Traffic Engineering Algorithms for Network Domains

Junaid Ahmed Zubairi
Department of Mathematics and Computer Science
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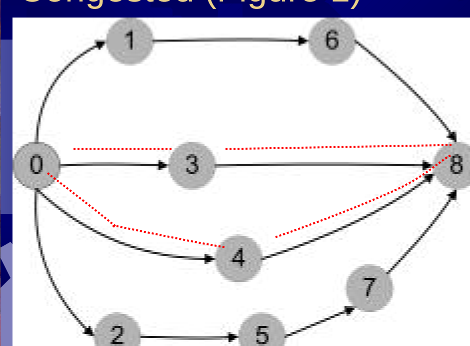
Outline

- The Problem Defined
- MPLS and Diffserv
- Constrained Routing
- Overview of Various Solutions
- TELIC and Its Objective
- Comparing TELIC With SHORTD
- Results and Discussion
- Conclusion

Traffic Engineering

- Internet selects best routes for the traffic if several paths are open
- Earlier, the routing protocols favored shortest or least cost paths, building up congestion on some paths
- This resulted in a situation where the network was overloaded in some segments and underutilized in others

Shortest Routes Become Congested (Figure 1)



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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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 (premium, mid-grade and regular)
- 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
- Diffserv protocol is defined to place the traffic in three different categories: EF, AF and DF (premium, mid-grade and regular)

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MPLS

- MPLS (Multi-Protocol Label Switching) provides LSP (Label Switched Paths) to the requesting traffic trunks
- MPLS installs and manages provisioned tunnels that are known as LSP (Label Switched Paths) in a network domain
- An LSP runs from an ingress node to an egress node of the domain
- LSP may have some QoS features besides bandwidth provisioning

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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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Constrained Routing

- Constrained routing looks for a path that satisfies one or more constraints
- For example, if routing looked for the path with the maximum available bandwidth, the results could be different for our example diagram in Figure 1
- In general, hop count and available bandwidth can be used as constraints however finding optimal path subject to more than one constraint is NP-complete problem

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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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Overview of TE Solutions

- Seok et. al. (Seoul N. Univ. IEEE ICCN'01) have proposed a heuristic that uses a hop count constraint
- R. Rabbat et. al. (MIT IEEE ICC'00) have proposed a central resource manager that runs Dijkstra's shortest path algorithm multiple times and allows traffic to be split across several paths
- Kodialam et. al. (Univ. of Maryland IEEE INFOCOM'00) proposed minimum interference routing where interference is defined as loading the links that may be the only feasible links for some other LSF

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TELIC

- In all the above solutions, main focus is on utilizing maximum available BW without regard to the possible sharing of links among premium and non-premium traffic
- 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++
- TELIC avoids sharing links between premium and non-premium traffic while utilizing the available bandwidth

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TELIC's Figure of Merit

- "Conjunction Factor" is defined as a figure of merit for measuring TELIC's performance
- It measures the degree of sharing links among EF, AF and DF class traffic
- $F_c = \Sigma D_i$
- Where:
- F_c = conjunction factor for the domain under consideration
- D_i = degree of conjunction for link 'i' and I=1 to 'n'
- ($\forall$i, Di = 0*CE + 2*CA + 5CD)
- TELIC tries to minimize conjunction factor

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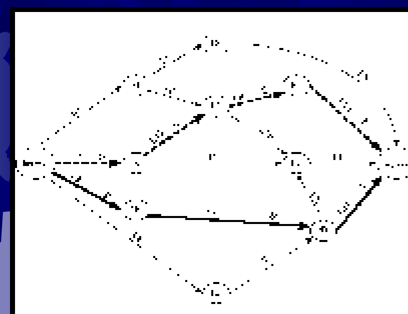
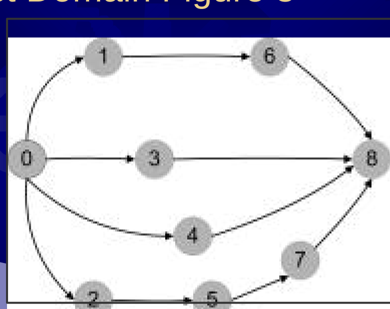
SHORTD

- SHORTD is an algorithm in the literature that uses the inverse of available bandwidth to find new label switched paths
- SHORTD was also implemented by us in order to compare its results with TELIC
- Conjunction factor computation software was developed and 24 traffic sets were tested against TELIC and SHORTD

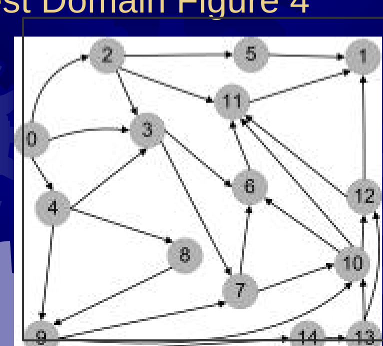
Test Domain Figure 2



Test Domain Figure 3



Test Domain Figure 4



Traffic Characteristics

- Test traffic was split 80-20 with 20% in the EF category
- In set 1, the DF (Best Effort) was the dominant class within the 80% non-EF traffic
- The DF ratio was reduced linearly from set 1 to set 24, increasing the AF traffic

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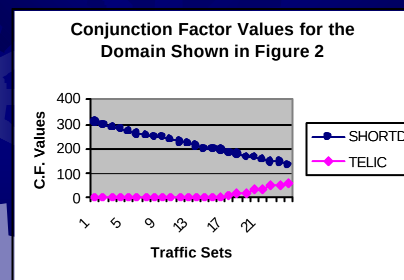
Results



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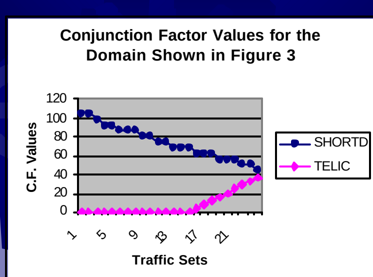
Results



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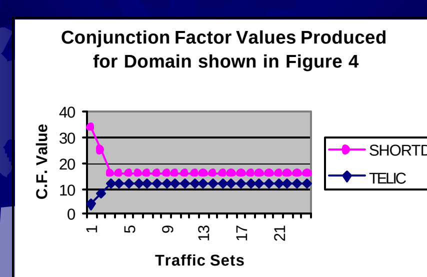
Results



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Discussion

- TELIC outperformed SHORTD in minimizing conjunction factor for the mix in which best effort traffic was dominant
- In the mix with AF dominant, TELIC still produced smaller CF values that were closer to SHORTD results
- However, EF behavior may fail with bursty best effort traffic and not with regulated AF traffic
- Therefore TELIC's performance is significantly better than SHORTD in terms of minimizing CF values

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Rejected Bandwidth

- In terms of rejected bandwidth, TELIC rejected more traffic than SHORTD
- This aspect of TELIC can be improved further
- Enhancements under consideration include
  - Arbitrary bandwidth request sizes
  - Splitting up the best effort aggregates
  - Identifying bottleneck links and adding links at strategic places

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Conclusion

- Traffic Engineering problem for network domains was specified and explained
- Constrained routing was defined and various approaches considered
- TELIC and SHORTD were introduced as LSP allocation algorithms in an MPLS-Diffserv domain
- Conjunction factor was defined for measuring the performance of TE algorithms
- Results of testing TELIC and SHORTD on three network domains with varying traffic sets were presented
- Enhancements were suggested in TELIC for reducing rejected bandwidth

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