Control Plane and Energy Considerations in PCE-Based WDM Networks

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Outline

- NEGONET
  - People
  - Current research interests
  - Current projects
- Recent results (selected)
  - Benefits of connection request bundling in a PCE-based WDM Network
  - Dynamic provisioning in power-aware transparent WDM networks

NEGONET: people

- Faculty:
  - Lena Wosinska
  - Paolo Monti
- Postdocs
  - Jiajia Chen
  - Cicek Cavdar (visiting from ITU)
- PhD students:
  - Amornrat Jirattigalachote
  - Jawwad Ahmed
  - Mohsan Niaz
  - Ajmal Muhammad (shared with LiU)
  - Pawel Wiatr
  - Mozhgan Mahloo

Current research interests

- Optical core networks
  - Network robustness and reliability
    - Fault and attack management
  - Impairment modeling and impairment aware routing
  - All-optical overlay network
  - Network control
  - Photonic circuit and packet switching
    - Node architectures
    - Contention resolution
- Fiber Access Networks
  - Hybrid WDM/TDM-PON
  - Dynamic Bandwidth Allocation (DBA) algorithms for EPON, GPON and 10G PON
  - Cost efficient protection schemes
- Green Networking
  - Energy aware routing solutions
  - Energy efficient optical network design
  - Green solution for access networks

Current research projects

- **EU Projects**
  - Eureka-Celtic: Management Platform for Next Generation Optical Networks (MANGO), 2008 - 2011
  - Network of Excellence: Building future Optical Network in Europe (BONE), 2008 - 2010
  - Integrated Project Optical Access Seamless Evolution (OASE), 2010 - 2012
  - Collaboration Project Security Planning Framework for Optical Networks (SAFE), 2010 - 2011
- **National Projects**
  - All-optical Overlay Networks [*VINNOVA*], 2007 – 2010 (Collaboration with LiU and NetInsight)
  - Bandwidth Allocation in Future TDM PON [*VINNOVA*], 2009 – 2010 (Collaboration with Ericsson AB)
  - Security in Optical Networks [*VINNOVA*] 2010 – 2013 (Collaboration with LiU and NetInsight)

”Benefits of Connection Request Bundling in a PCE-based WDM Network“

Jawwad Ahmed, Paolo Monti, Lena Wosinska

Sponsored by: Mango and All Optical Overlay Networks

Outline

- LSP provisioning
- PCE concept
- PCEP protocol
- LSP request bundling concept
- Bundling approach pros & cons
- Results
- Conclusions

LSP Provisioning in IP over WDM Networks

- LSP setup operations include
  - path computation
  - resource reservation
- Path computation computationally expensive and subject to multiple constraints
- Typically performed at ingress node in a distributed manner

Distributed LSP Path Computation

- Assumes all nodes with sufficient resources for multi-constrained paths computation
- Computational power may be limited at some nodes
- Legacy equipment may not support some control plane path computation functionality

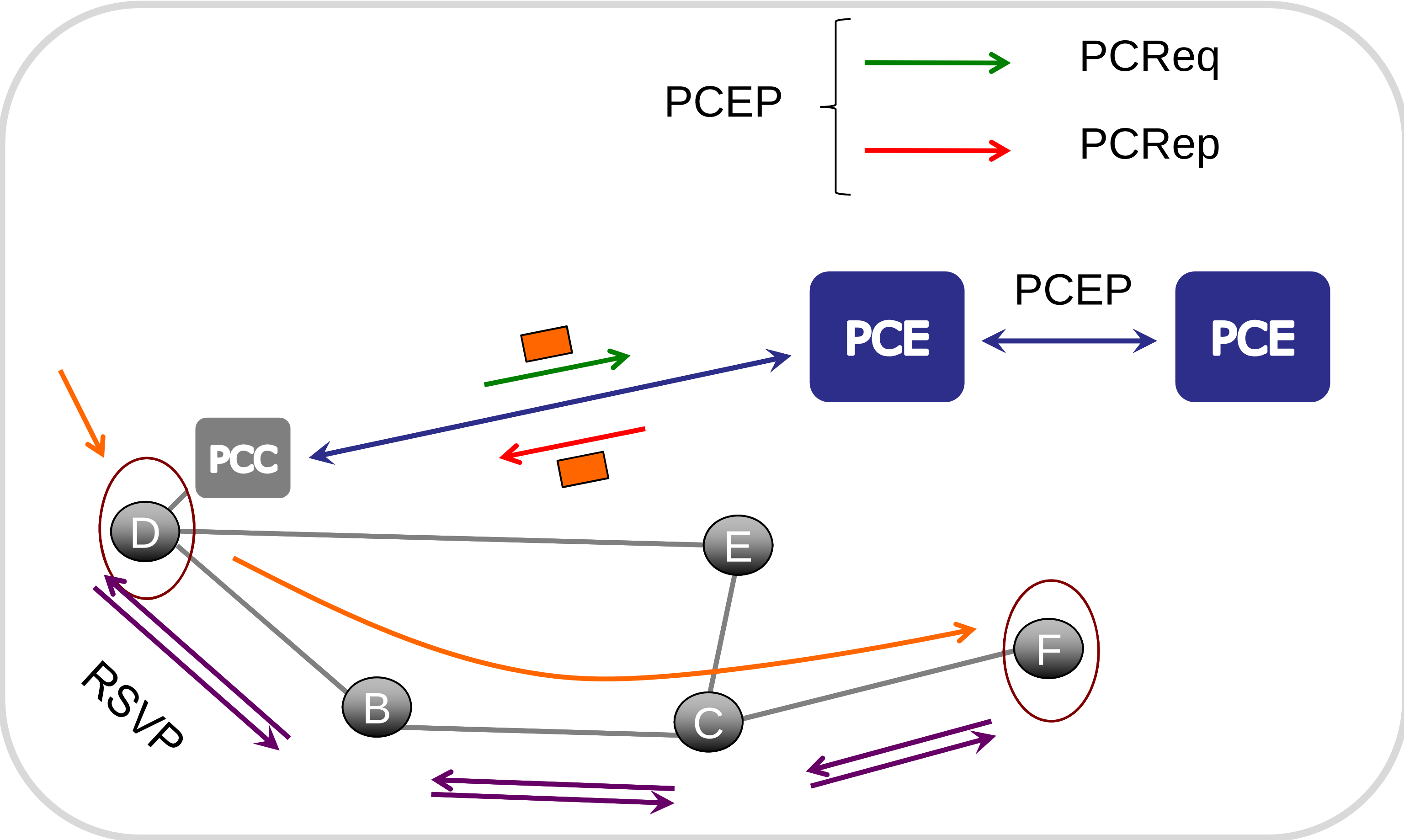
Path Computation Element (PCE)

- *"An entity that is capable of computing a network path or route based on a network graph"*
- *Path computation applicable in intra-domain, inter-domain, and multi-layer contexts*
- *Stateful vs. Stateless PCE*

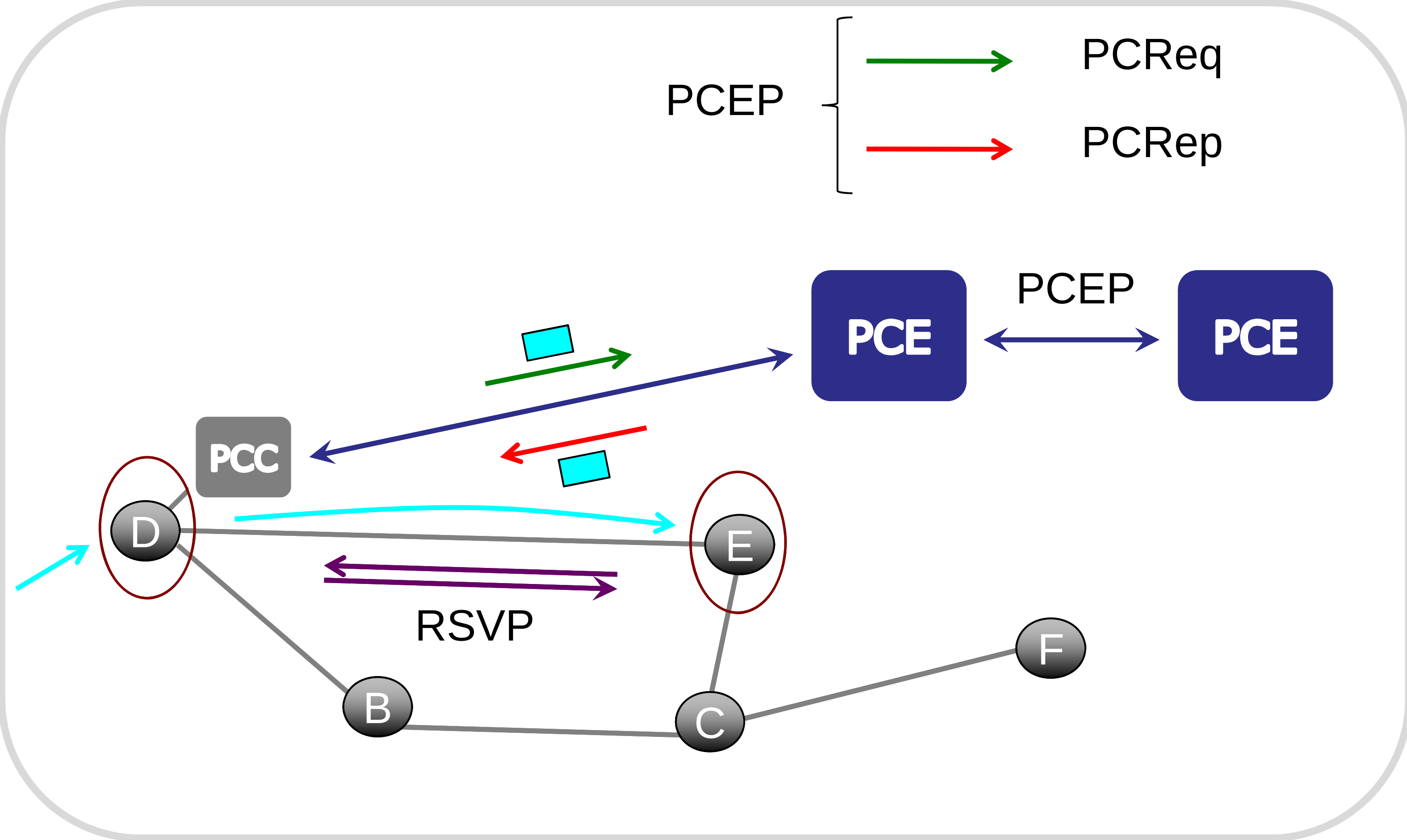
Path Computation Element Communication Protocol (PCEP)

- Communication protocol between a PCC (Path Computation Client) and a PCE, or between two PCEs
  - PCReq: sent by the PCC to the PCE for path computation request
  - PCRep: sent by the PCE to the PCC in response to a path computation request

PCE-Based Network Architecture



PCE-Based Network Architecture

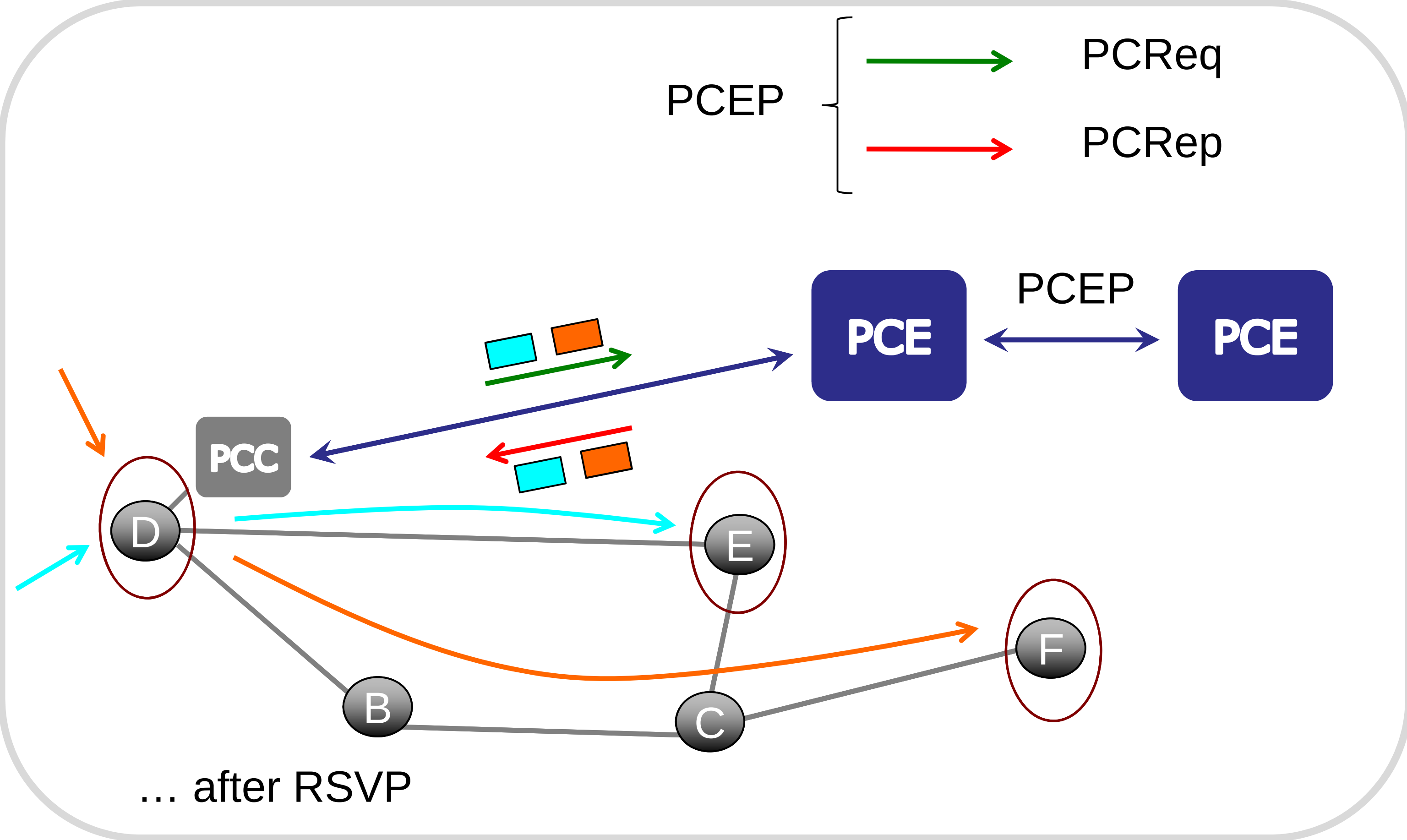


Bundling of LSP Requests

- *"Collect a no. of connection requests at source node and bundle them together before being sent to PCE for path computation"*

- Two scenarios:
  - Multiple LSP requests sent simultaneously in a single **PCReq** message with/without the **SVEC** (Synchronization Vector) object
  - Multiple computed LSP requests bundled and sent to PCC in a single **PCRep** message

LSP Bundling Example



LSP Bundling Approach: Pros & Cons

- **Pros(+)**
  - Reduction of control bandwidth overhead in the control plane
  - Concurrent optimization available for all LSP requests present in a bundle
  - Reduction of packet processing overhead at the PCE
- **Cons(-)**
  - Increased LSP setup-time
  - Increased blocking when a large number of connections needs to be setup in the network

Trade-Off Assessment

- Study the beneficial effects of bundling in terms of
  - control overhead reduction
  - concurrent path computation
- Evaluating the trade-off between connection setup delay and reduced communication overhead
- Identifying possible effects bundling may have on the network blocking probability
- WDM network with unprotected, DPP and SPP LSPs

Sequential RWA Algorithm

- For *each* LSP in the bundle the RWA problem is solved *separately* in two steps:
  - o Route computed using the Enhanced Weighted Least Congested Routing (EWLC) algorithm
  - o Wavelengths assigned using a Modified First Fit (MFF) algorithm

EWLCR Algorithm

- Objective: assign each LSP the least congested route, i.e., the one with more free resources

$$R \text{ s.t. } W(R) = \max_{i \in K} W(R_i)$$

$$W(R_i) = \left[F(R_i) + S(R_i)\right]$$

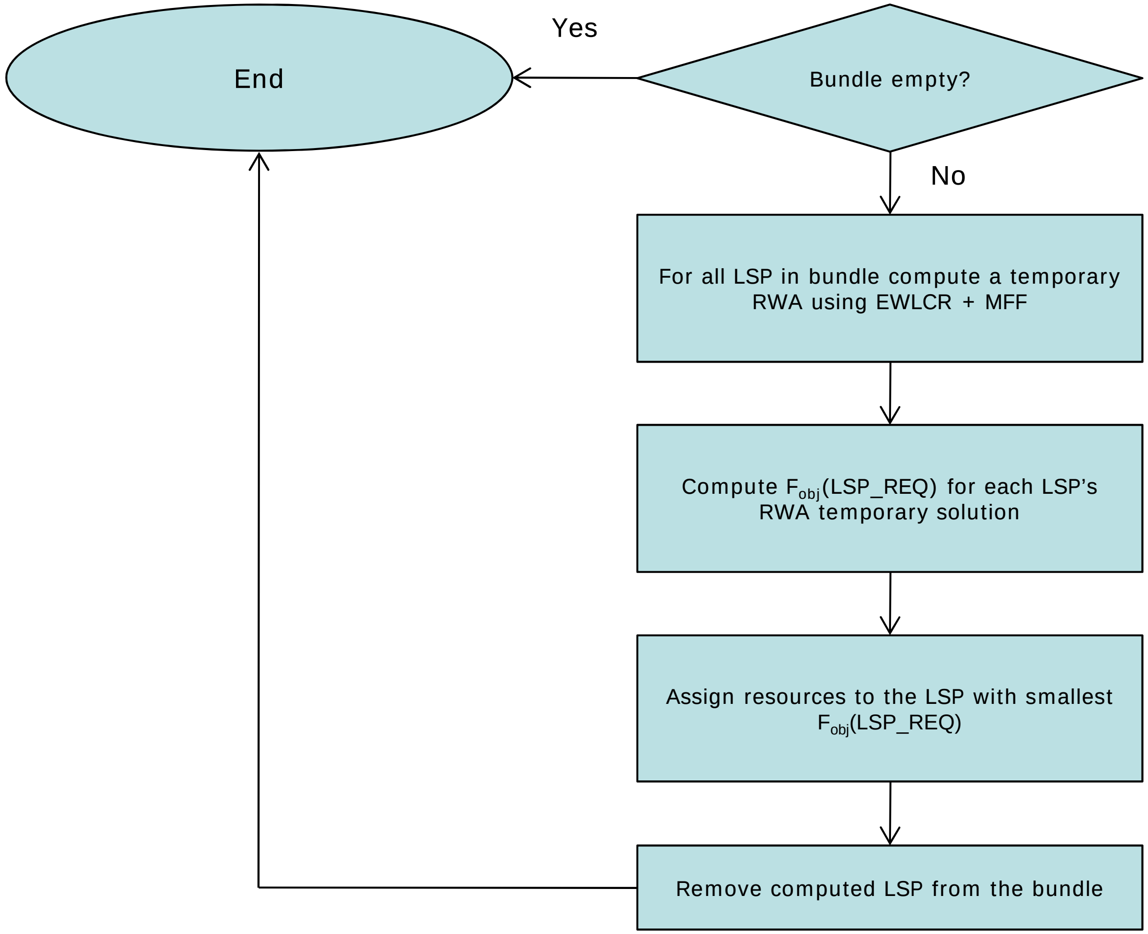
- $F(R_i)$: number of free wavelengths on R_i
- $S(R_i)$: number of shareable wavelengths on R_i

MFF Algorithm

- Basically First Fit approach that encourages the sharing of resources by:
  - always trying to find a sharable wavelength before allocating new ones to LSPs
- This applies only in the case of SPP

Concurrent RWA Algorithm

- For *all* LSPs in the bundle the RWA problem is solved *concurrently* with the following greedy approach



F_{obj}(LSP_REQ)

- $W_{New}(P_{pri})$ = # new wavelengths used by the primary path
- $W_{New}(P_{Sec})$ = # new wavelengths used by the secondary path
- $W_{Resv}(P_{Sec})$ = total # of wavelength used by the secondary path

$$F_{obj}(LSP\_Req) = \begin{cases} F_{obj}(P_{pri}), & \text{If no-protection case} \\ F_{obj}(P_{pri}) + F_{obj}(P_{Sec}), & \text{otherwise} \end{cases} \quad (1)$$

$$F_{obj}(P_{pri}) = W_{New}(P_{pri}) \quad (2)$$

$$F_{obj}(P_{Sec}) = \begin{cases} W_{New}(P_{Sec}), & \text{If dedicated-protection case} \\ W_{New}(P_{Sec}) + W_{Resv}(P_{Sec}), & \text{otherwise} \end{cases} \quad (3)$$

Pre-Processing Phase

- Both sequential and concurrent RWA algorithm pre-computes a set of candidate paths
- For each source-destination pair in the network
  - compute K-shortest (working) paths
  - for each of the K candidates compute L disjoint (protection) paths to be used should protection be required

Assumptions

- Single PCE scenario
- Bundling evaluated with a time-threshold based approach
- Connections may be synchronized and dependent, synchronization vector needed
- Control plane assumed to be implemented over Ethernet
- LSP set up time includes: path computation, communication/queuing time and signaling time
- Three different scenarios for protection: "*dedicated*", "*shared*" and "*no*" path protection
- Single link failure

Simulation Parameters

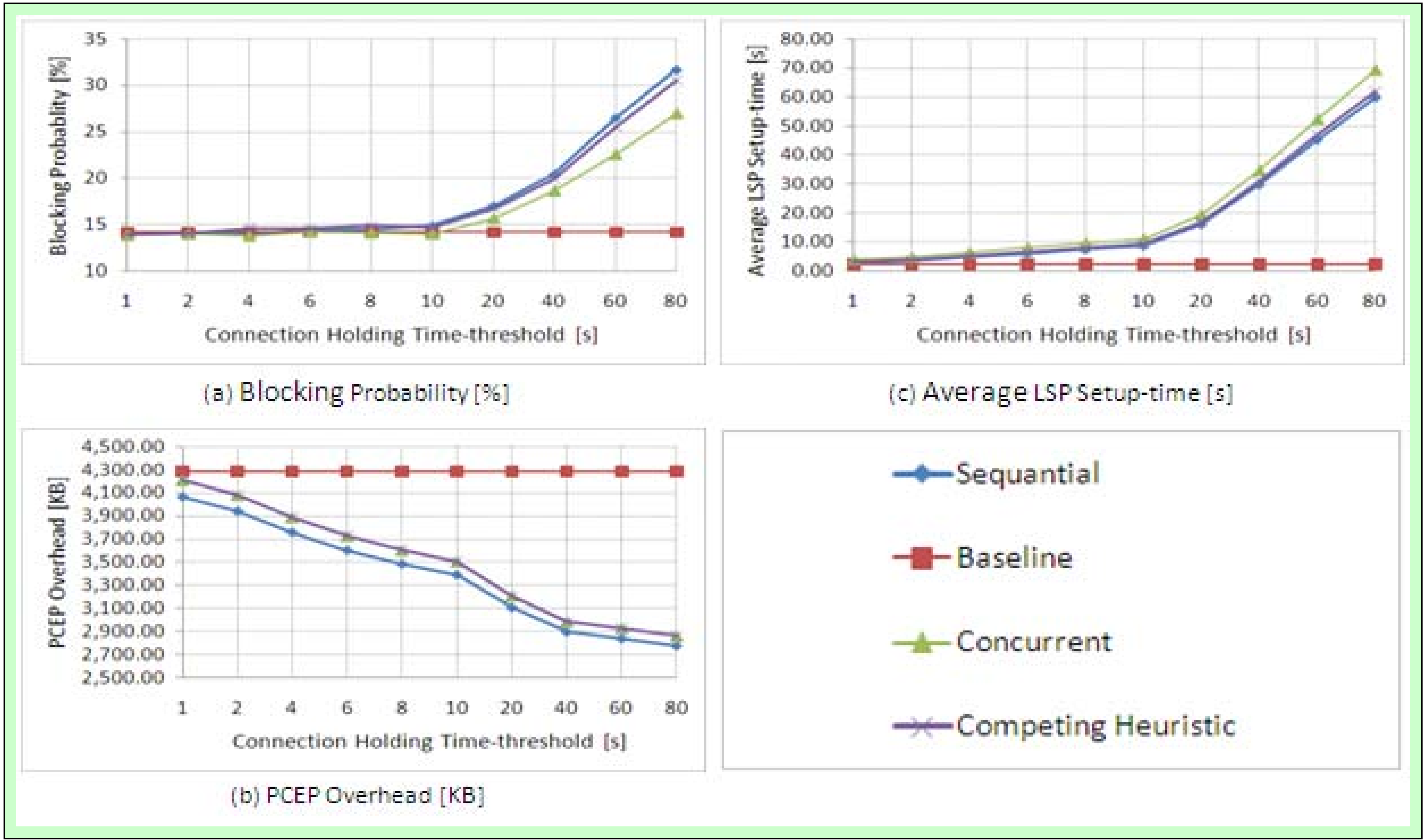
- Network Topology: EON (19 Nodes and 39 Links)
- Bidirectional fibers, 20 lambdas each
- DIR to emulate RSVP
- Connection request arrival follows Poisson distribution
- Connection holding time is exponentially distributed
- No wavelength conversion
- K = 4, L = 4

Performance Benchmarking

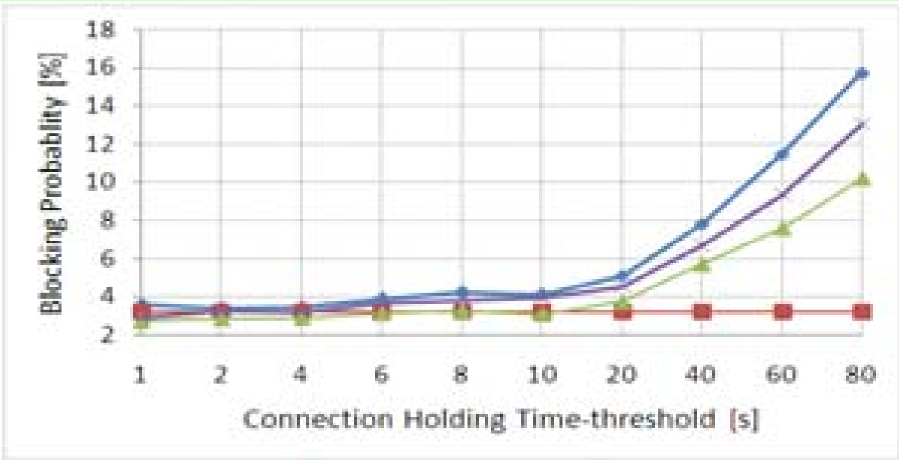
- Benchmarking of bundling approach performance done using the following heuristic:
  - *Baseline*: where bundling of connection request is not allowed
  - *Competing*: concurrent RWA algorithm from the literature [1]

[1] H. Zang, et al., "Path-protection Routing and Wavelength-Assignment in WDM Mesh Networks under Shared-Risk-Group Constraints". APOC 2001

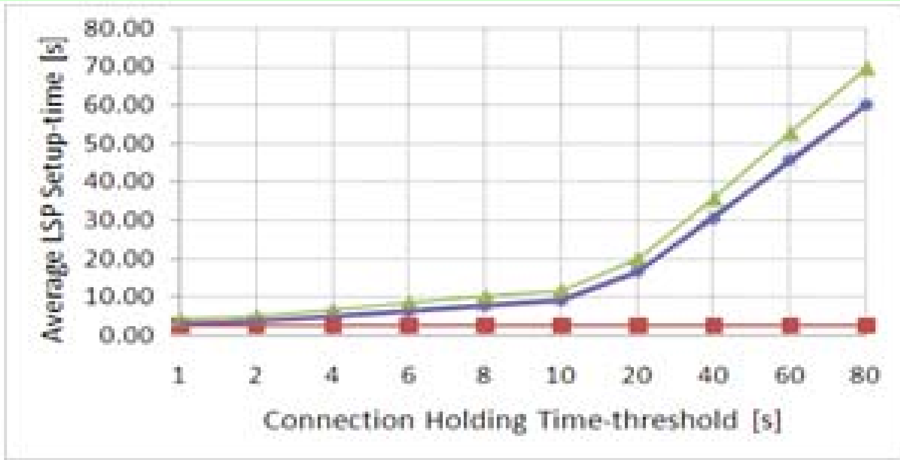
Results – Dedicated Protection



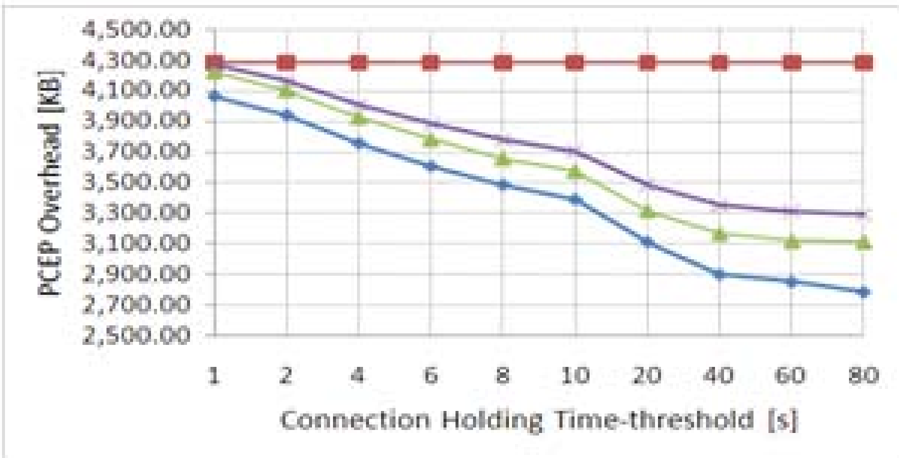
Results – Shared Protection



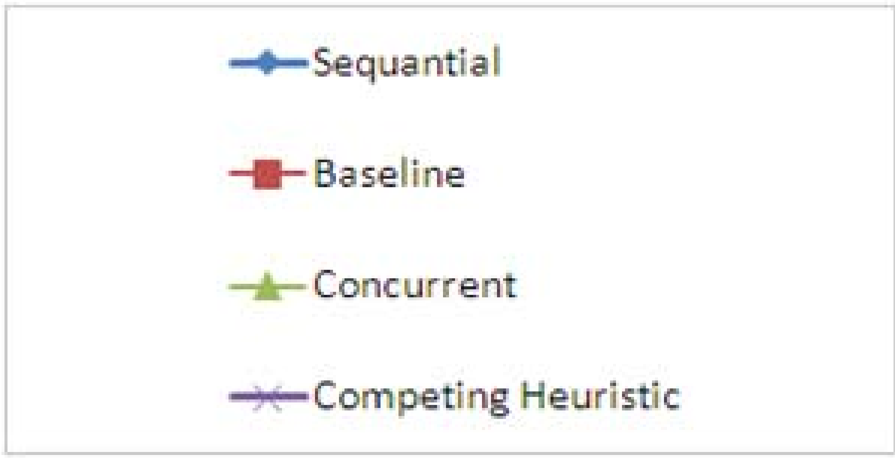
(a) Blocking Probability [%]



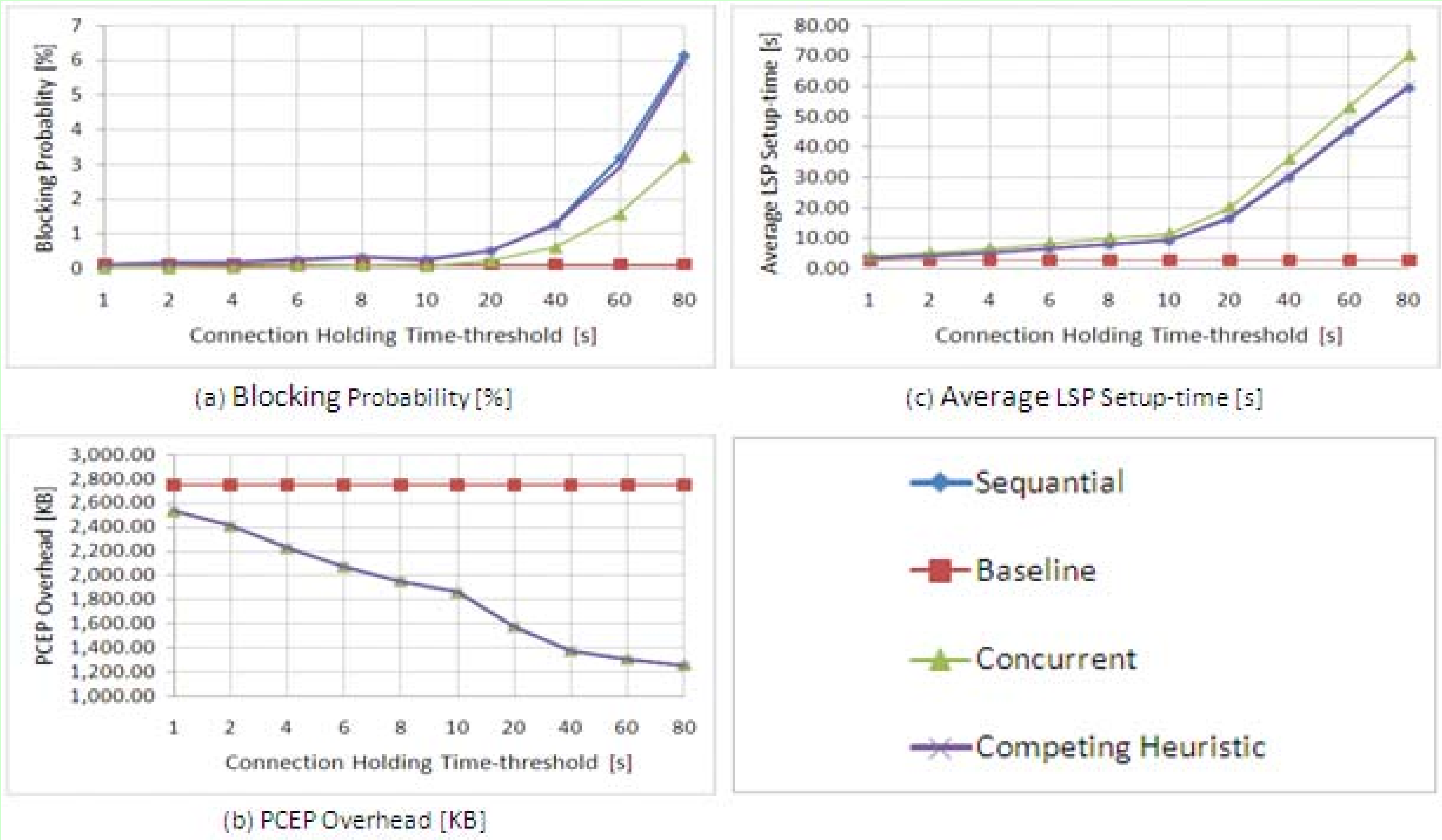
(c) Average LSP Setup-time [s]



(b) PCEP Overhead [KB]



Results – No Protection



(a) Blocking Probability [%]

(c) Average LSP Setup-time [s]

(b) PCEP Overhead [KB]

Conclusions

- Presented a performance study of a time-threshold based LSP requests bundling approach
- Benefits analysis of enabling the PCE to concurrently consider the entire LSP set in the bundle
- A concurrent RWA approach was presented and analyzed in a WDM network scenario where LSPs require dedicated, shared or no protection
- Carefully choosing an appropriate time threshold may lead to significant reduction in communication overhead without a noticeable increase of setup-time or overall network blocking probability

References

- J. Ahmed, P. Monti, L. Wosinska, “Benefits of Connection Request Bundling in a PCE-Based WDM Network,” in Proc. of European Conference on Networks and Optical Communications (NOC), (Invited Paper), June 10-12, Valladolid, Spain, 2009
- J. Ahmed, P. Monti, L. Wosinska, “Benefits of Connection Request Bundling in a PCE-Based WDM Network,” in Proc. of European Conference on Networks and Optical Communications (NOC), June 10-12, Valladolid, Spain, 2009
- J. Ahmed, P. Monti, L. Wosinska, “Concurrent Processing of Multiple LSP Request Bundles on a PCE in a WDM Network,” in Proc. of IEEE/OSA Optical Fiber Communication Conference and Exposition (OFC), March 21-25, San Diego, USA, 2010

Control Plane and Energy Considerations in PCE-Based WDM Networks

Amornrat Jirattigalachote, Pawel Wiatr, Ajmal Muhammad, Isabella Cerutti[1], Paolo Monti, Lena Wosinska

Sponsored by: Bone and All Optical Overlay Networks

[1] from Scuola Superiore Sant'Anna, Pisa, Italy

Energetic Issues in ICT

- Nowadays, energy consumption in Information and Communication Technology (ICT) is already between 2% and 10% in UK (total energy consumption)
- 2010 prediction: 15% overall, i.e., worldwide
- ICT sector is continuously increasing due to:
  - widespread use and high penetration
  - more and new applications and services → grids
  - always on: 24x7 from everywhere
- Expected growth rate of ICT energy is 10% per year
- Some ongoing initiatives are attempting to bring this problem to the ICT/users attention

Power-Efficient Networks: Opportunities (1)

Energy efficiency of networks can be improved by:

- Utilization of energy efficient systems and devices
  - high energy-efficiency devices
  - supporting multiple power modes
  - supporting multiple transmission speeds
- Making use of Multiple Transmission
  - dynamic and autonomous adjustment of the transmission speed with traffic
- Making use of Multiple Power Modes
  - full Power Mode (and Low Power Mode)
  - sleep Mode

Power-Efficient Networks: Opportunities (2)

- High-performance energy-aware networks
  - Support of QoS
  - Energy-aware deployment of the resources
  - Energy-aware exploitation of the resources
- Data and switching centers
  - Optimal placement of data/switching centers
  - Energy-efficient data/switching centers
- Monitoring the power consumption
  - Transmission system
  - Data/switching centers
  - Application level

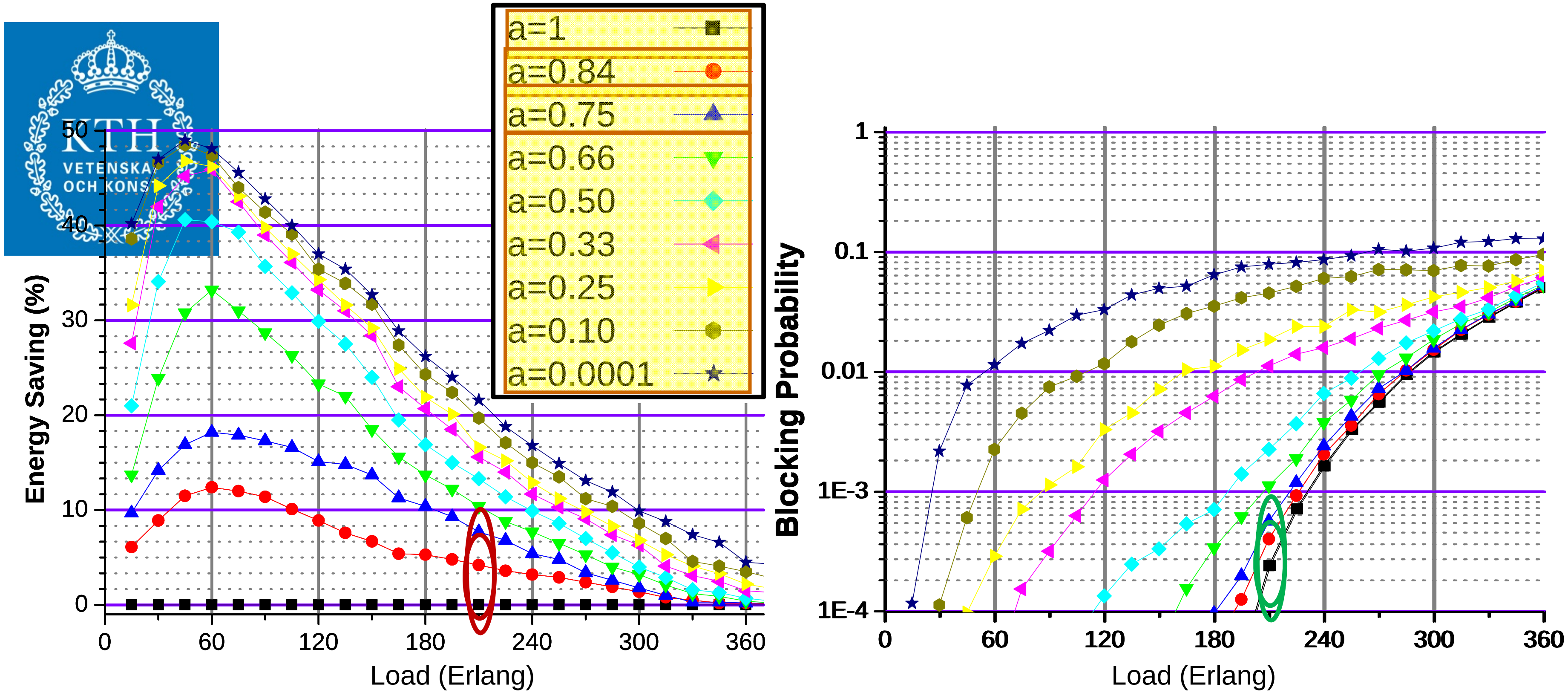
Power-efficiency and WDM networks

- WDM networks represent an important step towards energy efficiency
  - o lower per-bit switching cost (O-E-O not needed)
- Different green efforts in different contexts
  - o Traffic engineering
  - o Network engineering
  - o Network design
- Our focus is on
  - o Power aware routing and wavelength assignment (PA-RWA)
  - o Power awareness and resiliency

Power aware RWA

- Solutions for the PA-RWA problem: limit number devices to be switched-on while provisioning lightpaths
- This has an impact on length of the provisioned lightpaths
  - o they are on average longer
- There is a contradiction with goal of traditional RWA algorithms
  - o they tend to minimize the length of the lightpaths, in order to minimize network blocking probability
- Trade off between energy saved and network performance

PA-RWA – Trade off results



”Cost” of the link: use $C_{link} = a_{link} * E_{link}$, where $0 \le a_{link} \le 1$, E_{link} = energy consumption of a link; not in use $C_{link} = E_{link}$

Through proper selection of parameters, large energy saving can be obtained on the expense of small blocking performance degradation (see e.g. the results at load = 210 Erlang)

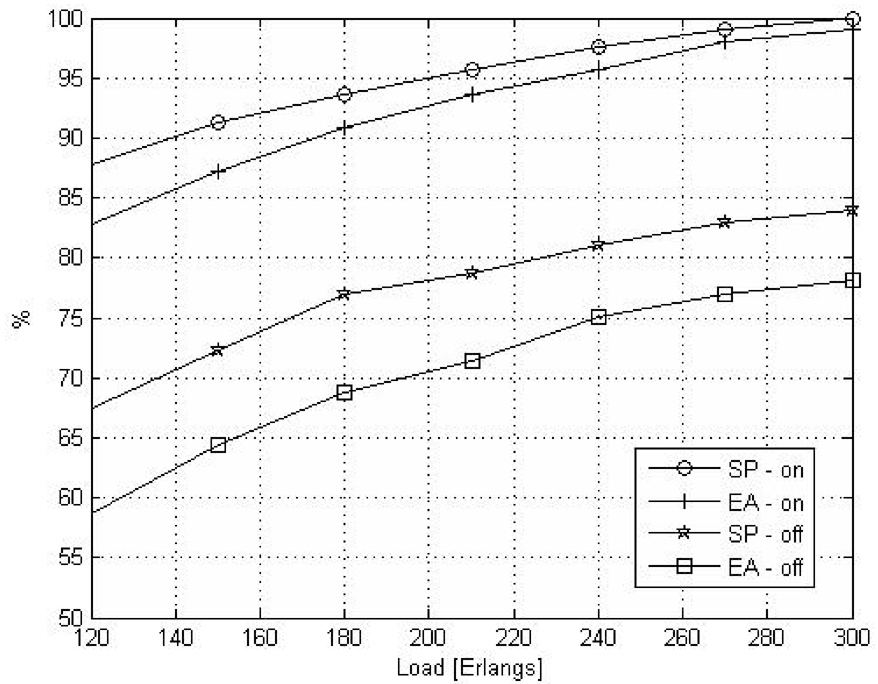
Power awareness and resiliency

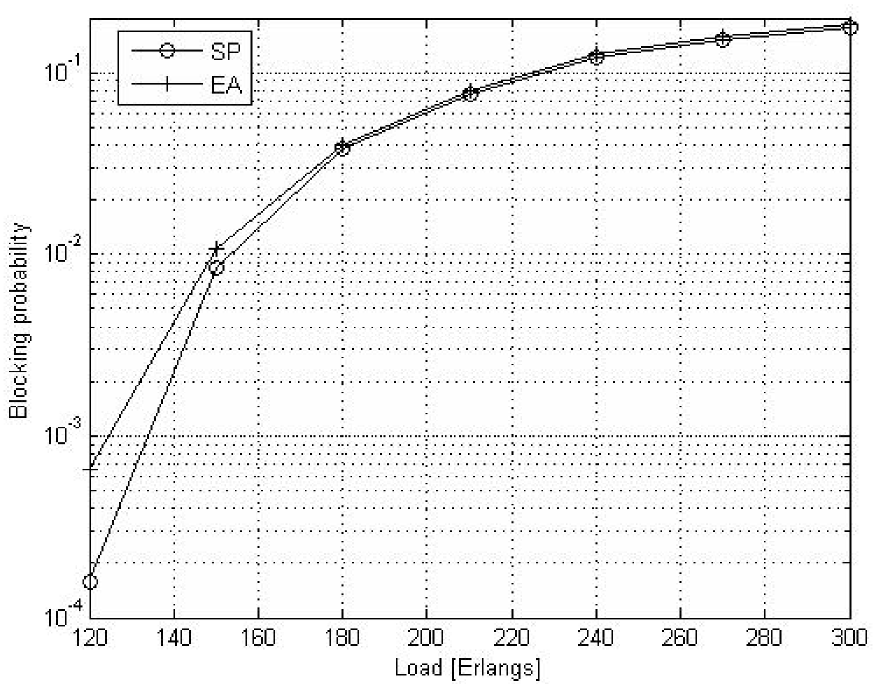
- Protection resources instrumental to guarantee resilience in WDM networks
- Protection resources utilized in different ways, e.g., 1+1 protection
- Issues
  - o protection resources always active along the secondary path
  - o protection paths are longer than their respective primaries
- Power consumed by protection resources in WDM networks becomes a key issue

Switch off of protection resources

SP: plain shortest path approach

EA: carefully chooses the route of secondary paths to maximize the power reduction achieved by switching-off protection resources





References

- A. Muhammad, P. Monti, I. Cerutti, L. Wosinska, P. Castoldi, A. Tzanakaki, “Energy-Efficient WDM Network Planning with Dedicated Protection Resources in Sleep Mode,” in Proc. of IEEE Global Communication Conference (GLOBECOM), December 6-10, Miami, FL, USA, 2010
- P. Wiatr, P. Monti, and L. Wosinska, “Green Lightpath Provisioning in Transparent WDM Networks: Pros and Cons,” , in Proc. of IEEE International Symposium on Advanced Networks and Telecommunication Systems (ANTS), Mumbai, India, December 16-18, 2010
- P. Monti, A. Muhammad, I. Cerutti, C. Cavdar, L. Wosinska, P. Castoldi, A. Tzanakaki, "Energy-Efficient Lightpath Provisioning in a Static WDM Network with Dedicated Path Protection," in Proc. of IEEE International Conference on Transparent Optical Networks (ICTON), (Invited Paper), June 27-30, Stockholm, Sweden, 2011
- P. Wiatr, P. Monti, L. Wosinska, "Power savings versus network performance in dynamically provisioned WDM networks," IEEE Communication Magazine - Optical Communication Series, Vol. 50, No. 5, pp. 48-55, May 2012

THANK YOU

QUESTIONS?

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