

# An Automated Traffic Engineering Algorithm for MPLS-Diffserv Domains

By

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## Outline of Presentation

- Traffic Engineering
- MPLS and Diffserv
- Need for Automated Provisioning
- TELIC: Colorful Traffic Engineering
- TELIC: Focus, Method and Results
- Conclusion

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## Traffic Engineering

- TE optimizes the network efficiency with the control of the
  - Mapping
  - Distribution
- Of the traffic across the network
- TE tries to balance the load across the network and addresses fault tolerance and congestion avoidance

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## Traffic Engineering

- Earlier, the routing protocols favored shortest or least cost paths, building up congestion on some paths
- TE was not practiced, leaving the network overloaded in some parts and underutilized in others

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## IETF's New Approach

- New applications on the Internet seek timely delivery besides correctness
- IETF has orchestrated the development of new service sensitive protocols for the Internet
- ISP organizations wish to provide most appropriate services for their customers and gain profits
- They want to utilize their bandwidth most efficiently

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## IETF, ISP's and Users

- The conventional Internet has been following the "make effort not promises" model, with all the traffic treated in almost the same manner
- The new protocols intend to change it and provide suitable services to various classes of traffic

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## Motivation for MPLS

- MPLS (Multi Protocol Label Switching) is a very interesting recent development
- Let us see why MPLS was developed
- ATM switches are deployed in the Internet backbones due to their extremely fast switching and provisioning
- All Internet traffic is based on IP. So IP must be carried over the ATM

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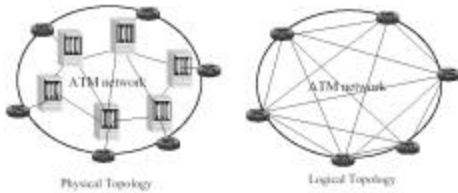
## IP/ATM → MPLS

- Classical IP over ATM (Overlay model) suffers from several problems
- First, all ATM switches are connected in a mesh. A small increase in the number of switches can drastically increase the number of virtual circuits
- The QoS features of ATM are not exploited and all connections are best effort
- IP and ATM have incompatible addressing and control protocols so overlaying is expensive

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## IP Over ATM

Traffic Engineering in IP over ATM (overlay) Networks



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## MPLS

- The industry developed tag switching and label switching to solve the above problems
- In label switching, a short fixed length label is encoded into the packet
- The intermediate LSR (Label Switched Router) finds the next hop from a table, using the label as an index
- If the LSR is an ATM switch, label is just the VPI/VCI identifier
- If the LSR is an IP router, the label helps eliminate the destination based routing and reduces the job of the router to label switching

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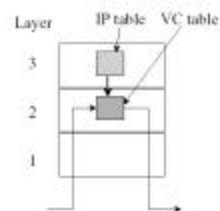
## MPLS

- A label switched path (LSP) must be set up prior to the start of transmission
- IP and ATM are tightly integrated with label switching
- IP takes over the control path and ATM switches are used only for data transmission
- IP can use the ATM switches as label switched nodes (or IP routers)

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## IP Over ATM With MPLS

### Structure of a Label Switching Router

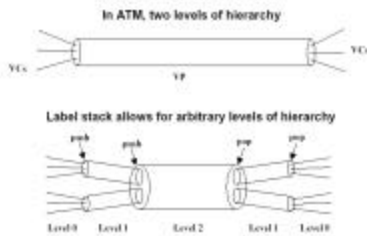


- Layer 3 (IP) performs routing and label distribution
- Layer 2 (ATM) performs fast forwarding

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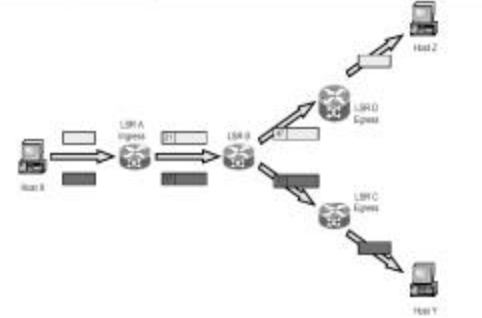
## LSP

### Tunnel Hierarchy and Label stacks



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## LSP's in an MPLS Network



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## MPLS

- MPLS simplifies the routing problem in an all IP subnet
- An MPLS domain has an ingress node that nails down paths through the maze of core routers for every requesting flow until the exit door (egress node)
- Thus every router does not have to decide about the path of each packet
- In MPLS, the connectionless network is converted into connection oriented network

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## MPLS

- Intermediate routers use a "shim header" or a layer 2.5 header to find out the next hop of a packet
- This shim header is inserted between the frame header and packet header
- It is used by the router to consult a table that tells what path is to be taken for this packet

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## MPLS

- Instead of routing, now the routers do label switching
- Since the path is pre-determined, routers can speed up the processing of packets
- Also, the network manager can decide LSP's (label switched paths) based on load distribution and other administrative goals
- Directing traffic on paths not determined by traditional IGP's provides flexibility and load balancing

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## MPLS

- MPLS (Multi-Protocol Label Switching) provides LSP (Label Switched Paths) to the requesting traffic trunks
- MPLS runs constrained routing to determine an LSP within an MPLS domain.
- This LSP will run from an ingress node to an egress node of the domain
- LSP may have some QoS features

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## MPLS

- MPLS works well with cell based and packet based networks
- It provides path calculation in advance of the traffic flow, thus introducing connections in the connectionless world!!
- The path could be strictly specified or loosely outlined and backup paths may be specified for handling link failures

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## TE With MPLS

- The LSP setup may follow TE principles thus solving the chronic inefficient utilization problem of the networks
- For example, constrained routing may prefer longer and lightly loaded paths over shortest paths
- MPLS + TE → Balanced and well utilized network

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## Automated Provisioning

- The networks are growing bigger!!
- The protocols are becoming more complex
- With Diffserv, MPLS, RSVP-TE, CR-LDP, COPS and associated protocols, it is impossible to allow manual provisioning
- Therefore, there is a need for automated TE-based path selection algorithms

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## Constrained Routing

- Constrained routing applies extended IGP parameters to the tree to find a suitable path
- $BW_{avail}$  and hop count may be used to determine paths
  - Shortest widest path
  - Widest shortest path
  - Shortest distance path ( $dist = 1/BW_{avail}$ )

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## QoS Traffic Considerations

- If only the available bandwidth is considered, the class of service may not be taken into consideration
- Thus, the best effort traffic may intersect the QoS traffic at several points within the domain
- In Diffserv, this may be a recipe for disaster!!

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## TELIC

- In this project, an efficient dynamic traffic engineering algorithm is developed for selecting paths across an MPLS-Diffserv domain
- TELIC (Traffic Engineering with Link Coloring) works with a set of traffic requests present at an ingress router of such a domain
- It allocates paths to an egress node using Dijkstra's shortest path algorithm

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## TELIC

- Each request specifies the amount of bandwidth requested followed by the Diffserv class of service (EF,AF,DF)
- While processing a request, TELIC partitions the network into several monochromatic subgraphs and makes an effort to match the request with an appropriate subgraph

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## TELIC

- In case a subgraph has no path to the egress node, TELIC merges it with another subgraph as per rules carefully built-in and starts the search all over again
- In case a search is exhausted, rules are available to deallocate a best effort class LSP and start the search again
- TELIC is written as a flexible tool in C++ by student programmer Jason Beuckman

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## Software Operations

- Traffic requests are read in and placed in a FIFO queue
- The program will then:
  - Look at the type of request
  - create sub-graphs based on color and available bandwidth to find the best match for a request

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## Software Operations

- If a path is found, the links on the path are updated to reflect the increase in usage
  - Higher cost, less bandwidth, different color
- Otherwise, the request is not allocated, and the next traffic request in the queue is processed

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## Software Features

- Variable bandwidth requests
- Domains and traffic requests can be placed in files so multiple configurations may be tested

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## Software Features

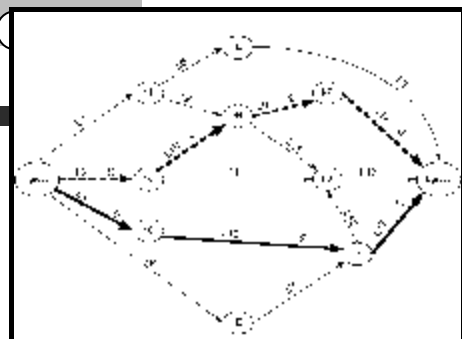
- Results displayed:
  - Bandwidth utilized
  - LSP Table (Traffic allocated and its path)
  - Overall condition of the domain
- Object-Oriented design promotes easy adaptability
  - Visual C++
- Questions? Email [Track605@aol.com](mailto:Track605@aol.com)

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## Results

- Traffic sets were prepared and applied to TELIC with various topologies of the domain
- The topologies tested include mesh, disjoint multipath, ISP and irregular ISP
- Results reflect a consistent behavior with 100 percent success rate for EF and variable success rates for AF and DF

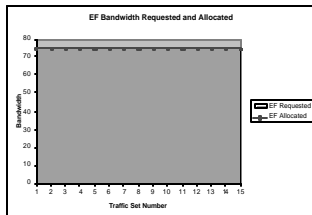
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An MPLS-Diffserv Domain With Several Links

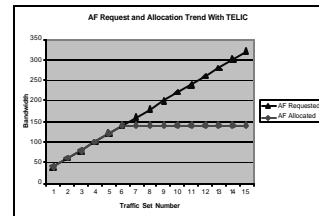
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## Results for EF Traffic



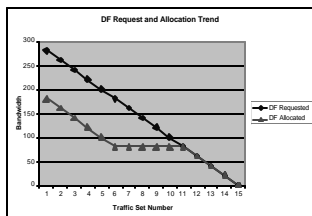
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## Results for AF Traffic



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## Results for DF Traffic



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## Discussion of Results

- Using class based priority, EF received 100 percent of the requested bandwidth
- AF's request and allocation remained identical until a fixed maximum beyond which AF could be not allocated additional bandwidth
- DF's trend is also similar but with a wider gap between demand and supply

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## Discussion of Results

- The request and allocation gap between AF and DF is due to the specific topology of the network being tested
- The network has two bottleneck links. Node 8 to egress and Ingress to node 1
- Both links become congested quickly, thus resulting in denial of additional bandwidth requests

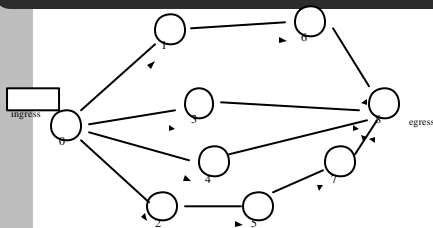
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## ISP and Disjoint Multipath Results

- We have also configured and tested networks that are based on ISP, disjoint multipath and mesh topologies
- In the ISP and disjoint multipath topologies, the results are similar to the ones shown
- In mesh topology, the allocated bandwidth falls short of demand considerably for AF and DF
- It is because of the reduced number of links from the ingress towards the egress node

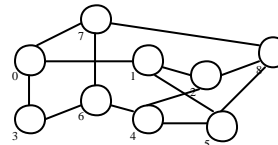
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## Disjoint Multipath Topology



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## ISP Topology



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## Current Work

- Currently, one student is working to implement a colorless shortest distance algorithm that is based on ( $\text{dist} = 1/\text{BW}_{\text{avail}}$ )
- Thus we will be able to compare the performance of TELIC vs. shortest distance routing

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## Future Work

- Future work includes modeling the request arrival and LSP holding time with different probability distributions
- Enhancements proposed for this algorithm include fault tolerance and prevention of excessive delays in best effort traffic
- We would like to extensively test the improved algorithm on OPNET's MPLS platform

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