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Multi-Commodity Based Widest Congested Edge Disjoint Path Algorithm (MBWCEDP) using MPLS

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Abstract

Objectives: The paper deals with the Online Multipath Routing of the Traffic flows in MPLS networks. A good multipath routing algorithm fulfills all the online traffic demands at real time. Many conventional multipath routing algorithms were considered good in respect of many parameters but still suffered from their highly rejected online traffic demands rate. **Methods/Statistical Analysis:** The algorithm presented classifies the traffic demands into various profile classes (which are generated based on the SLAs signed by the Internet users). These profile classes work as a rough estimator of future traffic demands and are used to solve a multi commodity network flow problem. In the proposed algorithm Multi-commodity network flow formulation groups the packet flows as per profile classes with the aim to minimize the cost, to prevent network hotspots i.e. bottleneck links and to ensure minimum rejected requests/ traffic demands. The algorithm works in two phases- In the preprocessing phase SLAs, Global and Local quasi static knowledge about the network are used to generate Multi-commodities based "Profile Classes" in the first phase and then these Multi-commodities based packet flows are distributed over widest residual bandwidth Disjoint Paths with respect to the bottleneck links in the second phase. The transmission of Multi-commodity based flows through disjoint paths w.r.t. bottleneck edges prevent the network from critical deadlock point which helps in minimizing the congestion, delays, rejected requests and maximizing the throughput, i.e. improving the overall performance of the network. **Findings:** To measure the performance of proposed algorithm to the Profile Based Algorithm a series of experiments were measured. Randomly generated request sequence is used for which a random sequence of individual flow request were generated and measured the performance both in terms of number of flows routed and total bandwidth request that was satisfied. Blocking probability for each edge is also considered random.In the findings is shown that out of total 1200 requests, performance of PBR is very poor as it rejects many requests due to overly strict admission control and minimum hop algorithm. The proposed algorithm cleverly controls traffic flow admission by considering congested edges in a disjoint way, so that one LSP does not interfere other LSPs. **Application/Improvements:** The network information is utilized to its extreme and most of the online path requests are accepted only a few requests are rejected.

Keywords: Equalizing Blocking Probability, Multi Commodity, Multiprotocol Label Switching, Profile Classes, Widest Disjoint Paths.

1. Introduction

MPLS may be described as a technology that brought the connection-oriented network to the connectionless IP network. Therefore, network sciences and applications can exploit all of the advantages of IP while being run over networks that are functional, reliable and predictable. In other words, MPLS is a connection-oriented technology that uses a label-swapping technique with IP network routing.

With the explosive growth of Internet, any multipath routing algorithm is considered good if it fulfills all the online traffic demands at real time. Most of the traditional routing algorithms[1, 2, 3] presented by researchers in the past suffered from shortcomings. Many conventional multipath routing algorithms have already been presented in the literature [4, 5, 6, 7, 8] that used MPLS technology to distribute traffic flows along multiple paths. Any multipath routing algorithm is better if it chooses multiple good paths instead of finding the best path. It is

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more important to utilize local/global information of the network such as- topology, previous hour/day/month/year traffic demands data pattern[11], SLA signed by users, congested edges/ node information over a periodic time. In the lack of additional network information about the traffic flows any online routing algorithm can perform poor in the worst case.

The proposed algorithm is inspired by concept of Multi-commodities based flows for various "Profile classes" introduced in Profile based routing algorithm[9]. In the present work in the preprocessing phase "Profile Classes" are generated with the help of "range of bandwidth requirement" specified by internet users while signing the SLA with Internet Service Providers. The traffic flows are grouped as multi-commodities based on these profile classes. A "Commodity" could be represented as an entity that needs to be "shipped" from the source to the destination node by using MPLS on the underlying network. To select any path in the path selection phase, widest residual bandwidth disjoint paths with respect to congested edges are generated with the help of blocking probability information about the global and local network. The present algorithm exploits the network information to its extreme, and allows the traffic flows to pass through widest paths which are disjoint with respect to congested edges only. With this restriction the number of accepted traffic demands increases since the congested edges are neither unutilized nor overburdened instead they are cleverly used based on the quasi static information provided after a fixed time period.

In the Rest of the paper, in section II Profile Based Routing algorithm[9] and WDP[10] including their key aspects and limitations are accounted. In Section III Multi-commodities based Widest Congested Edge Disjoint Path algorithm is presented. In Section IV performance results and simulation are discussed. Finally section V concludes the paper.

2. Existing Algorithms

In literature, on multipath routing schemes, there are many proposed algorithms that use specific capabilities of an MPLS network. Dynamic Routing with Partial Information (DR-PI)[4] , Dynamic Restorable Routing[5], Minimum Interference Routing Algorithm[7, 8] and Profile Based Routing[9] used the MPLS technique extensively in multipath routing. In DR-PI[4] and DORA[5] the number of rejected requests is not taken in consideration, considerable computation complexity is a major limitation for their online implementation, no local/segment backups are considered in these algorithms. MIRA[7, 8] focuses extensively on the interference effect of a single ingress-egress pair at a time so MIRA is computationally very expensive too. In PBR[9], the utilization of traffic profiles of data flows is proposed. PBR suffers from the limitation that there is no explicit fault recovery treatment. All these online multipath routing algorithms have given important contribution to the exploitation of the MPLS topology (ingress-egress nodes). A brief review and scope of improvement in PBR[9] and Widest Disjoint Path[10] algorithm is introduced next.

a. Profile Based Routing[9]

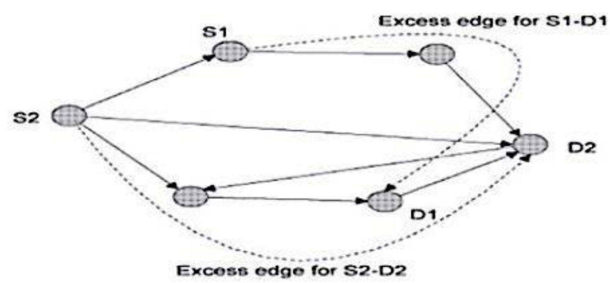

Figure 1. Excess edges are added to the Graph in the preprocessing phase to accept all the traffic demands in the preprocessing phase in PBR.

Profile based routing algorithm is the routing algorithm in which traffic going through network is measured, and the traffic flow is classified as per "Profile Classes". Each profile class, include Bi, which denotes the aggregate bandwidth requirement of the aggregated LSP setup requests between source si and destination di and is mapped to class ID. Each profile is symbolized by (class ID, si, di, B) called commodity i. For approximately satisfying all the requests on future, the authors have proposed simultaneous equations to find amount traffic of each ingress-egress pair distributed on every link (first step namely Multi-commodity Flow Preprocessing). If the problem has solution, they applied the solution to the network. For each LSP demand, its class is determined and use solution of the first step for each class to initialize the network topology, then use shortest path algorithm (MHA) to find optimal solution (second step namely Online Path Selection for LSP requests). On general case, not all the profiles can be completely satisfied. The authors have shown the merits of using profile classes by using various examples. The demerits that authors have not discussed are use of excess edges which is not practical. If a path between any source destination pair does not exist, a direct edge (dotted line) is considered which is totally hypothetical and impractical. Blocking Probability information is also not utilized since Minimum Hop Algorithm (MHA) is used for path selection.

b. Widest Disjoint Path Algorithm[10]

Most of the times multiple paths perform well individually but when traffic is routed along them collectively, may not perform so well and even quiet poor. The reason is sharing of the bottleneck links. The best way to reduce bottlenecks is to compute maximum disjoint paths but this approach is static and overly conservative.

In Widest Disjoint Paths algorithm, maximally disjoint paths are computed. If there are multiple such paths then path with the highest width (w.r.t bandwidth) are chosen for the network flow. But with this approach overall network performance is degraded and majority of network resources are not utilized. Sharing of nodes or links does not matter but the sharing of bottleneck links matters. To avoid congestion, sharing of bottlenecks must be avoided. Disjoint paths w.r.t. bottlenecks can enhance the performance of any network routing model. The knowledge about the bottlenecks is gained from the global link state updates. Proportioning the traffic to these disjoint paths can be done with the help of Equalizing Blocking Probability.

3. Multicommodity Based Widest Congested Edge Disjoint Path Algorithm

In this paper, Multi-commodity based Widest Congested Edge Disjoint Path algorithm for dynamic multipath routing using the advantages of two basic algorithms PBR and WDP using MPLS technique is presented. The quasistatic information about the network is used. The algorithm works in two phases: Multi-commodity Preprocessing phase and Path selection phase. Problem setup and basic routing requirements are mentioned next.

a. Problem Statement

The network is modeled as a graph G = (V, E), where V is the set of routers and E is the set of links. The current residual capacity of a link is denoted cap(e)–this is the additional bandwidth that can be routed on link e subset of routers are assumed to be ingress-egress routers, between which label switched paths (LSPs) can be set up. It is assumed that the ingress-egress pairs are known, and that this information is quasi-static, meaning it changes very infrequently. An example is shown in Figure 1, which is borrowed from Kodialam-Lakshman[7,8].

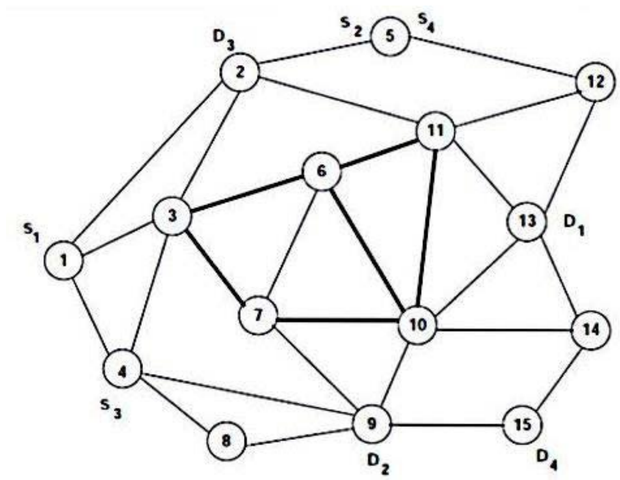

Figure 2. Graph Considered for traffic demands.

Any Label Switch Path setup request is considered as a quadruple (RID, si, di, Bi) where RID is the LSP request identity, si is the LIR (label ingress/ source router), di is the LER (label egress /destination router), and bi is the bandwidth required for the label switch path. For any (si, di) pair, there could be multiple LSP requests, separate RID is must for every request. For acceptance of any LSP request (ID, si, di, Bi) in the network the algorithm must find a path for (si, di) pair along which each edge must have minimum residual capacity Bi or the request is rejected. The traffic flow admission control is implemented by using any congested edge only in one LSP path i.e. by using congested edge disjoint paths, where each edge in path must have minimum residual capacity Bi.

It is assumed that all label switch path set up requests arrive online, one at a time, and the individual future requests are unknown for the algorithm. The traffic profile information used in the proposed algorithm records the expected traffic flow between pairs of source/ingress and destination/egress routers, and aggregates traffic demands as a "profile" between them. Such information can be either past data based, heuristic based or it can be calculated from Service Level Agreements that have been entered by a ISP with its users. Each traffic profile is also defined by a quadruple: (class ID, si, di, B) where CLASS ID is the traffic class, (si, di) are the ingress and egress nodes, and Bi is the aggregate traffic to be expected for this class between si and di. Between the same (si, di) pair, there can be multiple traffic classes (corresponding to different service types offered by the service providers). Each label switch path request is mapped to a unique profile class. A convenient way to think about this is that total sum of all LSP requests between Si and di for the class i is a random variable with mean bi.

b. Multi-Commodity Based Widest Congested Edge Disjoint Path Algorithm

Multi-Commodity Based Widest Congest Edge Disjoint Path Algorithm:

Step1: Multi-commodity Flow Preprocessing Phase-

- Predict optimized value of degree of multi-commodities i (where i is maximum number of commodity flows routed through edge e)
- Prioritize the commodities using Global Exchanged Link State Matrics
- Maximize the total carried traffic using Global Optimal Proportioning
- Minimize the Average Flow Blocking Probability br

Step2: Path selection for LSP request Phase

- Remove all edges e from Graph G, for which blocking probability is more than br (for the whole network with the help of Lacalized Adaptive Proportioning(These edges are critical edges having high blocking probability for any class C_{id})
- Find disjoint paths with widest residual bandwidth with respect to congested edges.

Step3. Decrease the residual bandwidth bi in all the edges e for all paths P.

Step4: Route along label Switch Path P(s, d, b).

i. Multi-Commodity Flow Preprocessing Phase

In this preprocessing phase traffic profiles (ID, Pi, si, di, Bi) are generated, corresponding to a real time network G=(V, E), where CID is traffic class identity, si the finite set of sources, di is the finite set of destinations and Bi is minimum aggregate bandwidth requirement for this traffic profile class Cid between set of sources si and set of destinations di. Pi is the priority assigned to this profile class based on the previous knowledge about the network. Each traffic class is treated as a separate commodity. The objective is to find widest disjoint routes w. r. t. the bottleneck links in the network to send maximum number of commodities along these disjoint routes, for the traffic flow demands between source nodes to the destination nodes. In the literature global optimal proportioning has been extensively studied.

Since each source node (LER) knows real time network topology information (which includes the maximum residual capacity cap(e) of every edge) and the traffic load to be routed between every ingress-egress pair. With the help of this globally exchanged knowledge gathered after every time period , offered traffic loads through the network and service level agreements SLA, the optimal proportions , for distributing multi-commodity based flows to the LSPs for each ingress-egress pair, can be computed as described below.

$\sigma = (s, d)$ denotes a source destination pair

λ_σ= average arrival rate of flows arriving at the source nodes destined for node d.

μ_σ = average holding time for the flows

ν_σ = offered load between source destination pair

So, $\nu_\sigma = \lambda_\sigma/\mu_\sigma$

R_σ = finite set of all the feasible paths for fulfilling traffic demands between pair σ

α_r = optimal proportions of the path for each $r \in R_\sigma$ and $\sum_{r\in R}\alpha_r = 1$

b_r is the average blocking probability

W is the total carried traffic,

The objective in preprocessing phase is to maximize the total carried traffic W, with the help of global data exchange by updating the network information after every periodic time q.

$$W=\sum_\sigma \sum r_{\sigma\in\hat{R}}\, \alpha_r \nu_\sigma (1-b_r) \text{ is maximized} \tag{1}$$

The same objective can be achieved by minimizing the average blocking probability br. To minimize br localized strategies are used in path selection phase. All such profile classes are generated by ensuring these objectives at the server side (i.e. router) before actual path selection, it seems highly complex but with the help of past data complexity can be reduced.

ii. Path Selection Phase

Once the Profile Classes (ClassID, si, di, Bi) are generated in the preprocessing phase, the traffic demand flows are now handled by grouping them as per Profile Class, between source destination pairs through LSPs. In path selection phase, Widest Disjoint Paths w.r.t. bottleneck links are generated for the corresponding Profile class flows generated and categorized in the preprocessing phase.

To find the bottleneck links average blocking probability br is computed as below:

$$b_r = \Sigma_{i=1} \alpha_{ri} . \beta_{ri} \quad (2)$$

The value of br must be minimized in preprocessing phase. Since a set of multiple paths between any pair may perform well or near optimal individually but may lead to congestion and poor network utilization when performed collectively, it is wise to discard those links whose blocking probability is greater than br, since these links are bottleneck links. So to ensure that multi-commodity flows do not share bottleneck links, what can be done is to remove the traffic flows from one of the paths and then shifting the load to another candidate path by ensuring that there is no increment in the average blocking probability br. Therefore, it is necessary to ensure that the candidate multiple paths are mutually disjoint with respect to the bottleneck links.

In Widest Disjoint Path algorithm w. r. t. bottlenecks, multiple disjoint paths are selected that don't share bottlenecks. If multiple such paths are found then the path the widest residual bandwidth is selected. With these widest residual bandwidth disjoint paths both the objectives-minimizing the no of rejected requests and maximizing the traffic flow are achieved with a balance.

4. Performance Results

a. Methodology Adopted

To evaluate the performance of the proposed algorithm, matlab software is used. Random traffic flow demands are considered at real time. Random blocking probability is considered. The graph shown in figure 2 is taken as a sample graph to compare the results. All the graphs considerations are same as taken in MIRA[7, 8] and PBR[9]. After the random traffic flow demands generation between any destination pair, multicommodity flows were generated based on the traffic profiles, after that group of packets were sent through the congested edge disjoint paths (between that source-destination pair). Here, any edge is considered as congested edge if the blocking probability of that edge is greater that mean blocking probability of all the edges of the network at a particular period of time. The proposed algorithm uses any congested edge only in a single path. Due to this reason the multiple paths do not interfere to other paths. PBR and Mira rejects most of the traffic demands due to admission control through these congested edges, so their traffic flow demands rejection is very high. The proposed algorithm is evaluated in terms of the acceptance and rejection of real time traffic demands. The graph in figure 3 shows the acceptance- rejection ratio out of 1200 traffic demands between s1 and d1 of figure 2 for both PBR and proposed algorithm. 10, 20, 30 and then 50 simulation runs of these random 1200 traffic demands were executed by both PBR and the proposed algorithm. The results about the proposed algorithms are convincing as shown in figure 3.

b. Worst-Case Results

Performance of the proposed algorithm is compared with the Profile based routing algorithm. In PBR if there is no path between a source destination pair, an excess edge is used to deal with the worst case situation. In the proposed algorithm in the worst case, maximum feasible traffic demands are accepted as compared to PBR. A traffic demand is rejected only when a single congested edge is required by more than one LSP request; in that case proposed algorithm identifies congested edges by using local and global periodic information. Then LSPs are generated by using these congested edges disjointly. The proposed algorithm performs better than PBR in the worst case, in the terms of number of accepted-rejected request ratio. The performance of PBR and the proposed algorithm is shown in Figure 3.

c. Simulation Results

To measure the performance of proposed algorithm to the Profile Based Algorithm a series of experiments were measured. Randomly generated request sequence is used for which a random sequence of individual flow request were generated and measured the performance both in terms of number of flows routed and total bandwidth request that was satisfied. Blocking probability for each edge is also considered random for each edge. The simulation results are generated for the graph shown in figure 2. The same graph is used as an example in many conventional multipath routing algorithms using MPLS[7, [8, 9].

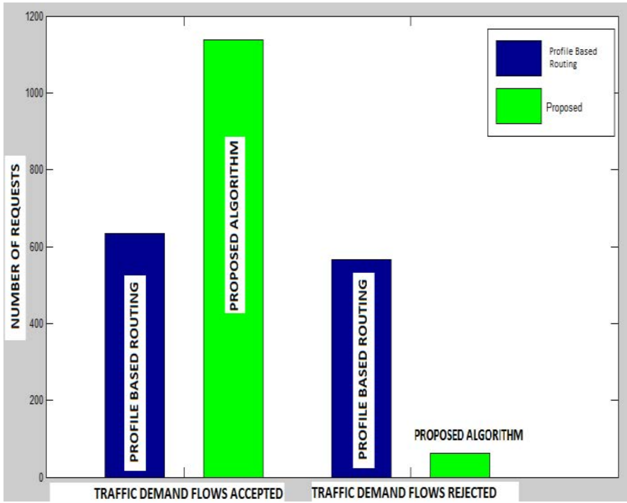

Figure 3. Path Accepted and rejected graphs for PBR and proposed algorithm.

In figure 3, it is shown that out of total 1200 requests, performance of PBR is very poor as it rejects many requests due to overly strict admission control and minimum hop algorithm. The proposed algorithm cleverly controls traffic flow admission by considering congested edges in a disjoint way, so that one LSP does not interfere other LSPs. The network information is utilized to its extreme and most of the online path requests are accepted only a few requests are rejected.

5. Conclusions and Future Work

The main contribution of this paper is the development of hybrid algorithm exploiting the concept of MPLS and profile classes generated using SLAs. The assumption is that the traffic demands are available and all ingress-egress pairs are known. The key idea is to pre-compute the paths between any source-destination pair using the global and local knowledge about the network in the preprocessing phase before the actual path selection, with the objective minimizing the number of rejected requests and to allow maximum of the online traffic demands for longest simulation runs. By using widest disjoint paths w. r. t. bottleneck edges both the objectives can be fulfilled. Heuristic parameters could be applied for the discarded paths which contain bottlenecks for rerouting or as backup paths. In the near future, experimentation of the algorithm in operational MPLS network and to compare the simulation results of the present algorithm to the already existing algorithms is in progress.

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