Reduction of Crosstalk in WDM Networks With optional FEC Coding

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Overview

- ▷ Introduction
- ▷ RWA with optional FEC coding
- ▷ Validation by simulation
- ▷ Conclusions

Introduction

- All-optical networks with no wavelength conversion
- Physical layer effects impair the QoS of lighpaths
  - typically we want to keep $BER \leq 10^{-9}$ at all times, for each lightpath
- Context: large networks where some paths are very long
  - some paths are so long no call can be established without breaking the QoS constraint
- Forward Error Correction coding trade-off
  - can improve BER and keep it below threshold
  - cost: bandwidth expansion

Metrics

- Average call blocking probability (BP): decrease
- Fairness: $0 \leq f(X) = E_S[X]^2 / E_S[X^2] \leq 1$
  - here, S is the set of all (source, destination) pairs, X is BP
  - meaning: all clients should have equal access to the network

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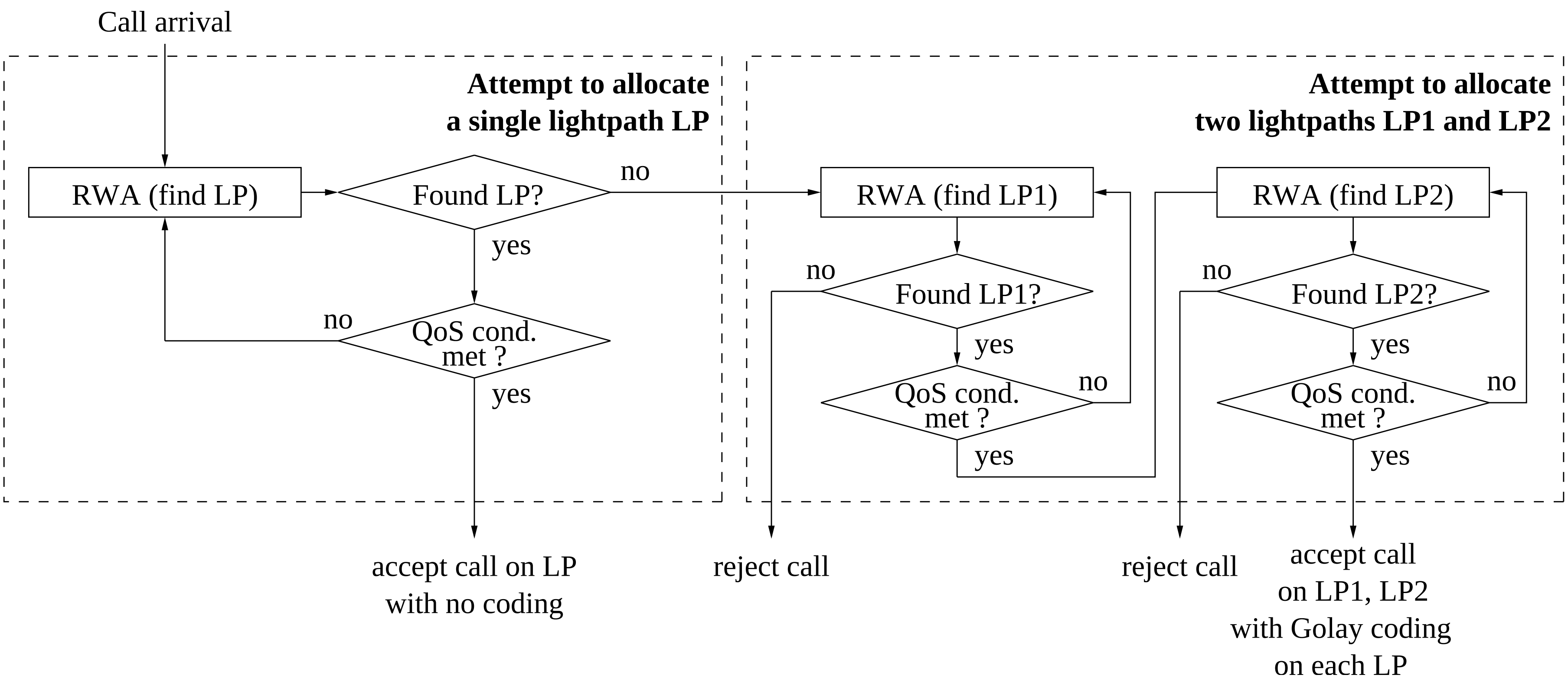
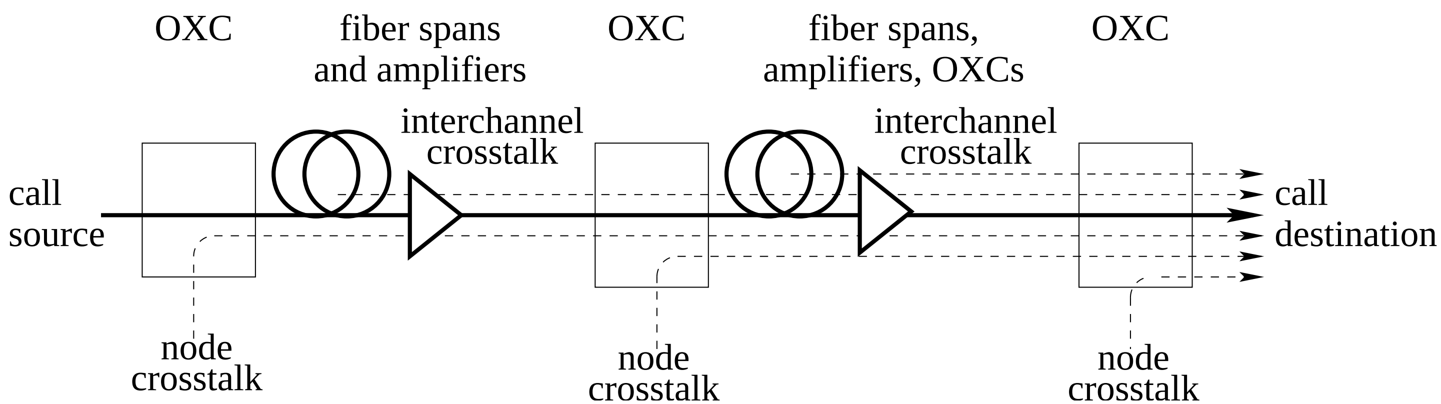
Algorithm flow



- ▷ Golay (23, 12) code, rate $\approx 1/2$: need 2 LPs per call
- ▷ RWA: alternate routing (k-SPF), random wavelenth assignment

BER estimator



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

$$Q = \frac{\mu_1 - \mu_0}{\sigma_0 + \sigma_1} = \frac{\mu_1 - \mu_0}{\sigma_0 + \sqrt{\sigma_i^2 + \sigma_n^2 + \sum_q \sigma_{nx_p}^{\ 2} + \sum_p \sigma_{ix_q}^{\ 2}}}$$

- μ_0, μ_1, σ_0, σ_1: means, st.dev. for the received “0s” and “1s”

BER estimator

$$Q = \frac{\mu_1 - \mu_0}{\sigma_0 + \sigma_1} = \frac{\mu_1 - \mu_0}{\sigma_0 + \sqrt{\sigma_i^2 + \sigma_n^2 + \sum_q \sigma_{nx}{}_p^2 + \sum_p \sigma_{ix}{}_q^2}}$$

- Further split σ_1^2 into ISI, ASE noise, node crosstalk crosstalk, interchannel variances
- Sum crosstalk terms over all interfering paths

Impact of crosstalk

- Impact of crosstalk accumulation on the maximum transmission distance (70-km spans), for a typical optical network
  - node crosstalk

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

  - XPM

Crosstalks	0	1	2-8
Spans	12	9	7

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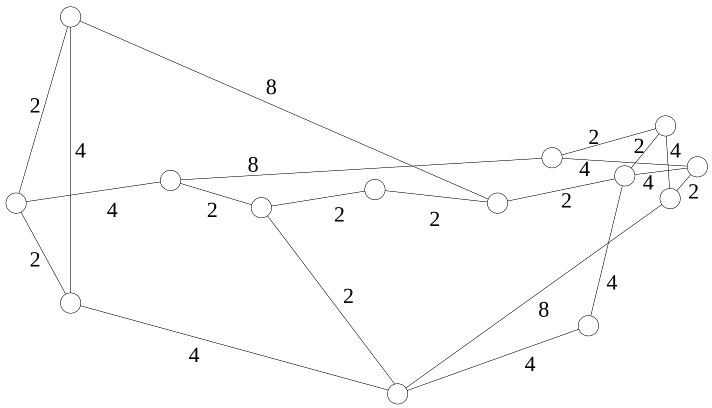
Topology and physical parameters

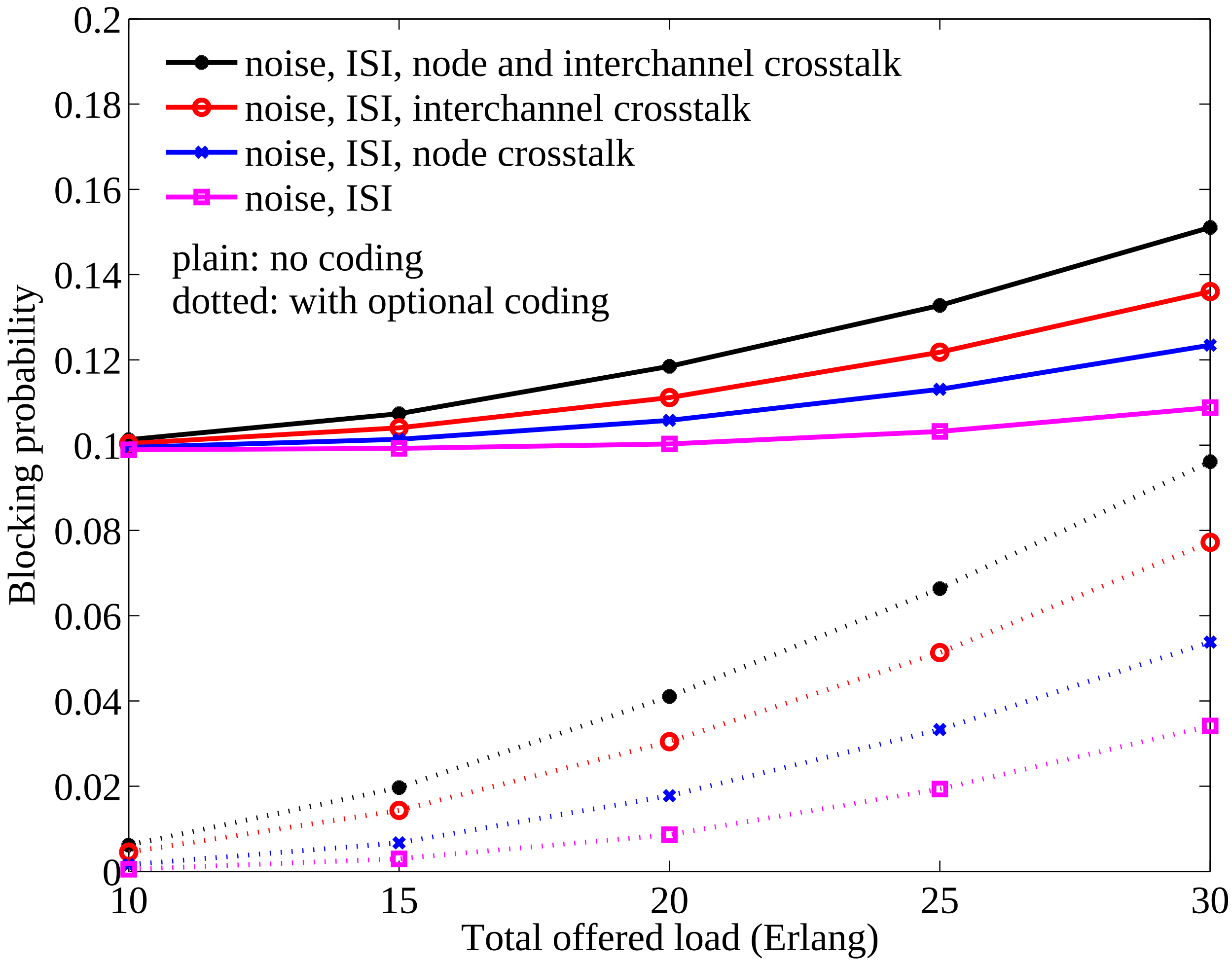


Downscaled NSF topology; the weights are the number of spans.

Spans	2-12	14+
Paths	164	18

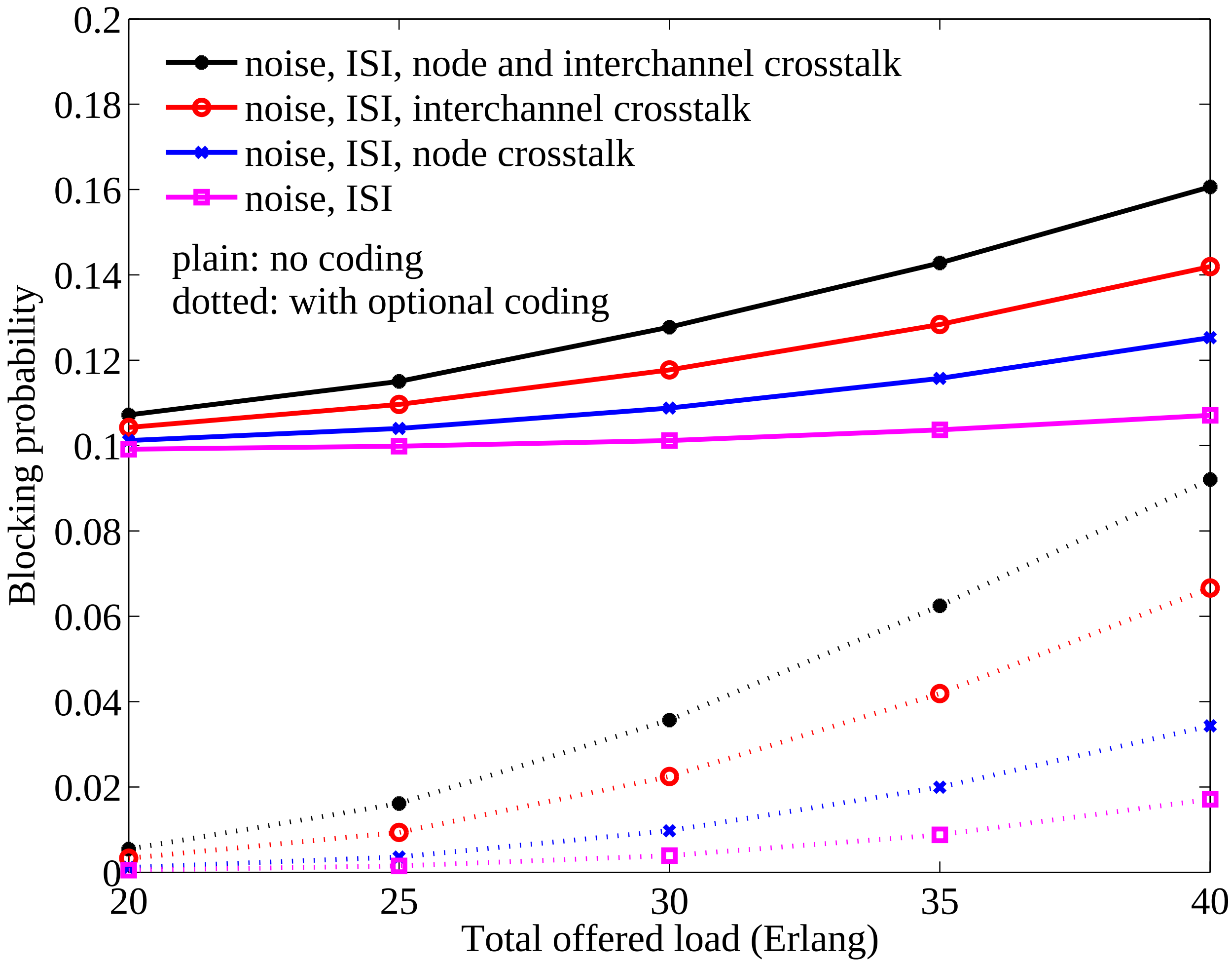
Description	Value
Span length	70 km
Signal peak power	2 mW
Bit rate	10 Gbps
Nonlinear parameter	2.2 $(\mathrm{W.m})^{-1}$
Pulse shape	NRZ
Fabric xtalk	−40 dB
Adj. port xtalk	−30 dB
Non adj. port xtalk	−60 dB
Fiber type	SMF
Dispersion compensation	100% post-DC
Number of WL	8
Minimum Q factor	$Q_1 = 6$ $Q_2 = 3.6$

BP for 1-SPF



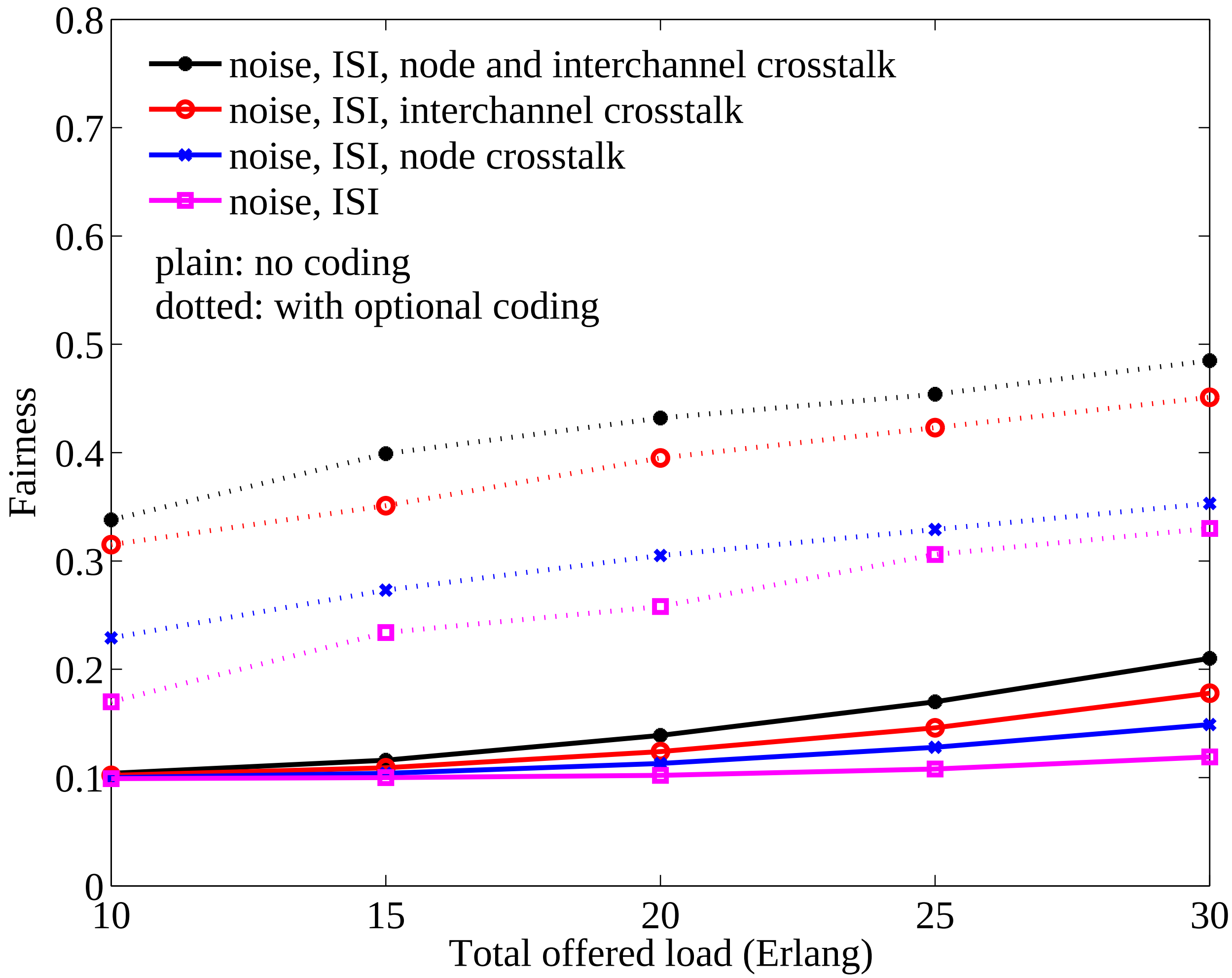
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
10
15
20
25
30
Blocking probability
Total offered load (Erlang)
noise, ISI, node and interchannel crosstalk
noise, ISI, interchannel crosstalk
noise, ISI, node crosstalk
noise, ISI
plain: no coding
dotted: with optional coding

BP for 4-SPF

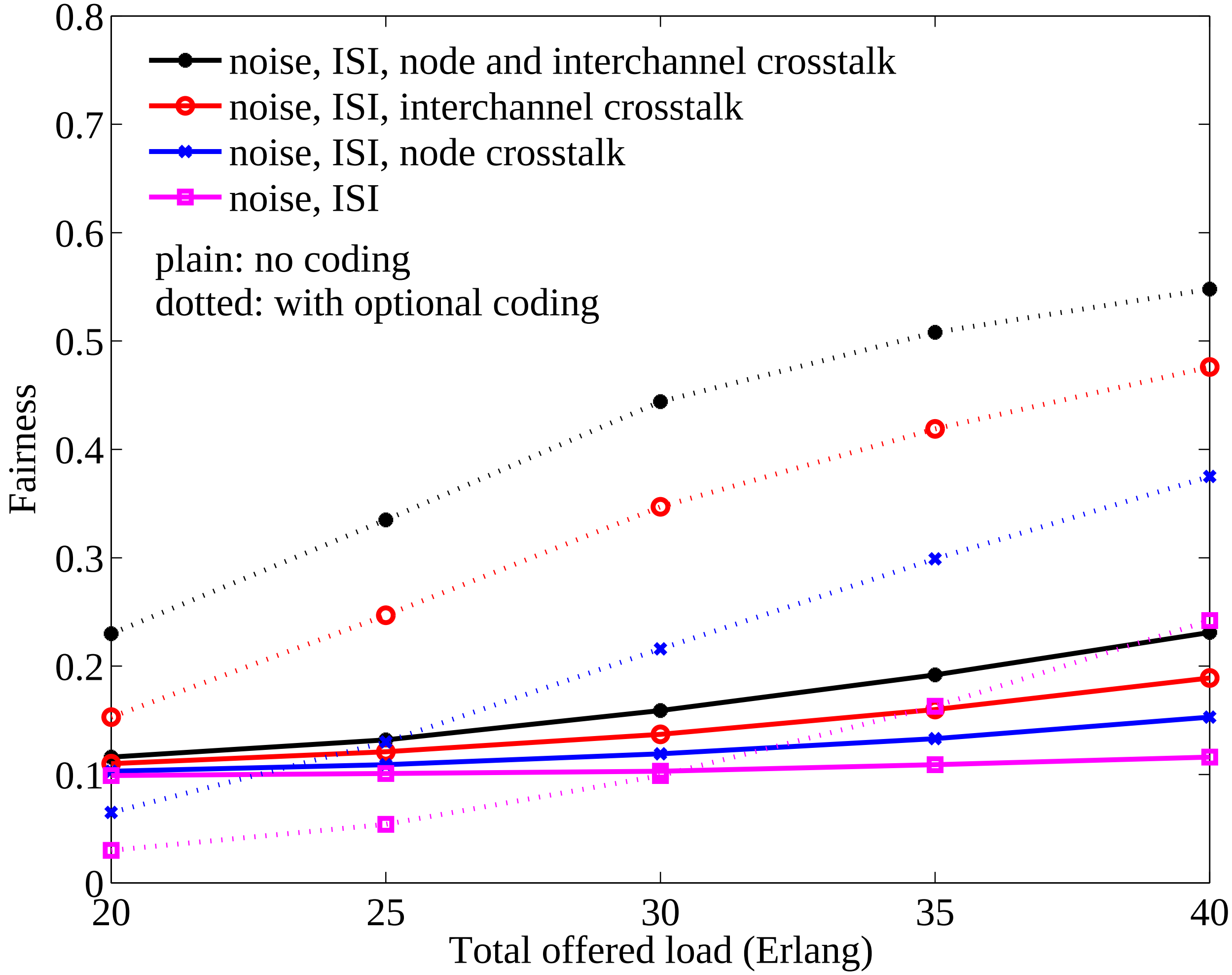


noise, ISI, node and interchannel crosstalk
noise, ISI, interchannel crosstalk
noise, ISI, node crosstalk
noise, ISI
plain: no coding
dotted: with optional coding
Blocking probability
Total offered load (Erlang)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
20
25
30
35
40

Fairness for 1-SPF



Fairness for 4-SPF



Conclusions

- Compared to situations where no coding at all is available, optional coding ...
  - helps reducing blocking probabilities in large networks
  - mitigates physical layer impairments
  - improves fairness among users