Minimizing re-routing in MPLS networks with preemption-aware constraint-based routing

Computer Communications

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Outline

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Introduction (1/2)

- Computation of explicit paths with bandwidth requirement
  - Local constraint-based routing by typically, CSPF (Constrained Shortest Path First) algorithms
  - Global path optimization
- Little work on the dynamics of LSP preemption
  - Most proposed CSPF algorithms operate in a simple way regarding LSP priorities
  - When computing the path for an LSP, reservations of lower priority LSPs are not taken into account

Introduction (2/2)

- In this paper
  - The effect of CSPF-based path selection methods on the dynamics of LSP preemption is studied
  - New CSPF algorithms are proposed. They take into account the available resource reservation information of lower priority LSPs.
  - The proposed algorithms aim at minimizing preemption of lower priority LSPs and thus, enhance the stability of multi-priority MPLS networks.

Preemption in MPLS Networks (1/2)

- RSVP-TE and CR-LDP both support ‘holding’ priority and ‘setup’ priority (range of 0 to 7)
- IGP extensions of OSPF and ISIS propose to
  - Flood the maximum bandwidth (B_{MAX}) and the maximum reservable bandwidth (B_{max})
  - Distribute $\mathbf{B_u}=(B_{u0},B_{u1},\ldots,B_{u7})$, *unreserved bandwidth* at each of the 8 priority levels on a specific link. $\mathbf{B_u}$ is counted in an accumulative way i.e.if a priority-*s* LSP is established, B_{ui} through B_{u7} will decrease.

Preemption in MPLS Networks (2/2)

- Simplest bandwidth constrained CSPF: an LSP with setup priority *s* and bandwidth requirement B_{LSP}
  - Mark all links invalid where $B_{us} < B_{LSP}$ where
  - Run Dijkstra's shortest path algorithm on the graph composed of the links not marked as invalid
- Admission control and preemption decision
  - Admission control function: upon a new LSP request, determines to admit, refuse or preemption required
  - Selection of LSPs to be preempted is a local matter: in this paper, LSPs can't be preempted from the *n*th level until there are LSPs on the (*n*+1)th priority level.

Previous Work

- Widest-shortest path algorithm (WSPF)
  - 2nd metric: bottleneck link unreserved bandwidth
- Residual bandwidth ratio method (RB-CSPF)
  - 2nd metric: $(B_{us}-B_{LSP})/(B_{max})$
- Discrete link cost method
  - 2nd metric: discretized load-based additive link-cost
- Shortest-widest path algorithm
- Shortest-distance algorithm
  - Dynamically balance the impact of hop count and path load by a variable n, i.e. $n=0 \rightarrow$ shortest path; $n=\infty \rightarrow$ widest path

Proposed preemption-aware CSPF methods (2/3)

- Preemption measures
  - Free bandwidth $B_{free} = B_{u7}$
  - Per priority preempted bandwidth $\mathbf{B_p}=(B_{p0},B_{p1},\ldots,B_{p7})$

procedure CalcBwPreemptionVector($\mathbf{B}_u$, B_{LSP})

  $\mathbf{B}_p = 0$

  $B_{u(-1)} = B_{max}$

  for ($i = 7, i \geq 0, i$–)

    if $B_{LSP} \leq B_{ui}$ **return** $\mathbf{B}_p$

    $B_{pi} = min((B_{LSP} - B_{ui}), (B_{u(i-1)} - B_{ui}))$

  end for

  return $\mathbf{B}_p$

end procedure

Proposed preemption-aware CSPF methods (3/3)

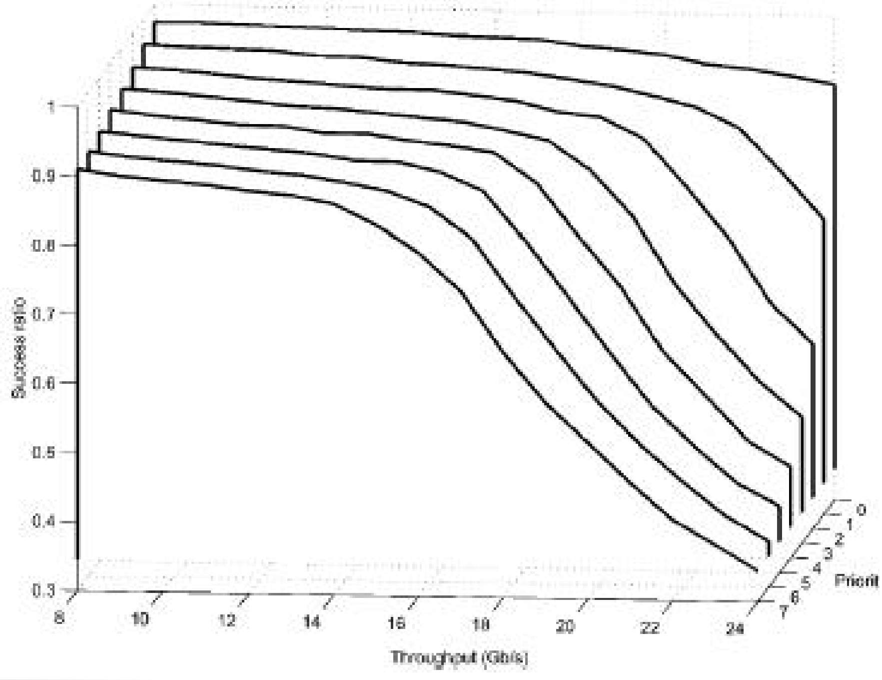
- Priority-aware CSPF metrics
  - Maximize free bandwidth
    - Aim at preempting the fewest possible lower priority LSPs in terms of sum bandwidth
  - Minimize affected priority levels
    - Aim at minimizing the affected priority levels
    - Define $\mathbf{B}_p^1 < \mathbf{B}_p^2$ iff for their first different coordinate with index *i*, $B^1_{pi} < B^2_{pi}$
- Priority-aware CSPF algorithm
  - Prune links for which $B_{us} < B_{LSP}$
  - Run shortest path selection based on original OSPF metric
  - Utilize preemption information to select a candidate path

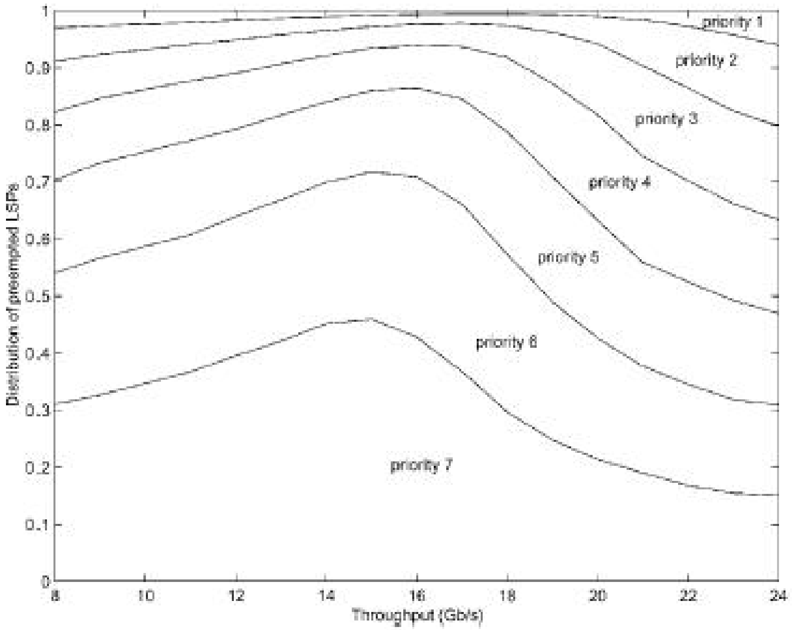
Numerical results (1/4)

- Simulation model
  - Network topology: 31 backbone nodes and 102 links
  - Link capacities: vary between DS-3 and OC-192, with the majority of links having OC-12 capacity
  - LSP: random placed with (0, B_{MaxLSP}] uniform-distributed bandwidth, B_{MaxLSP} is 8-10% of OC-12, and [0-7]uniform-distributed priority level
  - Compared algorithms:
    - ‘random’: basic shortest path first algorithm,
    - ‘widest’: widest-shortest algorithm
    - ‘residual bw’: residual bandwidth ratio method
    - discrete link cost method and
    - Proposed algorithms: ‘max free bw’ and ‘min affected levels’

Numerical results (2/4)

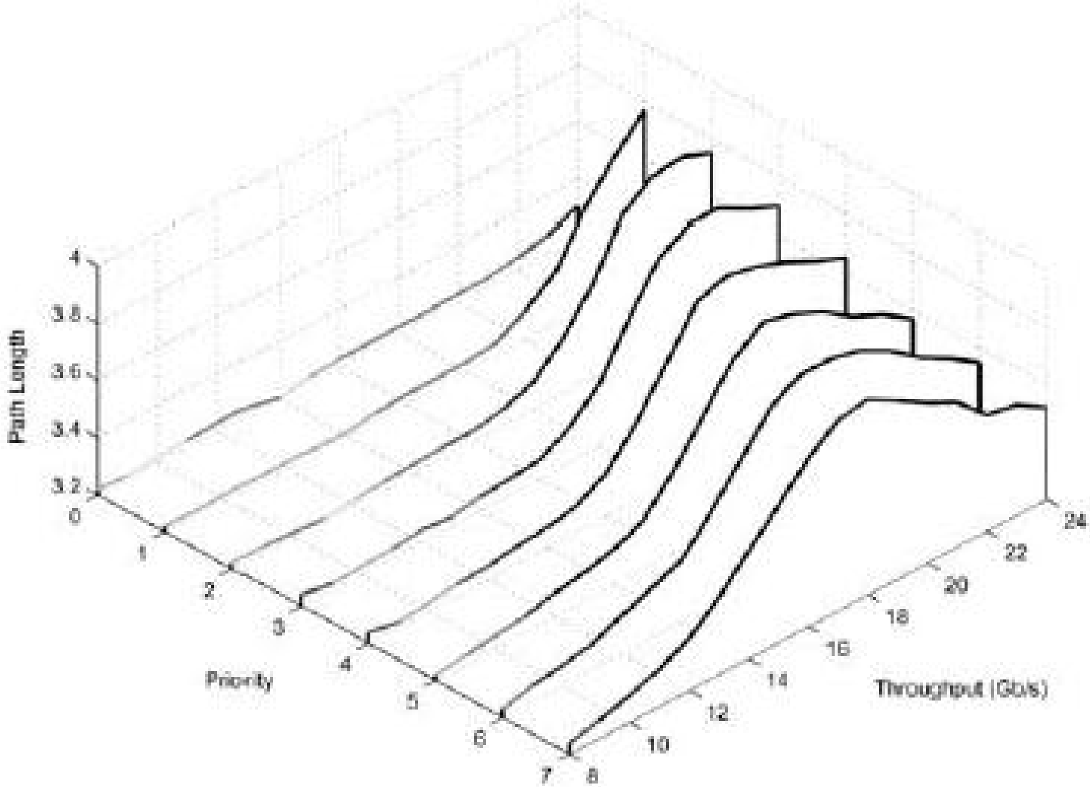
- Preemption effects on widest-shortest method





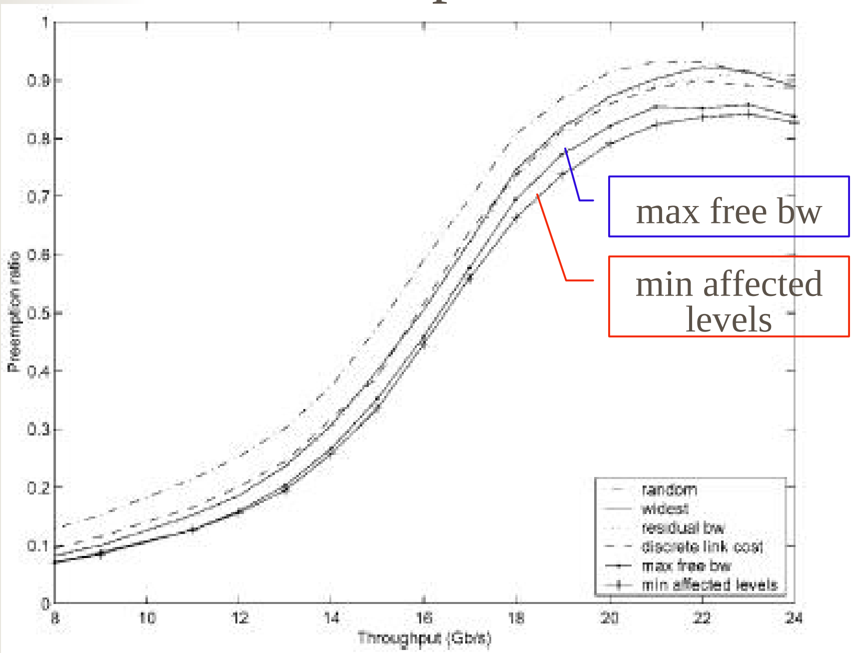
Numerical results (3/4)

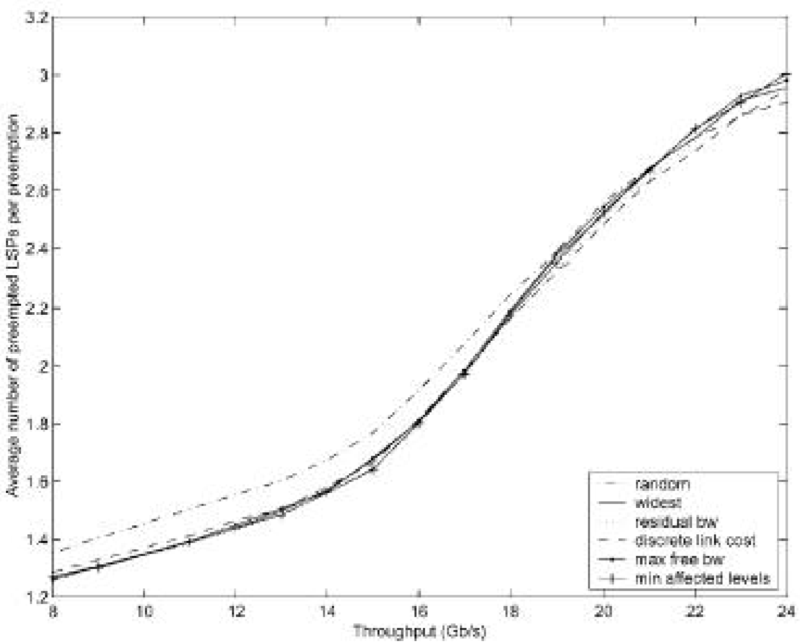
- Effect of preemption on path length of LSPs



Numerical results (4/4)

- Impact of preemption minimization
  - Success ratio: roughly the same with all CSPFmethods
  - Preemption ratio and Number of preempted LSPs





Conclusions

- Effects of bandwidth constrained path calculation on the preemption process have been investigated.
- Proposed priority-aware path selection algorithms are better than traditional CSPF methods in terms of total number of preempted LSPs, thus results in less re-routing in the network.
- Future work: carry out experiments
  - To determine the performance of proposed algorithms in case of inaccurate link-state information
  - Using more realistic traffic models in dynamic config.