Resilient Optical Networks

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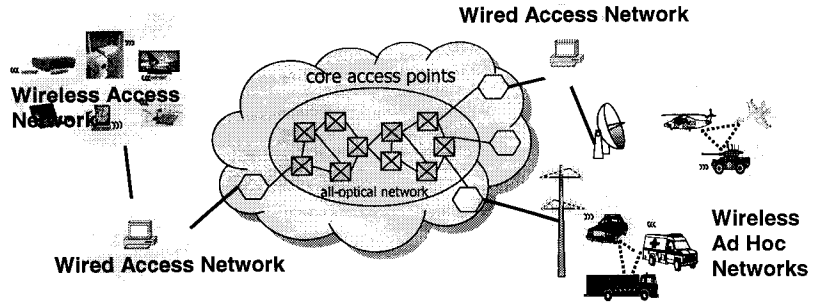
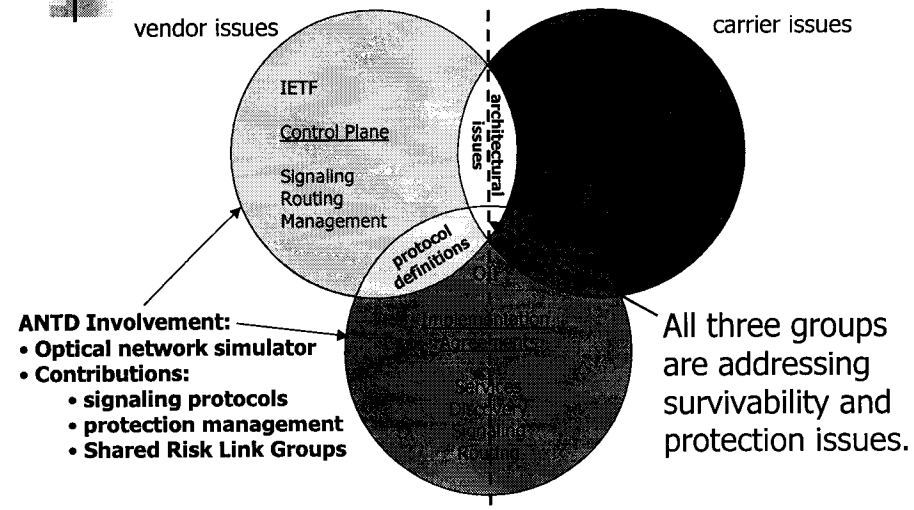
New Networks, New Issues



- Next generation optical networks will support more services and more traffic types, including virtual private networks. This requires additional connection control and management.
- The mesh connectivity in the core poses problems that one doesn't see in ring-type networks, for example choosing and activating backup paths.

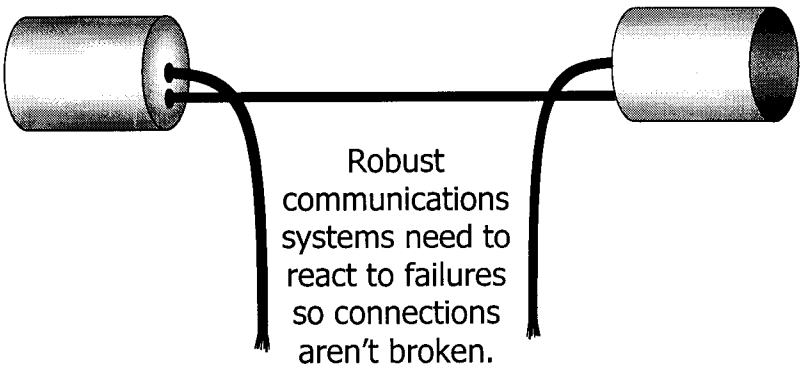
Principal Bodies Creating Optical Networking Standards



ANTD Optical Protection and Restoration Research Projects

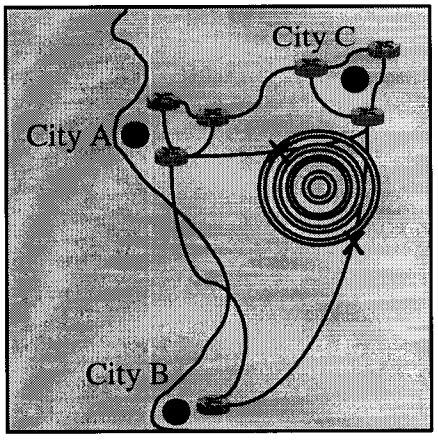
- **Determining optimum number of backup paths**
- Signaling protocols for activating backup paths
- Coordinating restoration procedures between different parts of the network
- Failure recovery for future optical networks

The Problem



Communications can't happen without a reliable network!

Recovering from Multiple Failures



- Many protection mechanisms for next-generation optical networks assume single failures (one link or one node)
- Multiple failures can overwhelm backup resources unless enough are provided
- Our goal: given probabilities for failure occurrence, repair completion, and number of failures, determine how much backup capacity is needed between two network access points

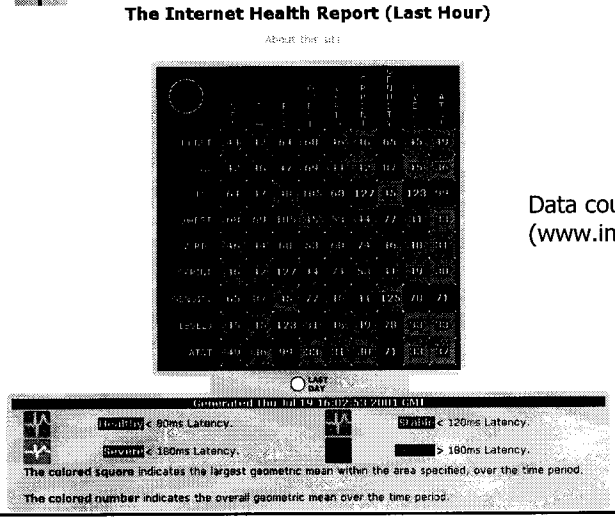
Example: Freight Train Fire, Baltimore (July 18, 2001)

- A train carrying hazardous materials derailed in the Howard Street tunnel, starting a fire that reached temperatures of 1500 deg C.
- Three carrier fiber trunks were directly impacted:
  - WorldCom Inc.'s UUNet
  - Metromedia Fiber Network
  - PSINet Inc.
- Quick repair of damaged lines was impossible due to environmental conditions in the tunnel
- The situation was not helped by the activities of the Code Red Worm at the same time!

A Sampling of Effects:

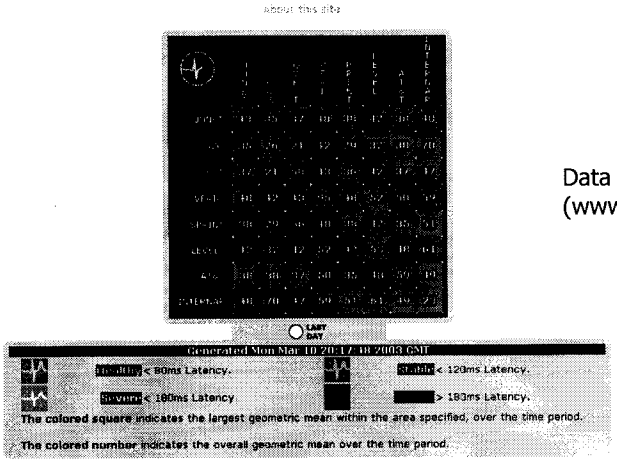
- Boo.net (Bethesda): customers could not access web pages or email
- Citicorp's call center (Hagerstown): 67% of phone capacity lost
- Verizon (Baltimore): loss of service to 2 buildings in accident area, loss of data services over some carrier networks
- MCI (Zambia): Disruption of email service between State Dept. and US facilities in Africa
- Carriers were forced to lay fiber detours, which was accomplished by July 20th (24,000 feet required)

Impact on Latency (7/19/2001)



Data courtesy of Keynote
(www.internethealthreport.com)

A Normal Day (3/10/2003)



Data courtesy of Keynote
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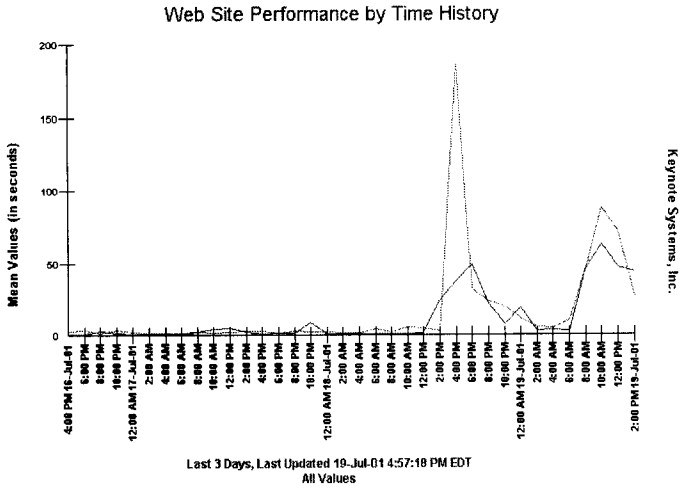
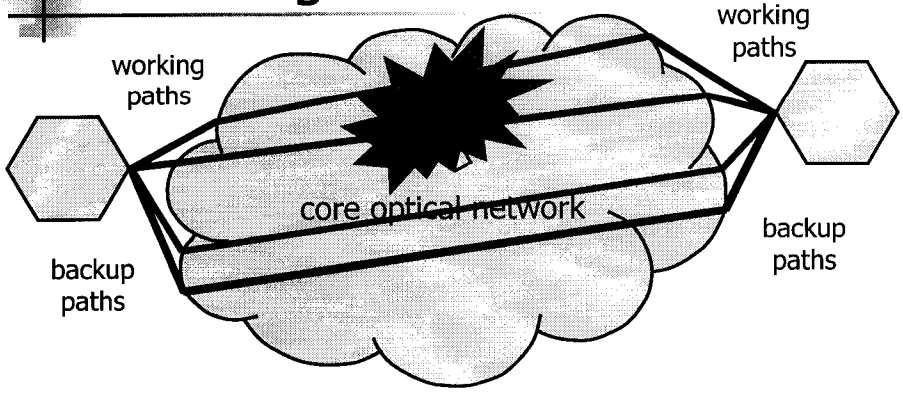
Impact on Latency (cont.)

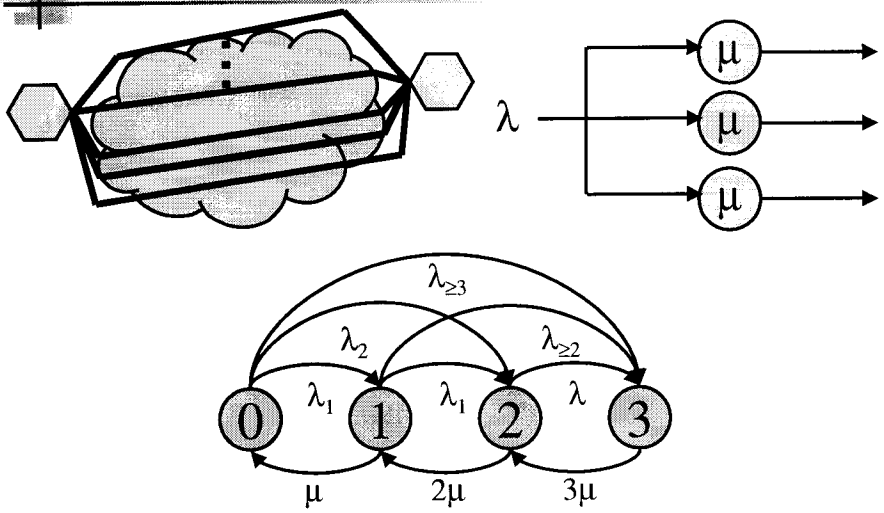


Modeling Failure Events

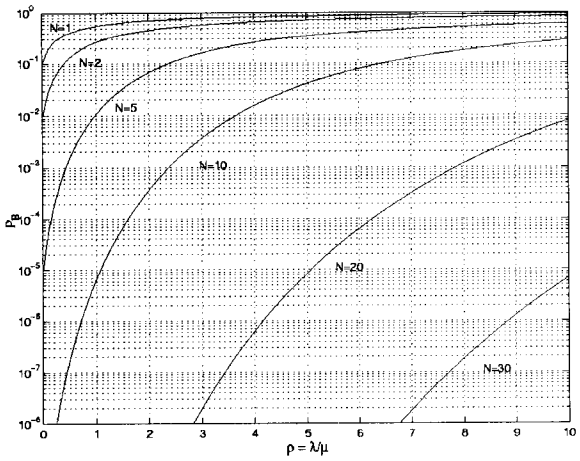


- Traffic is switched from working paths to backup paths when failures occur, and is switched back to working paths once the problem is repaired.
- If backup paths are not available, the network must set up a new working path, which takes longer than switching over to a backup path.

Analytical Model



Performance for Various Numbers of Backup Paths



- The graph shows the probability that a failed working path will not find a backup path available over various relative rates of failure occurrences.
- If failures are rare or repairs happen very rapidly, few backup paths are needed.
- Frequent failures or large numbers of failures in a single event require more backup paths.

NIST Contributions

- **Integrated simulator (GLASS 1.0)** that enables the performance evaluation of optical networks. GLASS was released to the public in July 2002. It is being used by university research groups collaborating with NIST and by equipment vendors and carriers.
- **Contributions to Standards Groups**
  NIST is working with the IETF to develop guidelines for using different types of recovery techniques and is analyzing the performance of newly proposed shared recovery schemes.

Publications, Contributions, and Talks

1. David Griffith, SuKyoung Lee and Liliya Krivulina, "**The Effect of Delay Mismatch in MPLS Networks Using 1+1 Protection,**" submitted to International Conference on Communications (ICC'03)
2. SuKyoung Lee and David Griffith, "**A New Analytical Model of Shared Backup Path Provisioning in GMPLS Networks,**" *Photonic Network Communications*, vol. 4, no. 3/4, 2002.
3. SuKyoung Lee, Chul Kim, and David Griffith, "**Hierarchical Restoration Scheme for Multiple Failures in GMPLS Networks,**" *Proceedings of the 2002 International Conference on Parallel Processing Workshops*, 2002.
4. David Griffith and SuKyoung Lee, "**Dynamic Expansion of M:N Protection Groups in GMPLS Optical Networks,**" *Proceedings of the 2002 International Conference on Parallel Processing Workshops*, 2002.
5. S.K. Lee, D. Griffith, V. Coussot and D. Su, "**ER-LSP Set-up for Multi-Service in Lambda Labeling Networks**", *Proceedings of IEEE Globecom'01*, vol. 1, pp 81-85, Nov. 2001.
6. S.K. Lee, D. Griffith, V. Coussot and D. Su, "**Explicit Routing for Multi-Service in IP over WDM Networks**", *IEE Proceedings-Communications*, Feb. 2002.
7. "**Restoration Mechanisms and Signaling in Optical Networks**", Jin-Ho Hahm, Kwang-il Lee, David Griffith, et al, 11/30/2001, IETF Internet Draft <draft-many-optical-restoration-01.txt>
8. "**A Comparison of RSVP-TE and CR-LDP,**" D. Griffith, OIF Forum oif2000.179.00, August 11, 2000.
9. "**A List of IETF Drafts that May Affect OIF NNI Work,**" D. Griffith, OIF Forum oif2001.318.00, July 6, 2001.
10. "**A Summary of IETF Work that Impacts the NNI,**" D. Griffith, OIF Forum oif2001.408.00, July 31, 2001.
11. "**IETF Work and the UNI in All-Optical Networks,**" D. Griffith, OIF Forum oif2001.415.00, August 1, 2001.
12. "**OIF and IETF work on the Optical Control Plane,**" D. Griffith, talk at George Washington University, November 16, 2001.
13. "**Protection and Restoration in Optical Networks,**" D. Griffith, talk at George Washington University, February 1, 2002.