On The Offline Physical Layer Impairment Aware RWA Algorithms in Transparent Optical Networks: State-of-the-Art and Beyond

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- 24 months, total cost=5M€, 40 man-years
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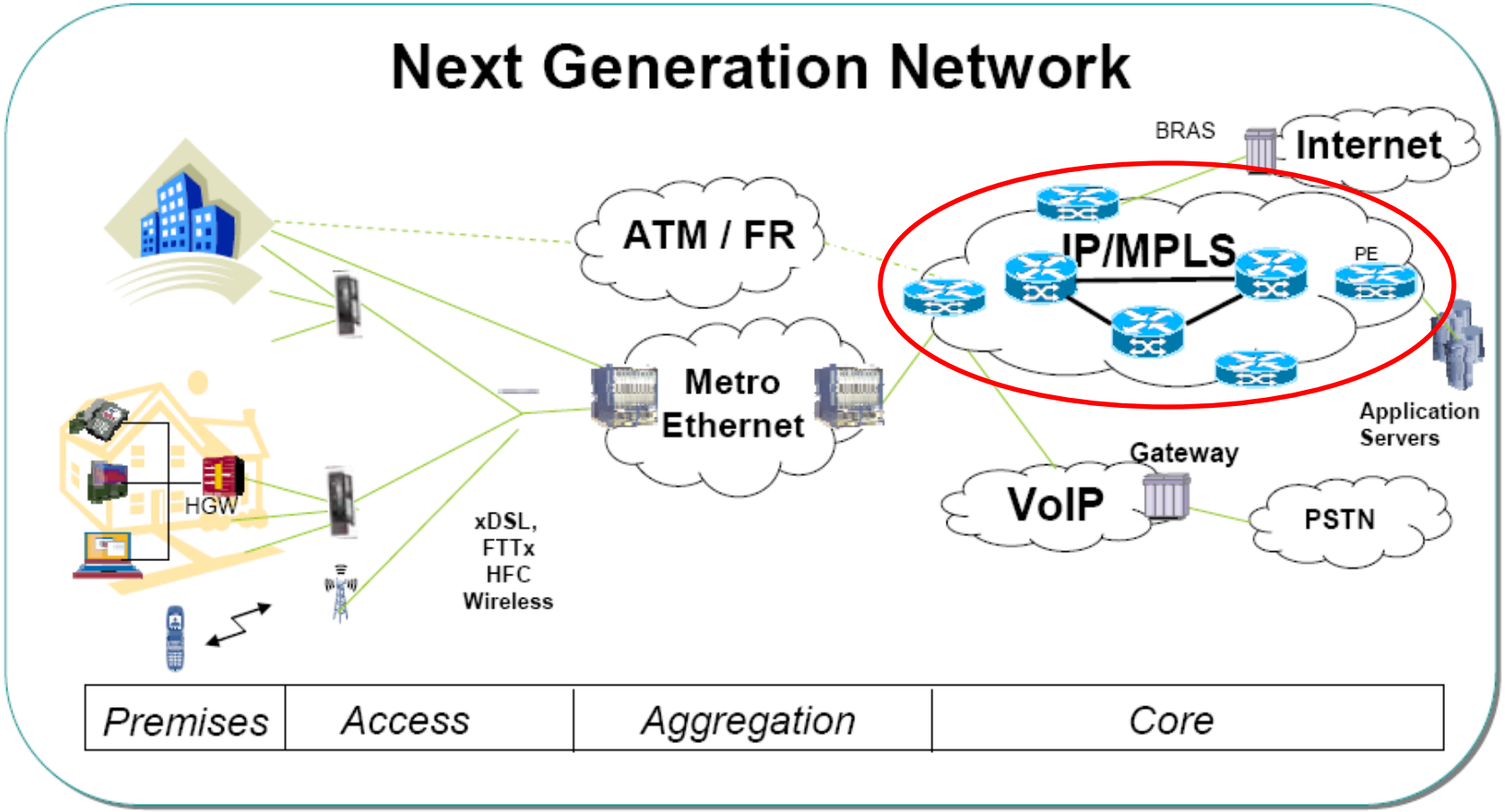
- 7 academic partners: AIT, Create-NET, IBBT, RACTI, Telecom ParisTech, Univ. Essex, UPC

Introduction

- To bring innovative new services (HDTV, VoD, Video IM, VoIP, tele-presence) to market, service providers traditionally adopted a "One Service per network" approach.
- To decrease CAPEX, OPEX (energy consumptions), and improve economies of scale, the focus shifted to designing a single network capable of delivering multiple services.
  - E.g. main motivation behind ATM (replaced by IP+(G)MPLS)
- The Next Generation Networks (NGN) will/(have to) support emerging services over a single IP-centric converged network.

Next Generation Networks

- An architectural view of a NGN
- Legacy (premises) Access, Aggregation, Core layers



Source: S. K. Mohapatra, M. H. Mortensen, "A Solution Framework for Next Generation Network Planning," OnePlan White paper, VPIsystems.

Towards future core optical networks

- **The network evolution aims at:**
  - **Improved cost economics (less costly electronics)**

    - Cost savings of a transparent solution over and opaque network design of up to 50% could be achieved
      - *Source: M. Gunkel, et. al. "A Cost Model for the WDM Layer", Photonics in Switching Conference, 2006.*

  - **Reduced investment and operations Efforts (CAPEX, OPEX)**
  - **Scalability (bit rate + modulation format independence)**
  - **Suitability to future services (e.g. cloud computing)**

- **The main drivers for network architecture migration:**
  - High bandwidth and end-to-end QoS guaranteed services
  - Dynamic (on-demand) technology-independent service provisioning

Some challenges of optical bypass networks

- **Physical impairments accumulation**
  - Signal impairments accumulate along a transparent optical path, therefore limiting the system reach and the overall network performance

    ➔ **Impairment-aware routing and wavelength assignment**

- **Failure localization**
  - Failure propagate in a transparent network environment and they can not be easily localized and isolated.

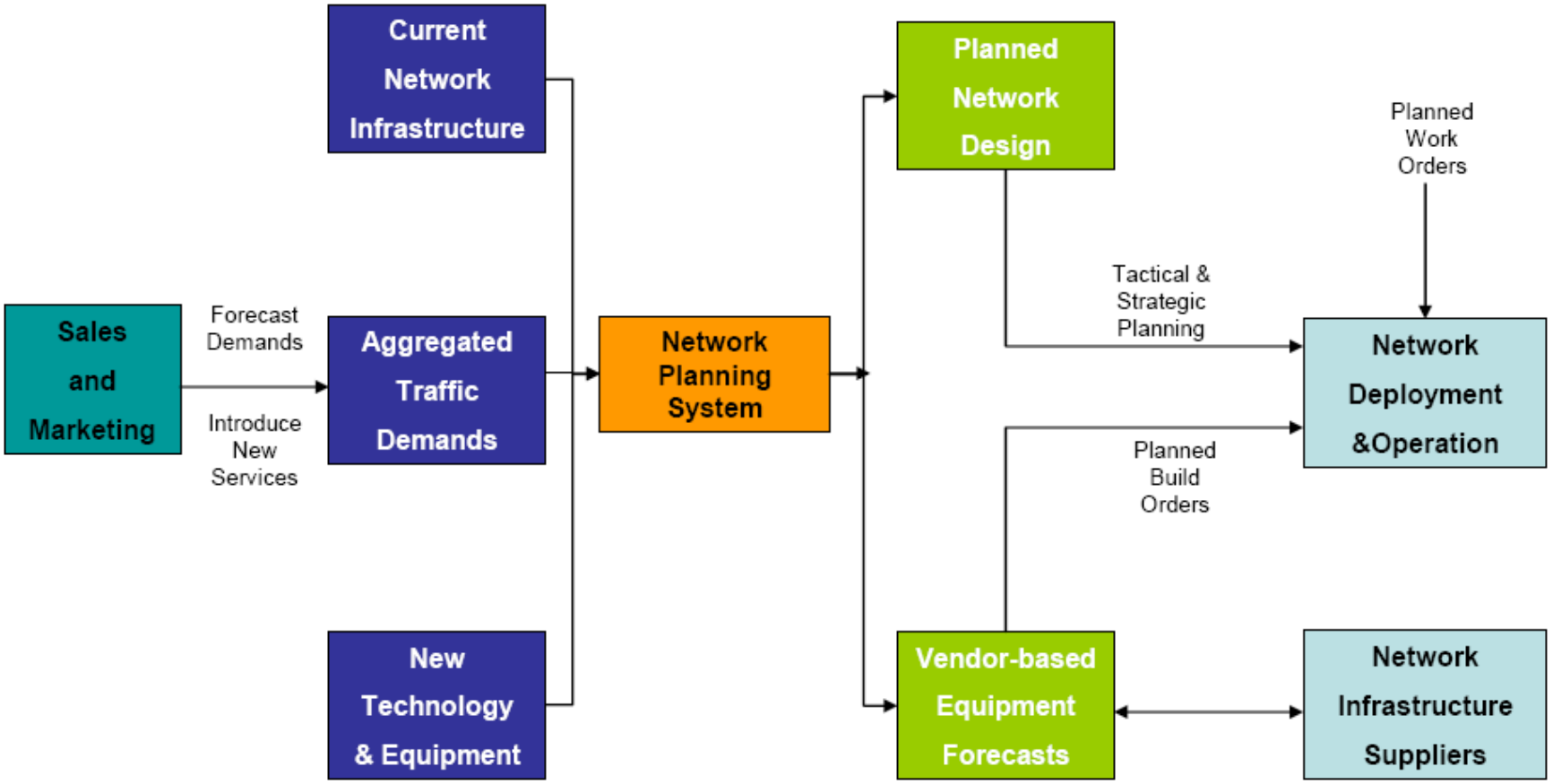
- **Control plane and hardware acceleration**
  - What to monitor?
  - Best control plane architecture? Implementation?

Proposed framework

- Cross-layer optimization
  - Physical layer impairment monitoring/management
  - Impairment Aware Lightpath Routing (a.k.a. IA-RWA)
- The main idea:
  - The development of a ***dynamic network planning/operation tool*** residing in the ***core network*** nodes that incorporates ***real-time measurements*** of optical layer performance into ***IA-RWA algorithms*** and is integrated into a unified control plane.

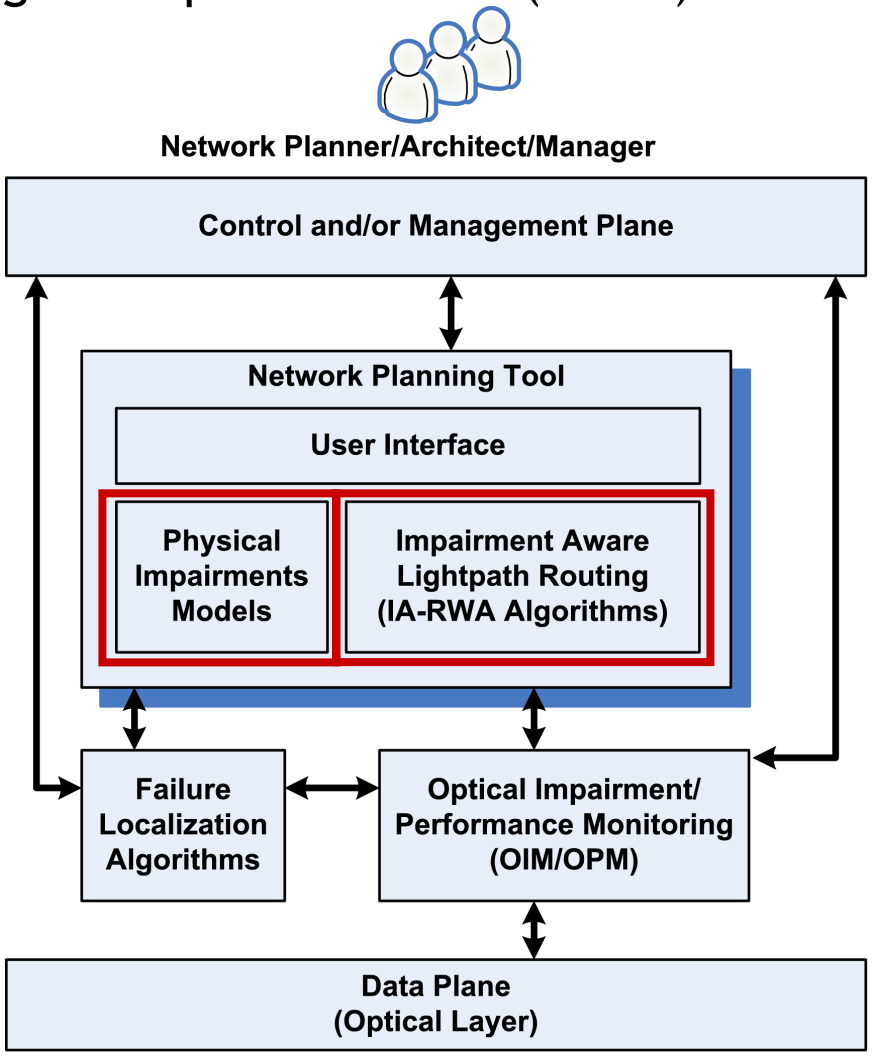
Network Planning and Operation Tool (NPOT)

- The main goal of a network planning tool is to provide and operate a network that is ready to handle current as well as future traffic with an objective of minimizing CAPEX and OPEX while ensuring the right QoS.



NPOT: Key building blocks

- Network Planning and Operation Tool (NPOT)



Physical Layer Performance Evaluator

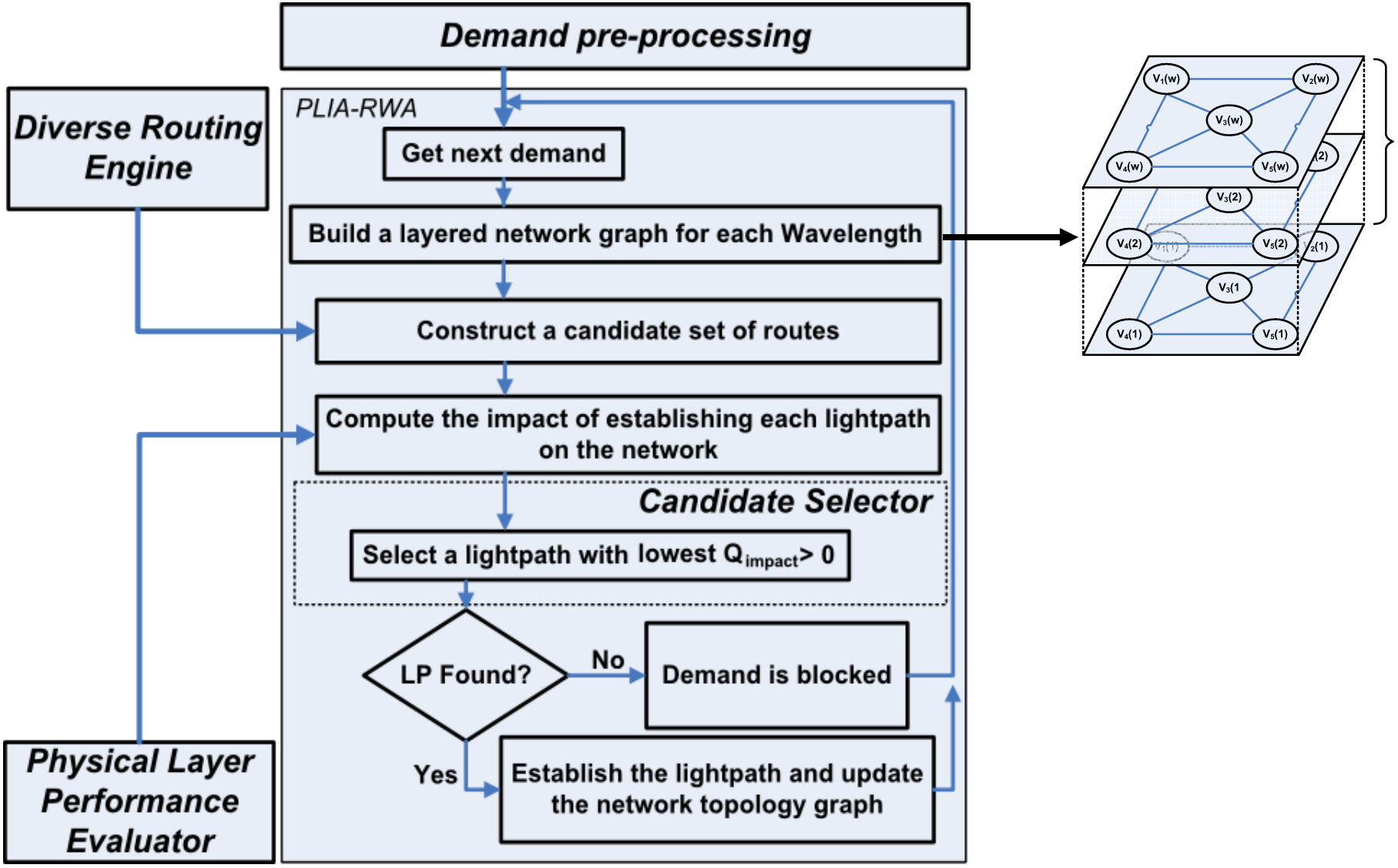
- Use “Q factor” as a BER indicator $Q = \frac{\mu_1 - \mu_0}{\sigma_0 + \sigma_1}$

- Account for ASE noise, PMD, node crosstalk, XPM, FWM
- Network-status dependent impairments = XPM, FWM
  - lengthy computations
  - Valid for 10 Gbps + OOK

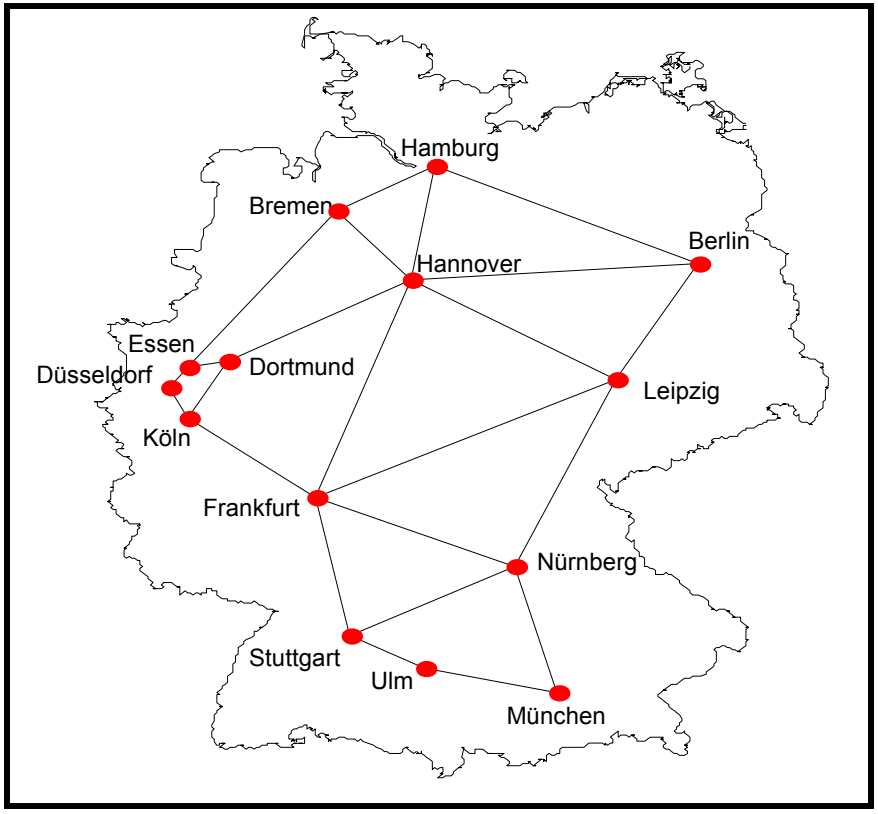
Offline PLIA-RWA Algorithms

- 100+ IA-RWA papers surveyed, only ≈10 offline
  - Azodolmolky et al., “A survey on PLIA RWA algorithms in optical networks”, in Elsevier Computer Networks, to appear, available online.
- RS-RWA
  - Supports regenerator placement
  - Routing: Generate random permutations of the demands; Wavelength assignment: First Fit
  - QoT test, keep best solution (lowest blocking rate); RWA then PLI verification
  - QoT test for each random permutation: “C-3” = RWA including PLI verification
  - M. Ali Ezzahdi et al., “LERP: A Quality of Transmission Dependent Heuristic for Routing and Wavelength Assignment in hybrid WDM networks,” in Proc. ICCCN 2006.
- ILP-RWA
  - Integer Linear Programming RWA
  - Some physical impariments used in constraints, QoT test at the end
  - I. Tomkos et al., “Performance engineering of metropolitan area optical networks through impairment constraint routing,” IEEE Commun. Mag., Aug. 2004.
- POLIO-RWA
  - Pre-Ordering Least Impact Offline RWA

Novel Offline PLIA-RWA Algorithm



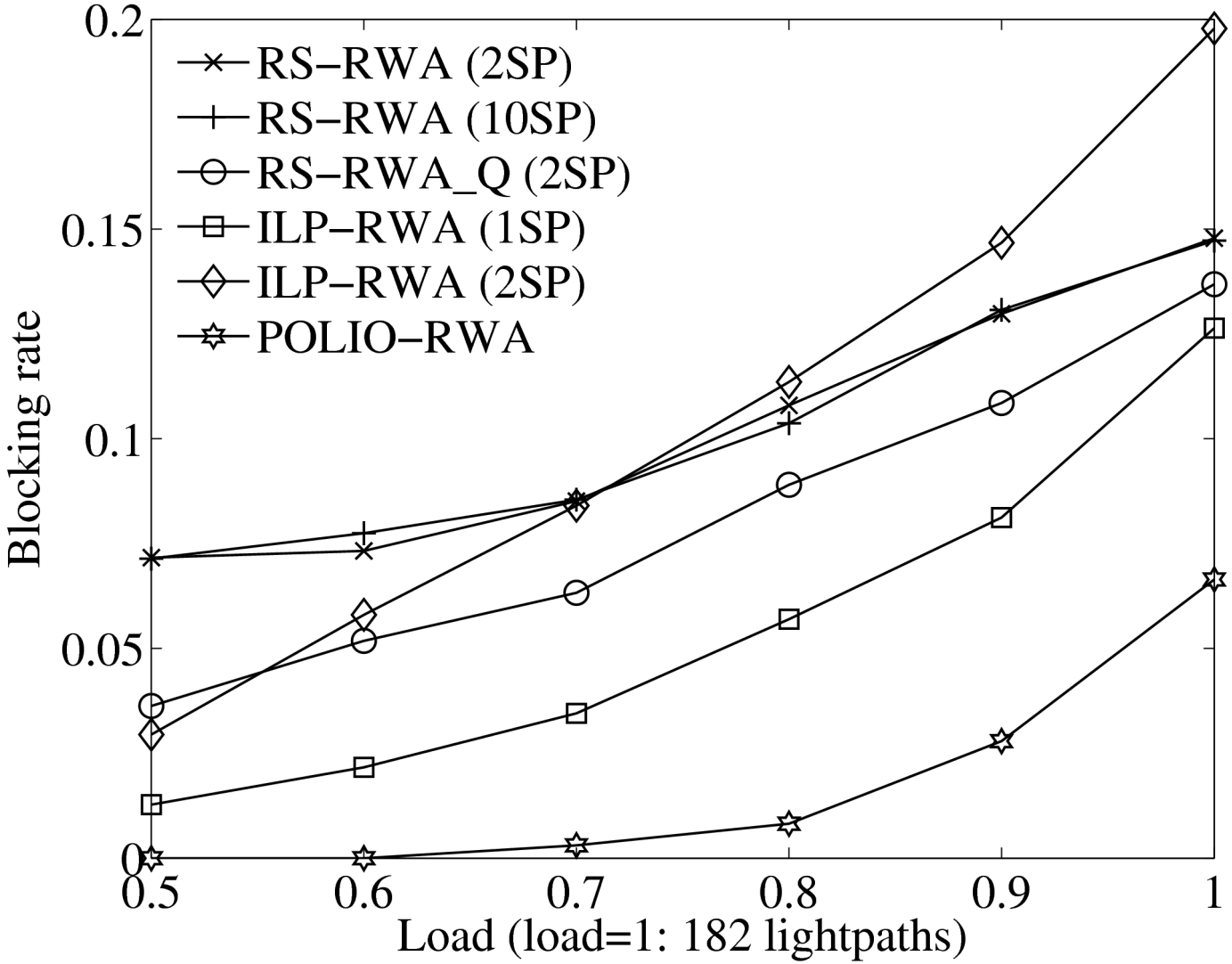
Network Characteristics



National German-inspired topology

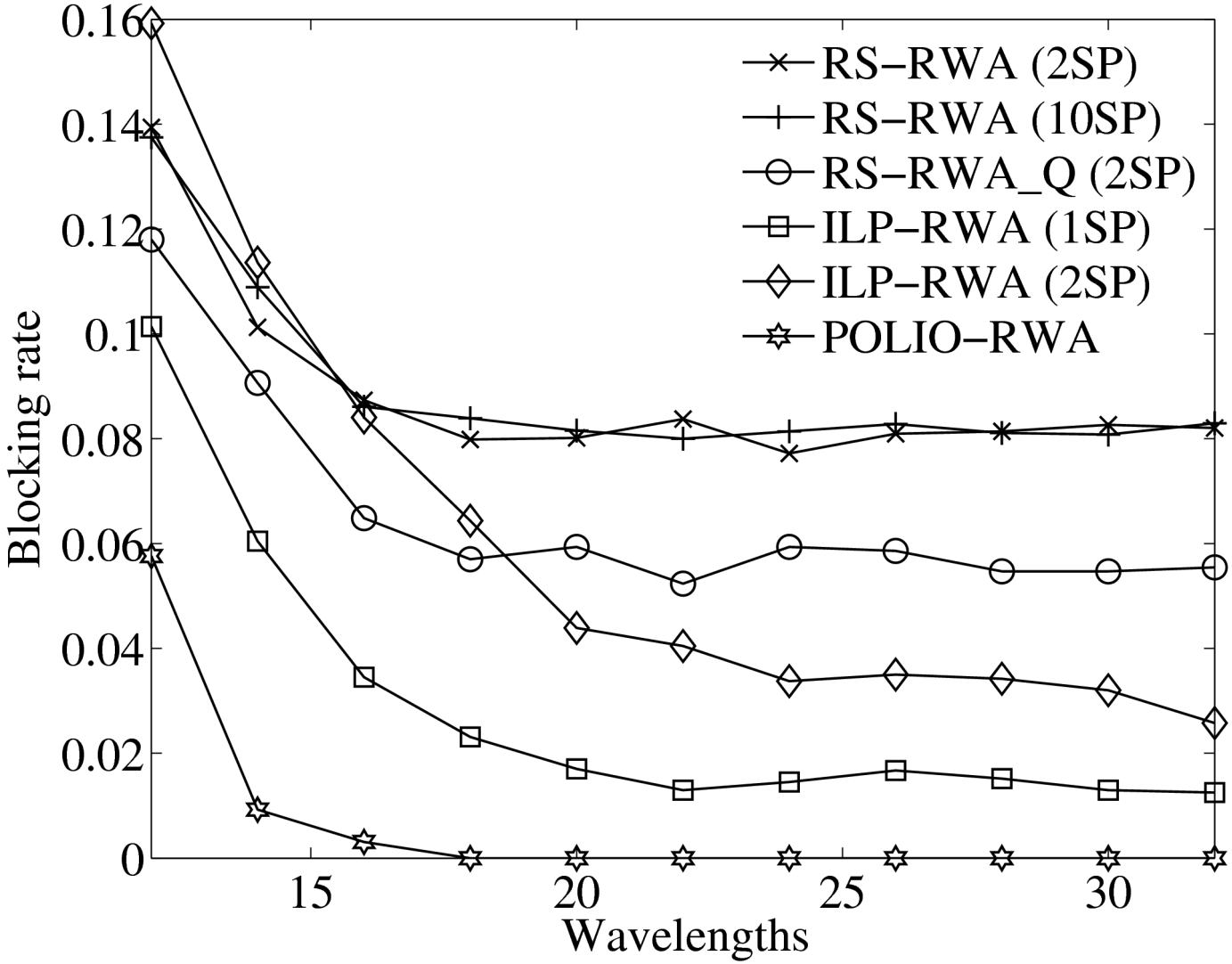
- 14 nodes
- 23 links
- National size
- Optimized dispersion map, standard physical layer parameters for 10 Gbps OOK networks
- No regeneration
- Load =1 ↔ 182 demands

Blocking rate



- RS_RWA vs RS_RWA-Q
- ILP perf.
- independence on #shortest paths
- POLIO perf.

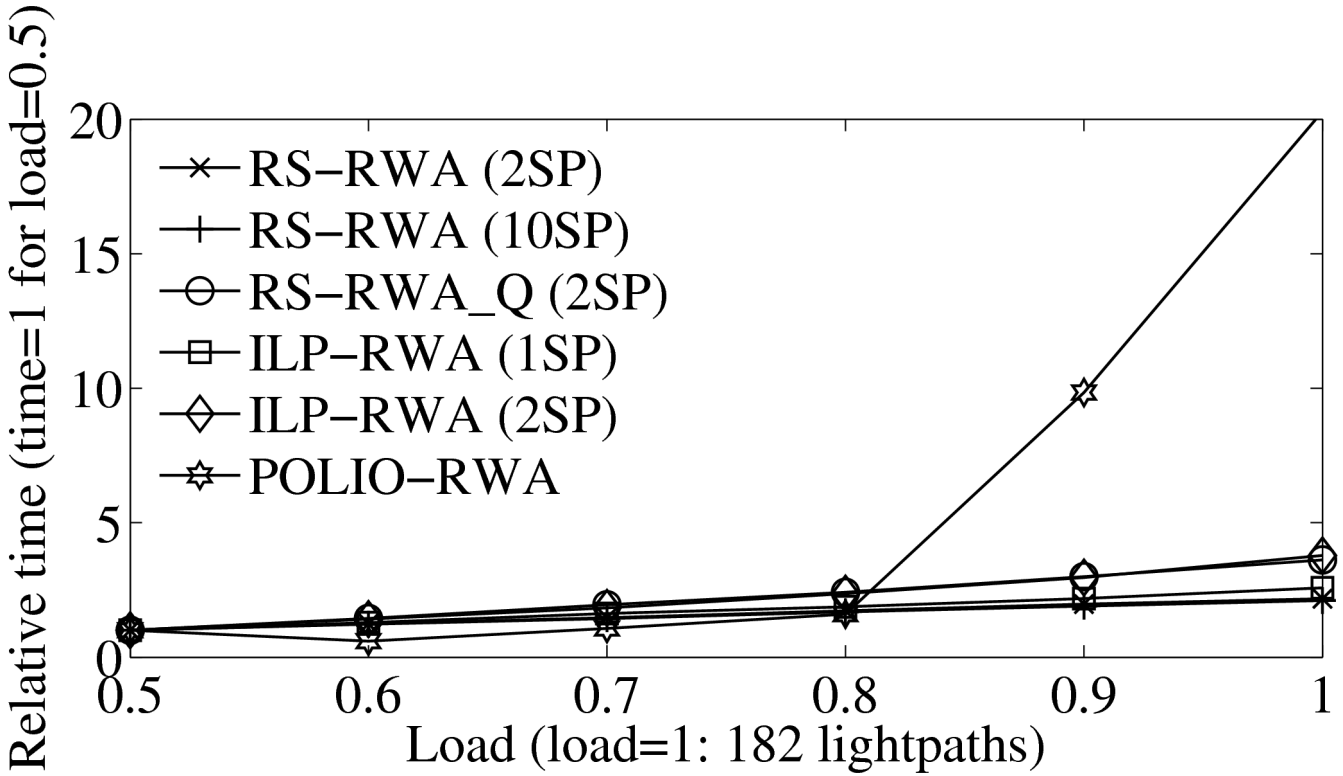
Wavelengths needed to achieve BR=0



- Pure preplanning problem
- POLIO: need 18WL s.t. BR=0
- Others: no IA in WA step

→ crosstalk

Scalability



- All algs. scale well with load but POLIO
- POLIO has more Q computations (bottleneck)

  → trade-off performance/speed
- In practice: a few minutes per run

Conclusions

- Future generation core optical networks
  - many papers around
  - many problems addressed
  - not many comprehensive works
- DICONET ➔ static and dynamic problems
- Example: planning/offline IA-RWA
- Future work/work in progress:
  - online IA-RWA, fault management, control plane design and implementation, FPGA implementations, NPOT "glue" tool implementation, validation with testbed