“Routing and Wavelength Assignment for Transparent Optical Networks With QoT Estimation Inaccuracies”

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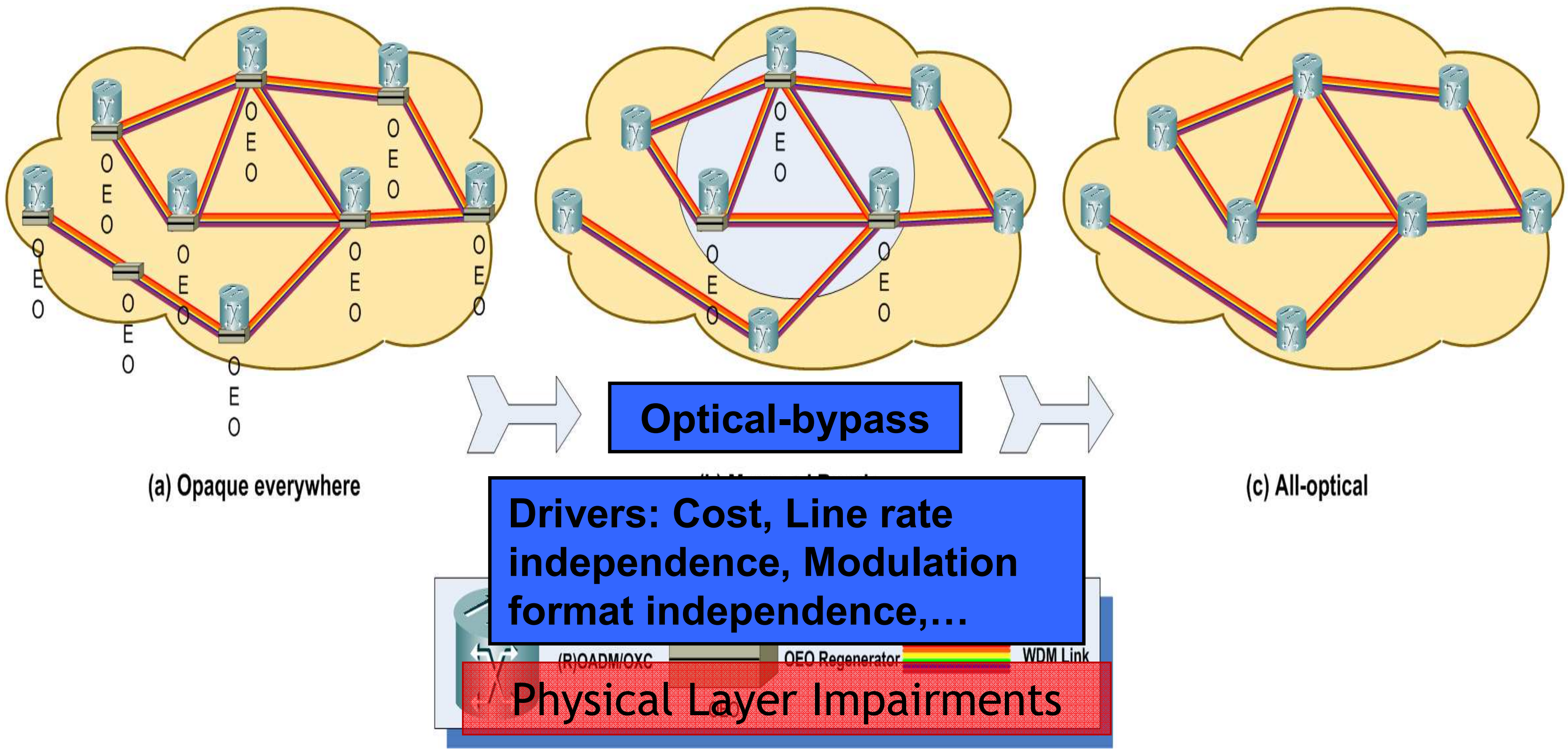
Introduction

- Evolution of core optical networks:
  - Past, Present, Future!



(a) Opaque everywhere

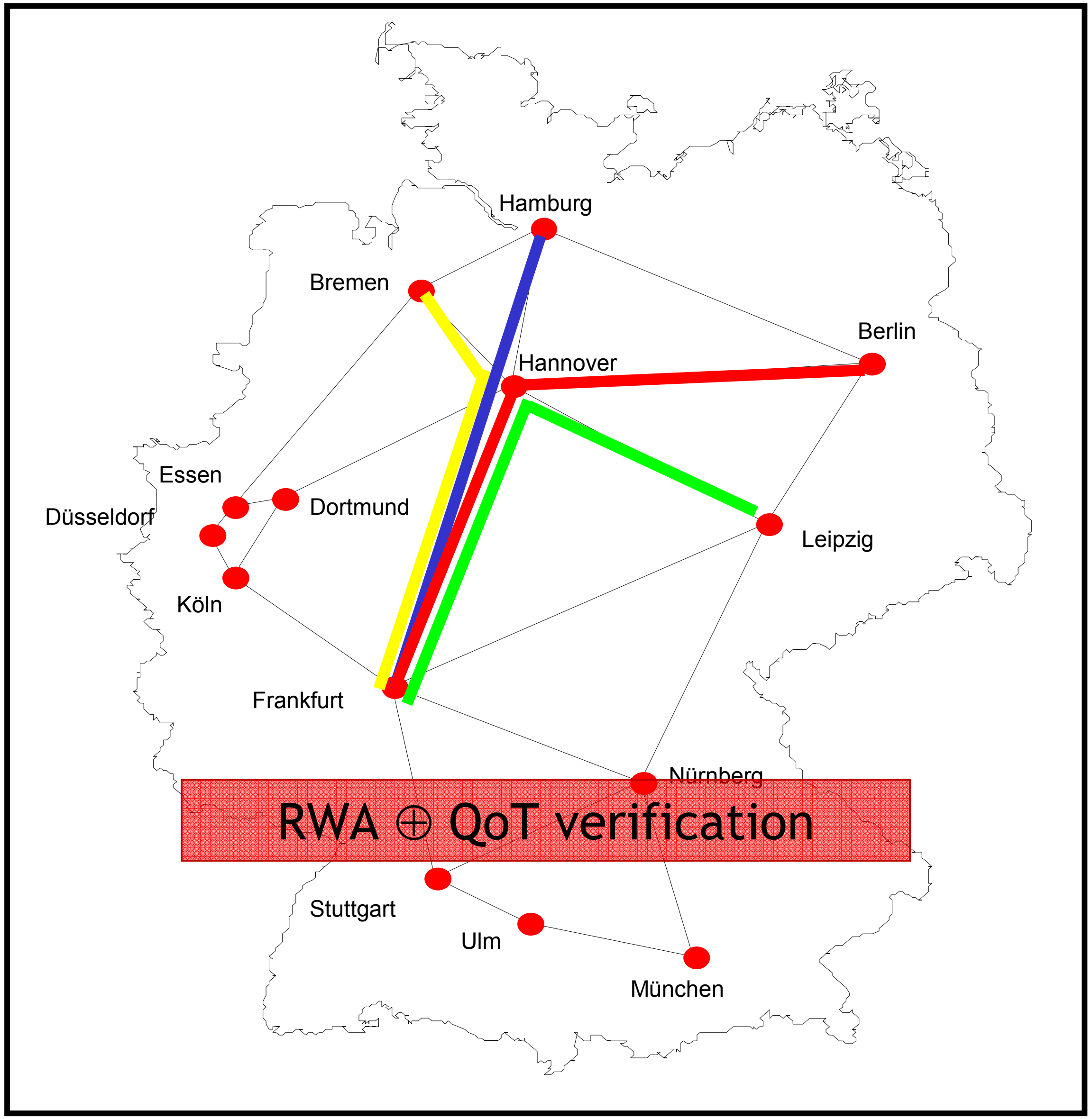
(c) All-optical

Optical-bypass

Drivers: Cost, Line rate independence, Modulation format independence,…

Physical Layer Impairments

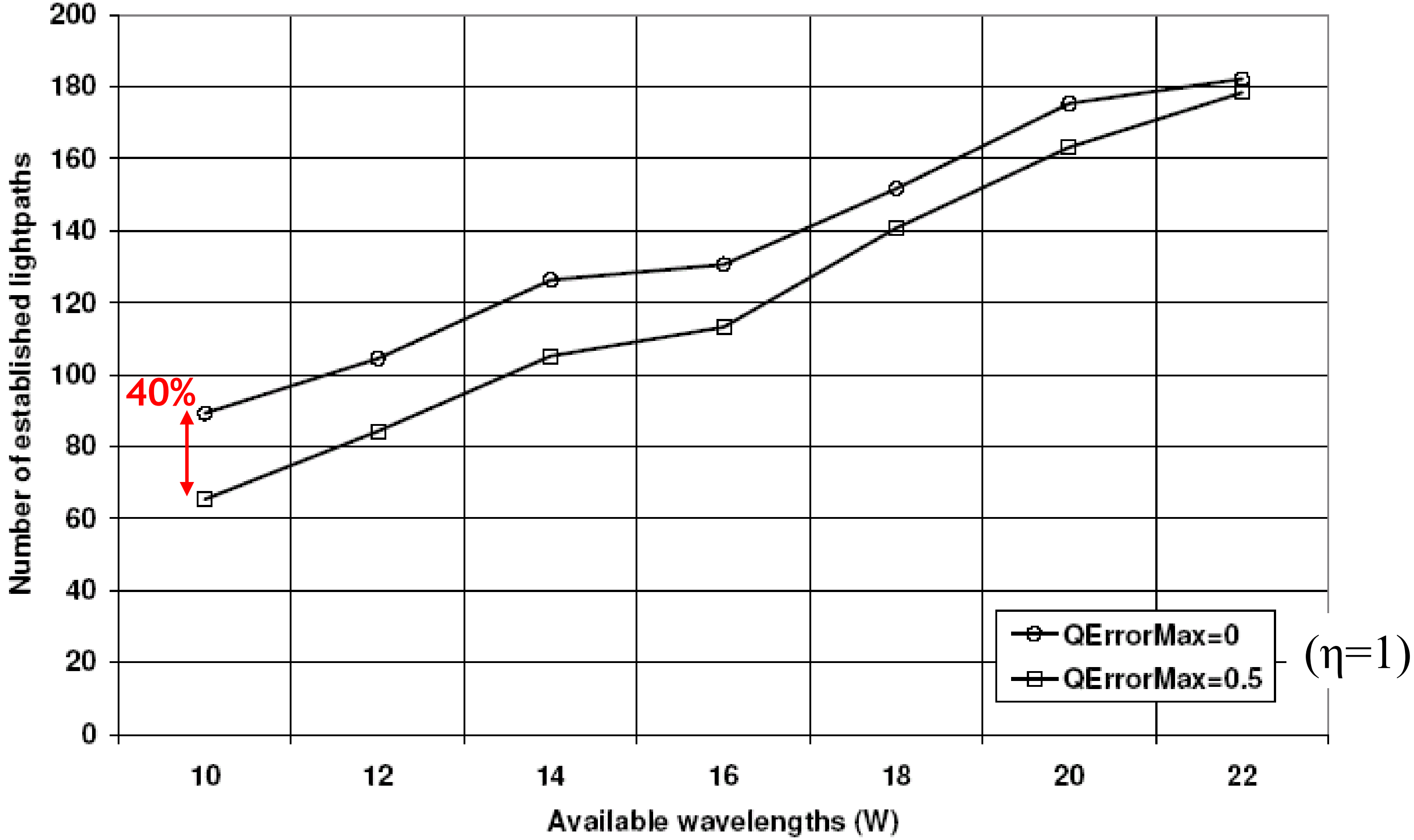
Generic IA-RWA proposals



Inaccuracy of the Q-Tool (1/2)

- Practical QoT estimators (including our Q-Tool) is a combination of analytical models and/or interpolations of measurements and simulations.
- Practical QoT estimators should be fast in order to support quick lightpath establishment.
- Inaccuracy of Q-Tool
  - Imperfect physical models (by nature)
  - Optimization for speed
- Incorrect QoT estimation has a direct impact on lightpath establishment
  - Q overestimate → accept LP with inadequate QoT
  - Q underestimate → block LP with adequate QoT

Inaccuracy of the Q-Tool (2/2)



$$Q_{est} > Q_{Threshold} + \eta Q_{ErrorMax}$$

Online “Rahyab” (1/4)

- The main idea behind online Rahyab algorithm is to design a multi-constraint IA-RWA algorithm that considers QoT inaccuracy through **optical monitor availability** information in routing decisions, in order to alleviate the inaccuracy of the QoT estimator (i.e. Q-Tool).
- “Rahyab” building blocks
  - Multi-Constraint Path (MCP) computation framework
    - Link cost vector and Single Mixed Metric Mapping
  - Online “Rahyab” IA-RWA engine

Online "Rahyab" – MCP framework (2/4)

- Considering a network topology G=(V,E), each link 'e' is characterized by M additive non-negative weights, $w_m(e)$, m=1,2,…,M. Given constraint C_m,m=1,…,M, the MCP problem is to find a path p such that:

$$\sum_{e \in p} w_m(e) < C_m; m = 1, 2, \ldots, M.$$

- Single Mixed Metric (SMM) (insight: can meet all C_m with high prob. using simple shortest path alg. on weighted graph): $SMM_d(e) = \mu_d(e)\left[\Delta_d(e) + \epsilon\right]; 0 \leq \epsilon \leq 1.$

$$\mu_d(e) = \frac{1}{m}\sum_{i=1}^{m}\left(\frac{w_i(e)}{C_i}\right)^d; d \geq 1,$$

$$\Delta_d(e) = \sum_{i=1}^{m}\left[\left(\frac{w_i(e)}{C_i}\right)^d - \mu_d(e)\right]^2$$

Online "Rahyab" (3/4)

- Link cost vector (2 costs, can be extended):
  - **Metric:** link length L(e)

    Constraint: max lightpath length: $L<L_{Max}$
  - **Metric:** impact of inaccuracy (on QoT estimator) based on monitor availability (m_i) for a given link e: Θ(e).

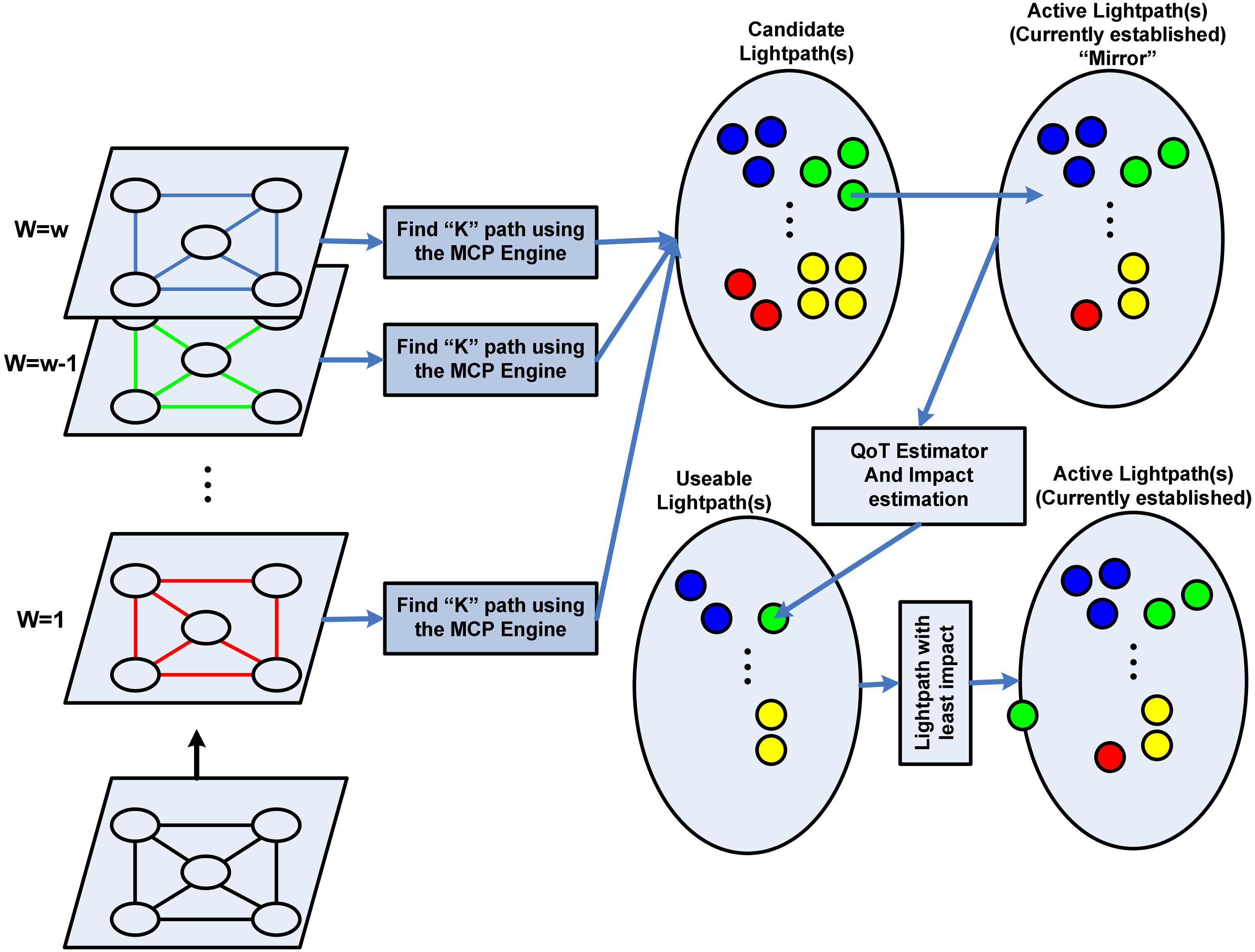
    Constraint: max inaccuracy over a lightpath: $\eta<\eta_{max}$

$$\Theta(e) = \sum_{k=1}^{n} \epsilon_k (1 - m_k).$$

$$\eta(p) = \frac{\sum_{e \in p} \Theta(e)}{\Theta_{max}(e)}.$$

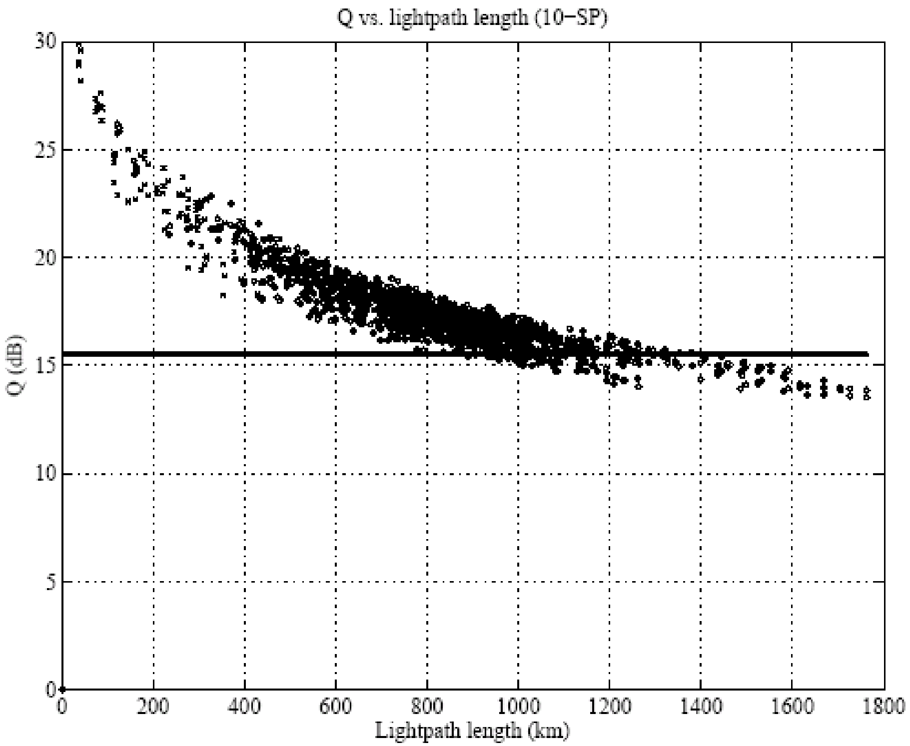
$$Q_{est} > Q_{Threshold} + \eta Q_{ErrorMax}$$

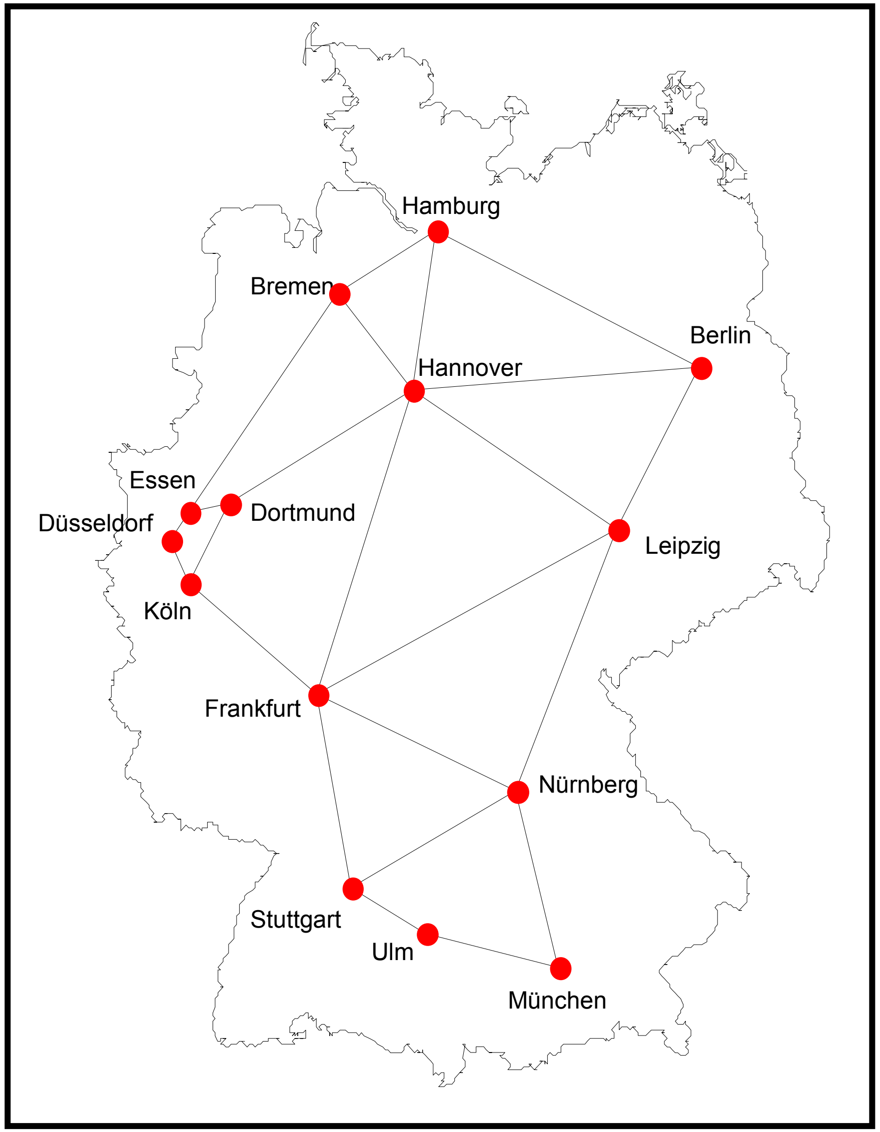
Online "Rahyab" (4/4)



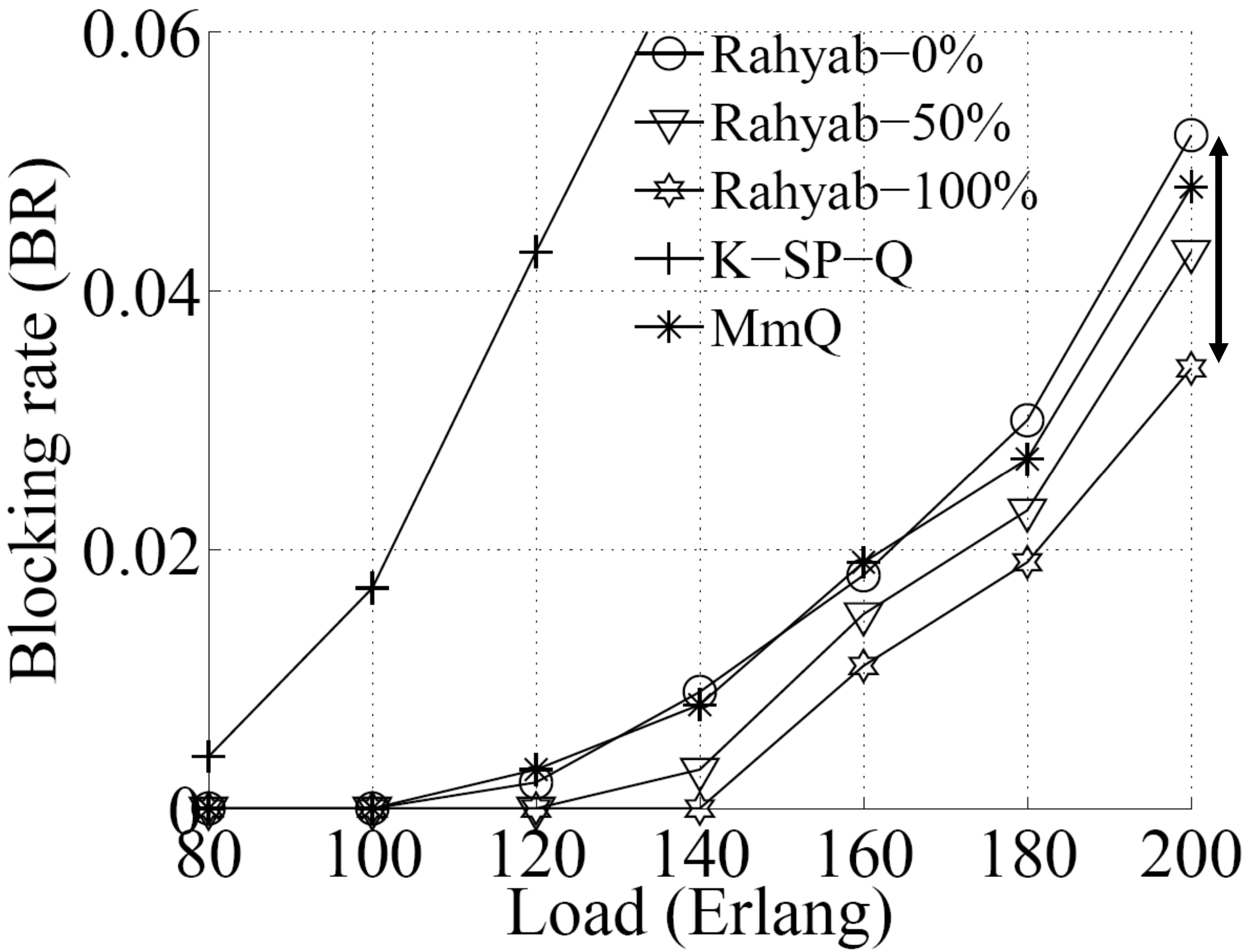
Simulation Setup

- **DTNet**
  - Number of nodes:14
  - Number of links:23
  - Average node degree:3.29
  - Diameter: 800 km

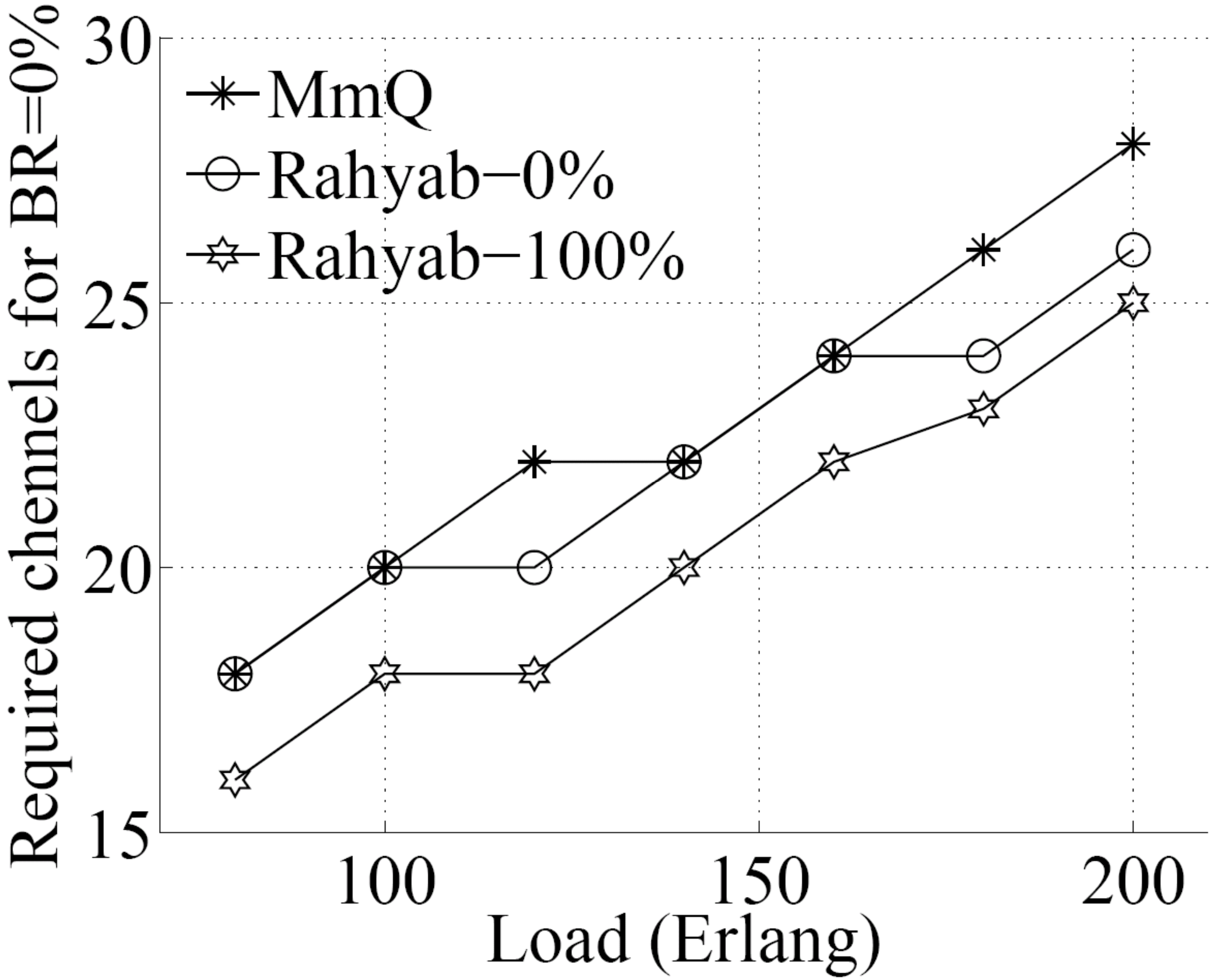




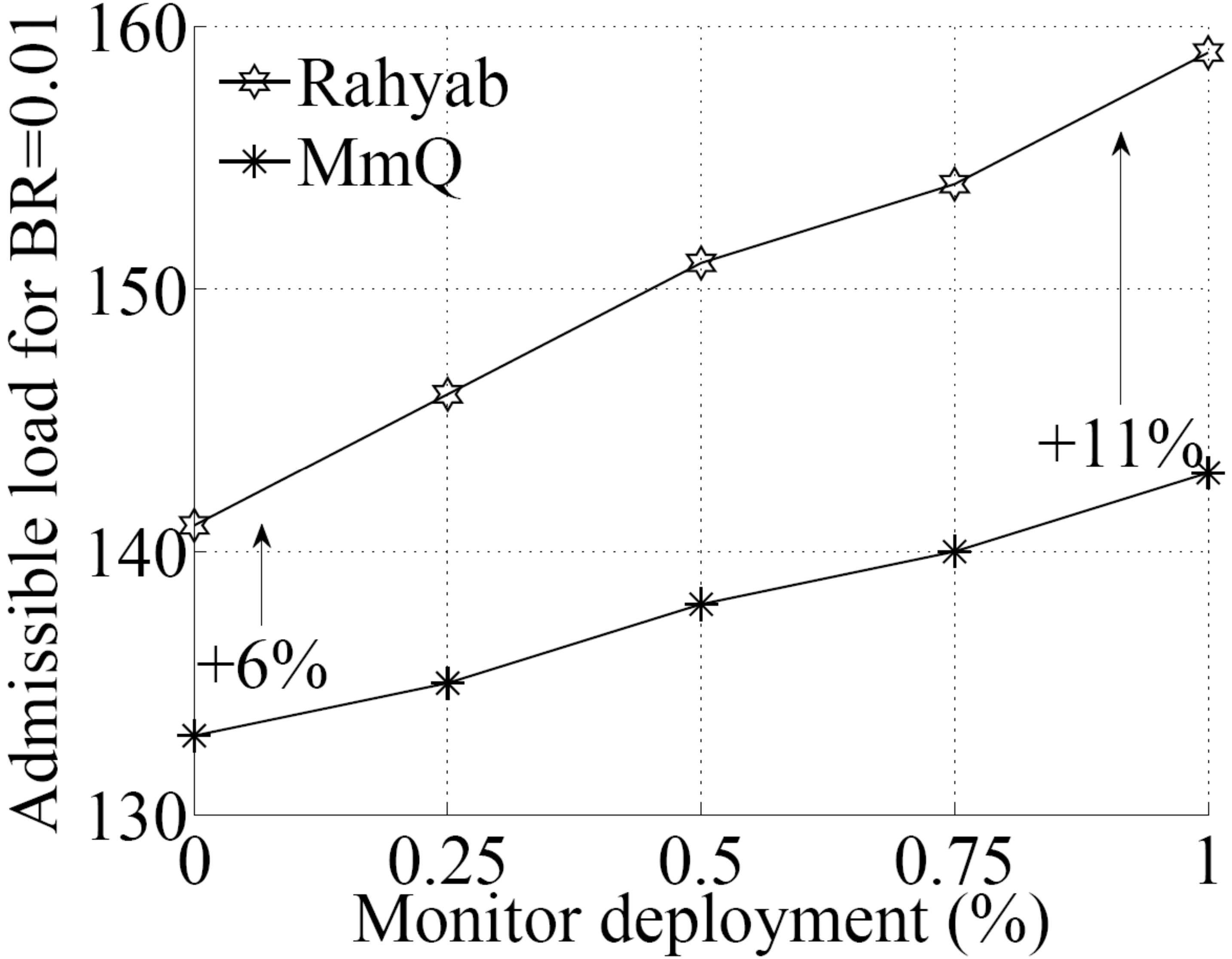
Blocking rate vs. Load



Required channels for 0% BR



Admissible load vs. Monitor deployment



Conclusions

- Next Generation Core Optical Networks
  - Many studies around
  - Many problem addressed
  - Not many integrated and comprehensive works
- DICONET → Integrated Network Planning and Operation Tool (NPOT)
  - Presented here: **IA-RWA algorithm with QoT estimation inaccuracies**
- Related works:
  - Monitor placement algorithms
  - Failure localization algorithms
  - Control plane design and implementation
  - Integrated Network Planning and operation tool

Thank you!

- Question & Answers

- Acknowledgements
  - This work is partially funded by the European Commission (FP7)

Dynamic Impairment Constraint Networking for Transparent Mesh Optical Networks

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