Optimally-driven Online Reservations in Elastic Optical Networks

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Introduction

Advances in optical communications and network programmability enable the creation and offering of network capacity services:

- Elastic optical networks lead to the efficient and dynamic use of the available spectrum.
- Software Defined Networking (SDN) provides network dynamicity and central point of control.

For the realization of such capacity services, network operators also require efficient algorithmic approaches in terms of execution time and performance.

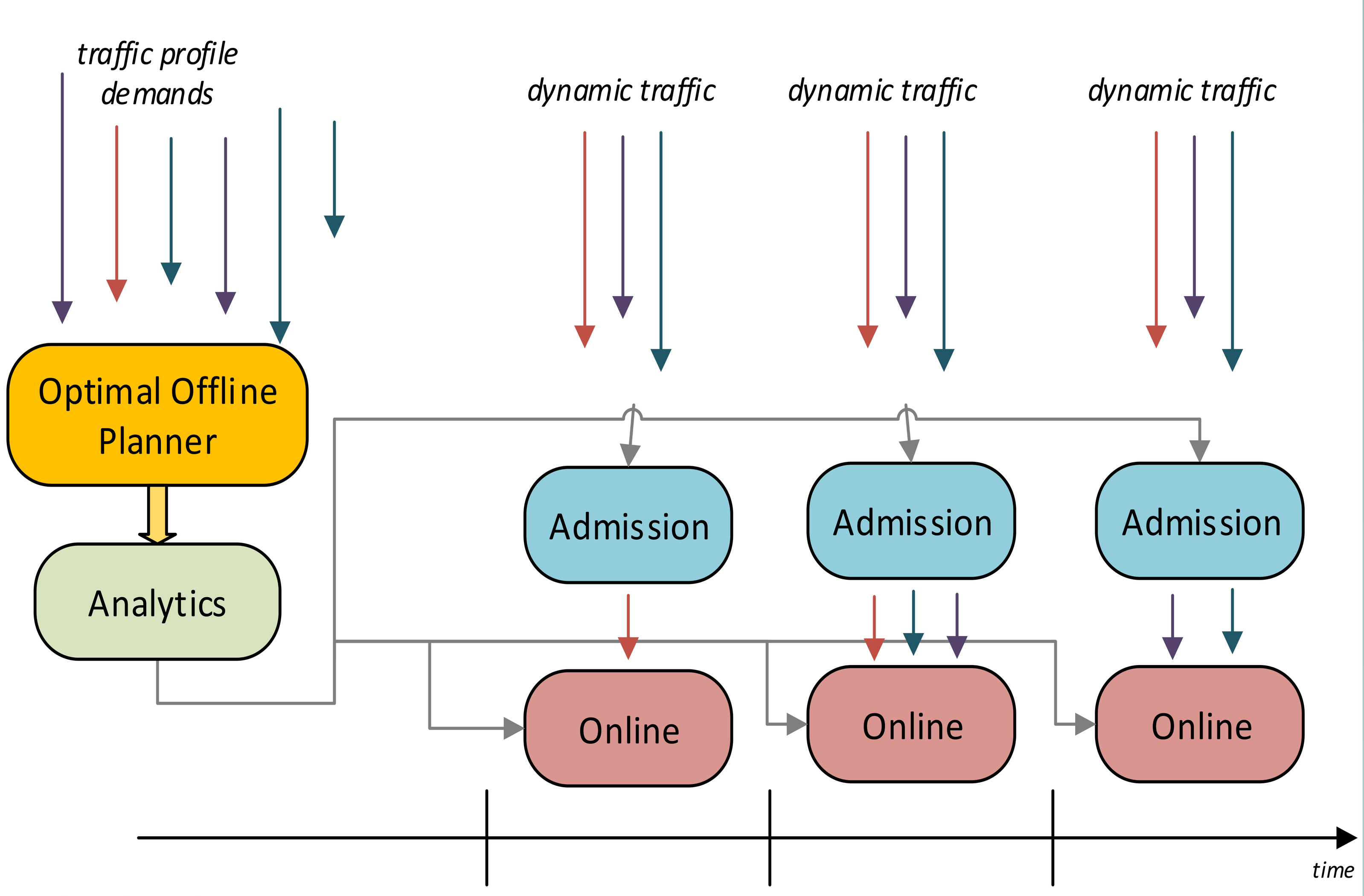
The related works for immediate or in advance reservation of network capacity:

- Consider both generic and elastic optical networks.
- Usually use an Integer Linear Programming (ILP) formulation, which is computationally intensive for large scale networks, proposing a heuristic with subsequent performance degradation.

Optimal-Driven Approach

We present an approach for the routing and spectrum allocation in elastic optical networks *that makes use of an optimal offline mechanism for parameterizing the way the online algorithm will operate*.

The operation of the proposed approach in time, along with the required modules and their interactions is illustrated in the following figure.



The basic components are:

- An *Optimal Offline Planner* (or *Planner*) that receives as input historical traffic data and makes an offline network resource allocation for these demands.
- The *Analytics* module that analyses the decisions taken by the Planner, so as to extract important (e.g., link utilization, total capacity served) parameters that will drive the online modules.
- The *Admission* module that blocks connection requests that may affect negatively the current network state, as defined/decided by the Planner.
- The *Online* module that serves the demands that are "accepted for establishment", reserving the respective network resources.

Details of operation:

- The Planner is executed at long periodic intervals (e.g., once a day).
- In case it is identified that the network traffic pattern has changed, then the Planner could re-run.
- The Online module performs "solution validation" by rejecting a valid solution, if this affects negatively critical network performance parameters as defined by the Analytics module.
- The Online module has to maintain a balance between the achieved performance and the execution time.

ILP model & Heuristic

For the Optimal Offline Planner, we have developed an Integer Linear Programming (ILP) formulation. It uses:

- The Offline Routing and Spectrum Allocation constraints.
- One constraint to ensure the service of the established demands.
- One constraint to block or serve the new demands.
- The objective function minimizes with fairness the number of blocked connections.

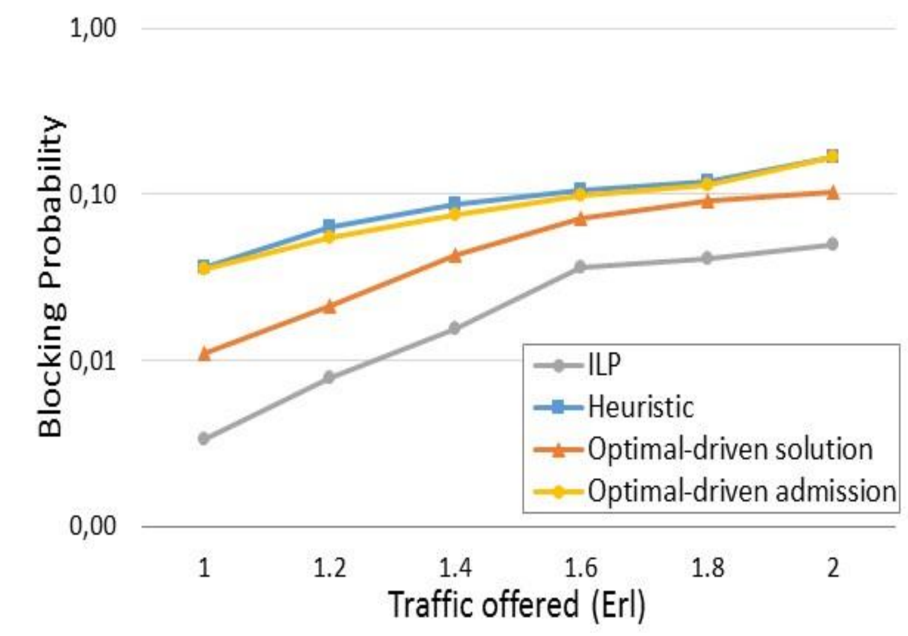
The Online heuristic:

- Selects *k*-shortest paths.
- Breaks the demand to connections based on the capabilities of the transponders.
- Determines if and where regenerators will be placed.
- Tries to establish the connections, selecting the spectrum void that minimizes the objective function.
- Compares each solution against the network links' utilization extracted by the Analytics module.
- If it does not find a valid solution, searches for a new one or performs spectrum defragmentation (push pull and rerouting).

Performance Evaluation

We compare the i) ILP, ii) the Heuristic: Online without admission control and solution validation, iii) the Optimal-drive solution: Online with admission control and solution validation and iv) the Optimal-driven admission: Online with admission control.

- We used a 6-node network topology consisting of 18 links.
- Spectrum slots occupy 12.5 GHz, with the network links supporting 320 spectrum slots.
- Elastic transponders transmit up to 400 Gbps, modulating up to DP-32QAM.
- Demands are generated uniformly at each src-dst pair according to a Poisson process.
- The requests' demand rate derive from a uniform discrete set: [100, 200, 300, 400]

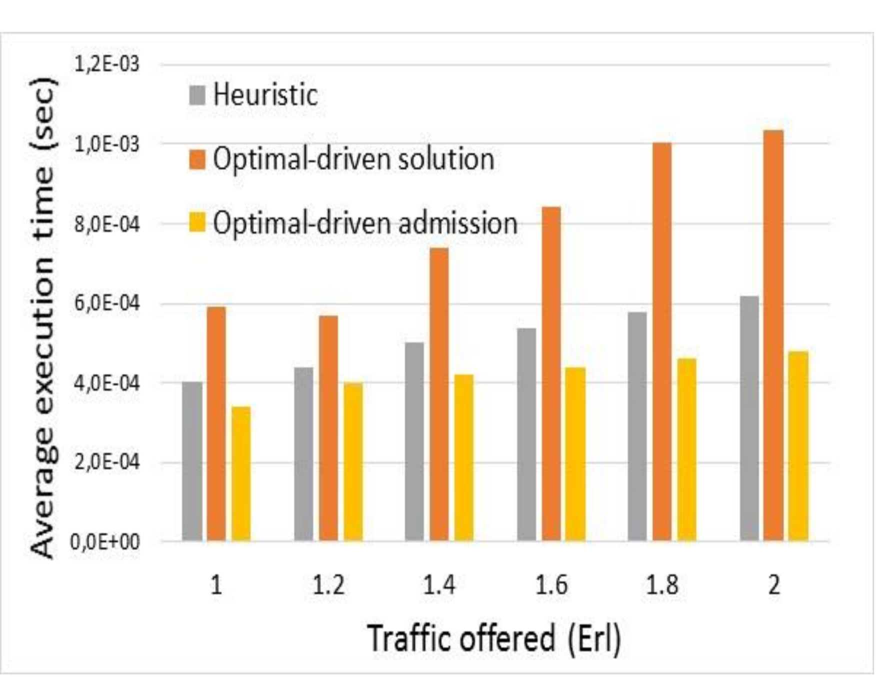


Regarding the achieved blocking probability:

- The optimal-driven admission heuristic's performance is close to the heuristic's.
- The optimal-driven solution heuristic performs better and it is close to the optimal one.

Regarding the average execution time:

- The optimal-driven heuristic with the admission module enabled, blocks demands before any processing, reducing the execution time.
- The optimal-driven solution heuristic, increases the execution time, introducing a trade-off with the achieved performance when searching for better solutions.



Conclusions

We present an approach that uses an optimal-ILP's algorithm output as input to a heuristic, so as to improve the performance and execution time of the respective online process.

In that case it (i) blocks connections that if served could negatively affect the network performance and (ii) evaluates the quality of the proposed heuristic solutions.

This approach can be used for both immediate and advance reservation of network resources.

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