Fix to Flex grid Migration Strategies for Next-gen optical Network

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Agenda

- Factors Effecting Migration to Flex-grid
- Existing Technologies for Flex-grid Migration
- Existing Migration Strategies
- Traffic Profile
- Traffic has changed !
- More Sophisticated Strategies
- Proposed Strategy
- Possible Results

Factors Effecting Migration to Flex-grid

Greenfield deployment of flex-grid is impractical

Factors effecting :

- Network topology
- Traffic profile
- Network load
- Network bottlenecks

Factors Effecting Migration to Flex-grid

The set of parameters concurring to the identification of the optimal migration strategy is wide:

1. Proper node upgrade metric
2. Islanding policy
3. Number of nodes to be updated at each a single step
4. Considering partial upgrades of the switching hardware

All these factors need to be investigated, first in isolation, and then jointly, to devise scalable and practical solutions.

Existing Technologies for Flex-grid Migration

- Brownfield migration at bottleneck nodes/links
- Operators are making their network future ready by deploying flexible switch(BV-ROADM)
- Flexible grid ROADMS are capable of supporting fixed grid channels simultaneously with flexible grid channels, which can allow existing fixed grid waves to co-reside on a flexible grid line system with multi-carrier superchannels

Existing Migration Strategies [1]

Which node should be upgraded first?

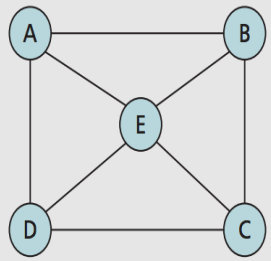
- **Highest Degree First (HDF):** High node connectivity may have a positive impact on the upgrade performance, as a node with a higher degree connects to a larger number of other nodes in the network, thereby facilitating traffic provisioning options.
- **Highest Generated Traffic First (HGTF):** so that more traffic might benefit from the upgrade.
- **Highest Carried Traffic First (HCTF):**Here, transit traffic includes all generated traffic as well as pass through traffic.

Existing Migration Strategies [1]

- **Most high bandwidth traffic first (MHTF):** Nodes generating the largest amount of high bandwidth traffic (e.g., 400 Gb/s or 1 Tb/s) will be upgraded first. The argument for this strategy is that flexible-grid nodes enable super-channels for high-bandwidth requests, thus saving spectrum resources.
- **Most low bandwidth traffic first (MLTF):** The intuition for this strategy lies in the fact that flexible-grid technology is spectrum efficient for low-bandwidth traffic due to its on demand spectrum provisioning instead of rigid provisioning in fixed-grid technology

Example [1]

For HDF, node E will be upgraded first, since it has the largest node degree (i.e., 4); for HGTF, node D will be chosen, since it generates the highest traffic load (i.e., 500 Gb/s in total); for HCTF, node B will be chosen, since it carries the highest traffic (i.e., 640 Gb/s); for MHTF, node D will be chosen, since it generates the largest number of high-bandwidth traffic demands (400 Gb/s); for MLTF, node A will be chosen, since it generates the largest number of low-bandwidth traffic demands (40 Gb/s).



(a)

Source	Destination	Bit rate (Gbps)	Route
A	B	40	A-B
	E	40	A-E
	C	200	A-B-C
D	E	100	D-E
	B	400	D-C-B

(b)

Node	Carried traffic (Gbps)
A	280
B	640
C	600
D	500
E	140

(c)

Fig. 1 : a) 5 node topology, b) traffic matrix, c) carried traffic by each node

Existing Migration Strategies [1]

Should we create "Flexible Island(s) ?"

- **Enlarging a single island**: start by upgrading the first node according to, say, HCTF, and then choose as the second node the one with the highest carried traffic, but only among nodes adjacent to those already upgraded. This policy leads to the formation of an island that will keep growing during the migration until a complete migration is done.
- **Enlarging multiple islands**: Since a traffic pattern in the network may have several centers (e.g., the east and west coasts of the United States may be observed with higher traffic volume than other places), a further improvement would be to have multiple islands growing independently.

How many nodes should be upgraded?

One or many ?

Should nodes be upgraded as a whole or starting from sub-components?

Operator can upgrade WSSs from fixed to flexible grid , even only a subset of them in a ROADM.

Migration Strategies [2]

- Subnetwork upgrade: migrating a set of connected OXCs to flexgrid
- Enlarging the core
- Extending the core towards the metro: core network can be extended toward metro by replacing metro nodes with flex-grid ready OXCs.

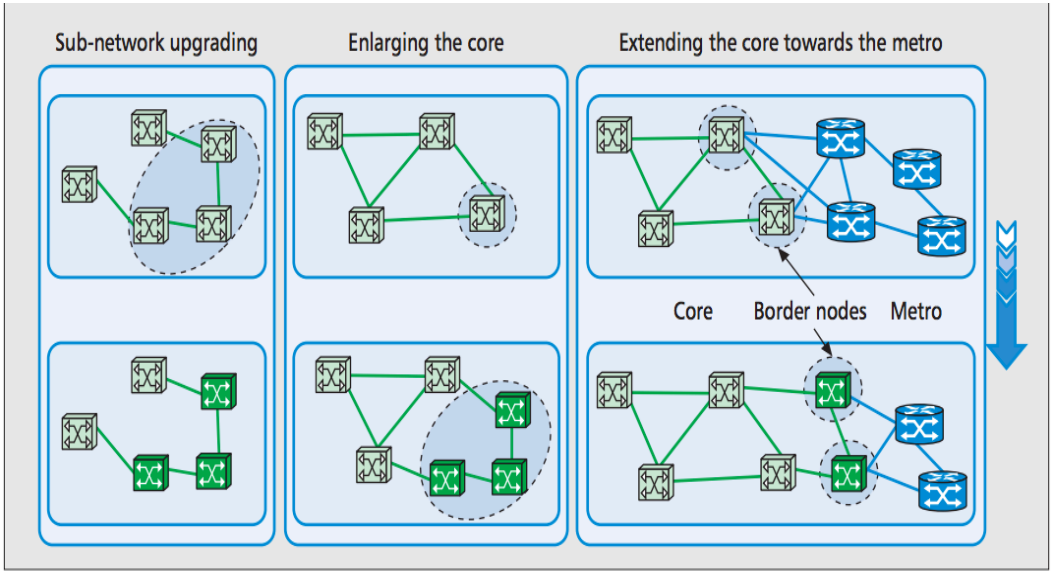


Fig. 2 *Migration scenarios creating flexgrid islands.*

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Traffic Profile [1]

- Low-bandwidth traffic is predominant
- In profile 2, 100 Gb/s traffic is predominant, with only 20 percent 40 Gb/s traffic
- In profile 3, all the traffic are 100G and beyond, with 400 Gb/s traffic as high as 20 percent.

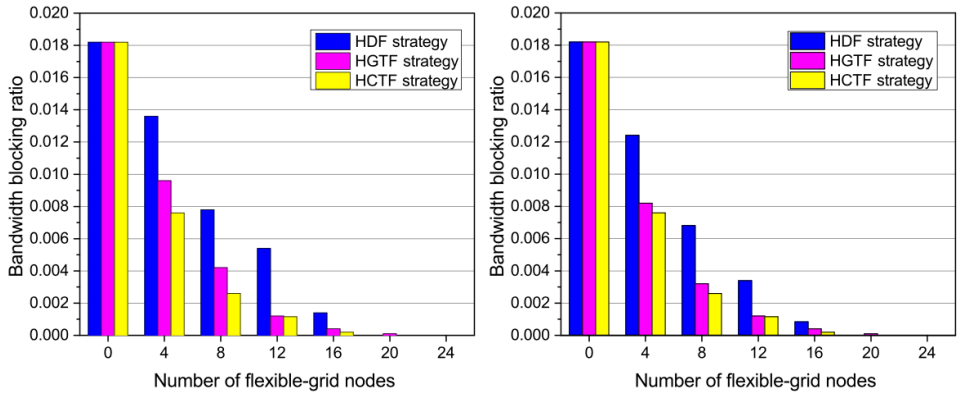
	Fixed grid		Flexible grid	
Channel	Spectrum	#wavelength	Spectrum	# slots
40 Gbps	50 GHz	1	25 GHz	2
100 Gbps	50 GHz	1	37.5GHz	3
200 Gbps	100 GHz	2	75 GHz	6
400 Gbps	200 GHz	4	125 GHz	10

(e)

	Profile 1	Profile 2	Profile 3
40 Gbps	50%	20%	0%
100 Gbps	30%	50%	40%
200 Gbps	15%	20%	40%
400 Gbps	5%	10%	20%

Fig. 3 a) optical channels in fixed-grid and flexible-grid technologies; b) connection demand ratios in different traffic profiles;

Case Study[1]



] Fig. 4 Bandwidth blocking ratio for different migration strategies forming one (left) or two islands (left).

Figure 4 shows that, as the number of upgraded nodes increases, BBR of all migration strategies decreases, confirming the benefits of migrating towards flex-grid. When we upgrade less than 12 nodes, HCTF provides significantly better performance, for both cases of one or two islands. Also, forming two islands (Fig. 4 (right)) is better than forming one island (Fig. 4 (left)) except for HCTF, where BBR is the same (because, using HCTF, the upgrade sequences of the nodes for one-island or two-island cases are the same)

Traffic has changed

- Heterogeneous traffic demand
- Time critical (medical devices, critical sensor network, real time communication)
- Big data
- High speed computing nodes (data center)
- Video on demand
- Internet of things

We should include effect of above traffics in our traffic profile

More Sophisticated Strategies

- Heterogeneous bandwidth demand first (HBDF)
- Time critical traffic first (TCTF)
- Only Flex-grid node first (OFNF)
- Low cost migration node first ..etc (LCMNF)

or , Combination of more than one strategies !

Proposed Strategy

We do not want to eliminate any strategy and take decision based on only one of them.
We propose a strategy where we
Will consider all the strategies, and select nodes to migrate based on highest no of strategies it has met.

Node	HDF	HGTF	HCTF	HBDF	TCTF	LCMNF	OFNF
1	x			x			x
2			x	x	x		x
3		x					
4	x		x	x	x	x	

Based on how many nodes will be migrated, priority will be given to node 4-2-1-3.

Possible Results

- Comparing bandwidth blocking ratio vs no of flex-grid nodes for previous strategies with the new one
- Network utilization, cost savings of new strategy compare to previous strategies
- Optical spectrum utilization in terms of bandwidth of flex-grid using proposed strategy

Reference

[1]Yu, X., Tornatore, M., Xia, M., Wang, J., Zhang, J., Zhao, Y., Zhang, J. and Mukherjee, B., 2015. Migration from fixed grid to flexible grid in optical networks. *IEEE Communications Magazine*, *53*(2), pp.34-43.

[2] Ruiz, M., Velasco, L., Lord, A., Fonseca, D., Pioro, M., Wessaly, R. and Fernandez-Palacios, J.P., 2014. Planning fixed to flexgrid gradual migration: drivers and open issues. *IEEE Communications Magazine*, *52*(1), pp.70-76.