OFC’13-Elastic Optical Networks

Presented by Jiawei Zhang

Outline

- Flexible optical networks
- FLEX
- Flexgrid networks
- Defragmentation

Flexible optical network

Code	Title	Author/Affiliate	Contribution
NM2E.2	**Toward Deeply Virtualized Elastic Optical Networks**	M. Jinno, Akira Hirano/ **NTT network lab, Japan Kagawa University, Japan**	Discuss the virtualization on elastic optical networks from elastic network level to sliceable equipment level
NTh1I.1	**Realizing the Benefits of Multi-Layer Packet-Optical Network Design**	Chris Bowers/ **Juniper Networks**	Examines evolving network design and traffic engineering practices that make more efficient use of packet and DWDM resources
NM1I.3	**Grooming Index for OTN/WDM Networks**	Yutaka Takita, Tomohiro Hashiguchi, Kazuyuki Tajima, and Takao Naito/ **Fujitsu Laboratories**	Present a new concept "Grooming Index" for judging the aptitude of OTN/WDM solution for any given network conditions.
NTh1I.5	**Lightpath Optimization in Multi-Domain Optical Networks**	K. Liang, M. Peng, S. Khan, A. Rayes, N. Ghani/ **University of New Mexico**	A multi-objective optimization model is developed for lightpath provisioning in hierarchical multi-domain optical networks. The proposed formulation is then solved and its results compared against some existing distributed heuristic strategies

Toward Deeply Virtualized Elastic Optical Networks

Multi-flow transponder and ***Elastic regenerator*** and ***BV-OXC*** can be seen as the computer hardware which can ***virtualized*** and ***shared*** by users.

Restoration and Spectrum defragmentation can be seen as the virtual machine ***migration*** in compute virtualization.

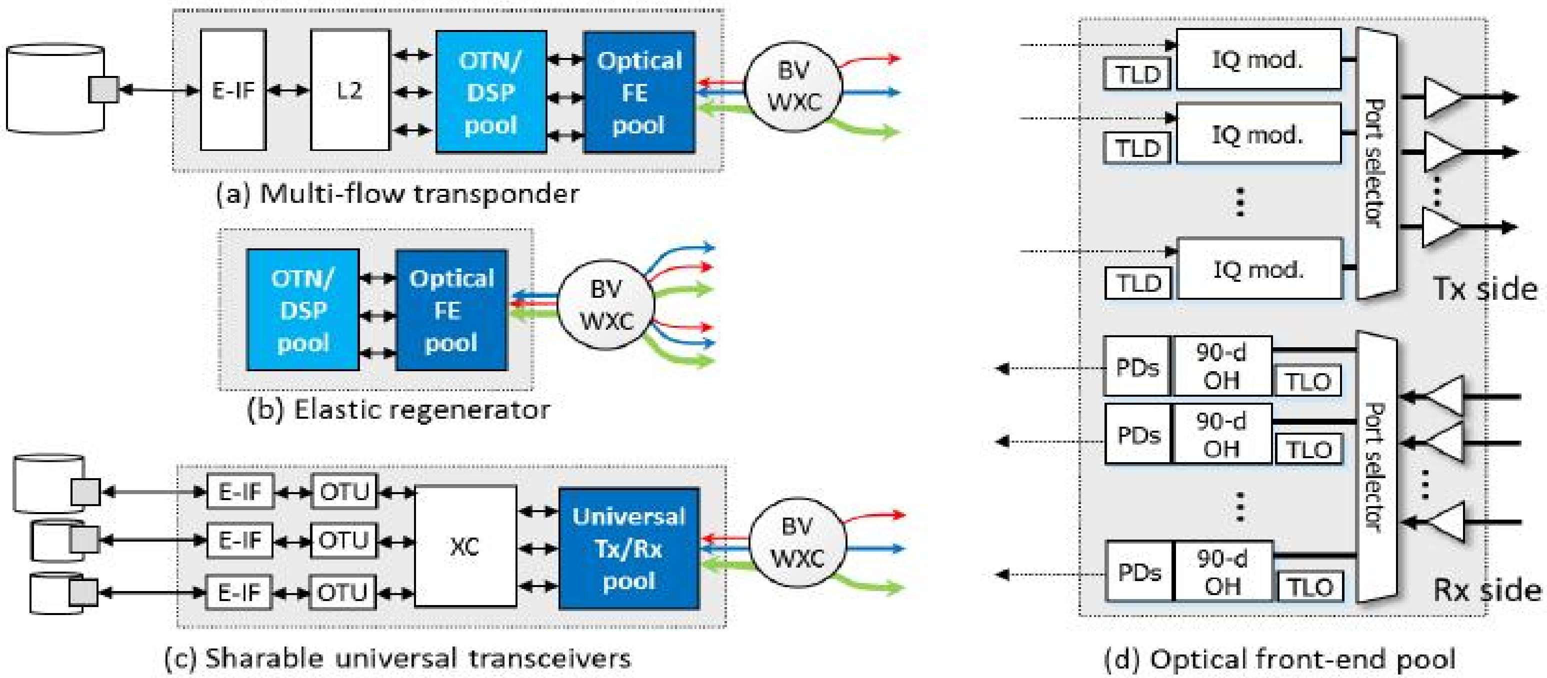


Fig. 1 Examples of equipment level virtualization

Toward Deeply Virtualized Elastic Optical Networks

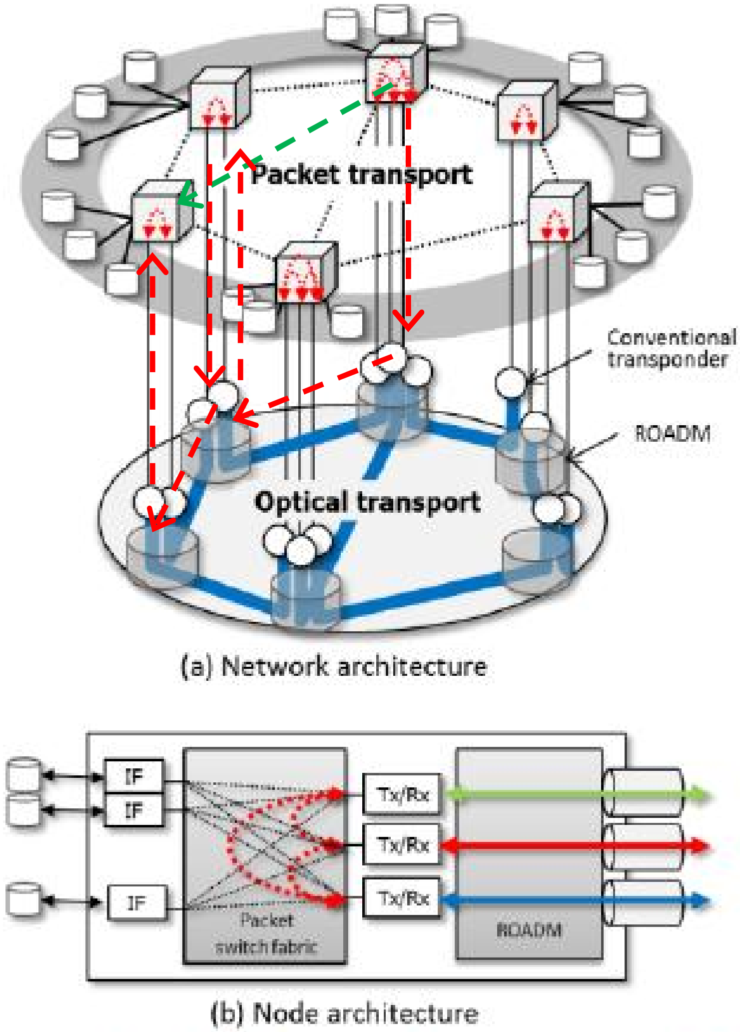


Fig. 2 Packet optical transport system (P-OTS)

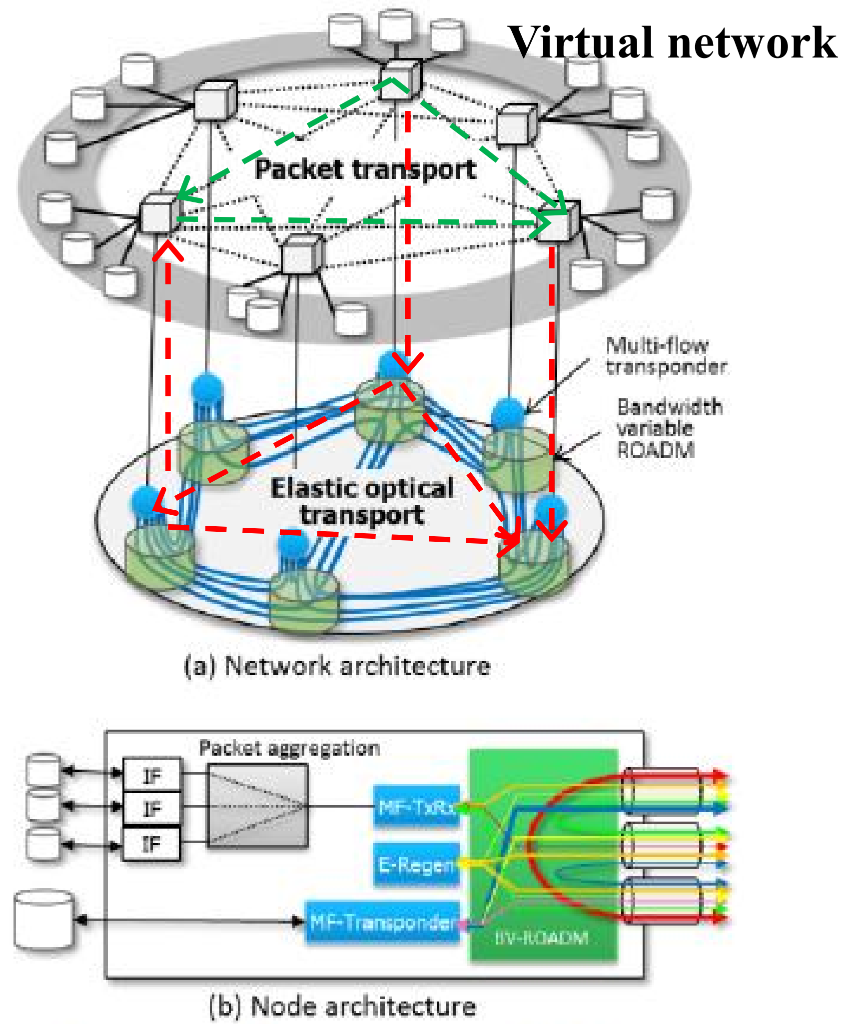


Fig. 3 Elastic optical transport system (EOTS)

Flexible optical network & FLEX

Code	Title	Author/Affiliate	Contribution
NTh1I.6	**Valuing Flexibility in the Migration to Flexgrid Networks**	Mathieu Tahon, Sofie Verbrugge, Didier Colle, Mario Pickavet, Paul Wright, Andrew Lord/ **Ghent University, BT Polaris House**	This paper researches the different migration paths using a real option analysis, showing the impact of uncertainty
OTu2A.1	**Can we use Flexible Transponders to Reduce Margins?**	Jean-Luc Augé/ **France Telecom Orange Labs**	The introduction of bit rate variable transceivers is expected to improve network reconfiguration and optimization. The different network margins are discussed along with the related strategies to reduce them.
OTu2A.2	**40/100/400 Gb/s Mixed Line Rate Transmission Performance in Flexgrid Optical Networks**	Liangjia Zong, Gordon Ning Liu, Andrew Lord, Yu Rong Zhou, and Teng Ma/ **Huawei Technologies**	40/100/400 Gb/s mixed line rate transmission performance is investigated for different spectrum allocation schemes in flexgrid optical networks

Three different migration paths:

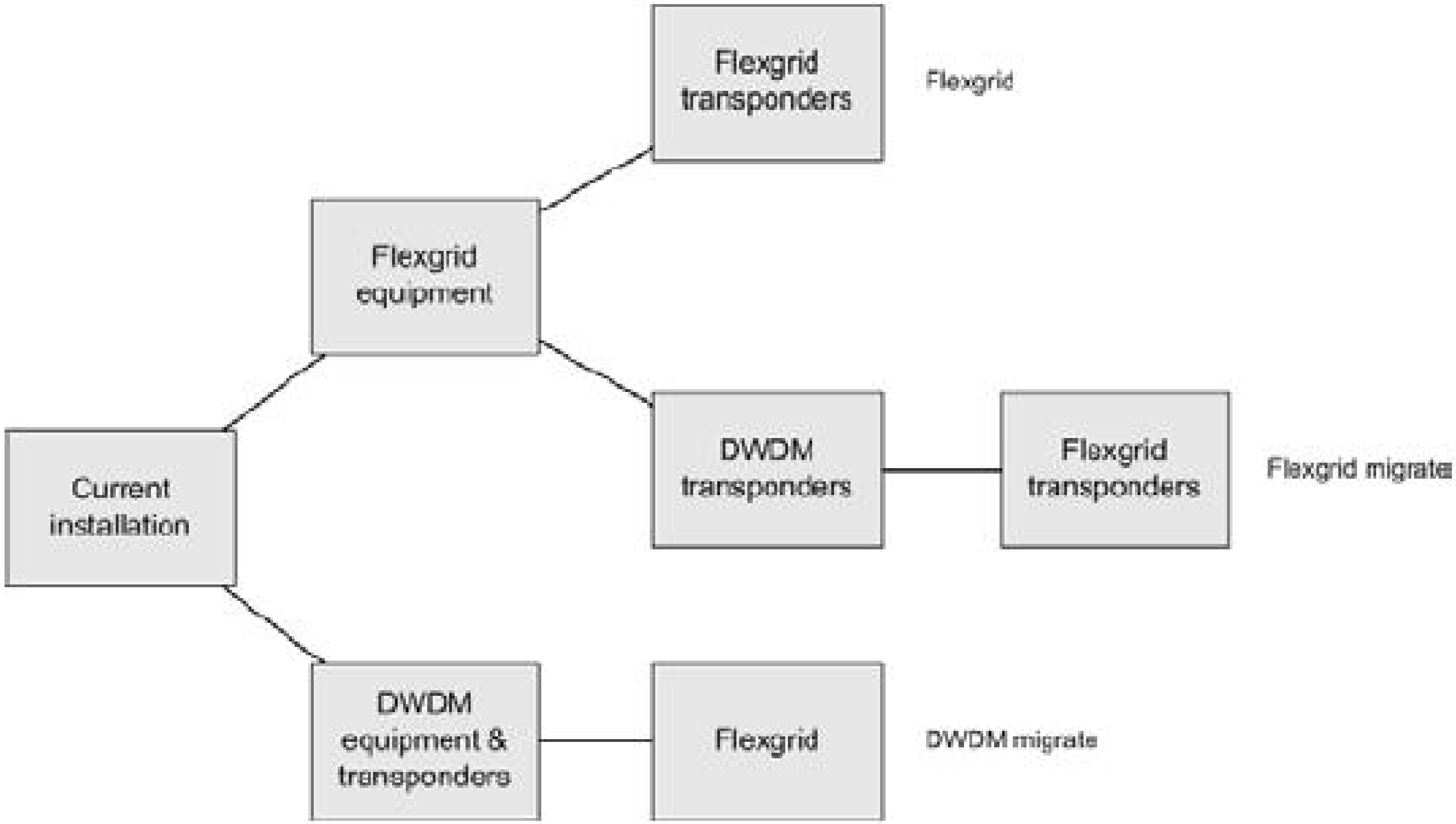


Fig. 1. Migration options towards flexgrid

Valuing Flexibility in the Migration to Flexgrid Networks

1. Real network: UK core network.
2. Expected traffic growth: 37% p.a. (certain traffic growth)
3. Cost input: STRONGEST CapEx model [1]
4. Evaluation period: next 5 years.

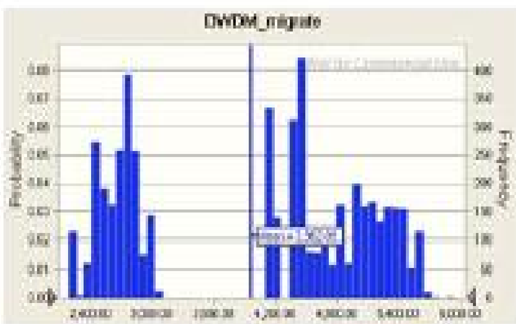
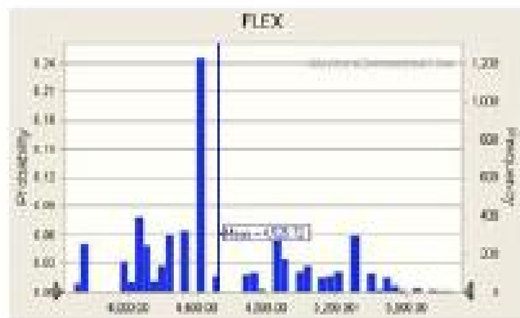
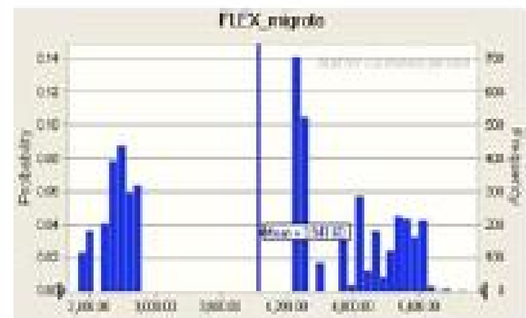
Table 1. Total cost for the three migration scenarios

	DWDM migrate	Flexgrid	Flexgrid migrate
Cumulative discounted cost	2.513 SCU	4.118 SCU	2.656 SCU

1. Network planning/dimensioning/optimization strategies and mechanisms for network operation, STRONGEST D2.3

Valuing Flexibility in the Migration to Flexgrid Networks

Traffic growth ranging between 30% and 70%, with 37% as the most likely. (uncertain traffic growth)

	DWDM migrate	Flexgrid	Flexgrid migrate
Cost distribution			
MCDC	3.962 SCU	4.526 SCU	3.942 SCU

FLEX

Code	Title	Author/Affiliate	Contribution
OTu2A.3	**Trading off Transponders for Spectrum in Flexgrid Networks**	K. Christodoulopoulos, P. Soumplis, E. Varvarigos/ **Trinity College Dublin, University of Patras**	Propose algorithms for planning flexgrid networks under physical layer impairments. Using an optimization function that accounts for both the spectrum used and the transponders cost.
OTu2A.4	**Optical multicast at 224 Gb/s with tunable frequency conversion in a flex-grid network testbed**	G. Meloni, N. Sambo, A. Malacarne, G. Berrettini, F. Cugini, L. Potì, and A. Bogoni/ **Photonic Networks National Laboratory - CNIT**	Multicasting with two tunable conversions is demonstrated with low power consumption in a flex-grid testbed with 224 Gb/s PM-16QAM signal
OTu2A.5	**On the Impact of Optimized Guard-Band Assignment for Superchannels in Flexible-Grid Optical Networks**	António Eira, João Pedro, João Pires/ **Nokia Siemens Networks, Instituto de Telecomunicações, Instituto Superior Técnico**	Present a planning method to find the best compromise between spectral efficiency and 3R regenerator requirements by optimizing the assignment of guard-bands in the deployment of Nx100G super channels.

FLEX & Flexgrid network

Code	Title	Author/Affiliate	Contribution
OTu2A.6	**Dimensioning of elastic optical packet switched metro rings**	Y. Pointurier and J.-C. Antona/ **Alcatel-Lucent, Bell Labs**	Propose a dimensioning algorithm for all-optical packet rings equipped with elastic or fixed mixed line rate (fMLR) transponders (TRX) and show that elastic TRX can reduce network cost by up to 40% with respect to fMLR networks.
OTu2A.7	**Fixed-length Elastic-capacity OFDM Payload Packet: Concept and Demonstration**	Yuki Yoshida, Takahiro Kodama, Satoshi Shinada/ **Osaka University**	A novel fixed-length elastic-capacity optical OFDM payload packet which can significantly ease the buffer scheduling is proposed. 1 x 2 switching and fiber delay line buffering of 19-30Gbps coherent OFDM payload packets is experimentally demonstrated
OTu3A.1	**Support Statistical Sharing in Circuit Switching WDM Optical Networks**	Xi Wang, Qiong Zhang, Inwoong Kim, Paparao Palacharla, Motoyoshi Sekiya/ **Fujitsu Laboratories of America**	We present a new optical networking paradigm in which statistical sharing is natively supported at the spectrum level. The proposed capacity approximation model enables well-balanced capacity requirement estimation and fine-tuning of statistical network capacity gain

Flexgrid networks

Code	Title	Author/Affiliate	Contribution
OTu3A.2	**Dynamic Cooperative Spectrum Sharing in Elastic Networks**	E. Palkopoulou, I. Stiakogiannakis, D. Klonidis, K. Christodoulopoulos/ **Trinity College Dublin, University of Patras**	Reductions in blocking probability can be achieved by introducing "neighbor avoidance" mechanisms. Trade-offs between blocking probability and the number of re-allocated connections are quantified.
OTu3A.4	**Spectrum-Efficient Provisioning for Multi-Channel Elastic Optical Networking**	Ming Xia and Stefan Dahlfort/ **Ericsson Research**	Spectrum-efficient provisioning is designed for multi-channel elastic optical networking. Our scheme achieves high spectral efficiency with fast computation independent of spectrum granularity
OTu3A.5	**Ant-based Alternate Routing Algorithm in Flexible Bandwidth Optical Networks**	Junyan Liu, Jie Zhang, Yongli Zhao, Xiaosong Yu, Xuefeng Lin/ **BUPT, ZTE**	Propose a novel ant-based alternate routing algorithm in the flexible bandwidth networks. Simulation results show that our algorithm outperforms other traditional algorithms by achieving a much lower blocking probability

Flexgrid networks

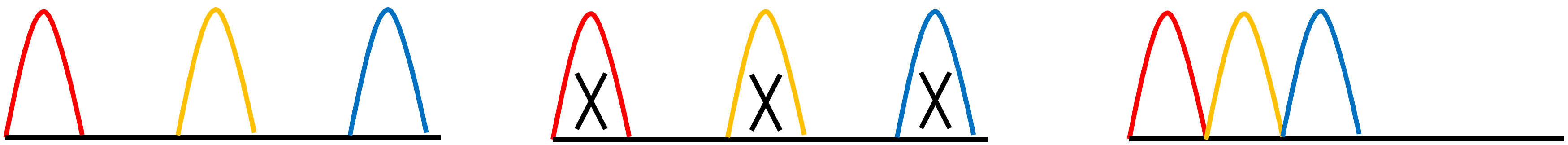
Code	Title	Author/Affiliate	Contribution
OTu3A.6	**A Traffic Intensity Model for Flexgrid Optical Network Planning under Dynamic Traffic Operation**	M. Ruiz*, L. Velasco, J. Comellas, G. Junyent/ **UPC**	We obtain a model to estimate the highest traffic intensity that a flexgrid-based network can support in dynamic scenarios. A design problem is introduced to illustrate its application. Numerical results validate both accuracy and utility.
OTu3A.7	**Performance of a Real IP over DWDM Network > 1000 Nodes Regarding Elastic and Mixed-Line-Rate Scenarios on a Flexible Frequency Grid**	Axel Klekamp and Ulrich Gebhard/ **Alcatel-Lucent Bell Labs**	Real network with 1113 nodes is studied regarding CAPEX and energy consumption to compare MLR/elastic and flat/hierarchical IP over DWDM flex-grid network scenarios. No significant benefit for any of the network concepts can be deduced

Flexgrid networks & Defragmentation

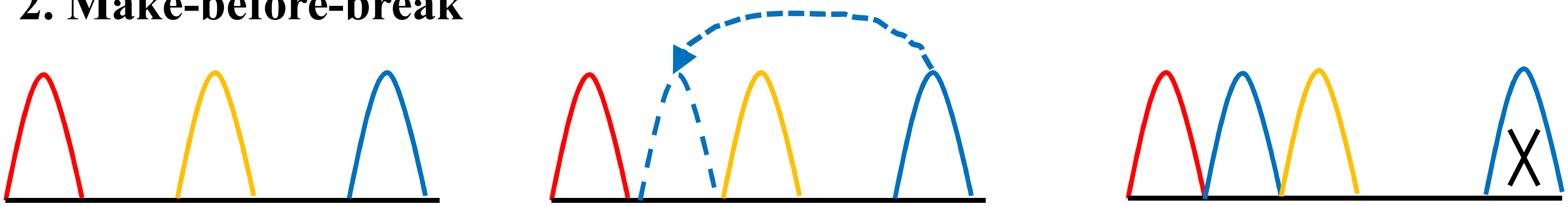
Code	Title	Author/Affiliate	Contribution
OTu3A.8	**How National IP/MPLS Networks can benefit from Flexgrid Optical Technology?**	L. Velasco1*, P. Wright2, A. Lord2, G. Junyent1 **UPC, BT**	We design a 1113-node network and show that the optimum is a large Flexgrid core serving small metro areas. Cost savings of about 31% in the core and 23% in the metro are shown.
OW3A.1	**Demonstration of Multi-channel Hitless Defragmentation with Fast Auto-tracking Coherent RX LOs**	Chuan Qin, Roberto Proietti, Binbin Guan, Yawei Yin, Ryan P. Scott, Runxiang Yu, and S. J. B. Yoo/ **UCDavis**	This paper demonstrates simultaneous defragmentation of two channels without causing errors (BER < 10-11) on other connections lying in the middle. The technique exploits fast tunable lasers and burst-mode coherent receivers with fast wavelength auto-tracking.
OW3A.2	**Feasibility Demonstration of Flexible Tx/Rx for Spectrum Defragmentation in Elastic Optical Networks**	Hyeon Yeong Choi, Takehiro Tsuritani, and Itsuro Morita/ **KDDI**	We demonstrate the feasibility of spectrum defragmentation in a flexible-grid optical network utilizing the flexible transmitter and receiver. According to the defragmentation controller, the flexible transmitter dynamically switches the modulation format/symbol rate/wavelength without hardware modification

Defragmentation technologies

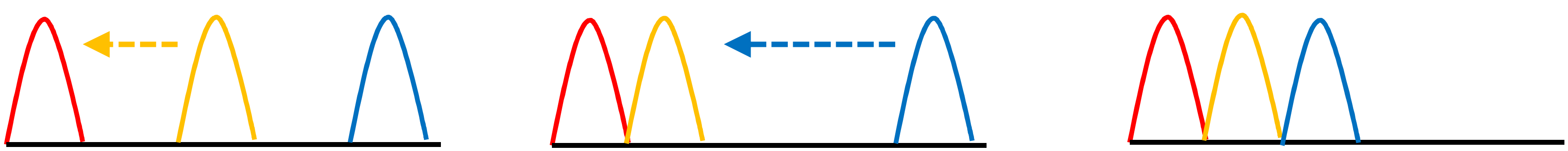
1. Re-optimization



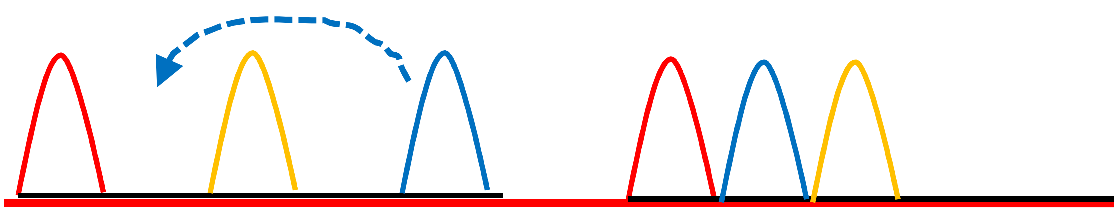
2. Make-before-break



3. Push-and-pull (wavelength sweeping)



4. Hop tuning

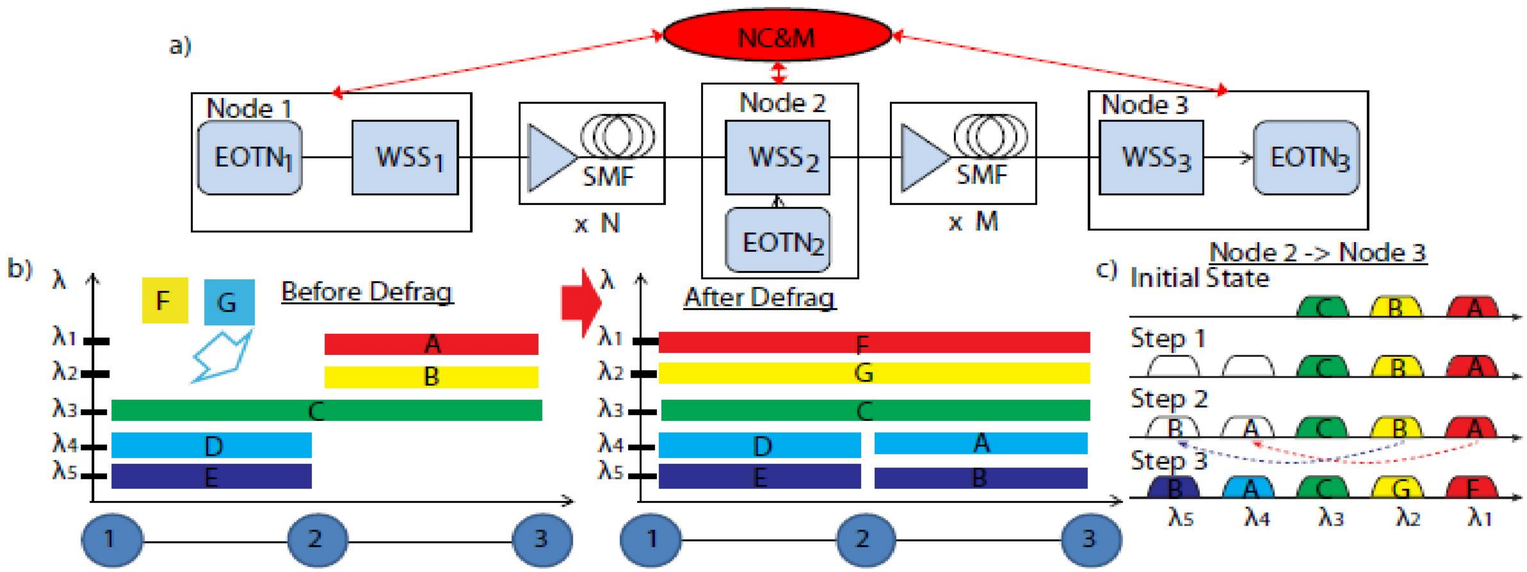


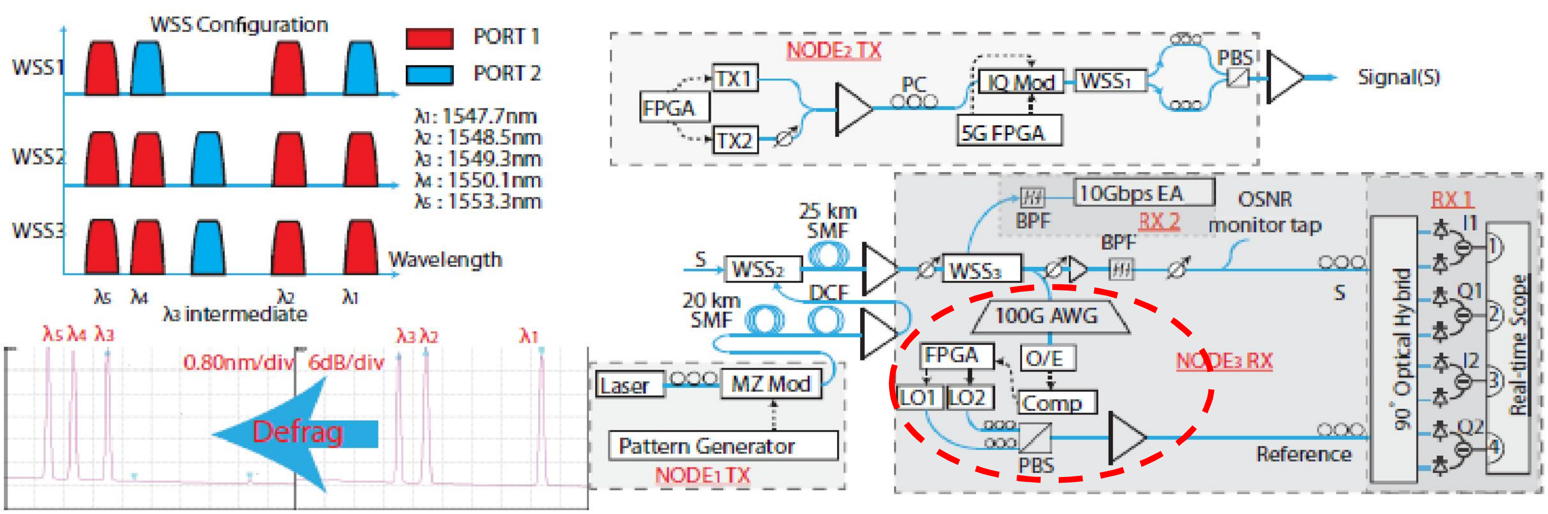
Defragmentation technologies

	Re-optimization [1]	Make-before-break [2]	Push-and-pull [3]	Hop tuning [4]
Extra transmitters	No	Yes	No	No
Interrupt traffic	Yes	No	No	No
Defragmentation spectral area	Any	Any	Limitation	Any
Defragmentation channels per time	Single channel	Single channel	Single channel	Multiple channel
Defragmentation speed	Long time	Slow	Slow	Rapid (1<us)

1. A. Patel, P. Ji, J. Jue and T. Wang, "Defragmentation of transparent flexible optical WDM (FWDM) networks" OFC2011
2. T. Takagi, H. Hasegawa, K. Sato, Y. Sone, A. Hirano, and M. Jinno, "Disruption minimized spectrum defragmentation in elastic optical path networks that adopt distance adaptive modulation," ECOC 2011
3. F. Cugini, M. Secondini, N. Sambo, G. Bottari, G. Bruno, P. Iovanna, and P. Castoldi, "Push-Pull Technique for Defragmentation in Flexible Optical Networks," OFC 2012
4. R. Proietti, R. Yu, K. Wen, Y. Yin, and S. J. B. Yoo, "Quasi-Hitless Defragmentation Technique in Elastic Optical Networks by a Coherent RX LO With Fast TX Wavelength Tracking," PS 2012.

Hop tuning





Wavelength tracking

Defragmentation

Code	Title	Author/Affiliate	Contribution
OW3A.3	**All-Optical Traffic Grooming in Elastic Optical Network**	M. Irfan Anis, N. Amaya, G. Zervas, S. Pinna, M. Scaffardi, F. Fresi, A. Bogoni, R. Nejabati, D. Simeonidou **University of Bristol**	Novel architecture based on all-optical traffic grooming in optical node for elasticoptical network is proposed. BER measurements experimentally demonstrate efficient adaptive switching and processing of variable fragmented traffic, leading to improved network scalability and efficiency.
OW3A.4 (Hop tuning)	**Spectrum Defragmentation Algorithms for Elastic Optical Networks using Hitless Spectrum Retuning Techniques**	Mingyang Zhang, Yawei Yin, Roberto Proietti, Zuqing Zhu, S. J. B. Yoo/ **University of Science and Technology of China, UCD**	We propose several algorithms to achieve hitless bandwidth defragmentation using spectrum retuning in elastic optical networks. Two retuning techniques, spectrum sweeping and hop tuning, are studied. Simulation results show that the hop tuning technique achieves better defragmentation performance.

Defragmentation

Code	Title	Author/Affiliate	Contribution
OW3A.5 (Hop tuning)	**Fragmentation-Aware Routing, Modulation and Spectrum Assignment Algorithms in Elastic Optical Networks**	Yawei Yin, Mingyang Zhang, Zuqing Zhu, and S. J. B. Yoo/ **UCDavis**	We investigate the principle of how dynamic service provisioning fragments the spectral resources on links along a path, and propose corresponding RMSA algorithms to alleviate spectrum fragmentation in dynamic network environments
OW3A.6 (Make-before-break)	**Node Handling Capacity Based Spectrum Fragmentation Evaluation Scheme in Flexible Grid Optical Networks**	Weiguo Ju, Shanguo Huang, Bingli Guo/ **BUPT, PKU**	Based on the reasonable modeling of the spectrum consecutiveness around the node, the concept of node handling capacity is proposed which can effectively indicate the degree of spectrum fragmentation in flexible grid optical networks.
OW3A.7 (Push-and-pull)	**Wavelength Defragmentation Algorithm for Transparent Multi-ring Networks with Multiple Fibers per Link**	Akihiro Kadohata, Takafumi Tanaka, Fumikazu Inuzuka, Atsushi Watanabe, and Akira Hirano/ **NTT**	We propose a scalable and effective wavelength defragmentation algorithm that considers multiple fibers per link. The number of fibers is reduced by more than 14% in multi-ring networks based on numerical evaluation

Thank you!