Issues on IP/MPLS over WDM Network Survivability

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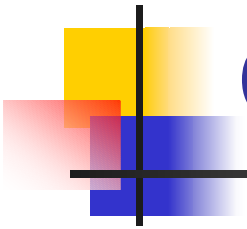
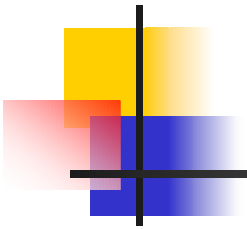


Outline

- Introduction
- Issues Discussion



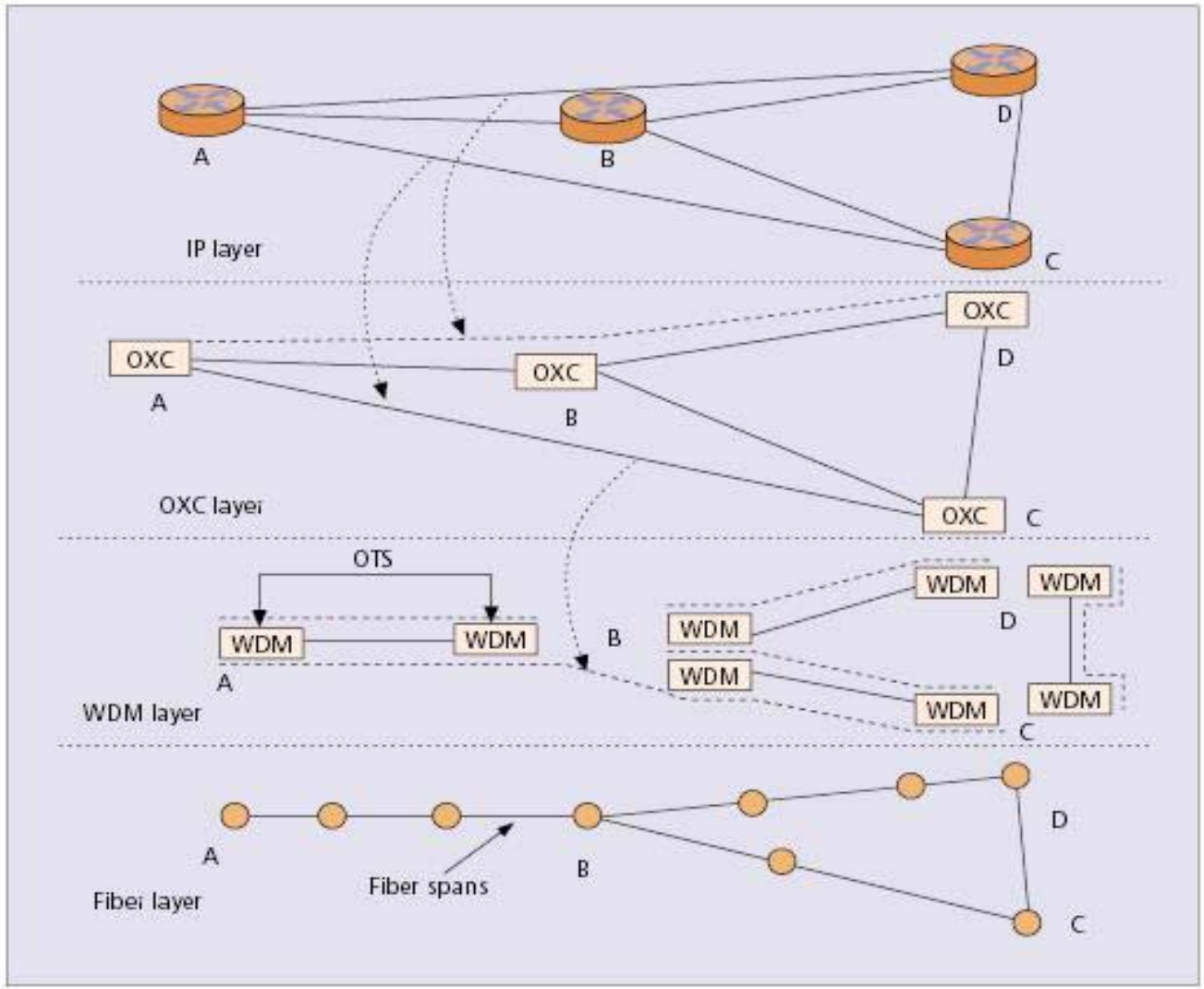
Introduction

- Recovery scheme of IP/MPLS over WDM
  - Architecture dimension
    IP/MPLS layer versus WDM layer
  - Time dimension
    LSP/lightpath creation/activation time
  - Technology dimension
    Protection versus restoration
  - Space dimension:
    Local versus end-to-end

Architecture dimension
Multilayer network example

- Recovery can be performed on
  - Pure IP
  - Pure IP/MPLS
  - Pure WDM
  - Both IP/MPLS and WDM independently
  - Integrated IP/MPLS and WDM

OTS: Optical Transport System



Time dimension
LSP creation and calculation

- LSP can be established either
  - Topology driven: based on IP routing table
  - Request driven: typically used for TE purpose
  - Traffic driven: used only in Ipsilon switch
- LSP routes can be calculated at
  - Network plan phase (under given traffic demands)
    - Optimization model solved by ILP, MILP
    - Heuristic algorithms
  - Network operation phase
    - Constraint-based SPF algorithms
    - Heuristic algorithms

Time and Technology dimension
Optical network restoration

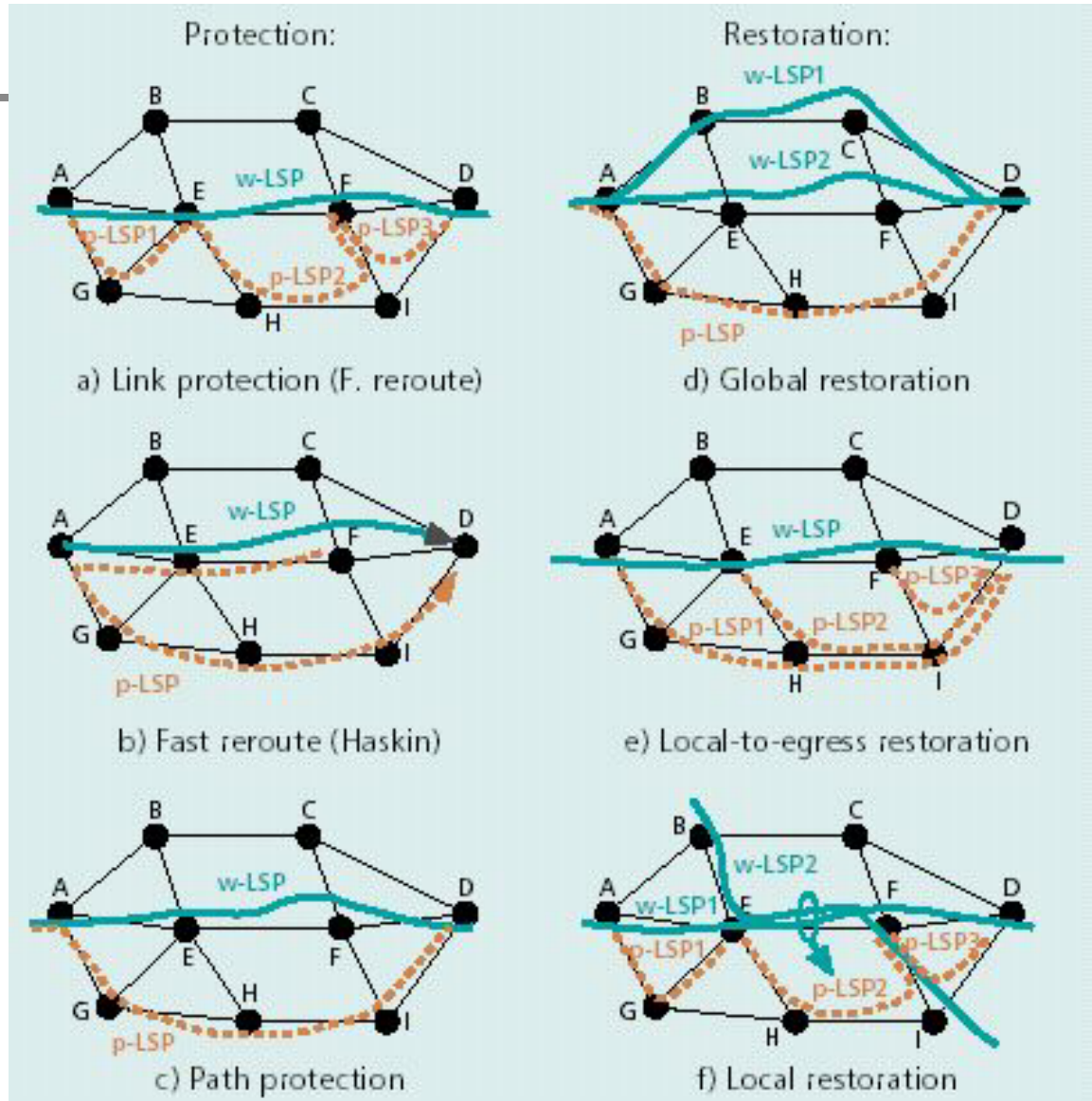
Category	Calculate path	Calculate channel assignment	Cross-connect	Typical Operation Mode
1	Before	Before	Before	1+1 Protection
2	Before	Before	After	Pre-planned cross-connect maps, difficult to implement
3	Before	After	After	Fixed-route dynamic restoration
4	After	After	After	Fully dynamic restoration

* Before / After **failure**

IP/MPLS Recovery Schemes

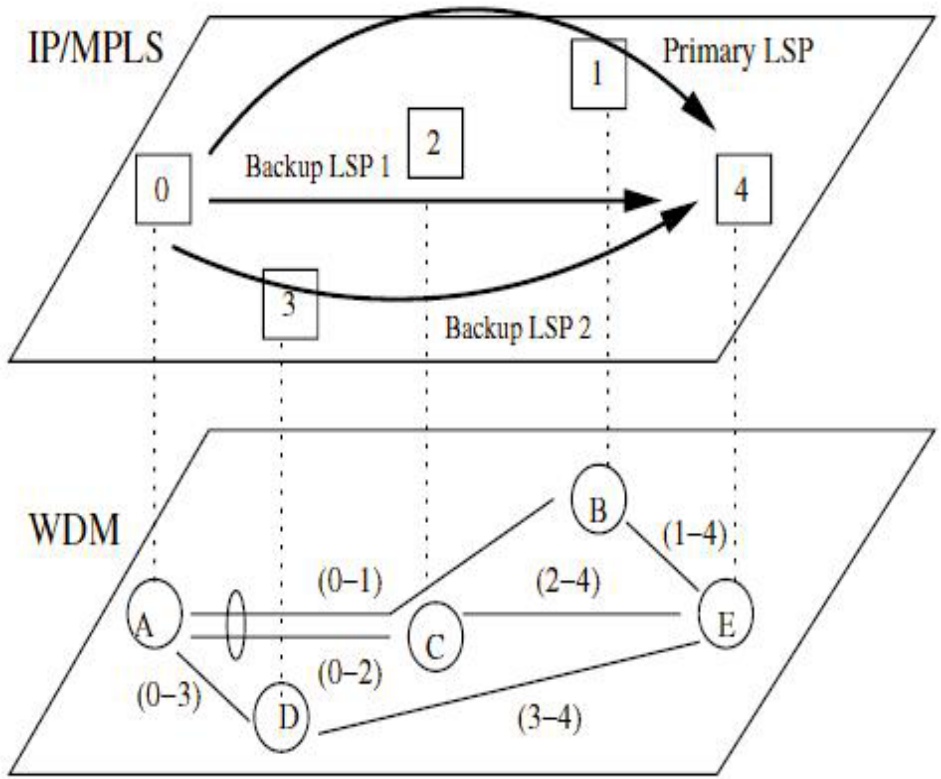
Technology dimension

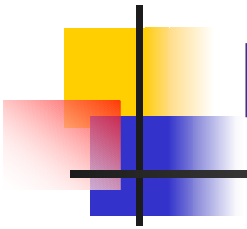
Space dimension



Issues

- Shared Risk Link Group (SRLG)
  - An SRLG is a set of links that have the same risk of failure
  - IP/MPLS recovery should find an SRLG-disjoint backup path
  - SRLG disjointness does not guarantee recovery from an LSR failure
  - SRLG information should be provided by WDM layer

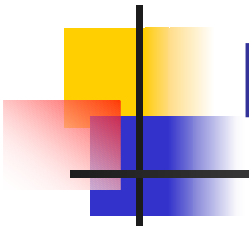




MILP solution

- Given traffic matrix, costs for setting up lightpath, and SRLG information
- Objective: to set up primary and backup LSPs
- MILP optimization by
  - Minimize (total cost for lightpath to be requested) subject to
    - Multi-commodity flow constraints
    - SRLG-disjointness constraints
    - Node-disjointness constraints
    - Constraints for capacity on each logical link

Heuristic solution



- Given:
  - Costs of IP/MPLS links between all node pairs
  - SRLG information
- Find: primary LSPs and backup LSPs
- Algorithm
  - Find a minimum spanning tree (MST) over a fully connected graph
  - Set up primary LSPs using MST found above
  - For each primary LSP, find its LSR- and SRLG-disjoint backup LSP

Alternative approach

- Back and forth approach
  - Determine lightpath in WDM layer based on IP/MPLS traffic demand matrix
    - Obtain better node- and SRLG-disjointness
  - Find primary LSPs and backup LSPs based on SRLG information and WDM cost function
  - Improve heuristic algorithm
    - Considering link capacity
    - Considering traffic engineering

Issues

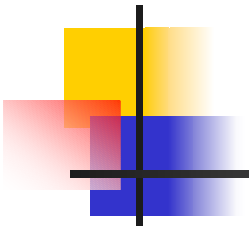
- Scalability limitation for MPLS fully meshed networks: number of LSPs is in order of N^2
- Solution: Hybrid routing method (HRM)
  - Some traffic via MPLS constraint-based routing
  - The remaining traffic via plain IP routing
  - Principle: based on greedy algorithm, transform plain IP flows to LSP
  - Objective: optimize total packet delay summed over all links

$$\Phi = \sum_{a \in A} \frac{f_a}{C_a - f_a}$$

C_a: link capacity, f_a: traffic load on link a

HRM algorithm

- Model HRM traffic routing to get plain IP flows
- Sort links by decreasing link utili. and select the highest one
- Sort plain IP flows on candidate link by decreasing flow size
- For each of ten largest plain IP flows, try constraint-based routing the candidate traffic demand
- If at least one solution results in improvement of objective, choose best one to implement MPLS tunnel. Update HRM traffic and new highest util. link is the next candidate
- Stop if reaching max. number of LSPs or next candidate link is the lowest util. link

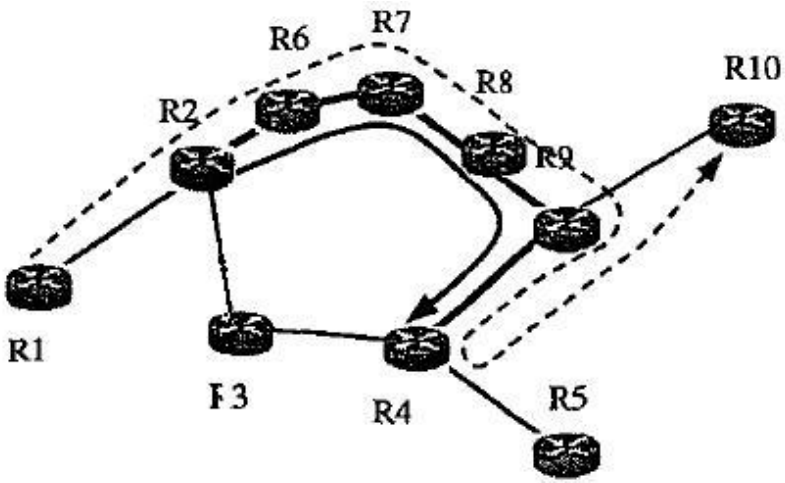


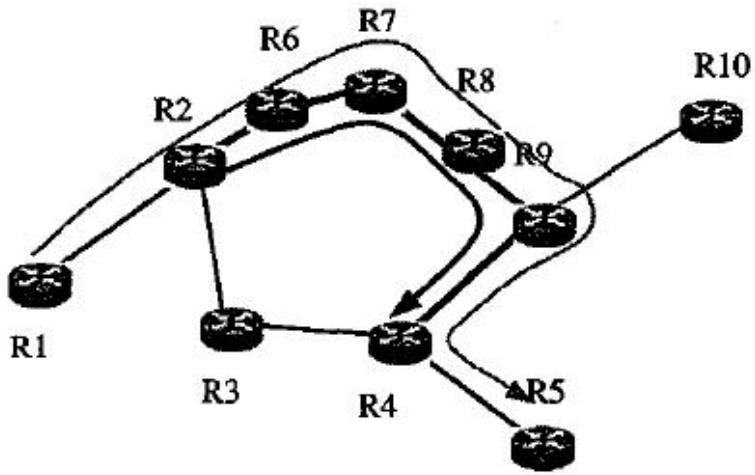
Issues

- Protection versus restoration
  - Protection: consumes double bandwidth and can not be shared among primary LSPs
  - Restoration: encounter longer recovery time

Issues

- Local versus end-to-end
  - End-to-end recovery scheme: longer response time to network failure
  - Local recovery scheme: sub-optimal flow back problem





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