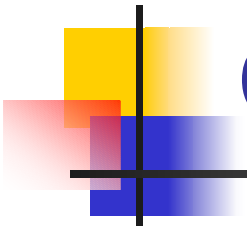

Outline

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- IP/MPLS over WDM Network Model
- A Joint Two-Layer Restoration Scheme
- An MPLS Layer Protection Approach
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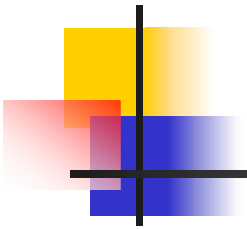
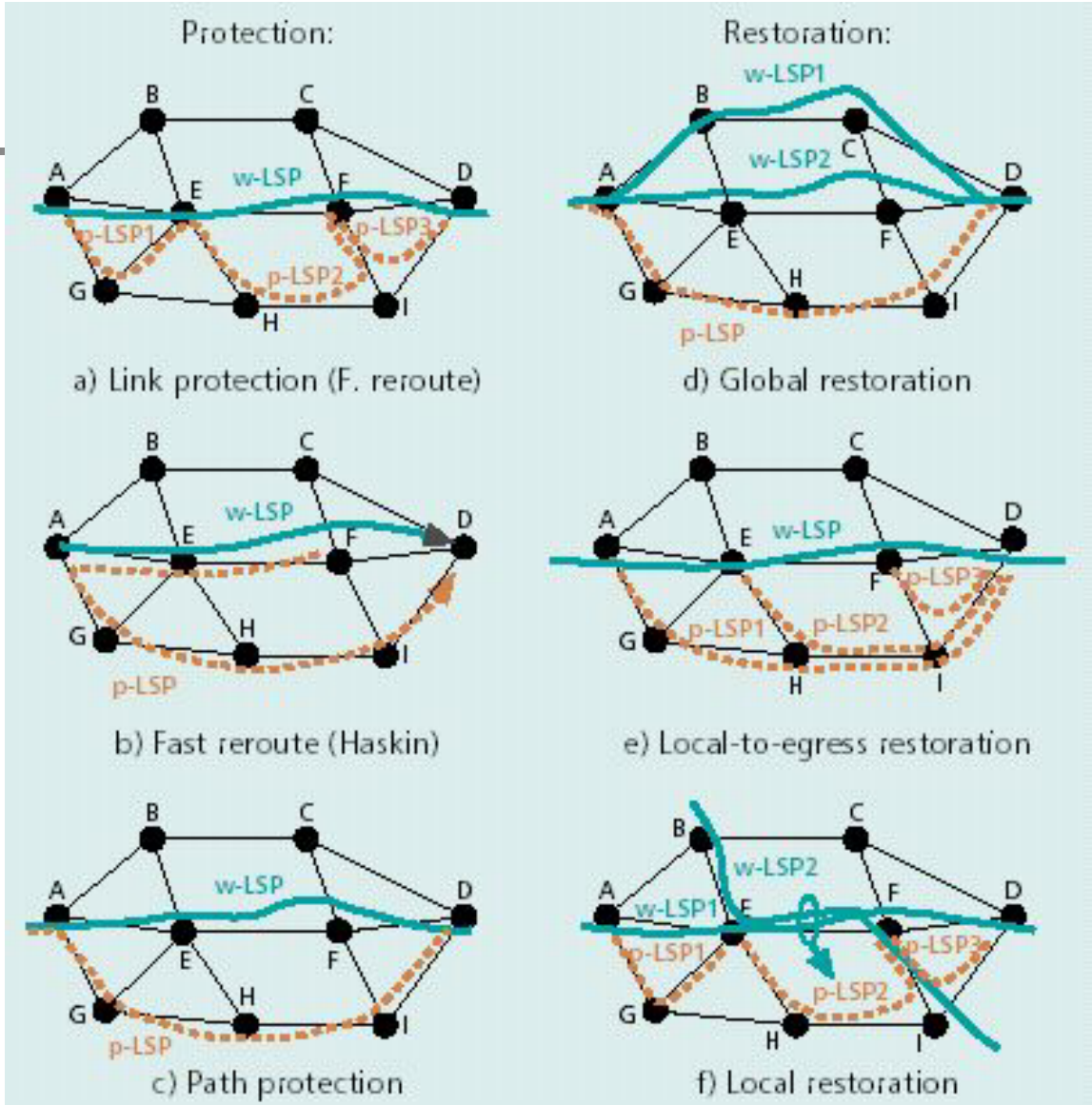


Introduction

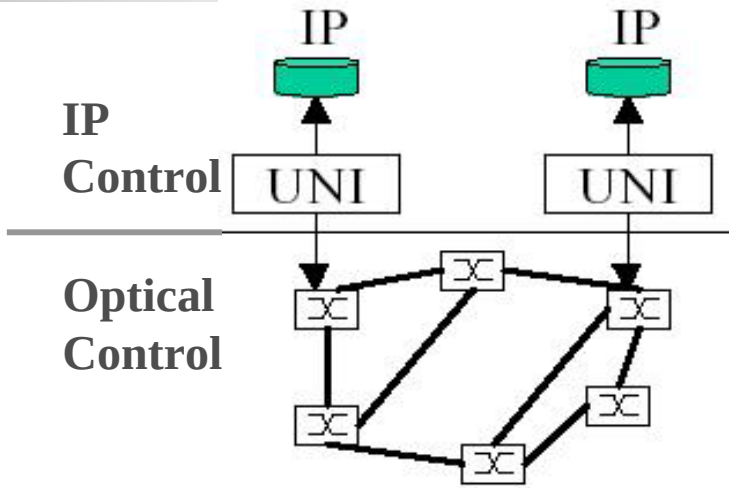
- The nature of IP implies that it reacts very slowly to network failures.
- Which layer should provide network survivability?
  - Optical layer: with coarsest granularity, thus fewer recovery actions are taken
  - MPLS layer: with finer granularity to differentiate LSPs with different reliability requirements, and optical layer can not recover all kinds of failures
- What kind of recovery scheme:
  - Protection-based: leads to faster recovery
  - Restoration-based: allows better resource utilization

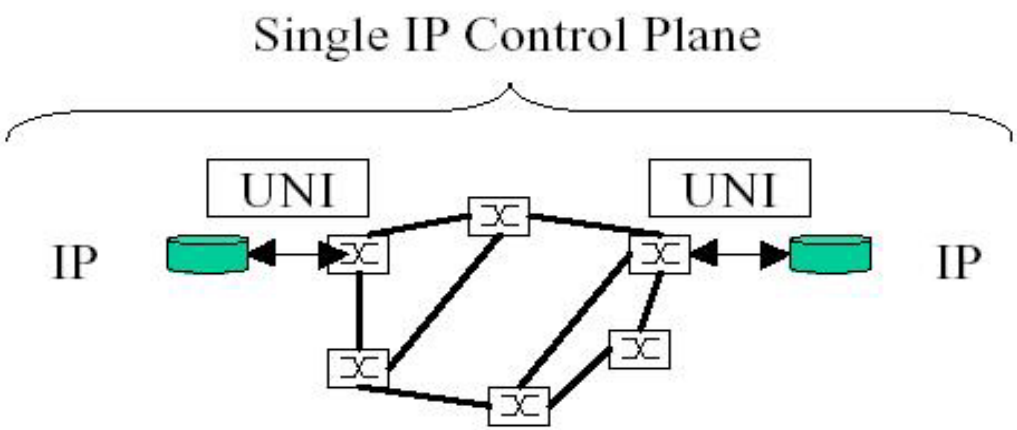
IP/MPLS Recovery Schemes



IP/MPLS over WDM

- Network model
  - Overlay model
    - Control separately
  - Peer model
    - Unified control plane
    - Physical fiber links and logical links (lightpath) coexist





Joint Two-Layer Restoration Scheme

- Idea of the scheme:
  - Based on Overlay model
  - Upon receiving the failure notification message, the ingress OXC of the affected lightpath starts optical layer recovery action
  - A heuristic algorithm to calculate the reroute path
  - When the optical layer fails to restore the affected lightpath, IP layer takes charge of restoring the affected LSPs
  - A heuristic algorithm to calculate the reroute LSP

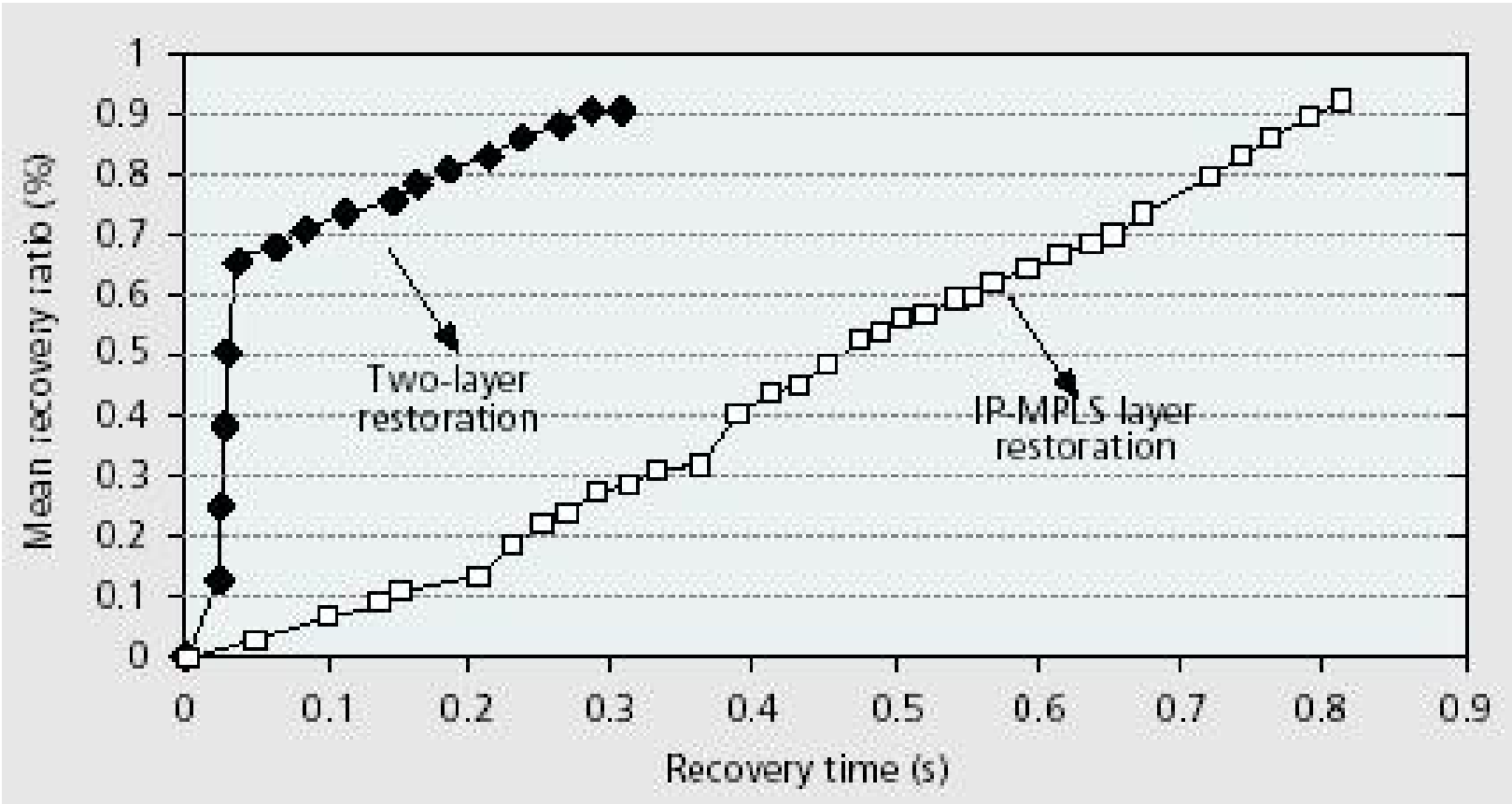
Algorithm to calculate reroute path in optical layer

- Construct an undirected graph G_l based on
  - Physical topology and wavelength availability
  - An edge connecting <s, d> in G_l denotes there are spare wavelength in the link between <s, d>
- Reroute an affected lightpath
  - Find an alternative path with least hops from s to d using Dijkstra's algorithm
  - Minimal number of spare wavelengths are used

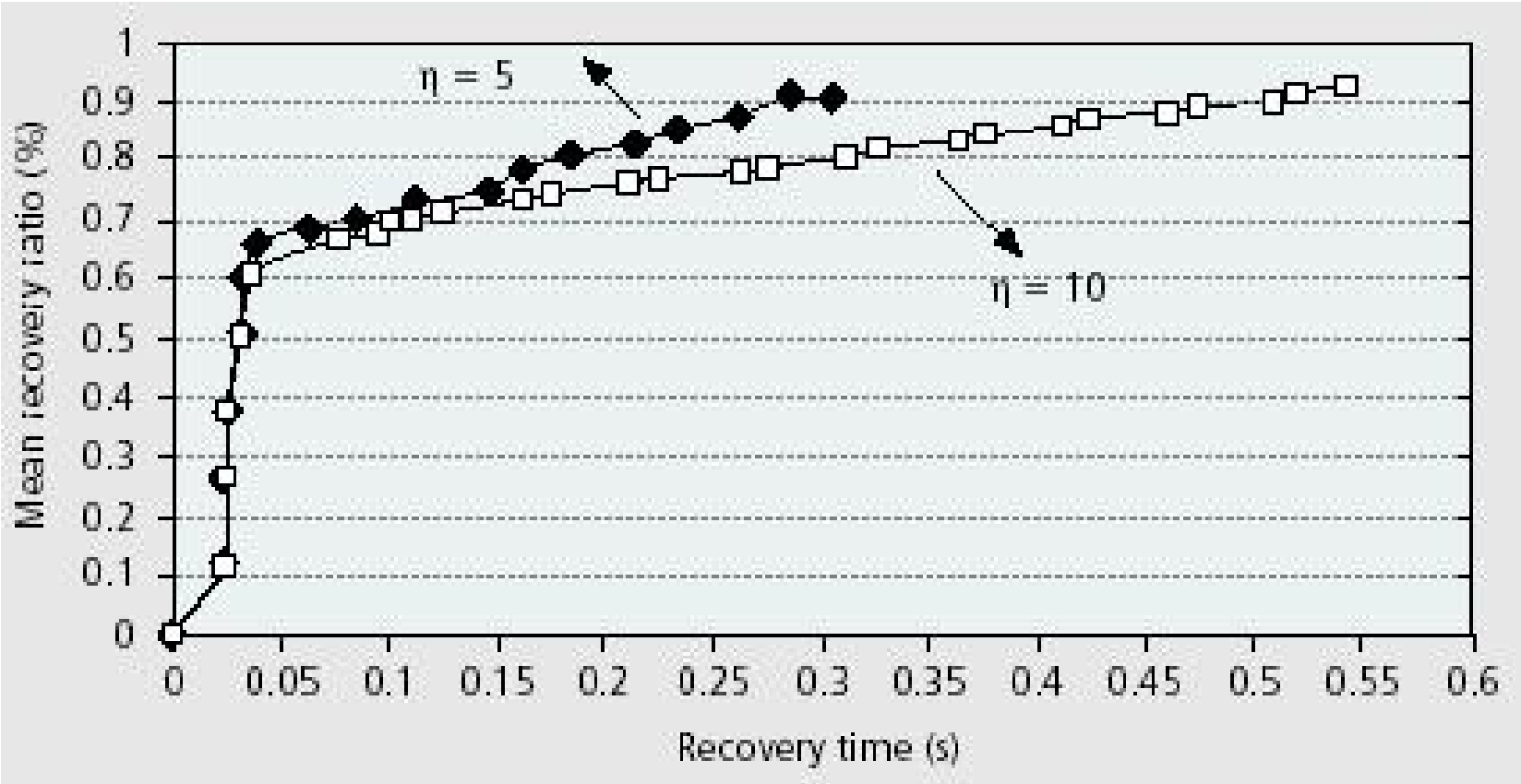
Algorithm to calculate reroute path in IP/MPLS layer

- Construct a directed graph G_V
  - Each edge represents existing lightpath that has enough spare bandwidth for the rerouted LSP
  - Tagged with “exist”
- Add an edge in each direction between vertices
  - Where there are spare wavelengths in the link
  - Tagged with “new”
- Find a path with least “new” edges
  - Dijkstra’s algorithm is used
- For the path found in step 3, combine consecutive “new” edges to one “new” edge

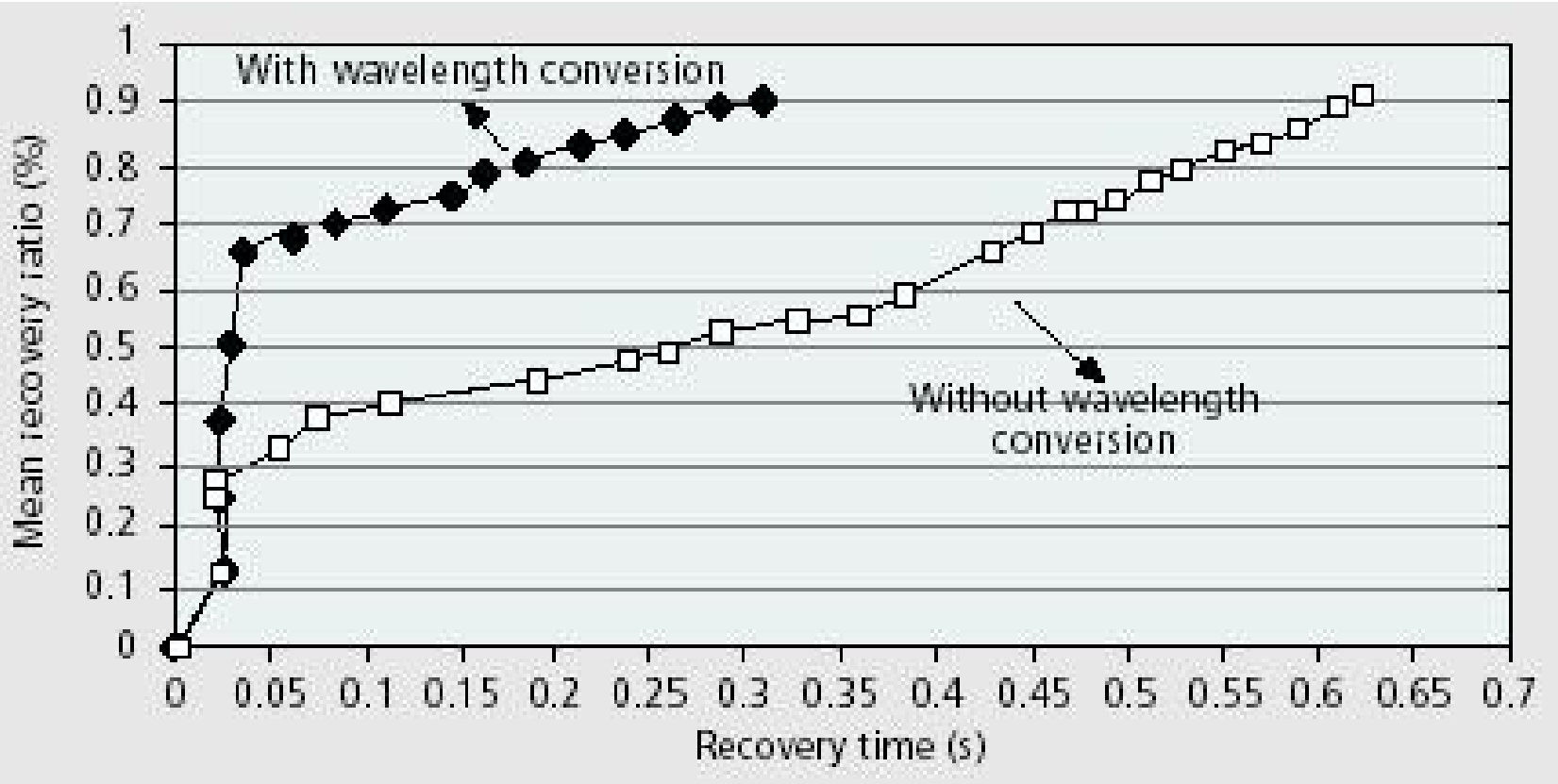
Comparison of Recovery Scheme



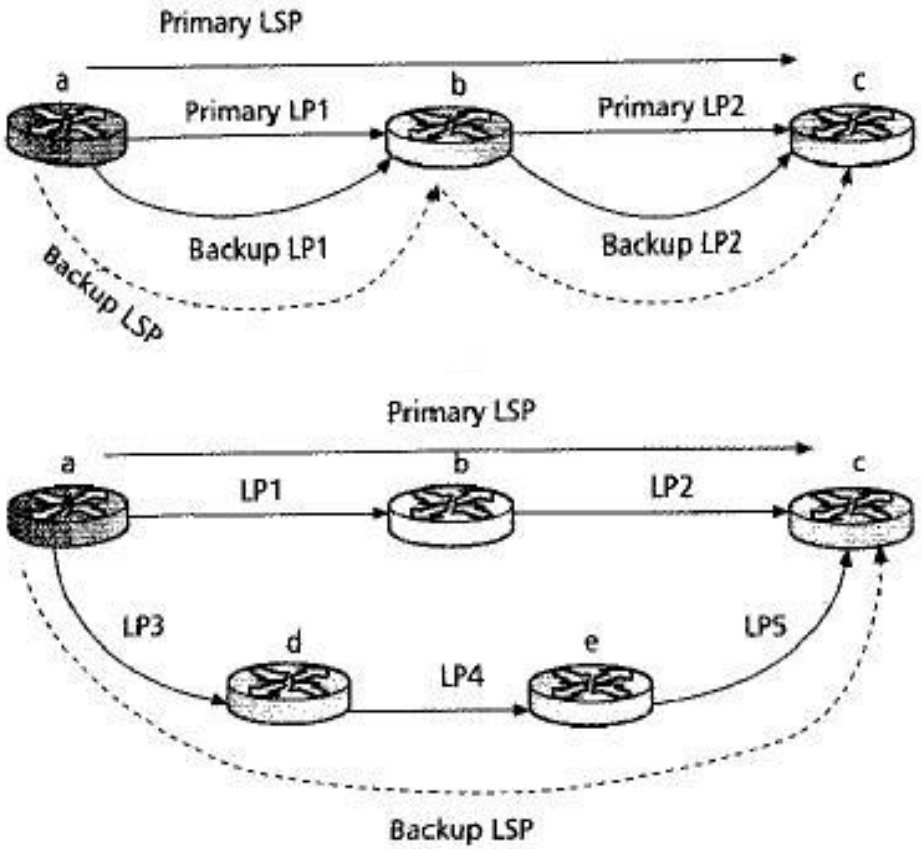
Influence of Granularity

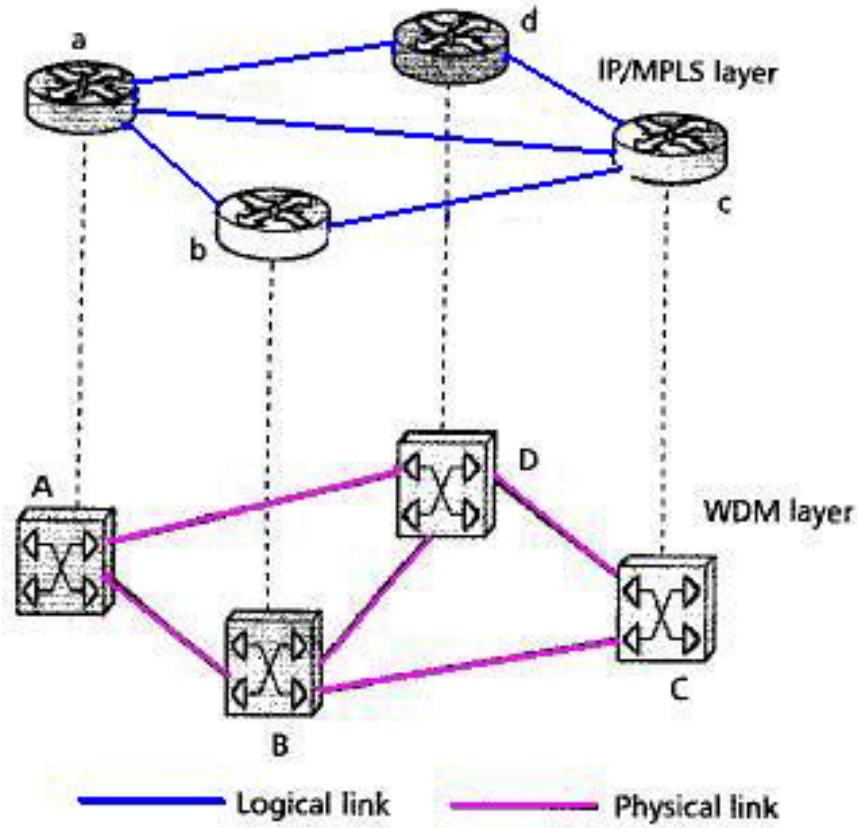


Influence of Wavelength Convertibility



Protection on WDM Layer vs. MPLS Layer





MPLS Layer Protection Approach

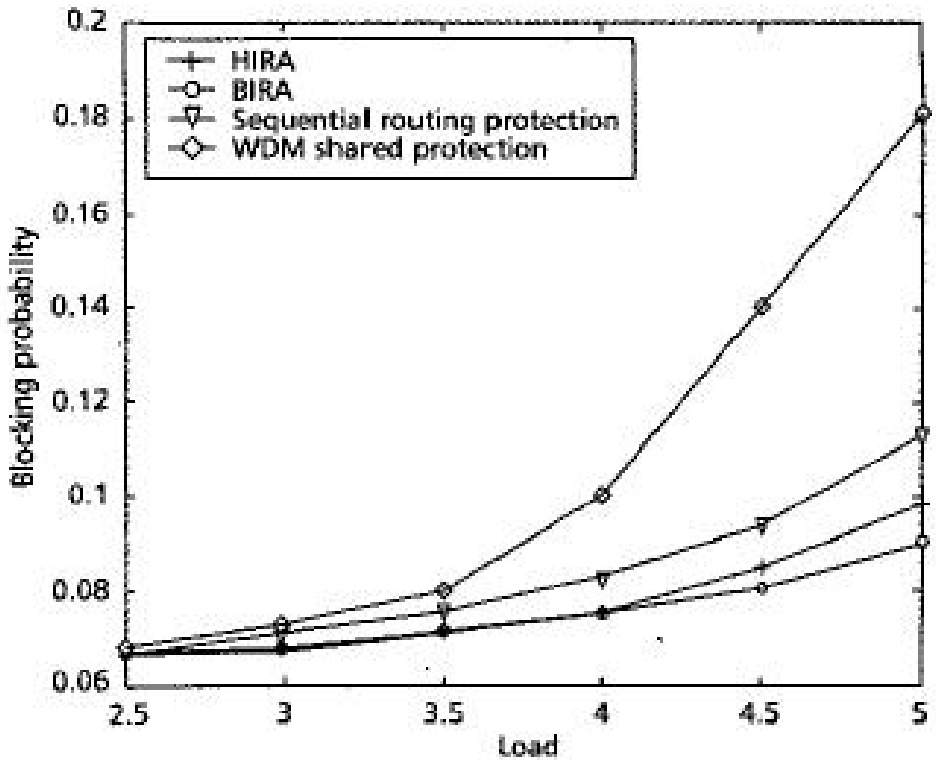
- Protection routing approach can be classified into
  - Sequential routing approach
    - Overlay model of LSRs and OXCs is assumed
    - When a request arrives, primary and backup LSPs are accommodated on existing lightpath (logical links)
    - If not successful, IP/MPLS layer requests optical layer to create new lightpath between edge routers
  - Integrated routing approach
    - Peer model is assumed
    - Able to select a mixture of existing lightpath and new lightpaths to route an LSP
    - Two integrated routing algorithms are developed

Integrated Routing Algorithms

- Basic approach
  - Construct an integrated graph with both physical links and logical links
  - Assign weights to different edges in the integrated graph
  - Optimize a certain cost metric and use Dijkstra's algorithm to choose primary and backup paths
- Hop-based integrated routing algorithm (HIRA)
  - Edge weight: proportional to the physical hops traversed, set to infinity if bandwidth not enough or on primary path
- Bandwidth-based integrated routing algorithm (BIRA)
  - Differ from HIRA in assigning weights for backup path proportional to h (hops) * b_a (additional bandwidth)

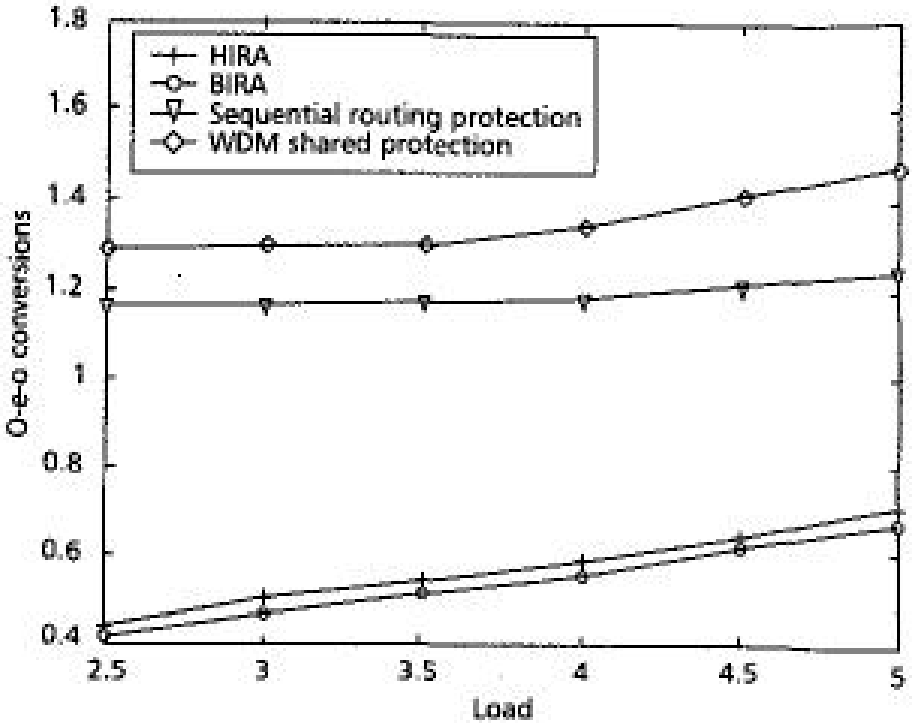
Performance Results

- Network with 32 nodes, 85 bidirectional links and 4 wavelengths/fiber
- Traffic arrival follows Poisson distribution
- Holding time: exponential distribution
- Destination node: uniform distribution
- Bandwidth requested: Uniform(0, 10)

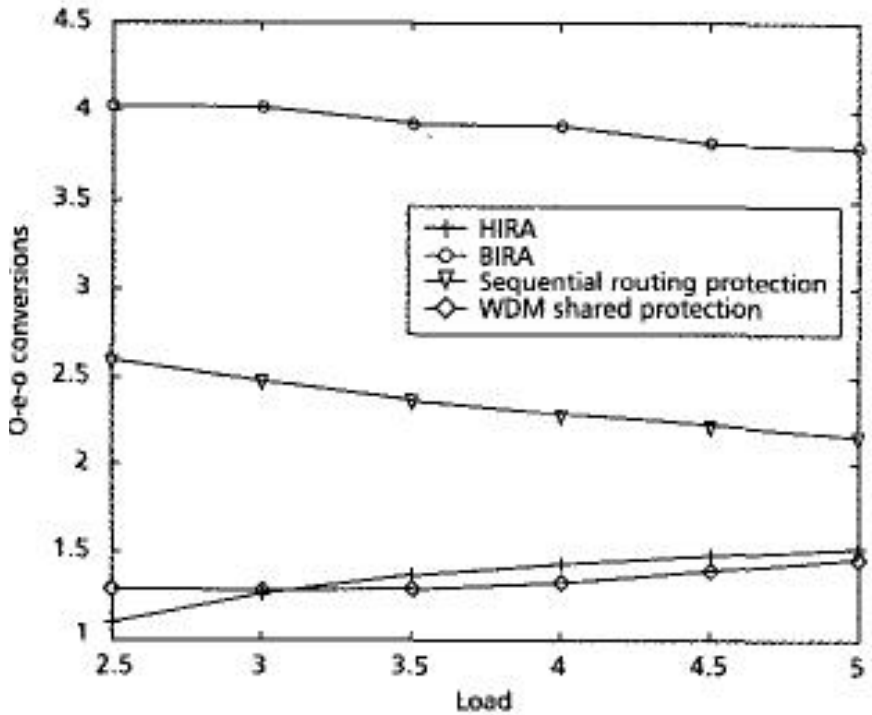


Number of o-e-o Conversion

Per primary path

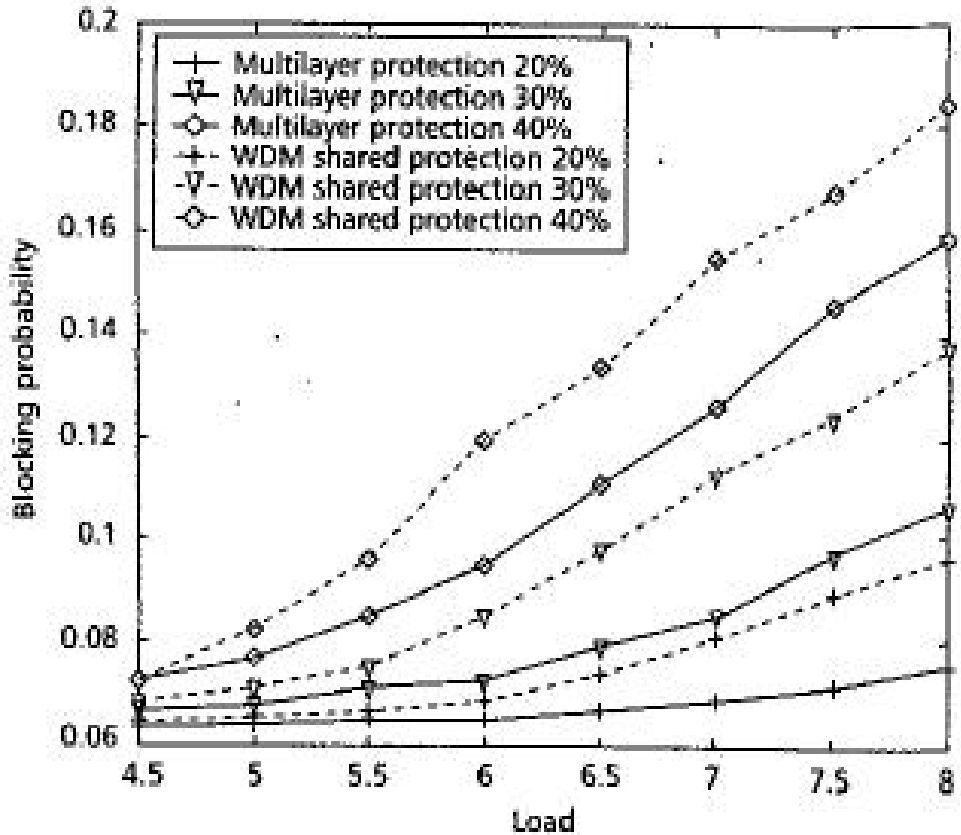


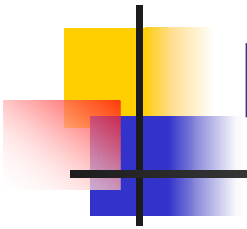
Per backup path



Multilayer Protection Scheme

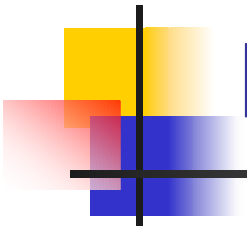
- Provide optical layer recovery for high-priority traffic and MPLS recovery for normal-priority traffic
- When failure detected
  - Optical layer recovery starts for the failed primary lightpaths
  - For the failed ordinary lightpath, notify the MPLS layer to enable recovery of failed primary LSPs





Discussion

- A recovery scheme for IP/MPLS over WDM network should consider three dimensions
  - Protection-based or restoration-based
  - Provide network survivability on WDM layer, IP/MPLS layer, or multilayer
  - Overlay model or peer model
- Traffic can be classified according to SLA
  - Bandwidth
  - Failure recovery time
  - Cost (resource utilization)
- Hybrid recovery scheme is a possible solution to satisfy the requirements of different traffic classes
  - Integrate protection-based and restoration-based approach with multilayer recovery capability



References

- Yang Qin, et. al. “Study on a joint multiple layer restoration scheme for IP over WDM networks,” IEEE Network, March/April 2003
- Qin Zheng and Gurusamy Mohan, “Protection approaches for dynamic traffic in IP/MPLS-over-WDM networks,” IEEE Optical Communication, May 2003