

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



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Siamak Azodolmolky^{1,2}, Yvan Pointurier², Mirosław Klinkowski¹, Eva Marin¹, Davide Careglio¹, Josep Solé-Pareta¹, Marianna Angelou², Ioannis Tomkos²

1:UPC, 2:AIT; Work partially funded by the European Commission (FP7)

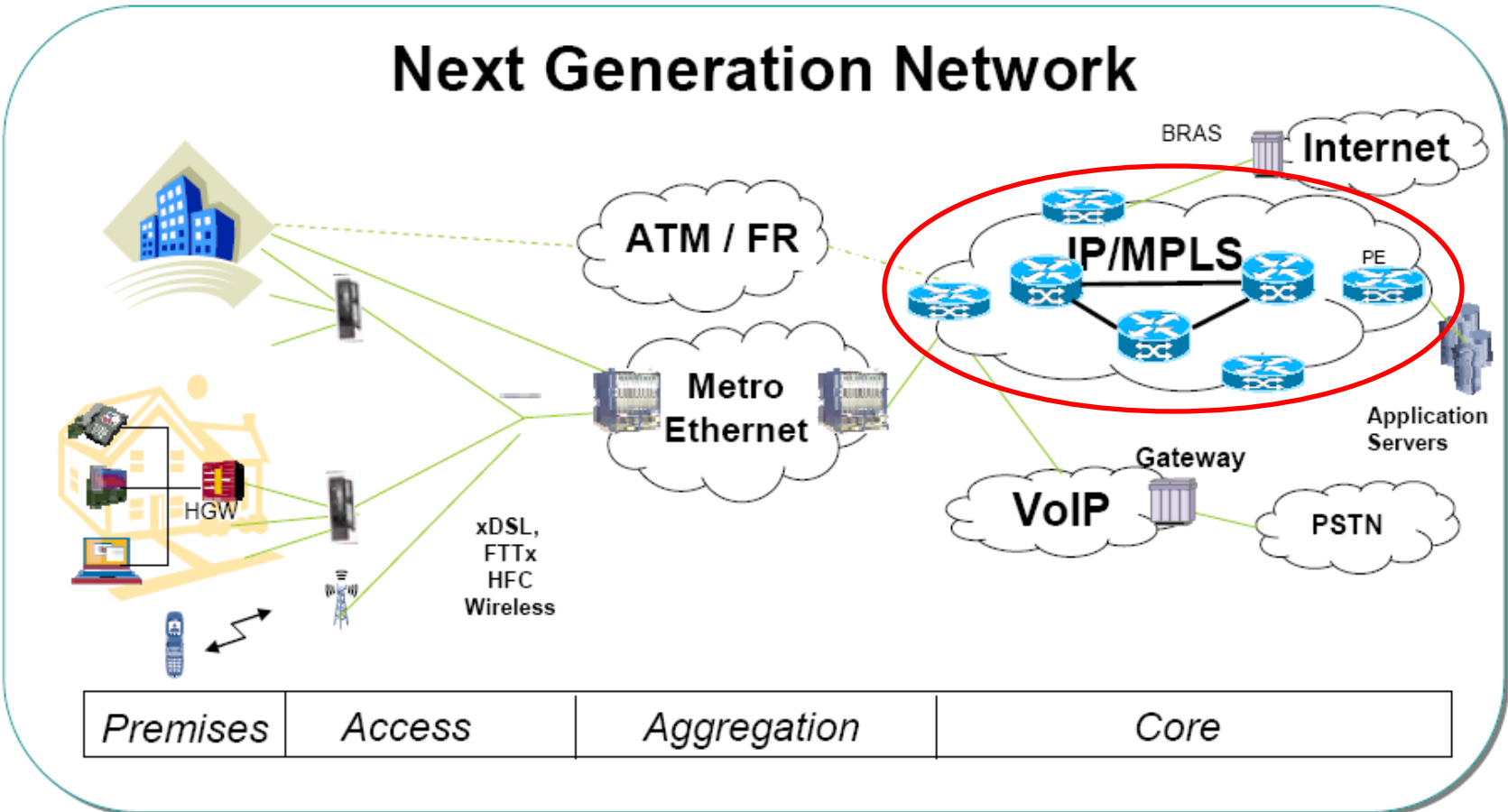


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- Partly funded by the European Commission (FP7)
- 24 months, total cost=5M€, 40 man-years
→ January 2007 June 2010
- 6 industrial partners: ADVA, Alcatel Lucent Bell Labs France, Deutsche Telekom, ECI, Huawei, JCP consulting
- 7 academic partners: AIT, Create-NET, IBBT, RACTI, Telecom ParisTech, Univ. Essex, UPC

- 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.

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



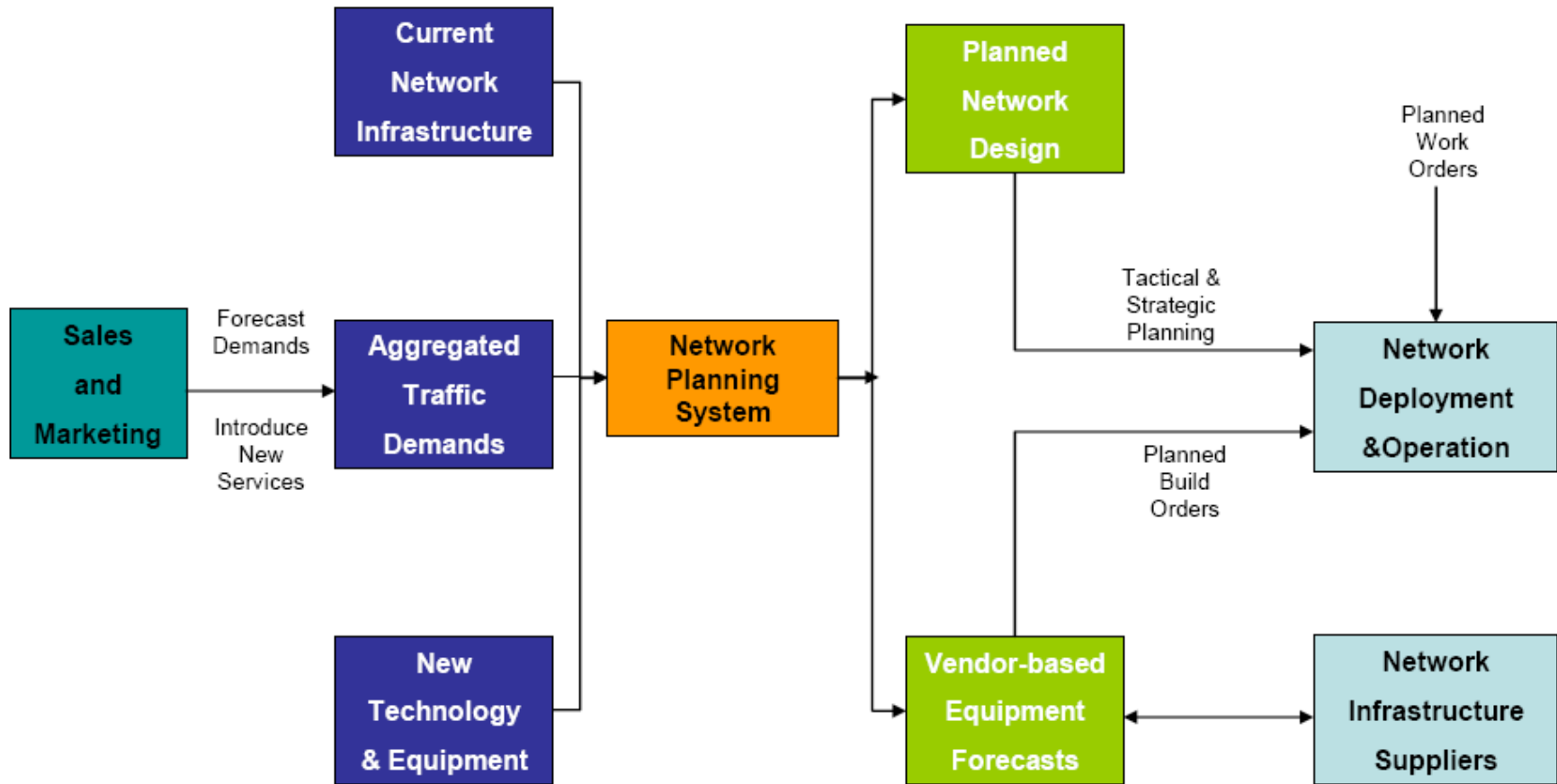
Source: S. K. Mohapatra, M. H. Mortensen, "A Solution Framework for Next Generation Network Planning," OnePlan White paper, VPIsystems.

- **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

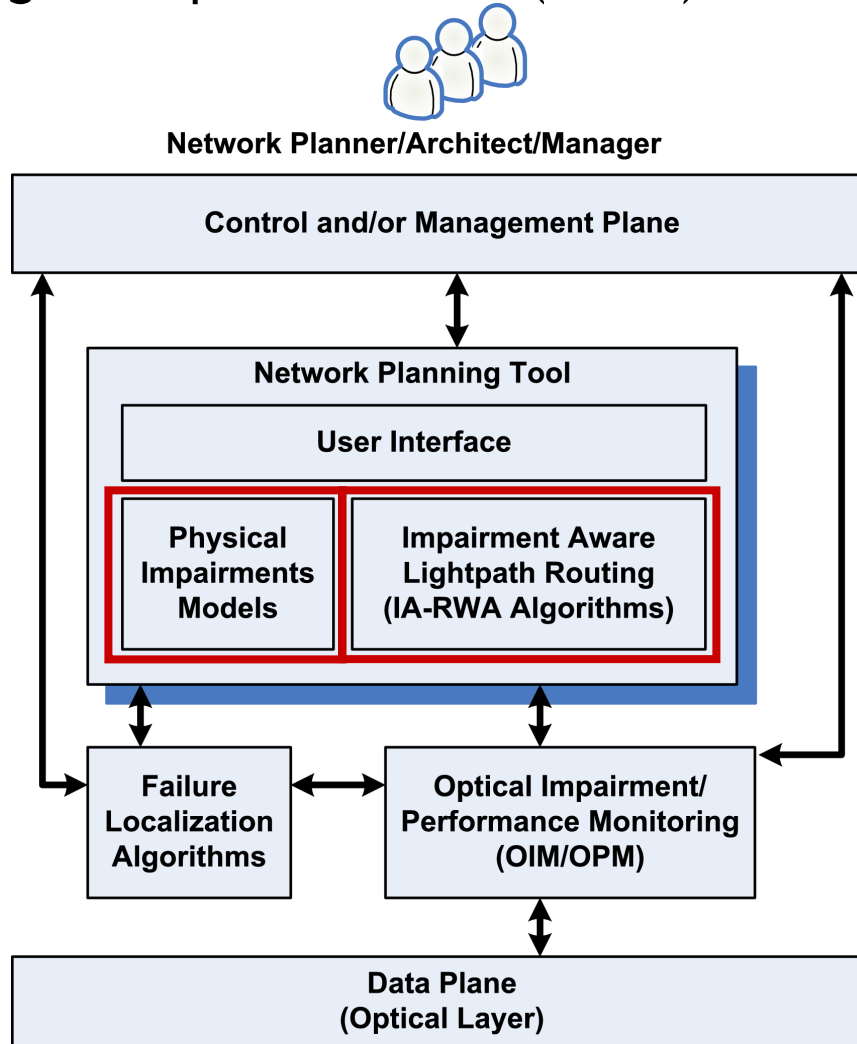
- **Physical impairments accumulation**
 - Signal impairments accumulate along a transparent optical path, therefore limiting the system reach and the overall network performance
 - ➔ **Impairment-aware routing and wavelength assignment**
- **Failure localization**
 - Failure propagate in a transparent network environment and they can not be easily localized and isolated.
- **Control plane and hardware acceleration**
 - What to monitor?
 - Best control plane architecture? Implementation?

- 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.

- 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.

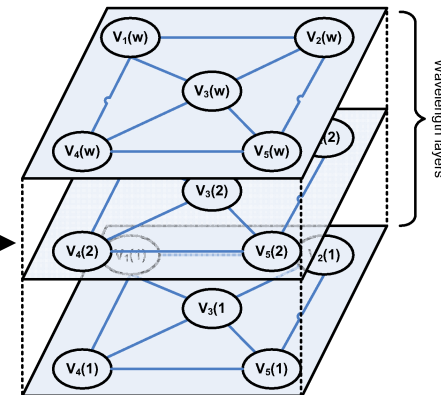
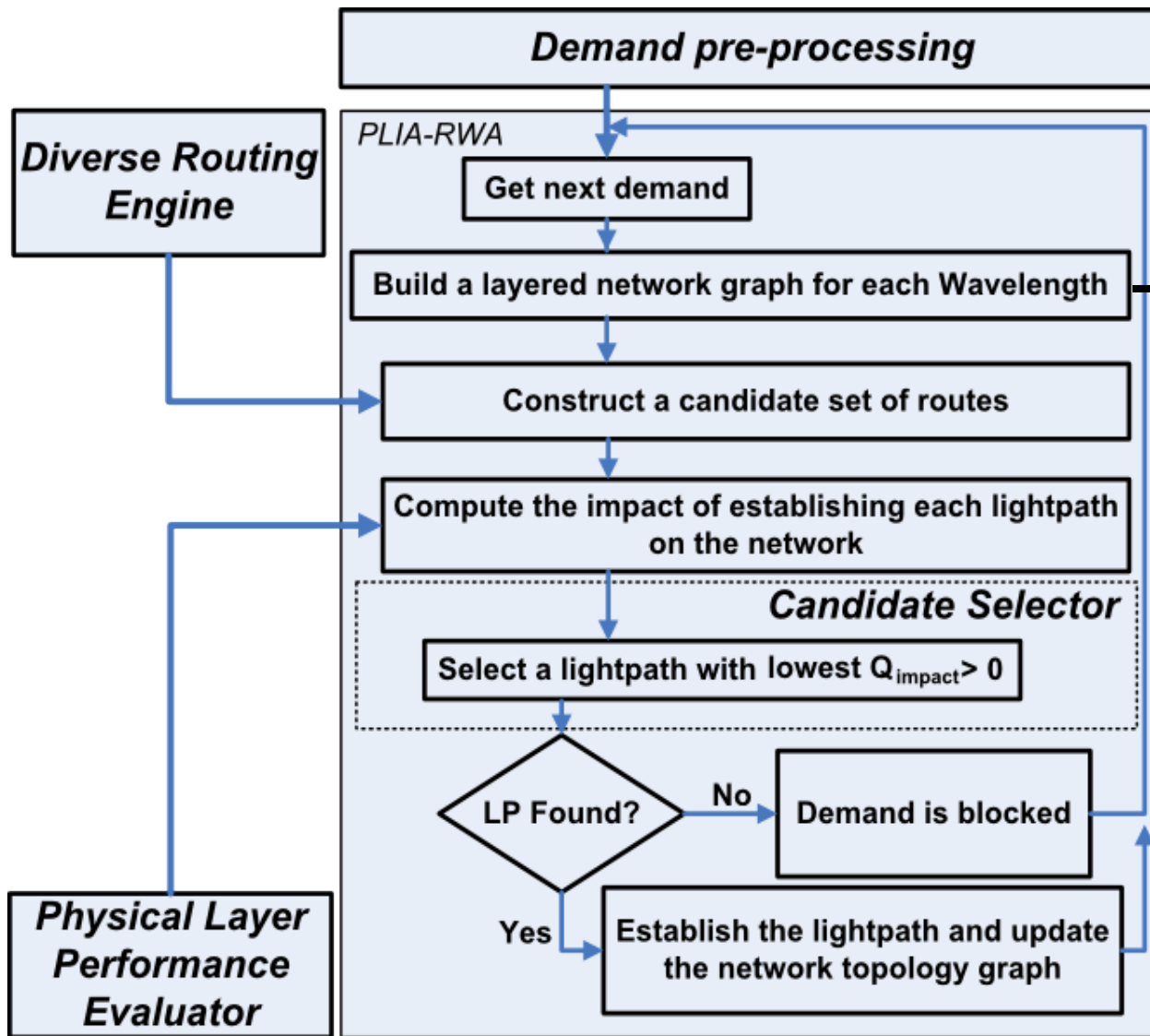


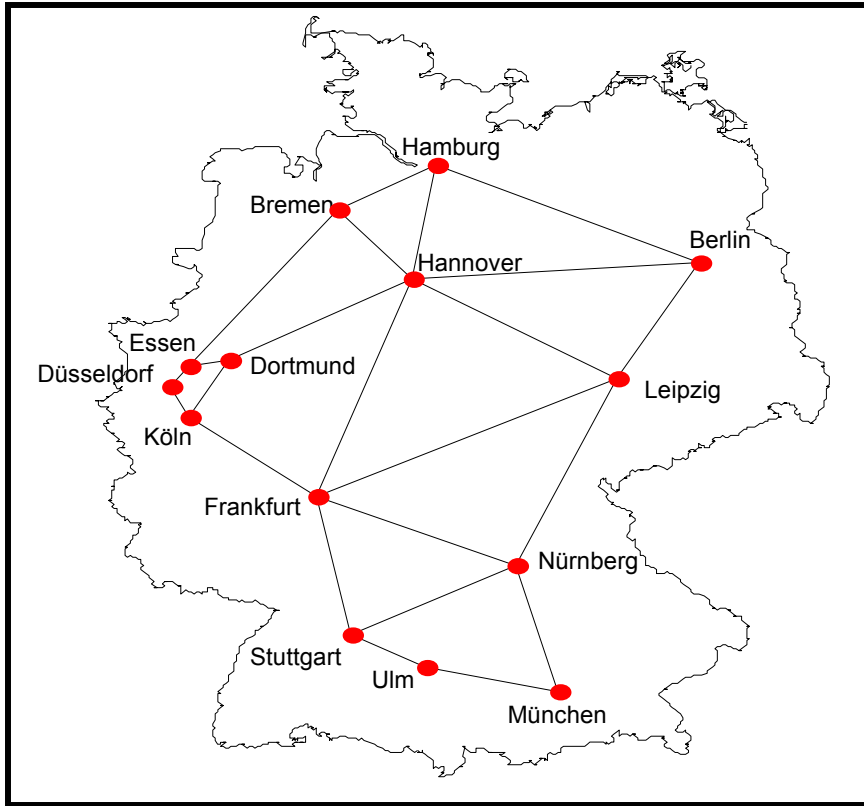
- Network Planning and Operation Tool (NPOT)



- 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

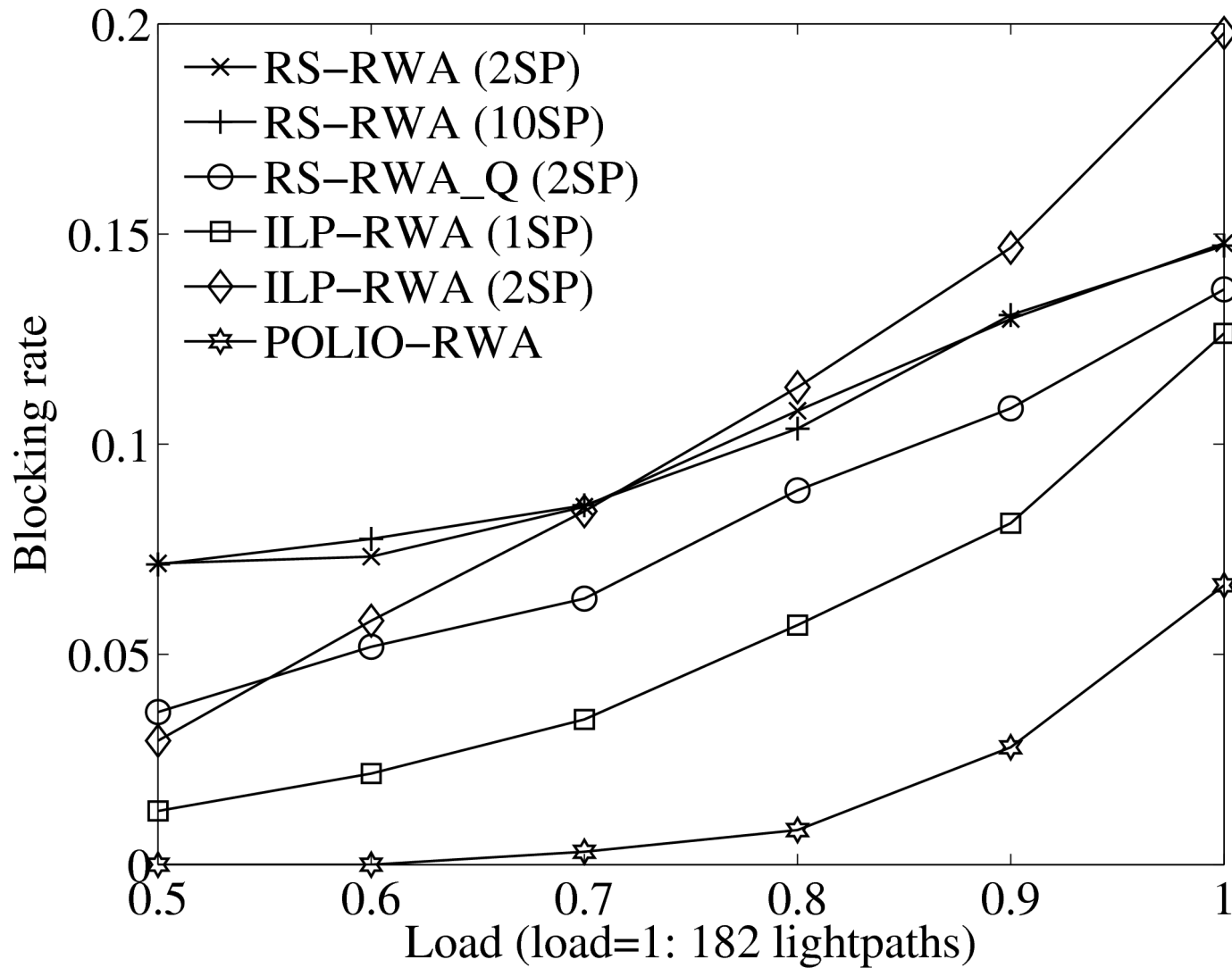
- 100+ IA-RWA papers surveyed, only ≈ 10 offline
 - Azodolmolky et al., “A survey on PLIA RWA algorithms in optical networks”, in Elsevier Computer Networks, to appear, available online.
- RS-RWA
 - Supports regenerator placement
 - Routing: Generate random permutations of the demands; Wavelength assignment: 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 impairments 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



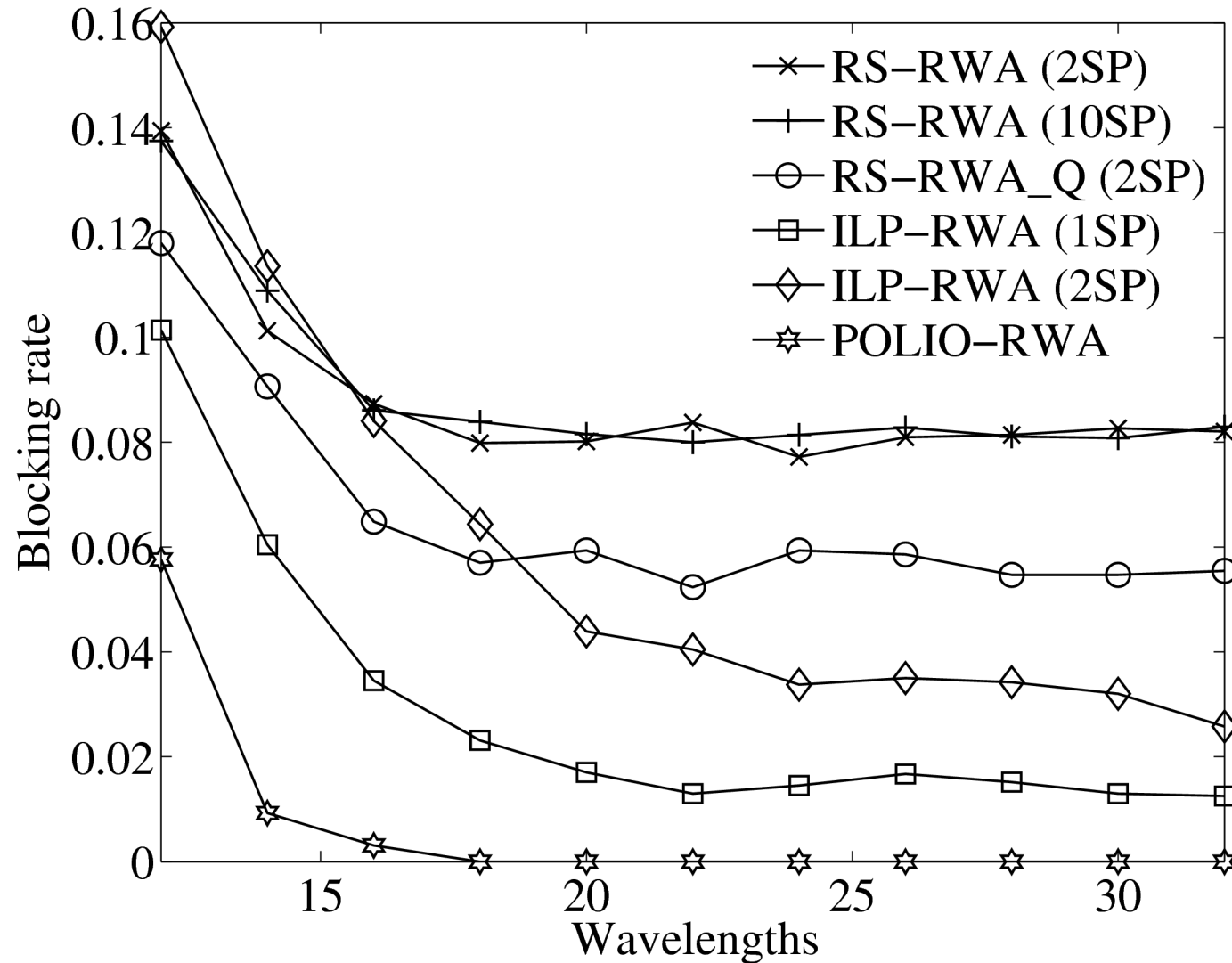


National German-inspired topology

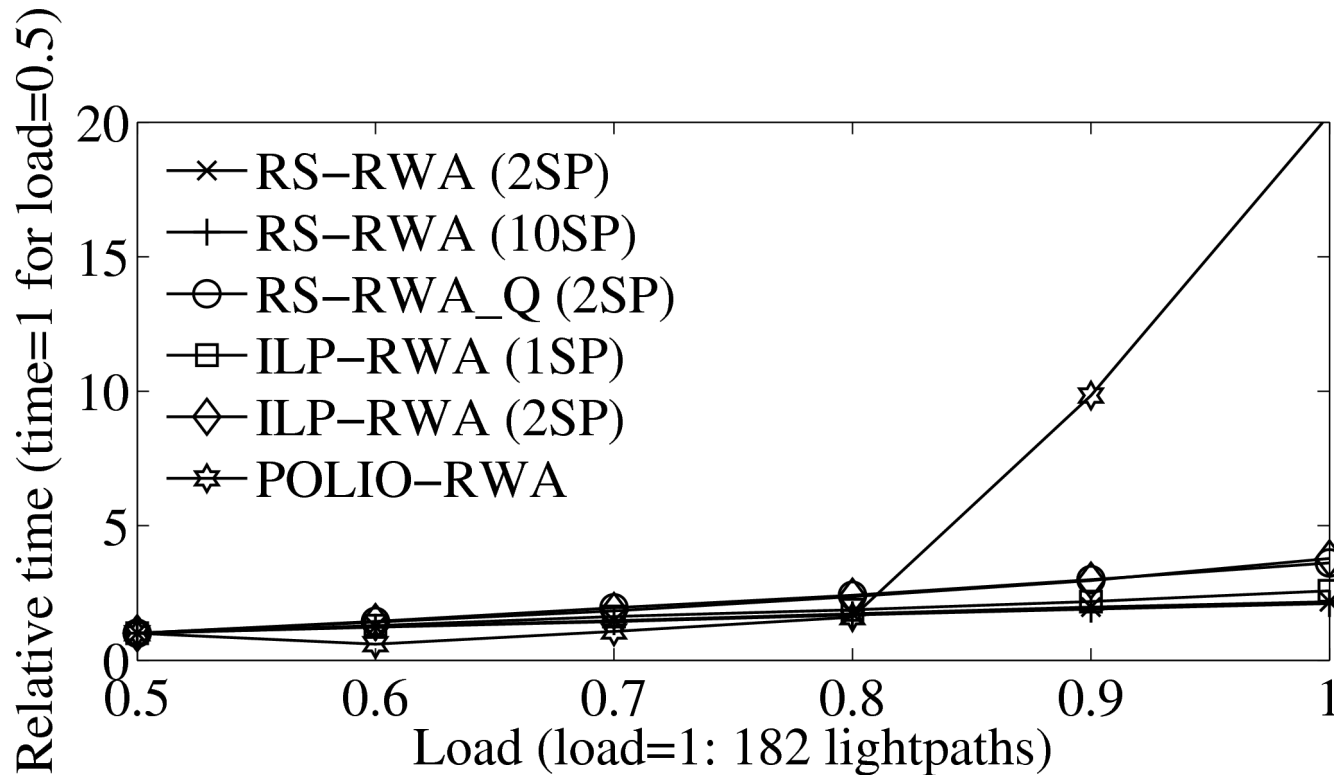
- 14 nodes
- 23 links
- National size
- Optimized dispersion map, standard physical layer parameters for 10 Gbps OOK networks
- No regeneration
- Load =1 \leftrightarrow 182 demands



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



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



- 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

- 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