A Comparative Study of Routing Label Switched Paths With Shortest Distance Algorithm and TELIC

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ABSTRACT

In this paper, the performance of TELIC, a traffic engineering algorithm for network domains is quantified and compared with shortest distance algorithm. TELIC uses centralized LSP assignment in an MPLS domain satisfying the QoS requirements of the traffic. Conjunction factor for a traffic set is developed as the figure of merit for comparing the extent of sharing links among various service classes. TELIC is used on traffic request sets that arrive at domains using different topologies. The same traffic sets and topologies are used with shortest distance constrained routing algorithm. The results of conjunction factor and rejected bandwidth are compared and the pros and cons of using each approach are discussed.

1 INTRODUCTION

This work focuses on evaluating and enhancing TELIC, a traffic engineering algorithm for network domains. TELIC is developed [1] for assigning label switched paths in an MPLS-Diffserv domain to competing service-differentiated traffic requests. TELIC allocates resources (paths) to trunks (traffic requests) that arrive at an ingress node of a network domain that may belong to an organization or a service provider. It works on the principles of graph theory and finds the shortest path to the egress node of the domain within several parameter-partitioned sub-graphs. The allocation of a label switched path results in updating the link parameters and their membership in the sub-graphs. TELIC is a flexible experimental tool with several configurable parameters. It can read the topology information from a file and construct different domains. Factors that can be modified include final residual bandwidth (if a non-zero value is desired), reliability, delay, color alteration limits, DF pre-emption limits and initial bandwidth available per link.

Service differentiated traffic requests can be satisfied with constrained routing. Constrained routing differs from plain IP routing in the sense that in addition to minimizing a scalar metric, the links included in the path from source to destination should also satisfy a set of constraints [2]. The constraints may be imposed by the network administrator and may include available bandwidth, propagation delay, link resilience or other parameters. The problem of finding a multi-constrained path is NP-complete because different constraints may conflict with one another [3]. Constrained routing algorithms must operate assuming the availability of complete information about all the links in the network.

Several constrained routing algorithms have been proposed [3,4,5,6,7,8,9]. Most algorithms use the approach of satisfying delay or bandwidth constraints in generalized network models. The work reported in [3] solves the delay-&-cost constrained routing problem by first reducing it to a simpler problem and then solving it with extended standard routing techniques.

More recent works has focused on finding routes as per MPLS traffic engineering principles [6,7,8,9]. In [6], a heuristic is proposed to solve the problem of hop-count constrained multipath routing in an MPLS domain. While this approach increases the overall utilization of the network, it does not consider the QoS requirements of traffic requests. In [7], a traffic engineering algorithm is proposed based on the PASTE [10] architecture. It uses a CRM (centralized resource manager) thus avoiding the overhead involved in flooding the network with control messages as in QOSPF [11]. The approach with CRM is similar to the approach taken in TELIC with a centralized LSP computation module in the ingress router. However, the CRM algorithm runs Dijkstra's SPF routing multiple times in order to find alternate paths. In this technique, the same aggregate may be split across several tunnels thus increasing the combination of premium and best effort traffic on internal links.

In [8,9], minimum interference routing is defined for MPLS domains for achieving the objectives of traffic engineering across the network. The authors assume that the LSP setup requests arrive one by one and future demands are unknown. Interference is defined as including those links in an LSP that may be the only feasible links (critical links) for a future LSP between a different pair of ingress-egress routers. The algorithms proposed by the authors use only the residual bandwidth and "criticality" information for including the links in an LSP. Therefore, it is highly likely that the LSPs carrying QoS traffic get routed on links that also carry best effort traffic. One of the contributions in [9] is a list of requirements for any MPLS routing algorithm. Following are some of the requirements as mentioned in [9]:

- The algorithm should work online
- It should know the ingress-egress pair of each request
- Good re-routing performance on link failure
- No splitting of traffic on different LSP's
- Easy on computation time
- It should be amenable to distributed implementation

The objective of TELIC (Traffic Engineering With Link Coloring) is to assign LSP (label switched paths) to incoming traffic requests that enter an MPLS-Diffserv domain in a service aware manner. In this paper, TELIC's performance is measured against certain topologies and traffic requests. The performance of TELIC is compared with the shortest-distance algorithm and some enhancements are suggested. The rest of the paper is divided into three sections. In the next section, TELIC is introduced formally as an algorithm for MPLS-TE applications. In section 3, the results of using TELIC and SHORTD (shortest distance routing) are presented. In the last section, the results and conclusions are summarized.

2 TELIC SPECIFICATIONS

TELIC performs constrained routing of label switched paths in an MPLS-Diffserv domain where the LSP requests are serviced in a CBQ (Class-based Queuing) method. The information available about each LSP request is a quadruplet. Besides ingress, egress and bandwidth, each request also carries a label of its FEC (forwarding equivalence class). TELIC uses the FEC information to look for the widest available path within a subgraph of the domain. The premium FEC uses a subgraph consisting of silver, white and green links in that order. The assured FEC uses a subgraph consisting of green, yellow, white and silver links and the best effort FEC uses a subgraph consisting of red, yellow and green links. Within the subgraph, TELIC looks for a minimum cost path where cost of the ith path is defined as:

$$C_i = \sum_{J=1}^{N} (1/B_J + D_J) * R_J \qquad (1)$$

Where:
C_i = Cost of the i^{th} path
B_J = Available bandwidth on link J
D_J = Delay for link J
R_J = Reliability for link J

The shortest distance algorithm does not consider the D and R factors for computing an LSP. It takes into account the residual bandwidth available on each link and it considers the whole domain for allocating a requested LSP tunnel. We may express the total distance of a k-hop path p as the sum of this inverse value:

$$dist(p) = \sum_{j=1}^{k} (1/nj) \qquad (2)$$

Where:
dist(p) = total distance for the k-hop path 'p'
n_j =bandwidth of the link j

2.1 Conjunction Factor Computation

TELIC partitions the domain under consideration into several subgraphs in order to avoid sharing links between EF and other traffic. It has been determined experimentally that the EF traffic can become delinquent if it shares links with other classes of traffic. Therefore, TELIC works on the strategy of routing the non-QoS traffic on links that do not carry any EF LSP. In order to quantify the effect of this strategy, a degree of conjunction is defined for each link in the domain. Degree of conjunction "D_i" for any link 'i' is defined as:

$$Di = 0*CE + 2*CA + 5*CD \qquad (3)$$

Where:
D_i =degree of conjunction for link 'i'
C_E=number of EF LSP's passing through this link
C_A=number of AF LSP's passing through this link
C_D=number of DF LSP's passing through this link

It is obvious from Equation (3) that the degree of conjunction will increase faster for DF as compared to AF. This is due to the fact that DF is considered as the "best effort" service that does not carry any guarantees or assurance of transmission. Once the degree of conjunction is calculated for each link, we can calculate the conjunction factor for the whole domain and use it as a figure of merit for evaluating the performance of TE algorithms. Conjunction factor for a domain consisting of 'n' links is defined as:

$$Fc = \sum_{i=1}^{n} (Di) \qquad (4)$$

Where:
F_c = conjunction factor for the domain under consideration
D_i = degree of conjunction for link 'i'

The objective of link coloring and graph partitioning in TELIC is to minimize the conjunction factor for a given set of traffic requests while trying to meet the maximum number of requests in a queue using class based queuing. A higher value of conjunction factor would lead to increased queuing delays for the label switched paths installed in the domain. Combining best effort traffic with the premium traffic would tend to make the overall traffic bursty as the best effort traffic tends to be bursty in nature. Increased queuing delays may also cause duplicate data transmission through the domain resulting in overall performance degradation. Therefore, minimizing Fc is one of the most important goals for TELIC. As shown later, this objective is achieved in with a small price, an increased rejection of lower priority requests, mainly the best effort traffic requests. TELIC is formalized as a traffic engineering algorithm in Figure 1.

TRAFFIC ENGINEERING WITH LINK COLORING (TELIC)
Input: A graph consisting of N nodes and M links, with each link specified as with available bandwidth B, delay D, reliability R and a color C
Output: An LSP between the designated ingress router and the egress router satisfying the minimum cost criteria of Equation (1) and meeting the FEC criteria with the color of the most congested link in the new LSP
Algorithm Steps: (TELIC reads the domain topology from a file before starting the listed steps) (1) Read the next request (2) Determine the FEC of the request (3) If it is EF, route the LSP with a subgraph that includes silver, white and green links in that order (4) If it is AF, route the LSP with a subgraph that includes green, yellow white and silver links in that order (5) If it is DF, route the LSP with a subgraph that includes red, yellow and green links in that order (6) Output the LSP, store it in the LSP table in the ingress router and reduce the available bandwidth in each link of the new LSP by subtracting the allocated bandwidth from Bj for each j (7) Update the colors of the links included in the new LSP as per the color table in the ingress node
Figure 1: TELIC Specifications

3 RESULTS AND DISCUSSION

TELIC's performance is measured by using it on a specific set of traffic requests that arrive at networks built with different topologies such as ISP, irregular ISP and disjoint multipath. Traffic sets are prepared with 20-80 split between premium and non-premium traffic. Within the non-premium traffic, the ratio of best effort traffic is changed in order to take into account varying types of requests. Measured results include the conjunction factor and the rejected bandwidth requests for all classes of traffic. The same traffic sets and topologies are used with the shortest-distance constrained routing algorithm (SHORTD) that utilizes inverse of available bandwidth as the distance and selects links for an LSP from the whole network.. We are thus able to compare the results with TELIC and determine the ratio of conjunction factor and rejected requests in each category. This provides us with an opportunity to enhance the performance of TELIC by reducing the gap between the demand and supply of bandwidth, while meeting the quality of service needs of the traffic requests.

Figure 2, 3 and 4 show the domains for which TELIC and SHORTD have been tested.

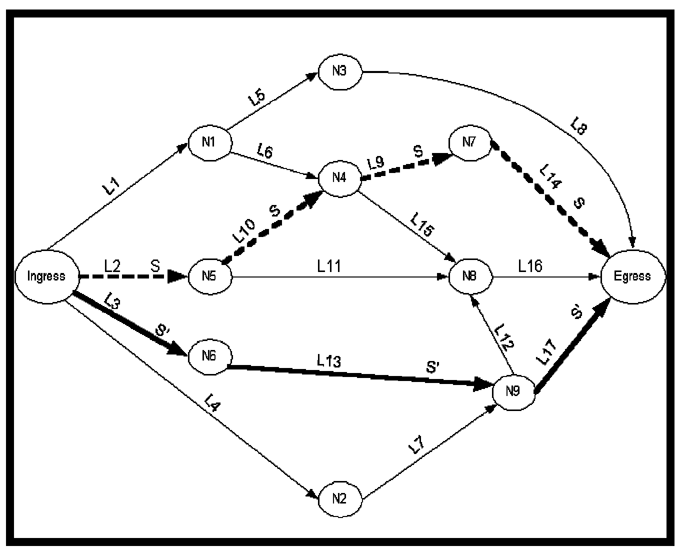

Figure 2: An MPLS Domain Showing Various Links and Nodes

The conjunction factor values for each of the three domains for a traffic set are shown in Table 1 and the rejected bandwidth is shown in Table 2.

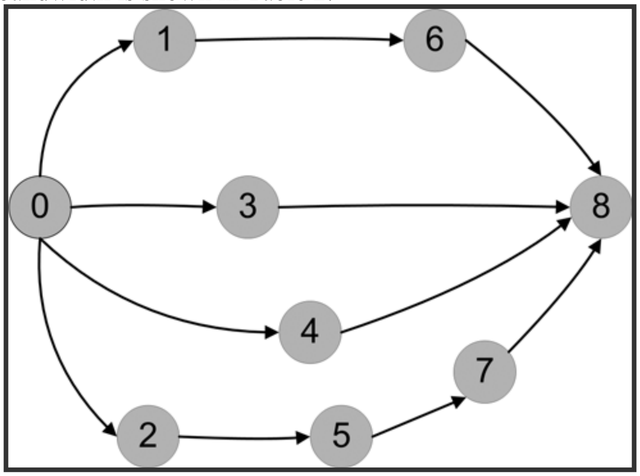

Figure 3: A Disjoint Multipath Domain

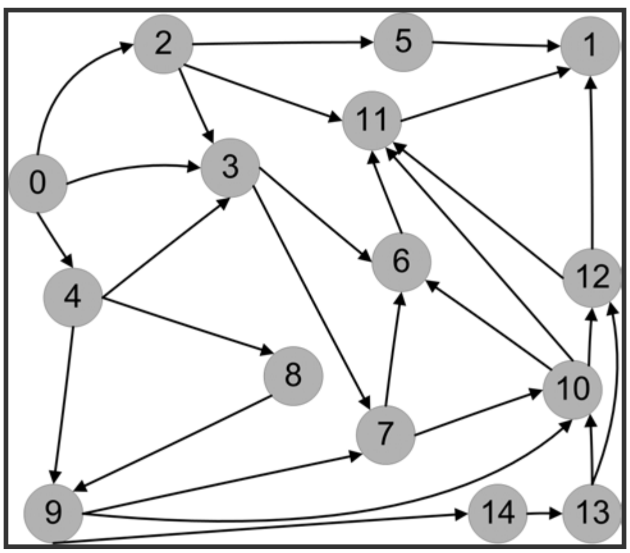

Figure 4: An Irregular Multipath Domain [9]

Table 1 Conjunction Factor Values for a Set

S. No.	Domain	TELIC	SHORTD
1.	ISP	0	306
2.	Multipath	0	104
3.	MIR	4	34

Table 2 Rejected Bandwidth Values for a Set

S. No.	Domain	TELIC	SHORTD
1.	ISP	DF=80	DF=10
2.	Multipath	DF=80	0
3.	MIR	EF=20 AF=0 DF=250	EF=0 AF=0 DF=230

Figures 5,6 and 7 show the conjunction factor results for all the three domains when 24 different traffic sets are processed. The traffic set 1 has EF service request for 20% of the overall bandwidth demand and the remaining bandwidth requests contain only 4% AF and 96% DF requests. The ratio of AF requests is increased linearly until the last traffic set in which about 92% of the non-EF demand is in the AF category.

It is obvious from the results that TELIC minimizes the conjunction factor whereas SHORTD routing results in very large values for the conjunction factor. It may be mentioned here that the conjunction factor has been computed with the premium traffic perspective. In other words, this value shows the degree of merging of other traffic with the premium traffic on the links within the domain under observation. Thus it is a very important parameter for the ISP who would like to charge the customer for the premium service and also provide the expected premium service to the customer. From the graphs of CF values, it can be seen that CF for SHORTD is too high for the sets in which best effort traffic dominates the non-EF portion. On the other hand, TELIC remains successful in minimizing CF and thus outperforms SHORTD by a large margin. As the ratio of AF service class is increased, TELIC and SHORTD produce closer results. This is due to the fact that the AF class traffic is regulated and thus it can share links with the EF traffic without jeopardizing the EF performance. From the table of rejected bandwidth, it is seen that mostly the best effort traffic requests get rejected. However, it is one aspect in which TELIC's performance can be improved. Enhancements under consideration include allowing arbitrary bandwidth requests, splitting only the best effort traffic requests in order to utilize the available bandwidth more efficiently and finally identifying bottleneck links and modifying the domain topology to reduce the rejected bandwidth ratio.

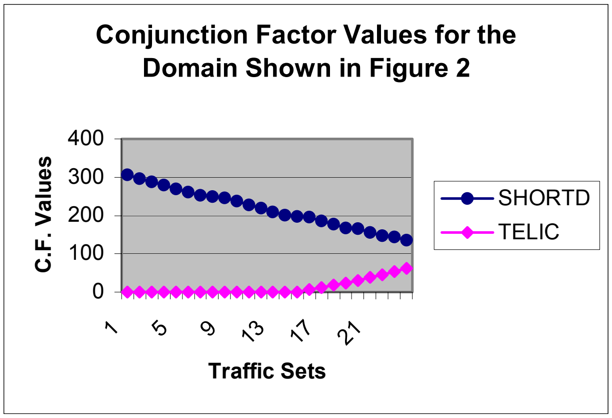

Figure 5: CF Values for ISP Domain

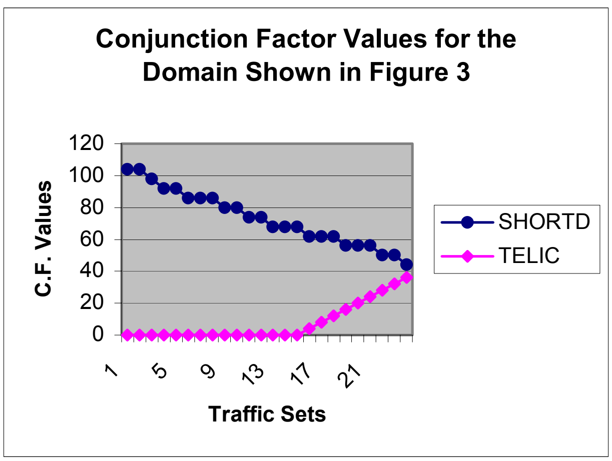

Figure 6: CF Values for Disjoint Multipath Domain

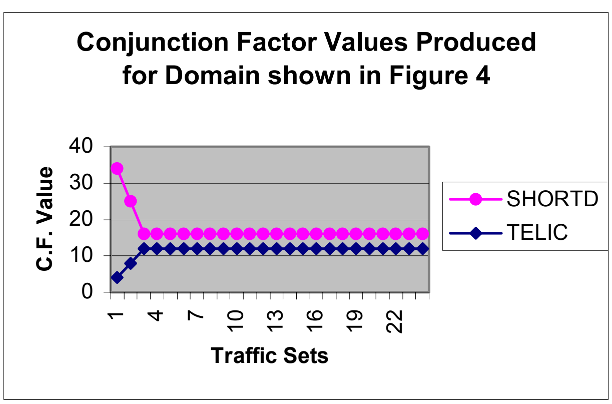

Figure 7: CF Values for Irregular ISP Domain

CONCLUSION

The traffic engineering algorithm TELIC has been formally specified. An extensive review of existing constrained routing and traffic engineering algorithms is performed and their strategies and deficiencies are discussed. Conjunction factor is defined for measuring the degree of merging of premium and non-premium traffic. Cost of paths is computed for TELIC and SHORTD algorithms. SHORTD is the shortest distance algorithm as discussed in the literature. TELIC's performance is compared with the performance of SHORTD in terms of rejected bandwidth and conjunction factor for three example domains. Results point the remarkable success of TELIC in keeping the premium traffic segregated from best effort traffic. Finally some proposed enhancements in TELIC are discussed to reduce the overall rejected bandwidth value.

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BIOGRAPHY

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