Lecture 7

WDM Network Design

Homework #3:

8.2 Ramaswami

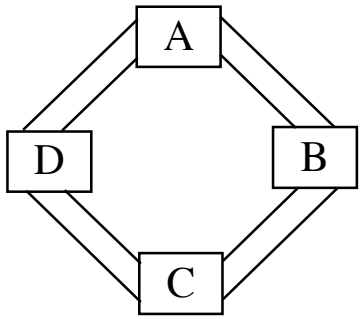
8.3 Ramaswami

8.4 Ramaswami

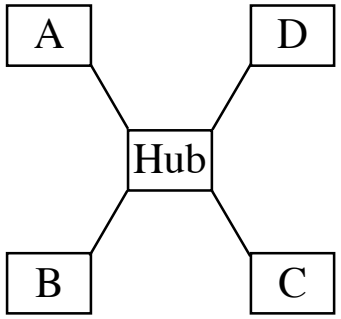
8.7 Ramaswami

Cost Trade-Offs

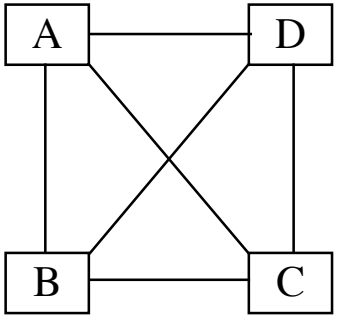
- Consider a 2-connected network topology.
  - Two node-wise disjoint routes between every pair of nodes in the network.
  - Examples can include ring and mesh 2-connected.
  - Rings are widely deployed today, but networks are moving to mesh connected. Lower fiber deployment cost - N nodes requires only N links for a 2-connected network.
- Consider 3 example topologies



P-t-P WDM ring



Hub

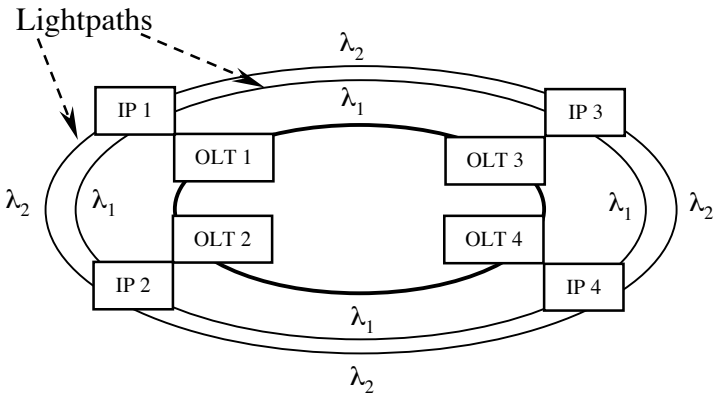


Full Mesh

Cost Trade-Offs Example Analysis

- Consider a traffic matrix with
  - ***t*** units of traffic to be routed from one IP router to all other routers on the network
  - ***N*** is the number of nodes on the network
  - Assume uniform traffic, i.e. ***t/(N-1)*** units of traffic routed between every pair of routers.
  - Normalize the capacity of a wavelength to **1** unit.
- RWA problem and assumptions
  - Find a route for each lightpath and assign it a wavelength on each link.
  - Assume lightpath must be assigned the same wavelength on all links it traverses (no λ-conversion)
  - Assume no two lightpaths traversing the same link can be assigned the same wavelength (no blocking)

Point-to-Point WDM Ring



⇨ All lightpaths are single hop between nodes - they terminate at OE interfaces at each node.

⇨ For W wavelengths on each fiber we can set up W lightpaths between each pair of adjacent nodes

⇨ Assume we route traffic along the "shortest path" between source and destination

⇨ For N even, the traffic load in units of lightpaths and number of wavelengths required are

$$L = \frac{N+1+\frac{1}{N-1}}{8}t$$

$$W = \lceil L \rceil = \left\lceil \frac{N+1+\frac{1}{N-1}}{8}t \right\rceil$$

⇨ Example t=3, N=4

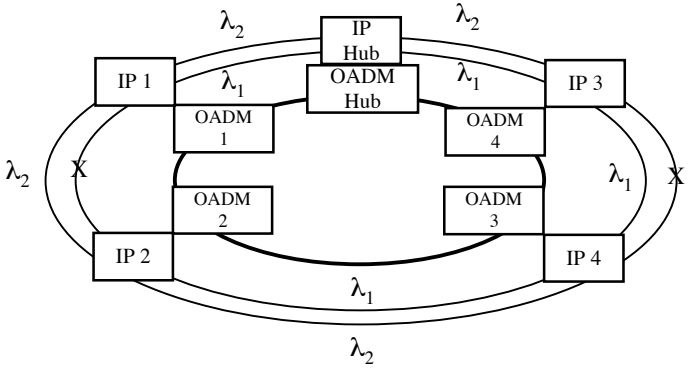
$$L = 2$$

$$W = 2$$

⇨ Number of router ports, given each wavelength is received and transmitted at each node

$$Q = 2W$$

Hubbed WDM Ring Architecture



⇨Each IP node has just enough ports to source/sink traffic to/from that node.
⇨Lightpaths are established between each node and the hub node h
⇨ Traffic from a non-hub node to another non-hub node is routed along two ligthpaths - i to h, then h to j.
⇨ Setup t lightpaths from each node to the hub node

⇨ Number of router ports, given each wavelength is received and transmitted at each node

$$Q = 2\lceil t \rceil$$

⇨ Assume lightpaths are routed and assigned wavelengths as follows:

⇨Two adjacent nodes use different paths alng the ring and reuse the same set of wavelengths

⇨ Then the number of wavelength required is

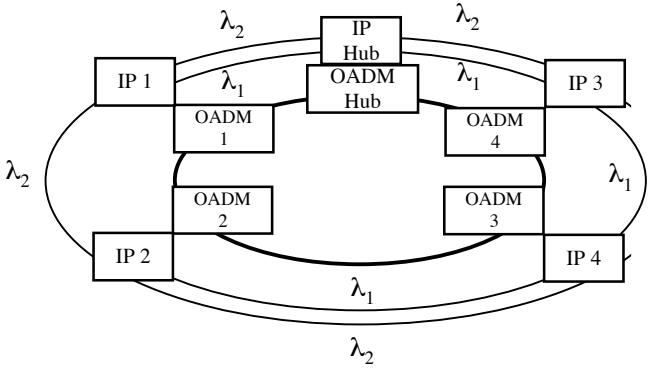
$$W = \frac{N}{2}\lceil t \rceil$$

⇨ The worst case number of hops is

$$H = N - 1$$

⇨ Tradeoffs: OADM and IP Hub have to scale with number of nodes and number of wavelengths

Hubbed WDM Ring Architecture



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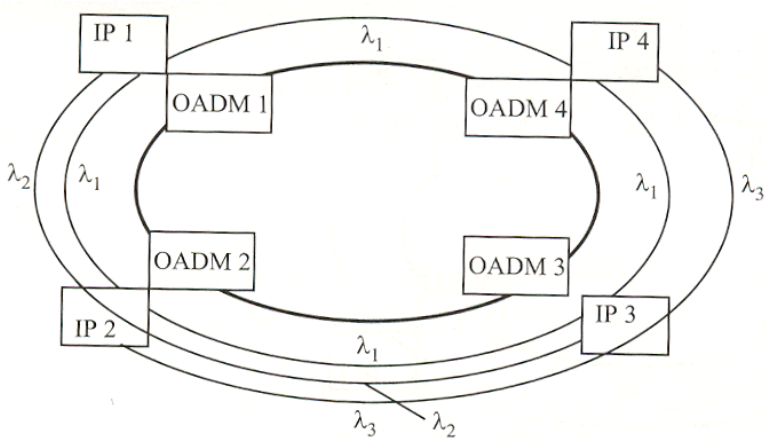
All-Optical Architecture



⇨ Data is transmitted on a single lightpath beteween each source and destination.
⇨ Data is passed by a node optically if it is not destined for that node (I.e. data does not terminate electronically at an node that is not the source or destination).

⇨ Number of lightpaths between each pair of nodes to handle t/(N-1) units of traffic between each node pair

$$\lceil t/(N-1) \rceil$$

⇨ Number of router ports per node

$$Q = (N-1)\lceil t/(N-1) \rceil$$

⇨ Number of wavelengths depend on how the lightpaths are routed. For N even

$$W = \left\lceil \frac{t}{N-1} \right\rceil \left(\frac{N^2}{8} + \frac{N}{4} \right)$$

Ring Architecture Comparison

⇨ For any design, Q ≥ upper bound on t

⇨ Lower bound on number of wavelengths is found from the minimum average number of hops. Assume h_{ij} is the minimum distance between nodes i and j in terms of number of hops.

⇨ Minimum average number of hops, H_{min} is

$$H_{\min} = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} h_{ij}}{N(N-1)}$$

⇨Which for a ring network is

$$\left(H_{\min}\right)\Big|_{ring} = \frac{N+1}{4} + \frac{1}{4(N-1)}$$

⇨ The maximum traffic load on any link is greater than the average load on that link

$$L_{link} \geq L_{avg} = \frac{H_{\min} \times \text{Total Traffic}}{\text{Number of Links}}$$

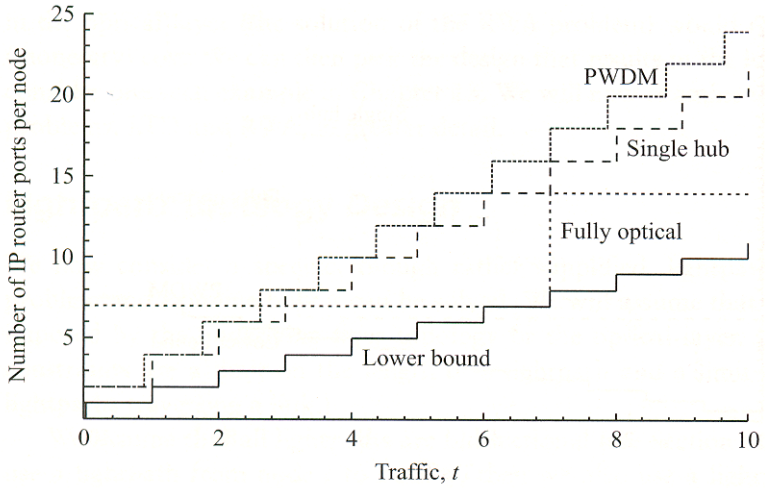
$$= \frac{H_{\min} \times \frac{1}{2}Nt}{N}$$

$$= \left(\frac{N+1}{8} + \frac{1}{8(N-1)}\right)$$

$$W \geq L$$

Ring Architecture Comparison

N = 8 Nodes



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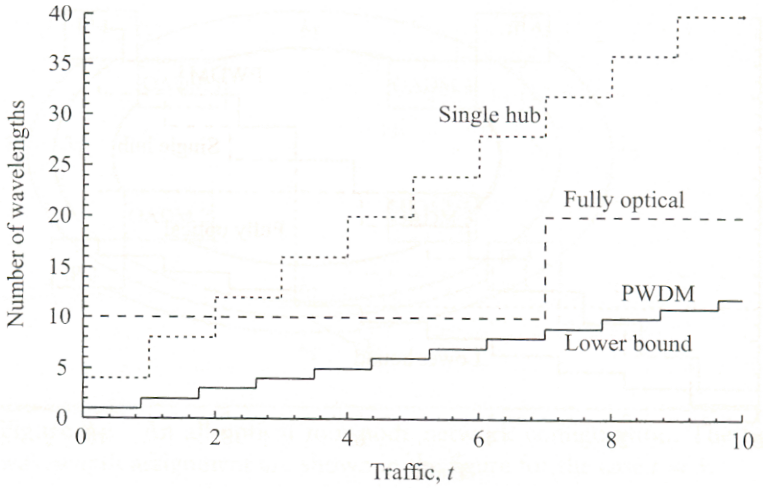

Ramaswami, Optical Networks