Optical Burst Switching (OBS): The Dawn of A New Era in Optical Networking

Presented by
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Outline

- Historical Review
- Burst reservation
- Burst assembly
- OBS node
- Towards the Optical Internet
- Conclusion
Burst switching--Historical Review

- **Electronic Domain**
  - Design for competition with ATM, etc.

- **Optical Domain**
  - Based on optical TDMA system, centralized control
  - Highball projects, U. of Delaware 1990

- **Common Issue**
  - Centralized transmission arrangement/scheduling
Burst switching--Historical Review

- ATM wins?
  - Compared with primitive Burst switching, ATM is more cost effective

- Research on burst transmission protocols went on.
  - In ATM network, I. Widjaja 1996
    - Tell and Go (TAG)/Tell and Wait
  - In Optical Network, G. Hudek and D. Muder 1995
    - Connect/Confirmation (CC), TAG, Reservation/Scheduling with Just-in-Time (JIT) Switching
WDM!!

- Huge bandwidth provisioning.
- How to use this bandwidth efficiently?
  - Wavelength Routed Network
    - Static connection, inefficient bandwidth allocation
  - Optical Packet Switching (OPS)
    - High processing speed requirement, big overhead, no practical optical buffer and control unit
  - Opaque WDM network
    - O/E/O conversion is required at each node for traffic grooming
Optical Burst Switching ---- A Reborn of Burst Switching

- What is OBS?
  - Separation of transmission and control
    - Offset time between control packet and data burst
    - Out of band signaling
  - Intermediate transmission granularity

- Advantages of OBS
  - More flexible and efficient compared with wavelength routed network.
  - More scalable and cost effective compared with OEO approaches
  - Smaller overhead and more practical compared with OPS.
OBS—A General Idea
OBS Network

Edge Router

LAN

Backbone

Packet Flow

Burst Flow

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Compared with O/E/O approaches
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Burst Reservation----Overview

- Two way reservation
  - Forward reservation
  - Backward reservation
  - Example: WR-OBS

- One way reservation
  - With/ Without offset time
  - With/ Without burst length info
  - Examples: TAG, JIT, JET.
Two Way Reservation ---- WR-OBS

- End-to-End connection setup
- Fast-circuit like switching

**Pro**
- Guaranteed transmission

**Con**
- Longer delay and inefficient bandwidth utilization
One Way Reservation ---- TAG

- BW reserved right after control packet is processed
- No burst length information, BW released with:
  - an explicit *release* packet (problematic if lost)
  - or frequent *refresh* with time-out (overhead)
- $T = 0$ (or negligible), otherwise wastes BW
- FDLs per node $> \max\{\text{proc.} + \text{switch time}\}$
- Later evolved to adopt JET’s features
One Way Reservation ---- JIT

- Based on Tell-And-Wait (TAW)
  - Just-In-Time (JIT) with centralized control
    - Sends a request, and the centralized scheduler decides the time to transmit, and informs the sender.
  - JIT with distributed reservation (RIT)
    - A scheduler on every switch, globally synchronized
  - JIT with two-way hop-by-hop reservation
    - Similar to fast circuit-switching under distributed control. Differ from RIT in that there is no burst length info.

- Based on TAG and JET
  - Uses offset time to avoid FDLs, and burst length info for reservation as in JET but no delayed reservation.
Just Enough Time (JET) signaling

- Proposed in 1997 by Yoo and Qiao.
- Basic ideas
  - Carrying information about the burst length in the control head to increase the bandwidth utilization
  - Cut through switching configuration using an offset time to reduce end-to-end delay
JET signaling

- Compared with TAG
  - JET does not require FDL set to compensate for the configuration delay; shorter delay
- Compared with JIT,
  - JET uses the bandwidth more efficiently due to possible Delayed Reservation (DR),
- However, it has stricter synchronization requirement
- It is well adopted by researchers
Delayed Reservation

![Diagram of Delayed Reservation](image)

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*Image Source: [Source Link]*
One way? Or two way?

- **Performance parameter**
  - Throughput
  - Burst delay
  - Bandwidth requirement

- **Determining factors**
  - End-to-end propagation delay
  - Optical Device configuration time
  - Burst transmission time

- **Tradeoff has to be made regarding to network dimension, burst size, transmission speed, etc.**
Routing and Wavelength Assignment

- **Routing**
  - Determine a path from source to destination

- **Wavelength assignment**
  - Determine which wavelength is used for data transmission

- **Wavelength conversion**
  - Two way reservation has central routing and wavelength assignment. Less burst loss when no wavelength converter provided, (Tradeoff: central control, extra delay)
  - One way reservations generally assume full wavelength conversion. Otherwise, multiple wavelength reservations or priority-based wavelength assignment will be considered in order to reduce burst loss.
Priority based Wavelength Assignment
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Burst Assembly

Burst Assembly Unit

BS: Burst Scheduler

Traffic from edge routers

BAU

Assembled bursts

BAU
Burst Assembly (cont.)
Characteristic of Assembled Traffic

Recent studies showed that
- The assembly traffic follows Gaussian distribution.
  - X. Yu and K. Laevens, Opticomm 2002
- Long range dependence still exists with traffic smoothing effect
- The smoothing effect on the traffic will enhance the performance of OBS network compared with OPS in a scenario with/without FDL set
Burst assembly does take effect

- Why the burst assembly is so important?
  - Simply changing the burst length will affect the whole network’s performance was recently reported.
  - Although inter-arrival time distribution does not affect core’s performance much, burst length distribution and its average value does make difference. (Ref K. Dolzer, Performance evaluation analysis of OBS network with JET)
Burst Assembly ---- Open Issues

- Reduce unnecessary delay time
  - Burst Length Prediction

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Burst Assembly ---- Open Issues

- Coordination with bypass traffic
  - Burst scheduling
- Traffic engineering
  - Admission Control
- Quality of Service (QoS)
  - Delay and Loss
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OBS Node

Switch Control Unit
- Conversion signal
- Switch configuration signal

Input port
- Burst header
- FDL set

Switch Fabric
- Demux
- Wavelength converter
- Mux

Output port
OBS Node ----- Reduce the Cost
Burst Scheduling problem
Burst scheduling

- Making wise choices
  - Increase the utilization
  - Leave more chances for future burst arrivals
  - Pack the reservations

- Typical Burst Scheduling algorithms
  - Horizon/Latest Available Unscheduled Channel (LAUC)
  - First-Fit (FF)
Burst scheduling

- Utilizing “void”s
  - Delayed reservation+difference on offset time
    length=possible voids between reservations
  - Making use of these voids will increase the bandwidth
    utilization but requires more information and
    computation

- Scheduling algorithms with void filling
  - LAUC-VF
  - FF-VF
Burst Scheduling

![Diagram showing burst scheduling with time axis and various time intervals and tasks]

- New Burst
- Time

- \( t_1'' \) and \( t_1' \) for task \( \text{C}_1 \) and FF-VF
- \( t_2'' \) and \( t_2' \) for task \( \text{C}_2 \) and LAUC-VF
- \( t_3'' \) and \( t_3' \) for task \( \text{C}_3 \)
- \( t_4' \) for task \( \text{C}_4 \) and FF
- \( t_5' \) for task \( \text{C}_5 \) and LAUC/Horizon

- Labels for time intervals and tasks: \( \text{C}_1 \), \( \text{C}_2 \), \( \text{C}_3 \), \( \text{C}_4 \), \( \text{C}_5 \)
Scheduling algorithm design

- Tradeoffs in design a burst scheduling algorithm
  - Bandwidth utilization
  - Scalability of information storing
  - Running time of the algorithm
Contention Resolution

- Wavelength Domain
  - Using wavelength converter
- Time Domain
  - Using Fiber Delay Line (FDL) set
- Space Domain
  - Deflection routing
- “Burst” Domain
  - Burst Segmentation, Optical Composite Burst Switching (OCBS)
Wavelength Domain

Without Wavelength conversion

Incoming Burst

occupied
occupied
occupied
Free
Free

With Wavelength conversion

Incoming Burst
Fiber Delay Line Set

(a)

(b)

$B = 2^0 + 2^1 + 2^n$
Deflection routing

- Pickup the alternate route carefully to balance the load
- Need to put a limit on the usage of deflection routing

Burst 1's reservation
Burst 2's reservation
Insufficient offset time problem

When a burst is deflected at B, an insufficient offset time problem occurs.
Burst Segmentation

- Drop head/Drop Tail
- Differentiation
- Difficulties
  - New header generation
  - Reservation cancellation/modification
Optical Composite Burst Switching (OCBS)

- When all of the output wavelengths are occupied, a switch discards only the initial part of an incoming burst and forwards the final part of the burst, beginning at the instant in which one wavelength becomes free.
Offset-time based Differentiation

- Burst arrival previously
- Class 0 burst
- Class 1 burst

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Segmentation based Differentiation

Introducing different priorities at a segment level

- Assign different weights to segments inside a burst, when compared with a contending burst, the segments with less weights will be dropped
## Service Differentiation

<table>
<thead>
<tr>
<th>offset-based</th>
<th>segmentation-based</th>
<th>active dropping-based</th>
</tr>
</thead>
<tbody>
<tr>
<td>greater offset for higher priority class</td>
<td>burst consists of independent segments</td>
<td>actively drop bursts</td>
</tr>
<tr>
<td>+ simple, inherently supported by JET</td>
<td>+ save part of burst in case of congestion</td>
<td>+ simple</td>
</tr>
<tr>
<td>+ differentiation of an arbitrary number of classes</td>
<td>+ offers a variety of different policies</td>
<td>+ independent of burst characteristics</td>
</tr>
<tr>
<td>- losses dependent on low priority burst characteristics</td>
<td>- increased complexity in core network (signalling and processing)</td>
<td>+ offers a variety of different policies</td>
</tr>
<tr>
<td>- unpleasant effects with different mean burst lengths</td>
<td>- smaller resulting burst length in larger networks</td>
<td>- higher overall burst loss probability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- needs additional dropping unit</td>
</tr>
</tbody>
</table>
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Towards the Optical Internet

- Labeled OBS (LOBS)
- TCP’s performance over OBS
- Multicasting in OBS Network
- Supporting Ethernet with OBS
LOBS

Physical layer performs functions for burst switching, wavelength conversion, burst delay/buffering, optical amplification, etc.

Optional monitoring “sub-layer” for fault detection. This may or may not use data-framing (e.g., for control channel). LOBS layer performs all recovery actions.

IP layer performs layer three functions (e.g., addressing, routing)

LOBS (MPLS) layer provisions OBS services. This includes burst assembly, WDM topology and resource dissemination, survivability, etc.

Electronic layer

Opto-electronic layer

Optical layer

Monitoring layer (optional)
TCP’s performance over OBS

- Take the impact of OBS mechanism on the external tunneled protocols
- Two characteristic of TCP traffic
  - Congestion control
  - Retransmission
- Two characteristic of burst transmission
  - One successful transmission will result multiple ack and one burst drop will result multiple Nack.
  - Burst assembly introduce extra delay
TCP’s performance over OBS

General conclusions

- Delay penalties at the burst assembly stage will reduce the link utilization
- Correlation among the loss events of TCP segments may compromise the TCP recovery
- Assembly period should be adaptive to the TCP window size
Multicast

- Performance parameter
  - Channel utilization, processing load.

- Affecting factors
  - Overheads due to control packets and guard bands

- Three strategies
  - Separate Multicasting
  - Multiple Unicasting
  - Tree-shared Multicasting
OBS in Metropolitan Area Network

- Ethernet promises to play an important role, offering a hierarchy of speeds, end-to-end protocol consistency, and technical features that are needed by both providers and users in a cost-effective way.

- Current approach: Ethernet over SONET
  - Problem: its synchronous time-division multiplexing (TDM) nature renders it inefficient for data-centric connections.

- Ethernet over OBS
  - Provides a better sharing of network resources and a robust and more efficient transport when coupled with (GMPLS)
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Conclusion

- OBS takes the advantage of both huge bandwidth in optical fiber and the sophisticated electronic control. Advances made in both worlds will help OBS.

- However
  - Many unsolved problems, such as fast optical switching
  - Need testing result from testbeds and prototypes

- Want to know more?
  - [http://www.cse.buffalo.edu/~yangchen/OBS_Pub_year.html](http://www.cse.buffalo.edu/~yangchen/OBS_Pub_year.html)