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Energy Efficiency Evaluation of RSVP-TE Extensions for Survivable Translucent WSON Networks

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Abstract

Energy consumption in communication networks is ever increasing. The target of reducing the energy can be approached from different points: energy usage reduction of different hardware components, sleep mode, energy efficient routing and signalling protocol extensions.
Another interesting aspect in communication networks is that connections must be protected against failures. The backup resources are normally connected and powered on, which also contributes to the energy budget. Using Shared Path Protection (SPP) minimizes the protection resources by efficient sharing of wavelengths, regenerators and wavelength converters. Furtheron signaling extensions that can reduce the energy usage by reducing the usage of electrical ports can be designed.
In this paper, we use GMPLS extensions to integrate energy-efficiency considerations into the network protection paradigm; and we use OPNET Modeler to evaluate our proposal.

Introduction

Energy consumption in communication networks is ever increasing. ICT alone is responsible for up to 10% of the world's power consumption [1]. Hence, an increasing number of studies have been looking into reducing the energy usage of communication networks.

Energy reduction methods

The target of reducing the energy can be approached from different points:

Energy usage reduction of different hardware components
The energy consumption rating initiative has recently been established to measure the energy efficiency of network and telecom devices [2]. Also in [3], it has been shown that telecom operators are now posing energy efficiency requirements for communication equipment. Hence, it has become important for vendors to make sure that their components and equipment can fulfill the latest energy usage and heat dissipation requirements.

Sleep mode
An intuitive and currently heavily investigated approach to power saving is to introduce sleep mode into network operation [4]. This is motivated by the fact that not all nodes, or only parts of a node are actually in service during normal operating conditions. Hence, it would be beneficiary from an energy perspective to put the unused parts to sleep. The nodes/components can then be awoken when their service is needed, e.g. during peak traffic hours or under failure conditions. The main drawback of the sleep mode approach is that waking up nodes and components actually takes time and the mechanisms may be somewhat difficult to control.

Energy efficient routing
Energy efficient routing deals with allocating traffic to paths which require least possible energy. Several approaches exist. One approach constantly monitors the energy distribution in the network (e.g. via SmartGrid), and allocates new connections to paths which provide the most favorable energy profile. A more advanced approach also allows for the re-routing of already established connections when a more energy-economic path appears.
In particular, energy efficient routing has been related to renewable energy sources [5]. The basic idea is to route traffic through nodes which can be powered with renewable energy sources. A well-known concept is "follow the wind – follow the sun" [6], but basically any green energy powered equipment will be preferred by the routing algorithm. In practice, the method is fulfilled by adding high costs to links connecting non-renewable energy powered nodes in the OSPF-TE protocol [7].

Signaling protocol extensions
Previous work in the field of energy efficient networking generally assumes that it is the actual path the traffic is routed on that should be chosen as energy efficiently as possible. In the work presented here, we assume that the path is given, and we only use signaling protocol extensions to improve the energy profile of a connection. This has the advantage that we can avoid route flapping caused by fluctuating energy availability, and it also greatly decreases the complexity of the connection establishment operation. In particular, we will describe how we employ RSVP-TE extensions in order to minimize electrical port usage, as O-E-O conversion consumes a lot of energy in an optical network. Details of the approach are described further.

Protection of network traffic

An important aspect in communication networks is that they must be protected against failures. In standard network protection, e.g. 1+1, 1:1, etc., the backup resources are normally connected and powered on, which also contributes to the energy budget. Using so-called Shared Path Protection (SPP) is a network-wide application of the 1:n method, meaning that several working connections can share a backup route. Working connections may share a backup path under the condition that they are link and/or node disjoint, and assuming a single failure condition. In particular, SPP provides the possibility to pre-calculate such a backup connection when the working path is setup, but the connection is only reserved in the control plane, whereas the actual cross-connection in the data plane is only executed when a failure occurs. A success criterion of SPP is to make the shareability of backup resources as high as possible without introducing sharing violations (e.g. through non-disjointness), including, in the presented work here, energy consumption as a parameter.

Paper organization

The remainder of this paper is organized as follows: the next section presents the networking environment including the considered node architecture and the energy efficiency extensions in a GMPLS framework. Then, the simulation study and results are presented. The last section concludes the paper.

Networking framework

Protocol environment

The task of regenerating the optical signal greatly contributes to the power budget of a long-distance transport network. Regeneration requires that the signal is converted to the electrical domain. Thus by minimizing the use of regenerators, e.g. through intelligent wavelength conversion (WC) and regeneration collocation, we can reduce the usage of electrical ports and hence save the energy required for operating the electrical domain part of a node. A schematic of the node considered is shown in Figure 1.

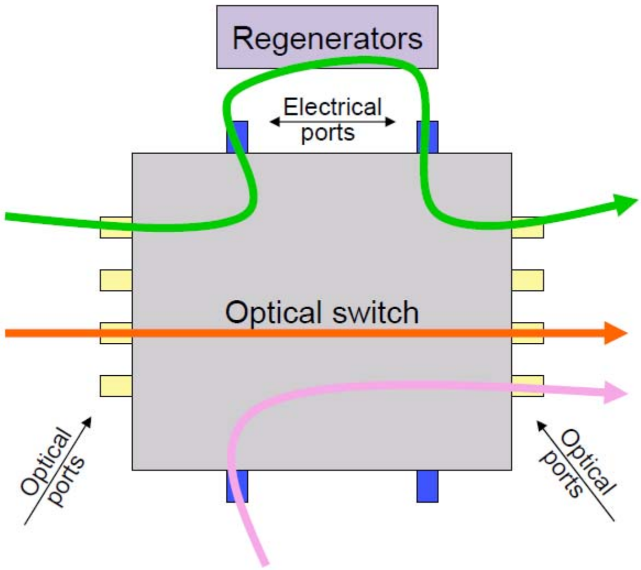

Figure 1: Schematic of optical switch.

In order to control the connections in the network we rely on the GMPLS framework [8]. GMPLS consists of the Link Management Protocol (LMP), the Open Shortest Path First (OSPF) protocol with Traffic Engineering (TE) extensions, and the Resource ReserVation Protocol (RSVP) also with TE extensions. OSPF-TE takes care of finding routes for new connections, including the backup routes. The actual resource allocation (wavelengths, converters, regenerators, etc.) is done by RSVP-TE. In this work, we focus on how we can apply extensions to RSVP-TE to make a route chosen by OSPF-TE more energy efficient. In particular, our approach focuses on minimizing the electrical port usage.

As a basis for our work we are using a generic GMPLS model developed earlier [9][10] and depicted in Figures 2 and 3, but we are changing the model behavior and algorithms to focus on energy efficiency.

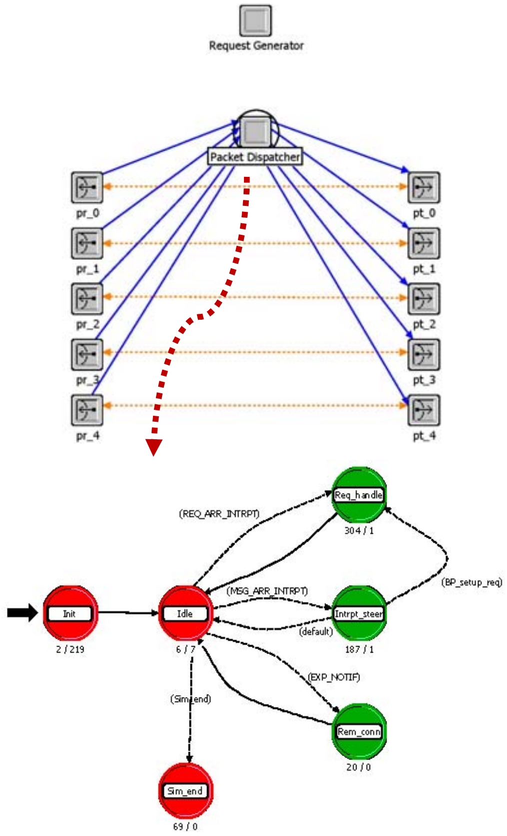

Figure 2: GMPLS controller node model and parent process model (Packet Dispatcher).

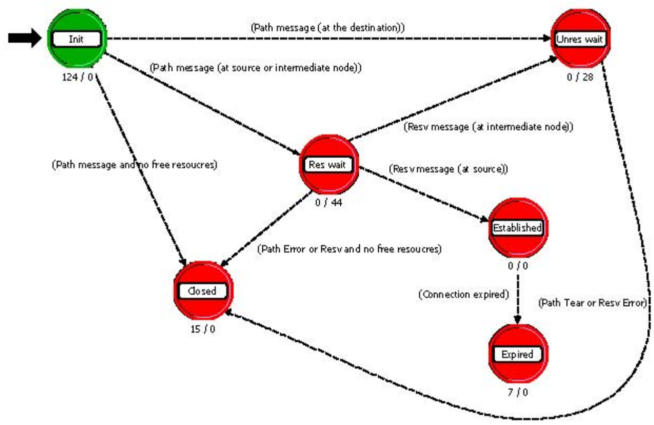

Figure 3: RSVP-TE child process.

Energy efficiency extensions

In this study, we compare the performance of two regenerator placement schemes called *DEST* and *DISTR*. They have been originally designed to optimize joint placement of regeneration and wavelength conversion points and are described in detail in [11]. In summary, under the *DEST* scheme the regenerator points are chosen solely by the destination node and then propagated back with the RSVP-TE Path message; while in *DISTR* the destination node can force a node to act as both a WC and a regenerator point and an intermediate may select the next regeneration and WC point in addition to selecting a new wavelength. The DEST scheme contains a Regeneration Availability Object (RAO) in the Path message [16], as shown inFigure 4. To make distributed decisions, the DISTR scheme introduces a new RSVP-TE extension called CNV (conversion node vector). The CNV includes an element for each wavelength contained in the LS, indicating the ID of the closest upstream node where wavelength conversion must take place for the corresponding wavelength [15]. Comparing the DEST and DISTR methods have previously shown that the DISTR strategy achieves lower blocking, lower regenerator utilization and higher fairness compared to the DEST strategy [11].

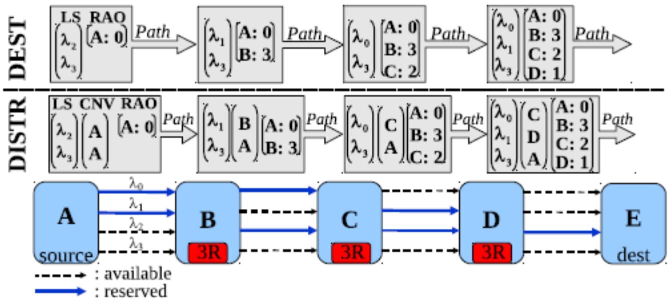

Figure 4: Example of LSP setup with DEST and DISTR [15]

In this current work, we investigate the energy consumption (in terms of electrical port usage) of these two designation schemes, under SPP scenario.

The electrical port usage per connection is calculated as:

$$El\_port\_usage = El\_source + El\_intermediate + El\_dest \quad (1)$$

Each connection consumes one electrical port at the source and destination respectively, while each regeneration and/or wavelength conversion at an intermediate node imposes the use of two electrical ports (see Figure 1).
The goal of this work is to minimize the usage of electrical ports and thereby reduce the overall energy consumption.

Simulation scenario and results

The performances of *DEST* and *DISTR* have been evaluated using OPNET Modeler [12]. A Pan-European topology [13] with 28 nodes and 60 bidirectional links is used (see Figure 5), with 16 wavelengths per link and 16 regenerators per node. The regeneration span is assumed to be two hops (we only consider a hop based scenario – but a distance based scenario is possible as well). LSP requests are generated according to a Poisson process. The mean interarrival time is depicted in seconds.

The working label switched paths (LSPs) are setup using a first fit wavelength assignment, whereas the backup paths' wavelengths are assigned utilizing the Most Shared Wavelength Converter (MSWC) scheme [14]. MSWC is based on an extended RSVP-TE object, which presents how many backup connections share a given wavelength converter/regenerator. Hence, the wavelength which will introduce the highest sharing ratio is chosen, resulting in a high backup resources sharing ratio desired for SPP.

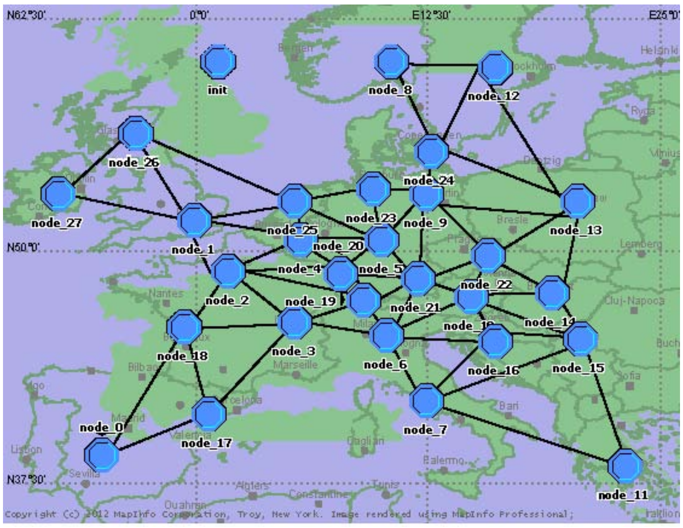

Figure 5: Pan-European topology.

We are showing results for both standard GMPLS operation using the Label Set [8] only, and for the Suggested Vector [9] which was originally designed for wavelength converter minimization.

In Figure 6 the results for the electrical port usage are depicted. We can see that the *DISTR* scheme reduces the electrical port usage for both the LS and the SV case, hence providing higher energy efficiency. This is caused by intelligent co-location of wavelength conversion and regeneration points in *DISTR*, and hence causing as few O-E-O conversions as possible. The SV scheme outperforms the LS scheme for both *DEST* and *DISTR* due to its wavelength converter minimizing properties.

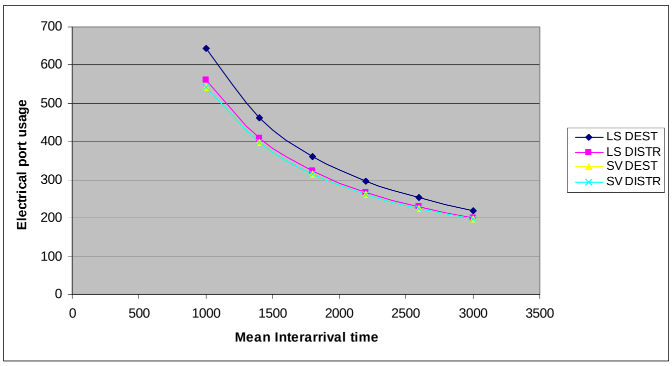

Figure 6: Electrical port usage.

Figure 7 illustrated the results for the optical port usage. We can see that all four schemes have an identical port usage. This is to verify that the gain in electrical port usages does not come at the expense of a higher optical port usage (indicating longer routes), which the numbers confirm.

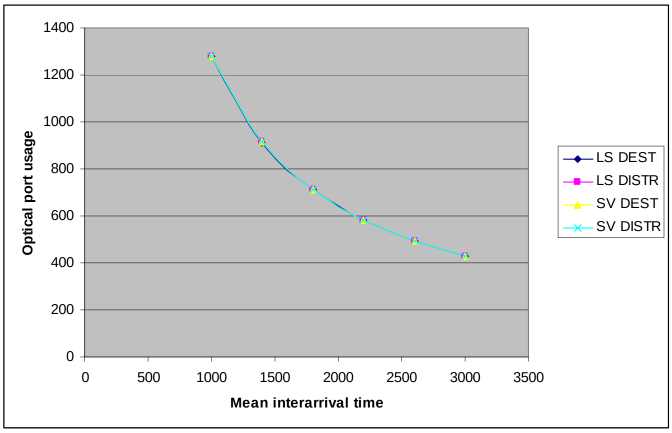

Figure 7: Optical port usage.

In Figure 8 the electrical port usage is depicted for a scenario with and without Quality of Transmission (QoT) requirements, meaning that only wavelength conversion but not signal regeneration is required in the non-QoT case. We can see that signal regeneration is responsible for a large amount of the electrical port usage. Again, the converter minimization of the SV scheme can significantly reduce the electrical port usage in the non-QoT case.

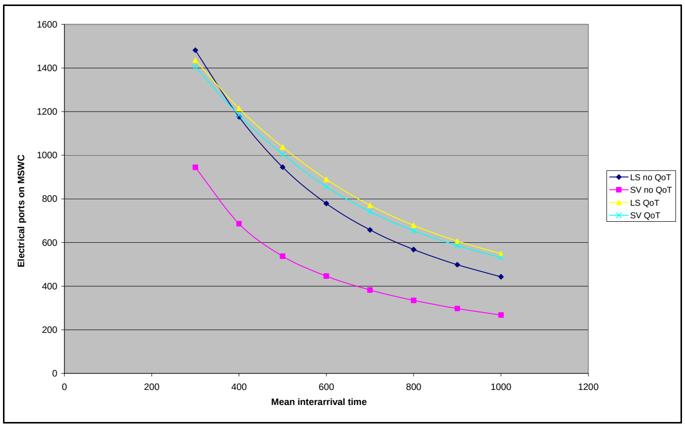

Figure 8: Electrical port usage with and without QoT requirements.

Conclusion

In this paper, we have used GMPLS extensions to integrate energy efficiency and network resilience. Our results show that the electrical port usage can be significantly reduced by using intelligent regenerator and wavelength converter placement strategies. Thus, the scarce usage of electrical ports can help to reduce the power budget of the overall communication system.

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