Chapter 12
Greening the Survivable Optical Networks: Solutions and Challenges for the Backbone and Access

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ABSTRACT
Electricity consumption contributes to a considerably large amount of the Greenhouse Gas (GHG) emissions while Information and Communication Technologies (ICT) have a significant impact on the electricity usage. Hence, novel network and component architectures leading to energy savings as well as energy-efficient network protocols have emerged since mid-2000s. On the other hand, telecommunication networks are being designed and managed to meet the bandwidth and quality of service requirements of the Internet users. As the bandwidth requests increase tremendously, service availability emerges as a key provisioning metric, since huge data losses may occur even if the service unavailability due to a network failure lasts a short time. Survivable network design and management increases resource-overbuild due to the deployment of spare resources. Obviously, deployment of spare resources increases energy consumption while establishing robust connections. Thus, “green survivability” arises as a new paradigm constrained to the trade-off between energy consumption of the network equipments versus high reliability for the subscribers. This chapter points out the challenges and explains the recent trends in provisioning green survivability for the optical backbone and access networks.

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INTRODUCTION

As a result of the global warming which is due to the increase in Greenhouse Gas (GHG) emissions, energy efficiency has become a critical concern for all industries. According to Heddegem et al., Information and Communication Technology (ICT) contributes to 4% of the global energy consumption as of 2008, and it is expected to double in the next decade (Heddegem, et al., 2009). In fact, energy efficiency in the Internet was initially addressed by Gupta and Singh in early 2000s (Gupta & Singh, 2003). Kumar and Mieritz (2007) reported that the telecommunication networks contribute to a big portion of the GHG emissions of the ICT. At the same period, Baliga et al. (2007) analyzed the contribution of each part of the telecom network to the total energy consumption of the Internet with respect to the peak data rate, and the results confirm that energy consumption of access networks stay almost constant with the increasing peak data rate however, it is forecasted to contribute more than 25% of the total energy consumption of the Internet in the next few years. On the other hand, energy consumption of the Internet core increases tremendously as the peak data rate increases (Baliga, et al., 2007). Hence, “greening” of the Internet core and the access networks seems to be critical for the GHG emissions of the telecommunication networks.

Several solutions including green routing, energy efficient packet forwarding, energy-efficient network design and selective turn-off have been considered to assure energy efficiency in the telecommunication networks. Zhang et al. have presented a detailed survey on the studies that have focused on energy-efficiency in telecommunication networks as of 2010 (Zhang, et al., 2010). Although each solution proposes different solutions for energy efficiency, the key issue is reducing the resource utilization without leading to service degradation.

Since the bandwidth demand in the Internet applications has increased dramatically, optical Wavelength Division Multiplexing (WDM) networks have appeared as a breakthrough technology for the backbone applications (Zheng & Mouftah, 2007). On the other hand, in order to fulfill the requirements of bandwidth demanding applications such as video on demand, online gaming and video conferencing, Passive Optical Networks (PON) enable the end users to operate at full wavelength capacity (Lam, 2007). High capacity advantage of optical networks also introduces the risk of huge data loss in case of even short failure durations since the data lost can be as huge as the capacity of the fiber. Hence, network operators and the subscribers sign a Service Level Agreement (SLA) to assure a certain level of reliability and availability. Network operators plan the networks with respect to certain survivability policies to assure restorability in case of a failure, and they further establish connections to guarantee service continuity with high probabilities under possible failure conditions (Mouftah & Kantarci, 2011).

Recent research for greening the survivable optical backbone revisits the existing solutions for network survivability and enhances them by incorporating energy-efficiency. Hinton et al. has shown that access network equipments and the core network routers dominate the overall energy consumption of the Internet (Hinton, et al., 2011). Therefore, this chapter initially focuses on the energy-efficiency of the survivable optical backbone. Further, as stated by Baliga et al., Passive Optical Networks (PONs) offer promising results in terms of energy consumption when compared to Fiber To The Node (FTTN) and Asymmetric Digital Subscriber Line (ADSL) access technologies (Baliga, et al., 2009). Hence, energy-efficiency in PON-based survivable optical access networks is also in the scope of this chapter. As it is stated by Hinton et al., Internet core and the access networks are the major energy consumers, and they are expected to dominate the energy consumption of the Internet in the next decade (Hinton, et al.,
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