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Path Segment Protection p -Cycle for Span Failure in Optical Networks

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Abstract: The path-segment-protecting p -cycles ("flow p -cycles" for short) have capacity efficiency near that of the Shared Backup Path-Protection (SBPP) scheme currently favoured for optical networking. In this paper a significant extension to the method of p -cycle is introduced for network protection. The Flow p -cycle is used to protect path segments of adjacent working flow, directly straddle the p -cycle or not only spans that lie on the cycle. This effectively extends the p -cycle technique to incorporate path protection or protection of any flow segment on a path, same as the original span protecting use of p -cycles. The work in the present paper is to optimize the spare capacity of path segment protecting p -cycle by using an improved IPL model which determine the required number of copies of p -cycle for the network and number of spare units on each span.

Keywords: survivability; p -cycle; flow p -cycle; protection and restoration; span failure recovery

I. Introduction

Optical networks are carrying tremendous traffic in today's life that is doubling virtually every year. This traffic includes data, voice, video and several real time application services such as Remote Surgery, control and remote observation etc. Optical fiber is being used for communication in the form of transmission medium from the first generation as point to point links. At every network node, traffic is subjected to O-E-O (Optical-Electrical-Optical) conversions. The nodes decide transmission bit rate, protocol and format i.e. they're transparent.

The objective of our work is to study the different approaches for protection and restoration of path segment failure scenario in optical networks and to realize the path segment failure restoration in optical networks using flow p -cycle techniques. The motivation for this work is the survivability in optical networks. It is really a difficult task to predict when and where a failure will occur in a network and network service outage causes tremendous revenue loss and service disruption for both unicast and multicast traffic. Up to now, some research on path segment protection p -cycle has been focused. In particular, p -cycle concept to secure path segments of adjacent working flow, directly straddle the p -cycle or not only spans that lie on the cycle, which effectively extends the concept of p -cycle technique to include protection of any flow segment along a path or path protection, as well as the protection of original span by use of p -cycles. It also gives an inherent means of protecting working flows that transit a failed node. Out of all the available schemes, the path segment protection p -cycles (pre-configured cycles) discovered by Gangxiang Shen et al. [1], outperform this schemes. Therefore, we started working on flow p -cycles. In depth study of flow p -cycles has been carried out as further and we have found that still many issues need to be addressed to make best use of p -cycles.

A. Survivability

Survivability of a network refers to the network's capability to provide continuous service in the presence of any network failures and recovering from these failures. With advances in optical network design it is now attainable to pack additional bandwidth of the order of terabits/s in optical networks. Amount of traffic carried by one fiber at any instant is extremely high and this traffic is expected to grow in the near future. A disconnection of only few milliseconds can cause a severe loss of data of the order of Gigabytes [2]. Thus it becomes very important to protect these networks against failures. Network Failures arise from basically two conditions, node failures and link failures. Node failures are easily protected against by using node redundancy, however fibers are an expensive investment and it is desirable to minimize the total cost of design. Thus minimizing the spare is another important design goal taken into consideration when designing survivable optical networks. However often minimizing spare capacity leads to, an increase in the restoration time of the networks.

B. Protection and Restoration

The network failure recovery schemes can be broadly classified into two categories, Restoration and Protection. Restoration schemes visit dynamic recovery after the onset of failure. Protection is outlined as pre provisioned failure recovery. These schemes will give secured protection since the demand set up completes only if the

secondary path is also available [2]. Despite the wide selection of survivability mechanisms available and the ease with that our networks can be designed for 100% single-failure restorability, they're still highly susceptible to failures, and outages are still frequent.

C. Link Failure and Node Failure

For link failure recovery, a unity p -cycle are often shared by one working unit on any on-cycle link in opposite direction and two working units in both directions on any straddling link. As long as the working capacity on each link is protected, all the multicast trees are protected against any single link failure.

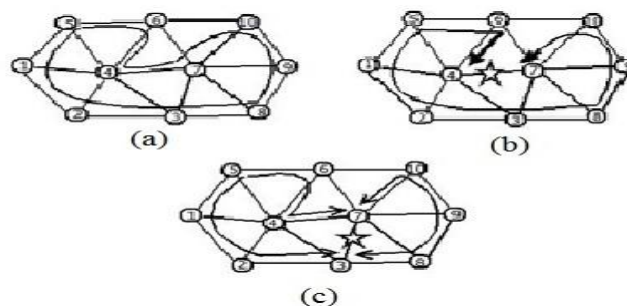
For node failure recovery, as a single failure at any time is assumed, different nodes can share a duplicate copy of cycle for protection [2]. However, for a specific common node of multiple trees, the amount of copies needed for a particular cycle is determined by the number of trees traversing it, as a result of the failure of this common node would affect multiple trees.

II. Overview of the p -Cycle

In optical communication networks two methods were developed and introduced for recovery and restoration, one was a mesh restoration and the second one was ring-based protection [3]. The mesh restoration offered higher capacity efficiency at the expense of slower recovery times, while the ring based protection basically offered a fast recovery time at the expense of higher capacity redundancy. In the year of 1998 [4] the p -cycle became a promising technique for recovery in mesh networks owing to the combined benefits of mesh like capacity efficiency and ring network recovery speed. In a mesh network, the spare capacity is used to create the ring like structures as shown in Fig. 1 with 10 nodes and 19 spans. In optical communication, p -cycles are basically a new approach for transport network protection. The p -cycles have switching characteristics and are Bidirectional Line Switched Ring (BLSR) ring like in structure, but it achieve mesh like spare-capacity efficiencies [4]. Fig. 1 shows a span-protecting p -cycle which is a Hamiltonian cycle and, thus, does not by itself have an on-cycle or straddling relationship to every span of the network. The overview of p -cycle has been given in [5] [6].

The spans (1, 2), (2, 3), (3, 8), (8, 9), (9, 10), (10, 7), (7, 4), (4, 6), (6, 5), and (5, 1) are *on-cycle* spans of the p -cycle shown. The span (3, 7) isn't on the cycle, however its two end nodes are, making it a straddling span. A p -cycle offers two protection paths for the failure of any (of probably several) disjoint straddling spans (one failure at a time) and one protection path for the failure of any on-cycle span. As an example, if span (4, 7) fails, the route (4, 6, 5, 1, 2, 3, 8, 9, 10, 7) on the cycle offers one protection path to restore the failed span, as similar as a BLSR operates, however if span (3, 7) fails, paths (3, 2, 1, 5, 6, 4, 7) and (3, 8, 9, 10, 7) both are (simultaneously) ready to provide the protection paths. If failure occurs, only two end nodes do any real time switching, and therefore it's effectively identical to a pre-planned BLSR switching reaction. In contrast, a ring (or any form of cycle cover [7]) only protects on-cycle spans.

Figure 1 (a) p -cycle, (b) On-cycle failure, (c) Straddling span failure



They share the ring like characteristic of protecting straddling span failures but also protect against on-cycle span failures through BLSR like switching at the end nodes. The p -cycles offer a totally pre-planned and pre-cross-connected span protection mechanism which is actually the same as in a BLSR ring. As soon as span failure occurs, the switching reactions at the end nodes of a failed span are fully pre-armed. The protection of straddling span failures is a distinctive property of p -cycles that allow networks to be designed with basically a same capacity efficiency as a span restorable mesh networks [7]. This permits p -cycle based networks to be, essentially, as capacity efficient as span-restorable mesh networks, whereas still providing BLSR switching speeds. Overall efficiency relative to ring-based networks is even greater than what the simple ratio of protection to working capacity would suggest, because p -cycles are "spare-capacity only" structures that, not like rings, do not constrain the routing of working paths to coincide with the layout of the cycles themselves. Working paths are liberated to take the shortest mesh like routes between their endpoints on the graph. In fact, it is additional advantageous for working capacity to "straddle" p -cycles than to underlie the p -cycles themselves,

because, in p -cycle each unit of protection capacity can protect two units of working capacity on a straddling span.

III. Path-Segment-Protection p -Cycles

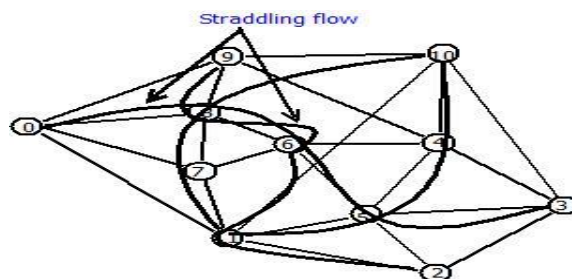
As a path-segment-based protection scheme, the spare capacity efficiency lies between the conventional span-restorable mesh networks and the conventional path-restorable networks. But being based upon fully preconfigured cycles, the protection action still involves switching at two “local” nodes, which has the inherent advantage of faster restoration times compared with the conventional path-based schemes which fundamentally require signalling and cross-connection at all nodes on the restoration path [8]. We do not know if path segment-protecting p -cycles (“flow” p -cycles for short) [1] will be as practically useful as span-protecting p -cycles are (because of their greater simplicity), but we think that in either case this work also contributes an important extension of the theory and understanding of the topic of p -cycles in general. It also adds another approach with some unique properties to be considered for path-based network protection techniques.

In addition, this new technique extends to consider network recovery from node failure as well. From one standpoint, a node failure is like several concurrent span failures, suggesting large amounts of extra spare capacity would be needed. On the other hand, the source/sink demands at the failed nodes are omitted from the recovery goal. Although one recent study for path-restorable networks [9] showed that only a small amount of extra spare capacity was required to recover transit traffic demands against node failures, it is not known if flow p -cycles will be similar in this regard.

A. Concept of Flow p -Cycle

The Fig.2 shows a conventional span-protecting p -cycle which is not a Hamiltonian cycle and, thus, does not by itself have an on-cycle or straddling relationship to every span of the network. The spans (1, 5), (5, 4), (4, 10), (10, 8), (8, 7), and (7, 1) are on-cycle spans of the p -cycle shown [1]. The span (1, 10) is not on the cycle, but its two end nodes are, making it a straddling span. A p -cycle can offer one protection path for the failure of any on-cycle span and two protection paths for the failure of any (of possibly several) disjoint straddling spans (one failure at a time). For example, if span (8, 10) fails, the route (10, 4, 5, 1, 7, 8) on the cycle offers one protection path to restore the failed span, in exactly the way a BLSR operates, but if span (1, 10) fails, paths (1, 7, 8, 10) and (1, 5, 4, 10) are both (simultaneously) available to provide protection paths. In either type of failure, only two nodes do any switching in real time, and it is effectively identical to a pre-planned BLSR switching reaction. In contrast, a ring (or any form of cycle cover [10]) only protects on-cycle spans. However, in Fig.2 that spans (6-7) and (7-2), and several others, of the basic p -cycle are close to being straddling spans but cannot actually be span-protected by the cycle shown. However, a path that crosses both spans (8-6) and (6-5), as shown below, can be considered to straddle the cycle shown when taking a path-level view of only the one demand that does flow all the way from side to side across the p -cycle. More specifically, the path segment (8-6-5) can be considered to straddle the cycle shown, between the nodes 8 and 6. Also, span-protecting p -cycles do not have the capability of transit traffic restoration in the event of intermediate node failure. For example, the affected transit traffic demands due to the loss of node 6 cannot be recovered by a span-protecting p -cycle. However, a path-based protection technique is capable of offering such a kind of recovery function.

Figure 2 Flow Protecting p -Cycle



If spans (5, 6) and (8, 6) in Fig.2 incur failures, they cannot be restored by a span-protecting p -cycle. But, under the flow p -cycle, the contiguous flows that traverse spans (5, 6) and (8, 6) can be restored by the cycle. Also, flow p -cycles can recover transit traffic demands due to the loss of an intermediate node on a flow. A failure of intermediate node 6 can break the flows between node pairs (0, 3) and (9, 2). The span-protecting p -cycle cannot restore these affected transit flows; however, under the flow p -cycle, the flows that transit node 6 can be recovered by the cycle. Note, however, that any demands being added or dropped at node 6 cannot be handled by the same flow p -cycle. The flow must be unchanged in its composition between the nodes where it intersects the flow p -cycle.

IV. Design Model for 100 % Span Protection Against Failure

The ILP (Integer Linear Programming) models have been used for designs of flow-protecting p -cycle networks with span failure recovery. The model is general enough to be applicable to not only DWDM networks, but also other kinds of networks like SDH/SONET, MPLS, and so on as well. The cost of this is assumed to be reflected in c_k below. Also, we will consider the “nonjoint” design case where working demands are first routed via their shortest paths, followed by optimization of the spare capacity for flow p -cycle placement [11].

The following formulation optimizes the spare capacity placement of a flow p -cycle network with 100% span failure protection given a fixed working capacity design. The objective function is to minimize the total spare capacity cost.

The parameters of the models are as follows.

- S** Set of spans in the network where index i denotes spans specifically in a failure context, k is used to index S in other general contexts;
- N** Set of nodes in the network, index n ;
- D_i** Set of end-node pairs of paths affected by failure of span i , index r ;
- P** Set of all simple cycles of the graph index j ;
- c_k** Cost of adding a unit capacity (for instance an additional lightwave channel) to span k . The costs are pre-computed constants;
- d^r** Number of demand units (for instance, lightpath requirements) on node pair r ;
- $\gamma_{i,j}^r$** It takes the value zero if flow r can't be protected by cycle j upon span failure i , 1 if span i is in an on-cycle relationship, and 2 otherwise
- $\delta_{j,k}$** Takes the value of one if cycle j includes span k , otherwise, 0;

Variables:

- n_j** Number of unit-capacity copies of cycle j to build in the design;
- s_k** Number of spare capacity units required on span k to support the set of flow p -cycles used;
- $n_{i,j}^r$** Family of intermediate variables that consider the number of copies of cycle j that are needed specifically for protection of path r against failure i ;

A. Design Model

The given formulation [1] optimizes the spare capacity placement of a flow p -cycle network with 100% span failure protection given a fixed working capacity design. The objective function is to minimize the total spare capacity cost.

$$\text{Minimize } \left\{ \sum_{k \in S} c_k \cdot s_k \right\} \quad (1)$$

Subject to

$$\sum_{j \in P} \gamma_{i,j}^r \cdot n_{i,j}^r \geq d^r \quad \forall i \in S_i; \quad \forall r \in D_i \quad (2)$$

$$n_j \geq \sum_{r \in D_i} n_{i,j}^r \quad \forall i \in S_i; \quad \forall j \in P \quad (3)$$

$$s_k \geq \sum_{j \in P} n_j \cdot \delta_{j,k} \quad \forall k \in S. \quad (4)$$

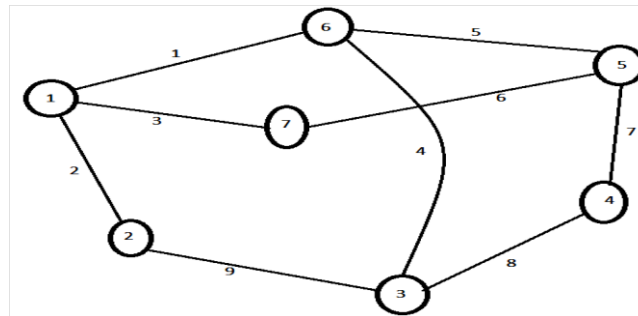
Equation (2) asserts that affected working flows upon a span failure must be fully restored. Equation (3) says that the number of copies of cycle j to build is set by the largest failure-specific simultaneous use for unit copies of cycle j . This is like setting the spare capacity of a conventional span or path restorable mesh network to satisfy the largest simultaneously imposed set of restoration flows over the set of all non-simultaneous failure scenarios. Equation (4) says that the spare capacity on span k must be enough to support the number of copies of each p -cycle that overlies the span.

B. Numerical Results

For the simulation, we have design a test network with 7 nodes and 9 spans to protect path segment which is given below. It is also assumed that each span has enough capacity to support the protection capacity required by the optimal solution. This test network has flows 21, {(1-2), (1-3), (1-4), (1-5), (1-6), (1-7), (2-3), (2-4), (2-5), (2-6), (2-7), (3-4), (3-5), (3-6), (3-7), (4-5), (4-6), (4-7), (5-6), (5-7), (6-7)} shorted path. In Fig. 4, 6, 8, it has been shown the total no. of p -cycles requires link failure during path-segment protection at different demand units. In

Fig. 5, 7, 9 it has been shown the total no spare units of links required to be reserved on each span of the test network 7n9s at different demand units.

Figure 3 Test network 7n9s and 21 flows

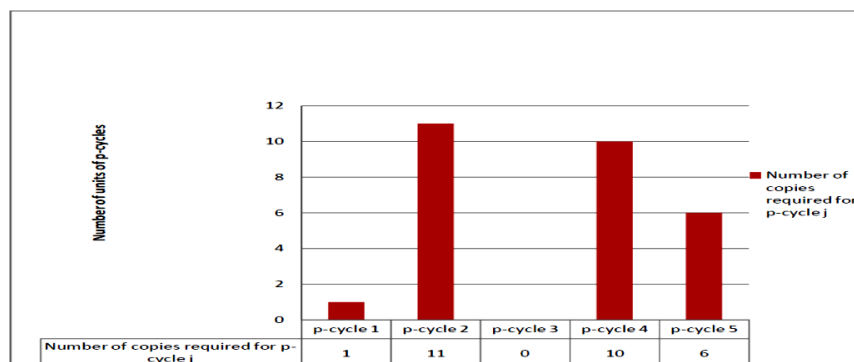


When number of demand unit (for instance, light path requirements) on node pair (path)

$d^r = [[0, 2, 0, 0, 0, 0, 0, 0, 0], [4, 0, 0, 0, 0, 0, 0, 0, 0], [0, 0, 5, 0, 0, 0, 0, 0, 0], [0, 1, 0, 0, 0, 0, 0, 0, 1], [1, 0, 0, 0, 1, 0, 0, 0, 0], [1, 0, 0, 0, 2, 0, 3, 0, 0], [0, 0, 0, 0, 0, 0, 0, 0, 1], [0, 0, 0, 0, 0, 0, 0, 4, 2], [0, 0, 0, 0, 0, 0, 10, 1, 1], [1, 1, 0, 0, 0, 0, 0, 0, 0], [0, 1, 1, 0, 0, 0, 0, 0, 0], [0, 0, 0, 0, 0, 0, 0, 1, 0], [0, 0, 0, 0, 0, 0, 1, 1, 0], [0, 0, 0, 1, 0, 0, 0, 0, 0], [0, 3, 5, 0, 0, 0, 0, 0, 4], [0, 0, 0, 0, 0, 0, 8, 0, 0], [0, 0, 0, 0, 1, 0, 1, 0, 0], [0, 0, 0, 0, 0, 2, 4, 0, 0], [0, 0, 0, 0, 5, 0, 0, 0, 0], [0, 0, 0, 0, 0, 1, 0, 0, 0], [1, 0, 1, 0, 0, 0, 0, 0, 0]];$

Optimum solution is 146. Number of copies finally required for p -Cycle j in the test network 7n9s and number of spare units required to be reserved on span k in the test network 7n9s graph as following.

Figure 4 Number of copies finally required for p -Cycle j in the test network 7n9s



When demand units on node pair increased as

$d^r = [[0, 8, 0, 0, 0, 0, 0, 0, 0], [7, 0, 0, 0, 0, 0, 0, 0, 0], [0, 0, 9, 0, 0, 0, 0, 0, 0], [0, 8, 0, 0, 0, 0, 0, 0, 6], [9, 0, 0, 0, 8, 0, 0, 0, 0], [9, 0, 0, 0, 12, 0, 5, 0, 0], [0, 0, 0, 0, 0, 0, 0, 0, 11], [0, 0, 0, 0, 0, 0, 0, 9, 3], [0, 0, 0, 0, 0, 0, 10, 4, 5], [5, 6, 0, 0, 0, 0, 0, 0, 0], [0, 9, 7, 0, 0, 0, 0, 0, 0], [0, 0, 0, 0, 0, 0, 0, 1, 0], [0, 0, 0, 0, 0, 0, 9, 11, 0], [0, 0, 0, 7, 0, 0, 0, 0, 0], [0, 3, 5, 0, 0, 0, 0, 0, 4], [0, 0, 0, 0, 0, 0, 4, 0, 0], [0, 0, 0, 0, 2, 0, 7, 0, 0], [0, 0, 0, 0, 9, 4, 0, 0], [0, 0, 0, 0, 12, 0, 0, 0, 0], [0, 0, 0, 0, 0, 5, 0, 0, 0], [5, 0, 6, 0, 0, 0, 0, 0, 0]];$

Optimal solution is 250 and span and p -cycle graph as.

Figure 5 Number of spare units required to be reserved on span k in the test network 7n9s

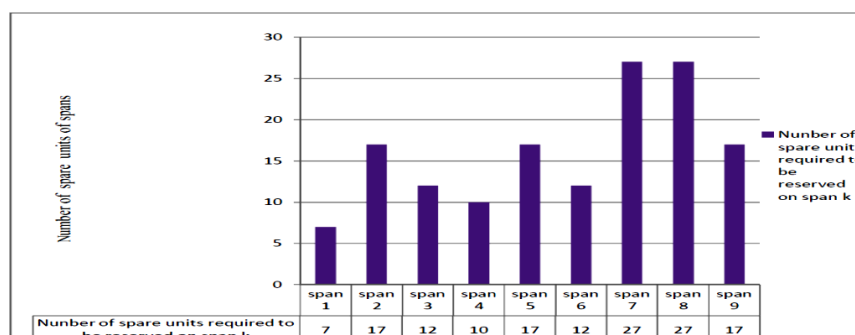


Figure 6 Number of copies finally required for p -Cycle j in the test network 7n9s

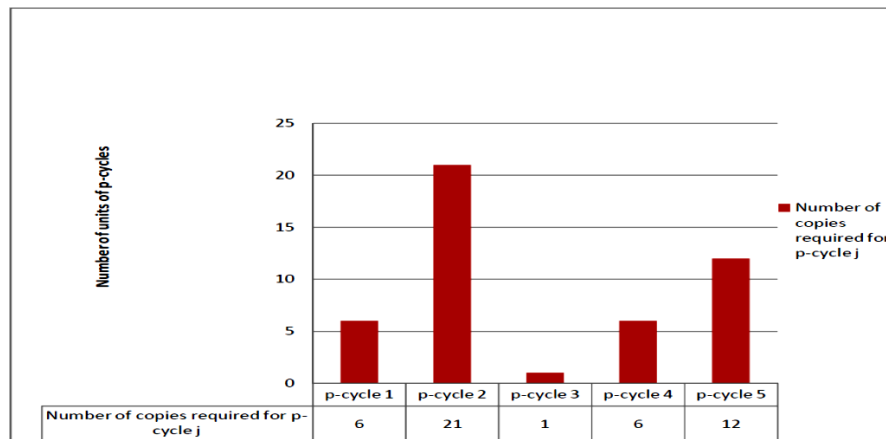
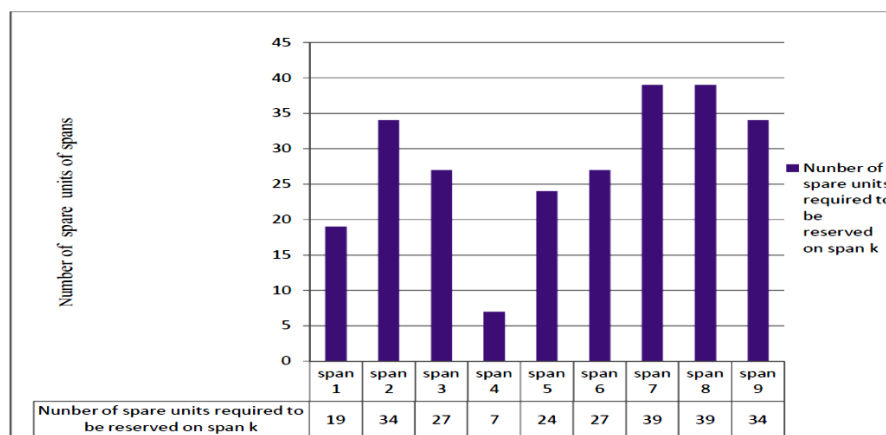


Figure 7 Number of spare units required to be reserved on span k in the test network 7n9s



When further increased the demand units on node pair r as

$d^r = [[0, 9, 0, 0, 0, 0, 0, 0, 0], [10, 0, 0, 0, 0, 0, 0, 0, 0], [0, 0, 12, 0, 0, 0, 0, 0, 0], [0, 11, 0, 0, 0, 0, 0, 0, 10], [9, 0, 0, 0, 11, 0, 0, 0, 0], [9, 0, 0, 0, 12, 0, 5, 0, 0], [0, 0, 0, 0, 0, 0, 0, 0, 11], [0, 0, 0, 0, 0, 0, 0, 9, 11], [0, 0, 0, 0, 0, 8, 9, 7], [5, 11, 0, 0, 0, 0, 0, 0, 0], [0, 10, 7, 0, 0, 0, 0, 0, 0], [0, 0, 0, 0, 0, 0, 0, 11, 0], [0, 0, 0, 0, 0, 14, 13, 0], [0, 0, 0, 13, 0, 0, 0, 0, 0], [0, 3, 12, 0, 0, 0, 0, 0, 9], [0, 0, 0, 0, 0, 0, 7, 0, 0], [0, 0, 0, 0, 12, 0, 9, 0, 0], [0, 0, 0, 0, 0, 9, 12, 0, 0], [0, 0, 0, 0, 10, 0, 0, 0, 0], [0, 0, 0, 0, 0, 11, 0, 0, 0], [9, 0, 13, 0, 0, 0, 0, 0, 0]]$;

Optimal solution is 374.

Figure 8 Number of copies finally required for p -Cycle j in the test network 7n9s

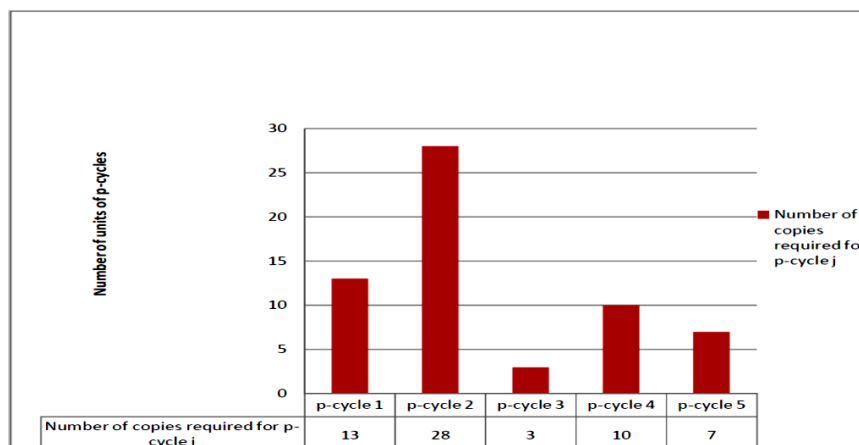
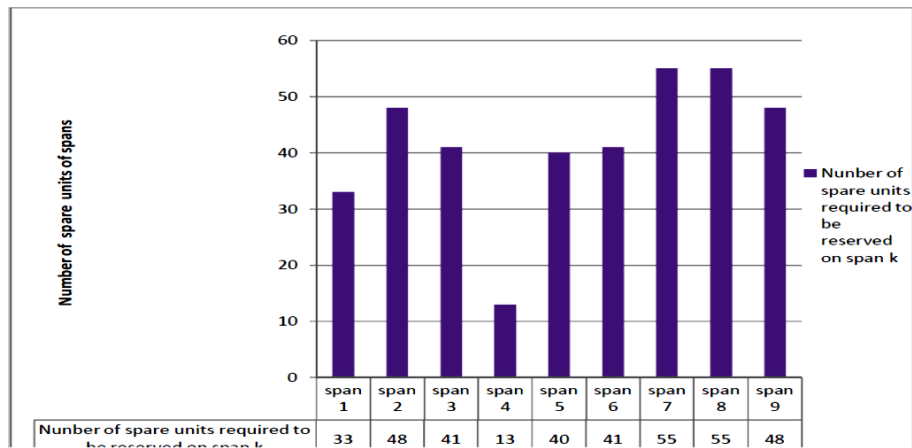


Figure 9 Number of spare units required to be reserved on span k in the test network 7n9s

V. Conclusion and Future Work

A. Conclusion

The flow p -cycles have been found to protect the path segments of contiguous working flows and also for transiting working flows passing through a failed node. The flow p -cycles have better capacity than that of the span protecting p -cycles. In optical networking Path-segment-protecting p -cycles (“flow p -cycles” for short) have capacity efficiency near that of the shared backup path-protection (SBPP) scheme. But because it protects path segments and protection paths are fully pre-connected (not entire paths) it has the potential for both higher speed and higher availability than SBPP.

In this report different approaches and techniques related to the path-segment protection and restoration have been discussed. Different techniques have been analyzed and discussed for flow p -cycle. The flow p -cycle can also provide path protection (if the source and destination nodes are on the cycle), node protection (for any intermediate node between two intersecting nodes) and the usual span protection. It has been shown that a very small additional capacity is required to provide 100% span failure.

B. Future Work

The proposed integer linear programming based on spare capacity, optimizes the selective use of flow p -cycles with long-reach optics for express network flows or regional transiting flows and to determine how much extra spare capacity is needed to allow for 100% transit flow for recovery from span loss which can further extended to the study of node failure recovery.

References

- [1] G. Shen and W. D. Grover, “Extending the p -cycle concept to path segment protection for span and node failure recovery,” IEEE J. Sel. Areas Commun., vol. 21, no. 8, pp. 1306–1319, Oct. 2003.
- [2] John M. Senior, “Optical Fiber Communication: Principles and Practice,” Second Edition, Prentice Hall of India, pp.1034-1038.
- [3] Claus G. Gruber and Dominic A. Schupke, “Capacity-efficient Planning of Resilient Networks with p -Cycles,” 2002.
- [4] W. D. Grover and D. Stamatelakis, “Cycle-oriented distributed pre-configuration: Ring-like speed with mesh-like capacity for self-planning network restoration,” in IEEE International Conference on Communications (ICC 1998), June 1998, pp. 537–543.
- [5] Rachna Asthana, Y.N. Singh and Wayne D. Grover, Fellow, IEEE, “ p -Cycles: An Overview,” IEEE Communications Surveys & Tutorials, Vol. 12, No. 1, First Quarter, 2010.
- [6] Rachna Asthana and Y. N. Singh, “Second Phase Reconfiguration of Restored Path for Removal of Loop Back in p -Cycle Protection,” IEEE Communications Letters, Vol. 11, No. 2, February 2007.
- [7] A.Kodian and W.D. Grover, “Failure-Independent Path-Protecting p -Cycles: Efficient and Simple Fully Preconnected Optical Path Protection,” Journal of Lightwave Technology, Vol. 23, No. 10, October 2005
- [8] B.T. Doshi, S. Dravida, A.P. Harshavardhana, O. Hauser, and W. Yufei, “Optical network design and restoration,” Bell Labs Tech Jour., vol.4, pp. 58-84, Jan-March 1999.
- [9] Zhenrong Zhang; Wen-De Zhong; Mukherjee, B., “A heuristic method for design of survivable WDM networks with p -cycles,” Communications Letters, IEEE, vol.8, no.7, pp. 467- 469, July 2004.
- [10] G. Ellinas, A. G. Hailemariam, and T. E. Stern, “Protection cycles in mesh WDM networks,” IEEE J. Select. Areas Commun., vol. 18, pp. 1924–1937, Oct. 2000.
- [11] Mohammad S. Kiaei, Samir Sebbah, Anton Cerny, Hamed Alazemi, and Chadi Assi, “Efficient Network Protection Design Models using Pre-Cross-Connected Trails,” IEEE Transactions On Communications, Vol. 59, No. 11, November 2011.