Multiple Failure Resilience in WDM Networks

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Outline

- Motivations
- On failure events
- Multiple failures
- Solution approaches
- Results
- Conclusion
Motivations

- Unpredictable demand patterns
  - Flexible resource reconfiguration is necessary
  - More intelligence appears in the network
  - Service provisioning may also benefit from the installed functions
- Applications with high-capacity short-lived real-time connection demands
  - Distributed computing
  - GRID
Motivations

- Trade-off between resource-efficiency and reliability
- Dedicated or shared scheme?
- Is it possible to guarantee connection availability with economical resource usage and simple reliability computations even in the presence of multiple failures?
On Failure Events: Sources of Failures

- Cable failure
  - Cable cut
  - Bit Error Rate threshold violation
    - Aging and/or extreme environmental conditions
    - Non-linear effects
- Node failure
  - Component failure
  - Software bug
On Failure Events: Event Taxonomy

- Independence  \( P(A|B) = P(A) \)
  - Failures of two LEDs in two OXCs

- Dependence
  - Positive  \( P(A|B) > P(A) \)
    - Failures of two fibers in the same duct
  - Negative  \( P(A|B) < P(A) \)
    - Activation of shared backup resources
On Failure Events: Failure Models

- Two-state components
  - Independence
    - Single failures only
    - *Multiple failures*
  - Dependence
    - Multiple failures only
- Multi-state components
Multiple Failures: Sharing Conflicts

Diagram showing working and backup lightpath with nodes A, B, C, and D.
Multiple Failures: Significance

- Significance of multiple failures grows with number of components ($P_f = 0.0001$)

- Component availability has strong impact on feasible service guarantees (1000 components)
Multiple Failures: Significance

Only links are failure-prone, EU topology scaled to 1:50, 1:5, 1:1
Solution Approaches

- Dedicated backup resources
- Shared backup resources with bounds on availability
  - Lower bound on FP considering any number of failures
    - \( P_f = P(\text{at least two components fail}) \)
    - \( P_f = P(\text{working resources fail}) \times P(\text{protection resources are N/A}) \)
    - Sharing unavailability
Results: Simulation

MFP = 0.05
EU network

MFP = 0.0005
metro network


March 1, 2005  WDM Workshop 2005, Budapest
Results: Sharing Unavailability

- A backup resource becomes less likely to be available once it is shared
- \( P_f(\text{backup resource}) = P(\text{physical failure}) + P(\text{another connection activates it first}) \)
- Second term is sharing unavailability
  - \( q_s(\text{link, wavelength, connection demand}) \)
Results: Sharing Unavailability

\[ q_s(e,w,CD) \]
Results: Sharing Unavailability

- Sharing unavailability threshold can be an input parameter of the CAC policy
- Limits sharing and guarantees availability of shared backup resources
Results: RWA Algorithm

- Evaluation of working and backup lightpaths
  - Disjointness of working lightpath from other working lightpaths where backup resources are shared
  - Connection availability conforms requirement \((r)\)
    - Upper bound is easy to compute
  - Admission does not violate \(q_s\) threshold
    - Upper bound is easy to compute
- A uniform constant \(q_s\) is used here
Results: Simulation

$\frac{r}{0.005}$

EU network


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Results: Simulation

Conclusions

- Provisioning using single-failure resilient protection schemes might be sufficient
  - Seems acceptable at the metropolitan scale
  - Must be checked at the national scale
- It is important to deal with multiple failures under certain circumstances
  - Especially at the continental scale
  - More sophisticated protection schemes might be necessary
Conclusions

- On-line RWA algorithm that guarantees connection availability in the presence of multiple failures
- Attractive and efficient adaptation of Shared Path Protection
  - Offers gain in blocking while still fulfilling availability requirements
  - Computations remain simple
- Choice of appropriate threshold value requires further experiments