EFFECT OF TRAFFIC SPLITTING ON LINK AND PATH RESTORATION PLANNING*

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Abstract

Link restoration and path restoration are the two major techniques used for telecom network restoration in DCS (Digital Cross-connect System) mesh networks. For rerouting to be possible, sufficient spare capacity must exist in the links of the chosen alternate paths. Path restoration results in lower additional cost compared to link restoration. Traffic splitting can be used to further reduce the additional cost. There are several methods of performing traffic splitting. We have chosen to study even-splitting and best-splitting methods.

We have evaluated traffic splitting techniques by enhancing the link and path restoration modules of the Restoration Network Planning Tool developed by Alcatel Network Systems. We have observed, through several experiments, that traffic splitting results in significant reduction in the spare capacity and the corresponding augmentation cost.

1 Introduction

We consider the problem of planning in advance to cope with single link failures in DCS (Digitial Cross-connect System) mesh networks. In order to restore the traffic of a faulty link, the traffic must be rerouted through alternate paths. The links of the alternate paths must have adequate spare capacity. Spare capacity assignment is an important problem since several restoration algorithms for Self Healing Networks (SHN) assume the existence of spares [1, 2, 4, 5]. The network is said to be fault tolerant to single link failures if it has enough spare capacity to reroute all disrupted traffic in the event of every single link failure. Two major techniques used for spare capacity allocation are the following:

1. Link restoration: A faulty link's traffic is to be rerouted between the end nodes of that link through one alternate path. Every link in the alternate path must have spare capacity at least equal to the traffic of the faulty link.
2. Path restoration: Each path going through a faulty link can be rerouted separately through one alternate path between the source and destination nodes of that path. Every link in the alternate path must have spare capacity at least equal to the corresponding rerouted (failed) traffic.

The idea behind traffic splitting is to use two or more alternate paths to reroute the traffic of a single disrupted path. If we split the traffic equally and use two alternate paths for rerouting the traffic, then it is called *even-splitting*. Even-splitting results in significant savings in network augmentation cost. In *best-splitting*, we try to use the existing spares in the links to the full extent. So there can be several alternate paths with small amount of rerouted traffic on them. Best-splitting results in significant improvement over even-splitting, but the complexity of the restoration algorithm also increases since the number of alternate paths increases.

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A restoration planning tool that uses the link and path restoration schemes has been discussed in [6, 7]. We have evaluated traffic splitting by enhancing the link and path restoration modules of the tool. We have performed several experiments using several realistic random networks and found that the addition of traffic splitting to link and path restoration techniques significantly reduces the total spare capacity requirement and the corresponding cost.

2 Model

In a telecommunication network, each node represents a high speed digital cross-connect system (DCS). The working and spare capacities are expressed in units of DS3s. (The general design principles discussed in this paper are valid for any unit of bandwidth capacity.) Every link is specified by end nodes and the total capacity. All links are bidirectional. There are several paths of traffic in the network, where each path is specified by source node, destination node and the amount of traffic. Rerouting is achieved by reconfiguring the DCSs that belong to the nodes of the original and the alternate paths. Upon repair of a faulty link, the DCSs revert back to the original configuration and the spare capacities used in the restoration are returned back to the spare pool. Simultaneous multiple link failures are not considered.

3 Motivation for Traffic Splitting

Addition of traffic splitting to link and path restoration results in fewer spares. We will illustrate the potential advantages of traffic splitting by an example. Figure 1 shows a network with 6 nodes and 9 links. Let us say there is only one path (of traffic) *A-B-D-F* going through the link (*B*,*D*). Other paths are not shown for clarity. Let the traffic of this path be 8 DS3s and let all links be of equal length with 5 spare DS3s each.

In link restoration, a faulty link is replaced by one alternate path. Assume that the faulty link (*B*,*D*) is replaced by the path *B-C-D*. As the links (*B*,*C*) and (*C*,*D*) have only 5 spare DS3s each, both links need 3 more spare DS3s each to make the restoration possible. Now consider the traffic splitting version of link restoration (Figure 2). There are two alternate paths *B-C-D* and *B-C-E-D* for the link (*B*,*D*) and each alternate path carries 4 DS3 of traffic. The links (*C*,*D*), (*C*,*E*), and (*E*,*D*) have enough spares and only the link (*B*,*C*) needs 3 new spare DS3s.

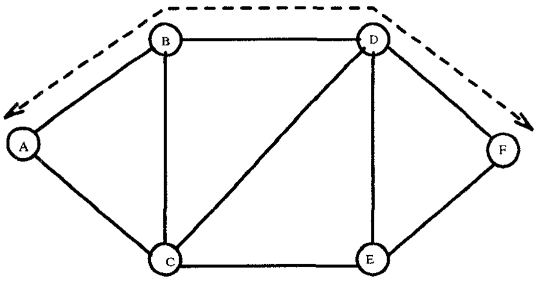

Figure 1: An example network

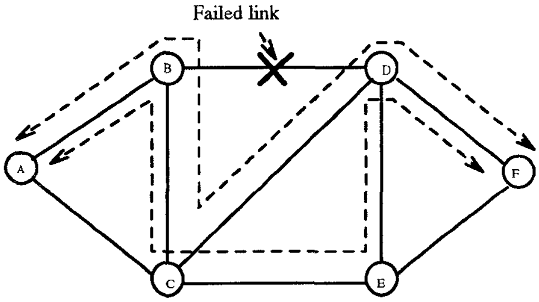

Figure 2: Link restoration with traffic splitting

In path restoration, for each path disrupted by the faulty link, one alternate path is found between the source and the destination nodes of that path. In the example network shown in Figure 1, the path *A-B-D-F* is severed when the link (*B*,*D*) fails. So one of the least cost alternate paths is *A-B-C-D-F* which requires 3 new spare DS3s in the links (*B*,*C*) and (*C*,*D*). When we allow traffic splitting, there are two possible alternate paths *A-B-C-D-F* and *A-C-E-F* and each path can carry 4 DS3s as shown in Figure 3. Clearly this solution does not require any new DS3s because these alternate paths are link-disjoint and all links already have 5 spare DS3s.

This example demonstrates that the use of traffic splitting in the link and path restoration schemes may result in lower spare capacity requirement.

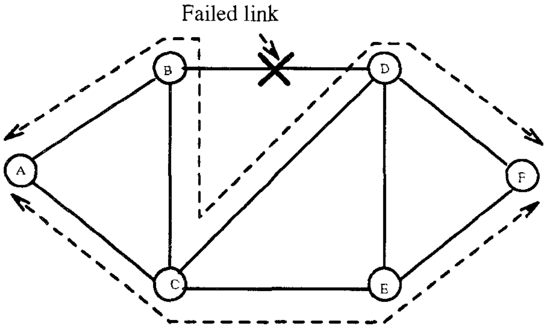

Figure 3: Path restoration with traffic splitting

4 Algorithm

In this section, we discuss the algorithm for best-splitting (Figure 4). We do not discuss the algorithm for even-splitting separately because it is essentially a part of *Best_Split* algorithm. Two procedures *Dijkstra* and *Update* are used in the algorithm. *Dijkstra(G, A, B, n, P)* takes the network structure G, two nodes A and B and n, the number of DS3s as input, and returns the least cost path P computed using Dijkstra's shortest path algorithm [3]. Note that the least cost path will change when spare capacities of the links change, even though the underlying topology remains the same. Also, the cost of each link is linearly related to link-length and non-linearly related to the total capacity of the link. So the least cost path changes when n changes. *Update(G, n, P)* removes n DS3s from the spare capacities of the links used by the alternate path P and marks those DS3s as "used". It also allocates new spare DS3s if sufficient spares do not exist. *Update* returns the modified network structure G.

Best_Split first uses all the zero cost alternate paths (i.e. spare DS3s should be available in all links of such alternate paths to achieve zero cost). Then we perform no-splitting, even-splitting, and multi-splitting for the remaining traffic. The local best-split is chosen by selecting the lowest cost path.

Traffic splitting module is essentially the same for path and link restoration. For path restoration, A and B will be the source and destination nodes of a path and n will be the amount of traffic. For link restoration, A and B will be the end nodes of a link and n will be the working capacity of the link. Refer-

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{ Input: Network structure G, two nodes A and B,
    traffic DS3s n }

best_split(G, A, B, n)

  { First use all the zero-cost alternate paths }
  while ((n>0) and (Dijkstra(G,A,B,1,P)=0)) do
    Update(G, 1, P);
    n = n - 1;
  endwhile;
  saveG = G;

  { no-splitting }
  cost[1] = Dijkstra(G, A, B, n, P);
  Update(G, n, P);
  tmpG[1] = G;

  { even-splitting }
  G = saveG;
  cost[2] = Dijkstra(G, A, B, n div 2, P);
  Update(G, n div 2, P);
  cost[2] = cost[2] + Dijkstra(G,A,B,n-(n div 2),P);
  Update(G, n - (n div 2), P);
  tmpG[2] = G;

  { multi-splitting }
  G = saveG;
  cost[3] = 0;
  while (n > 0) do
    cost[3] = cost[3] + Dijkstra(G, A, B, 1, P);
    Update(G, 1, P);
    n = n - 1;
  endwhile;
  tmpG[3] = G;

  { Choose the splitting with the lowest cost }
  Let cost[i] be the minimum of cost[1..3];
  G = tmpG[i];
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Figure 4: Algorithm *Best_Split*

ences [6, 7] contain the algorithms for link and path restoration respectively.

5 Description of the Tool

The tool described here is an enhanced version of the tool presented in [6], which assigns spare capacity using link restoration.

5.1 User inputs

The user inputs include (i) network optimization parameter options, (ii) link list for the existing backbone network, (iii) path list for the existing backbone network, and (iv) network node definition data. The nodes are numbered sequentially from 1 to n. The maximum number of nodes is limited to 256, the maximum number of links is limited to 512, and the maximum number of paths is limited to 512. If the user does not want to restore all the paths, a priority level for each path can be specified. In that case, only paths that have priority level greater than or equal to the user specified priority value are restored.

5.2 Tool outputs

The main results that appear in the output are listed below. One set of following information for each restoration technique is provided: total network cost (or DS3 miles) and average number of DS3 miles/link, total number of DS3s in the network, total number of DS3 cross-connect ports in the network, percentage of paths protected, the required spare capacity, transmission cost and transmission equipment details, the required number of DS3 cross-connect ports and cost for digital cross-connect systems, and the list of chosen alternate paths.

6 Comparative study

In this section, we analyze the performance of two versions of link restoration and two versions of path restoration. We have considered 60 randomly created communication networks. For each network, the path and link restoration schemes are used to design spare capacity. A random network generator takes the number of nodes (N), number of links (L) and number of paths (P) as input from the user, generates a random network, and prints the link, path and node information into a file. This file is used as the input to the tool.

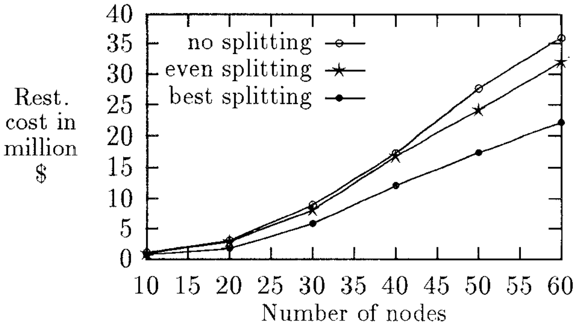

Figure 5: Restoration cost for link restoration

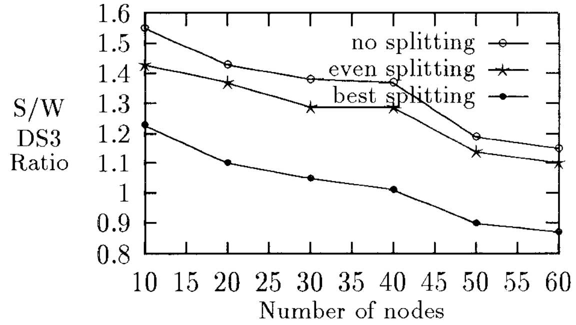

Figure 6: S/W DS3 ratio for link restoration

From the results of link restoration experiments (Figure 5), we found that even-splitting version, on the average, results in 11% savings in cost compared to no-splitting version. Also best-splitting version, on the average, results in 35% savings in cost compared to no-splitting version. From the results of path restoration experiments (Figure 7), we found that even-splitting version, on the average, results in 4% savings in cost compared to no-splitting version. Also best-splitting version, on the average, results in 8% savings in cost compared to no-splitting version. Figure 6 and Figure 8 indicate that Spare/Working DS3 ratio decreases as the network size increases, for both link and path restoration schemes, which implies that these schemes result in higher sharing of

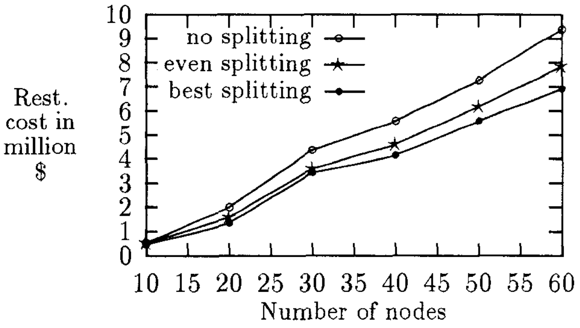

Figure 7: Restoration cost for path restoration

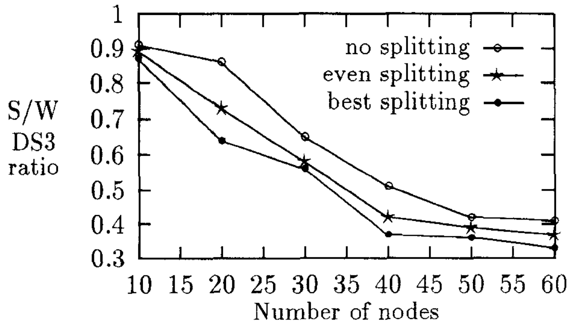

Figure 8: S/W DS3 ratio for path restoration

spares as the network size goes up.

Clearly, traffic splitting results in higher savings in link restoration than in path restoration. Intuitively, path restoration has already exploited the network topology to reduce the cost of augmentation. Thus, the possibility of further reduction in cost is less when using path restoration than when using link restoration.

7 Conclusion

We have studied the advantages of combining traffic splitting with link and path restoration schemes. We have also discussed the design and implementation of traffic splitting to be used with the link and path restoration schemes. A comparative study was performed among link restorations with no-splitting, even-splitting and best-splitting using 60 randomly created networks. Similar experiments were performed for path restoration also. We have found that the use of traffic splitting in conjunction with link and path restoration results in higher sharing of spares and reduces the network augmentation cost significantly.

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