

Reliability Issues in IP over WDM Networks



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Past Researches in the Area

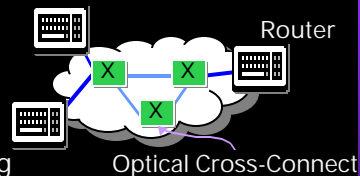
❑ Routing and Wavelength Assignment (RWA) Problem

✗ Static assignment

- ✓ Optimization problem

✗ Dynamic assignment

- ✓ Natural extension of call routing
- ✓ Call blocking is primary concern
- ✓ No wavelength conversion makes the problem difficult

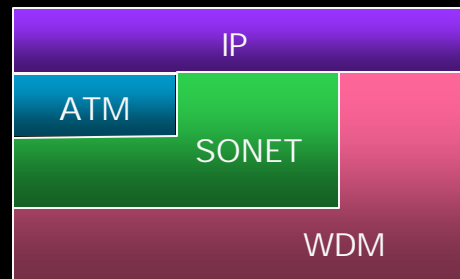


❑ Optical Packet Switches for ATM

✗ Fixed packets and synchronous transmission

Several Views for IP over WDM Networks

- IP over ATM over SONET over WDM
- IP over SONET over WDM
- IP over (PPP or HDLC) over WDM



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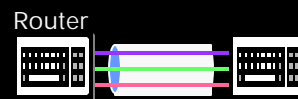
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Photonic Internet Architecture

- Four Kinds of Architecture

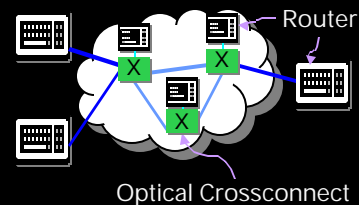
1. WDM link network

- ✓ Connects adjacent routers by WDM (multiple wavelengths)



2. WDM path network

- ✓ Logical topology is built by wavelength routing



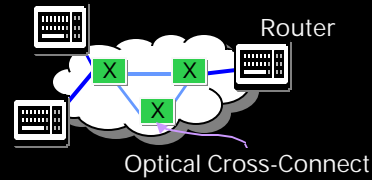
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Photonic Internet Architecture (Cont'd)

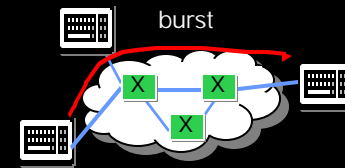
3. WDM Path Network

- ✓ Lambda switching by MPLS technology

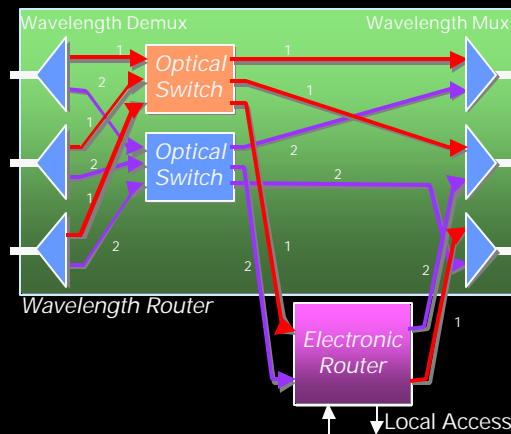


4. WDM Packet-switched Network

- ✓ E.g., burst switching by routing and wavelength assignment on demand basis

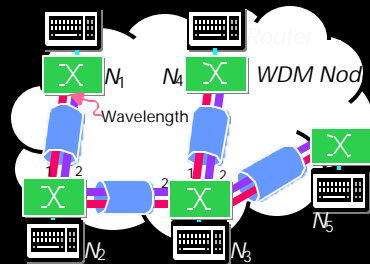


Wavelength Router in WDM Path Network

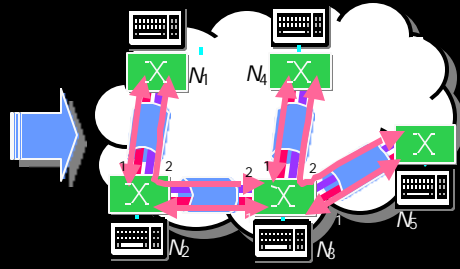


Logical Topology by Wavelength Routing

Physical Topology



Logical Topology

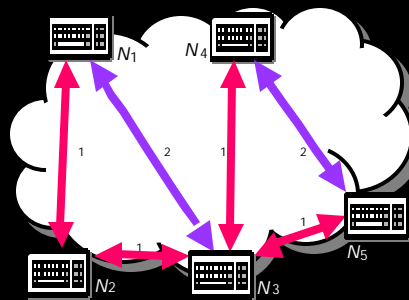


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Logical View provided to IP

- Redundant Network with Large Degrees
- Smaller number of hop-counts between end-nodes
- Decrease load for packet forwarding at the router
- Relief bottleneck at the router



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How should IP over WDM be Established?

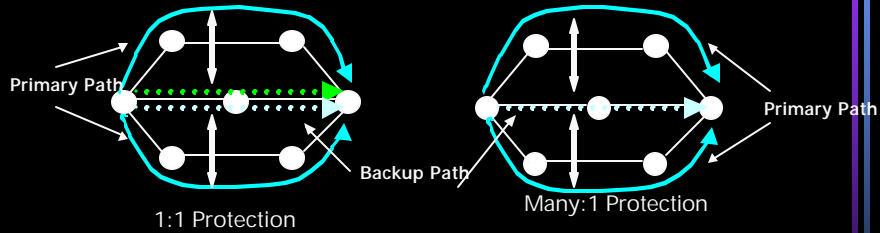
- WDM network itself has network control capabilities
 - ✗ Routing function
 - ✓ IP also has it!
 - ✗ Congestion control function
 - ✓ TCP also has it!
 - ✓ TCP over ATM (ABR service class) is difficult to work well
 - Parameter tuning of control parameters in ABR is not easy
 - ✗ Connection establishment
 - ✓ IP is connectionless
 - ✓ Multimedia application does not require 10Gbps channel
 - Functional partitioning vs. Multi-layered Functionalities?
- Important is reliability

Functional Partitioning between IP and WDM?

- Reliability functionalities offered by two layers
 - ✗ IP Layer: Routing
 - ✗ WDM Layer: Path Protection and Restoration
- WDM should provide its high-reliability mechanism to IP
 - ✗ Protection mechanism
 - ✓ link protection
 - ✓ dedicated-path protection
 - ✓ shared-path protection
 - ✗ Network dimensioning is important to properly acquire the required capacity of IP paths (traffic grooming)
 - ✓ Reconfiguration mechanism of logical topology by wavelength routing

WDM Protection

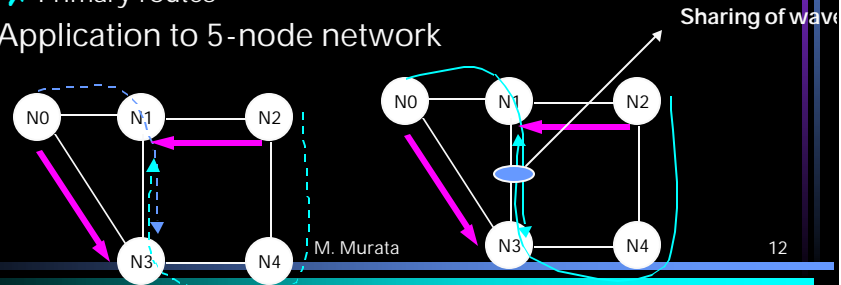
- Immediately switch to backup path on failure of nodes/links
 - ✗ In the order of 10ms
- 1:1 Protection vs. Many:1 Protection



- Protection technique suitable to IP over WDM network?
 - ✗ IP has its own protection mechanism (i.e., routing) while it is slow
 - ✗ We want an effective usage of wavelengths
 - ✗ Many:1 protection is reasonable

Formulation of Reliability Design Problem for Many-to-1 Path Protection

- Objective
 - ✗ Minimize the utilized wavelengths in total
- Given Conditions
 - ✗ The number of wavelengths on the fiber
 - ✗ Physical topology and logical topology
 - ✗ Primary routes
- Application to 5-node network



Application to Large-Scaled Network

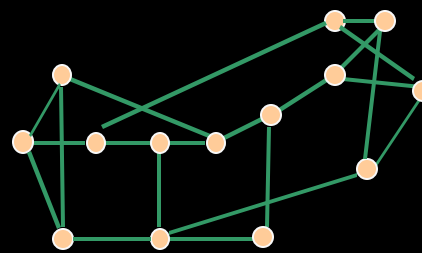
- ❑ Previous formulation is MILP (Mixed Integer Linear Problem); difficult to be applied to the large-scaled network



- ❑ *Min-hop-first approach*
 - ✗ It is rare that lightpaths with a small number of hop counts contend the backup lightpaths
 - ✗ First protect the lightpaths with small hop-counts, and then protect lightpaths with large hop-counts using the remaining wavelengths
- ❑ *Largest-traffic-first approach*
 - ✗ Assign the paths in a descending order of the traffic loads
- ❑ *Random approach*
 - ✗ For only reference purpose

Network Model

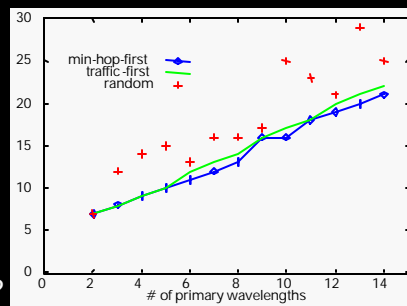
- ❑ NSFNET;
 - ✗ 14 node
 - ✗ 20 physical links
- ❑ Logical topology is first determined by MLDA
 - ✗ First set up the lightpaths between adjacent nodes
 - ✗ Set up the lightpaths for the path in a descending order of traffic volume



NSFNET

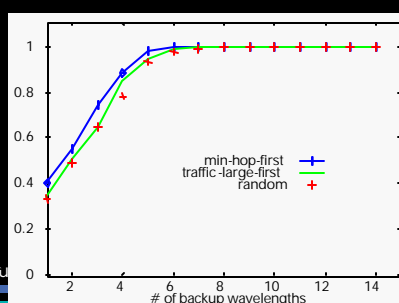
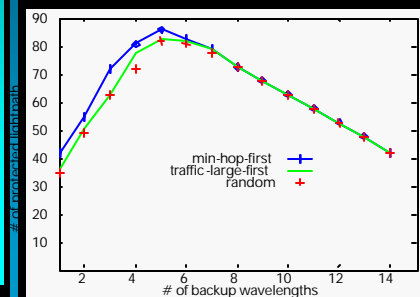
Effect of Min-Hop-First Approach

- The required number of wavelengths to protect all lightpaths with
 - ✗ Random-selection method?
 - ✗ Traffic-large-first method?
 - ✗ Min-hop-first method?



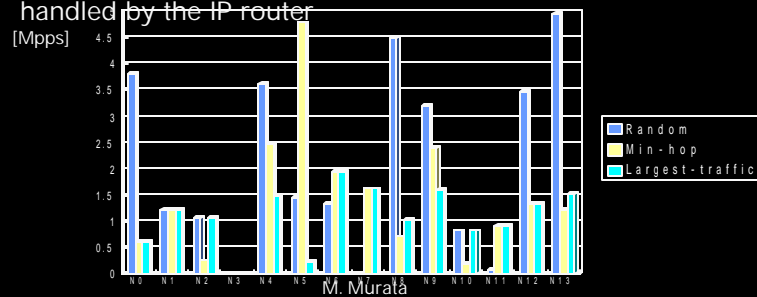
Effect of Min-Hop-First Approach (Cont'd)

- Fix the wavelength on the fiber to be 16
- Change the number of wavelengths dedicated to primary lightpaths to compare the number of protected lightpaths



Effect on IP Routers

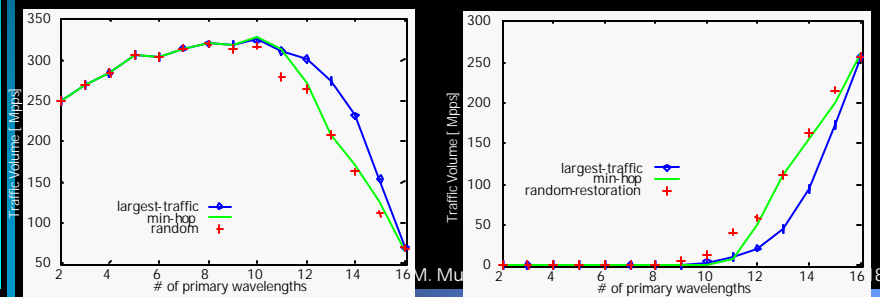
- ❑ A increased amount of traffic load at the IP router after the failure?
 - ✗ We choose the largest traffic increase among all possible cases for failures
- ❑ Primary wavelengths; 12, Backup wavelengths; 4
- ❑ Largest-traffic-first approach can decrease the traffic handled by the IP router



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Functional Partitioning in IP over WDM

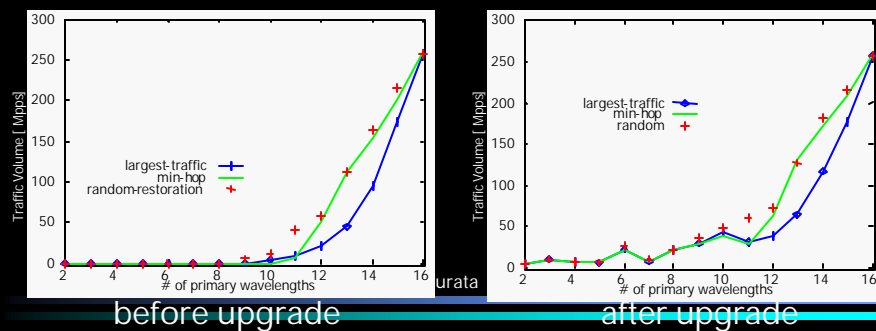
- ❑ Total volume of the traffic **protected/non-protected** by backup lightpaths **before** routing table upgrade
- ❑ Sum of total traffic volume for each fiber failure scenario
- ❑ Largest-traffic-first approach provides better performance
 - ✗ Lots of traffic is protected by a lower number of backup wavelengths



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Effect of IP Routing Table Update

- traffic volume of **non-protected** lightpath **before/after** routing table upgrade
- Largest-traffic-first approach also provides good performance
- Traffic volume increase after routing tables are updated
 - ✗ Another path is selected after update



Concluding Remarks

- WDM Protection is useful to increase reliability of IP over WDM networks
- A cost effective way must exist by partially protecting lightpaths by WDM protection
- Several backup paths (8/182) are not used IP after IP updates its routing table.