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**Study of ILP RMLSA performance based on k-shortest paths
(work in progress)**Ivan Ríos¹

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Elastic Optical Networks (EON) is a network with capabilities of traffic with different speed improving the spectrum use in comparison to its predecessor Wavelength Division Multiplexin (WDM) networks. EON divides the spectrum in small pieces called frequency slots. EON imposes optical layer constraints to the traffic connections: contiguity, continuity, and non-overlapping spectrum. Under these constraints, the Routing and Spectrum Allocation (RSA) is the main challenge in EON. Another issue is the modulation format selection. Each modulation format have associated a transmission speed subject to distance between source and destination nodes. If distance does not exceed 625 Km, 1250 Km, 2500 Km, and 5000 Km then 16QAM, 8QAM, QPSK, and BPSK modulation format is assigned, respectively. In this context, RSA problem is extended to the Routing, Modulation Level and Spectrum Allocation (RMLSA), that is the focus in this work.

RMLSA Problem Statement. Given a graph $G = (V, A)$, where V is the set of EON nodes and A is the set of links (optical fiber), and a demand matrix $T = [t_{sd}]$ with t_{sd} that is the spectrum demand to connect source s and destination d nodes. The objective is to calculate the solution RMLSA that minimizes the maximum used spectrum subject to optical layer constraint.

Related works. The literature reports several Integer Linear Programming (ILP) models [1,2]. These can be classified according to routing approach and problem scheme. In terms of routing approach, there are (i) path-oriented, and (ii) link-oriented routing. In path-oriented routing the optimizers consider a set of k candidate paths for each pair source-destination nodes, while in the link-oriented routing a path is build considering all set A . On the other hand, problem scheme can be divide in two classes: (a) complete problem (RMLSA), and iterative problem (RML+SA) approaches. Unlike the complete problem approach, an iterative problem approach is formed by two phases: in the first phase the Routing and Modulation Level problem is solved, and later in the second phase, the Spectrum Allocation problem.

Contribution. A key factor is the quality of the ILP solution based on path-oriented routing and iterative problem approach. The value of k will be determinant to reach good

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Table 1: Maximum spectrum and run time vs traffic load.

Models	k	Run Time (sec)								Spectrum							
		100	150	200	250	300	350	400	Average	100	150	200	250	300	350	400	Average
ILP 1	1	0.763	0.663	0.718	0.672	0.639	0.616	0.626	0.671	288	429	571	713	854	996	1138	712
ILP 1	2	13.083	30.195	42.865	24.787	66.510	72.324	35.892	40.808	186	277	369	461	552	644	736	460
ILP 2	1	0.710	1.055	0.795	0.648	0.647	0.778	0.689	0.760	288	429	571	713	854	996	1138	712
ILP 2	2	5.013	0.493	0.536	0.557	0.519	0.763	0.505	1.198	186	277	369	461	552	644	736	460
ILP 3	-	3993	14404	14412	14414	14409	14412	14423	12923	186	277	369	461	552	644	736	460
ILP 4	-	12.410	16.367	5.711	5.960	5.843	5.871	6.185	8.335	186	277	369	462	601	702	736	476

solutions with cheap computational cost in comparison to ILP based on link-oriented routing and complete problem approach. This is the central issue approached in this work. For that, in this work a ILP model based on link-oriented routing and iterative problem approach was proposed. In this context, 4 ILP models was studied.

Experimental Results. The used network topology is the bidirectional 6N9L, Figure 1. Experimental results are shown in Table 1. The experimental was addressed with different uniform traffic load scenarios: 100, 150, 200, 300, 350, and 400 frequency slots; and k=1, 2 considering k-shortest path. The 4 ILP models was implemented in IBM ILOG CPLEX Optimization Studio Version 12.6 and the automation of experimental in JAVA on the computer with Intel Xeon Processor E5530 Quad Core CPU (2.40 GHz) and 15 GB RAM. In Table 1, ILP 1 and 2 are based on path-oriented routing while ILP 3 and 4 are based on link-oriented routing. At the same time, ILP 1 and 3 are based on complete problem scheme, and finally ILP 2 and 4 are based on iterative problem scheme.

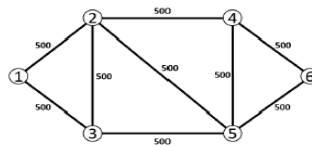


Figure 1: 6N9L Network. The number on links indicates distance in Km.

Conclusion. Clearly, when traffic load increases maximum spectrum increases too. Performance of solutions obtained by path-oriented routing improve with k=2 in comparison to k=1, but run time gets worsen. Note that, ILP 3 is the model that can calculate the best solution. In this small topology ILP 4 obtains solutions similar to ILP 3. As future work, we will perform models in other larger network topology to investigate the effect of the number k.

References

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