NETWORKS Conference, Budapest, 2008

Benchmarking RWA Strategies for Dynamically Controlled Optical Networks

Arie Koster[1] and <u>Sarah Ruepp</u>[2]

1) DIMAP, The University of Warwick
2) Networks Competence Area, DTU Fotonik, Technical University of Denmark

Outline

- Background and motivation
- Off-line and dynamic RWA
  - Wavelength assignment schemes for dynamic RWA
- Benchmarking study
  - Comparing off-line and dynamic RWA
  - Two case studies
- Results
- Conclusions

Background and motivation

Network control and traffic engineering are important in optical networks → Both off-line and dynamic approaches are considered for routing and wavelength assignment

Emerging technologies permit wavelength conversion → Investigate how the use of these converters influences the network performance

Previous studies show that advanced WA schemes save WC → How does dynamic WA compare to off-line optimization?

RWA in Dynamic and Off-line Case

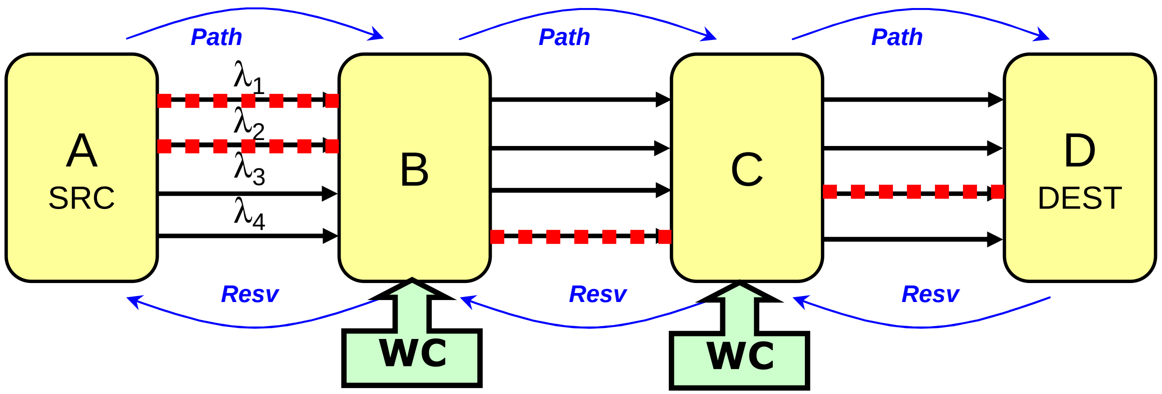
- Two different ways of carrying out RWA
  - Off-line: demands are known beforehand
  - Dynamic: demands arrive on the fly
- Challenges
  - Off-line case most likely allows better RWA, but what if demands are not known?
  - Dynamic case reflects dynamic arrival of traffic demands, but how big is the penalty of not knowing all demands?
  - Dynamic case requires updated knowledge of available resources, but how can the routing protocol handle this information demand (scalability)?

RWA in the Dynamic Case

- In an optical network, we need a route and a wavelength
- Updated wavelength availability does not scale well
- Find route and wavelength in de-coupled approach
- In the GMPLS framework
  - Use OSPF-TE to find the shortest route
  - Use RSVP-TE to find the best possible wavelength on that found route

A Closer Look on RSVP-TE

- Resource reservation (RSVP-TE):
  - Reserves required resources on specific route
  - *Path* messages: request a wavelength (label)
  - *Resv* messages: reserve resources



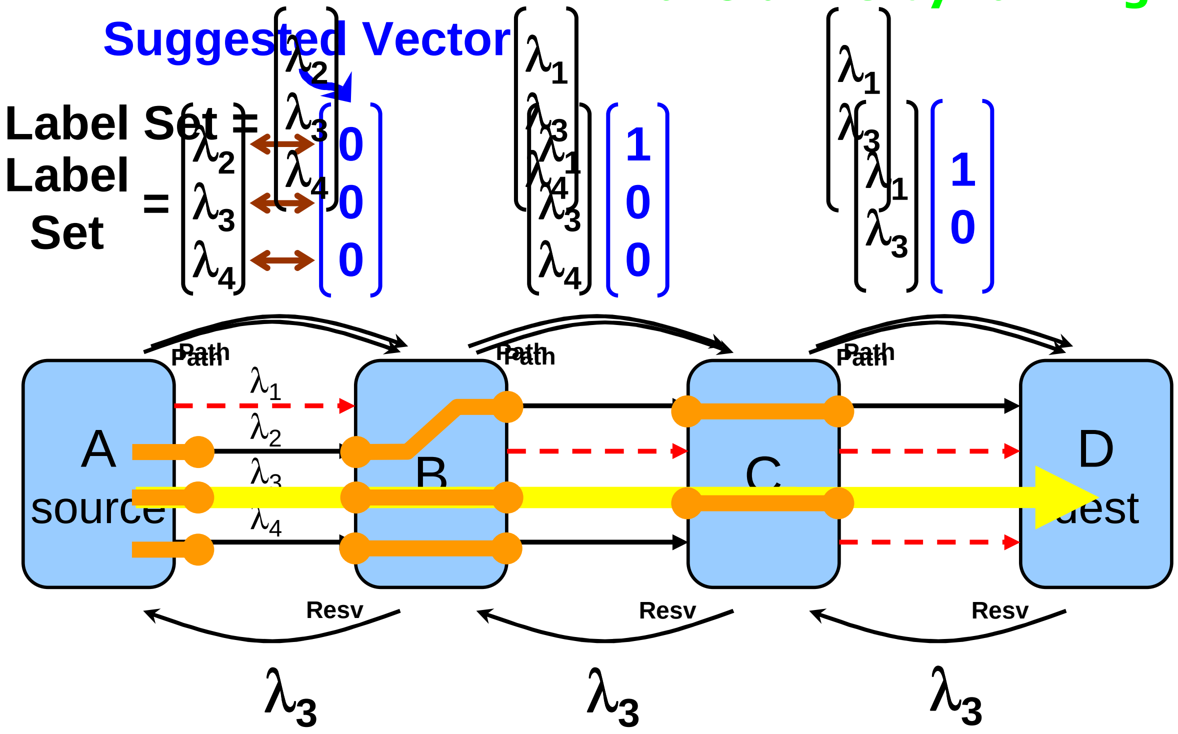
- Resources to reserve:
  - Span resources: wavelengths (labels)
  - Node resources: wavelength converters (WCs)
- Which wavelength should we choose?
- Can we minimize the use of expensive WCs?

Wavelength Assignment Schemes

- Find wavelength on specified route
- Different wavelength assignment schemes
  - Label Set (LS)
  - Suggested Vector (SV)

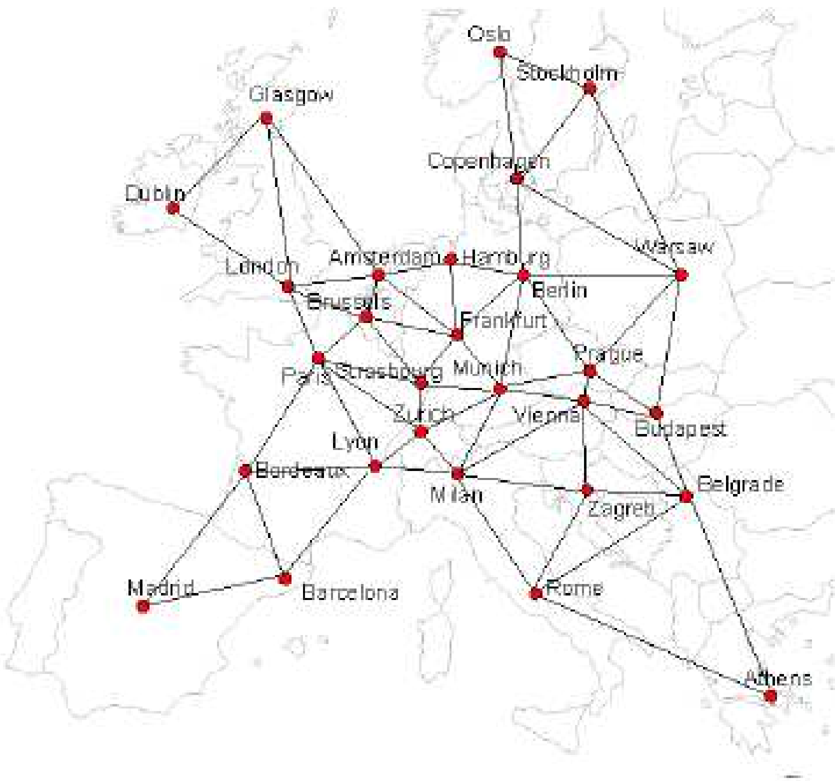
Standard protocol extensions: Not designed to avoid WC

Novel scheme: Designed to avoid WC by ranking labels



Performance study

- Comparison and combination of dynamic and off-line provisioning in a wavelength convertible network
- Tools:
  - Dynamic: OPNET
  - Off-line: CPLEX
- Two cases:
  - Case 1: WA comparison with unlimited WC
  - Case 2: RWA comparison with limited WC
- Metrics:
  - WC usage
  - Connection blocking



Case 1: WA comparison with unlimited WC

- Goal: count WCs used to accommodate connections to reach a specified network load
- Constraints:
  - Bidirectional connections -> same wavelength in both dir.
  - Compare WA only -> same routes for dynamic and off-line

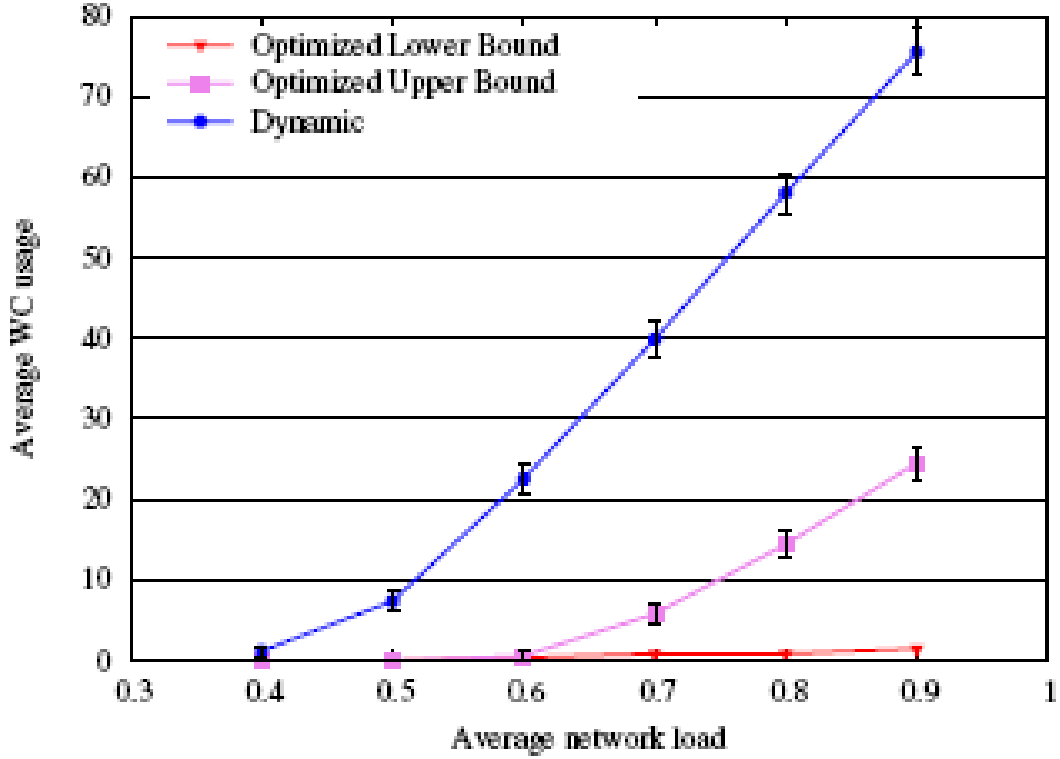
Dynamic approach:

- Dynamic connection arrival (i.e. no re-ordering possible)
- Find route based on hop count
- Use RSVP-TE for resource reservation
- Use Sugg. Vector for WC minimization

Off-line approach:

- Upper bound:
  - Beginning with the first link, repeatedly select a wavelength that can be assigned as far as possible, until no links of the lightpath are left anymore.
  - Push all lightpaths that need conversion to the beginning of the ordering, reversing the order of these lightpaths.
- Lower bound:
  - Based on edge coloring problem
  - Lower bound computed based on number of paths that cannot be colored with at most A colors, and hence form a lower bound for the number of converters.

Case 1: Results



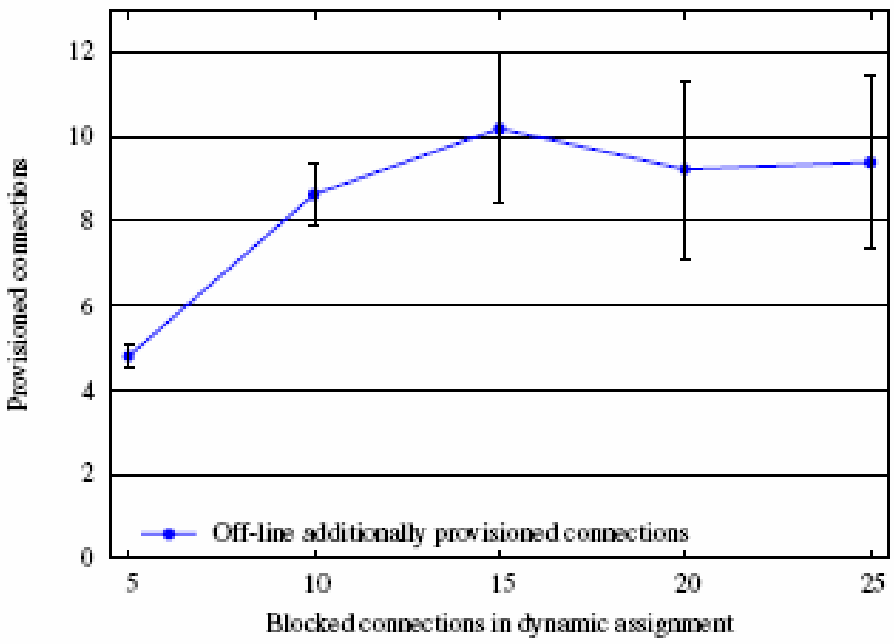
- WC increase at high loads
- Performance deviation between schemes at high loads
- In dynamic case, provisioning of later connections must fill gaps between already provisioned ones, while off-line schemes are allowed to re-order requests

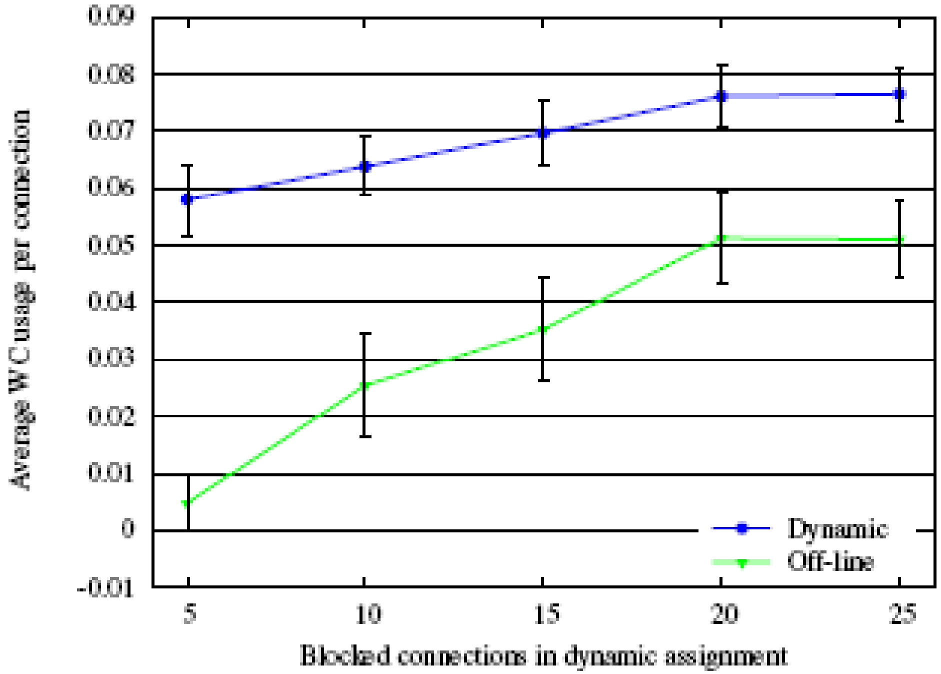
Case 2: RWA comparison with limited wavelength conversion

- Goal: count WC usage per connection and number of blocked connections
- Both R and WA may be optimized
- Stopping criterion for dynamic case: a given number of demands is blocked in dynamic simulation due to WC or bandwidth unavailability.
- Off-line RWA then tries to accommodate both accepted and blocked requests from dyn. sim

- Setup: severely limited conversion -> only 2 WCs per node

Case 2: Results





- Off-line provisioning case can accommodate many connections that are blocked in the dynamic case
  - Exact number likely based on network topology
- Dynamic case uses more WCs, their exhaustion leads to connection blocking

Conclusion

- Comparison of off-line provisioning to dynamic provisioning
  - using novel signaling protocol extension (Sugg. Vector) for RSVP-TE
- Re-ordering allows off-line scheme to achieve better performance
- Dynamic scheme does not know future demands, but still gives a good performance, especially at low-medium network loads

- Future work
  - Combination of off-line optimization and dynamic provisioning
  - Extension to network resilience

Thank you for your attention

- Contact info: Sarah Ruepp
  sr@com.dtu.dk
  DTU Fotonik
  Technical University of Denmark