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Enhanced Restoration Algorithm in Virtual Private Network with Qos Support

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Abstract: A Virtual Private Network (VPN) aims to emulate the services provided by a private network over the shared Internet. The endpoints of VPN are connected using abstractions such as Virtual Channels (VCs). Reliability of an end-to-end VPN connection depends on the reliability of the links and nodes. VPN service providers provide new services with Quality of Service (QoS), guarantees are also resilient to failures. Supporting QoS connections requires the existence of routing mechanisms that computes the QoS paths, where these paths satisfy the QoS constraints. Resilience to failures, on the other hand, is achieved by providing, each primary QoS path, a set of alternative QoS paths, upon a failure of either a link or a node. We aim at to minimize the total bandwidth reserved on the backup edges. The above objectives, coupled with the need to minimize the global use of network resources, imply that the cost of both the primary path and the restoration topology should be a major consideration of the routing process. It turns out that the widely used approach of disjoint primary, restoration paths is not an optimal strategy. Hence, the proposed approximation restoration algorithms construct a restoration topology and this topology protects a portion of the primary QoS path. This approach guarantees to find a restoration topology with optimal cost which satisfies the QoS constraints.

Key words: Restoration schemes, QoS models, QoS constraints, restricted shortest path, primary path and restoration topology

INTRODUCTION

Traditionally, a Private Network (PN) is established by leased lines connecting the PN sites over a WAN. Since the lines are dedicated, security and bandwidth guarantees are ensured. As the Internet becomes a commercial infrastructure, not only the number of endpoints of a PN gets increased but also the endpoints get geographically dispersed. Thus, connecting a large number of dispersed PN sites with dedicated lines becomes expensive. As a result, in recent years there has been much interest in offering Virtual Private Network (VPN) services over the public Internet. The main challenge has been to provide performance guarantees comparable to private WANs without dedicated leased-lines. To offer new services with Quality of Service (QoS) guarantees that are also resilient to failures also be resilient to failures. This goal, namely, providing QoS paths with failure resilience, can be achieved by provisioning primary and restoration paths that satisfies the QoS constraints.

Restoration algorithm: A restoration algorithm must select set of "backup edges" and allocate necessary bandwidth on them in advance, so that the traffic disrupted by failure of a primary edge can be re-routed via backup paths. Reliability of an end-to-end VPN connection depends on the reliability of the links and nodes in the fixed path that it traverses in the network. In order to ensure service quality and availability in a VPN, seamless recovery from failures is essential.

The restoration techniques can be categorized into link-based and path-based. Link restoration finds alternate paths between the nodes of the failed link. The optimal link restoration approach may involve circuitous restoration routes. Path restoration overcomes this problem by rerouting flow between the source and destination pairs affected by a link failure. This is illustrated in Fig. 1. Figure 1a shows a network consisting of 6 nodes and 8 links without any link failure. It also shows one of the possible ways for reaching at node 4 starting from node 1. Figure 1b shows one way of recovery when link 2-3 fails. This is called as link

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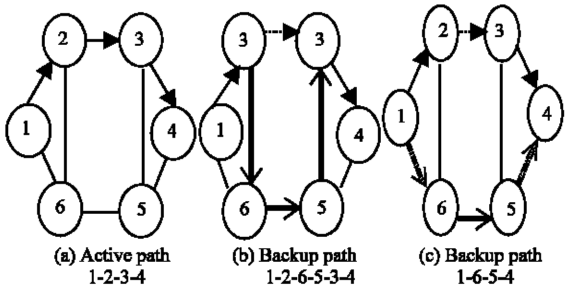

Fig. 1: Restoration scheme

restoration where we find another path for the failed link. Another way of restoration is shown in Fig. 1c. In this study, we do not find alternate path for the failed link. We try to find an alternate path for the original source destination pair.

There seems to be a growing interest among the service providers to offer their customers new revenue-generating services with Quality of Service (QoS) guarantees. This is facilitated by current efforts to provide resource reservations and explicit path routing. On the other hand, physical network infrastructures may be prone to failures.

VPN QoS models: There are 2 popular models for providing QoS in the context of VPNs:

- Pipe model
- Hose model

In the pipe model, the VPN customer specifies QoS requirements between every pair of VPN endpoints. Thus, the pipe model requires the customer to know the complete traffic matrix, that is, the load between every pair of endpoints. However, as the number of endpoints grow and as the connectivity dynamics increase, it may be difficult to obtain pair wise statistical bandwidth requirements between the endpoints and it is shown in Fig. 2.

In the hose model (Italiano *et al*., 2002; Yu-Liang *et al*., 2005) each VPN site specifies its aggregate ingress and egress bandwidth requests. The ingress bandwidth for an endpoint specifies the incoming traffic from all the other VPN endpoints into the endpoint, while the egress bandwidth is the amount of traffic the endpoint can send to the other VPN endpoints. The hose model is scalable since the customer manages the allocated bandwidth at per flow basis at the network edge while the VPN provider is concerned only with the flow aggregates inside the network. Several provisioning algorithms in VPN require identifying a sub graph to connect the VPN endpoints and reserving the necessary bandwidth on the physical links which are used by this sub graph. It is shown that a

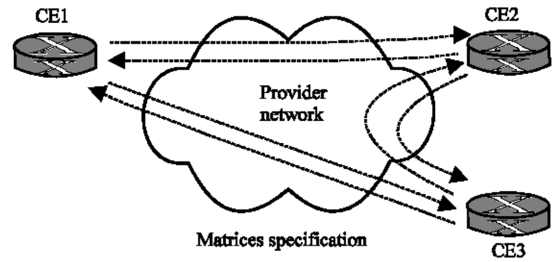

Fig. 2: Pipe model

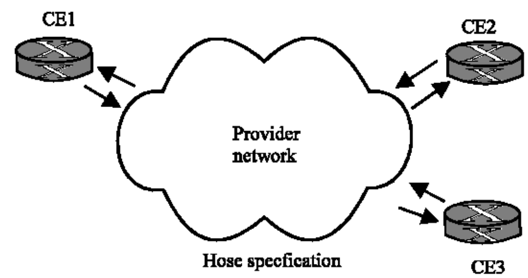

Fig. 3: Hose model

tree is the optimum topology when the ingress and egress bandwidth requests are symmetrical and it is shown in Fig. 3.

VPN QoS constraints: QoS constraints occur naturally in a number of practical settings involving bandwidth and delay sensitive applications such as voice over IP, audio and video conferencing, multimedia streaming, etc. QoS constraints can be divided into bottleneck constraints, such as bandwidth and additive constraints, such as delay or jitter. Bottleneck QoS constraints can be efficiently handled by pruning infeasible links. However, additive QoS constraints are more difficult to handle. Indeed, the basic problem of finding an optimal path which satisfies an additive QoS constraint is NP-hard. Moreover, it turns out that, in the presence of additive QoS constraints, the widely used approach of disjoint primary and restoration paths is not an optimal strategy. A better solution is to provide a restoration topology, which protects a portion of the primary path. The advantage of the disjoint paths strategy is its ability to switch promptly from the primary path to the backup path in the event of a failure.

MATERIALS AND METHODS

Network model: We represent the network by an undirected graph G (V,E), where 'V' is the set of nodes and 'E' is the set of links. We assume that the network does not contain parallel links. We denote by N and M the number of network nodes and links, respectively, $N = |V|$ and $M = |E|$. An (s, t)-walk is a finite sequence of nodes W = (s = v_0,v_1,….t = v_n) such that, for 0≤i≤n -1, (v_i, v_{i+1}) € E. Here, N = |W| is the hop count of W. Note that nodes and links may appear in a walk several times. An (s,t) -path is an P-walk whose nodes are distinct. The subwalk (subpath) of W(P) that extends from v_i to v_j is denoted by W(v_i,v_j)(P(v_i, v_j)). Let W1 be a (v,u) -walk and W2 be a (u,w) -walk; then,W1 o W2 denotes the (v,w)-walk formed by the concatenation of W1 and W2. Each link l € E offers a bandwidth guarantee which is typically the available bandwidth and a delay guarantee. The bandwidth of a walk is identical to the bandwidth of its worst link. The delay D (W) of a walk W is the sum of the QoS requirements of its links, D(W) = $S_{l€w}$ d_l. In order to optimize the global resource utilization, we need to identify QoS paths that consume as few network resources as possible. Accordingly, we associate with each link a nonnegative cost, which estimates the quality of the link in terms of resource utilization. The link cost may depend on various factors, e.g., the link's available bandwidth and its location. The cost C (W) of a walk W is defined to be the sum of the costs of its links, C (W) = $S_{l€w}$ c_l.

PROBLEM STATEMENT

A fundamental problem in QoS routing is to identify a minimum cost path between a source's' and a destination 't' that satisfies delay and bandwidth constraints (Lorenz and Raz, 2001; Hassin, 1992).

Problem RSP (Restricted Shortest Path): Given a source node 's', a destination node 't' and a delay constraint 'd', find an path 'p' such that:

- D(p)< d and
- C(p)<C(P) for every other's)- path P that satisfies D(P)<d.

RSP that also includes the two problems of problem RT, Problem P+RT.

Problem RT (Finding the Restoration Topology for a primary QoS path): Given an (s, t) -path and a QoS constraint 'd', such that, D(P) ≤ d find a minimum cost restoration topology R for (P,d).

Problem P+RT (Primary QoS Path and Restoration Topology): Given a source's', a destination 't', and a QoS constraint 'd', find an (s, t)-path 'P' that satisfies D (P)≤d and a restoration topology 'R' for (P, d) such that their total cost C (P) + C(R) is minimum.

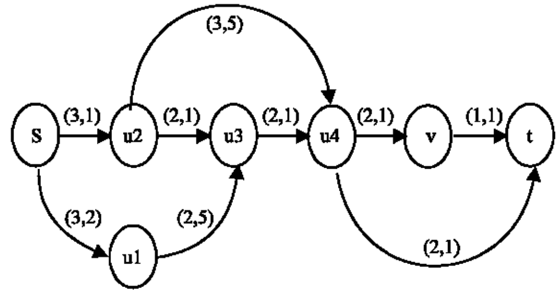

Fig. 4: Example of network

RELATED WORK

As mentioned earlier, our study focuses on provisioning QoS paths with restoration. The QoS path that is used during normal network operation is referred to as the primary path. Upon failure of a network element (node or link) in the primary path, the traffic is immediately switched to a restoration path. Thus, we require that in addition to the primary path, the restoration paths also satisfy the delay constraint.

A common approach for path restoration is to find the disjoint paths which satisfy the delay constraint. However, as we illustrate below in some cases, such disjoint paths do not exist, although it is possible to provision a primary path with a set of restoration paths. Consider the network depicted in Fig. 4.

The only two disjoint paths between the source node 's' and the destination node 't' are P1 = {s, u2,u4,v,t} and P2 = {s,u1,u3,u4,t}. For a delay constraint d = 7, P_1 and P_2 cannot be used as primary and restoration paths, because D (P_1) = 8>9 and D (P_2) = 9>7. However, it is possible to provision a primary path 'P' and a set of restoration paths that satisfy the delay constraint d = 7. Specifically, we use the approximation restoration algorithm for finding primary QoS path P = {s, u2, u3, u4, t} and restoration path RP_1 defined as follows. Upon failure of links (s,u2) we use restoration path RP1 = {S,u1,u3,u2,u4,v,t} and D(RP1) = 4 < = 7. As demonstrated in this example, a restoration path comprises portions of the primary path and a bridge, which serves as a backup for the failed segment of the primary path.

PROPOSED ALGORITHM

Approximation restoration algorithm: Approximation restoration algorithm that also used to find the primary QoS path and restoration paths and it is given below:

Step 1: To identify the number of nodes, source and destination node and get the random values of bandwidth and propagation delay of each link of network and to get value of delay constraint.

Step 2: To determine the primary path, for finding minimum delay of each links of (s,t)- path with the optimal cost.

Step 3: To construct the Restoration Topology, by selecting a subset of bridges and each link of 'P' is protected and total cost is minimum.

- Construct an auxiliary directed graph 'G^1' for each link $(v_{i+1},v_i) \in$ 'P' and to add in 'G^1' a link (v_{i+1}, v_i) and assign the zero value for delay of link.
- To substitute each link l = (u, v) ∈ 'G', l ∈ 'P', by two directed link l_1 = (u, v), l_2 = (u, v) such that $c_1 = c_2 = c$ and $d_1 = d_2 = d$.

Step 4: Find the low cost feasible restoration topology as 'RT' can be determined by applying the adjusted delay concept that satisfies the delay constraints with optimal cost value.

Step 5: To find the delay of the walk D (W) is sum of delay, D (W) = S $_{l€w}$ d_l And to find cost of walk C (W) is sum of cost of its link, i.e., C (W) = S $_{l€w}$ c_l for both primary and restoration topology and total cost C(P)+C(RT) in optimum.

Primary QoS path: Sample network is shown in Fig. 5 for finding a primary QoS path from source 's' to destination 'd' to satisfy the QoS constraints(delay and bandwidth constraints) and to assign bandwidth and delay values for each link connected between the nodes and to identify the number of nodes, source 's', destination 'd' and delay constraints 'd'.

For considering the Fig. 5, there are 2 links exists between the source node's' to the corresponding node value u1,u2, (s,u1),(s,u2) and for finding the minimum delay value and to choose the link exist between the node 's' to 'u2' and delay value as '1' and D(P(s,u2)) = 1, C(P(s,u2)) = 2 and to set flag value as one for visiting node between source node's' to 'u2',from current node 'u2' there are 2 links exists, (u2,u3), (u2,u4) and to find minimum delay as '1' in the pair (u2,u3) and D(P(s,u3)) = 2, C(P(s,u3)) = 4 and to set the flag value as one for visiting node u3. From current node value u3, there is only one link exist between node u3 to u4 and to find minimum delay value as '1' and D(P(s,u4)) = 3, C(P(s,u4)) = 6 and to set flag value for visiting edges between 'u3' and 'u4'. From the current node 'u4', there are 2 links exists between the pair (u4, v) and (u4, t), to find the minimum delay as '1' between pair (u4, t) and to set the flag value for link as 'u4' to 't', D(P(s, t)) = 4,C(P(s,t)) = 9 and to satisfy the delay constraints, 4< = 7 as well as to obtain optimum cost.

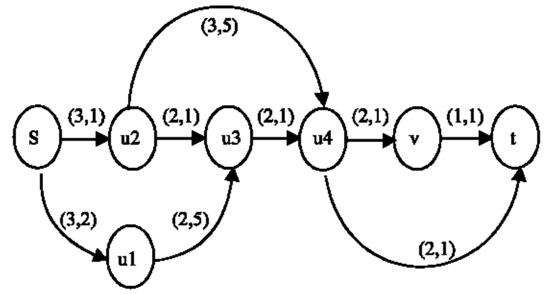

Fig. 5: Primary QoS path

Restoration topology: As mentioned earlier, our study focuses on provisioning QoS paths with restoration. The QoS path that is used during normal network operation is referred to as the primary path. Upon failure of a network element (node or link) in the primary path, the traffic is immediately switched to a restoration path. Thus, we require that in addition to the primary path, the restoration paths also satisfy the QoS constraint.

Auxiliary graph: We construct a directed auxiliary graph 'G^1' from 'G' by reversing each link 'l' $_{€P}$ and assigning it a zero cost. In addition, we also substitute each link 'l' = (u, v) $_{\_G,\ link}$ l ∉ P, by two directed links l_1 = (u,v) and l_2 = (v,u) and $c_1 = c_2 = c$ and $d_1 = d_2 = d$. Clearly, each (s,t)-walk in the auxiliary graph corresponds to a set of bridges that protects each link 'l' $_{€P}$. For example, Fig. 6 depicts the auxiliary graph 'G1' for the network depicted in Fig. 7 and the primary path P = {s, u2, u3, u4, t}. The walk W = {s, u1……u_k} in auxiliary graph corresponds to a set of bridge. In general, however, as explained below, not every (s, t)-walk in the auxiliary graph corresponds to a feasible restoration topology, which satisfies the delay constraint.

Adjusted delay: One of the key contributions of this study is an efficient method for verifying, during its construction, whether a given walk represents a feasible restoration topology. This method is used as a basic building block in our algorithm and enables us to find a low-cost feasible restoration topology. In order to identify a walk in that corresponds to a feasible restoration topology, we introduce the notion of adjusted delay for a walk.

The adjusted delay D (W) of a walk

W = {s, u0,u1…..u_{k-1},u_k } in 'G^1' is defined recursively as follows:

- The adjusted delay of an empty walk is 0, D(s) = 0;
- Otherwise the adjusted delay D (w) of the walk W = {u_0, u1…..u_{k-1}, uk} is

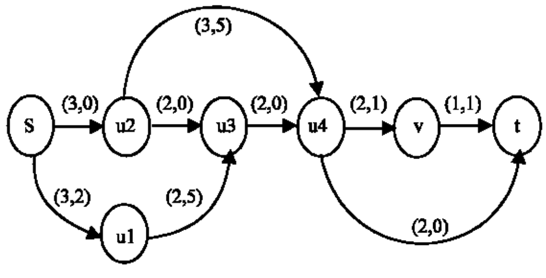

Fig. 6: Auxiliary graph

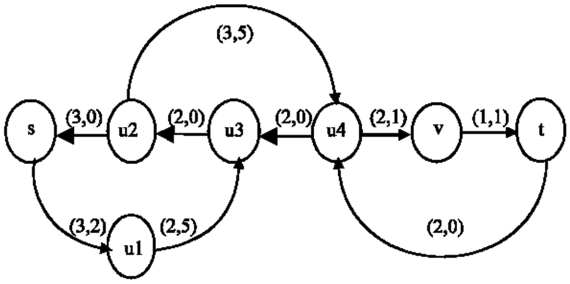

Fig. 7: Adjusted delay

- min { D (P $_{(s, uk)}$), D)}, if u $_{k-1}$ ∉ P, u $_k$ ∈ P and D < = D (P $_{(s, uk)}$)) + Δ.
- D (P $_{(s, uk)}$), if (u_{k-1}, u $_k$) ∈ P and D (W (s,u_{k-1}))< = D (P (s,u_{k-1})).
- D, otherwise where D = (D(W (s,u_{k-1}))) + d(u_{k-1},u_k).

Case 1: If u $_{k-1}$ ∉ P, u $_k$ ∈ P and D < = D (P $_{(s, uk)}$) + Δ. Then node u_k may be either the termination point or an internal node of a bridge. As a result, since u_k may be the starting point of a new bridge, we set D (W($_{s, uk-1}$)) = min {D (P $_{(s, uk)}$, D)}.

Case 2: If u $_{k-1}$ ∈ P, u $_k$ ∈ P and D(W($_{s,uk-1}$)) < = D (P $_{(s, uk-1)}$), then node u_k is not a termination point of a bridge and u_k may be the starting-point of a new bridge, we set D (W($_{s,uk}$)) = D (P $_{(s, uk)}$).

Case 3: If u $_{k-1}$ ∉ P, u $_k$ ∈ P and D > = D (P $_{(s, uk)}$) + Δ. Then node u_k can not be the termination point of a valid bridge and it may only be an internal node of a bridge. Thus, D (W($_{s, uk}$)) = D.

We illustrate the calculation of the adjusted delay using the walk shown in bold in figure. Here the primary path P = {s,u3,u2,u4,t}.The delay of every link l ∈ P, d_l = 1 and delay constraint d = 7. Thus D(P) = 4 and Δ = d-D(P) = 7-4 = 3.The delay of every other link 'l '∉'P' is depicted in the figure. Let us calculate the adjusted delay of the walk W(s, t) and its various prefixes. At the base of recursion D{s} = 0. Since node 'u1' does not belong to 'P', we set D(W(s,u1)) = 2,the pair (s,u1) and u_{k-1} ∉ 'P' and u_k ∉'P' and case3 is satisfied, D(W(s,u_{k-1})) + d(uk-1,u_k) = 0+2 = 2.D(W(s,u1)) = 2 and u1 is not a termination point of the valid bridge and it may be an internal node of bridge, thus D(W(s,u1)) = 2. For computing a adjusted delay of the node 'u3' and there is only one link exists between node 'u1' and 'u3' and u_{k-1} ∉ P, u_k ∈ P and also to satisfy D< = D(P(s,u_k)) + Δ, 2< = (2+3),2< = 5 and case1 can be satisfied and to find minimum {D,D(P(s,u_k)) = min(2,2) = 2 and 'u2' may be either the termination point or an internal node of a bridge, D(W(s,u3)) = 2. For computing a adjusted delay of the node 'u2' and there is only one link exists between node 'u3' and 'u2' and u_{k-1}∈'P',u_k∈'P'and also to satisfy D(W(s,u_{k-1}))< = D(P(s,u_{k-1})), 2< = 2 and case2 can be satisfied, D(P(s,u3)) = 1 and 'u3' is not a termination point of a bridge. Since u3 may be internal node of new bridge, D (W(s, u3)) = 1. For computing a adjusted delay of the node 'u4' and there is only one link exists between node 'u2' and 'u4' and u_{k-1}∈'P',u_k∈'P'and also to satisfy D(W(s,u_{k-1}))< = D(P(s,u_{k-1})), 1< = 1 and case2 can be satisfied, D(P(s,u3)) = 3 and 'u4' is not a termination point of a bridge and starting point of new bridge, D (W(s,u4)) = 3. For computing a adjusted delay of the node 'v' and there is only one link exists between node 'u4' and 'v' and u_{k-1}∈'P',u_k ∉ 'P'and also to satisfy case3 can be satisfied, D(P(s,u4)) = 4 and 'v' is not a termination point of a bridge and only a internal node of bridge. For computing a adjusted delay of the node 't' and there is only one link exists between node 'v' and 't' and u_{k-1} ∉ P, u_k ∈ P and also to satisfy D< = D(P(s,u_k)) + Δ, 4< = (4+3),4< = 7 and case1 can be satisfied and to find minimum {D,D(P(s, u_k)) = min(4,4) = 4 and 't' may be either the termination point or an internal node of a bridge, D(W(s,t)) = 4 and C(R) = 13. We conclude that the given walk represents a feasible restoration topology.

Primary QoS Path and Restoration Topology (P+RT): From the Fig. 4 to find the cost of primary QoS path is C (P) = 9 and cost of the restoration topology is C(R) = 13 and their total cost 22 is minimum.

RESULTS AND DISCUSSION

The approach has been tested by simulations and the simulated results show that the proposed approximation algorithm identifies restoration path whose cost is significantly smaller than those provided by other approaches.

In this Fig. 8 'x' axis that shows the number of nodes and 'y' axis that shows the values and to draw graph for Disjoint path and the ARA methods.

In this Fig. 9 'x' axis that shows the number of nodes and 'y' axis that shows the cost of primary (s,t) -a path for an disjoint path and ARA.

- ARA always exhibits superior performance by finding paths of lower cost over the disjoint paths.

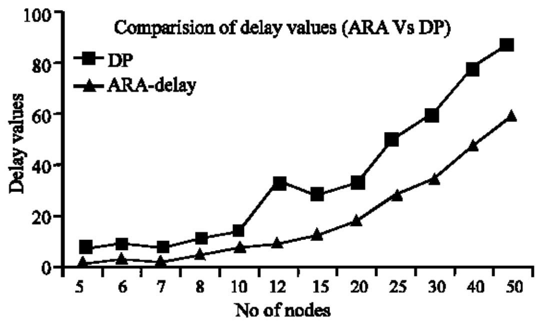

Fig. 8: No of nodes vs delay values

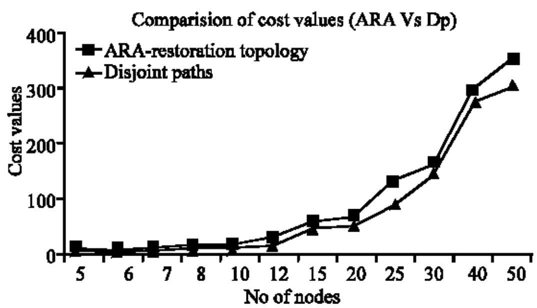

Fig. 9: Number of nodes vs cost of (s, t)-path

- ARA are finding the minimum delay of a (s, t)-path that is closer to delay constraints over the disjoint paths.

The following observation can be made from simulation results.

CONCLUSION

In this study, we investigated the problem of provisioning QoS paths with restoration. Specifically, we developed algorithms that compute a primary QoS path and a restoration topology comprising of a set of bridges, each of which protects a different part of the primary QoS path.

A major contribution of this study is the concept of adjusted delays, which allows existing path algorithms to be adapted in order to identify suitable restoration topologies. This enabled us to devise efficient approximation algorithms with proven performance guarantees.

We emphasize that, in our algorithms, the primary path as well as restoration path always satisfies the QoS constraint.

FUTURE WORK

Further interesting research in this area of research topic includes the multiple link failures which are yet to be addressed.

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