Introduction to Optical Burst Switching (OBS)

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Optical Switching
Optical cross-connect switch

- Can cross-connect:
  - fiber-to-fiber
  - wavelength-to-wavelength
  - timeslot-to-timeslot

Optical Circuit Switching
Wavelength routing

Wavelength converter

OXC
OXC

◆ Today: overwhelmingly O/E/O
  ▪ Bottleneck

◆ All-optical commercial products are imminent. Successful technology must demonstrate:
  • Low Insertion loss, Polarization-dependent loss (PDL), WL dependency, Low Crosstalk High Speed,
  • Scalability, Small Size, Low Cost, Manufacturability, Serviceability

◆ Technologies
  • Electromechanical : low switching time, large, large mass
  • Guided-wave solid state switched: high losses, high crosstalk =&gt; low scalability
  • MEMS: submillisecond switching times
OXC based on MEMS
(Micro ElectroMechanical Systems)

Micro electromechanical actuators and micro-optical integrated monolithically in the same substrate

NxN mirrors

Not advisable in cascade (e.g. Clos networks)
MEMS mirrors

2D vs 3D
A 3D MEMS switch has mirrors that can rotate in 2 axes
Light can be directed with precision in multiple angles (at least as many as input)

Less loss from input
Less tx in open space

Agere Systems: 64x64
IL=6dB, T= 10ms

Source: IEEE Communications . Nov 2001
Nortel X-1000 switch

Xros 1152x1152 50ms
..already in development
New alternative for IP/WDM networks: OBS
Evolution

- Optical Network Functionality
- Optical Packet Switching
- Optical Burst Switching
- Meshed Networks
- Ring Networks
- Label Switching
- Point-to-Point WDM Links

1995 - 2000
IP over WDM

- **OWS or OCS (Optical wavelength switching)**
  - Switching granularity = wavelength
  - Lightpaths between ingress-egress edge routers
    - Low overhead
      - Path per route, per LSP
    - Bandwidth inefficiency for bursty traffic

- **OPS (Optical packet switching)**
  - Switching granularity = (variable size) packet
    - More efficiency through statistical mux
  - Drawbacks
    - Optical memory technology not mature
    - High control overhead
      - DWDM múltiples OC-192 o OC-768 (many packets!)

- **OBS (Optical Burst switching)**
  - Switching granularity = (variable size) burst
  - Objective: combine advantages of OWS & OPS

- **OLS (Optical Label Switching)**
  - Switching granularity = (variable size) flow -- data driven LSPs
OPS Node

Requires intelligence in the optical layer
Need to store packet during header processing plus a variable contention resolution time (this implies variable delay arrays)

Optical buffers are extremely hard to implement
1 pkt = 12 kbits @ 10 Gbps requires 1.2 µs of delay => 360 m of fiber)
FDL = Fiber Delay Loop
Optical Packet Switch still has a long way to go
OBS network

G = Guard band
CP = Control Packet

offset

Wavelength interface
Optical Switch
Switch Controller

burstifier
OBS Controller
OBS Edge Node

Burst assembly/dissassembly

- Burstifier
- OBS Controller: Burst scheduler
- Out of band signaling:
  - Control packets carry info for Switching/routing, resource reservation, etc.
  - Configures OXCs and reserves bandwidth only for the duration of the following data burst at each core router so that associated data burst can cut through core routers without O/E/O conversions
  - ACK from egress node is not awaited
Advantages of OBS

- All-optical O/O/O burst switching
- Data buffered at the edge (cheaper)
- No optical RAM or FDL in intermediate nodes required
  - Optional FDLs and wavelength converters can reduce burst loss
- Lower control overhead per bit than in OPS
- Less O/E conversions of control packets
- Statistical MUX at burst level (vs OCS)
  - Benefits from transmission silence
  - Dealing with optical switches ~100ms connection setup/teardown times
Comparison

(a) OCS node

(b) O/E/O switch/node

(c) OPS node

(d) OBS node
Aspects of OBS

- Burst Assembly
- Burst Reservation Protocols
- Burst switching
  - Scheduling
  - Contention resolution
Burst assembly

Burst assembly/dissassembly

Tasks:
- Create control packet for burst
- Determine offset
- Schedule burst in an output lambda
- Forward the burst

Burst: same FEC (same egress, QoS,..)
Burst Assembly

◆ Assembly algorithms
  ● Timer-based: time > Timeout
  ● Burstlength-based: l > b_threshold
  ● Mixed (either condition happens first)

◆ Optimizations
  ● Adaptation <Timeout , b_threshold> to the traffic in real time
  ● Burst length prediction
    ▪ Reserve for l + f(offset)
Burst Reservation Protocols

- Origins: TDMA, ATM 1990
- Tell-and-wait
  - Wait for confirmation of reservation by return (ACK) before sending burst (NAK => retransmisión)
  - Variant: Just In Time, with centralized scheduler
- Tell-and-go
  - Without pre-reservation. Need to wait only for each node control to establish a circuit. (NAK => retransmisión). It needs FDL.
    - Tell-and-wait better only if propagation delay is negligible compared to burst length.
- Just-enough-time
  - Prevailing distributed protocol
Burst Reservation Protocols

◆ Just-enough-time
  ➢ does not require optical buffering/delay at intermediate node

● Keys
  ▪ One-way reservation
  ▪ Control packet carries offset time info
  ▪ Makes “delayed reservation” for the corresponding burst
  ➢ Reservation starts at the expected arrival time of the burst
Burst switching

- Optical switch: contention not resolved by buffering

- **Scheduling**
  - Choose a wavelength for the burst according to existing reservations \( (\text{latest available unused chann.}) \)
    - E.g. LAUC O(W), LAUC-VF O(WlogM),… Best-fit O(log^2M)
      - \( W = \# \text{ lambdas in ports, } M = \text{Max. } \# \text{ of reservations} \)

- **Contention resolution**
  - Resolution
    - Deflection (wavelength, space, time (FDL))
    - Dropping
    - Preemption
  - Other techniques
    - Burst segmentation
Optical Aggregation and GMPLS

- LOBS (Labeled OBS, 2000)
  - GMPLS OCS with lambda=label
  - Problem:
    - In order to groom or aggregate traffic carried over different lightpaths: O/E/O required
  - Solution:
    - control packet carries label info
    - Label-wavelength association in the burst-scale rather than in a connection-scale
      - Subwavelength granularity feasible
      - Statistical multiplexing
      - LSP merging
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Optical networks and MPLS
Optical MPLS

- Label not prepended to packet
- Instead is represented by a fiber number or a wavelength
Generalized MPLS (GMPLS)

◆ What is GMPLS?
  ● A distributed control plane for dynamic provisioning of data paths within optical networks
  ● GMPLS - Extension to MPLS-TE
    ▪ A single unified control plane
    ▪ Integration of different switching paradigms (packet, L2, Time, Wavelength, Waveband, Port switching)
    ▪ The separation of the control and forwarding planes.
    ▪ Reuses IP routing (OSPF and ISIS) and MPLS tunnel LSP and traffic engineering mechanisms (RSVP-TE and CR-LDP)
    ▪ The flexible control of topology constraints.
GMPLS Protocols and Functions
The Intelligent Optical Network

ITU-T G.8080 (2001)
Automatically Switched Optical Network (ASON)

Optical Topology Discovery, Routing, Signaling Layer

Management System

OCC: Optical Connection Control
CCI: Connection Control Interface
IrDI_NNI: Inter-Domain Interface NNI

UNI: User-Network Interface
NNI: Network-Network Interface
NMI: Network Management Interface
Services objective in the short term

- Long-haul
  - SONET/SDH private lines
- Metropolitan & Access
  - Gigabit ethernet
    - Metro-ethernet
- Application-oriented
  - FibreChannel
- Flexibility
  - Granularity in Mb/s, switch-over time (50ms-..)
Treat these as labels

- Using MPLS, we can think of each of these as a label:
  - Fiber number \( N \) in the bundle (\( N \) is the label)
  - Wavelength \( \lambda \) on the fiber (\( \lambda \) is the label)
  - Timeslot \( T \) on the fiber (\( T \) is the label)
- Changing \( N \), \( \lambda \), or \( T \) going through an optical switch is thus a label swap
- Can use CR-LDP / RSVP-TE to set up the cross-connects
## ASON Building Block Development

<table>
<thead>
<tr>
<th>Architectural Component</th>
<th>Standards Activity</th>
<th>Standards Forums</th>
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| ASON Architecture       | Framework and Architecture Documents | • Architecture and carrier service requirements are being defined in the ITU.  
• In addition US activity is coordinated via T1X1. |
| UNI                     | LDP                | • Carrier service requirements driven via OIF  
• Detailed protocol work within IETF |
| NNI                     | CR-LDP OSPF OSPF, ISIS | • Requirements driven via OIF  
• Detailed protocol work within IETF |
| CCI                     | GSMP               | • Requirements driven via Multi-Service Switching Forum (MSF)  
• Detailed protocol work within IETF |
| IrDI                    | Detailed work to be commenced | • Will be based on UNI with possible extensions for routing information exchange |
| NMI                     | Detailed work to be commenced | • SNMP MIBs to be defined.  
• Higher level managed capabilities to be based on existing management paradigms such as CORBA. |