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Networking Laboratory

Adaptive Load Balancing Using MPLS

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Introduction

- MPLS provides capabilities to
  - predefine paths between source and destination pair
  - split traffic arbitrary to different paths
- Load balancing
  - increases the throughput by moving traffic from the congested part of network to some other part
- Adaptive load balancing
  - Balancing based on measured link loads
    - End-to-end monitoring (probe packets)
    - Link monitoring: Label Switched router (LSP) monitors its outgoing links

Proposed concepts

- MPLS Adaptive Traffic Engineering (MATE).
  - *A. Elwalid et al.: MATE: MPLS Adaptive Traffic Engineering. Infocom 2001.*
  - The traffic load is balanced using distributed adaptive algorithm.
  - The knowledge of the traffic demand matrix is not required.
  - The optimization is based on the measured link load.
- Label Distribution over Multipath (LDM)
  - *J. Song et al.: Adaptive Load Distribution over Multipath in MPLS Networks ICC'03, Anchorage, Alaska, May, 2003.*
  - The traffic is split dynamically on flow-level into multiple paths.
  - The set of LSPs is defined statistically. The LSP for the incoming traffic is selected based on congestion and the length of the path.

Objectives of research

- To study how load can be balanced adaptively based on measured link loads
- To find reasonable convergence times for the algorithms
- To study the stability of adaptive routing
- To study the effect of the measurement errors
  - The effect of EWMA

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Algorithms

1. Minimizing the maximum link utilization
   - Traffic loads of LSPs that use the most congested link are moved to some other LSPs
   - The choice of a new LSP varies

2. Minimizing the delay of the paths
   - For each OD-pair traffic loads of LSPs which have a longest delay (or the derivative of delay) are moved to some other LSPs
   - Also three ways to choice a new LSP

Testing of algorithms

- We like to know
  - how many iterations are needed to balance the load
  - difference between the obtained result and optimal value
- Initial phase: traffic allocated using shortest paths
- We assume a constant traffic load
- Traffic load moved away from congested links/paths per OD-pair is d_k/g, where d_k is the traffic demand of OD-pair k and g is the level of the granularity
- Test-network: 10 nodes, 52 links and 72 origin-destination pairs

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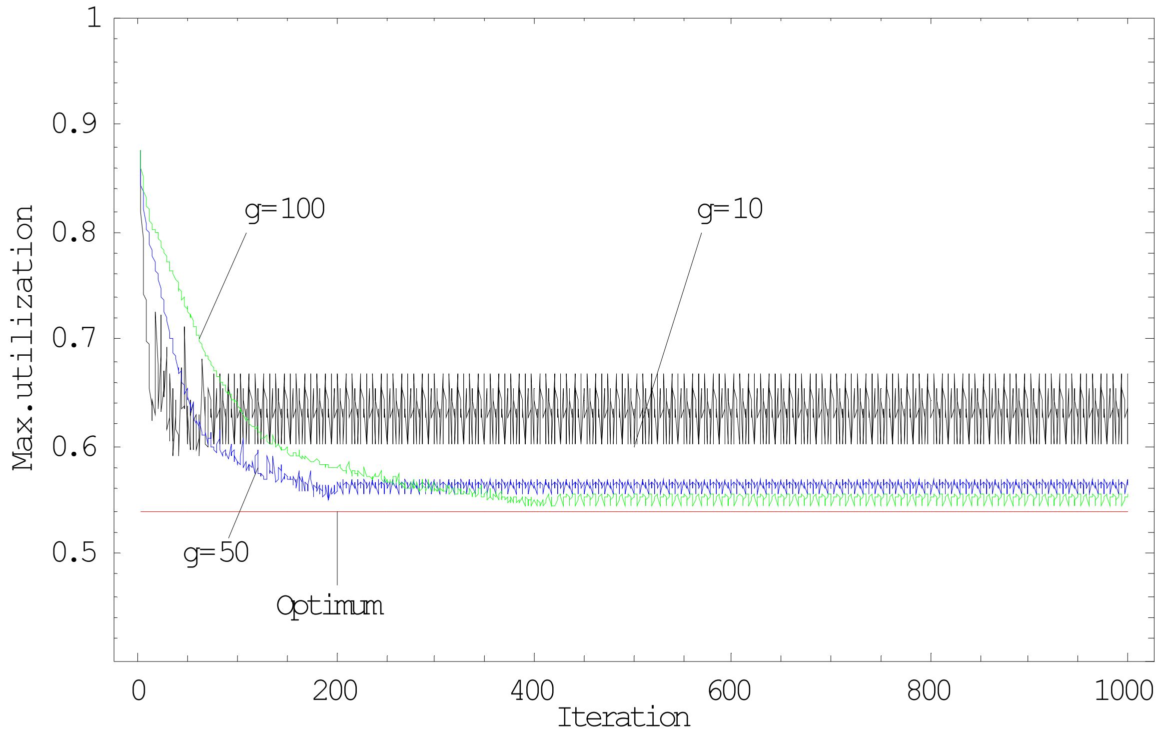
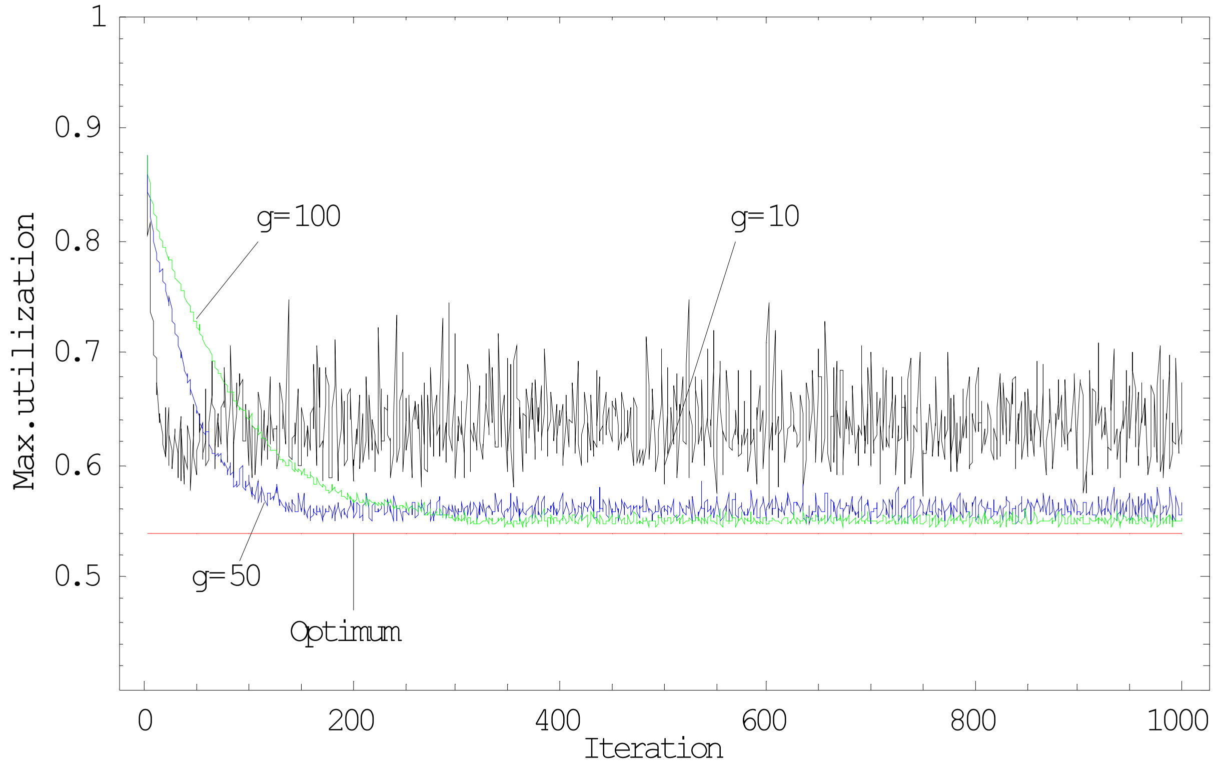
Results

1. Minimizing the maximum link load
   (1a) The choice of the next LSP deterministic



(1b) The choice of the next LSP probabilistic



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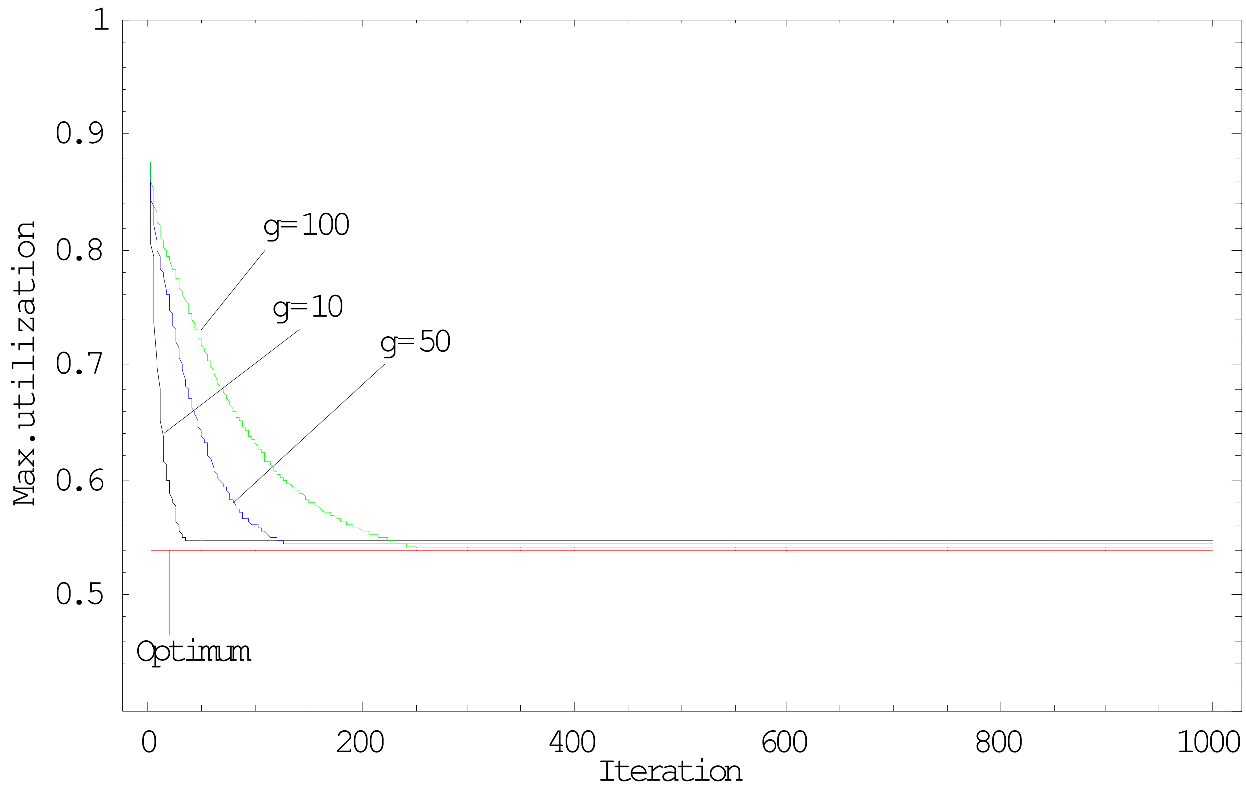
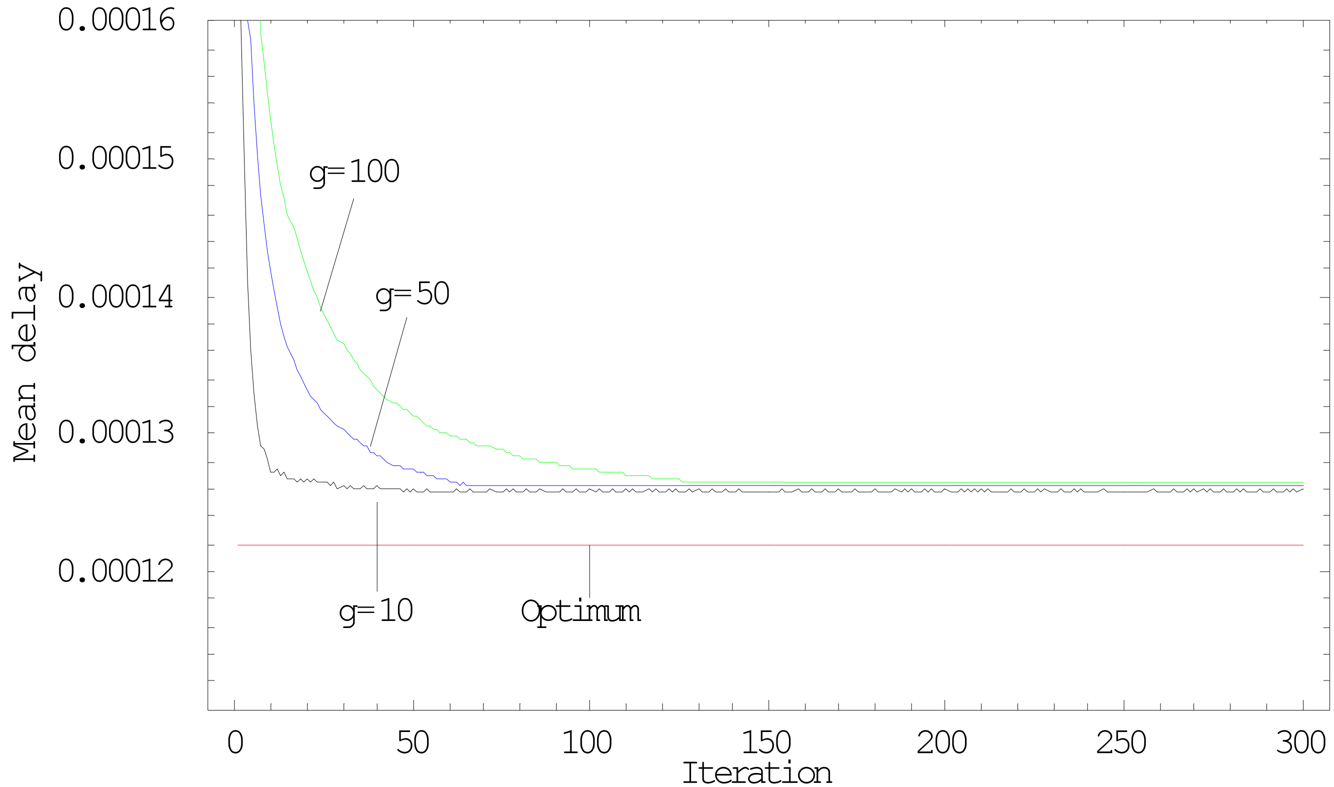
(1c) The choice of the next LSP probabilistic with the condition that the maximum load does not increase

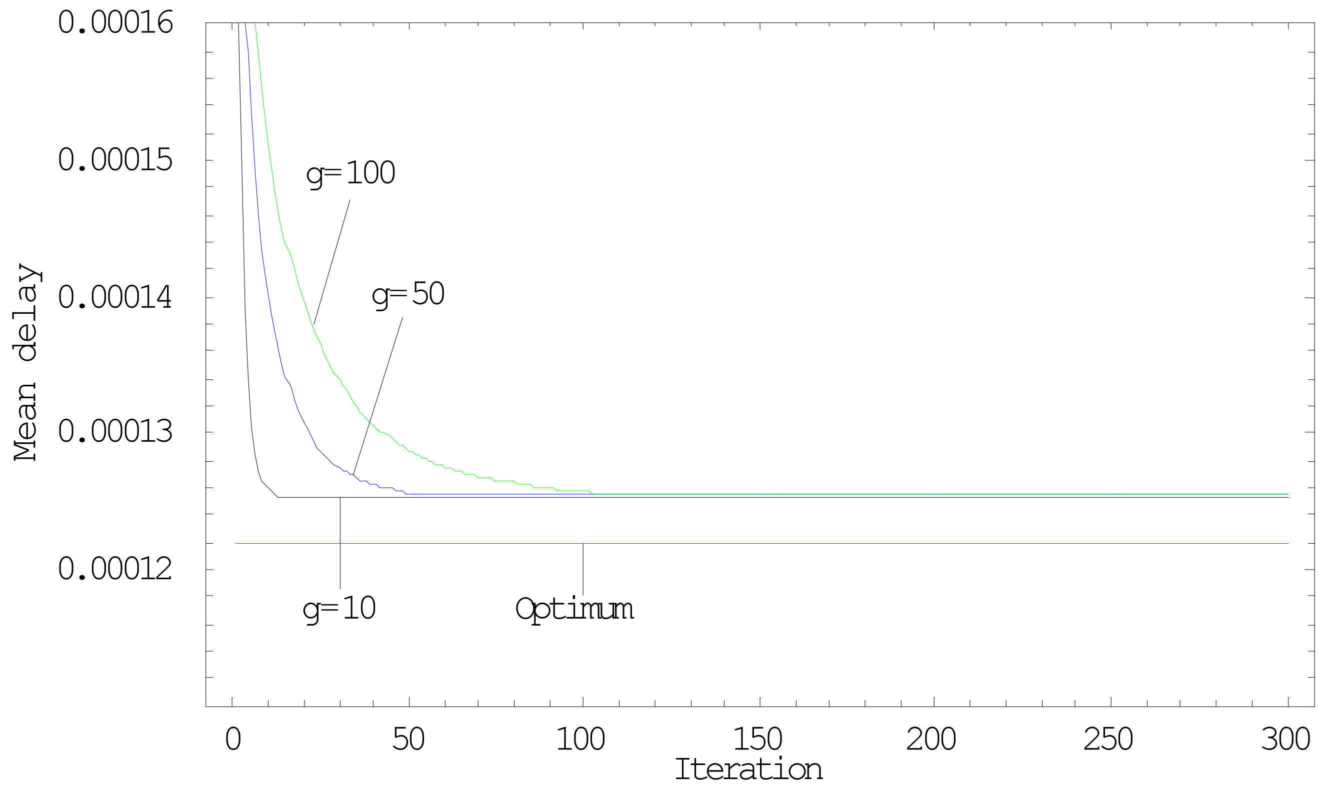


2. Minimizing the delay of the paths

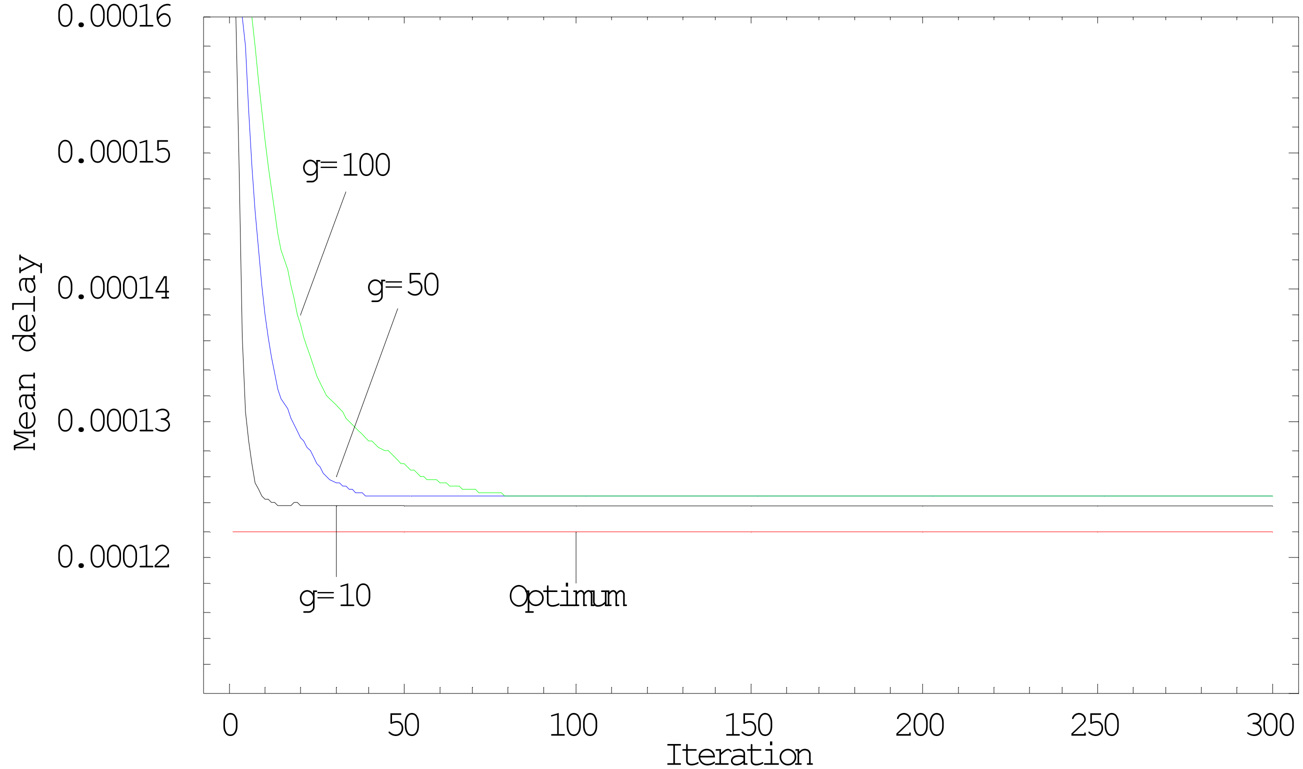
(2a) The choice of the next LSP probabilistic



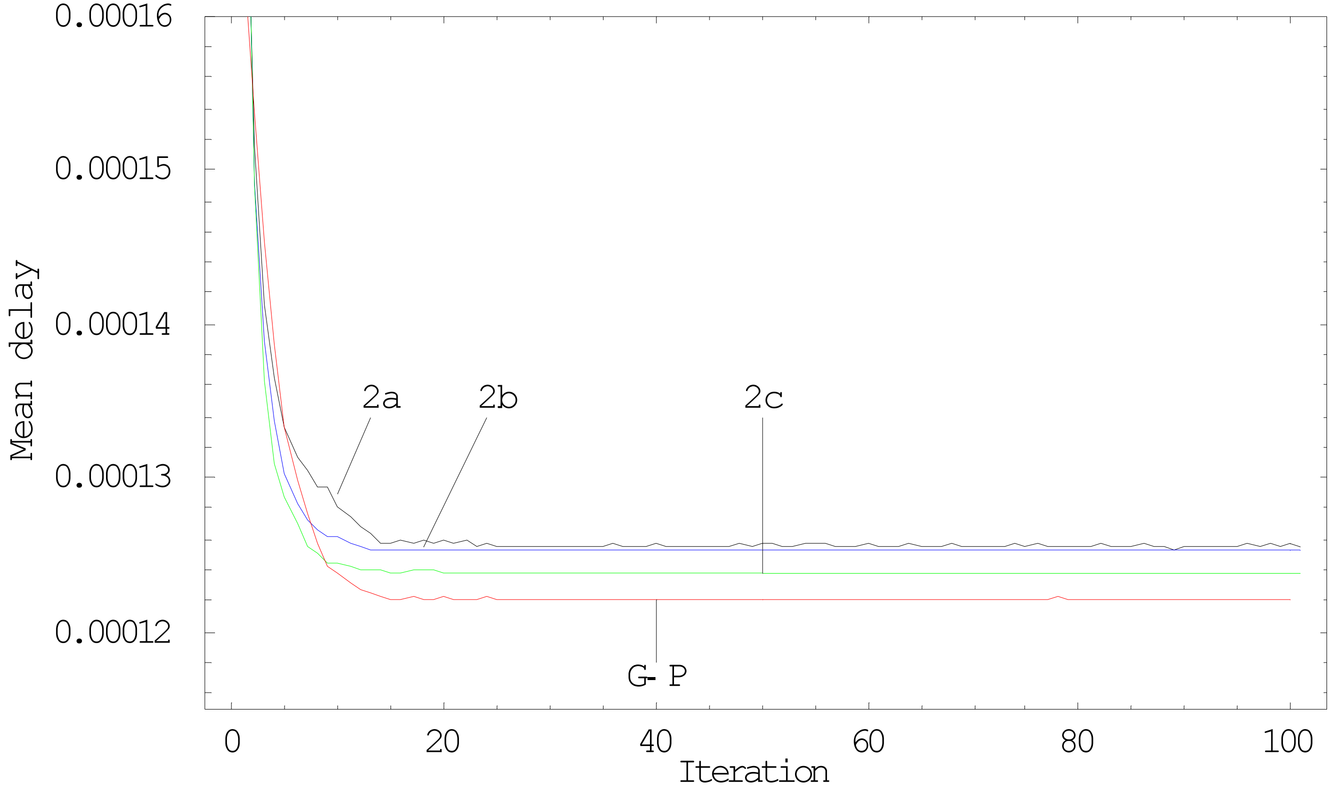
(2b) The next LSP is path with the smallest delay



(2c) The load is moved from path with the maximum first derivative length to the path with the minimum first derivate length



- Comparison of the algorithms to minimize the mean delay



Adaptation to traffic measurement errors

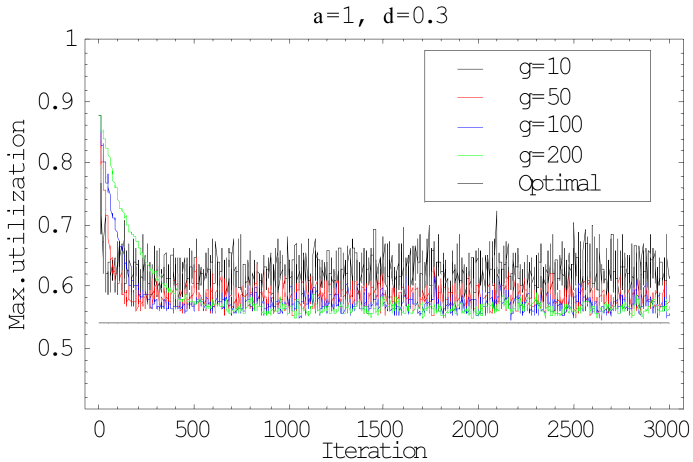
- The measurement results may be biased due to measurement errors or too long or short measurement periods
- Exponential weighted moving average (EWMA) is a common approach to reduce the effect of measurement error

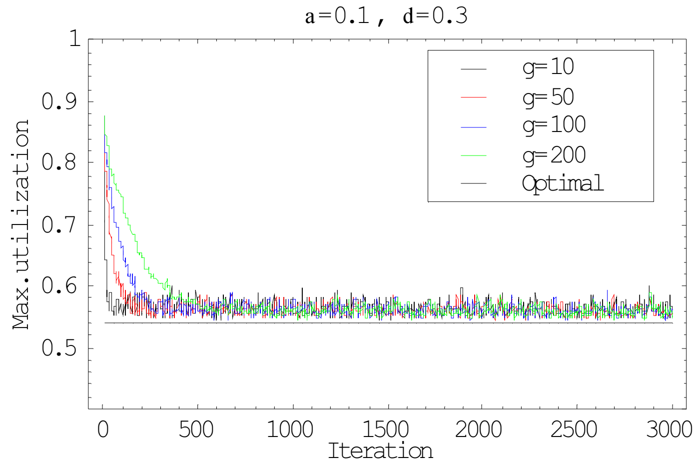
$$\hat{x}(t_n) = \alpha x(t_n) + (1-\alpha)\hat{x}(t_{n-1})$$

- We model the variability in the link measurements by a normal distribution, the variation coefficient of the measurement is δ times the mean traffic load

Results

- The results for algorithm 1c: The choice of the next paths probabilistic with constraints





Conclusion

- We have studied how load can be balanced in a network using simple heuristic approaches.
  - Measured link loads
  - Incremental changes
- The obtained result in many cases are very similar the optimal values.
- Small step-size ensures convergence also when information of the link loads is unreliable.

Further work

- Comparison of traffic engineering based on MPLS and OSPF
  - Setting optimal OSPF-weights and splitting ratios
- Use of real traffic traces in evaluation process of the algorithms