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Green and Resilient Design of Telecom Networks with Shared Backup Resources
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Abstract

Backbone telecommunication network infrastructures are deployed with redundant resources taking into account the backup capacity for protection in order to be resilient against link failures, and serving extremely large amount of data transmission resulting in increasing power consumption. In this study, the interplay between green and resilient network design, and flow routing mechanisms is analyzed. We propose Mixed Integer Linear Programming (MILP) models to obtain optimum solutions under various objectives: Minimizing consumption of (I) Capacity, (II) Capacity+Power, and (III) Power. Two different shared backup protection (SBP) schemes (1) SBP-ind (failure independent) and (2) SBP-dep (failure dependent) are compared with dedicated path protection (DPP). It is assumed that network links utilized by only backup paths can be put into sleep mode. It is observed that when power consumption is minimized, the backup sharing decreases in SBP and, in the extreme case, it behaves similar to DPP. The models are generalized and valid for both IP traffic flow routing and lightpath routing. It is shown that for a sample network topology, to save e.g., 32.33% power, capacity consumption increases significantly, e.g., in SBP-ind up to 127.53%. In order to achieve a compromise between power and capacity consumption, we propose a multi-objective approach. All the MIEP models are run and results are presented for a small scale European network topology as well as a larger scale sample US network topology. For larger problem instances ILP solutions are not scalable. Therefore, a novel energy efficient and survivable routing and network design algorithm, called energy-aware shared path protection (EASPP), addressing the trade-off caused by conflicting objectives of green and resilient network planning is proposed. Moreover this study presents a complete picture of various survivability mechanisms when power consumption is minimized together with the capacity consumption.

Keywords: Green network design, energy-aware, network resiliency, shared path protection, IP over WDM networks.

I. INTRODUCTION

There has been growing interest among telecom industry and Internet providers towards green network infrastructures [1] due to the increasing traffic demand. As stated by Cisco in the global IP traffic forecast report in May 2015 [2], there will be 24 billion networked devices and connections globally by 2019, up from 14 billion in 2014 and internet traffic is expected to be tripled from 2014 to 2019. Network energy requirement profile is estimated to be 35.8 TWh in 2020 in European networks as reported by the Global e-Sustainability Initiative [3]. As a result the capacity requirement in backbone networks increase rapidly, leading to a significant increase in power consumption [4]. By utilizing wavelength division multiplexing (WDM) technology optical backbone networks can carry a tremendous amount of data, which makes the reliability performance of such networks very crucial. Sub 50ms protection switching time is required upon a failure in backbone links. Therefore, network infrastructures are deployed with redundant backup resources to make sure that the network can provide its services in the presence of failures.

In order to reduce the network power consumption, intelligent traffic engineering and routing approaches need to be applied taking into account both primary and backup capacity by utilizing e.g. sleep mode operation of the redundant active network equipment. There has been significant amount of work done addressing energy efficiency for virtual topology design [5] and routing and wavelength assignment [6] in optical networks by eliminating the under utilized network elements in the design process. In the previous studies, energy efficient survivable design approaches have been proposed and sleep mode option is introduced for the links used by backup paths in dedicated path protection (DPP) [7] and shared backup protection (SBP) [8] in optical layer. Compared with DPP, SBP is a promising protection scheme in terms of capacity consumption due to backup capacity sharing [9] which has been recently the focus of industry to reduce the cost of increasing capacity demand. SBP approach can be either (1) failure dependent (SBP-dep) or (2) failure independent (SBP-ind) [10]. In the SBP-dep scheme, backup routes are chosen separately for each link failure scenario in the primary path while SBP-ind represents the conventional shared path protection scheme where backup and primary paths need to be link-disjoint. In [11], different protection schemes DPP and SBP-ind are compared in terms of power consumption assuming the line cards and chasis of the routers can be put in sleep mode when not used. It is found out
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