Dynamic Resizing of Traffic Engineering-Label Switched Paths in MPLS Networks

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Abstract

• We analyze Dynamic resizing of Traffic Engineering Label Switched Paths (TE-LSP) in Multi-Protocol Label Switching (MPLS) Networks.

• While analyzing a commercially deployed mechanism, comparison metrics are derived and used as guidance for the development of new mechanisms, which include modification of the original resizing conditions and methodology.

• To develop a practical scenario, we use real life TE-LSP size distributions, self-similar traffic and existing Internet Service Provider backbone topologies.
Outline

• Overview of Traffic Engineering
• The what and why of MPLS-TE
• Motivation for Dynamic Resizing
• Present Commercial Implementation
• Replicating a real life scenario
• Metrics for comparison
• New Mechanisms
• Implementation
• Conclusion
Overview of Traffic Engineering

- To deal with network growth and expansion
  - Network Engineering
  - Traffic Engineering

- Network Engineering
  - Manipulate network to suit traffic
  - Throw bandwidth and expensive equipment at the problem
  - At 70% Annual Traffic Growth: *Expensive, Time consuming*

- Traffic Engineering (TE)
  - Manipulate Traffic to suit network
  - Balancing and moving traffic around
  - General Practice: Used in IP, ATM and MPLS
What is MPLS?

- A paradigm to de-couple Routing and Forwarding
- Prevents IP lookup at core routers (Approx. 100,000 entries)
- Assigns every packet a label depending on characteristics
- Forwards packets on predetermined paths called “Label Switched Paths” or LSPs
- LSPs have an associated size along with other attributes
- Every router maintains a list of labels and the corresponding outgoing and incoming interface
- Paths can be setup to distribute flows depending on network status
- Core network implements MPLS, edge routers change back to IP
Why does MPLS help?

Router A has to send 40Mb to Router F and Router G

- IP Tries to send 80Mb across the shortest path
- Congestions and results in Packet Drop

- Service Provider sets up 2 LSPs
- Distributes Traffic
- No congestion

OC3: 155Mbps
DS3: 45Mbps
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Motivation for Dynamic Resizing

- Traffic Matrices are known by Service Providers
  - Knowledge of over and underloade links
  - Dynamic Resizing can be applied selectively

- Dynamic Resizing helps in cost reduction
  - Prevents installing expensive equipment to fight traffic growth
  - Optimizes existing bandwidth resources

- Reservation governs latency
  - Higher reservation causes LSPs to be on longer paths
  - Dynamic Resizing can put LSPs on shorter paths

- Service Providers can “overbook” resources to be on the safe side. Dynamic Resizing optimizes afterwards
Commercial Implementation

- Cisco Auto Bandwidth
  - LSP Bandwidth changed every 'A' hours
  - LSP Traffic sampled every 'C' seconds
  - Highest Sample collected 'H'
Auto Bandwidth Functionality

• Constrained Shortest Path First (CSPF)
  • Finds shortest path to a destination
  • Considers available bandwidth along with the link cost
  • Prunes paths not satisfying bandwidth constraint
  • Runs Dijkstra's SPF on the residual network

• Resource reSerVation Protocol (RSVP)
  • RFC2205 : Base RSVP
  • RFC3209 : TE Extensions for RSVP
Constrained Shortest Path First

- Before resizing, the “Head End” router runs CSPF with the new size to find the new path
- Already reserved bandwidth is “locally” restored before computing new path
- This prevents “double booking” and longer paths

Router A has to send 40Mb to Router F and Router G
Once the path has been determined by CSPF, the “Head End” router sends an RSVP “PATH” message to all the routers on the new path.

It then waits for the RSVP “RESV” message to come back.

Once the new path has been setup, traffic is forwarded onto the new path after 200ms.

Change of path causes **Jitter**
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Replicating real life scenarios

- ISP Topologies
  - Link bandwidth distribution
  - Link latencies (IGP Metric) and weights (TE Metric)

- Traffic patterns
  - Internet Traffic
  - Voice Traffic

- Relative behavior of traffic with location
  - Effect of time-zones
  - Special events – Flash Traffic

- LSP characteristics
  - Size Distribution
  - Setup Time
  - Order of Setup
Real Life Topology

- Helps to analyze performance when scaling
- Research behavior when exposed to real life scenarios
- Uncovers overlooked cases and problems

- Service Providers keep topology confidential
- Random Topology Generators do not represent ISP topologies
- Very difficult to create manually
Obtaining Real Life Topologies

- **Obtaining Topology:** Rocketfuel
  - ISP Mapping Engine
  - ISPs mapped using Traceroute servers all over the world
  - Accurate maps of 9 ISPs from various continents

- **Visualization of Topology:** Otter from CAIDA
  - Visualize any network in Otter format
  - Create custom data structures to isolate links or nodes with specific properties

- Rocketfuel files are very complex and inconsistent
- Otter does not recognise Rocketfuel
Rocketfuel + Otter

Telstra - Australia
Full Topology

Sprintlink – United States
Backbone Nodes
Extracting the backbone

Irregularities: Congestion, Bottleneck links, Prevents accuracy
Link Bandwidths not available
Custom distribution: OC3: 10%  OC48: 70%  OC192: 20%
Real Life Traffic

- Real traffic patterns help in accurate analysis
- Different traffic patterns need different algorithms
  - Internet Traffic
  - Voice Traffic
  - VPN Traffic
- Traffic patterns are not disclosed by service providers
- Traffic has to be modelled based on descriptions
- Effect of time zones on traffic has to be accounted for
Generating Traffic

- Traffic on an LSP proportional to its reserved size
- Sources have Exponential or Pareto ON/OFF times
- Traffic has a “peak” period during the day
- Time zones effect the positioning of the peak period
- Time zones calculated based on the IGP Metric (shortest path latency)
LSP Characteristics

• Service Providers do not disclose exact LSP sizes
• Size distribution based on relatively accurate information
  • 1Kb to 1Mb : 60%
  • 1Mb to 20Mb : 30%
  • 20Mb to 50Mb : 10%
• Full mesh of LSPs : \( N*(N-1) = 6806 \) LSPs
  • “Full mesh” setup only in the core of the network
• LSPs assigned time-zones according to IGP Metric (Shortest Path Latency)
• LSPs from the same router start at the same time
  • For the same head end router : Largest LSP setup first
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- **Metrics for comparison**
- New Mechanisms
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Metrics for Comparison

- **Average Reserved Bandwidth:Actual Traffic**
  - Gives the amount of bandwidth wastage on average
  - How closely the reserved bandwidth follows the actual traffic
- **Resizes taking place on an average**
  - Resize requires RSVP messaging, has overhead
  - If path changes, old path needs to be torn down and traffic has to be forwarded on the new path
  - Causes traffic jitter
- **Average Link Utilization**
- **LSPs not on their shortest (IGP) path**
- **Worst case number of LSPs passing through a node**
  - 5Kb per LSP required by the router to maintain state
New Resizing Methods

• Original Mechanism
  • Take samples every 5 minutes
  • Resize to the maximum of the samples every X hours

  Simple modifications based on initial observations
• Mechanism 2
  • Take samples every 5 minutes
  • Resize to the average of the samples every X hours
• Mechanism 3
  • Take samples every 5 minutes
  • Resize to the maximum if it is greater or lesser than present by y%
• Mechanism 4
  • Take samples every 5 minutes
  • Resize to the average if it is greater or lesser than present by y%
Maximum of Samples

LSP26 Traffic Behavior, Mechanism 1

LSP26 Traffic Behavior, Mechanism 3
Average of Samples

LSP26 Traffic Behavior, Mechanism 2

LSP26 Traffic Behavior, Mechanism 4
Performance Comparison

**Link Utilizations**

- **Number of Links** vs. **Utilization**

**Resizes per Mechanism**

- **Resizes** across **Mechanisms**
  - Avg

**LSPs not on IGP path**

- **Number of LSPs** vs. **Time**

**Worst case LSP count for a node**

- **Max LSPs at anynode** vs. **Time**

- **Mechanism 1**
- **Mechanism 2**
- **Mechanism 3**
- **Mechanism 4**
• Resizing to the average of samples seems to be optimize bandwidth better than resizing to the maximum
Other constraints and combinations

• So far we only considered fraction of change of traffic
• Changing reservation may cause change in path
  • Smaller reservation may find shorter path: less delay
  • Larger reservation may find longer path: more delay
  • New path may have more hops
  • More hops = Queuing Delay, Processing Delay....
  • Less hops = faster

• Resize only if new path is shorter by 'x%'
• Resize only if new path has less than 'y' hops
• Use a combination of fraction of traffic change and new path characteristics
A different approach

- Performance very specific to traffic pattern
- Voice Traffic has more peak periods in 24hrs
- Mechanisms are reactive, cannot predict

- Mechanism should predict and behave accordingly during peak and flash traffic periods
- Have memory and remember the past
- Should use information from the past when resizing
- Should also keep in mind the previous metrics
Using Behavior Patterns

- Study the traffic pattern
- Assign symbols to each sample based on the traffic characteristic
  - % of original size
  - % change in traffic
- Assign a value to the string obtained over the resizing period
- Keep track of the time and the value for the next resize about the point of symmetry
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Implementation

- **TE for QoS in the Internet, at Large Scale (TEQUILA)**
  - RSVP-TE Daemon for DiffServ for MPLS under Linux
    - LSPs setup over two Linux PCs
    - Traffic sent through them using 'udpgen'
    - Reservation changed using RSVP-API (RAPI)
  - Extremely small scale setup
  - Traffic does not represent true patterns
- Black Box communicating to the routers
  - Monitors traffic over an interface
  - Uses Mechanism algorithm to calculate resizing
  - Communicates with the routers using SNMP
    - jSNMP Enterprise
  - Slow, “Black Box” needs to process very fast
- Cisco IOS
  - Code directly into the IOS (in C)
Conclusion

- We have analyzed the Dynamic Resizing of TE-LSP sizes to demand
- Carried out detailed simulations to understand the effect of Dynamic Resizing on an ISP's network
- Identified trade-off points
- Suggested simple modifications to the commercial implementation to improve performance
- Development of a more “intelligent” algorithm for resizing is underway
- Fully deployable implementation is being developed
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Questions..