Lifetime-Aware Provisioning in Green Optical Backbone Networks

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Outline

- Goal
- Optical Line Amplifier (OLA) Lifetime Model
- Network Model
- Least Acceleration Factor (LAF) Model
- Network Scenario
- Results
- Conclusions and Future Work

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Goal

- Green networking as a well established topic [1]
- Focus:
  - Setting unused network devices into Sleep Mode (SM) keeping other devices in Active Mode (AM)
  - Optical backbone network with Optical Line Amplifiers (OLAs) targeted for energy saving
- Tradeoff between
  - Energy saving and
  - Devices lifetime
- Research question:
  - Is it possible to save energy and avoid OLA lifetime decrease?

[1] Vereecken et al., "Power Consumption in Telecommunication Networks: Overview and Reduction Strategies," IEEE Com. Mag., 2011.

OLA Lifetime Model [2]

- Metric called Acceleration Factor (AF) based on HardWare (HW) parameters

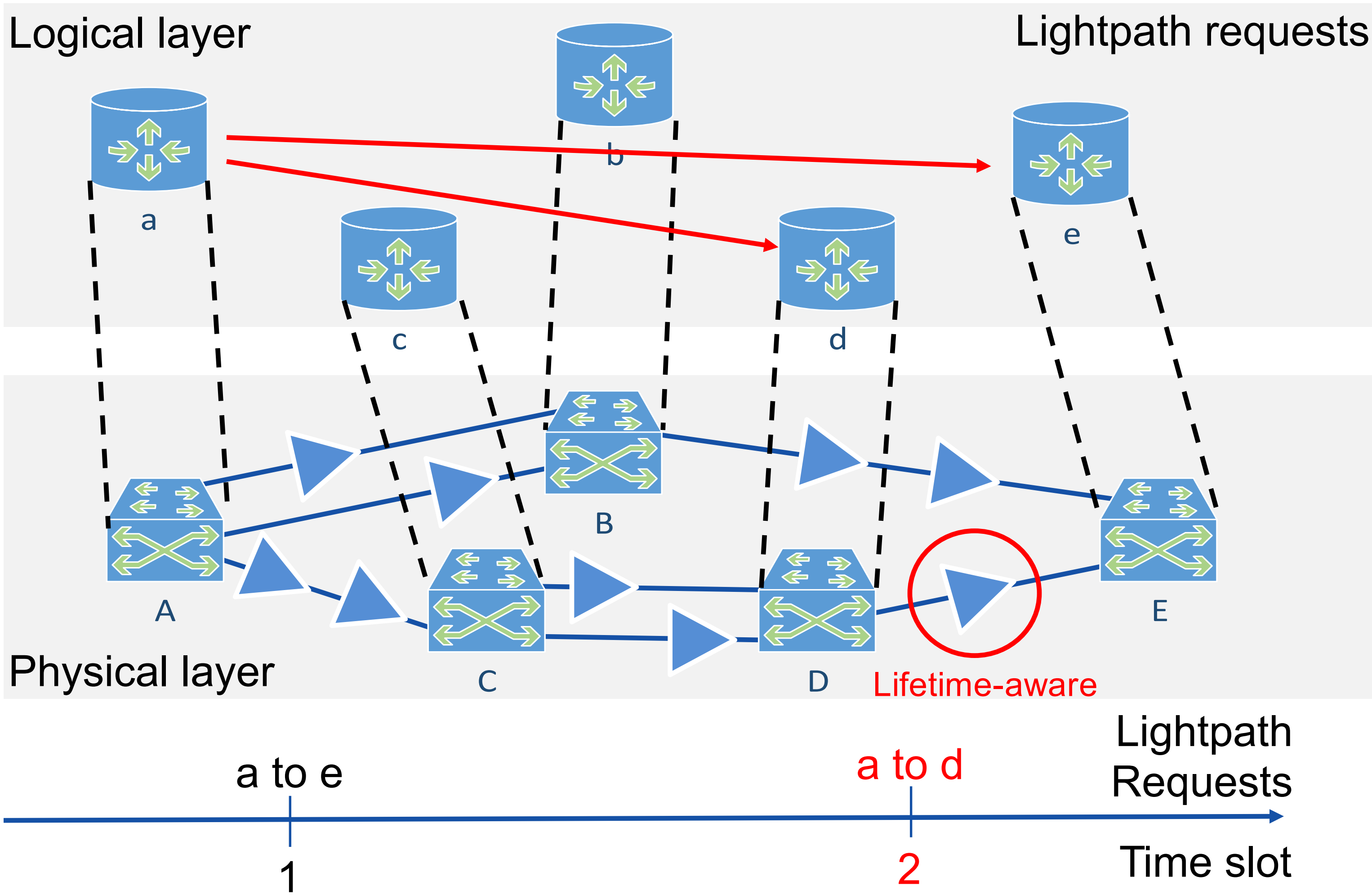
Lifetime increase   Lifetime decrease

$$AF = \frac{\gamma^{on}}{\gamma^{tot}} = 1 - \underbrace{(1 - AF^{sleep})\frac{\theta}{T}}_{\text{Lifetime increase}} + \underbrace{\chi \frac{c}{2}}_{\text{Lifetime decrease}}$$

Symbol	Description
γ^{on}	Mean lifetime when OLA always at full power
γ^{tot}	Mean lifetime when OLA periodically set into SM
AF^{sleep}	AF when OLA is in sleep mode
θ	Time an OLA spent in sleep mode up to the previous time period [h]
T	Total observation time [h]
χ	HW parameter accounting for the AF increase due to power state transitions
$c/2$	Total number of AM – SM cycles

[1] Chiaraviglio et al., "Is green networking beneficial in terms of device lifetime?," IEEE Com. Mag., 2015.

Network Model



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Least Acceleration Factor (LAF) Model (1)

- Given:
  - Network topology $[G(V, E)]$
  - Set of fiber links K_{ij} on physical link $(i, j) \in E$
  - Set of OLAs OLA_{ijk} installed at fiber link (i, j, k)
  - Previous power state of each fiber link (X_{ijk})
  - Hardware and energy information about each OLA (e.g., AF_{ijkq}^{sleep} and χ_{ijkq})
  - Traffic matrix (lightpath requests) and duration for the next traffic period (t^{sd} $\forall(s, d) \in V \times V$ and δ_t)

- Calculate:
  - Routing of each lightpath (f_{ijk}^{sd})
  - Power state of each fiber link (x_{ijk})

Least Acceleration Factor (LAF) Model (2)

- LAF modeled with Mixed Integer Linear Programming (MILP)
- Objective Function

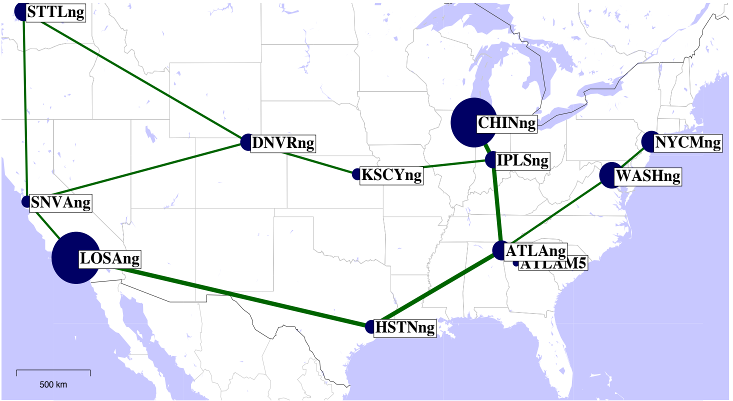
$$min \quad AF_{avg} = \frac{\sum_{i=1}^{|V|}\sum_{j=1}^{|V|}\sum_{k=1}^{|K_{ij}|}\sum_{q=1}^{|OLA_{ijk}|} AF_{ijkq}}{\sum_{i=1}^{|V|}\sum_{j=1}^{|V|}\sum_{k=1}^{|K_{ij}|} |OLA_{ijk}|}$$

- Subject to
  - Flow conservation constraints
  - Maximum number of wavelengths on each fiber
  - Number of transitions of the OLAs on each fiber link (i, j, k)
  - Total number of power state transitions
  - Total time spent in SM up to current time period
  - AF value for each OLA up to current time period

Network Scenario

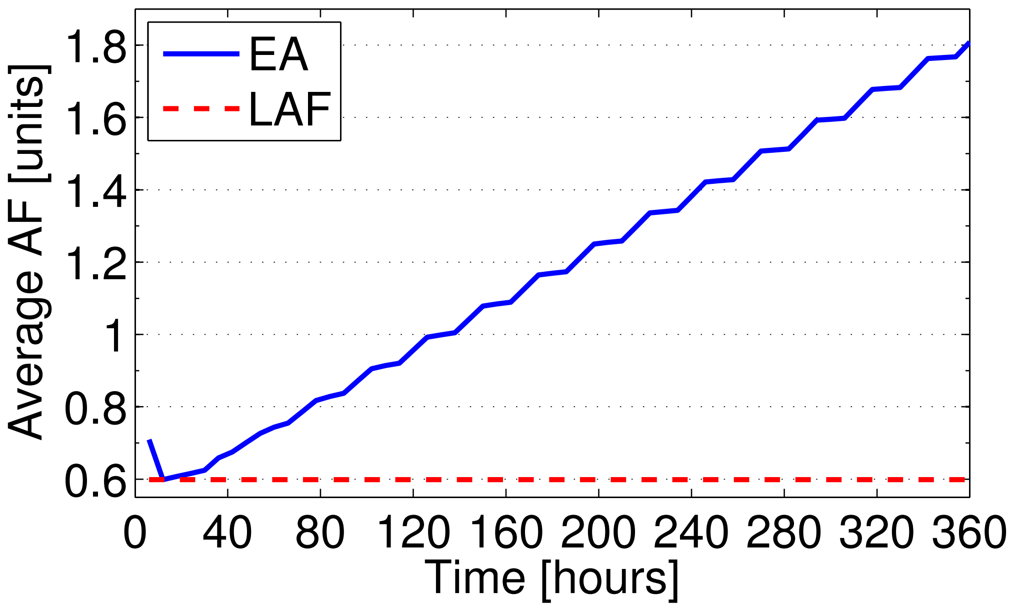
- Abilene-based topology (designed for the IP traffic measured [5])
- Traffic demands (number of lightpath requests)
  - Low-traffic period (12:00 am – 05:45 am)
  - High-traffic period (06:00 am – 11:45 pm)

  based on logical topologies [6],
  repeating over 15 days.



- Wavelengths per fiber: 80
- Amplification span: 80 km
- Power of an OLA: 18 W [2]
- Hardware parameters (equal for all OLAs)
  - $AF_{ijkq}^{sleep} = 0.2$
  - $\chi_{ijkq} = 0.5$
- Purely Energy-Aware (EA) strategy [4] used as a reference

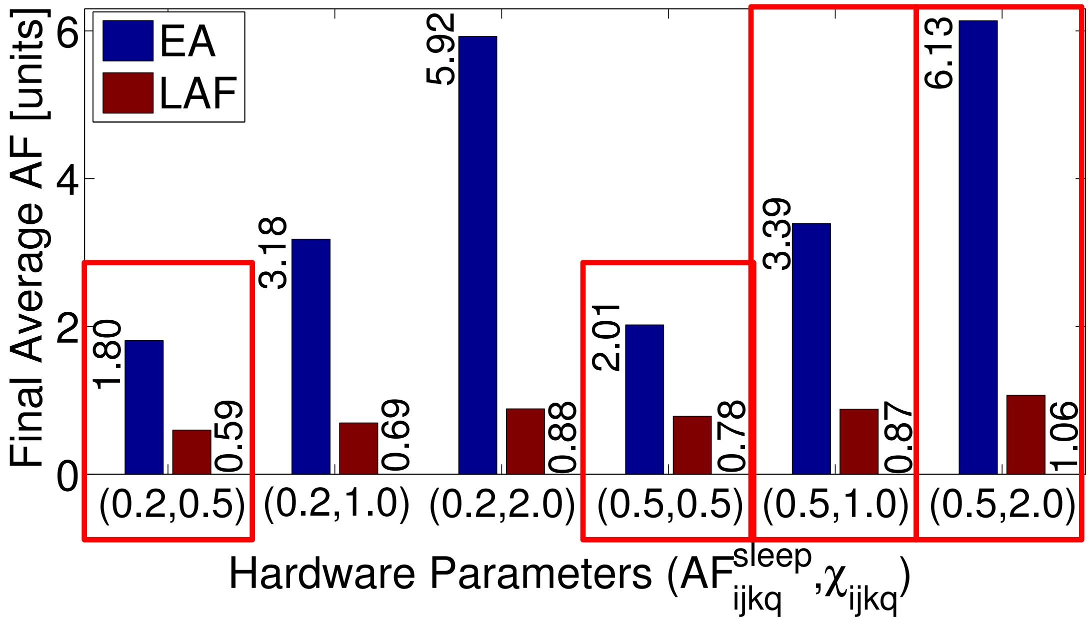
Results – average AF and Energy consumption



- Lifetime increase of 40% after 15 days with LAF (average AF equal to 0.6)
- Lifetime decrease of 80% with EA
- Energy Consumption (and saving) identical for EA and LAF

	EA	LAF ($AF_{ijkq}^{sleep} = 0.2$ *and* $\chi_{ijkq} = 0.5$)
Energy Consumption [kWh]	2967.84	2967.84
Energy Savings [%]	62	62

Results – variation of HW parameters



- When AF_{ijkq}^{sleep} is increased, the gain of putting OLAs into SM is reduced (final average AF increases, because the gain of putting OLA into SM is lower in terms of AF)
- When χ_{ijkq} is increased, the impact of power state transitions on AF is higher, and hence the final average AF increases

Conclusions

- Framework to optimize the OLA lifetime in green optical networks
- LAF able to
  - efficiently avoid the OLA lifetime decrease, and
  - save energy by putting selected OLAs into SM during low-traffic periods
- Future work
  - Maximizing electricity savings while minimizing the reparation costs driven by lifetime variation
  - Measurement analysis of the HW parameters impacting the lifetime in an operator network

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Thank you

- **Questions?**

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