Energy Saving in Optical Operator Networks: the Challenges, the TREND Vision, and Some Results

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Abstract *We discuss how to save energy in IP-over-WDM networks, presenting the vision of TREND, the FP7 NoE, and the saving that can be obtained with an adaptive routing solution that puts network interfaces of various granularities to sleep in periods of low traffic. Results refer to two operator networks, considering power and traffic forecasts for 2020.*

Introduction

Today's core networks are designed with a multi layer structure, in which a layer 3 network is realized over an optical layer. IP-over-WDM architecture is usually used due to the high capacities that it provides, flexibility of reconfiguration, and interoperability with the other segments of the network. Even if this technology is able to manage the huge amount of data generated by users and data centers, its energy consumption is far from being negligible. This is due to the fact that the deployed devices like IP routers consume a lot of power (typically tens of kW[1]) to guarantee high performance. Moreover, optical links connecting devices require amplifiers and signal regenerations, which also increase the total power consumption. Thus, the network power consumption has become a critical aspect for operators[2].

In this context, different initiatives[3,4] are being put into place to reduce power consumption in core networks and more in general in the Internet. Of particular note is TREND[5], the Network of Excellence on energy-efficient networking funded by the EU within the FP7 Programme, which supported our work. In this paper, we first sketch the TREND vision to reduce power consumption in telecommunication networks. Then, we identify a set of challenges which are critical for adopting energy-efficient algorithms in current backbone networks. Moreover, we present some results obtained with FUFL (Fixed Upper Fixed Lower)[6], an algorithm developed with the support of TREND. We assess the performance of FUFL over the France Telecom (FT) and Telefonica (TID) networks, showing that there is ample room to reduce energy consumption in IP-over-WDM networks while guaranteeing Quality of Service (QoS) for users. Finally, we analyze FUFL in the light of the challenges proposed by operators, and we discuss how FUFL could be practically adopted in operational networks.

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n. 257740 (Network of Excellence "TREND").

TREND Vision

The TREND project acts as a communication hub among universities, operators, research centers and networking manufacturers. The main goals of the project are to quantitatively assess the energy demand of current and future telecom infrastructures, and to design energy-efficient, scalable and sustainable future networks. To pursue these goals, a holistic approach has been taken, considering all network segments, from user terminals through access networks up to backbones and to data centers.

Focusing on backbone networks, TREND activities target energy-efficiency under different aspects, ranging from design of network nodes, to network planning and management, and to service provisioning. In particular, TREND partners, in one of the joint activities, investigated adaptive mechanisms to concentrate traffic on a subset of network resources according to traffic variations. The idea is to switch off network devices when traffic decreases, e.g. during off-peak traffic periods, and to activate them when traffic increases again. However, the energy saving in a backbone network while guaranteeing QoS is a complex problem, that has to be evaluated at different network layers, and with different solutions. Therefore, rather than proposing a single solution, we have studied and evaluated different algorithms to reduce power consumption in backbone networks. Moreover, we have developed our algorithms driven by feedback provided by operators, and considering realistic case-studies. Our goal is to pave the road for the deployment of such algorithms in operational networks. Finally, we have identified a set of challenges that are critical for operators and that are being currently under investigation within the project.

Challenges

Adaptive mechanisms reducing power consumption of the network need to face several challenges. TREND partners, within the Integrated Research Action 3.1, have identified a set of evaluation criteria to assess these mechanisms from the perspective of a network operator. We summarize them in this section.

Uninterrupted service availability guaranteeing the contracted QoS is the fundamental requirement for the deployment of adaptive mechanisms in core networks. Therefore resilience of power-aware and power-unaware networks should be at the same level.

In this sense, a) the power-saving approaches must be aware that overdimensioning is required for protection and QoS, and that energy saving in one layer may have impact on the reliability of other layers in a multilayer network; b) events triggering the execution of the algorithms (e.g. end of an observation period, or hitting thresholds on link utilization) need to be precisely defined and parametrized in order to avoid instability in the network and minimize the chance of traffic loss; c) the time required for a device to go into sleep mode and wake up, and the time needed to run power adaptation algorithms are also relevant parameters for both the frequency of reconfiguration and their procedures.

Many works evaluating energy-aware adaptive routing solutions assume knowledge of future traffic demands between all node pairs in the network. Although traffic forecasting is non-trivial, the power-aware adaptive mechanisms should be evaluated using predictions of future traffic demands, and not the actual demands. In addition, centralized or distributed operation of the algorithm and required information about the state of the network (local or global) are important issues from the perspective of a network operator. They imply a different degree of control messages exchange needed to disseminate how the network has been reconfigured (for instance, after switching off a line card), having an impact on the scalability of the control plane.

The use of existing control mechanisms (e.g. GMPLS) is highly recommended to avoid incompatibility issues within the commercial telecommunications networks and to enable easier adoption by operators.

Finally, the power-aware adaptive mechanisms must also take into account the capacity of the installed devices and the constraints imposed by the physical layer in optical transport deployments, such as minimum received Optical Signal to Noise Ratio.

FUFL Case-Study Results

FUFL[6] is a simple, distributed mechanism, which fulfills most of the criteria described in the previous section (protection has not been investigated in the context of FUFL yet). The mechanism assumes no reconfiguration of the IP-over-WDM network. Both the routing of traffic demands in the upper (IP) layer and the routing of lightpaths in the lower (WDM) layer are fixed. In order to save power, the mechanism releases lightpaths together with corresponding transponders and line cards when they become empty due to traffic decrease. The lightpaths are established back again when the traffic increases. The set of available lightpaths is limited, and corresponds to a Static Base Network (SBN) designed for a peak demand. FUFL cannot establish any lightpath that does not exist in the SBN. We assume that a lightpath is torn down as soon as it is empty, and is established as soon as a corresponding parallel lightpath gets full. It is however possible to use thresholds on the utilization of the parallel lightpath(s) to trigger establishment and release of a lightpath in order to guarantee QoS in case of drastic traffic changes.

The two investigated networks are described in[7]. The logical topologies consist of 38 nodes and 72 bidirectional links for FT, and 113 nodes and 127 bidirectional links for TID. Medium traffic predictions for the year 2020 are used. The total demand during the peak hour equals 33 Tbps for FT and 55 Tbps for TID. We use profiles of daily traffic variation originating from measurements reflecting representative working days.

Evaluation of power savings of any mechanism is dependent on the assumption of power consumption of single devices. We start from the values in[1] and propose values of the potential of power saving when entering a sleep mode for three Single Line Rates (SLRs): 40G, 100G and 400G (Tab. 1). Putting devices into sleep mode instead of switching them off allows lower activation times, which are important from the QoS perspective. Making a prediction for the year 2020 is not an easy task. We assumed that vendors will fo-

Tab. 1: Potential of power saving when entering sleep mode in Watts – prediction for 2020

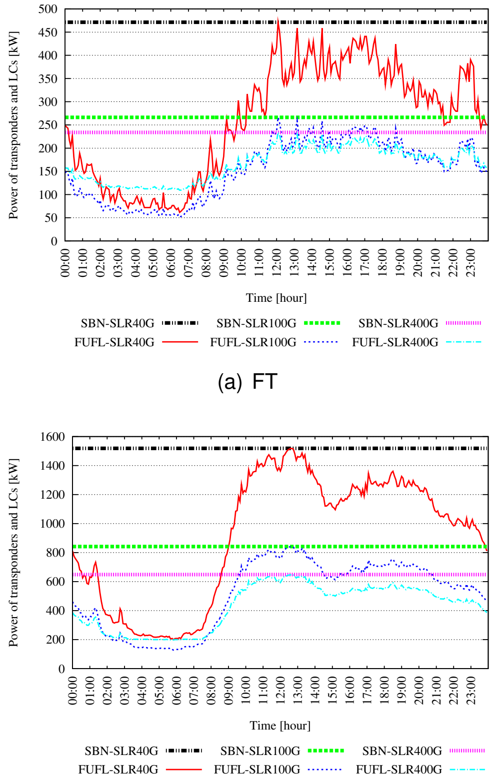
SLR [Gbps]	Transponder	Line card	Total
40	100	300	400
100	120	420	540
400	300	1180	1480

cus on the development of high capacity devices (100G and 400G), while energy-efficiency of the 40G devices will be only slightly better than today. We assume that power consumption in the sleep mode will be negligible.

Fig. 1 shows power consumption of transponders and line cards for both networks using the three SLRs. As expected, the smaller FT network consumes less power than the TID one. The power consumption of the network using FUFL follows the traffic variation, and reaches the consumption level of the SBN only during the peak hour. Particularly large power savings are achieved during the night. Interestingly, while the SBN using 400G interfaces consumes less power than the ones using 100G and 40G interfaces, power consumption of the networks with FUFL reaches similar level for all SLRs at night, meaning that better power-efficiency (in Watt per provided capacity in Gbps) of high capacity interfaces is compensated by the possibility to switch off less power-efficient interfaces providing capacity of finer granularity. The highest power savings against the SBN (up to 87% in both FT and TID networks) are reached for the networks using 40G interfaces. However, also for the 100G/400G interfaces (which are more likely to be used in 2020) the savings are significant, namely up to 81%/53% and up to 85%/69% for the FT and TID networks respectively. Looking at the whole day, the SLR 40G/100G/400G FUFL energy savings accumulate to 5096/2707/1649 kWh (45/42/29%) for the FT network, and to 14649/7927/5254 kWh (40/39/34%) for the TID network.

Conclusions

We presented the TREND vision to reduce power consumption in telecommunication networks. In particular, we focused on IP-over-WDM networks, and briefly presented a set of challenges that need to be considered when saving energy using Traffic Engineering techniques and putting idle devices into sleep mode. Furthermore, we presented exemplary results of the reduction of power saving in two operator networks using a simple, distributed mechanism called FUFL. The case study, assuming predictions of traffic and power consumption estimates for the year 2020, showed that significant power savings are possible without the global knowledge of the network, and without the need for dynamic network reconfiguration. The computation time of FUFL is negligible, and no control mechanism is needed, therefore current observation of traffic on the node interfaces should be enough in practice to make quick decisions about their activation and deactivation. Switching off protection resources remains the only open issue in the context of FUFL.



(a) FT

(b) TID

Fig. 1: Power consumption of transponders and line cards (LCs) in a Static Base Network, and when using FUFL.

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