Network Working Group G. Bernstein (ed.)
Internet Draft Grotto Networking
Young Lee (ed.)
Huawei
Intended status: Informational June 30, 2008
Expires: December 2008

Performance Evaluation of PCE Architectures for Wavelength Switched Optical Networks

draft-bernstein-pce-wson-evaluation-00.txt

Status of this Memo

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Abstract

In this note a number of PCE architectural and computational options are evaluated against a medium sized wavelength switched optical network. The key performance measures of overall and backward blocking are reported under different dynamic traffic scenarios. The corresponding reduction in connection blocking probabilities and computational advantages enabled by these architectural alternatives strongly warrant their inclusion in continuing PCE WSON work.

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1. Introduction

Path computation in Wavelength Switched Optical Networks (WSON) is typically subject to a wavelength continuity constraint. The nature of this constraint has lead to a number of different practical schemes for path computation in WSONs. The general class of these computational problems is typically referred to as Routing and Wavelength Assignment (RWA) problems. It must be emphasized that the wavelength assignment (WA) mentioned here is an integral part of path computation and not a part of network planning or static configuration problem and hence falls within the scope of the path computation element (PCE) architecture.

In the WSON Framework draft [Frame] three basic computational architectures were described:

o Combined RWA --- Both routing and wavelength assignment are performed at a single computational entity.

- o Separate Routing and WA --- Separate entities perform routing and wavelength assignment. The path obtained from the routing computational entity must be furnished to the entity performing wavelength assignment.

- o Routing with Distributed WA --- Routing is performed at a computational entity while wavelength assignment is performed in a distributed fashion across nodes along the path.

The implications to the control plane of these three approaches are described in [Frame] and [WSON-PCE]. In reference [ECOC-08] initial simulations are reported on the performance of these different approaches along with various computational options. Here we will review those aspects of [ECOC-08] relevant to WSON PCE standardization efforts and discuss further simulations under different traffic load and network sizing parameters. Note that these results are expressed in the form of graphs that do not appear in the text version of this draft.

In circuit switching networks such as WSON a key performance measure used to evaluate network performance under dynamic loads is the probability that a connection request will be blocked. For GMPLS based network there can be a portion of the overall blocking, termed "backward blocking" in [ECOC-08] due to resource contention during the signaling phase of lightpath set up, i.e. when two different RSVP-TE instances try to reserve the same wavelength on the same link. In this note we will primarily be concerned with the overall blocking performance of the various PCE computation architectures for WSON.

The simulations were carried out on a Pan European network topology with 27 optical nodes and 55 WDM links [Should we reference Alessio's OFC paper?] as shown in Figure 1. Each link carries either 32 or 80 wavelengths depending upon the simulation run. The traffic is uniformly distributed among all node pairs, lightpath requests arrive following a Poisson process with an exponentially distributed inter-arrival time (with average 1/u seconds) and holding time (with average 1/lambda=60s seconds or 6000s depending on simulation run). The load offered to the network is thus expressed in Erlang as lambda/u and it is varied by controlling the inter-arrival time. In all the figures, each simulation point is plotted with the confidence interval at 90% of confidence level.

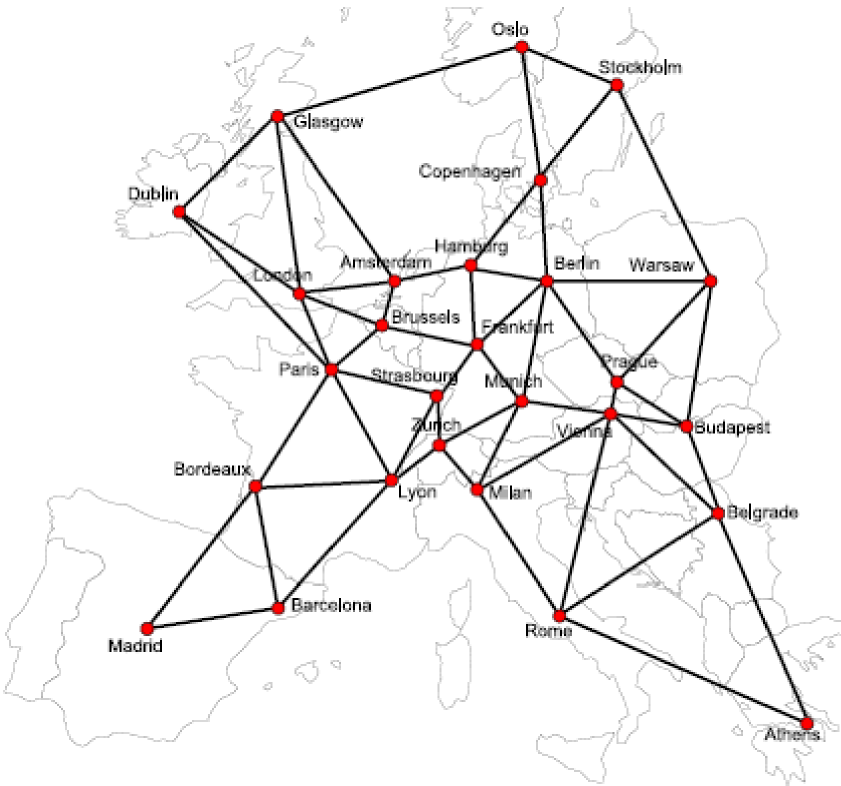

Figure 1

2. Simulated PCE Architectures and Variations

2.1. Routing with Distributed RWA

The following variants were studied:

1. In the "Fully Distributed" (FD) case the PCE was assumed to reside on the originating node for the light path and only had aggregate wavelength usage (bandwidth) information. In this case a least congested route (LCR) path selection algorithm was used.

2. In the "R-" case a centralized PCE was assumed to compute paths (but not wavelength assignment) based on the same LCR algorithm as above. Then distributed wavelength assignment via signaling was utilized. For the purposes of blocking probability calculation this leads to similar results as the previous case.

3. In the "R+" case a centralized PCE was assumed to compute paths (but not wavelength assignment) based on detailed link wavelength utilization/availability. A variant of the LCR algorithm that understood the wavelength continuity constraint was employed.

2.2. Separate Routing from Wavelength Assignment

In this case it was assumed that routing (but not wavelength assignment) was performed at the ingress node based only on aggregate wavelength utilization (bandwidth). The results of this computation are then passed to a separate PCE server for wavelength assignment (WA). It was assumed that this separate WA PCE had detailed knowledge of link wavelength utilization.

An important variation of the above is when the first route computation element (in this case on the ingress node) calculates K alternative paths which are then fed to the WA PCE which will then choose one of the paths and a viable wavelength (where possible). This scenario is denoted by "WA-k" on the various graphs and simulations were performed for k = 2 and k = 3.

2.3. Combined Routing and Wavelength Assignment

In this case in the simulations a central PCE was responsible for both routing and wavelength assignment. This requires the PCE to run a reasonably sophisticated algorithm and have detailed link wavelength utilization information. This is denoted by "R+WA" in the simulation results.

3. Simulation Runs and Results

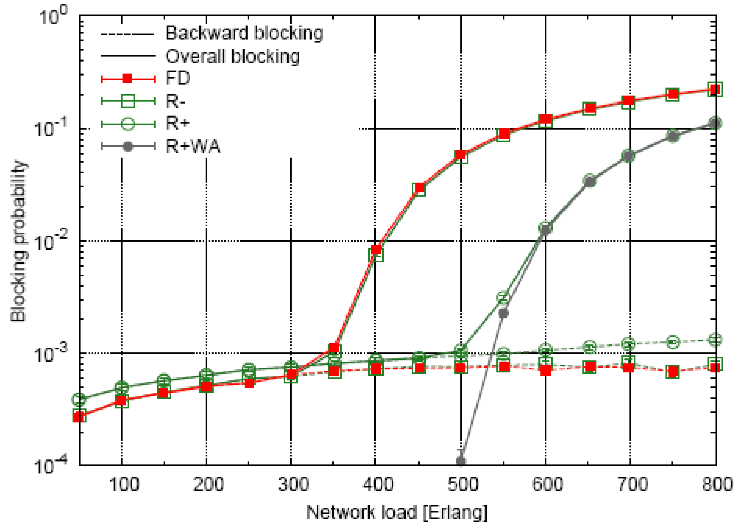

Figure 2. FD, R-, R+ and R+WA scenarios with 32 wavelengths per link, $1/\mu = 60s$.

Figure 2 shows the following inferences:

o R+WA (Combined Routing and Wavelength Assignment) performs the best due to the absence of backward blocking while FD suffers a highest blocking.

o In the heavy network load, R+ is as good as R+WA due to wavelength-continuity aware routing scheme (WC-LCR) employed by R+ scheme in which case there is virtually no backward blocking similar to R+WA.

o R- and FD suffer the worst blocking performance due to the routing scheme employed that is not wavelength continuity aware.

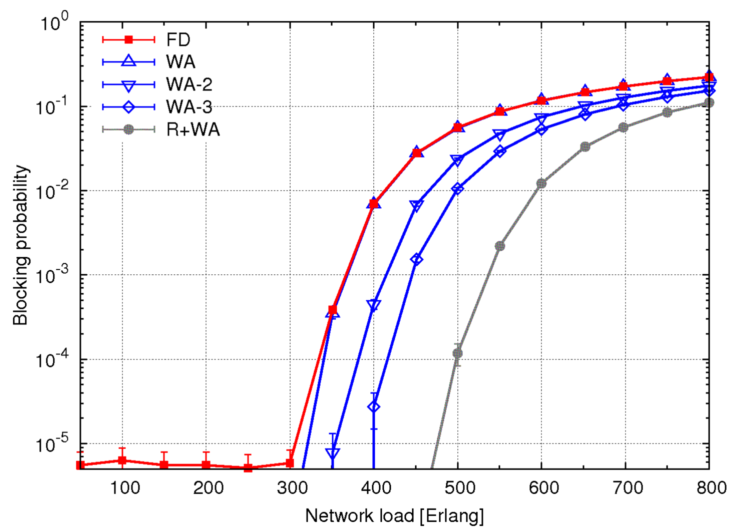

Figure 3. WA, WA-2, WA-3 and R+WA scenarios with 32 wavelengths per link, 1/u = 60s.

Figure 3 shows the following inferences:

- o For the medium and heavy loads, WA and FD show high blocking probability due to the routing schemes that is based on aggregated bandwidth information.

- o WA-k (k=3) significantly improves the WA assignment performance.

Simulation results with a longer holding time (100x) maintain the similar inferences obtained for the case of a shorter holding time.

4. Interpretation of results and Conclusions

(a) Importance of accurate wavelength usage information, e.g., FD and R- compared to R+, WA
(b) Reduction (elimination) of backward blocking in the R+WA, WA, and WA-K situations
(c) The usefulness of WA-k in reducing blocking compared to R+, WA and the simplification compared to R+WA

In terms of the PCE architecture options, centralized wavelength assignment shows a clear performance benefit over distributed wavelength assignment.

In regards to routing, separating routing from wavelength assignment could be a viable option to consider. In this case, the number of routes fed to a central WA PCE affects the overall performance.

5. Security Considerations

This draft in showing the advantages of the PCE R+WA and WA-k architectures in WSON networks, makes clear the need for securing the PCE architecture in general but does not add any new security requirements. It should be noted that WSON light paths and link resources are relatively scarce and expensive resources and hence a potentially higher value target for attacks.

6. IANA Considerations

This draft does not require IANA services.

7. Acknowledgments

This document was prepared using 2-Word-v2.0.template.dot.

References

7.1. Informative References

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[WSON-PCE] Y. Lee and G. Bernstein, "PCEP Requirements and Extensions for WSON Routing and Wavelength Assignment", work in progress: draft-lee-pce-wson-routing-wavelength-02.txt.

Author's Addresses

Aessio Giorgetti
Scuola Superiore Sant'Anna, Pisa, Italy
Email: a.giorgetti@sssup.it

F. Paolucci
Scuola Superiore Sant'Anna, Pisa, Italy
Email: fr.paolucci@sssup.it

Filippo Cugini
CNIT, Pisa, Italy
Email: filippo.cugini@cnit.it

L. Valcarenghi
Scuola Superiore Sant'Anna, Pisa, Italy
Email: valcarenghi@sssup.it

P. Castoldi
Scuola Superiore Sant'Anna, Pisa, Italy
Email: castoldi@sssup.it

Greg Bernstein (Ed.)
Grotto Networking
Fremont California, U.S.A.

Phone: (510) 573-2237
Email: gregb@grotto-networking.com

Young Lee (Ed.)
Huawei Technologies
1700 Alma Drive, Suite 100
Plano, TX 75075, USA

Phone: (972) 509-5599 (x2240)
Email: ylee@huawei.com

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Acknowledgment

Funding for the RFC Editor function is currently provided by the Internet Society.