IP Restoration on WDM Optical Networks

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Abstract — **An important requirement in IP over Wavelength Division Multiplexing(WDM) Optical networks is to ensure the network survivability, i.e., ability to provide reroutes of ongoing connections after a fault of network components [1, 2]. Such a recovery can be done in two ways using: (1) a protection scheme in the WDM layer that reserves dedicated backup re-routed paths in advance, and (2) a restoration scheme in the IP layer that finds available re-routed paths dynamically. Our focus in this paper is on the embedding of an IP layer topology in the WDM transport network layer with the objective of achieving the network's survivability in the IP layer.**

I. Introduction

Several optical internetworking overlay models are considered for data networks to access an underlying optical transport network [1, 2]. In particular, IP over WDM (an IP network, made of IP routers, built on top of a WDM infrastructure) is considered as the most promising internetworking structure.

Our focus in this paper is on the embedding of an IP layer topology in the WDM transport network layer with the objective of achieving the network's survivability in the IP layer.

II. Problem Formulation

The problem of our interest is defined as follows.

Given: an IP layer topology G, and a WDM topology G_0.

Objective: to find mappings f and h, where f maps each vertex of $V(G)$ into a vertex in G_0 and h maps each link of $E(G)$ into a lightpath in G_0, such that , for any source-sink pair s and t, if G has two link-disjoint paths from s to t, there exist two sequences of link-disjoint lightpaths from s to t.

Without loss of generality, we assume that, for any nodes $u, v \in V(G)$, $f(u) \neq f(v)$ in any mapping f.

It is observed that any feasible solutions satisfying condition (i) ensures that there exists a re-routed path in G after any single link faults in H, hence, providing the IP layer's survivability.

In this paper, we approach the problem by first considering the ring network as the underlying WDM transport network's topology and develop some interesting results.

III. Main Results

The following Lemma 1 shows that, if G is *3-edge-connected*, there exists a mapping of which $\max_{e \in E(G_0)}\{the\ number\ of\ wavelengths\ on\ an\ edge\} \leq \mathbf{2}$. Therefore, there must be at least one live path in the case of single link faults causing at most 2 edge disable.

Lemma 1: If G is *3-edge-connected*, for any mapping $f : V(G) \rightarrow V(G_0)$, there exists a mapping $h : E(G) \rightarrow P(G_0)$ ensuring that G is tolerant to single link faults of G_0.

Although any vertex mappings are acceptable if G is *3-edge-connected*, in case of *2-edge-connected* graph G, each vertex of edge cut of size two should be carefully mapped. Lemma 2 depicts the mapping condition.

Lemma 2: Suppose G is *2-edge-connected.* Let $f : V(G) \rightarrow V(G_0)$, and $h : E(G) \rightarrow P(G_0)$ be mappings such that G is tolerant to single link faults, if and only if, for any edge cuts of size two $\{e_i = (a, b), e_j = (c, d)\}$ in G if there exists any, ordering of vertices in G_0 is not $f(a) - f(c) - f(b) - f(d)$ in the clockwise or counterclockwise direction.

Based on Lemma 1 and Lemma 2, the following Theorem is obtained.

Theorem: Given that G is *2-edge-connected* and G_0 is a ring, G is tolerant to single link faults of G_0.

IV. Conclusion

Under the assumptions that G is *2-edge-connected* and G_0 is a ring, Lemma 1 contributes significantly to the main results, saying any vertex mappings are acceptable in case of *3-edge-connected* graph G.

More strictly, if G is *2-edge-connected*, G is tolerant to single link faults of G_0 if and only if edge cuts of size two of G are mapped with f and h, satisfying Lemma 2.

Further work could consider a mesh topology as the underlying WDM structures.

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