Spare Capacity Utilization for Restoration of Mesh Based Networks

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ABSTRACT

WDM optical networks provide enormous speed & capacity. In case of any failure event due to any physical damage to the network or any other reason, the network should have restoration capability. Restoration requires planning and resources. There are several approaches available to ensure fiber network survivability [1]-[2]. But efficiency and cost optimization becomes deciding factor.

This study examines different approaches to survive link failures [3]-[4]. We have used mathematical programming (using AMPL) for working capacity allocation model, spare capacity allocation model and joint capacity allocation model for mesh-based survivable networks. The performance of above models has been compared and to study the total capacity utilized by network these model are simulated using CPLEX software.

Keywords-AMPL, CPLEX, Mesh, Networks, Restoration

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1. INTRODUCTION

To establish a network which has restoration capability, we require planning. Planning consists of selecting the available restoration models and protection schemes which will be activated upon failure occurrence. Each and every restoration model has its pros and cons. We need to establish the model which is not only cost effective but also efficient.

There are many network architectures available based on either dedicated resources or dynamic resources. We studied working capacity, spare capacity and joint capacity models for total number of backup path maximum120 and minimum 90. We also investigated change in capacity utilized by a network when total number of backup path increased or decreased.

2. WORKING CAPACITY ALLOCATION MODEL

The one of the network design problem is to determine the least capacity needed to satisfy a set of given point-to-point demands.

This is called the working capacity allocation problem and can be modeled as an integer linear program (ILP) using either a node–arc or an arc-path formulation [5].

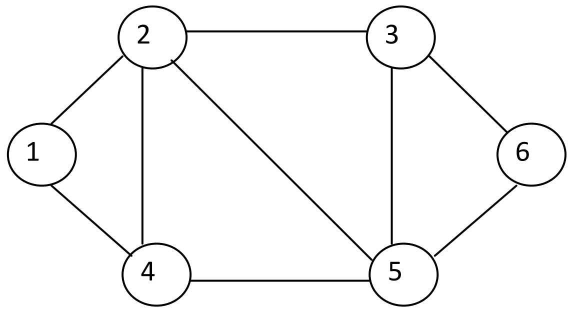

Fig.1 *Example problem with the following demand matrix*

Link	Demand
(1,2)	10
(1,4)	10
(2,3)	10
(2,4)	10
(2,5)	10
(3,4)	10
(3,5)	10
(3,6)	10
(4,5)	10
(5,6)	10

Table 1

A code in AMPL was used to simulate the illustrated example problem in CPLEX. An optimal solution of the working capacity allocation model for 120 backup paths is illustrated in Fig 2 & Fig 3

- **Solution to the node-arc model**

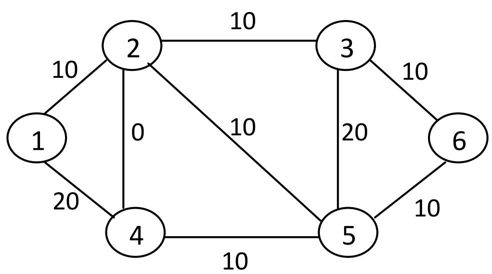

Fig 2

- **Solution to the arc-path model**

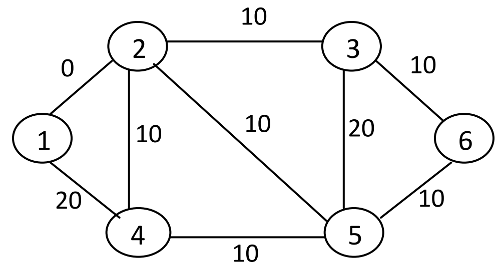

Fig 3

3. SPARE CAPACITY ALLOCATION MODEL

This section presents optimization models for the spare capacity allocation. Restorable networks are designed to continue to operate even when a failure occurs. It is assumed that the probability of multiple link failures during the time required to repair a failure is so small that network designers plan restoration strategies based on single link failures.

The simplest idea for protecting the links in a path is to provision a node-disjoint backup path. This is also called 1+1 protection since each working path (the path(s) a demand normally takes when all links are functioning) has a backup path in reserve that will be used whenever, and only when, a link in the working path fails [6].In shared protection schemes, the spare capacity on a link is not dedicated to any given demand pair and may be used in the restoration of various demand pairs. Shared protection schemes come in two varieties: link restoration and path restoration. Solution for different models for 120 backup paths will follow in Fig 4 to Fig 7.

- **Solution to node–arc formulation of the link restoration**

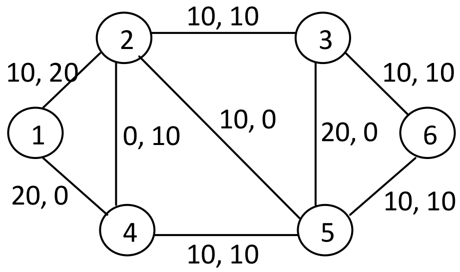

Fig 4

- **Solution to arc-path model of the link restoration**

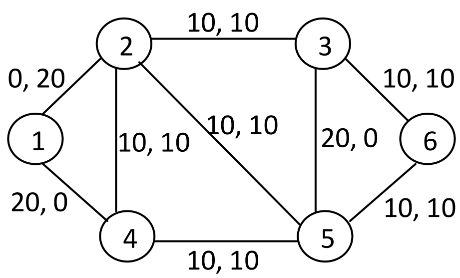

Fig 5

- **Solution to p cycle model for link restoration**

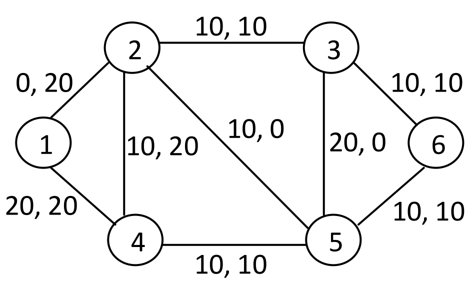

Fig 6

4. JOINT CAPACITY ALLOCATION MODEL

A joint model is one in which both working and spare capacity can be determined in a single model. In the previous sections, working capacity was determined with one model and then spare capacity was determined to protect the optimal working capacity against single link failures. Of course, the amount of working capacity on a link determines the amount of spare capacity needed elsewhere to provide for restoration, so joint optimization should require less total capacity.

One of the first investigations using a joint model was by Murakami and Kim [7]. A column-generation technique was used to obtain new variables as needed. They experimented with a pair of problems from the literature achieving a 10% cost savings for their joint model. A full report of their investigation can be found at Murakami and Kim [8]. Joint capacity models have also been investigated by Saito et al. [9] and Iraschko et al. [10].

- **Solution to Joint Capacity Planning Model**

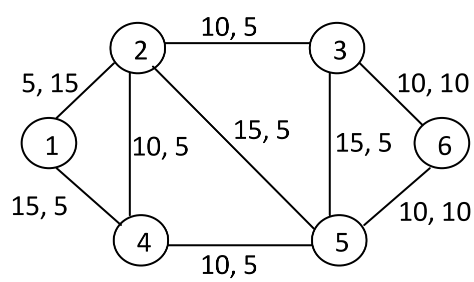

Fig 7

5. SUMMARY OF RESULTS FOR EXAMPLE PROBLEM TAKING 120 BACKUP PATHS

	Model	Working capacity	Spare capacity	Total Capacity
Working Capacity Allocation	Node-Arc	100	-	-
	Arc-Path	100	-	-
Link Restoration Model	Node-Arc	100	70	170
	Arc-Path	100	80	180
	P-Cycle	100	100	200
Joint Working & Spare Capacity Model		100	65	165

Table 2

6. SUMMARY OF RESULTS FOR EXAMPLE PROBLEM TAKING 90 BACKUP PATHS

The same example was also solved using 90 back up paths to analyse the effect of number of backup paths in spare capacity utilization

	Model	Working capacity	Spare capacity	Total Capacity
Working Capacity Allocation	Node-Arc	100	-	-
	Arc-Path	100	-	-
Link Restoration Model	Node-Arc	100	90	190
	Arc-Path	100	100	200
	P-Cycle	100	140	240
Joint Working & Spare Capacity Model		100	73.5	173.5

Table 3

7. CONCLUSION

In this study the different capacity allocation strategies for protection and restoration of single link failure scenario in mesh-based survivable networks have been thoroughly analyzed. The performance of working capacity allocation model, spare capacity allocation model and joint capacity allocation model has been compared. In each capacity allocation model the effect on total utilized capacity of example network for number of backup path maximum 120 and minimum 90 has been compared.

It has been found the joint capacity planning model saved most capacity for 120 back up paths in comparison to other capacity allocation model. Also we can see that if we increase the no. of backup path then the spare capacity utilized by the network is decreased and if we reduce the no. of backup path then the spare capacity utilized by the network is increased.

The main contributions of the study are as follows.

- Study of working capacity, spare capacity and joint capacity for total number of backup path 120 & 90.
- Investigation of change in capacity utilization when total number of backup path increased or decreased.
- Formulation and comparison of the different capacity allocation strategies.

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