Lightpath establishment in distributed transparent dynamic optical networks using network kriging

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Abstract *The network kriging framework is exploited to estimate lightpath QoT and decrease the number of lightpath establishment attempts before success. Simulations show how this can be exploited with a lightpath provisioning scheme.*

Introduction

Transparent dynamic optical networks are affected by physical impairments, which can bring lightpaths quality of transmission (QoT) below an unacceptable threshold. Thus, lightpath set up has to consider QoT constraints dynamically, in addition to network resources information (wavelength availability). Then, dynamic transparent networks require the knowledge of QoT parameters through numerical modeling or monitoring, and the associated control plane support[1]. This paper investigates a monitoring-based approach.

It is possible to measure the physical characteristics of the links at installation time, but this method is not applicable to dynamic optical networks where the physical layer parameters vary with time. End-to-end monitoring may be used to verify the actual feasibility of a "candidate" lightpath by injecting probe traffic on the lightpath that has been set up before transmitting real data[2]. Then, if the measured QoT meets the transmission requirements, the lightpath is activated. Otherwise, the lightpath is rejected and another setup trial is required, delaying data transmission and wasting temporarily resources that would otherwise have been available for data transmission. This could be avoided if the knowledge of the lightpath QoT was known a priori: in this paper, we use an end-to-end estimation framework called "network kriging[3]" to perform QoT estimation by exploiting the knowledge of the network physical layer gained through past probing. We propose an innovative distributed lightpath establishment mechanism that includes network kriging, which reduces the number of successive attempts to successfully establish lightpaths. Simulations show that, for a sample transparent optical network and for medium load values, utilization of network kriging decreases the number of required number of establishment attempts from 3 to 2 to achieve a blocking rate of 10^{-3}.

Lightpath provisioning with network kriging

We consider the following framework: a transparent optical network is equipped with a *distributed*, impairment-aware GMPLS control plane than can disseminate QoT parameters to network nodes (e.g., through signaling protocol extensions[4]). At some point in the operation of the network, some lightpath QoT parameters have been monitored, and hence, QoT information for a number of lightpaths (still established, or

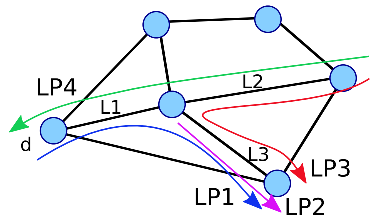

Fig. 1: Principle of network kriging.

already torn down) is available at the network nodes. Assuming that a new lightpath request arrives, for which no QoT parameter information exists yet, network kriging can estimate link-additive parameters by combining the following information: a) QoT parameters from some other lightpaths already known from past probing; and b) the network topology. Kriging exploits the correlation in terms of physical layer impairments (and hence QoT) between the lightpaths that share the same links; indeed lightpaths that use the same link(s) sustain similar physical degradations. For instance, in Fig. 1, if node d has probing information for lightpaths LP1, LP2, and LP3 then d can determine the contribution in terms of physical impairments of links L1, L2, and L3 and hence compute the physical impairments sustained by LP4 and hence its QoT.

We propose the *lightpath provisioning with network kriging scheme (NKS)*, where we estimate in turn the four following link-additive metrics: OSNR (additive through its inverse, $1/OSNR$), PMD (additive through PMD^2 in ps^2), CD (in ps/nm), and SPM (additive through the nonlinear phase shift φ_{NL}); each of these can be measured using appropriate monitors; in particular, φ_{NL} can be estimated with power monitors[5]. BER can be computed from these parameters[4]. In the considered network, each node maintains a *measurement database (MD)* containing the performed end-to-end measurements of OSNR, PMD, CD and ϕ_{NL} QoT parameters. The MD may be filled through signaling protocol extensions, hence the MD is distributed and each node has its own view of the network's QoT parameters. Upon lightpath request from source s to destination d, s randomly selects a path p within a set $P_{s,d}$ of pre-computed paths. If the MD holds the QoT parameters for p from previous probing, BER is derived. Otherwise, by applying network kriging to the parameters ($1/OSNR, PMD^2, CD$ and ϕ_{NL}) contained in the MD at s, the parameters related to p are estimated and the

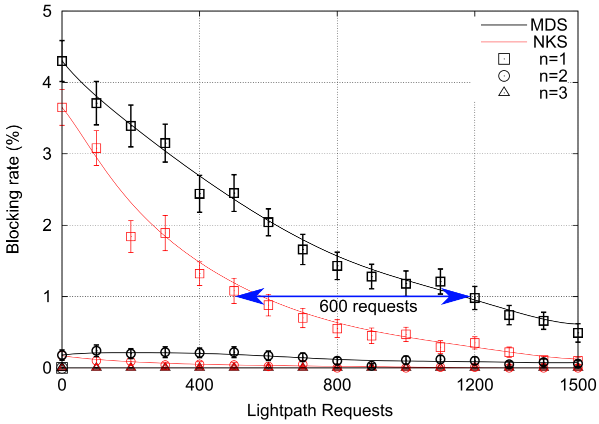

Fig. 2: Evolution of the blocking rate after $n \in \{1, 2, 3\}$ setup attempts.

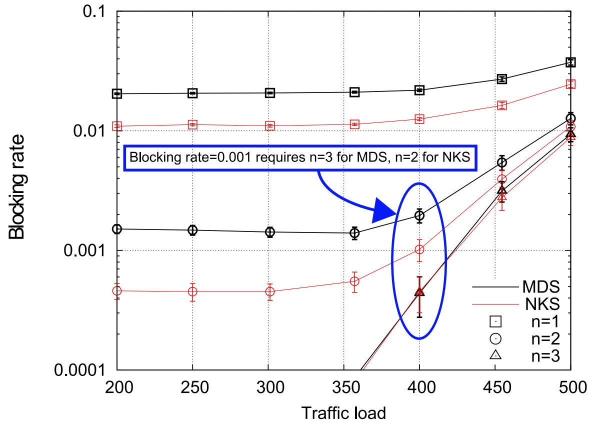

Fig. 3: Blocking rate after $n \in \{1, 2, 3\}$ setup attempts for a varying load.

BER is derived. In both cases, if the derived BER is acceptable, s starts signaling along p, otherwise another path is computed and tentatively established. During the signaling session, link resources (i.e., a wavelength along p) are reserved and optical crossconnects configured. To verify the lightpath QoT is acceptable, probing is performed and QoT measurements are gathered at d, which sends the measured values back towards s. Each node along p fills its proper MD entry with the updated end-to-end measurements. Note that the QoT measurements are not flooded by OSPF-TE in the network, to keep the scheme scalable. If the measured parameters indicate an unacceptable QoT for p, s frees resources along p and performs another setup attempt. Otherwise, the lightpath is activated and data transmission begins.

Simulation Results

The performance of the proposed scheme is evaluated for a Pan-European topology with 17 nodes, 32 bidirectional links, and 40 wavelengths per direction. To benchmark NKS, we disable the network kriging estimation step and call *measurement database based scheme* (MDS) this new establishment technique, which uses the information contained in MD without exploiting Network Kriging. Lightpath requests are uniformly distributed among all node pairs, following a Poisson process with mean inter-arrival time $1/\lambda$, and holding times are exponentially distributed with a mean $1/\mu$. The offered network load in Erlang is λ/μ. $P_{s,d}$ is the set of all paths connecting s and d that are within one hop from the shortest path and wavelength assignment is first fit. NKS and MDS are compared in terms of blocking rate after a variable number of setup attempts n: blocking occurs if no wavelength can be found on any path of $P(s, d)$ or if the monitored QoT parameters (using probing, after establishment) indicate unacceptable lightpath QoT.

Fig. 2 shows the blocking rate of NKS and MDS for a fixed load (200 Erlang, low enough such that blocking is due to QoT only) after $n \in \{1, 2, 3\}$ setup attempts along alternate routes measured after a varying number of lightpath requests. The plotted results are obtained by averaging 100 randomly generated sequences of lightpath requests and blocking rate is computed for a sliding window containing the last 100 requests. In both NKS and MDS, as the MD is populated, more information is gathered and the blocking rate decreases with lightpaths demands. Convergence is faster for NKS, which is able to better exploit than MDS the information in the MD. For instance, if a single establishment attempt is considered, MDS achieves a 1%-blocking rate after the arrival of 1200 lightpaths, twice as many as with NKS.

In Fig. 3, we show the lightpath blocking rate for a varying traffic load after $n \in \{1, 2, 3\}$ setup attempts. Each point is obtained by averaging 100 independent trials of 1500 lightpath requests each. In the range [200,300] Erlang, blocking probability is constant for $n \in \{1, 2\}$ because within 1500 requests, the MD is not completely filled in case of MDS, or, in the case of NKS, network kriging does not have enough information to provide confident estimations for every (s, d) pairs. For low and medium loads, if a target blocking rate of 10^{-3} is set, 3 setup attempts for each lightpath arrival are required by MDS while NKS needs only 2.

In conclusion, we harnessed the “network kriging” estimation framework to estimate lightpaths' QoT before establishment based on prior measurements and using the correlation between lightpaths' QoT induced by the network topology. Simulation results show that with network kriging, fewer attempts are required to successfully establish lightpaths.

Acknowledgement

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