Virtual Fiber Configuration Method for Dynamic Lightpath Establishment in Large-Scaled WDM Networks

Graduate School of Osaka University
Advanced Network Architecture Laboratory
Shinya Ishida
s-isida@ist.osaka-u.ac.jp

Contents

- Growing WDM networks
  - Topology of large-scale WDM networks
  - Influence of the power-law connectivity
- Our solution
  - Quasi-static lightpath
  - Virtual fiber
  - Degree-based virtual fiber configuration
- Evaluations
- Conclusion and future work

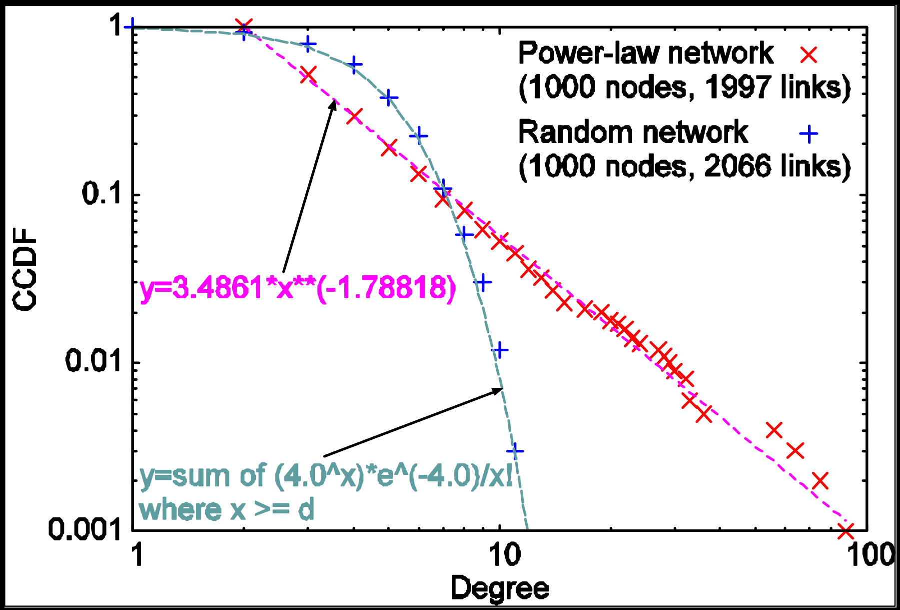
Growing WDM networks

- Rapid increase of the Internet's traffic volume
  - WDM technology
- Growth of WDM networks
  - Interconnections by GMPLS and ASON
  - A large-scale WDM network will be constructed
- Performance of a large-scale WDM network
  - What topology?
    - Random mesh network (used in traditional studies on WDM)
    - Another

Topology of the Internet

- AS level topology of the Internet
  - Power-law connectivity
    - Most nodes have a few connections
    - Some nodes have lots of connections (hub nodes)

<u>Power-law connectivity</u>
The probability $p(k)$ that a node is connected to k other nodes is proportional to k^{-r} (r is constant).



Degree distribution

Topology of large-scale WDM networks

- BA (Barabási-Albert) model
  - Incremental growth
    - Nodes join a network one by one
  - Preferential attachment
    - High-degree nodes are likely to be connected with new nodes

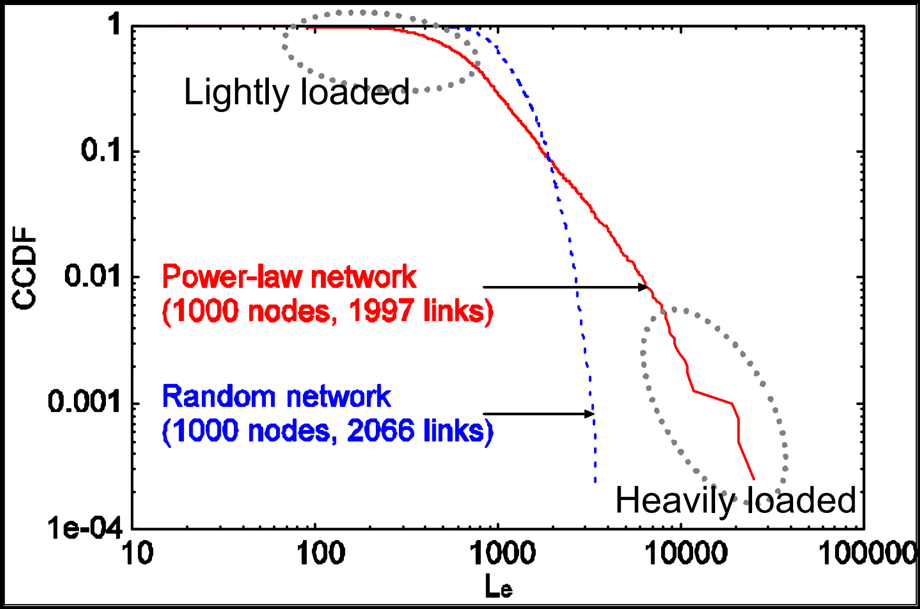
- Large-scale WDM networks
  - Nodes join incrementally
  - Links are added selfishly
    - No coordinators for the entire networks
    - Limits of costs for equipments

⇨ Power-law connectivity

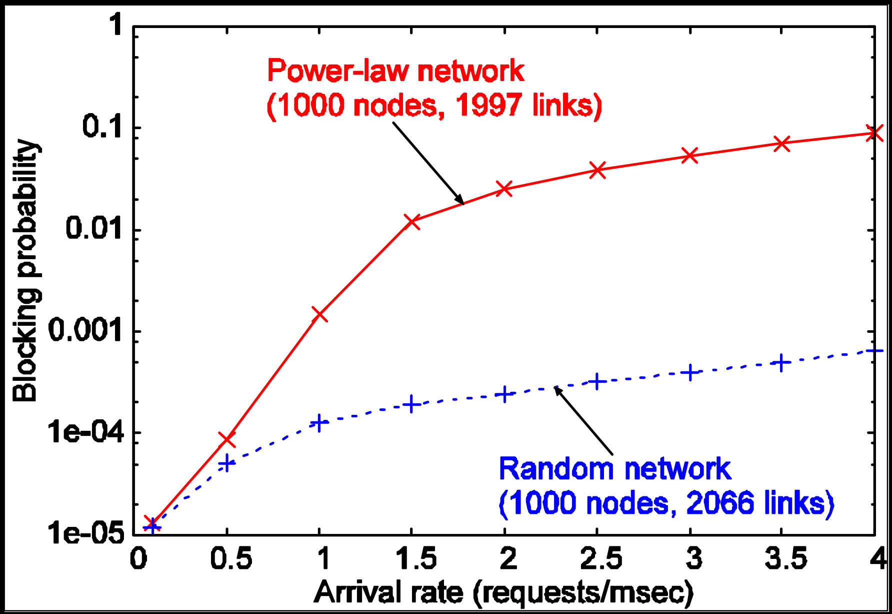
Influence of power-law connectivity

- Unbalanced load
  - Many lightpaths through hub nodes
  - Blocking probability is increased

Simulation model
- Links are bi-directional
- Routing is Shortest hop routing
- No wavelength conversion



Distribution of L_e
L_e: **Number of node pairs whose lightpaths go through a link e**



Blocking Probability (32 wavelengths)

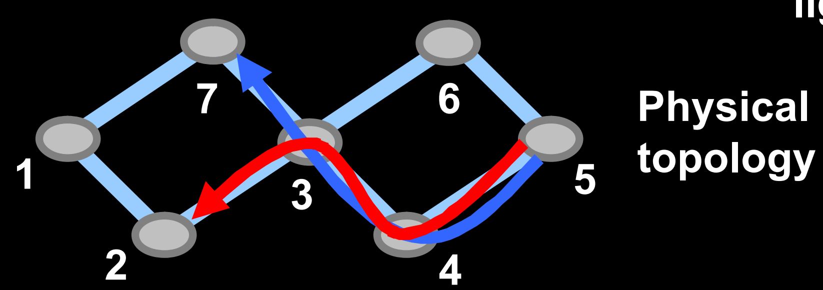
Our solution

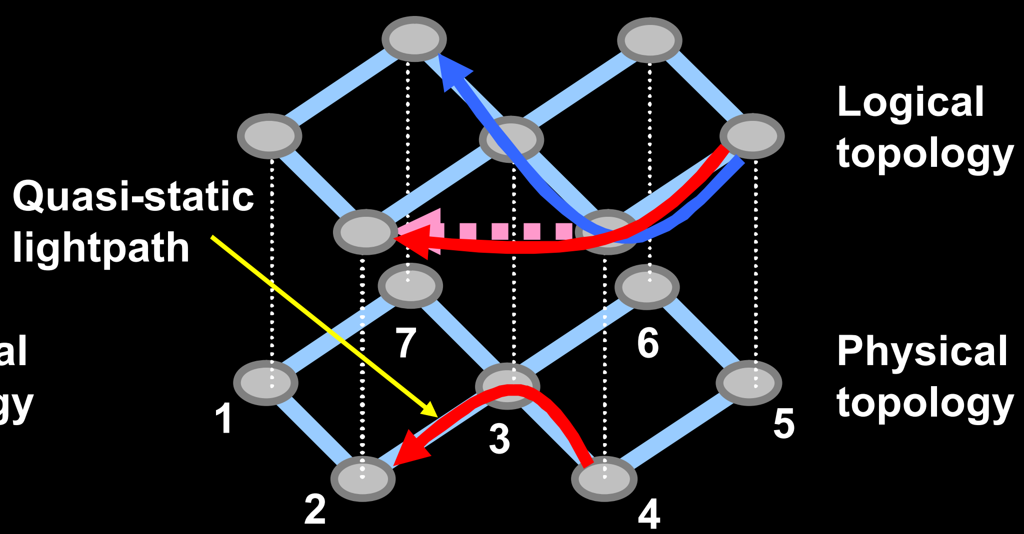
- Changing topologies logically
  - Enhancement of network equipments is expensive
  - Link state based routings increase overheads

Solution	Merits	Demerits
Enhancement of network equipments such as fibers and OXCs	Any other architectures are not required	Costs for installing and managing network equipments become high
Using a link state based routing	Wavelength resources are highly utilized against dynamic changes of traffic pattern	Overheads for distributing link state information and updating routing tables are increased
Changing topologies by configuring virtual fibers	Any more resources are not needed and a routing has not to be changed	Flexibility of wavelength utilization is limited

Quasi-static lightpath

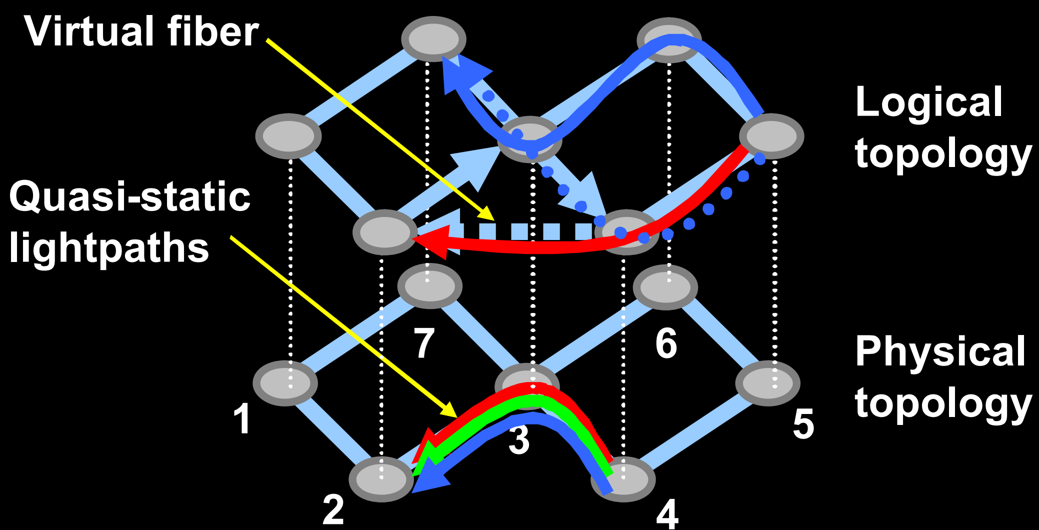
- Setup static lightpaths in advance
  - Regard static lightpaths as logical links
  - Reserve and release wavelengths of logical links as wavelengths of physical links
- Moderate the affect of the wavelength continuity constraint





Virtual fiber

- Cut-through operation
  - Setup quasi-static lightpaths for all of the wavelengths
- Degrees of intermediate nodes are reduced
  - Routes of some lightpaths have to be changed

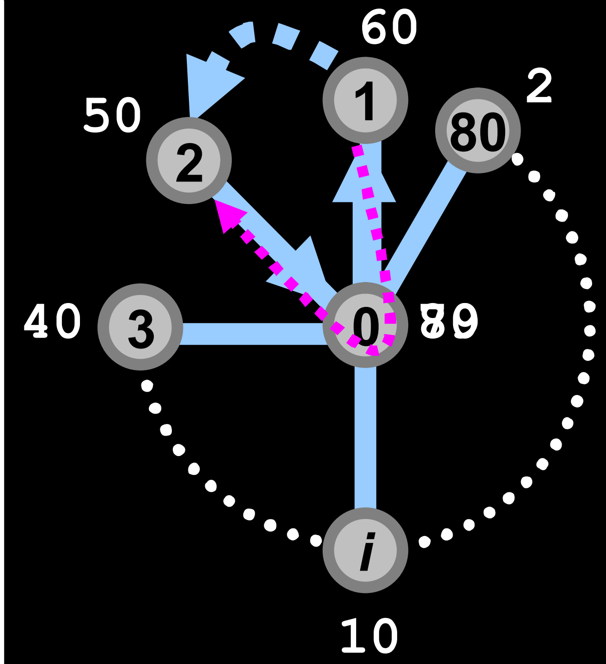


Degree-based virtual fiber configuration

- Reduce degrees of hub nodes by cut-through
  - Some lightpaths are diverted from hub nodes
  - Loads for links around hub nodes are distributed

<u>Outline of</u>
<u>degree-based virtual fiber configuration method</u>

Step 1: Set the degree threshold th. Go to Step 2.
Step 2: Find a node n_0 having maximum degree d_{max}. If $d_{max} > th$, go to Step 3. If not, go to Step 5.
Step 3: Select such two adjacent nodes of n_0, n_1 and n_2, that the sum of their degrees is maximum. Go to Step 4.
Step 4: Cut through n_0 from n_1 to n_2. Go to Step 2.
Step 5: Quit configuring virtual fibers.

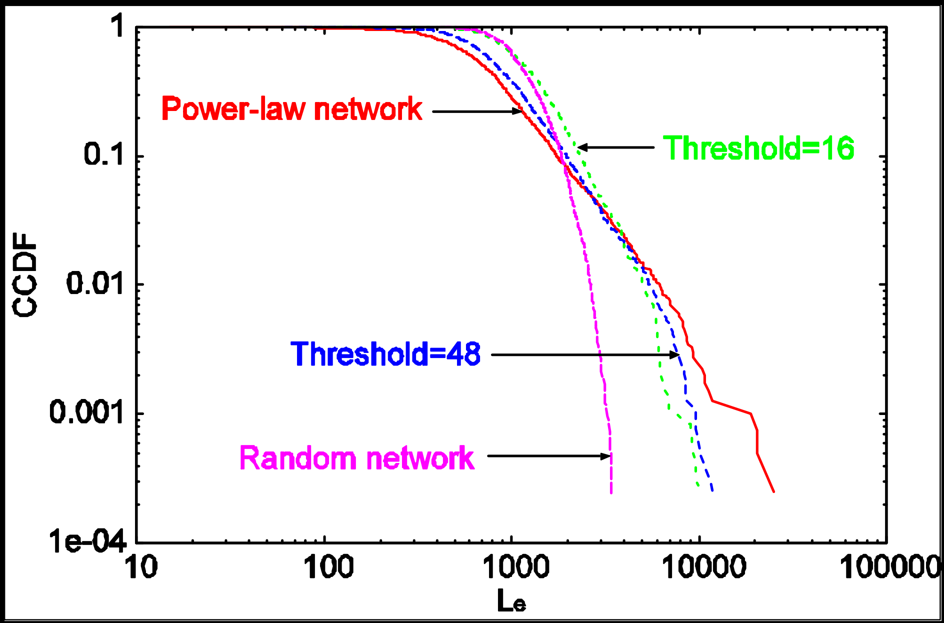


Evaluations

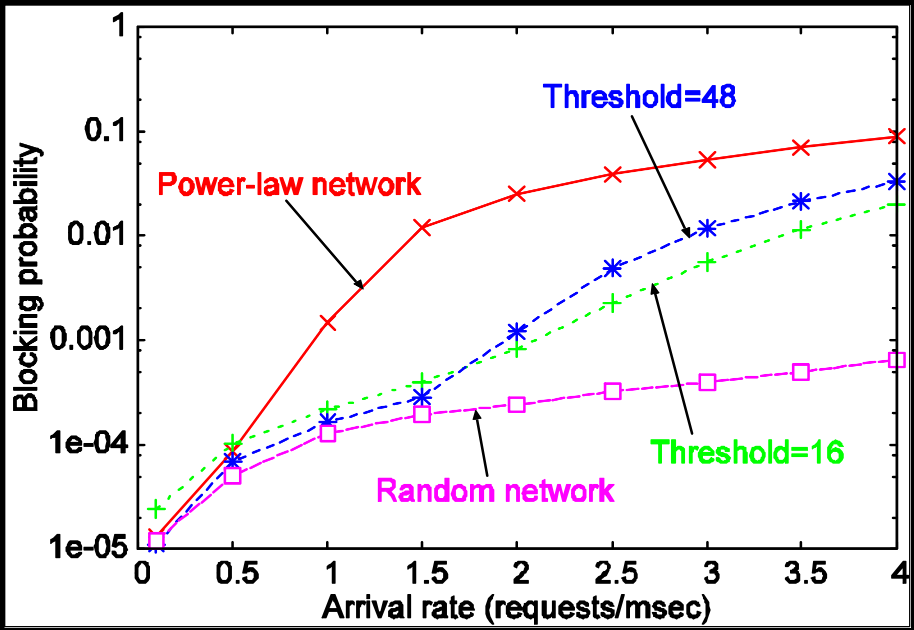
- Compare blocking probabilities
  - for the cases with and without virtual fiber configurations
  - Simulation model
    - Maximum degree: 88
    - Propagation delay: 0.1 msec (uniform)
    - Processing delay: 0
    - Lightpath setup requests: Poisson arrival
    - Holding times: Exponential distribution (rate 1.0 sec)

Comparison of blocking probability

- Our method reduces more than one order of magnitude of blocking probability
- Optimal threshold depends on arrival rate
  - Main factor for blocking probability changes



Distribution of L_e



Blocking probability (32 wavelengths)

Comparison of topological property

- Virtual fiber configuration
  - Average link load is increased
  - Variance of link load is reduced
- Main factor changes according to arrival rate
  - Average link load when the arrival rate is low
  - Maximum link load when the arrival rate is high

Properties of each topology

Topology	Power-law	64	48	32	16	8	Random
Average distance	3.99	4.15	4.33	4.47	5.09	5.92	5.06
Average L_e	998.89	1046.0	1107.1	1166.0	1406.9	1787.1	1222.5
Maximum L_e	25120	12905	11863	11786	9993.0	8745.0	3442.0
Minimum L_e	15	48	62	55	117	325	414

Conclusion and future work

- Conclusion
  - Future large-scale WDM networks
    - Power-law connectivity
    - Hub nodes decline the performance of blocking probability
  - Virtual fiber configuration method
    - Investments and complicated routing are not required
    - Balances link load by logically reducing degrees of hub nodes
    - Reduces the blocking probability by more than one order of magnitude
- Future work
  - A way to determine the optimal threshold in advance

Thank you