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
  - Wavelength converter

Optical Circuit Switching
Wavelength routing
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 => 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 cascasde (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

Lucent:
WaveStar MEMS mirror from a WaveStar Lambda router

Nortel X-1000 switch

Lens array
Fiber array
Optical path
MEMS mirror array

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

Evolution

1995
2000

Optical Network Functionality

- Optical Burst Switching
- Meshed Networks
- Ring Networks
- Point-to-Point WDM Links

Optional Packet Switching

Label Switching
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 multiples OC-192 or 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

**OBS Core Node**

- Wavelength interface
- Optical Switch
- Switch Controller
- O/E/O
**OBS Edge Node**

**Burst assembly/dissassembly**

- **burstifier**

- **Burst**: same FEC (same egress, QoS,...)

- **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

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**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

![Comparison Diagram](image)

Aspects of OBS

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

**Burst assembly/dissassembly**

- **burstifier**
- **OBS Controller: Burst scheduler**

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

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### 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
    - **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 (*latest available unused chann.*)
    - E.g. LAUC O(W), LAUC-VF O(WlogM),… Best-fit O(log^2M)
      - W= # lambdas in ports, M = Max. # 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
References

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Optical MPLS

- Label not prepended to packet
- Instead is represented by a fiber number or a wavelength

MPLS - Label Hierarchy

- StatMux
- TimeSlot
- Fiber
- Bundle
- Waveband
- Wavelength
  - $\lambda_0$, $\lambda_1$, $\lambda_2$
  - $\{\lambda_0, \lambda_1\}$
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

Routing
- OSPF/IS-IS
- OSPF/IS-IS
- OSPF/IS-IS

Signaling
- RSVP/CR-LDP
- RSVP/CR-LDP
- RSVP/CR-LDP

Management
- LMP
- LMP
- LMP

Data channels
- MPLS
- LSR
- OXC
- MPLS
- LSR
- OXC
- MPLS
- LSR
The Intelligent Optical Network

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

Management System

Optical Topology Discovery, Routing, Signaling Layer

OCC: Optical Connection Control
CCI: Connection Control Interface
IrDI: Inter-Domain Interface NNI
UNI: User-Network Interface
NNI: Network-Network Interface
NMI: Network Management Interface

Client Traffic

Client Signaling I / F

OXC

OXC

OXC

IrDI

The Intelligent Optical Network

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-..)
Using MPLS, we can think of each of these as a label:
- Fiber number N in the bundle (N is the label)
- Wavelength λ on the fiber (λ is the label)
- Timeslot T on the fiber (T is the label)

Changing N, λ, or T going through an optical switch is thus a label swap.

Can use CR-LDP / RSVP-TE to set up the cross-connects.

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**ASON Building Block Development**

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