Dynamic resource allocation in different ultrawideband optical network topologies

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***Abstract*—We study the blocking performance of dynamic resource allocation strategies in ultrawideband elastic optical networks under different topologies. State-of-the-art heuristics are evaluated on four different network topologies. Results show consistent better performance of heuristics that prioritise allocation based on the connections bitrate.**

I. Introduction

Using an ultrawideband transmission regime in optical fiber transmission systems can provide a much-required increase in capacity. State-of-the-art system demonstrations have already shown promising results using C, L and S bands to achieve 244.3 Tb/s over 54 km in a point-to-point link [1]. The development of subsystems capable of transmitting, receiving and amplifying optical signals is required for enabling transmission in such systems. Additionally, managing optical fiber linear and nonlinear impairments are vital to guarantee sufficient signal quality after transmission. Optical signals propagating in ultrawideband systems experience significant power transfer between co-propagating WDM channels due to stimulated Raman scattering. Even more, together with the noise figure variation of optical amplifiers in different bands can lead to significant differences in signal quality across the available transmission bands.

In ultrawideband optical networks, also referred to as multi-band networks, an efficient resource allocation that also considers the above physical-layer related aspects can significantly impact the overall network performance. For multi-band networks, such resource allocation means finding a route, a transmission band, a modulation format and spectral position in such a way that blocking of requests is minimized and the quality of transmission is kept to acceptable levels.

Recent studies have introduced strategies to perform the above-described task. These include heuristic approaches [2], [3], and the use of deep reinforcement learning [4]. To date, the best performing approaches are the heuristics proposed in [3]. However, they were evaluated using a single topology. The network topology can have a significant impact on the overall performance and offered throughput, as shown in [5]. In this paper, we extend the study of the network topology's impact on an ultrawideband regime by evaluating the performance of recently proposed heuristics for different topologies.

II. Models and heuristics

We consider a network made of N nodes and L links. Each link corresponds to a single mode optical fiber with multiple transmission bands available (E,S,C and L-band).

For each transmission band, a conservative maximum transmission reach was computed for DP-BPSK, DP-QPSK, DP-8QAM and DP-16QAM following the methodology from [6]. A constant input power across the optical spectrum was assumed and the ISRS GN-model [7] was used to include nonlinear distortions generated in the ultrawideband regime. Table I summarizes the main band-dependent parameters used based on state-of-the-art low loss fibers.

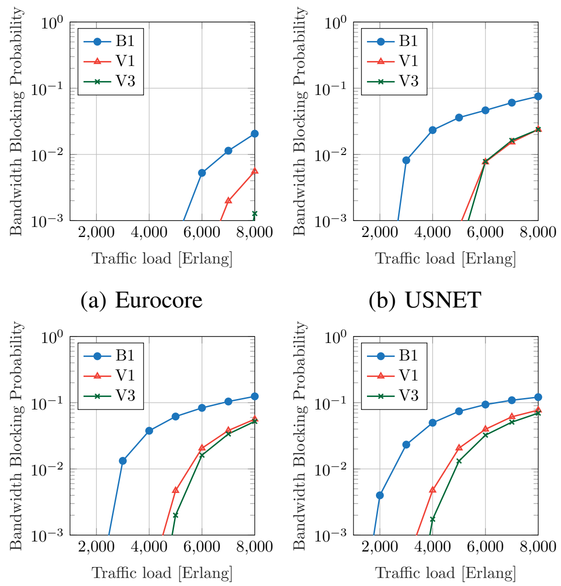
	E	S	C	L
Attenuation [dB/km]	0.2	0.18	0.16	0.17
Frequency slot units (12.5 GHz)	1136	760	344	480
Reach DP-BPSK [km]	3100	10200	13000	14400
Reach DP-QPSK [km]	1500	5100	6500	7200
Reach DP-8QAM [km]	900	2900	3500	3900
Reach DP-16QAM [km]	400	1400	1700	1900

TABLE I

Three resource allocation algorithms were studied. The first, used as a baseline, was proposed in [2]. The other two correspond to the best performing heuristics proposed in [3], named V1 and V3. They rely on an off-line stage that divides the connection requests into sets and subsequently associates each set to a given band order. The band order determines how the resource allocation will be attempted. The main difference between V1 and V3 and the baseline lies in the number and types of partition sets and the different orders used to attempt the bands. Both variants used in this work use 2 partitions for the connection requests, based on the shortest path length (V1) and on the bitrate (V3).

III. Simulation and results

We used a C++ simulator [8] to evaluate the bandwidth blocking probability (BBP), defined as the ratio between the blocked traffic (in Gbps) and the total traffic offered to the network. We considered 4 different network topologies, namely: Eurocore, USnet, ARPANet and NSFNet. Their main parameters are detailed in Table II A connection request is



(a) Eurocore (b) USNET

(c) ARPANet (d) NSFNet

Fig. 1: Bandwidht blocking probability as a function of traffic load for Eurocore, USNet, ARPANet, NSFNet networks.

defined by the triplet (src, dst, b), where src and dst are the source and destination nodes, respectively and b the bitrate. Connection request arrivals are modeled as a Poisson process of parameter μ and average arrival rate λ. The holding time of each connection is exponentially distributed, with mean value $1/\mu$. The network traffic load is given by λ/μ. The source and destination nodes of a connection request are randomly selected, following an uniform distribution, whilst the bitrate is uniformly selected from the set {10, 40, 100, 400, 1000} Gbps.

	Eurocore	USNet	ARPANet	NSFNet
N	11	46	20	14
L	50	152	62	42
Shortest path (SP) (km)	163	178	199	250
Average SP (km)	408	380	527	547
Longest SP (km)	1725	4688	3985	4550
Avg. longest SP (km)	1010	2018	2025	2462

TABLE II

Fig.1 shows the BBP of the studied algorithms for the (a) Eurocore, (b) USNet, (c) ARPAnet and (d) NSFNET topologies. In general, for all networks and algorithms, it is observed that as the size of the network increases the BBP also increases. The increase of the network size is observed in the average length of the candidate routes seen in table II. The higher blocking is due to the fact that to transmit longer distances modulation formats with low spectral efficiency are required regardless of the selected transmission band. Additionally, for studied network typologies the baseline algorithm (B1) exhibits the highest BBP for all traffic loads. In general V3 offers lower blocking compared to V1, however, the improvement is related to the network topolgy. In particular, for the Eurocore topology significant reduction in BBP is observed for V3 compared to V1. Moreover, for ARPANet and NSFNet topolgies smaller blocking benefits are observed when using V3 compared to V1. Finally, for USNET both algorithms exhibit the same performance. In addition to the network size, the number of nodes and links is the main difference observed between USNET and the other studied topologies. This indicates that in fact the topolgy will affect the efficiency of the used resource allocation strategy in a multiband optical network.

IV. Conclusion

The performance of different resource allocation algorithms for ultrawideband optical networks was studied using different network topologies . The results show that grouping connection based on their parameters, such as route length and bitrate, and associating them to a given band order yields reduced blocking performance over all studied network topologies. In general, the algorithm that prioritizes allocation based on the connection bitrate (V3) was observed to present the lowest blocking performance. Despite this, the network topology was shown to have an impact on the performance of the studied algorithms, in particular reducing the improvement observed in algorithm V3 compared to V1. Future work on this topic should focus on a exhaustive analysis using a large number of network topologies in order to identify key parameters that can improve the resource allocation process.

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