Should Like Demands be Grouped in Mixed Line Rate Networks?

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Abstract: Grouping same line-rate channels makes no difference in growth-only networks, but significantly reduces fragmentation in dynamic networks and improves overall network throughput, particularly in congested operation scenarios.
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1. Introduction

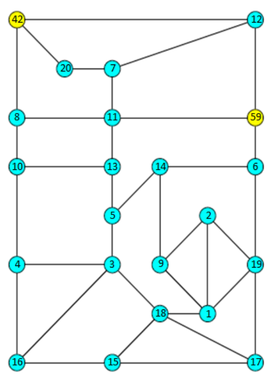
The IP traffic growth and the heterogeneity of the generated traffic form a challenging environment for the future optical networks. 100 Gbit/s systems are commercially available but there is an increased need for 400Gbit/s and 1Tbit/s systems to be standardized and introduced to the industry. Existing DWDM optical networks operate with a fixed grid width of 50 GHz per channel, which is inadequate for supporting these future data rates.

Consequently, more efficient and adaptive networks are under consideration. Mixed Line Rate (MLR) systems using flexible spectrum are a much discussed approach [1], but create RSA (routing and spectrum assignment) issues due to the different spectral bandwidths associated with each line rate + modulation format combination. How should the individual demands be assigned: with the same line rates grouped together, or ungrouped? An answer to this question requires an assessment of both physical layer [2] and network demand performance and this paper focuses on the latter of these.

Part of the issue depends on whether operators expect future traffic demands to become more dynamic. In addition, in [3] it was shown that the fragmentation of the spectrum can affect the efficiency of the Flexgrid networks. If traffic grows, even unpredictably, the resulting fragmentation is limited, whereas a more dynamic optical layer induces more fragmentation. This paper shows how grouped RSA can significantly reduce this effect, thereby reducing the need for risky defragmentation operations.

2. Network model, traffic assumptions and simulation methodology

The simulations were carried out using a proprietary network modeling simulator. An existing core optical network topology was used (British Telecom's core optical network, shown in Figure 1a).



1 (a)

Bitrate (Gbit/s)	Modulation Format	Spectral Width (GHz)		
		Fixed Grid	Flexgrid Scenario 1	Flexgrid Scenario 2
40	DP-QPSK	50	50	25
100	DP-QPSK	50	50	37.5
400	DP-16QAM	100	75	75

1 (b)

Figure 1: (a) BT Core Optical Network Topology, (b) Modulation format parameters

The network has 22 nodes. 20 of them have add/drop capabilities while the remaining 2 (nodes 42, 59 in the yellow cycles) cannot add/drop local traffic of their own and are used only for routing. Adjacent nodes are connected with a pair of optical fibres, utilising the full C band capability of 5THz. Many simulations (e.g. ILPs) use a smaller spectrum to give reduced simulation time, but this can be at the expense of realistic results. The network granularity (spectral slot width) is 12.5 GHz. Consequently, each fibre has 5,000 GHz/12.5 GHz= 400 spectral slots available.

The network operates under a mix of demands: 40 Gbit/s, 100 Gbit/s and 400 Gbit/s, with probabilities of 35%, 35% and 30%, respectively. Fig.1b shows the modulation formats used here, and the spectrum used by them. Whilst Flexgrid Sc.2 tracks closely the actual spectrum, the other two scenarios explore potentially simpler demultiplexing options than full flexgrid. During the simulations, traffic demands are generated between random source and destination nodes. The developed RSA algorithm routes the demands based on the utilization of the individual links.

Two traffic scenarios are used to explore the cases of ‘growth only’ and dynamic operation. Traffic scenario 1 (TS1) allows demands to be added randomly, one by one, and then left throughout a simulation. The run is then repeated with different random seeds. In TS2 there are two steps. During the first step, demands are added to the network as with TS1. The purpose of step 1 is to load the network until it reaches a certain static traffic load (STL). In step 2, demands are added and removed from the network dynamically. In the case where a demand is blocked, another one is added to the network and this process is repeated until a demand is finally allocated and the blocking probability determined. As a result, the total traffic remains at the mean traffic level reached in step 1. The dynamic simulation is run for 10,000 added and removed demands, as this number was found to be adequate in order for stable results to be obtained. The output gave a measure of dynamic blocking probability (DBP) for a given STL. Different MLR configurations were compared by measuring the different STLs required to give the same DBP.

3. Static Growth Results

Figure 2 shows the blocking probability of the network under growth only traffic (TS1) for fixed grid and both flexgrid scenarios, with all cases repeated using a grouped and ungrouped RSA.

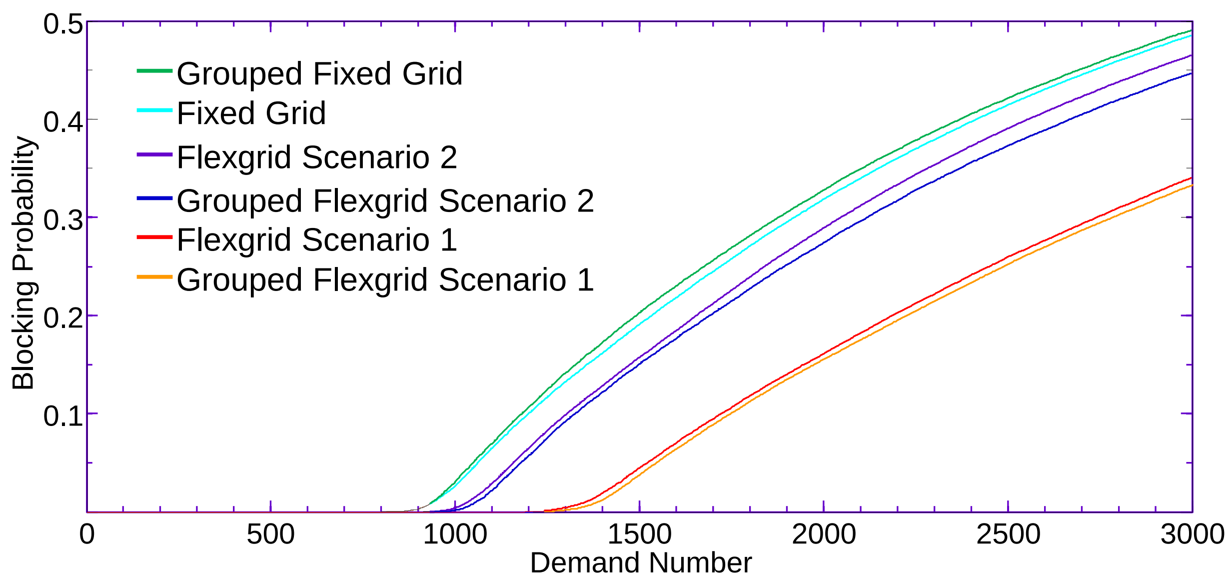


Figure 2: Blocking probability of the network for TS1 traffic loading and various RSA strategies

Results show not only that flexgrid Sc.2 is significantly better than the other MLR schemes, but also that grouping makes only a small difference to performance. Therefore, if growth dominated traffic is anticipated, there is no reason to require an additional RSA restriction (given that physical layer performance is good for both grouped and ungrouped cases).

4. Dynamic traffic results

In this case, as explained above, the network is loaded to a point such that, after many applications of dynamic traffic, the DBP gives a specific value – here chosen as 1.6%. This value is high enough to see regular blocking but without the network becoming inoperable, and therefore is a good value for observing the key effects. The method used to study dynamic performance is the network fragmentation for a given DBP. Link fragmentation was calculated as the ratio of free spectral slots that couldn’t be used divided by the total number of free spectral slots (i.e. the fraction of the link’s free spectrum that can’t be used).

Fig.3 shows the evolution of network fragmentation, as measured this way. Both ungrouped flexgrid Sc.1 and 2 have high fragmentation values, caused by the non-commensurate nature of the spectral widths for the different line rates. Fixed grid uses only 50GHz and 100GHz spectra, which are commensurate numbers and hence the fragmentation is very low (arising when a 100GHz demand can't use a 50GHz slot).

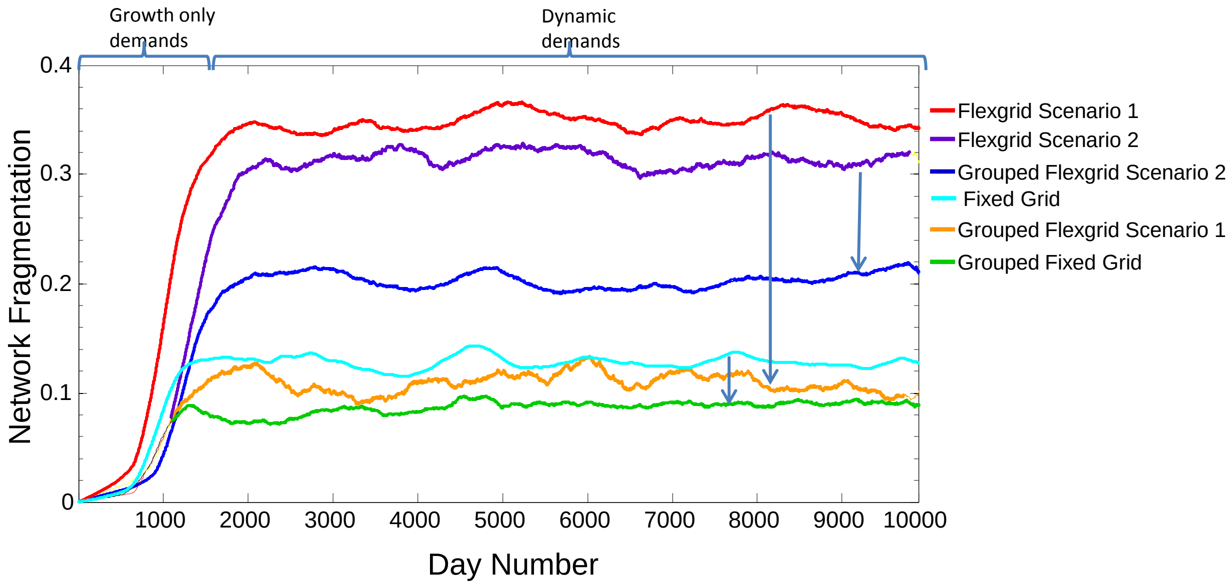


Figure 3: Fragmentation of the network for dynamic TS2 traffic loading and various RSA strategies

Consequently, moving to grouped operation only makes a significant difference for the two flexgrid scenarios: Sc.1 is improved a substantial amount due to the mapping of 2 x 75GHz demands into 3 x 50GHz, and Sc.2 is also improved because 75GHz = 3 x 25GHz or 2 x 37.5GHz. Therefore, two dropped 37.5GHz or 3 dropped 25GHz can be assigned to 75GHz without any fragmentation.

Fig.4 shows the average number of demands supported to give a DBP of 1.6%. It is noticed that although grouping aids significantly with fragmentation, it has a smaller impact on overall network capacity. This is thought to be due to the low value of DBP selected for these simulations.

	Fixed Grid	Grouped Fixed Grid	Flexgrid Sc.1	Grouped Flexgrid Sc.1	Flexgrid Sc.2	Grouped Flexgrid Sc.2
	828	823	900	940	1115	1167

Fig.4: Average number of demands supported to give a DBP of 1.6%.

5. Conclusions and discussion

Grouped RSA is seen not to be necessary in networks dominated by static traffic growth. It is also unnecessary in dynamic operation if the network is operated at low blocking probabilities. However the improvement in fragmentation under grouped RSA suggests that it would be helpful to reduce defrag operations or when network operation is more congested. This mode of operation might be relevant to networks providing best-effort service and this will be explored in further work.

6. References

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