Considering physical constraints in WDM networks

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The network guy point of view

- Network people have an "ideal" model of optical networks
  - Transparent or opaque solutions
  - Each fiber link may transport a large number of wavelength (e.g., >128)
  - Each node can optically route every incoming lightpath to every outgoing fiber
  - Wavelength converters may be used
- Using ideal components we face design problems like LTD, RWA:
  - Static and dynamic scenarios

The optical guy point of view

- Network transmission level is composed by
  - Fiber links, amplifiers, OXCs and OADMs supporting a limited number of λ (up to 64)
  - No wavelength converters
- There are several physical limitations:
  - Power budget, noise, dispersion, non linear effects…
- Every time a new lightpath is turned on, the operating point of the overall network may vary
- Hence, a transparent WDM network is far from being ideal, many physical constraints should be considered by network design algorithms

Routing and Wavalenght Assignament

Given

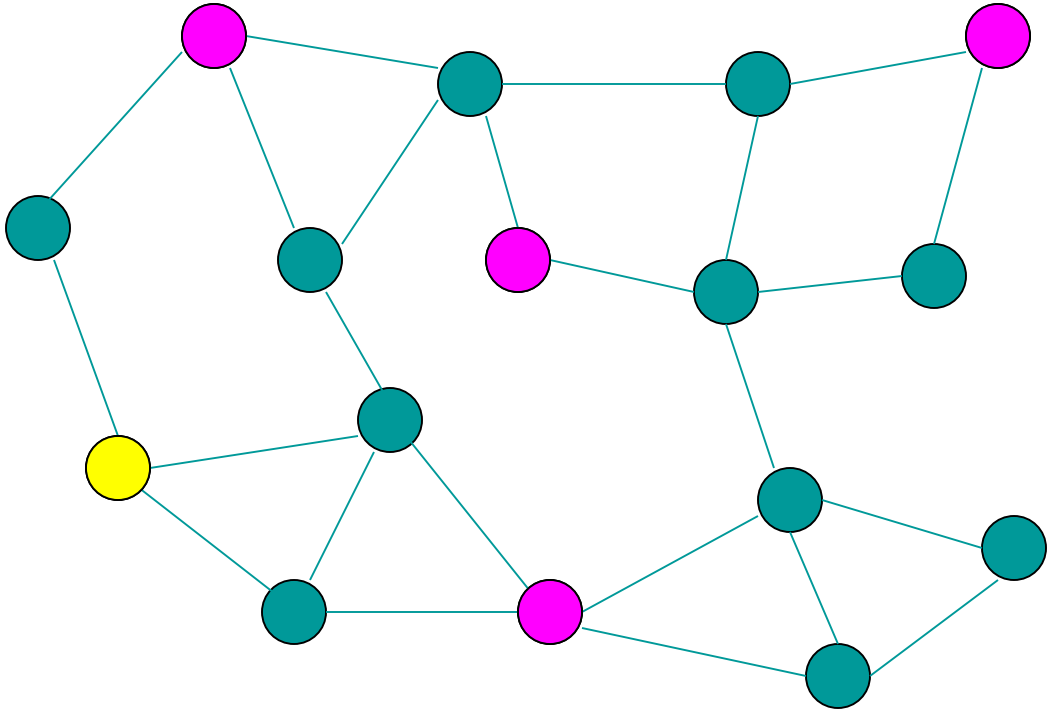
- A physical topology
- A set of lightpath request

- Find for each lightpath request
  - A physical route
  - And a suitable wavelength
- Constraints
  - Wavelength unicity: no more than a lightpath can be identified by a wavelength on fiber
  - Wavelengt[AVAILABILITY]length must be used on all [illegible] lightpath (no wavelength conversion)

RWA: example

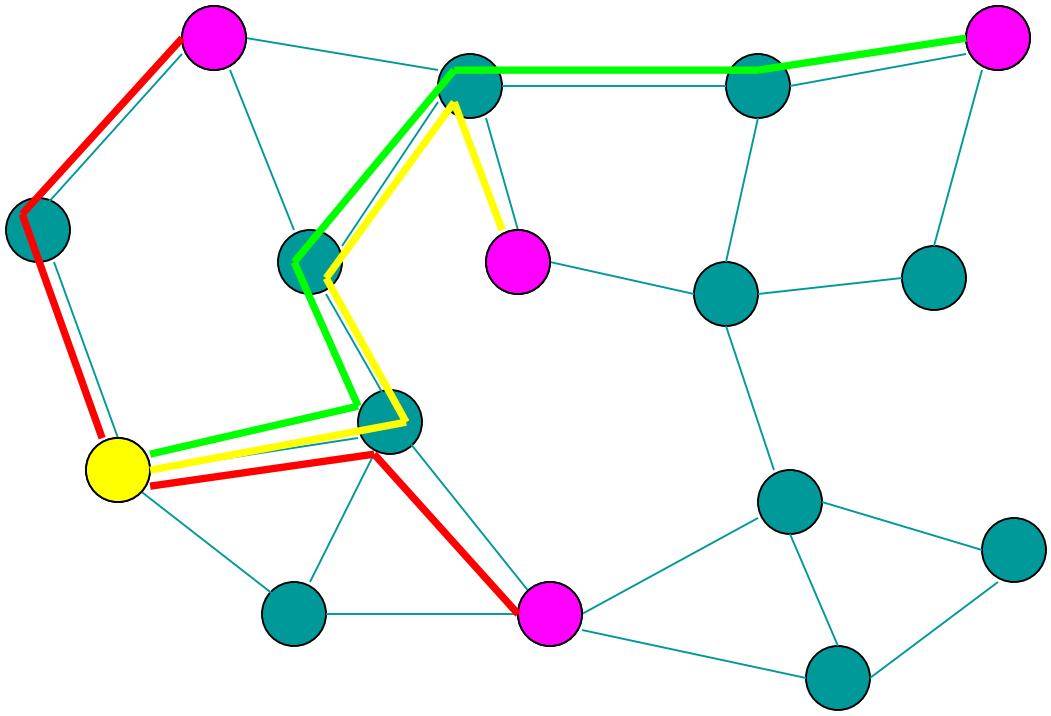
Source

Destinaion



RWA: example

λ	Used fibers
3	13



The idea

Given a “real” optical network comprising fibers, amplifiers, OXCs, OADMs, etc.

At the transmission level, optical constraints are evaluated and given to the networking design solver

At the logical level, these constraints are used as weights for the network design

Physical level constraints

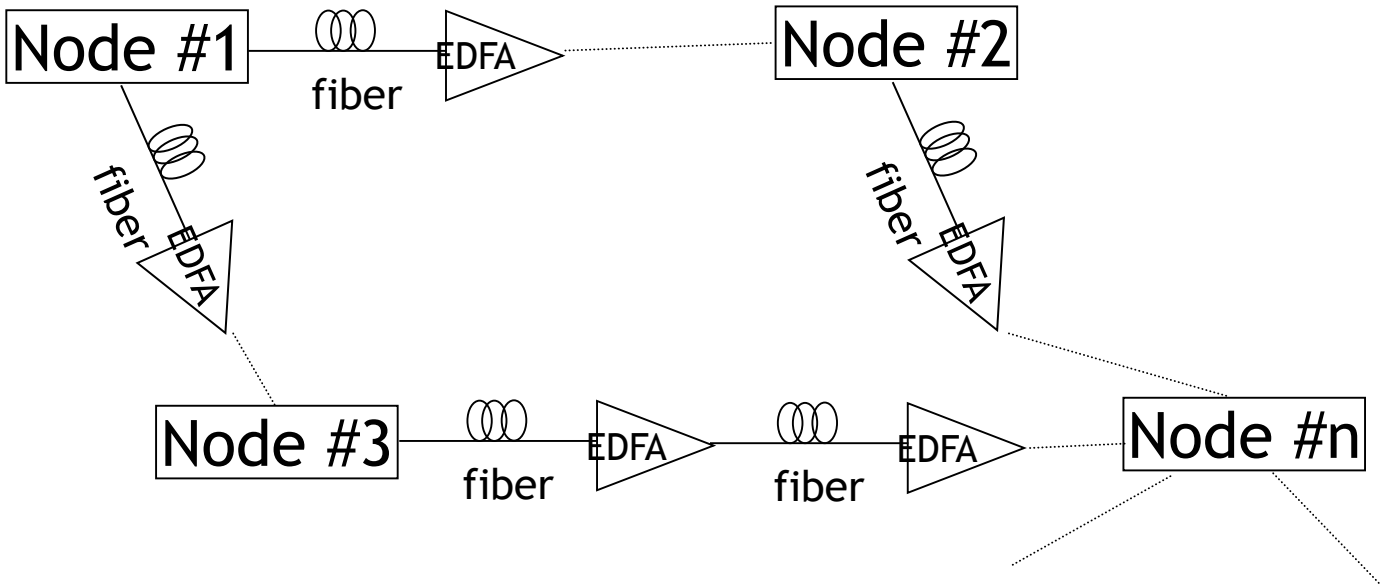
- We assume that each phenomenon leads to an equivalent noise component for each link
  - ASE noise $\Rightarrow \sigma_{ASE}$
  - Dispersion $\Rightarrow \sigma_{disp}$
  - Non linearity $\Rightarrow \sigma_{NL}$ (this depends on the number of simultaneous active λ on a fiber)
  - … other …

Impacts the path length

Impacts the λ assignment

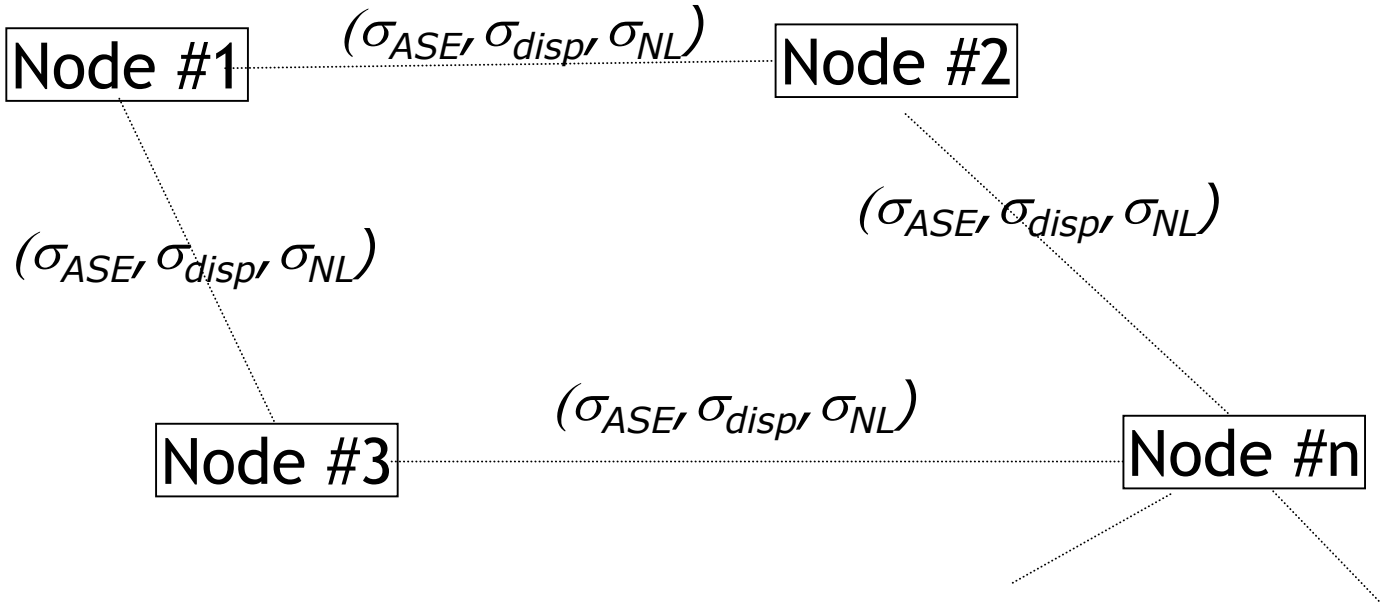
- We evaluate $OSNR = P_{ch} / (\sigma_{ASE} + \sigma_{disp} + \sigma_{NL})$
- *OSNR* may be used as quality parameter

Network model



- Node: cross-connect matrix, attenuation, dispersion
- Fibre: length, attenuation, dispersion, non linear effects
- EDFA: gain, noise level

Network model



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Goal

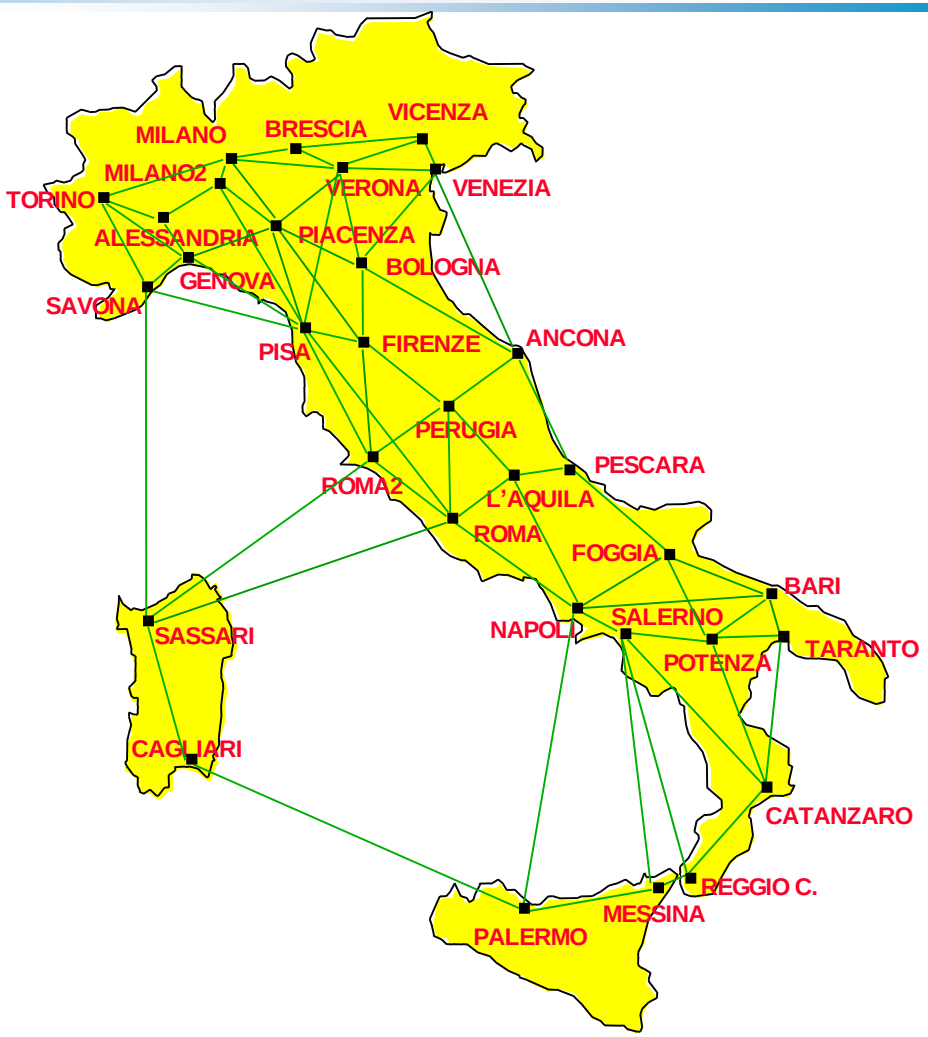
What is the impact of physical layer constraints on the RWA problem?

- We consider
  - Transparent Wavelength Routed network
  - Dynamic scenario

- Lightpath request is refused if
  - Hard Block: no wavelength is available on any path
  - Soft Block: OSNR on the selected path is smaller than a minimum $OSNR_{min}$

Results

- Physical scenario
  - Italian Topology
  - All fibers are identical, 16 λ
  - All nodes are identical, non blocking
  - All EDFA are identical
- Different span length: EDFAs recover fiber losses every 40, 60 or 80 km



Traffic scenario

- Uniform traffic pattern
- Lightpath requests follow a Poisson process
- Average connection holding time set to 1 unit of time

	D1	D2	D3	…
S1	0	1/n	1/n	…
S2	1/n	0	1/n	…
…	…	…	…	…

RWA?

RWA algorithm

Classic algorithm

- R: Least congested path
  - Select the path that has the maximum number of available wavelength
- WA: First Fit
  - Allocate the first available wavelength on the selected path

Novel algorithm

- R+WA
  - Select the path and wavelength that has the max OSNR

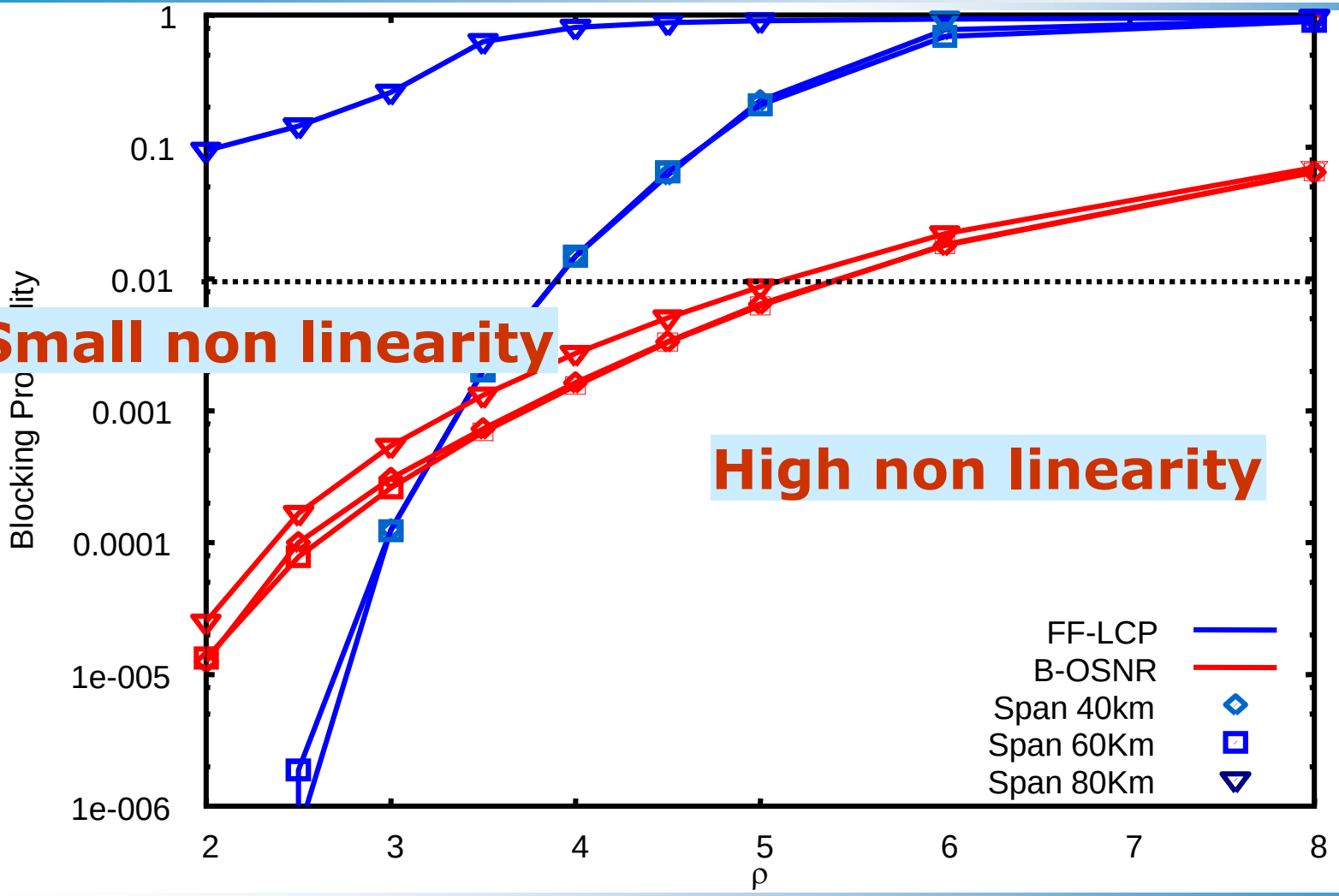
- These are just two possible choices.

Performance metric

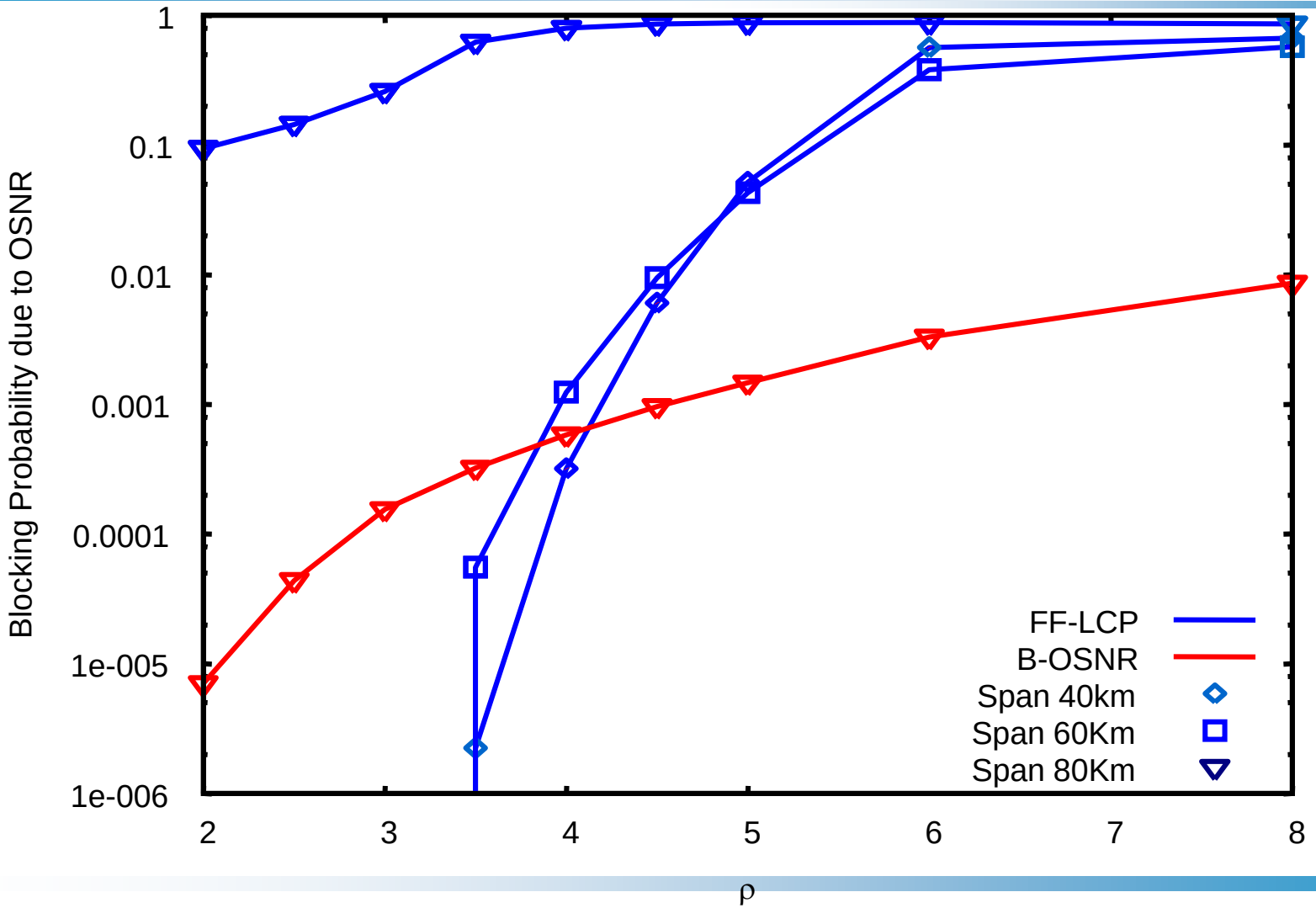
- Blocking probability
  - Due to lack of wavelength
  - Due to lack of OSNR

- Hint: among the available paths, consider only those for which $\max(OSNR) > OSNR_{min}$

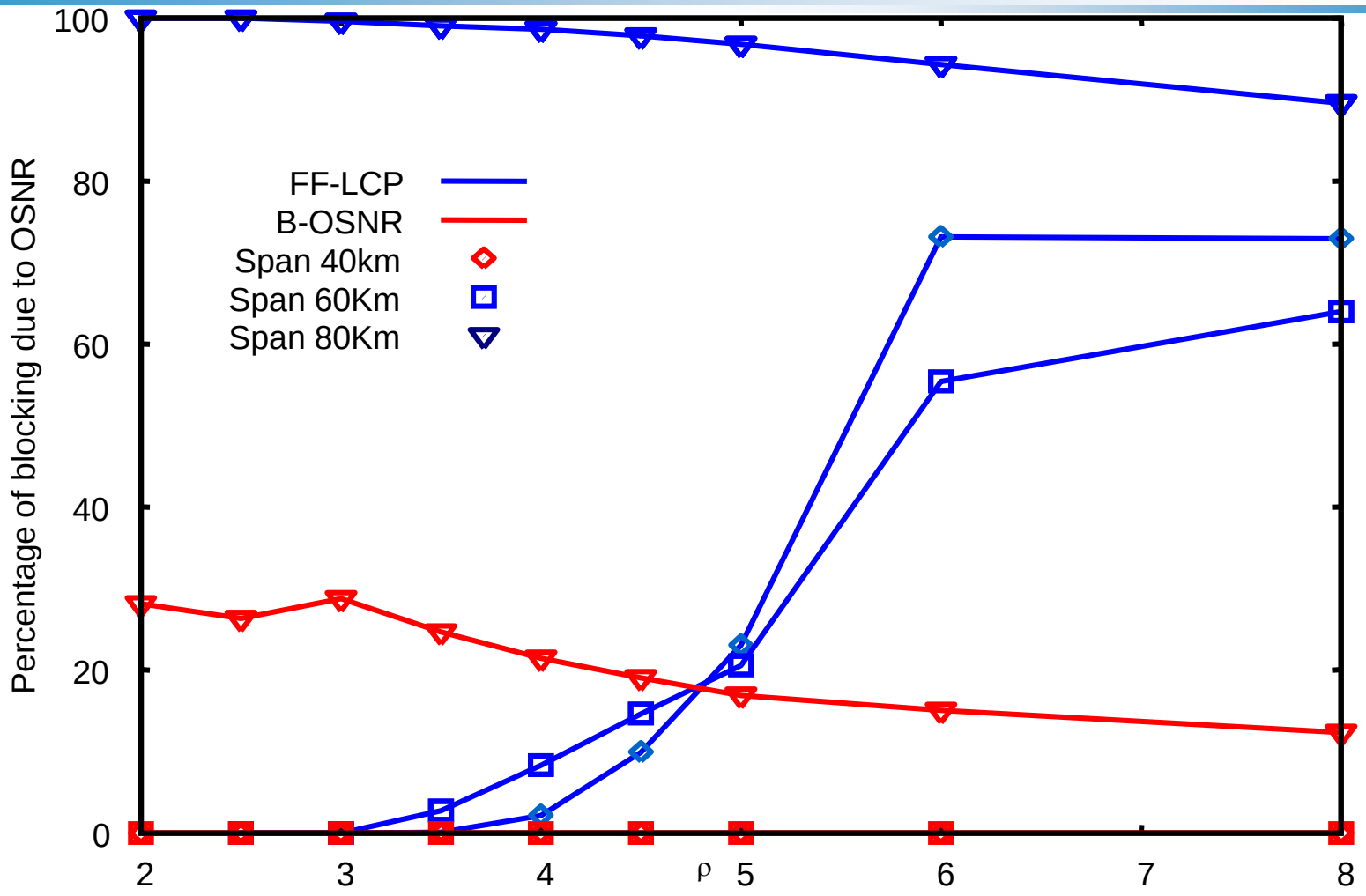
Total blocking probability



Blocking probability due to OSNR impairments



Percentage of blocking due to OSRN



Conclusion and future work

- We faced dynamic RWA problem under physical impairment
  - Simple model for the physical layer
  - Efficient algorithm for RWA of dynamic requests
- Physical constraints play a big role in the RWA problem
  - Non linear effects must be considered in transparent WR networks
- What impact on the off-line RWA problem?
  - Optimization must be carried over considering simple physical models

Thanks

Blocking probability versus span