QoT-aware Routing in Impairment-constrained Optical Networks

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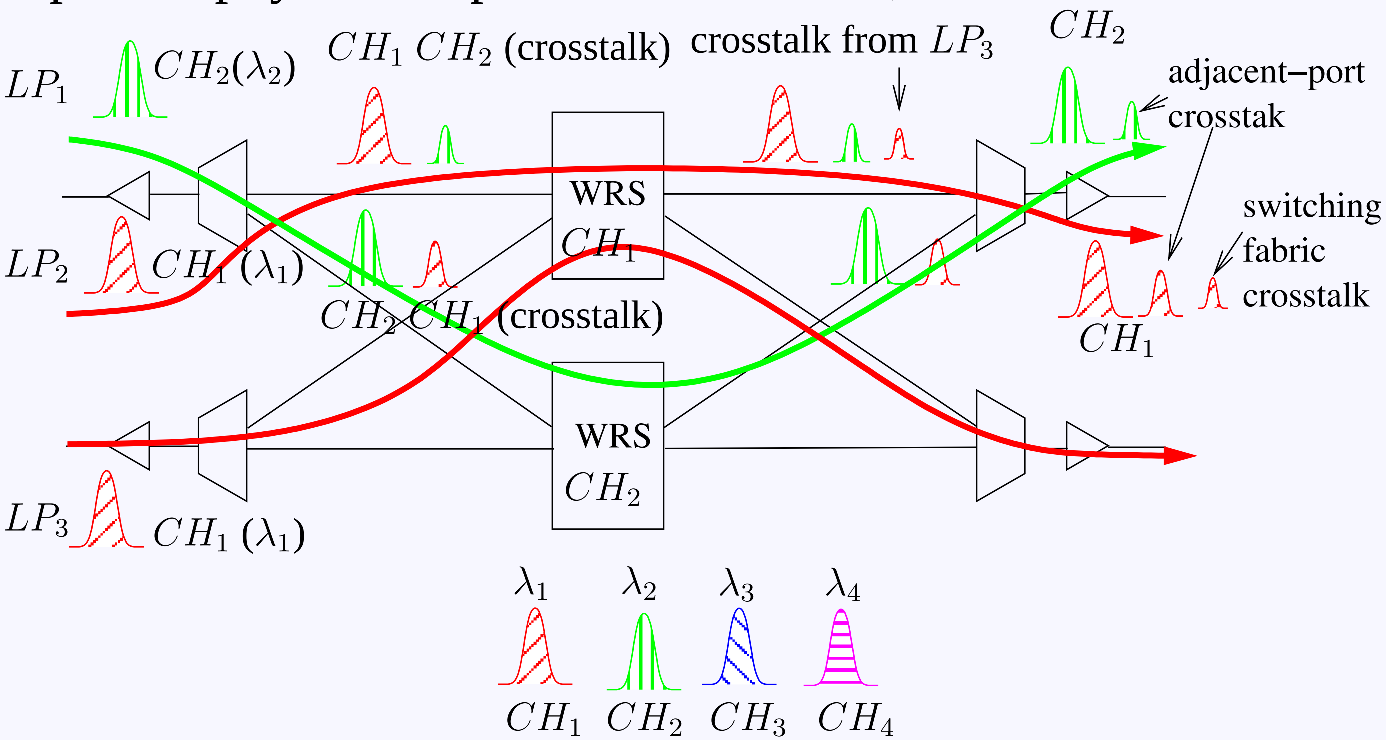
Background

- Wavelength routed all optical networks
  - Circuit switched end-to-end optical channel or lightpath
  - No optical-electrical-optical regenerators
  - Advantages
    - Huge bandwidth,
    - Transparency,
    - Cost
    - Wavelength reuse, etc.
  - Applications
    - Backbone network, now being deployed in metropolitan area networks
    - Large file transfer and E-science
  - Problems
    - Routing and Wavelength Assignment
    - Physical impairments in the physical layer
    - Challenges to find a good route simultaneously considering both constraints

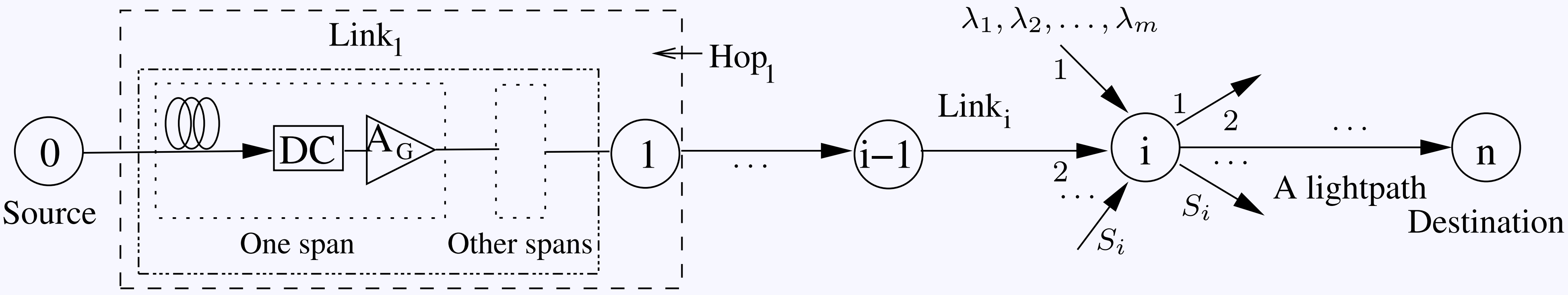
Research Motivation

- Previous works;
- The impact of physical impairments on RWA;



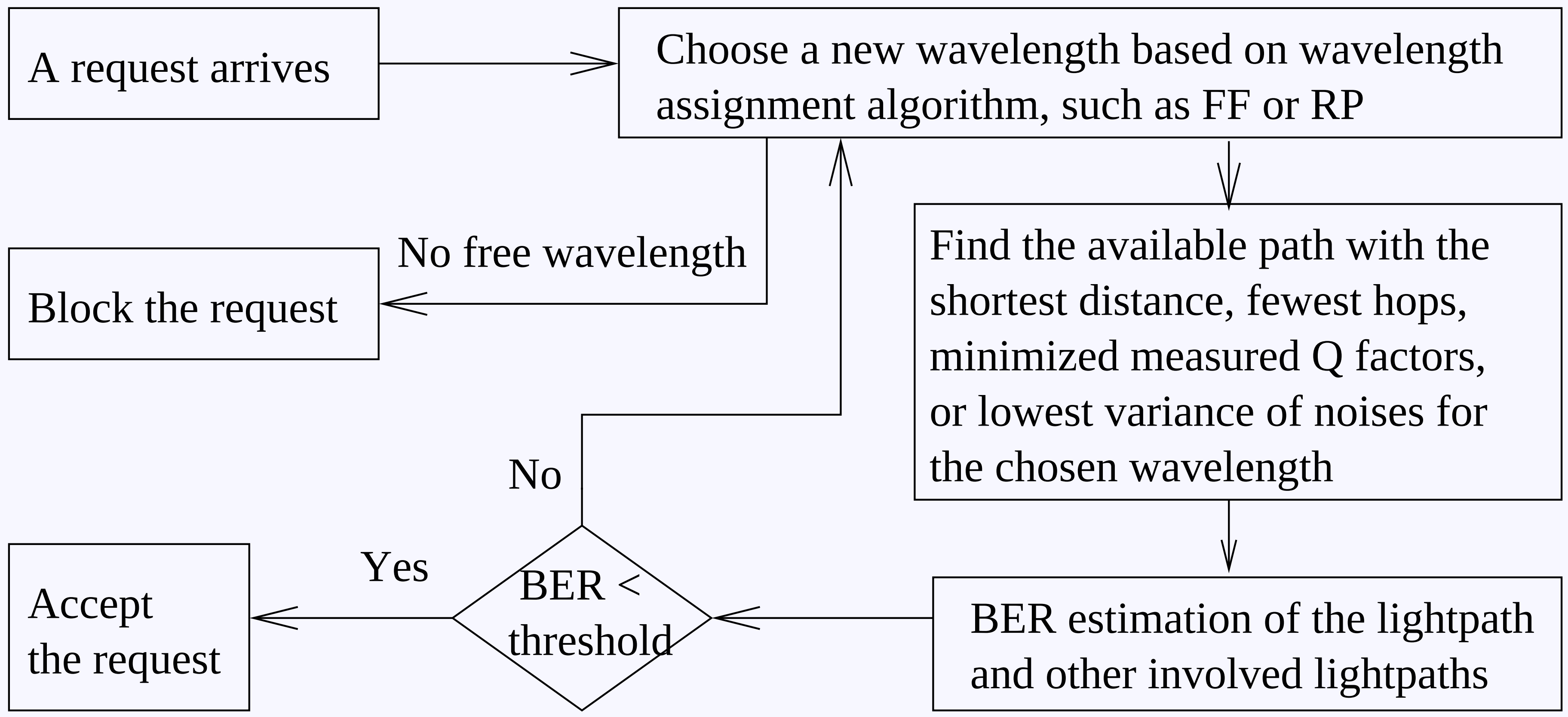
- Two QoT-aware routing schemes.
  - Route admission control with impairment constraints.
  - Routing incorporates impairments into the cost of routes.

BER Estimation Model



- Dominant physical degradations
  - Amplified spontaneous emission (ASE) noise from EDFAs;
  - Linear crosstalk from OXCs and Demux;
  - Nonlinear effect from four-wave mixing (FWM) and cross-phase modulation (XPM);
  - Shot noise and thermal noise.
- Power of impairments propagates to the next hop until arriving at receiver;
- Other linear/nonlinear impairments can be integrated in the model.

QoT-Aware Routing Algorithms



- ◇ SD: find a route with shortest fiber length (decreasing link impairments);
- ◇ FH: find a route passing fewest intermediate nodes (decreasing node impairments);
- ◇ QM: the link weight is estimated by the average link degradation to the existing;
- ◇ LV: the link weight is estimated by the impairments variance on candidate wavelength.

Cost Functions in QoT-Aware Routing

- Routing with QoT constraints: the link weight doesn't represent QoT
  - ◇ The weight of hop i in Shortest distance routing (SD) is assigned as $D(i) =$ Length of link$_i$;
  - ◇ The weight of hop i in fewest hop routing (FH) is assigned as $D(i) = 1$;
- Routing based on QoT: the link weight considers QoT
  - ◇ The weight of hop i in Q-maximizing routing (QM) is assigned as

$$D(i) \quad = \quad \frac{\sum_{l=1}^{T_i} 10\log[Q^{(s)}(i,l)/Q^{(d)}(i,l)]}{T_i}; \qquad (1)$$

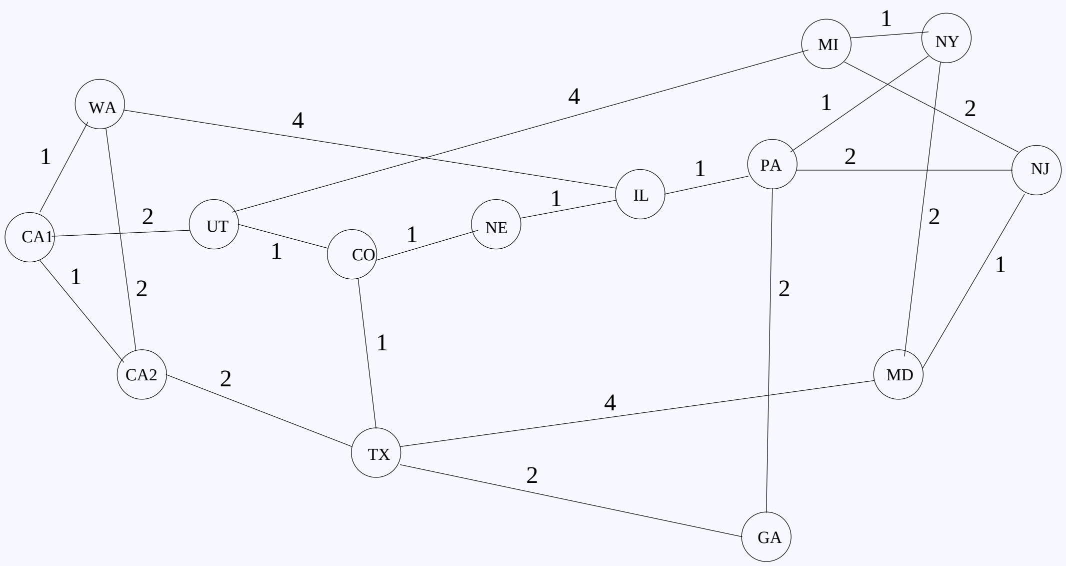
  - ◇ The weight of hop i (if considering λ_j) in routing based on least variance (LV) is assigned as

$$W(i,j) = \sigma^2_{XT}(i,j) + \sigma^2_{NL}(i,j) + \sigma^2_{ASE}(i,j) + \alpha_i; \qquad (2)$$

$$\alpha_i \Longleftarrow \max\{\alpha_i + \Delta\alpha, \alpha_{\max}\} \quad \text{if detecting wavelength blocking;}$$

$$\alpha_i \Longleftarrow \min\{\alpha_i - \Delta\alpha, \alpha_{\min}\} \quad \text{if detecting QoT blocking.}$$

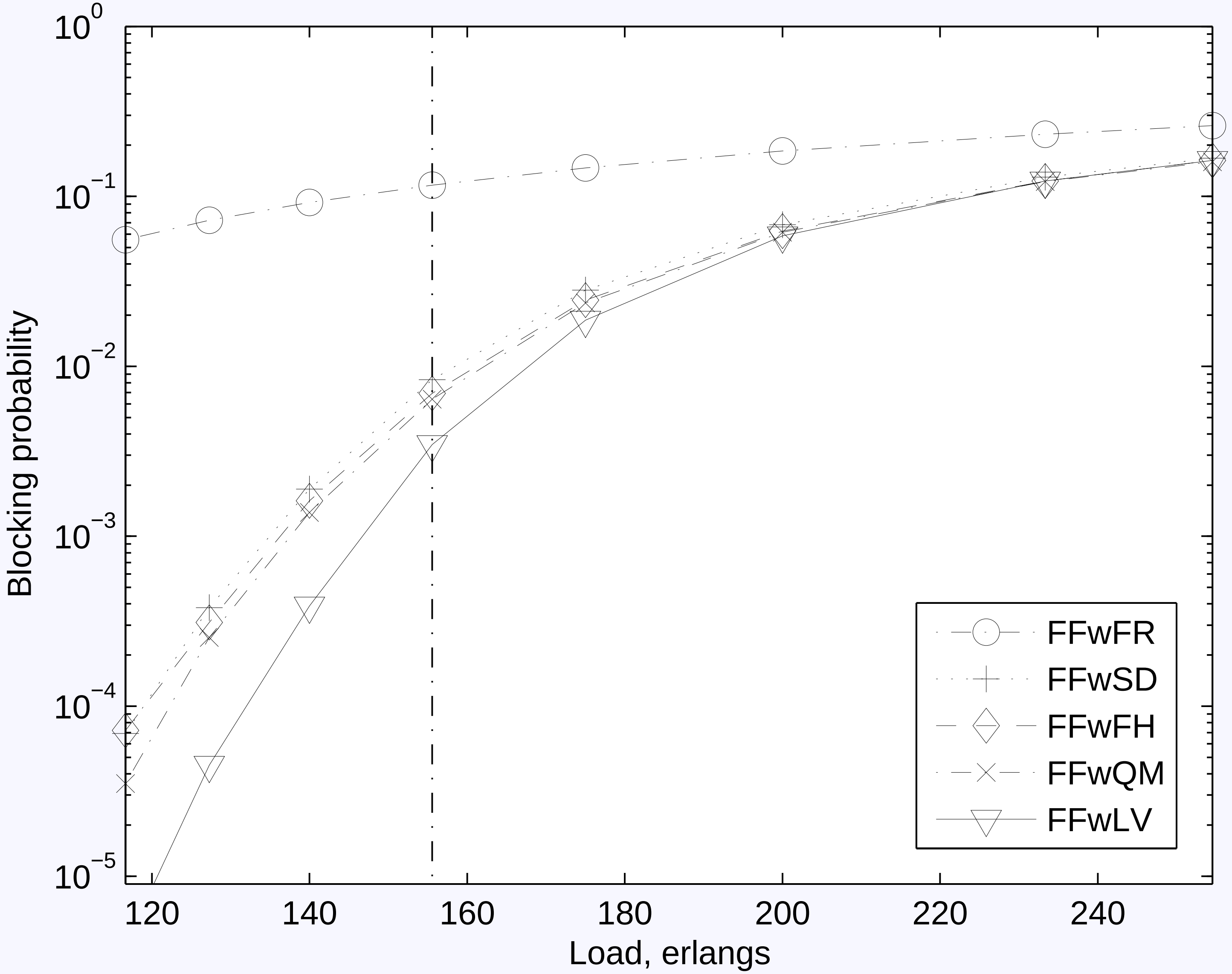
Simulation Settings



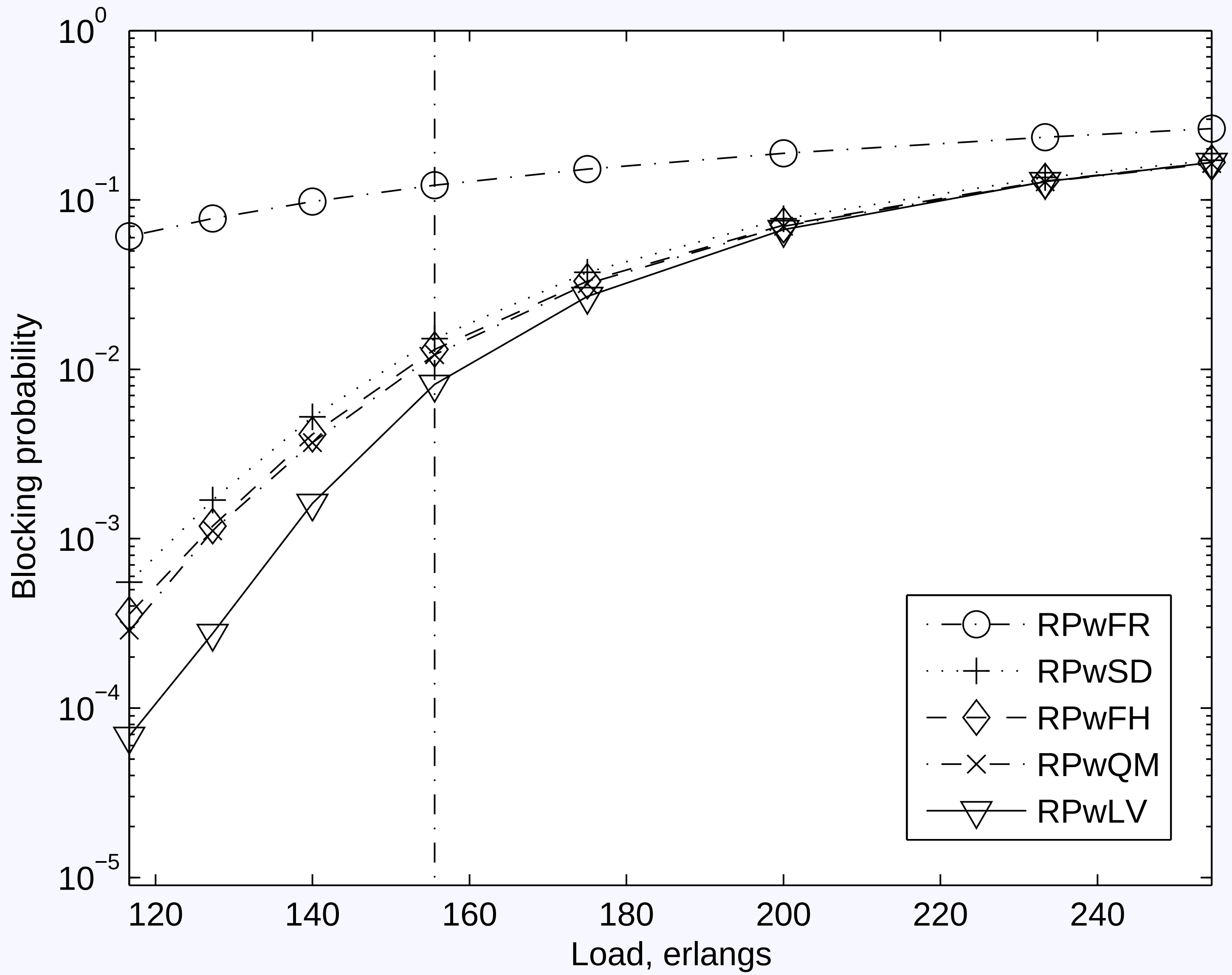
Topology of a downsized version of the NSF network with 14 nodes and 21 bidirectional links. The numbers on the links represent number of spans along the link. Each span is 70 km long.

Parameters	Value
Number of Wavelength	32
Wavelength spacing	25 GHz
Data rate per channel	10 Gps
Fiber loss (L_f)	0.2 dB/km
ASE factor (n_{sp})	1.5
Laser source power	0 dBm
ρ	0.95 A/W
BER threshold	10^{-12}
Dispersion compensator	100% post
Chromatic dispersion	17 ps/nm/km
Nonlinearity constant	2.2 $(\text{W.m})^{-1}$
$\alpha_{\max}$	$3 \times 10^{-10}\ A^2$
$\alpha_{\min}$	$1 \times 10^{-10}\ A^2$
$\Delta\alpha$	$1 \times 10^{-11}\ A^2$

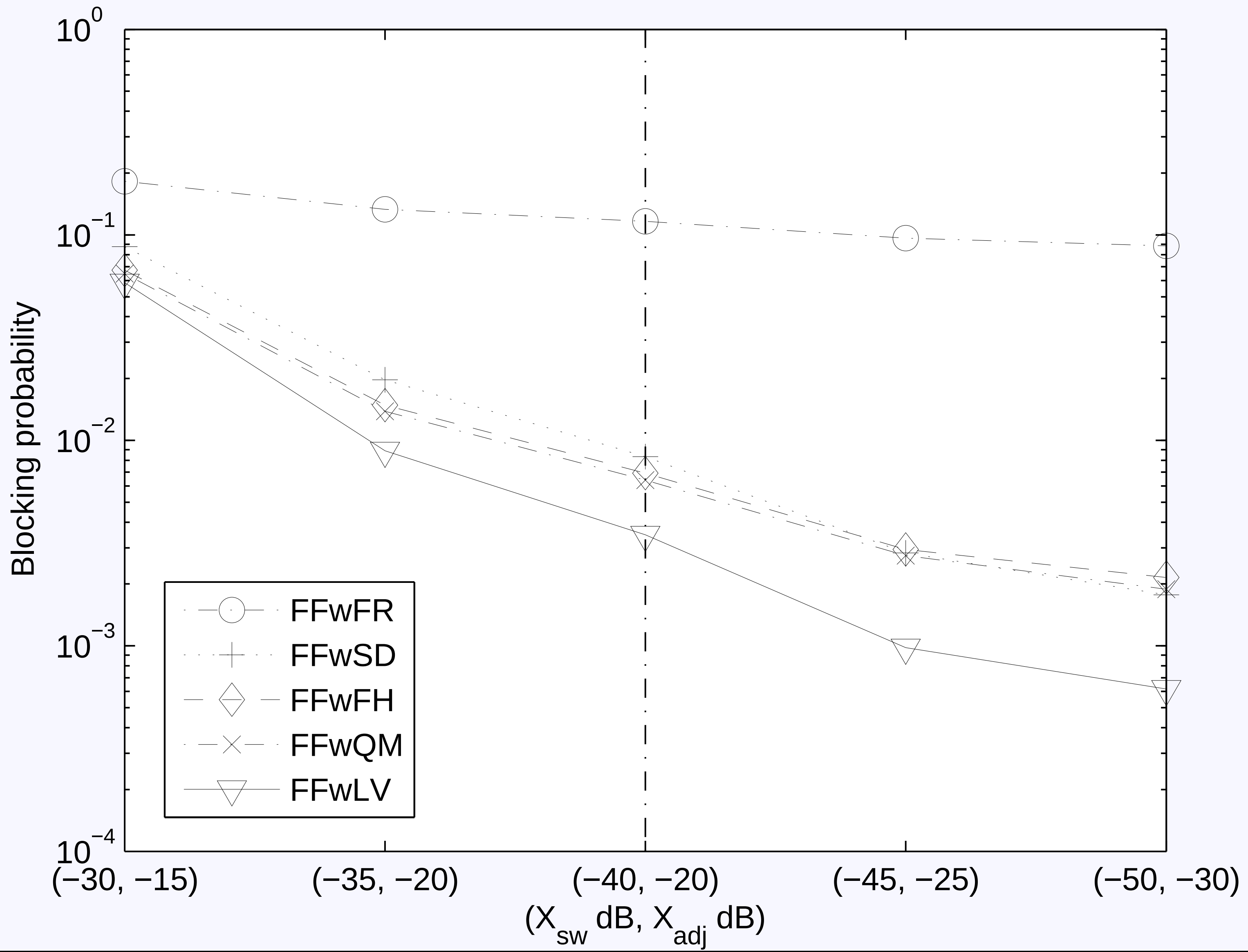
Blocking Probability vs Network Load if WA uses FF



Blocking Probability vs Network Load if WA uses RP



Blocking Probability vs Node Crosstalk if WA uses FF



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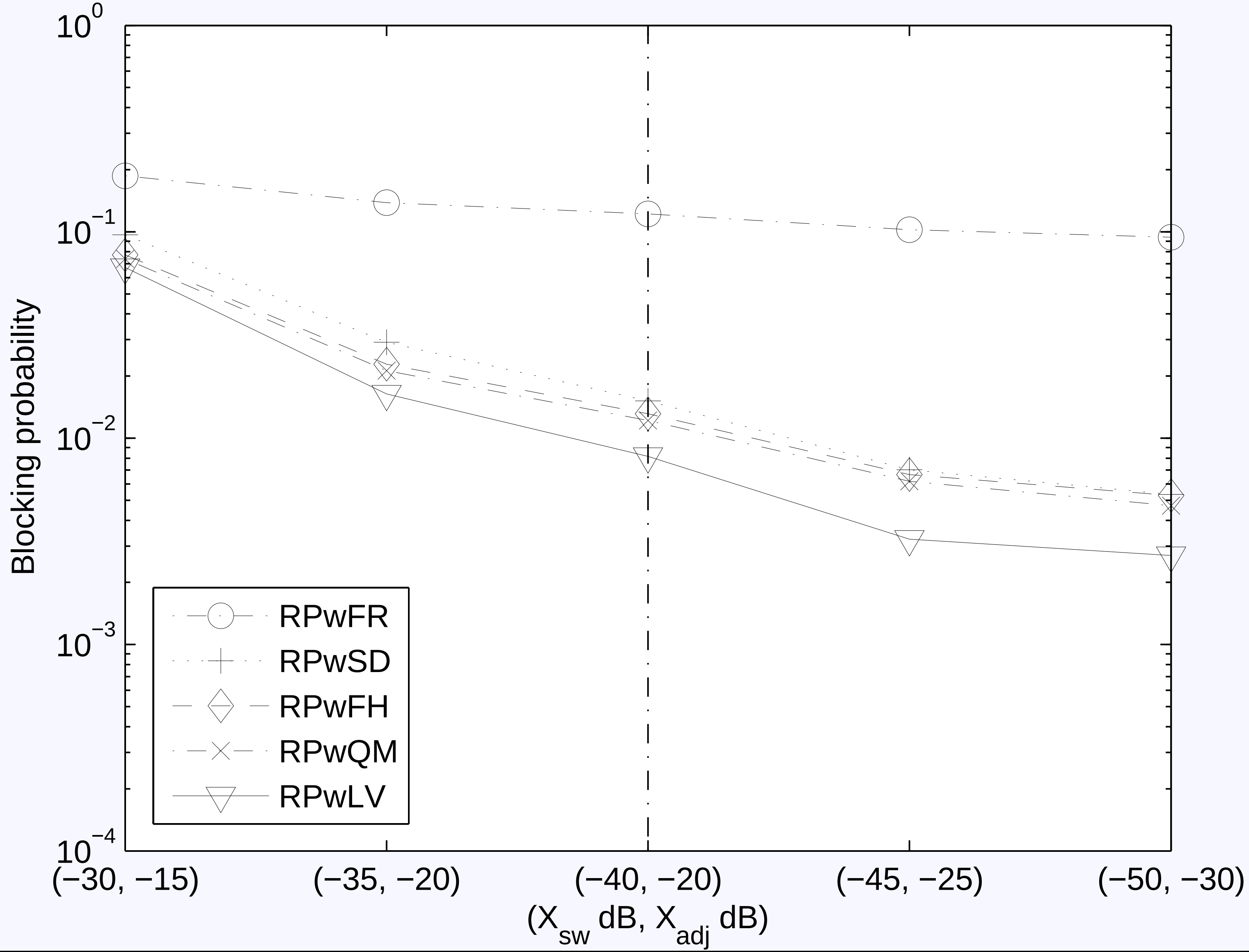
Blocking Probability vs Node Crosstalk if WA uses RP



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Conclusions and Future Work

- Current work
  - We studied the impact of incorporating QoT constraints on the performance of adaptive routing algorithms for wavelength-routed networks.
  - A new adaptive routing algorithm is proposed and compared with other routing algorithms.
    - New routing algorithm can effectively minimize the blocking probability.
    - New routing algorithm only uses the state of the links between a node and its neighbors.
- Future work
  - More network topologies and traffic patterns are applied to test the new routing algorithm.
  - QoT-aware WA algorithms can be applied to our adaptive routing algorithm to further improve the performance.

Questions?


당신을 감사하십시오
شكرا
Merci
THANK YOU!
Grazie
谢谢
Danke
Gracias
ありがとう
Obrigado