EFAH: an Energy and Fatigue Aware Heuristic for Provisioning Highly Available Connections in Optical Backbone Networks

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***Abstract*—Optical backbone operators need to meet the availability requirements specified in the Service Level Agreements (SLAs). While less stringent availability constraints, i.e., less than three 9's might be met by provisioning connections without any protection, more stringent requirements, i.e., five 9's, force operator to use proactive protection strategies. The connection provisioning process becomes more cost-efficient when green aspects are considered. On the other hand, energy awareness introduces thermal fatigue effects, which may in turn lower the lifetime of devices that undergo frequent power state transitions, i.e., between Active Mode (AM) and Sleep Mode (SM). As a result the availability level experienced by the unprotected connections may decrease. At the same time, with devices failing more frequently the protection level chosen for a given connection might not be enough to guarantee the required average connection availability performance.**

This work tackles the problem of managing an optical backbone network when green and thermal fatigue aspects are introduced. We propose an Energy and Fatigue Aware Heuristic (EFAH) that is able to balance between thermal fatigue effects and energy saving performance. When compared to the pure Energy-Aware (EA) strategies, EFAH manages to significantly improve the value of the average connection availability of both unprotected and protected connections. On the other hand, there is a price to pay in terms of lower energy saving performance.

***Index Terms*—Optical backbone network operations; Thermal fatigue; Devices lifetime; Connection availability; Acceleration factor, Green provisioning;**

I. Introduction

Connection availability is one of the most important parameters defined in a Service Level Agreement (SLA). The level of the required connection availability depends on the criticality of a connection. In the case where the connection is not very critical the required availability level may be lower than three 9's, and thus, it might be sufficient to provision a lightpath over links with good availability characteristics and without a need for allocating extra protection resources. However, for critical connections, where the required availability level is five 9's or higher, a network operator needs to proactively provision redundant resources in order to account for possible failures, e.g., Dedicated Path Protection (DPP) 1:1 in the case of single failure scenarios.

In order to help operators reducing their operational costs, provisioning strategies can be combined with energy-awareness [1]. Green network strategies usually leverage on the temporal and geographical traffic variations (i.e., day vs. night time). This is done to minimize the number of network elements that are kept in Active Mode (AM) to provision the required number of lightpaths during a given traffic period and in a certain area. On the other hand, repeated power state transitions between AM and Sleep Mode (SM) may lead to reduction of the device lifetime due to temperature changes [2]. For instance, in an optical network, the impact of temperature variation on the reparation cost of Optical Line Amplifiers (OLAs) is quite significant [3]. Their mean lifetime referred to as Mean Time To Failure (MTTF) decreases with frequent power state transitions. As a result the optical backbone network may experience more frequent link failures. This would have a direct impact on the availability of unprotected connections, which might lead to deteriorated average connection availability levels. With some devices failing more frequently, the probability of having multiple failure scenarios in the network also increases, which would also affect the protected connections. With a failure scenario more severe than anticipated, the protection level chosen for a given connection might not be sufficient to guarantee the required average connection availability performance. As a result, operators might have to reserve additional backup resources to meet their SLAs, e.g., use DPP 1:N with N>1, which provisions N disjoint backup paths to a single connection request, in order to allow a connection to survive N concurrent failures [4]. With the above considerations in mind, it becomes clear that a green provisioning strategy needs to be also fatigue-aware.

This paper proposes a new Routing and Wavelength Assignment (RWA) strategy called Energy and Fatigue Aware Heuristic (EFAH), which accounts for both lifetime degradation (due to thermal fatigue caused by temperature variation) and energy consumption levels when provisioning lightpaths with a given availability requirement. More specifically, the work focuses on the power savings vs. lifetime degradation aspects of the OLA when they are switched between AM and SM to manage the power state of fiber links in an optical backbone network. The proposed EFAH can be configured to provision both protected (i.e., DPP 1:N, $N\geq1$) and unprotected connections. The performance of EFAH is assessed via simulation considering a multi-period traffic scenario, i.e., when network reconfiguration is triggered to adapt the power state of the fiber links to the day/night traffic variations. We model the lifetime degradation of OLAs due to thermal fatigue, and consider the fiber link failures caused by OLA failures. Our evaluation shows that EFAH manages to significantly improve the value of the average connection availability in comparison to pure Energy-Aware (EA) strategies. This is true in case of both unprotected and protected connections.

The reminder of the paper is organized as follows. Section II presents an overview of the related work. Section III introduces the network and devices lifetime model based on the thermal fatigue concept. The proposed RWA strategy is presented in Section IV, and its performance assessment is shown in Section V. Section VI concludes the work and provides an outlook on the future work.

II. Related Work

We review the related work with respect to three main aspects: *(i)* energy-awareness utilizing SM, *(ii)* lifetime- and thermal-fatigue-awareness, and *(iii)* connection availability/resiliency. We focus on the research efforts addressing point *(ii)* (i.e., lifetime- and thermal-fatigue-awareness), which is the main aspect addressed in this work. In fact, energy-awareness utilizing SM is well-investigated (see [1] for a detailed survey), and the connection availability/resiliency related research has been around for several decades [5], with disaster-related disruptions being studied recently [6].

The authors of [7] quantify the cost savings in a core Wavelength Division Multiplexing (WDM) network where elastic optical transponders can adapt their modulation format to the link transmission conditions that degrades due to fiber aging. The study considers a greenfield deployment on the 44-node core Italian network and analyzes the costs of operating this network for a period of 10 years. Results show that the main cost savings are achieved at the beginning, i.e., after the network is initially deployed, and are strongly dependent on the traffic volume. Energy saving is not directly analyzed, and connection availability aspects are not taken into account. The work in [8] analyzes the lifetime degradation in optical and cellular networks caused by frequent component power state changes, but no connection availability requirements are taken into account. The same problem, but focusing only on optical networks, is further studied in [9] where an optimal trade-off between energy saving and component lifetime degradation is presented using an Mixed-Integer Linear Programming (MILP) formulation. The authors show that their proposed approaches can achieve a good lifetime performance without consuming significantly more energy than purely energy-aware approaches. The work, on the other hand, does not consider any connection availability aspects. The authors in [10] focus on Internet Protocol (IP) backbone networks and propose an optimal formulation and a heuristic called Acceleration Factor Algorithm (AFA). Their results indicate that lifetime-aware network management should be pursued when deciding to put network devices into SM. Differently from [10], this work addresses the effect that SM has on the connection availability performance in the optical layer. Furthermore, we are not aware of any work that jointly addresses aspects *(i)–(iii)* in optical backbone networks.

III. Component Lifetime Variation Model

We consider an optical backbone network where the power status of a fiber link can be controlled. The average lifetime of fiber links depends on how much time their OLAs spend in a given power state (i.e., AM or SM) and on the frequency of the OLAs power state changes. A fiber link is in SM when all OLAs on the link are in SM, while it is in AM when all OLAs are activated.

The impact of thermal fatigue on the lifetime of a device can be calculated using the Acceleration Factor (AF) concept presented in [9]. The AF is the ratio between the value of the mean lifetime when a device is always in AM (i.e., γ^{on} [h]) and the value of the mean lifetime (i.e., γ^{tot} [h]) when a device goes through a number of power state transitions. More formally, the AF can be defined as:

$$AF = \frac{\gamma^{on}}{\gamma^{tot}} = 1 - (1 - AF^{sleep})\frac{\theta}{\Delta_t} + \chi\frac{c}{2}, \qquad (1)$$

where AF^{sleep} is a HardWare (HW) parameter that represents the value of the AF when the device is always kept in SM, θ [h] is the amount of time spent by the device in SM, Δ_t [h] is the total time the device has been in use, χ is a HW parameter that represents the AF variation caused by a power state transition, and c represents the number of power state transitions during Δ_t. An increase in the device lifetime is expected when AF<1. The lifetime decreases when AF>1.

Assuming that failed devices are always replaced (i.e., no reparation time), the value of the MTTF of a device can be computed as follows:

$$MTTF = \frac{\gamma^{on}}{AF}. \qquad (2)$$

From (2) it becomes clear that thermal fatigue has a direct impact on the value of the MTTF of a device.

IV. Energy and Fatigue-Aware Multi-Period Provisioning for Optical Networks

This section provides more details about the problem targeted in the paper, i.e., how to jointly account for energy consumption and thermal fatigue of a device during the RWA phase in the presence of a multi-period traffic scenario. Then, the section presents an energy- and fatigue-aware RWA strategy called EFAH.

A. Problem Definition

This study considers an optical WDM backbone network where an operator aims at saving energy by dynamically managing the power state of the fiber links, i.e., by controlling the operational mode of the OLAs belonging to these links. Information on multi-period traffic fluctuations, e.g., day vs. night variations, are used to decide when to put a subset of the fiber links into SM in order to save energy. We assume a multi-period traffic scenario where in each traffic period there might be significant traffic changes compared to the previous one (e.g., night- to day-time traffic variations). In each traffic period, if needed, the WDM network might undergo reconfigurations. Traffic periods last for a known number of hours, which is an input to our problem. Each traffic period is associated with a traffic matrix containing the lightpath requests to be provisioned during that particular period. Based on this information, fiber links in the network might be put into SM/AM to adapt to the changes introduced by the change of traffic matrix. When undergoing power state changes, OLAs experience the thermal fatigue effect introduced in Section III. This in turn might reduce the lifetime of some OLAs and consequently generate more frequent fiber link failures.

In this scenario, a smart RWA strategy should be able to balance between energy saving levels and thermal fatigue effects. By monitoring how the AF of the OLAs varies over time, it is possible to decide (in each traffic period) whether or not an extra power state transition will reduce the lifetime of an OLA below a given threshold. In this way it is possible to control the negative effect of thermal fatigue. This potentially comes at a cost of a lower energy saving.

B. Energy and Fatigue Aware Heuristic (EFAH)

This section presents the EFAH whose goal is to find a good trade-off between the minimization of the OLAs lifetime degradation and the maximization of the energy saving. The heuristic is aware of the power state and of the AF value of all OLAs in the network. The notation used in the heuristic is the following:

- $G(V, F)$ is the network topology graph with $|V|$ nodes and $|F|$ fiber links;
- $f \in F$ represents a fiber link;
- $f_{am} \in \{0, 1\}$ is equal to 1 if the fiber link $f \in F$ is currently in AM, 0 otherwise;
- $f_{failed} \in \{0, 1\}$ is equal to 1 if at least one of the OLAs on fiber link $f \in F$ is failed, 0 otherwise;
- f_{free} is the number of free wavelengths on fiber link $f \in F$;
- f_{ola} is the set of OLAs along fiber link $f \in F$;
- ola_{AF} represents the AF of OLA $ola \in \bigcup_{f \in F} f_{ola}$, calculated according to (1) considering the particular OLA HW parameters, θ, Δ_t and c;
- $\lambda \in \mathbb{N}$ is the total number of wavelengths at each fiber link in the network;
- K is the set of pre-calculated k-shortest-paths between all node pairs, each path $k \in K$ terminating at $k^{src}, k^{dst} \in V$, and containing $k_f \subset F$ fiber links composing the path;
- R represents the traffic matrix for the current traffic period, where $r \in R$ is a lightpath to be established from $r_{src} \in V$ to $r_{dst} \in V$ requiring one wavelength resource;
- $N \in \mathbb{N}$ defines the number of disjoint protection paths assigned to each $r \in R$ requiring DPP 1:N. $r \in R$ does not require DPP if $N = 0$;
- α is a weighting factor to balance between power fatigue effects and energy saving levels;

Algorithm 1: Energy and Fatigue Aware Heuristic (EFAH)

Data: power state of fiber links from previous time period, R, K, M, λ, α, β, N
Result: RWA for all $r \in R$, power state f_{am} of each fiber link $f \in F$ at current time period

1 Sort set R by descending order of the wavelength resources used by each $r \in R$ on their $1+N$ shortest disjoint paths `// Initialization`
2 **foreach** $r \in R$ **do** `// RWA`
3   minWeight $\leftarrow M$;
4   $lp_{n=1...1+N} \leftarrow$ null;
5   **foreach** $k_{n=1...1+N} \in K \mid k^{src}_{n=1...1+N} = r_{src} \wedge k^{dst}_{n=1...1+N} = r_{dst} \wedge \mathit{ff}(k_{n=1...1+N}) \geq 0 \wedge f_{failed} = 0,\ \forall f \in fibers(k_{n=1...1+N}) \wedge disjoint(k_{n=1...1+N})$ **do**
6   switchesOn $\leftarrow 0$;
7   noSleep $\leftarrow 0$;
8   **foreach** $f \in fibers(k_{n=1...1+N})$ **do**
9   **if** $f_{am} = 0$ **then**
10   switchesOn $\leftarrow$ switchesOn + $|f_{ola}|$;
11   **if** $f_{free} = \lambda$ **then**
12   noSleep $\leftarrow$ noSleep + $|f_{ola}|$;
13     $w = \alpha \times switchesOn + noSleep$;
14   **if** $w <$ *minWeight* **then**
15   minWeight $\leftarrow$ w;
16       $lp_{n=1...1+N} \leftarrow k_{n=1...1+N}$;
17   **if** $lp_{n=1...1+N} \neq$ *null* **then**
18   Perform RWA for r using paths $lp_{n=1...1+N}$ and wavelength ff($k_{n=1...1+N}$);
19   Put OLAs of fiber links in $lp_{n=1...1+N}$ in AM;
20   **else** Block d;
21 **foreach** $f \in F$ **do** `// Post-RWA`
22   **if** $f_{free} = \lambda \wedge \nexists\ ola_{AF} > \beta\ \forall ola \in f_{ola}$ **then**
23   Put fiber link f into SM;

- β is the maximum allowed value of the AF for each OLA;
- M is a sufficiently big number;

Alg. 1 describes the steps used for solving the RWA for each $r \in R$ to be provisioned during each traffic period. The function ff(k) returns the wavelength ID to be used on path k. The value is obtained with a First Fit (FF) strategy, assuming wavelength continuity. ff(k) returns -1 if no wavelength is available. The function $fiber(k)$ returns the set of all fibers traversed by path k. The function $disjoint(k_1, k_2, ..., k_N)$ returns $true$ if paths $k_1, k_2, ..., k_N$ are disjoint, $false$ otherwise.

The heuristic works as follows. First, all $r \in R$ are sorted based on the number of wavelength resources that they require, including their protection paths (line 1). Afterwards, for each $r \in R$ (line 2) the variables necessary to remember the best routing solution found so far are initialized (lines 3–4).

Then, the algorithm needs to prune set K to find all the

TABLE I
RWA STRATEGIES CONSIDERED FOR PERFORMANCE EVALUATION.

Strategy	Initialization	RWA	Post-RWA
SP 1:N	-	For each $r \in R$ assign the shortest available primary path and up to N shortest disjoint available backup paths.	-
EA 1:N	Sort set R by descending order of the wavelength resources used by each $r \in R$ for its primary path and for its N disjoint backup paths	For each $r \in R$ assign the primary path and the (up to) N disjoint backup paths which traverse the minimum number of OLAs currently in SM.	Puts unused fiber links into SM.
EFAH 1:N		For each $r \in R$ assign the primary path and the (up to) N disjoint backup paths which lead to the smallest value of weight w defined in line 13 of Alg. 1 for EFAH and $w = switchesOn$ for FAH.	Put into SM those unused fiber links where the AF value of OLAs is smaller than β.
FAH 1:N			-

possible sets of link disjoint paths $k_{n=1...1+N} \in K$ between $r_{src} \in V$ and $r_{dst} \in V$ with continuous wavelength resources, and also which do not contain any failed fiber link (line 5). The algorithm then checks all these paths to identify and save the one leading to the smallest value of the weight w (lines 6–16). The rationale is to balance the number of OLAs that will have to undergo a transition from SM to AM (line 10) vs. the number of OLAs that could be turned off (line 12). In fact, with more OLAs switching to AM the overall network energy consumption increases, while some of these OLAs might also experience a decrease in their lifetime because of thermal fatigue. On the other hand by putting more OLAs into SM the network energy consumption can be reduced. This tradeoff is addressed with the link weight w defined in line 13 of Alg. 1. The variables necessary to remember the best routing solution are updated based on w (lines 14–16). If a suitable path set $k_{n=1...1+N} \in K$ is found (line 17), the algorithm provisions r using paths $k_{n=1...1+N} \in K$ and the first available continuous wavelength (line 18). Then, the power state of the OLA on fiber links that experienced a power state change is updated (line 19). Otherwise, if a set of routes is not found, the traffic demand is blocked (line 20).

Finally, the algorithm performs a post-RWA procedure, where fiber links with no traffic are set into SM (lines 21–23). Two conditions need to be met for a fiber link to be put into SM (line 22): *(i)* the fiber link is not traversed by any lightpath in the current traffic period; and *(ii)* none of the OLAs on the fiber link has a value of the AF greater than the threshold β. This is done to limit the impact on the OLA lifetime. The fiber link is put into SM (line 23) if both conditions are met.

In the study we also consider a variant of the EFAH, called Fatigue-Aware Heuristic (FAH). In FAH the focus is only on minimizing the effect of thermal fatigue. This is done by limiting the number of power state transitions experienced by the OLAs, regardless of the energy saving performance of the chosen paths. As a result, the weight w accounts only for the number of OLA that should be set into AM ($w = switchesOn$ in line 13 of Alg. 1). Additionally, the post-RWA procedure (lines 21–23) is not performed, keeping the thermal fatigue at the lowest possible level for all the OLAs.

V. PERFORMANCE ASSESSMENT

This section presents the performance assessment of the proposed EFAH and FAH strategies introduced in Section IV. In addition, two benchmark heuristics are considered: *(i)* Shortest Path (SP), which assigns to each $r \in R$ the shortest available 1+N link disjoint paths. With SP all OLAs are kept always on, i.e., the objective of SP is to minimize the wavelength resources usage in the network; *(ii)* Energy-Aware (EA) derived from the heuristic presented in [11]. EA assigns the 1+N link disjoint paths that traverse the minimum number of OLAs currently in SM, i.e., the objective of EA is to minimize the network energy consumption. A summary of features of the RWA strategies considered in this section is presented in Table I.

A. Simulation Scenario

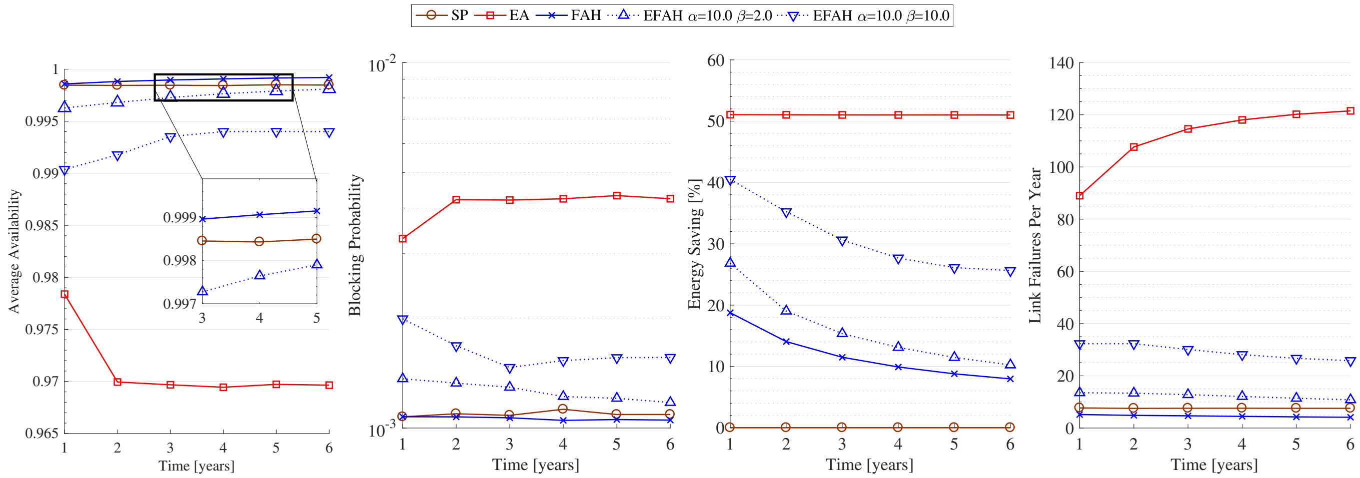
The simulation experiments are carried out by a Java-based event-driven simulator specifically tailored for the energy and fatigue-aware multi-period provisioning on optical backbone networks. The results are averaged over 200 experiments, and each experiment considers 6 years of network operational time. At the beginning of each experiment, all fiber links are considered to be in SM. The only exception is for the simulations with the SP strategy.

We use the physical topology designed for the Géant network and the set of lightpath requests (dynamic logical topologies) provided by [12], where day vs. night traffic variations are considered. The 24 hours in each day are divided into two traffic periods: a low traffic period lasting 6 hours during the night time, and a high traffic period lasting 18 hours during the day time [9]. For each traffic period, a degree of randomness is added to the traffic matrix provided by [12]. The number of lightpath requests between each source-destination node pair in the Géant network is calculated as:

$$r_{s,d}^{rnd} = \max(\lceil r_{s,d}^{LT} + \text{uniform}[-\theta, +\theta] \rceil, 0), \tag{3}$$

where $r_{s,d}^{LT}$ is the number of lightpath requests from the logical topology design results derived from [12], θ is the randomness degree added to the traffic. The value of r_{sd}^{rnd} is then used to create the lightpath set R to be provisioned in each given traffic period. In our work, we assume θ equal to 10.

We assume that all the fiber spans between the OLAs are 80 [km] long. Each OLA in AM consumes 110 [W] [13] and a negligible power in SM, and γ^{on} is 10^5 [h] [8]. After running the RWA procedure in each traffic period, the power state of each fiber link is updated. The same applies to the AF and the MTTF values of all the OLAs in the network. The impact of the thermal fatigue is calculated using the following HW parameters: AF^{sleep} is set to 0.2, and χ is set



(a) Connection availability. (b) Connection blocking probability. (c) Energy Savings. (d) Number of link failures per year.

Fig. 1. Results for the scenario with unprotected connections over 6 years of network operational time.

to 0.5 [9]. The lifetime is exponentially distributed with mean value (MTTF) calculated according to (2). The reparation time is exponentially distributed with a Mean Time To Repair (MTTR) equal to 6 hours. The reparation procedure assumes always the replacement of a failed OLA with a new one, with no thermal fatigue.

When an OLA failure is detected, the fiber link containing the OLA also fails. In this case, if the lightpaths traversing the failed fiber link have no backup path in operational conditions, they are dropped and their residual service time is accounted as downtime. In addition, if a fiber link is failed, it cannot be used for provisioning new connections, potentially impacting the blocking probability performance of the network.

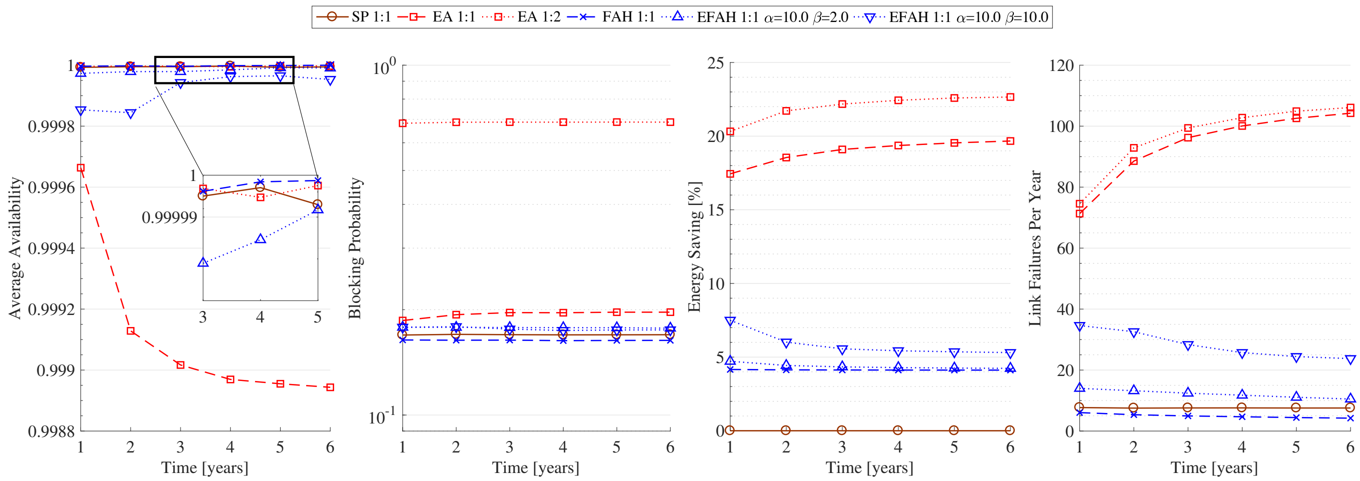
The experiments presented in the paper consider two different scenarios. In the first one, a less strict SLA, i.e., targeting three 9's availability, allows for each connection to be provisioned without backup paths (N=0), potentially saving more energy. In the second scenario, a more strict SLA is considered, and dedicated protection (DPP 1:$N \geq 1$) is required in order to achieve availability level of at least five 9's for each connection.

B. Results

The results are evaluated in terms of: *(i)* average connection availability defined as the ratio between the uptime of established lightpaths and their total service time; *(ii)* average blocking probability defined as the ratio between the number of blocked lightpath requests (i.e., either due to lack of resources or to the presence of failed fiber links) over the total number of lightpath requests; *(iii)* average energy savings defined as the amount of energy saved in relation to the amount of energy consumed by the network when all devices are always in AM; and *(iv)* average link failure rate defined as the number of link failures observed in the network over the total observation time (i.e., 6 years of network operational time).

Fig. 1 shows the results for the scenario with unprotected connections. From Fig. 1a it becomes clear that accounting for the thermal fatigue in the RWA phase helps in keeping the connection availability performance at acceptable levels. EA presents the worst performance, while FAH is the only strategy to achieve three 9's availability, followed closely by SP and EFAH. EA presents also increased blocking probability values (Fig. 1b) in relation to the other strategies. This is because trying to provision connections while limiting the number of OLAs in AM creates bottlenecks in the network. In Fig. 1b, FAH presents the best performance, with SP following very close. On the other hand the performance of EFAH varies depending on the value chosen for the α and β parameters. The good performance of FAH is due to its ability to limit the OLA lifetime degradation, thus lowering the number of failed links in the network. Fig. 1c quantifies the price payed by FAH (in terms of energy saving) while trying to maintain a good connection availability performance. While EA is able to save more than 50% of energy, FAH can save less than 10% at the end of the sixth year. Also in this case the performance of EFAH can be tuned via α and β parameters allowing for the energy savings depending on the required values of connection availability. SP considers OLAs always in AM, resulting in no energy saving. Fig. 1d shows that EA incurs a high number of link failures per year, explaining the reason for the poor connection availability performance in Fig. 1a, and the high blocking probability values in Fig. 1b. FAH presents the best performance, followed by SP and EFAH.

Fig. 2 presents results for the second scenario (i.e., protected connections) where the SLA requires at least five 9's availability. Results in Fig. 2a show that EA with DPP 1:1 is not able to reach the desired SLA level, i.e., only three 9's availability is achieved. EA is able to reach five 9's availability only when using DPP 1:2, i.e., two link disjoint backup paths for each working path. However, FAH only requires DPP 1:1 to achieve similar availability level. Fig. 2b shows that, when using DPP 1:2, EA incurs higher blocking probability, while EA with DPP 1:1 presents a slightly higher blocking probability than the other strategies using DPP 1:1. On the other hand, EA outperforms the other strategies in terms of energy saving (Fig. 2c), where the better energy saving values



(a) Connection availability. (b) Connection blocking probability. (c) Energy Savings. (d) Number of link failures per year.

Fig. 2. Results for the scenario with protected connections (DPP 1:1 and 1:2) over 6 years of network operational time.

obtained by EA with DPP 1:2 are explained by its high blocking probability. In the case of FAH, energy saving is over 4%, which is 15% lower than in the case of EA 1:1 at the end of 6 years. It is possible to further increase the energy saving by 1–3% when using EFAH with a higher β parameter, and still achieve nearly four 9's of availability. Fig. 2d shows similar trends as Fig. 1d, where the EA strategy presents more than 20 times higher number of link failures per year than FAH at the end of 6 years. Moreover, by tuning the EFAH α and β parameters, the operator is able to have a finer control over the power state decisions taken. In summary, adopting a fatigue-aware strategy slightly reduces the blocking probability, and greatly reduces the protection level needed and the link failures per year.

VI. Conclusions and Future Work

This paper proposes a new RWA strategy called Energy and Fatigue Aware Heuristic (EFAH). A variant of this strategy called Fatigue-Aware Heuristic (FAH) is also presented. The benefits of introducing fatigue-awareness in the green RWA strategies are analyzed in scenarios where certain levels of connection availability need to be met. Simulation results show that fatigue-aware strategies result in a higher availability and a lower blocking probability, at the expense of lower energy saving.

As future work, a more advanced OLA failure model accounting for the lifetime degradation due to load can be investigated. A measurement campaign of HW parameters for the OLAs is another item to do in the future. Furthermore, other types of protection schemes can be combined with EFAH.

Acknowledgment

This work has been partially sponsored by COST Action CA15127 ("Resilient communication services protecting end-user applications from disaster-based failures - RECODIS") supported by COST (European Cooperation in Science and Technology). The work of F. Idzikowski was supported by the Polish National Science Center under Grant DEC-2014/12/S/ST7/00415.

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