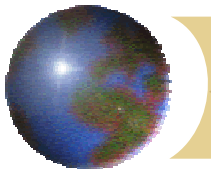


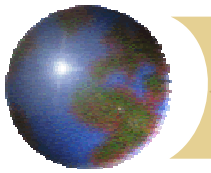
*A New Bandwidth Guaranteed
Routing Algorithm for MPLS Traffic
Engineering*

Bin Wang, Xu Su and C.L. Philip Chen
IEEE ICC 2002



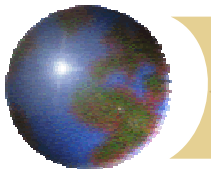
Outline

- ⊕ Introduction
- ⊕ Problem Formulation
- ⊕ Existing Routing Algorithms
- ⊕ Proposed Algorithm
- ⊕ Performance Studies
- ⊕ Concluding Remarks



Introduction

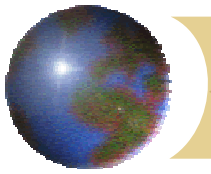
- Traffic Engineering
 - Optimize the utilization of network resources
 - Provide for Quality of Service
- MPLS vs. IP Routing
 - Explicit routing vs. Static routing
 - Link state information
 - Constraint-based routing vs. Dynamic routing
 - Connection-oriented vs. Connectionless



Problem Formulation

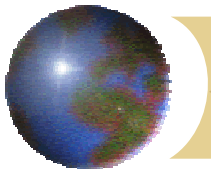
❁ System Model

- ❁ A network of n routers, $G=(V, E)$ $|V|=n$
 - ❁ LSP location information is known as a set of ingress-egress router pairs, denoted by L
 - ❁ Residual bandwidth of link l , denoted by $R(l)$, is accessible
 - ❁ Request r_i for LSP setup is represented by a triple (s_i, d_i, b_i) where $(s_i, d_i) \in L$
- ❁ **Objective:** find an LSP routing algorithm to satisfy the demands and make efficient use of network resources



Existing Routing Algorithms

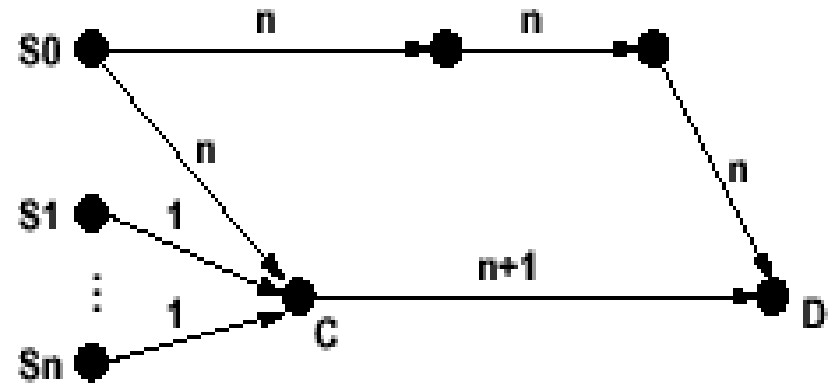
- Routing decision based on
 - Only current network status
 - MHA: Minimum hop routing algorithm
 - WSP: Widest(residual capacity) shortest path
 - SWP: Shortest widest path
 - Traffic profile
 - PBR (Profile-based routing): use measurement based profile to predict future distribution
 - MATE (Multipath Adaptive Traffic Engineering)
 - Interference to potential unknown future requests
 - MIRA (Minimum Interference Routing)



Shortcomings of MIRA (1/2)

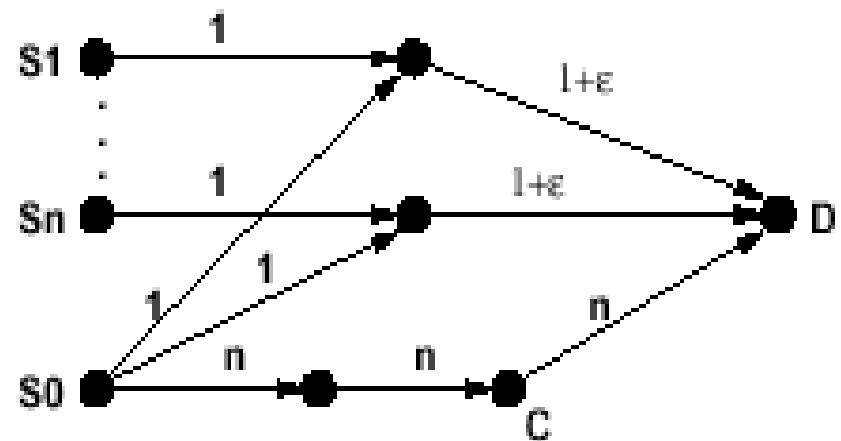
Concentrator graph

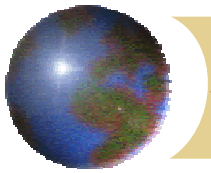
- $n+1$ requests $(S_0, D, n), (S_1, D, 1), \dots, (S_n, D, 1)$ arrive in sequence
- MIRA will route (S_0, D, n) along the path $\{S_0, C, D\}$



Distributor graph

- n requests of $(S_0, D, 1)$, followed by n more requests $(S_1, D, 1), (S_2, D, 1), \dots, (S_n, D, 1)$ in sequence
- MIRA will not route $(S_0, D, 1)$ along the path $\{S_0, C, D\}$





Shortcomings of MIRA (2/2)

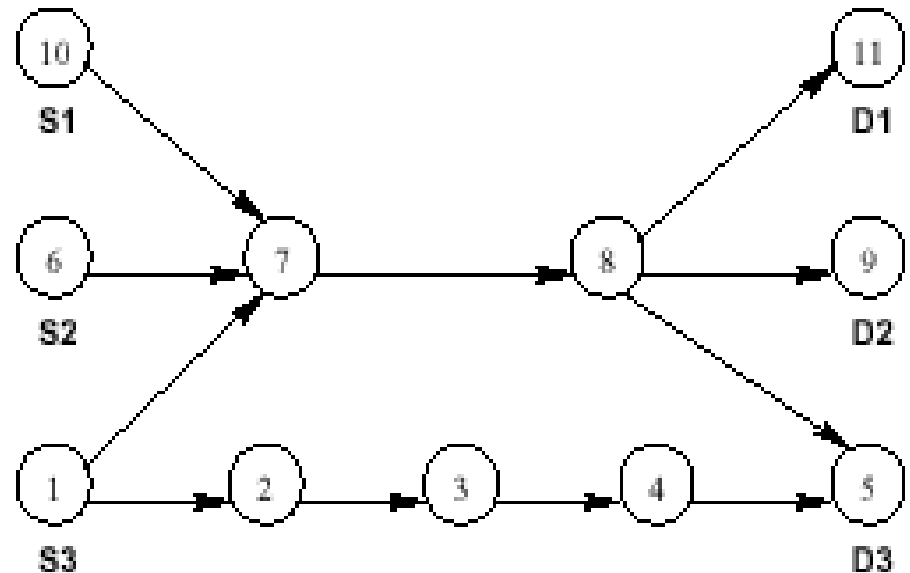
❖ Bottleneck-link graph

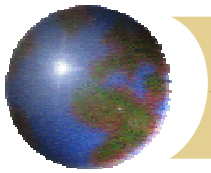
❑ 3 requests $(S_3, D_3, 1)$, $(S_2, D_2, 1)$, $(S_1, D_1, 1)$ arrive in sequence

❑ According to MIRA, if link $\{7,8\}$ has 1 unit residual bandwidth, it is a critical link, then

$(S_3, D_3, 1)$ will be routed along the path $\{1,2,3,4,5\}$

❑ If link $\{7,8\}$ has 2 unit residual bandwidth, it is not a critical link, $(S_3, D_3, 1)$ will be routed along $\{1,7,8,5\}$



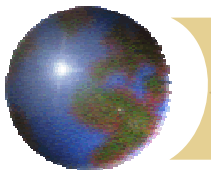


Proposed Algorithm (1/2)

✿ Idea

- Similar to MIRA, take into account the importance of critical links
- Also consider link residual bandwidth and path hop counts
- Given an LSP request (s, d, b) , the impact of routing this LSP on future LSP setup requests is characterized by assigning weights on links

$$w(l) = \sum_{(s', d') \in L} \frac{f_l^{s' d'}}{\theta^{s' d'} \cdot R(l)}, \quad l \in E,$$



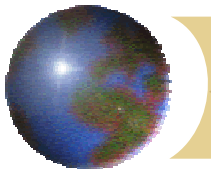
Proposed Algorithm (2/2)

INPUT: $G(V, E, B)$, L , an LSP request (s, d, b) .

OUTPUT: A route between s and d having a capacity of b units of bandwidth.

Procedure *LSP_Online_Routing* ($G(V, E, B)$, $r(s, d, b)$)

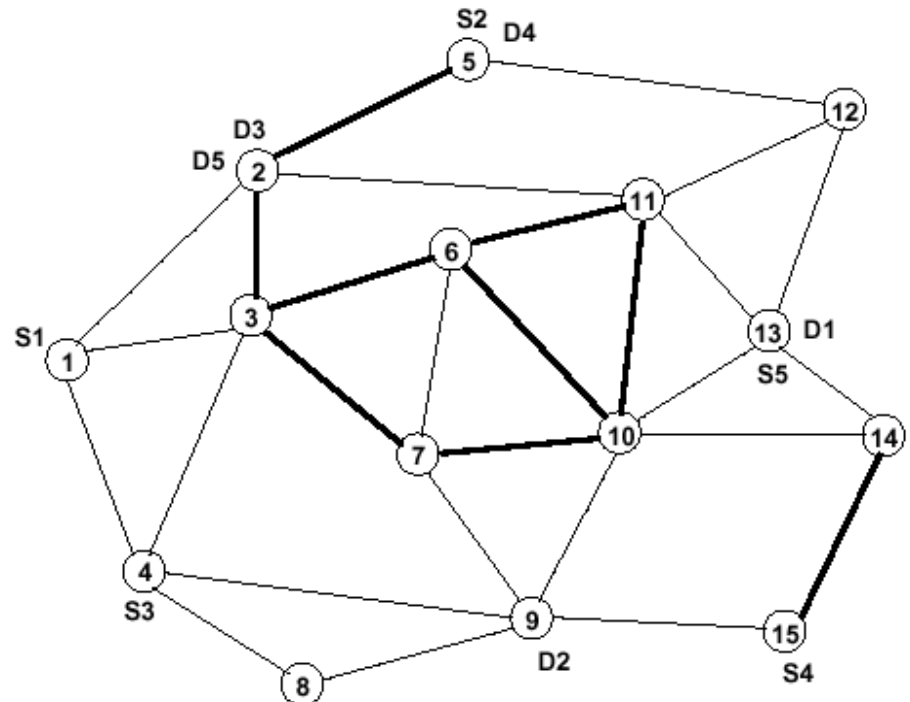
- {
- 1. Compute the maximum network flow values for all $(s', d') \in L$;
- 2. Compute the weight $w(l)$ for all $l \in E$ according to Eq. (2);
- 3. Eliminate all links that have residual bandwidth less than b and form a reduced network topology with remaining links and nodes;
- 4. Using Dijkstra's algorithm to compute the shortest path in the reduced network using $w(l)$ as the weight on link l ;
- 5. Route the bandwidth requirement of b units from s to d along this shortest path and update the residual link capacities;
- }

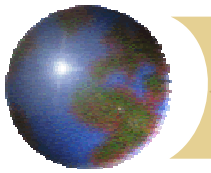


Performance Studies (1/4)

Simulation network topology

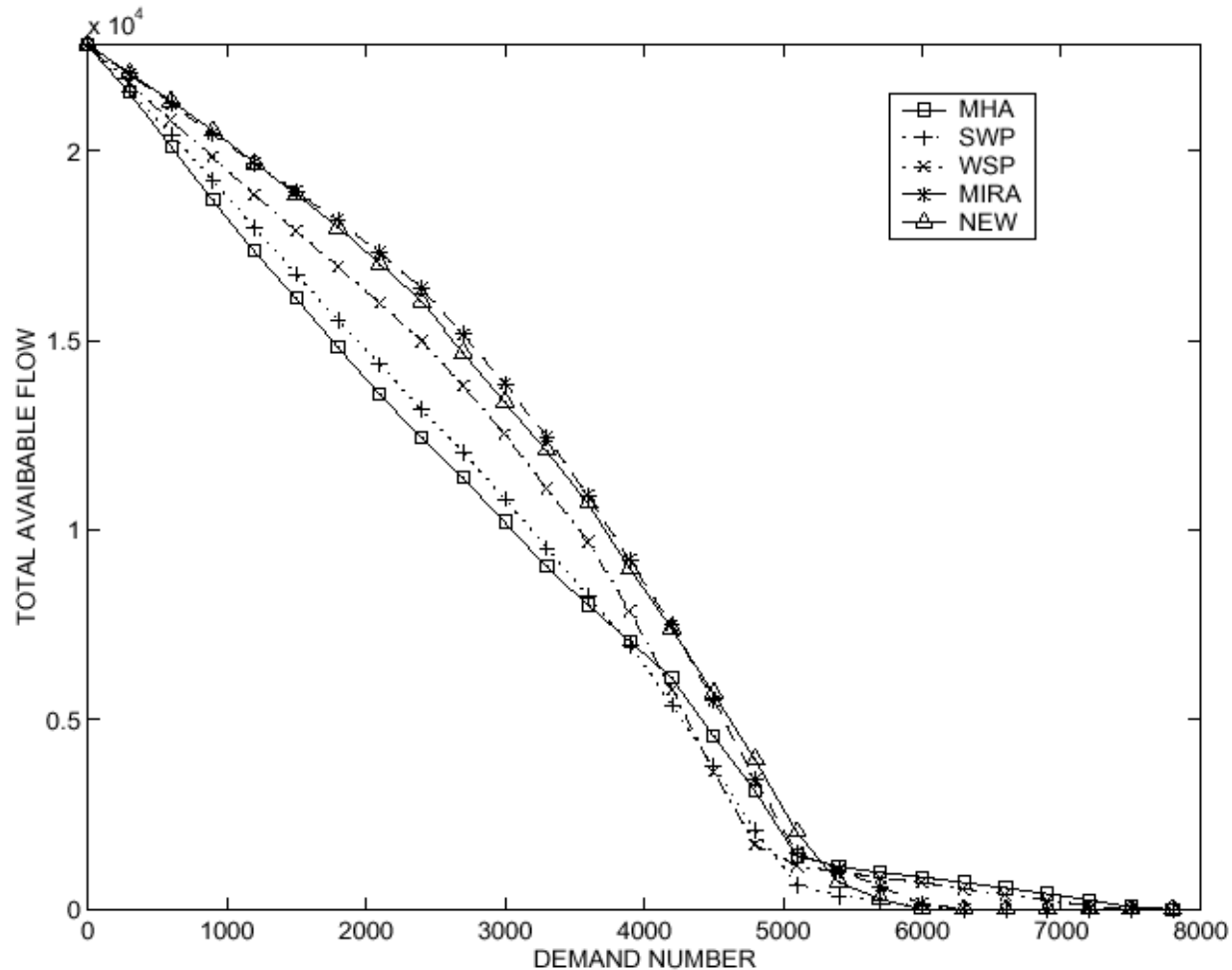
- 5 potential LSP location pairs
- Link capacity
 - 1200 units (light link)
 - 4800 units (dark link)
- LSP requests are randomly chosen from the above pairs
- LSP bandwidth demands: Uniform(1,4)

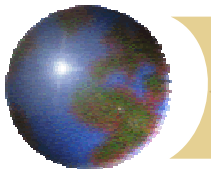




Performance Studies (2/4)

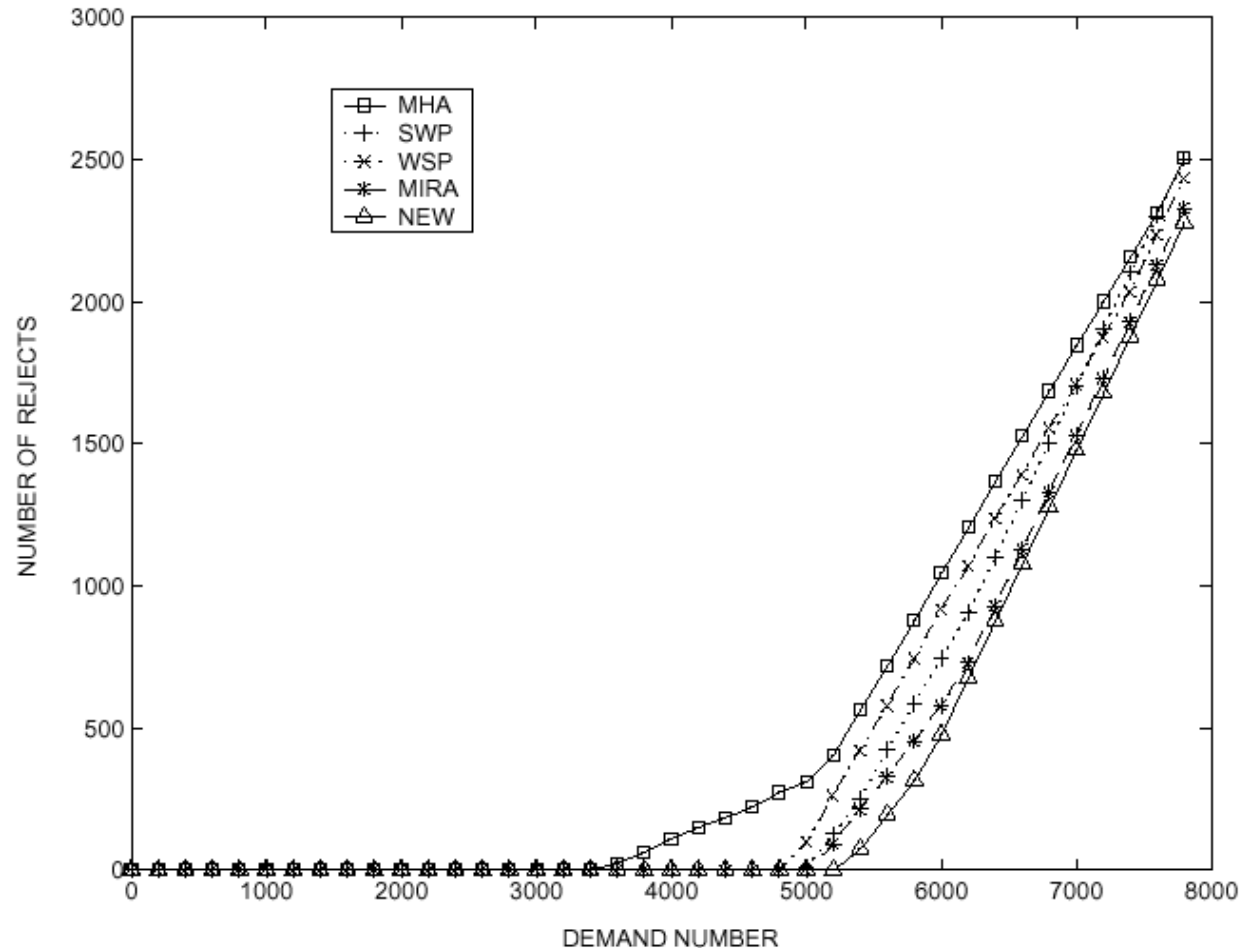
- Total available bandwidth v.s. demands
 - Considering long-lived LSPs

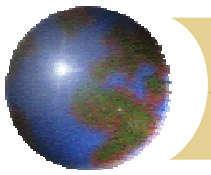




Performance Studies (3/4)

- Rejected requests v.s. demands
- Considering long-lived LSPs

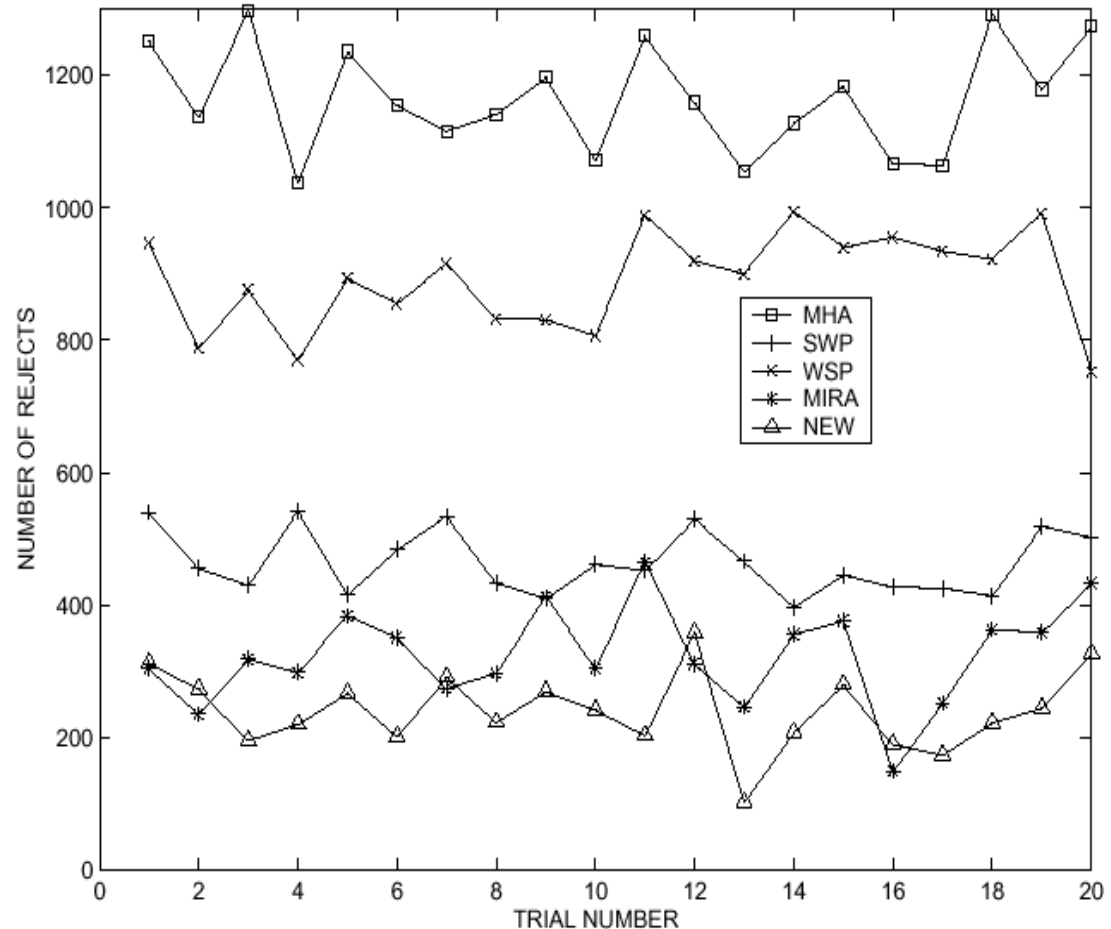


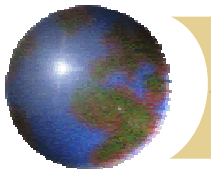


Performance Studies (4/4)

Dynamic rejected requests

- 4000 long-lived LSPs, and 4000 LSPs with exponential holding time





Concluding Remarks

- ❖ An online algorithm for dynamically routing bandwidth guaranteed LSP is developed.
- ❖ The proposed algorithm considers not only the importance of critical links, but also their relative importance to routing possible future LSP setup requests
- ❖ The proposed algorithm leads to improved performance and provides better network resource utilization.