Dynamic Routing and Spectrum Assignment in Brown-field Fixed/Flex Grid Optical Network

Tanjila Ahmed

UCDAVIS
UNIVERSITY OF CALIFORNIA

Outline

- ➢Abstract
- ➢Why we need flexible grid?
- ➢Challenges to handle mixed grid
- ➢Existing Solutions
- ➢Our Proposed Solution
- ➢Methodology
- ➢Simulation Setup
- ➢Performance Analysis
- ➢Conclusion

Abstract

We are solving dynamic routing and spectrum assignment(RSA) problem in a brown-field fixed and flex grid optical networks. Heuristic algorithm is provided to route and spectrum provisioning for a dynamic, heterogeneous incoming traffic type. Spectrum utilization and bandwidth blocking ratio is been measured to analyze the performance of the algorithm compare to baseline approaches such as first fit, shortest path etc.

Why Flexible grid is needed?

As described by Cisco's recent white paper on **The Zettabyte Era:Trends and Analysis** total Internet traffic has experienced dramatic growth in the past two decades.

- Greater adoption of personal devices and machine-to-machine (M2M) connections—from 17.1 billion to 27.1 billion from 2016- 2021
- Video will continue to dominate IP traffic and overall Internet traffic growth—representing 80 percent of all Internet traffic by 2021, up from 67 percent in 2016
- Global IP traffic is expected to increase three-fold reaching an annual run rate of 3.3 zettabytes by 2021, up from an annual run rate of 1.2 zettabytes in 2016.
- By 2021, VR/AR traffic will increase 20-fold and represent one percent of global entertainment traffic.
- Emerging mediums such as live Internet video will increase 15-fold and reach 13 percent of Internet video traffic by 2021

Existing solutions

X. Yu, Y. Zhao, J. Zhang, B. Mukherjee, J. Zhang and X. Wang, "**Static routing and spectrum assignment in co-existing fixed/flex grid optical networks,**" *OFC 2014*, San Francisco, CA, 2014, pp. 1-3.
- Minimize the utilized spectrum when serve all the connections in a traffic matrix. First presented Integer Linear Programming (ILP) formulations, and then propose several heuristic algorithms, with their performance compared.

B. Rahimzadeh Rofoee, G. Zervas, Y. Yan, N. Amaya and D. Simeonidou, "**Flexible and adaptive optical metro networking on Fixed/Flex Grid exploiting hybrid time/frequency for shared resource allocation,**" *2012 38th European Conference and Exhibition on Optical Communications*, Amsterdam, 2012, pp. 1-3.

- A metro network architecture for co-existing Fixed-Grid and Flex-Grid networks is proposed. It delivers adaptive resource allocation in time and frequency dimensions for Fixed-Grid and Flex-Grid services over AoD optical nodes.

Challenges to Handle Mixed grid

- Due to having different spectral granularity, traffic needs different number of frequency slots in fixed and flex grid. In a fixed grid each additional slots need a new channel, new wavelength, guard bands and filter.
- As fix grid links does not have super channeling capability, when traffic flow originating from a flex-grid super-channel enters a fixed grid node, it requires multiple channels to avoid blocking.
- Super-channels are made of contiguous flex-grid slots. However, traffic from a super-channel entering into a fixed grid node cannot maintain contiguous slots in a fixed grid anymore.
- In short, if the network is of mixed nature, allocating spectrum efficiently without any waste is difficult.

UCDAVIS

Proposed Solution

- Given: traffic profile, topology, flex and fix grid links,
- Objective: Maximize spectral utilization, minimize bandwidth blocking
- Constraint: Capacity constraint
- Assumptions:

1. Fixed grid slots to be 12.5 GHz, Fixed grid slots to be 50 GHz
2. Modulation format is QAM (Quardature Amplitude Modulation) for all transmitters
3. Bandwidth fragmentation is not considered when calculating spectrum efficiency in flex-grid network

Methodology

Things to Remember:

- ✓ Flex grid is capable to have super and sub channels. Whereas, fix grid only have fixed channel slot of 50 GHz.
- ✓This makes flex grid links best for large and small bandwidth allocation. Larger bandwidth requests can be served using contiguous slots or super channeling. Smaller bandwidth requests can be served using granular slot width or sub channeling.
- ✓If large bandwidth request(>100 Gbps/50GHz) needs to be carried by fixed grid links, it can be served using multiple slots, which means multiple channels. Each channel will require guard bands, transmitter and filters of its own. Resulting in lower spectrum utilization.
- ✓If very small bandwidth request (<100 Gbps/50 GHz) needs to be carried by a fixed grid links, it will engage atleast one slot (50 GHz). Resulting in lower spectrum utilization.

UCDAVIS

Methodology-Spectral Utilization

- Speed request quantified into bandwidth request for fixed and flex grid
- Calculate k-shortest path for particular connection request
- For each of the k-shortest path allocate required bandwidth in each path by assigning various number of slots at each link
- These paths can be of fixed, flexible and combination of both type of links
- For each link on one path, calculate unused spectrum of each allocated slot
- Calculate the total unused spectrum for one complete path and hence find spectral utilization of that path for specific connection request.
- Do the same for all k-shortest path.
- Choose the path which has highest spectral utilization for route the connection request.

Methodology-Bandwidth Blocking

- If non of the path from k-shortest path has required bandwidth then a connection will be blocked
- For each traffic demand (speed) of a certain profile calculate the bandwidth blocking ratio.
- Find which of the profile and speed request gets blocked the most.

Simulation Setup

- Performance of the proposed algorithm is evaluated on the 14-node NSFnet topology. In our simulation, each link is supposed to have a total of 8 THz spectrum, evenly divided in each direction. 500,000 connection requests following Poisson arrivals are generated with exponential service rate, and their bandwidth demands are chosen uniformly among 40, 100, 200, 400 Gbps. Each slot in the link have width of 50 GHz for fixed grid and 12.5 GHz for flexible grid.

Traffic Demand	Fixed Grid		Flex Grid	
	Bandwidth	#slots	Bandwidth	#slots
40 Gbps	50 GHz	1	25 GHz	2
100 Gbps	50 GHz	1	37.5 GHz	3
200 Gbps	100 GHz	2	75 GHz	6
400 Gbps	200 GHz	4	125 GHz	10

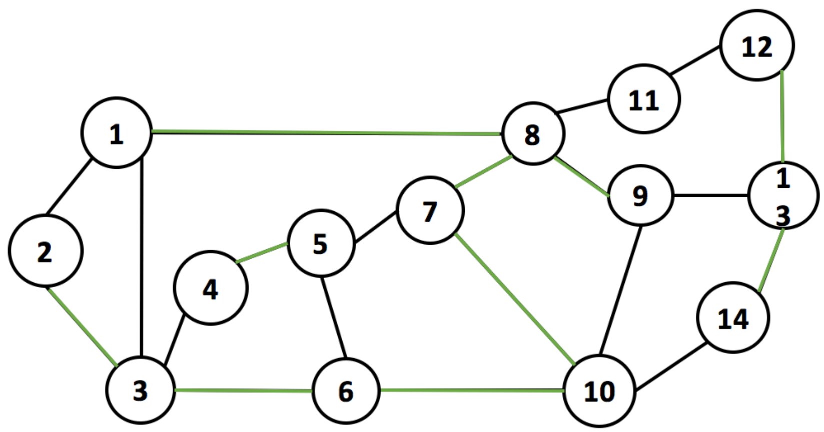
UCDAVIS

Simulation Setup

- Traffic profile:

	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%

- Topology:



UCDAVIS

Performance Analysis

- For all three traffic profile we will compare our algorithm with shortest path algorithm.

1. Spectral utilization vs no of connection request
2. Bandwidth utilization vs no of connection request