BALANCED RESOURCE SHARE MECHANISM IN OPTICAL NETWORKS

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Abstract: Existing protection mechanisms to rapidly recover the failures allocate the backup path just SRLG-disjointed with working path. However, these mechanisms have the low resource utilization because the resource is not shared among the backup paths. To complement it, Kini (Kini et al., 2002), Somdip (Somdip et al., 2001) and so on, have proposed the mechanisms to share the resources of the backup paths. Although these mechanisms can improve the efficiency of bandwidth usage, those did not consider the unbalanced resource share of backup paths. The backup paths can be centralized on the specific link so that the idle resource is not used. As a result, as those do not use the resource efficiently the whole resource utilization is not good. So we propose the mechanism to enhance the resources utilization as settling down the unbalanced resource share to recover simultaneous failures. We formulate the problem to minimize the number of the used backup resource (exactly, wavelengths) as considering the maximum link load. We compare the existing mechanisms with our mechanism by the spare resource capacity as the result of the simulation.

1 INTRODUCTION

Because the granularity of the optical connection is coarser than that of the existing network, a single fiber cut can potentially influence a total of 1.6 Tb/s of traffic in optical networks. So, the fiber cut results in the significant loss of traffic and thus the survivability in optical networks is important.

The mechanism proposed by Kini can save bandwidth by ensuring the sharing of the backup path among all working paths with the same source and destination node. And Somdip's mechanism can improve the efficiency of bandwidth usage by pooling backup path capacity. However, the resource of these mechanisms can be centralized on the specific link so that the idle resource is not used.

So we propose the mechanism to enhance the resources utilization as settling down the unbalanced resource share. We formulate the problem to minimize the number of the used backup resource (exactly, wavelengths) as considering the maximum link load.

In our mechanism, two-level SRLG for the backup path selection is used: the first level, Low-SRLG is for SRLG-disjoint path with its working path, that is, for the backup path sharing decision and the second level, High-SRLG is for the same effect such as the threshold hop limit using the sub-domain information of the working path. Besides, this High-SRLG can be the information to eliminate the link accommodated the unbalanced sharing backup paths. For the balanced resource sharing through two-level SRLG the backup paths are allocated the same as the sub-domain of the working path as much as possible.

We give the problem definition and Integer Linear Programming ILP formulations. The ILP formulation has much more time consumption and is difficult to solve with increasing problem size. So, we provide the heuristic algorithm of the proposed resource shared mechanism and the backup path selection algorithm and present experimental results.

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2 RELATED WORKS

2.1 Single Link Failure Recovery Mechanism (SFRM)

In general, most of the protection and restoration mechanism consider the failure of just the single component such as a link or a node. It is a typical approach to provide the survivability.

In Somdip's mechanism, when a failure occurs in the SRLG and the restoration protocol for the corresponding lightpaths' activation of the restoration channels RCs on backup path starts to be processed, the mechanism finds primarily available RCs in the pool and uses them for the restoration.

2.2 Multiple Link Failures Recovery Mechanism (MFRM)

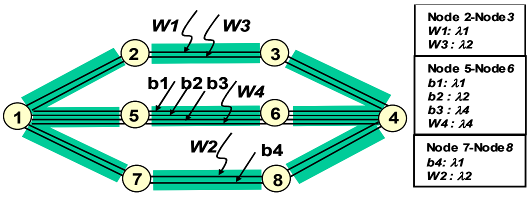
In the real world, in general, several failures in an optical network occur simultaneously. The mechanisms for the multiple failures consider the working/back-up paths with the same source and destination node.

Doucette proposed the design formulation and procedure for the planning any span-restorable network for a known set of SRLGs. And it showed how total capacity depends on the relative number or frequency of co-incident SRLGs and quantified how the type of SRLG will impact design costs. That is, it emphasizes which SRLG is the most deleterious to network efficiency. However, because SRLG is configured at the start of the network initialization the co-incident SRLGs depends on the network plan including the placement of SRLGs.

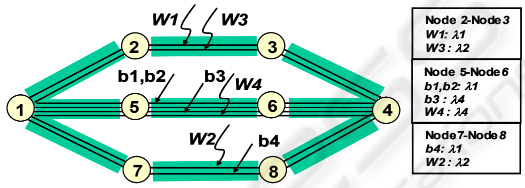
3 PURPOSE OF THE PROPOSED MECHANISM

Fig. 1 describes why the network needs to accommodate the balanced sharing backup paths. All backup paths are allocated to disjoint their working paths. Fig. 1 (a) represents the backup paths are not shared on the same wavelength between node 5 and 6. Therefore, the resources are wasted. In case of Fig.1 (b), although b1 and b2 share the wavelength it still wastes the resources due to b3. If 1 fiber accommodates 2 wavelengths, Fig. 1 (b) needs two fibers. However, if the backup paths are decentralized to the wavelength in use, the above resource constraint is fulfilled and the Fig. 1 (c) satisfies this condition.

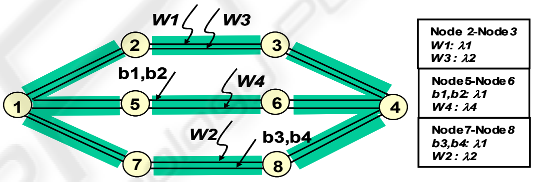
As a result, our purpose is to minimize the number of the wavelength used for the backup path in the network.



(a) Unshared backup paths



(b) Shared backup paths without considering maximum link load



(c) Proposed Shared backup paths with considering maximum link load

Figure 1: The resource (wavelengths) sharing in the network.

4 PROBLEM DEFINITION AND BACKUP PATH ALGORITHM

4.1 ILP Formulations

The proposed mechanism includes two level SRLG, Low-SRLG and High-SRLG. Low-SRLG means a group of links that are subject to a common risk, such as a conduit cut. High-SRLG is defined to select the backup path closed to its working path due to the hop counts or the link length. In addition to the link length, High-SRLG is defined to avoid the unbalanced link load due to the concentrated sharing in a link. Thus, this High-SRLG is defined into the geographical region as a domain concentrated with the network nodes.

We formulate the problem to minimize the used resource. We consider the SRLG information (two-level SRLG) to select the backup paths. We give the ILP formulation to provide optimal solution as follows: The objective function equation (1) minimizes the sum of the number of wavelengths (*w*) used for backup paths (*B*) on the link *i, j* between source *s* and destination *d*.

Objective :

$$MIN \sum_{sd}\sum_{ij}\sum_{w} B_{ijw}^{sd} \quad (1)$$

For the objective function the constraints are as follows:

(2) The number of backup paths is the same as the number of working paths in the network. (It means that there are the source and terminal node over its paths in the network whether the distance of the paths is long or short.)

(3) The total link capacity (the number of wavelengths) in link i,j is greater than the total number of wavelengths used for backup paths in link i,j.

(4) The backup path is conserved at each link along the path (In case of the working path, this constraint is not necessary).

(5) The spare capacity in the link i,j is that one subtracted the working path capacity (the number of wavelengths used for the working paths) from the total capacity in the link i,j.

Subjects to:

$$\sum_{sd}\sum_{ij}\sum_{w\in W} B_{ijw}^{sd}\cdot\beta^{w} = P, \quad P=\sum_{uv}\sum_{w} P_{uvw}^{sd}, \ \forall(i,j),\ i=s_{b,}\ i\neq t_{b,}\ j\neq s_{b}$$
$$\forall(u,v),\ u=s_{p,}\ u\neq t_{p,}\ v\neq s_{p,}\ v=t_{p} \quad (2)$$

$$\sum_{sd}\sum_{w} B_{ijw}^{sd}\leq L_{\max}.C_{ij}, \quad \forall(i,j),\ L_{\max}=Int\sum_{ijw} B_{ijw}^{sd} \quad (3)$$

$$\sum_{j(i,j)}\sum_{w} B_{ijw}^{sd}\cdot\beta^{w}-\sum_{i(j,i)}\sum_{w} B_{jiw}^{sd}\cdot\beta^{w}=0, \quad \forall s,d,\ i\neq s_{b}, i\neq t_{b}$$
$$\sum_{j(i,j)}\sum_{w} B_{ijw}^{sd}\cdot\beta^{w}-\sum_{i(j,i)}\sum_{w} B_{jiw}^{sd}\cdot\beta^{w}=1, \quad \forall s,d,\ i=s_{b}, i\neq t_{b} \quad (4)$$
$$\sum_{j(i,j)}\sum_{w} B_{jiw}^{sd}\cdot\beta^{w}-\sum_{i(j,i)}\sum_{w} B_{jiw}^{sd}\cdot\beta^{w}=-1, \quad \forall s,d,\ i\neq s_{b}, i=t_{b}$$

$$\sum_{sd}\sum_{w} B_{ijw}^{sd}\leq S_{ij}, \quad S_{ij}=C_{ij}-\sum_{sd}\sum_{w} P_{ijw}^{sd}, \quad \forall(i,j) \quad (5)$$

In addition to single failure, the constraint for dual failures is considered as shown in Fig. 2. The link *cd* on the backup path p1 is simultaneously failed when the link *ij* on the backup path B1 of the working path w1, B2, and B3 is failed. For the previous objective function, the constraint of the dual failures is as follow:

$$\sum_{sd}\sum_{w} B_{ijw}^{sd}\bullet\Gamma_{ijw}^{ab}\leq S_{ij}, \quad \forall(i,j), \forall(a,b) \quad (6)$$

(6) There is enough spare capacity to recover the dual failures (two links or two paths at once. (If the required capacity (at the left side) is greater than the spare capacity, it is infeasible. For example, if 3 backup paths share the wavelength w, to recover the failure of the link (i,j) 3 wavelengths are needed in link (a,b)).

Notations :

constant

w: The total number of wavelengths on each link and $1\leq w\leq W$.

C_{ij}: The total link capacity units (total wavelengths) on the link (i,j).

p_{uvw}^{sd} : The working path with wavelength w on the link (u,v).

s_p, t_p : The starting or terminal node of the working path p.

variable

B_{ijw}^{sd} : 1, if the backup path for a working path (s,d) uses wavelength w in link(i,j), 0, otherwise.

β^{w} : The inverse of the number of the backup paths sharing the wavelength w, $(1\leq w\leq W)$

(If 3 backup paths share wavelength λ_1, then β^{w} is $1/3$)

S_{ij} : Spare capacity (the number of wavelengths) on the link (i,j).

Γ_{ijw}^{ab} : The number of backup paths sahring the wavelength w link (i,j) The number of wavelength needed to recover the backup paths in link (a,b)

s_b, t_b : The starting or terminal node of the backup path b.

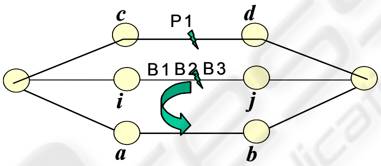


Figure 2: Simultaneous link failures in the network.

4.2 Algorithm for Backup Paths

The working path and the backup path are basically selected based on Low-SRLG mechanism like Somdip's mechanism. In addition to Low-SRLG, the High-SRLG (Fig. 3) is added in the proposed mechanism. The backup paths is selected the same as the sub-domain of the working path as much as possible.

```
cur_connection : current connections
WP_list : the link list of the selected working paths
accept_region = find_region() //find the whole sub-domains
on the working path //find the rest sub-domains
not_accept_link_list =
find_not_accept_region (accept_region)
// disable the links on the rest of the working paths
set_link_disable(not_accept_link_list)
result = find_Low_backup()//applies the Low-SRLG
algorithm
if result == fail
  then set_link_enable(not_accept_link_list) //discharges the
sub-domains
      find_Low_backup()
end if
set_link_enable(){
for bk_link // for all backup links
  if (backup Path == share)//check the backup path with the
others
  then increase band-width of backup links
else not increase band-width of backup links
increase simultaneous two failures count
end for }
```

Figure 3: Backup path selection algorithm : Low-SRLG and High-SR LG based.

5 SIMULATION RESULTS

We assumed that the working path of the proposed mechanism is selected by the shortest. The test network model is consisted of 7 sub-domains, 39 nodes and 69 links. The nodes from the node number 1 to 18 are used as a source node and the nodes from the node number 19 to 39 are used as a destination node.

For the comparison, we simulated the algorithm for the Somdip's mechanism represent by Low-SRLG algorithm, without considering unbalanced link load. And High-SRLG algorithm means the proposed mechanism with considering unbalanced link load by High-SRLG identification. We setup 50 connections, 1connection a unit time. And it is repeated 50 through 100 times. We suppose the shortest working and backup paths. We considered the following cases.

Static path selection: predefined working paths and backup paths for the simultaneous two failures : Fig. 4
: The resource usage of working/backup paths
by Low-SRLG algorithm/by High-SRLG algorithm

Dynamic (Random) path selection: dynamically select working paths and backup paths for the simultaneous two failures : Fig. 5
: The resource usage of working/backup paths
by Low-SRLG algorithm/by High-SRLG algorithm

As shown Fig. 4, the High-SRLG algorithm compared with the Low-SRLG can distribute more resource in case of the dynamic connection. That is, the number of non shared backup paths in case of High-SRLG is 216 and Low-SRLG is 184. In Fig. 5, the high-SRLG algorithm also can distribute more resource in case of static connection.

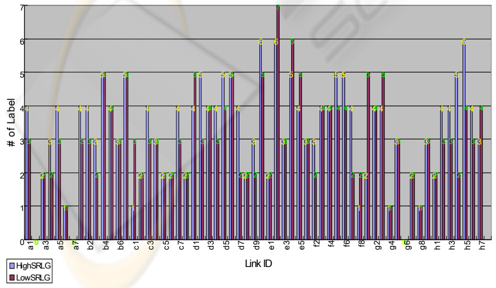


Figure 4: The resource usage of working paths/backup paths: Low-SRLG/High-SRLG algorithm under Random Connections.

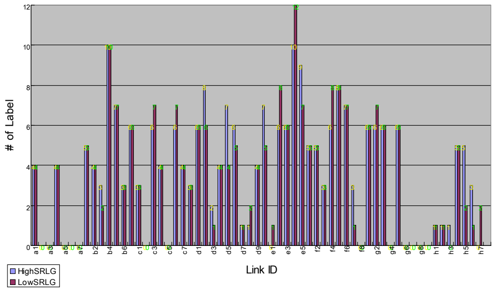


Figure 5: The resource usage of working paths/backup paths: Low-SRLG/High-SRLG algorithm under Static Connections.

6 CONCLUSIONS

In this paper, we proposed the shared resource path provisioning mechanism to guarantee the survivability. We presented the capacity design method and the optimization model to improve the link utilization and simulated to measure the resource utilization of the proposed mechanism.

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