Departament d'Arquitectura de Computadors
CENTRE DE COMUNICACIONS AVANÇADES DE BANDA AMPLA

Reaching Optical MPLS from an OBS network interoperable with GMPLS

1. OMPLS: Optical MPLS
2. E-OBS: Off-set Time Emulated OBS Architecture
3. Interoperable GMPLS/OBS Control Plane

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Migration towards OPS

	OCS optical circuit switching	**C-OBS** conventional optical burst switching	**E-OBS** offset time-emulated OBS	**OPS** optical packet switching
Signalling:	out-of-band	out-of-band	out-of-band	in-band
Offset time:		offset in edge	offset in core	offset in core
Data unit:	long-living optical circuits	long bursts	short bursts	short packets
Complexity:	✓ low	✓ relaxed	✓ relaxed	× high
Flexibility:	× low	✓ high	✓ high	✓ very high
FDL buffering:	-	× impractical	✓ possible	✓ yes

lower *hardware/processing/switching requirements* **higher**
longer *transmission unit (granularity)* **shorter**

nowadays/near future *mid term* *long term*

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Reaching Optical MPLS from an OBS network interoperable with GMPLS

1. OMPLS: Optical MPLS

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UPC & UniBo join work

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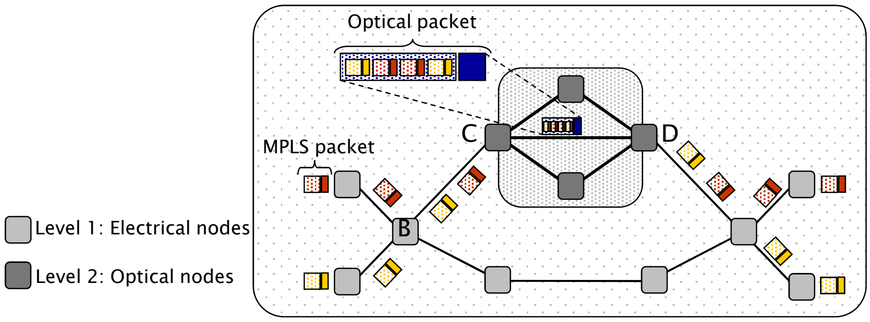
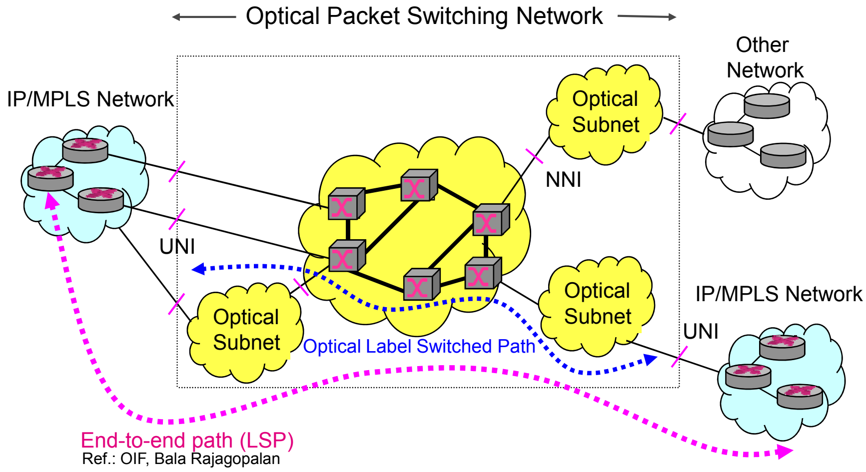
Connection Oriented OP/BS Scenario

- Hierarchical Meshed Core network:
  - MPLS-like approach, path concept
    (separation of routing and forwarding)
  - Traffic aggregation
    (fixed/variable optical burst/packet duration, transparent to bitrates)



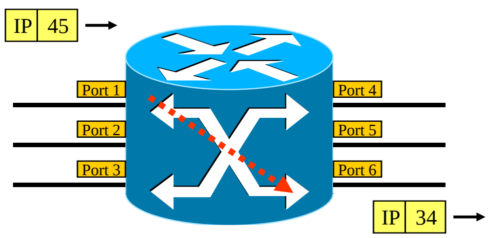
Connection Oriented OP/BS Scenario



Ref.: OIF, Bala Rajagopalan

MPLS Fundamentals

- Label Switching Router (LSR) Operation



Forwarding Table

Input (port, label)	Output (port, label)	Operation Label
(1,35)	**(4,56)**	**Swap**
(1,45)	**(6,34)**	**Swap**
(2,12)	**(4,13)**	**Swap**
(3,24)	**(5,24)**	**Swap**
(3,37)	**(6,49)**	**Swap**
(3,19)	**(6,19)**	**Swap**

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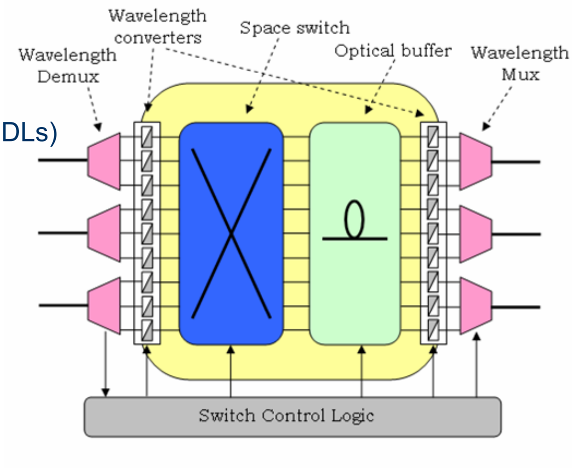
Optical Packet Switch architecture

- Assumptions:
  - Use optical buffer for resolving contentions
  - Dedicated buffer (B FDLs) per wavelength



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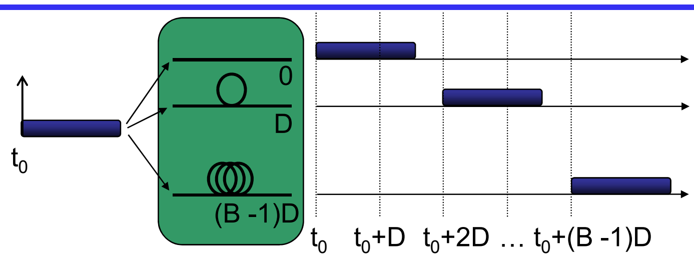
Optical Packet Switch architecture



- Contention resolution in time domain
- Consisting of B Fibre Delay Lines (FDLs):
  - Packets are delayed until the output wavelength is available
  - The delay is chosen at packet arrival
  - Usually the available delays are multiples of the **delay unit** D
    D = (FDL-size / Average IP packet-size) x (Vt / Vp)
  - Packets are lost when the required delay is larger than the maximum delay achievable D_M = (B -1)D

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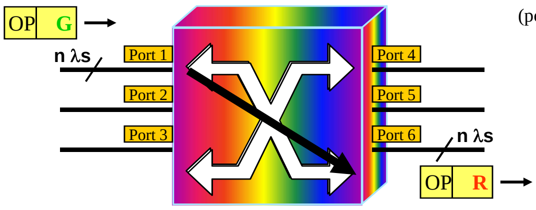
MPLS over OPS

- Optical Packet Switch Operation:
  - The output wavelength is a degree of freedom
  - We can select any, among the "n", wavelength of the forwarding output port



Forwarding Table

Input (port, label, lambda)	Output (port, label, lambda)
(1,35)	(4,56)
(1,45, λ_G)	(6,34, λ_R)
(2,12)	(4,13)
(3,24)	(5,24)
(3,37)	(6,49)
(3,19)	(6,19)

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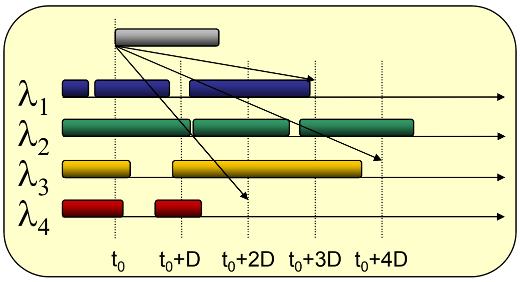
MPLS over OPS

- At packet arrival the forwarding table determines
  - *The output fibre*
  - *The label*
  - *The output wavelength*

Example:
- 4 FDL per wavelength
- 4 wavelengths per fiber
- Asynchronous arrivals
- Variable-length packets



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Wavelength assignment

- Problem formulation:
  - WDM links
    - *Several wavelengths to choose from on the same routing path*
  - New requirement (compared with the electrical case)
    - *It is necessary to map the Optical Virtual Circuits (Optical LSPs) into a wavelength*
  - Static allocation:
    - *Map Optical LSPs into Traffic Demand Evolution at the Optical LSP set up (wavelength assignment in the forwarding table) and never change*
    - *Although the Optical LSPs are assigned to the optimum wavelength, this is not the optimal solution in terms of performance*
  - Dynamic allocation
    - *Lower Packet Loss Probability expected, but higher process cost and possible out of sequence packets*
      - *Per packet dynamic allocation (no wavelength assignment in the forwarding table)*
      - *Per Optical LSP dynamic allocation: the wavelength assignment in the forwarding table is changed when congestion is experienced*

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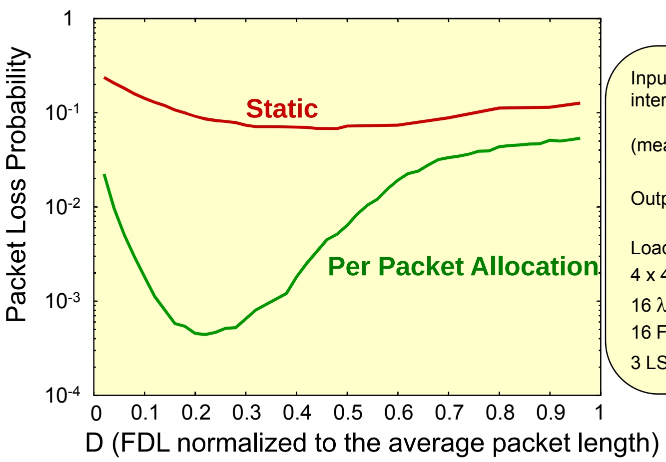
MPLS over OPS

- Static allocation vs per packet allocation: Single node performance



Input traffic (packet size and interarrival time distribution): Exponential
(mean packet size = 500 Bytes)

Output traffic distribution : Uniform

Load = 0.8
4 x 4 switch
16 λs per fiber
16 Fiber Delay Lines
3 LSP per λ

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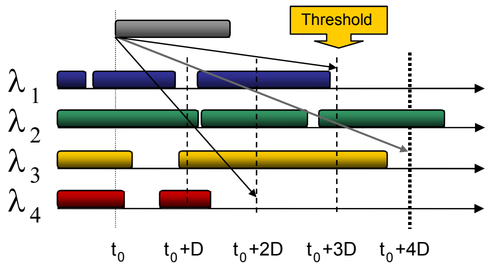
MPLS over OPS

- Per LSP dynamic allocation:
  - When a queue is congested move LSPs to less congested wavelength
  - Congestion may be defined by means of a threshold in the queue occupancy: When queue over threshold, search for a new wavelength
    - *E.g. wavelength searched with a round robin algorithm:* Round Robin Wavelength Selection *(RRWS)*



  - The forwarding table is updated to keep the same destination for all subsequent packets belonging to the same LSP

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Round-Robin Wavelength Selection

- Actions in case of congestion
  - Wait until a new packet arrives
  - Start a round-robin search for another not congested wavelength of the same fiber
  - If such a wavelength is found, the forwarding table is updated and new packets of this LSP are sent through it

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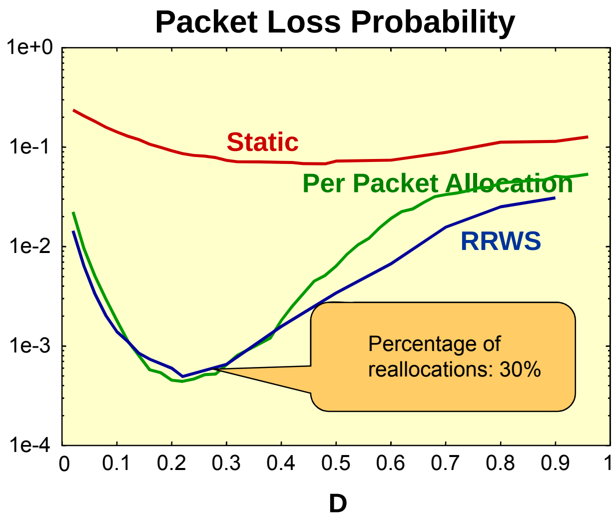
RRWS Performance



Input traffic (packet size and interarrival time distribution): Exponential (mean pk size = 500 Bytes)

Output traffic distribution: Uniform

ρ = 0.8

4 x 4 switch

16 λs per fiber

16 Fiber Delay Lines

3 LSP per λ

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Per LSP Dynamic Allocation (cont.)

- RRWS is simple to implement but not very efficient
- Other more efficient algorithms are:
  - Min-Queue Wavelength Selection (MQWS)
    - *Which search for the minimum length queue*
  - Empty-Queue Wavelength Selection (EQWS)
    - *Which exploits the LSP Grouping Effect*
  - Sequence Keeping Wavelength Selection (SKWS)

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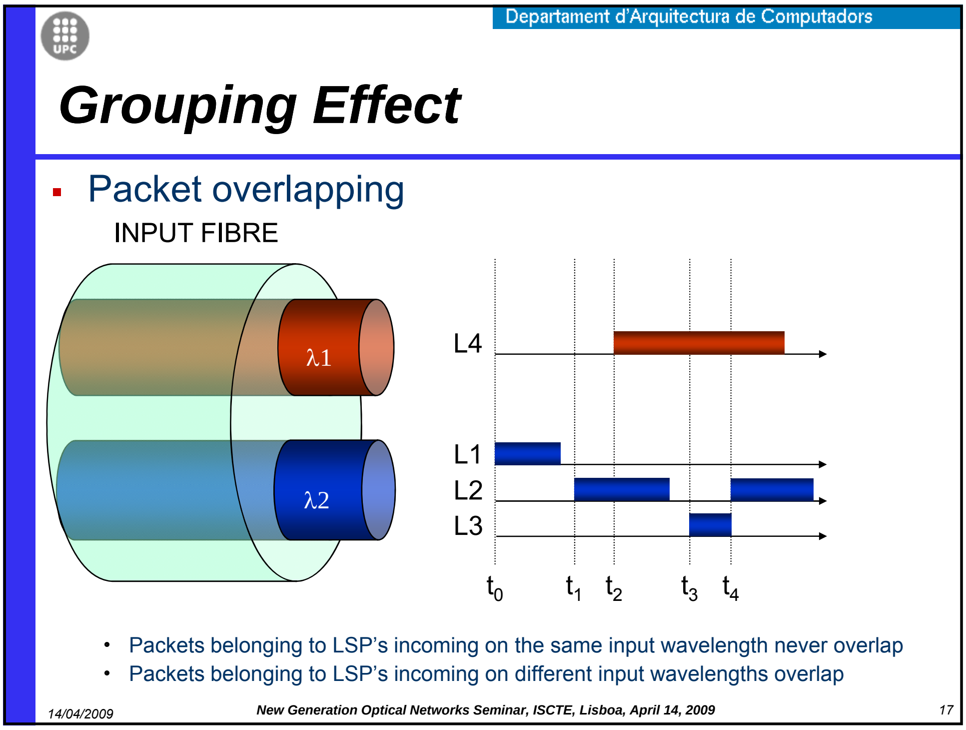
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Grouping Effect
Packet overlapping
INPUT FIBRE
λ1
λ2
L4
L1
L2
L3
t_0 t_1 t_2 t_3 t_4
Packets belonging to LSP's incoming on the same input wavelength never overlap
Packets belonging to LSP's incoming on different input wavelengths overlap
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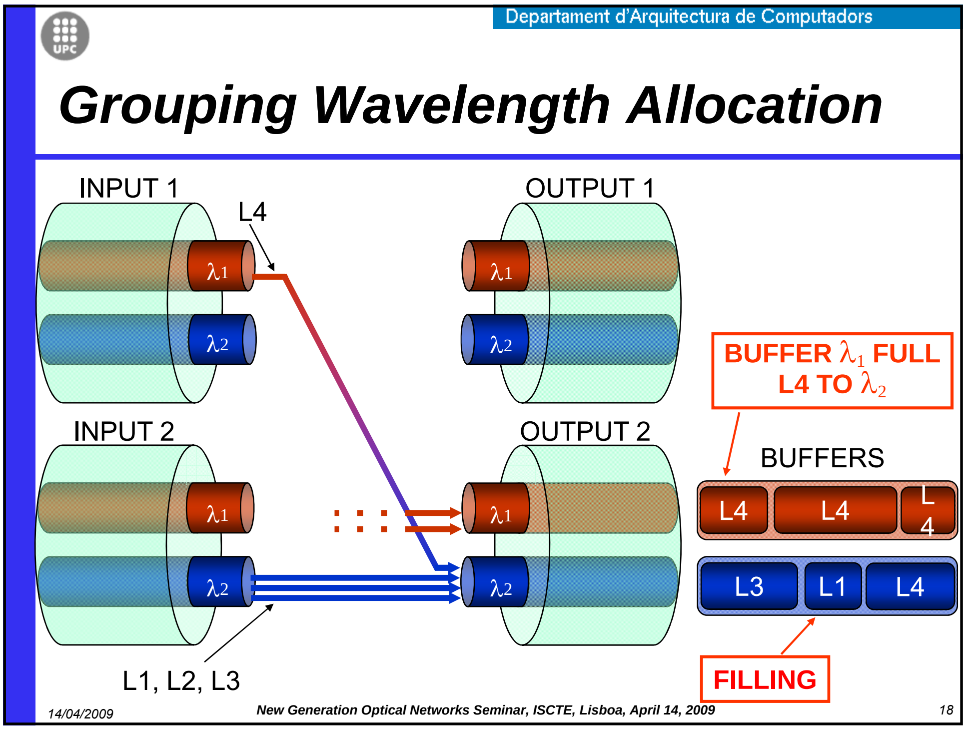
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Grouping Wavelength Allocation
INPUT 1
L4
OUTPUT 1
λ1
λ2
BUFFER λ_1 FULL
L4 TO λ_2
INPUT 2
OUTPUT 2
BUFFERS
L4
L4
L 4
L3
L1
L4
L1, L2, L3
FILLING
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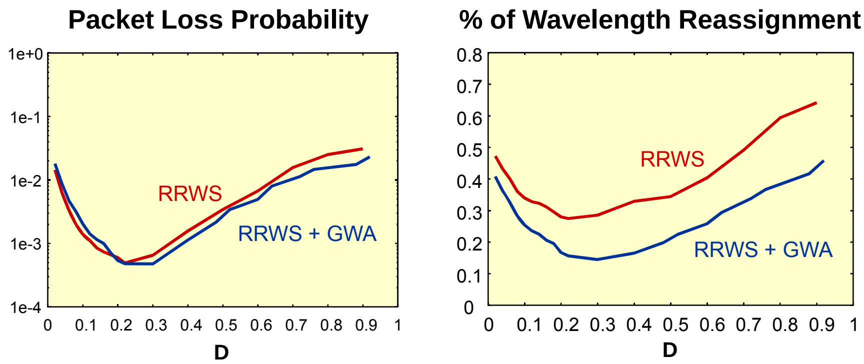
Exploiting the Grouping Effect

- Performance of the RRWS enhanced with the Grouped Wavelength Allocation (GWA)



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Empty Queue Wavelength Selection(EQWS)

- Actions in case of congestion
  - wait until a new packet arrives
  - search for a wavelength in optimal allocation, i.e. an empty queue
  - LSP is assigned to that wavelength up to
    - *congestion arises also in the new wavelength, then the algorithm starts a new search*

      OR
    - *congestion disappears from the previous one, then the LSP is switched back to the original wavelength*

- This algorithm achieves full exploitation of the optical buffer capacity

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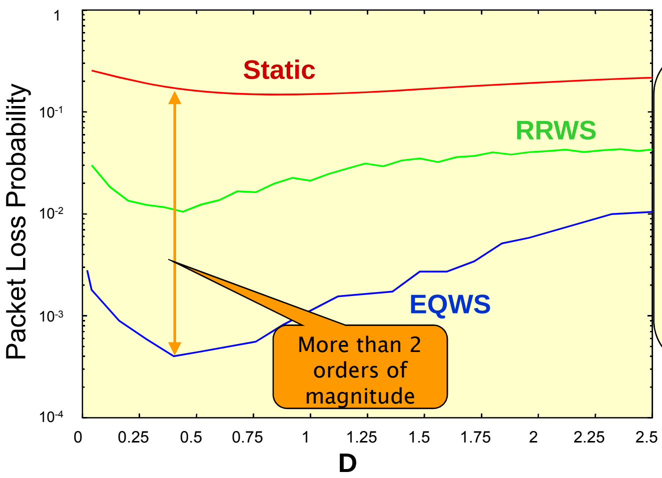
EQWS Performance



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4 x 4 switch
16 λs per fiber
4 Fiber Delay Lines
3 LSP per λ

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Per LSP Dynamic Allocation (cont.)

- Problem of the EQWS algorithm
  - Out of sequence delivery of packet belonging the same LSP due to the LSP reallocation
  - Causing complex reordering operation at the edge
  - Throughput degradation at upper layers (e.g. due to TCP behavior)
- Answer
  - The dynamic algorithms have to take into account the time constraint in order to keep the correct packet sequence
- Two new algorithms
  - Sequence Keeping Wavelength Selection v1: SKWS (1)
  - Sequence Keeping Wavelength Selection v2: SKWS (2)

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Sequence Keeping Wavelength Selection (I)

- Actions in case of new packet arrives
  - if the previous packet belonging the same LSP is still in the buffers
    - *assign to the new packet an amount of delay (D_{min}) at least as long as the residual transmission time of the previous one,*
    - *if the assigned wavelength (queue) cannot provide the delay D_{min}, LSP is assigned to the wavelength that introduce the minimum delay greater than D_{min}*
  - if not, whatever time and wavelength is valid, those selects the queue among those not full which introduces the minimum gap between subsequent queued packets
- LSP is assigned to that wavelength up to
  - congestion arises also in the new wavelength, then the algorithm starts a new search

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Sequence Keeping Wavelength Selection (2)

- Actions in case of new packet arrives
  - if the previous packet belonging the same LSP is still in the buffer
    - *assign to the new packet an amount of delay (D_{min}) at least the residual waiting time of the previous one,*
    - *if the assigned wavelength (queue) cannot provide the delay D_{min}, LSP is assigned to the wavelength that introduce the minimum delay greater than D_{min}*
  - if not, whatever time and wavelength is valid, shortest queue is selected
- LSP is assigned to that wavelength up to
  - congestion arises also in the new wavelength, then the algorithm starts a new search

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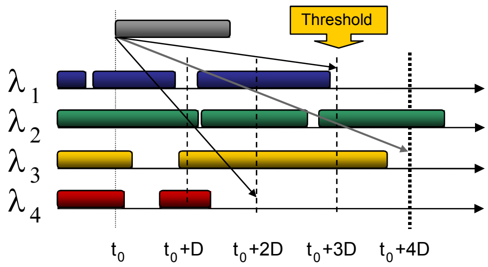
MPLS over OPS

- Per LSP dynamic allocation:
  - When a queue is congested move LSPs to less congested wavelength
  - Congestion may be defined by means of a threshold in the queue occupancy: When queue over threshold, search for a new wavelength
    - *E.g. wavelength searched with a round robin algorithm:* Round Robin Wavelength Selection *(RRWS)*



  - The forwarding table is updated to keep the same destination for all subsequent packets belonging to the same LSP

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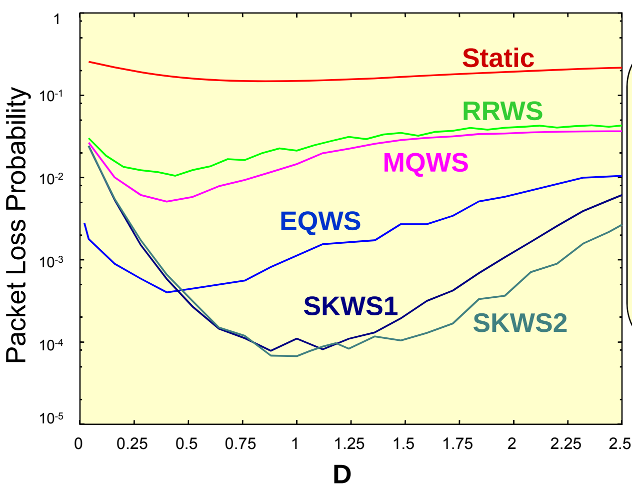
SKWS Performance



Input traffic:
packet size and interarrival distribution: Exponential (mean = 500 Bytes)
Load = 0.8
Output traffic distribution: Uniform
4 x 4 switch
16 λs per fiber
4 Fiber Delay Lines
3 LSP per λ

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Summary I

- As expected, there is a trade-off to reduce:
  - The PLR,
  - The percentage of reallocations and
  - The percentage of out of sequence packets

Input traffic (packet size and interarrival time distribution: Exponential (mean packet size = 500 Bytes)
Load = 0.8
Output traffic distribution: Uniform
4 x 4 switch
16 λs per fiber
4 Fiber Delay Lines
3 LSP per λ

Algorithm	Min PLR	% Reallocations	% Packet out of sequence
Static	10^{-1}	0	0
Per packet allocation	$8\ 10^{-3}$	81	4
EQWS	$5\ 10^{-4}$	13	3.3
SKWS	$8\ 10^{-5}$	54	0

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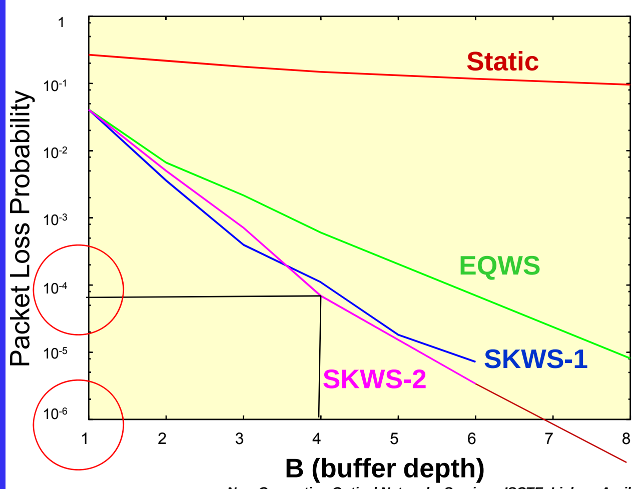
Summary II

- Acceptable PLR can be obtained



Input traffic:
packet size and interarrival distribution: Exponential (mean = 500 Bytes)
Load = 0.8
Output traffic distribution: Uniform
4 x 4 switch
16 λs per fiber
B Fiber Delay Lines
D: The best in each case (e.g. for SKWS, D = 1 and for EQWS, D = 0'5)
3 LSP per λ

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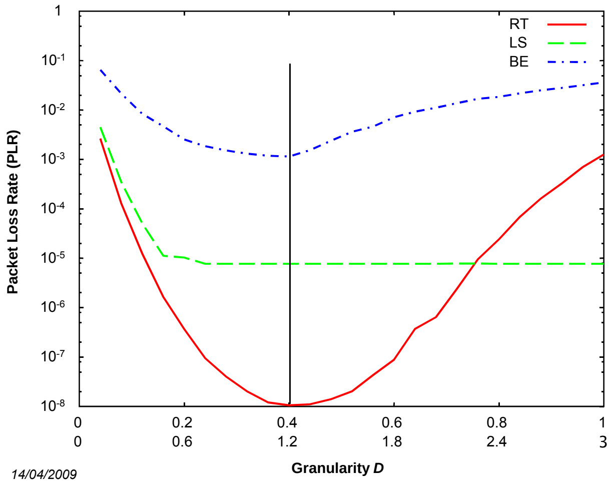
Summary III

- WS algorithms can be used to provide QoS



Input traffic:
packet size and interarrival distribution: Exponential
(mean size = 500 Bytes)
Load ρ = 0.8
RT 30%
LS 20%
BE 50%
Output traffic distribution: Uniform
4 x 4 switch
16 λs per fiber
6 Fiber Delay Lines
3 LSP per λ

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References

- D. Careglio, J. Solé-Pareta, S. Spadaro, *"Service category-to-wavelength selection technique for QoS support in connection-oriented optical packet switching",* Computer Networks Journal (Elsevier), vol. 51, No. 1, pp. 14-30, January 2007, ISSN: 1389-1286

- F. Callegati, D. Careglio, W. Cerroni, G. Muretto, C Raffaelli, J. Solé-Pareta, P. Zaffoni, "*Keeping the packet sequence in optical packet-switched networks",* Optical Switching and Networking Journal (Elsevier), Vol. 2, No. 3, pp. 137-147, November 2005, ISSN: 1573-4277

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Reaching Optical MPLS from an OBS network interoperable with GMPLS

2. E-OBS: Off-set Time Emulated OBS Architecture

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Main features of OBS networks

- Main features
  - Aggregation of quite large (μs÷ms) data bursts at edge nodes
  - All-optical switching of data bursts in core nodes
  - Out-of-band signalling: control packets sent on a dedicated wavelength
  - Statistical multiplexing: sharing of wavelength resources between burst flows

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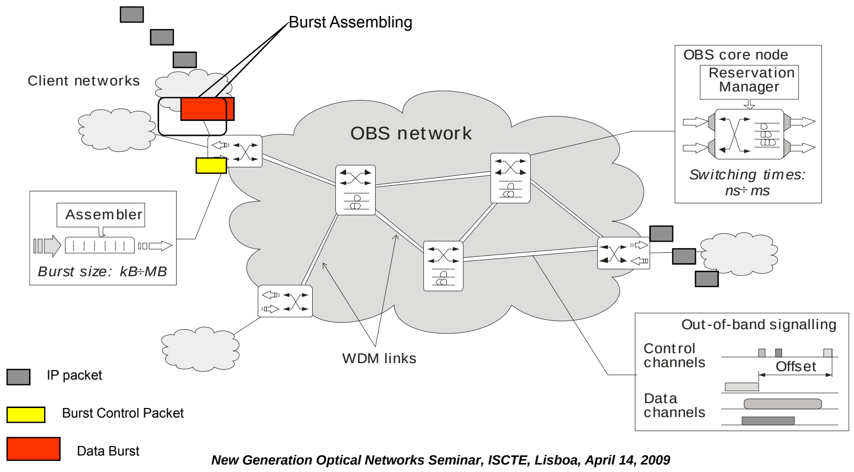
Main features of OBS networks

- Optical Burst Switching: How it works



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Main features of OBS networks

- Advantages
  - High flexibility (suitable for bursty internet traffic), efficient network utilization
    - *OBS offers the necessary flexibility for grid applications: high bandwidth, no electronic bottleneck, low set-up times, varied granularity (short/long grid jobs)*
  - Moderate switching, hardware, and processing requirements
- Challenges
  - High amount of data losses (bursts are long and can be hardly buffered in FDLs)
  - Control complexity: QoS, routing, possible burst reordering, etc.
  - Not GMPLS compliant

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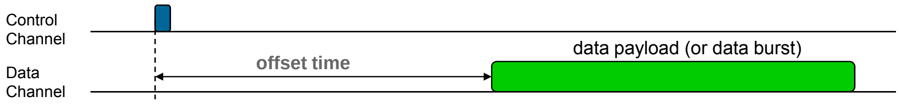
C-OBS vs. E-OBS

- The difference relays on the Offset time introduction
  - The Offset time corresponds to the time budget for
    - *the processing of a Burst Control Packet (BCP), and*
    - *the reconfiguration of the switching matrix.*



- C-OBS (Conventional OBS)
  - The offset time is introduced at the edges: Source-based offset time provisioning
- E-OBS (offset time-Emulated OBS)
  - The offset time is introduced at the input of the core nodes: Distributed offset time provisioning

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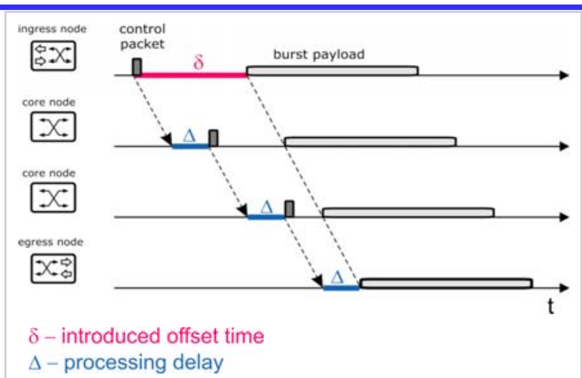
Offset times: The C-OBS case



- The offset time varies since it decreases hop-by-hop (at each core node) by the processing time.
  - C-OBS is the most extensive studied case in the literature
  - Was suggested by C. Qiao and M. Yoo in "Optical Burst Switching (OBS) -- a New Paradigm for an Optical Internet", J. High Speed Networks, Mar. 1999

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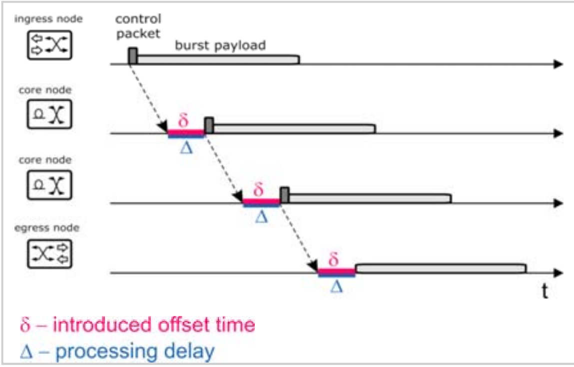
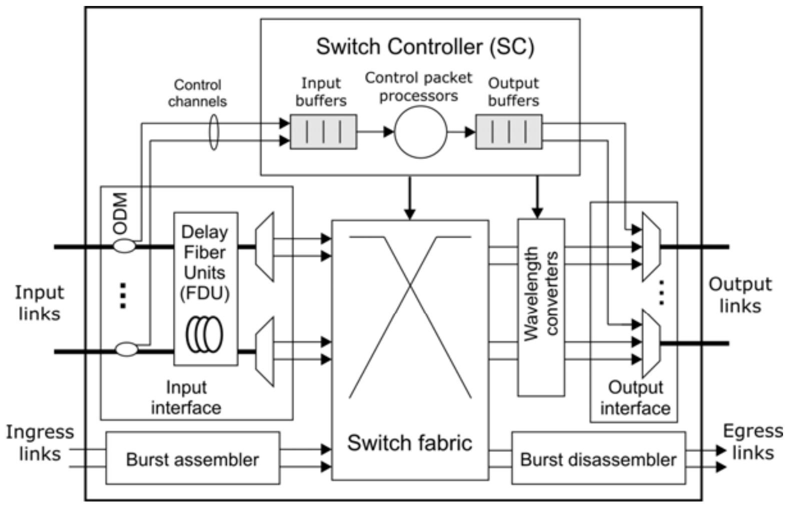
Offset times: The E-OBS case



- The offset time can be kept fixed, since it is introduced at each core node
  - Was suggested by Y. Xiong, M. Vanderhoute, and C. Cankaya in "Control Architecture in Optical Burst-Switched WDM Networks", IEEE JSAC, Oct. 2000

E-OBS Architecture



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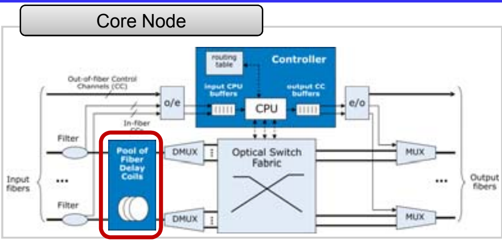
E-OBS Architecture

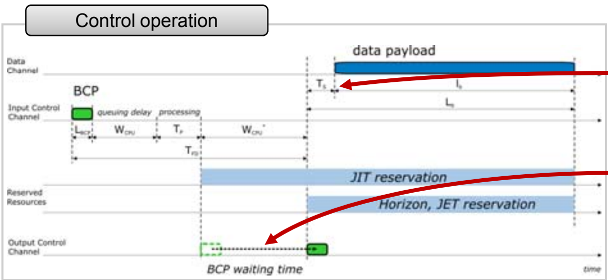
Core Node



Fibre Delay Coil (FDC)

- A passive piece of fibre of fixed length; less complex than an FDL buffer
- Only one FDC per each input port

Control operation



Assumptions

1. A small switching offset introduced at the edge node
2. Delayed forwarding

⇒ **the offset time does not vary in the network**

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E-OBS: Feasibility

✓ Fibre Delay Coil commercially available

General Photonics Newport

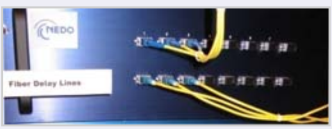
Typical FDC parameters

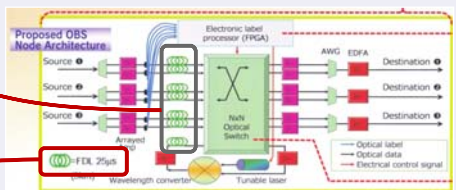
- 4 km of fibre ≡ **20μs of delay**
- insertion loss **< 0.3db/km**
- dimension: **6.00" x 6.00" x 1.59"**
- operating wavelengths: **1260 ~ 1650nm**

✓ An E-OBS node at ECOC 2006

OIDA (Japan) test-bed

A. Al Amin et al, "40/10 Gbps Bit-rate Transparent Burst Switching and Contention Resolving Wavelength Conversion in an Optical Router Prototype"





Offset time of 25μs

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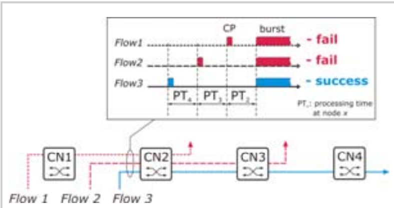
Offset time variation in C-OBS

- Variation of offset times, which is inherent in C-OBS networks, results in the following (unwanted) effects:

1. **Unfairness** in access to transmission resources ⇒ bursts of bigger offsets have more chances to reserve resources

   e.g.:

   - a burst that is approaching its destination is overtaken by a burst just released from an edge node
   - a burst on a shorter path is overtaken by a burst on a longer path



K. Dolzer, C.M. Gauger, "On Burst Assembly in Optical Burst Switching Networks – a Performance Evaluation of Just-Enough-Time", *ITC 17*, Dec. 2001.

B.-C. Kim et al, "An Efficient Optical Burst Switching Technique for Multi-Hop Networks", *IEICE Transactions on Communications*, Jun. 2004.

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Offset time variation in C-OBS

2. A path length constraint imposed in alternative routing ⇒ the maximum length of a routing path is determined by the offset time (introduced at the source).

   Ch.-F. Hsu et al, "Performance Analysis of Deflection Routing in Optical Burst-Switched Networks", *IEEE Infocom 2002*.
   T. Coutelen et al, "An Efficient Adaptive Offset Mechanism to Reduce Burst Losses in OBS Networks", *IEEE Globecom 2005*.

3. Voids appear between burst reservation ⇒ need for more complex (i.e., void-filling capable) resources reservation algorithms

   Y. Xiong et al, "Control Architecture in Optical Burst-Switched WDM Networks", *IEEE JSAC*, Oct. 2000.

4. Scheduling performance gets worsen with variable offsets

   J. Li et al., "Maximizing Throughput for Optical Burst Switching Networks", *IEEE INFOCOM 2004*.

5. Effective QoS classes in the offset time differentiation mechanism are multiplied and hence less controllable

   K. Dolzer, C.M. Gauger, "On Burst Assembly in Optical Burst Switching Networks – a Performance Evaluation of Just-Enough-Time", *ITC 17*, Dec. 2001.

- E-OBS helps to overcome these (unwanted) effects

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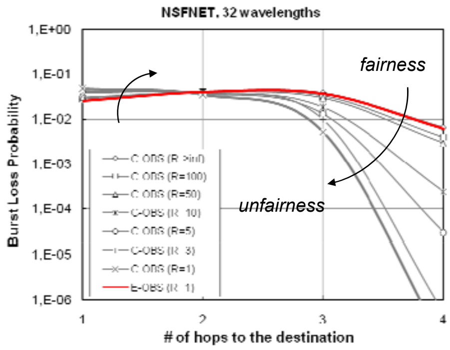
Fairness

fairness ≡ each burst treated equally in the network (if no QoS)
≡ BLP does not depend on the # of hops to the destination



$$R = \frac{av.\ burst\ length}{offset\ time}$$

Network: NSFNET (15/23)
Routing: Shortest Path
Link dimension: 32λs
Load: 0.8
Offset time (1hop): 10µs

C-OBS: fairness achieved only with very long bursts (i.e., when R is high)
E-OBS: **fairness achieved even with short bursts** (R=1)

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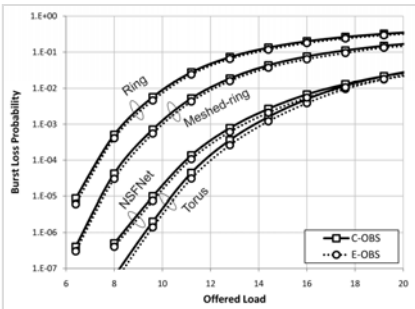
Overall BLP and Delay



Network: 4 topologies
Routing: Shortest Path
Link dimension: 32λs
Load: 0.8
Offset time (1hop): 10µs
Burst Scheduling:
JET/LAUC-**VF in C-OBS**
Horizon/LAUC **in E-OBS**

E-OBS can operate with a less complex scheduling algorithm (Horizon), and it still achieves at least as good performance as C-OBS!

$$\boxed{\overline{D}_{C-OBS} = \overline{D}_{E-OBS}} = \overline{B} + \sum_{i=1}^{n}(d_i + \Delta_i) + \delta_s$$

B: burst assembly delay
d: link propagation delay
Δ: processing offset
δ_S: switching offset
n: # of hops

There is no transmission delay penalty when using E-OBS

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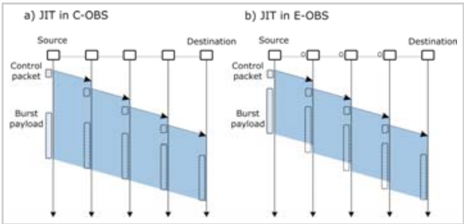
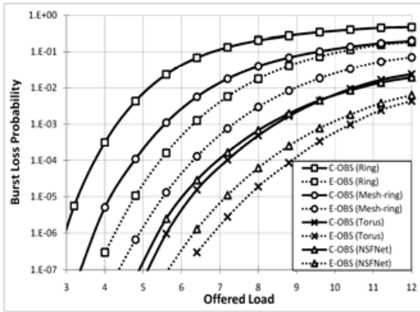
Resources Reservation: JIT





Just-In-Time (JIT) protocol

- immediate wavelength reservation (just after the processing of BCP)
- low complexity, but the over-provisioning of resources

JIT protocol can be applied effectively in E-OBS, it substantially improves the burst loss performance provided by C-OBS

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Resources Reservation (cont.)

Protocol	Protocol Complexity	C-OBS	E-OBS
JIT (Just-In-Time)	Low (immediate reservation)	Low efficiency (high resources over-provisioning, because of longer offsets)	High efficiency (low resources over-provisioning, because of shorter offsets)
Horizon	Moderate (delayed reservation, no void-filling)	Low/Moderate efficiency (due to the voids)	High efficiency (no voids in E-OBS)
JET Just-Enough-Time	High (delayed reservation, void-filling)	Has to be implemented for efficiency	No need

E-OBS can effectively apply the JIT and Horizon algorithms, since the processing of BCP can be less-complex (faster) in E-OBS

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Routing and Survivability

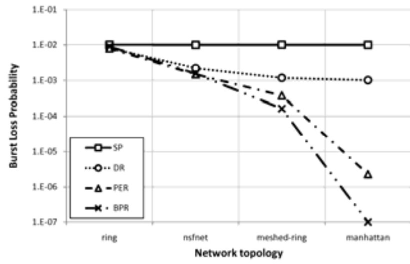
- In C-OBS the offset time has to correspond to the maximum length of the routing path; otherwise, **the insufficient offset problem** may occur (and the burst loss)
  - alternative/deflection routing path can not be created freely
  - also, it affects some restoration schemes that consider deflection routing to coop with link failures

<u>Case study</u>

SP: shortest path routing

DR: a deflection routing algorithm in C-OBS with additional offset time accommodating 2 deflections at most

PER/BER: 2 different deflection routing algorithms in E-OBS



E-OBS does not suffer the insufficient offset problem ⇒ better BLP performance

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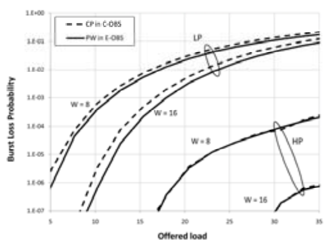
QoS Provisioning

- Offset Time Differentiation (OTD) and burst preemption (BP) are the most effective QoS mechanisms and, when applied in C-OBS:
  - OTD performance may be affected by the offset variation,
  - BP creates **phantom bursts** (i.e., bursts that are preempted, but the reserved resources are not released on the ongoing path)
- On the contrary, in E-OBS the offset is kept fixed and the problem of **phantom bursts** can be resolved by applying **a Preemption Window (PW)** mechanism.



PW mechanism

- a small offset added in each core node
- no preemption allowed after the BCP is released

⇒ **no phantom bursts in the network**

⇒ **BLP performance slightly better than in C-OBS**

M. Klinkowski, D. Careglio, D. Morató, and J. Solé-Pareta, "Effective Burst Preemption in OBS Network", IEEE HPSR, June 2006.

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Summary I

	C-OBS	E-OBS
Fairness	No	Yes
Performance	Slightly better BLP in E-OBS End-to-end delay the same	
Resources reservation, scheduling complexity	High	Low / Medium
QoS	Some difficulties	Some facilities
Alternative/deflection routing	Limited	Not limited
Hardware complexity	Memory (in edge)	Fibre delay coil (in core)

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Summary II

- Migration towards OPS
  - E-OBS facilitates the coexistence of OBS and OPS

	OCS optical circuit switching	**C-OBS** conventional optical burst switching	**E-OBS** offset time-emulated OBS	**OPS** optical packet switching
Signalling:	out-of-band	out-of-band	out-of-band	in-band
Offset time:		offset in edge	offset in core	offset in core
Data unit:	long-living optical circuits	long bursts	short bursts	short packets
Complexity:	✓ low	✓ relaxed	✓ relaxed	× high
Flexibility:	× low	✓ high	✓ high	✓ high
FDL buffering:	-	× impractical	✓ possible	✓ yes

lower / longer — *hardware/processing/switching requirements* / *transmission unit (granularity)* — higher / shorter

nowadays/near future *mid term* *long term*

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- M. Klinkowski, D. Careglio, J. Solé-Pareta, and M. Marciniak, "*A Performance Overview of Quality of Service Mechanisms in Optical Burst Switching Networks",* Chapter 1, pp. 1-20, (ed.) Maode Ma, Current research progress of optical networks, Springer, 2009, ISBN 978-1-4020-9888-8
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- M. Klinkowski, D. Careglio, D. Morató, and J. Solé-Pareta, "Effective Burst Preemption in OBS Network", IEEE HPSR, Poznan, Poland, June 2006
- M. Klinkowski, D. Careglio, and J. Solé-Pareta, *"Comparison of Conventional and Offset Time-Emulated Optical Burst Switching Architectures",* in Proceedings of the 8th IEEE International Conference on Transparent Optical Networks (ICTON 2006), Nottingham (UK), June 2006

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CENTRE DE COMUNICACIONS AVANÇADES DE BANDA AMPLA

Reaching Optical MPLS from an OBS network interoperable with GMPLS

3. Interoperable GMPLS-OBS Control Plane

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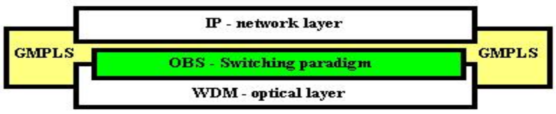
Optical Networks evolution

- Light Protocol stack: IP directly over WDM
- Efficient and fast Switching Layer: OBS
- Automatic and fast provisioning of connections: Signalling
- Automatic management of network resources: Routing

GMPLS Control Plane



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Why Optical Burst Switching?

- Trade-off between performance and current available technology

Advantages	Drawbacks
High bandwidth transport service at optical layer fitting with the Internet traffic characteristics	*High burst block probability due to the impractical use of FDL buffering*
Optimized network resource utilization due to statistical multiplexing	*Control complexity (signalling, routing, QoS, scheduling, protection...)*
An Open Issue	
Well-defined CONTROL PLANE able to respond to those high control complexity demands	

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Requirements of the OBS Control Plane

- Packet-Switched like network
  - Fast and dynamic provisioning of short duration connections
  - Fast processing
  - Network's resource availability dissemination
- Signalling
  - Two-way reservation: not viable due to burst traffic dynamics
  - One-way reservation
- Routing
  - Connectionless (IP-based): not viable due to the large routing table and processing delay
  - Virtual connection, LOBS → GMPLS-based control plane

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Quick look at GMPLS

- IP-oriented architecture, encompassing a set of IP protocols
  - Signalling, Routing and Automatic Network Discovery
- Common control plane to operate across dissimilar network technologies
  - Packet, time, wavelength and fibre switching domains
- Simplify the network control and management by automating
  - End-to-end provisioning of connections
  - Management of network resources
- Separation of the Control Plane and the Data Plane
  - Not only logical but also physical
- Fast forwarding and TE capabilities
  - Label and Explicit Routing concepts

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Why Integrating GMPLS in the OBS control?

GMPLS and OBS share the same basic rule: Separation between CP and DP
GMPLS offers an efficient and automated control and management platform Automatic end-to-end provisioning of connections Automatic management of network resources
GMPLS reduces the network complexity allowing an IP-over-WDM network
Speed up the process developing and standardizing the OBS technology
It is an easy way to migrate from OCS to OBS while providing a natural OCS/OBS coexistence

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GMPLS/OBS Control Plane Architecture

- Proposed Architecture
  - Hybrid OBS Control Plane
    - •GMPLS Control Layer
    - •OBS Control Layer
  - Transparent OBS Data Plane

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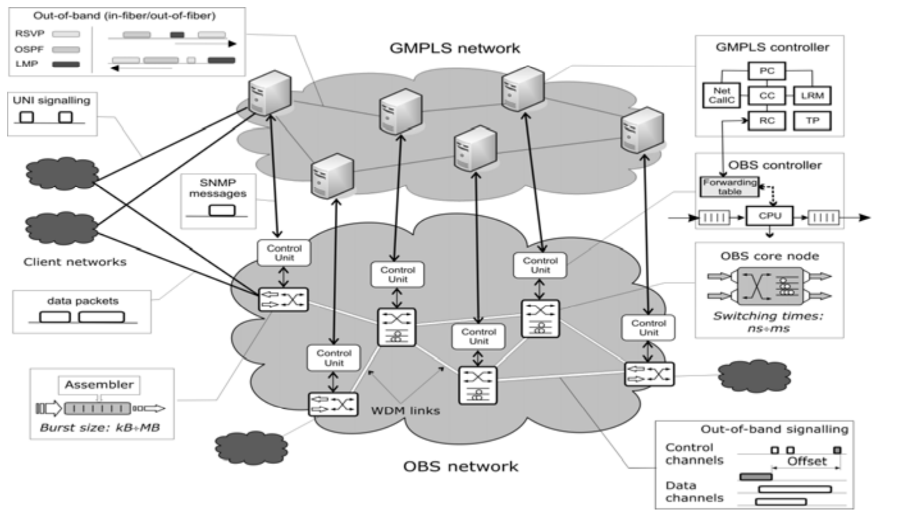
GMPLS/OBS Control Plane Architecture



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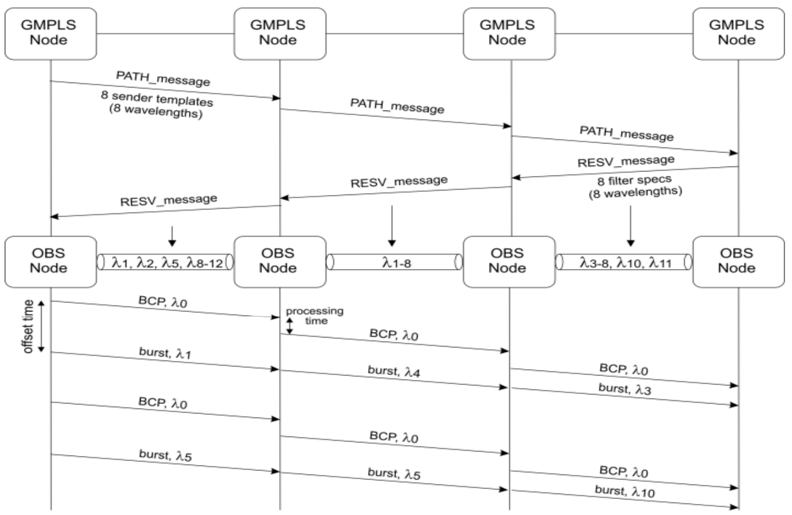
RSVP-TE Signaling Extensions



Problem formulation

- We focus in:
  - An innovative GMPLS/OBS Control Plane Architecture
    - *Horizontal interworking issues*
    - *Vertical interworking issues*
  - Required GMPLS Protocol Extensions to cope with such an architecture

Horizontal Interworking issues

	OBS Signaling Block	OBS Routing Block
OBS Background Task (GMPLS)	Virtual Topology Management	Network Topology Discovering
OBS Specific Task (OBS-CP)	Burst Transmission Resources Reservation	Network Resources Availability

- **OBS background tasks** to be carried out by GMPLS
- **OBS specific tasks** to be carried out by the OBS-CP through the Burst Control Packets (BCP)
- **OBS signaling block** to be carried out through RSVP-TE messages and BCPs
- **OBS routing block:** based on OSPF-TE, and extended Link State Advertisement (LSA) messages

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OBS Signaling Block

	OBS Signaling Block	OBS Routing Block
OBS Background Task	Virtual Topology Management	Network Topology Discovering
OBS Specific Task	Burst Transmission Resources Reservation	Network Resource Availability

- Virtual Topology Management (GMPLS)
  - Set up, maintain and tear down LSPs between edge nodes in a two-way RSVP-TE process, without resource reservation
  - A group of wavelengths (1 to all) should be selected for this LSP according to TE oriented policies
  - More than one LSP should be established between pair of nodes
  - LSPs follow an explicit route

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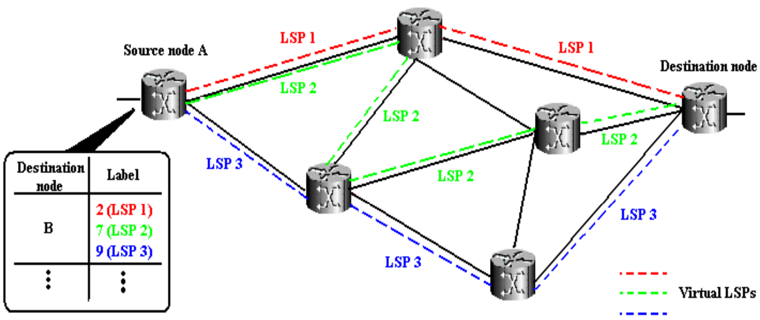
OBS Signaling Block

- GMPLS is used to create an overlay logical network of LSPs where to route the incoming bursts



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OBS Signaling Block

	OBS Signaling Block	OBS Routing Block
OBS Background Task	Virtual Topology Management	Network Topology Discovering
OBS Specific Task	Burst Transmission Resources Reservation	Network Resource Availability

- Resource Reservation (OBS BCP)
  - One-way resource reservation process
  - The Burst Control Packet is labeled at the edge node to follow one of the pre-established LSP provided by GMPLS
    - *The Burst Control Packet format is an open issue: It could be based on the RSVP-TE messages format*
  - The Burst Control Packet allocates a wavelength in a per hop basis when passing through the selected LSP

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OBS Routing Block

	OBS Signaling Block	OBS Routing Block
OBS Background Task	Virtual Topology Management	Network Topology Discovering
OBS Specific Task	Burst Transmission Resources Reservation	Network Resource Availability

- Network Topology/State Information (GMPLS)
  - Auto-discovery of network topology
    - *No time critical dissemination of information*
  - Path Computation
    - *The highly dynamicity of OBS results in the inaccuracy of the network state information*
    - *Instead of using the network state information, Path Computation of the set of static explicit routes composing the overlay logical network is based on statistics of traffic demands, traffic planning, operator policies…*
    - *There is also the possibility to serve explicit client requests to establish routes on demand, when the destination is not available or when all LSPs get congested*

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OBS Routing Block

	OBS Signaling Block	OBS Routing Block
OBS Background Task	Virtual Topology Management	Network Topology Discovering
OBS Specific Task	Burst Transmission Resources Reservation	Network Resource Availability

- Network Resource Availability Information (OBS CP)
  - The collection and dissemination of the "current" state network information is restricted to the resources (links and nodes) belonging to the virtual LSPs to a pair of edge nodes:
    - *More than one LSP for the each pair of edge node are set up and are constantly supervised with Network Resource Availability Information*
  - Link State Advertising placed at the Burst Control Packets
    - *Feedback based on BCP traveling in the backward direction*
    - *Not exact due to the high traffic variation of the OBS network*
    - *Estimation of a set of important parameters*

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Problem formulation

- We focus in:
  - An innovative GMPLS/OBS Control Plane Architecture
    - *Horizontal interworking issues*
    - *Vertical interworking issues*
  - Required GMPLS Protocol Extensions to cope with such an architecture

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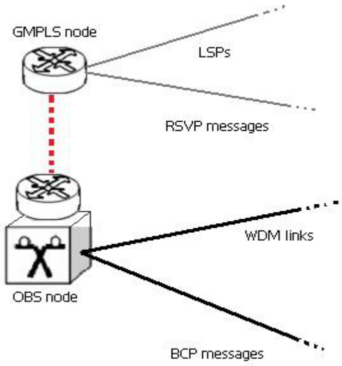
Vertical Interworking Scheme

- Problem formulation
  - Which information should "travel" between the GMPLS and OBS nodes?
  - And how to handle it?



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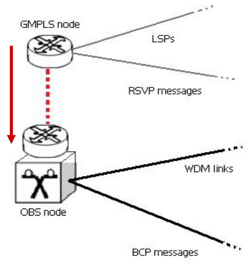
Vertical Interworking Scheme

- From GMPLS to OBS: WU2
  - Send information about the created LSPs between a pair of edge nodes: **Forwarding table**

1. Send control channel information (LMP protocol):
   - Creation
   - Mantainment
2. Failure report of a given LSP (to the source edge node)
3. LSP capacity update information for each LSP belonging to a pair of edge nodes



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Diapositiva 69

WU1 mudar o texto!!!
Windows User; 29/02/2008

Diapositiva 70

WU2 GMPLS TE Tunnel paths - single LSP or a set of them
Windows User; 29/02/2008

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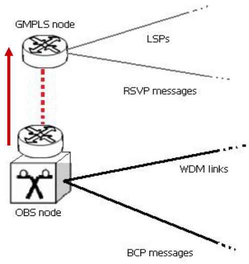
Vertical Interworking Scheme

- From OBS to GMPLS

1. Resource information:
   - Physical failure report to the correspondent GMPLS node in a way to start the protection and restoration mechanisms (LMP tool)
   - Individual link and node status information: inf. to be used by the OSPF-TE to find new routes (Periodicaly)
   - Global LSP status inf. (by the edge nodes): helps in traffic planning
2. Request of new LSP:
   - Automatic: due to traffic requirements, changes in the network or other LSP requirements
   - Explicit: client specifies the desired route (LSP)



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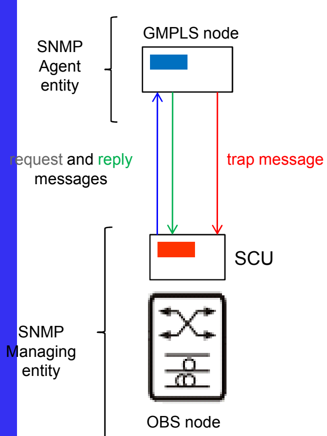
SNMP – A first approach

Simple network management protocol



- Request-response mode:
  - SNMP managing entity (i.e. OBS node) sends a request to an SNMP agent (i.e. GMPLS node), who receives the request, performs some action and reply.
- Notification mode:
  - SNMP Agent (i.e. GMPLS node) sends an unsolicited message, know as trap message, to a managing entity (i.e. OBS node) used to notify the managing entity of an exceptional situation.

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Problem formulation

- We focus in:
  - An innovative GMPLS/OBS Control Plane Architecture
    - *Horizontal interworking issues*
    - *Vertical interworking issues*
  - Required GMPLS Protocol Extensions to cope with such an architecture

10th March 2008

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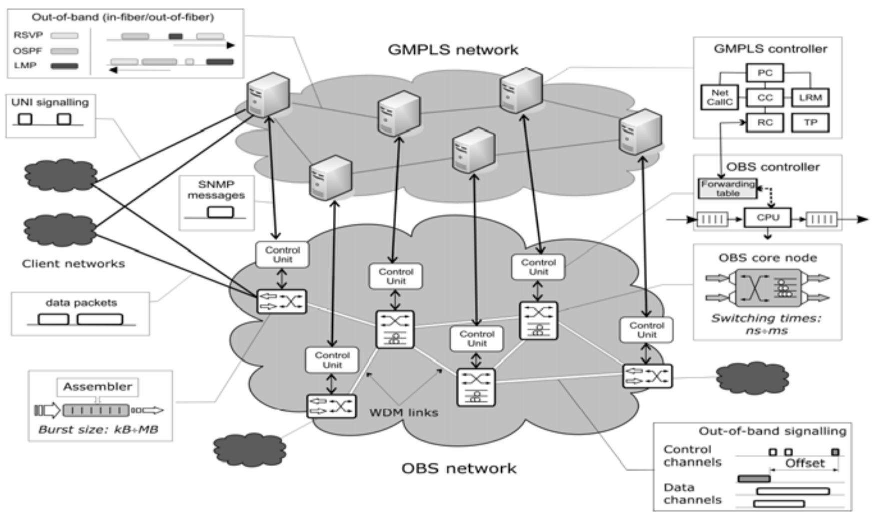
GMPLS/OBS Control Plane Architecture



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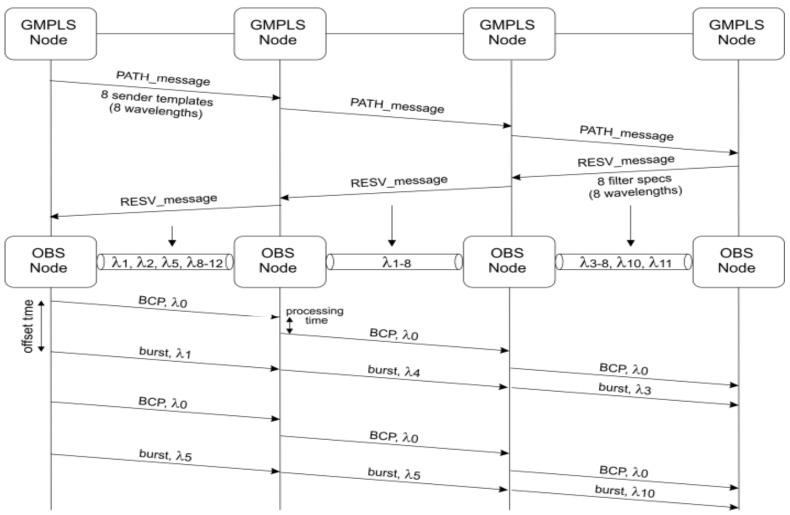
RSVP-TE Signaling Extensions



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Proposed GMPLS Protocol Extensions

- Related IETF Draft:
  - *Bernstein, G., Lee, Y., "Routing and Wavelength Assignment Information for Wavelength Switched Optical Networks", work in progress: draft-bernstein-ccamp-wson-info-01.txt, November 2007*
- OSPF-TE Routing Extensions
  - *Extend the Wavelength bitmap concept: A new state to "share" resources (LSPs / λs) among some Tunnels is required*

• It is worth to have three wavelength states: Reserved λ, Free λ and Shared λ

Lambda	State	
λ_1	Reserved	(Tunnel 1)
λ_2	Shared	(Tunnel 1 and 2)
λ_3	Reserved	(Tunnel 2)
λ_4	Reserved	(Tunnel 2)
λ_5	Free	

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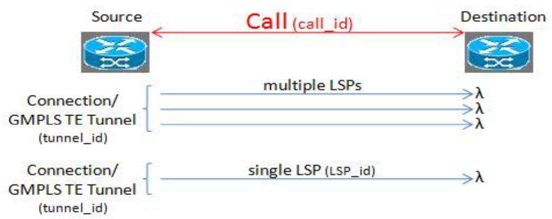
Proposed GMPLS Protocol Extensions

- Related IETF RFCs:
  - *[RFC4974] - GMPLS RSVP-TE Signaling Extensions in Support of Calls*
  - *[RFC 3473] - GMPLS Signalling RSVP-TE Extensions*



- RSVP-TE Signaling Extensions
  - *Single Path-Resv message to establish a TE Tunnel of multiple LSPs (λs)*

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Example

- Two tunnels may share a wavelength in order to save resources. With this new state we can indicate it.
- If a third tunnel would be setup it would be convenient that not used the shared wavelength to avoid congestion situation in high load periods. Now we know which wavelengths are reserved, free and shared

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Summary

- GMPLS is the Control Plane Standard for next generation of networks
- OBS is the current switching paradigm to enable the envisioned IP-over-WDM network
- A GMPLS-OBS interoperable Control Plane is a natural solution that enforces the migration from OCS to OBS and the coexistence of this two technologies
  - We, in our group started with some initial steps into the definition of this Control Plane

Work in progress

- Definition of a OBS Switch Capable Interface for communicating with GMPLS nodes
- Formal definition of the Bursy Control Packet format
- Horizontal interworking issues: Implementation and test of the suggested GMPLS protocol extensions
- Vertical interworking issues: Study SNMP as an approach for the vertical signalling
- Proof-of-concept of our GMPLS-based OBS Control Plane architecture

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References

- Pedroso, P.; Careglio, D.; Casellas, R.; Klinkowski, M.; Sole-Pareta, J. *"An interoperable GMPLS/OBS Control Plane: RSVP and OSPF extensions proposal",* in proceedings of 6th International Symposium on Communication Systems, Networks and Digital Signal Processing, 2008 (CNSDSP 2008), 25-25 July 2008, Graz (Austria)

- Pedroso, P.; Sole-Pareta, J.; Careglio, D.; Klinkowski, M.; *"Integrating GMPLS in the OBS Networks Control Plane",* in Proceedings of the 9th IEEE International Conference on Transparent Optical Networks (ICTON 2007), Rome, Italy, July 2007

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Reaching Optical MPLS from an OBS network interoperable with GMPLS

1. OMPLS: Optical MPLS
2. E-OBS: Off-set Time Emulated OBS Architecture
3. Interoperable GMPLS/OBS Control Plane

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From OCS to OPS: The Road Map

- Definition an interoperable GMPLS–OBS Control Plane
- Star to deploy E-OBS nodes coexisting with the OCS ones in the ASON/GMPLS "current" network
- Reduce progressively the burst size (until having OPS sizes)
- Reduce the FDL at the imput of the E-OBS nodes, as far as the optical technology allow for it.
- Star to deply OMPLS nodes coexisting with E- the OBS and OCS ones

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