Integrated Routing and Grooming in GMPLS-Based Optical Networks

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Outline

- Introduction
- Problem definition and network model
- Blocking island paradigm and MS heuristic
- Integrated routing and grooming algorithm
- Performance studies
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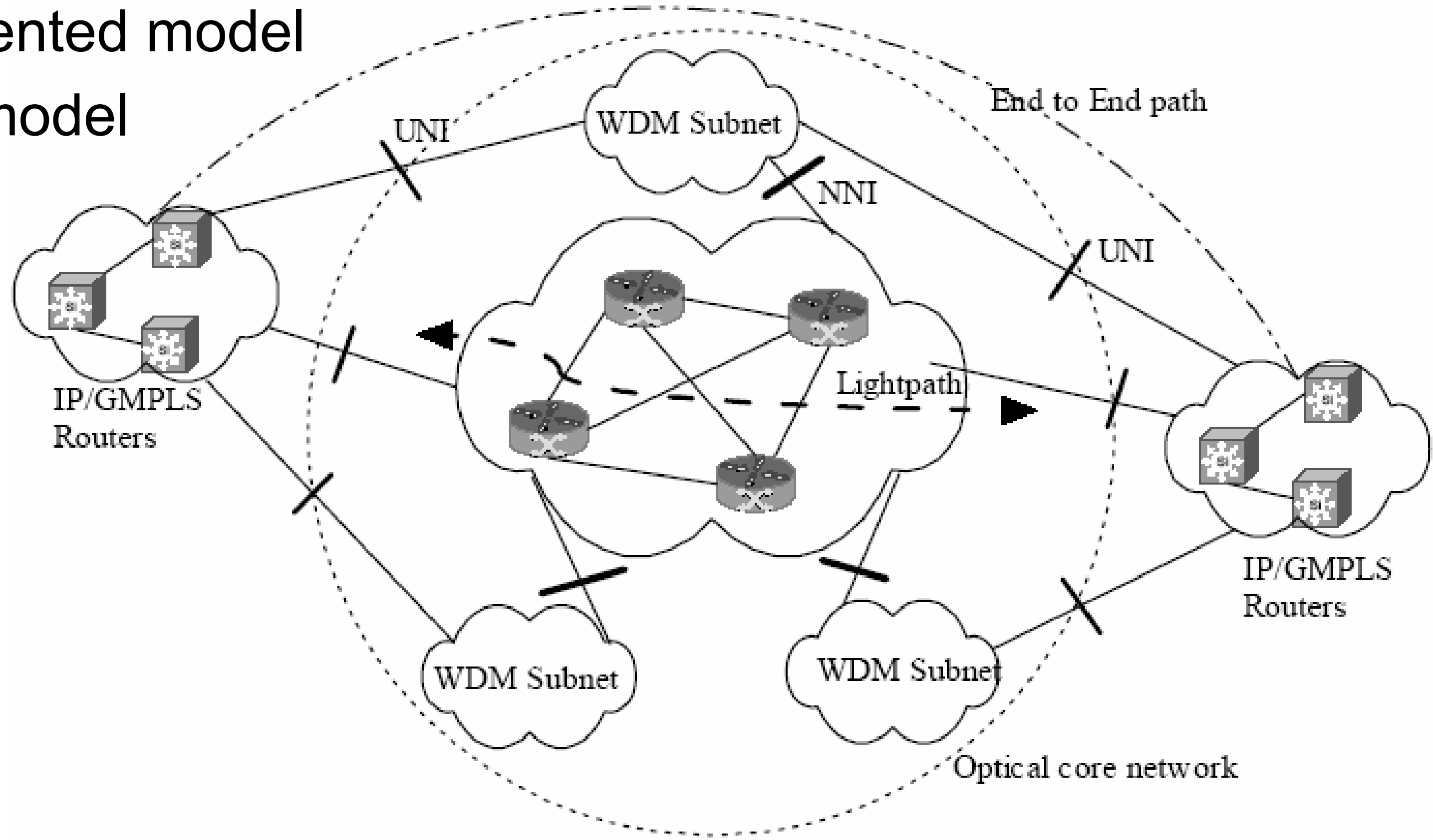
Introduction

- IP over WDM optical network
  - Overlay model
  - Augmented model
  - Peer model

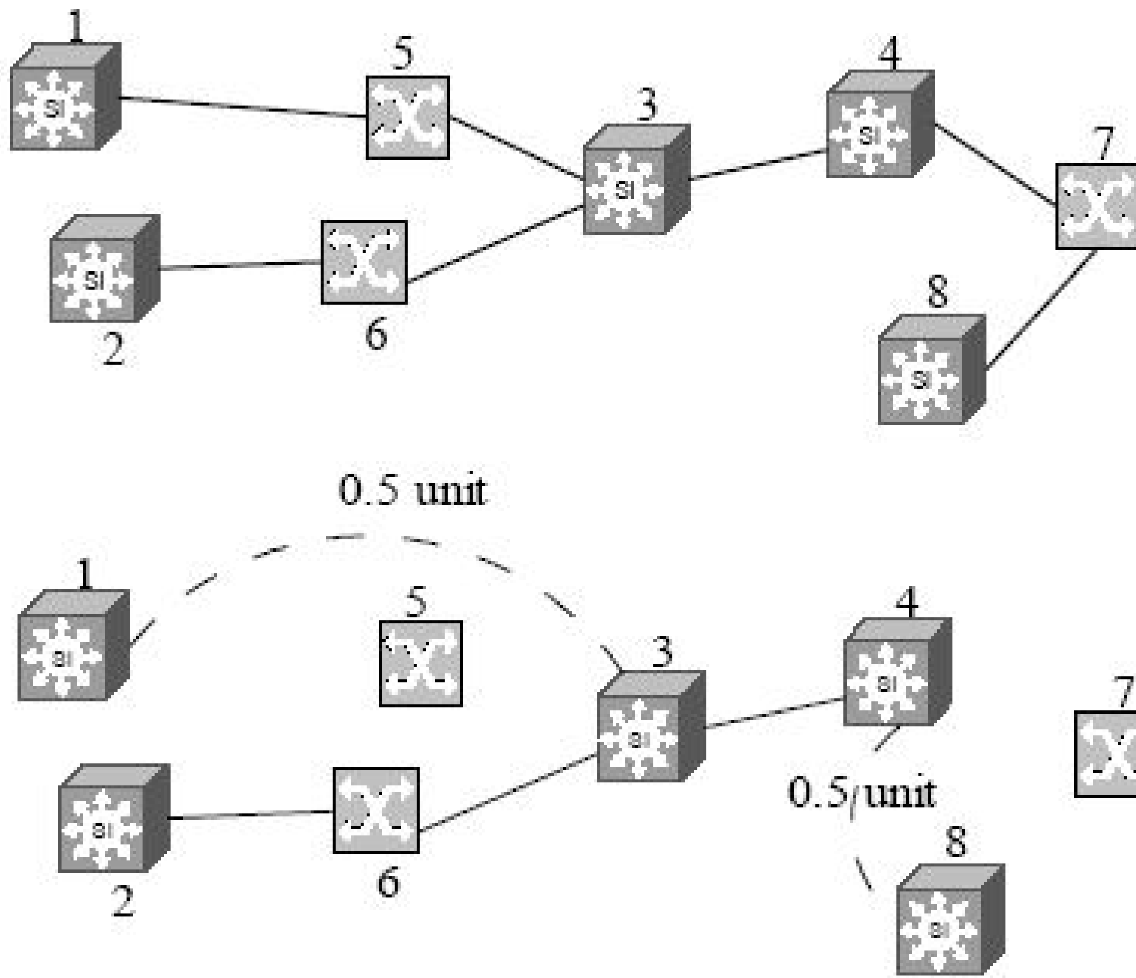


Problem definition and network model

- IP/WDM network topology G(V, L, W)
  - V(R,O): set of all nodes,
    R: integrated router/OXC nodes; O: OXC nodes
  - L: set of bidirectional optical links
  - W: set of wavelengths per fiber link
- Based on GMPLS framework, an optical channel (λ -LSP) request is defined as
  - $(X_\mu, Y_\mu, \beta_\mu)$: source X_μ and destination Y_μ with required bandwidth β_μ

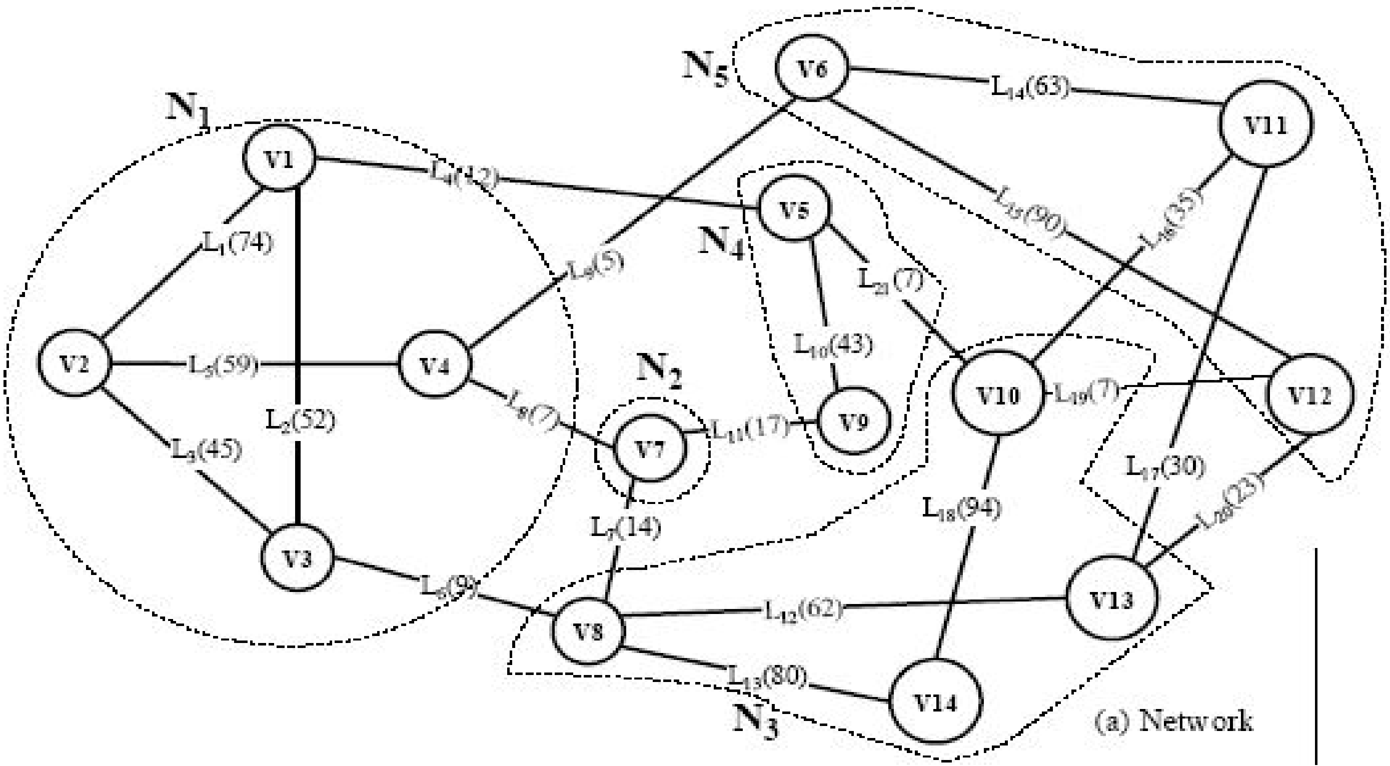
IP over WDM example network

- Assume each fiber has only one wavelength
- A traffic request arrives (1, 8, 0.5)
- Assume a LSP path of (1->5->3->4->7->8) has been found
- Two new lightpaths (cut through arcs) are introduced to form a new topology



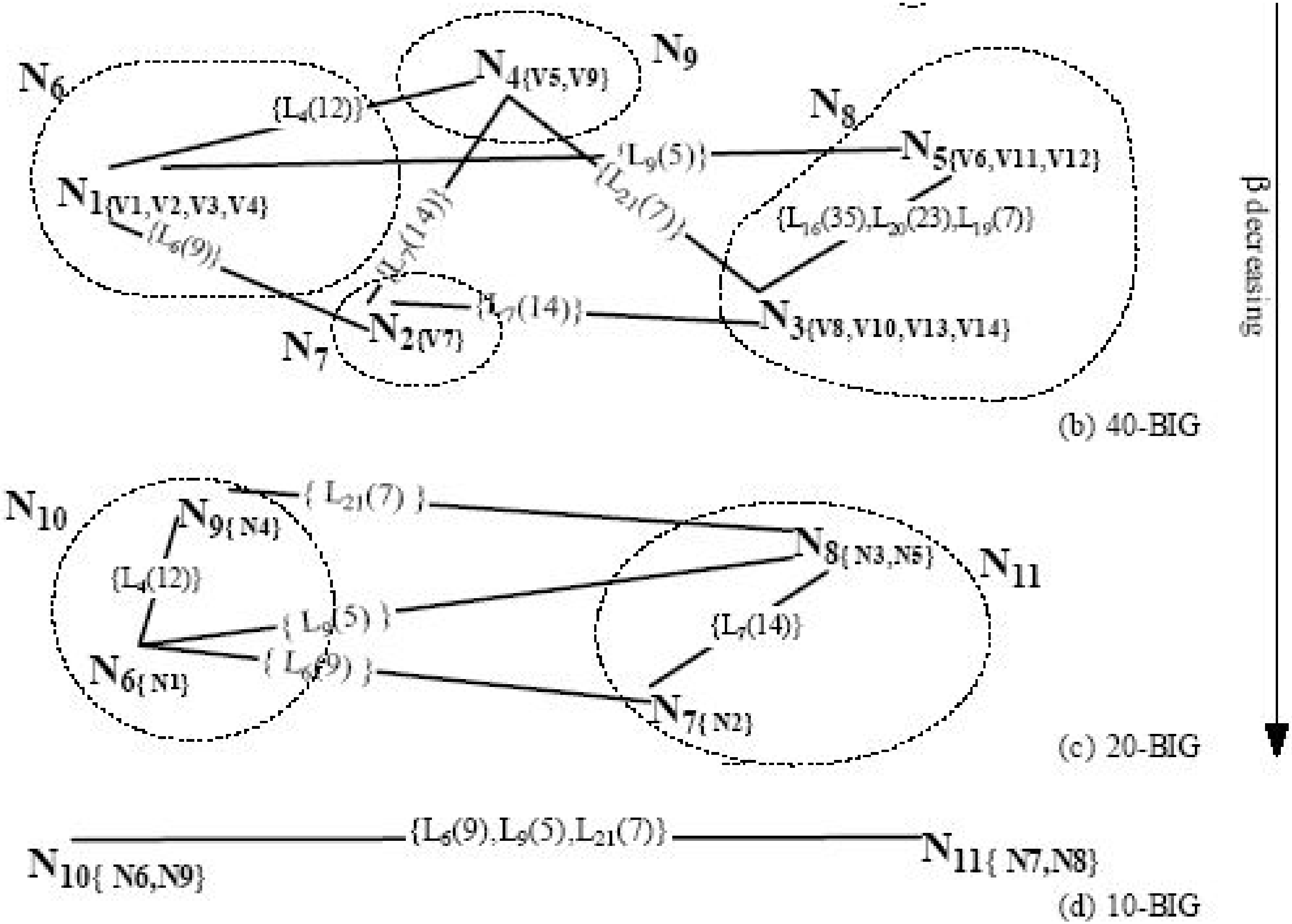
Blocking island paradigm

- β-BI for node x is the set of all nodes that can be reached from x using links with at least β available bandwidth
  - $N_1=(V_1, V_2, V_3, V_4)$ is a 40-BI for node V_1



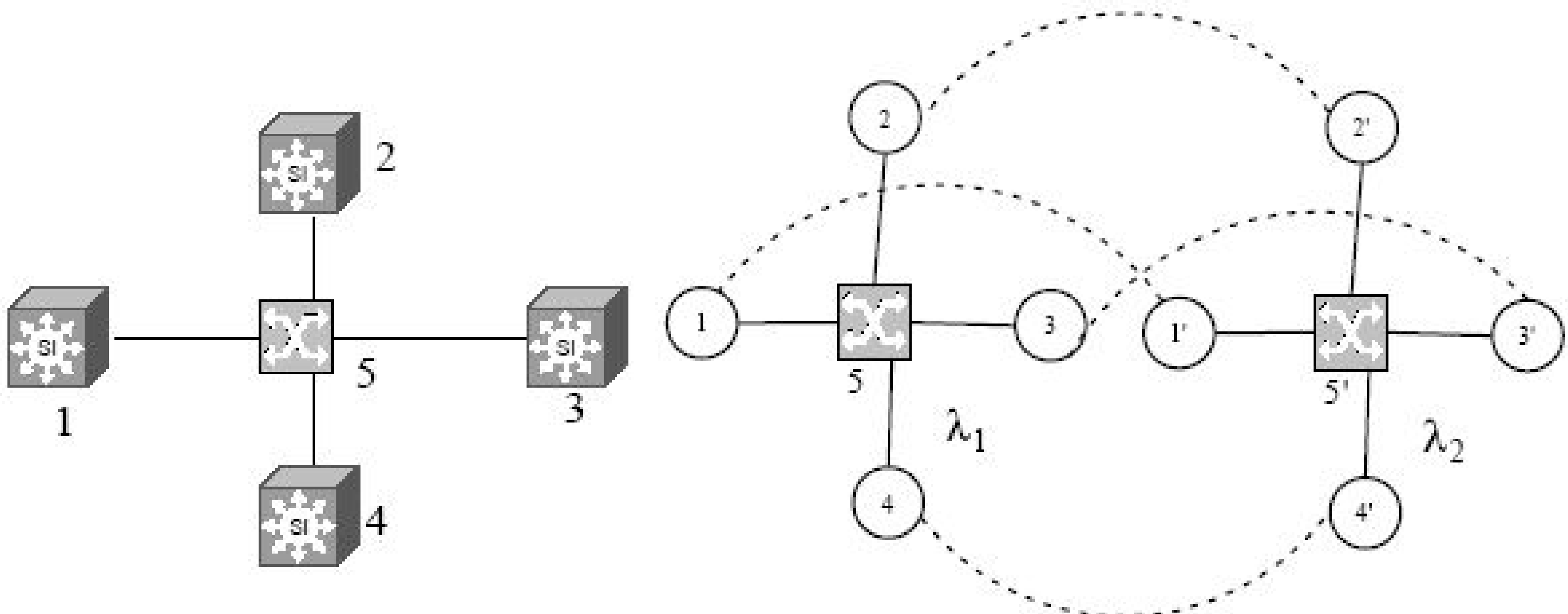
(a) Network

Blocking island hierarchy



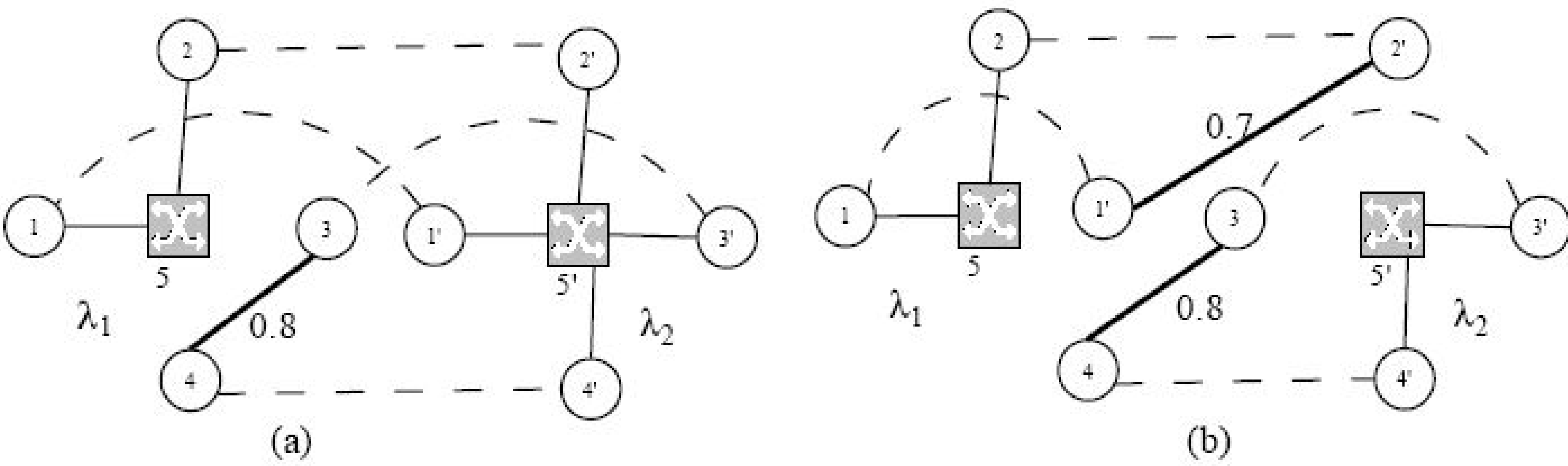
BIG model

- Assume each fiber link carries two wavelength
- Integrated router/OXC nodes have the capability of wavelength conversion
- Add virtual links with weight (distance) of 0



Minimum Splitting heuristic

- MS heuristic: try to find a route which doesn’t provoke a split in the corresponding BI graph
- Example: given a request (4, 3, 0.2), another request (1, 2, 0.3) arrives, what’s the better route?



Integrated routing and grooming algorithm

- Input: traffic request D(x, y, β); a BIG network and corresponding BIH
- Steps
  - Assign D to appropriate BIG of BIH according to β
  - Route existence check; if route not available, D is blocked
  - Compute K different weighted shortest routes using path cost function
  - Assign each route to all levels of BIH to compute splitting cost
  - Pick the route with minimum splitting cost
  - Update BIG network and affected blocking islands in BIH

Enhanced BIG and BIH construction

- Network topology $G(V,L,W)$, $V=(R,O)$
  - Replicate original topology G $|W|$ times
  - Each integrated node r has $|W|$ copies, add virtual links r_1r_2, r_2r_3, …, $r_{|W|-1}r_{|W|}$ with unlimited bandwidth and no weight (distance)
- Predefine BIH
  - Pick up β's according to incoming traffic statistics
  - Example: 0.2, 0.5 and 0.8

Route existence check

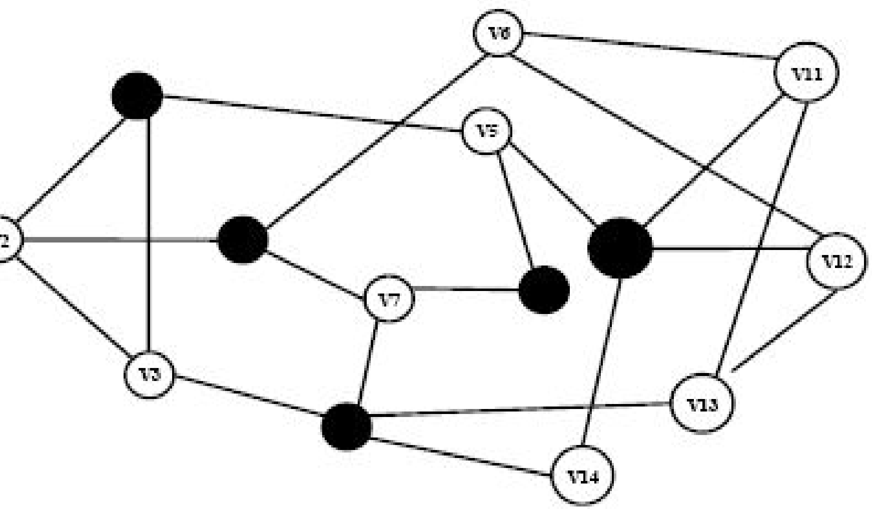
- Assume a predefined H-level BIH ($\alpha_1, \alpha_2, \ldots \alpha_H$) where $\alpha_1 < \alpha_2 < \ldots < \alpha_H$
- Consider a request $D_\mu(X_\mu, Y_\mu, \beta_\mu)$
  - $\beta_\mu = \alpha_i$
  - $\beta_\mu > \alpha_H$: check whether X_μ, Y_μ are in the same BI of α_H-BIG; if no, blocked, else, further check
  - $\beta_\mu < \alpha_1$: check whether X_μ, Y_μ are in the same BI of α_1-BIG; if yes, route exists, else, further check on whole network
  - $\alpha_i < \beta_\mu < \alpha_{I+1}$: check whether X_μ, Y_μ are in the same BI of α_{i+1}-BIG; if yes, route exists, else, check in α_i-BIG, if no, blocked, else, further check

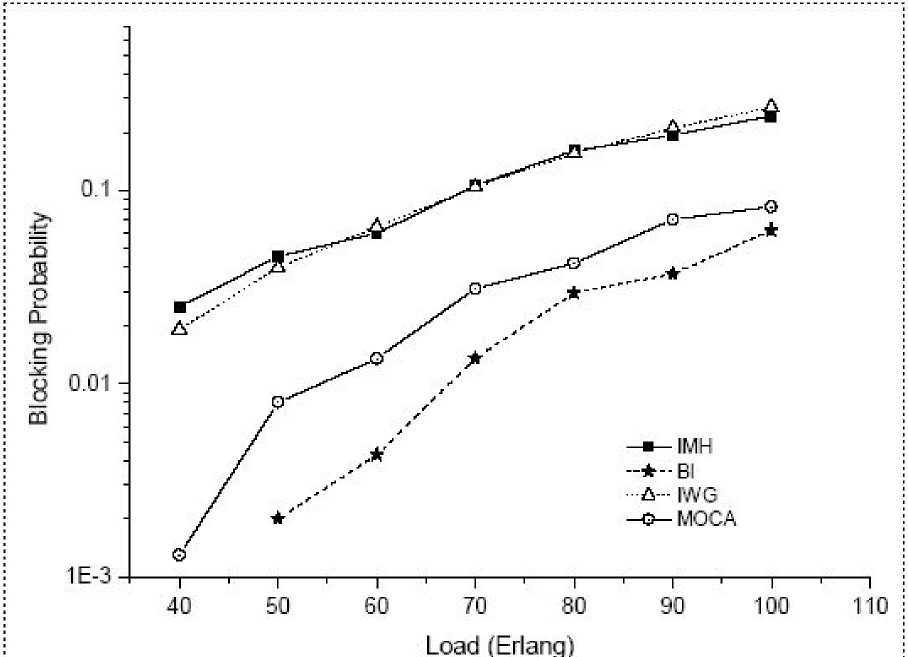
Path cost and splitting cost

- Path_Cost = N links + P * Active_Lightpaths
  - N: number of new optical links along the path
  - Active lightpaths: cut through arcs already set up
  - P: cost coefficient, usually <1
- Splitting_Cost= N_i*number of splitting in level *i*
  - N_i : cost coefficient of hierarchy level *i*
  - Assume H levels, $N_1 = H$, $N_2 = H-1, \ldots N_H = 1$

Performance studies

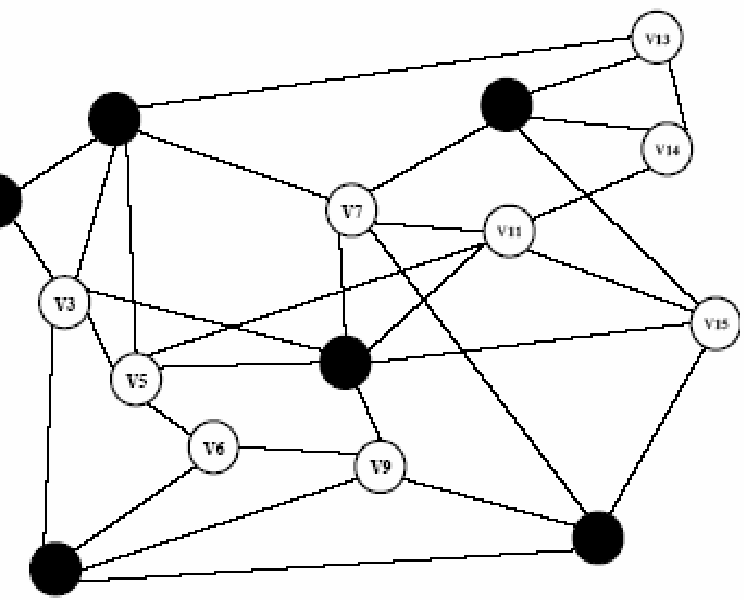
- Compare the performance of BI-based routing algorithm with others
  - IMH: Integrated Min-hop routing algorithm
  - MOCA: Maximum Open Capacity algorithm
  - IWG: IP-WDM Grooming algorithm

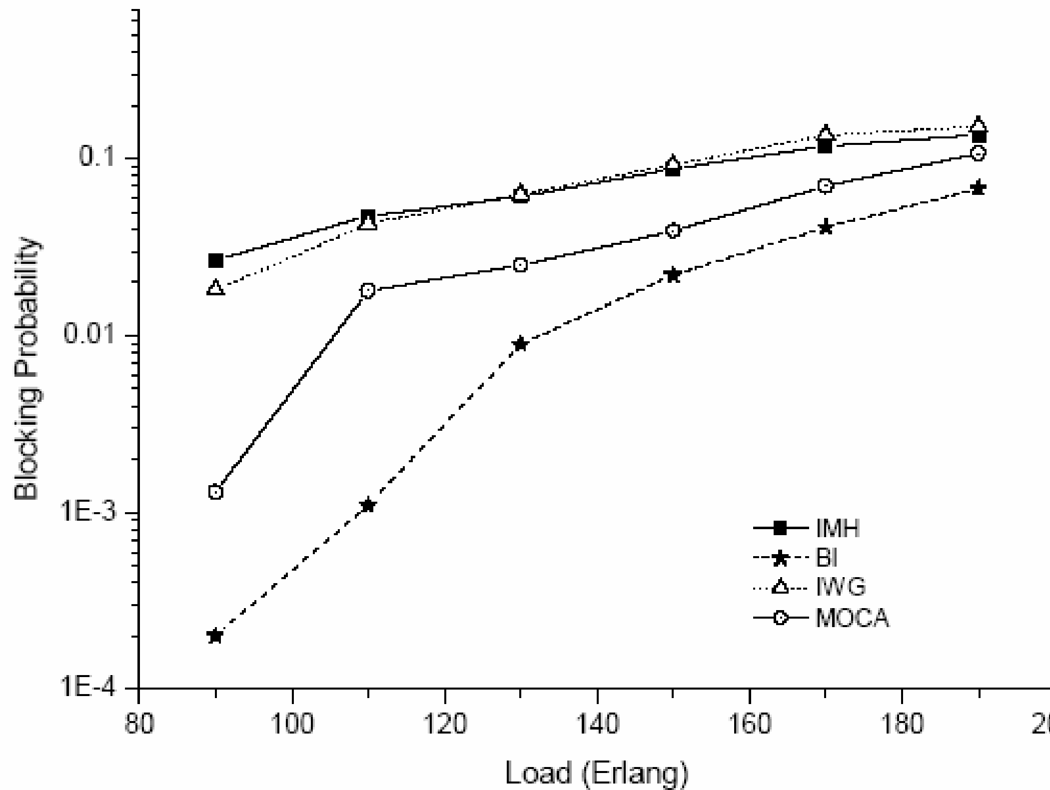




Performance studies

- Performance for a random generated network topology
- Pre-define the BIH with 0.1-BIG, 0.3-BIG, 0.5-BIG and 0.8-BIG





Conclusion

- The contribution of this paper is to propose a novel integrated routing and grooming algorithm for routing bandwidth guaranteed paths.
- Simulation results demonstrate the proposed algorithm has a very good blocking probability performance compared with IMH, IWG and MOCA.