Fair QoS-Aware Routing and Wavelength Assignment in All-Optical Networks

Yvan Pointurier*, Maïté Brandt-Pearce*,
Tao Deng† and Suresh Subramaniam†
{yvan, mb-p}@virginia.edu, {tdeng,suresh}@gwu.edu

*Charles L. Brown Department of Electrical and Computer Engineering, University of Virginia, USA
†Department of Electrical and Computer Engineering, George Washington University, USA

ICC'06, June 2006
Paper OS02.1

Overview

- Introduction
- Adaptive QoS-aware RWA
- Validation by simulation
- Conclusions

Introduction

- All-optical networks with no wavelength conversion
- Crosstalk impairs the QoS of lightpaths
  - typically we want to keep $BER \leq 10^{-9}$ at all times, for each lightpath
- Design Routing and Wavelength Assignment (RWA) algorithms to mitigate crosstalk effects
  - wavelength continuity constraint and QoS constraint
  - adaptive RWA is a class of RWA with low blocking probability due to the wavelength continuity constraint

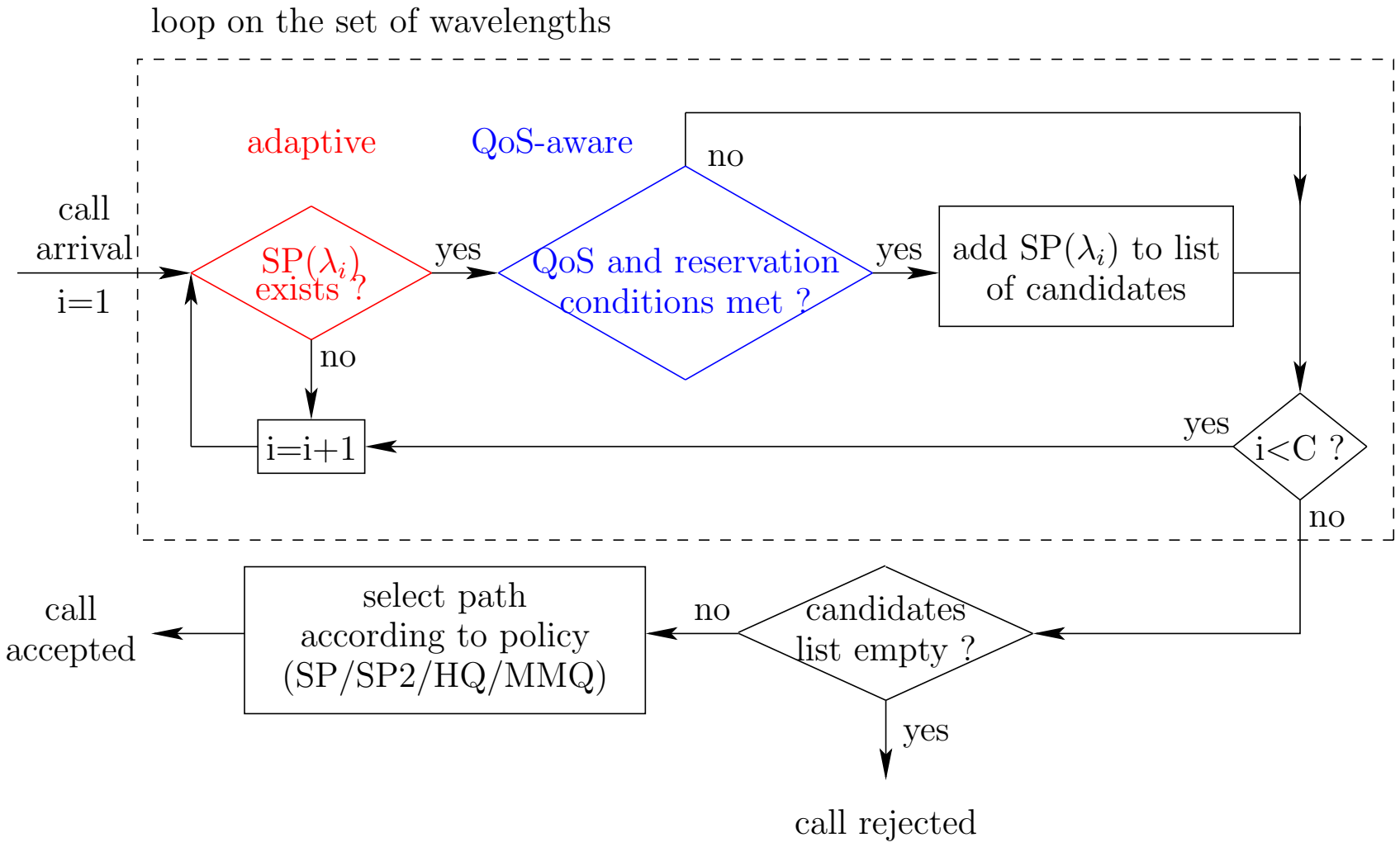
Metrics

- Average call blocking probability (BP): keep low
- Bit-error rate (BER)
  - a margin allows for greater scalability, flexibility, robustness, fewer retransmissions at higher layers
- Fairness: $0 \leq f(X) = E_S[X]^2/E_S[X^2] = \frac{1}{1+(s/m)^2} \leq 1$
  - here, S is the set of all (source, destination) pairs and X is either BP or BER
- BP fairness: all clients should have equal access to the network
- BER fairness: more fair $\Rightarrow$ need FEC for fewer paths

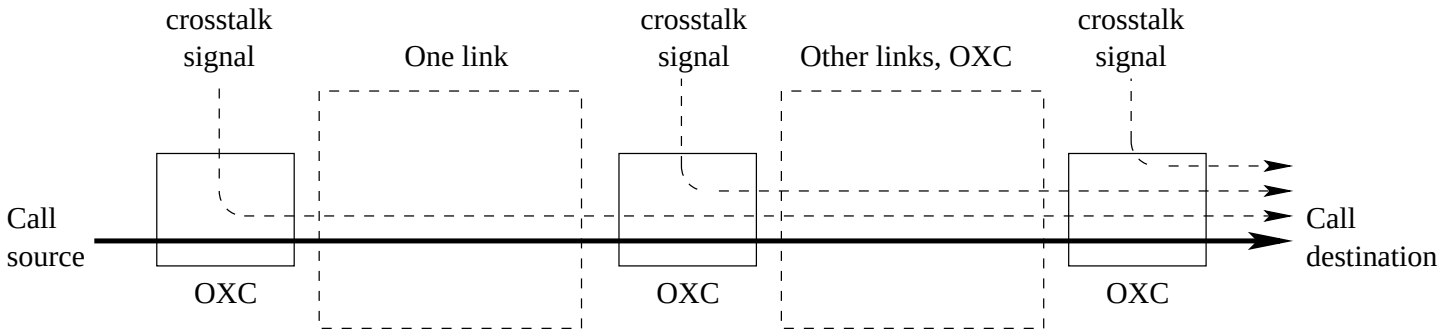
Overview

- Introduction
- **Adaptive QoS-aware RWA**
- Validation by simulation
- Conclusions

Generic QoS-aware adaptive RWA algorithm



BER estimator



- Fast, dynamic estimation of BER: $BER = 0.5 \operatorname{erfc}(Q/\sqrt{2})$

$$Q = \frac{\mu_1 - \mu_0}{\sigma_0 + \sigma_1} = \frac{\mu_1 - \mu_0}{\sigma_0 + \sqrt{\sigma_i^2 + \sigma_n^2 + \sum_k \sigma_{x_k}^2}}$$

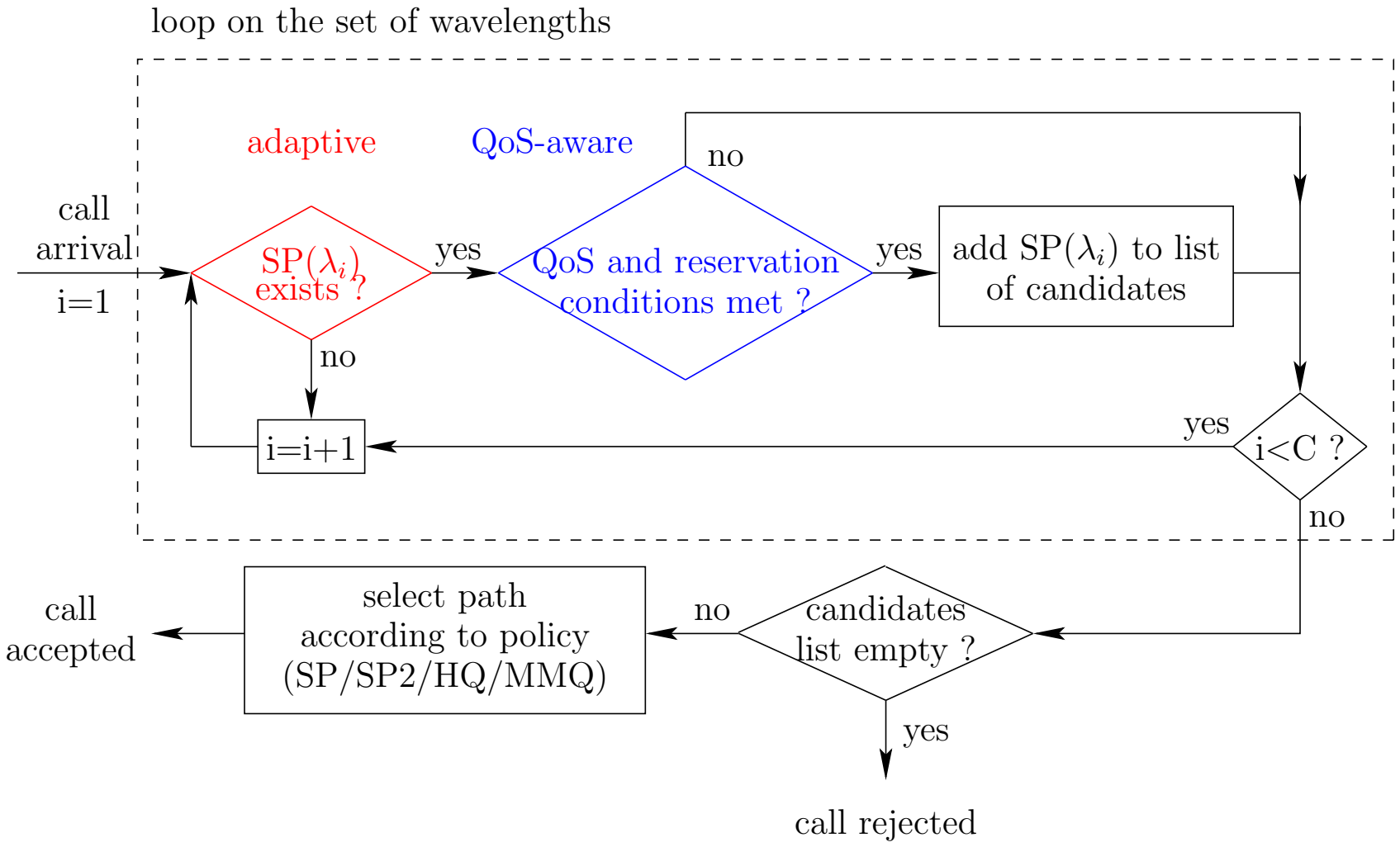
- μ_0, μ_1, σ_0, σ_1: means, st.dev. for the received "0s" and "1s"
- Further split σ_1^2 into ISI, ASE noise and crosstalk variances
- Sum crosstalk terms over all interfering paths

Impact of crosstalk

- Impact of crosstalk accumulation on the maximum transmission distance, for a typical optical network
  - each span is 70 km long

Crosstalks	0, 1	2, 3	4	5, 6	7, 8	9	10
Spans	12	11	10	9	8	7	6

Generic QoS-aware adaptive RWA algorithm



Reference policy: SP, SP2

- Considered algorithms are as complex as traditional adaptive RWA with BER guarantee
- SP is the traditional Shortest Path policy
- SP2 is SP with protecting threshold – single-hop paths accepted only if 2 or more wavelengths are available
- Insight: put aside wavelengths for longer paths, which are more likely to be blocked due to both wavelength continuity and QoS constraints
- Reference for standard adaptive RWA/SP: Mokhtar/Azizoğlu'98

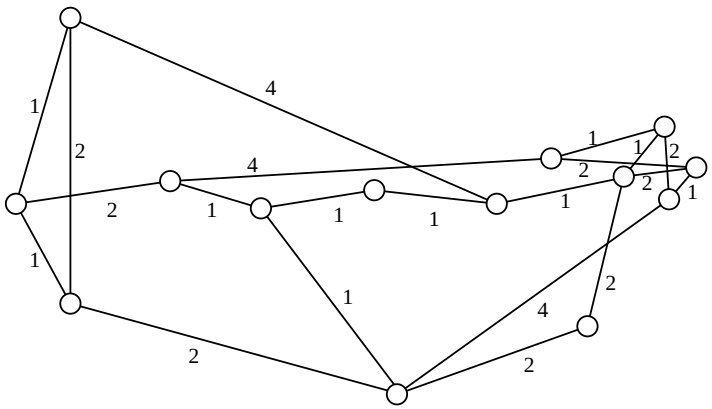
Our novel policies: HQ, MMQ

- HQ selects the lightpath with the highest Q factor
- MMQ: inserting a new lightpath "LP1" in the network changes the BER for all LPs that cross LP1; MMQ maximizes (over the set of wavelengths) the minimum Q (over the set of LPs that cross each candidate lightpath)
- Insight: optimize QoS by selecting the path that manages the largest QoS (HQ) or QoS margin (MMQ) in the network
- HQ/MMQ are QoS-enhanced but may waste resources compared with SP2

Overview

- Introduction
- Adaptive QoS-aware RWA
- **Validation by simulation**
- Conclusions

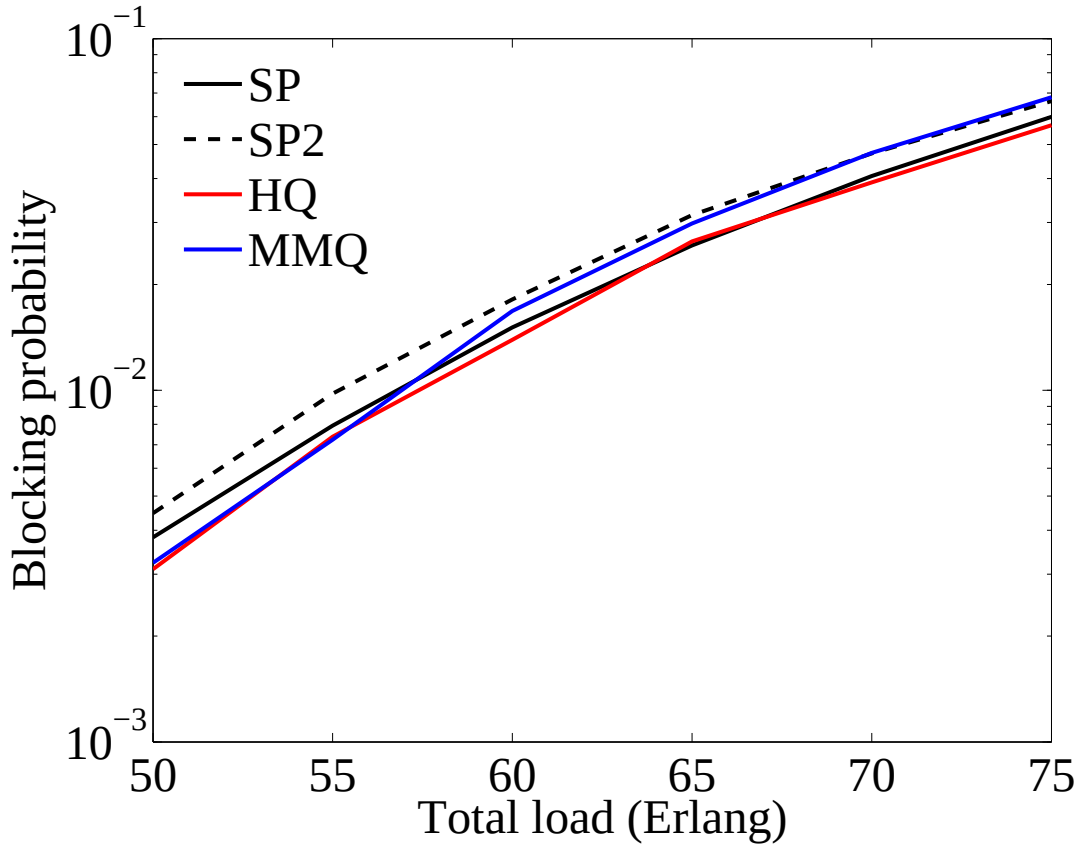
Topology and physical parameters



Downscaled NSF topology; the weights are the number of spans.

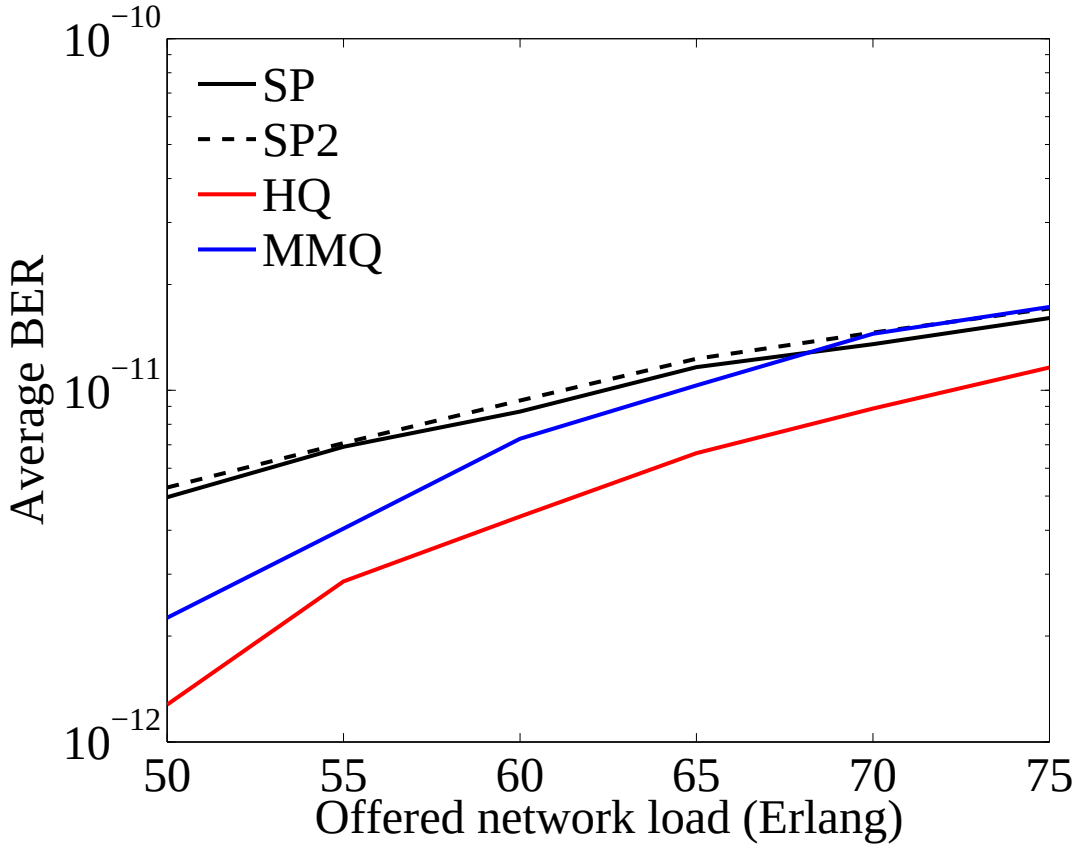
Description	Value
Span length	70 km
Signal peak power	2 mW
Bit rate	10 Gbps
Pulse shape	NRZ
Fabric crosstalk	−40 dB
Adj. port crosstalk	−30 dB
Non adj. port crosstalk	−60 dB
Fiber type	SMF
Dispersion compensation	100% post-DC
Noise factor	2
Receiver elec. BW	7 GHz
Number of WL	8
Maximum BER	10^{-9}

Blocking Probability



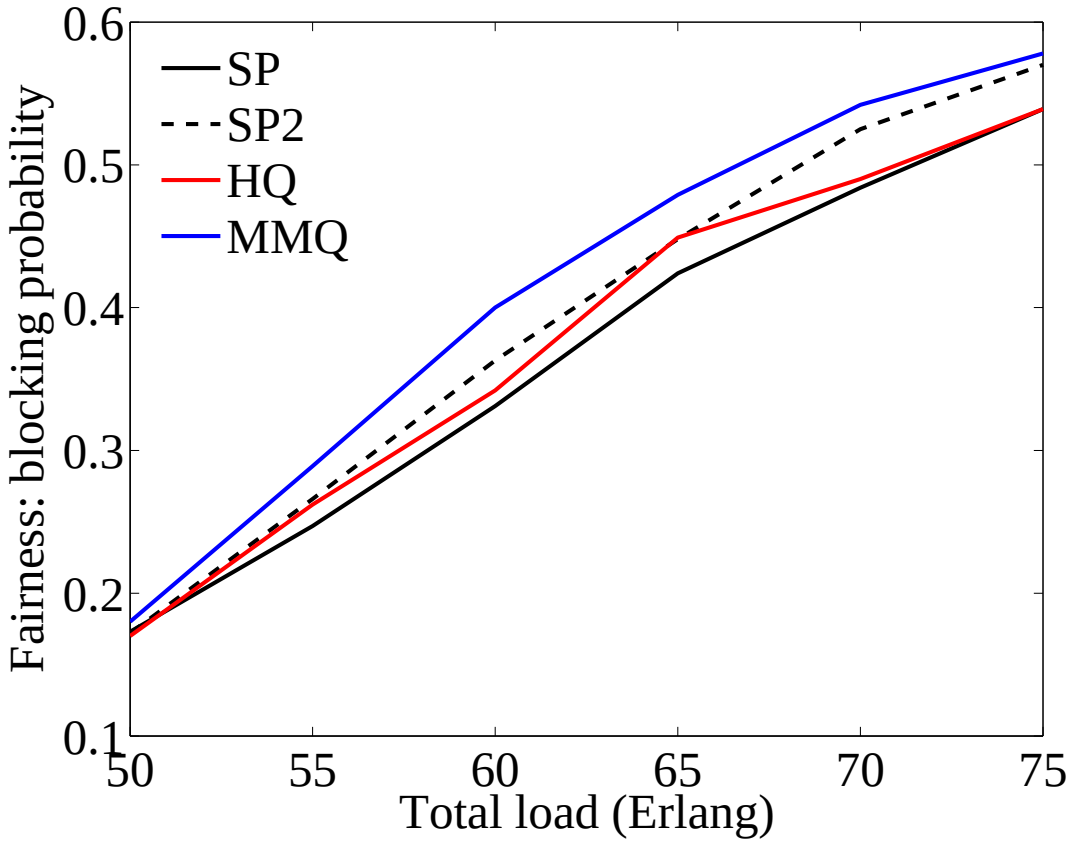
▷ BPs are equivalent for all algorithms

BER



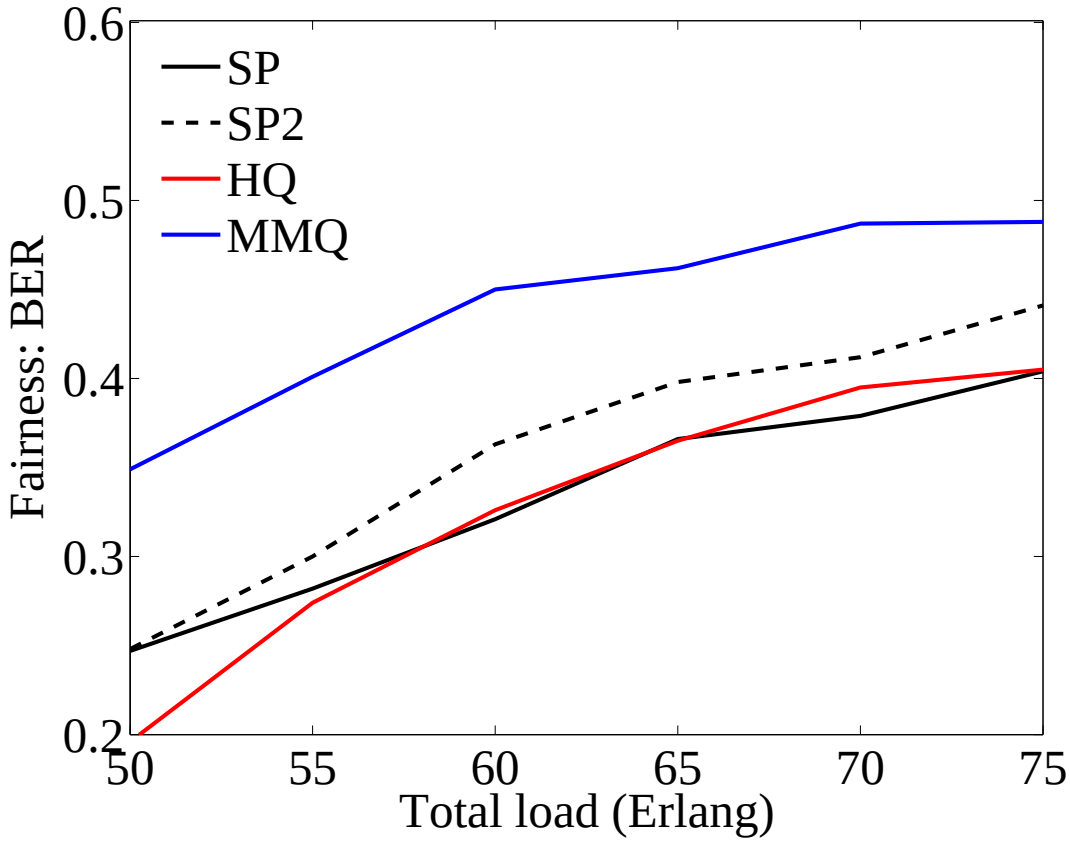
- Our QoS-enhanced RWA algorithms perform better for BER than SP/SP2

Fairness: Blocking Probability



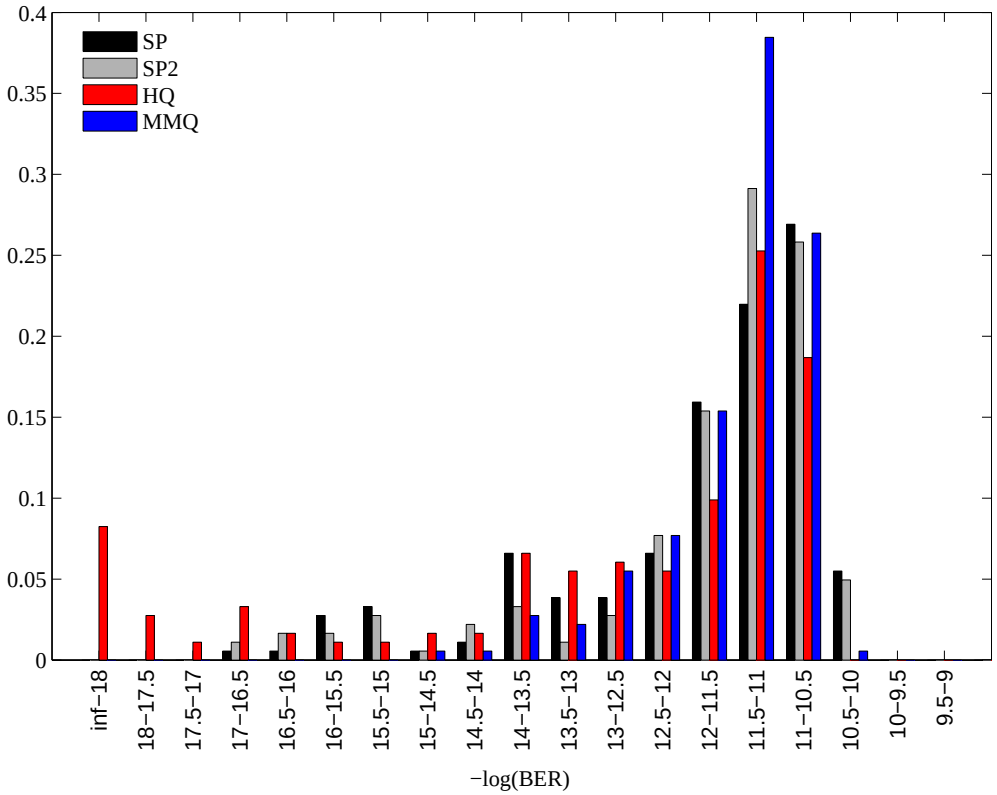
- MMQ, SP2 exhibit highest BP fairness

Fairness: BER



- MMQ exhibits highest BER fairness

Fairness: BER (distribution)



Recall: $f(X) = \frac{1}{1+(s/m)^2}$

Conclusions

- Presented two new QoS-enhanced RWA algorithms based on adaptive RWA: HQ, MMQ
- Introduced new metrics to evaluate RWA algorithms
- Perform well in terms of BP
- Perform better than others in terms of QoS and fairness